TECHNICAL PAPERS
Presented at the

NATIONAL ASSOCIATION OF BROADCASTERS
NAB

Engineering Conference

March 23-26, 1969

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ENGINEERING DEPARTMENT
NATIONAL ASSOCIATION OF BROADCASTERS
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Opening of the Conference

Vincent T. Wasilewski, President
National Association of Broadcasters

It is with great pleasure that I welcome you to this Broadcast Engineering Conference to start you off. I don't want this occasion to pass without commending our Vice President for Engineering, George Bartlett, and I think that we should add also his able right hand, without whom George could do nothing, Shirley Ostmann.

In all truth, without the ladies on our staff, throughout the staff, we could really never have a convention. They've done a wonderful job, George and Shirley, in putting this meeting together for you and George does a splendid job all year long as your Engineering man at NAB. I personally feel very fortunate in having George on our staff.

Each year I'm amazed when I walk down through those exhibits on Sunday to see what has gone on in the broadcast engineering world during the past year. It seems that each year we see products which were not in existence a year ago. There are improvements made in nearly all of the products, I guess, that were exhibited in Chicago last year.

That is the measure, of course, of the quiet but tremendously effective job that is being done in the broadcast engineering fraternity to make our industry among the most progressive in the world and I only wish that we could be as progressive in all other aspects of our broadcasting problems as we are in our engineering pursuits and probably, if that were true, we wouldn't have the problems that we're having today in Washington.

Industries don't survive by standing still. People have always wondered what became of the buggy-whip manufacturers when the automobile came along and some of them undoubtedly did stick to the old ways and probably continued to produce buggy-whips until the demand dried up and they were out of business but I suspect there were others who anticipated the trend and diversified their buggy-whip manufacturing companies to make accelerators or tires or some product needed by the changing industry.

So, come what may for our industry, be it in the area of CATV, pay-TV, satellite transmission, electronic video recording or some other development of the future, I know that broadcast engineering will continue to lead the way for this industry by providing the equipment that broadcasting must have to survive in this changing world.

So I thank you very much. I know you will have an interesting and a successful conference, as you always do, and, as usual, I have looked over the titles of some of your papers and again I haven't mastered the understanding of some of those titles but I do, however, intend to get in on occasion to listen to some of the things that I think perhaps I might understand.

So I hope you will go home refreshed in body—as I know you will from spirits and rich food that you will get here—but also I hope that you're refreshed in mind by the great variety of information about this great field of broadcast engineering. I am honored to be invited each year. I look forward to seeing all of you around the Convention the next couple of days and have a good meeting.

NAB Engineering Advisory Committee Report

Malcolm M. Burleson (Chairman, Engineering Advisory Committee)
Vice President for Engineering, Metromedia, Inc.

As Chairman of the 1968 Engineering Advisory Committee, I am pleased to bring you this final status report on the Committee's activities during the past year. As you know, appointment to the Advisory Committee is for a two-year period, and this report brings to an end my term of office as Chairman. Let me say, it has been a very gratifying experience, filled with the many problems which have been facing the industry. This report will, as usual, be brief.....just a review of the highlights of the more important aspects of our work and accomplishments over the past 12 months.

First, I would like to express my appreciation for the assistance which has been given me by the members of the Committee...a group of fine engineers working quietly and tirelessly behind the scenes, acting as your liaison to the NAB, the industry, the FCC, and other government agencies. Those serving on the Committee this year are: Joe Epperson, Scripps-Howard Broadcasting Company; Eugene R. Hill, Kaiser Broadcasting Corporation; Leslie S. Learned, Mutual Broadcasting System; James D. Parker, CBS Television Network; Verne Pointer, American Broadcasting Company; Russell B. Pope, Golden Empire Broadcasting Company; Henry E. Rhea, Triangle Stations; Dan H. Smith, Capital Cities Broadcasting; and William H. Trevarthen, National Broadcasting Company. I would also like to recognize the valuable contributions and assistance provided the Committee by Clure H. Owen of the American Broadcasting Company, and Clyde M. Hunt, Post-Newsweek Stations, who have subsequently retired since last we met.

The past year has been another very busy period for the Advisory Committee—a year in which many problems were discussed, evaluated, and in some instances, even resolved and terminated. Subjects ranging from microphone to antenna..... camera to receiver.....seminars to allocations. But as can be expected, we did not come up with solutions and answers to all the problems.....we thought we should leave a little work for the new Advisory Committee, which will be appointed by President Wasilewski in the coming weeks.

Again, as last year, a major emphasis has been on two continuing projects.....the efficient utilization of the spectrum and the development, adoption, and utilization of new technology in broadcast operations. Much of our time has been spent in the matter of sharing our presently allocated VHF and UHF-TV channels with the land mobile service. As was reported to you last year, we are still engaged in evaluating the feasibility of sharing VHF-TV Channels 2-13 with the land mobile service. The field tests which have consumed the better part of 1968 have now been concluded and the results are being analyzed. A series of laboratory tests have also been conducted and concluded to augment the field experiments. This data will be transmitted to the Commission shortly for evaluation and a final determination in this proceeding.

Another aspect of the problem has been the Commission's Notice of Proposed Rule Making in which the sharing concept will be extended to Channels 14 through 20 with the possible re-allocation of additional spectrum space in the 900-MHz region to the land mobile services. Needless to say, the Engineering Advisory Committee is following these proposals very closely to assure the industry that any final determination will be based upon sound engineering concepts.

I'm sure you will remember that on August 14, 1968, the Association filed a second petition with the Commission requesting a modification of the Rules to permit the remote control of VHF television transmitting facilities. The Commission has now issued a Notice of Proposed Rule Making in this matter and comments are due March 28th, 1969. We hope that this last and final effort, which, incidentally, was conducted after the expenditure of considerable time, money, and effort, will be successful. For those who have not yet done so, we urge you to participate in this proceeding and file appropriate comments.

Another interesting matter in which we have been participating is the support of the Commission's proposal to change the rules to authorize remote control return-metering information to be transmitted to the AM carrier through the use of subaudible tones. To support this concept, the Association conducted a series of field tests at stations KXYZ, Houston, Texas, WFAA, Dallas, Texas, and WBAP, Fort Worth, Texas, to attest to the feasibility of utilizing such a technique. Although the results of these experiments conclusively proved that no listener interference would result from the use of the subaudible tones, opposition was voiced as to the potential interference problem. Once again, to assure all interested parties that the system is compatible with listener reception, additional tests have been conducted within the past few days at station WTOP, Washington, D.C. I hope this will once and always eliminate any concern there may be against this concept.

We are, of course, very encouraged with the Commission's recent action in the matter of proposed amendments to the rules which would relax the logging and inspection requirements at remotely-controlled directional AM stations. On January 20, 1967, the NAB filed with the Commission a petition suggesting amendments of Section 73.67 to permit logging of phase indications at the remote control point and to require logging of phase monitor indications at the transmitter only once a day for any directional pattern. This amendment would relax the so-called two-hour inspection requirement for remotely-controlled directional stations, and permit the inspection of the directional antenna to coincide with the five-day-per-week inspection which is now required of non-directional stations. Stations wishing to take advantage of this relaxation would be required to utilize the FCC type-approved remotely-controlled phase monitor. Comments on this proceeding are due April 17, 1969. Again, I urge you to participate by filing your comments.

As you know, over the past four years we have been engaged in an investigation and evaluation of AM/FM and TV modulation monitor performance. This program was instituted when it was found that results obtained by the Commission's method of measuring modulation were not compatible with those obtained by broadcasters when using the FCC type-approved instruments. There is little need for me to recite the cause and effect produced by these varying concepts, but a real free-for-all has been engaged in to determine whether or not the (1) meter is the determining factor, or (2) the peak flasher is the gospel measurement, or (3) the peak method as used by the Commission is the answer. Nevertheless, I think the whole matter has been brought into focus by a recent petition requesting the use of a flashing light indicator to measure percentage of modulation in lieu of the presently adopted metering system.

A highly successful Engineering/Management Seminar was held during 1968 at Purdue University, with 41 broadcasters attending from all sections of the United States and Canada. This was an advance program offered only to those who had participated in a previous seminar. At the last meeting of the Advisory Committee it was recommended that the basic course be continued for another year. We strongly recommend that any of you who have not attended one of the past seminars make every effort to attend the 1969 course. Also, within the coming months the NAB will sponsor a technical training program to be structured over a two-day period dealing with directional antennas. In a survey conducted last fall, enthusiastic response was received for this type of technical program and it is hoped that this will be only the beginning of courses on such subjects as stereophonic broadcasting, video tape, color, and others.

The revision of the NAB Engineering Handbook is progressing slowly. This effort is under the direction of Dan Smith of Capital Cities Broadcasting Company and is now in the final process of developing a finished manuscript. Although we have fallen somewhat behind the hoped-for publication date of June 1st, we are still optimistic that this project will be completed during 1969. An announcement will be made within a few weeks as to time and location.

Color compatibility has been recently highlighted in both the trade and public press. We are cooperating with SMPTE, IEEE, and EIA in this project, and progress is being made in solving this very complex problem.

These are but a few of the more important matters the Committee has dealt with since I reported to you 12 months ago. They have been reviewed for your information and to remind you that the Engineering Advisory Committee is your Committee. It was established not only to advise the NAB staff and the Board of Directors in technical matters, but also to make your thoughts in all areas of engineering known to the industry and to the Commission. If you have a technical problem which may affect the industry as a whole, make it known to your NAB Engineering Advisory Committee. Let us hear from you. It is only through such feedback that we are able to represent you properly and adequately.

On behalf of myself and the other Committee members, I would again like to say it has been a privilege to serve as your spokesman on this important Committee.... We hope that our efforts have met with your approval.

The Use of Satellites in Television

MODERATOR: James D. Parker
CBS Television Network
New York, N. Y.

PANELISTS: John H. Gayer
General Electric Missile & Space Division
Valley Forge, Penna.

John Serafin
American Broadcasting Company
New York, N. Y.

Robert D. Briskman
Communications Satellite Corporation
Washington, D. C.

A. M. Greg Andrus
National Aeronautics & Space Administration
Washington, D. C.

MODERATOR PARKER: The general subject of communications satellites is a fascinating and exciting story which could be discussed for hours and it is a subject which has many ramifications and implications for the future of communications. Now, we are going to limit our discussion to "The Use of Satellites in Television." Even so, in the short time which is available to us, we can only cover the highlights —those features which are of greatest interest to us in the broadcasting industry.

Before proceeding, however, I would like to take a moment to introduce the members of the panel. First will be John Gayer, who is Program Manager of the Communications System of the General Electric Company, Missile and Space Division, Valley Forge, Pennsylvania. He will discuss a particular technical facility of great practical value for the broadcaster. Next is John Serafin. He is Manager of Quality Control of the ABC Engineering Department and he will discuss some practical operational problems. Thirdly will be Robert Briskman who is Manager of Domestic and Special Projects Office of COMSAT and he will discuss some proposals of interest relating to TV distribution systems. The final presentation will be by Dr. A. M. Greg Andrus. He is Chief of the Communications Programs, Space Applications Programs of the National Aeronautics and Space Administration (NASA). He will discuss some of the possible applications of broadcasting from space.

The increasing use of satellites for the purpose of intercontinental relaying of television programs has done more to enhance the general public's awareness of communications satellites than any other application of this rapidly advancing technology. The byline "via satellite" is appearing on home television screens with increasing frequency. Although communications satellites are being used to provide a number of other services, none of these other applications has had such a direct and dramatic impact on the general public. The objective of this panel presentation is to

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discuss briefly the current status of communications satellite technology, and its present and planned application, particularly with respect to television. The purpose of this introductory presentation is to review some general background information which will serve to put into perspective the presentations to follow.

Interesting though it might be, time does not permit a discussion of the history of communications satellites. Let it be pointed out simply, however, that the concept of using orbiting earth satellites for communications purposes is over two decades old, having been proposed as early as 1945; but with the launching of the Russian Sputnik in October, 1957, the possibility became a reality, because the practicability of launching a man-mad satellite into earth orbit had been demonstrated. From then on it became a two-pronged-extension of known technology. On the one hand, there was the problem of developing increased launch capability (i.e., the ability to put larger satellites into more precisely defined and useful orbits); on the other hand, there was the question of applying known electronic technology to developing appropriate communications satellites and associated earth terminals. The political, regulatory, economic, and social issues which have been raised by this new method of communications, both internationally as well as domestically, are very complex and must be recognized, but it is not the purpose of this panel to explore these nontechnical matters.

Initially, some of the earlier satellites were "passive"; i.e., simply reflectors. Echo I and II, launched in 1960 and 1964, respectively, were of this variety. However, for practical purposes, all communications satellites now in use are of the "active" type; i.e. they receive signals transmitted from the earth on one frequency, transfer them to another frequency where they are amplified and redirected back to earth. Early U.S. active satellites were Score and Courrier, launched in 1958 and 1960, respectively, and the Telstar and Relay series launched between 1962 and 1964.

The electronic equipment on a satellite is normally solar-powered; experiments have indicated that solar power may be practical up to the 50- to 100-KW range. On the other hand, for station-keeping purposes (i.e. to maintain the satellite in proper orbit and in proper orientation), satellites are normally equipped with some form of chemical jets, the action of which may be controlled from the ground. These jets require fuel, which is a consumable item, and is one of the factors which determines the life of a satellite.

With regard to orbit, satellites have been employed in a variety of orbits—polar, inclined, and equatorial. These orbits may be circular or elliptical; and may be of high, medium, or low altitude. However, for practical, commercial application, an orbit which is equatorial and circular, and at such a height—22,300 miles—that its angular rotation is the same as that of the earth, has many advantages. Such a satellite is said to be a "geostationary" or "synchronous" satellite, since from the earth it appears to be at a fixed location over the equator. The first successful launch of this type of satellite was Syncom II in July, 1963. The principal advantage of such a satellite is that the orientation of the antennas of the earth stations remains fixed—there is no requirement for the earth station to track a moving satellite. There is an exception to this condition, as will be discussed later, when the earth station is mounted on an unstable platform, such as a ship afloat in the ocean. Under these conditions, a tracking requirement is imposed on the earth station—but for a different reason.

So that there may be a better appreciation of the complete picture, one should be aware that communications satellites are being used for both military and peaceful purposes. According to published information, the U.S. military services deployed, during the years 1966-1968, some 25 sub-synchronous satellites in equatorial orbits, at approximately 18,000 miles above the earth, in the Initial Defense Communications Satellite Program, known as IDCSP. It is interesting to note that these satellites were deployed in clusters, up to seven at one time. They have been programmed to shut off at the end of 6 years. This system has provided a worldwide communication system for nontactical military purposes. It is understood that a replacement synchronous system has been planned for the early 1970's when the IDCSP system is automatically phased out.

The military recently announced the deployment of the first-satellite of its Tactical Satellite Communications System (Tacsatcom). This system is to provide a communications capability to military tactical elements such as ships, submarines, airplanes, trucks, jeeps, and even to individuals.

To study the application of satellites for peaceful purposes, the National Aeronautics and Space Administration (NASA) requested the National Academy of Sciences to conduct a study on "the probable future usefulness of satellites in practical Earth-oriented applications." These studies, initiated in early 1967, were undertaken by eleven Technical Panels in the fields listed in Fig. 1. The reports of these Panels are now being released in published form.

Time does not permit discussion of these fields of no concern to broadcasting, but it is important to note the experimental work being done by NASA, because some aspects of this work do have a bearing on television. Experimental work in satellite technology and application tests in all these fields are being done or have been programmed through the NASA Applications Technology Satellite (ATS) project. Two satellites under this program are currently in orbit—ATS-1 and ATS-3; another is scheduled to be launched later this year, with two others scheduled to be launched in 1972/1973. As will be shown later, the two operational ATS satellites have been used for television purposes. Also, NASA has launched a number of near polar-orbit satellites (TIROS and NIMBUS) for use and experimentation in the meterologi-

APPLICATION OF SATELLITES

PANEL 1:	FORESTRY-AGRICULTURE-GEOGRAPHY
PANEL 2:	GEOLOGY
PANEL 3:	HYDROLOGY
PANEL 4:	METEOROLOGY
PANEL 5:	OCEANOGRAPHY
PANEL 6:	SENSORS AND DATA SYSTEMS
PANEL 7:	POINTS-TO-POINT COMMUNICATIONS
PANEL 8:	SYSTEMS FOR REMOTE-SENSING INFORMATION AND DISTRIBUTION
PANEL 9:	POINT-TO-POINT COMMUNICATIONS
PANEL 10:	BROADCASTING
PANEL 11:	NAVIGATION AND TRAFFIC CONTROL

Fig. 1

COMMUNICATIONS SATELLITES IN TELEVISION

RELAY	RELAYS PROGRAM MATERIAL POINT TO POINT BETWEEN RELATIVELY FEW FIXED LOCATIONS
DISTRIBUTION	DISTRIBUTES PROGRAM MATERIAL TO EARTH TERMINALS WHICH DELIVER IT TO LOCAL BROADCAST STATIONS, EITHER DIRECTLY, OR INDIRECTLY THROUGH TERRESTRIAL CIRCUITS
BROADCASTING	BROADCASTS PROGRAM MATERIAL FOR RECEPTION BY INDIVIDUAL OR MASTER RECEIVING INSTALLATIONS

Fig. 2

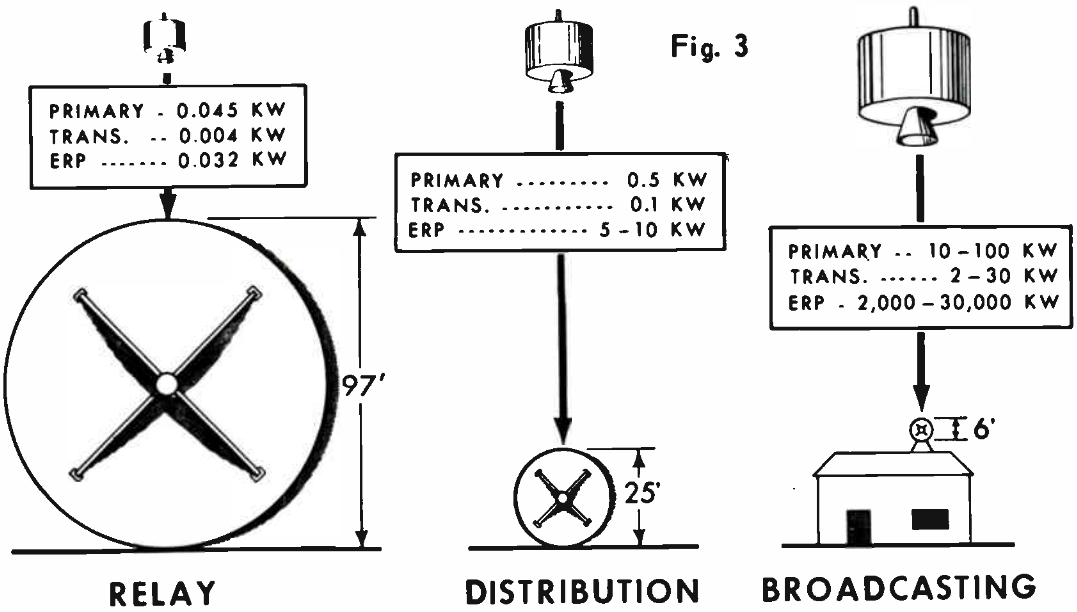
cal field. These low altitude satellites are being used to transmit, on a daily basis, cloud cover pictures back to earth which are being used for weather reporting.

Returning now to the use of satellites for television, of the eleven application fields shown in Fig. 1, there are two which are of direct interest to the broadcasting industry: (a) Point-to-Point Communications; and (b) Broadcasting. Within the field labeled "Broadcasting," various sub-definitions have been proposed. From an industry point of view, however, it is helpful to generalize the applications related to television broadcasting, included in these two fields, into three broad categories listed in Fig. 2.

From a technical point of view, the essential differences among these three television applications revolve around trade-offs between satellite effective radiated power and earth station capability, for the transmission loss between a point on the earth and the synchronous satellite is constant for a particular operating frequency. On the one extreme, for the relay application, relatively low power can be used in the satellite (e.g. 4-10 watts of RF power at 4,000 MHz) as long as the earth station employs a large dish (97 feet) and sophisticated, low-noise receiving equipment, but such earth stations cost between 3 and 6 million dollars. At the other extreme, for broadcasting, in order for the receiving station to be inexpensive and relatively simple in configuration, the burden must be placed upon the satellite and substantially higher power is required in the satellite; i.e. of the order of 10-100 KW of primary power if conventional modulation is to be employed. Fig. 3 illustrates these differences graphically.

As of this point in history, the only application of satellites available for commercial television use in the United States is the relay mode; i.e. for long-distance transmission of television programs to and from points outside the continental limits of the United States. This service is normally provided by the International Telecommunications Satellite Consortium, known as Intelsat, which was organized in 1964, to establish a Global Commercial Communications Satellite System. This Consortium now consists of 68 member countries. The development of this system will be reviewed, but it should be noted in passing that prior to the recent expansion of the capability of the space segment of the Intelsat System, NASA made available its ATS satellites for the transmission of television programs of worldwide interest, such as the Apollo 7, 8, and 9 recoveries, the 1968 Olympics, and the Papal visit to Columbia.

SATELLITE POWER VS EARTH STATION ANTENNA REQUIREMENTS



The Intelsat Global System was established on the basic concept that a synchronous satellite covers roughly one-third the area of the earth, except for the extreme northern and southern latitudes. This then calls for three groupings of satellites: one over the Atlantic Ocean; one over the Pacific Ocean; and one over the Indian Ocean. As of now, Intelsat satellites are operational only over the Atlantic and the Pacific Ocean, so that only those two segments of the Global System are currently in operation. The first Indian Ocean satellite is scheduled to be launched later this year.

The Intelsat System as it is now configured is shown in Fig. 4A; this map also shows the satellites and earth stations projected through 1969. As of now there are 13 earth stations operating in the Atlantic Ocean segment and 8 earth stations operating in the Pacific Ocean segment, for a total of 21 operating earth stations. By the end of 1969, the number of Atlantic Ocean earth stations will be increased by 6 for a total of 19; the number of Pacific Ocean earth stations will be increased by 3 for a total of 11; and 10 earth stations will be operating in the Indian Ocean segment. Therefore, by the end of this year, the total number of operational earth stations will be increased to 40.

Looking further into the future, Fig. 4B shows the additional earth stations currently projected through 1972. By that date, 20 additional stations will be operating in the Atlantic Ocean segment, 6 additional stations in the Pacific Ocean segment, and 12 additional stations in the Indian Ocean segment, making a grand total of 78 earth stations in 54 countries throughout the world that will be operational by the end of 1972. These figures do not include 3 non-standard stations currently in operation in Ascension Island, the Canary Islands, and Australia.

Intelsat is responsible for and is the owner of the space segment of the Global System; i.e. the synchronous satellites. The first Intelsat satellite, designated as Intelsat I, but generally known as Early Bird, is stationed over the Atlantic and has been providing commercial service between North America and Western Europe since the middle of 1965. Intelsat I is graphically illustrated in Fig. 5. Note that it employed a "squinted" antenna; i.e. its coverage was limited to the Northern Hemisphere.

The Pacific Ocean segment of the Global System became operational with the first successful launch and orbit of one of the Intelsat II series of satellites in January, 1967, over the Pacific Ocean. An earlier attempt to launch an Intelsat II satellite failed when the satellite did not go into proper orbit. Later that year, March, 1967 and September, 1967, two additional Intelsat II satellites were launched, one over the Atlantic and one over the Pacific. Up until last fall, there were then a total of four operational Intelsat satellites, two over the Atlantic Ocean and two over the Pacific Ocean. Intelsat II is graphically illustrated in Fig. 6. The circuit capacity of Intelsat I is the same as that of Intelsat II, but the latter satellite covers both hemispheres.

The next series of Intelsat satellites, Intelsat III, had significantly greater capacity. Intelsat III is graphically illustrated in Fig. 7. This satellite has a television capacity equivalent to four television channels. It is expected that one of these channels will be set aside to be available for television use; the remaining capacity will normally be used for other forms of traffic. The first launch of this series failed, but the second Intelsat III was successfully positioned over the Atlantic Ocean in December, 1968. Another Intelsat III satellite was placed in geo-stationary orbit in the Pacific in February, 1969. Additional Intelsat III satellites will be launched this year for positioning over the Indian Ocean and the Atlantic Ocean. When these satellites become operational, the Indian Ocean segment of the Global System will be operational and the Atlantic Ocean segment will have its capacity considerably increased.

As to the future, a contract has been placed for a new series of satellites, Intelstat IV. This satellite is considerably more sophisticated and has substantially greater capacity than its predecessor. Intelsat IV is graphically illustrated in Fig. 8. Besides having normal earth coverage, this satellite also will have two steerable dish antennas which provide narrow "spot" beams that can be pointed on command at specific areas of heavy traffic. The first of this series is planned for a 1971 launch.

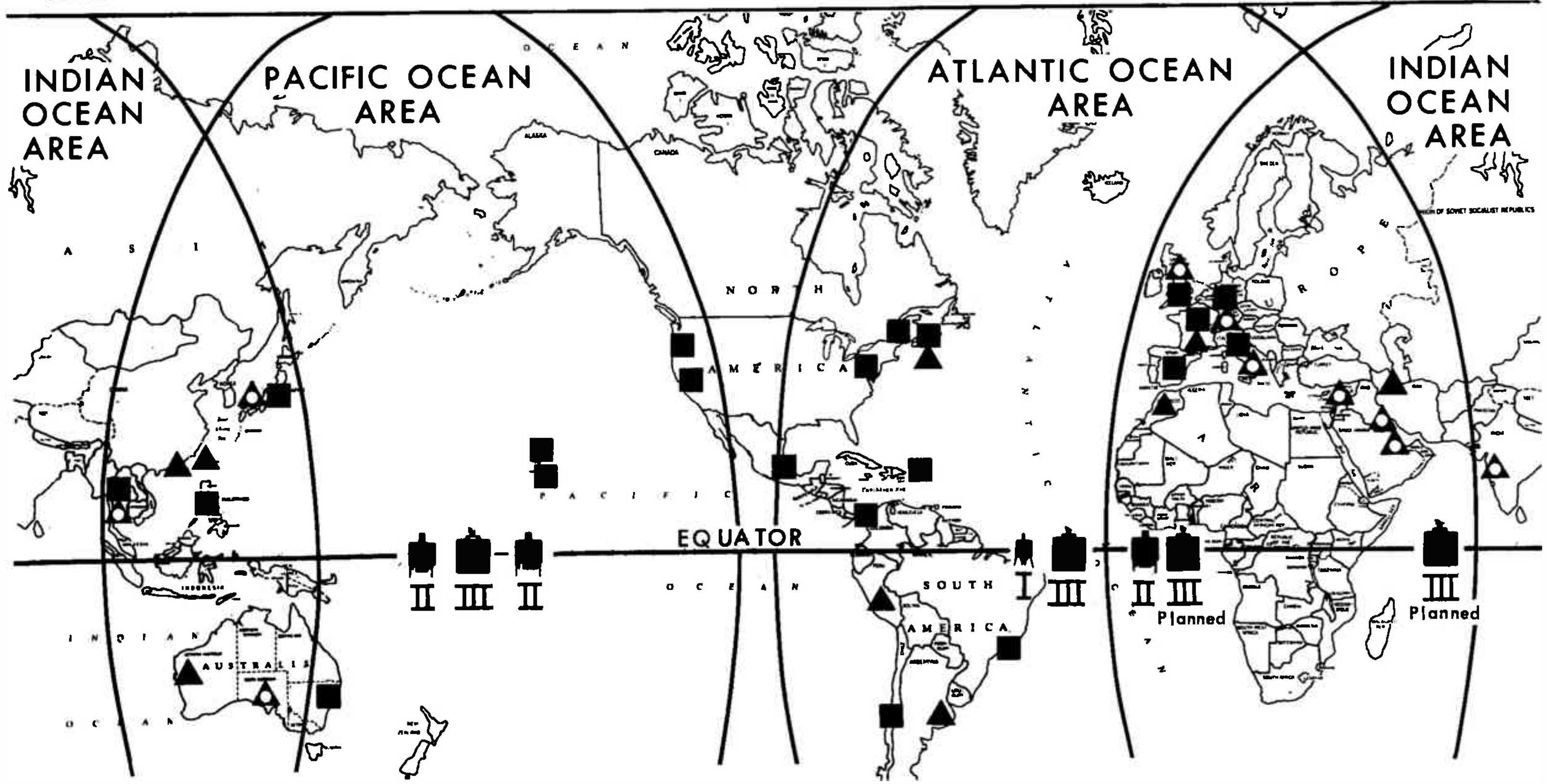
The principal physical features and operational capabilities of the several Intelsat satellites are summarized and listed for comparison in Fig. 9.

To recapitulate, the map shown in Fig. 10 illustrates the date of launch, current equatorial positioning, and identity of all synchronous satellites, excluding military satellites, that have been launched, or are to be launched in 1969, by the United States, and which are still operational. Although Intelsat operates the space segment, the earth stations are owned and operated by the member countries. In the United States, the earth stations are jointly owned by Comsat and the international common carriers.

Comsat, the Communications Satellite Corporation, was incorporated on February 1, 1963 under the provisions of the Communications Satellite Act of 1962. It is a private corporation, and was 50% owned by the public and 50% owned by the United States international common carriers. Comsat was designated by the United States Government to represent the United States in Intelsat. Under the terms of the multilateral Agreement Establishing Interim Arrangements for the Global Satellite System (Intelsat), Comsat was designated to act as the manager in the design, development, construction, establishment, operation and maintenance of the space segment of this system. A formal conference was convened in Washington, D.C. on February 24, 1969 to review and revise the Interim Arrangements. Although not members of the Intelsat Consortium, several eastern European countries sent observers to this Conference. The Conference recessed after four weeks, following an exchange of views, and is to reconvene in November, 1969.

Fig. 11 is a photograph of the United States earth station at Etam, West Virginia.

THE INTELSAT GLOBAL COMMERCIAL COMMUNICATIONS SATELLITE SYSTEM



EARTH STATIONS	
OPERATIONAL -	■
OPERATIONAL - 1969	▲

NOTE: SYMBOL WITH DOT DENOTES INDIAN OCEAN AREA

Fig. 4A

THE INTELSAT GLOBAL COMMERCIAL COMMUNICATIONS SATELLITE SYSTEM

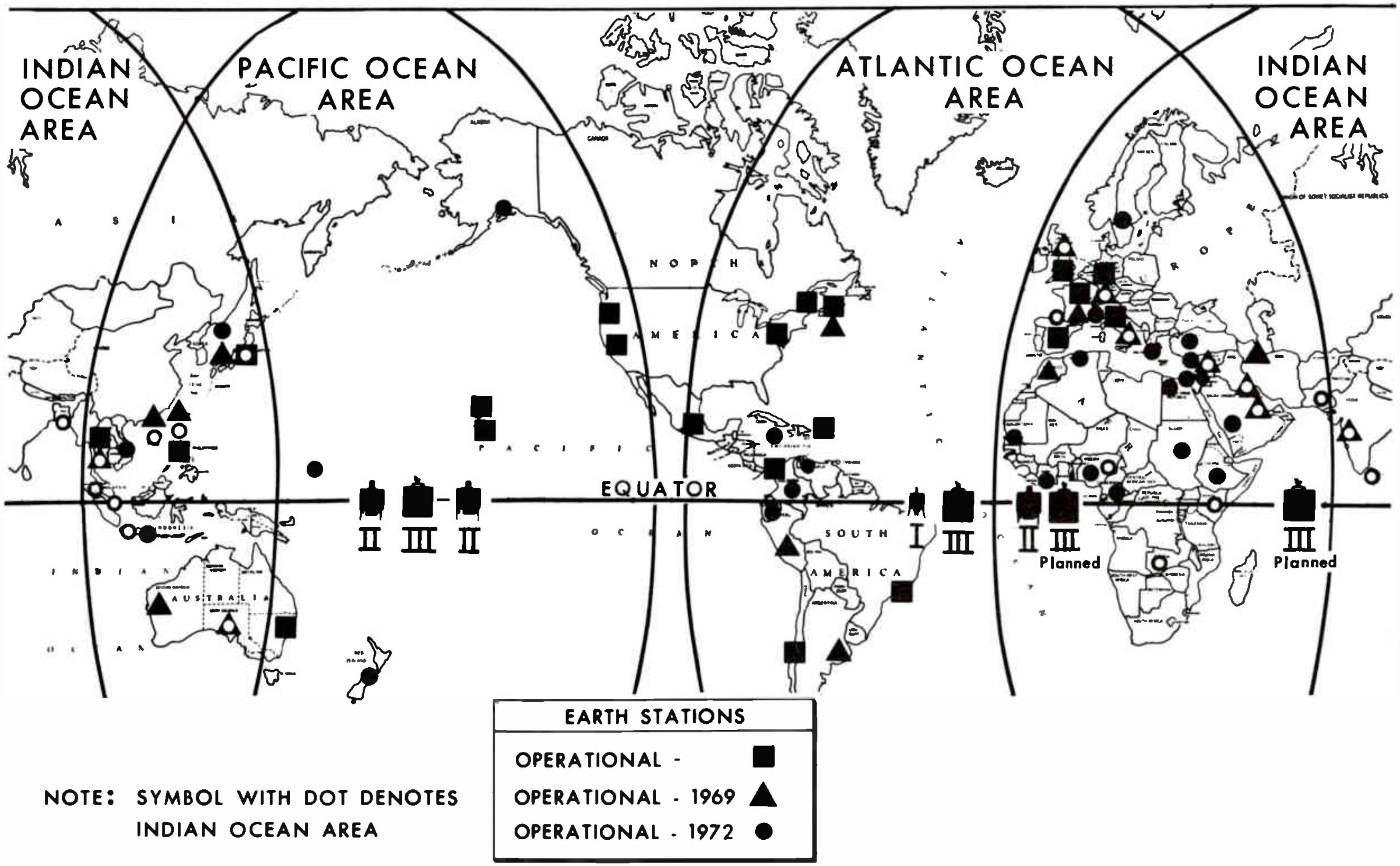
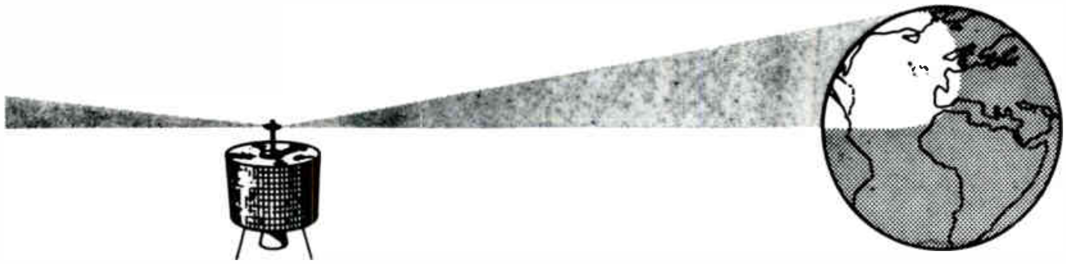
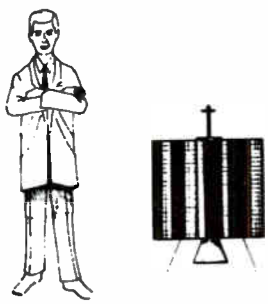


Fig. 4B

INTELSAT I

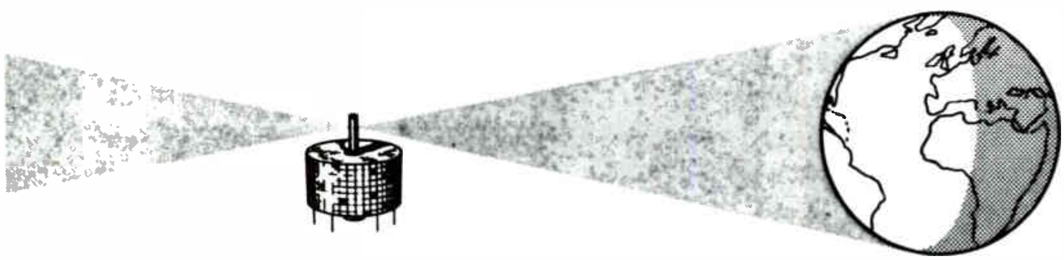


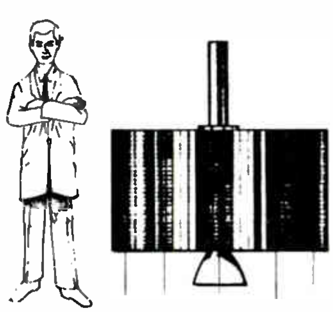


- LAUNCHES
  APRIL 1965
- CAPACITY
  240 VOICE CIRCUITS
- FINAL ORBITAL WEIGHT
  85 LBS

Fig. 5

INTELSAT II

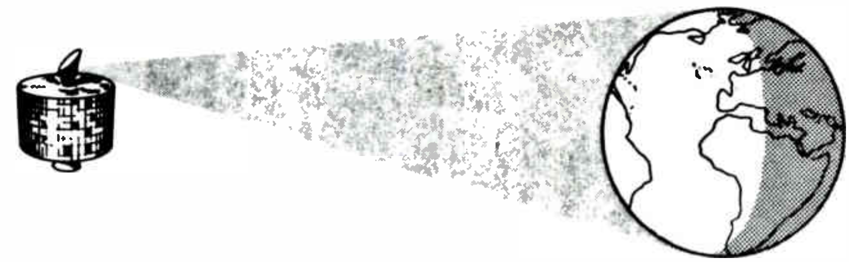


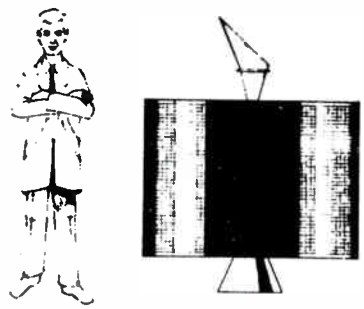


- LAUNCHES
  OCT 1966
  JAN 1967
  MAR 1967
  SEPT 1967
- CAPACITY
  240 VOICE CIRCUITS
- FINAL ORBITAL WEIGHT
  190 LBS

Fig. 6

INTELSAT III

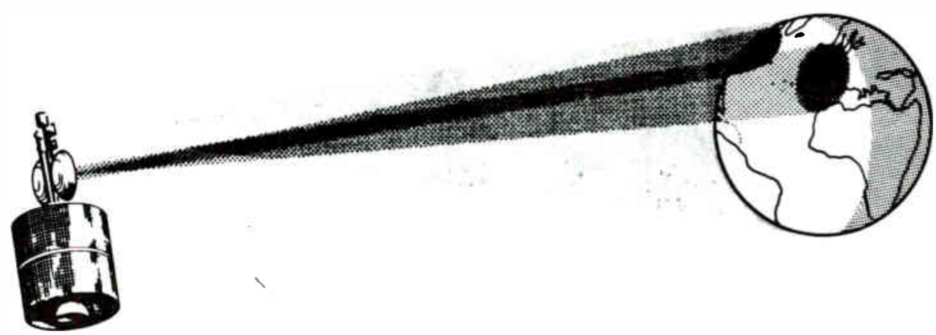


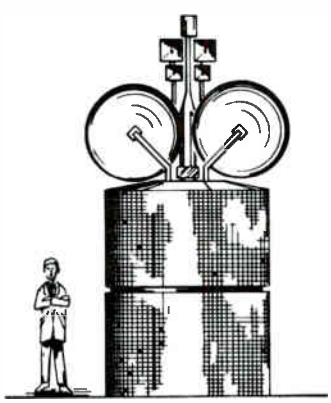


- LAUNCHES
  - SEP 1968
  - DEC 1968
  - FEB 1969
  - —— 1969
  - —— 1969
- CAPACITY
  - 1200 VOICE CIRCUITS
- FINAL ORBITAL WEIGHT
  - 322 LBS

Fig. 7

INTELSAT IV





- LAUNCH
  - 1971
- CAPACITY
  - 5000—8000 VOICE CIRCUITS
- FINAL ORBITAL WEIGHT
  - 1200 LBS

Fig. 8

Fig. 9 ITEM	INTELSAT I (Early Bird)	INTELSAT II	INTELSAT III	INTELSAT IV
Diameter, inches	28.4	56.0	56.0	93.0
Height, inches (overall)	47.1	51.0	78.0	193.0
Weight, lb. (in orbit)	85	190	322	1200
Design Lifetime (Years)	1-1/2	3	5	7
Total two-way telephone circuits	240	240	1200	5000 to 8000
or TV Channels	1	1	4	12

SYNCHRONOUS SATELLITES IN ORBIT

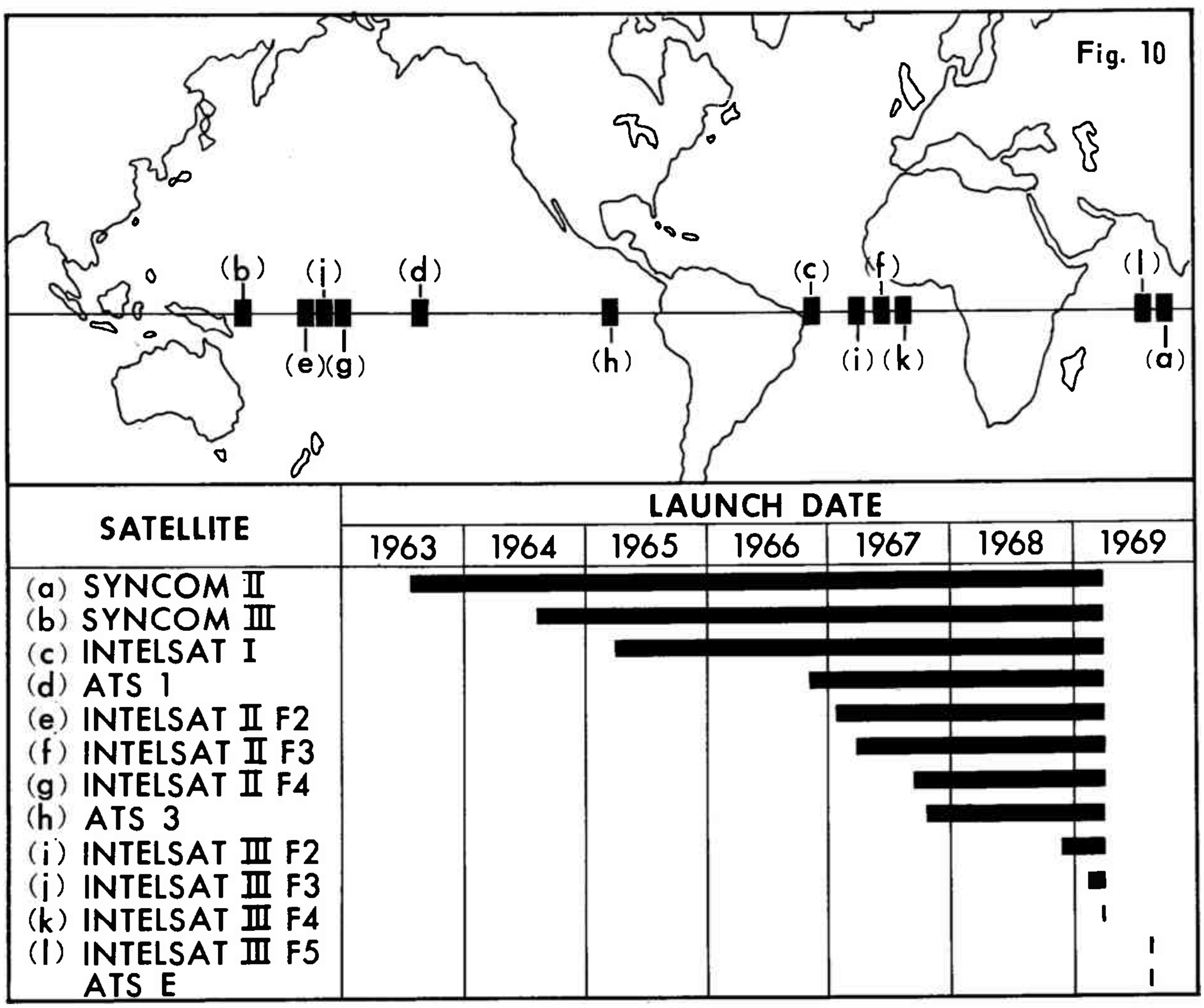


Fig. 10

It can be seen that the station is so situated that it is surrounded by hills to provide shielding from terrestrial radio frequency interference. Fig. 12 is a photograph of the 97-foot dish mounted on a pedestal behind the building. The overall height exceeds that of a 10-story building. Fig. 13 is a side view of the dish, the total weight of which is about 470 tons. Fig. 14 is a view of the operating console at the Etam station, and Fig. 15 shows the television operating center (TOC) in a nearby room. Fig. 16 is an exterior view of the United States earth station at Cayez, Puerto Rico, and Fig. 17 shows the 97-foot dish associated with this station.

The ability to present to the United States television viewing public important news events occurring elsewhere throughout the world, where the value of immediacy is of paramount importance, has always been of interest to the television networks. This capability was demonstrated very early when experimental relay transmissions of television programs between the United States and Europe were conducted with the Telstar nonsynchronous satellite in 1962. Subsequently, the Relay satellite, also nonsynchronous, was used to transmit overseas events relating to the Kennedy assassination in 1963, and the Syncom satellite was used in 1964 for transmission of the Winter Olympics from Japan.

With the introduction of commercial satellite service through Intelsat in mid-1965, even though it was necessary to remove all other services from the satellite circuit in order to accommodate television, because of the limited capability of the satellite, a total of 36 hours of television programming was transmitted via satellite. This figure rose to 81 hours for 1966, to 225 hours for 1967, and to 666 hours for 1968.

However, now that a channel is available for television transmission on a full-time basis in the Intelsat III series of satellites, it is anticipated that use of these circuits for this purpose will increase. This expected increase has already been indicated; for example, the total number of hours used for television transmission in the first two months of 1969 has already reached 120 hours. This increased usage has also been manifested in one other way. Prior to this year, all transmission of television programs through the Intelsat System either originated or terminated in the United States. This is no longer true, as, for example, television programs have been exchanged between Europe and South America.

A natural by-product of the increased capability of the Intelsat System is a signifi-

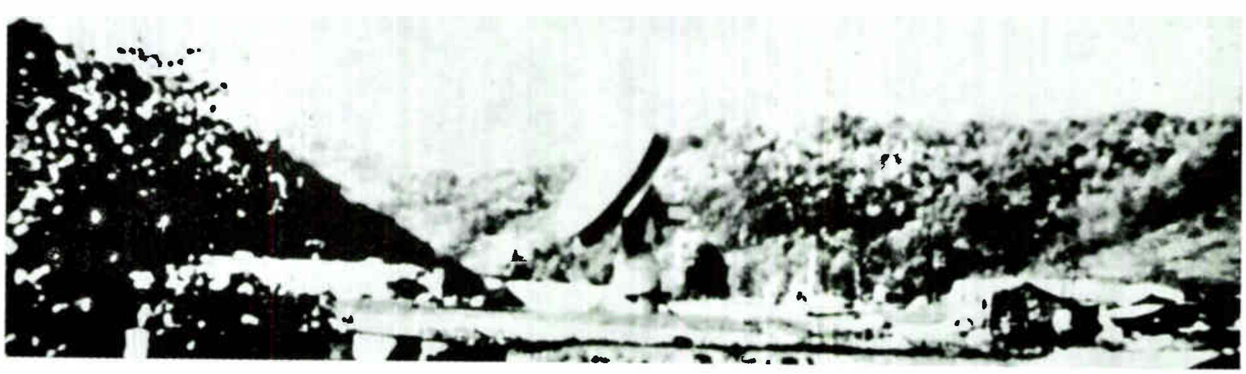


Fig. 11

cant reduction in transmission costs to the consumer. While it is not intended to dwell upon the specifics of transmission cost, there is one point which should be understood. The total transmission path from, say, a New York television network headquarters to, say, a European television program distribution point really involves four separate segments: (a) the terrestrial circuit from the New York "gateway" to the United States earth terminal; (b) the link from the United States earth terminal to the satellite; (c) the link from the satellite to the European earth terminal; and (d) the terrestrial circuits from the European earth terminal to the European equivalent of the gateway. Thus the total cost for the circuit is derived from rates established over four separate, individual segments, only two of which are subject to United States control; that is, from the gateway to the earth station, and from the earth station up to the satellite. The terrestrial circuits within the United States are the responsibility of our domestic common carriers. The circuit from the United States earth station to the satellite is purchased by the broadcasters from the United States international common carriers, which in turn purchase it from Comsat. The procurement of a satellite circuit, therefore, is not entirely a simple matter.

The expansion of the Intelsat System, both in capacity and in worldwide geographic coverage, has focused attention upon a technical problem of considerable concern—

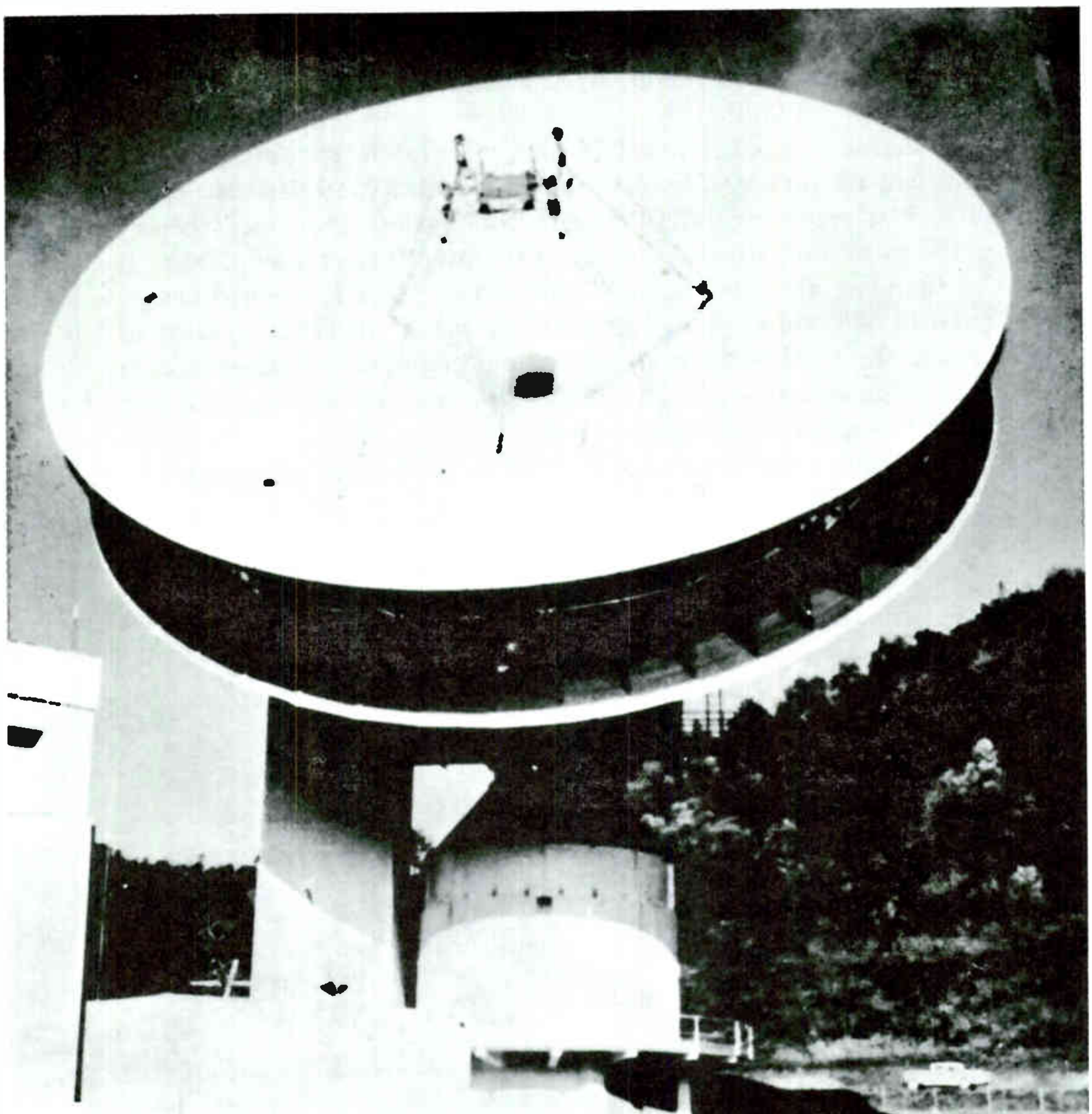


Fig. 12

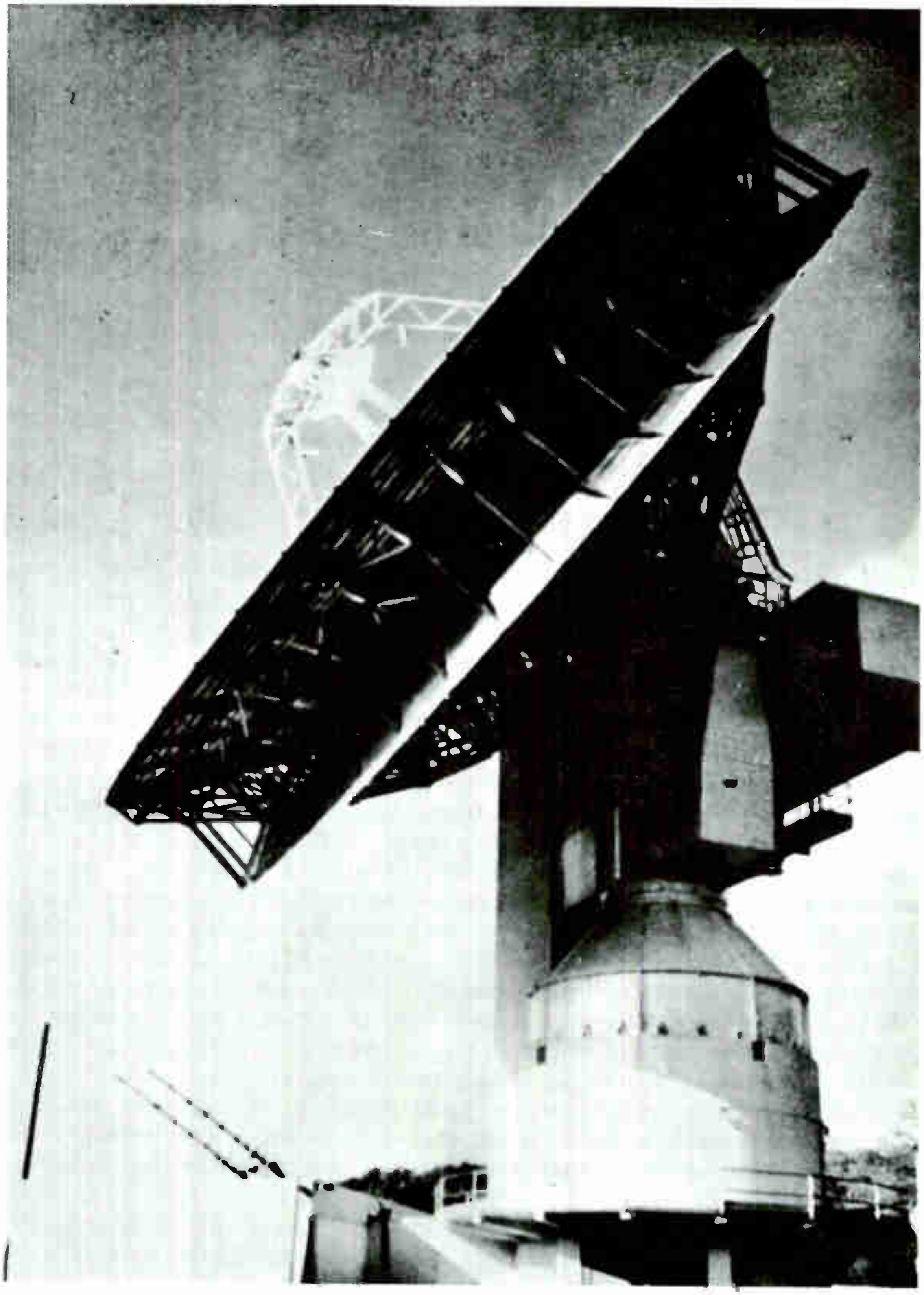
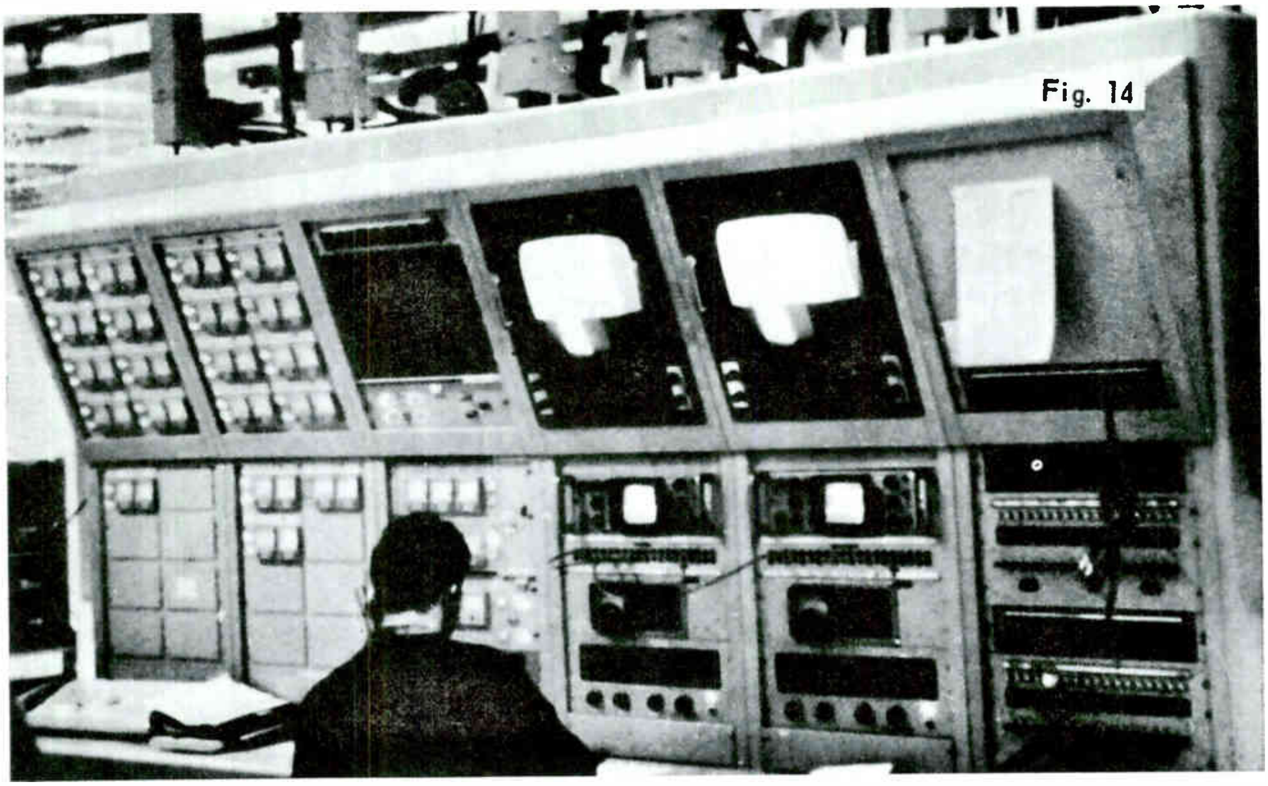


Fig. 13



the problem of standards conversion. How much simpler it would have been if the countries of the world had been able to agree upon uniform standards. The questions of who should be responsible for conversion, where it should be done, what technology should be used, are all now under active consideration. The problem becomes increasingly complex when one considers that as the number of earth terminals increases, the requirement for multidestination transmissions will increase.

Ever since the long-distance transmission capability for television by satellites was first demonstrated, the newsmen envisioned the possibility of a new tool for "electronic journalism"—a transportable transmission facility which could be transported by air on short notice to any location in the world for the purpose of providing news coverage of major events of international importance. Even though the developing Intelsat System will ultimately provide the capability to reach a greater number of remote points of the globe, there will undoubtedly be points not readily accessible to an Intelsat earth station. A good example of this, of course, is a requirement to provide coverage from a point at sea—the Apollo recoveries. Another example would be to provide coverage from a land-based point where facilities do not exist for providing a terrestrial circuit between the point of origination and an Intelsat earth station in the same, or even a nearby country.

In the past, such events were handled on an individual, or special case basis. For example, for the Gemini recoveries, IT&T placed one of its earth terminals on the deck of an aircraft carrier. The dish was installed on a mount modified to track the synchronous satellite, to counteract the pitch and roll of the aircraft carrier. Although the transmitted pictures were not in color, the feasibility of the concept was first demonstrated. In August of 1968, the Hughes Aircraft Company flew a transportable earth station to Bogota, Columbia, where it was set up to provide television coverage in color of the Pope's visit.

More recently the networks' dream of having an earth station, which could be transported in a single commercial airplane and which would be capable of transmitting television programs in color, available on relatively short notice, has been realized. Mr. John Gayer will now tell the story of this interesting and spectacular development. It was through his optimism and perseverance that this facility was assembled in record time to provide color coverage of the Apollo 7 recovery in the Atlantic Ocean using the ATS-3 satellite, and which was also used for the Apollo 8 recovery in the Pacific Ocean with the ATS-1 satellite and for the Apollo 9 recovery in the Atlantic Ocean.

MR. GAYER: Thank you, Jim. I highly appreciate the honor to be with you and I am deeply grateful to you, Jim, for your invitation and the introduction.

I will be talking about the special application of relay through satellites. It was Jim's foresight, confidence and continued cooperation that made it possible for GE to televise in real time the Apollo splashdowns. This service was provided for the television networks through a contract with Western Union International (WUI).

I want today to share with you my enthusiasm, experience and convictions for the use of small communication satellite terminals for television relay and distribution, particularly today for the relay of special events, bringing world events to all peoples in real time, for the whole world to share the great accomplishment of Apollo flights and splashdowns and other great world events.

We often see rapid technological growth and success confronted and stalled by frustrations of lack of policy decisions and legislative action. G.E. welcomed the opportunity to contribute by making it possible to televise for the world to view the Apollo splashdowns.

Excellent quality color television pictures of the Apollo 7, 8, and 9 recoveries have been relayed from three aircraft carriers, two in the Atlantic and one in the

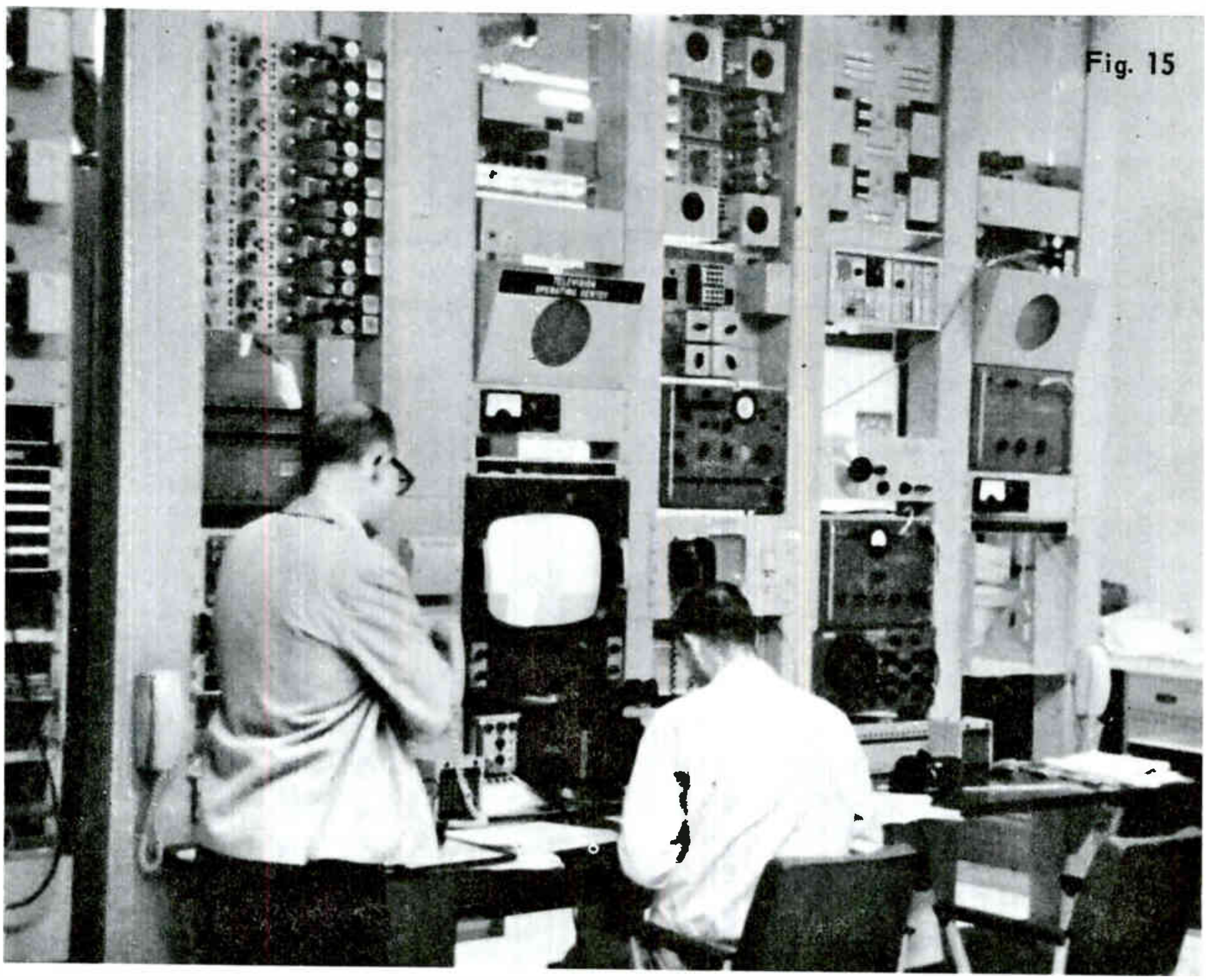


Fig. 15

Fig. 16

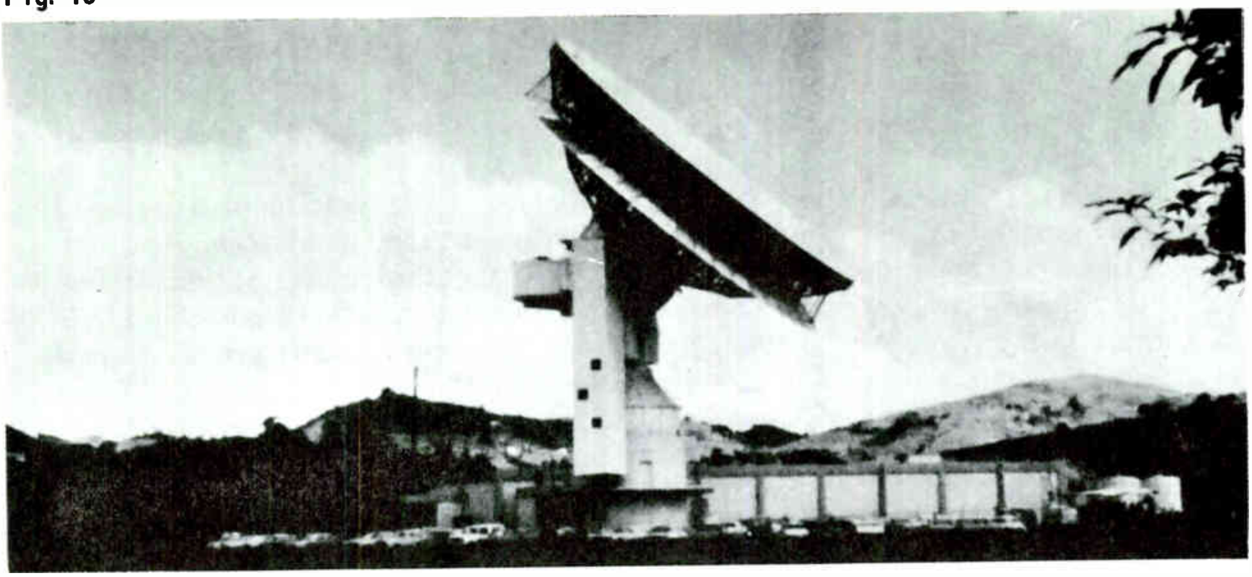


Fig. 17

Pacific, using a small GE portable communications satellite terminal, "Transatel," which employed a 15-foot antenna. May I take a moment to quote the wife of one of the astronauts on the splashdown: "I have never seen it so good. I couldn't believe that the communications and pictures could be so good. We screamed and clapped our hands."

We also like what Jack Gould of the New York Times wrote: "The steadiness of the picture, even when the Guadalcanal altered course or felt the swells of the sea, was nothing short of remarkable, virtually studio quality."

We were not sure of success late last August. It was the last Friday of August. a little over six months ago and six weeks before the station needed to be put on the Carrier Essex if the Apollo splashdown of 7 was to be televised. We got together and produced a small terminal suitable for this installation. In discussing this development with Jim Parker, John Serafin, and others, we determined that the small terminal that we had been working on in collaboration with NASA would be suitable for this mission. However, we needed six months to put it together, not six weeks.

The stabilization mounts, the high-power transmitters, the monopulse tracking receivers and their devices all had to be assembled and made available for putting on the ship.

The challenge was there and we are pleased that we were successful in meeting it and we went forward with a contract through Western Union International to provide this service for the three networks.

It was in 16 days that we were given the go-ahead to put this station together, construct some parts that were still missing and get it aboard the Essex. The carrier went to sea on Monday the 7th of October with our terminal and crew aboard. We still had some problems to work out and still some testing to do.

Success was possible through the technical competence and devotion of the crew, the crews that we put on board and the collaboration and crews of the networks, Western Union International, NASA, Comsat, the Navy, subcontractors, et cetera.

I will bring the story to you with the following illustrations showing the few extracts of the three Apollo transmissions that were made.

As Jim mentioned, this was done in 1963 and I was proud to be a part of the first one that was done internationally when the ITU space radio conference was televised to New York for the participation of Secretary General U Thant on that time. That was my first experience with this type of operation.

The Transatel station (slide*) which stands for Transportable Satellite Telecommunications Terminal, a small communications satellite terminal portable for special events and fixed with a stabilization for it on shipboard for the Apollo splashdown relay of television.

The key to the development of this portable station was an antenna (slide) that we developed for NASA at the Goddard Space Flight Center. This is to show the transparency of this antenna looking through it. It is folded up like an umbrella. Here (slide) is the tripod it works on. It weighs something like 85 pounds, and total with the mount and so forth it is 195 pounds. You put it in a vertical position and crank it out (slide). It is now automatically crankable down by the use of automatic motor controls.

This is the first model (slide). As you crank it down, it goes into a 15-foot parabola. You see it here (slide) at Goddard being put into position for its initial test. The feed (slide) is the only adjustment necessary for the use of different satellites and the feed that we now have on it is unpluggable and changeable so that it is useable with ATS-I, III or Intelsat 2 or 3.

This is the first demonstration (slide), which was a joint demonstration, on the occasion of the IEEE International Communications Conference in Philadelphia last June. This was set up to demonstrate the portability and practicability of the small terminal in the center or wherever you wanted to operate. This was set up on the ice skating rink right near the exhibit in the Center of Philadelphia. It was hauled in on Monday night, set up Tuesday morning and put in operation and locked onto the satellite by eleven o'clock, something like two hours from the first, should we say, field installation to operation.

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*The slides for Mr. Gayer's presentation were unavailable.

It was also demonstrated at the Smithsonian Institute by NASA and this (slide) is the second model of the bubble where you have a top on it a little higher and to keep off some of the reflections from the sun. The transparent bubble you saw in the other slide was particularly for demonstration. This one also is clear for demonstrational purposes but does keep some of the sunlight off. It gets very hot in there and it's a heavy load for air conditioning.

Here is the diagram (slide) of the concept that we worked out last August for relaying the Apollo splashdown where we took the small terminal, put it on the ship stabilized, took the camera feed of the Apollo as it was coming down from space and landing in the Atlantic and putting that feed into the antenna, going up to the ATS-3, in this case, and down to the communications satellite Etam station, feeding across by microwave to the New York Center, the Communications Satellite Corporation being responsible for the space link, through Western Union International who had the contract for the service. Of course before we said it would work we went through the normal space link calculation (slide) where you calculate the db's required to have a satisfactory service and you increase your power, increase the size of the antenna so that you obtain the necessary signal strength to insure a quality picture. I will not take time to discuss all these figures except to mention to you that the 15-foot antenna is a 46 db antenna and, if some of you wish to discuss these in a little more detail afterwards, and also, of course, the paper will be published.

Here are the uplink and downlink calculations (slides) for this particular circuit as conceived and proposed to the networks through Western Union International last August and most of the figures we found were exceeded and perhaps that was why we had better color in the result.

The terminal consisted of the 15-foot paraboloid dish (slide) which folded up like an umbrella, the tracking mount, the satellite beacon, receiver-tracking beacon, the air feed plastic bubble and the antenna feed. There is the transmitter and its assembled equipment as well and then there was, of course, the receiving equipment (slide) that went with the monopulse receiver for tracking.

We had three ways of tracking. You could crank and hope you were on the satellite and get a feedback from the receiving ground station. You could use a gyroscopic type of mount where if the ship moved the antenna stayed fixed on the satellite, and this was necessary in case the satellite was lost when the ship bridge came in between the small terminal and the satellite itself.

Here is the terminal (slide) as put together in a packing crate in the back of the building. We couldn't even get delivery of a van to put it in in the first instance, so we took a packing crate in the back of the building and put the station in it for the first case. We took another bubble. These bubbles are swimming pool covers but this one we had the factory out in California work a little slower and take a couple of weeks and make us one that was a little more reflective to the sun and a little more protective for the crew. The power generator is on the right and the VHF antenna is on top of the van itself. The slide shows the equipment on the truck.

This is on board the carrier (slide) where you have the beacon mount which is another thing we had in the GE plant ready to be covered with the bubble so that it could be blown up. This beacon was used in our plant for laser measurements and was modified with the necessary stabilization and monopulse receiving tracking devices so that we took again something we had available to meet this critical delivery date. You see the power generator, emergency power in the back.

In this slide it is blowing up now. You will see a little better view of the ship, next to the bridge, and this inflatable bubble is taking on size and shape. In the next slide it is now blown up and the antenna has been taken through the airlock door and put on its pedestal inside and erected inside the bubble.

The first test (slide) shows a picture of the station as it is aboard the ship. The color bar that was taken (slide) at the ground station in the United States and, of course, the camera that took the picture (slide) from the ship itself.

This was the terminal (slide) that was used on Apollo 7, at Etam, just to note here the comparison of size of these two antennas and the facilities that went with it. We are talking about at Etam something like 5 million. Here is something less than a $500,000 station.

The test patterns (slide) that were taken in Etam of the testing that went on. Continuous testing was necessary, particularly in the first phase and on the ship after we went to sea.

Special events (slide) is what we are interested in furthering, not just the Apollo but the special events that happen around the world. Here is one slide that we are particularly interested in. It's a splashup known as the Tektite underwater sea station in the Virgin Islands off the coast of the Isle of St. John. There is a small station down there under water which will splash up on the 15th of April. Our proposal is that this small station be put on a barge next to this and when this splashup comes it can be again televised to the satellite for television news and also for the NTC conference that will be here in Washington with a small terminal located here in Washington to show the use of two small terminals up and down, a complete circuit by satellite ATS-3 using the small terminals.

This was for data, telephone, like the Philadelphia demonstration, as well as one-way television. This may not be realizable now because of conflicts in schedule but this was something that was certainly feasible from a technical point of view and this demonstrates special events which we would like to have you all see the great possibility for using small terminals for. In this respect I would like to show you a little bit how the transportable station will look (slide). It's a standard air van that goes into a Boeing 707 or DC-8. It's a standard van and the equipment will be put in two vans so that it can go right on the aircraft and flown to wherever it may be used.

This is the rack of equipment (slide) inside the van in the model that is now in production. Also we have proposed a mobile van of this type (slide) where the antenna unfolds on the back of a small portable van and the equipment goes right in there on racks so it can be taken out of this van and put into the air-transportable mode or vice versa.

MODERATOR PARKER: Thank you, John. Our next speaker will be John Serafin who is going to discuss some of the technical operational problems which have been involved in the international or intercontinental exchange of programs via satellite. John.

MR. SERAFIN: Thank you, Jim. Fellow broadcasters, ladies and gentlemen. Because of numerous mutual problems, both operational and technical, which confronted the broadcasters in the United States and Canada, and carriers involved with international television transmissions, via the Intelsat satellite, a meeting was held early in 1967 to provide for liaison between the carriers and users involved in international television. The need for an international quality control committee was most apparent.

A committee was formed to resolve the problems associated with international television transmission, and by the third meeting the designation "Satellite Technical and Operational Committee-Television," or STOC-TV, was adopted.

The schedule of meetings is bimonthly. The chairmanship has continued to rotate alphabetically. However, the chairman's responsibility continues until the convening of an ensuing meeting and includes the preparation of an agenda for the next meeting. The incoming chairman sends out notices of the forthcoming meeting. In order to promote a more efficient functioning of the committee, a permanent secretary has been designated.

STOC-TV has two basic tasks:

1. To standardize operating and testing techniques so far as possible for current day-to-day satellite transmissions.

2. To standardize on a long-range basis the U.S. and Canadian approach on which to base international understanding and agreement, with recommendations to CCIR, CCITT and CMTT.

The following organizations are now represented on STOC-TV: ABC, AT&T, Canadian Overseas Telecommunications Corporation, CBC, CBS, CTV-TV, Comsat, FCC, Hawaiian Telephone Company, IT&T World Communications, NBC, RCAC, TransCanada Telephone System (represented by Bell Canada and Maritime Tel and Tel Company) and Western Union International.

Active subcommittees of STOC-TV are working on test signal standards, vertical interval test signals, operational procedures, test equipment, standards converters, glossary of technical terminology and chronic problems. In order for us all to better understand international television transmission. the following terminology should apply:

a) International television transmission—The transmission of television signals over the international telecommunication network for the purpose of interchanging television material between television authorities in different countries.

b) Television authority (send)—The television authority (broadcaster or user) at the sending end of the international television connection.

c) Television authority (received)—The television authority at the receiving end of international television connection.

d) International television center (ITC)—A center at which at least one international television circuit terminates and in which international television connections can be made by the interconnection of international and national television circuits. The ITC is responsible for setting up and maintaining international television connections and for the supervision of the transmissions made on them.

e) International television link—The unidirectional transmission path for television transmissions between the ITC's of the two terminal countries involved in an international television transmission. The international television link comprises one or more international television circuits interconnected at intermediate ITC's.

f) International television connection—The unidirectional path between the television authority (send) and the television authority (receive) comprising the international television link extended at its two ends over national television circuits to the television authorities.

g) International television circuit—The unidirectional transmission path between two ITC's and comprising one or more television circuit-sections (national or international), together with any necessary video equipment.

h) Television circuit-section—Part of an international television circuit between two stations at which the program is transmitted at video frequencies.

Since the international television circuit contains many interconnected elements and each element adds some degradation to the video signal, the objective is to keep the total impairment below the level where the average observer can notice the effects of the impairment on the television picture.

The question of how the impairments add is an interesting one and is one that is not fully understood. We know that some impairments add linearly, others increase at a rate which is less than linear, while others can be compensatory. The concern of the committee is that the signal delivered to each user is the best possible consistent with the state of the art, and within applicable governmental rules and regulations.

The STOC-TV Subcommittee on Test Signal Standards has made recommendations on: test signals to be utilized; transmissions objectives for an overall connection; and types of signal generators and measuring systems.

The parameters for which tests and measurements are being recommended are:

For video: insertion gain; field time distortion; line time distortion; short-time distortion; gain-frequency response; differential gain; differential phase; color-hue and saturation; luminance-chrominance-delay and gain; and noise and crosstalk.

For audio: gain-frequency response; nonlinear distortions; and signal to noise.

The STOC-TV is directing its activity to:

1. Develop and recommend operational procedures for handling international television services.

2. Develop a system of accepted standard television test signals.

3. Develop a system of accepted standard test procedures for use of the test signals during lineup and for trouble location purposes.

4. Recommend adequate and reliable engineering service circuits and order wires to be made available for use during television lineup and service periods.

5. Define overall responsibility and develop fault-location procedures for an international television service.

6. Recommend action and documentation for effecting the procedures and techniques developed by the STOC-TV.

7. Consider and act upon such other items as may come before the STOC-TV and be accepted as appropriate.

It is expected that the work of STOC-TV will provide for agreement on methods and techniques which experience will show are compatible, workable and satisfactory and would go a long way in providing procedures which can be recommended on a worldwide basis. Thank you, gentlemen.

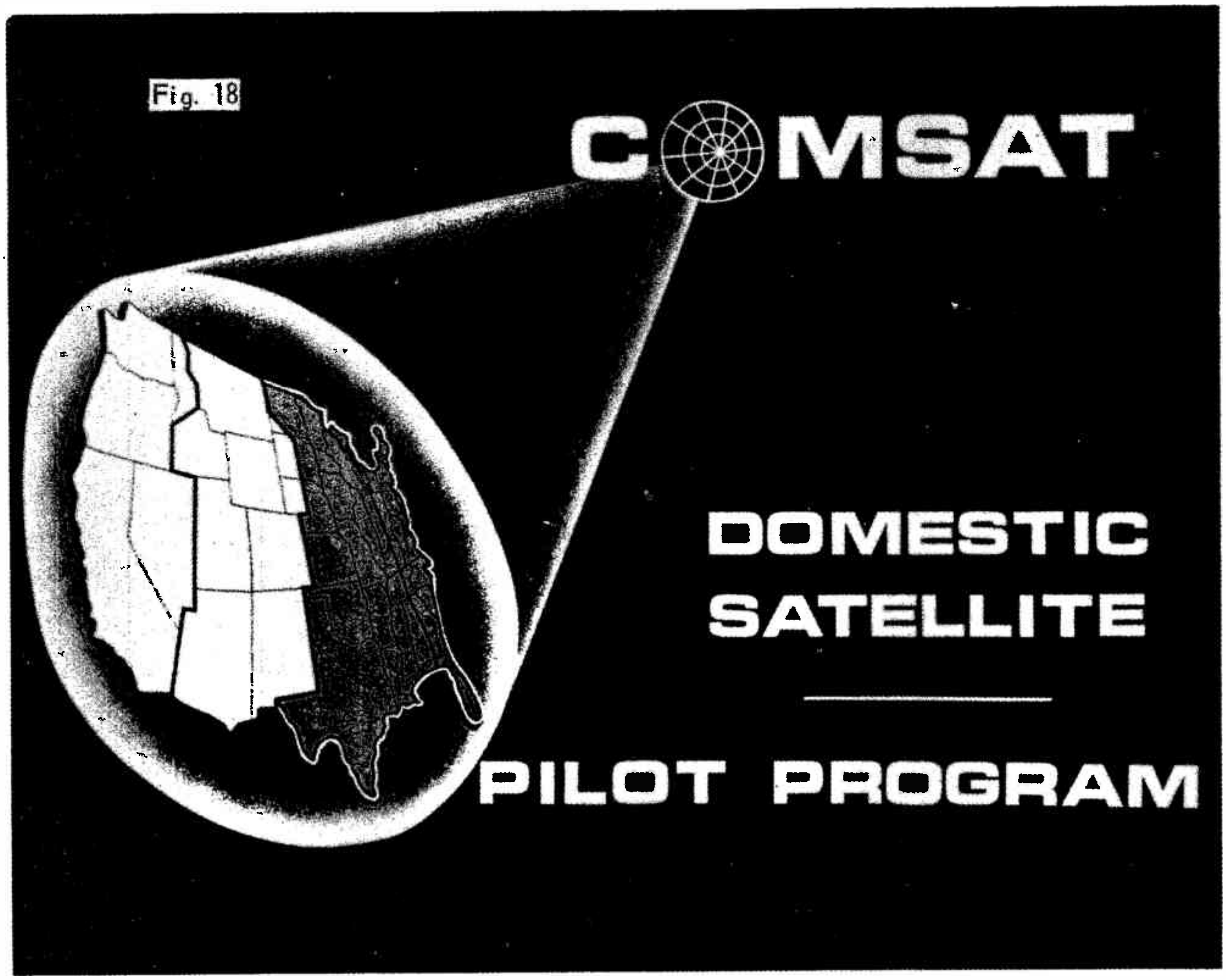
MODERATOR PARKER: Thank you very much, John. You may remember in my introduction I broke down the use of satellites into three broad areas; namely, relay, distribution and broadcasting. So far the only subject or only area which we have discussed is the relay mode, namely, the mode which is now in actual operation. To get some insight as to the thinking into the other modes of use of satellites, we have with us now Bob Briskman from Comsat who will discuss the distribution mode.

MR. BRISKMAN: Thank you, Jim. Good afternoon, ladies and gentlemen. It's a pleasure to be here.

Jim asked me to talk about the Comsat pilot program for providing domestic satellite services. Now, as you probably all know, this is a plan that was proposed to the Federal Communications Commission over one-and-a-half years ago and no action has yet been taken on it.

After some discussion with Jim, we decided to assume that the audience would have some knowledge of the domestic satellite program as we proposed it or as has been similarly proposed by the Ford Foundation, ABC or AT&T. You will find, by the way, these are all relatively similar, at least insofar as technical and engineering aspects. So what we decided to do is try to concentrate on specific areas which would be of the most interest to the broadcasters. The topics that I am really going to cover today are what we call the local earth station facilities, the quality of the transmission, its reliability and certain switching and networking possibilities.

As a general background, what we have proposed is to establish rapidly an operational/demonstrational satellite earth station system initially of a limited ex-



tent (Fig. 18). Actually, the purpose of the pilot program was to meet three interrelated objectives. The first objective is what we call operational and that is simply to provide assessment of actual commercial uses. The second one we call demonstrational and that was an effort to provide some realistic evaluation of various technical and operational alternatives which are possible. The last objective was what we call experimental and this was to provide accurate data for improving future system design. In other words, the growth of the system after that time.

This was to be accomplished by providing what we call major earth station facilities in New York and Los Angeles. These would be capable of transmitting and receiving. Approximately 30 smaller earth stations, which we will discuss in some detail, would be located in the western half of the country. These would be used primarily for receiving television and radio broadcast transmissions. A few medium-sized earth stations would also be employed possibly near Portland, Oregon and Huntsville, Alabama.

Now, these earth stations would work through two high-capacity satellites providing capability for both broadcast and for general communications. We call this aspect of providing both general communications and broadcast services a multiservice approach and it's something that we certainly wanted to test during the early phase to show if this is the right way to go.

In addition to this, and I won't be covering it today, the program would include such things as mobile transmitters and also different types of earth stations other than I mentioned. These would be used not only for operations but also primarily, in fact, to meet various demonstrational and experimental objectives of the program. Now, essentially one can conceive a building-block approach (Fig. 19). Essentially the satellite on the left would work with basically three types of earth stations.

The top right, and these are just artist's sketches, represent the small earth stations that we are going to be discussing in some detail. The point is that one satellite could provide at least 12 television broadcast channels into a small station, which I will describe in detail. Eventually, we would plan to see such small stations near every major community.

The bottom two earth stations are larger ones and more capable ones. These would be used not only for television service but for general communications, in other words, telephone and voice.

Obviously the affiliates and the broadcast stations would be most interested in the small earth stations which are reflected by the upper right-hand corner of Fig. 19. The reason is that these would be the actual facilities providing the service to them.

Now I am going into the detail that I mentioned before. Fig. 20 describes what we call the small receive-only station. The point I am trying to make is that they are small, simple and relatively cheap. The antenna is a 30-foot stationary antenna which would be locked into position pointed at the satellite. The satellite would be held to such a degree of accuracy that it would not be necessary to reposition the antenna on that particular satellite.

The total electronics equipment, other than power supply, is housed in one six-foot electronics rack. It's all solid-state. When I say all the electronics, this includes redundancy for at least three working channels plus one protection channel. It also includes all the control and monitor equipment.

BASIC SATELLITE BUILDING BLOCK

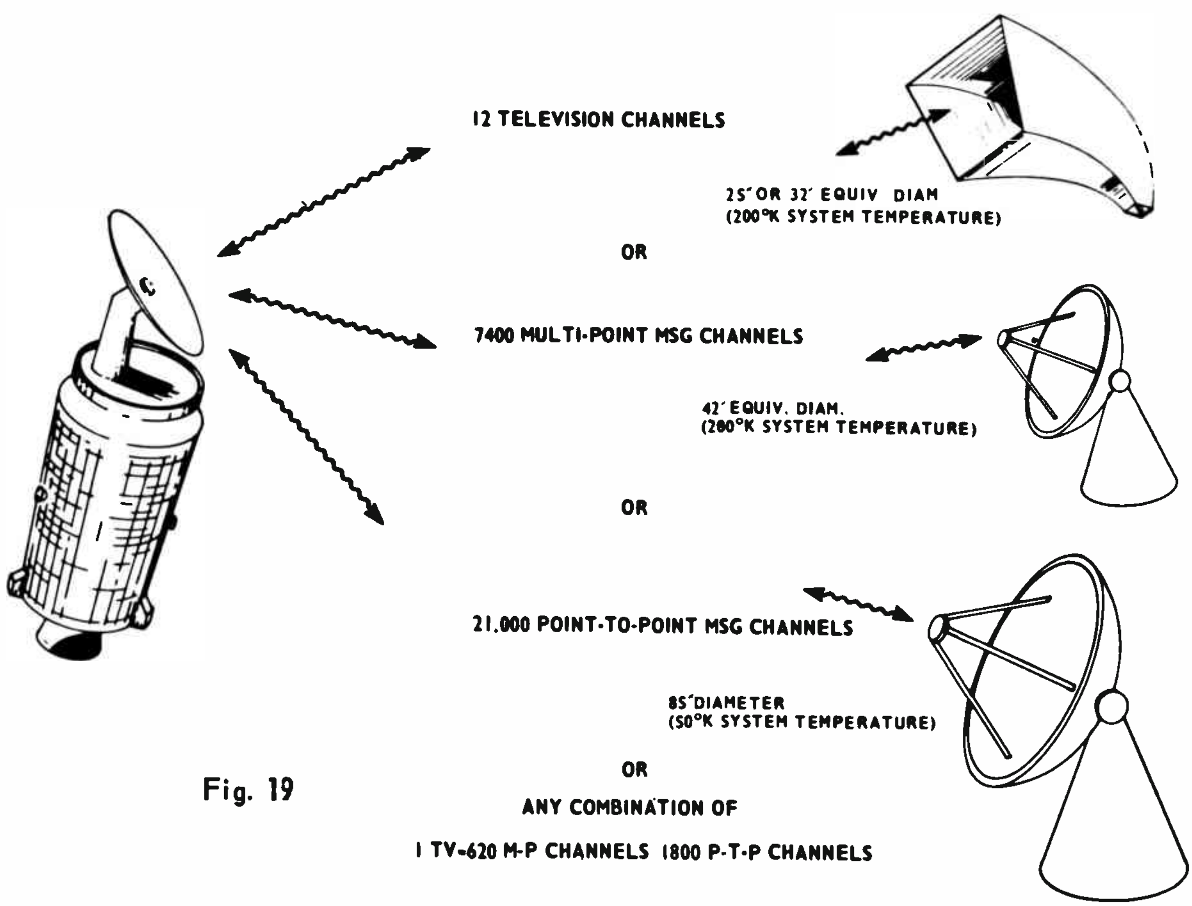


Fig. 19

TYPICAL RECEIVE-ONLY EARTH STATIONS

30-foot Stationary Antenna

6-foot Rack Electronics (Equipment Shelter)

Includes Redundancy/All Solid State

Control & Monitor

3 Working + 1 Protection Channel

Dual Radio-Preamplifier

Fig. 20

Power Rack

No Break Supply/Distribution

Cost $\simeq$ \$200,000 (20 Units Minimum)

Unattended

Exit Link Not Included

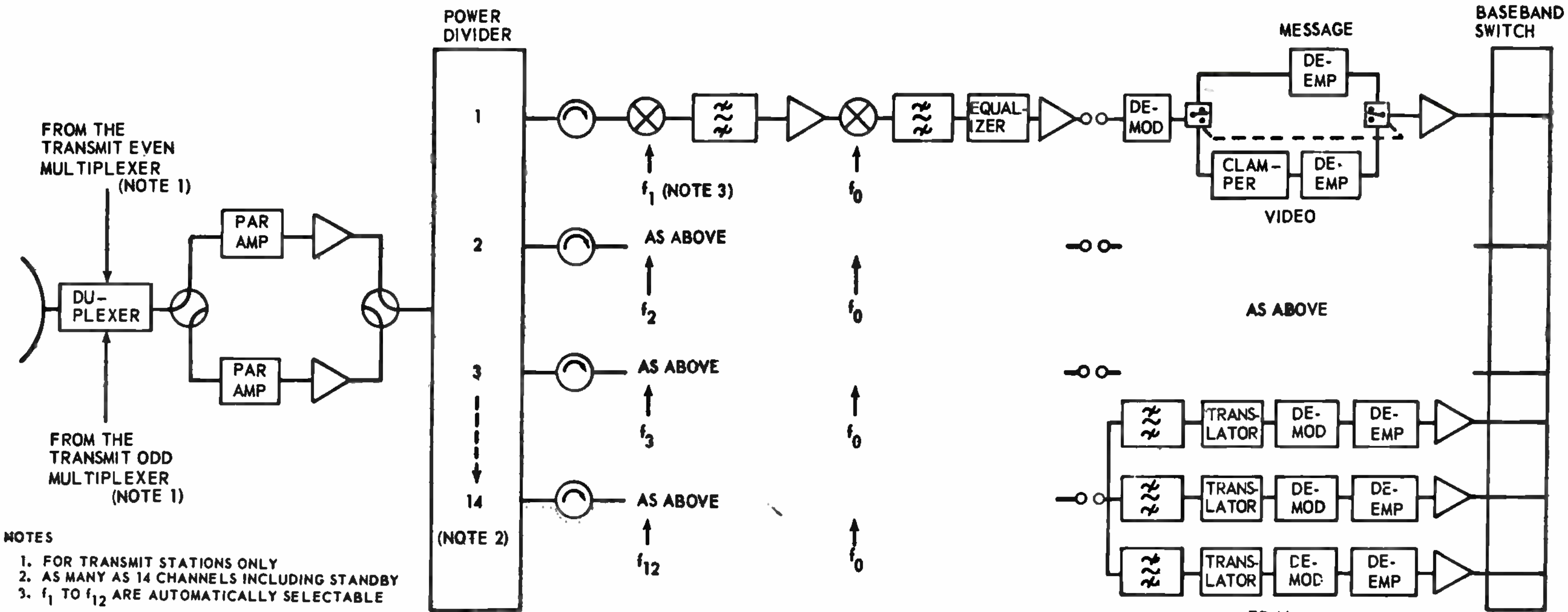
In addition to this, there is a dual radio preamplifier which is in a little box behind the antenna structure itself. There is also a power rack which contains a no-break supply. This is so that a commercial power outage would not put the earth station out of business.

We believe that, if bought in reasonable bulk, we'll say 20 units minimum, the cost would be approximately \$200,000 for the full station in operation. The station is designed for unattended operations and does not require operators there. I do want to caution you that this does not include the cost of the link from the earth station to the broadcaster's studio or transmitters in town. I also would like to note one thing. We call it a receive-only earth station. It's technical characteristics are such that one could not transmit from the facility.

I would like to get a little more technical on the next slide. Fig. 21 is a block diagram of the earth station. Jim was not able to tell me how many engineers are in the audience but here is an engineering diagram of the station and its equipment.

Please don't let this scare you. If you see the power divider, the big block, sort of on your left, everything from that switch in front of it, including the baseband switch, is all in one six-foot rack. Now I know this sounds nice to you but, if you would like to see the equipment, John Gayer mentioned the national telemetering conference April 22nd to 24th. Two companies, Motorola and Raytheon, are planning to exhibit this equipment working. So you can come and see it. It's not a fiction of someone's imagination.

I think the next question that a broadcaster would ask is: What is the quality you are going to provide? Fig. 22 shows the objectives in this regard. Essentially, all of the time, you have 56 db peak-to-peak weighted to RMS noise. That's the signal-to-noise ratio for 99.99 per cent of the time. Now this is from earth station baseband to earth station baseband and, as I mentioned, there have to be interconnect



NOTES

1. FOR TRANSMIT STATIONS ONLY
2. AS MANY AS 14 CHANNELS INCLUDING STANDBY
3. f_1 TO f_{12} ARE AUTOMATICALLY SELECTABLE
4. ANY CHANNEL(S) CAN BE STANDBY

Fig. 21 EARTH STATION - RECEIVE SIDE CONFIGURATION

VIDEO QUALITY

Signal-to-noise

98%: 58.2 dB peak-to-peak/rms weighted

99.99%: 56.0 dB

+ terrestrial degradation (mainly uncorrelated)

Uniform quality provision/Double-hop provision

Echo - Negligible

Differential Phase & Gain

Fig. 22

Phase $\simeq 3^{\circ}$

Gain $\simeq$ 0.7 dB

No Signal Processing or Baseband Equalization

links to get to and from the broadcasters and the earth station, so there would be some degradation to this.

I would like to point out that this degradation, and John Serafin mentioned they are looking at this problem, is different than terrestrial. The terrestrial degradation would in general, according to our studies, be uncorrelated with the satellite degradation. I could go into the details of this, if anyone is interested. Secondly, also different from terrestrial facilities, which currently give you your signal, this is a sort of one-hop microwave radio relay put up on a long pole. If you think of the microwave radio relay system, it's a series system and, as the signal goes through repeater after repeater, it suffers a very minute degradation. Therefore, those receiving the signal closer to the point of origin would get in general a better signal than those further down the road in the country.

With the satellite system, virtually every station would receive a uniform quality, no matter how far or how near he is from the actual point of origination. I would also like to point out that, without going into the details because we don't have the time, in these calculations we then made provision for a double hop. What I mean by this is, assuming that the program originates somewhere other, let's say, than New York or L.A., one could take this transmission, go up to the satellite, down to New York or L.A., give it back to the broadcaster for, let's say, commercial insertion, then go back up through the satellite from New York or L. A. and down to a series of these small earth stations. There is a degradation in doing this. This is all calculated in these figures.

Now, signal-to-noise is, of course, only one of the problems when you talk about quality. We feel that at least three others and, as John has said, a lot of other things have to be specified. Particularly we have looked at echo which for our case we feel would be negligible and we have established some objectives for differential phase and gain, differential phase being 3 degrees or less and the differential gain being .7 db. These numbers are all without signal processing or baseband equalization and it is actually possible to improve on some of these numbers with such techniques, if required.

I have sort of neglected, by the way, the provision of radio services. This is only due to time. We have similar objectives for radio services and I hope I haven't offended the radio broadcasters.

The next question I would like to get into is the reliability (Fig. 23) and I don't know what reliability means. All sorts of people can play wonderful numbers games. I try to use what we call continuity of service and we hope to maintain a 99.99-percent-of-the-time continuity of service.

I have outlined in Fig. 23 how we hope essentially to get this. We have a plan for a satellite with a very conservative design. It would have, of course, complete redundancy in it. We would also have enough orbital capacity at any one time that with failure of one satellite we would still be able to provide all full-time services via another satellite.

If you recall Jim Parker's remarks about the gas in the satellite running out, there are a few other things that wear out, the solar cells degrade due to bombardment by high-energy particles up there. These articles are called wear-out mechanisms. We have a very good handle on them now. In the design of the satellite, you can design the wear-out lifetimes far in excess of the electronic component failure ones.

As far as the earth stations, we use a combination of both redundancy and protection. I could go back to the previous chart and show you exactly how we employ this but we don't have time, I'm afraid. We also, of course, have complete modularity and McNamara's old word "commonality". Please don't ask me what that means.

I would like to move to Fig. 24 and make some hasty, brief comments on switching and networking possibilities. Unfortunately, this requires a lot of time for a full discussion, which we don't have. Essentially, Fig. 24 is a matrix and you should concentrate on the top line and the bottom line. Essentially what this says is that the receive and origination points have the capability (this is built into the large and small stations) to select instantaneously channels of the satellite. Now, once you have that, then there are many possibilities for regional and national time zone networking and switching possibilities. The message I am trying to get over with Fig. 24 is that there are considerable flexibilities and possibilities in this regard.

RELIABILITY

Continuity-of-Service: 99.99%

Satellite

Complete Redundancy/Conservative Design

Full-Time Service Reserve

Wear-out Mechanism Overlifing

1 Stations

Redundancy/Protection

Modularity

Commonality

Fig. 23

SWITCHING/NETWORKING POSSIBILITIES

Fig. 24

Local Receive

Instantaneous Channel Selection

Regional

Transmitted from Region

Transmitted Elsewhere

Transmitted by Network (Direct/2-Hop)

National/Time Zone

Transmitted by Network (Direct/2-Hop)

Transmitted Elsewhere

Local Originate

Instantaneous Channel Selection

In conclusion, we are still hopeful of proceeding some day soon and we think that domestic satellite service will be very beneficial to the broadcast industry.

I would like to thank you for your attention.

MODERATOR PARKER: Thank you very much, Bob. So far now we have devoted our attention to the two modes, relay and distribution mode, which I outlined earlier. We are going to conclude by a discussion of the third mode, namely, the broadcasting mode, and for that we have asked Greg Andrus of NASA to be present. Greg.

MR. ANDRUS: Thank you very much, Jim. Ladies and gentlemen: I am very glad to be here this afternoon with you.

I think two things that you can see very clearly from what John Gayer and what Bob Briskman had to say this afternoon are that the size of the earth terminals are getting to be smaller and the cost is going down, as a matter of fact, going down to almost what you people pay normally in the routine and everyday broadcast business for a good quality video tape recorder or a camera, \$100,000 to \$200,000 investment. This is the most striking thing that these two people said this afternoon about what has happened in the 10 years of the space business, a very short time.

You saw the wonderful pictures that the small 15-foot terminal with a mounted transmitter, 5 or 10 kilowatts, on board a pitching ship, was able to send through a rather unsophisticated satellite, not representing today's state-of-the-art by any means and providing you and your public high quality television reception of live recovery of the astronauts. I looked at that. I knew what was coming but I must say I sat with complete amazement at what was going on, and with such austere terminals being used at a cost which is commensurate with everyday, garden-variety studio equipment.

Now, what these people asked me to talk about today was something a little further along down the pike, say, 5 years, 10 years down the road. What are we doing? What sort of things can you imagine will take place?

The principal concern that some of the people in the broadcast business have expressed in the various writings that have appeared in the technical journals and Fortune is that "direct broadcast satellites" is a dirty word. It's going to put the broadcasters out of business. What are we going to do? We've got a lot of investment here.

If they can now start talking about transmitting down to 30, 25-foot, 22-foot terminals which cost only $200,000, why can't they do it to a terminal that costs only $200 or $500 within reach of the people at least in those sparsely settled areas of the country, those parts of the country which Mr. Briskman's chart indicated might be served by their pilot domestic program, an area of the country which has proven to be uneconomically viable to put in ITV, ETV, and commercial broadcast stations?

Don't go out and sell your stations or your stock just yet. It's a long way from it, gentlemen. We are making tremendous progress in the space business. We have many difficulties, not only from a technological point of view but there are problems with regard to frequencies.

There are no frequencies allocated for space broadcasting at this time and, of course, in order to have an operational capability, one will require a portion of the spectrum set aside for space broadcasting, either the UHF-TV broadcast band that we talked about assigning for other purposes in which great competition is now going on among the mobile communicators and others, or the 12 gigaHertz band, 11.7 to 12.7 gigaHertz band, which some people talk about as being a possibility for broadcasting direct to at least institutions or community-type reception facilities. But this band is plagued with other factors such as propagation, rainfall and things of this nature. We also have something like 1,000 assignments of fixed terminals in the U.S. alone, I am told, even in that band.

Frequency is a big problem and this is one of the things which has to be resolved before broadcasting from space, in terms of direct-to-the-home or more directly to the consumer, is going to take place.

I address those words primarily to those of us who are interested primarily in the coterminous U.S., the 48 contiguous states. In Alaska, this could be quite different because they don't have the spectrum crowding at this time that we now have here. But even there, suitable means must be found to constrain the transmissions from space so that interference does not take place in adjacent areas.

It does not apply either to other portions of the world. India is an example. It is extremely interested in expanding on what they now have. What do they now have? It is one VHF-TV station located in New Delhi and some 6,000 TV sets. They are starting from scratch and they don't have a tremendous infrastructure, cables and the like, to fuss with. They can make up their minds, compare terrestrial systems, community systems, space systems, a combination of relays, distribution, direct broadcast, community TV, for their purposes.

Now, one thing that we are doing with them is planning, studying a method by which we might be able to agree upon a community-type experiment in 1972 using one of our satellites, one of our Applications Technology Satellites, ATS-F.

Here, just as a slight insight into what we are talking about, our satellite would have a 30-foot antenna on it. Now, those satellites you saw up here have about a one-foot aperture. So here you are talking about 30 feet. This is twice as large as what John Gayer was talking about and about the size of what Bob Briskman was talking about, but being able to put this up into synchronous orbit and direct it down to an area, a region or to a country like India, Australia, or even Brazil.

With this kind of capability you could reach a village having a very cheap, 10-foot antenna and an FM-to-AM converter. These two things produced in very large quantities in India—and I mean of the order of a half million and more because there are 568,000 villages in India, containing about 80 per cent of their population—would cost, if projections are correct, a modest 100 to $200, instead of $100,000 to $200,000, with a more sophisticated satellite. The cost of the satellite sort of disappears because the number of ground receiving installations so overpowers the total cost of the system.

That's one possible application that could come into being in the early '70s. These people need to receive information on hygiene, family planning, agricultural productivity, and so forth.

Now, those of you who have heard many of the aerospace industry people talk about direct-to-the-home TV, that's the thing that frightens a lot of people. That's your prime market. But the satellites that would be capable of transmitting directly to the home to the conventional receiver, unaugmented, is like 1980 to 1985. You don't have to worry about it for another decade, maybe even longer. But if you have a fringe-area type of antenna and preamplifier out beyond your Grade B contour, where the guy has to go out and invest $100 or $200 into an antenna mast, put a rotor on it and maybe a $50 antenna on it and a preamp, then the satellite service could be earlier, 1975.

So you see technology is moving and the direction in which it will move will depend on many, many factors. Perhaps we will not see it here in this country because our needs are different. We have already built up a great capability and the question which always comes to my mind, and you may view this as criticism, personal criticism on my side, is: How much would I pay as an individual to receive another program of the type that is broadcast today just because it comes from a satellite?

I'll tell you, gentlemen, not very much. Not very much at all. Unless people don't have a service or the service that they now have is inadequate they will not be willing to pay much for this add-on equipment to receive a program from a satellite.

On the other hand, there are over 8400 one-room schoolhouses in this country and a lot more two- and three-room schoolhouses. There are pockets which you don't now reach in Appalachia, in Maine, New Hampshire, Vermont, in the Rocky Mountain regions and in Alaska, and you are not likely to reach them using conventional means unless you have some sort of a means for subsidization.

Those guys, however, will pay the additional cost for either CATV facilities or perhaps an augmentation of their existing TV sets, which may run several hundred dollars. The more you pay on the ground, the faster you can have the service. I think you understand that. The more power you transmit out of your own towers, you are going to be able to get more people with modest receiving facilities and cheaper sets.

I think the future is bright in space, not just for transmitting programs of all kinds of the astronauts coming down and alighting on the oceans but being able to have that kind of capability that reports on every single major happening throughout the globe at a modest cost, being able to transmit these things through satellites on modest, transportable terminals that can be flown in and out of disaster areas and provide almost immediate news programs, entertainment programs and exchange of intellectual, cultural and social programs.

I think the future is bright. I just wanted to say a few words about the fact that in terms of time, because I know frequently you are told that broadcast satellites are going to be right on the horizon in the early '70s and see these and think they are a threat to local broadcasting, I dare say that local-interest programs, like in the case of radio, are not likely to be put out of business by many things and, least of all, satellites.

I thank you very much for your attention.

MODERATOR PARKER: Thank you very much, Greg. This concludes the formal flow of words of wisdom from the panel members. I am sure you can appreciate that we have only been able to hit the highspots and, therefore, it possibly may have provoked some questions in your minds. We do have a few moments for questions from the audience.

A MEMBER: I wonder if Greg would describe for us what a typical schoolhouse receiving component might look like in a couple or three years.

DR. ANDRUS: If one had the frequencies within the ITFS band, which is the 2500- to 2690-MHz band, then I think it could be something of the order of a 5-foot antenna, parabolic antenna, costing on the order of a couple of hundred dollars with an FM-to-AM converter and I would say the uninstalled price for something like this would be about $500.

Of course, these would be production items in very large quantities. Again, let me emphasize there are no frequencies allocated, but it is not a technological problem that we are faced with.

A MEMBER: Are there any plans to increase the power of the satellites in the near future?

MODERATOR PARKER: Bob, do you want to field this one?

MR. BRISKMAN: Well, I don't know how I can exactly answer that. I can certainly talk about the Intelsat series as Jim Parker started off. He had a list of powers. Intelsat I and II had about 10 to 12 dbw. That's about, say, 13, 14 watts of radiated power from the satellites. The satellites that we have just launched in the previous few months, Intelsat III, have much more, have over 100 watts of power. As he also mentioned, we have under contract what is called an Intelsat IV and Intelsat IV has spot beams with an e.i.r.p. of roughly 7 kilowatts.

The power I was talking about for a domestic satellite service and, as I said, was talked about by my friends in ABC, the Ford Foundation, et cetera, runs about 8 kilowatts per wideband channel. So you can see there is progression. The ATS-E that Greg was talking about would run what, Greg, in the 30-foot?

DR. ANDRUS: I'd say. Our satellites in NASA of the ATS variety had one that had 2 TWT amplifier units in parallel and that satellite had effective radiated power of one kilowatt. Now in the case of the ATS-F or the one with the 30-foot antenna, in comparison to the other one which I spoke of which was at a higher frequency and only had about a square foot of transmitting antenna aperture, the 30-foot dish at 850 megaHertz would deliver 50 dbw or 100,000 watts of radiated power over isotropic.

Now, if you do some fast mental calculations, you will find that this isn't really very much at all, considering the fact that you would only have to provide an 80-watt transmitter on board which can be achieved at about 50 per cent efficiency with solid-state componentry.

Now, insofar as technology is concerned, this can be in the kilowatt range. So all you have to do is add things up. So I merelv added 19 db for your 80 watts and the rest is in the antenna in order to get your 50 dbw. So you have about 31 db of gain in your antenna at the 3 db point. So it can go up from 100,000 to a million watts of effective radiated power without exceeding technology limitations in the early '70s.

MODERATOR PARKER: Any more questions?

A MEMBER: At one time I understand that one of the limitations was considered to be the primary power. From what I gather here now it is considered that solar energy is adequate without getting into any sophisticated power.

DR. ANDRUS: Understand what I said, for this particular one which would deliver 100,000 watts of effective radiated power. That's a product of the gain of the antenna, which is 31 db, and the power of the transmitter into that antenna, which is 80 watts. So you are really only working on 50 per cent efficiency. You only have to provide a prime power of about 160 or 170 watts. So you're not talking about much power at all.

SAME MEMBER: What I was asking was: Has there been a change in the thinking?

DR. ANDRUS: I think that 5 kilowatts in 1975 will probably be demonstrated in space on some vehicle. I know of 3 kilowatts which will go in a year or two. So there are designs for up to 50 kilowatts of primary power. No flights, so far as I know of, planned but the technology is coming along.

So you see the power can go up. Frankly, though, when you're working in the higher frequencies, you don't need all that power because you have the gain of the antenna working in your behalf. You get an awful lot.

MODERATOR PARKER: Al Chismark has a question.

CHAIRMAN CHISMARK: What is the expected operating life of a Bird?

MR. BRISKMAN: What satellite are you talking about?

CHAIRMAN CHISMARK: Well, Intelsat IV.

MR. BRISKMAN: Intelsat IV, the design lifetime is seven years.

MODERATOR PARKER: And the chart which I showed had the life expectancy of the design life of the four series and I think it was seven years for Intelsat IV and five for Intelsat III and three for Intelsat II and one-and-a-half years for Intelsat I. However, Intelsat I has far exceeded the original design life and I think they expect almost all of them will exceed their original design life.

DR. ANDRUS: It just so happens that the space environment is just not as hostile an environment as we originally imagined and the degradation of the solar rays when we understand—when we do the right things—is very slow. If we don't do the right things, however, it can be very fast, and I think we are learning by experience and the old school of hard knocks with profiting by your errors to make these things long-lived. 5 to 7 years certainly seem to be good objective goals and the experimental satellites which have been launched so far certainly indicate that this is possible.

MODERATOR PARKER: Is there a question here?

A MEMBER: Yes. With that 30-foot dish that you were talking about, what amount of area of the earth's surface would that cover? In other words, how wide is the beam from it?

DR. ANDRUS: Again this is dependent upon the frequency at which you operate it but at 850 megaHertz this gives you a 2.6 degree half-power beamlet. That means that within the 3 db contour of the antenna from the synchronous orbit looking down, say, at a country like India, it would cover all of India, which is 1.2 million square miles.

Looking at it in another way, it would cover the entire Eastern Seaboard up to the Mississippi River. Of course, if you want to operate it at 8 gigaHertz, you can get the area of a megalopolis and smaller, the area between Baltimore and Washington, a very small spot beam.

MODERATOR PARKER: Are there any other questions?

A MEMBER: How far away are we from the direct reception of FM from a satellite? How many years?

DR. ANDRUS: A long way, a very long way, and I'll tell you why, because people are not likely to want to spend very much, because I wouldn't myself, even to receive a TV broadcast from space. People just wouldn't spend very much, I don't think, for an antenna to receive it. Now, if you were willing to put gain on the FM

radio instead of the pull-out type of antenna that you normally have in your house, well, that's a different proposition.
MODERATOR PARKER: I'm not sure everybody heard the question. The question had to do with direct FM reception.
DR. ANDRUS: We've looked at this. It takes a great deal of power, a great deal of power, a great deal more power than we have been talking about today, on the order of kilowatts in order to deliver one FM station.

The reason for this is quite simple. FM radios that you normally have just don't have very much of an antenna and you need gain on the ground if you are going to be able to use smaller, lower-cost statellites. If you're not, if you're going to have these pull-out type antennas, you're a long way from it and I don't know of anyone who wants it.
MODERATOR PARKER: We have a question out in the center. I wonder if you would use the microphone right beside you. Thank you.
A MEMBER: I'd like to know could anyone hazard a guess as to when this distribution system to a television network affiliate would be operative? ABC has proposed this $200,000 for affiliate. Could anyone hazard a guess as to when?
MODERATOR PARKER: Bob, I'd like to hear your answer to this one.
MR. BRISKMAN: It's very simple. I think that's a matter that the FCC is trying to wrestle with and I certainly won't try to second guess them
MR. GAYER: I agree. We're waiting for governmental resolution of this particular problem.
MODERATOR PARKER: Down at Puerto Rico, didn't one of the FCC men say "the only thing I can assure you is that the decision will be made on Wednesday."
MR. GAYER: Yes. Commission Chairman Hyde said at the Senate, Pastore hearings, the decision of the FCC would be coming by the end of the year.
A MEMBER: How much tropospheric effects are there at, say, 850 megaHertz?
DR. ANDRUS: Insofar as we have been able to tell not very much. One would have to provide, however, circular polarization in order to take care of Farraday rotation at the early morning hours and at dusk. There's not much stepping at those frequencies.
A MEMBER: Since the great emphasis of the capability to 850 megaHertz on a broadcast system, it would in effect be initially limited to one channel, what would you put on the channel?
DR. ANDRUS: I've only been talking to one group of people and one of the representatives from the government of India, who have made it abundantly clear that they are responsible for the programming.
MODERATOR PARKER: If there are no other questions, I am going to turn the program back to Al Chismark but first, on behalf of the panel members and myself, I would like to thank you for your attention to this afternoon's program.

Audio Signal Processing by Means of AM/FM Limiters and AGC Amplifiers

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Gates Radio Company, Quincy, Illinois

Current broadcasting practices and techniques have spawned a new generation of automatic "frequency and/or level controlled" devices. Never before has there been such a complete, yet bewildering variety to choose from. Specialized units for AVERAGE LEVEL CONTROL; FM TRANSMITTER CONTROL; and AM TRANSMITTER CONTROL, using limiting with asymmetrical clipping versus asymmetrical limiting are discussed. A graphic display of the effect of different attack and decay times, asymmetrical clipping and limiting on various types of programming is presented here.

The ideal automatic level controlling device would have to be so complex and sophisticated to meet every requirement in every application that few companies have demonstrated the courage to attempt one. This may seem contradictory to advertising claims but how many companies market only <u>one</u> unit for AVERAGE LEVEL CONTROL, FM TRANSMITTER CONTROL and AM TRANSMITTER CONTROL? Of course, there are many other applications of automatic level controlling devices, but this discussion is limited to broadcast requirements and the units marketed to fill them.

The three major applications of such devices are generally matched by three models by the larger broadcast equipment manufacturers: The AGC AMPLIFIER for average level control, the FM LIMITING AMPLIFIER and the AM LIMITING AMPLIFIER for FM/TV and AM Transmitters. Most of the new units are quite sophisticated in the processing of differing types of programming, providing a variety of time constants and other control actions to meet the many typical requirements in each application. In the following illustrations and text a comparison is drawn between the major conflicting features and operation of the principal contenders in each of the three areas of application. A brief explanation of each of the newer units, some recently introduced, is included for backgroud information.

AVERAGE LEVEL CONTROL UNITS

Best results are generally obtained in broadcasting systems by the series combination of an AGC Amplifier and a Limiter to effectively cope with the wide range of conditions encountered. The AGC Amplifier must handle the wide dynamic range of levels from many program sources such as microphones, tapes, turntables, projectors, network and remote lines; and produce a nearly constant average output level. In many systems, such as in station automation systems, the various sources are switched in with no manual level control and the AGC Amplifier must automatically adjust to provide this control. Slower time constants, gated expansion and limiting with a large range of input level handling capability are requirements of a modern AGC Amplifier.

Recent AGC Amplifier designs have incorporated the useful parameter of volume expansion. This feature is used to bring the low-level signals up to the compression region when they are within the operating range of the expander. In addition to improving the uniformity of the output level, this action provides another important feature: The unit has full gain only in the presence of a useful and controlled signal level, which effectively masks the noise increase due to the increase in gain. In the absence of signal or when the low signal level is below the threshold of expansion, the gain and accompanying noise is reduced to an appreciably lower level.

Fig. 1 shows the Block Diagram of a new AGC Amplifier which incorporates all of the desirable features discussed so far. It employs an open-loop expansion section, with the gain increase directly proportional to the level of the input signal over the operating range. This is shown in Fig. 2 in the area from -50 dBm to -40 dBm input level and the resulting -15 dBm to +10 dBm increase in output level. Thus, with a change in input level of 10 dB there is a corresponding 25 dB change in output level, which gives a net result of 15 dB of expansion. Referring to Fig. 1 again, the unit has a closed-loop compression or gain reduction section, which samples the output signal voltage and converts it into gain control voltage. This negative feedback type of control prevents any possibility of over-control or "ducking," where the output may drop with an input signal increase. This effect is difficult to prevent with open-loop gain reduction circuits with high compression slopes.

Fig. 2 shows the gain reduction in the area from -30 dBm to 0 dBm input level and the resulting increase of 1 dB in output level. The unit typically compresses a 40 dB range of input level into approximately a 1 dB increase in output. Disabling switches permit the expansion and/or gain reduction to be turned off for special effects, proof-of-performance measurements, etc.

One current AGC Amplifier on the market uses average rather than peak detection of signal voltages for expansion control. However, it uses peak detection for gain reduction control. This resulted in their choice of only 10 dB of expansion, followed

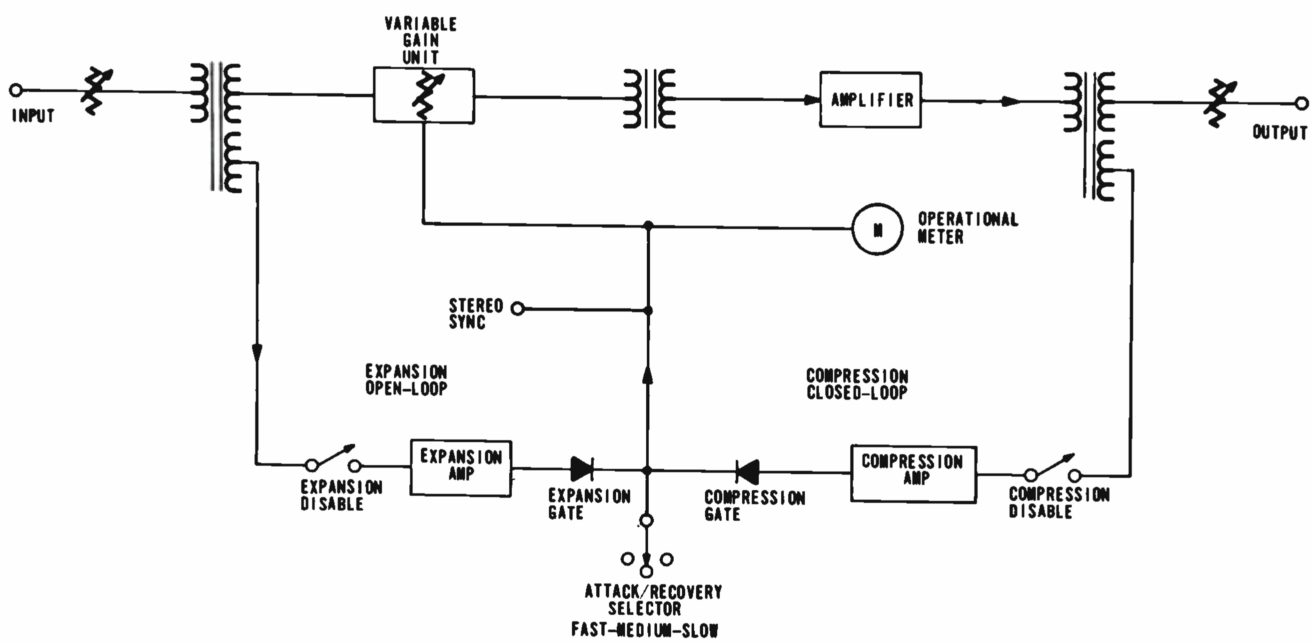


Fig. 1. Block diagram, AGC limiter.

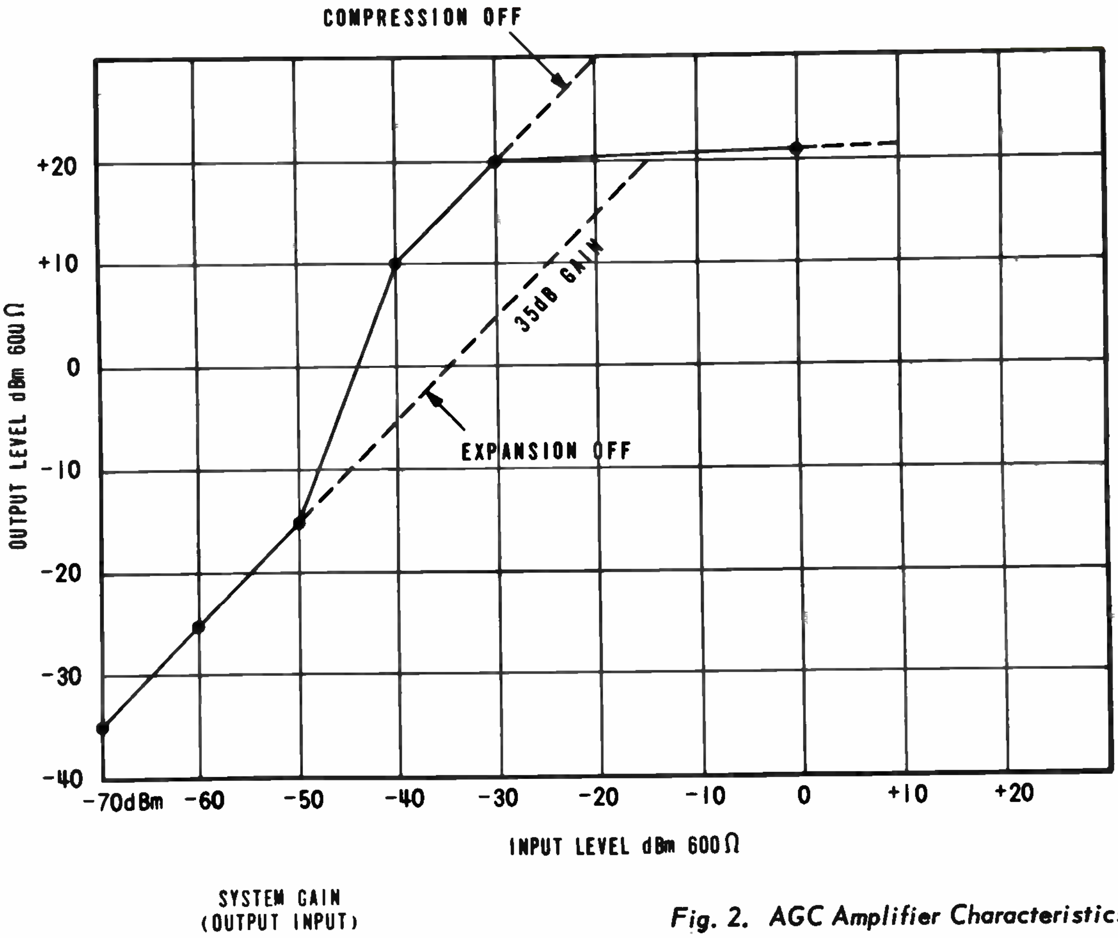


Fig. 2. AGC Amplifier Characteristics.

by a 10 dB linear region to prevent interaction on much programming between the two sections. With a shorter linear region some signals had the proper average level to cause expansion, yet the high peak-to-average ratio was sufficient to cause simultaneous limiting. This prevented full expansion and a consequent conflict in operation between the sections.

The unit plotted in Fig. 2 uses peak detection for both the expansion and gain reduction sections. This permitted 15 dB expansion with the threshold safely above the average noise for broadcast service. A smaller linear portion is possible in this unit but the 10 dB is subjectively pleasing on most programming. This portion is shown in the -40 dBm to -30 dBm input level area, +10 dBm to +20 dBm region of the output level on Fig. 2. The use of peak detection for both areas prevents interaction sufficiently to permit reduction of the linear portion to only 1 dB for special applications, as shown in Fig. 3. This feature should be a big advantage in radio relay link service, where a very poor S/N condition exists. Careful control of the input signal is practiced to increase the signal-to-noise in pauses, by allowing the expander to increase the unit gain only with signal. Fig. 4 shows the Input/Output curve on another popular AGC Amplifier with many characteristics similar to those in the unit just described. It shows an increase of 15 dB in the output level with an increase of around 4 dB in input level, for 11 dB of expansion. The linear portion between the expander and gain reduction section is only 6 dB, indicating the probability of peak detection in both. The gain reduction slope is 8:1 for a 2.5 dB increase in output with a 20 dB increase in input. The curve above 20 dB of gain reduction soon becomes linear again. The approximate 25 dB range of input level handling capability of this section may not be adequate to control the levels in some systems as described in the first paragraph of "Average Level Control Units." The 40 dB range shown in Fig. 2 provides considerably more range for unusual circumstances.

Of the many parameters such as frequency response, distortion and signal-to-noise that can be measured, the effect of the various attack/recovery times on human response can not be. This judgment falls in the area of subjective evaluation. Lengthy listening sessions by many critical panels resulted in a "hung jury" in effect. The consensus of opinion was that no one attack/recovery time was adequate for the different major types of programming and that a selection should be made available to accommodate them.

One position should provide a fast attack/recovery time combination for those stations desiring maximum modulation, and hopefully using appropriate programming for this effect. A slow attack/recovery time position is provided for the very conservative station wanting control but hoping it will never be noticed in their "high quality" sound. Between these two extremes another type of programming is required, the "popular music" station type. Their requirements are quite different from the other two and a position is provided which is intermediate in timing for their service. This choice of three different attack/recovery times offers optimum AGC operation for practically every type of programming in broadcasting. Since fast attack time in an AGC Amplifier is normally used to obtain "tight" programming, the recovery time should also be fast in this position to permit maximum use of the unit. However, very fast conventional RC recovery circuits cause partial recovery on each half cycle at low frequencies with resulting excessive harmonic distortion. Minimum recovery times set by maximum tolerable harmonic distortion may be considerably longer than desired for maximum control action. A dual storage circuit with cross-coupling of two capacitors through a series resistor provides very

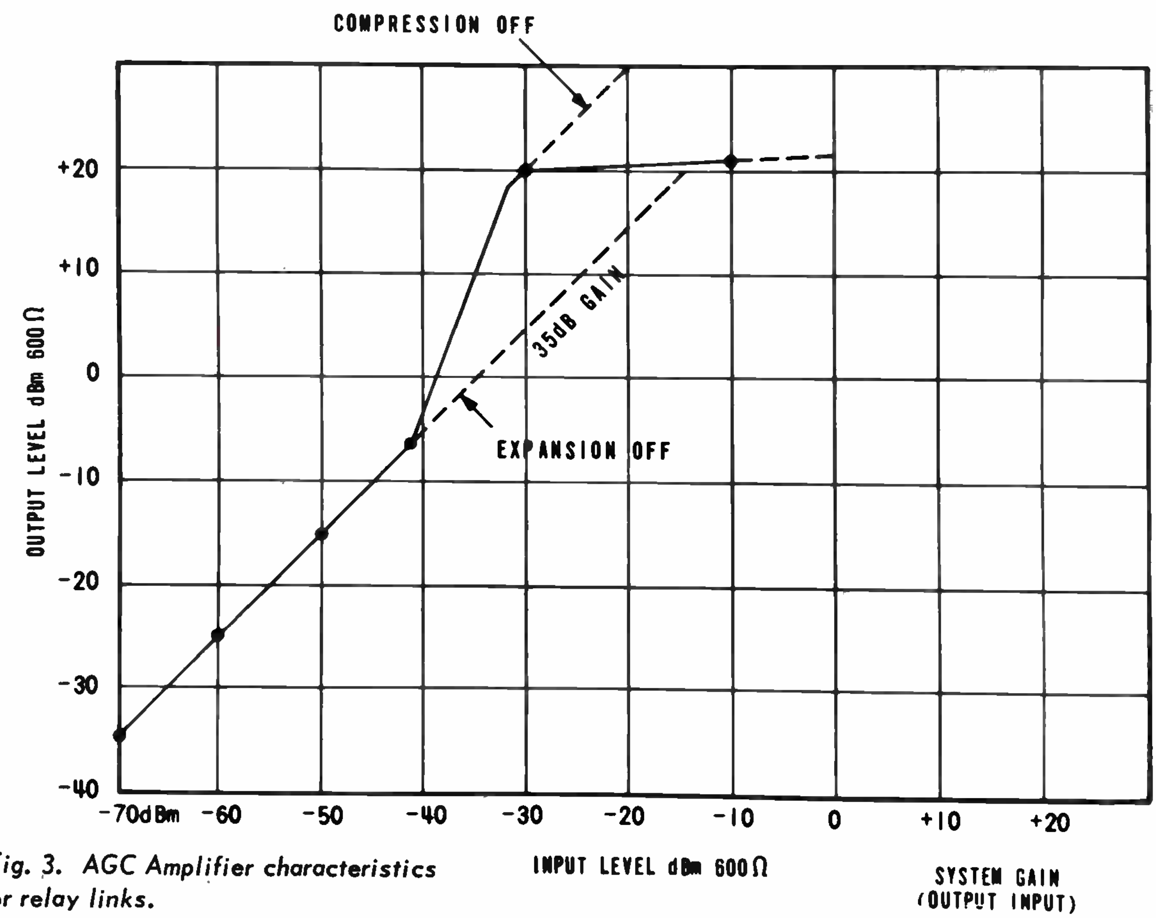


Fig. 3. AGC Amplifier characteristics for relay links.

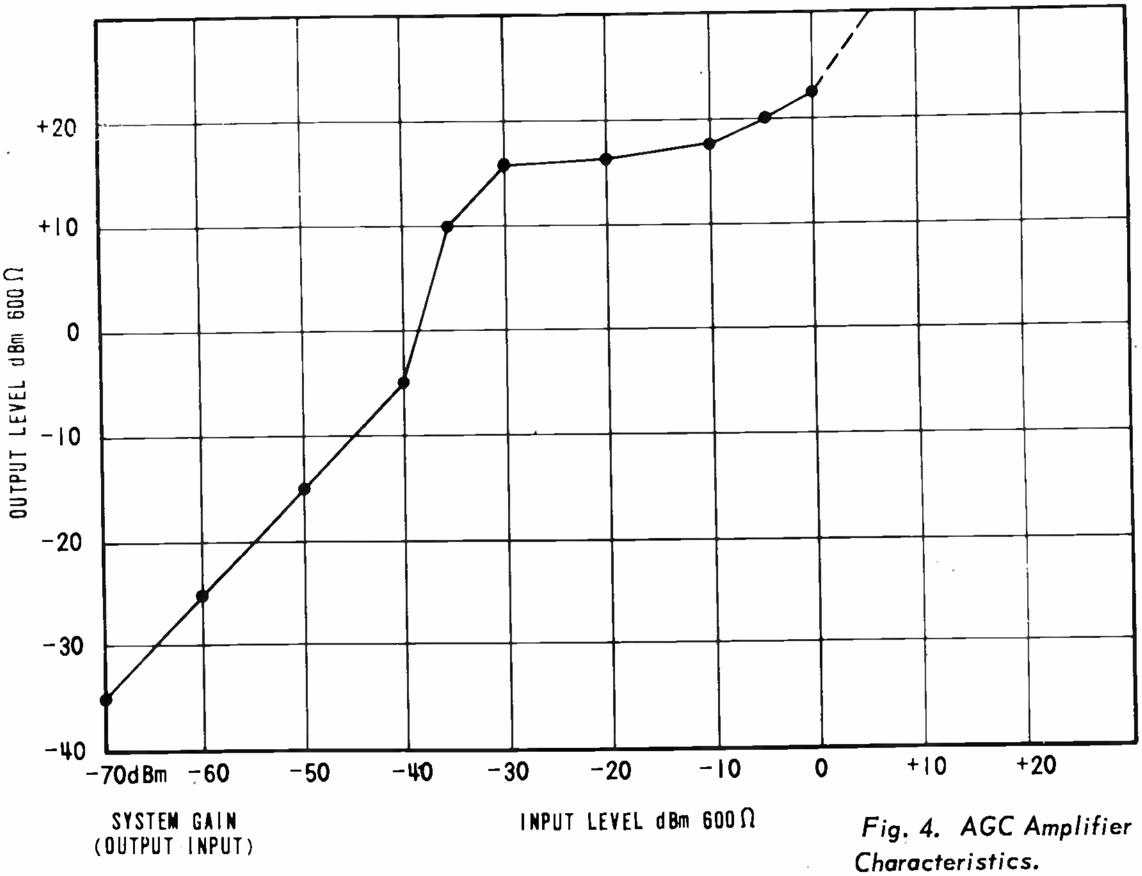


Fig. 4. AGC Amplifier Characteristics.

fast recovery time from isolated or random peaks, longer recovery time from heavy or sustained peaks. This approach makes maximum use of the fast attack time without causing harmonic distortion problems at low frequencies.

Fig. 5 shows chart recordings from a relatively high-speed recorder with peak detectors on the channel inputs. Since transmitter program control is concerned primarily with peaks, this presentation is a graphic display of the modulation meter action. Due to some confusion between the photographer and author, the unprocessed input signal is on band 3 of Fig. 5. It is identical for all of the graphs of the output of the units, where the duplicated input sections were sheared off to save space in the illustration. The chart speed is 1 mm/sec., and each of the six segments are approximately 1 minute sections dubbed on a test tape. The sections are: #1—1 kHz tone from oscillator; #2—Procession of the Nobles, (Pops Festival, Reader's Digest RD4-48-8 1TRS-1416); #3—Java, from the Best of Al Hirt (RCA LSP-3309); #4—America, (Longines Symphonette LWS-331B); #5—"Ain't That A Groove" (King K-12-985-A); #6—"LBJ Radio" (Mercury SR-61015), all speech.

The normal operating level or the mid-point of operation set on the units compared in Fig. 5 is at line 50 of the chart grid. The grid has 10 major divisions, each of which is subdivided into 5 minor divisions. Thus, each minor division will be assigned a value of 2 (X50 for a total of 100). -10 dB from the mid-point reference is at line 16, -6 dB at line 25, and +6 dB is at line 100.

The top band of Fig. 5 is the output of the new AGC Amplifier described above, in the "slow" position of the attack/recovery time switch. Note that it shows little effect on the short-term dynamic range of the various selections. Yet, it brings them all up to a uniform long-term average level. The effect is a gentle control on even wide range classical music, such as may be required for FM stations with automation systems.

The second band of Fig. 5 shows the action of the "medium" position of the attack/

recovery time switch. Some of the wider signal level excursions are smoothed out to give a more uniform level, such as generally desired for popular music, most speech signals, and miscellaneous programming.

The fourth band of Fig. 5 illustrates the "flat-out" action a "top forty" station may desire to keep the avid listener content with the loudest sound around! The unprocessed input level, shown in the third band, was adjusted for most of the signal to fall below "normal level" in sections 4, 5 and 6. Thus, band four indicates some quite rapid expansion in those sections as well as fast gain reduction.

The fifth band of Fig. 5 illustrates the single set of attack/recovery times provided by the AGC Amplifier whose Input/Output characteristics are illustrated in Fig. 4. It does not appear to restrict the dynamic range of the programming seriously. It even seems to expand the dynamic range of the music from Al Hirt in section 3. The long term average level is not as well controlled as the slow position of the other AGC as demonstrated in the first band.

Combining monophonic units for stereo operation is a generally accepted practice. The best method of combining has been the subject for considerable discussion and is apparently not resolved at this date. One approach is to let each unit work independently on the Left and Right stereo channels. This will hold each channel at the maximum operating level, but it will invariably change the Left/Right balance. The change in stereo "placement" or balance is most noticeable and objectionable with independent AGC action. Another method employed is to combine the Left and Right signals to form a compatible monophonic signal, then use this to control the output level of both the Left and Right channel AGC Amplifiers. Although this seems to have many good features, careful examination will show several interesting points.

First, the stereo Left/Right balance will probably not be changed. Since few, if any, of the various control voltages and elements used are linear, different combinations of levels (from Left and Right channels) may cause a random overall shifting of output levels. Second, although the summing method seems to allow maximum modulation with a stereo signal (assuming that the combination of Left and Right modulation can always add to the maximum permissible), the peak limiter generally employed after the AGC Amplifiers using "summing" does not appear to take advantage of it. The referenced limiter(s) uses the "OR" gate method of control (explained in the following paragraph), with each channel set for a maximum of half of the total permissible modulation. Thus, instead of permitting an 80/20% share of maximum Left/Right modulation, the referenced limiter(s) seem to allow only 50/12% share with a 4:1 mix in levels.

The "OR" gate method is defined as the cross-coupling of the DC control signals between the Left and Right AGC Amplifiers. Thus, the unit with the most gain reduction will control the other unit. Since both units receive the same amount of gain control signal, the stereo balance is preserved. The main requirement is that the gain control characteristics of the cross-coupled units track each other with a close tolerance. The output level of the unit with the controlling signal will be maintained at half of the total permissible modulation, with the other channel contributing the share established by the initial stereo relationship between the two.

AM TRANSMITTER CONTROL UNITS

Limiters used for AM Transmitter peak program level control are commonly used after an AGC Amplifier. This reduces the average level excursion to an optimized range for good peak limiting action. The range of input level handling capability of some popular peak limiters is inadequate for much of the current station program-

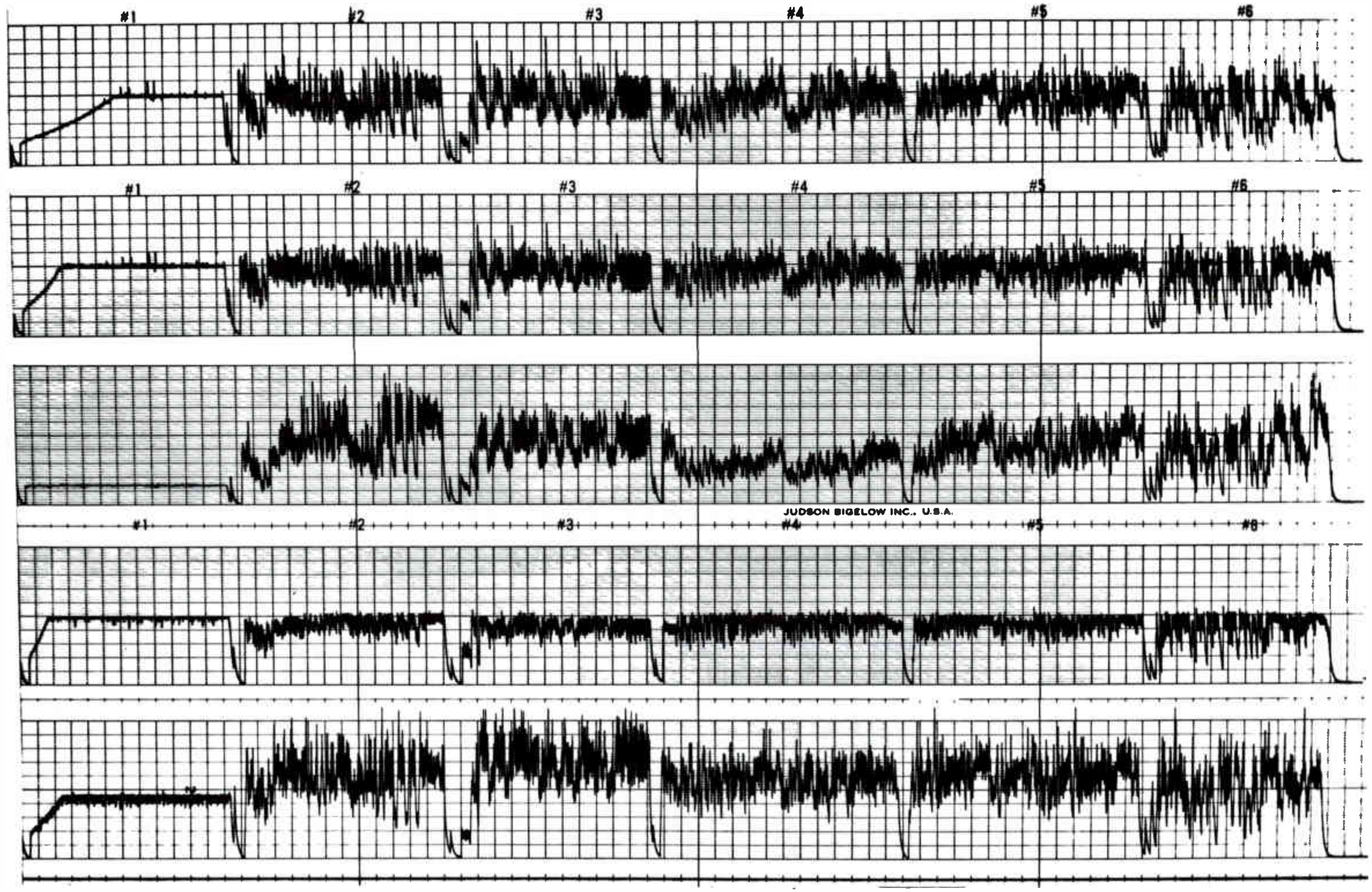


Fig. 5. Chart recording of AGC amplifier operation.

ming. Pre-processing by a good AGC Amplifier or expert manual gain adjustment is required for them.

The limiter must prevent overmodulation on any program peak. Thus, it must have fast attack time. Since it reduces gain on relatively fast peaks, it must recover rather rapidly in order to maintain a high level of modulation. If this fast operation is used in conjunction with a widely varying signal level, the result is often a "pumping" or "swishing" effect. A much smaller amount of gain control is typically used for peak limiting than for average level control. Limiters specifically designed for AM Transmitter Control, as shown in the Block Diagram in Fig. 6, have one or two features that are seldom used in other services: A provision for asymmetrical limiting or clipping, and automatic peak phasing to take best advantage of the asymmetrical limiting. Of course, the associated transmitter must be capable of being modulated more than 100% on the positive peaks to utilize these features.

Fig. 7 shows the Input/Output curve of one popular limiter with a 2 millisecond attack time, followed by a peak clipper with the provision for asymmetrical clipping. One of the advantages of this unit is that it does not exhibit much gain reduction on very fast isolated signal peaks, which are clipped to prevent overmodulation. This is especially advantageous over peak limiters with fast attack times that employ a single compromise recovery time. They would give excessive gain reduction on the program immediately following the fast isolated signal peak. One disadvantage of this limiter/clipper is the separation allowed between the threshold of limiting and the point of "hard clipping." This results in the threshold of limiting being set about 3 dB below the "hard clipping" point as measured on a H-P Distortion Analyzer. Presumably this separation is intended to accommodate component tolerances controlling the two thresholds, yet retain a sufficient margin to avoid excessive distortion that may be created by operating around the knee of the clipping diodes. On some units, at least, this results in a maximum negative modulation capability of considerably less than 100% on much programming, especially that with fairly uniform peaks of a somewhat recurrent nature. Since there is no provision for asymmetrical limiting, this type of programming would restrict the positive modulation as well.

Fig. 8 contains the Input/Output curve of another popular limiter of more recent vintage. It has a very fast attack time, limiting will occur within 10 microseconds after the signal level exceeds the threshold of limiting. If it made use of a single compromise recovery time, it would certainly reduce average modulation by an appreciable amount on at least some programming. However, it employs a dual storage circuit, cross-coupled to give very fast recovery time from fast isolated

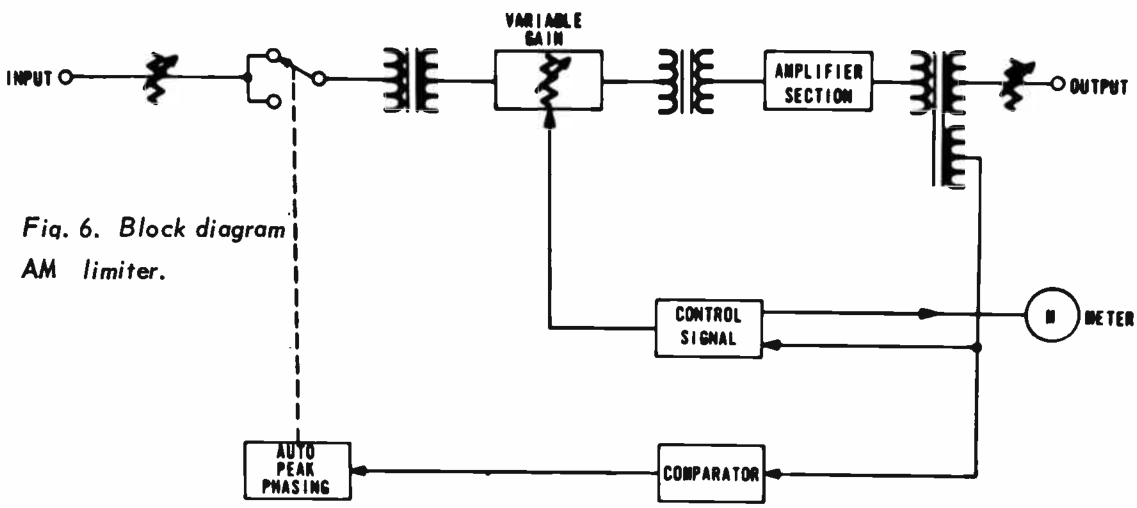


Fig. 6. Block diagram AM limiter.

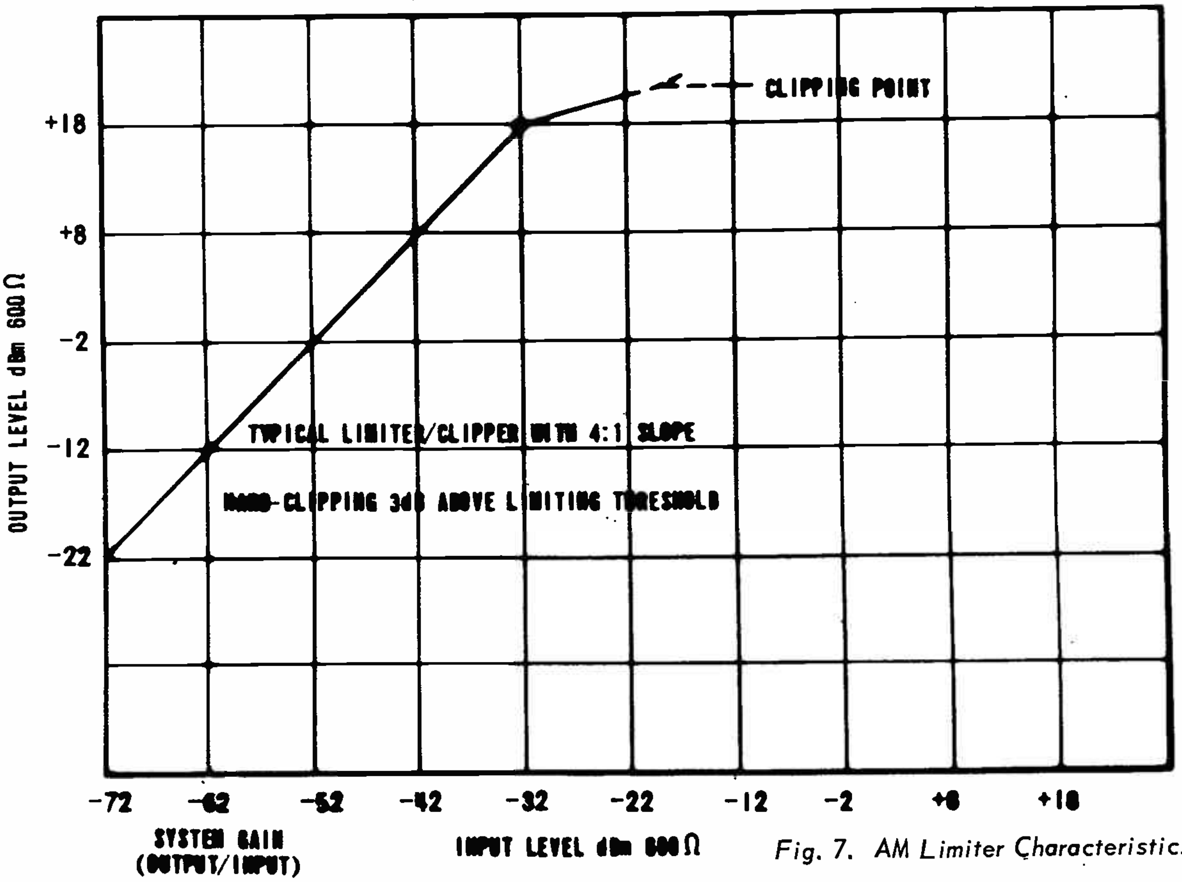


Fig. 7. AM Limiter Characteristics.

peaks and a longer recovery time from heavy sustained peaks. In addition, three switched positions are provided for fast, medium and slow recovery times to fit the normal programming of the individual station.

In the fast recovery position, it takes approximately 0.7 seconds for complete recovery from a sustained 5 dB of limiting. The recovery slope is practically linear. Thus, it takes the same length of time to return from 10 dB to 5 dB, from 15 dB to 10 dB, etc. In the medium position it takes 1.2 seconds for each 5 dB, and in the slow position 1.7 seconds is required for each 5 dB segment of gain recovery. However, for random peaks, the recovery time is much faster and dependent on the amplitude and width of the random peak, compared to the associated program peaks of more recurrent nature. For example, the recovery time from a random peak of 5 dB above the average peak level of associated programming might range from 10 to 70 milliseconds, much faster than a syllabic rate.

The fast recovery time from random peaks is essentially unchanged by the fast, medium and slow positions listed above. Thus, in the fast position the recovery times range from a few milliseconds to 0.7 seconds, depending on the program content. In the medium position they range from the same few milliseconds to 1.2 seconds, and in the slow position up to a maximum of 1.7 seconds for 5 dB of gain recovery.

Although the use of a good AGC Amplifier would restrict the range of input level to the point that the 30 dB of limiting provided by the unit shown in Fig. 8 would seldom be needed, it is good insurance for an emergency. For example, it could handle the failure of the AGC Amplifier and accept unprocessed signal levels without fear of overmodulation. In contrast, the very small range of the unit shown in Fig. 7 makes the use of pre-conditioning of signal level by an AGC Amplifier almost mandatory. The difference in compression slopes between the two AM limiters discussed is appreciable. The 50:1 slope retains a constant peak output level with a much wider range of input levels than a 4:1 slope, obviously. For AM transmitter signal level control, no offsetting advantage of the 4:1 slope was discovered in the analysis.

The calibration of the chart grids in Figs. 9 and 10 is changed from that shown in Fig. 5 to show signal levels of up to 10 dB above the normal operating point. Again, the 50 divisions are assigned a value of 2, which gives a maximum of 100 on the charts. Since the grid is a linear scale while the levels are shown in dB's, which are logarithmic, the presentation is quite crowded at the bottom compared to the top. The 100% modulation reference is calibrated at line 30. Thus, the following:

30% modulation (-10 dB)	=	line 08
50% modulation (-6 dB)	=	line 15
70% modulation (-3 dB)	=	line 20
80% modulation (-2 dB)	=	line 22
90% modulation (-1 dB)	=	line 26
100% modulation (REF.)	=	line 30
110% modulation (+0.8 dB)	=	line 33
120% modulation (+1.6 dB)	=	line 36

+3 dB = line 43, +4 dB = line 48, +5 dB = line 55, +6 dB = line 62, +7 dB = line 70, +8 dB = line 78, +9 dB = line 88 and +10 dB = line 99.

The top band of Fig. 9 shows the unprocessed input signal level of the musical selection Maria Elena (RCA/Reader's Digest T2RM-0821-1S) at a chart speed of 1 mm/sec. Note that several of the program peaks are 10 dB above normal and are causing 10 dB of limiting in the unit, the output of which is shown in the second, third and fourth bands. Band 2 is the output of the limiter shown on Fig. 8 in the fast position, band 3 is the medium position and band 4 is the slow position of the

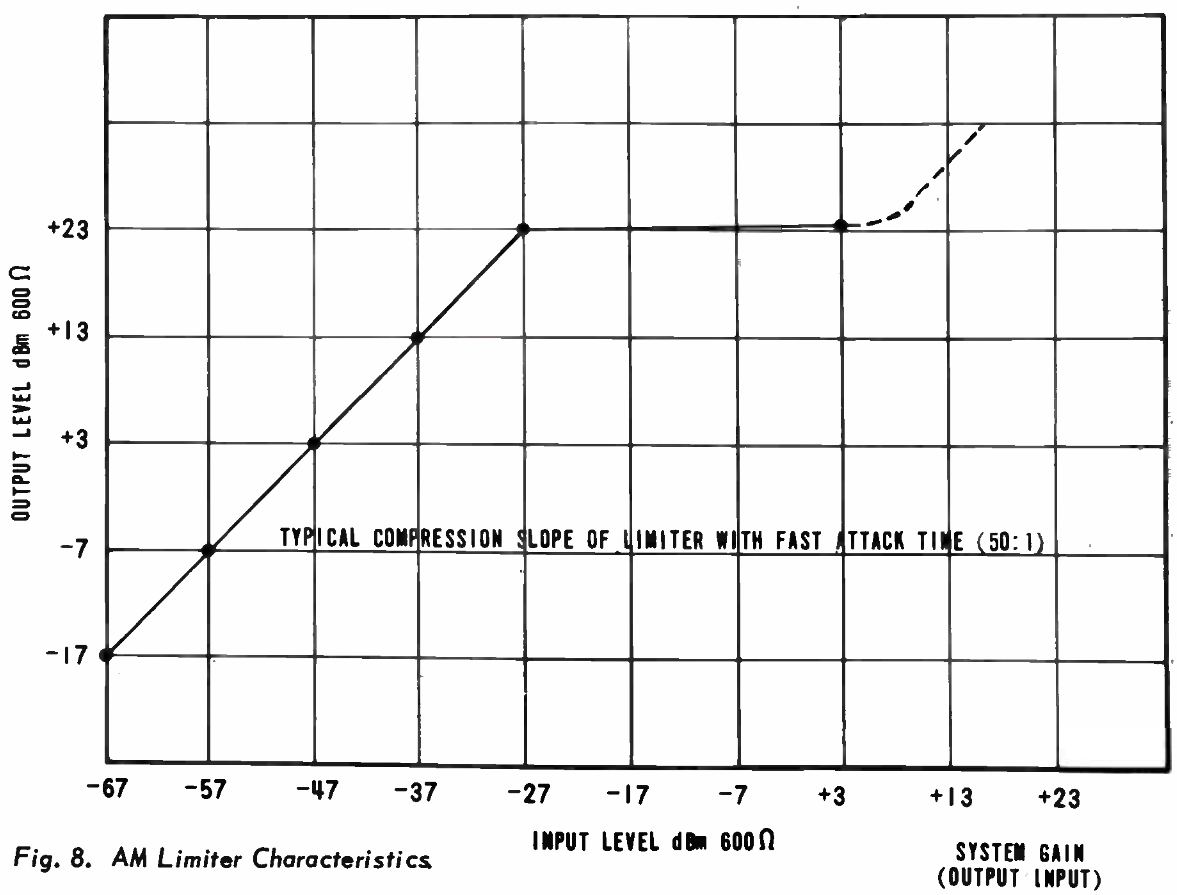


Fig. 8. AM Limiter Characteristics

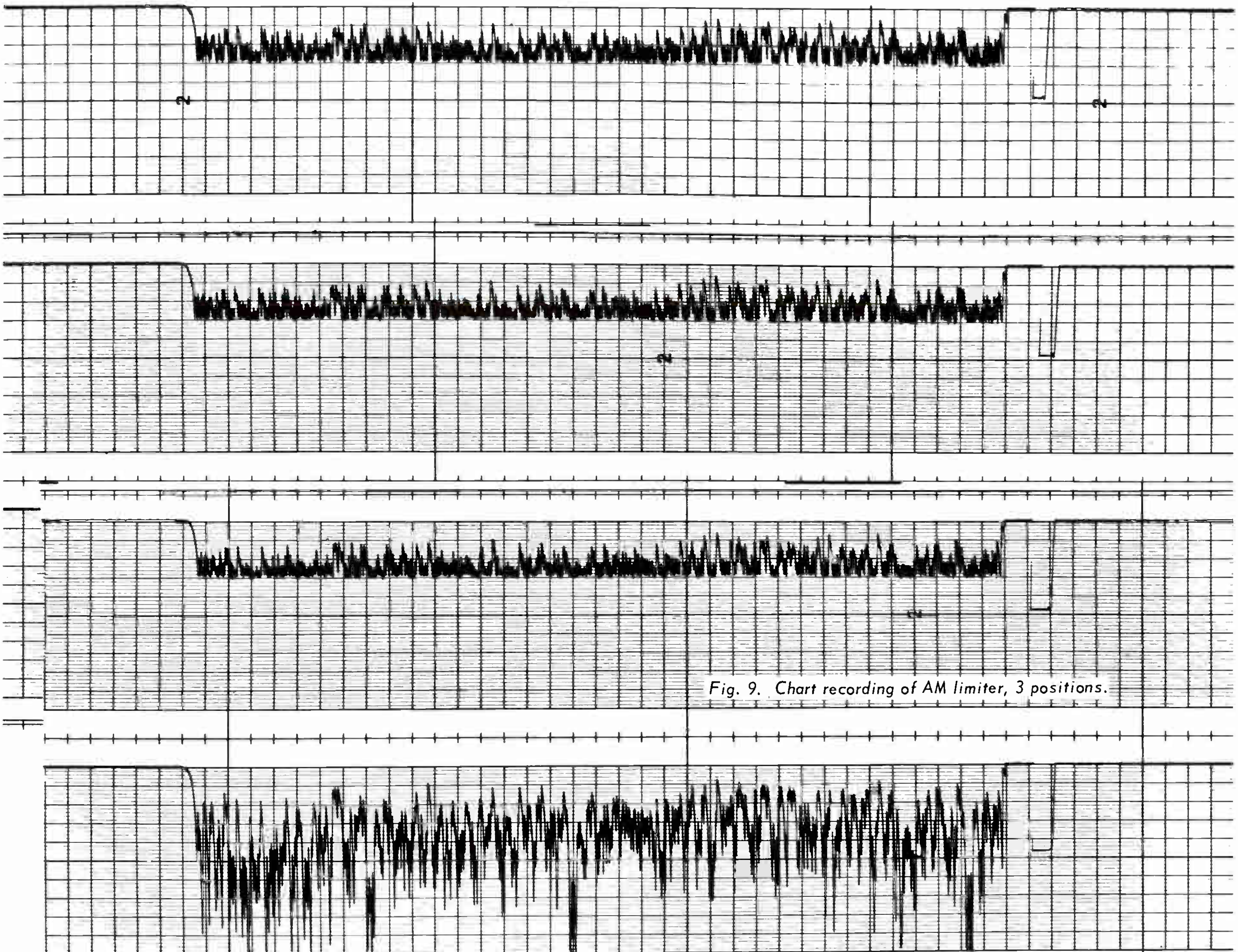


Fig. 9. Chart recording of AM limiter, 3 positions.

Another philosophy is incorporated in a unit on the market, designed to prevent FM overmodulation based on the premise of eliminating the effect of the transmitter pre-emphasis. The high-frequency response of this unit is dynamically controlled by the high-frequency signal levels. For low-level signals, the response is nearly flat. However, as the high-frequency signal level rises, the high-frequency response of the unit exhibits a pronounced roll-off. At a level which corresponds to 100% modulation the high-frequency response is the inverse of the pre-emphasis curve: That is, it is 3 dB down at 2 kHz and 17 dB down at 15 kHz. With this inverse-cancellation of the transmitter's pre-emphasis, there is no boost of the high-frequency audio peaks to cause overmodulation. Additional protection against overmodulation as a result of slow attack time in the limiter section is provided by hard-clipping zener diodes at the output. Of course, this entire approach to solve the problem of overmodulation has created another problem: An apparent loss in fidelity at the listener's receiver, since the receiver has the standard de-emphasis to complement the transmitter pre-emphasis.

It is plausible that a more acceptable means to prevent FM overmodulation is the use of hard-clipping on the higher frequencies. Even though this approach may seem drastic, it has several important advantages: Clipping provides positive control of the peak amplitude. No apparent change in frequency response (the instantaneous action occurs only for the duration of the offending peak, less than 1 millisecond). If the clipping occurs after the signal has been pre-emphasized, the following de-emphasis will remove much of the harmonic content which was generated by the clipping action. This solution retains the use and any noise advantage of the pre-emphasis/de-emphasis concept. Hard-clipping has been used for the last several years in equipment marketed by two leading broadcast manufacturers for the prevention of FM overmodulation.

An integral Combination - Limiter and Clipper: FM systems which use separate limiting and clipping units for prevention of overmodulation usually have one major problem, the calibration of the clipping threshold of one unit so that it is only a few tenths of a dB above the maximum limiting threshold of the other unit. If this calibration is not done precisely the broadcaster will be clipping more than is desirable; or, he won't have the maximum modulation which his clipping protection will allow. Thus, it seems logical to have the two types of equipment integrated into a single unit with pre-aligned thresholds, as shown in the Block Diagram, Fig. 11.

In order to allow a maximum modulation level, so that protective clipping can

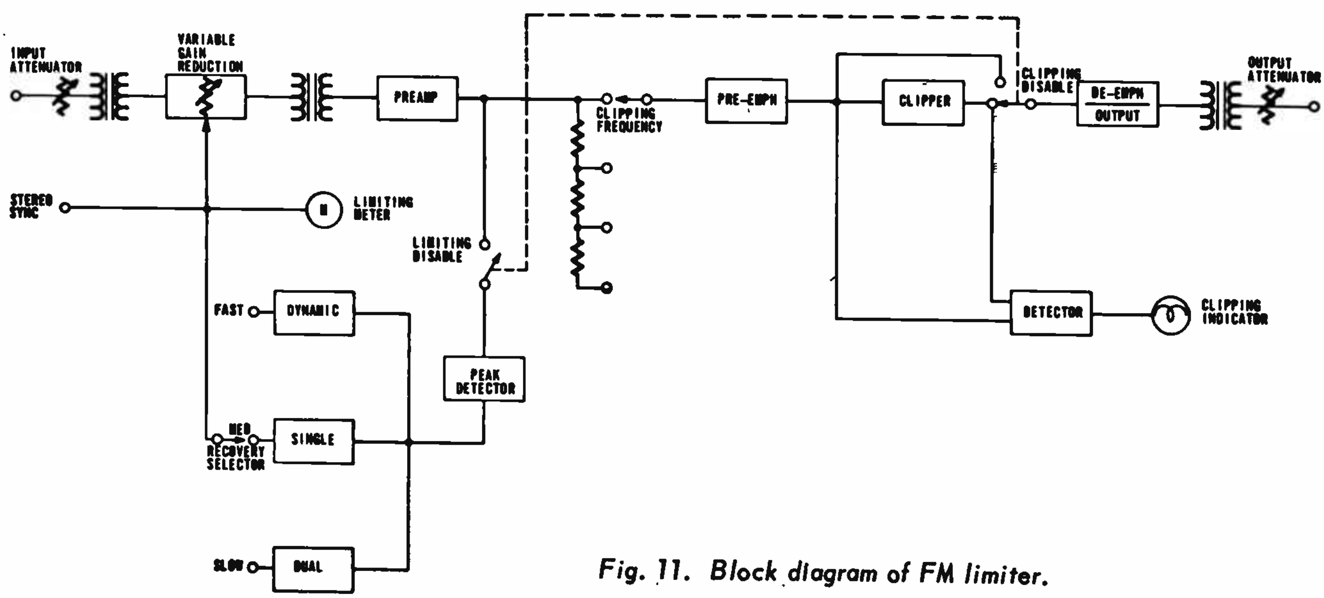


Fig. 11. Block diagram of FM limiter.

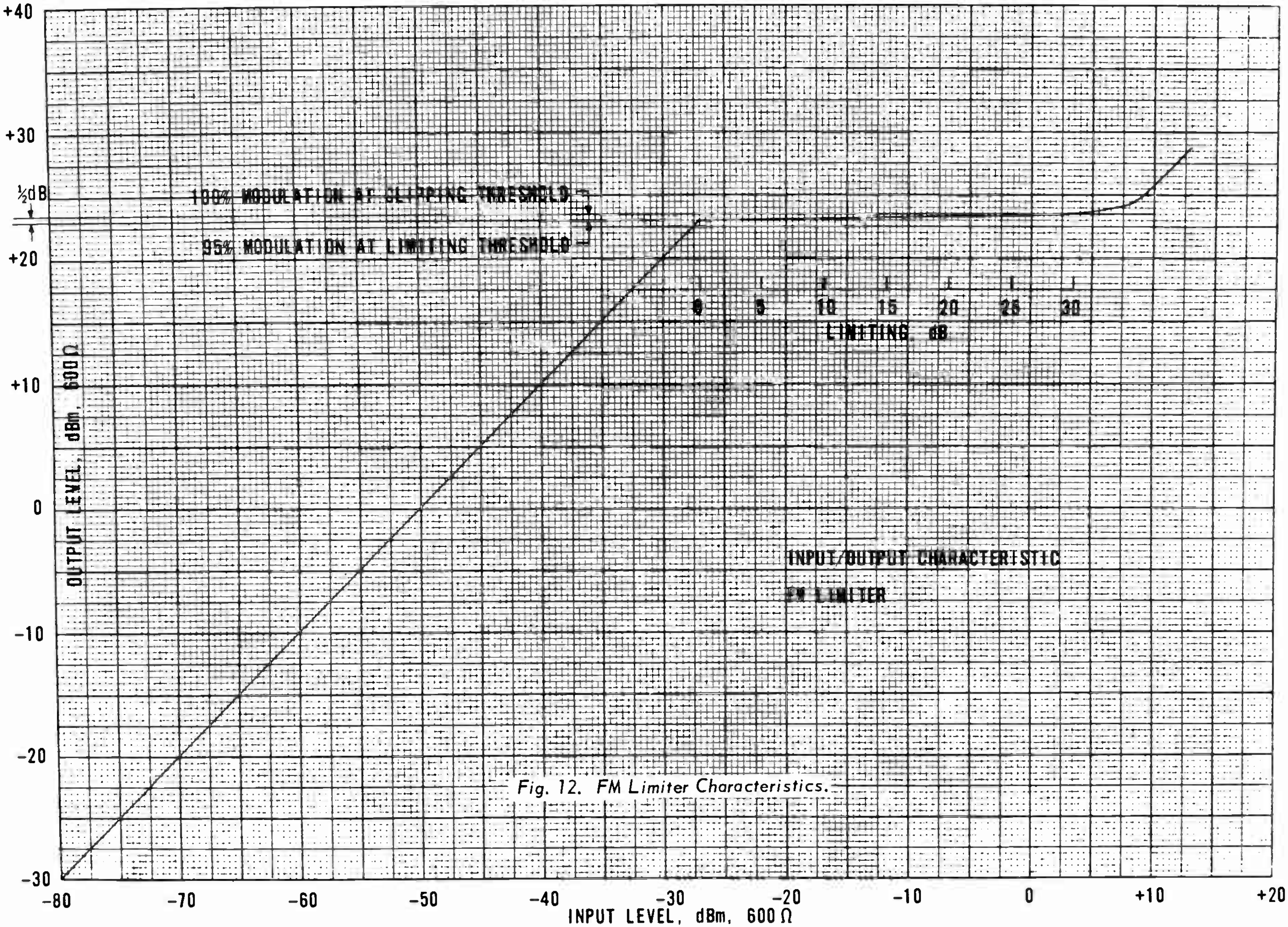


Fig. 12. FM Limiter Characteristics.

occur within a few tenths of a dB above the limiting threshold, it is very important that the limiter Input/Output curve be as nearly flat as possible. For example, above the limiting threshold a 20 dB input variation should result in only a few tenths of a dB of output variation. In other words, the slope of the Input/Output curve above the limiting threshold should probably exceed 50:1. This curve and slope are shown in Fig. 12. It is also desirable to have this range of control extend to 30 or 40 dB of input variation, even though the normal amount of limiting will be in the range of only 5-10 dB. Emergency situations may require the extended operating range.

Since the recovery to normal gain has such a significant effect on the "sound quality" of the limiter, it is very desirable to provide optional recovery timing so that each station can switch-select the mode of operation best suited to its programming: Fast, a newly-developed dynamic recovery circuit allows gain recovery in 100-200 milliseconds for highest average modulation, but without excessive low-frequency distortion. Medium, a single recovery time constant of about 1/2 second for 5 dB of recovery is provided for light programming. Slow, dual-recovery time constants with a maximum recovery time of about 2-1/2 seconds for 5 dB is provided for classical programming.

Pre-emphasis Amplifier: In order to know which peaks contain high frequencies and would cause overmodulation as a result of pre-emphasis in the transmitter, the FM limiter has a standard pre-emphasis circuit to amplify the previously limited peaks in the same manner as the transmitter. This pre-emphasis destroys the constancy of peak amplitude and is evidence of the basic requirement of an "FM" limiter to prevent overmodulation in FM systems.

So that the operator may have some idea as to the amount of clipping which is occurring in the circuit, a detector samples the clipper input and output waveforms, compares them and causes an indicator lamp to flash when the output waveform contains even a slight amount of clipping. The fast (10 microseconds) attack time of the circuit and associated storage capacitor provides a bright indication on short record "ticks," etc.

In the event the operator feels there may be excessive clipping with some programming (even though this effect is generally inaudible), a clipping-frequency switch adjusts the modulation level into the pre-emphasis and clipper circuits. This switch is approximately calibrated in terms of the lowest frequency on which clipping will occur. The operation of the switch is illustrated in Fig. 13, which is a graphic display of the peak amplitude of the audio signal after it has been processed by the clipper circuit. Even though this waveform is not at the actual output of the FM limiter, the following de-emphasis in the output stage acts to complement the pre-emphasis in the exciter, which results in a flat frequency response that restores the clipped waveform. Therefore, the actual modulation of the transmitter is limited to 100% by the clipping action, as shown in Fig. 13.

De-emphasis/Output Amplifier: At first thought the complementary de-emphasis/pre-emphasis just referenced seems ridiculous since the net result of the two is a flat frequency response, which includes potential error due to the tolerance of the individual curves. It seems to be more desirable to omit the de-emphasis in the FM limiter and omit the pre-emphasis in the transmitter.

This would allow the standard pre-emphasis in the center of the FM limiter to be the main and only pre-emphasis in the entire system. However, there is the question of the legality of disabling the transmitter pre-emphasis circuit since this unit was type-accepted by the FCC. Even though a satisfactory pre-emphasis circuit may appear in a preceding unit, such as the FM limiter, this unit was not part of the transmitter when the latter was type-accepted. Since there is already a pre-emphasis/clipper unit for FM transmitter control on the market which requires

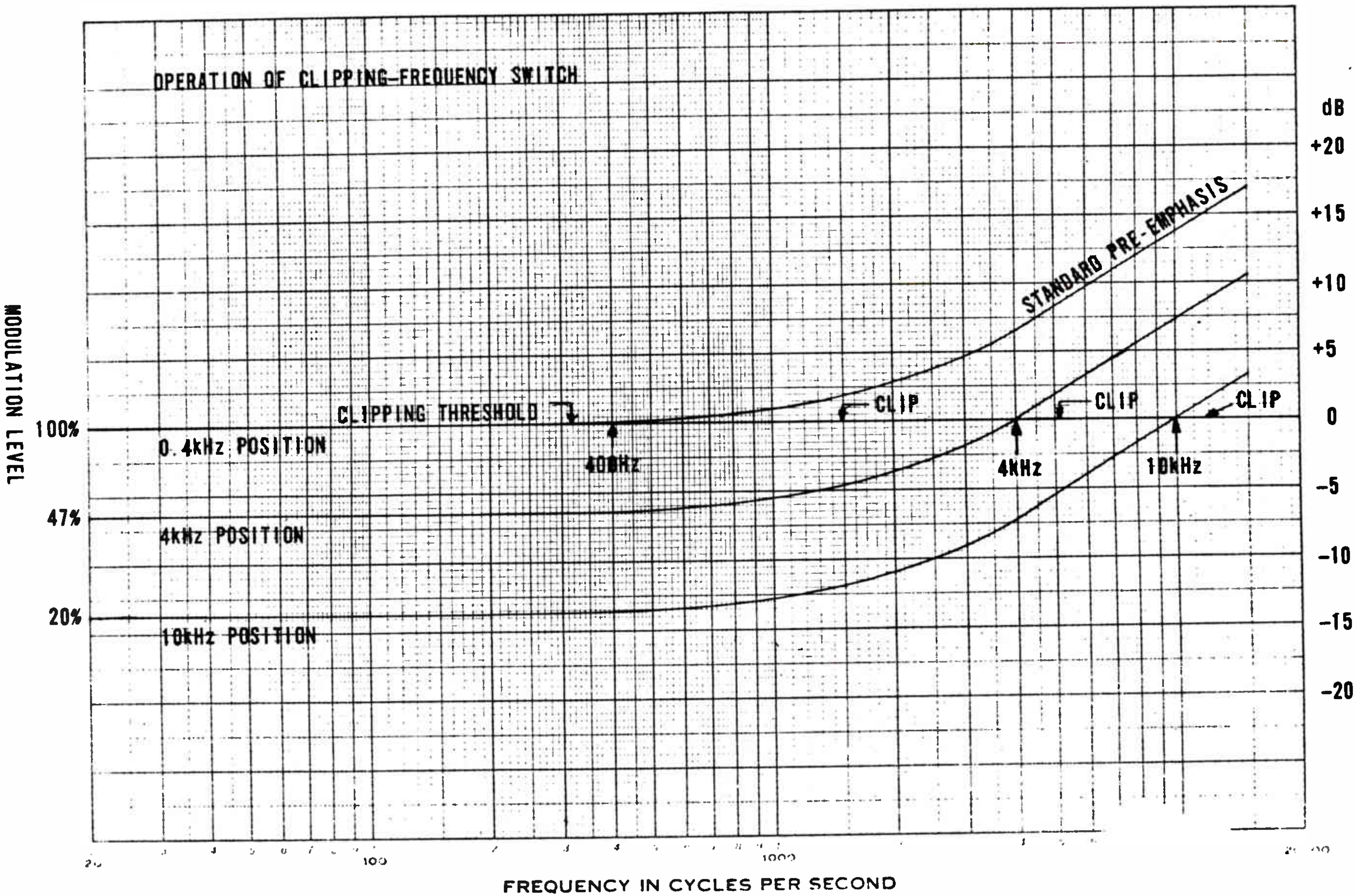


Fig. 13. FM limiter clipping/frequency characteristics.

this modification of the transmitter, the legal aspects of this approach should be thoroughly investigated.

CONCLUSION

There is a definite application and need for the three categories of automatic gain-controlling devices marketed for broadcast service. The many varying programming requirements for each of the three categories of equipment are too broad for a single set of attack/recovery time constants. This is verified by the fact that most of the units discussed have at least a dual set of control actions, such as limiting/clipping, etc. Even this duality of control action is inadequate for optimum processing of the major different types of programming. Thus, the new family of AGC/Limiting Amplifiers with a switch selection of three different sets of time constants is appropriate. The information shown in the illustrations and accompanying text is that which is not readily available to the current or prospective user, for the most part. Yet, it contains data and philosophical descriptions that should be considered in his particular operation.

The Use of Computers in Broadcast Engineering

Serge Bergen, Consulting Engineer
Fairfax, Virginia

In 1958, more than ten years ago, a digital computer was employed by the author to compute a three-tower directional radiation pattern (Fig. 1). The exaggerated accuracy was intended to show the capabilities of the system, yet no decimal point was available and it had to be defined by a vertical bar; the computing time was 32 minutes, about a minute per line.

±ϕ	E		MEOV*	
0	7378912	MWM		
50000000	7199153			
100000000	6666569			
150000000	5802421			
200000000	4646182			
250000000	3263150		3381362	MWM
300000000	1772199		2008592	
350000000	736615		1244212	
400000000	1701758		2001799	
450000000	2911831		3111059	
500000000	3754078		3918263	
550000000	4023560		4179436	
600000000	3569071		3739636	
650000000	2307966		2546207	
700000000	736569		1244157	
750000000	3110025		3235522	
800000000	6796493		6835969	
850000000	11021290		11032401	
900000000	15494341			
950000000	19915454			
1000000000	23992687			
1050000000	27473969			
1100000000	30173933			
1150000000	31990242			
1200000000	32907238			
1250000000	32987599			
1300000000	32355007			
1350000000	31171993			
1400000000	29617315			
1450000000	27866376			
1500000000	26076860			
1550000000	24380330			
1600000000	22879303			
1650000000	21648506			
1700000000	20738732			
1750000000	20181639			
1800000000	19994178			

DECIMAL POINT DECIMAL POINT DECIMAL POINT

* MAXIMUM EXPECTED OPERATING VALUE

Fig. 1

AZ	VERTICAL ANGLE 0
0	98.2
5	95.9
10	89.3
15	78.7
20	64.8
25	48.6
30	31.6
35	17.5
40	16.0
45	24.7
50	31.4
55	31.8
60	24.6
65	14.5
70	31.6
75	69.7
80	119.1
85	177.1
90	241.2
95	308.6
100	376.3
105	441.5
110	501.5
115	554.3
120	598.6
125	633.6
130	659.5
135	676.9
140	686.9
145	690.8
150	690.3
155	686.8
160	681.9
165	676.7
170	672.2
175	669.3
180	668.2

RUNNING TIME: 01.6 SECS

Fig. 2

PARAMETERS: FIELD, PHASE, SPACING, ØRIENT.

.5	-120	0	0
.945	6	100	20
.5	120	200	20

AZ	MV/M	M.P.	MARGIN	
40	27.3			
50	20			
60	18.5			
62	18.9	16	-3	***
70	21			
80	20			
85	18.3	16	-2	***
90	19.6	25	5	
100	41.7	40	-2	***
110	82.9			
120	133.9			
130	187.3			
140	236.6			
150	277.2			
160	307.2			
170	327			
180	338.8			
200	346.3	400	54	

TØWER NØ.:, PHASE, RØTATE ? 2 2 3

PARAMETERS: FIELD, PHASE, SPACING, ØRIENT.

.5	-120	0	3
.945	2	100	23
.5	120	200	23

AZ	MV/M	M.P.	MARGIN
40	25		
50	14.3		
60	6.1		
62	6.3	16	10
70	10.3		
80	11.2		
85	8.2	16	8
90	6.4	25	19
100	28.5	40	12
110	67.9		
120	117.6		
130	171.4		
140	222.7		
150	266.3		
160	299.6		
170	322.4		
180	336.4		
200	346.6	400	53

Fig. 3

By comparison, a similar three-tower pattern with the same number of lines was recently computed in 1.6 seconds (Fig. 2), 1200 times faster. The increased speed, a great advantage in itself, opened the door for extended computer procedures, heretofore considered too slow and too costly. Besides rapid calculations, the computer can be used for:

Mathematical experimentation and analysis
Sorting of data or results
Maximum and minimum determinations
Seeking optimum solutions
Simulation

and other routines. Some of the methods are illustrated by the following descriptions.

In years past, because of cost and time factors, the preliminary design of directional antennas was done by hand and only the final pattern was determined by computer. At the present time we are able to proceed with a <u>complete</u> design of directional patterns without leaving the computer console (Fig. 3).

At first the proposed parameters are printed. The pattern is then computed every 10 degrees and at additional bearings where maximum permissible values are specified (M.P.). The asterisks indicate where the maximum permissible value was exceeded. The computer is operated in an interrogatory mode; after the computation is completed, new parameters are requested, entered, and a modified directional pattern is computed. By a systematic procedure the proposed pattern can be tailored for a given set of conditions without intermediate drafting and visual estimates to its final shape.

Before attempting a design of a directional system it is important to analyze a prospective array with respect to its operating impedances, power distribution, and efficiency. Fig. 4 shows such an analysis of a proposed cloverleaf-type pattern. It is noted that the operating impedances are low, the center tower is parasitic; the horizontal RMS value with a loss resistance of 1 ohm is far below the minimum required of 175 mv/m for 1 kw, and about 600 watts is dissipated in ground losses. Fig. 5 shows the analysis of a cardioid-type pattern which in absence of an excellent ground system would not meet the minimum RMS value.

The computer analysis thus gives advance indication of possible operating problems

```
ØPER. LØØP VALUES, NØ LØSS:
FIELD          PHASE          SPACING        R, ØHMS        X, ØHMS
 .67           -165            0              2.76          -62.09
 1              0              60            -1.54          -62.11
 .67            188            120            3.3           -62.81


LØØP
LØSS:
ØHM= 0   RMS= 196.729   K= 626.295   RAD. PWR KW= 1
ØHM= 1   RMS= 121.854   K= 387.928   RAD. PWR KW= .383653
ØHM= 2   RMS= 95.8461   K= 305.13    RAD. PWR KW= .237362
ØHM= 3   RMS= 81.5507   K= 259.62    RAD. PWR KW= .171837
ØHM= 4   RMS= 72.1927   K= 229.828   RAD. PWR KW= .134663
ØHM= 5   RMS= 65.4586   K= 208.39    RAD. PWR KW= .110712
```

Fig. 4

ØPER. LØØP VALUES, NØ LØSS:

FIELD	PHASE	SPACING	R, ØHMS	X, ØHMS
.5	129.7	0	-2.75	-83.36
1.25	0	80	4.72	-78.44
.5	-129.7	160	2.38	-65.47

LØØP
LØSS:

ØHM= 0	RMS= 201.589	K= 186.307	RAD. PWR KW= 1
ØHM= 1	RMS= 177.956	K= 164.465	RAD. PWR KW= .779274
ØHM= 2	RMS= 161.065	K= 148.855	RAD. PWR KW= .638369
ØHM= 3	RMS= 148.222	K= 136.985	RAD. PWR KW= .540617
ØHM= 4	RMS= 138.03	K= 127.566	RAD. PWR KW= .468827
ØHM= 5	RMS= 129.687	K= 119.856	RAD. PWR KW= .413868

Fig. 5

ORIGINAL PATTERN:

ØPER. LØØP VALUES, NØ LØSS:

TWR.	RATIØ	PHASE	SPACE	ØRIEN.	HEIGHT	R, ØHMS	X, ØHMS
1	1.	0	0	0	100.	98.64	336.58
2	2.91	0	210.	89.	100.	18.64	328.52
3	2.91	0	420.	89.	100.	16.76	332.33
4	1.	0	630.	89.	100.	94.16	351.72
5	3.9201	125.597	90.	0	100.	57.34	92.33
6	11.407	125.597	229.912	65.9587	100.	46.45	103.05
7	11.407	125.597	431.068	76.9508	100.	46.71	103.74
8	3.9201	125.597	637.949	80.8911	100.	58.48	94.69
9	5.60013	251.691	180.	0	100.	24.49	56.96
10	16.296	251.691	278.961	48.8229	100.	26.1	63.28
11	16.296	251.691	459.825	65.9587	100.	26.4	63.36
12	5.60013	251.691	658.224	73.132	100.	25.53	57.24
13	2.91544	17.288	270.	0	100.	-2.24	47.92
14	8.4839	17.288	344.933	37.497	100.	4.86	47.87
15	8.4839	17.288	503.248	56.5588	100.	5.06	47.72
16	2.91544	17.288	689.737	65.9587	100.	-1.51	47.52

LØØP
LØSS:

ØHM= 0	RMS= 653.441	K= 25.0197	RAD. PWR. KW= 10
ØHM= 1	RMS= 642.357	K= 24.5953	RAD. PWR. KW= 9.6636
ØHM= 2	RMS= 631.817	K= 24.1918	RAD. PWR. KW= 9.3491
ØHM= 3	RMS= 621.781	K= 23.8075	RAD. PWR. KW= 9.05442
ØHM= 4	RMS= 612.207	K= 23.4409	RAD. PWR. KW= 8.77776
ØHM= 5	RMS= 603.063	K= 23.0908	RAD. PWR. KW= 8.5175

Fig. 6

IMPROVED PATTERN:

ØPER. LØØP VALUES, NØ LØSS:

TWR.	RATIØ	PHASE	SPACE	ØRIEN.	HEIGHT	R,ØHMS	X,ØHMS
1	1.	0	0	0	100.	73.41	121.51
2	2.91	0	210.	89.	100.	52.71	132.56
3	2.91	0	420.	89.	100.	52.68	133.73
4	1.	0	630.	89.	100.	73.79	125.71
5	1.9209	125.597	90.	0	100.	31.07	66.85
6	5.5897	125.597	229.912	65.9587	100.	29.46	73.88
7	5.5897	125.597	431.068	76.9508	100.	29.77	74.09
8	1.9209	125.597	637.949	80.8911	100.	32.19	67.51
9	1.3446	251.691	180.	0	100.	7.63	50.42
10	3.9128	251.691	278.961	48.8229	100.	13.4	53.17
11	3.9128	251.691	459.825	65.9587	100.	13.64	53.17
12	1.3446	251.691	658.224	73.132	100.	8.52	50.57
13	.343	17.288	270.	0	100.	13.5	44.94
14	.99813	17.288	344.933	37.497	100.	14.47	42.57
15	.99813	17.288	503.248	56.5588	100.	14.35	41.95
16	.343	17.288	689.737	65.9587	100.	13	42.83

LØØP
LØSS:

ØHM= 0	RMS= 653.441	K= 72.9416	RAD. PWR. KW= 10
ØHM= 1	RMS= 642.356	K= 71.7042	RAD. PWR. KW= 9.6636
ØHM= 2	RMS= 631.817	K= 70.5278	RAD. PWR. KW= 9.3491
ØHM= 3	RMS= 621.78	K= 69.4074	RAD. PWR. KW= 9.05442
ØHM= 4	RMS= 612.207	K= 68.3388	RAD. PWR. KW= 8.77776
ØHM= 5	RMS= 603.062	K= 67.318	RAD. PWR. KW= 8.5175

Fig. 7

and suggests the desirability of a modified design where necessary. As a general rule, more than one set of parameters (i.e. phases and field ratios) will yield an identical radiation pattern. While the pattern remains the same, one of the several sets of parameters will result in a most favorable condition of operating impedances and power distribution among the various towers. This knowledge can be successfully applied to the analysis of existing arrays to improve their stability of operation.

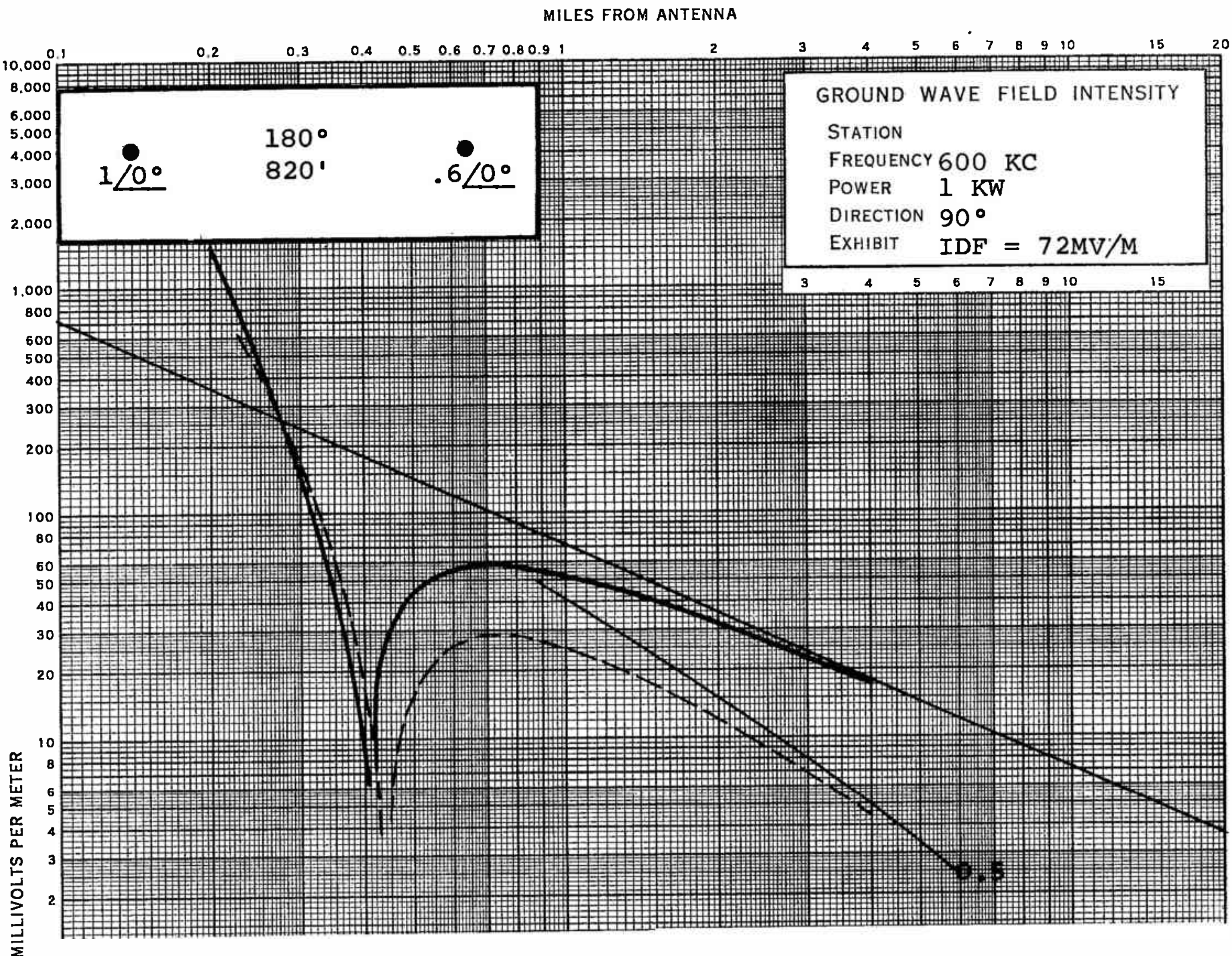
Fig. 6 shows a 16-tower system which easily meets the RMS value requirements and has adequate efficiency; it is noted, however, that towers 1 through 4 have a rather high reactance, while towers 13 and 16 have a negative operating resistance. By synthetizing an optimum set of field ratios the above deficiencies are removed (Fig. 7). All towers now have a positive resistance component, hence, are driven and easily controlled; the high reactance values of the first four towers are also lowered. The computation yields identical radiation patterns in both cases (Fig. 8).

In the course of adjusting a directional system it is sometimes necessary to make close-in measurements because of inaccessible terrain at a greater distance. In close vicinity the array cannot be considered a point source because the distance

RADIATION VALUES, MV/M

ORIGINAL		IMPROVED	
AZ	VERTICAL ANGLE 0	AZ	VERTICAL ANGLE 0
0	95.4	0	95.4
5	88.8	5	88.8
10	73.8	10	73.8
15	54.7	15	54.8
20	36.3	20	36.3
25	21.4	25	21.4
30	11.2	30	11.2
35	5.1	35	5.1
40	1.9	40	1.9
45	0.5	45	0.5
50	0.0	50	0.0
55	0.0	55	0.1
60	0.0	60	0.0
65	0.1	65	0.1
70	0.0	70	0.0
75	0.3	75	0.3
80	0.9	80	0.9
85	1.8	85	1.8
90	2.9	90	2.9
95	3.5	95	3.5
100	3.1	100	3.1
105	1.6	105	1.6
110	0.3	110	0.3
115	1.2	115	1.2
120	0.0	120	0.0
125	1.7	125	1.7
130	3.4	130	3.4
135	30.3	135	30.3
140	101.3	140	101.3
145	241.2	145	241.2
150	468.4	150	468.4
155	784.2	155	784.2
160	1164.7	160	1164.7
165	1560.0	165	1560.0
170	1903.0	170	1903.0
175	2126.4	175	2126.4
180	2183.2	180	2183.2

Fig. 8



FREQUENCY 600. KC

IDF = 72. MV/M

MILES	FIELD, MV/M
.2	1518.37
.3	146.59
.4	8.57
.5	46.65
.6	57.12
.7	58.85
.8	57.47
.9	54.97
1.	52.14
1.1	49.31
1.2	46.62
1.3	44.11
1.4	41.8
1.5	39.68
1.6	37.74
1.7	35.96
1.8	34.33
1.9	32.83
2.	31.45

Fig. 9

FREQUENCY 600. KC

IDF = 72. MV/M

MILES	FIELD, MV/M
.2	205.88
.3	160.88
.4	17.6
.5	16.2
.6	26.15
.7	28.58
.8	28.26
.9	26.89
1.	25.17
1.1	23.38
1.2	21.66
1.3	20.06
1.4	18.58
1.5	17.24
1.6	16.03
1.7	14.93
1.8	13.92
1.9	13.02
2.	12.19

to each tower from a reference point is different. This effect is especially pronounced at low frequencies with widely spaced towers. Fig. 9 shows a pre-computed field distribution for a two-tower array in an easterly direction. The field shows a pronounced dip, then increases and asymptotically approaches the theoretical value; a marked deviation from the theoretical straight line distribution is apparent.

The field can be pre-computed to move along the inverse distance line for high conductivity values or it can follow an actual conductivity line (Fig. 9). In this manner, meaningful results can be obtained from close-in measurements which do not comport to the constant directional to non-directional field ratio valid for greater distances.

It is generally recognized that day-to-day phase and field ratio variations in the elements of a directional system will change the inverse distance field. Advance assessment of these variations is important in determining the magnitude of deviations from the nominal radiated field. With an increasing number of towers the number of various combinations of phases and ratios becomes too large for manual computation.

The computer is ideally suited for that purpose. Fig. 10 shows such an analysis of a six-tower array. The printed values show the field resulting from nominal parameters and the highest field resulting from the most unfavorable combination of indicated ratios and phases, consistent with the assumed deviations. This is a "worst case" absolute showing.

We assume, however, that the deviations would not always reach the maximum value but are most likely normally distributed around the nominal value. Additionally, it is not likely that the worst alignment will occur consistently. This leads to a simulation of the operation of a directional antenna by computer. The computer is preset to generate normally distributed deviations of phases and ratios within the specified magnitude (Fig. 11). The resulting fields are then computed and stored. After the completion of the simulation the computer prints the specified deviation of parameters, the nominal field, the maximum ("worst case") field and the frequency of occurrence of the various field values within given intervals (Fig. 12). As a result of the analysis it is shown that the field deviations are rather evenly distributed above and below the nominal value. The largest field deviation registered during the run is about 40% of the maximum possible "(worst case") value.

An interesting departure from the above case occurs when the nominal field is zero or close to zero for a pattern with very high suppression. Intuitively one would assume that the resulting field deviations would be evenly distributed above the nominal; i.e. the zero value. The simulation analysis, however, points to different results: In the case of zero nominal field every parameter deviation results in a higher field, and because of a peculiar superposition the frequency of field deviations follows a skewed distribution shown in Fig. 13. The peak of the histogram occurs at about 10-15% of the maximum value; the directional system will, therefore, most frequently deviate from the nominal zero value. The largest deviation is again close to 40% of the maximum value.

The use of computers is indicated where the computations are simple but repetitive and the amount of information is large. Such is the case in seeking new FM channel assignments, or changing existing allocations because of interference problems to or from other services. Fig. 14 shows part of a computer study of the FM spectrum; the Class A channels are properly sequenced and the reasons for the deletion of a channel are indicated. (In this example some assignments were deliberately left out to show a "Clear" print.) The program leads to a rapid analysis and multiple options become apparent. Fig. 15 shows a similar program for the allocation of television channels.

```
THETA= 0 +-DEG.= 1 +-PC= 1

RATIØS   PHASES
NØMINAL:
 1.8   0
 1.8 -102
 1.  -110
 1.  -8
 1.   8
 1.  -24
--------------

AZ= 125 NØM.MV/M= 17.0124
* 1.8   0
* 1.782 -103
* 1.01 -109
* 0.99 -9
* 1.01   7
* 1.01 -93
*MAX. VALUE: MV/M= 44.2173 *
:

AZ= 130 NØM.MV/M= 22.6901
* 1.8   0
* 1.782 -103
* 1.01 -109
* 1.01 -9
* 1.01   7
* 1.01 -93
*MAX. VALUE: MV/M= 49.9213 *
:

AZ= 135 NØM.MV/M= 18.2526
* 1.8   0
* 1.782 -103
* 1.01 -109
* 1.01 -9
* 1.01   7
* 1.01 -93
*MAX. VALUE: MV/M= 45.1127 *
:

AZ= 140 NØM.MV/M= 6.96705
* 1.8   0
* 1.782 -103
* 1.01 -109
* 1.01 -9
* 0.99   7
* 1.01 -93
*MAX. VALUE: MV/M= 34.112 *
:

AZ= 145 NØM.MV/M= 5.46871
* 1.8   0
* 1.818 -101
* 1.01 -111
* 0.99 -7
* 1.01   9
* 0.99 -95
*MAX. VALUE: MV/M= 33.0887 *
```

Fig. 10

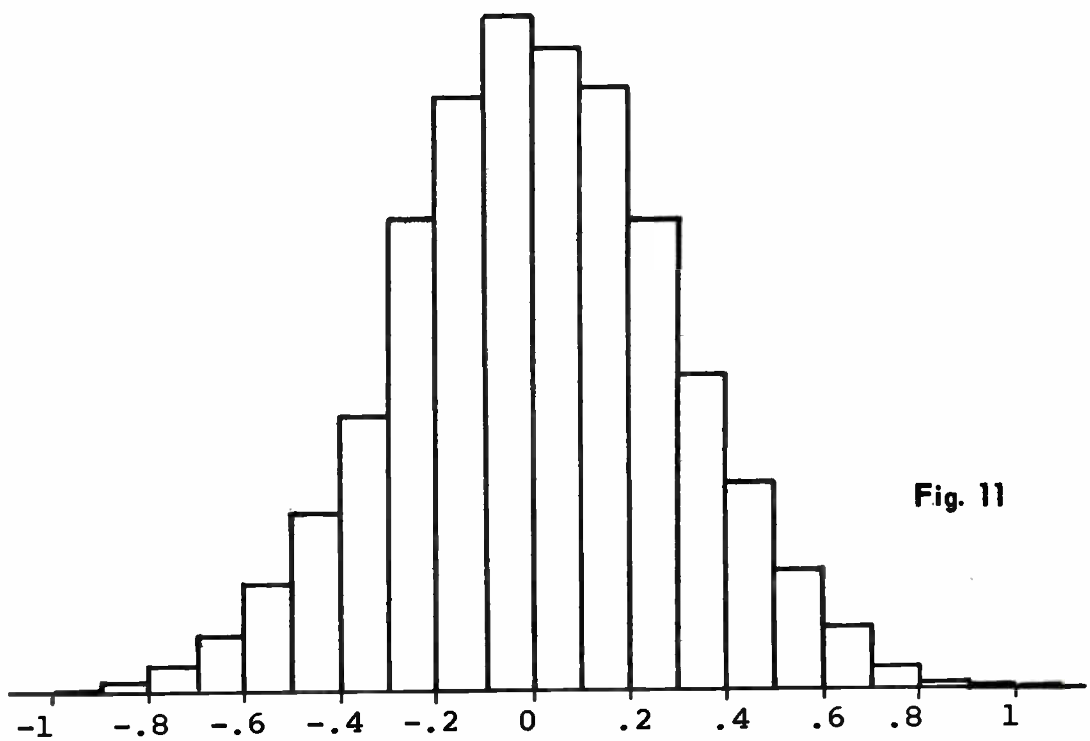
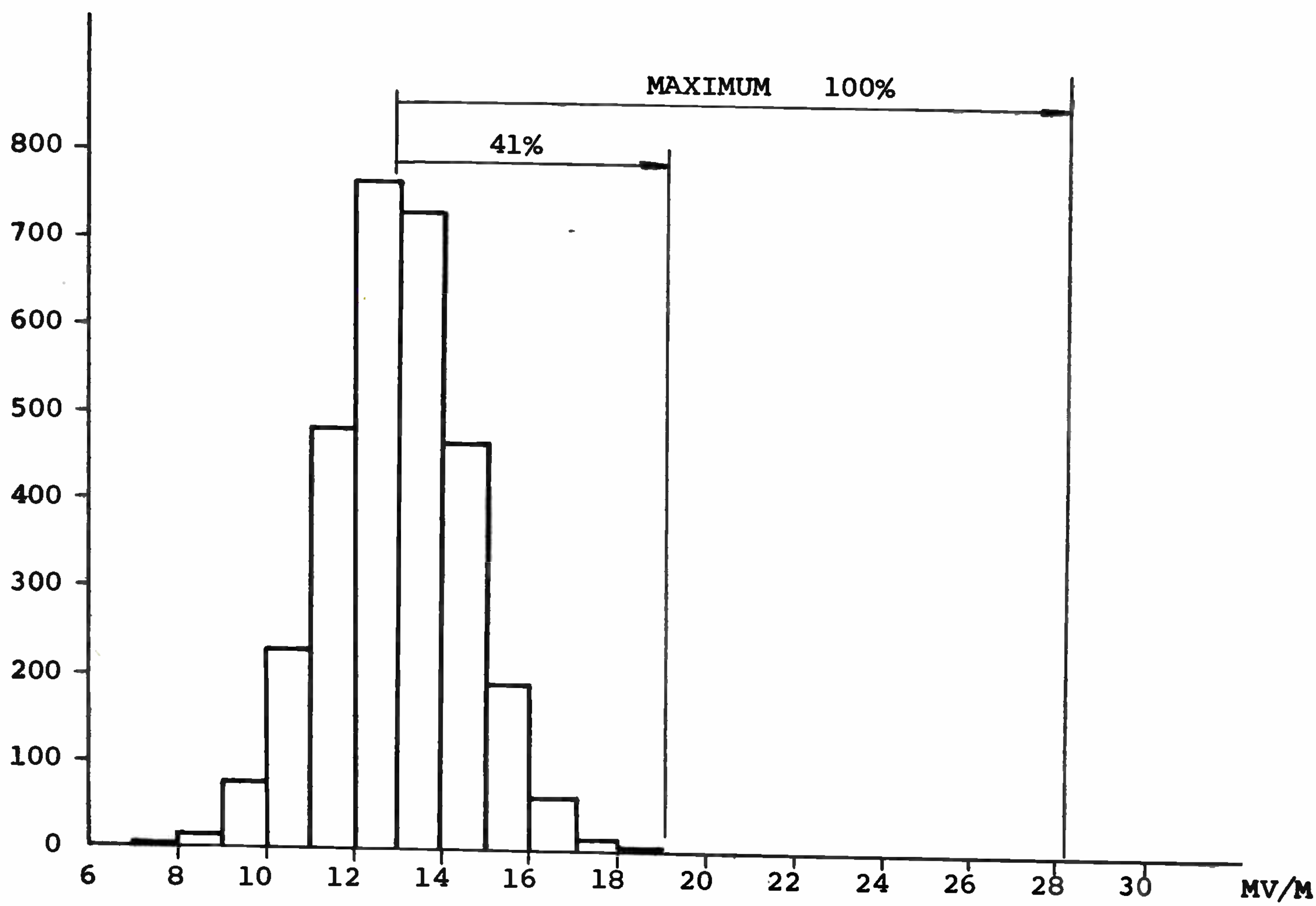


Fig. 11

AZ. 135
VARIATIØNS 3 PERCENT, NØRM. DIST.
NØMINAL RADIATIØN= 12.8 MV/M
MAXIMUM RADIATIØN= 28.2 MV/M

BETWEEN				NØ. ØF TIMES
0	AND	1	MV/M:	0
1	AND	2	MV/M:	0
2	AND	3	MV/M:	0
3	AND	4	MV/M:	0
4	AND	5	MV/M:	0
5	AND	6	MV/M:	0
6	AND	7	MV/M:	0
7	AND	8	MV/M:	2
8	AND	9	MV/M:	11
9	AND	10	MV/M:	74
10	AND	11	MV/M:	229
11	AND	12	MV/M:	479
12	AND	13	MV/M:	763
13	AND	14	MV/M:	723
14	AND	15	MV/M:	465
15	AND	16	MV/M:	189
16	AND	17	MV/M:	53
17	AND	18	MV/M:	9
18	AND	19	MV/M:	3
19	AND	20	MV/M:	0
20	AND	21	MV/M:	0

Fig. 12



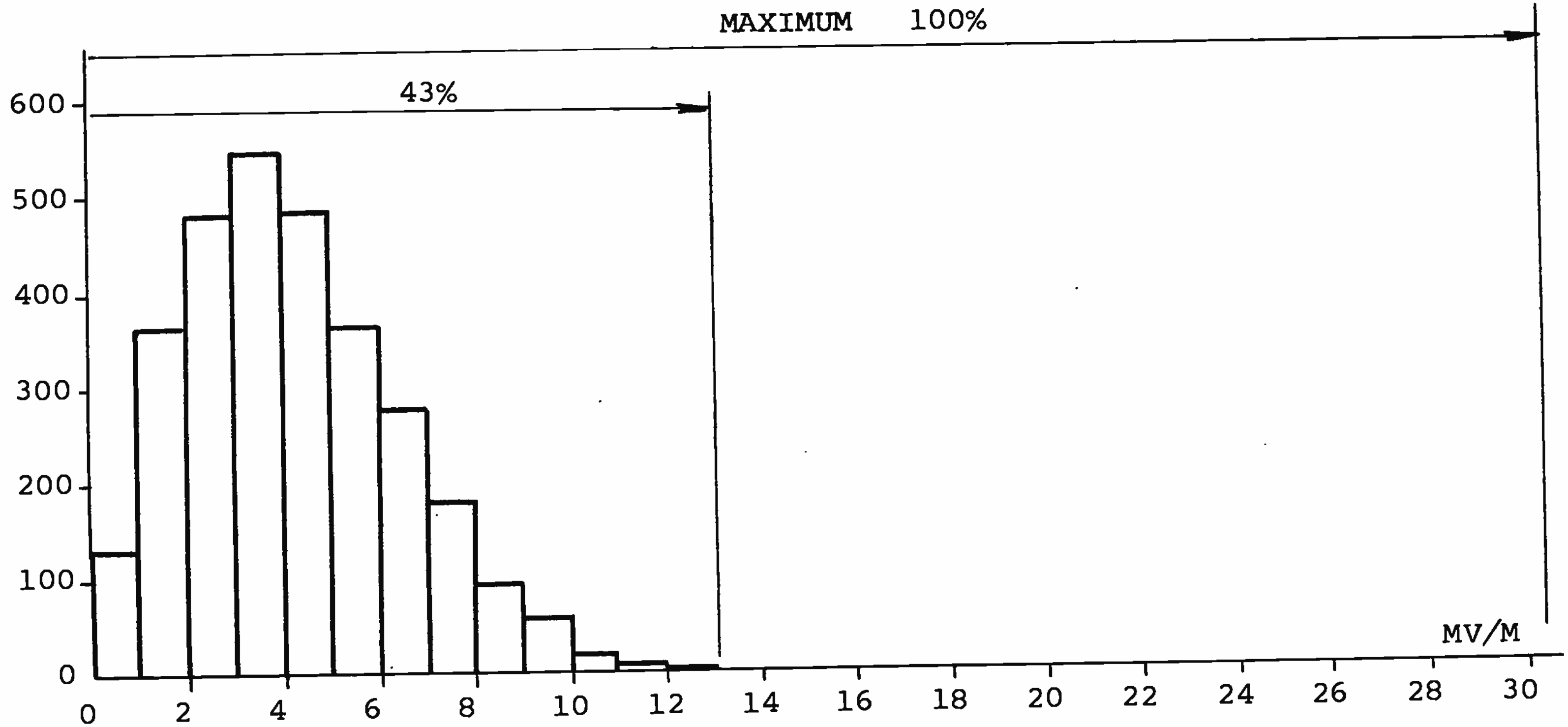


Fig. 13

AZ. 70
VARIATIØNS 1 PERCENT, NØRM. DIST.
NØMINAL RADIATIØN= 0 MV/M
MAXIMUM RADIATIØN= 30.4 MV/M

BETWEEN				NØ. ØF TIMES
0	AND	1	MV/M:	134
1	AND	2	MV/M:	364
2	AND	3	MV/M:	483
3	AND	4	MV/M:	548
4	AND	5	MV/M:	483
5	AND	6	MV/M:	360
6	AND	7	MV/M:	278
7	AND	8	MV/M:	175
8	AND	9	MV/M:	96
9	AND	10	MV/M:	52
10	AND	11	MV/M:	20
11	AND	12	MV/M:	5
12	AND	13	MV/M:	2
13	AND	14	MV/M:	0
14	AND	15	MV/M:	0
15	AND	16	MV/M:	0
16	AND	17	MV/M:	0
17	AND	18	MV/M:	0
18	AND	19	MV/M:	0

```
REF. POINT: 43  4  23      89  22  55

B OR C ? C
CH.    MHZ          CH.   MHZ    CITY, STATE        MIN.   D= (MILES)

221 A 92.1   CLEAR**

222 C 92.3   CLEAR**

223 C 92.5   CLEAR**

224 A 92.7   CLEAR**

225 C 92.9   CLEAR**

226 C 93.1   OUT: 227 C 93.3   LACRØSS WI L       150   105
226 C 93.1   OUT: 227 B 93.3   MILWKEE WI L       135   74
226 C 93.1   OUT: 229 A 93.7   MØNRØE WI L        65    35

227 C 93.3   OUT: 227 C 93.3   LACRØSS WI L       180   105
227 C 93.3   OUT: 281 B 104.3  MADISØN WI L       25    2    IF
227 C 93.3   OUT: 227 B 93.3   MILWKEE WI L       170   74
227 C 93.3   OUT: 229 A 93.7   MØNRØE WI L        65    35
227 C 93.3   OUT: 228 A 93.5   NEWLNDN WI L       105   95

228 A 93.5   OUT: 227 C 93.3   LACRØSS WI L       105   105
228 A 93.5   OUT: 281 B 104.1  MADISØN WI L       10    2    IF
228 A 93.5   OUT: 229 A 93.7   MØNRØE WI L        40    35

229 C 93.7   OUT: 228 A 93.5   NEWLNDN WI L       105   95

230 C 93.9   OUT: 229 A 93.7   MØNRØE WI L        105   35

231 C 94.1   OUT: 231 C 94.1   EUCLARE WI L       180   159
231 C 94.1   OUT: 229 A 93.7   MØNRØE WI L        65    35

232 A 94.3   OUT: 235 B 94.9   BARABØØ WI L       40    28

233 C 94.5   OUT: 235 B 94.9   BARABØØ WI L       65    28
233 C 94.5   OUT: 233 B 94.5   MILWKEE WI L       170   75

234 C 94.7   OUT: 235 B 94.9   BARABØØ WI L       135   28
234 C 94.7   OUT: 237 A 95.3   BVERDAM WI C       65    39
234 C 94.7   OUT: 233 B 94.5   MILWKEE WI L       135   75

235 C 94.9   OUT: 235 B 94.9   BARABØØ WI L       170   28
235 C 94.9   OUT: 237 A 95.3   BVERDAM WI C       65    39
235 C 94.9   OUT: 236 B 95.1   KENØSHA WI L       135   86

236 C 95.1   OUT: 235 B 94.9   BARABØØ WI L       135   28
236 C 95.1   OUT: 237 A 95.3   BVERDAM WI C       105   39
236 C 95.1   OUT: 236 B 95.1   KENØSHA WI L       170   86

237 A 95.3   OUT: 235 B 94.9   BARABØØ WI L       40    28
237 A 95.3   OUT: 237 A 95.3   BVERDAM WI C       65    39

238 C 95.5   OUT: 235 B 94.9   BARABØØ WI L       65    28
238 C 95.5   OUT: 237 A 95.3   BVERDAM WI C       105   39
238 C 95.7   OUT: 239 B 95.7   MILWKEE WI L       135   74
```

Fig. 14

Throughout the years design engineers made ample use of curves and nomograms, depicting instant solutions to relations between variables. The advent of the high-speed computer has modified that well established practice. Where curves are used in a repetitive procedure, there is a temptation to mechanize the process: the chances of visual errors are then reduced and the designer is freed for other activities.

A case in point is a set of Standard Broadcast propagation curves (Fig. 16). Unfortunately, there is no mathematical equation to express the relation between the variables across the entire range. To overcome this deficiency, the computer is used in a tandem manner. First it is employed to find an artificial relation between field and distance. The derived information is then used for the actual computation of contours. Fig. 17 shows a computer procedure which determines the directional antenna field on a given bearing and then the distances to the specified contours including the showing of the ground conductivity value and the appropriate correction for conductivity transitions.

Fig. 18 is an example of an optimum solution for sidemounting an FM antenna on an existing tower. Any height between 500 feet and 900 feet is available. The power reduction above 500 feet as required by the Rules of the Federal Communications Commission is determined by the computer. The least expensive transmitter and antenna combination is then selected by computer for the given height. It would appear that at 775 feet the best combination has been reached and a greater height would merely result in a lossy transmission line. We may, however, decide to

```
CH. 27 ØUT: CH 27 TØPEKA   KA CC      MIN. 175 D= 45.9   MI.
CH. 27 ØUT: CH 27 SPGFLD MØ C         MIN. 175 D= 152.1  MI.
CH. 27 ØUT: CH 41 KANS CTY MØ CA      MIN. 60  D= 20.1   MI.

CH. 28 ØUT: CH 28 SEDAN   KA EA       MIN. 175 D= 146.5  MI.
CH. 28 ØUT: CH 28 KING CTY MØ E       MIN. 175 D= 75.7   MI.
CH. 28 ØUT: CH 27 TØPEKA   KA CC      MIN. 55  D= 45.9   MI.
CH. 28 ØUT: CH 43 TØPEKA   KA CA      MIN. 75  D= 48.4   MI.

CH. 29 ØUT: CH 22 ST JSPH MØ C        MIN. 60  D= 53     MI.
CH. 29 ØUT: CH 43 TØPEKA   KA CA      MIN. 60  D= 48.4   MI.

CH. 30 ØUT: CH 30 CHANUTE KA EA       MIN. 175 D= 95.1   MI.
CH. 30 ØUT: CH 16 ST JSPH MØ C        MIN. 60  D= 53     MI.

CH. 31 ØUT: CH 16 ST JSPH MØ C        MIN. 75  D= 53     MI.

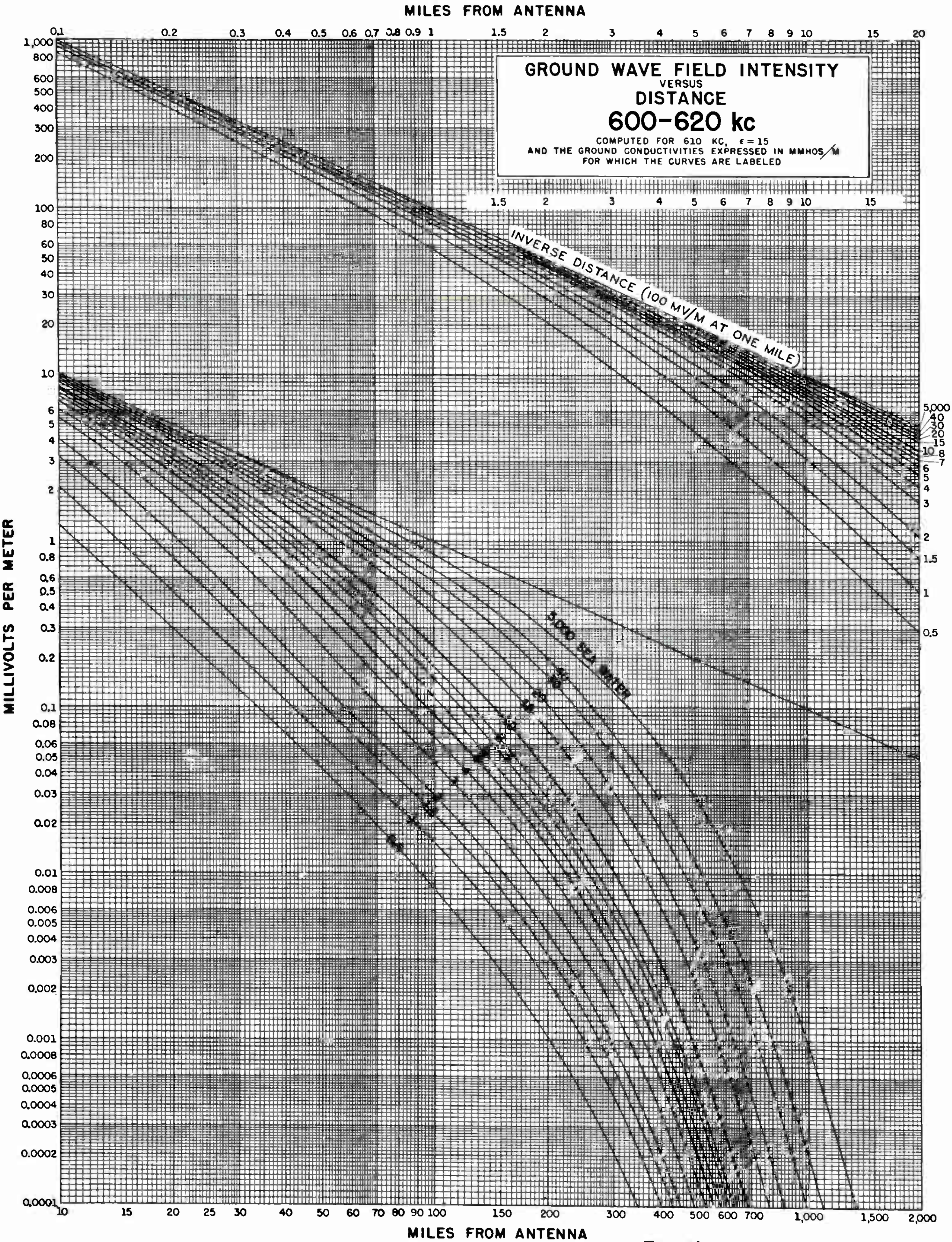
CH. 32 ØUT: CH 32 CNCL BLFF IA E      MIN. 175 D= 163.1  MI.

CH. 33 ØUT: CH 33 WICHITA KA CA       MIN. 175 D= 161.6  MI.
CH. 33 ØUT: CH 19 KANS CTY MØ EA      MIN. 60  D= 20.3   MI.

CH. 34 ØUT: CH 34 CØLMBS KA EA        MIN. 175 D= 126.3  MI.
CH. 34 ØUT: CH 34 SALINA   KA CL      MIN. 175 D= 143.6  MI.
CH. 34 ØUT: CH 41 KANS CTY MØ CA      MIN. 60  D= 20.1   MI.
CH. 34 ØUT: CH 27 TØPEKA   KA CC      MIN. 60  D= 45.9   MI.
CH. 34 ØUT: CH 49 TØPEKA   KA CA      MIN. 75  D= 39.7   MI.
CH. 34 ØUT: CH 19 KANS CTY MØ EA      MIN. 75  D= 20.3   MI.

CH. 35 ØUT: CH 49 TØPEKA   KA CA      MIN. 60  D= 39.7   MI.
CH. 35 ØUT: CH 50 KANS CTY MØ CA      MIN. 75  D= 19.9   MI.
```

Fig. 15



GRAPH 3

Fig. 16

CØNTØUR, MV/M:		1000	25	5	2	.5	.025	.005	
AZ.	IDF								
0	94.1	*	3	9.9	17	33	115	197	MI
CØND.		8	8	8	8	8	8	8	
CØRR.		0	0	0	0	0	0	0	
10	217.8	.2	5.8	16.3	25.8	47.5	156	243	MI
CØND.		8	8	8	8	8	8	8	
CØRR.		0	0	0	0	0	0	0	
20	379.2	.4	8.6	21.7	33.1	60.1	185	268	MI
CØND.		8	8	8	8	8	8	4	
CØRR.		0	0	0	0	0	0	43.1	
30	553	.5	11	26	39.1	70.4	201	284	MI
CØND.		8	8	8	8	8	4	4	
CØRR.		0	0	0	0	0	38.8	38.8	
40	707.8	.7	12.8	29.1	43.5	74.9	175	252	MI
CØND.		8	8	8	8	2	2	2	
CØRR.		0	0	0	0	35.7	35.7	35.7	
50	817.2	.7	13.9	31	46.2	70.4	174	253	MI
CØND.		8	8	8	8	2	2	2	
CØRR.		0	0	0	0	28.5	28.5	28.5	
60	869.2	.8	14.4	31.9	47.3	67.8	173	252	MI
CØND.		8	8	8	2	2	2	2	
CØRR.		0	0	0	24.7	24.7	24.7	24.7	
70	868	.8	14.4	25.8	36.4	57.9	163	242	MI
CØND.		8	8	4	4	2	2	2	
CØRR.		0	0	4.5	4.5	14.8	14.8	14.8	
80	830	.8	13.3	24.3	34.7	61.8	169	248	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	3.4	3.4	3.4	3.4	23	23	
90	776.1	.7	12.2	23	33.1	59.3	168	246	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	2.7	2.7	2.7	2.7	24.5	24.5	
100	724.8	.7	11.9	22.4	32.2	57.6	165	242	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	2.7	2.7	2.7	2.7	24.5	24.5	
110	689.2	.6	11.7	22	31.5	56.4	162	240	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	2.7	2.7	2.7	2.7	24.5	24.5	
120	676.6	.6	11.6	21.8	31.3	55.9	162	239	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	2.7	2.7	2.7	2.7	24.5	24.5	
130	689.2	.6	11.7	22	31.5	56.4	163	240	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	2.7	2.7	2.7	2.7	25.2	25.2	
140	724.8	.7	12.2	22.8	32.5	57.9	167	245	MI
CØND.		8	4	4	4	4	2	2	
CØRR.		0	3.1	3.1	3.1	3.1	27.1	27.1	

Fig. 17

```
ANTENNA
BAYS: 2     DB GAIN: 0        PRICE: $ 2250    HEIGHT, FT: 10
BAYS: 3     DB GAIN: 1.76     PRICE: $ 3190    HEIGHT, FT: 20
BAYS: 4     DB GAIN: 3.22     PRICE: $ 4260    HEIGHT, FT: 30
BAYS: 5     DB GAIN: 4.31     PRICE: $ 5325    HEIGHT, FT: 40

XMTR KW: 1     PRICE: $ 6995
XMTR KW: 3     PRICE: $ 10950
XMTR KW: 5     PRICE: $ 13995
```

Fig. 18

```
LINE: $ 4    PER FØØT,  HØRIZ. RUN: 50   FEET
```

RAD.CENTER FT AAT	AG	MAX.ERP KW	LINE FT	BAYS	XMTR KW	AVAIL. ERP KW	TPØ PC	PRICE $
500	286	10.	316	5	5	11.7	86	20584
525	311	8.9	346	4	5	8.9	99	19639
550	336	7.9	371	4	5	8.8	89	19739
575	361	7.1	396	4	5	8.7	81	19839
600	386	6.3	416	5	3	6.7	95	17939
625	411	5.7	441	5	3	6.6	87	18039
650	436	5.2	466	5	3	6.5	79	18139
675	461	4.7	496	4	3	5.	94	17194
700	486	4.3	521	4	3	5.	87	17294
725	511	4.	546	4	3	4.9	81	17394
750	536	3.6	571	4	3	4.8	75	17494
775	561	3.3	601	3	3	3.4	98	16544
800	586	3.1	626	3	3	3.4	92	16644
825	611	2.9	651	3	3	3.3	86	16744
850	636	2.7	676	3	3	3.3	81	16844
875	661	2.5	701	3	3	3.3	76	16944
900	686	2.3	726	3	3	3.2	71	17044

operate the transmitter at a reduced power, e.g. at 86% as shown in Column 8. The mounting height of 825 feet would then represent an optimum solution for the assumed set of conditions. A similar procedure can be employed where multiple options have to be considered involving different equipment proposals, terms and large expenditures.

Numerous other computer applications have been developed, some complex and extensive, in response to a need for better predictions and analysis. Among such applications are nighttime studies in the standard broadcast band, propagation predictions and shadow losses in the very-high-frequency bands, and others. Benefits accrue to the designer whose computational efforts are alleviated and to the proponent who can be provided with better proposals.

An Aural STL System for Composite FM Stereo Signals

Howard M. Ham, Jr.
Vice President - Engineering
MOSELEY ASSOCIATES, INC.

The ever increasing popularity of aural STLs in the 942-MHz to 952-MHz band serves to point out the fact that there are many advantages in using an aural STL. It is not the purpose of this paper to itemize the advantages of an aural STL; however, when an STL is being considered, usually the only point of comparison or reference is the anticipated performance of a program-quality telephone line. In many cases the transmitter site is located in an area which makes the installation or use of telephone facilities very expensive and somewhat questionable in terms of reliability. In this case, of course, the decision to use an Aural STL would be an easy one.

The superior performance of an aural STL in terms of signal-to-noise ratio, frequency response, transient response, and reliability is usually the deciding factor when a telephone line is readily available and must be rationally compared with the characteristics of an STL. Cost, of course, is always an important factor and must take its proper position in the equation when the installation of an STL is being considered.

In the early years of stereophonic development when the various systems were being tested and the Regulations were in the process of being adopted by the FCC, it became quite apparent that some consideration must be given to the transmission of stereophonic program from the studio to a remotely located transmitter site. Where telephone lines were being used, the installation and cost of additional lines were thought to be the only problems to be considered. However, it soon became apparent that the problem of differential amplitude and phase between a set of program lines was indeed a serious problem if cross-talk specifications were to be met. In the case where an aural STL was used, or was being considered for use, the FCC chose not to permit the same licensee to hold more than one aural STL channel. The squeeze for spectrum space soon proved that this was indeed a wise decision.

At that time Moseley Associates, Inc. began studies to investigate the possibilities of transmitting two full-fidelity 15-kHz audio channels within the limits of a single 500 kHz aural STL channel. Our tests clearly showed that this scheme was indeed feasible and readily obtainable with standard state-of-the-art transmitting and receiving equipment. These tests were submitted to the Commission and, as a result, the Rules were changed to permit the use of two carriers operating within the assigned 500 kHz channel. Thus began the operation of what is now considered a standard dual STL operation for FM stereo. It became immediately apparent that in certain circumstances the ideal way to handle the stereophonic signal would be to generate a composite stereophonic signal in the studio and transmit it directly to the transmitter without further processing. This permits the stereophonic generating equipment to be located at the studio. In many installations this greatly simplifies the maintenance problems.

Although the receivers were capable of wide-band operation, the transmitters used in the early STLs were, for the most part, phase modulated. A quick study of the fundamental requirements points out the basic reason the early STLs were not applicable to wide-band or composite stereophonic operation. In order for the transmitted signal to appear as frequency modulation to a frequency modulation receiver, the amplitude of the signal applied to a phase-modulated transmitter must be amplitude predistorted at a rate of 6 db downward per octave. Since the amplitude response of such a system must be flat from 50 Hz through 53,000 Hz, this would indicate that an amplitude predistortion of approximately 66 db would be required. That is to say that the signal applied to the modulator at a 53-kHz rate would be required to be 66 db below that of a 50-Hz rate applied to the same modulator. In order to achieve the required signal-to-noise ratio, it would be necessary for the phase-modulator system to have either an extremely large phase modulation ability at 50 Hz or an extremely quiet phase modulator and multiplying system, neither of which is at all practical. The only other approach in attempting to apply a composite stereophonic waveform to a phase-modulated system is that of splitting the sum and difference channels of the composite stereophonic signal and inserting them into the phase-modulated transmitter in the appropriate spots so as to optimize the modulation capabilities for the given frequency range involved. Splitting of the sum and difference channels creates an almost insurmountable problem of differential phase and amplitude between the sum and difference channels after they are applied to the separate modulator sections. It is the purpose of this paper to describe a successful field-proven system for transmission of composite FM stereo signals.

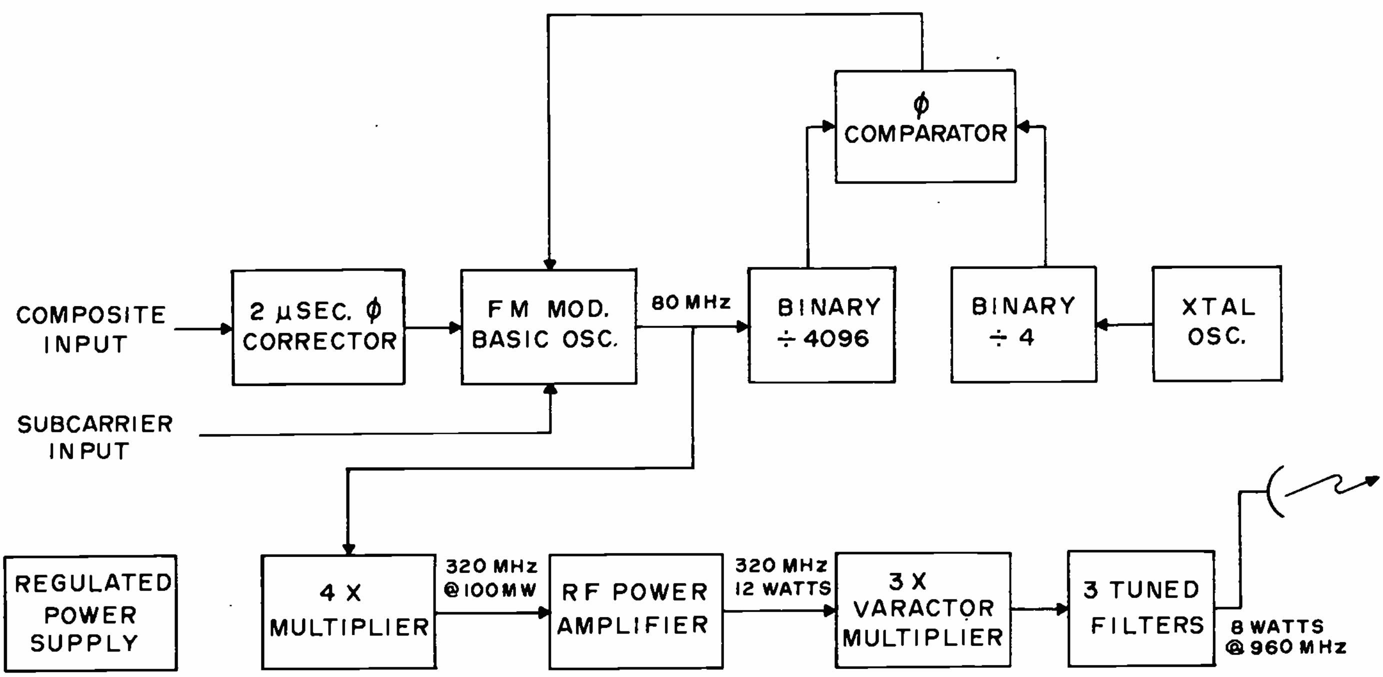
As the state-of-the-art continued to advance in solid-state technology, a rather simple but yet very stable system of direct frequency modulation was developed. Our first application of this scheme to a practical product was its use in the Model PCL-303 Aural STL. This system was rated essentially flat from 50 Hz through 15 kHz and was capable of multiplex operation for use in remote control, SCA, or other subcarrier schemes. The fact that the Model PCL-303 utilized direct frequency modulation made it a very likely candidate for conversion to a wide-band or composite STL system. Work began on the development of a wide-band STL system utilizing the major components of the PCL-303. This offered the advantage of using components and circuitry that had enjoyed the benefits of more than two years of field testing. This, in turn, provided a considerably higher degree of predictable reliability. The new STL system, which is essentially a first cousin to the original PCL-303, was given the model number of PCL-303/C.

Fig. 1 shows a basic block diagram of the PCL-303/C Composite STL transmitter. The composite stereophonic signal is applied to the frequency-modulated oscillator through a small amount of phase correction. This correction is required to offset the slight degree of phase degradation that occurs in the receiver. The corrected composite stereophonic signal is applied to a pair of back-to-back varicap modulators. The varicap diodes (voltage-variable capacitors) form a part of the capacity of the resonant circuit portion of the basic oscillator. Since the frequency of oscillation is determined solely by the resonant frequency of the tuned circuit, variation of the capacity will result in frequency modulation of the basic oscillator. The basic frequency-modulated oscillator operates at approximately 80 MHz. The modulated oscillator drives a buffer amplifier which is coupled to a series of binary dividers to divide the oscillator frequency by 4096. This provides a frequency of approximately

19.5 kHz that is directly proportional to the frequency and phase of the 80-MHz modulated oscillator. A fact worth noting at this point is that not only has the frequency of the modulated oscillator been divided by 4096 but also the deviation has been divided by the same factor. A crystal oscillator operating at approximately 78 kHz is applied to a pair of binary dividers and divided by 4. This process results in a crystal-controlled frequency reference source of approximately 19.5 kHz. The crystal-controlled reference and the divided output from the modulated oscillator are applied to separate inputs of a dual input AND circuit. The output of the AND circuit is a variable width pulse. The width of the pulse is proportional to the difference in phase of the two signals being applied to the AND gate. Therefore, when the variable pulse output is integrated to an average DC voltage, it will be proportional to the difference of the two frequencies being compared. The DC is applied as feedback to a separate pair of varicap diodes in the frequency-modulated oscillator. This will lock the modulated oscillator to a reference frequency that is directly proportional to the stability of the crystal-controlled reference oscillator. This scheme is simply a variation on the early phase-locked AFC loops used in some of the first direct frequency-modulated systems developed. The primary difference is the application of solid-state technology in the development of totally untuned, stable, frequency divider systems, including extensive use of integrated circuits. The result is a well behaved and reliable automatic frequency control system.

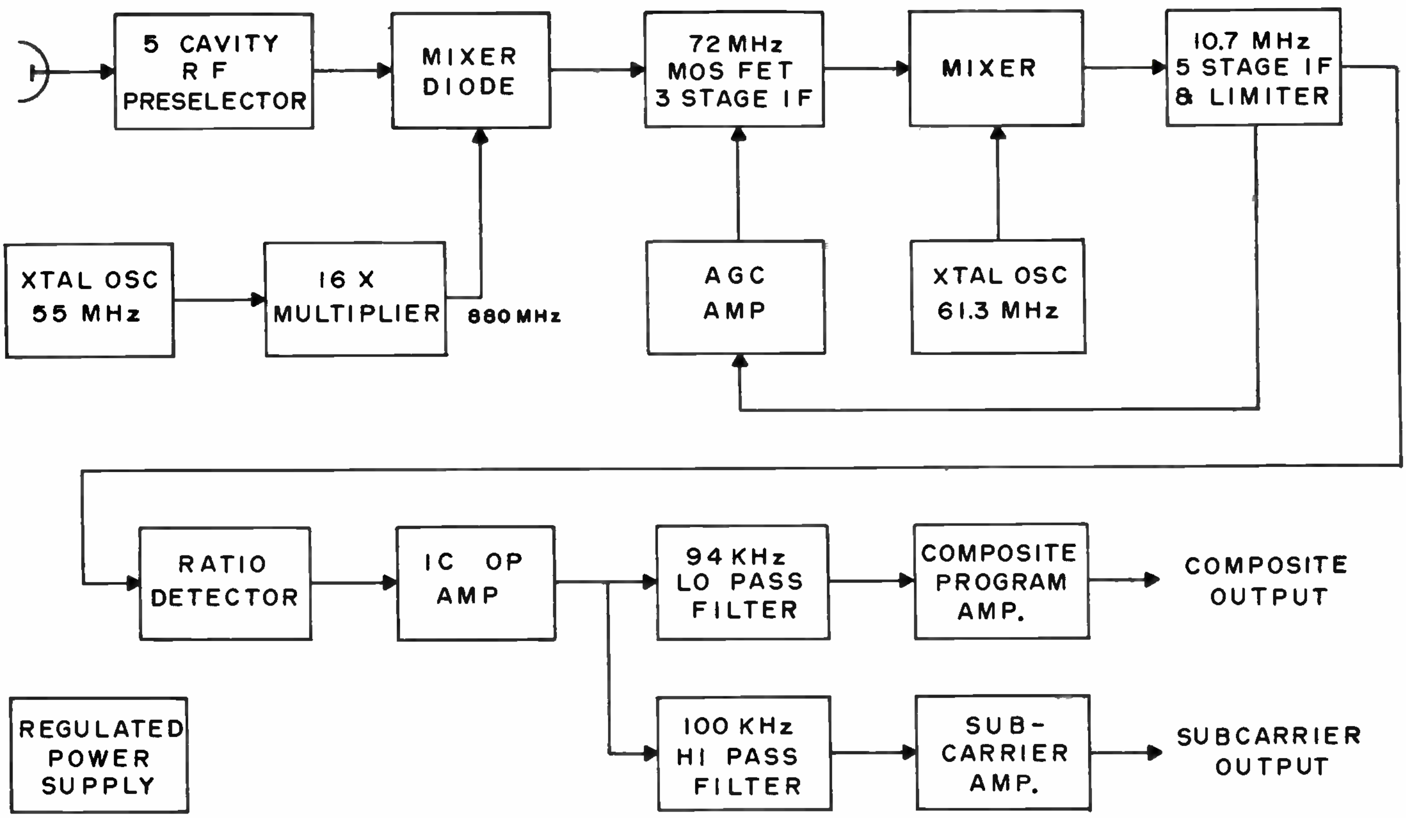
The same buffered output from the modulated oscillator that is applied to the 4096 divider is also applied to a four-times-frequency multiplier, which has an output of 100 mw. The output of the frequency multiplier is applied to the input of a 3-stage RF power amplifier. The overlay transistors used here represent state-of-the-art devices for RF power amplifiers. This amplifier elevates the power level of the 320-MHz RF to approximately 12 watts. The output of the power amplifier is then

FIGURE I



MOSELEY ASSOCIATES INC.
PCL-303/C Composite STL Transmitter
BLOCK DIAGRAM

FIGURE 2



MOSELEY ASSOCIATES INC.

PCL-303/C Composite STL Receiver

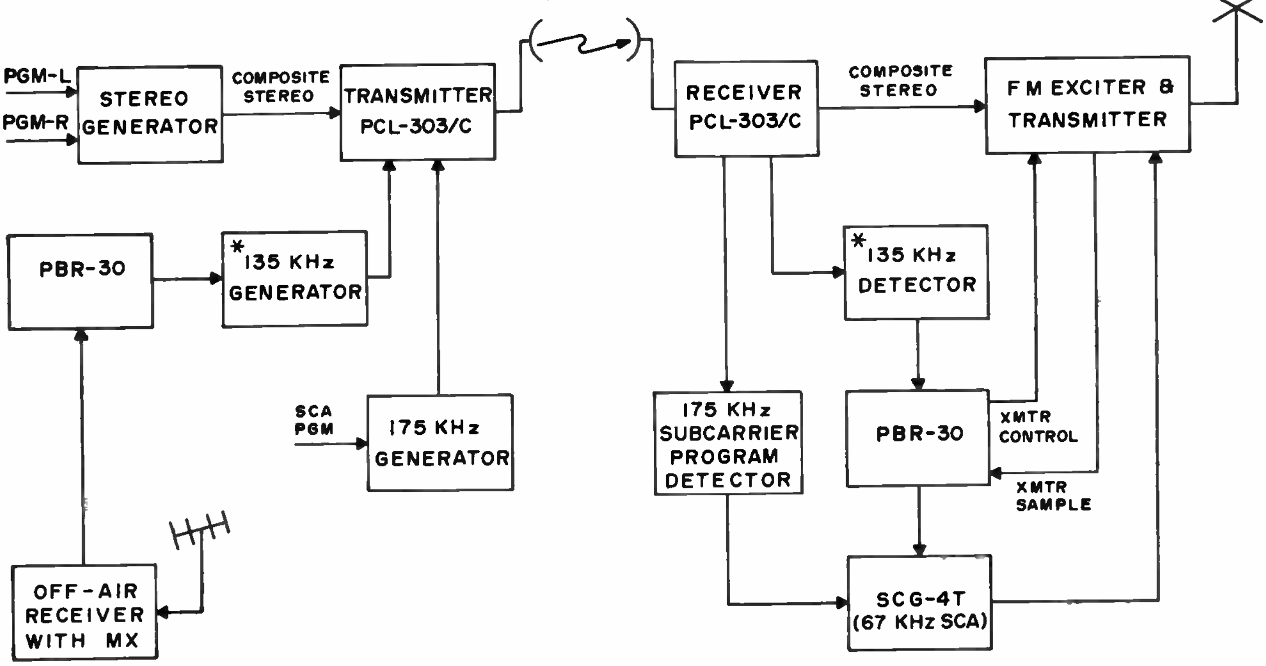
BLOCK DIAGRAM

applied directly to a varactor tripler. The tripler circuitry is followed by three tuned cavities to reduce the harmonic content of the transmitter output. The final output is approximately 8 watts at 960 MHz. Two subcarrier input connectors are provided on the rear of the transmitter to facilitate the addition of multiplex subcarriers for SCA and remote control purposes.

Fig. 2 shows a basic block diagram of the PCL-303/C Composite STL receiver. A 5-cavity RF preselector precedes the first mixer diode. The local oscillator signal for the first mixer is provided by a crystal-controlled oscillator operating at approximately 55 MHz. This is multiplied by 16 to approximately 880 MHz. The output frequency of the first mixer is 72 MHz and is applied to a three stage MOSFET 72-MHz IF amplifier. The output of the 72-MHz IF is coupled to the second mixer. The conversion oscillator for the second mixer is a crystal-controlled oscillator operating at 61.3 MHz. The output of the second mixer is 10.7 MHz and is amplified by a 5-stage IF amplifier and limiter. A DC voltage proportional to the signal level within the 10.7 IF is applied to an AGC amplifier. The output of the AGC amplifier controls the gain of the 72-MHz IF by varying the voltage on Gate 2 of the first two field effect transistors. The 10.7-MHz limiter drives a wide-band ratio detector which is coupled to an integrated circuit operational amplifier. The output of the operational amplifier provides a low-impedance wide-band signal that can be easily processed. Processing is accomplished by applying the output of the operational amplifier to two separate filters. One filter is a 94-kHz low-pass phase linear filter, and the other is a 100-kHz high-pass filter. The output of the 94-kHz low-pass filter will be the composite stereophonic program. If a 67-kHz SCA subcarrier has been applied to the STL transmitter, it will appear at the output of the 94-kHz low-pass filter summed with the composite stereo signal. The output of the 94-kHz low-pass filter is applied to a composite program amplifier. The output of the 100-kHz high-pass filter is applied to a subcarrier amplifier. From all outward appearances the PCL-303/C Composite STL receiver is a straightforward dual-conversion receiver. This is essentially true with one possible exception. The 10.7-MHz stage requires careful attention to alignment procedures to assure that the passband of the receiver offers optimum phase linearity in order to preserve the integrity of the composite stereophonic signal.

Fig. 3 shows a block diagram of the complete PCL-303/C Composite STL system with SCA and remote control. This particular example demonstrates the use of two subcarriers operating above the cut-off frequency of the phase linear, low-pass filter located in the PCL-303/C receiver. The first of these subcarriers operates at 135 kHz and is used to convey remote control information from the studio site to the transmitter site. A second subcarrier operating at 175 kHz is used to convey SCA program material to the transmitter. The 135-kHz subcarrier is demodulated and the control tones are applied to the transmitter control unit of the remote control system. The 175-kHz subcarrier is demodulated and provides the program material for the 67-kHz SCA generator. The system pictured in Fig. 3 uses the 67-kHz SCA not only as a means to carry the SCA program but also as a means to convey the metering information from the transmitter back to the studio site. The metering signal is generated within the remote control system by converting the DC samples from the transmitter to a frequency that is proportional to the DC sample. The frequency range of the metering system, shown in this example, is from approximately 22 Hz to 36 Hz. This subaudible information is applied to the 67-kHz SCA generator and in turn is transmitted back to the studio via the main FM transmitter.

FIGURE 3



MOSELEY ASSOCIATES INC.

PCL-303/C Composite STL System with SCA & Control / Metering showing FM Xmtr.

* CONTAINED WITHIN PBR-30

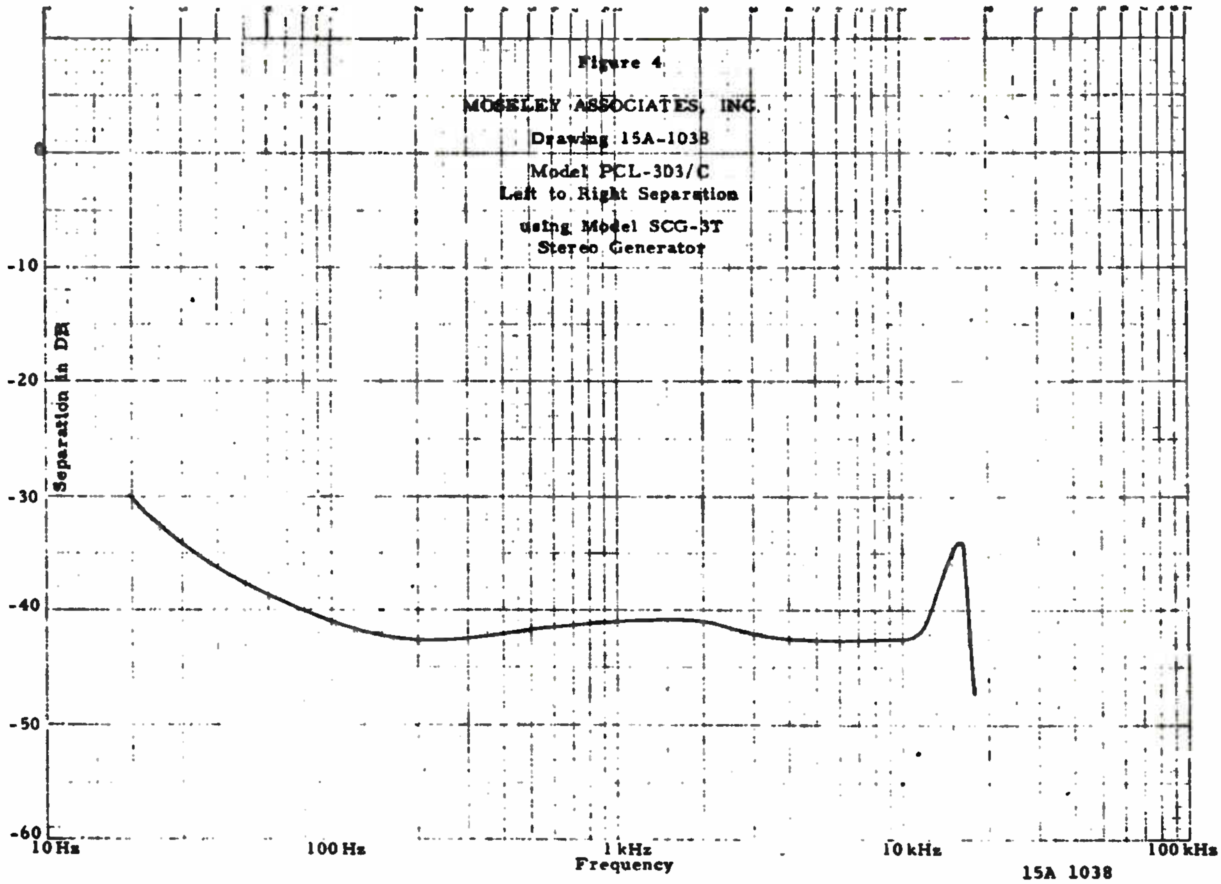


Figure 4
MOSELEY ASSOCIATES, INC.
Drawing 15A-1038
Model PCL-303/C
Left to Right Separation
using Model SCG-3T
Stereo Generator
Separation in DB
0
-10
-20
-30
-40
-50
-60
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
Frequency
15A 1038

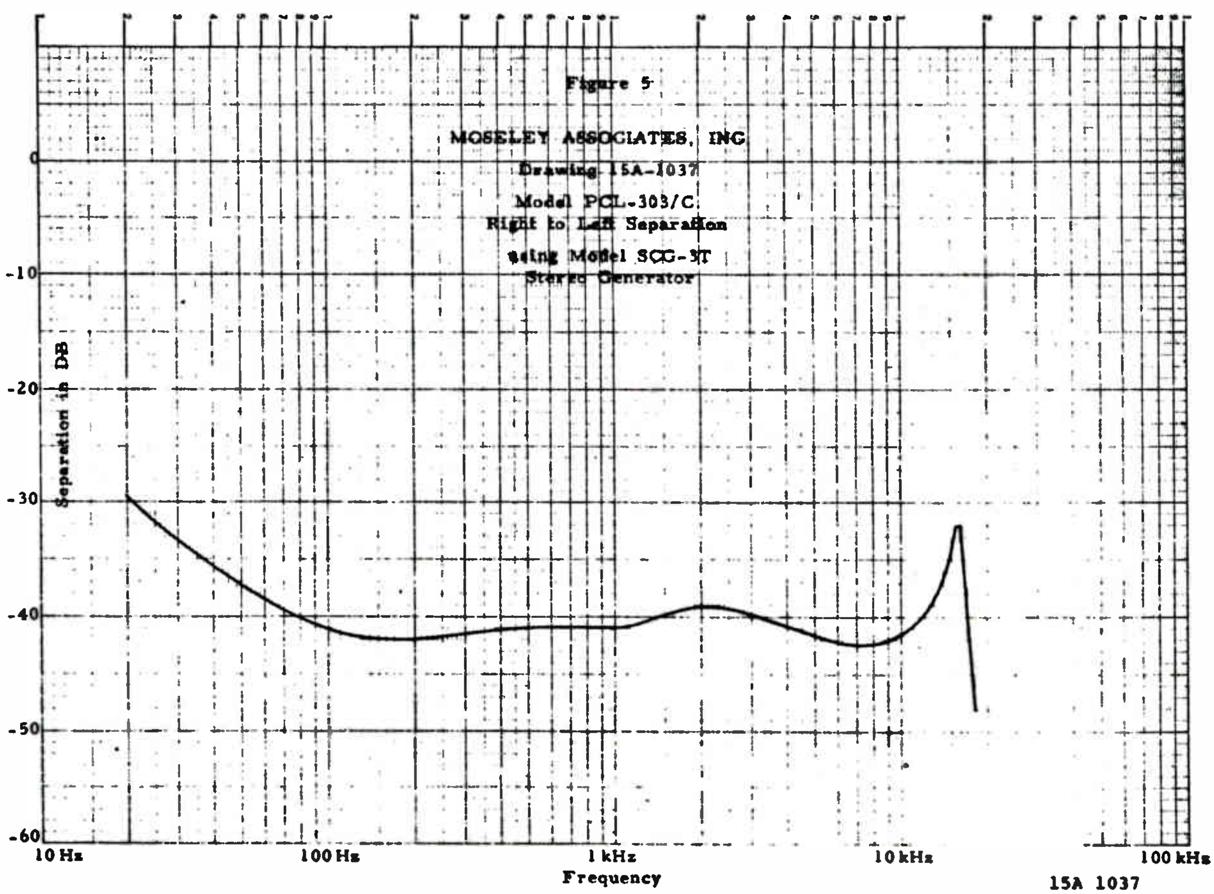


Figure 5
MOSELEY ASSOCIATES, INC
Drawing 15A-1037
Model PCL-303/C
Right to Left Separation
using Model SCG-3T
Stereo Generator
Separation in DB
0
-10
-20
-30
-40
-50
-60
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
Frequency
15A 1037

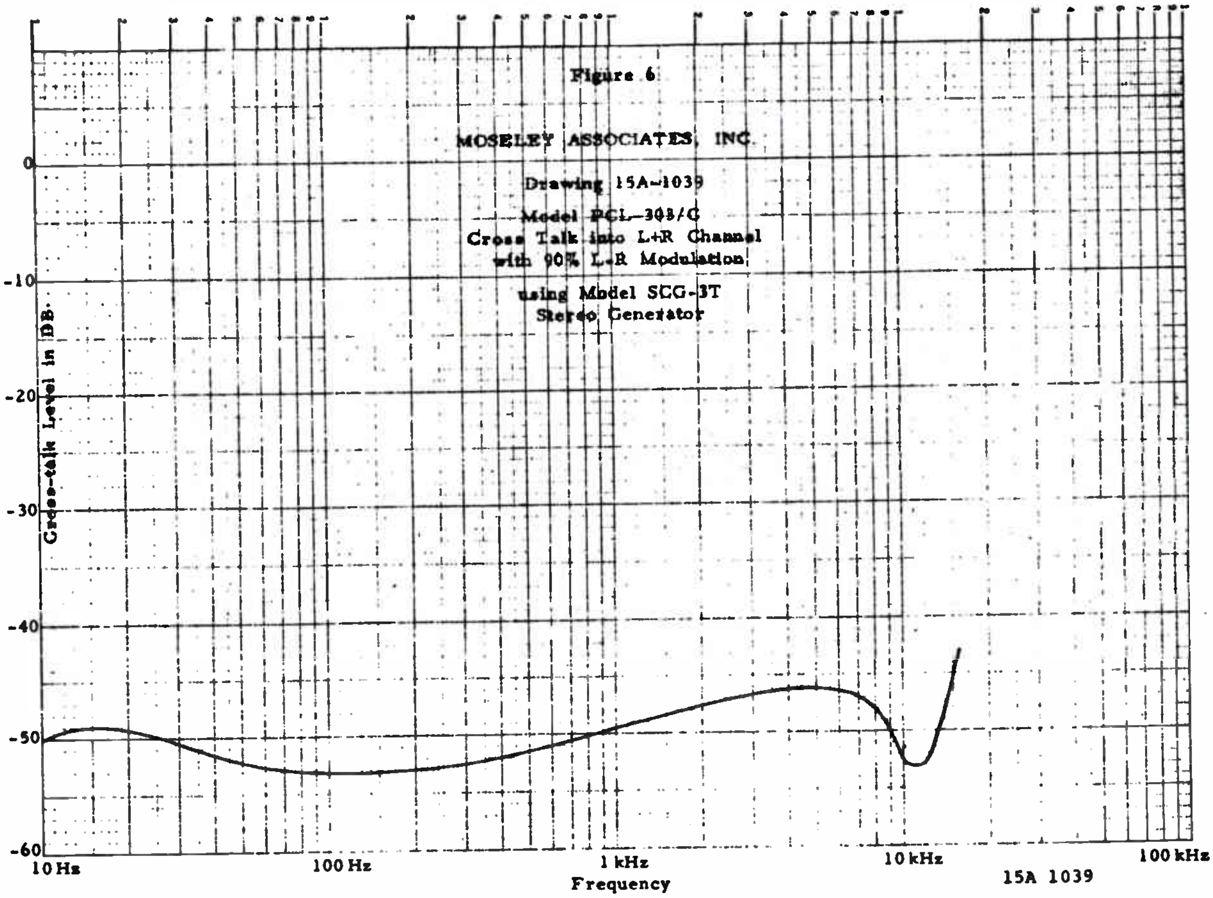


Figure 6
MOSELEY ASSOCIATES, INC.
Drawing 15A-1039
Model PCL-303/C
Cross Talk into L+R Channel
with 90% L-R Modulation
using Model SCG-3T
Stereo Generator
Cross-talk Level in DB
0
-10
-20
-30
-40
-50
-60
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
Frequency
15A 1039

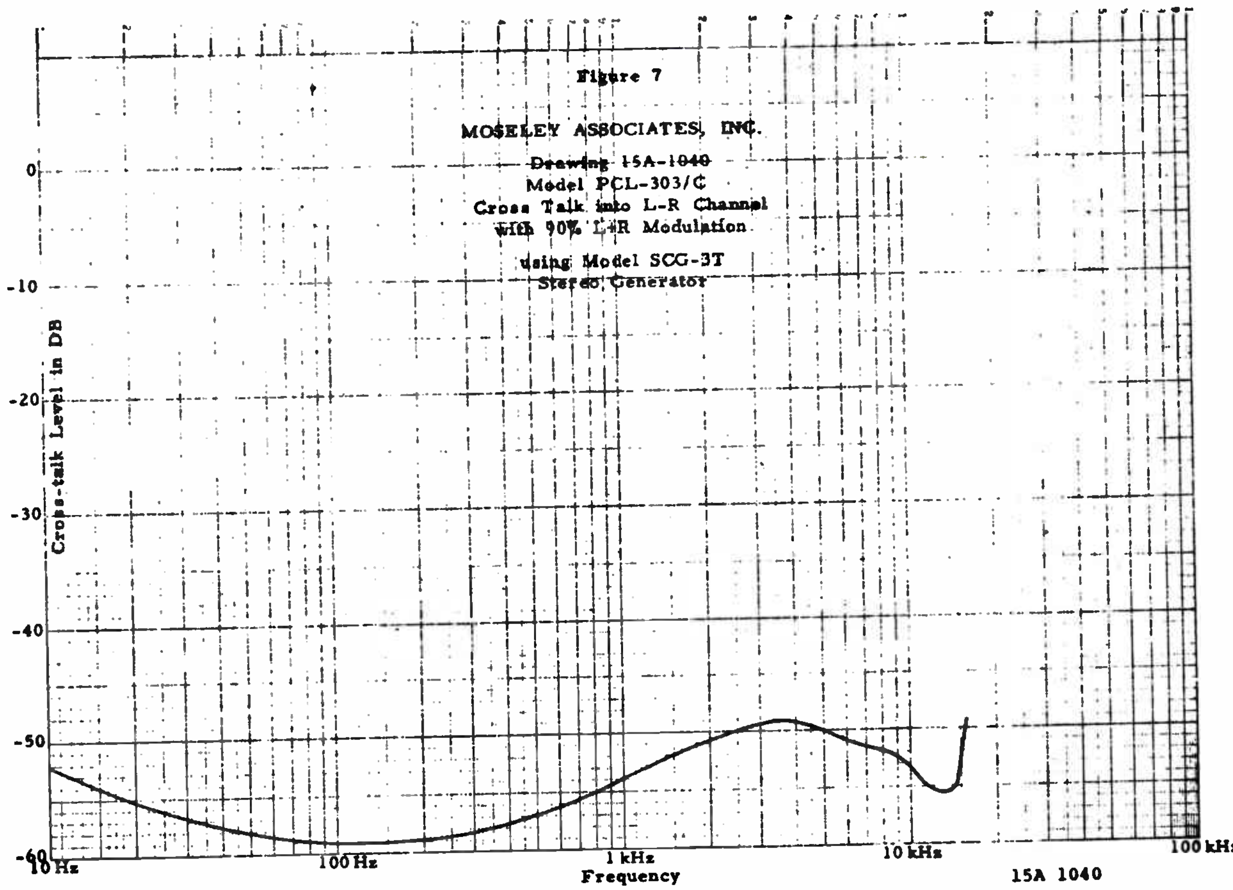


Figure 7
MOSELEY ASSOCIATES, INC.
Drawing 15A-1040
Model PCL-303/C
Cross Talk into L-R Channel
with 90% L+R Modulation
using Model SCG-3T
Stereo Generator
Cross-talk Level in DB
0
-10
-20
-30
-40
-50
-60
10 Hz
100 Hz
1 kHz
10 kHz
100 kHz
Frequency
15A 1040

Since the metering information is in the subaudible range and its amplitude is held to 10% or less than that of the actual SCA program, this system of remote metering offers very little degradation to the SCA performance. A standard SCA receiver, with minor modifications for removing the subaudible metering tones, is located at the studio. Subaudible metering signals from the receiver are applied to the studio unit of the remote control system. Here the metering information is converted back to a linear DC voltage proportional to the original sample. The DC is then applied to a properly scaled meter for final readout.

The stereo generating system used with the composite STL must, of course, generate a composite stereophonic signal on a single output connector. Although a properly adjusted PCL-303/C System is nearly transparent, some small amount of degradation of the composite stereophonic signal will occur. Therefore, the stereophonic generating system must be capable of exceeding the specifications for stereophonic broadcasting. A typical amount of degradation of the separation to be expected is approximately 3 db. For example, if the stereophonic generator is producing a separation of 35 db, the output of the composite receiver may degrade the separation to approximately 32 db. Therefore, it is recommended that the stereophonic generator be basically capable of producing separation of at least 40 db and crosstalk of no worse than 45 db over the entire 50-Hz to 14-kHz range.

Figs. 4, 5, 6, and 7 show typical separation and cross-talk performance. This data was taken with a Model SCG-3T Stereo Generator driving the PCL-303/C STL. The slight but abrupt degradation of separation at 10 kHz to 15 kHz, as shown on Figs. 4 and 5, is a result of minor phase nonlinearity of the output filter located within the stereo generator. The crosstalk performance, as illustrated in Figs. 6 and 7, shows small irregularities as a result of differential phase error between the two audio channels. This error (less than 1°) originates in the two 17-kHz low-pass audio input filters in the stereo generator. These low-pass filters provide greater than 50 db rejection at 19 kHz and above in order to protect the pilot region from any program material that might extend into this region.

Certainly a composite STL system is not everybody's cup of tea. Although such a system offers many advantages, like all other good things it has a few disadvantages. The obvious and most often considered advantage is that of cost. If a single microwave system can be made to perform properly where previously two systems were required, the cost savings are obvious. The fact that the stereophonic generating equipment can be located at the studio site simplifies the considerations of maintenance and adjustment. The dual STL offers the obvious advantage of redundancy and has, in addition, slightly greater versatility in terms of selection and use of subcarriers. The increased bandwidth and lack of de-emphasis in a composite receiver requires that the RF signal at the receiver input be slightly higher than that required for a standard aural STL.

In the final analysis the selection of a telephone line, a dual STL, or a composite STL is going to depend upon which is best for the specific circumstances involved. The addition of a composite STL to the variety of equipment already available should, in certain cases, make profitable broadcasting more easily realizable.

Construction of Directional Antenna Systems

by Orville J. Sather

Director of Engineering, WOR-AM-FM-TV

The first high-power AM directional antenna system in the United States was built in 1936 by Radio Station WOR at Carteret, New Jersey, then a 50 KW clear-channel station operating on 710 kHz. It consisted of a three-element broadside array—two quarterwave towers and a center vertical wire—all fed in phase. It produced a figure-8 pattern, with the lobes directed toward New York City, 20 miles to the northeast, and toward Philadelphia, 65 miles to the southwest. The purpose of the directional antenna system was then, and still is, to include the greatest number of people within its primary coverage area.

At that time reception in both New York and Philadelphia, as well as in the surrounding metropolitan areas, was excellent. Electrical interference was low, buildings were not as well shielded, and there were few tall buildings to act as a curtain to reduce the signal on the shadowed side. By the early 1960's coverage by WOR in certain areas of Manhattan, Queens, and the Bronx had become poor because of intervening building construction and increased electrical noise. As an example, WOR's signal on the west side of Manhattan measured 77 mv/m while directly opposite and equidistant on the east side it measured 17 mv. Electrical noise at street level in Manhattan measured 25 mv.

In 1963 WOR engaged the firm of Silliman, Moffet and Kowalski, Consulting Radio Engineers, to design a new directional antenna system which would provide maximum signal throughout the New York City metropolitan area (our major sales market), encompass the maximum number of homes within the 25 mv and 50 mv contours, and still not substantially reduce the existing signal in any direction. WOR acquired 67 acres of garbage filled meadowland just 5 miles west of Times Square, and just west of the Hackensack River in the town of Lyndhurst, New Jersey. This location of the new transmitter site is shown in Fig. 1, which also shows other stations in the vicinity. Silliman recommended a 3 tower directional array, with 177° radiators 690 feet tall, spaced and located as shown in Fig. 2.

The former radiation pattern from the Carteret site, indicating the 1,000 mv/m contour is shown in Fig. 3. Silliman's predicted radiation pattern from the Lyndhurst site is shown in Fig. 4. You will note that the upper lobe has been rotated 15° clockwise in order to provide greater coverage of the heavily populated Long Island area and the north shore of Long Island Sound. The greater area within the predicted pattern is attributable to the higher radiation efficiency of the halfwave towers.

We filed our application in July of 1965, and received our construction permit on September 1, 1966. We began at once to draw up architectural plans for foundations

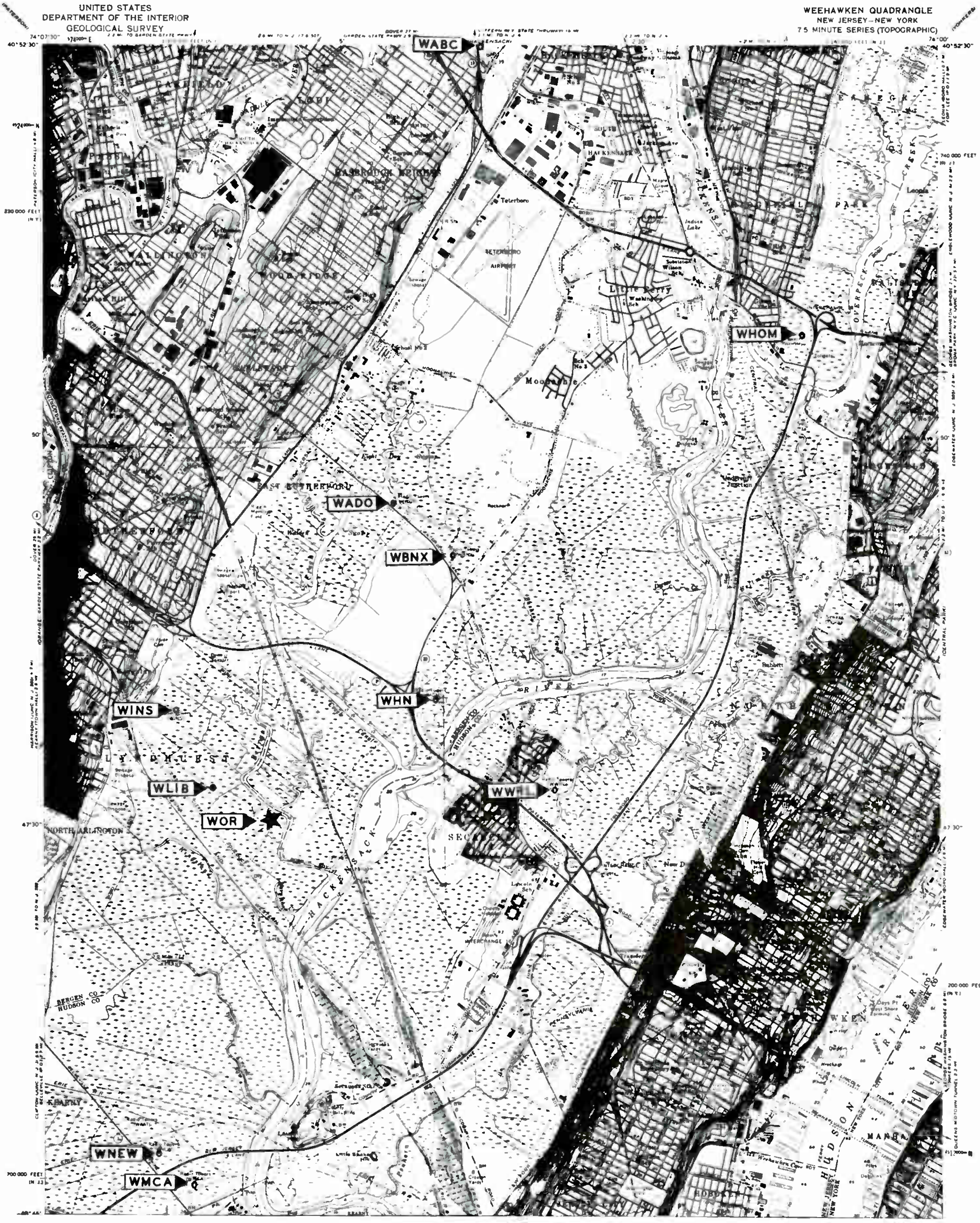


Fig. 1. Location of WOR transmitter.

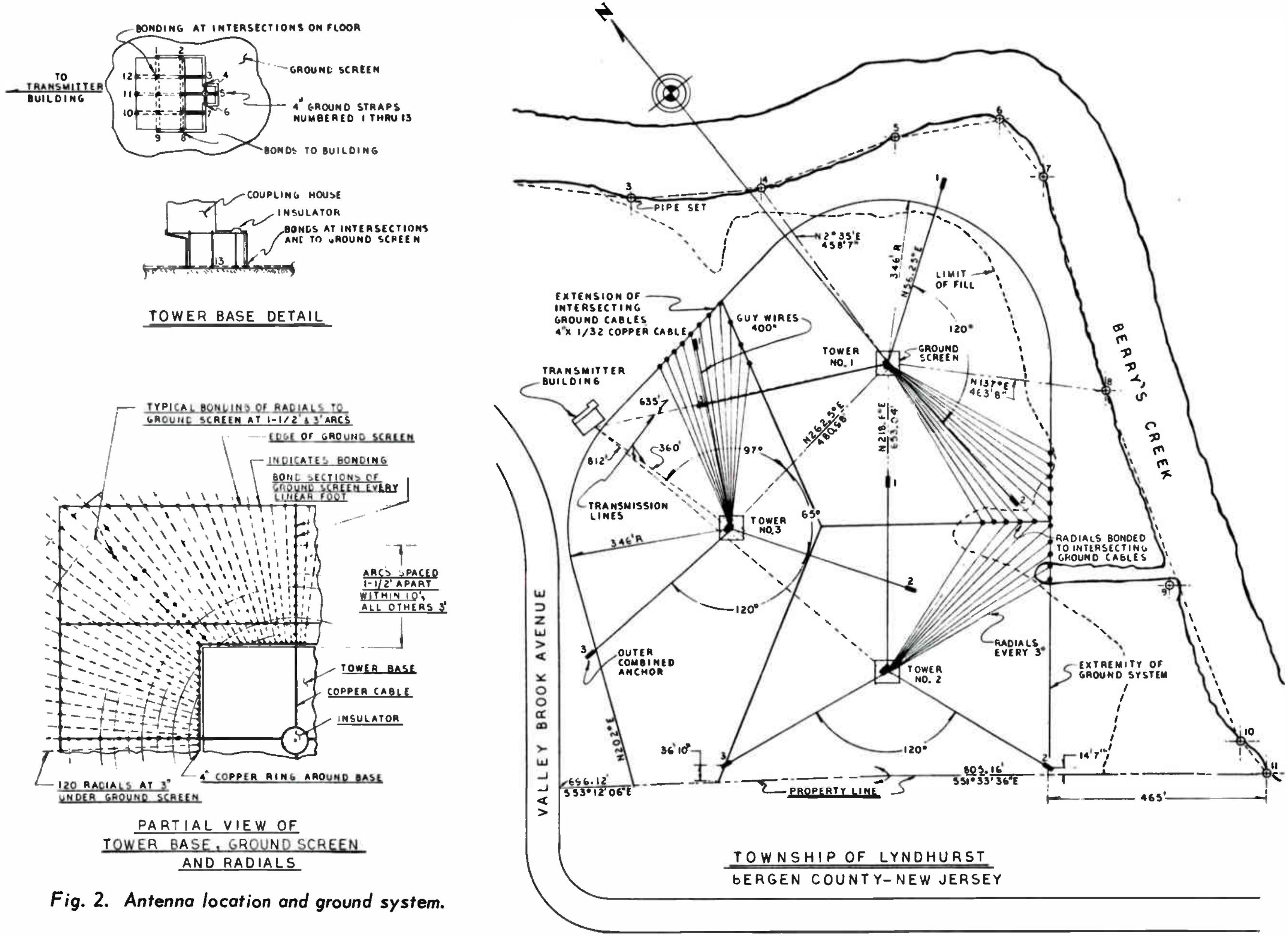


Fig. 2. Antenna location and ground system.

and buildings, specifications for the towers and ground system, and layout and design for the equipment.

Test borings were made, and it was found that under the 6 feet of decomposed garbage fill there was 20 feet of soft mud, then a layer of 50 feet of glacial deposit composed of a mixture of soil, sand, gravel and boulders, under which there was another 75 feet of mud and silt deposited over a period of 3,000 years. The annual silt deposits were clearly identifiable. Our soil consultants recommended spread footings resting on the glacial deposit for tower and building foundations, since if pilings were used they might puncture the glacial layer. Construction work on the foundations and of the transmitter building began in December of 1966, and was completed in July, 1967. Tower bases and floor levels are above the highest tide-water that can be expected in 500 years.

Because of the tower height, the ground conditions, and the lower cost, we elected to use guyed uniform triangular cross section towers, 4 feet on a side, with an inside ladder. An extra heavy galvanized coating was specified because of the corrosive effect of polluted and salt air at this location. Wind loading is 50 pounds per square foot. Because of limited space, single guy anchors were installed with a radius of 400 feet. Empire glass-strain 36-inch fiberglass insulators were used to connect the guys to the towers. Double glass-strain fiberglass insulators 24 inches long spaced 1/8 wave length were used in the guys. Lightning rods were extended above the beacon on each tower.

The ground system consists of a 48-foot square expanded copper mesh ground screen laid over a gravel base at the foot of each tower, and 120 radials 400 feet long (except where they intersect) extending from each tower. Our experience at the old WOR transmitter location and at other RKO General stations was that 4-inch copper strap traditionally used around the base of the towers and at the intersection of the radials gradually corroded and disintegrated. For this reason we used instead 000 guage soft drawn 7 stranded bare copper cable.

Another problem was that the garbage fill contained a great deal of waste chemicals from nearby industrial plants, and we were quite certain that these would destroy many bare copper radials. Therefore, we specified radials of No. 8 polyethylene covered hard drawn solid copper wire—the insulation to protect the wire, and hard drawn to discourage theft. Initially and during our Proof of Performance measurements the radials were lying on top of the ground. Two months after putting the station on the air we began pumping fill from the nearby turnpike right-of-way construction. At times there was as much as 2 feet of water and mud over most of the ground system, and it is now covered with 6 inches to 1 foot of silt; at no time has there been any variation in our antenna base currents, the antenna impedance, or the sampling loop currents, such as is usually encountered when the moisture in the soil changes. We attribute this to the insultated radials and we recommend this type of installation. The contract for installing the antenna and ground system was awarded through competitive bidding to the Dresser Company, Crane, Hoist and Tower Division, of Columbus, Ohio.

At the base of each tower we installed a 10-foot x 12-foot prefabricated steel coupling house manufactured by Armco at a cost of $600 each. We selected this size to accommodate the cabinets for our fairly elaborate antenna tuning units and trap circuits, and to provide comfortable working space. These buildings are very sturdy, well designed, and provide good shielding. I recommend them highly for this purpose. A picture of a coupling house, protective fence, and tower base is shown in Fig. 5.

Since we intended to go to remote control, the transmitter building was designed

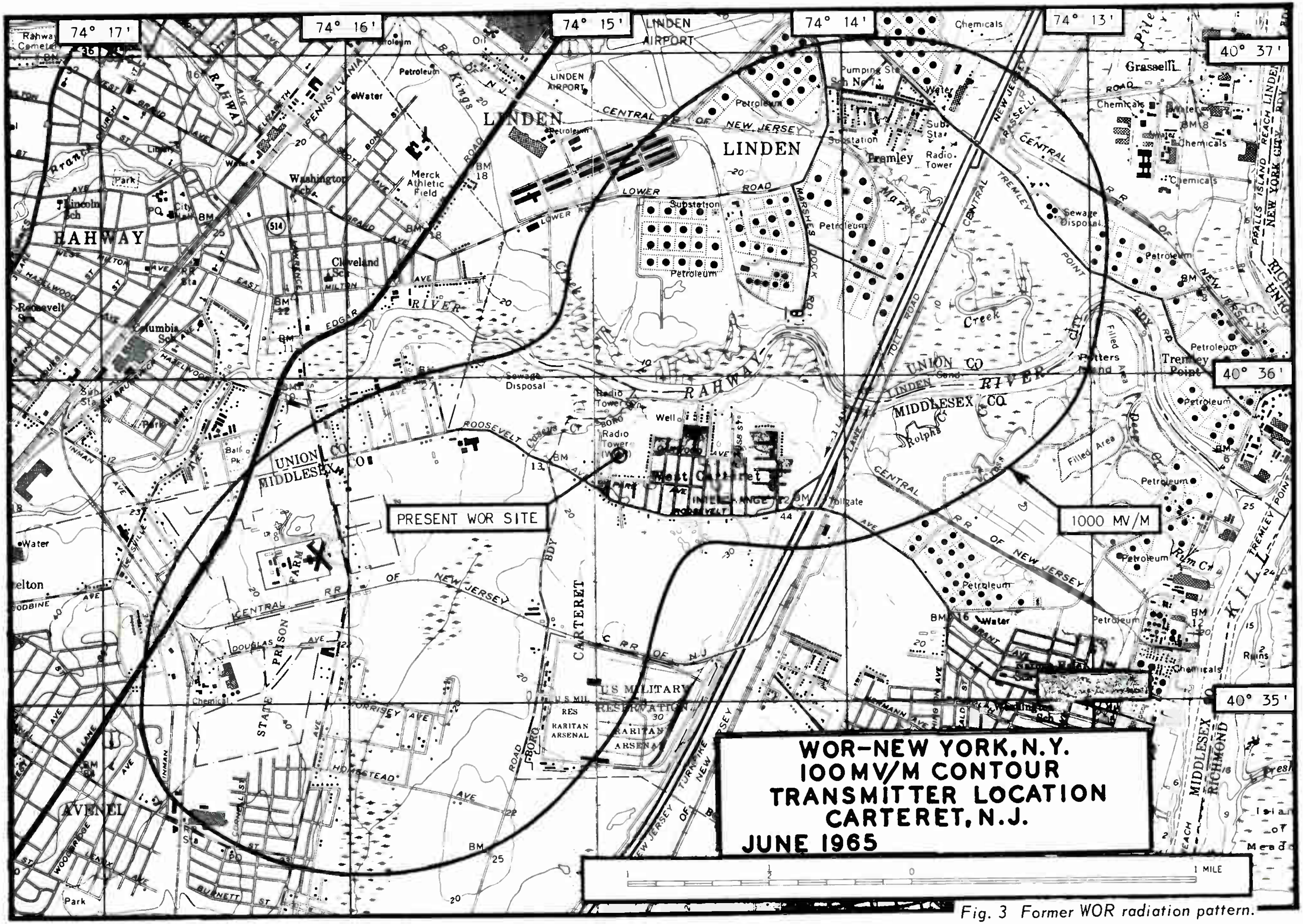


Fig. 3 Former WOR radiation pattern.

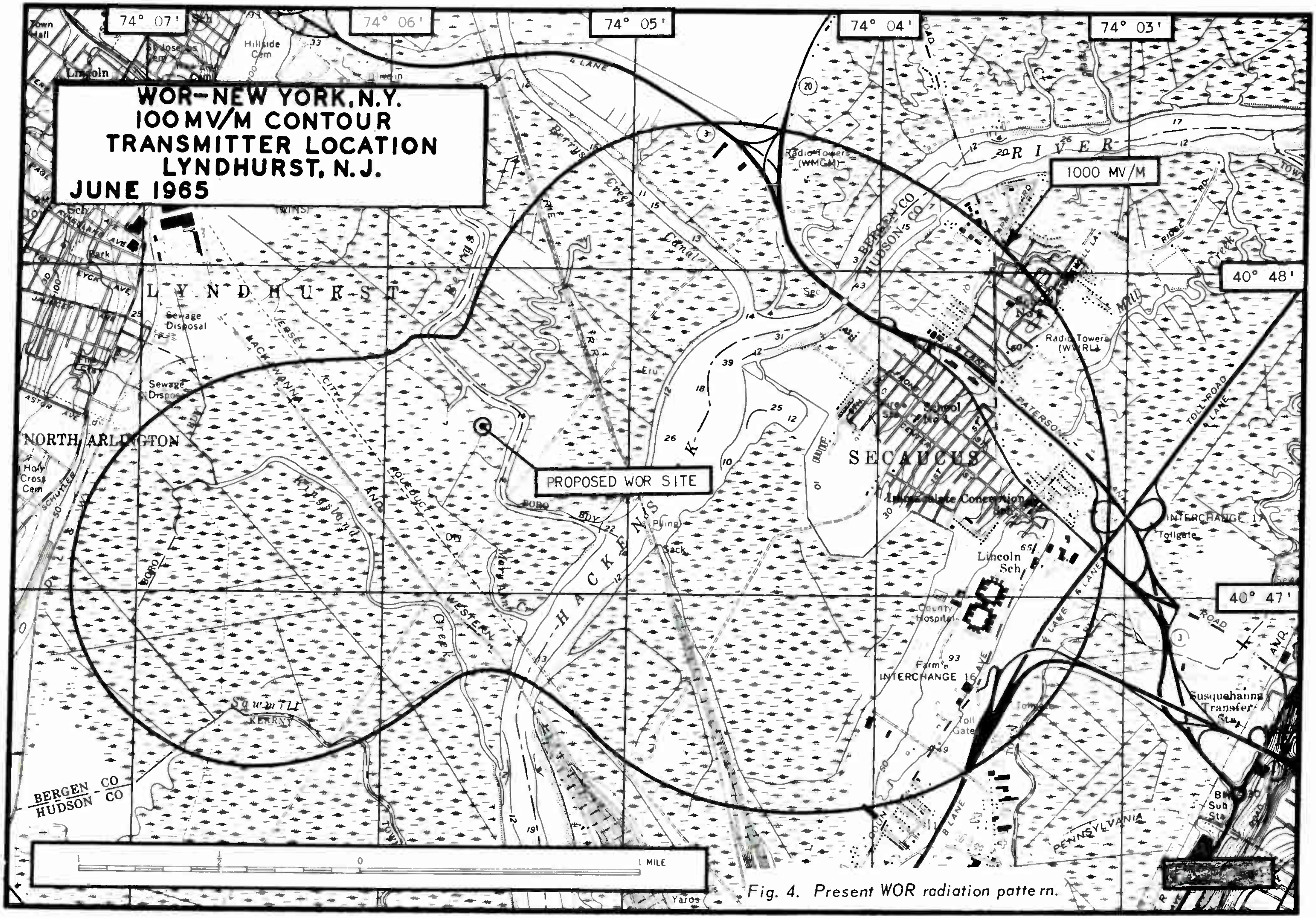


Fig. 4. Present WOR radiation pattern.

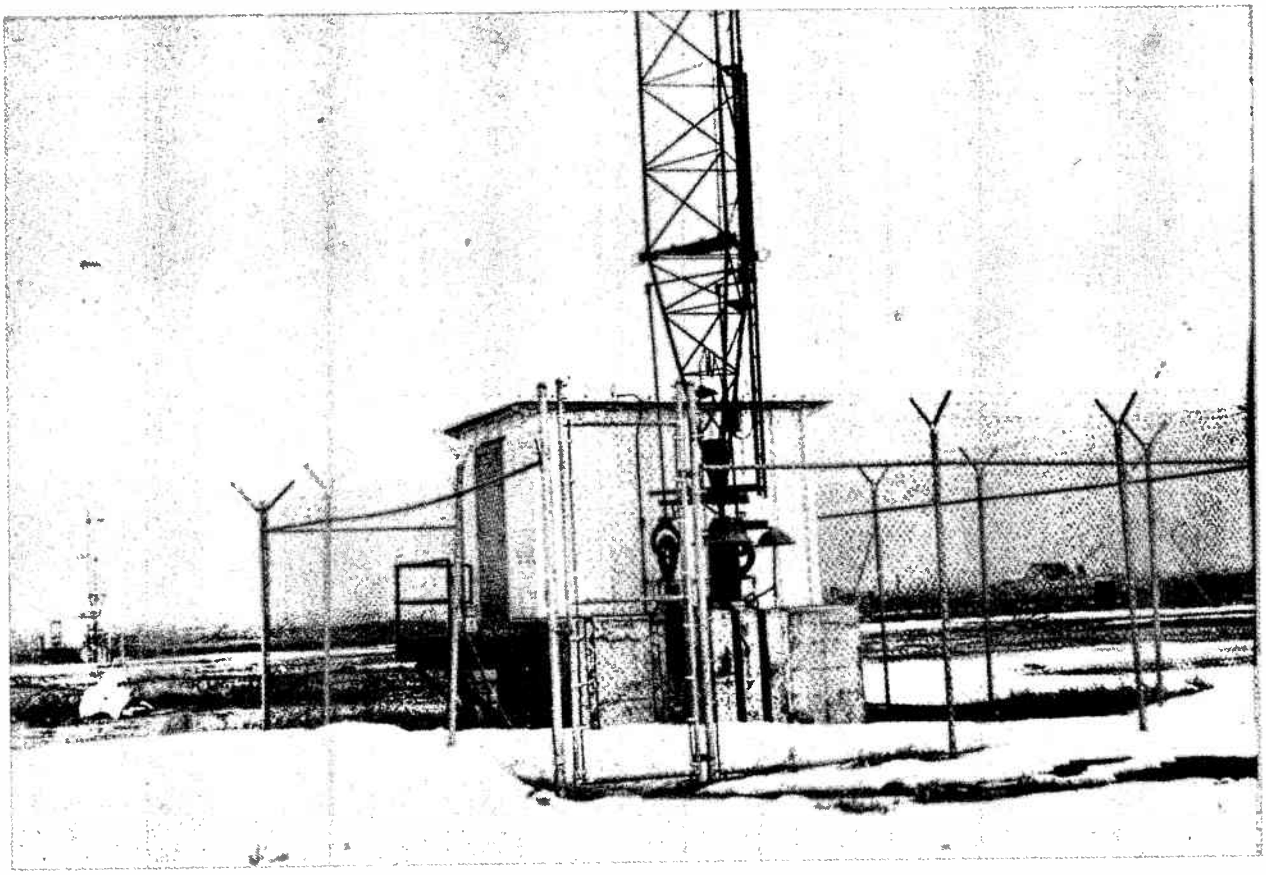


Fig. 5. Coupling house and tower base.

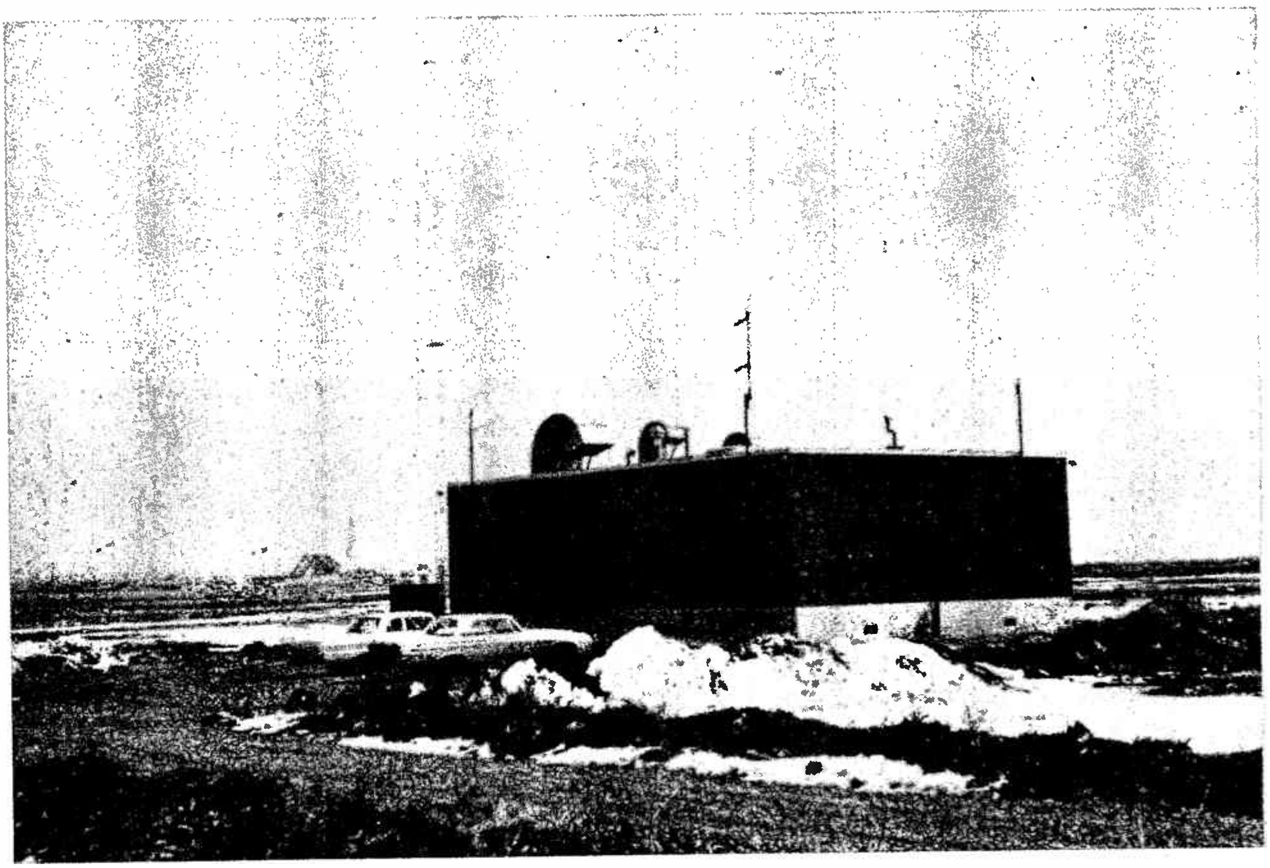


Fig. 6. Transmitter building.

for maximum efficiency and security, minimum maintenance, and not too much consideration for personnel comfort. We haul in water for drinking and washing; we have a pail under the sink, and we have an electric toilet which cremates the refuse. This created a slight problem when the heating coil burned out when the outdoor temperature was zero and the wind was 30 MPH Fig. 6 shows the transmitter building. Notice the Empire State Building to the left.

Fig. 7 shows a floor plan of the transmitter building. Notice that the kitchen is also a fallout shelter; it contains equipment for originating emergency broadcasts and remote control of the transmitters. A 200 KW emergency generator has been installed, with its 4,000 gallon fuel tank—enough to last for two weeks—under the loading platform. Two Continental Electronics 50 KW transmitters were installed—a main and an alternate—with provision for instantaneous switchover from one to the other, either locally or by remote control. One of the transmitters is equipped for cutback to 10 KW, either directional or non-directional from any one of the three towers. We received FCC authorization to operate at 10 KW NDA with regular programming during daytime hours when making our antenna adjustments and in connection with our Proof of Performance Measurements.

A feature which has proved very successful is our air filtering and cooling system. Outside air is brought into a walk-in compartment equipped with Cambridge Filter Company Type 45HC1500 filters, which remove major particles of dirt and dust. The air is then drawn through another walk-in compartment and through a set of Cambridge Micretain Model 7A-990 filters which are 95% efficient on .3 micron particles. Air is then forced under positive pressure to the transmitter in use. While each transmitter has its own built-in blower, the positive air supply allows some air to escape into the transmitter room so that the building is always at

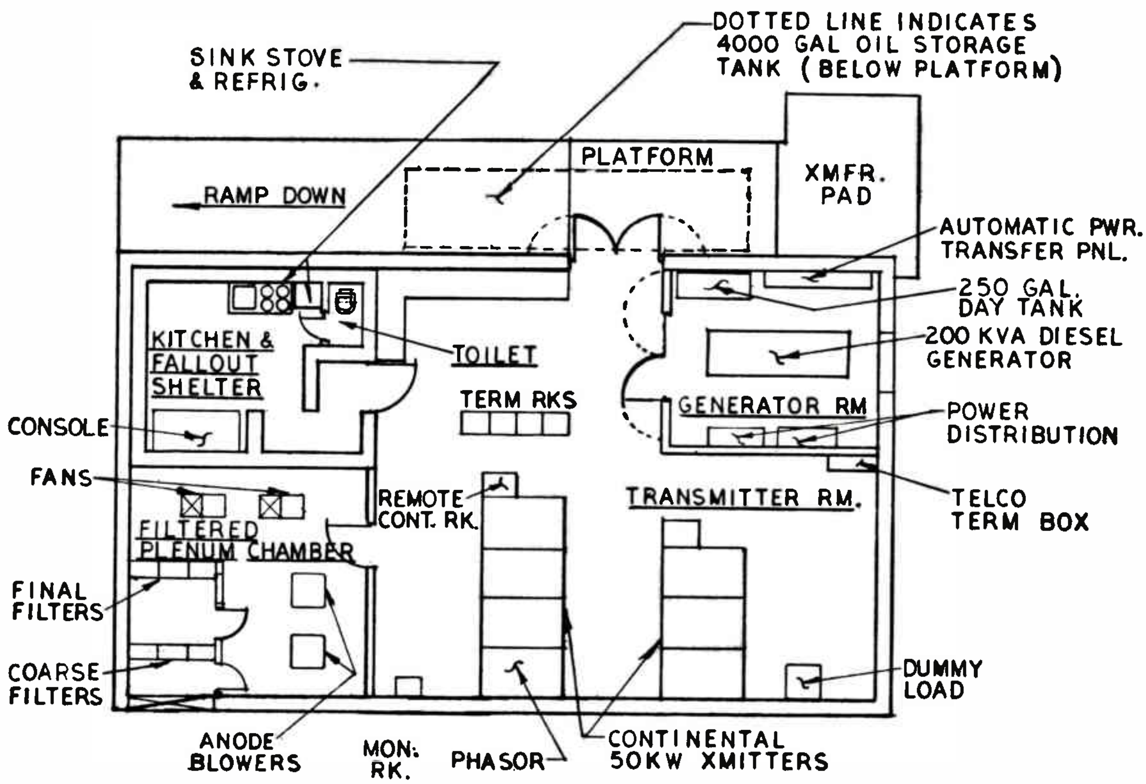


Fig. 7. Floor plan Transmitter Bldg.

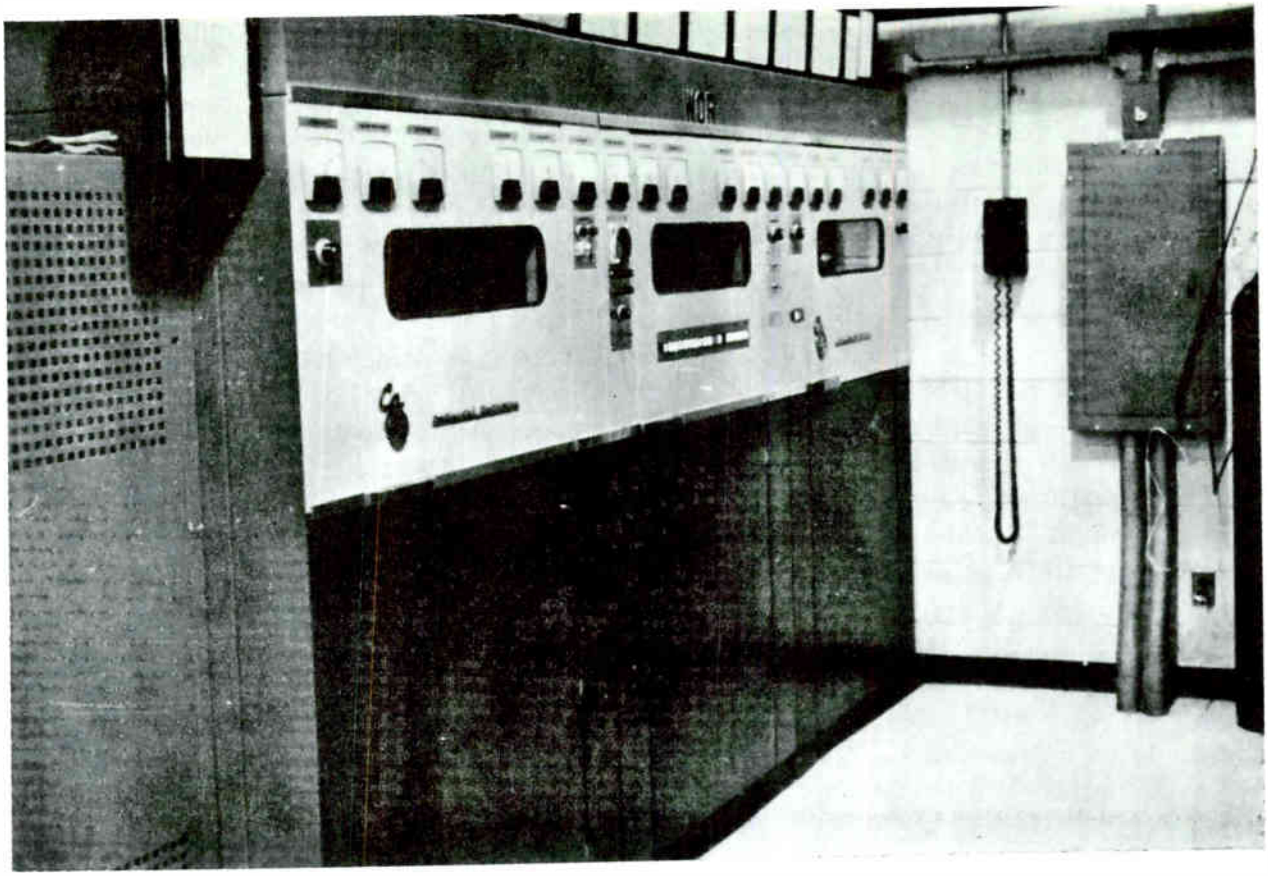


Fig. 8. Continental Electronics 317-C Transmitter.

positive air pressure with respect to outside. This prevents any dust from seeping into the building. In addition, during cool weather a regulator directs part of the warm exhaust air from the transmitter into the room for heating purposes. As an indication of the effectiveness of the filtering system, our transmitter operated continuously for four months before it was cleaned. Even then there was very little dirt in it, and it could easily have gone for several more months.

The new 317-C transmitter is shown in Fig. 8. The older 317-B and the phasor are shown in Fig. 9. We use a Continental Electronics phasor, contained in a single 4' x 6' cabinet, and Continental antenna tuning units, both designed by our engineering consultant. A photograph of the phasor is shown in Fig. 10. The antenna tuning unit is shown in Fig. 11.

We found that upon completion of the installation of our antenna, ground, and transmission line system in December of 1967 our troubles had just begun. WOR is surrounded by 12 other radio stations within a 6-mile radius. Our towers proved to be excellent receiving antennas for nearly all of them. Upon initial test of our new 50 KW transmitter the noise level caused by crossmodulation from signals feeding back through the transmission lines measured 19 db. In addition, our towers re-radiated the signals from several of the other stations, particularly those of WLIB and WINS, whose directional field patterns we badly distorted.

We were able to reduce the cross-modulation by the installation of pass-reject filters in series with the antenna feed. The schematic diagram for these filters is shown in the upper portion of Fig. 12. A picture of this series trap circuit is shown in Fig 13. We were unable, however, to detune the towers at 1010 kHz, the frequency of Station WINS located one mile to the west, and at 1190 kHz, the frequency of Station WLIB located 3/8 mile to the west. The tower impedance at

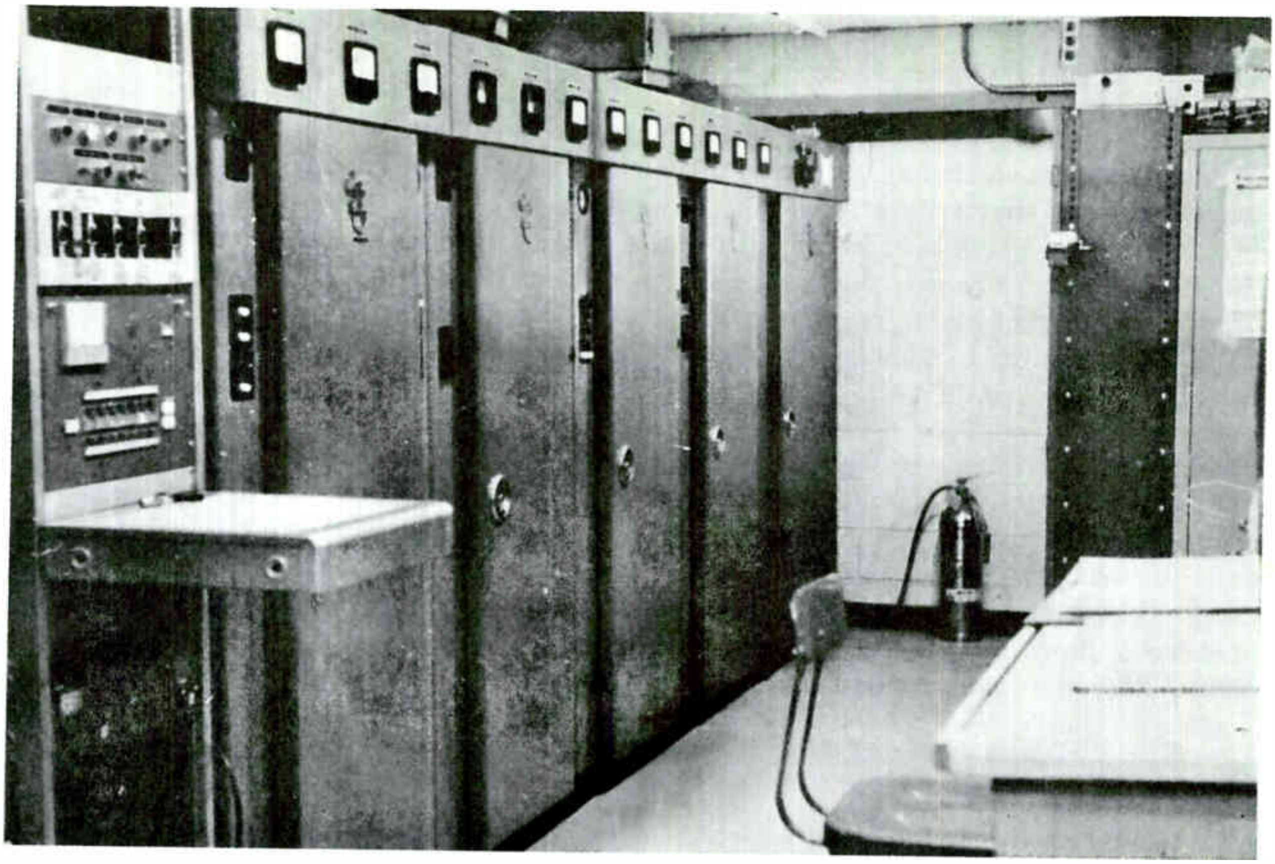


Fig. 9. 317-B transmitter and phasor (at far end).

the base was simply so low at those frequencies that anything we did to detune them had practically no effect upon the re-radiation.

This problem was finally resolved by the addition of tuned skirts for each frequency on each tower. A schematic diagram of the skirts is shown in Fig. 14. Each skirt consists of three No. 6 hard-drawn solid steel copper clad wires, each wire spaced 24 inches from a leg of the tower and held in place by standoff fiber-glass insulators. The wires are under high mechanical tension to prevent their motion in the wind. One end of the skirts is connected solidly to the tower; the open end is tuned by a Jennings variable vacuum capacitor, 20 to 750 mmf with 10KV rating, between the three skirt wires and the tower. Electrical length of the skirts is approximately 70°. Installation of the skirts allowed us to vary the electrical length of the towers at the critical frequencies. Shunt pass-reject tuning circuits were installed at the base of each tower, as shown in the lower portion of Fig. 12, to completely detune the towers at 1010 kHz and 1190 kHz. Photographs of the circuits are shown in Fig. 15 and 16.

Two methods were used to check the detuning of the towers to minimize re-radiation: (1) by adjusting the skirt capacitors and detuning circuits for minimum currents in the sampling loops at the 150 ft. level, and (2) by taking monitoring point measurements of WLIB or WINS while fine tuning adjustments were made simultaneously to the applicable skirts of each tower to bring the readings within FCC specifications. With several monitoring points for each of those stations and six sets of skirts to adjust on three towers, the operation became tricky and time consuming. There was no reaction, by the way, between the WLIB skirts and the WINS skirts.

As a condition of the WOR CP the FCC required us to protect the field patterns of all other nearby stations. Before we erected our own towers we therefore took complete field strength measurements on all radials on 8 other stations; we repeated many of these measurements during the tuning and adjustment stages, and again took complete measurements for our final Proof of Performance report to show that we had not adversely affected their radiation patterns.

In adjusting a directional array, it is first necessary to take non-directional measurements in order to determine the conductivity in all directions. The unused towers must first be anti-resonated with an L-C combination to ground adjusted for minimum sampling loop current while feeding power into another tower, or, in case of a move, while operating from the old location. The sampling loop, of course, is placed at the maximum current location on the tower.

Measuring the impedance of an antenna in an area with strong nearby stations can present a problem, since voltages induced by those stations can easily burn out a conventional General Radio bridge. Also, getting all 24-hour stations to shut down simultaneously while one takes the measurements is often difficult to arrange, though I must say we had excellent cooperation from the other stations. The impedance of the WOR towers with the other two anti-resonated measured 240-J430 ohms, 255-J430 ohms, and 249-J433 ohms. Incidentally, the portable Delta

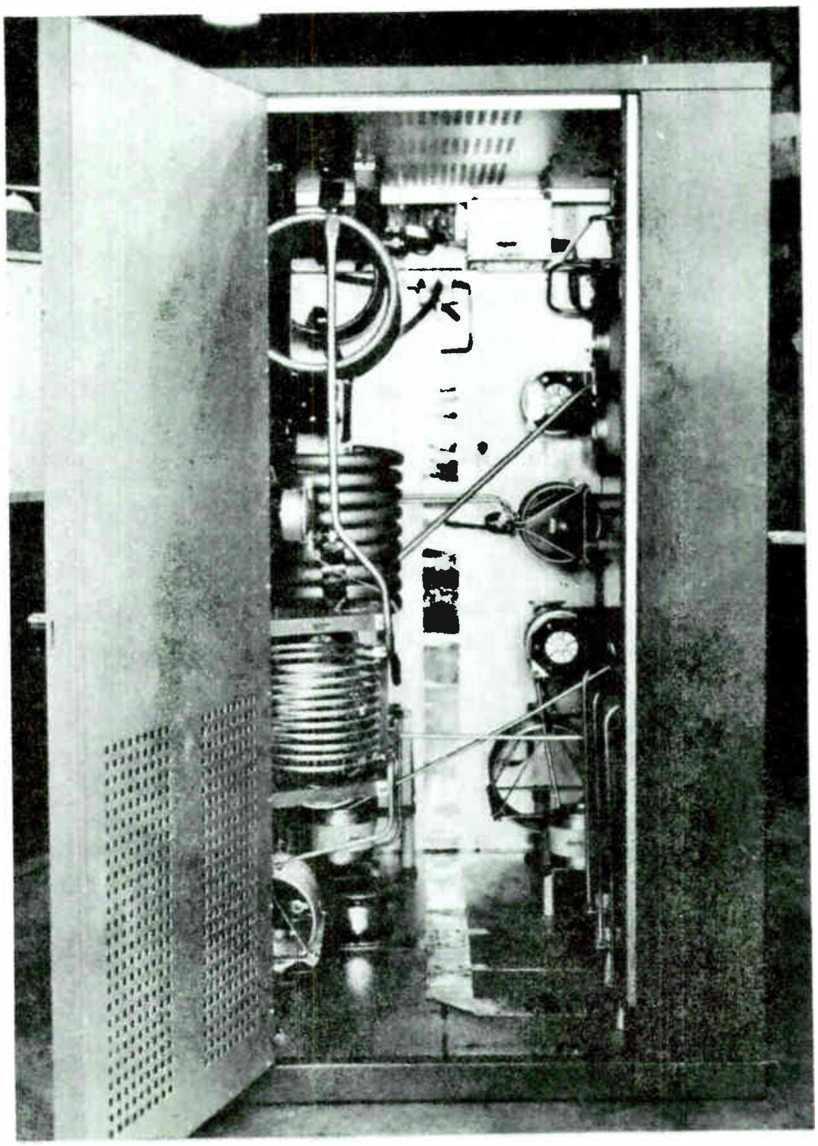


Fig. 10. Phasor.

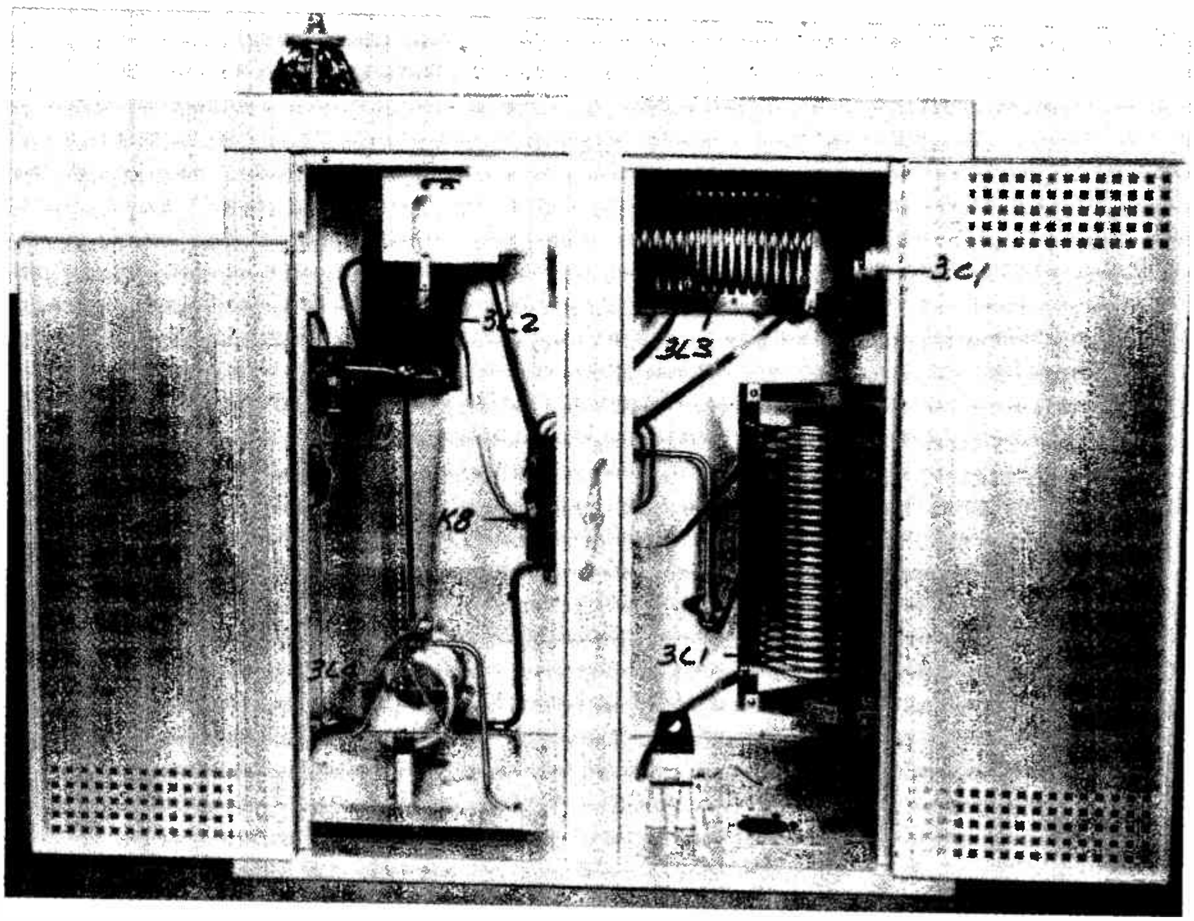


Fig. 11. Antenna tuning unit.

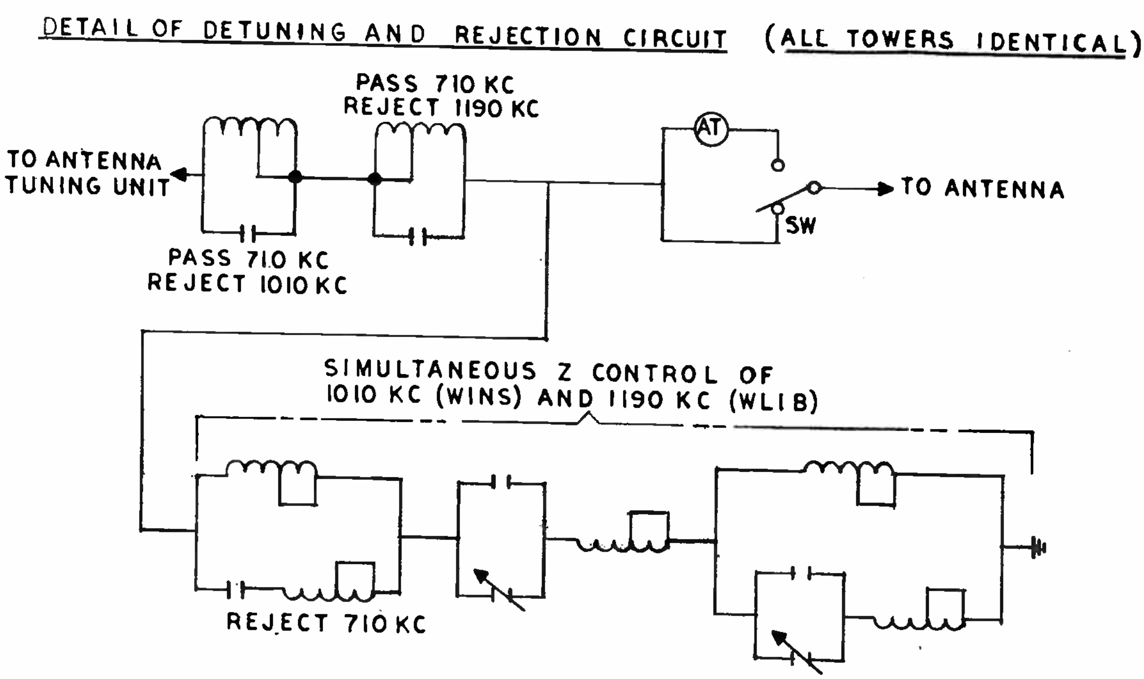


Fig. 12. Pass reject filters and tuning circuit.

Operating Impedance Bridge is very useful when the resistance does not exceed 400 ohms and the reactance does not exceed 300 ohms at 1 MHz. It will handle any generator power up to 5 KW, and you don't have to worry about it burning out from external sources. When used with a high-power generator or exciter it also resolves the problem of making annual Proof of Performance measurements when there are other stations on your same frequency and you cannot detect a null with a low-power generator. I will not go into detail on the methods used in determining the directional antenna pattern. These are covered thoroughly in the FCC Rules and Regulations to which every station should have access.

When taking non-directional measurements the pattern should be fairly circular if the conductivity in all directions is uniform. Our initial NDA pattern was distorted, which was a clue that other stations or objects were causing re-radiation.

In attempting to make adjustments on our own directional field pattern we found we could not get sufficient radiation in our 235° lobe toward Philadelphia, and we could not sufficiently reduce the radiation in our 330° null toward Canada. All adjustments of antenna phasing and power ratios simply distorted the pattern in

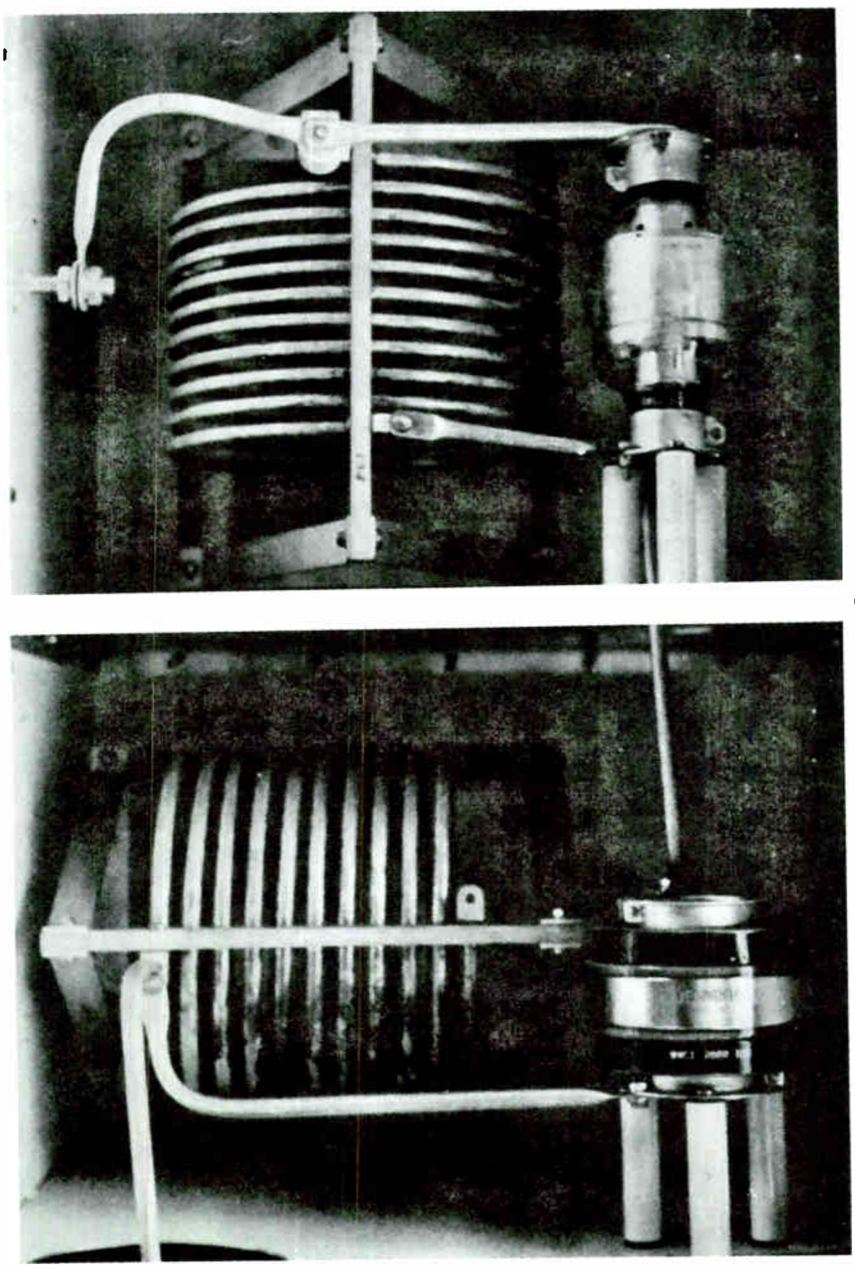


Fig. 13. Series pass-reject filter.

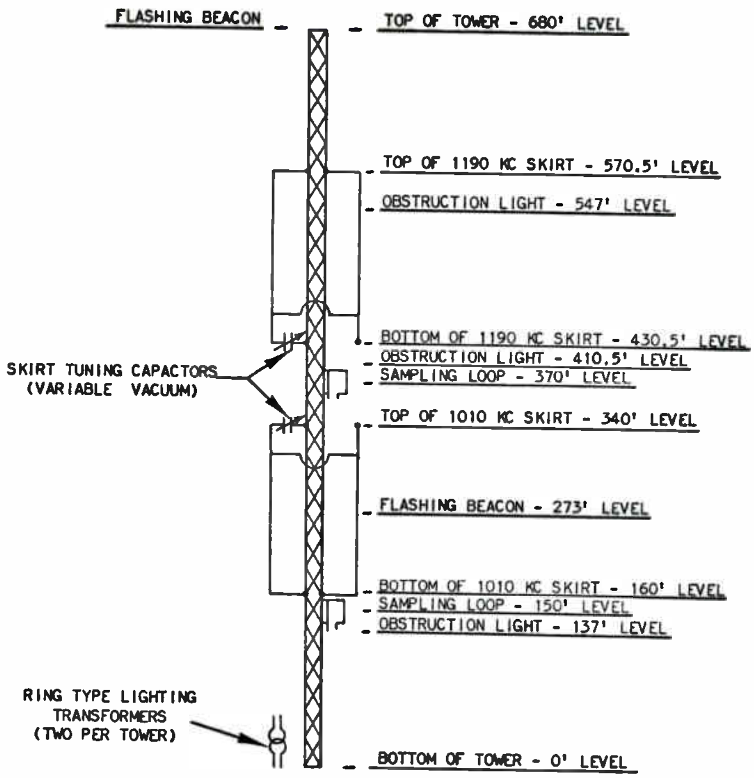


Fig. 14. Details of tower configuration.

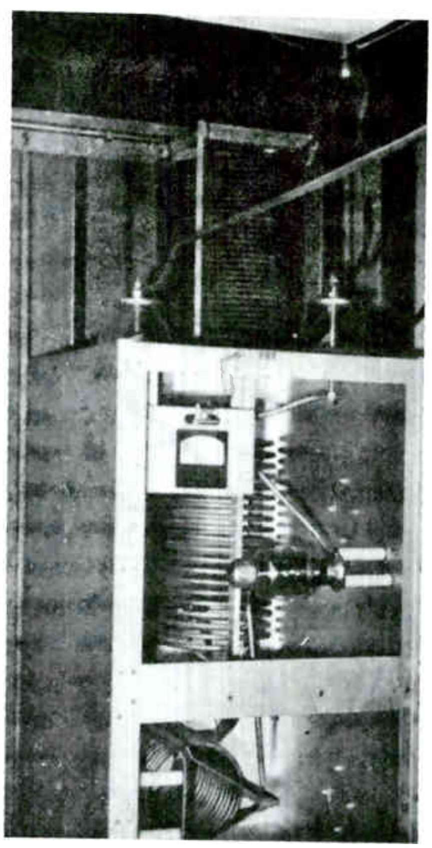


Fig. 15. Shunt pass reject filter isolation coil above cabinet.

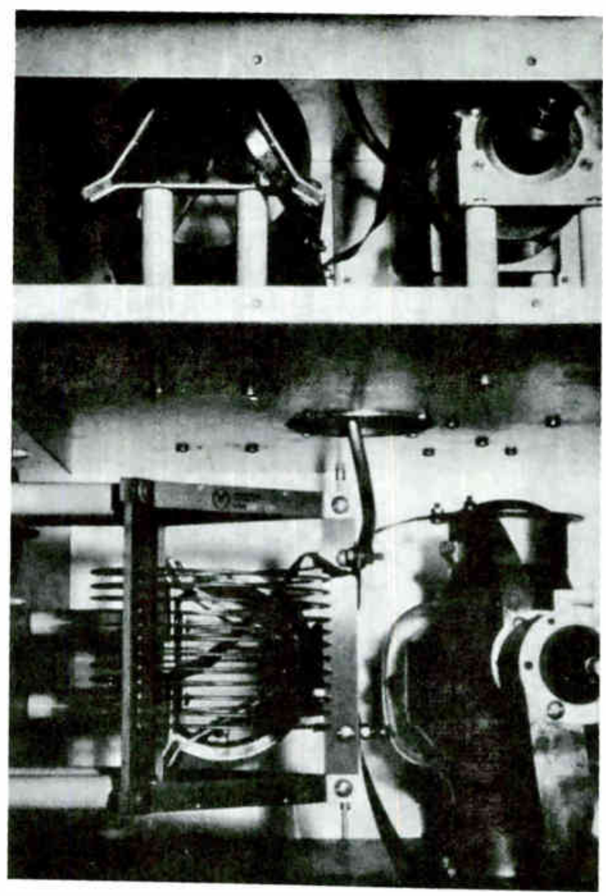


Fig. 16. Shunt detuning circuits lower section

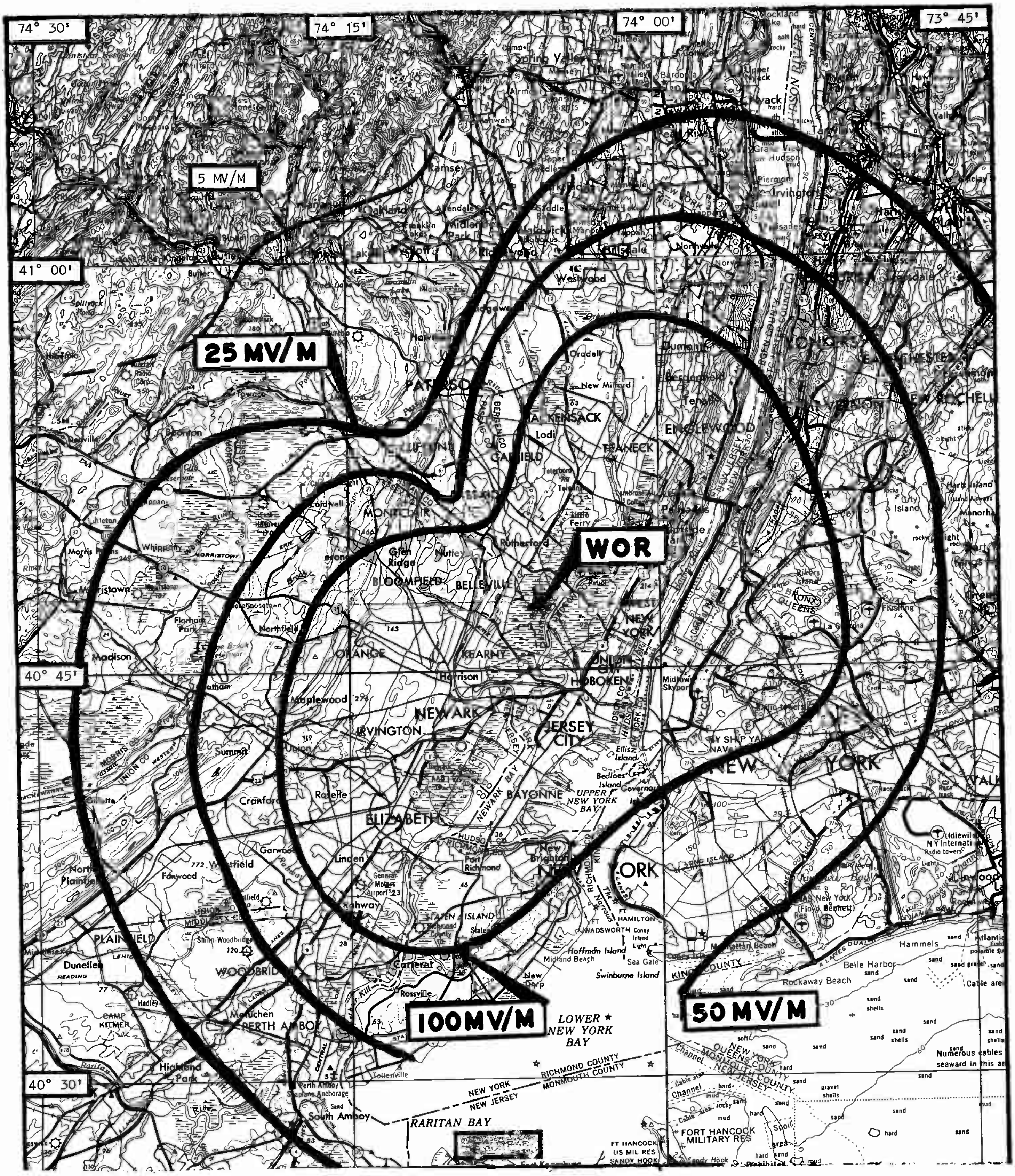


FIG.17 WOR COVERAGE
NEW YORK CITY AREA

other directions. We then measured the re-radiation of the WOR signal from all radio towers, high-line towers, and water tanks within a 2-mile radius and we found the offenders: the three WLIB towers, and to a lesser extent twelve 125-foot power line towers along a high-tension line a half mile to the southwest. WLIB seemed the easiest to start on and its management was most cooperative so we tackled its towers first. Fortunately, we were able to detune them without too much trouble. The detuning and trap circuits installed at each WLIB tower were similar in design to those installed at the WOR towers. We were then able to pull in the mull toward Canada to the required amount, and we were able to compensate for the re-radiation from the power line towers.

Another problem which arose was that the antenna array was more efficient than was anticipated and we had some trouble adjusting the pattern within proposed limits in all directions. This required numerous minor phasing and ratio adjustments, accompanied by extensive field measurements. Fortunately, the antenna system is extremely stable and we have had no trouble in keeping it in adjustment since we went on the air on October 1, 1968.

The results have been excellent. WOR now puts a signal of 550 mv/m into the west side of Manhattan, and 275 mv into the east side. All of New York City's five boroughs are now within the 50 mv contour, and most of it is within the 100 mv contour, as shown in Fig. 17. There are now approximately 8,500,000 people within the 25 mv contour. We have received several thousand letters commending us on our improved signal. We have received a few letters from scattered locations complaining of a poorer signal—areas in which we know the signal is stronger. We attribute this to cancellation effects from nearby hills or structures. Several of these letters even came from New York City. One telephone call was from a recording company in New York complaining that our programs were getting into all of its recordings.

I would like to make some suggestions for consideration in the construction of a directional antenna system. Write rigid and thorough specifications for the antenna and ground system, and make certain that the contractor complies with them. Specify only the best material and workmanship. Select your contract through competitive bidding. You will find costs vary greatly. (See the supplement at the end of this report.)

Usually you will be required to make measurements on at least 8 radials. Pick and mark your measuring points carefully; you will have to go back to them frequently while making adjustments—particularly those in the 2- or 10-mile range. Stay away from power lines, telephone lines, or buildings with steel girders. Measurements within a quarter of a mile of other radio towers, water tanks, or tall chimneys are almost meaningless. Try to find open fields, cemeteries, golf courses, parks, or large vacant lots.

Select your monitoring points with still greater care. Avoid locations where the surroundings will change because of construction. Pick spots readily accessible in all kinds of weather: someone will probably have to take these weekly measurements for the next 20 years.

Use vacuum capacitors wherever possible. WOR uses 67 of them in its phasor, antenna tuning circuits, and trap circuits. They are extremely stable and reliable, and will take much greater abuse.

Make certain all connections and contacts are solid and tight. Use lock nuts or lock washers. Bond securely together and ground all transmitter cabinets; terminal racks; phasor; tuning units; trap circuit cabinets; conduits; ducts and trays; the emergency generator; power distribution cabinets; transformers; motors; air ducts; the coupling houses; the tower base and ball gaps; the ground system. Use 4-inch copper strap where protected, and 000 copper cable where not. Use silver solder or braze; do not use soft solder. Allow plenty of margin of safety in voltage, current, heating and insulation ratings of coils, capacitors, resistors, conductors, insulators.

Use non-ferrous shielded cabinets for all RF circuits. Steel pre-fabricated coupling houses are recommended on larger installations.

Use solid-state terminal equipment wherever possible to reduce maintenance costs and increase reliability. This is especially important if remote control is planned.

Avoid conditions which will allow dirt and dust to accumulate on equipment.

Design the transmitter building for maximum efficiency and security and minimum maintenance. Windows are not necessary. Use fireproof construction. Use hot air exhaust from the transmitter to heat the building. Otherwise use electrical heat if and where needed; it is safer and cleaner, and since transmitter power consumption is high the cost is low.

Do not underestimate the cost, or the length of time it will take to build and get a directional system in operation, particularly if the pattern is tight, or if there are other stations in the vicinity. Expect the unexpected. If anything can go wrong it will.

Make sure you have a good engineering consultant. The problems you encounter, particularly in a congested area, are numerous and severe, and your consultant can provide invaluable guidance based on similar problems and experience. I especially want to give credit to our consultants, the firm of Silliman, Moffet and Kowalski who so ably engineered this project with such favorable results. If any of you wish to inspect our installation at any time the staff at WOR will be most happy to accommodate you.

SUPPLEMENT

Specifications: WOR's Guyed 3-Tower Array

A. <u>General</u>

1. Contractor shall install a complete 3-tower array and ground system for Radio Station WOR, on property owned by WOR-RKO General in Lyndhurst, New Jersey. Installation shall be according to details on WOR Engineering Department Drawing No. 900-1A titled WOR-AM ANTENNA & GROUND SYSTEM, and the following specifications.

2. The contractor shall agree to indemnify and save WOR-RKO General, the owner, harmless against and from all liabilities, obligation, damages, penalties, claims, costs, charges and expenses which may be imposed by reason of any accident, negligence, carelessness or other action on the part of the contractor in connection with said installation.

3. The contractor shall be required to submit certificates of insurance in the following form and amounts and with such insurers as are satisfactory to RKO General, Inc., 1440 Broadway, New York, New York, prior to the commencement of any work:

a. Minimum coverage and liability:

Each person	$ 500,000
Each accident	1,000,000

b. Property damage liability:

Each accident	500,000
Aggregate	500,000

c. Workman's compensation as required.

4. The specifications herein contained shall become part of the contract and no deviations shall be made without the express approval of the owner.

B. <u>Tower Design and Detail</u>

1. Tower height is to be 685 feet from base of insulator supporting the tower mast to the top of the mast itself (not including the beacon on the top of the tower). Guy radius will be 400 feet. Single guy anchors are to be used.

2. Tower shall be triangular in cross section 4 feet on a side, unless otherwise agreed upon.

3. Tower to be designed for 50 psf wind loading in accordance with the latest EIA-RS222 specifications.

4. Tower shall be welded construction. Tower shall be shop welded in sections 20 or 30 feet long with the leg members flanged on the ends for field bolting together. All sections shall be welded or bonded together at each flange on each leg.
   a. All fabrication is to be in accordance with the latest AISC specs. All welding to be by welders certified under AWS specs. All material to be of ASTM-A36 quality or better for the structural elements of the mast.

5. Web members shall be of solid rod or angle construction (no pipe or thin-walled tubing).

6. Tower shall have an inside climbing ladder at least 12 inches in width and shall run the full height of the tower. Ladder shall be welded in one corner of the tower as an integral part of each tower section.

7. Guys shall be of bridge rope or bridge strand construction having factory zinced in place fittings on the ends of all segments for attachment. All guy assemblies shall be proofloaded and prestressed to 50% of the breaking finish.

8. After fabrication, tower is to be hot dip galvanized in accordance with ASTM-A123 specifications. Galvanized coating is to be double that normally used because of salt and corrosive air environment. After galvanizing, all tower steel is to be primed for field painting by the proper application of a copper sulphate solution to the galvanized finish.

9. All bolts and other miscellaneous fasteners are to have a hot-dip galvanized finish in accordance with ASTM-A123 specifications.

10. Bottom plate of bottom tower section shall have three 1/2-inch drilled holes 120° apart in convenient location to provide connection point for RF transmission line.

11. The top beacon on each tower shall be enclosed in a four-sided steel cage, and a sharp pointed lightning rod shall extend two feet above the cage and shall be welded to the cage and the tower.

C. Insulation

1. Maximum power input to any one tower will be 25 KW.

2. Frequency of operation will be 710 kHz.

3. Base insulator (under tower mast) shall be adequate electrically to provide the required insulation and shall be adequate structurally to provide the required support for the tower mast. The base insulator shall be provided with a spark gap lightning arrestor. A rain shield shall be installed over the base insulator of each tower in such a way that it will prevent the insulator from becoming wet at any time except due to gale force winds.

4. The guy lines shall be insulated immediately adjacent to the tower with insulators of adequate capacity to insulate the guy lines from the tower as required by the power input to the tower. Empire glass-strain insulators are recommended adjacent to the tower with a length of not less than 36 inches of fiberglass and a minimum tensile strength equal to or greater than that of the guy cables. Suggested type numbers of Empire insulators are #500, #650, #703 or #800, depending upon the breaking strain required. Address of the Empire Metal Products Company is 5443 West Roosevelt Road, Chicago, Illinois, telephone-312 Bishop 2-1770. As an alternative a minimum of three close-spaced strain insulators shall be installed on each of the top three guys with similar strain specifications. Spacing shall be as close as practical. At intervals along the guy lines (not to exceed 1/8 wavelength in spacing) 24-inch fiberglass insulators shall be inserted for secondary insulation. All insulators shall have structural capacity equal to or greater than that of the guy lines in which they are inserted.

   The insulator brackets and connecting hardware shall have a hot-dip galvanized finish per ASTM-A123.

5. Additional insulators shall be placed in the guy lines near the turnbuckles at the anchors if the guy wire below the lowest insulator is over 90 feet.

D. Lighting

1. Lighting for each tower shall be type A5 in accordance with FCC and FAA requirements, unless FAA recommends differently.

2. All wire on towers is to be run in conduits. All conduit is to be steel with hot dip galvanized finish. Separate wiring is to be used for flasher lights and for obstruction lights.

3. Two ring-type air-core transformers are to be used at the base of each tower to carry lighting across the base insulator. Spark gaps are to be included with each transformer. Transformers are to be of sufficient capacity to handle the maximum lighting load specified. One transformer is to be used for flasher lights and the other transformer is to be used for obstruction lights and a 400-watt mercury vapor floodlight.

4. A separate photo cell shall be used to turn on the lights for each tower. Owner shall supply and install photo cells.

5. All junction boxes and all vertical runs are to have wire supports at the proper intervals (per National Electric Code) to support the circuitry wires.

6. All wire and conduit are to terminate on the secondary side of the lighting transformer.

7. Source voltage will be 115/230 volts, 3-wire, single-phase, to be supplied by owner.

8. In addition to FAA lighting, one mercury vapor floodlight of 400-watt capacity on the suitable support with a clear protective globe shall be mounted on each tower approximately 20 feet above ground.

9. Individual circuit breakers shall be supplied and mounted by owner in transmitter building. Additonal circuit breakers shall be mounted in each tower coupling house by owner.

10. A flasher control in a weatherproof box shall be mounted on each tower.

E. Erection

1. Field erection to be accomplished by an experienced tower erection crew using equipment of proper type and capacity, adequately maintained to erect all towers.

2. Field erection to include:

    a. Hauling towers to site.

    b. Erecting towers on foundations previously installed by others. Setting tensions accurately in all guy lines by the use of tensiometers. Towers to be accurately plumbed in all directions by transit under a no wind load condition.

    c. Installation of complete lighting system beyond primary side of the isolation transformers at base of tower. Electrical connections on primary side of transformers run to source by owner.

d. Field painting complete on all towers with one coat of field paint per FCC and FAA requirements. International orange and aviation white paint to be supplied in accordance with MIL spec TT-E-489C or better with color per federal color specs governing.

3. After complete erection, all towers to be thoroughly inspected by a qualified tower inspection engineer and a complete report submitted to Station WOR certifying to the compliance of all specification requirements on the finished installation. Inspection will also be made by owners' consulting engineer.

F. Ground System

1. Within a radius of 35 feet from the base of each tower owner will install porous pea gravel graded from normal grade at periphery to approximately 1 foot depth at base of tower. Ground radials and ground screen shall be laid over gravel.

2. 120 ground radials of #8 hard drawn polyethylene covered copper wire shall extend approximately 400 feet from the base of each tower every 3^{o} to the extremity of the ground system, or to an intersecting ground cable, as shown on the WOR Engineering Department Drawing No. 900-1A. Radials shall be buried not less than 2 inches nor more than 6 inches below grade except within 35 feet of tower where radials shall be laid over gravel base. Radials shall be bonded to a copper cable around the base of each tower, and to intersecting ground cables between towers. Intersecting ground cable as shown shall be of 000 guage soft drawn 7 stranded bare copper wire without steel strands; junction of ground cable is at intersection of bisectors of the angles of the triangle formed by the three tower array. Intersecting ground cable between towers No. 1 and No. 3 shall be extended with 4-inch copper strap along the extremity of the ground system to the transmitter building, with a surplus of 30 feet of strap to the transmitter building. All radials from tower No. 3 along this extension of the intersecting ground cable shall be bonded to the ground strap. Ground strap shall be covered with thick coating of asphalt paint after connection to ground system.

3. At the base of each tower a 48 foot square ground screen of stranded expanded copper mesh shall be installed over porous gravel fill. Ground screen shall be laid over exposed radials after radial installation is complete. Sections of ground screen shall be bonded together approximately every linear foot. Screens are to be bonded to radials at periphery of screens and along circular arcs approximately 3 feet apart to within 10 feet of tower base; within 10 feet of tower base radials are to be bonded to ground screen at 1 1/2 ft arcs, and at copper cable and ground screen inside edge of ground screen. Four 4-inch wide by 1/32-inch thick copper straps 20 feet in length shall be bonded to the copper screen and base ring on each of four sides of the foundation pier and shall extend upward and be bonded together and connected to the base insulator.
Owner will install a pre-fabricated aluminum coupling house approximately 10 ft. x 12 ft. near base of each tower. Over foundation of coupling house

will be a copper strap grid as shown on WOR Engineering Department Drawing No. 900-1A extending to the fill, approximately 1 foot in all directions from foundation. Contractor will install copper cable bonded to this grid. Radials intersecting coupling house are to be bonded to copper cable on each side of coupling house and extending to tower base. Regular ground screen is to be bonded to grid and cable. Copper strap is to be provided at each coupling house to connect ground screen and equipment cabinets within coupling house.

After installation, ground screen shall be covered by two to three inches of gravel. Gravel base and cover shall be supplied by owner.

4. All bonds to ground screen, radials, ground strap, or ground cable shall be accomplished by means of brazing, silver solder, or sil-foss. Soft solder shall not be used any place in the ground system.

5. Prior to installation of radials and ground screen, contractor shall install coaxial transmission line, and miscellaneous cables between the transmitter building and coupling house at each tower. Owner will supply transmission and miscellaneous cables to consist of 3 1/2-inch flexible transmission line, 3-pair AC cables, sampling line coaxial cable, remote metering cable, telephone circuit, and spare circuits. A trench approximately 15 in. deep is to be dug in the clean fill between the transmitter building and each tower; cables are to be laid in place; cables are to be buried approximately 1 foot and are to be covered with clean earth fill. Care must be taken to remove any rocks or abrasive objects from the trench and the cover fill in order not to damage cables.

6. Sufficient slack shall be left at all junctures of the ground radials, ground cables, copper strap, transmission lines and cables to prevent connections from pulling loose because of contraction due to temperature changes.

G. Miscellaneous

1. Tower designer is to specify all final loads from the towers to the foundation piers and from the guy lines to the guy anchors so that owner may have his own foundation engineer design the foundations. Tower designer to consult with this foundation engineer to assure most efficient and adequate foundations are designed from a detail standpoint. All tower and anchor loads and stresses are to be included with bid.

2. Owner shall install all foundations.

3. Owner shall supply complete survey.

4. Owner shall obtain soil boring data with soils loading data recommendations.

5. Owner shall supply and install pre-fabricated coupling houses at each tower location.

6. Owner shall supply and install fencing around all towers and anchors.

7. Owner shall supply and install phasing equipment, antenna tuning equipment, and trap circuits to be located in coupling houses.

8. While these specifications are believed to be complete, contractor is to comply with those additional specifications which he knows are necessary to provide a first class installation, plus those specifications which are accepted as standard practice for an installation of this nature. All work must be performed in a neat and workmanlike manner to the complete satisfaction of the owner and his consulting engineer.

Maintenance of Directional Antenna Systems

Fred L. Zellner, Jr.

Manager of Radio Frequency & Allocation Engineering ABC

Unfortunately, in the last ten or fifteen years the operation and maintenance of a directional antenna system has become a mystery to the technical heads of most standard broadcast radio stations. This has happened for a number of reasons, most of them financial.

After the design, installation, and licensing of a directional antenna system, the consulting engineer no longer becomes actively involved. It is then the total responsibility of operation falls upon the technical head and his staff of technicians. If, during the period of design, construction, and proof of performance, these people actively involve themselves, the normal day-to-day operation and its associated problems are better understood.

No adjustments should be attempted under any circumstances when a directional antenna system deviates from its normal operating parameters. If the individual involved feels he must turn a knob, it is suggested that this energy be expended in using the dial on the telephone. If adjustments at this time are attempted, the only result will be complete chaos. The first action instituted should be to determine what the problem is and then what caused it. Only by following this procedure can the system be restored to its normal operating parameters. This point cannot be over emphasized.

Routine maintenance procedures should be instituted in order to eliminate most problems with an antenna array. An accurate, readily available record should be kept of any and all work performed. Such records should include:

1. Field intensity readings at all monitor points
2. Base currents
3. Loop currents
4. Phases
5. Transmitter operating parameters
6. Common point impedance measurements
7. Weather conditions during periods of maintenance and inspections
8. A description of any and all changes around the antenna system and or the monitoring points
9. Record of all dial settings on phasors and transmitters
10. Accurate description of any and all work performed during maintenance periods and daily inspections

Certain basic information, test equipment, and spare parts should be on hand in order to perform adequate maintenance:

1. Proof of Performance as submitted to the FCC at time of licensing and any skeleton proof of performance made thereafter
2. A current copy of the FCC Rules and Regulations
3. Schematics of all circuitry, listing component parts by manufacturer, model, and value
4. Instruction manuals on transmitter and phase monitor, as well as other associated equipment within the transmitter plant.
5. Spare capacitors, inductors, relays, RF ammeters, and any other spares as recommended in the instruction manuals
6. Test equipment, such as an RF bridge and its associated generator and detector, field intensity meter, volt-ohmmeter, megger, oscilloscope, audio oscillator, distortion meter, vacuum tube voltmeter, etc.
7. Adequate supply of tools including commercial vacuum cleaner and some type of torch capable of silver soldering and brazing

Routine inspections should be made of the antenna system and its associated equipment. During these inspections, close attention must be given to such things as loose, corroded or broken connections, heating of components and connections, and the general cleanliness of the various cabinets. Regardless of how insignificant any of the above conditions may seem, they can cause variations in operating parameters. If these conditions are permitted to exist over long periods of time, the accumulated effect will cause large variations in operating parameters, even beyond the accepted tolerance specified by the Federal Communication Commission. The amount of work and cost in restoring the array to normal operation can far exceed the cost of routine maintenance.

Very often strict attention is given to such things as tower painting, relamping, etc. However, in some cases, too little attention is paid to the sampling loops and ground system. These items are exposed to all types of weather and seasonal changes. It is in this area that severe deterioration can occur and go unnoticed for long periods of time. Some points that are extremely vulnerable are tower lighting conduits, junction boxes, sampling lines, and lighting transformers. In some cases parts of the ground system are stolen, connections become corroded and eventually break or loosen. Wind can cause sampling loops to develop loose connections and corrode. Any or all of these conditions can occur over long periods of time with their independent effect on the operating parameters being minute. If these conditions are permitted to continue, however, serious changes may occur in the operating parameters and in many cases the operating tolerences will exceed FCC tolerances. Here again, the cost of restoring the array to specifications will far exceed the cost of routine maintenance. Ground systems should be inspected periodically and all discrepancies noted and corrected, and again, a complete description recorded in the maintenance log. The same procedure should be followed on the sampling system. Any or all of the conditions I have discussed could not have been corrected by making any type of adjustment on the phasor, transmitter, or line terminating units.

All standard broadcasting stations using a directional antenna system have installed some type of transmission lines to interconnect the line terminating units with the phasor. These lines can be either of the air or solid dielectric type, continuous or sectionalized. In cases where these lines are mounted above the surface of the ground they are extremely vulnerable to the usual problems. Actual physical damage can occur for any number of reasons such as normal expansion and contraction due to climatic changes, line stress due to high wind conditions and even possibly being damaged by vehicles such as lawnmowers, tractors, and in one particular case, a snow plow. Sectionalized line is most often subject to electrical failure because of galling of inner conductors where bullets are located. If, in the original array design, some type of line lightning protection circuitry has not been installed, lines can be damaged by flashovers due to lightning. In the case of gassed lines, loose end seals can allow the pressure to be relieved in the line, thus paving the way for entrance of moisture which can cause arcovers and high resistance paths over which RF currents can flow.

During the maintenance inspection, gas leaks can be detected most readily by observing pressure gauges, permanently installed on the lines, usually in the transmitter building. If any appreciable reduction in pressure is noted the lines should be inspected in order to determine where a leak is occuring and the necessary corrective action instituted. Transmission lines are usually gassed with dry nitrogen or dehydrated air.

Transmission lines which are mounted above the surface of the ground are connected into the station ground system by the use of copper ground straps clamped to the line and brazed into the station grounds. Deterioration of this grounding can cause minute, abrupt variations in operating parameters.

Just as an example of what we are talking about, I will give two case histories, one where an antenna system was properly maintained and proper procedures followed in correcting a variance in operating parameters, and a case where a discrepancy in operating parameters occurred, adjustment was attempted by the technical head, and the result was many hours of unnecessary engineering expenses to reestablish the array:

Case 1—In 1965 a call was received from one of our owned stations operating with a directional antenna. The technical head advised that a shift had occurred in the operating phases and loop currents of this system. He also indicated there had been noticeable increases in the field intensity at two of the station's monitoring points. He also indicated that no adjustments had been attempted. After proper notification to the FCC as required under the rules, the operating records of the station were analyzed. These records indicated that the changes were abrupt. A systematic check-out of the system was made which indicated a defective connection on the sampling loop which is located on the No. 2 tower. Corrective action was immediately instituted which consisted of repair and replacement of the faulty connection. After this work was completed, the array returned to its normal operating parameters. If adjustment had been attempted in this particular case, the result would have undoubtedly been the establishment of a new set of operating parameters which then would have to be submitted to the Commission. However, maintaining these new parameters would only have been possible over a short period of time and then the problem would have reoccurred, but it would have been much more serious.

Case 2—In late 1968 we had just finished the tuning and adjustment of a rehabilitated antenna system in the southwest. We were operating this antenna system to prove its stability before submitting a proof of performance. The operating parameters—transmitter efficiency, phase, base current ratio, and field intensities—had indicated very stable operation for approximately three weeks.

On a Tuesday morning the ABC Engineering Department was notified that the operating parameters had deviated severely from their adjusted value. The chief transmitter technician in reporting to my office indicated that he had corrected the condition by readjusting the phasing and reestablishing the transmitter efficiency by adjusting the common-point impedance to its normal 50-ohm value. However, he also reported that after about 12 hours of operating it was necessary for him to make more adjustments. No attempt at this point had been made to establish:

1. What the problem was
2. Its cause

Investigation on the part of the Engineering Department indicated the problem was a defective mica capacitor in the power dividing network. The defective component was then replaced. As could be expected it was then necessary to readjust the array. After readjustment had been completed the array returned to the operating parameters as originally established. Had adjustment not been attempted, the defective component would have been located and the array would have returned to its established parameters.

If an antenna system is properly maintained and proper records of such maintenance are readily available to the station personnel, few problems can result. However, it must be pointed out that there are occasions that array adjustments are necessary. The person making these adjustments must have a thorough knowledge of antenna and network design. In most cases station personnel are not qualified for this type of work. If such tuning and adjustments are necessary the services of a qualified consultant should be sought. Past experience has proven, in the vast majority of cases where this procedure has not been followed, extreme difficulty and high costs have been incurred for the simple reason that eventually a professional engineer is needed to clean up the problem.

Enhancement of Telephone Line Performance

Leonard R. Kahn
Kahn Research Laboratories

Benjamin Wolfe
Post-Newsweek Stations

Telephone systems were designed primarily for mass public usage and therefore a limited frequency range for each channel is provided as a reasonable compromise between cost and fidelity. Thus, the low-frequency response is generally restricted to approximately 300 Hz. An appreciable improvement in the low-frequency response of the telephone systems would greatly increase the cost of the channel filters, increase crosstalk, and low-frequency noise such as hum. Therefore, the choice of approximately 300 Hz has been almost universally set by telephone engineers.

Of course, it is well known that such a restriction does not greatly diminish intelligibility; however, it does reduce the naturalness of voice and produce a less pleasant, tinnier sound which is somewhat unpleasant and fatiguing to the listener. Thus, this restriction of fidelity is a very severe problem for broadcasters. Therefore, he uses special, more expensive lines or STL radio links between his studios and transmitters. Such special lines are impractical for use in long-distance operation and the broadcaster either drastically reduces the amount of long-distance remote programming or is forced to use low quality lines.

Attempts to equalize the frequency response of a telephone line can be quite frustrating because extremely sharp filters are used in telephone carrier systems. Also, the extreme amount of equalization required increases low-frequency noise proportionately, making the circuit too noisy for broadcast use.

DESCRIPTION OF THE VOICE-LINE SYSTEM

Voice-Line is a patent pending technique which was developed for the transmission of voice over long distances. It is also useful for application over short distances when special lines cannot be ordered up in time because of an emergency news event.

Voice-Line is based upon the recognition of the fact that a small cut in the frequency response at 2 kHz is not noticeable to the listener even under careful A/B type tests. Recognizing this fact, the low-frequency sounds between 100 and 300 Hz, which are so important to the naturalness and pleasantness of speech, are encoded so that they can pass through the 2 kHz slot. Since any practical telephone circuit must respond to at least 2 kHz the encoded wave is easily transmitted by normal inexpensive telephone circuits. Thus, the encoded wave bearing the low-frequency portion of the voice wave is allowed to pass through the normal low quality telephone system and a normal pleasant and natural voice circuit is achieved. Also, since frequencies below 300 Hz are transmitted by the special coded wave, the Voice-

Line receiver can and does incorporate very sharp HP filtering, removing low-frequency noise, crosstalk, and other undesired sounds.

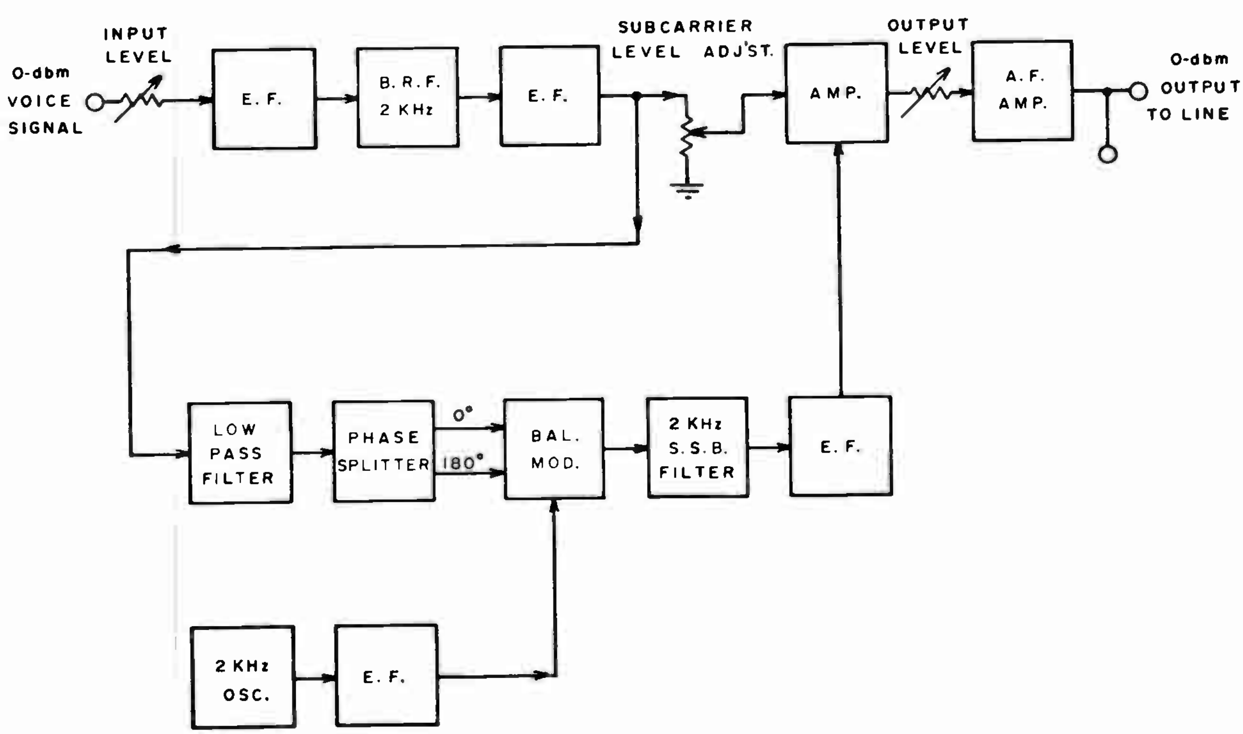
To see how this is accomplished, block diagrams of the transmitter and receiver will be used. First, the transmitter operation. The input audio signal is fed through a front panel level and adjust potentiometer. The signal is fed to an emitter follower, which in turn feeds a band-reject filter, which greatly attenuates voice components from approximately 2 kHz to 2.3 kHz. As mentioned previously the resulted hole in the spectrum cannot be detected when listening to voice signals.

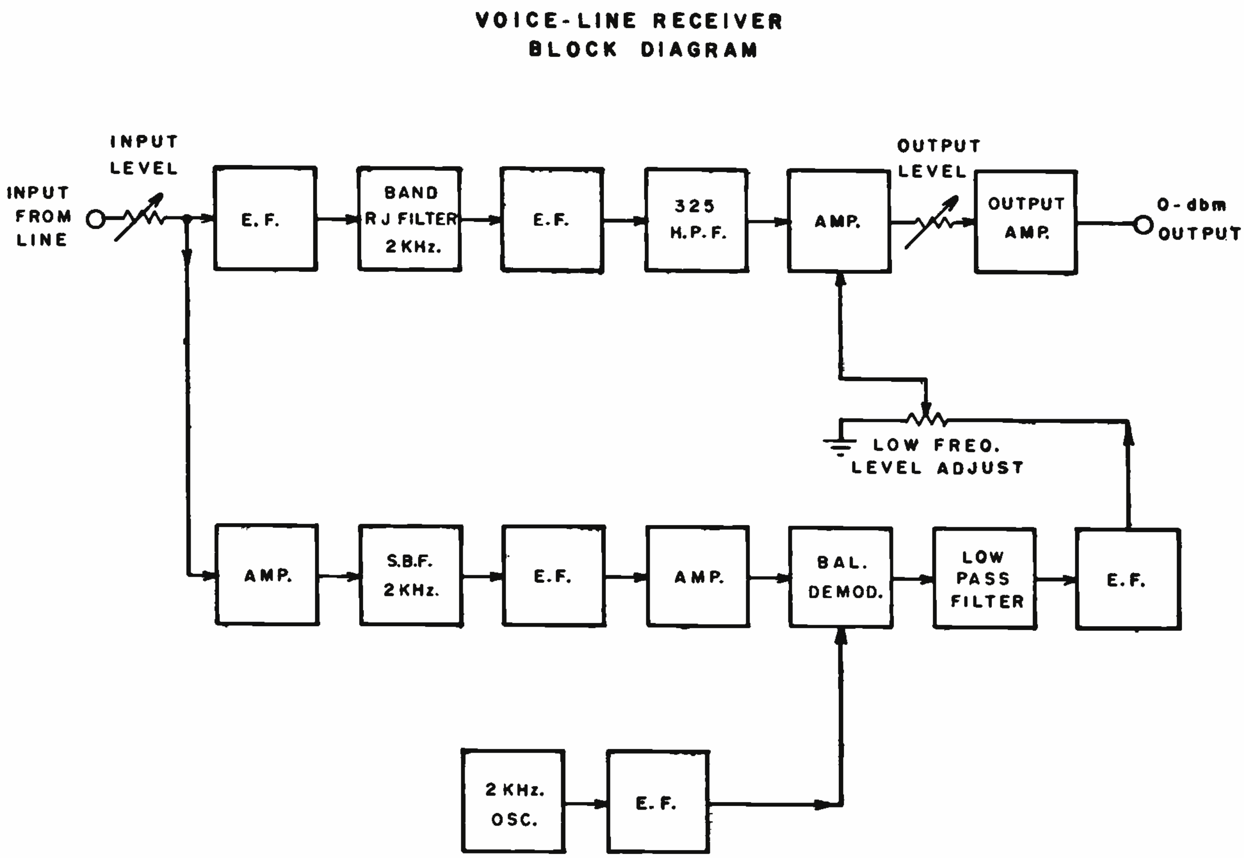
The output of the filter feeds two circuits; one, is a potentiometer adjusting the ratio of normal frequency components to the amplitude of the subcarrier. This voice wave, with the 2-kHz slot, is fed to a common base adder circuit and finally to the output audio frequency amplifier which in turn feeds the telephone or radio line.

The emitter-follower which is fed by a band-rejector filter (with a 2-kHz slot), also feeds a low-pass filter which passes the low audio frequency voice components to a balanced modulator. At this point there is a resemblance to the system of single side-band transmission. The balanced modulator is also fed by a 2-kHz audio frequency oscillator. The resulting wave is a double side-band suppressed carrier signal. The upper side band is selected by the side-band filter. The output of the side-band filter feeds an emitter-follower. The output of the emitter-follower is fed to the common base adder. In this fashion a 2-kHz single side-band wave representing the low-frequency voice components is added to the voice wave and the signal is so constructed as to make it suitable for transmission over a poor quality communication line. Of course, to detect the low-frequency components, a receiver must be used at the far end of the communication line.

Referring to the block diagram of the receiver, the input from the telephone or radio line is fed to the input level potentiometer, which in turn feeds two circuits, one of which is an emitter-follower. The emitter-follower is used to drive a

VOICE-LINE TRANSMITTER
BLOCK DIAGRAM





highly selective band-reject filter. This filter removes the 2-kHz single side-band wave. The output of the band-reject filter feeds a 325-Hz high-pass filter. The filter removes low-frequency components that may pass through the telephone line and prevents low-frequency components from the direct path as well as from the subcarrier path from being passed. This is important because if both paths were active the relative phase of the waves would create difficulties.

Another reason for the use of the low-pass filter is to attenuate 60 Hz, 120 Hz, and other hum and low-frequency noise components which may be introduced by the telephone line. The output from the high-pass filter feeds a common base adder, which in turn feeds the output amplifier.

The 2 kHz single side-band wave carrying the low-frequency components is processed in the following manner. The output from the input level control is fed to an amplifier which feeds an upper side-band filter. The output of the filter is the isolated single side-band wave. This signal is amplified and fed to a balanced demodulator wherein the single side-band is demodulated by mixing the wave with the 2-kHz oscillator output. The resulting wave is the low-frequency audio component required, plus other mixing products as well as the original input waves. The wave is freed from these undesired components by use of a low-pass filter. The resulting wave has a signal to noise ratio of almost 50 db. The low-frequency components are then fed to the common base adder circuit and finally to the AF output amplifier. The output produced is a natural sounding voice wave.

We would like to acknowledge the works and reports of the following people:

1. Mr. Richard Monroe, and Mr. Charles Brailer of the Westinghouse Broadcasting Company, who have made several useful modifications. They found that the carrier frequency of the receivers of the transmitter system must be helped to a specified point of 2000 Hz. Deviation from

this frequency by more than 4 or 5 Hz results in objectionable audio. The equipment has a stable oscillator, but initial frequency checking and periodic re-checking was felt to be necessary. Rather than use frequency counters at each location, the equipment was modified to provide the local oscillator at a front panel jack. By zero-beating the carrier at this jack with a reference tone transmitted from a central point all units in the system are quickly calibrated. The central point, in Group W's case, is the Washington News Bureau, which is equipped with a frequency counter.

Another problem was that it was desired to have, particularly in the voices of male newscasters, a "crispness" together with the restorations of the low-frequency content, augmented by using the Voice-Line. It was reasoned that this effect could be achieved by accentuating the high-frequency content near the upper end of the bandwidth. Preliminary checks using a conversation audio equalizer were encouraging. Based on these tests the Kahn Laboratories was asked to design a treble boost circuit centered at 2900 Hz, which could be added to the basic receiver. Such a modification has been supplied and is at this writing being installed at each of the Group W Stations. The reactions have been favorable.

We would like also to acknowledge Mr. David N. Gregory of the British Broadcasting Corporation for conducting tests on Voice Line over a New York-London-New York loop.

We would like to acknowledge the suggestion of Mr. Herbert B. Michels of Time-Life Broadcasting, who suggested the use of Voice Line with slow reduced tape speed for improving high-frequency as well as low-frequency performance.

A New Solid-State TV Demodulator

George Weber and George Stoeppel
Rohde & Schwarz

TV demodulators find application in TV transmitter installations for monitoring the picture and sound quality and measuring the transmitter characteristics during interruptions in transmission. The instrument therefore plays a dual role. During broadcasting it performs as a closely toleranced and reliable standard for the receiver in the home, demodulating the signals transmitted so that the video and sound can be evaluated using respectively an oscilloscope and monitor or amplifier and loudspeaker. The TV demodulator can also monitor the video modulation depth and the sound frequency deviation. Both the linearity and phase response of the instrument must be in keeping with that of the home receiver so that optimum picture quality can be attained when setting the pre-equalization of amplitude and phase distortion.

BASIC CONCEPT

For the TV demodulator to fulfill all the above tasks satisfactorily, the selectivity provided must have a Nyquist slope and considerable carrier suppression relative to the video modulation. To facilitate the monitoring of video modulation depth an optional zero reference marker is provided. This generates a white level in the form of a short pulse every line, corresponding to a carrier level of 0%. (Fig. 1.)

FM sound demodulation is carried out by an intercarrier demodulator which derives an IF of 4.5 MHz from the video and sound carriers. Because TV transmitters use vestigial sideband methods, which were first proposed by Nyquist as a method of economizing on bandwidth, the TV demodulator like the home receiver must have a particular frequency response. For modulation frequencies up to 0.75 MHz, the transmitter radiates the carrier and both sidebands. Above 1.25 MHz, the lower sideband is suppressed and only the carrier with the upper sideband is emitted. The Nyquist slope of the receiver ensures that, for modulation frequencies up to approximately 1.25 MHz, the smaller lower sideband and the larger upper one add up to 100%. Beyond 1.25 MHz, the upper sideband with 100% amplitude is demodulated, the lower being less than 1%. When the transmitter and the receiver are taken together the overall video response is a straight line (Fig. 4). If the transmission signal is demodulated with a double sideband demodulator, an ideal response as in Fig. 5 is obtained. In practice, the filter is not as angular as shown in Fig. 2, and Fig. 5 exhibits a smooth transition from 100% to 50% relative amplitude.

When testing the video transmitter during pauses in transmission (or a reserve

TV - Demodulator Type AMF

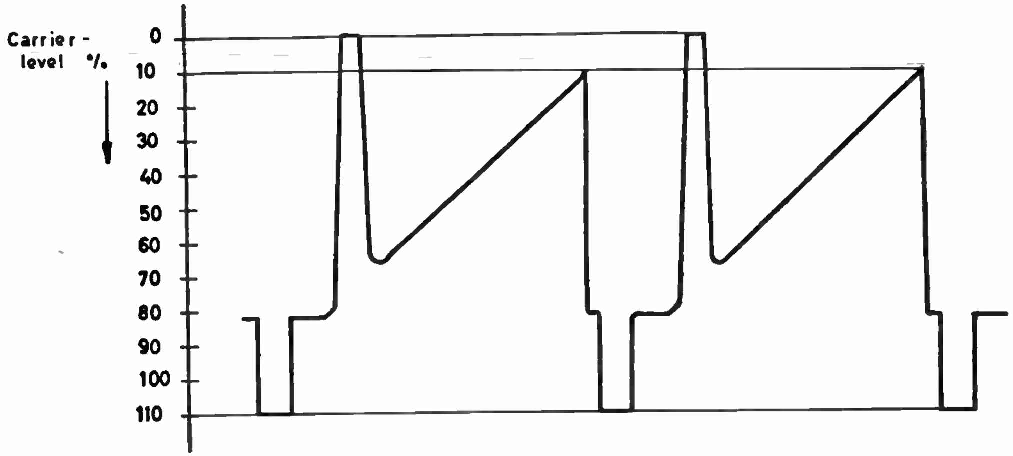


Fig. 1. Sawtooth signal and reference marker for 10% residual carrier.

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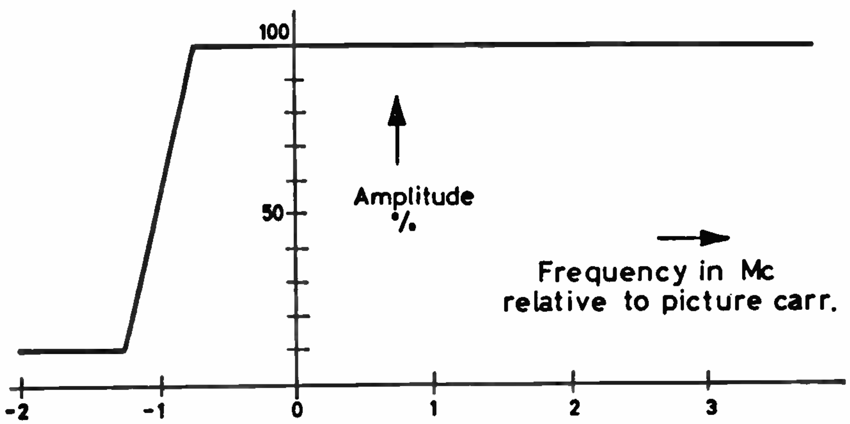


Fig. 2. Ideal frequency response of a TV transmitter close to the picture carrier.

TV - Demodulator Type AMF

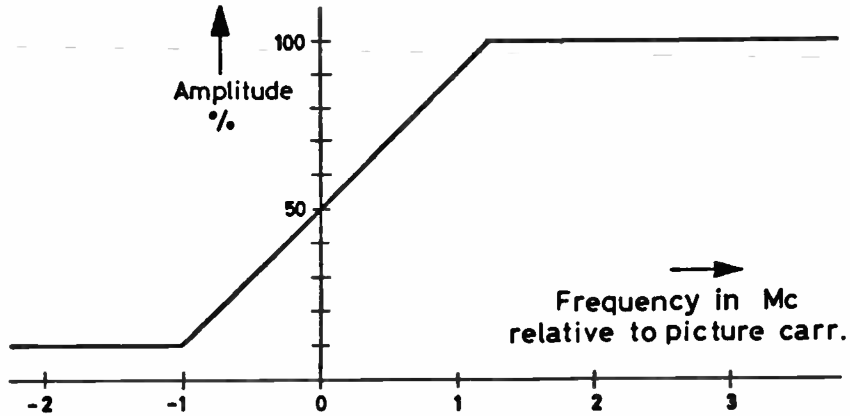


Fig. 3. Ideal frequency response of a receiver close to the picture carrier.

TV - Demodulator Type AMF

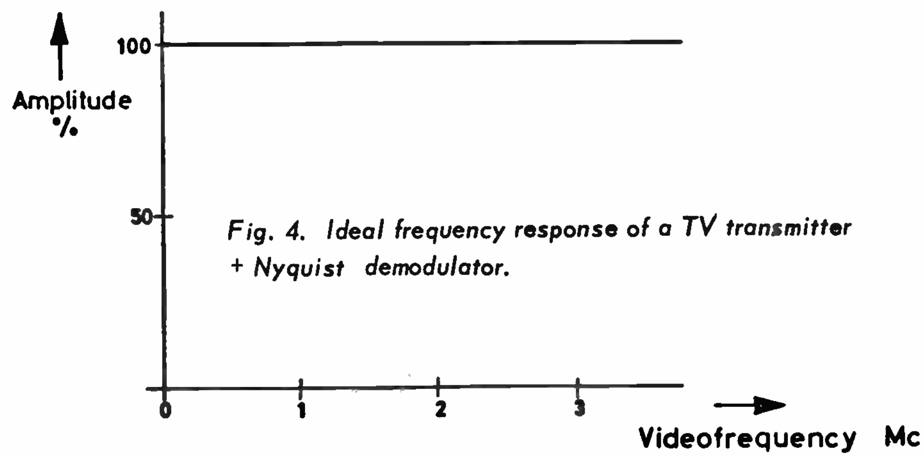


Fig. 4. Ideal frequency response of a TV transmitter + Nyquist demodulator.

TV - Demodulator Type AMF

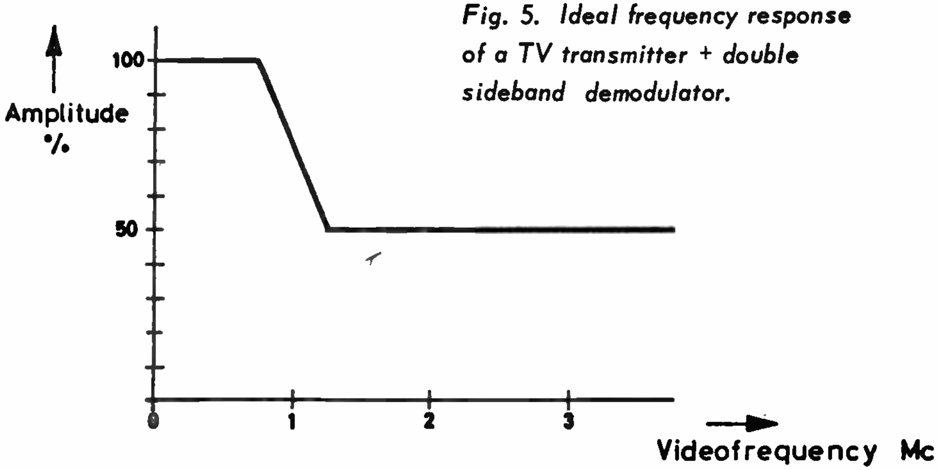


Fig. 5. Ideal frequency response of a TV transmitter + double sideband demodulator.

TV - Demodulator Type AMF

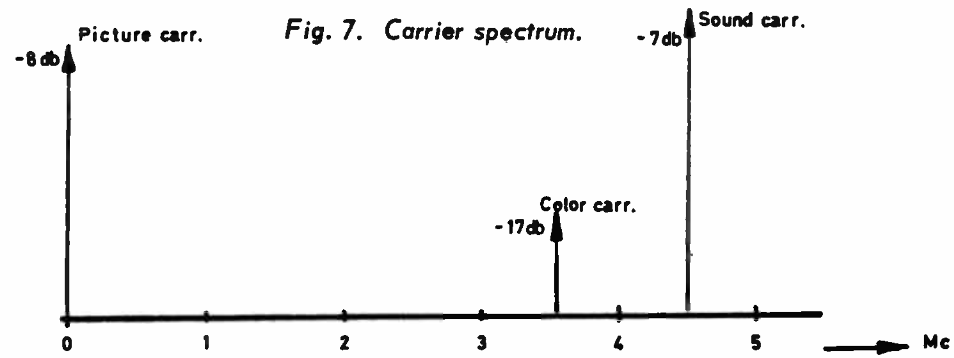


Fig. 7. Carrier spectrum.

TV - Demodulator Type AMF

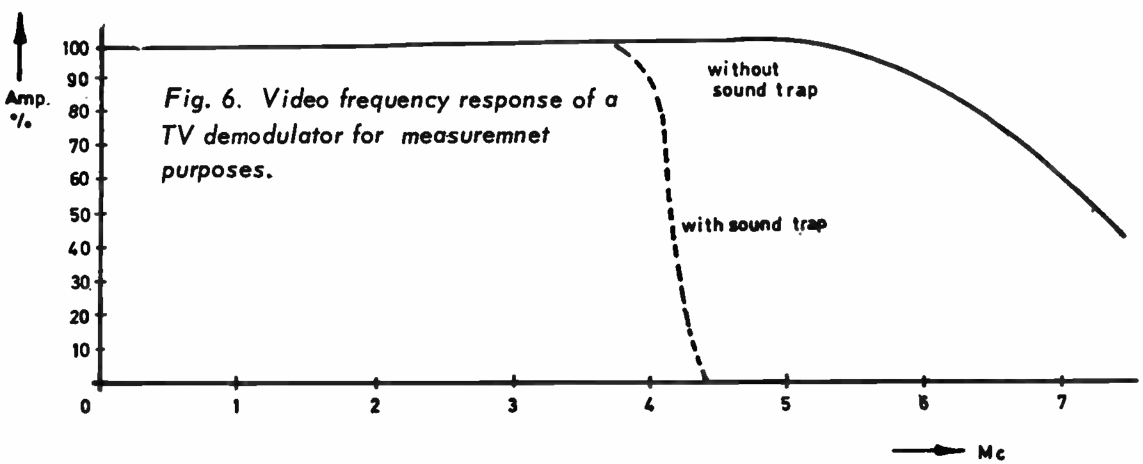
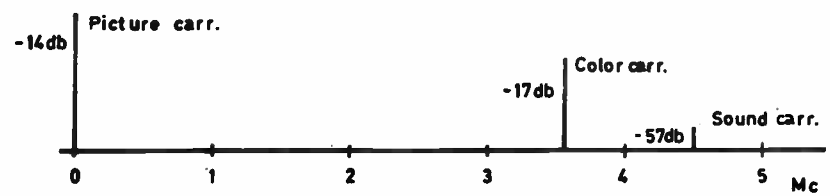


Fig. 6. Video frequency response of a TV demodulator for measuremnet purposes.

TV - Demodulator Type AMF

Fig. 8. Carrier spectrum on demodulation diode.



transmitter), it is advantageous to be able to switch out the sound trap. With the sound carrier inoperative, the broadband demodulator can then be used for measuring and checking the video transmitter up to the upper frequency limit. With the introduction of color television, interest in the upper video frequencies was increased and they must be demodulated with fixed amplitude and linear phase when the sound trap is switched off. The Nyquist slope is effective in both types of operation (Fig. 6).

In order to satisfy the above conditions in all the television channels, it is essential to convert the channel frequency to a standard IF. Conversion is most commonly carried out using a frequency-multiplied crystal oscillator signal. If it is possible to readjust the oscillator and multiplier, after a crystal change, without using external test equipment, the TV demodulator can be used for all the channels in a TV band. Because IF modulated transmitters are being used more and more, a demodulator using an IF technique has the added advantage that its selectable IF input can be used for step-by-step testing.

DISTORTION

An important requirement of any test demodulator is that it should exhibit no distortion on a monitor screen, other than that due to the normal system conditions. It must also be suitable for the measurement of distortion in a transmitter and both these factors necessitate extremely low, linear and nonlinear distortion. System distortion, in the case of envelope demodulation, results from the heavily modulated single-sideband signals. This so-called quadrature distortion does not arise if demodulation is performed with carrier reinsertion. This method artificially reduces the depth of modulation, prior to detection, by reinserting a suitable picture carrier. Because this involves relatively elaborate circuitry and high expense it is not used in home receivers. It would therefore be unfavorable to use the technique in a demodulator for transmitter monitoring because the instrument would lose its character as a home standard. When measuring a transmitter during transmission breaks or by using the test line facility, it is in any case customary to transmit signals at low modulation depths which themselves show up quadrature distortions.

NON-LINEAR DISTORTION

Linearity departures, chiefly caused by quadratic characteristics of the mixer, amplifier, and above all the demodulator stages, must remain small to prevent errors in the brilliance or color saturation.

Differential phase alterations; i.e. phase changes in the color carrier between high and low modulation levels due to complex gain variations, should be low to avoid chromaticity faults between light and dark pictures.

Intermodulation distortion, arising from cubic curving of the characteristic, leads to mutual degrading of brilliance, chromaticity and color saturation.

Linearity departures and differential phase alterations are relatively easy to take care of. As intermodulation distortion is almost always a problem with the sound carrier (SC) it is useful to consider this more closely. An assessment of intermodulation effects shows that a maximum amount of carrier suppression before detection is required and this has consequences for the selectivity and group delay requirements at high video frequencies. To take a simplified view of the likely interference, consider a signal, consisting of picture, sound and color carriers (PC, SC and CC) with the color carrier behaving as information that modulates the picture carrier from black to white. The following spectrum is then generated (see Fig. 7):

BT	-	PC
TT	-	SC
FT	-	CC

Interference components falling within the video band are then:

SC	-	RC	=	4.5 MHz
SC	-	CC	=	0.9 MHz

This model does not show spurious signals derived from the luminance components around 0.9 MHz and the sound carrier, which fall in the color range at about 3.6 MHz. All these signals involve the sound carrier which must be suppressed at the earliest possible point in the IF amplifier.

If one assumes that no spurious components arise in the stage before the sound trap, it can be seen from Fig. 8 that intercarrier signals will be attenuated 40 db relative to the wanted frequency. Moreover, the wanted sideband takes over the role of the sound carrier at the demodulator so that the now permanent 0.9-MHz spurious signal is also of this order. Except for the intercarrier interference at 4.5 MHz, which can be further suppressed by a trap, these components are fixed and cannot be eliminated subsequently.. The magnitudes are permissible for home receivers as they are below the level of perceptibility. For measurement quality demodulators, however, these form the absolute upper limit. From these arguments, it follows that sound carrier suppression of more than 50 db is required before demodulation, and that the stages which amplify both sound and video signals must be extremely linear.

There are two more methods of reducing interference, namely:

a) Reduction of the color carrier signal before demodulation by several db, and restoration in the video section. This has the added advantage (with envelope demodulation) that less quadrature distortion of the color signal is produced.
b) Lowering the sound carrier power by 3 db; i.e. a picture-sound ratio of 10:1. This has been used in several countries for 1 1/2 years without any disadvantages appearing.

LINEAR DISTORTION

When considering linear distortion effects, one must differentiate between the linear demodulator without sound suppression and the measuring receiver mode with domestic characteristics. With the sound suppression switched off, the receiver must exhibit constant amplitude and group delay time up to the highest video frequencies; i.e. the group delay time of the Nyquist filter must be compensated for. With the sound trap connected, the TV demodulator should function as a standard for the home receiver. It should at least contain traps for the sound, neighboring picture and neighboring sound signals (Fig. 9).

DESIGN OF THE SOUND TRAP

In principle, three possibilities exist for the construction of a sound trap (Fig. 10):

TV - Demodulator Type AMF

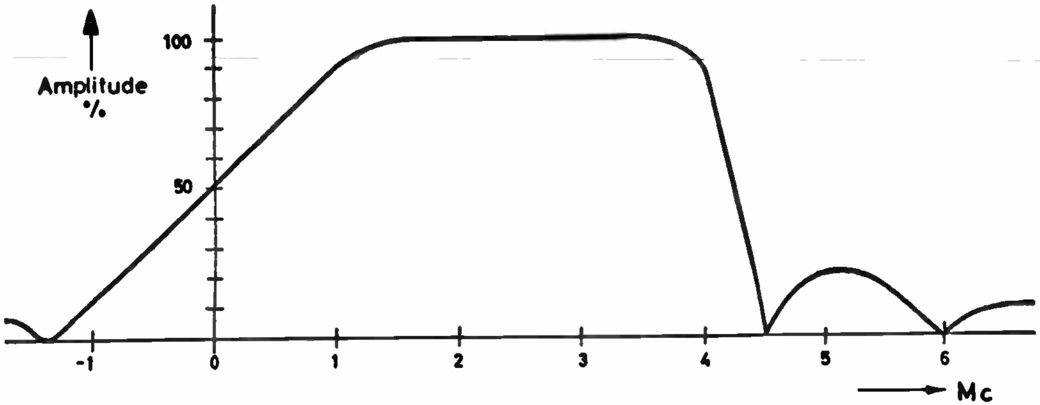
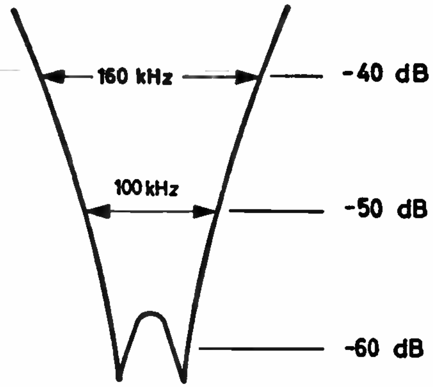


Fig. 9. Frequency response of a home receiver.

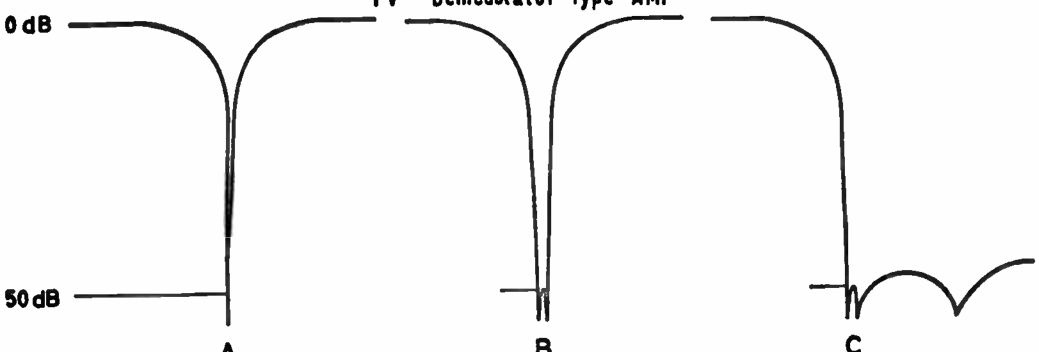
TV - Demodulator Type AMF



Sound level		2o %
Sound carrier - unmodulated		54 db
Sound carrier - modulated with 1 kc		
Deviation	± 3o kc	53 db
	± 5o kc	44 db

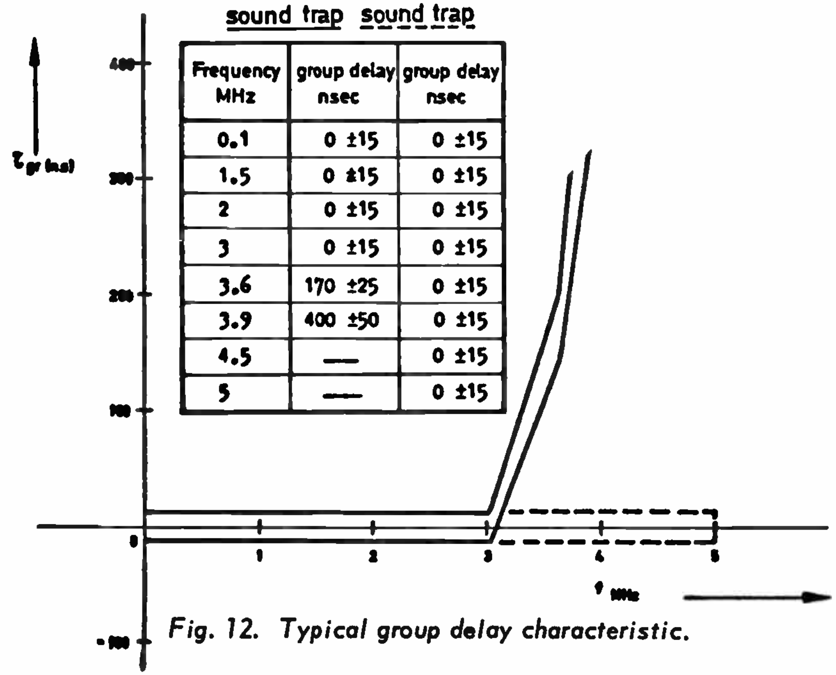
Fig. 11. Whiteband carrier filter for sound.

TV - Demodulator Type AMF



Group delay - curve	A c. 15 kc	B c. 16o kc	C c. 2oo kc
o,1 Mc	o	o	o
3,6 Mc	+ 75 nsec	+ 13o nsec	+ 17o nsec
3,9 Mc	+ 16o nsec	+ 3oo nsec	+ 4oo nsec
4,18Mc	+ 43o nsec	+ 6oo nsec	+ 7oo nsec

Fig. 10. Three different sound trap adjustment curves.



Frequency MHz	group delay nsec (with sound trap)	group delay nsec (without sound trap)
0.1	0 ±15	0 ±15
1.5	0 ±15	0 ±15
2	0 ±15	0 ±15
3	0 ±15	0 ±15
3.6	170 ±25	0 ±15
3.9	400 ±50	0 ±15
4.5	—	0 ±15
5	—	0 ±15

Fig. 12. Typical group delay characteristic.

a) Using one trap, which is made sufficiently high Q by loss compensation.
b) By two or more traps arranged symmetrically about the sound carrier frequency.
c) With a filter whose return characteristic remains below a certain value.

Assuming that the traps have a fall off of less than 3 db at the end of the pass band (4.18 MHz) and that the attenuation is 50 db, the following bandwidths at -40 db are obtained:

Type A	Type B	Type C
approx. 15 kHz	approx. 160 kHz	approx. 200 kHz

The group delay curves are correspondingly diverse.

	A	B	C
0.1 MHz	0	0	0
3.6 MHz	+ 75 nsec	+ 130	+ 170
3.9 MHz	+ 160 nsec	+ 300	+ 400
4.18 MHz	+ 430 nsec	+ 600	+ 700

When using an FM sound carrier with ±30-kHz deviation yielding main spectral components extending up to ± 45 kHz from the carrier, trap A provides insufficient picture interference rejection. This is because the sidebands of the sound signal fall on the slopes of the filter response and are converted into AM which is demodulated as interference at the video detector. This trap is also unsuitable for home receivers because of the instability of the local oscillator.

Two sufficiently broad traps, as in Fig. 10B, give much better results regarding interference but exhibit a much sharper increase in the group delay at the passband extremity. An example can show this more clearly. If a trap, with a response as in Fig. 11, is used to suppress the sound carrier by 58 db, the following picture interference rejection values result from the sound signal alone (minus noise and hum):

Power ratio — Picture: Sound	= 5 : 1
Unmodulated sound carrier	= 54 db
Sound carrier modulated with 1 kHz:	
Deviation ± 30 kHz	53 db
± 50 kHz	44 db

The spurious signal rejection values are referred to the sync level. The waveforms are roughly sinusoidal so that the figures are valid for both peak or rms measurements.

In practice the intermodulation and sound interference on the picture tube are of more interest than the numerical amount of sound suppression. For this reason the intermodulation product (SC-CC) and video spurious signal level are often quoted in preference to the frequency response of the sound trap, when sound modulation is applied.

To conclude, it is clear that to keep intermodulation distortion low, the sound carrier suppression, before video detection, must be sufficient (150 db). Moreover, the sound trap must have a minimum bandwidth to reduce sound-on-picture and achieve adequate stability. Neighboring channel suppression must also be adequate in home receivers.

The selectivity specifications, for a system with minimum phase correction—e.g.

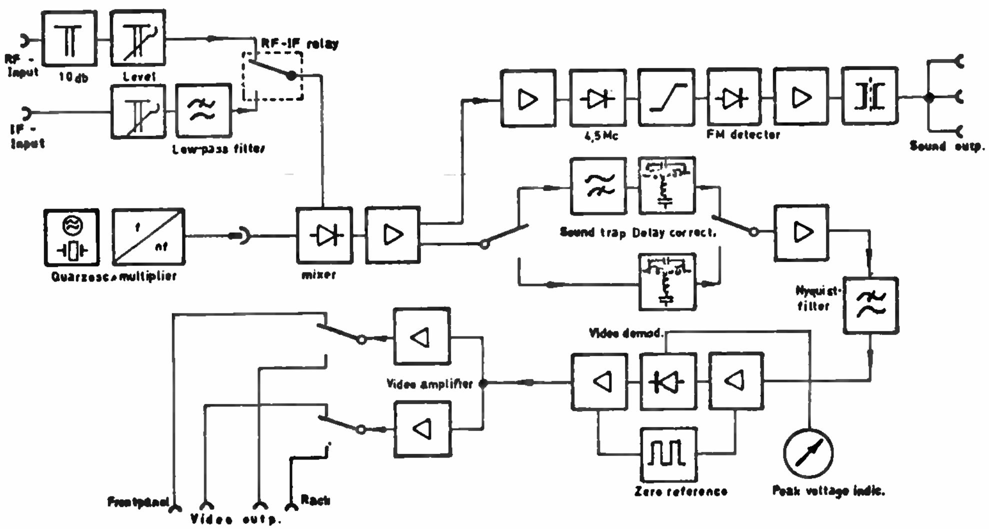


Fig. 13. Block diagram of the TV demodulator, Type AMF.

Fig. 14. TV demodulator Type AMF.

TV - Demodulator Type AMF

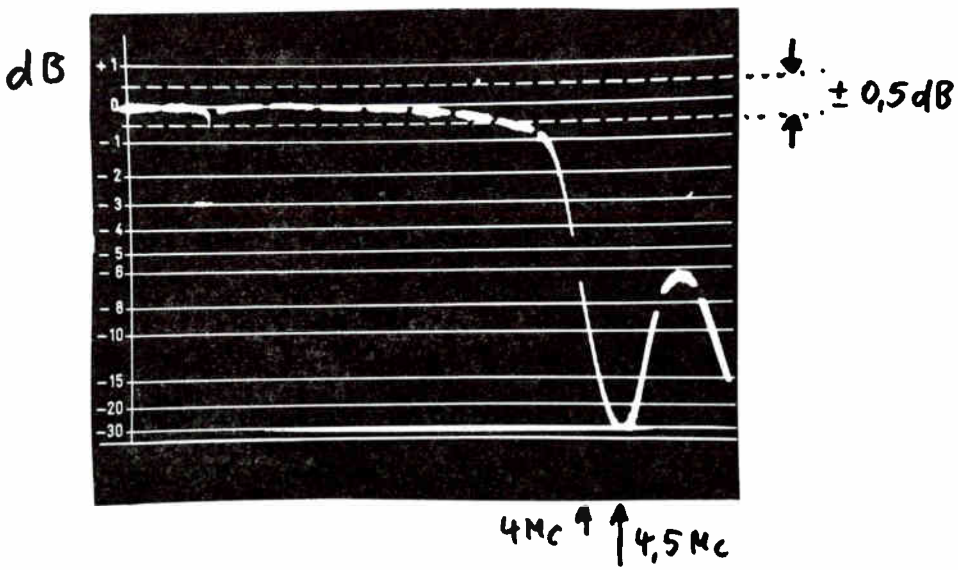


Fig. 15. Video frequency response with sound trap, measured with a video sweep generator and RF modulator; frequency markers 0.5 MHz.

TV - Demodulator Type AMF

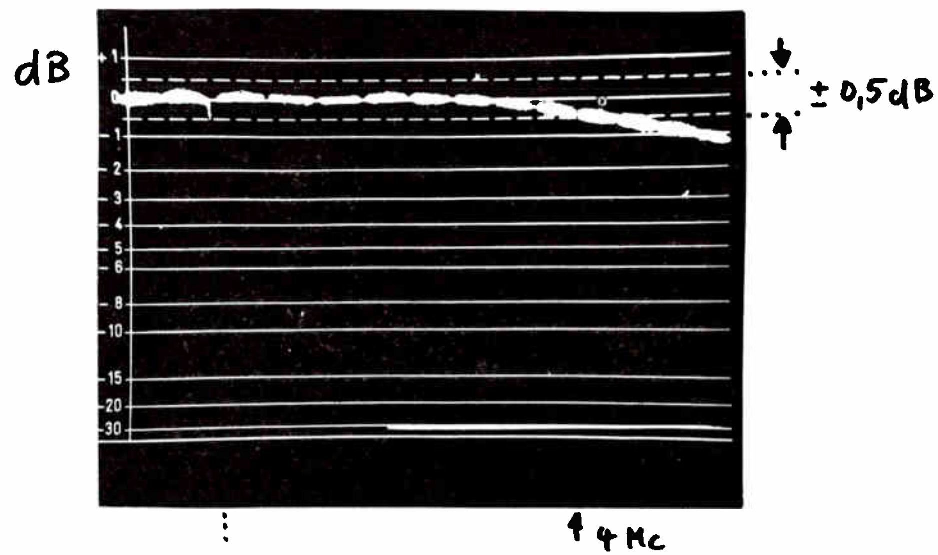


Fig. 16. Video frequency response without sound trap, measured with a video sweep generator and RF modulator; frequency markers 0.5 MHz.

home receivers where costs must be kept low—require a sharp increase in the group delay at the upper end of the video band and a gradual fall-off of amplitude beyond the color carrier frequency (Fig. 12). The illustrations show the more important tolerances required of a demodulation standard. The ones that are dotted apply when the sound trap is switched out. If the transmitter pre-equalization is set to give a constant group delay time for the transmitter and receiving standard together, one can expect optimum quality for the range of contrast and color on the home receiver. Nowadays, transmitter pre-equalization is often applied after the modulator in the IF stages. This avoids the evident disadvantages of equalization at video frequencies.

SHORT DESCRIPTION OF A TV DEMODULATOR

An instrument with the characteristics already discussed is shown in the functional diagram in Fig. 13. The RF input (50 ohms $\pm$ 1.5%) accepts a level of approximately 1 V_{rms} from the diplexer or any test output on the transmitter. The IF channel, which requires approximately 150 mV $_{rms}$, can be connected to one test point or to several by interposing coaxial relays. A low-pass filter is included to eliminate any RF (channel frequency) signals appearing in the IF chain. Either the RF or IF signal can be switched to the broadband mixer using the RF/IF relay. When an IF signal is applied, the mixer operates merely as a damping circuit but, when appropriate, converts the RF signals to the IF range by means of a multiplied crystal frequency.

After common IF amplification the sound and picture components are split into two paths. The sound signal is further modified and demodulated in an intercarrier sound section and the video component can follow one of two routes. The upper one contains the sound carrier suppression and all-pass elements for equalization of the receiver group delay characteristics. The lower path, sound trap out, has no selectivity, only all-pass elements to achieve a constant group delay from 0 to 5 MHz. An amplifier stage boosts the signal level and feeds the IF signal to the NYQUIST FILTER which has the correct frequency response close to the carrier for the addition of the vestigial sideband (see Fig. 3). After further amplification to about 7 V $_{rms}$, the signal is linearly detected and a peak responding meter can be used to adjust the demodulation level to optimum. The source impedance is then corrected and four video outputs are fed with the standardized video signal via two decoupled video amplifiers. A zero reference circuit derives short pulses from the video signal, which block the IF amplifier so that the voltage corresponding to zero signal level appears at the video output for the pulse duration (see Fig. 1). All the filter and amplifier inputs and outputs have a fixed impedance of 60 ohms. The filters and all-pass networks are entirely passive and constructed from ceramic inductors to obtain maximum frequency stability.

MEASUREMENTS ON A TV DEMODULATOR

The following illustrations show the frequency response of amplitude and group delay for a measuring demodulator with and without the sound trap. They were obtained using a double-sideband demodulator. In Fig. 15 one can see the sharp amplitude rise above the sound carrier frequency. Better neighboring channel rejection is desirable. Fig. 17 shows the sharp increase of the group delay above 3 MHz.

Fig. 19 represents the sideband characteristic of a TV signal generator in Band V and Fig. 20 shows the group delay equalization. For this test the TV demodulation was operated with the sound trap switched out. Up to 3 MHz, the transmitter delay

TV - Demodulator Type AMF

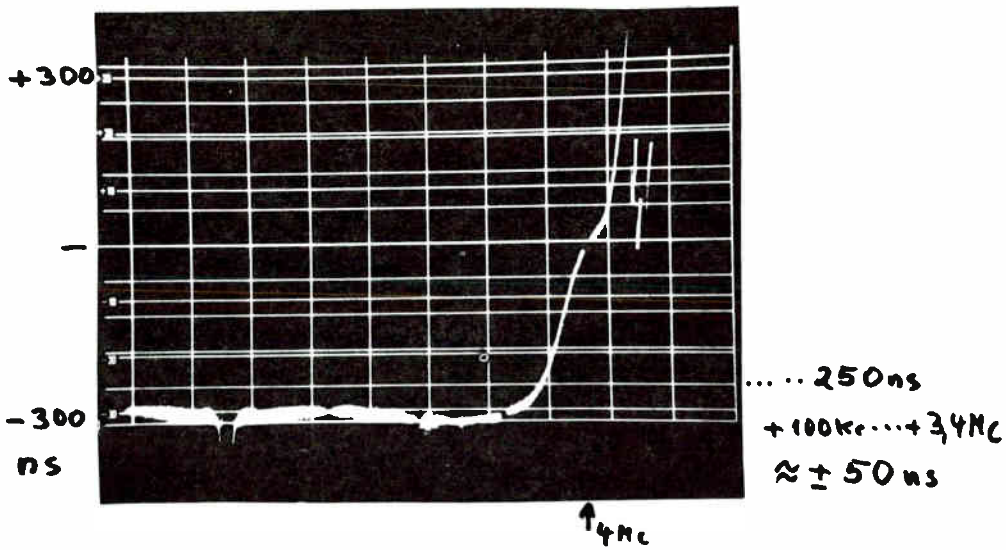


Fig. 17. Group delay behavior with sound trap, measured with the LFM Group Delay Test Assembly; marker spacing 1 MHz.

TV - Demodulator Type AMF

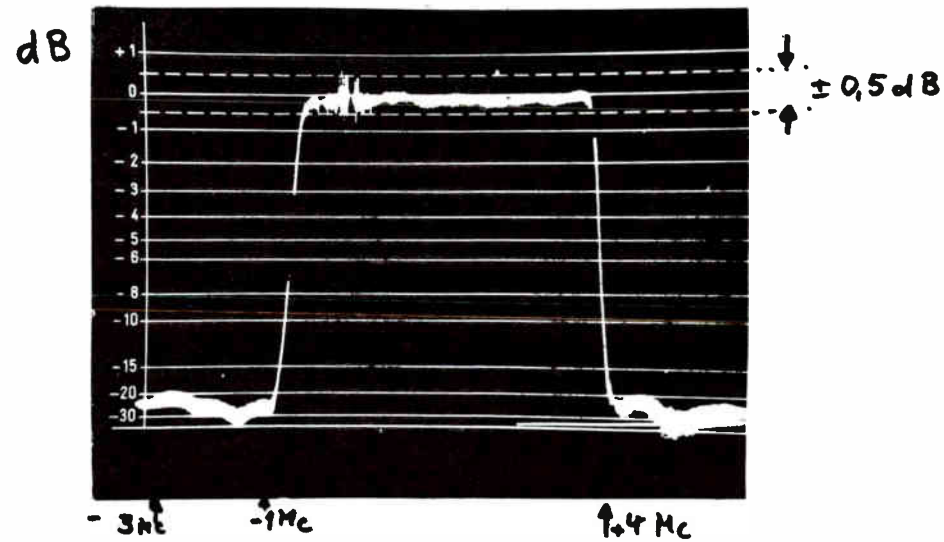


Fig. 19. TV transmitter response curve, measured with a video sweep generator and sideband adapter; marker spacing 0.5 MHz.

TV - Demodulator Type AMF

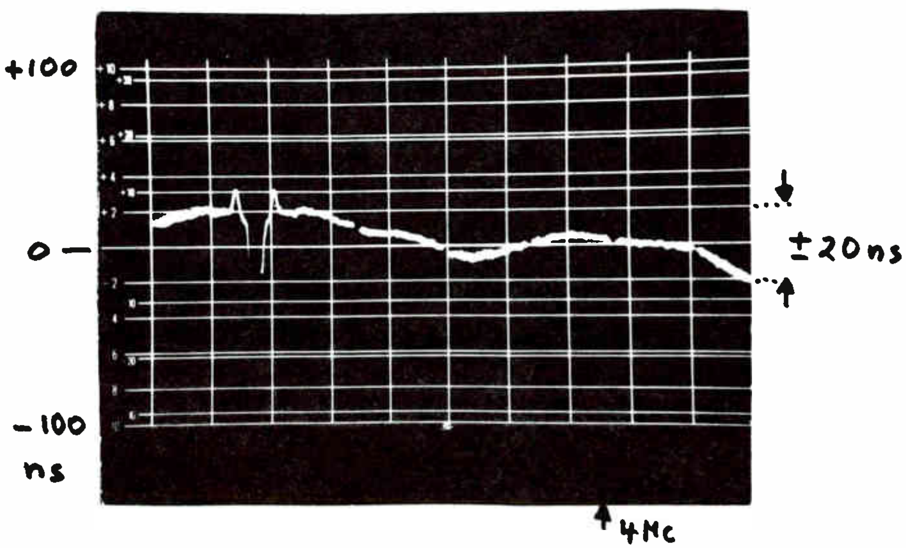


Fig. 18. Group delay behavior without sound trap, measured with the LFM Group Delay Test Assembly; mcrker spacing 1 MHz.

TV - Demodulator Type AMF

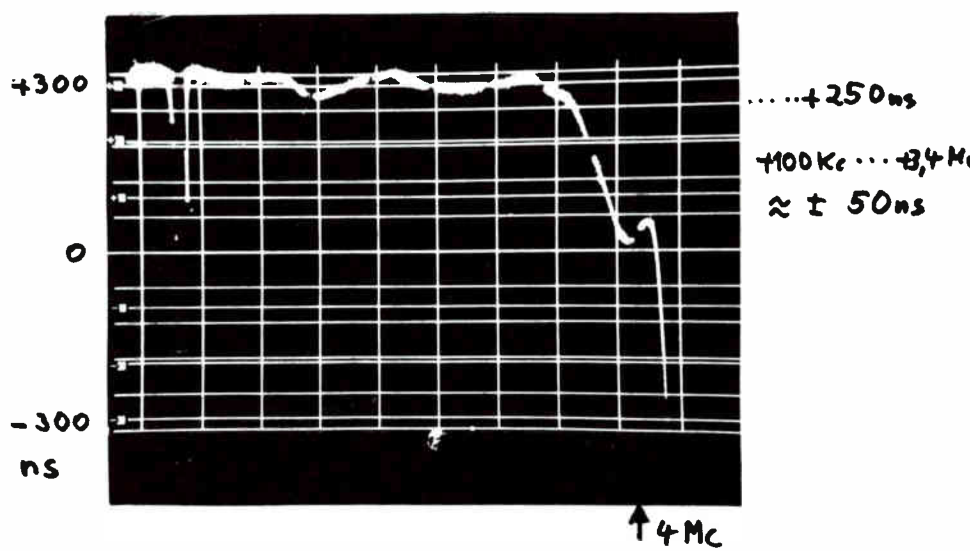


Fig. 20. TV transmitter group delay behavior, measured with a TV demodulator without sound trap; marker spacing 0.5 MHz.

TV - Demodulator Type AMF

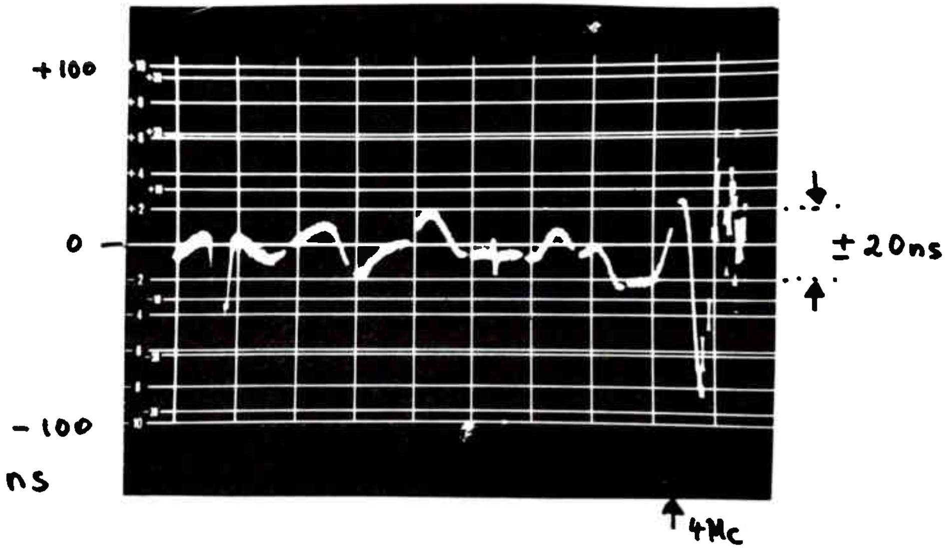


Fig. 21. TV transmitter group delay behavior, measured with a TV demodulator with sound trap; marker spacing 0.5 MHz.

TV - Demodulator Type AMF

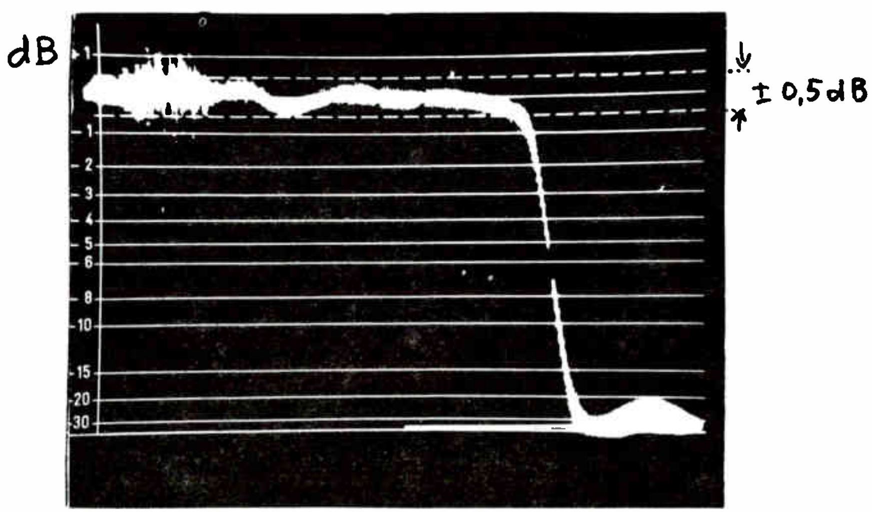


Fig. 22. Video frequency response of a TV transmitter and AMF, measured with a video sweep generator; marker spacing 0.5 MHz.

TV - Demodulator Type AMF

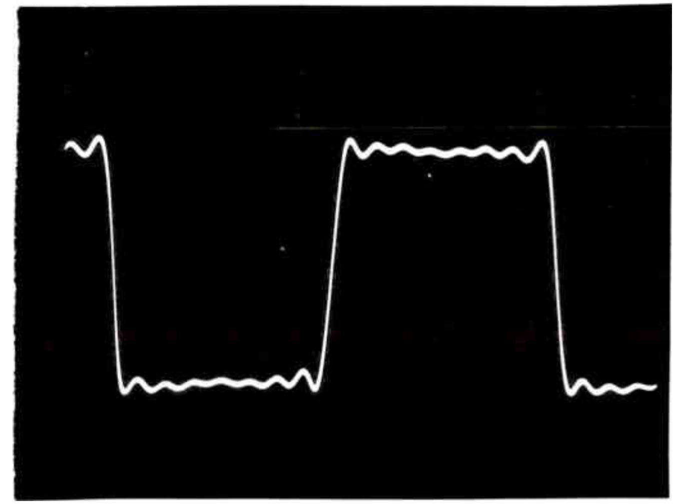


Fig. 23. Transient response of a 250-kHz squarewave (50%/70%), rise time 90nsec. TV transmitter measured with a TV demodulator.

TV - Demodulator Type AMF

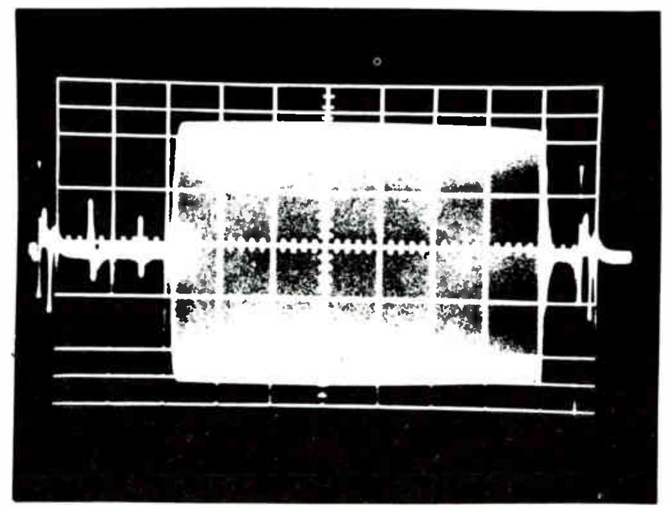


Fig. 24. Linearity (differential gain) of a sawtooth superimposed with a 3-MHz signal between 10% and 70%. TV transmitter measured with a TV demodulator.

response is linear and falls to compensate for the corresponding increase at the receiver.

Fig. 21 is the group delay response for the transmitter plus receiver. It remains within ± 20 nsec up to 4 MHz. The overall frequency response of transmitter plus receiver is given in Fig. 22. The transient response of the system is seen from Fig. 23 to be clean and symmetrical. The spectrum of the 250-kHz squarewave extends to 10 MHz so that, having passed through the 4-MHz low-pass filter, ringing at 4 MHz is obtained.

A Logical Approach to Video Switching Systems

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Visual Communication Products Department
General Electric Company

During the past decade there has been an ever increasing demand for new and improved switching facilities. This has been true in the broadcast industry as well as in the constantly expanding closed-circuit educational field. The introduction of video tape machines and color equipment has increased the need for more and larger systems with exceptionally stringent performance specifications. In large systems the routing of the video signal becomes enormously complicated; in turn, delay compensation becomes extremely difficult.

Video switching systems, within a given installation, perform various functions. There may be several studio production switchers; a master-control switching system, including audio follow; a routing switcher with machine control; as well as distribution and monitor switching. All of these have one thing in common—a switching matrix and control system.

Video signal routing and delay compensation can be greatly simplified if all of the video switching matrices for the various functional systems are of the same type and located in one central location. This, of course, requires a switching system which, in order to meet specific objectives, first must be flexible in design to handle the various input/output combinations and, secondly, must have a switching matrix which can be readily expanded while still maintaining its electrical characteristics. In effect, the switching matrix becomes a switching wall in which various sections perform different functions. At times the circuitry may be more sophisticated than necessary for a given application; however, it is felt that the advantages of a common switching center outweigh the slight extra cost.

We will limit our discussion to the development of a video switching matrix and the associated control circuitry to operate the individual cross-points. In certain cases, however, information regarding the interface with periphery equipment such as audio follow, and source tally will be described. Studio production switchers make use of the video switching matrix which, in turn, feeds the special effects and mixing amplifiers, and other processing equipment as required. As we proceed with the discussion, you will find that the steps in presenting the subject are the steps you would take in designing a system, with a little guidance from the author.

OBJECTIVES

Before proceeding with the design of the system, we must first determine our objectives. These are not necessarily presented in their order of importance, since relative importance will vary from application to application.

1. System expandable to 100 inputs by 96 outputs. The switching matrix and control system must be modular in construction so that it can be assembled to accept any number of inputs from 2 to 100 and feed any number of outputs up to 96. The matrix will be, in effect, a switching wall and provide the complete switching facilities for the whole installation.
2. Capable of expansion in the field with minimum effort on the part of the purchaser. The mechanical layout and electrical characteristics must be designed to permit expansion without obsoleting existing equipment such as the control system, control cable (which may be installed in conduit), or upsetting the electrical performance of the existing system.
3. Provide a non-destructible latch device which will not fail due to power failure. This is particularly important in semi-attended and preset switching applications.
4. Incorporate a control system which lends itself to efficient interface with preset memory or automatic control.
5. Provide a reliable latch and interlock control system that is free from erratic switching and will positively prevent double video signals on an output bus.
6. Provide unsurpassed electrical performance characteristics required in present-day color video signal transmission.
7. Eliminate the existence of switching transients due to control signal crosstalk which upsets the clamping in video tape recorders.
8. Readily interface with peripheral equipment such as audio switching and source tally logic as well as machine control.

SYSTEM ANALYSIS

Now that the guide lines have been established, the route of attack must be plotted. Fig. 1 illustrates a simplified functional diagram of a switching system incorporating audio and video switching along with source tally. Each of the functional groups such as audio, video, etc., are arranged together. Although there is interconnection vertically within a group, the only connection between groups is control circuitry, shown by the horizontal line. If one horizontal row is removed, and our attention concentrated on this one output, the analysis of the system can be greatly simplified. Fortunately, interconnection between rows is a relatively simple bridging process of a number of high-impedance loads across a low-impedance terminated

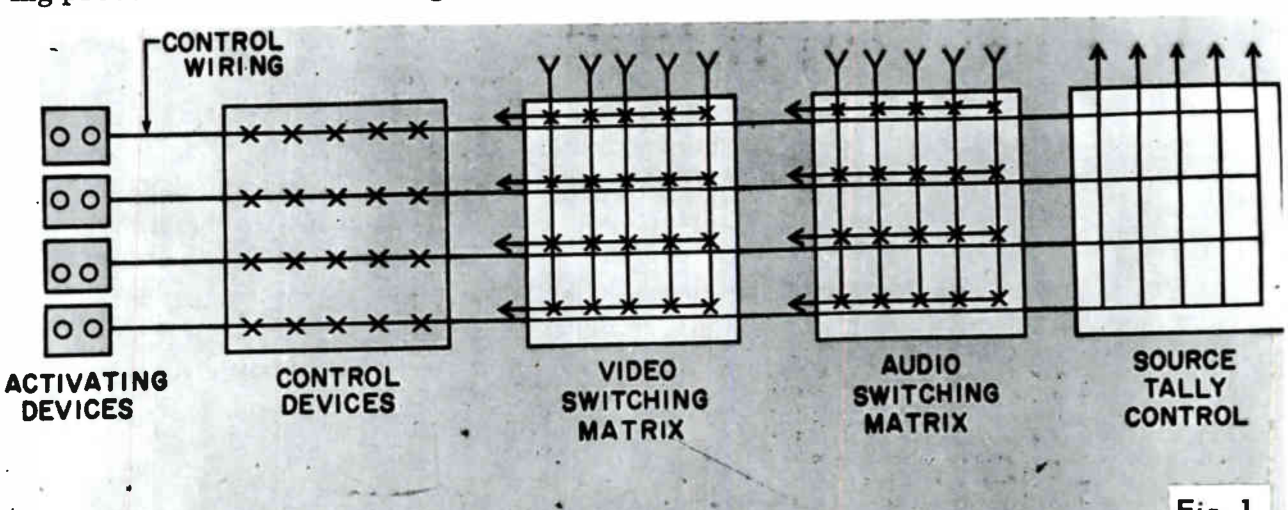


Fig. 1

TOTAL SYSTEM FUNCTIONAL DIAGRAM

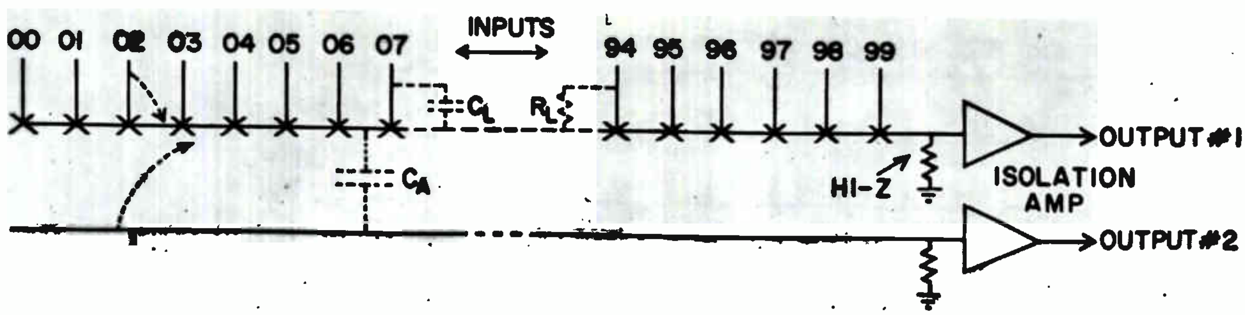


Fig. 2 **VIDEO OUTPUT BUS FLOW DIAGRAM**

line and will not be discussed further, except to state that individual crosspoint isolation must be used to prevent momentary signal feedback during overlap switching.

Fig. 1 shows that for a large complex switching system consisting of multiple functions, the primary emphasis should be placed on the arrangement of the output bus and the lines parallel to it. This is also demonstrated in Fig. 2 which shows an expansion of the video matrix alone. As the number of video inputs is increased, the output bus becomes longer and, in turn, it becomes more difficult to control frequency response and interference between channels. The above factors defined the mechanical and physical layout of the system to be described.

VIDEO CIRCUITRY

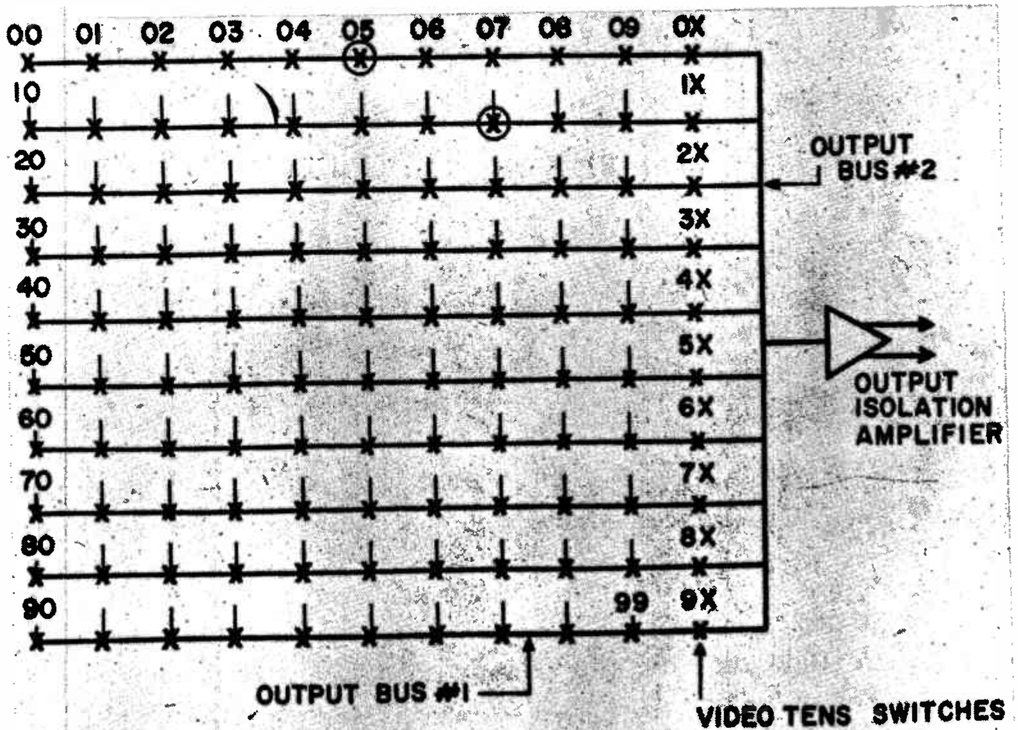
Referring again to Fig. 2 and expanding the input capability to 100 inputs, it is obvious that the video output bus becomes extremely long and therefore subject to crosstalk from adjacent output buses. This principle cause of crosstalk can be attributed to three factors. First, the leakage within the actual crosspoint itself, represented by C_L and R_L; secondly, leakage between output buses (C_A); and finally, intermixing of signals due to cross-coupling of power supply lines and ground loops. If a system is designed for 100 inputs and is to have a crosstalk figure of 60 db, then the crosstalk contributed by crosspoint leakage, assuming no other source of crosstalk, must be 100 db below the original signal level.

60 db = 1/1000 total for all crosspoints

$$\frac{\frac{1}{1000}}{100} = \frac{1}{10,000} = 100 \text{ db per crosspoint}$$

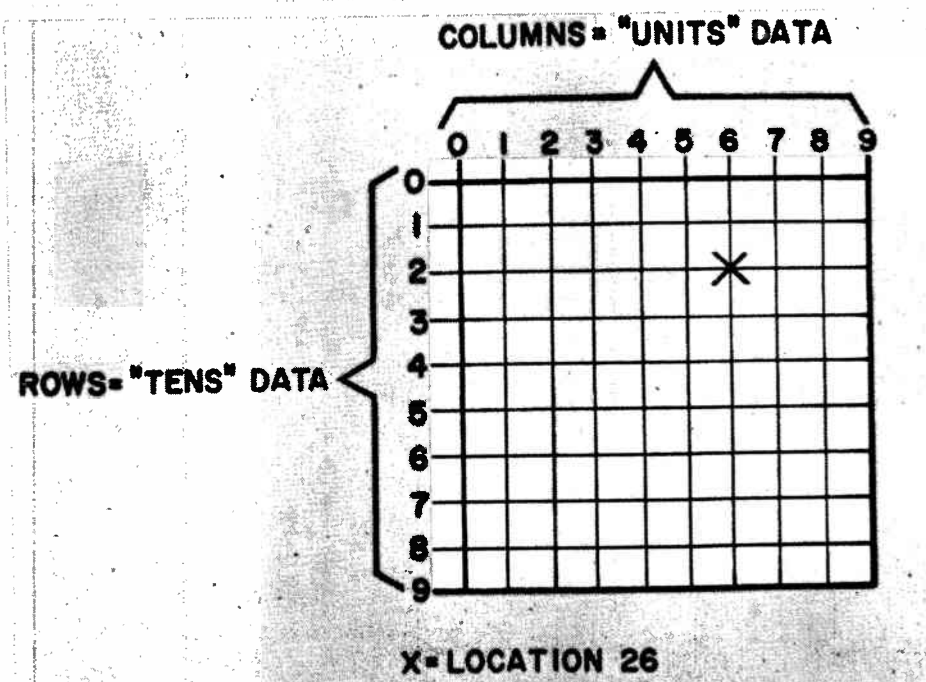
If additional crosstalk is contributed by the other two offenders, the 100 db per crosspoint figure must be further increased. From a practical standpoint, it is impossible to obtain. The stray capacity to ground also increases as the bus is increased, causing difficulties in maintaining flat frequency response especially when driving a high-impedance load.

If, however, the output bus is broken up into groups of ten inputs as shown in Fig. 3, and these groups switched in the circuit as required, the detrimental effects, previously described, can be reduced. The "Video Tens Switch" performs this function. Actually, two simultaneous video switches take place when, for example,



VIDEO OUTPUT FLOW DIAGRAM GROUPED
100 INPUTS x 1 OUTPUT

Fig. 3



DECIMAL CONTROL MATRIX
100 INPUTS x 1 OUTPUT

Fig. 4

switching from input 05 to input 17. Crosstalk due to crosspoint leakage is not as critical in this configuration, as only ten crosspoints are on an output bus at a time. The other ninety crosspoints have an open switch, the Video Tens Switch, in series with them to produce further attenuation. A crosspoint rejection of 80 db produces the same results as a 100 db in the original circuit. In like manner, crosstalk contributed by coupling between output buses and power supply cross coupling is also reduced by a factor of 10.

CONTROL SYSTEM

Control circuit interconnection in a system has always been a cumbersome problem due to the number of wires involved. As systems become bigger, the wiring harness becomes larger. A hundred input, one output system usually requires one wire per crosspoint or 100 wires for control alone and another 100 wires for tally. As smaller systems are expanded, additional wiring must be added, which can be difficult—if not expensive—to handle.

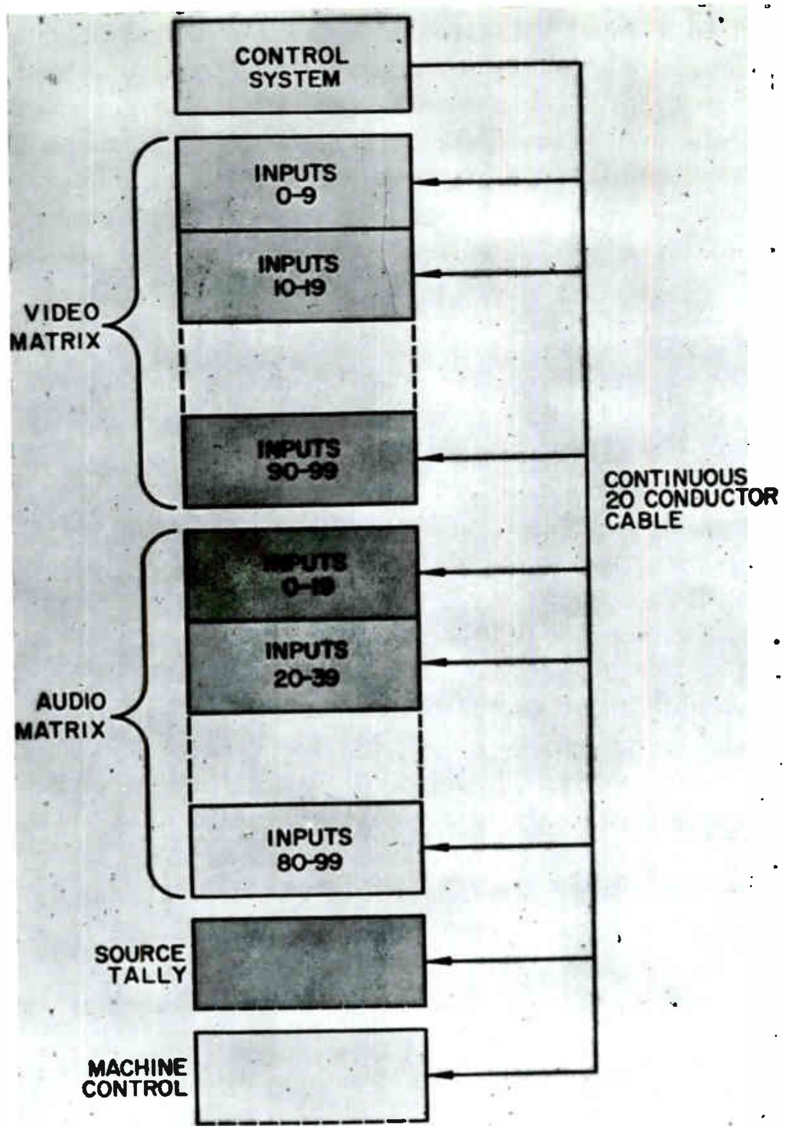
The video flow diagram shown in Fig. 3 suggests a revision of the conventional control circuit wiring technique. If we let the crosspoints in the top row represent inputs 00 through 09, the next 10-19, the next 20-29, etc., we end up with a 10 x 10 matrix as shown in Fig. 4. The ten columns represent "units" while the rows represent a group of ten units or "tens" information. Any point in the matrix may be chosen by selecting the proper "units" and "tens" control line. By using this approach only 20 wires are required to control 100 inputs instead of the conventional 100 wires. Fig. 5 shows the twenty-conductor cable running vertically from row to row. All necessary data to activate any one of one hundred crosspoints is in this cable. Activating any two wires, one of which is the "tens" group and the other in the "units" group, will select one crosspoint. If audio switching, source tally or machine control is required, this same cable is extended to these areas and the required data sampled from it. The cable does not require changing, only extending, if a system is expanded.

Latching and interlock devices must be supplied some place in a control system. The latch is a device which changes state after a momentary pulse is applied, the interlock assures that all other latching devices are off when a particular latch is energized. Normally, one latch is used for each crosspoint. The decimal system, or twenty-wire system just described, requires only 20 latching devices for 100 inputs. This is a considerable saving in large installations. If a binary system is used to code each group of ten data lines, the number can be further reduced to eight.

This Binary Coded Decimal (BCD) is used in the control system. In essence, the control system is designed to be always capable of handling 100 inputs and, therefore, requires no change when a system is expanded, yet it only contains eight latching devices which is less than most conventional systems. True, additional encoders and decoders are required to convert from one system to another, but the overall complexity is equivalent to about a 20-input conventional system.

In addition to the above advantages, the binary coded latch system automatically provides a reliable interlock. Each time an input selection is made, all eight latches receive data directly from the activating device telling them whether to be ON or OFF. Most conventional systems rely on a secondary pulse derived from the latch being turned ON to turn the other latches OFF. Failure of this pulse can cause multiple signal pickup which may, in some designs, be difficult to clear.

Preset and automated switching systems all require additional control circuitry and memory banks. Information must be stored describing what is to take place in future events. Since cost is directly proportional to the number of storage ele-



INTER-FRAME CONTROL CABLES

Fig. 5

ments, it is desirable to reduce the number of storage devices required. The Binary Coded Decimal System, used extensively in computers, provides an efficient storage method. Depending upon system requirements, storage can be retained in relays, flip flops, punch cards or tape, magnetic cores or by other methods. Only eight bits are required for each event and these may be fed directly into the system latching module without having to convert from one system to another.

One objective stated previously was to provide a switching system which would return to its previous switching position after the loss of AC main power. This, in turn, means that the latching devices must not depend upon electrical power to hold their ON and OFF state. Most bistable electronic devices cannot be relied upon to retain a particular "state" upon the loss of power. Magnetic-latching reed relays which depend upon magnetic energy to lock-in fulfill this requirement. These are small and reliable and, since the circuitry is coded to a binary system, only eight relays are required. Unfortunately, these are slow acting, requiring a few milliseconds to operate. To solve this, fast acting D.T.L. integrated circuit flip flops are added to actually trigger the switch. The magnetic-latch reed relays thus serve only as back up.

Fig. 6 shows two typical flow diagrams of the control system. In the Type A System, data fed the latching devices from an activating device such as the push button is carried as a BCD code to reduce the size of the control cable and make it standard for any size system. The cable actually carries data to the latch to perform an operation and also carries data back to the control device to indicate that the operation has been properly performed. If automatic control is desired this equipment is inserted between the control head and the control manifold at the right. Data fed into, and received from, the automatic system is in BCD.

Although the system may be operated from a conventional pushbutton panel with one push button for each input signal, this becomes unwieldy for systems of approximately thirty or more inputs. A decimal-type control head, as shown in Fig. 7, where twenty buttons arranged in two vertical rows, one row for "tens" information and the other for "units" information, makes a compact control device for large systems. The buttons are mechanically interlocked to provide a preset memory and a "TAKE" bar is furnished to transfer data to the latching devices located in the rack. The next event can be preset in the push buttons at any time and transferred at the operator's discretion. This system requires encoding of the decimal data to BCD and transmitting it down the cable. Readout data returning on the cable is decoded and fed to the pushbutton lights.

Other types of control heads are easily adapted to the system. The touch system used on modern telephones along with a digital readout provides a convenient means of controlling large numbers of inputs. Another important feature is that various control heads may be intermixed or even changed after an installation has been completed, without requiring a change in any part of the system, including the control cable to the head.

Mechanical devices such as switches and relays inherently have contact bounce which can cause erratic electrical signals during the first few milliseconds of operation. Data taken during this period is not reliable. If, however, the transmission of data is delayed until the contacts settle down, the system becomes more reliable. Delayed clock pulses are used for this purpose. In effect, data is preset in a memory and transferred at the proper time. This also increases the reliability of the system since it will accept new data only during this narrow clock pulse; noise pulses in between are ignored.

A simpler version for "off-air" applications, shown in Fig. 6B, employs a similar type of control package, but uses the decimal data direct from the control head to operate the crosspoint matrix. The latch and interlock function, in this case, is the mechanical part of the push button assembly and the control manifold is not required.

SYSTEM LAYOUT

The Video Flow diagram of Fig. 3 dictates the physical layout of the system. Crosspoints are arranged in rows and columns; a "Video Tens Switch" is located at the end of each group of tens crosspoints; its function being to switch the video in that row to the No. 2 output bus which runs vertically between groups. In turn, output bus No. 2 feeds a video amplifier which provides isolation to the output load. Fig. 8 illustrates how this is converted into hardware. Each rack frame or manifold, as they will be referred to from here on, represents one row of crosspoints and a tens switch. These are arranged vertically in a rack, the number being determined by the input capacity of the specific system. A 38-input system requires four video crosspoint manifolds. If audio follow is included, these can be located directly below the video matrix and assembled on another rack. The control mani-

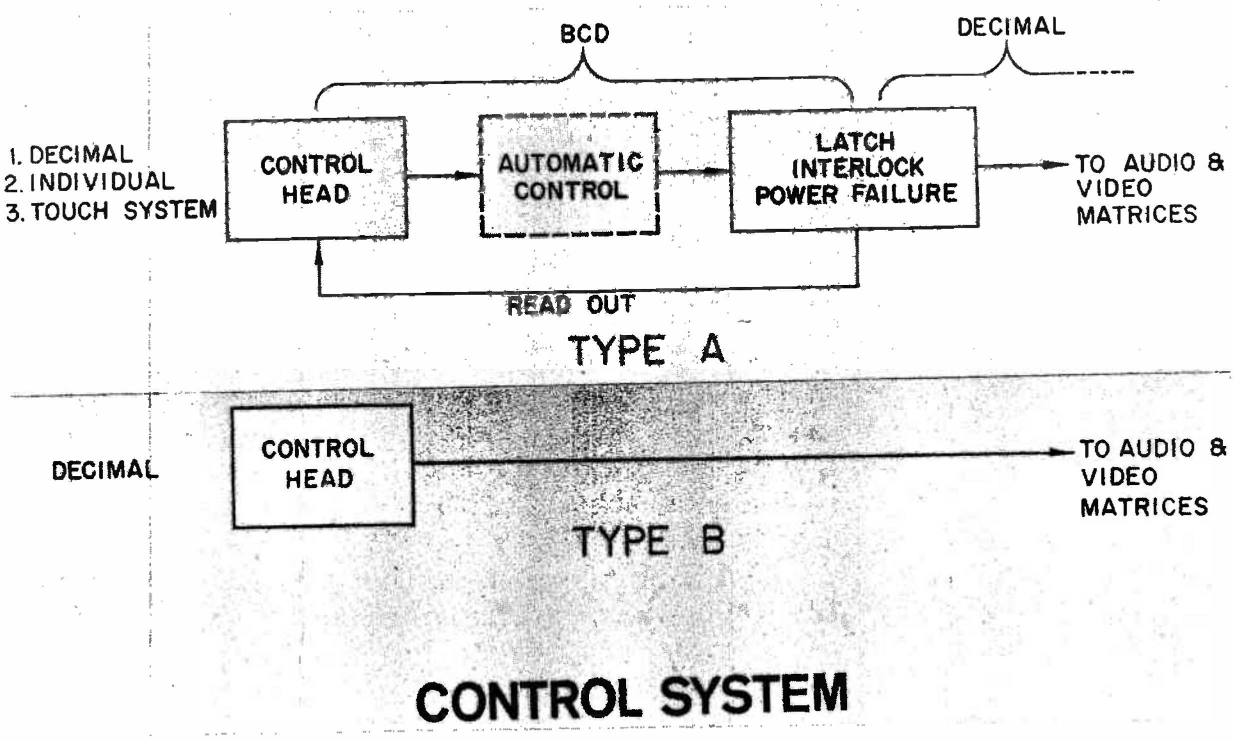
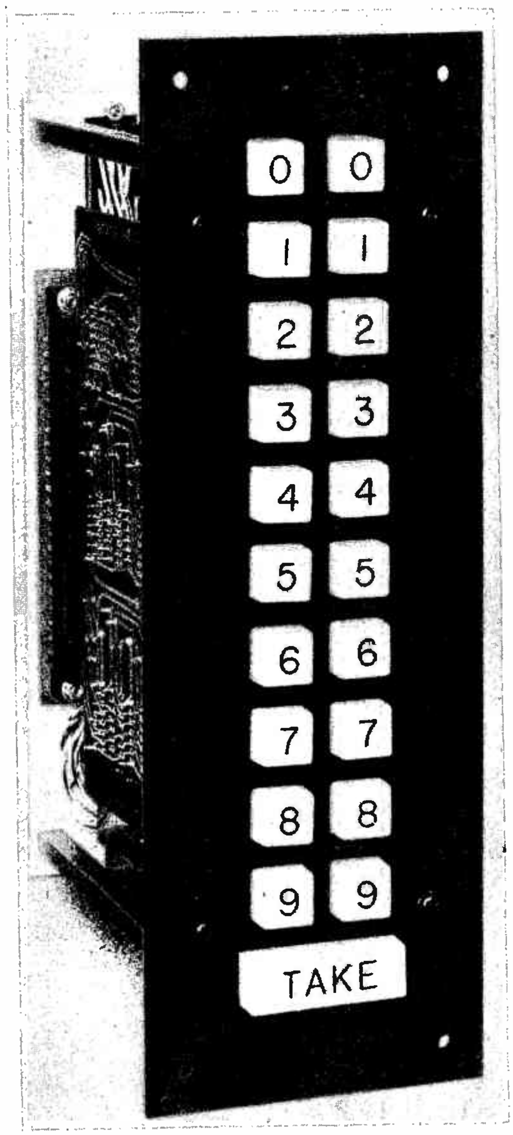

BCD
DECIMAL
1. DECIMAL
2. INDIVIDUAL
3. TOUCH SYSTEM
CONTROL HEAD
AUTOMATIC CONTROL
LATCH INTERLOCK POWER FAILURE
TO AUDIO & VIDEO MATRICES
READ OUT
TYPE A
DECIMAL
CONTROL HEAD
TO AUDIO & VIDEO MATRICES
TYPE B
CONTROL SYSTEM

Fig. 6


0
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TAKE

Fig. 7

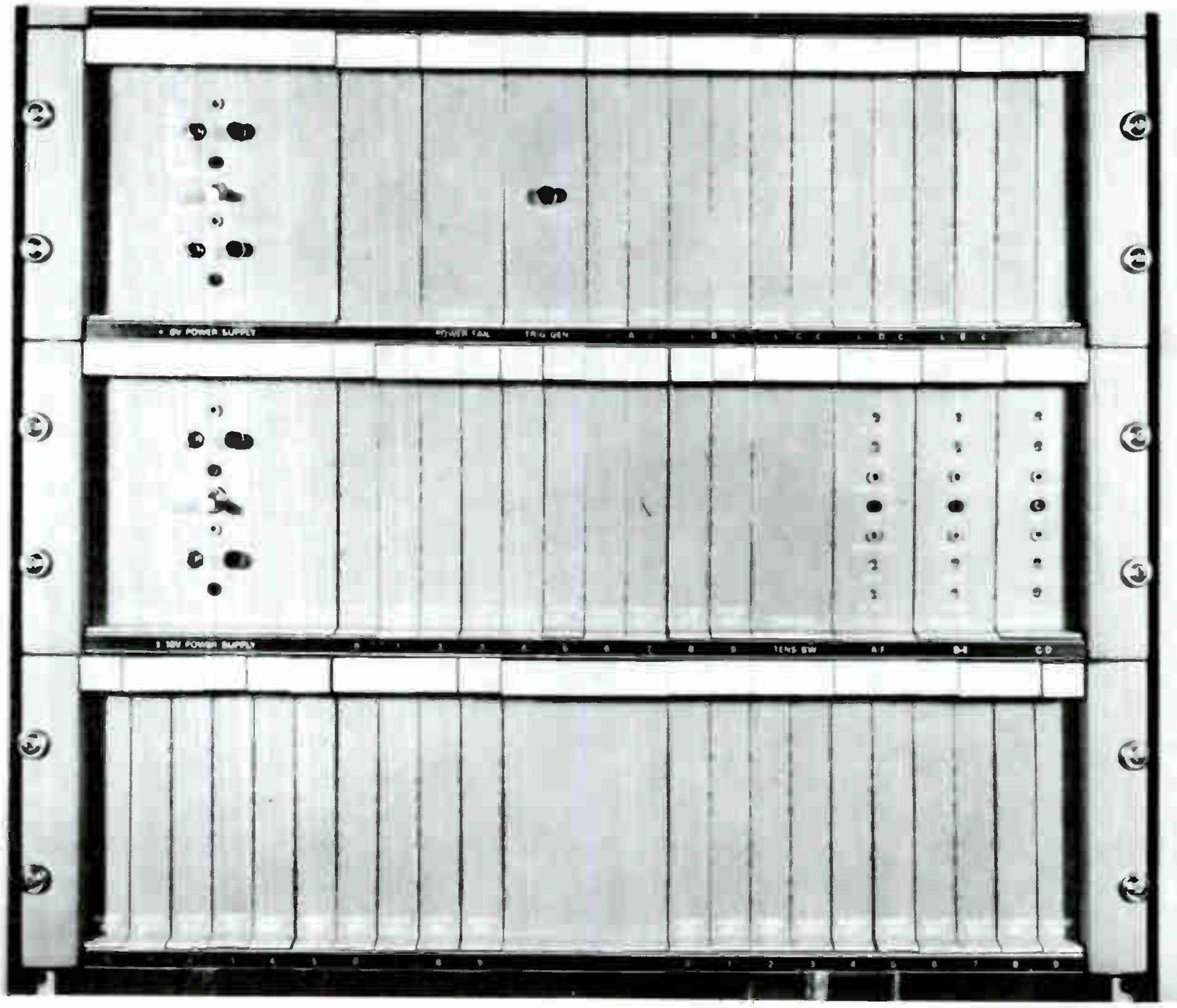


Fig. 8

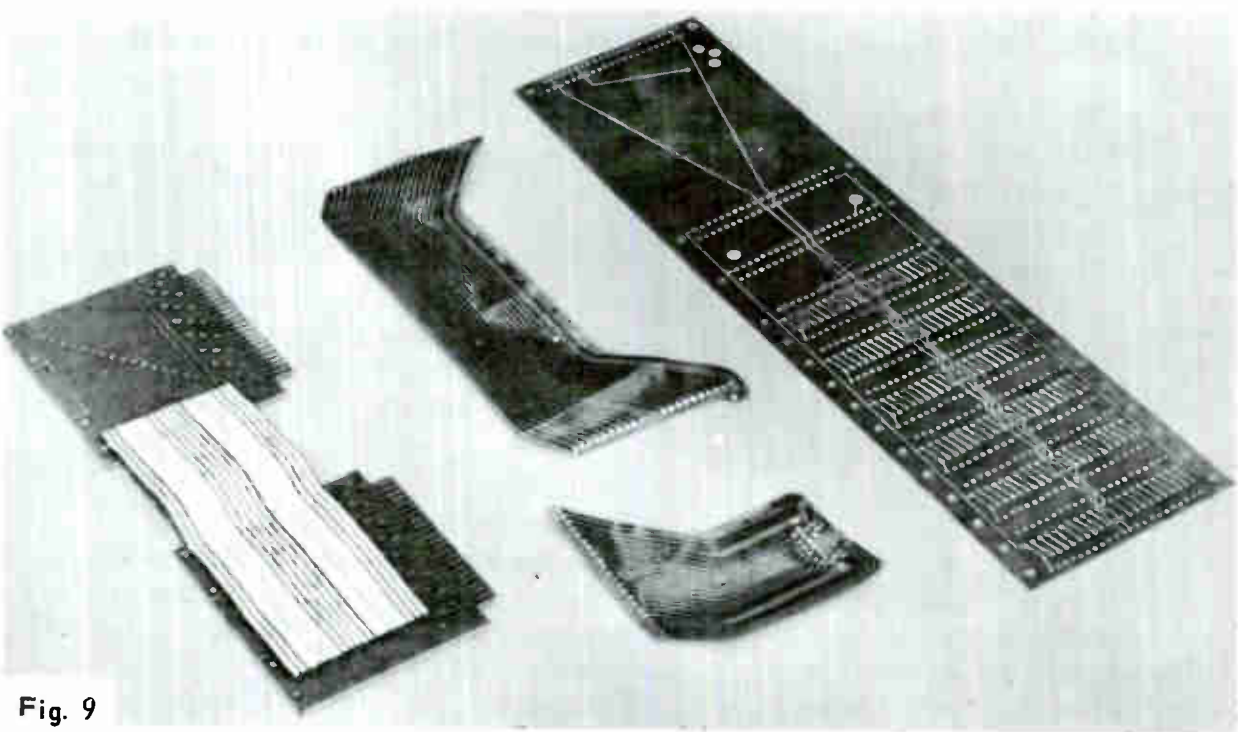


Fig. 9

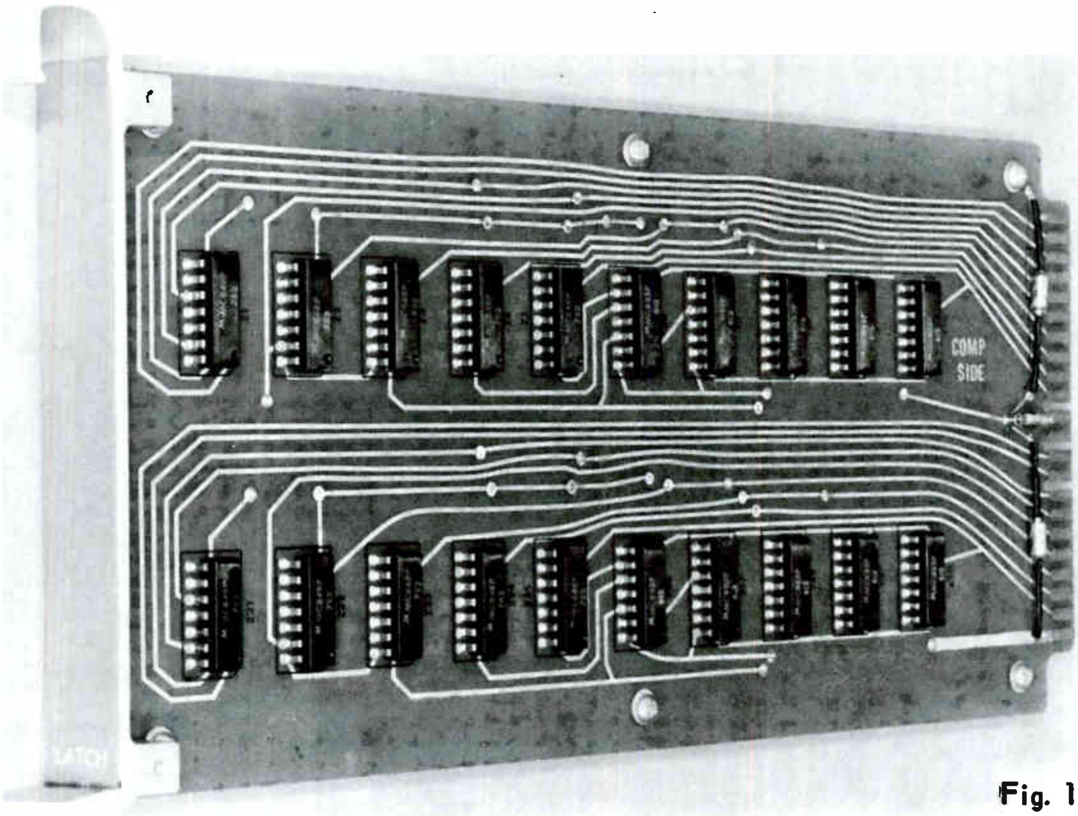


Fig. 10

fold, which contains the latch and interlock circuitry, as well as decoding logic, is placed directly above the video matrix. The 20-wire control cable, which carries all the necessary data to select a crosspoint, interconnects all manifolds. If source tally is required, this same cable is extended to include this manifold. The tally manifold actually samples data from several output banks and, in the case of a production switcher, data from the control panel, to determine which video sources are actually "on the air." In actual practice, six levels of outputs are incorporated in the layout to reduce the overall space requirements. Each crosspoint module handles one input and six outputs. The control, audio, and tally manifolds each, in turn, handle six outputs.

In order to assure predictable characteristics between units, reduce wiring errors in manufacturing, and simplify troubleshooting, extensive use has been made of printed circuit wiring. The conventional printed circuit component hardboard is used for all rigid interconnections, while in addition, printed flexible circuitry, as shown in Fig. 9, replaces many internal cable harnesses. The control circuitry is almost exclusively built of low cost DTL integrated circuits. Fig. 10 shows the latch module capable of controlling 100 inputs. The 20 IC's provide the latch and interlock functions plus gates for decoding BCD data to decimal.

CONCLUSION

The systematic approach to the design of a video switching system has made it possible to produce a system which is conveniently expandable to larger systems while still maintaining excellent performance characteristics. The method used inspired changes in the conventional control system which lend themselves to digital techniques currently used in computers, and made interfacing with preset and automatic control relatively simple through the use of the BCD control system. The system is modular and can be easily adapted to specific customer requirements.

Automatic Light Control for Television Film Cameras

Kenneth D. Erhardt and Kenneth W. Jorgensen
N.B.C. Burbank

Film materials prepared for television presentation vary considerably in both density and contrast. This variation must be compensated for during transmission to achieve the best picture at the home receiver. Manual control of projector light has been used for many years to accomplish part of this compensation. A new Automatic Light Control (ALC) system uses a control device which directly replaces the manual light control potentiometer. This provides a convenient way of adding ALC to a manual light control system with a minimum of modification to the manual system. Light dependent resistive elements are used as the control device.

Variation in the light and dark densities of motion picture and slide film materials, prepared for television presentation, must be compensated for during transmission by operation of appropriate controls associated with the television camers. If this is not done, the variations in density will produce undesirable degradation in the picture quality at the home receiver. Manual control of these factors has been used for many years, but now automatic means are becoming available to reduce the need for manual attention. One of the means of achieving the best pictures from a television camera is to adjust the light arriving from the scene so that the lightest areas in the scene remain at the same value of peak beam current. This can be done by placing a variable light attenuator in the light path and holding other factors constant. The General Electric Company presented a paper on this area of subject matter at the March 1966 NAB Convention. That paper was prepared by Mr. H. H. Martin, Consultant in Video Engineering to G.E. This presentation describes an alternative approach to the problem, one particularly adaptable to equipment which was originally built with manual light control.

A system of light control, in service for some time, uses a neutral density disc to control the light. This disc has a light reflecting material deposited on its face such that a light beam parallel to the axis of, and passing through, the wheel will experience a variation in attenuation as the wheel is turned. This system has been used for manual control of light by turning the wheel using a servo system from a remote location. A video operator uses that remote control to keep the camera output at the value needed for optimum picture transmission. A system has been developed which can automatically perform, essentially, the same function. This system has been in constant use at N.B.C., Burbank film studios for approximately one year and at N.B.C., New York for about 4 months.

EXISTING MANUAL LIGHT CONTROL

The basic television film chain consists of a film or slide projector, which pro-

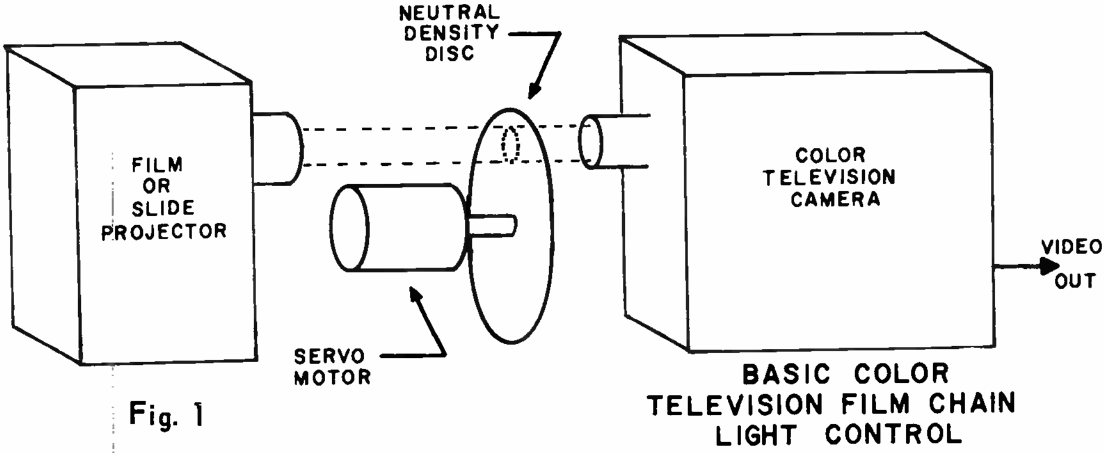


Fig. 1

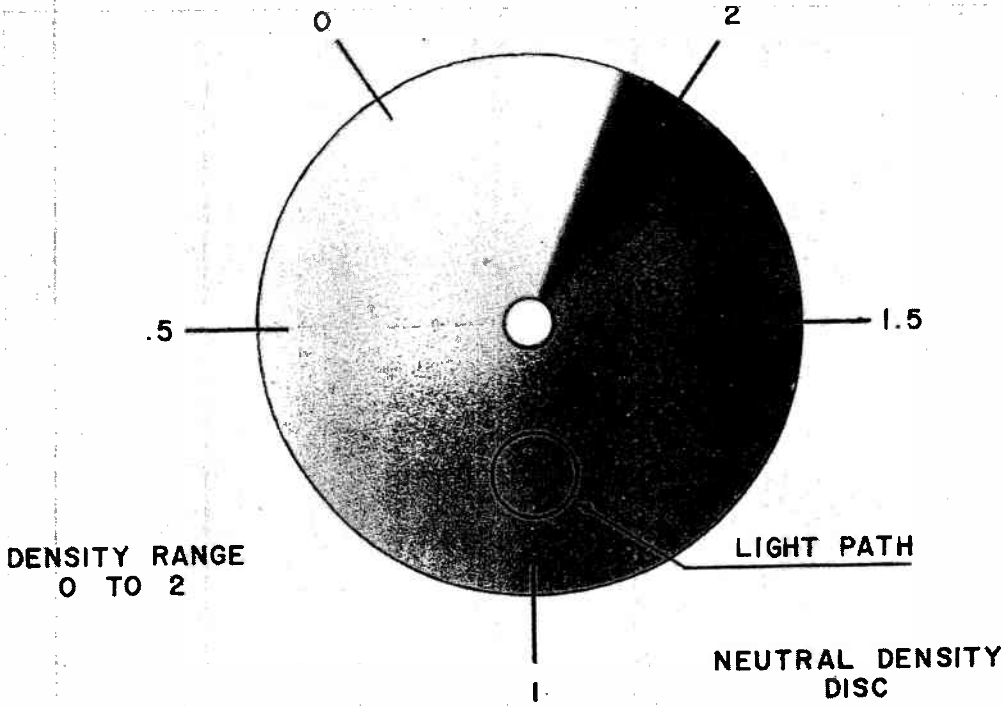


Fig. 2

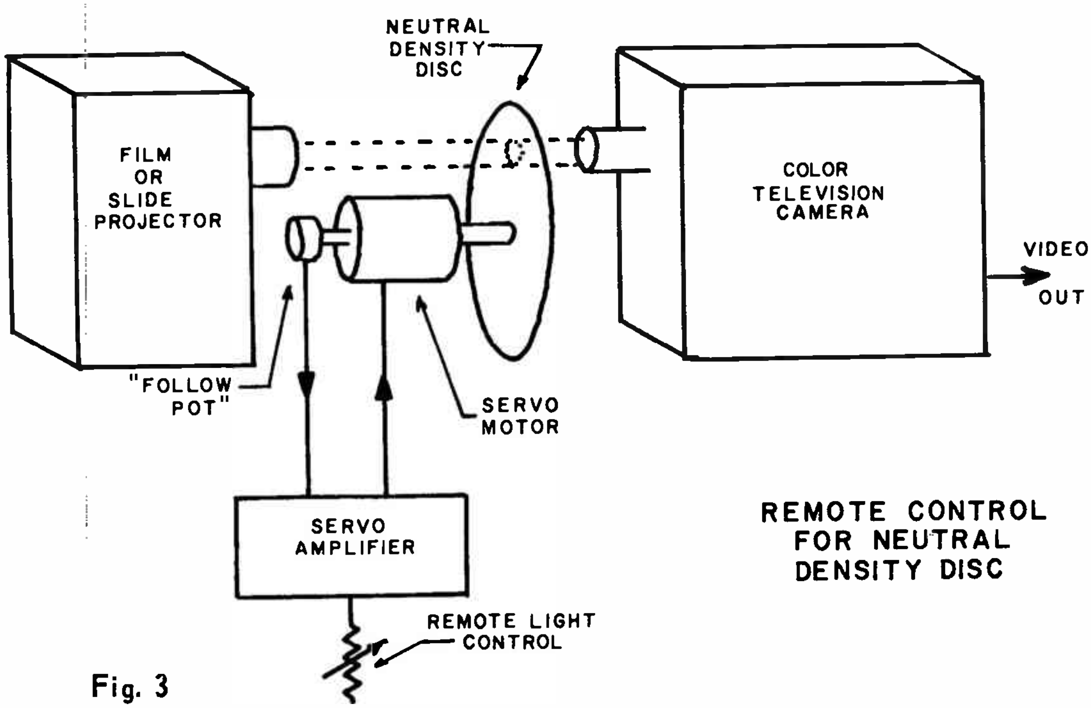


Fig. 3

jects a light image into a television camera (Fig. 1). In a color film chain, the intensity of light striking the film and transmitted through it to the camera is usually controlled by means of a device inserted in the light path between the light source and the camera. A well known system uses a remotely controlled servo motor which controls the rotation of a neutral density disc.

A neutral density disc (Fig. 2) consists of a disc of glass onto which neutral density material is deposited. Neutral density material attenuates all colors of light equally. This material is deposited on the glass surface in gradually increasing amounts, from one extreme of rotation to the other. The disc becomes very dense at one extreme of rotation (equivalent to a two point zero Wratten Filter) and is clear at the other extreme. When a neutral density disc is placed in the light path of a projector, the amount of light passing through the disc will increase or decrease depending upon the direction of rotation of the disc. The position of the disc is controlled in a manual system by a remote light control located at the video control console (Fig. 3). The video operator adjusts the control so that the oscilloscope indication of camera output is correct.

The servo motor which rotates the neutral density disc is driven by a remotely controlled servo amplifier (Fig. 4). The shaft of a "follow pot" is coupled to the shaft of the servo motor and is electrically connected to the servo amplifier to provide feedback information. The "follow pot" indicates to the servo amplifier the exact position of rotation of the neutral density disc. It is important to understand the relationship between the "follow pot" and the remote light control.

When the remote light control and the "follow pot" are at the same mechanical position of rotation, no signal is developed across the input transformer of the servo amplifier. When the remote light control swinger is moved, a signal is developed across the servo amplifier input transformer. This signal is amplified by the servo amplifier and fed to the servo motor. The servo motor shaft rotates just enough and in the right direction to cause the "follow pot" to cancel the input signal to the servo amplifier. The neutral density disc mounted on the servo motor shaft will, therefore, rotate in the same direction and by the same amount as the remote light con-

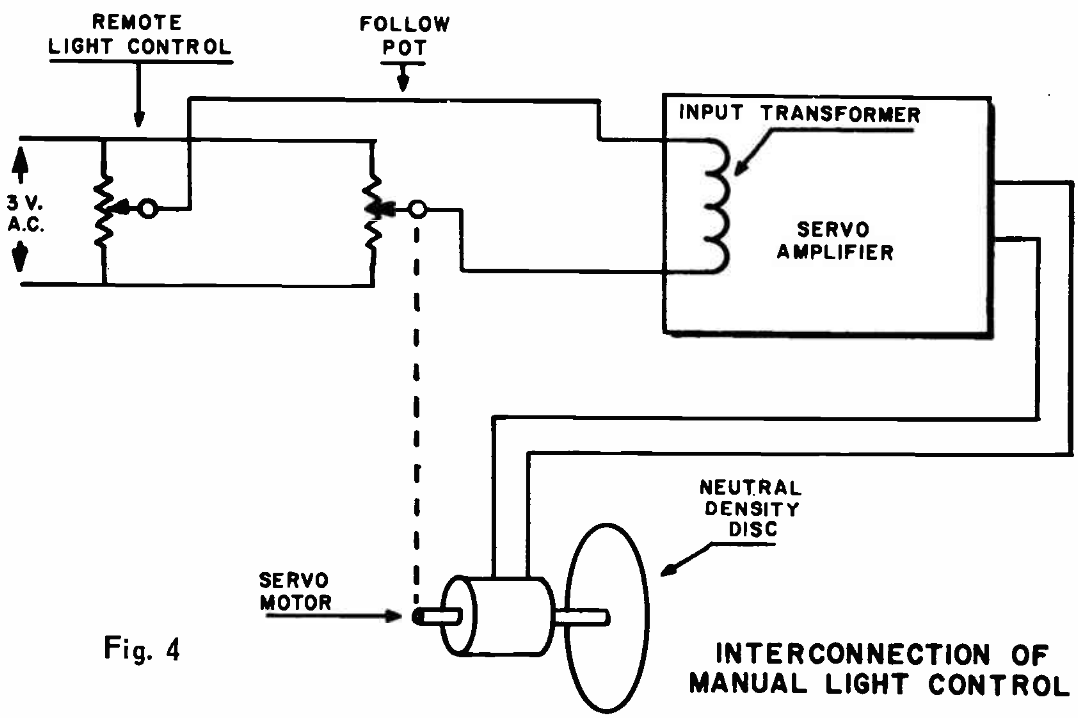


Fig. 4

INTERCONNECTION OF
MANUAL LIGHT CONTROL

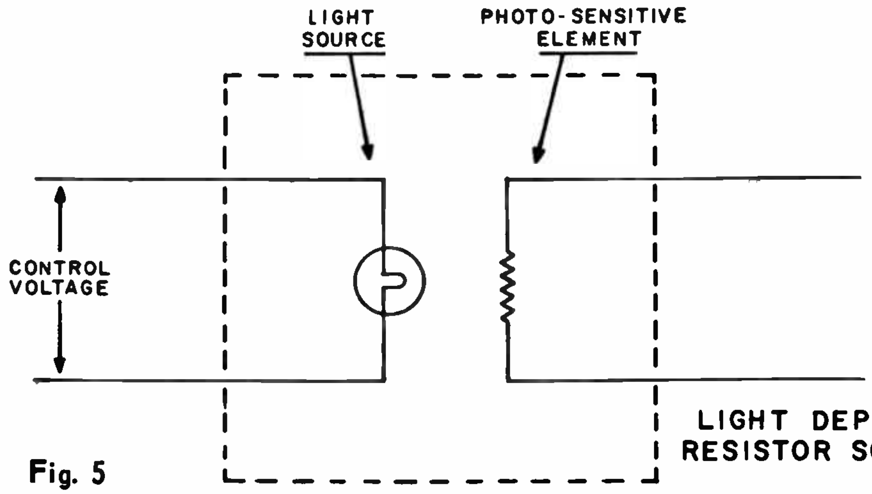


Fig. 5

LIGHT DEPENDENT RESISTOR SCHEMATIC

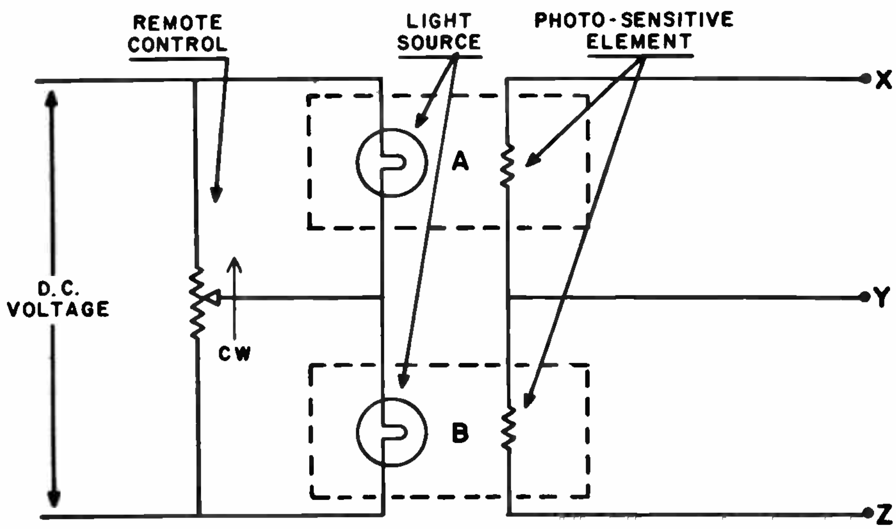


Fig. 6

TWO LDRs USED AS REMOTE CONTROLLED POTENTIOMETER

trol. This manual light control system has been automated by means of a device which takes the place of the remote light control.

PREPARATION FOR AUTOMATION

A device which lends itself to this application (Fig. 5) is a light dependent resistor (LDR). An LDR consists of a light source and a photo-sensitive element in a light-tight case. A variation in the voltage to the light source causes a change in resistance of the photo-sensitive element. An LDR can be used as a remotely controlled, variable resistor.

Two LDR's can be used to operate as a remote controlled potentiometer (Fig. 6). When the swinger of the remote control is fully clockwise, all the DC voltage is applied to light source "B" and no voltage is applied to "A." Under this condition the resistance of the photo-sensitive element "B" is low (about 100 ohms) and "A" is high (about 10 meg). The reverse is true when the swinger of the remote control is fully counterclockwise. When the remote control swinger is at midpoint, equal voltage is applied to each light source and the two photo-sensitive elements have approximately the same resistance (about 500 ohms each). Thus, terminals X, Y, and Z can be used to operate as a remotely controlled potentiometer, with terminal Y as the swinger and terminals X and Z as the ends.

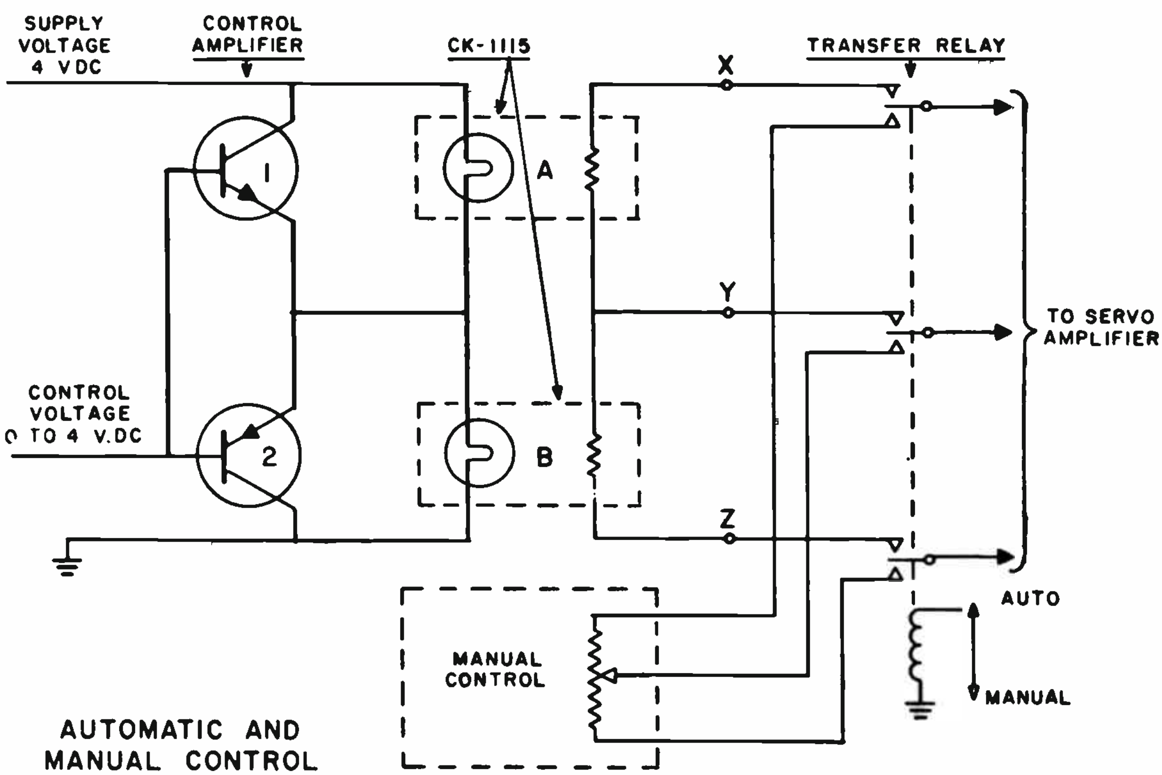
In order to operate this remote controlled potentiometer with a control voltage, a control amplifier is used (Fig. 7). The control amplifier consists of two transistors connected in a complementary configuration. When the control voltage is zero, transistor 1 is open and transistor 2 is conducting heavily. Under this condition, nearly all of the supply voltage is developed across light source "A" and very little voltage is developed across light source "B." The resistance between terminals X and Y is low and between Y and Z is high. The reverse is true when the control voltage is four volts. When the control voltage is two volts, the voltages across the two light sources are equal to each other and the "swinger" terminal Y is mid-point. As the control voltage is gradually varied from zero to four volts, the "swinger" terminal Y appears to move smoothly from X to Z.

A relay is used to transfer from manual to automatic control. The voltage controlled potentiometer directly replaces the manual control when in the automatic mode. Raytheon CK-1115 Raysistors are used in this circuit as the LDRs. This Raysistor was selected because of convenient packaging (To-5 Case), the resistance range available (100 ohms to 10 meg ohms) and low control voltage required (4 volts).

COMPLETING THE AUTOMATIC SYSTEM

In order to make the light control system action automatic, the camera output signal must be sampled and compared to some reference in order to generate the control signal to feed the control amplifier (Fig. 8). The output signal of a camera can be used to develop a control voltage which corresponds to the peak white information in the picture. The control voltage can be used to drive a pair of Raysistors which will function as a remote light control for the servo amplifier.

The position of the neutral density disc and thus the amount of light reaching the camera, as modified by the density of the film being viewed, will be a function of the



AUTOMATIC AND MANUAL CONTROL WITH TRANSFER RELAY

Fig. 7

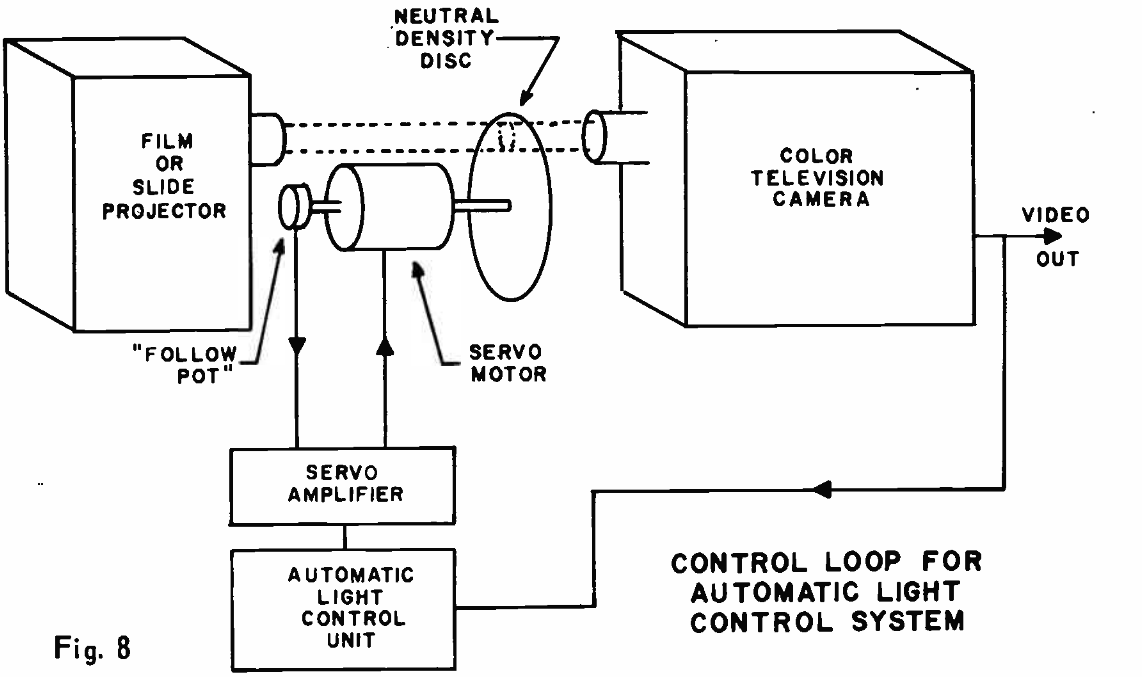


Fig. 8 CONTROL LOOP FOR AUTOMATIC LIGHT CONTROL SYSTEM

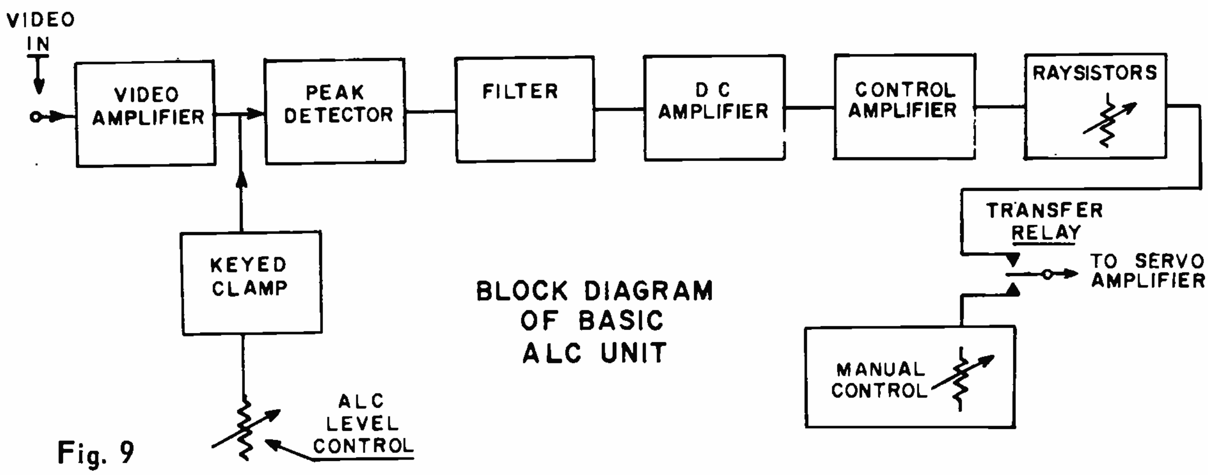


Fig. 9 BLOCK DIAGRAM OF BASIC ALC UNIT

video output signal of the camera. This completes a control loop from the camera out, through the ALC system and back to the neutral density disc, which allows the camera chain to be operated automatically. The operation is such that the lightest element in the scene is continuously compared to the reference and the neutral density disc is turned to maintain the value originally set up.

THE ALC UNIT

In the basic ALC unit (Fig. 9) a sample of the output video from the camera is amplified, clamped, peak detected and filtered in a conventional way to produce a control voltage. The control voltage is amplified and fed to a control amplifier. The control amplifier Raysistors, manual control, and transfer relay circuits are exactly the same as described with Fig. 7.

The peak detector samples the white peaks of the incoming video and the filter charges to the peak white level. By controlling the clamp reference, the ALC level control adjusts the voltage to which the filter charges on white peaks. When the picture white information increases in amplitude, the filter charges to a higher voltage. This causes the Raysistors to operate in a way which rotates the neutral density disc to a denser position. Thus the peak white signal out of the camera is held to the desired level.

This ALC system operates in such a way that when the film goes to black the neutral density disc rotates to its least dense position. When the film returns to normal level, the amount of light presented to the camera is too high. The picture will bloom momentarily until the neutral density disc rotates to its correct operating position. The importance of this problem can be realized when it is noted that it happens every time a film chain is rolled and a leader goes through ahead of the program picture material. The leader is black for the last 2 seconds, just about the right time interval for the disc to go wide open. This undesirable momentary blooming problem can be eliminated by adding a preset facility to the basic ALC unit (Fig. 10).

PRESET CONTROL

The preset control facility consists of a preset detector, preset control amplifier, and disconnect diode. The preset detector detects the presence of video from the video amplifier and holds the preset control amplifier at cut-off. When the film goes to black, there is no video present at the output of the video amplifier and the preset detector allows the preset control amplifier to conduct. When the preset control amplifier conducts, the disconnect diode disconnects the DC amplifier from the ALC control amplifier. The preset control amplifier via the ALC control amplifier, causes the neutral density disc to rotate to a mid-range position and remain there until the film level returns to normal. A preset voltage is also fed to the filter to keep it charged during the black period so that the transistion back to normal level will be smooth.

This ALC system as described will accommodate a monochrome film chain or the monochannel of a 4-channel color film chain. It will maintain the peak white picture information at proper level. Certain color picture material such as slides, may not contain any white information. With such a slide, the output amplitude of a color channel in a 4-channel color camera chain may be higher than that of the monochrome channel. Therefore, the output level of all four channels must be independently sampled in order to adjust the light for correct output level of the chain. Otherwise, one or more channels may be overloaded while the monochrome channel is correct.

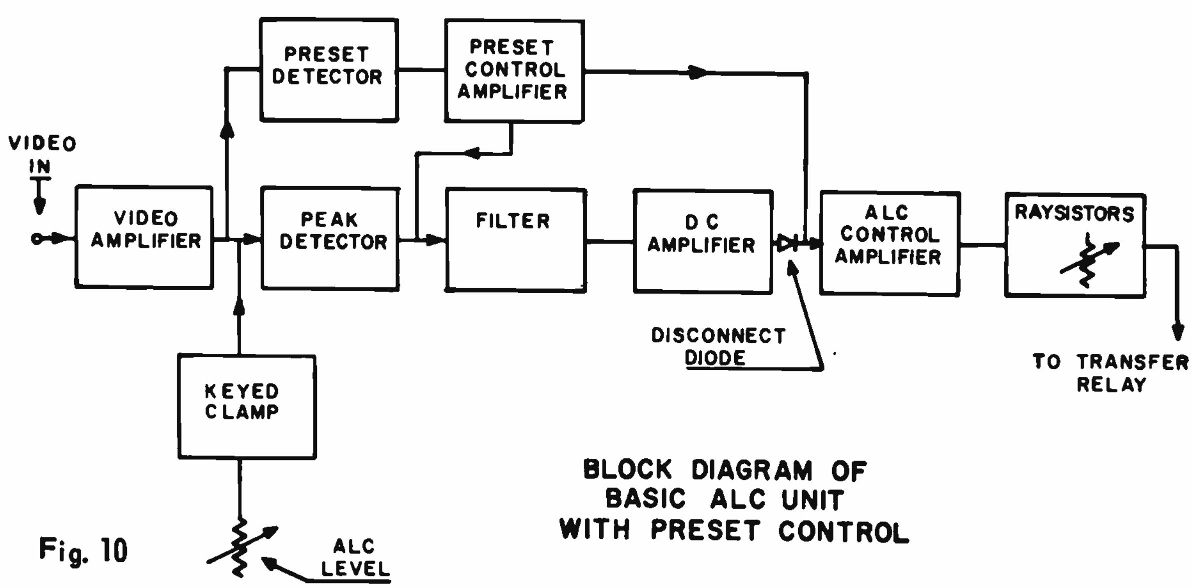


Fig. 10

BLOCK DIAGRAM OF BASIC ALC UNIT WITH PRESET CONTROL

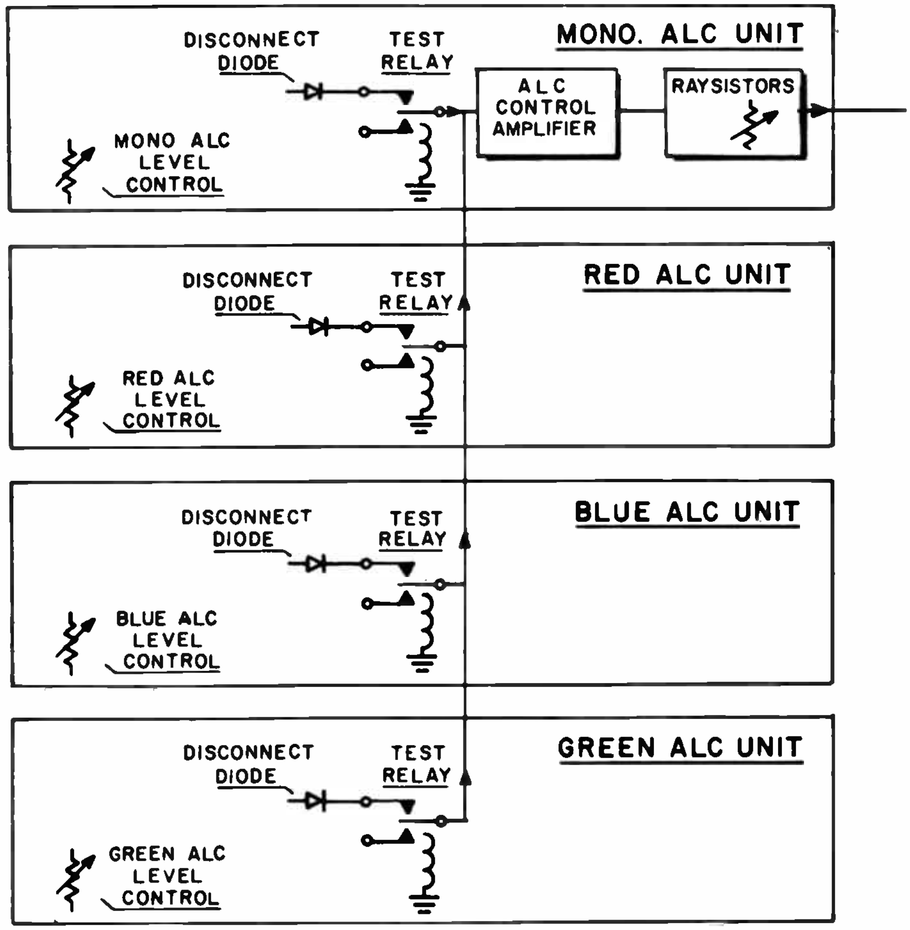


Fig. 11

PARTIAL
BLOCK DIAGRAM OF
ALC UNITS IN
FOUR CHANNEL
FILM CHAIN

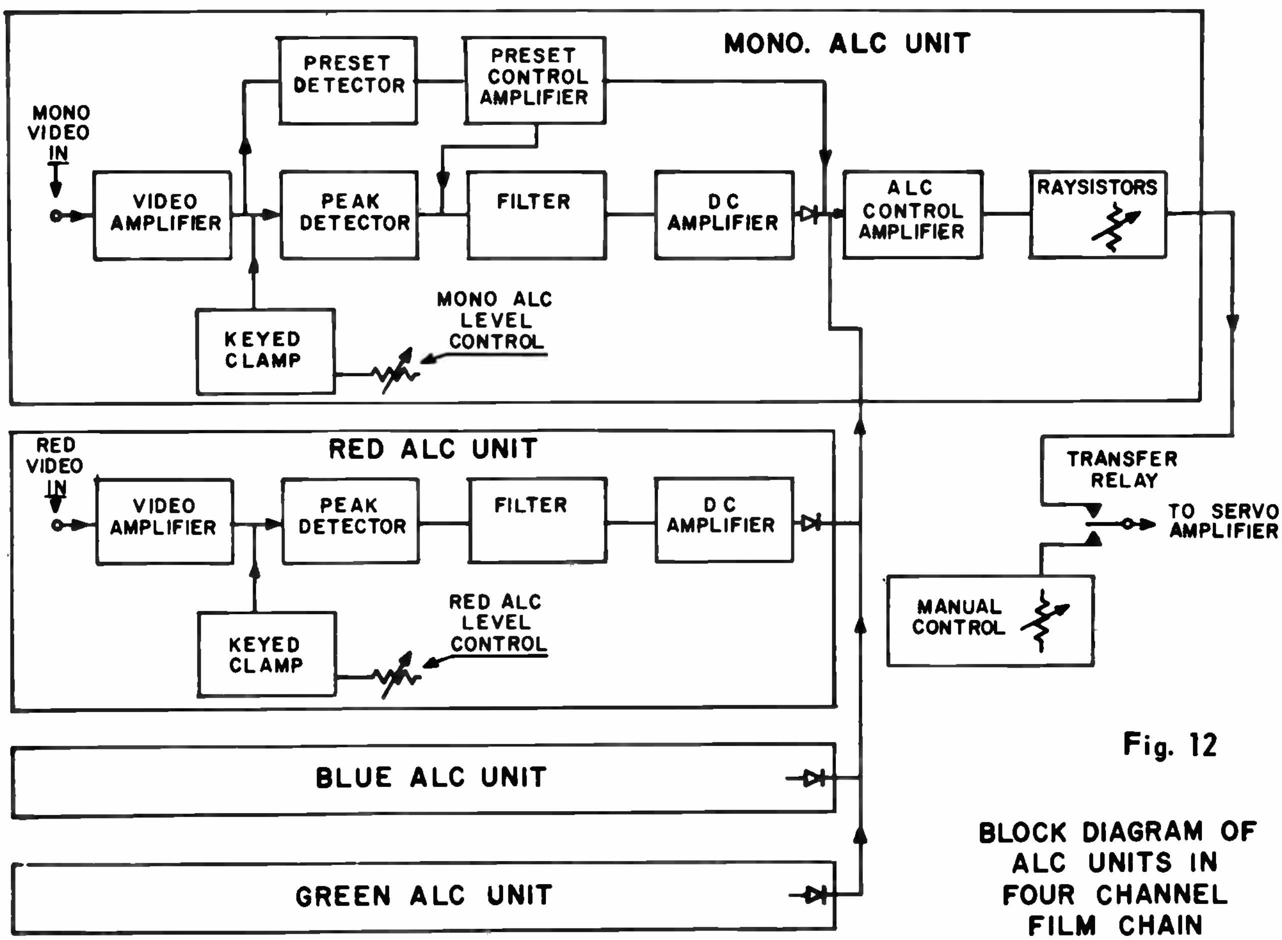


Fig. 12

BLOCK DIAGRAM OF
ALC UNITS IN
FOUR CHANNEL
FILM CHAIN

EXPANSION TO 4-CHANNEL CAMERA OPERATION

Three separate ALC detector units are used for the color channels of a 4-channel film chain (Fig. 11)—one each for red, blue, and green. These units are identical to the monochrome ALC unit except that they do not have the preset facility, ALC control amplifier or Raysistors. Each of the four units has a disconnect diode. The one with the highest control voltage will control the light level, and the other three will be disconnected by the disconnect diodes. This means that for some program material, the monochrome ALC unit will control the light level and for other material one of the color units will control the light level. The transfer of control from one unit to another is smooth and automatic once the ALC system is set up.

SETUP PROCEDURE

To facilitate the ALC set-up procedure, test relays are used (Fig. 12). Each ALC unit has a test relay which allows its control circuit to operate independently of the other three. When a test relay is energized, the control circuit of that unit is disconnected from the ALC control amplifier. The ALC level control of each unit must be adjusted with the control circuits of the other three units disconnected. For example, when adjusting the monochrome ALC level control, the test relay in the monochrome unit must be de-energized and the test relays of red, blue, and green units must be energized. Using a monochrome picture source such as a test pattern or target, each ALC level control in turn is adjusted for proper level at the chain out. After this adjustment is made, all four test relays are de-energized and the light level will be controlled automatically. The ALC system just described has been in constant use at the N.B.C. color film facilities in Burbank for approximately one year and at N.B.C. in New York for about four months. It is a practical system which operates well and is simple to set up.

Two, Three, Four-Tube Live Color Camera Experience at ABC

Max Berry

ABC, New York

Ever since March 1965, we have been faced with strong arguments, pro and con, for 3-tube versus 4-tube cameras. Prior to that time the two major suppliers of film cameras had independently concluded that the proper color camera was a 4-tube camera. This decision made our job of film camera selection easier as there obviously was no choice involved. However, by the spring of 1966, in the case of live color cameras, it was a different situation as there were several modern 4-tube and one 3-tube live color cameras from which to choose. Casting aside equipment design differences, we were faced with the serious question as to the theoretical and practical advantages, pro and con, of 3 and 4 tubes. There were many heated discussions in those days, but the results were usually somewhat nebulous. ABC, like other large users, ended up with quantities of both types which has turned out to be of good fortune to all of us for the experience it has provided.

Now (in March 1969), there are available at least four 3-tube cameras, five 4-tube cameras and an added starter in the form of a 2-tube camera, all made by well established broadcast equipment manufacturers, offering these cameras for general broadcast use. We at ABC, by now have had some experience with all three types of live color cameras and are pleased to share our findings with you.

It is extremely difficult to differentiate between experiences derived from the number of tubes per camera and specific equipment design. However, I have carefully analyzed the performance characteristics observed during the past several years and did everything possible to keep the electrical and mechanical camera design out of the picture. Furthermore, comparisons are based on completely standard Plumbicon tube cameras to help us on even terms. I will discuss the various camera configurations in terms of the following characteristics:

A. Registration (Picture Sharpness)
B. Sensitivity
C. Signal to Noise
D. Shading
E. Colorimetry
F. Chroma Key Performance
G. Setup Time
H. Noticeability of Tube Defects (spots, blemishes)
I. Motion Break-up
J. Operating Cost

A. Registration (Picture Sharpness): All types demand precise operator attention. You have all been exposed to advertising about how sensitive one camera type or the other is to misregistration, but we have had to touch up centering on 2-, 3-, and 4-tube cameras during a show because the operator saw colored edges. Experience with Plumbicons, their excellent deflection components and stabilized transistor circuitry has made this a relatively minor problem. By the way, ABC has not used "contours out of green" and has found performance of the 3-tube camera to be very satisfactory without it. We do use vertical as well as horizontal aperture equalization in all three camera configurations to improve picture sharpness.

B. Sensitivity: ABC has been using both 3- and 4-tube cameras in the studio and outdoors. In studios, the base lighting for both types of cameras is set at an average of approximately 300 foot candles with higher and lower levels used for various effects. Under these conditions, the performance is of the same order with both types. Operators can and do provide production personnel with good pictures down to 50 foot candles at the expense of depth of field and extra care to keep camera movement to a minimum because of lag at these low light levels.

In the field, problems are generally more predominant due to wide lighting changes from sunlight to deep shade. Both 3- and 4-tube cameras have the same type of problem; namely, clipping of highlights to enhance lowlights or compression of lowlights to prevent clipping of highlights.

Two-tube cameras have been used successfully both at the Political Conventions where lighting varied from about 100 foot candles to 300 foot candles and in outdoor work. The performance has been found to degrade if the camera is set up for use below 100 foot candles by both increased noise and colorimetry shift. However, quite good pictures are obtained at 50 foot candles where the 2-tube camera has been used as a portable camera with a lens labeled f2.6 but with T stop of only T3 plus.

C. Signal to Noise: The 2-tube camera has a lower S/N than the 3- or 4-tube version. Generally, 30% of the available light is provided for the luminance channel in the 2- and 4-tube cameras. Our experience has shown that this is sufficient to result in about equal S/N to the matrixed luminance signal in the 3-tube camera. However, in the 2-tube camera the luminance signal is further matrixed with relatively noisy R/B signals whose S/N has been further decreased by the field delay to generate G signals. The encoded luminance signal is then matrixed from the R, B, and G signals, resulting in a S/N about 6 db down from the 3- and 4-tube cameras. We believe the results can be improved 3 db in the 2-tube camera, however, by utilizing the luminance signal directly just as is done in certain 4-tube cameras.

D. Shading: Non-uniform response in Plumbicons has been generally found to fall within limits of about 10% of peak response. In the 3- and 4-tube cameras this causes more inconvenience in setting balance among the R, G, and B channels than variable gain or defects in gamma tracking, resulting in somewhat extended set-up time. However, in the 2-tube camera we have found the same amount of shading to be more significant because the G is derived from the Y and R/B signals and the R and B shading from the same tube must be the same! Amperex has selected tubes at a surcharge of $10 per tube which has made this a minor consideration.

E. Colorimetry: Three- and 4-tube camera colorimetry accuracy has been debated for years but it is very difficult to find a really significant difference from a practical viewpoint. In our experience, the 4-tube cameras generate a somewhat more saturated color picture than the 3-tube camera. Some people find this pleasing, others not. The 2-tube camera colorimetry would appear to be a bit more of a mystery because of its novelty, but its performance is predictable, and readily calculated and measured. When this camera type has been interswitched with both

3- and 4-tube cameras, the colorimetry difference was in the same order as observed between 3- and 4-tube cameras themselves or even the same breed of camera. In careful split screen tests with 4-tube cameras, the colorimetry difference has been observable. The major difference arises from the color contamination between Red and Blue caused by Plumbicon lag. The camera can be adjusted to minimize this effect and tubes are selected for the same purpose. This results, however, in potential increased operating cost as noted below.

F. Chroma Key Operation: Shading, Resolution and Colorimetry being equal, the degree of success of Chroma Key rests with the S/N of the coloring channels. There is no question that the 3-tube camera gives the highest S/N in the chroma channels among the 2-, 3-, and 4-tube cameras. We have, however, used 4-tube cameras regularly in chroma key situations and very acceptably, too. We have never tried to use the 2-tube camera for chroma key, but the absence of wideband R, G, and B signals makes the prognosis poor, although I am told by Ampex that they have made it work.

G. Setup Time: I wish I could tell you how long it really takes to set up each of the camera types. Setup time seems to be more a function of operator familiarity, meticulousness, and company policy or union agreement than the obvious difference in the number of controls associated with each type. I have seen operators breeze through a 4-tube camera and stumble on the 3-tube version and vice-versa. Similarly, there have been instances when absolutely no adjustment had to be made after a short warmup on all three types. This was especially true in the case of the 2-tube camera operating on batteries where normal operation specifically calls for setup of camera and then turn off to conserve battery power. The off time has been in the order of hours. The fact that the 2-tube camera has about half the controls of the 4, and two-thirds of the 3-tube version, makes for a faster registration. However, other additional controls effectively equalize all three camera types. In any case, it appears that the well designed camera of whatever number of tubes will lend itself to rapid setup.

H. Prominance of Tube Defects: The 2- and 3-tube cameras definitely show spots and blemishes more dramatically than the 4-tube camera. This is due to the fact that each tube is used to generate the luminance signal as compared to the 4-tube camera in which only the luminance tube is used for this purpose. This results in earlier rejection of tubes, usually soon after warranty has expired, compared to the unnoticeability of spots and blemishes in the tubes of the 4-tube camera. Spots and blemishes in these channels only show up as R, G, and B hue changes without any luminance, thereby making them virtually unnoticeable.

I. Motion Break-up: All three types of cameras exhibit smear upon rapid motion of the camera or object with respect to camera. Because the present 2-tube camera has a sequential R/B tube we might expect motion break-up. However, the simultaneous luminance channel very effectively masks the color break up and the effects are virtually unnoticeable for normal TV pickup. The 2-tube camera has, of course, been used most successfully to televise rapidly moving athletes. It has been used successfully in motion for dramatic effects at football games and the political conventions.

J. Operating Cost: Considering equal setup time and assuming reliable equipment design, tube life is the obvious major factor in operating cost. It has become clear that four tubes do NOT cost more to operate than three or two. Our experience indicates that we can expect longer life by more than a factor of 2 to 1 from tubes in a 4-tube camera over 3-tube cameras. We can't be more definitive about this because ABC has varying criteria for tube replacement depending on camera utilization. However, one of the major reasons for the tube retirement is loss of output, with attendant lower S/N.

It is the most notable characteristic of the 4-tube cameras that poor S/N in the chroma channels is virtually unnoticeable in the average color picture (low saturated colors), whereas loss of S/N in the chroma channels shows up markedly as decreased luminance S/N in the 3-tube camera pictures. Operators, therefore, complain of noisy pictures more often in the case of 3-tube cameras resulting in more frequent replacement of tubes in these cameras. In fact, it is often found that tubes unusable in the 3-tube cameras can be operated for manyhundreds of extra hours in the 4-tube cameras. Another reason for the longer tube life in 4-tube cameras is the decrease in the tube rejection because of spots. Four-tube cameras generally mask spots that develop in the chroma tubes. As noted previously, 3-tube cameras generate the luminance signal from their chroma tubes which, when they have spots, makes them much more noticeable and gives cause for rejection.

The previous reasoning would lead one to believe that 2-tube camera tube life would be in the same order as in 3-tube cameras, all other things being equal. However, lag is more significant and critical in a 2-tube camera than in the 3- or 4-tube camera. In the 3- or 4-tube camera lag generally shows up as colored or black and white smear of moving objects. The effect disappears when motion stops. The 2-tube camera has the same effects plus a contamination of the red and blue signals derived from the sequential tube. Increasing lag is a definite sign of age in all Plumbicon tubes and we can, therefore, expect more frequent replacement of tubes in 2-tube cameras, even though we have not yet had the cameras in operation long enough to make a practical determination of this.

The foregoing observations, although qualitative in nature, have been presented from an engineering viewpoint in as objective a manner as possible in areas that are not easily measureable. On the other hand, what do operational members of our organization feel? Our own experience can be summed up in words similar to those in a recent Canadian Broadcasting Corporation Publication comment that those operators familiar with Norelco Cameras like three tubes; those familiar with G.E. Cameras, think four tubes are great. Although we see definite differences in the results of Plumbicon Cameras of the various configurations, our experience has shown that detailed mechanical and electrical design, costs and manufacturer's service reputation are more significant factors in the determination of the camera most suitable for us than the theoretical arguments of three and four tubes pro and con. We believe that 2-tube cameras have significant applications which must be considered on a case-by-case basis in comparison with other tube configurations.

A Completely New VHF Television Transmitter of Advanced Design

Howard E. Small
RCA, Meadow Lands, Pa.

During the past two decades in which most of the growth has taken place in the television industry, design improvements in VHF transmitters have been slow and gradual. Better materials and components have made it possible to build smaller and more reliable transmitters, but the performance specifications have not been tightened significantly.

Although a large percentage of the VHF television transmitters now in use are over 15 years old, the quality of transmission from these units, in most cases, compares favorably with the newer transmitters. Hence, there has not been much incentive for television stations to buy new transmitters. The addition of a solid-state exciter and a video processing amplifier is not what the broadcaster wants. He is looking for a completely new design which will give him a noticeable improve-

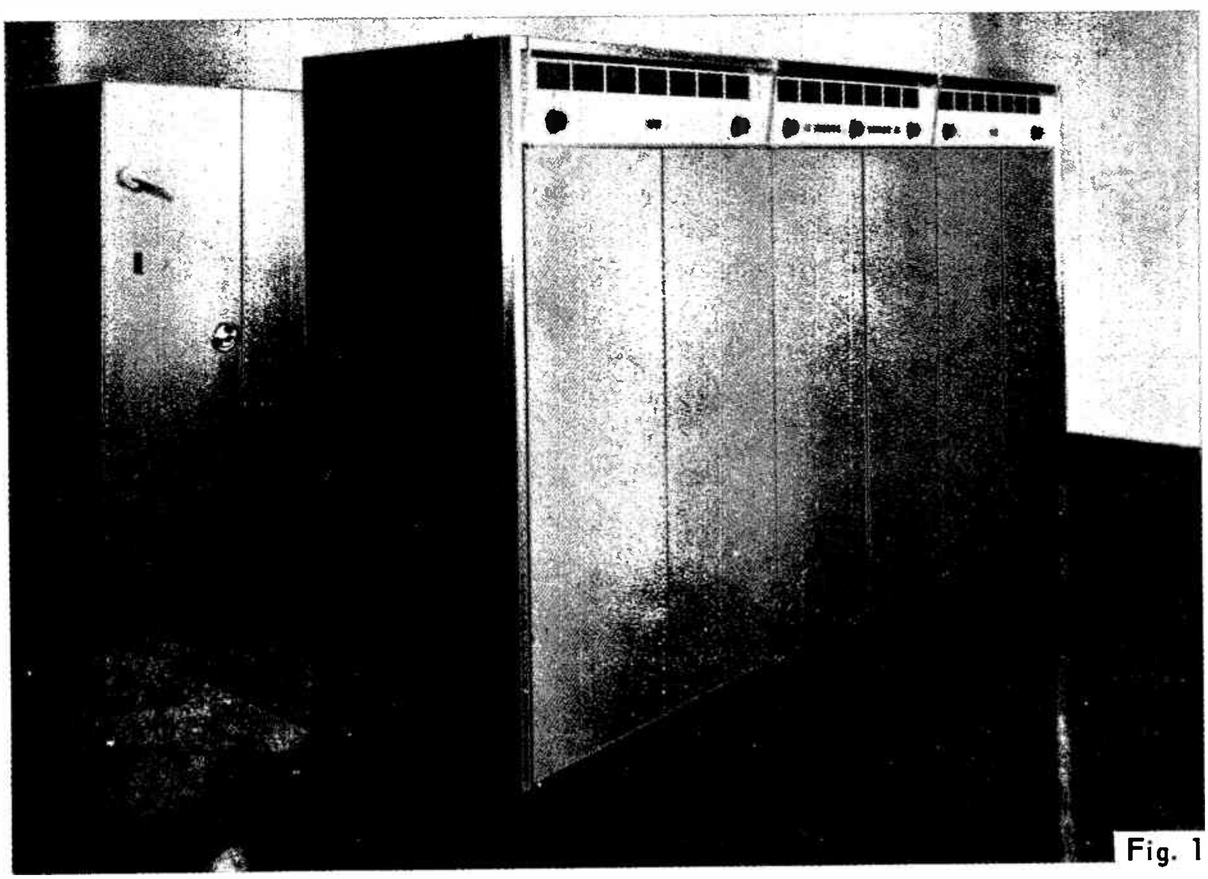


Fig. 1

SPECIFICATION	EIA /FCC	TT-30FL
Amplitude vs Frequency Response	± 1.5 db	± 0.75 db
Variation in Frequency Response vs. Brightness	No spec.*	± 0.75 db
Carrier Frequency Stability	± 1 kHz	± 0.5 kHz
AM Noise - Visual	-40 db	-50 db
Amplitude Variation over One Frame	5%	2.5%
Regulation of Output	10%	3%
Burst vs. Subcarrier Phase	-	± 3°
Differential Phase	± 7°	± 3°
Differential Gain	1.5 db	0.7 db
Harmonic & Spurious Radiation	-60 db	-80 db
Audio Frequency Harmonic Distortion	1.0%	0.5%

* Previous RCA Specification ±1.5 db

Fig. 2

ment in picture quality, as well as many other desirable features which would reduce operating costs and improve reliability.

While RCA was in the early stages of planning the design of such a transmitter, they were approached by one of the leading multiple station owners, Westinghouse Broadcasting Company, and asked if RCA would be interested in designing a low-band VHF transmitter to meet specifications compiled by Westinghouse. Since the Westinghouse specifications were in close agreement with what others were seeking, RCA agreed to design and build the transmitters for Westinghouse, and then make it a part of their standard broadcast equipment line.

As a result of the combined engineering efforts of Westinghouse Broadcasting Company and RCA, a completely new VHF television transmitter of advanced design is now available to all low-band VHF television stations. This transmitter is desig-

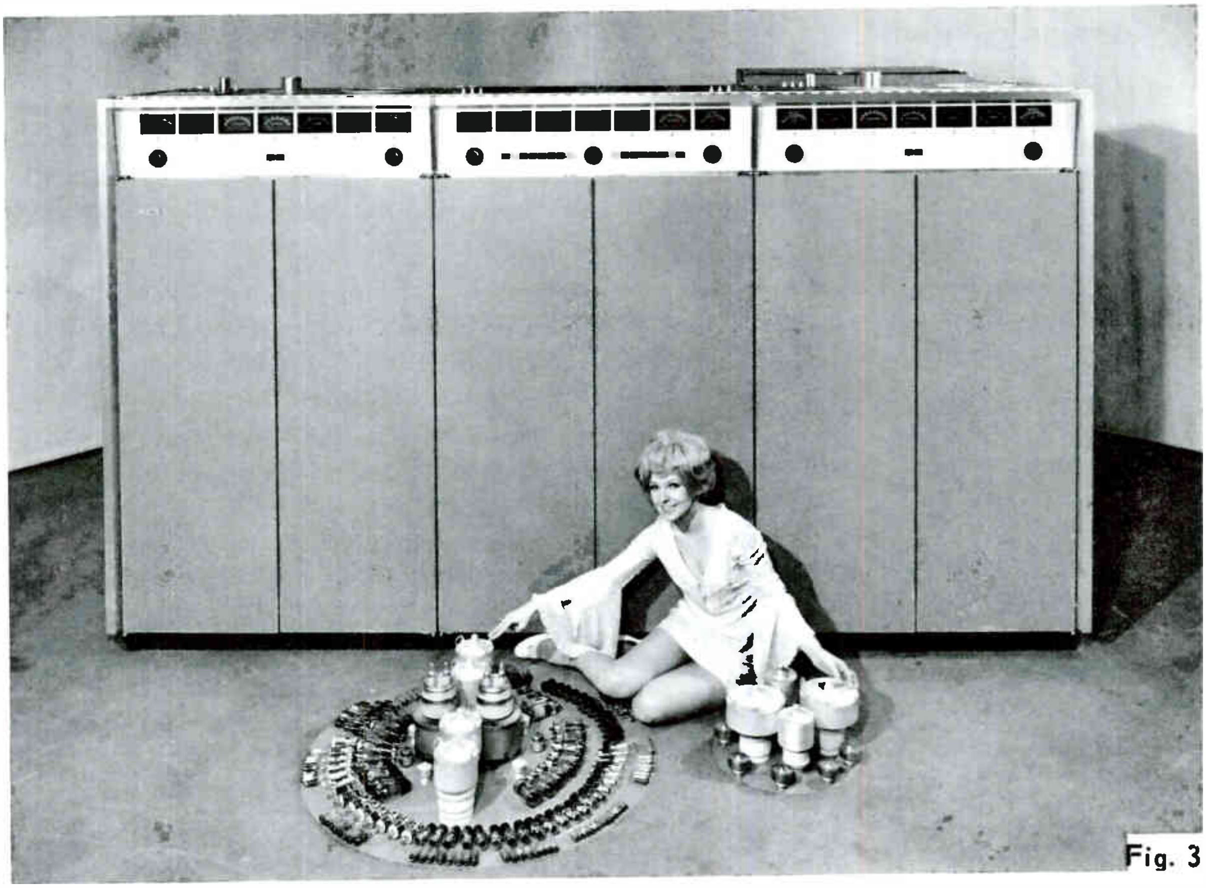


Fig. 3

nated as the RCA Type TT-30FL, and is rated at 30 KW peak visual and 7.5 KW aural power output. A front view of the transmitter is shown in Fig. 1.

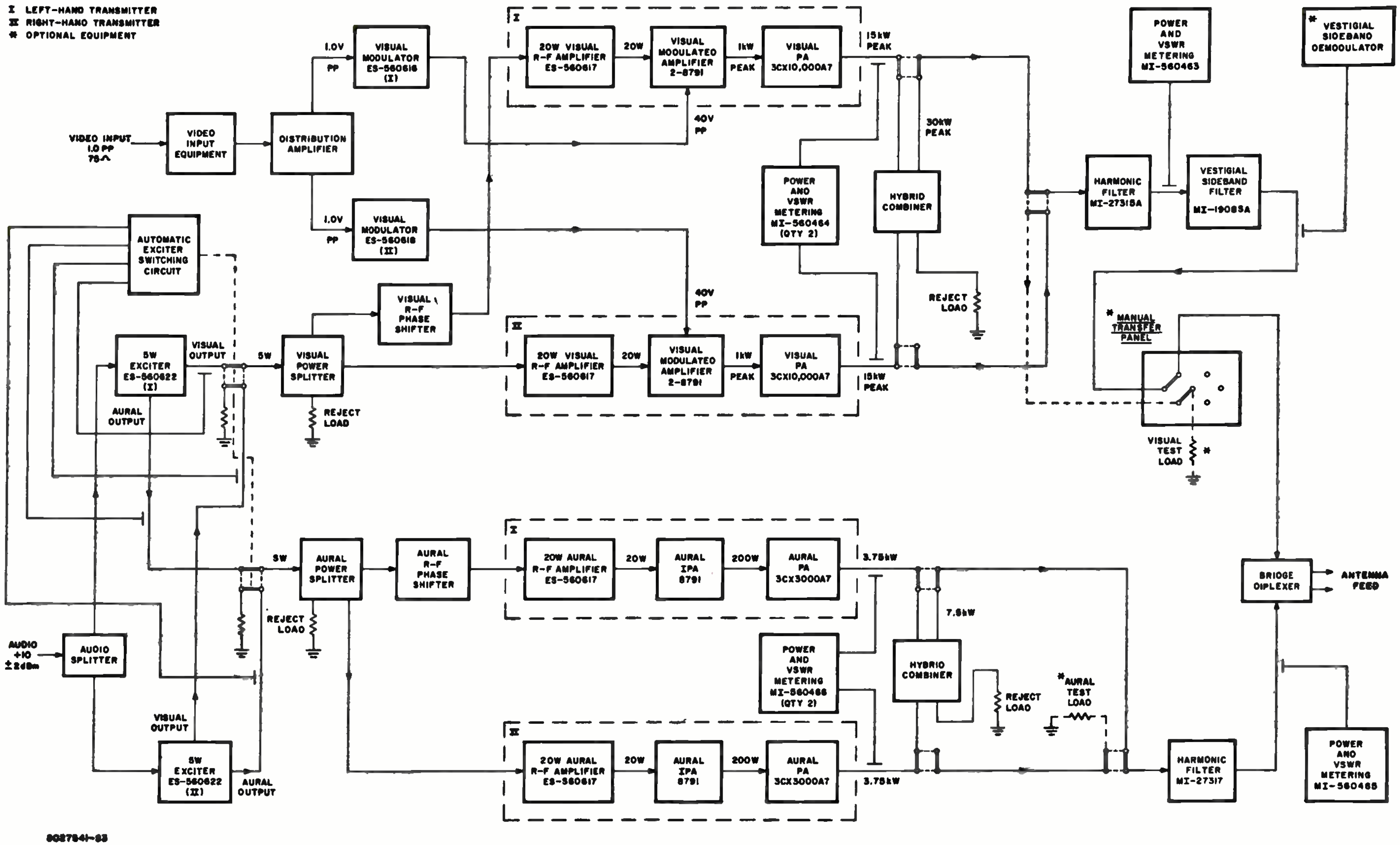
The design philosophy behind this new generation of transmitters was to provide the broadcast industry with transmitters that were more adaptable to remote control, as well as having superior performance. It was felt that one of the most important design goals for remote control operation was a high degree of stability, making frequency adjustments unnecessary. Hence, the TT-30FL performance specifications are guaranteed to hold over a 30-day period without adjustment.

Fig. 2 shows a comparison of the significant performance specifications with the EIA specifications. The design goal was to meet these specs by a two-to-one safety margin, to ensure compliance with the 30-day stability spec, and this goal has been attained.

Another important requirement for remote control is reliability. To achieve a higher degree of reliability in the TT-30FL, all components have ratings considerably higher than the normal operating parameters. The maximum use of solid-state devices, and parallel operation of two 15 KW transmitters with automatic switching of exciters also contribute greatly toward attainment of this design goal.

It was decided that the power amplifier tubes should be high gain to keep the number of stages to a minimum, and they should be long-life tubes for high reliability and low operating costs. These objectives were realized by the selection of the 3CX3000A7 and the 3CX10,000A7 high-gain, zero-bias triodes for the aural and visual final amplifier stages, respectively. Two additional advantages were also gained from these tubes: (1) the use of triodes eliminated the need for screen power supplies and bypass capacitors, and (2) no bias supplies are required, since the tubes operate Class B with zero bias. The grid of the visual PA is at DC ground, thus another bypass capacitor is eliminated.

A new RCA Cermalox Tube, Type 8791, was selected for the visual modulated



I LEFT-HAND TRANSMITTER
II RIGHT-HAND TRANSMITTER
* OPTIONAL EQUIPMENT
VIDEO INPUT 1.0 PP 75Ω
VIDEO INPUT EQUIPMENT
DISTRIBUTION AMPLIFIER
1.0V PP
VISUAL MODULATOR ES-560616 (I)
VISUAL MODULATOR ES-560616 (II)
20W VISUAL R-F AMPLIFIER ES-560617
20W
VISUAL MODULATED AMPLIFIER 2-8791
1kW PEAK
VISUAL PA 3CX10,000A7
15kW PEAK
40V PP
30kW PEAK
POWER AND VSWR METERING MI-560464 (QTY 2)
HYBRID COMBINER
REJECT LOAD
POWER AND VSWR METERING MI-560463
* VESTIGIAL SIDEBAND DEMODULATOR
HARMONIC FILTER MI-27318A
VESTIGIAL SIDEBAND FILTER MI-19083A
* MANUAL TRANSFER PANEL
VISUAL TEST LOAD *
AUTOMATIC EXCITER SWITCHING CIRCUIT
5W EXCITER ES-560622 (I)
VISUAL OUTPUT
AURAL OUTPUT
5W
VISUAL POWER SPLITTER
VISUAL R-F PHASE SHIFTER
AURAL POWER SPLITTER
AURAL R-F PHASE SHIFTER
20W AURAL R-F AMPLIFIER ES-560617
AURAL IPA 8791
200W
AURAL PA 3CX3000A7
3.75kW
7.5kW
POWER AND VSWR METERING MI-560466 (QTY 2)
*AURAL TEST LOAD
HARMONIC FILTER MI-27317
POWER AND VSWR METERING MI-560465
BRIDGE DIPLEXER
ANTENNA FEED
AUDIO +10 ±2dBm
AUDIO SPLITTER
5W EXCITER ES-560622 (II)
8027841-83

Fig. 4

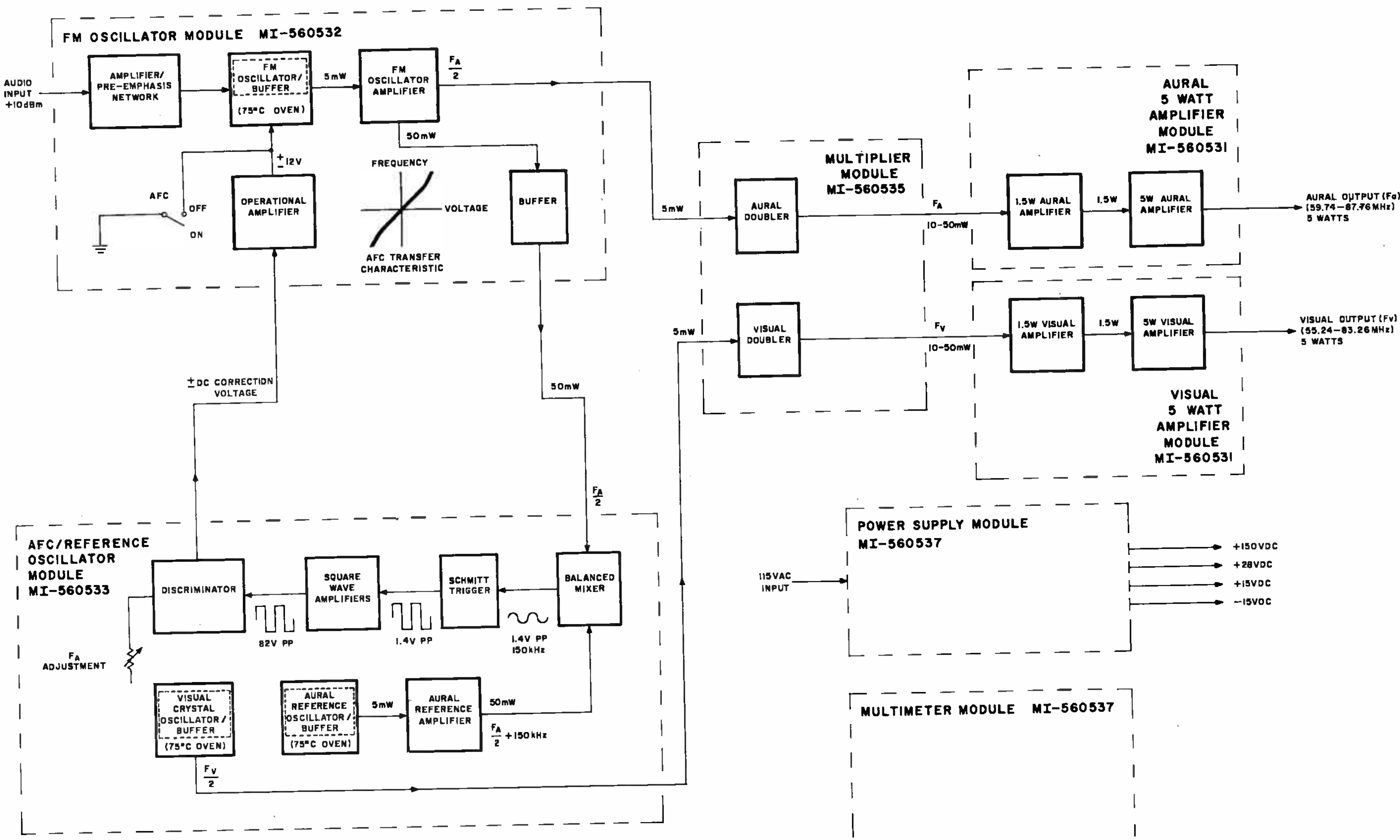

FM OSCILLATOR MODULE MI-560532
AUDIO INPUT +10dBm
AMPLIFIER/ PRE-EMPHASIS NETWORK
FM OSCILLATOR/ BUFFER (75°C OVEN)
5mW
FM OSCILLATOR AMPLIFIER
FA/2
50mW
±12V
AFC
OFF
ON
OPERATIONAL AMPLIFIER
FREQUENCY
VOLTAGE
AFC TRANSFER CHARACTERISTIC
BUFFER
±DC CORRECTION VOLTAGE
50mW
FA/2
AFC/REFERENCE OSCILLATOR MODULE MI-560533
DISCRIMINATOR
SQUARE WAVE AMPLIFIERS
SCHMITT TRIGGER
BALANCED MIXER
82V PP
1.4V PP
1.4V PP 150kHz
FA ADJUSTMENT
VISUAL CRYSTAL OSCILLATOR/ BUFFER (75°C OVEN)
AURAL REFERENCE OSCILLATOR/ BUFFER (75°C OVEN)
5mW
AURAL REFERENCE AMPLIFIER
50mW
FA/2 +150kHz
FV/2
MULTIPLIER MODULE MI-560535
5mW
AURAL DOUBLER
FA
10-50mW
5mW
VISUAL DOUBLER
FV
10-50mW
AURAL 5 WATT AMPLIFIER MODULE MI-560531
1.5W AURAL AMPLIFIER
1.5W
5W AURAL AMPLIFIER
AURAL OUTPUT (FA) (59.74-87.76MHz) 5 WATTS
1.5W VISUAL AMPLIFIER
1.5W
5W VISUAL AMPLIFIER
VISUAL OUTPUT (FV) (55.24-83.26MHz) 5 WATTS
VISUAL 5 WATT AMPLIFIER MODULE MI-560531
POWER SUPPLY MODULE MI-560537
115VAC INPUT
+150VDC
+28VDC
+15VDC
-15VDC
MULTIMETER MODULE MI-560537

Fig. 5

Fig. 6

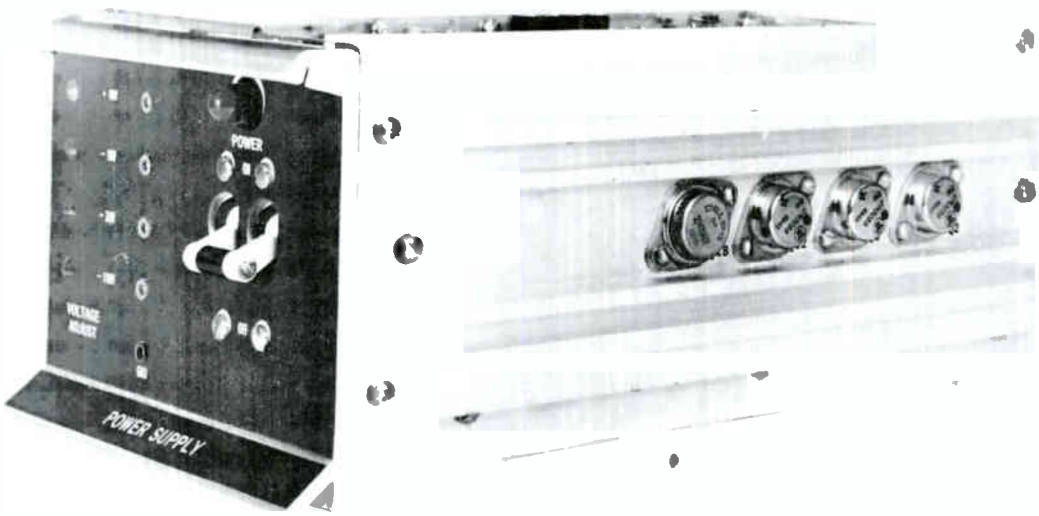


Fig. 7

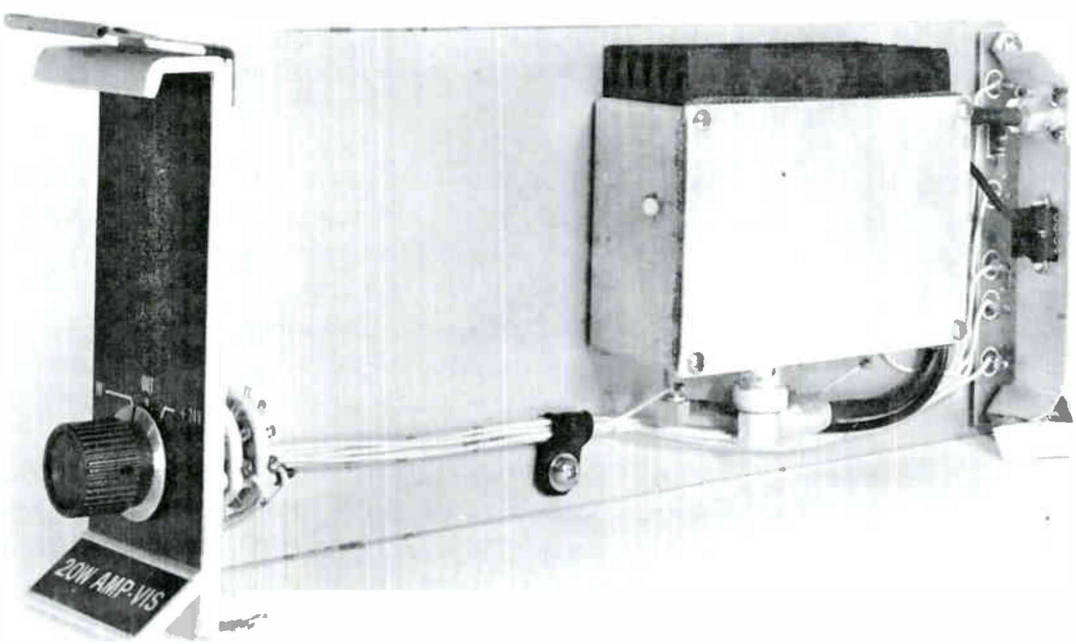


Fig. 8

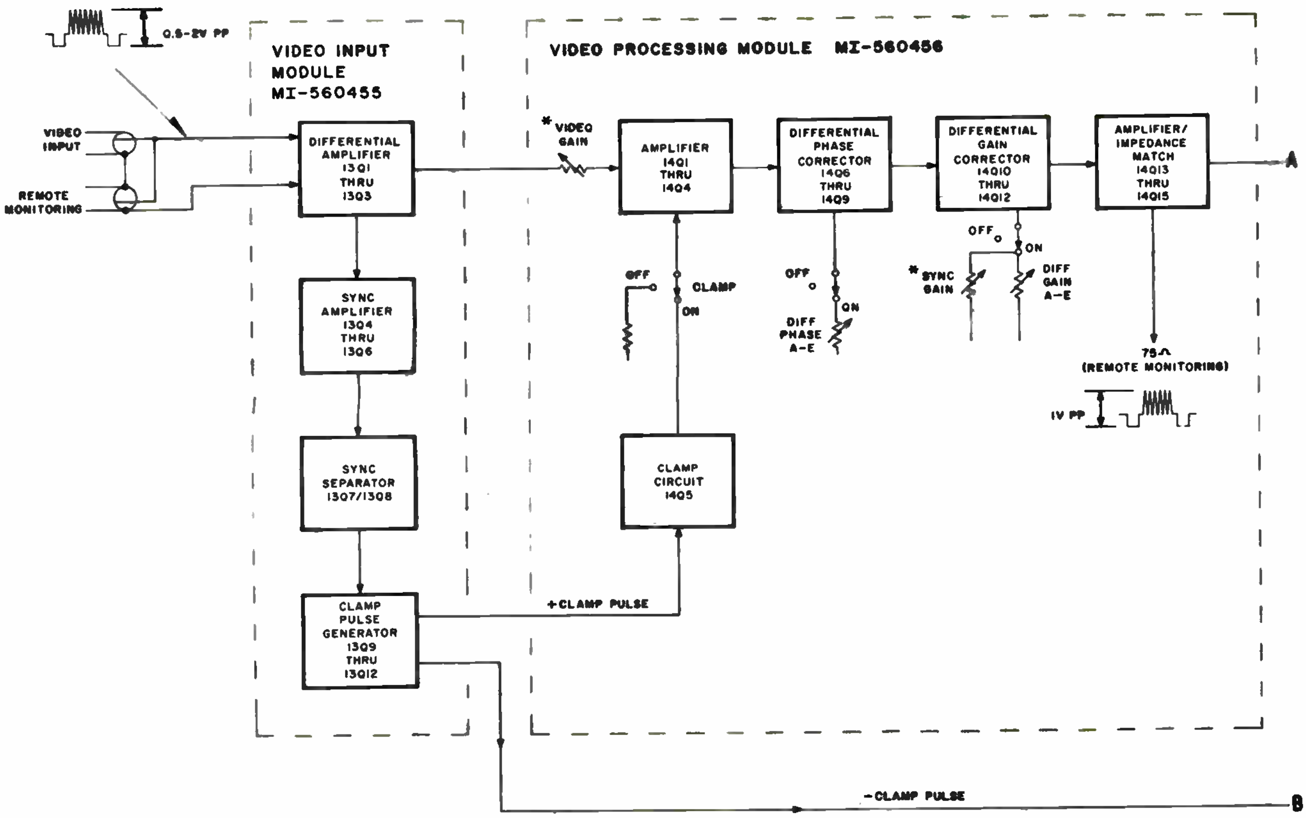


Fig. 9

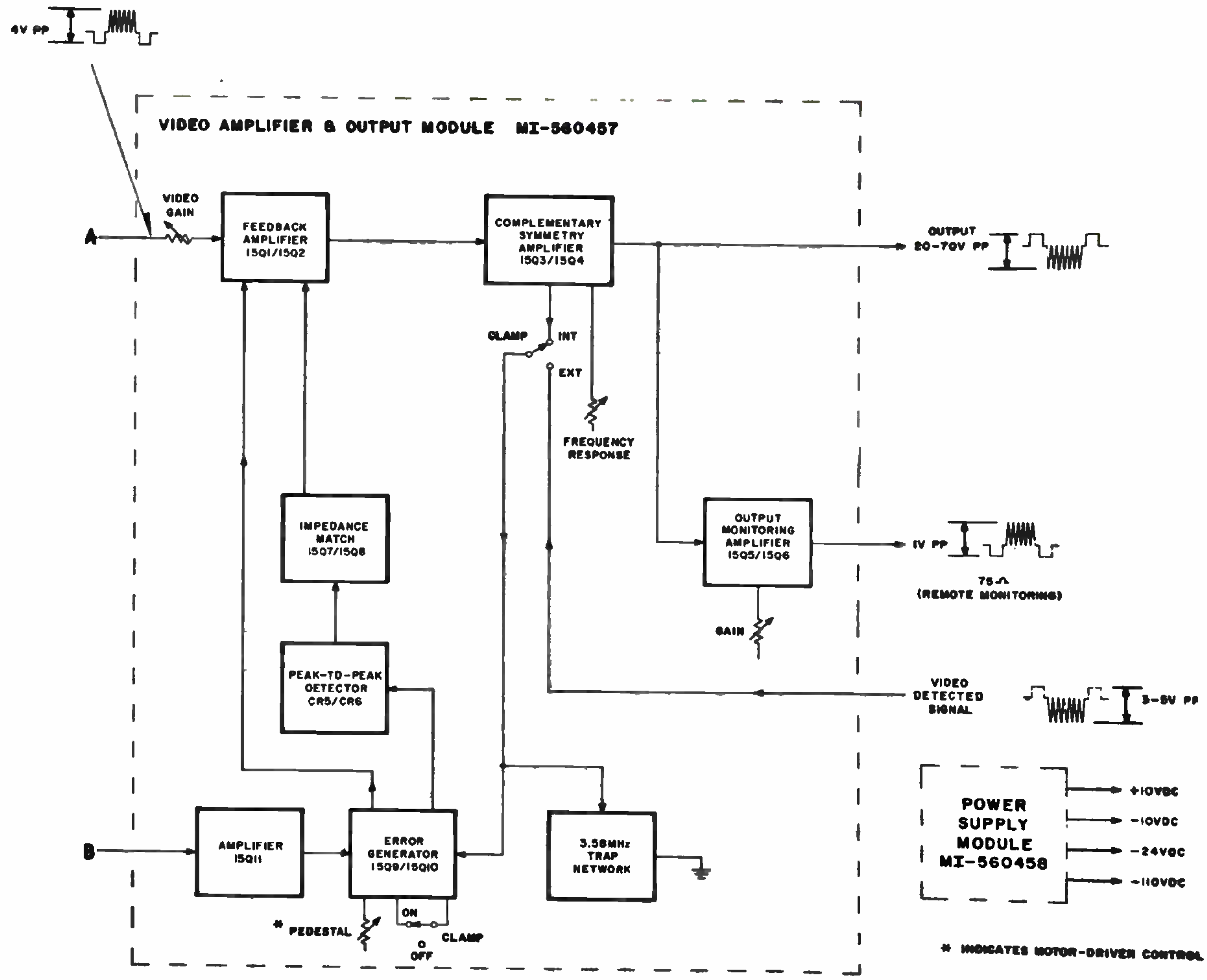
amplifier because of its improved transfer characteristic, high gain, low input capacitance, and low modulating voltage requirement. A push-pull circuit configuration was used because it can be operated more efficiently, can be cross-neutralized for optimum performance, and has a convenient point of zero RF potential for applying the video modulating voltage to the grid circuit. The video voltage required to modulate the stage is very easily obtained from a completely transistorized modulator. The same tube type was used for the aural driver (IPA) to keep tube types down to three for the entire transmitter.

Each 15 KW transmitter employs only five tubes in two aural and two visual RF amplifier stages. A pictorial comparison with the 192 tubes used in our most recent parallel 12.5 KW transmitters is shown in Fig. 3. The ten tubes to the right of the center of attraction are the entire tube complement of this high quality 30 KW television transmitter.

Fig. 4 is a functional block diagram of the TT-30FL transmitter. The RF power levels shown for the various stages are the rated outputs which are easily obtainable. The typical operating levels are at least 20% below these values for full rated power output. The audio and video levels shown are typical operating values.

Either of the 5-watt exciters can be selected as the frequency-controlled source for both transmitters. In the event that either the aural or the visual output should drop below a preset level, the exciters are automatically switched with no noticeable interruption of the output signal. The standby exciter is always terminated by 50-ohm loads, and is in operation at all times to permit this fast switchover.

Of course, parallel operation of TV transmitters is not exactly new, and there have



been several articles published extolling the advantages of such a system. The most valuable feature is probably the fact that the transmitted signal is never interrupted by the failure of one transmitter. The signal strength merely drops 6 db, and at a convenient time the output combiner can be bypassed, with only a momentary interruption of carrier. The signal strength is then only 3 db below normal, and the defective unit can be serviced while programming continues. The motorized output switching system is part of the TT-30FL transmitter, and it automatically terminates the disabled transmitter with test loads.

A block diagram of the solid-state exciter is shown in Fig. 5. The performance of the exciter plays a critical part in determining the overall performance of the transmitter. This is especially true of the aural transmitter. For this reason, great care was taken in the exciter design to make certain there were no marginal areas of performance.

The source of the aural carrier is the frequency modulated oscillator operating at one-half of carrier frequency. The entire circuit is contained in a DC proportional temperature-controlled oven which maintains the temperature with extremely great precision. A varactor diode is employed to frequency modulate the oscillator. The center frequency is accurately maintained by a feedback AFC loop which employs a crystal-controlled reference oscillator in another precisely controlled oven, and operating at 150 kHz above the FM oscillator. A normal difference frequency of 150 kHz is obtained from the balanced mixer, and is fed to a counter type discriminator circuit. If the difference frequency changes, a DC voltage from the dis-

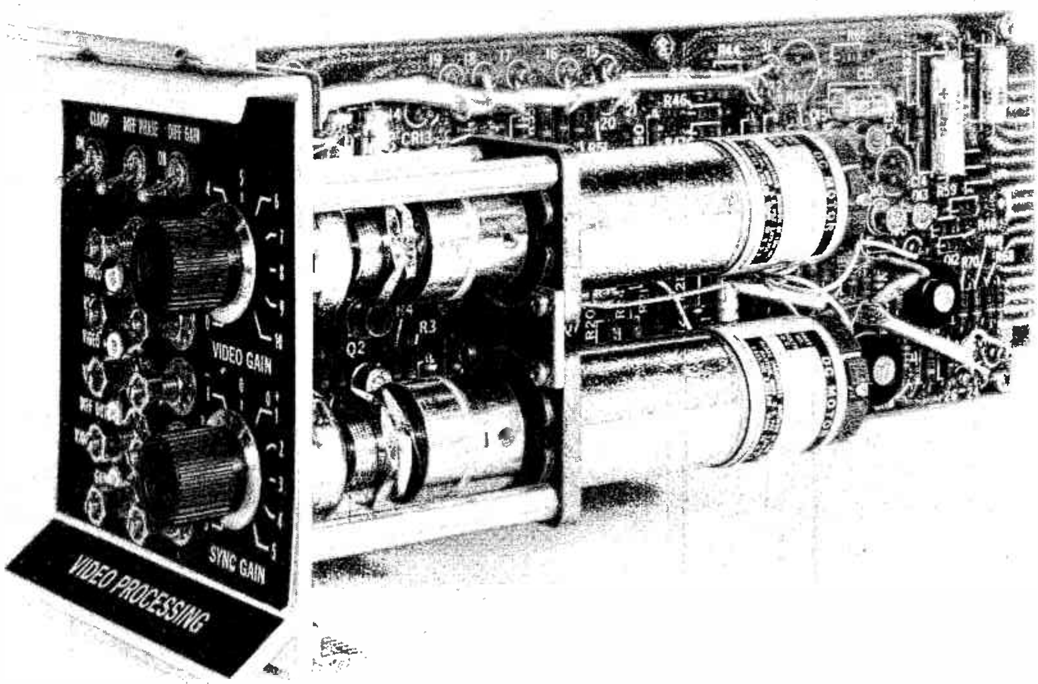

CLAMP
DIFF PHASE
DIFF GAIN
VIDEO GAIN
SYNC GAIN
VIDEO PROCESSING

Fig. 10

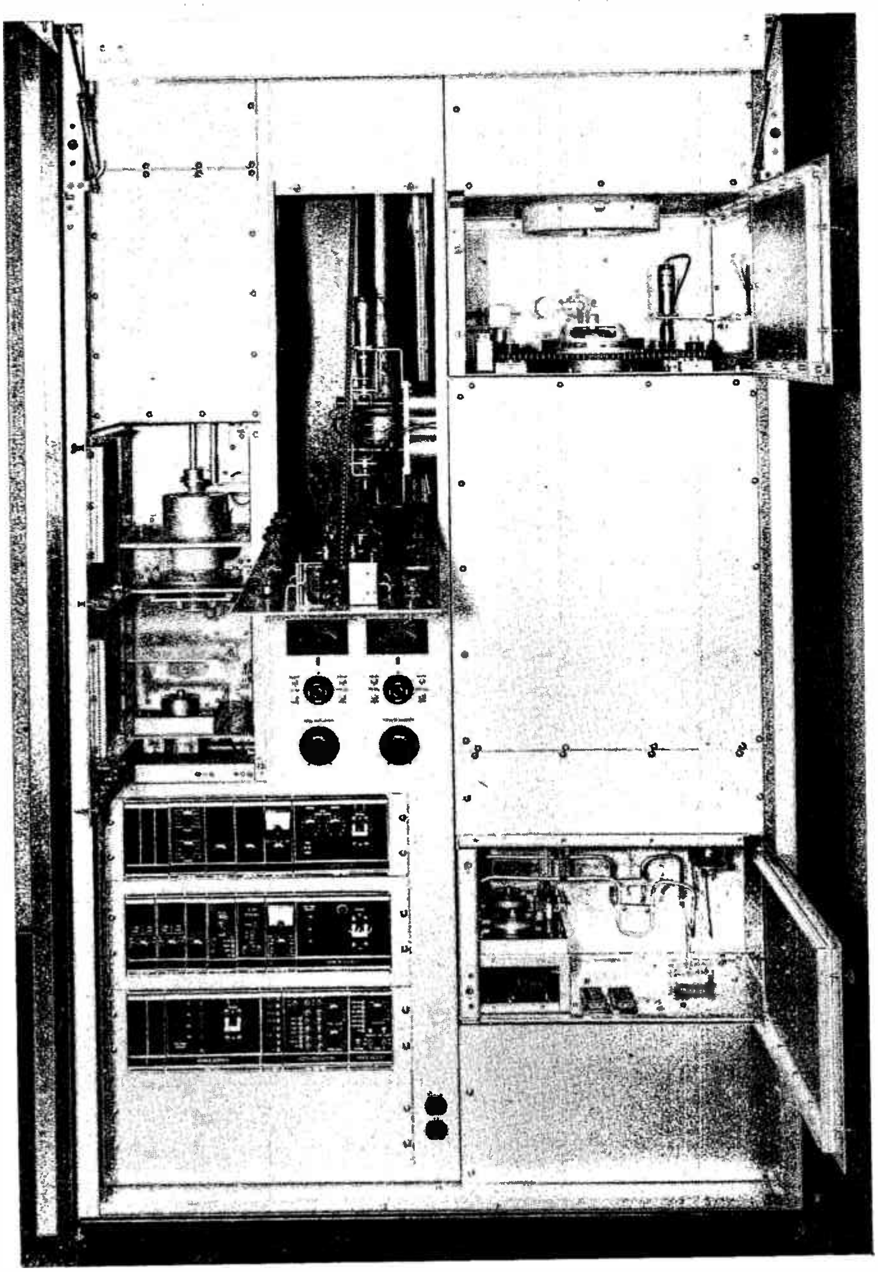


Fig. 11

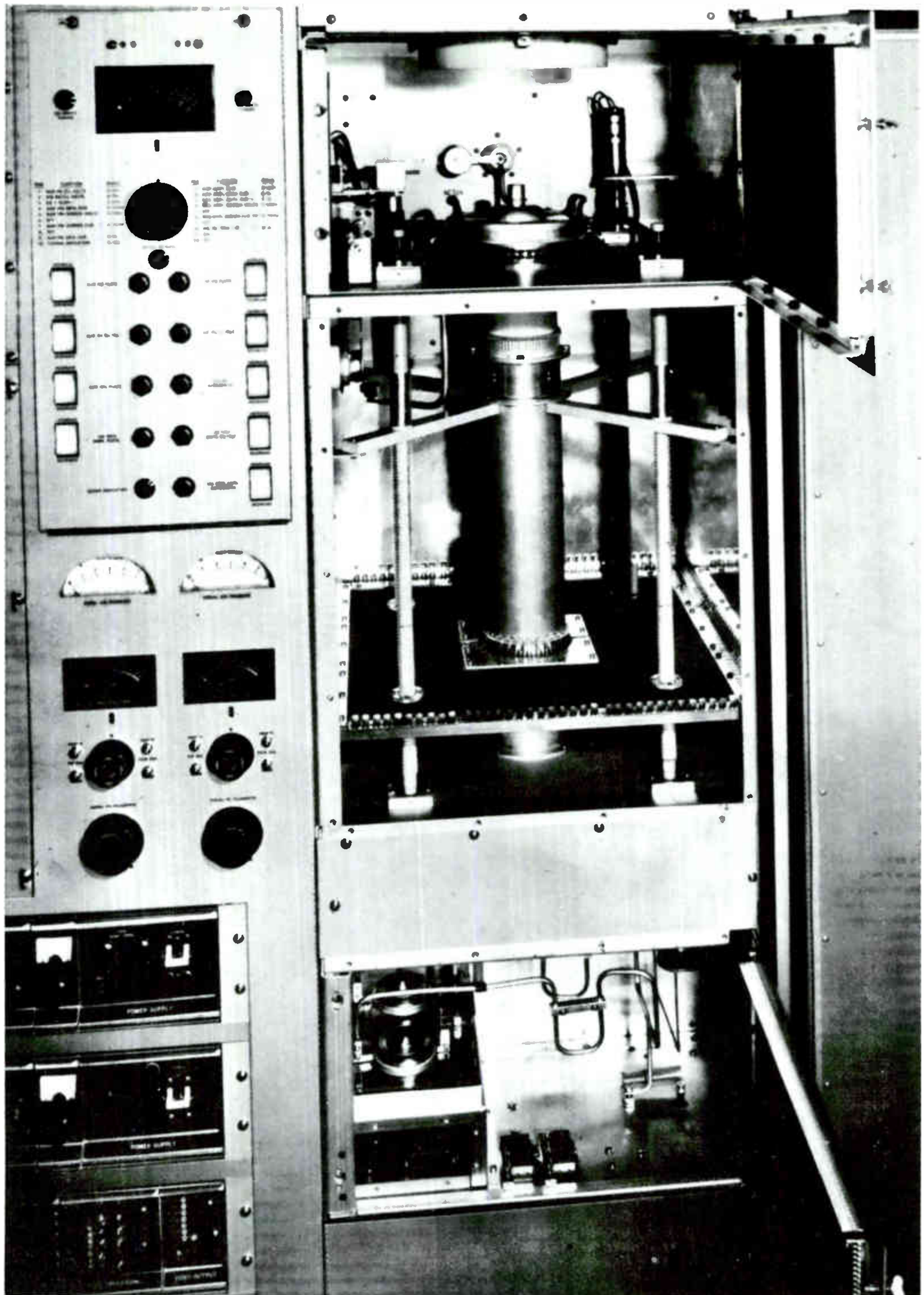


Fig. 12

criminator is applied to another varactor diode in the FM oscillator circuit, and corrects for the oscillator drift.

The output of the FM oscillator is also fed to a buffer amplifier, a frequency doubler, and then to two more amplifiers to provide an output of five watts at the aural carrier frequency. A similar RF chain follows the visual crystal-controlled oscillator to also provide five watts at the visual carrier frequency. An oven identical to the one used for the aural reference oscillator, houses the visual oscillator circuit. The exceptional frequency stability of the two carriers makes it unnecesary to lock them together.

A front view of the complete 5-watt exciter is shown in Fig. 6. It consists of

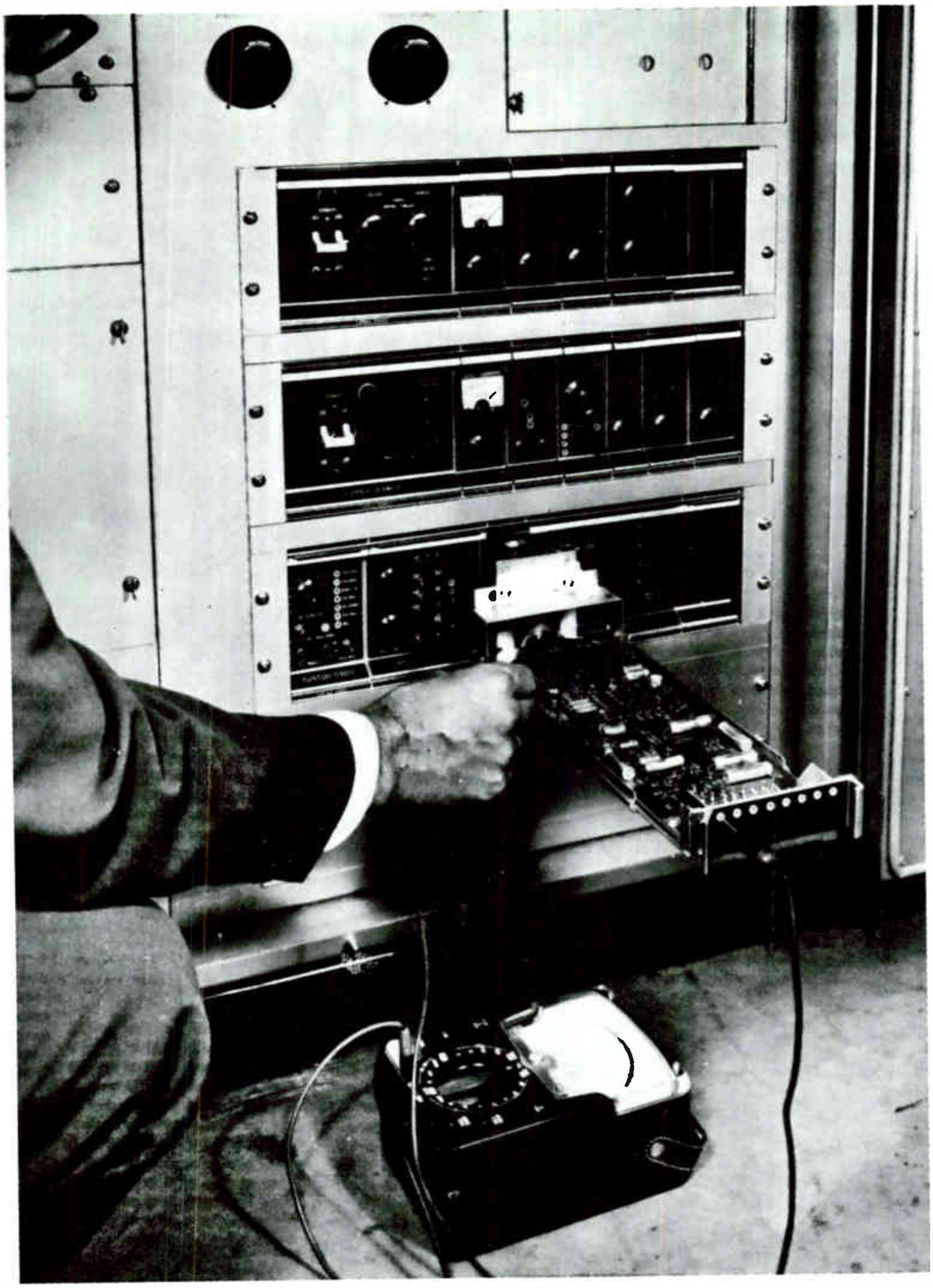


Fig. 13

seven plug-in modules, including a well regulated power supply, mounted in a sturdy frame. The 20-watt solid-state amplifier and the visual modulator use the same type of construction. The power supply modules are all similar in appearance and construction, as typified in Fig. 7, which shows the visual modulator power supply.

The 20-watt amplifier unit contains two identical amplifier modules like the one shown in Fig. 8. A single transistor, mounted on the heat sink at the top of the RF shield, delivers 20 watts with plenty of reserve, and can operate into an open or short circuit without damage. A multimeter module in the 5-watt exciter frame, and another in the 20-watt amplifier frame provide a convenient means of tuning and checking the operation of each stage in these two units.

Fig. 9 is a block diagram of the visual modulator showing the arrangement of stages contained in three modules, in addition to the power supply. A loop-through input to the modulator is used to allow monitoring of the video input signal. The input stage is a differential amplifier which removes any hum or noise that might appear on the input cable because of ground loops within the transmitter plant.

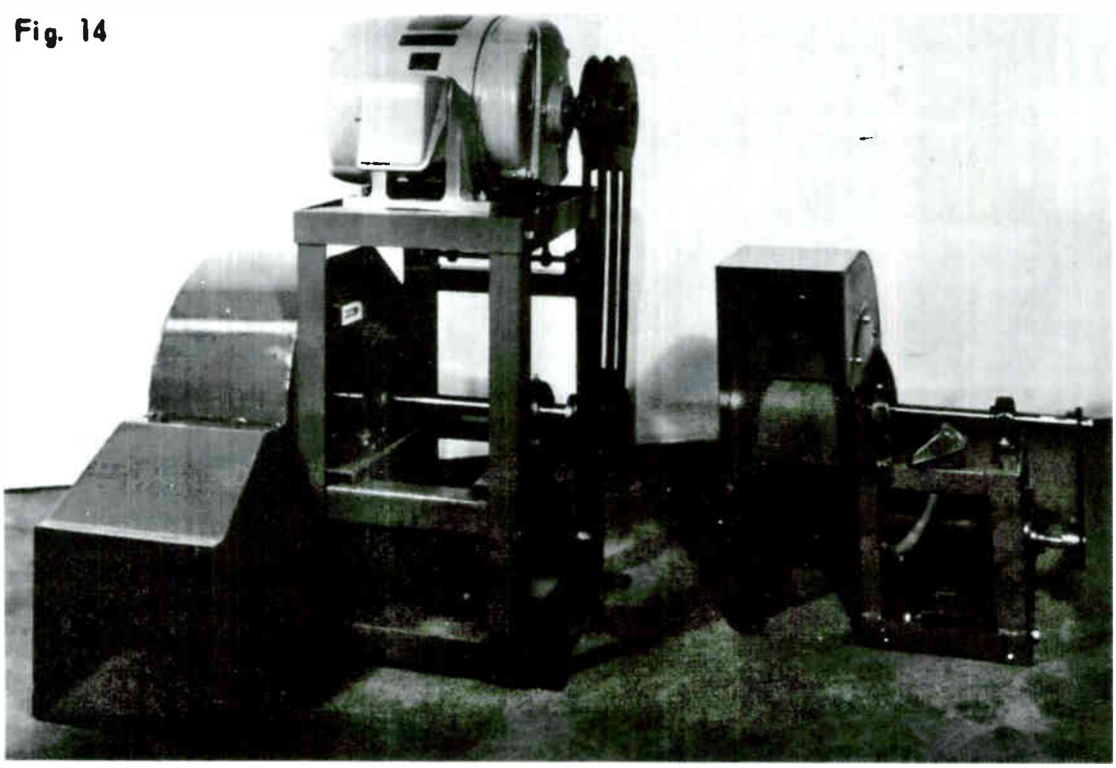
A driven clamp circuit inserts the DC component for the differential phase and differential gain correction stages which are independent of each other, and have negligible interaction. The video signal out of the differential gain corrector is maintained at approximately 4 volts, and the gain control on the amplifier which follows is adjusted for the required output amplitude. The output video swing capability is 70 volts peak-to-peak, which is about twice the normal requirement. After the initial setup, any required gain adjustments are made with the motor-driven control at the input to the processor module. Motor-driven sync gain and pedestal level controls are also provided for remote operation.

The modulator output stage is a complementary symmetry emitter-follower with high current capability to match the requirements of the capacitive load presented by the modulated amplifier grid circuit. DC restoration in the output module is accomplished by means of a feedback clamp circuit which avoids clamping disturbances, and greatly reduces any low-frequency errors which might take place in the last two stages. Provision is also made to allow operation of the feedback clamp using the signal detected from the RF output of the visual PA. This alternate mode minimizes the variation of output over each field, and helps maintain a constant peak output with changes in average picture brightness.

Fig. 10 is a view of the video processing module. Front panel controls are provided for making the differential gain and phase adjustments. Note that the video gain and sync gain controls can be operated manually by knobs on the front panel, or remotely, by the two motors shown.

The mechanical construction of the transmitter was dictated to a large extent by the performance specifications. It was necessary to provide much better shielding of the individual units, and more effective electrical bonding between the various units. It was also deemed desirable to improve accessibility of components and sub-assemblies, and to reduce the acoustical noise of the air cooling system.

Fig. 14



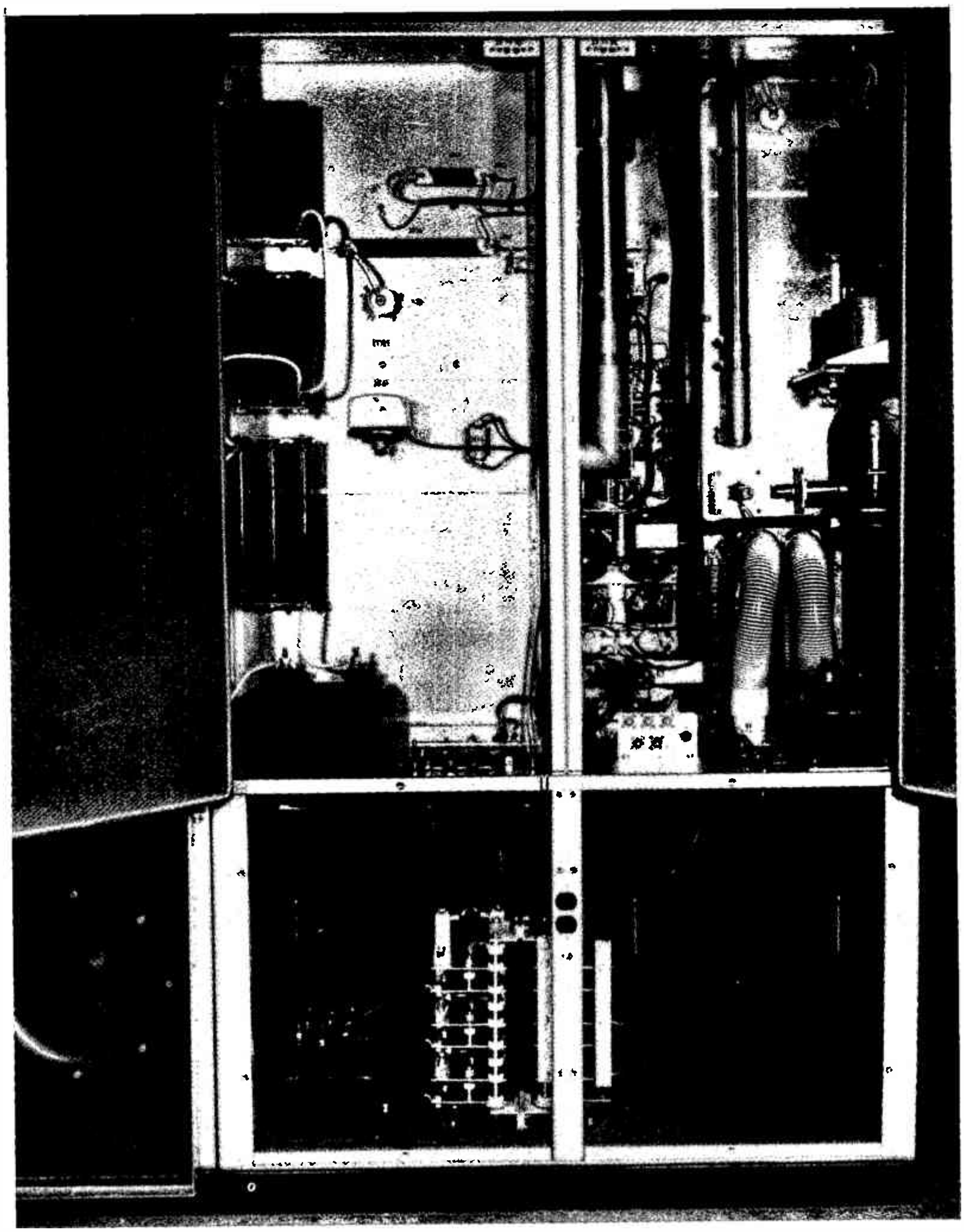


Fig. 15

The desired degree of shielding and electrical bonding were attained through the use of aluminum sheet metal cabinets with no painted surfaces being joined. The aluminum is treated with iridite to prevent oxidation. Copper plated steel bases are used to support the cabinets and give them strength and good electrical bonding. All sub-assemblies are built in RF-tight enclosures, and are well bonded to the cabinet. Differences in ground potentials between various points in the system are virtually eliminated by this treatment, and stray RF radiation is reduced to an extremely low level.

Even though the physical size of this new transmitter has been greatly reduced, as compared with previous designs, the accessibility has been greatly improved. This highly desirable feature was accomplished by the use of plug-in modules, hinged panels, and easily removable access panels, as shown in Fig. 11. This is a front view of the amplifier cabinet with the front doors removed. Note that the meter panel swings up, the tuning control panel swings down, and the RF compartment doors swing out to allow easy access to the tubes and components. Fig. 12 shows the visual PA with the access panel removed from the plate cavity. Note the simplicity of the cavity and the accessibility of all contact fingers. Fig. 13 depicts the use of the module extender for tuning or servicing the plug-in modules with power applied.

The first step in designing a quieter air-cooled transmitter was the selection of a power tube complement requiring a low-volume, low-pressure cooling system. The second step was to design an air distribution system which would introduce minimum turbulence and pressure losses. The third and final step was acoustical treatment of the transmitter to absorb the noise and limit its transmission to the outside of the cabinets.

The air requirements of each 15 KW transmitter are such that a single blower equipped with 1 1/2 horsepower motor is more than adequate for cooling all tubes and components at altitudes up to 7500 feet above sea level. Fig. 14 shows how this blower compares in size to the one used in our latest 12.5 KW transmitter. The blowers are located in the lower portion of the center control cabinet. Each blower delivers its air directly into the plenum chamber in the amplifier cabinet as shown in Fig. 15. The access covers have been removed from the rear of the plenum chamber exposing the filament rectifier assemblies. No interconnecting ducts, with their inherent pressure drop, are necessary. The visual power amplifier cavity sets on top of the plenum chamber, and air flows through a large opening into the cavity. Again, no ducts are required, and the cavity becomes part of the plenum chamber.

The shorting bar for tuning the plate cavity is constructed of an aluminum honeycomb material which is an ideal RF shield while offering practically no restriction

Fig. 16

Fig. 17

to the flow of air. It also helps to straighten the air flow and prevent turbulence. Actual measurements indicate that the total pressure loss of the system between the blower output and the visual PA tube cooling radiator is less than 0.1 inch of water.

The blower noise, already reduced by the small size, is absorbed to a very large extent by effective sound absorbing material which lines the blower compartment and plenum chamber. The air rush noise is confined to the transmitter interior by the use of insulated and gasketed doors on the cabinets. The result of this carefully designed air system is an air-cooled transmitter which approaches the quietness of a water-cooled system without the associated water problems. The resultant reduction in vibration also plays an important part in meeting and maintaining the tight performance specifications.

Simplicity of mechanical design is an added bonus which not only contributes to the ease of accessibility, but greatly reduces the required maintenance time. The use of motor-driven tuning controls and electrical position indicators eliminates the need for complicated and troublesome mechanical linkages. A fail-safe electronically-operated high-voltage grounding contactor is used in place of mechanical grounding devices which require a great deal of maintenance, and even then are likely to hang up.

Fig. 16 is a view looking down on the TT-30FL transmitter showing a typical arrangement of the power supply cabinets behind the front line cabinets. The two power supply cabinets are identical, and an interior view is shown in Fig. 17. Note that the heavy transformers and filter reactors mount in the lower compartment, and set on the floor. The high-voltage rectifier stacks and the grounding contactor are mounted near the top across the rear wall.

The TT-30FL has many other features, too numerous to cover in the time allotted, which also help to make it the ideal transmitter for the broadcaster who is concerned with performance, reliability, economy of operation, ease of tuning and maintenance, stability, personnel safety, equipment protection against faults of all kinds, and remote control operation.

Automatic Correction of Network Chrominance & Luminance Levels

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The transmission of color television signals over great distances has become an everyday occurrence in North America and in fact on a worldwide basis. The difficulties that were encountered a few years ago in transcontinental or round-robin color television networks have been eclipsed by the difficulties involved in the transmission of color television signals by satellites between continents. In all transmission links—the satellite, the microwave, cable, and even local coaxial wiring itself, distortions are generated in the television signal which ideally should be eliminated before the signal is used for recording purposes or is used to be transmitted to the ultimate viewer. Fortunately, the nature of the television signal is such that many of the annoying distortions can readily be removed from the signal itself. For a number of years it has been possible to remove distortions in the synchronizing pulse train and the blanking portion of the signal. More recently it has been possible to remove distortions and errors in the color synchronizing burst part of the signal. These corrections have been made readily, reliably and automatically with modern video processor designs. It has also been possible to manually correct errors in the picture portion of the signal. Up to now, however, it has been extremely difficult, if not impossible, to make accurate corrections of the video level and the chrominance level, without making some arbitrary assumptions about their original value. The reasons are fairly obvious; there is nothing inherent in the luminance waveform or in the chrominance waveform that gives any clue at all about the original value of the waveform at the point where the program was originated. There are a few indirect clues that one can use, such as the amplitude of the color burst or the synchronizing pulse but, as we shall see shortly, this frequently can turn out to be an erroneous source of information.

It is, therefore, implicit that it is necessary to use some additional reference signals to determine the correct values for the luminance and chrominance portions of the television waveform and for this, of course, it is necessary to turn to reference signals transmitted during the vertical blanking waveform. Armed with this information, it is no longer necessary to adjust levels manually on an arbitrary basis. It is now possible to correct levels automatically such that the final processed output from the equipment is completely correct in every possible way and is also a faithful replica of the waveform transmitted from the point of origin.

THE NATURE OF THE PROBLEM

First of all, I would like to review briefly the make up of the standard color television waveform so we can keep the various distortions separated in our minds as we proceed. The standard color television waveform is, of course, a very complex waveform which uses time, amplitude, and frequency division multiplexing to transmit over one broad band channel the vertical and horizontal synchronizing information, the color demodulator synchronizing information, an analog waveform of the luminance level, and a phase modulated subcarrier waveform of the two color difference signals. It is fairly obvious that a channel to handle such a complex waveform must be extremely good in terms of linear distortions and in terms of cross-modulation distortions, if we are not to suffer intolerable difficulties in recovering the original signals at the receiver. The practical network, of course, is not ideal and each network link contributes significant amounts of distortion to the waveform.

It is not my intent, at this time, to make an extensive analysis of the cross modulation products that can be produced in a system of this nature but rather to review the techniques for correcting most of the signal distortions that commonly occur in the various signal components, with particular emphasis on those that effect the luminance levels and the color difference signal levels. In Fig. 1 is shown a breakdown of the waveform into:

(a) Scanning Synchronizing Signal
(b) Color Demodulator Synchronizing Signal
(c) Luminance Signal—Brightness
(d) Color Difference Signals

The total signal extends from a very low frequency to approximately 4.5 MHz and if faithful reproduction is to be obtained, then it is necessary to ensure that the transmission channel has a very uniform response over this bandwidth. It is also necessary that the channel be highly linear to minimize crosstalk between the components, particularly between the low-frequency brightness component and the higher frequency signals of luminance detail response and color difference signals.

A practical circuit is never perfect, though modern technology can get very close if money is no object. In our industry, money is of course a very important consideration and we must, therefore, be prepared to do the best job possible at minimum cost, which means inherently that a less than perfect transmission path must be accepted. Fortunately, we do not have to use this degraded transmission path as it is; a little thought will reveal that a less than perfect circuit will be greatly improved by the application of negative feedback in one form or another and we can readily apply it to this problem to improve considerably the apparent performance of the best transmission path that we can afford for the job at hand.

Fig. 2 shows the generalized arrangement and it is immediately obvious that this arrangement has a number of difficulties for our application, not the least of which is that it requires a full performance path back to the input. We can, however, obtain most of the benefits from this arrangement by simply transmitting the comparison information in a slightly different way as shown in Fig. 3. In this arrangement, we have moved our decision making to the receiving end and now both information paths go in the same direction. For this to be successful, however, we must be able to transmit distortion-free information over the comparison line. This seems to be an insurmountable problem until we realize that it is not necessary to transmit all the signal over this line to perform an effective comparison but only that information that is variable if we provide suitable storage in the comparator for the non-varying part. The television signal fits very well into this scheme and, in fact, contains enough space during the vertical blanking to add specialized reference sig-

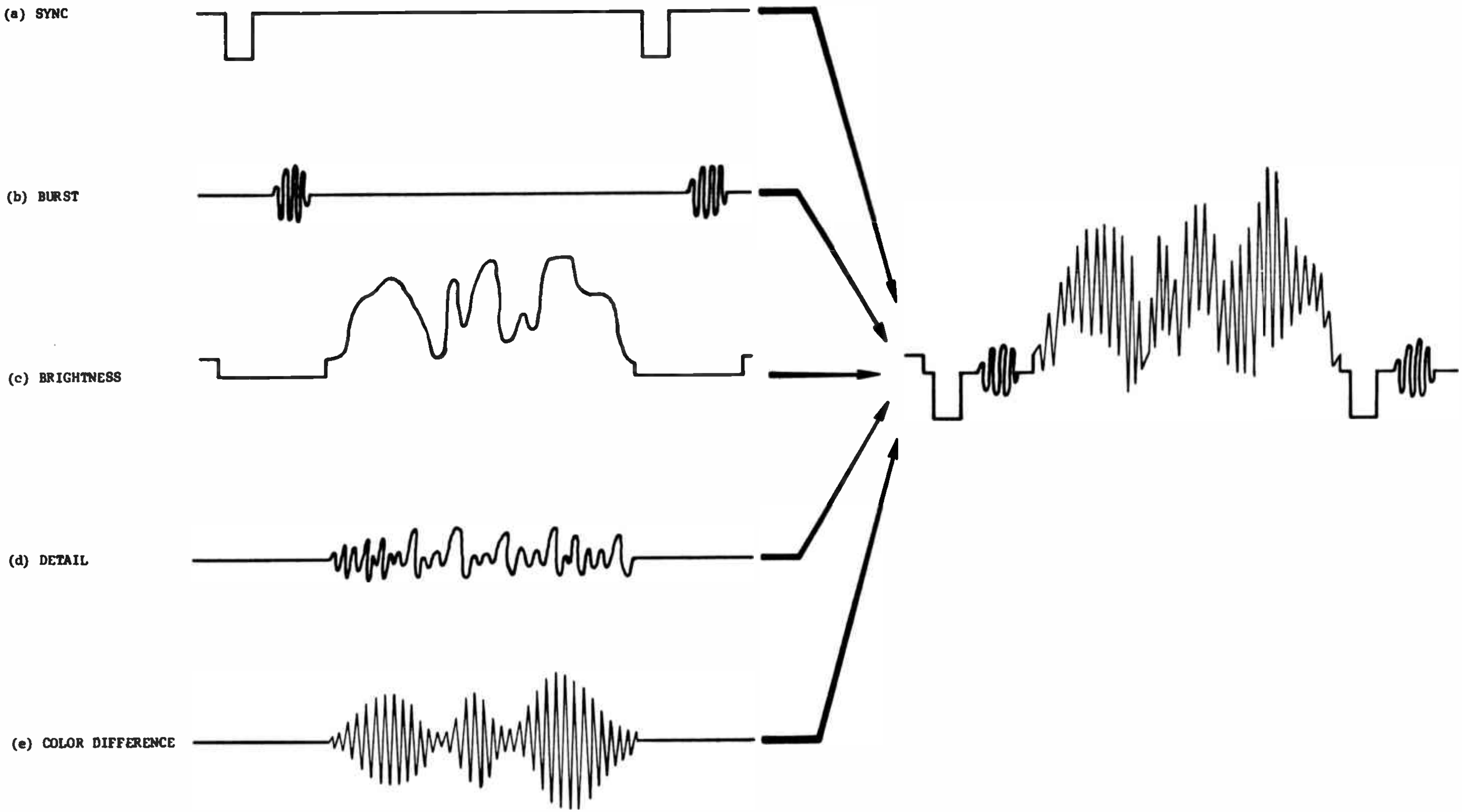
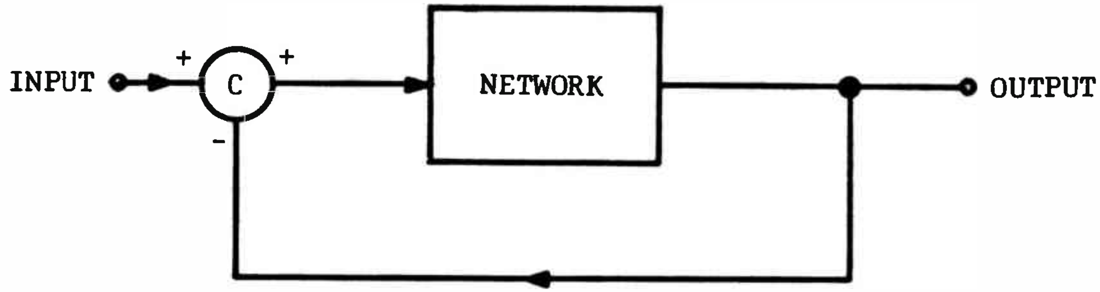


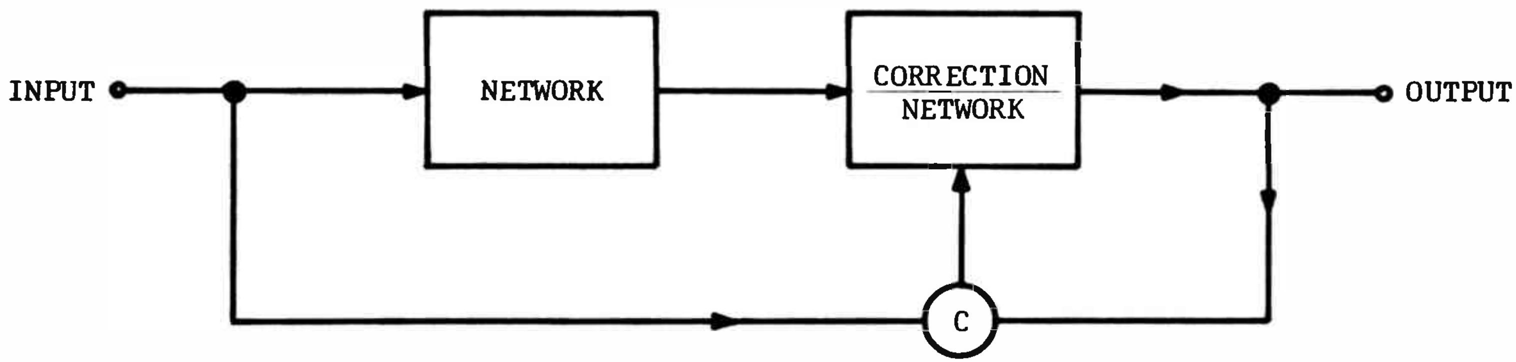
Fig. 1

THE TELEVISION WAVEFORM



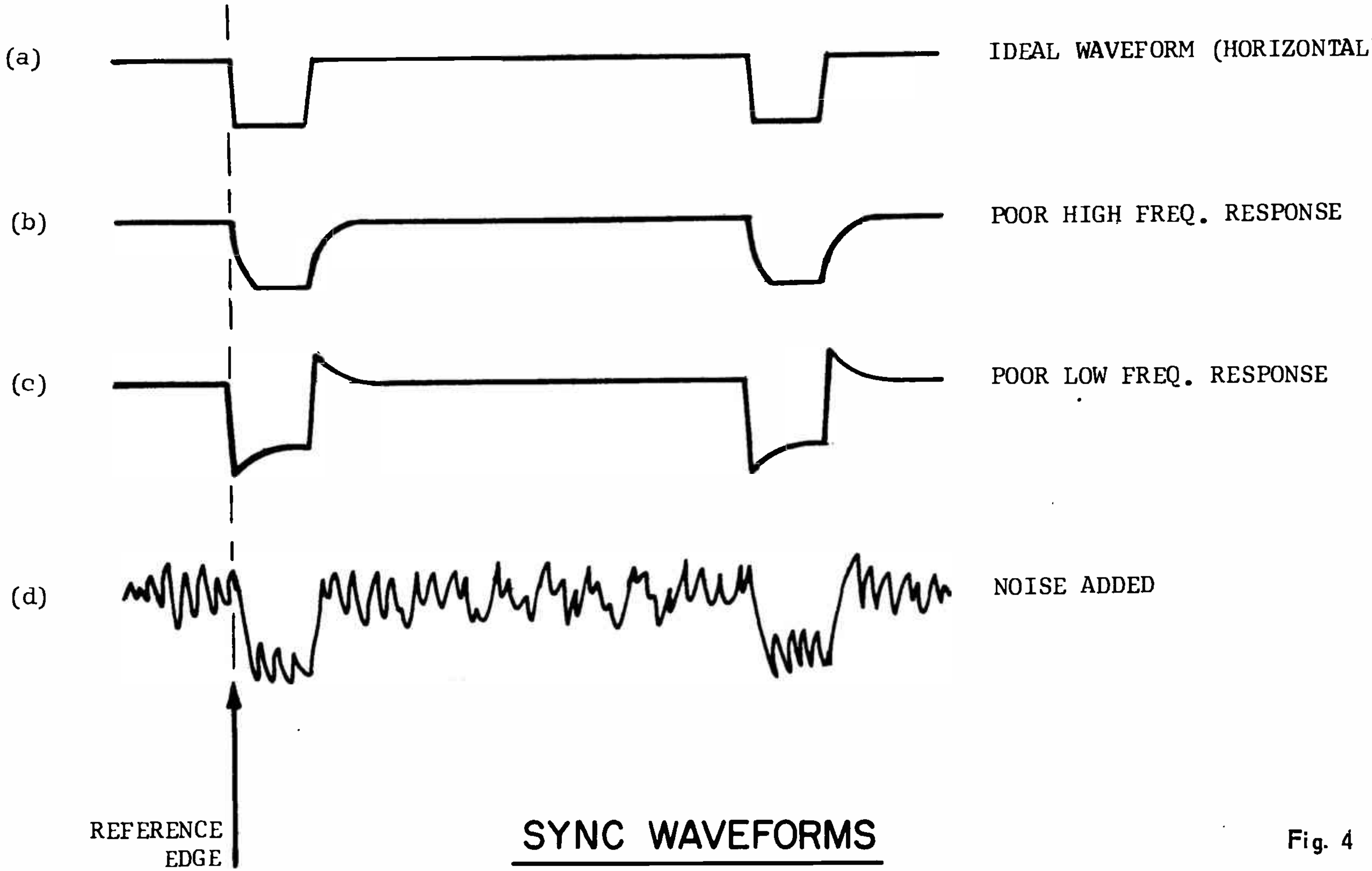
NEGATIVE FEEDBACK

Fig. 2



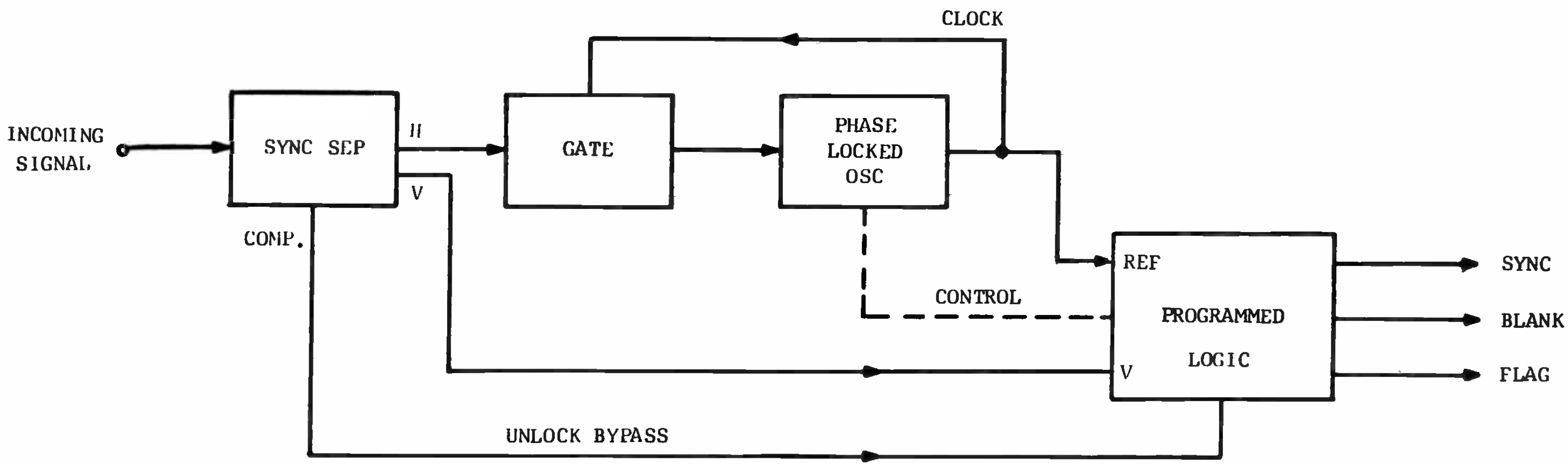
CLOSED LOOP CONTROL

Fig. 3



SYNC WAVEFORMS

Fig. 4

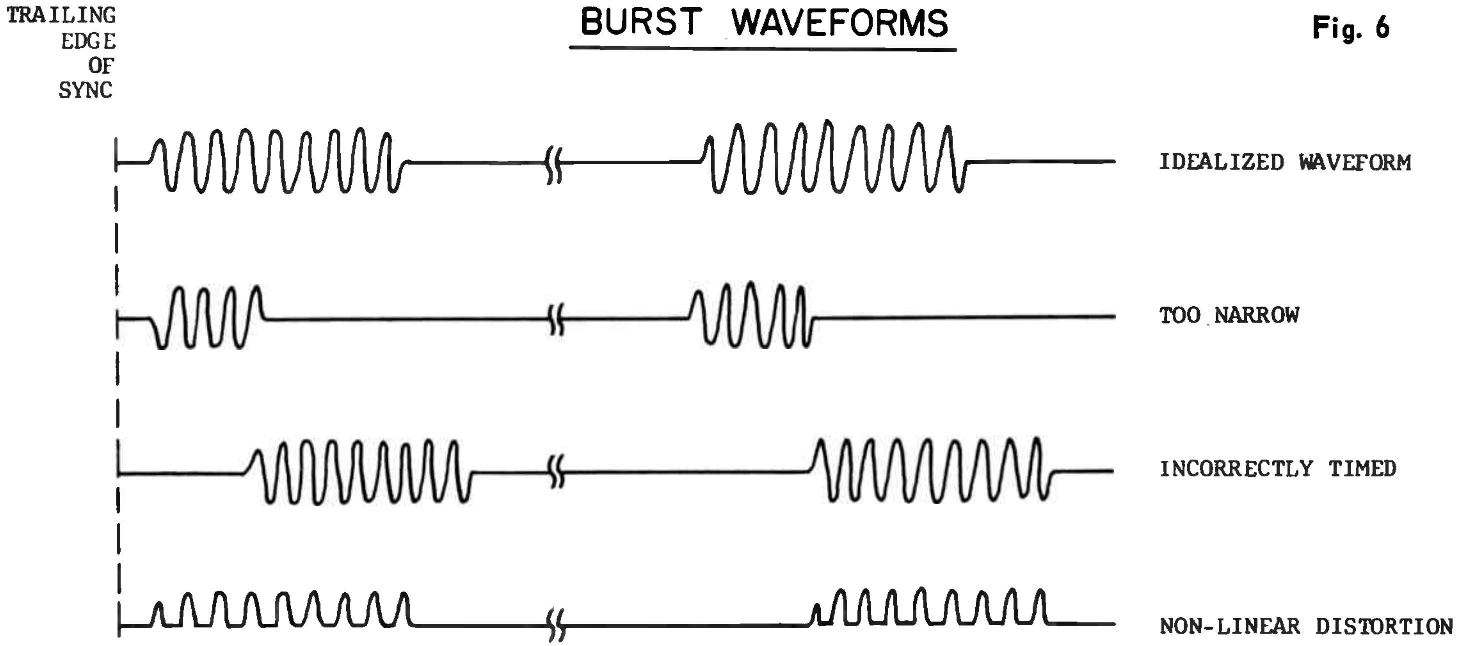


SYNC REGENERATION

Fig. 5

BURST WAVEFORMS

Fig. 6



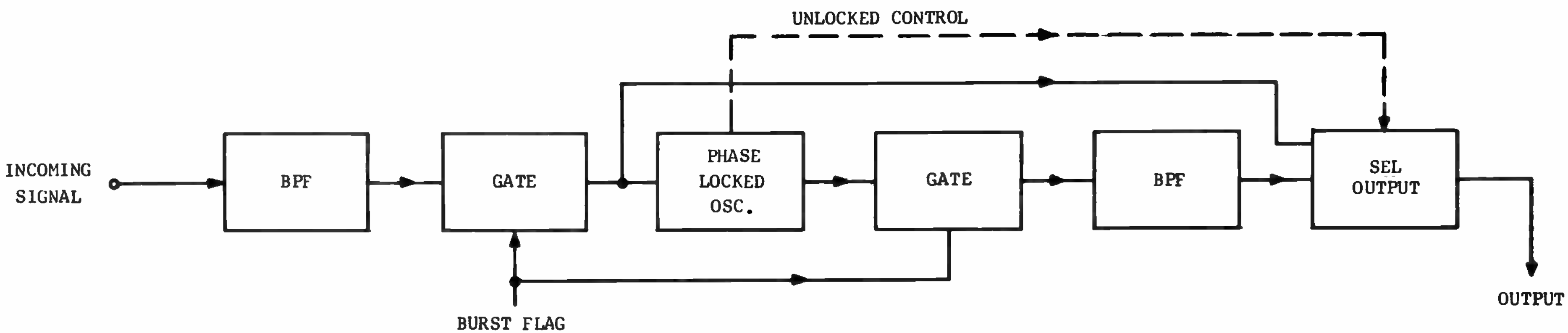


Fig. 7

BURST REGENERATION

nals suitable for simple analysis by the comparator and of such a nature that they are likely to arrive at the receiving point without excessive distortion.

RECONSTRUCTION OF THE SIGNAL

Let us now see how this simple, well-tried concept can be applied to the television signal to create a performance that is as close to perfect as we can make it.

Synchronizing Signal: The ideal sync waveform is shown in the upper part of Fig. 4 and we can easily construct this waveform and its related waveforms of blanking and burst flag as the amplitudes, widths, rise-times and timing relations are well known and can be made a permanent part of our system. The only unknowns are the precise point in time that they will occur. Conceptually, we can then store the standard information and use only the timing reference edge. Even under conditions

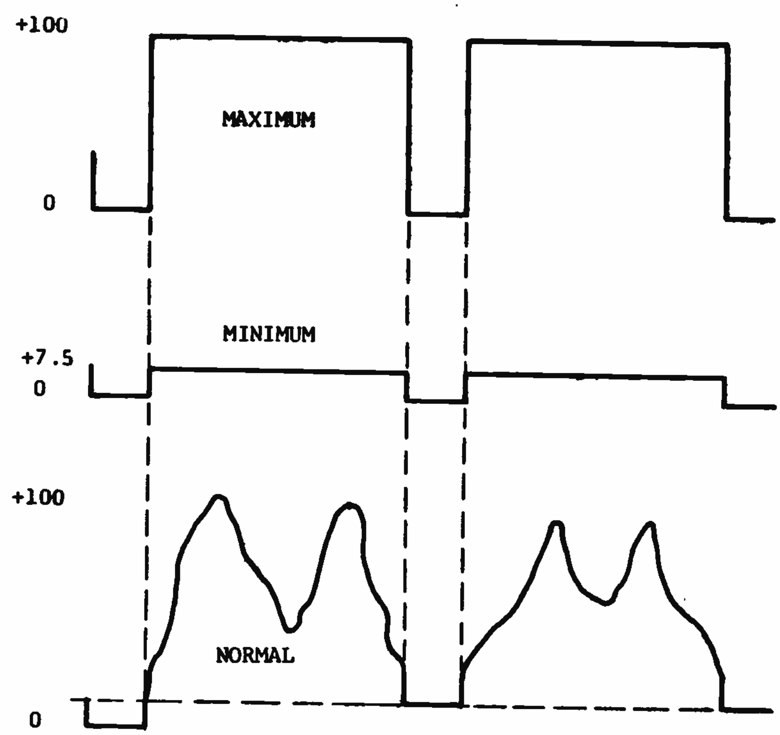


Fig. 8

LUMINANCE WAVEFORMS

of severe distortion and heavy interference, we can come very close to the ideal waveform, using the logic scheme shown in Fig. 5.

Color Synchronizing Signal: The ideal color synchronizing waveform is shown in the top of Fig. 6 and several common problems are illustrated below. Again, the waveform can readily be reconstructed—if we can detect the zero crossing points of the burst to provide us with a new source of locked subcarrier and if we have a convenient source of sync or burst flag to establish the envelope. Again, we can readily recreate this signal, even when heavy distortions are present. Fig. 7 shows a typical solution to this requirement. The amplitudes, rise times, and widths are well known and can be built into the equipment, while the precise phasing of the signal is controlled by comparing the regenerated signal with the incoming burst over a short period of time.

Luminance Signal—Low and Mid Frequencies (Brightness): Fig. 8 shows that the brightness waveform can vary greatly, dependent on the scene being televised and also that it is not readily recreated without knowing a little more about it. The blanking portion of the waveform is defined and programmable, using sync as reference, but the only known facts about its amplitude are that the lower limit is + 7 1/2 IEEE units (set-up) and that the maximum excursion is +100 IEEE units. We can then define only its limits in time and its maximum excursions; not enough to do a thorough job. Considering that the most significant correctable distortion is gain error, we might employ a feedback control system based on comparing the maximum excursions of the signals to fixed references and then varying circuit gains to maintain them constant. Equipment working in this fashion is available and is capable of doing a fair job under average conditions. If, however, our interest is to control the signal under all conditions of gain adjustment errors, dynamics gain errors, and the like, we need a reference signal. About the only space to place such a signal is during vertical blanking and the signal employed must be capable of indicating the circuit gain performance under widely varying conditions of distortion, noise, and cross-modulation. It has been found that the V1 white reference signal, commonly employed on network signals, is quite satisfactory as long as the signal path does not contain significant clipping and as long as we sample the signal well away from the edges to avoid smearing. The white flag signal on multiburst can also be used with slightly less accuracy. If we now sample this signal and compare

Fig. 9

THE CHROMA SIGNAL AND LUMINANCE DETAIL

it with a fixed reference value, we can set up a closed-loop control system to maintain correct luminance levels. Such a circuit has to be a sample and hold arrangement with a very long time constant, as it is also necessary to sample once every frame to accommodate split-frame VIT signal schemes such as frequently occur outside the U.S. Where severe clipping is likely to exist, then it may be necessary to use a lower amplitude reference signal (50 IEEE units for example) to avoid gain ambiguities. In this case, slightly less accuracy is available in the gain control servo.

Chroma and Luminance Detail Signals: Typical waveforms of these signals are shown in Fig. 9 and it can be readily seen that the situation here is very similar to that for the luminance signal, in that it is essential to have a reference signal to measure and compare with a standard. It is possible to use the color burst or part of it for this, but the burst signal is not in the general area of the picture components and frequently is quite distorted even though the picture is not. Then there is also the obvious problem of monochrome signals. It would seem desirable then, in theory and in practice, to employ a reference signal at approximately the level of the picture components and of such amplitude that it is likely to be relatively undisturbed by circuit nonlinearities. The 3.6-MHz burst in the multiburst signals has been found to be quite satisfactory and, of course, is available in all modes. Again, we can blank the signal as necessary to remove extraneous components as is done for the luminance signal.

Practical Considerations: In any closed-loop system such as we have been discussing, it is necessary to ensure that the system is stable and produces good results, even under the most adverse conditions, and hence it is necessary to provide a few interlocks. The principle interlocks should...

(a) Inhibit automatic control until timing information is available to reshape sync, blanking, reference sampling, and burst gating.
(b) Inhibit burst reinsertion until locked subcarrier is available.
(c) Inhibit automatic control of luminance until the luminance reference is inside some reasonable limits and control of frequency response until the luminance control is operational and the reference signal is inside some reasonable limits. Obviously, some means must be available to do the best job possible under all circumstances, and this usually means some form of bypass or partial correction under preset manual control. In the event of total video failure, a means can be provided to maintain continuity of sync pulses until video returns. It is also important to perform all gain setting operations prior to the establishment of blanking and clipping operations to avoid potential conflicts.

By the use of the techniques outlined, it is now possible to build a completely solid-state video processor to act as a signal restorer that will remove most, if not all of the imperfections picked up by the signal in the course of its transmission. Following is an example of such a device:

2084 DESCRIPTION (Fig. 10):

The 2084 processing system is built up from a number of modules which form the building blocks for a family of related units. In addition, there is a mounting frame and a dual regulated power supply with built-in overload protection to house and feed the system. The basic video modules are as follows:

(1) Switching Module: This module contains the input transfer switch to enable the selection of either main or a standby video input. Alternatively, a test signal may be substituted. This module also contains the bypass switch to enable the complete removal of the unit from service. The switching is fairly conventional relay switching and the bypass can be operated either manually or automatically from system power failure. Due to the design of the power supply, a major short anywhere in the system will also bypass the system. The switching module is an essentially passive device and is plugged in from the rear of the mounting frame so that all active modules can be removed with no likelihood of breaking the continuity of a bypassed video signal.
(2) Pulse Processor (Fig. 11): The pulse processor contains all the circuitry associated with the reconstruction of the timing waveforms. The master clock for this operation is a locked 31.5-kHz oscillator whose reference is derived from video sync pulses. The sync separator is preceded by a small AGC loop with a range of about 20 db to optimize sync level under a wide range of adverse conditions, and the horizontal and vertical components are gated to minimize the effects of noise. The gate in the horizontal sync feed to the oscillator has two modes of operation—a broad (31 microsec) or a narrow (250 nanosec) sampling period. If the oscillator is locked, the narrow gate is used to provide maximum noise immunity but the broad gate is used to give minimum lock-up time. A means is also provided to ensure that only horizontal sync pulses are sampled to eliminate any hooking. By these techniques, a very stable reference is generated, locked very tightly to the

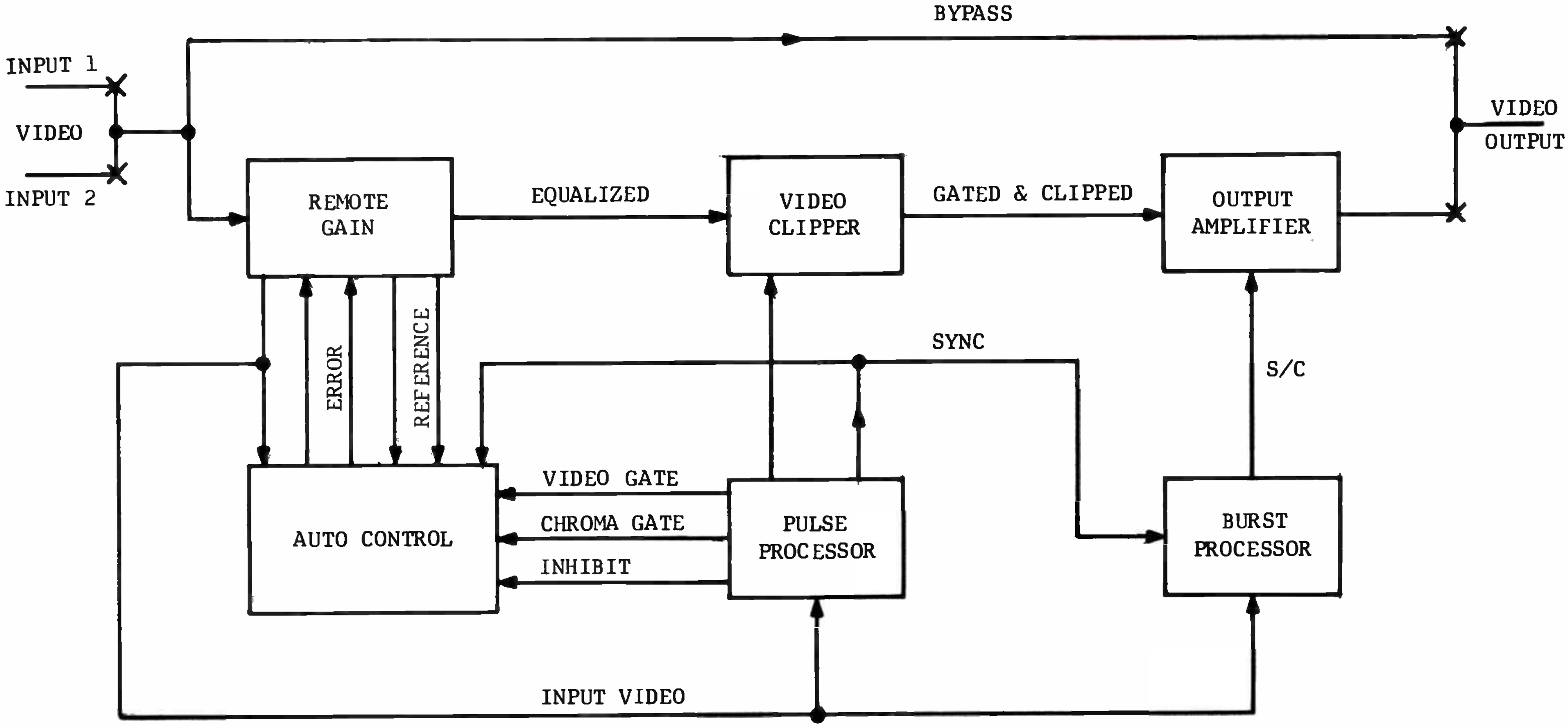


Fig. 10

THE VIDEO PROCESSOR 2084

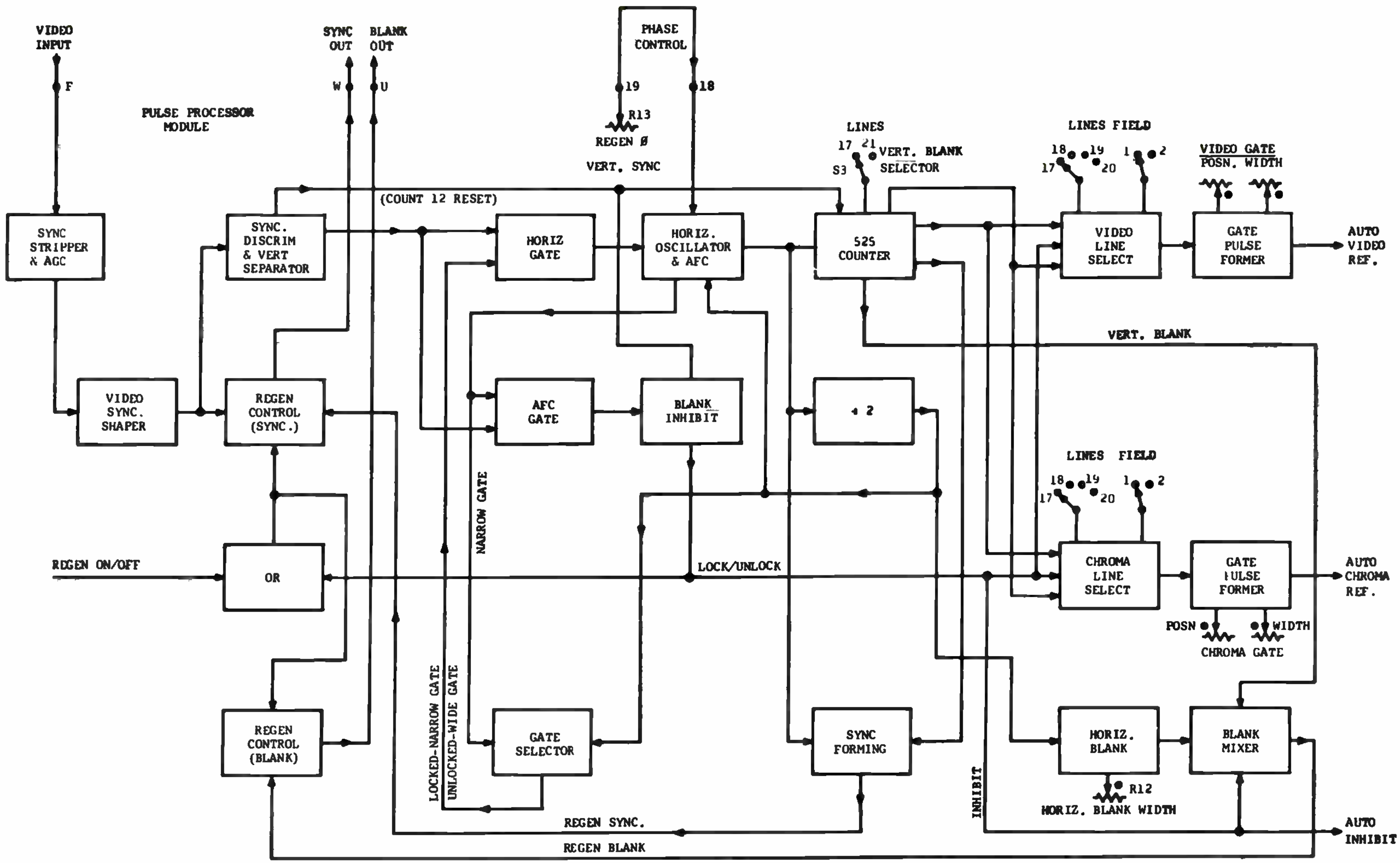
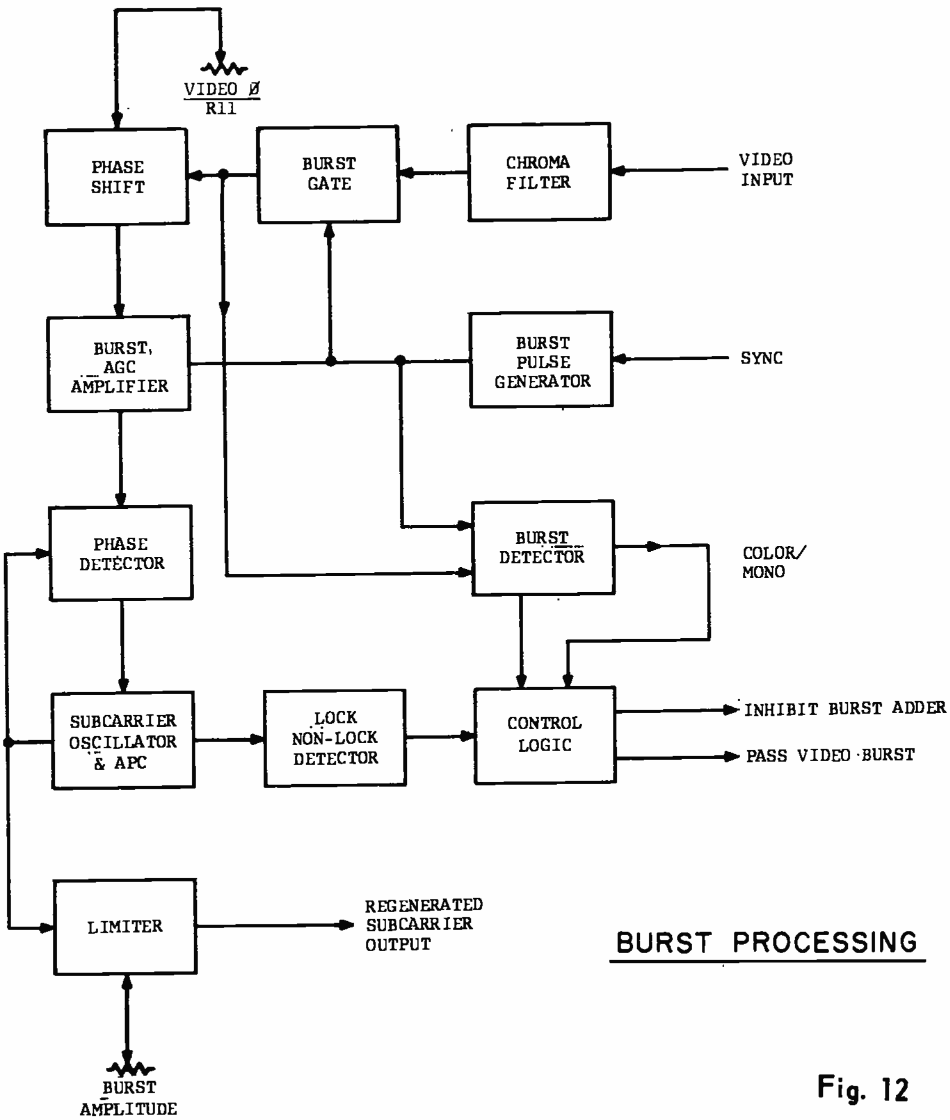


Fig. 11

PULSE PROCESSOR

original. Two other minor circuits are contained in this area, a sync detector to provide a logic drive to enable internally-generated black in the absence of video input and an oscillator unlocked detector which provides a logic level to enable the use of the separated sync during oscillator lock-up time to effectively eliminate the generation of transients when non-synchronously switched signals are fed to the inputs. The vertical reference is generated by a combination of separation and counting from the clock frequency to establish vertical lock in less than one field. Again, gating is used to minimize noise contributions.

All timing waveforms, sync, blanking, VIT pass/delete, luminance sample and



BURST PROCESSING

Fig. 12

chroma sample are then obtained by digital logic from these basic references (burst flag where required is generated from sync). Extensive use is made of integrated circuits in this process. It is noteworthy that all mode switching is vertical interval, where applicable, to further improve the performance. Controls are provided to select the field, line, and position of each of the two sampling pulses to accommodate a wide variety of operating standards and to make fine adjustments to system standards. Versions of the module have been produced for 525/60 and 625/50 systems.

(3) Burst Processor: The burst processor shown in Fig. 12 is designed to provide a source of subcarrier accurately referenced to the original burst and the module

also controls the logic circuitry to enable the proper use of burst reinsertion under all operating video conditions (color-mono-absent) and internal state (oscillator locked/unlocked). The main channel in the module removes the incoming burst by band-filtering and gating and then applies it via gated AGC and remote phase control stages to the reference input of the phase locked oscillator. The separated burst is also applied directly to a gated level detector to generate a color/mono logic signal.

The phase-locked oscillator is designed for maximum stability but by the careful use of gating and servo control techniques it also can very closely match the original reference, even under bad jitter conditions. The circuitry is also highly noise immune. The output from the oscillator is limited to a standard amplitude and added to the reconstructed video in the output module by means of a gate driven from sync and a suitable shaping filter. Logic is also contained in the module to control the burst gate in the video path from the logic signals mentioned previously. It should be pointed out that this burst circuitry is in no way connected to the automatic equalization circuitry in the processor and can readily be removed in cases where burst processing is not required.

(4) Gain Control Module: This module shown schematically in Fig. 13 serves to provide remote adjustment of video level and video equalization. At the same time it also provides video feeds to the pulse processing circuits from ahead of the equalizer and video feed to the burst processor from after the equalizer to eliminate any possible phase errors from this source. This module also contains the delay line required in the video channel to allow for the use of reshaped sync during pulse oscillator unlocked conditions. The circuitry in the module is fairly conventional, with video gain being controlled by an FET with appropriate temperature compensation. This arrangement gives minimum distortion at all gain settings. The equalization circuitry in the module is a novel arrangement that employs phase-linear aperture corrector type circuitry to provide corrections up to ± 4 db without the generation of spikes and problems of variable chroma delay. With the equalizer at zero or switched off, there is no significant difference in response between this module and a standard video D.A. The general arrangement is shown in Fig. 14.

The main video path is through DELAY 1 to output and added or subtracted from it is the high-frequency information filtered from the video by DELAY 2 and its differential amplifier. DELAY 3 is merely for matching delays. The amount and polarity of correction is determined by the state of balance of the bridge network which employs as one leg an FET controlled from the equalizer drive circuits. This arrangement produces a good approximation to optimum equalization, accompanied by essentially zero phase error. When the equalizer is inhibited, then all frequency sensitive circuitry is removed, thus providing an excellent flat response.

(5) Auto Control Module (Fig. 15): This module contains two solid-state sampling servo controls for the video gain and equalization circuits in the remote gain module. Additionally, it contains the high-low limit detectors for the reference signals and the necessary logic to ensure the correct operation of the system. Assuming that the luminance reference is within range (± 6 db from 0.7 volt) and the pulse processor is operating correctly, then the luminance AGC servo maintains the reference signal level at the output of the video gain circuit at a constant amplitude by comparing its amplitude at frame rate with the voltage from the preset potentiometer and making appropriate adjustments to the video gain control voltage. If the reference is not present, outside range, or the pulse processor is not locked, then the system re-

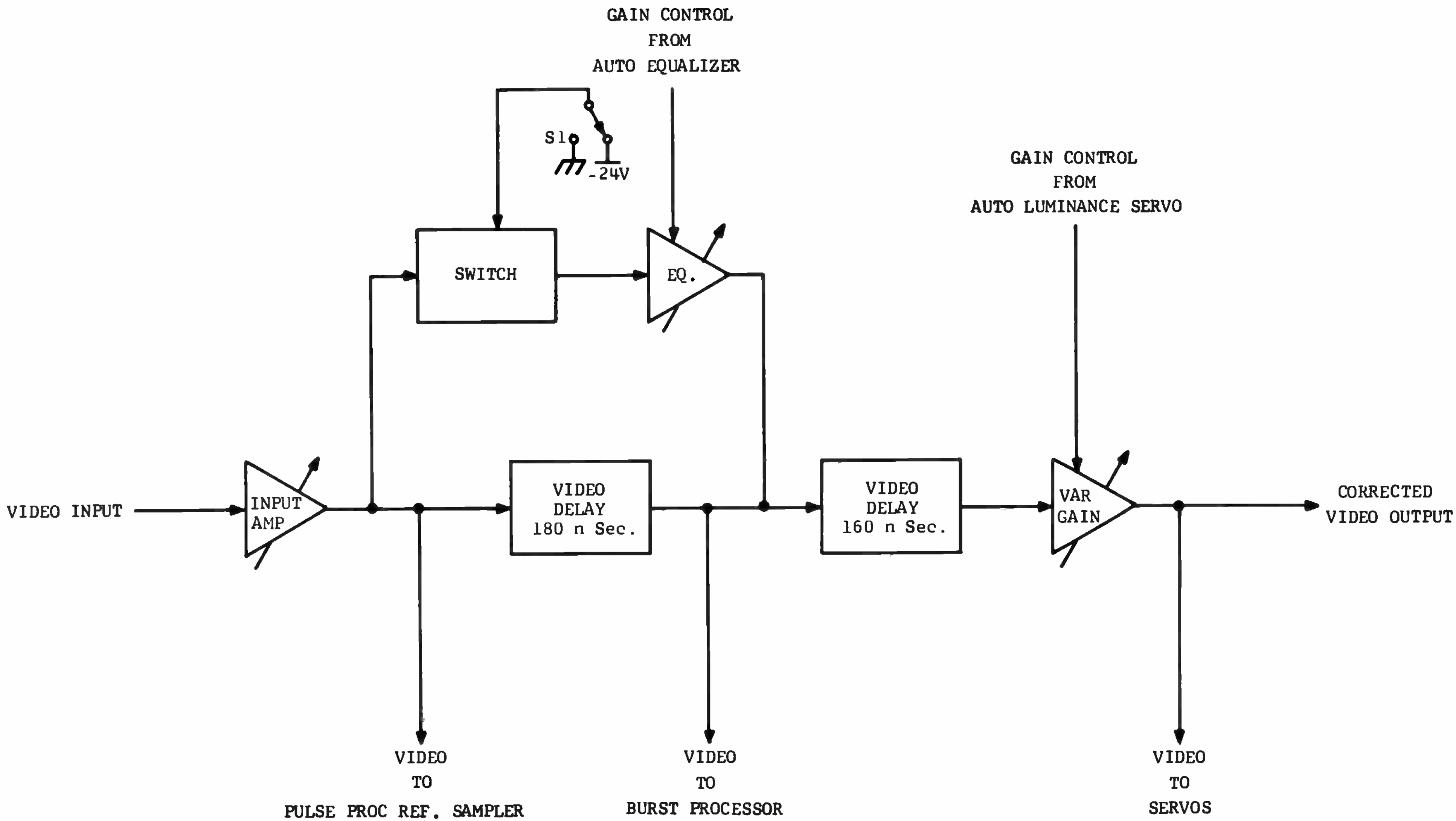


Fig. 13

REMOTE GAIN MODULE

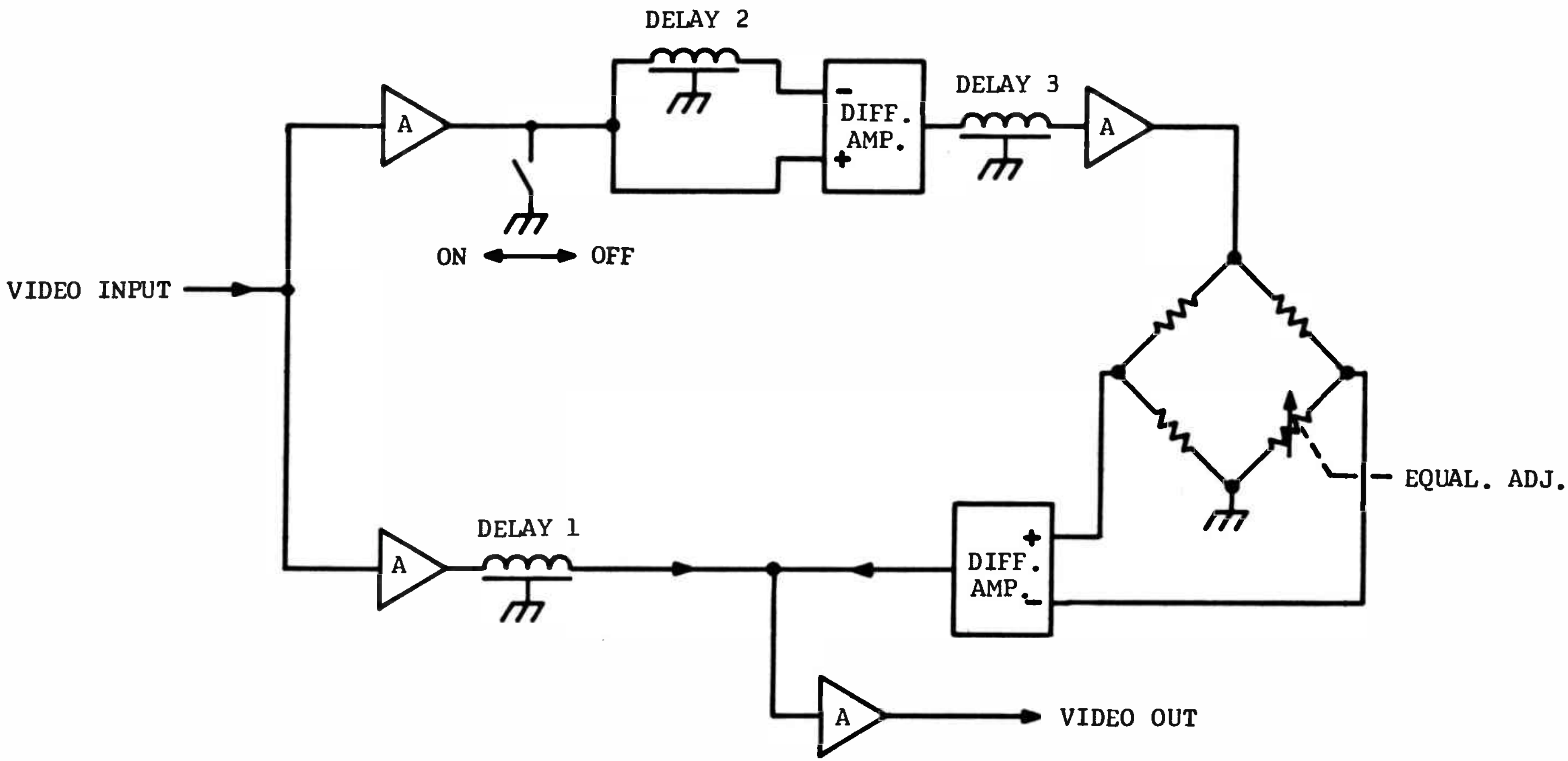


Fig. 14

EQUALIZER

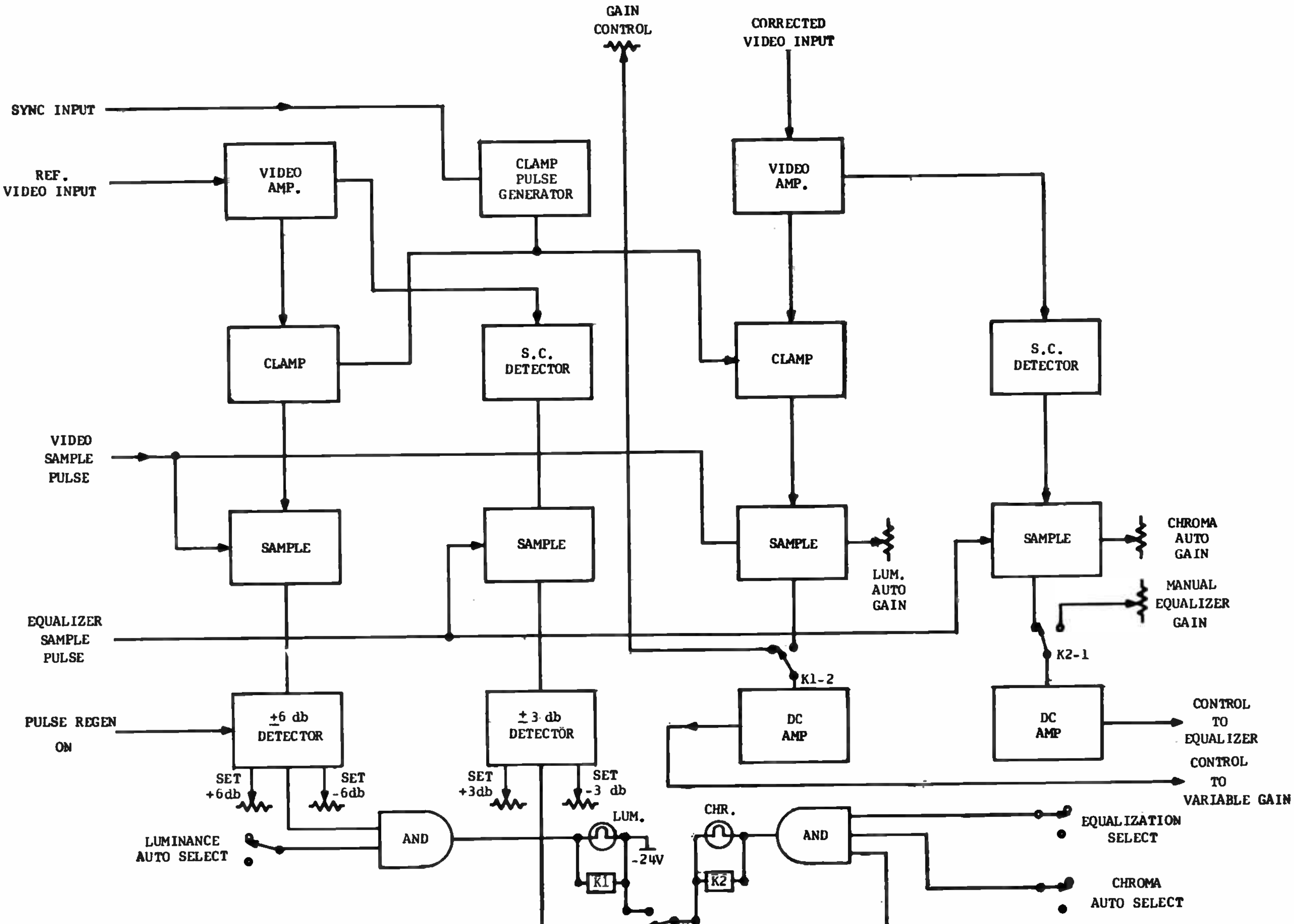


Fig. 15

AUTO CONTROL MODULE

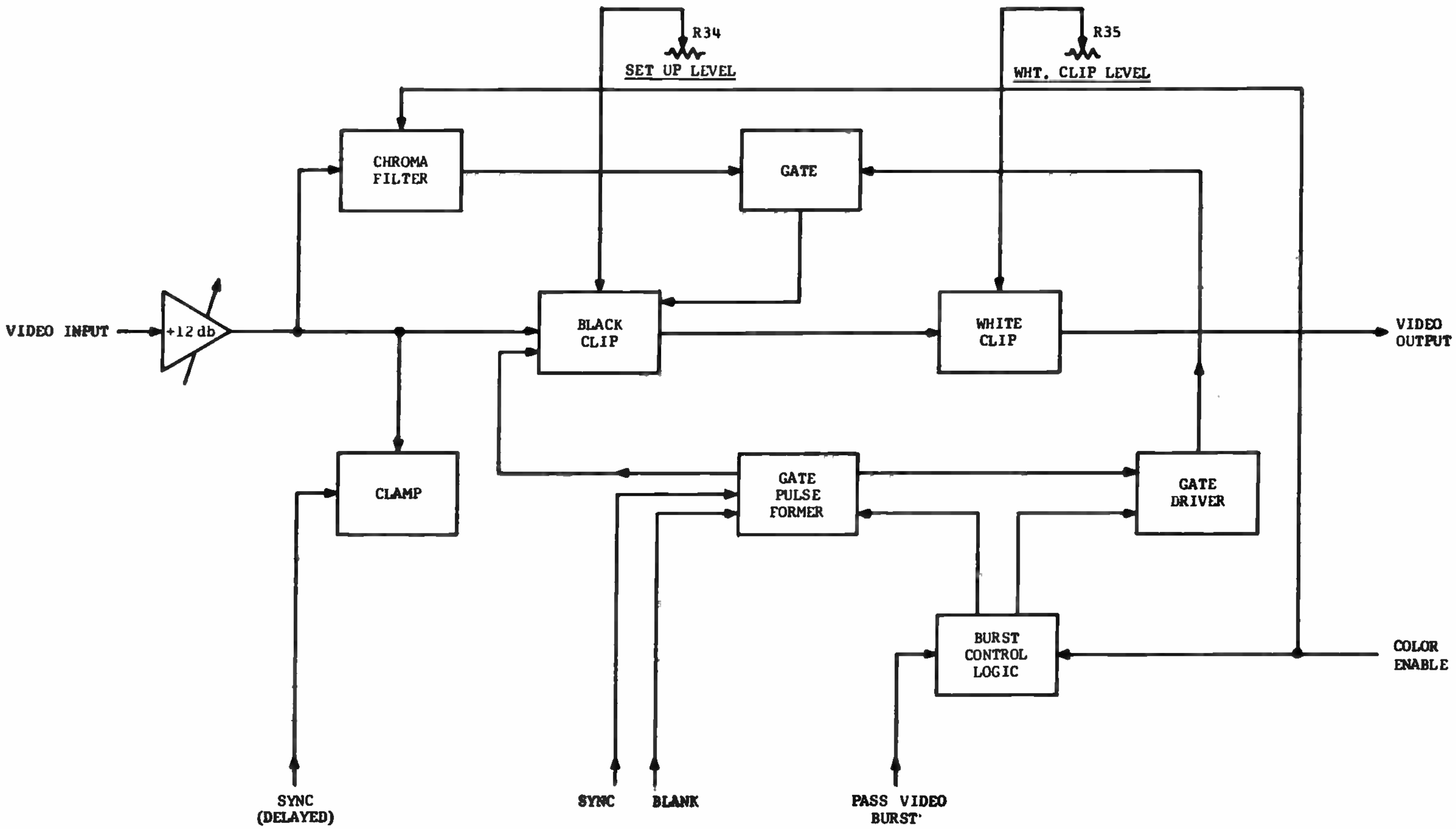


Fig. 16

VIDEO CLIPPER

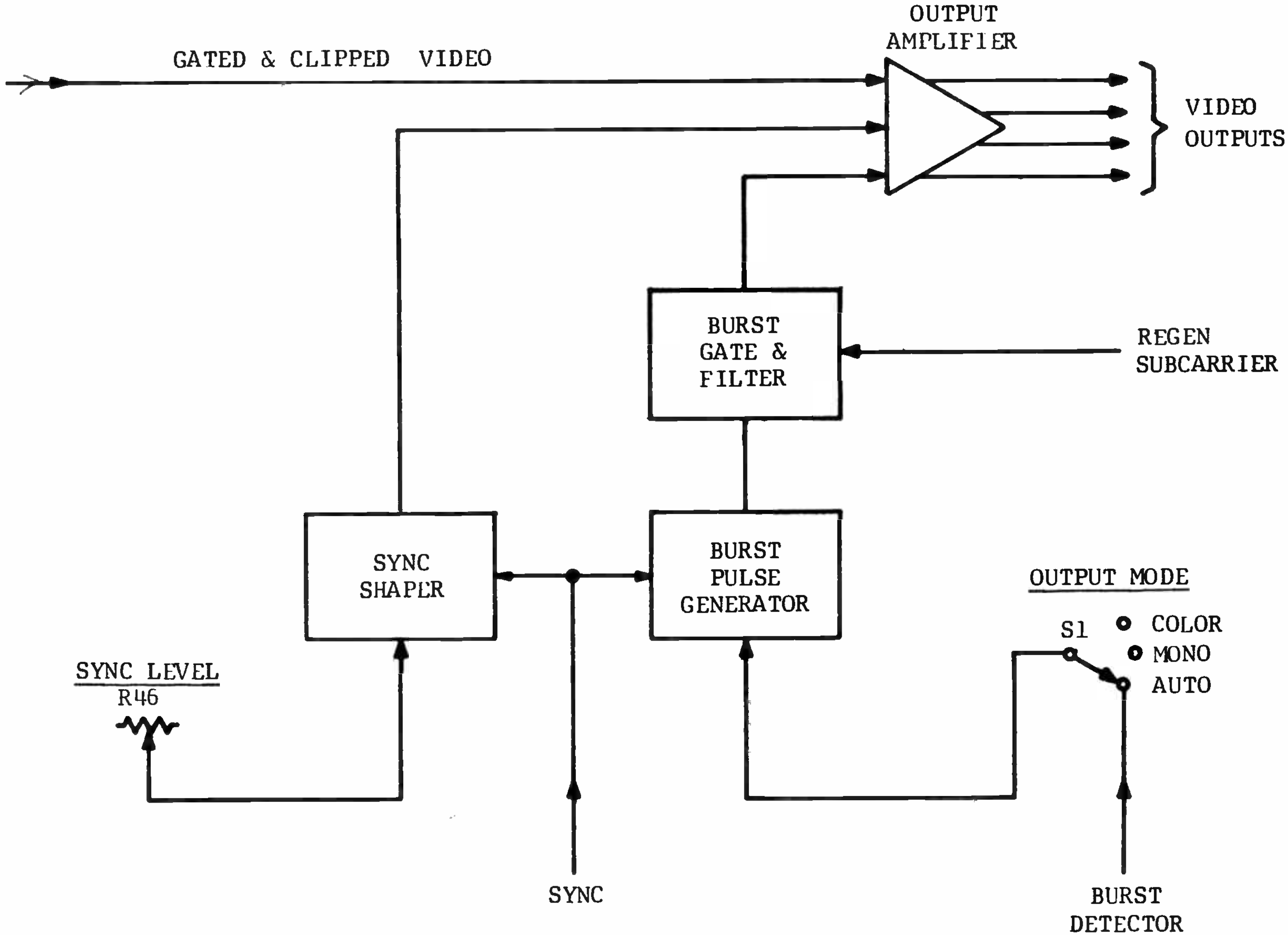


Fig. 17

OUTPUT AMPLIFIER

verts to manual control, with appropriate delays to minimize gain transients. A tally lamp is provided to indicate the proper operation of the circuit.

The automatic equalization circuitry operates very similarly to that of the luminance circuitry, except that interlocks are provided to ensure that the luminance control is operative before equalization takes place. In this way, large errors will be avoided if a non-standard video level is fed with the luminance reference absent. There is also a somewhat greater time constant in the equalizer circuit to reduce any tendency to instability under transient conditions.

The time constant in the luminance control circuit for a step change in level is about one second and in the equalizer circuit about three seconds. These values have been found to be optimum for network usage but are readily changed for other applications. The performance of the servo system is such that no gain variation is detectable between sample times. This performance is notable in view of the one in ten thousand duty cycle. The servos will hold the reference amplitudes stable within better than 0.1 db under all allowable conditions.

(6) Video Clipper: The video clipper module shown in Fig. 16 provides black-and-white clipping and video gating for the video signal with high precision and negligible distortion of the output signal. The black clipper is desensitized for color components in the COLOR mode of operation but the white clipper operates on all video components. By internal strapping, the white clipper can be arranged to clip luminance components only. The gating pulse used in this module is normally blanking, but under conditions of pulse oscillator unlock, widened sync is used. When burst regeneration is not used and the COLOR mode is selected, either automatically or manually, the gating pulse is notched to enable the original burst to pass directly through to the output and the burst adder is then inhibited.

(7) Output Amplifier: This module shown in Fig. 17 is essentially a combining amplifier to reform the composite video signal from some or all of the components, (i) Gated and Clipped Video, (ii) Reformed Sync, (iii) Regenerated Burst. The amplifier provides four outputs, of which one is selected by the bypass switch module to feed the output line. The outputs from this module are resistively split from a zero-impedance, AC-coupled driving point resulting in excellent isolation and freedom from stray signals. The module also contains the circuitry to produce a burst keying pulse from sync and to generate a correctly shaped and filtered burst from the burst keying pulse and CW subcarrier.

CONCLUSIONS

The unit described above has been extensively field tested and is currently in production for a number of users. The performance attained on a main network link has been most gratifying. In this application, the unit serves to correct sync, blanking, and burst timing errors and to remove the cumulative effects of dynamic gain on video levels. It will also be used to correct gain errors at network switching times. The automatic equalizer facility, in the main, only operates at switching points and when corrections are made to the transmission facilities. It has, however, exposed a fairly small random variation in high-frequency level previously unsuspected. The output, in all cases, has been judged to be most satisfactory. At the present time, the unit is undergoing field tests on the more difficult network branch feeds and off-air feeds. Again, the results leave little to be desired and the approaches taken in the design of this unit appear to come very close to the ideal complementary black box to upgrade a less than perfect circuit to a very satisfactory level of performance for television purposes.

tions of synchronizing signal and chrominance burst timings and waveforms at the input to a video tape recorder on the signal as reproduced. Varying burst amplitude at the input to a recorder is reproduced as constant burst amplitude; but the variations of the input burst amplitude are transferred to the amplitudes of the chrominance signal. Many correction circuits in recorders utilize the duration of the burst in their operation so that variations of burst duration can affect the reproduction of color. Incorrect timing of the burst with respect to the horizontal sync pulse also can affect the reproduction of color. It was pointed out, too, that unless a video tape recorder is carefully adjusted, level of the front porch less than that of blanking or duration of the front porch less than that called for in the FCC Rules may introduce distortion, although the reproduced colors may not be affected noticeably. Further investigation involving equipment performance measurements are scheduled to be undertaken by the SMPTE Video Tape Committee.

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In December a field test program was conducted in Chicago which consisted of a series of 16 closed-circuit tests involving predetermined variations in signal specifications and six off-air tests involving the three television stations. All 16 closed-circuit tests and all six off-air tests were repeated for each of five color slides on each of four test receivers. The receivers were new "top of the line" models from four leading manufacturers, all having automatic chroma control (ACC).

A set of five slides selected for the tests were representative of typical program material involving low-key, high-key, indoor and outdoor scenes—all including people and, thus, flesh tones. In all tests, the observers were shown, on one color receiver at a time, a "condition A" representing one set of conditions or one station for about three of four seconds and then "condition B" representing a different set of conditions or a different station for about the same length of time. Before observing the difference between "A" and "B" for each test, each receiver was adjusted by a representative of the manufacturer for optimum performance on condition "A" on an SMPTE slide. The observers then noted their opinion of the change in terms of the TASO 6-level evaluation scale.

In compiling the data, for each test, an average change rating was determined for each receiver based on the data for the five slides. Additionally, the data for all receivers were averaged for each test to arrive at a single rating for the test. A total of 5,139 ratings were processed. A video tape was made of all the tests for future reference and demonstration of the signal variations and of the off-air signals.

TEST RESULTS

The significant points which have been gleaned from an analysis of the field test data follows:

a. The laboratory tests generally confirmed the work of those who originally determined the allowable tolerance on signal specifications. A possible exception resulted from simultaneously combining the tolerances affecting hue and saturation. The applicable data will be turned over to the EIA Broadcast Television System (BTS) Committee for further investigation and subsequent recommendations of any revisions they deem necessary.

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JCIC Ad Hoc Committee on Color Television—A Status Report

K. Blair Benson, Chairman

For those who are not fully acquainted with the work of the Ad Hoc Committee on Color Television, before proceeding with a report on the current status, a brief review of the organization and initial activities will be of interest.

BACKGROUND

At the suggestion of the SMPTE, a meeting of the Joint Committee on Inter-Society Coordination (JCIC) was called in June last year to determine the most effective way to deal with the problem of improving the uniformity of color as observed on home television receivers. The JCIC, representing the Electronic Industries Association, the Institute of Electrical and Electronics Engineers, the National Association of Broadcasters and the Society of Motion Picture and Television Engineers, agreed that an ad hoc committee should be set up to (a) examine the entire television system from the original scene through all equipment to the picture viewed in the home, (b) determine the origin of significant deviations in color in the received picture, and to (c) allocate to existing industry organizations questions for further investigation and resolution. It further was agreed that administration of the ad hoc committee would be the responsibility of the SMPTE.

ORGANIZATION

Subsequent to the meeting, a committee was appointed consisting of representatives from the JCIC member organizations, the AT&T and the NCTA. In addition, observers were invited from the FCC, the CBC, and the Canadian Telecasting Practices Committee. The combined knowledge of the membership covers all areas of television—network as well as non-network broadcasting, transmission, broadcasting and receiving equipment manufacture, film production, and CATV.

INITIAL ACTIVITY

Since September, five meetings have been held, the first two primarily for the purpose of organization and to refer problems which could be singled out initially without any further study to other standing committees for investigation and resolution. As a result of these meetings, the following steps were taken:

A. The SMPTE Television Committee was urged to accelerate their investigation of color film characteristics suitable for television and the development of appropriate Recommended Practices intended to promote more uniform and acceptable television quality.

B. The SMPTE and EIA were requested to investigate standardization and tighter control of studio color monitor setup and the characteristics of picture tube phosphors.

C. The SMPTE Video Tape Committee has been requested to investigate variation in video tape equipment performance relative to video signal specifications.

D. The IEEE was requested to establish liaison between their Broadcasting and Receiver committees for the purpose of developing test signal standards suitable for overall system performance evaluation and control. In addition, liaison is being established with a similar industry committee in England in order to benefit from their findings.

E. A task group was appointed to develop questions on camera colorimetry warranting investigation.

F. A second task group was organized to arrange laboratory and field tests to determine the effect of video signal waveform variations, within approved specifications, upon receiver performance and variations in performance among several transmitters in one city.

CURRENT STATUS

COLORIMETRY INVESTIGATION

The colorimetry task group, in short order, progressed to the point where a specific program of investigation could be outlined. Accordingly, this was referred to the SMPTE, and the Society in turn appointed the task group chairman to head up a new SMPTE working committee to continue the investigation. This has resulted in the development of a computer program which, in turn, will be used to specify the appropriate idealized camera colorimetric performance to provide reproduction in accordance with NTSC specifications. In addition, it is planned to suggest instrumentation suitable for measuring the input and output colorimetric characteristics.

COLOR FILM INVESTIGATION

The task group on motion picture films reported the results of subjective observations and objective measurements on more than 200 16mm and 35mm motion picture films which had been used for broadcasting. These films included program material, news shots, and commercials. In brief, the 35mm films varied less in color than did the 16mm films; and program and news material varied less than did the commercials. With respect to the commercials, it was concluded that of 180 samples in all, there were 30 that would not look good to any observer whether viewed by television or by direct project. The picture quality of another 40 films would be considered questionable by most observers. This whole problem has been referred to the Engineering Committees on Color and on Television of the SMPTE for their study.

VIDEO TAPE INVESTIGATION

The task group on video tape recording reported a study of the effects of variations of synchronizing signal and chrominance burst timings and waveforms at the input to a video tape recorder on the signal as reproduced. Varying burst amplitude at the input to a recorder is reproduced as constant burst amplitude; but the variations of the input burst amplitude are transferred to the amplitudes of the chrominance signal. Many correction circuits in recorders utilize the duration of the burst in their operation so that variations of burst duration can affect the reproduction of color. Incorrect timing of the burst with respect to the horizontal sync pulse also can affect the reproduction of color. It was pointed out, too, that unless a video tape recorder is carefully adjusted, level of the front porch less than that of blanking or duration of the front porch less than that called for in the FCC Rules may introduce distortion, although the reproduced colors may not be affected noticeably. Further investigation involving equipment performance measurements are scheduled to be undertaken by the SMPTE Video Tape Committee.

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b. Receivers may be affected by burst timing duration and amplitude. Variations among receivers utilizing different circuit designs reflected the different trade-offs made by the several manufacturers. This problem will be referred to the EIA receiver committee and the IEEE Broadcast and Television Receiver Group for consideration of the design problem, and to the EIA BTS Committee for consideration of the need for revised standards.

c. The test which included transmitters and propagation paths showed definite variations in color which, while not seriously objectionable, were quite noticeable. The cause of the variations, whether transmitters, propagation, or receiver was not readily determined. Thus, additional tests are planned to attempt to locate the causes of these variations.

OTHER INVESTIGATIONS

The SMPTE, CCIR and EBU are actively studying film transmission and plan to propose recommended practices for greater color uniformity, as well as higher quality.

CONCLUSION

From the foregoing, it is apparent that the disturbing lack of uniformity among color television pictures is being attacked from many sides. Most encouraging is the enthusiasm and energy of those engaged in the study. Thus, although the task is a difficult one embracing all phases of television, broadcasting and reception, significant progress may be expected.

The Importance of Color Temperature*

Salvatore Bonsignore
CBS Television Network
New York, N.Y.

We at the CBS Television Network were prompted to make the demonstration film to be shown when it became clear that color temperature was not such a fearsome problem in color television lighting as tradition would have us believe. Color film, it is true, gives best results at the lowest light level when exposed to illumination of the color temperature for which it was designed. Color correction filters can be used but with some loss in film speed when the lighting color balance is too far off.

Color television cameras, on the other hand, can be adjusted to provide good results over a wider range of illumination color balance. Color temperatures ranging from 2700 degrees Kelvin to 18,000 degrees Kelvin can be accommodated by electronic balance adjustment. In both film and television color lighting the various sources used on a scene, of course, must be held within certain tolerances whatever the nominal color temperature being used. It will be noted in the film that 3,000 or 3100 degrees Kelvin is a common color balance used in studio operation, usually achieved by running so-called 3200 degree Kelvin sources at voltages reduced slightly by dimmer adjustment.

I ask your indulgence with respect to the quality of the film accompanying this presentation. This is a film-recorded transfer from the video tape record of the demonstration and because it would be extremely difficult and time-consuming to adjust properly enough color monitors to show the tape to an audience of this size, we chose to use film instead. Although there is some sacrifice in resolution and fidelity, we have viewed the film alongside the tape and can assure you that the comparative values relating to color balance, with which we are concerned, show up fully in the film projection. (Following is the film narration).

THE NARRATOR: CBS presents this program in color. In the demonstration to follow, we will attempt to show the importance of color temperature. For purposes of the demonstration, we have selected three girls and placed each in front of a single background panel. The panel on the right approximates primary red, the one in the center primary blue and the one at left primary green. The girls were selected as representing a wide range of skin tones. Their costumes are neutral to avoid reflecting colored light onto their faces.

Now, before going further, let's compare the color of the lights we are going to use. Beginning with a curve representing 2700 degrees Kelvin, successive curves show the increase in spectral energy of tungsten filament lamps with each 100 degree increase in color temperature. As indicated by the color bars, the left por-

*Reprinted from the official transcript. Not edited by author.

tion of the curve shows a quantity of blue energy, the middle portion green and the extreme right portion shows red. The wattage of the lamps is identical but the size of the filaments produce different color temperatures.

Please note how spectral energy increases with increased color temperature. The term "color temperature" refers to the spectral energy produced by a black body radiator at a given temperature. Since incandescent tungsten filaments resemble such radiators, the term is applicable. Nontungsten light sources are said to have simulated or apparent color temperatures.

As we go back to our first curve representing 2700 degrees and then to the 3500-degree curve, please note how the blue energy of the 3500-degree curve is four times greater but the red energy only double. The conclusion is obvious. Lamps of higher color temperature produce bluer light.

A color temperature of 3400 degrees was used to light the subjects in the upper picture and 3100 in the lower. Both upper and lower shots were taken with the same identical camera and the same identical camera adjustments and dubbed into this split-screen presentation later. Note the bluer skin tones above and the yellower below. In succeeding comparisons the color temperature of the upper picture will be changed but the lower kept at 3100 degrees.

Color temperature of the upper picture has been reduced to 3200 degrees. The girl here with the lightest skin tones still looks a little bluer above and a little yellower below. The difference between 3200 degrees above and 3100 degrees below is not spectacular. Reducing the top picture to 3,000 degrees and still maintaining 3100 below, the effect on skin tone is now reversed. The faces above are now slightly yellow and those below slightly blue. Remember, the shot below remains unchanged. It is exactly as you saw it the first time. This would indicate that you can't tell color temperature without something to compare it with.

Now we have further reduced the upper picture to 2900 degrees and it is looking more yellow, while the picture below looks bluer. The difference in color temperature is 200 degrees and clearly discernible. May we remind you that there has been no change in the lower picture. Lighting levels in both pictures were kept exactly the same.

As we further reduce color temperature above to 2800 degrees, the difference becomes more marked. Please note that all lighting, key, back, cross, modeling, and base, is at the color temperature specified. With changes in color temperature, lighting levels on the subject were maintained by changing the lamp-to-subject distances.

Color temperature is now 2700 degrees in the upper picture and skin tones are becoming quite yellow, at least by comparison with the lower shots, which, as you recall, looked yellow compared with 3400. Since this test demonstration was conducted, CBS has reduced its color temperature standard from 3100 to 3,000 degrees. This provides greater head-room in achieving lighting balance.

In this last step, we have reached 2600 degrees in the upper picture. The difference in appearance of skin tones illuminated by 2600 and 3100 is quite wide. 2600 degrees appears to be the lowest color temperature acceptable for broadcast purposes.

We are combining several different color temperatures in one setting in this next sequence. The girl in this instance serves only to show that the camera is properly adjusted at 3100 degrees to reproduce good skin tones.

Having satisfied ourselves that it is, we pan now to six manikin heads placed in front of neutral gray backings flanked by the same colored props. In fact, they are identical in every respect except the color temperature of the lighting. Color temperature ranges from 2600 to 3200 degrees Kelvin. This is 2600 in closeup in steps of 100 degrees. Next to the left is 2700 and still further to the left 2800. Top right is 2900. These are not significant changes.

Next to the left is 3,000. Still no significant change. Now we jump 200 degrees to 3200, a rather obvious change. From this we note changes of 100 degrees are not significantly noticeable and, therefore, quite acceptable. On the other hand, changes of 200 degrees are obvious and probably unacceptable. The conclusion is that a tolerance of plus or minus 100 degrees is quite acceptable. Now just to be sure the adjustment of the camera has not changed, we pan back to the live models. It hasn't.

In this sequence we will mix fill light of one color temperature with the key and back light of another. Here on the left fill light is 3400 degrees and on the right 3100. All other lighting, both left and right, is 3100. Of light illuminating the girls' face, fill is contributing only 33 per cent. With this monor contribution, color temperature tolerances for fill light in particular may be less stringent than indicated generally in the previous sequence.

May we remind you that the fill light on the girl in the left-hand shot is 300 degrees higher than the rest of her lighting. Although this produces a slightly cooler or bluer skin tone, it does seem acceptable. The fill light on the left has now been reduced to 2100 degrees. All other lighting in both left- and right-hand shots remains unchanged at 3100. With the fill on the girl's face in her lefthand shot 200 degrees lower than the rest of her lighting, a slightly yellowish effect is barely perceptible but seems well within the limits of acceptability, even in this closeup in which her face occupies about 20 per cent of the total screen area.

The effect is even less perceptible in this longer shot in which the facial area is reduced to about 10 per cent. Fill light on the left has now been reduced to 2600 degrees. The color temperature of all other lighting, in both left- and right-hand shots remains unchanged at 3100. Although this difference of 500 degrees is clearly discernible, it may be within acceptable bounds, depending upon the closeness of the closeups. Certainly there would be no problem in the areas where skin tones are absent. May we point out that both left- and right-hand pictures were shot with the same camera adjusted exactly the same and later re-recorded into this split-screen presentation for comparative evaluation.

Color temperatures ranging from incandescent to sunlight can be accommodated through the adjustment of video control. A color temperature of 3100 degrees is presently used in lighting the lower picture. The upper picture, employing a color temperature of 3400, is being shot with a camera adjusted for 3100. With the higher color temperature, the shot above looks a little cold or blue as compared with the lower picture, which looks a little warm or yellow. However, by readjusting the video controls for 3400 degrees, we should be able to make the upper picture match the lower. Although these are time-consuming adjustments, we will undertake to make them in one continuous take so that you may observe the process.

We will accelerate the procedure somewhat and, therefore, it will not be perfect but it should be good enough to illustrate the principle. May we suggest you look carefully at the girl before we begin readjustment of the video controls. The color temperature of the illumination on the Gray scale is 3400 degrees. Each of the three primary color channels of the camera are being set so that they have equal amplitudes at all iris positions.

With the camera now adjusted for 3400 degrees, please note the improvement in the match of the upper and lower shots of the girl. The closeups provide a little better comparison. The color temperature of the lower shot remains 3100 degrees, exactly as it was before. The picture above has now been reduced to 2800. With the lower color temperature, the picture above tends to look a little warmer or yellower compared with the picture below, which now looks cooler or bluer.

The appearance of the two pictures has now been completely reversed, even though the shot below has not been changed. We will now attempt to readjust the camera taking the upper picture from 3100 degrees down to 2900 degrees. May we suggest you observe the girl in the upper picture once more before the readjustment takes place.

We have an illumination of 2900 degrees on the Gray scale test pattern and we are readjusting the three primary channels for equal amplitudes at all iris settings. Now that we have approximated the adjustment for 2900 degrees, the shots above and below are a much closer match. Again, the closeups provide a better comparison.

The creative use of color in lighting is demonstrated in this last sequence, which is a clip from Repertoire Theatre. The girl in the glass enclosure is lighted with colored light. The color is changed to create an atmosphere of fantasy. The walls and floor over which the dancer moves are painted with colored light.

The rules governing color temperature, which we have demonstrated in previous sequences, should not be applied to inhibit creative illusion. Here the effect is more important than reproducing accurate skin tones. In the wide movements about the set the dancer goes through areas keyed in different colors. Rather than realism, the object here is surrealism.

(End of movie.)

A New Color Camera to Meet Today's Operational Requirements

Anthony C. Cuomo, Manager of Engineering
Philips Broadcast Equipment Corp.

Today's trend toward on-the-spot live color broadcasting of major events, such as the Olympic Games, Presidential Conventions and Inaugurations, has pointed up the need for a highly mobile studio type performance color camera. See Figs. 1, 2, and 3. Today the PC-70 is best suited to satisfy this need because of its small size and light weight. Further reduction would, of course, be welcomed, particularly in reducing the size and weight of the camera cable. This would provide increased programming flexibility and substantial reduction in operating costs.

Approximately 2 1/2 years ago, during the peak of the PC-70 production, an engineering study program was initiated to develop the system for a new generation color camera. Various approaches were investigated, and approximately 1 1/2 years ago the development of the hardware was started. The system design formulated gave prime consideration to the requirement for a compact, rugged, light weight camera that would be highly mobile and still maintain the high performance and operational features of the studio type camera. This was accomplished in the PC-100 Plumbicon Color Television Camera Chain. The PC-100 is the fourth generation of the Philips Plumbicon Camera and it represents a radical new approach as compared to the designs of the previous cameras. It's small size and light weight was made possible by improved circuit designs and new state-of-the-art components and construction techniques. The following items were of particular importance in reducing the size and weight of the PC-100 System.

1. A one-inch broadcast quality Plumbicon
2. A small size, low weight lens with elements of higher light transmission
3. Specialized thick film hybrid and integrated circuits
4. Computer type digital control circuits
5. Multi-layer printed circuit cards
6. Multiplexing techniques enabling the use of triaxial cable

As can be seen in Fig. 4, the PC-100 camera head has a low silhouette. It uses three of the newly developed broadcast quality one-inch Plumbicon tubes. It has a removable lens and viewfinder and uses magnesium castings to give a light weight, rugged design. The camera can be connected to its control unit through one mile of lightweight triaxial cable. This camera cable carries DC power to the camera, along with three channels of multiplexed information. The multiplexed information includes encoded video, monitor video, external viewfinder video, intercom, program sound, tally, and 120 channels to camera control information. The studio

Fig. 1

Fig. 2

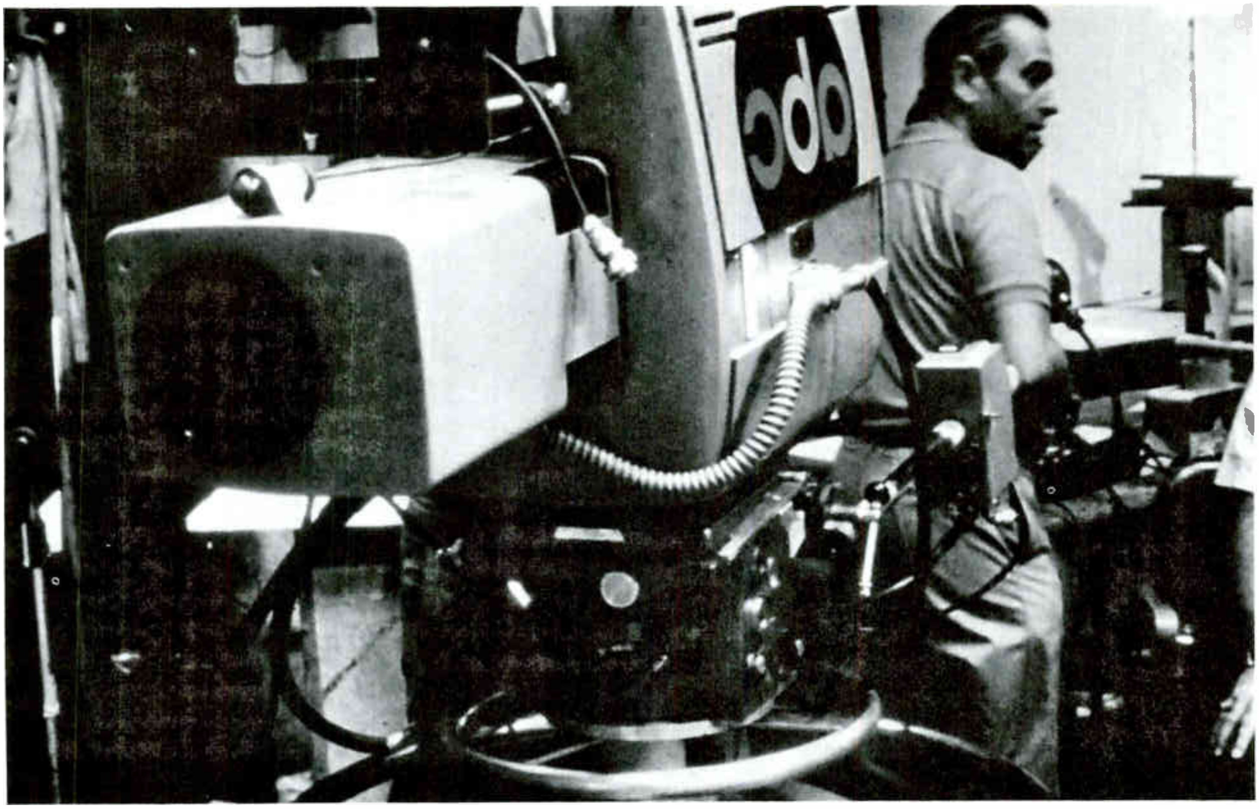
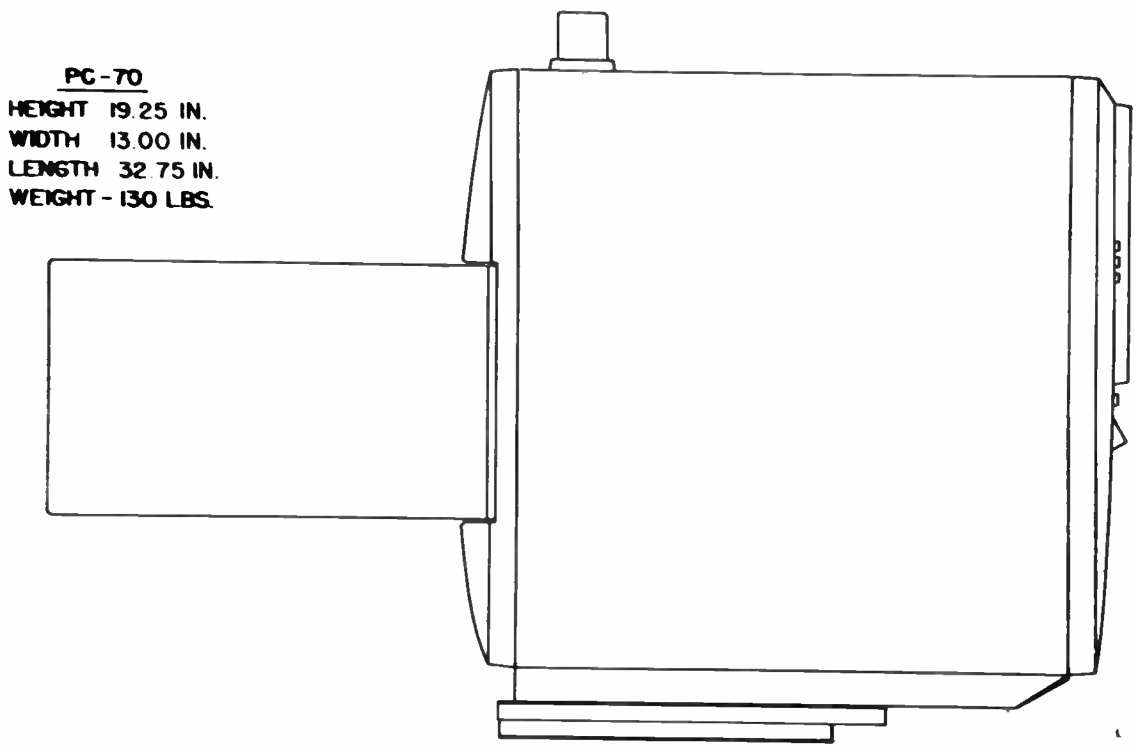


Fig. 3

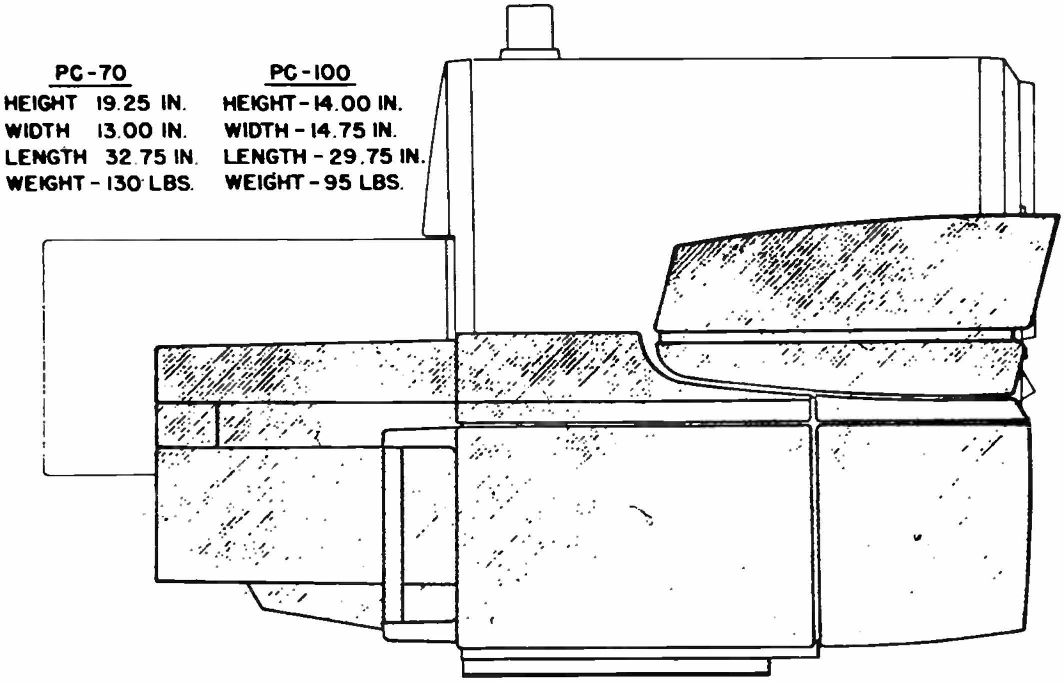
Fig. 4

Fig. 5



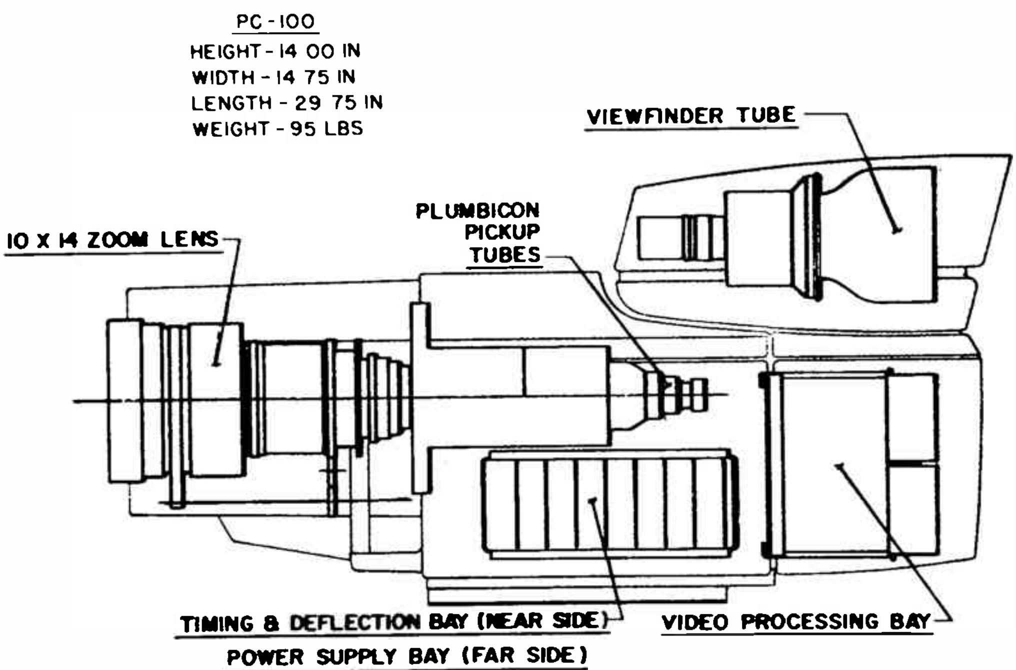
COLOR TELEVISION CAMERA

Fig. 6



COLOR TELEVISION CAMERA

Fig. 7



(INTERIOR PC-100)

Fig. 8

type Camera Control console has mounted in it a picture monitor, waveform monitor, registration panel, operations panel and the electronics unit. Mobile transit cases are also available (Fig. 5). One case houses the monitors and the other, of equal size, contains the registration panel, operations panel, and electronics unit. The small size and light weight of the PC-100 can be appreciated by viewing Figs. 6 through 11 which are overlays of the PC-100 on to the PC-70.

Fig. 12 shows an exploded view of the camera body. The major assemblies of the camera head can be seen, which include the main assembly, removable lens, viewfinder, and focus drive pan handle assemblies. The lens and viewfinder are removed by lever activated "fire hose" type clamps on the camera body. Lens drive rods are internal, and automatically mate into spring loaded sprockets. The "electronics" is packaged into three major card bay assemblies. These include the deflection and timing bay, camera main bay, and the power supply bay. Video preamplifiers and Plumbicon filter networks are assembled on top of the power supply and deflection bays. The electronic bays are removable assemblies, and are interconnected through pendent type cable harnesses.

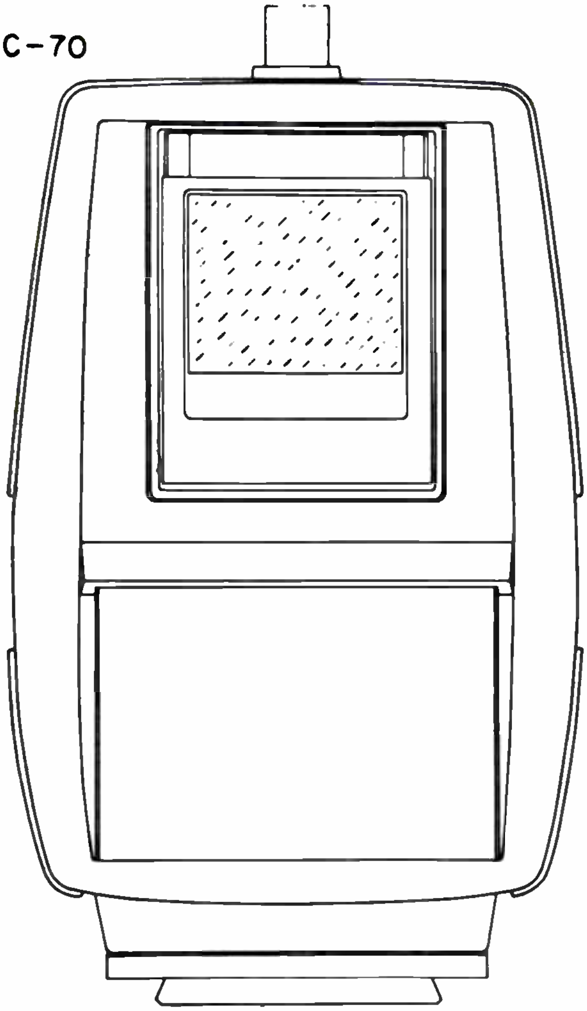
The lens design (Figs. 13, 14, and 15) is an integral part of the PC-100 system design. It is optically designed for the one-inch Plumbicon format with an f stop of 1.8 and a zoom range of 14 to 140mm. Mounting arrangments have been simplified, and the insertion of range extenders is easily done through an access port in the lens cover. Provisions have been made for both manual and servo drive mechanisms. Tally lights are provided, which can be seen from all angles including when looking directly into the lens. The lens weighs approximately 30 pounds.

The lens drive mechanisms are internal. Fig. 16 shows the details of both the zoom and focus controls. One of three zoom rates can be selected by means of a lever arm which protrudes from the base of the camera. A high inertia flywheel is provided to give a fine control of the lens zoom element. A rate control is also provided on the manual focus drive. The focus drive control is part of the pan bar and a knurled sleeve activates a 3-position gear shift for focus rate. The focus pan bar is easily removable during transport. The viewfinder (Fig. 17) uses a 7-inch diagonal tube and has 600-line resolution with a brightness of over 150 foot lamberts. It has a separate 16KV regulated high-voltage supply and operates directly from 100v DC from the camera. An electronic zoom indicator is superimposed on the video signal on the top of the picture. The viewfinder is rotatable, tiltable and can be removed. It weighs approximately 15 pounds. Fig. 18 shows the camera body with lens, viewfinder, and focus pan bar removed. This main assembly weighs approximately 55 pounds and, therefore, can be easily transported by one man.

The RGB assembly (Figs. 19 and 20) is designed around a rugged "spider" casting, which gives long term optical stability. This main casting houses a remotely controllable four disk filter wheel, two overlapping slide filter holders, the well-known beam-splitting prism block, and three one-inch precision wirewound Plumbicon yoke assemblies. Linear matrixing is included in the camera system, enabling the use of a more efficient color beam-splitting prism. Yoke rotation and focus is accomplished by separate knurled shafts as shown.

A version of the one-inch Plumbicon (Fig. 21) has been developed for professional broadcast applications, with modulation depth of 35% at 400 lines. In addition, other features such as rear loading, low capacity target lead and ceramic centering ring have been added. Target capacity is substantially lower than the standard 30 mm Plumbicon due to the smaller target surface and shorter target lead length. As can be seen in Fig. 21, a small tab is used rather than the conventional contact

PC-70



COLOR TELEVISION CAMERA

Fig. 9

COLOR TELEVISION CAMERA

PC-70

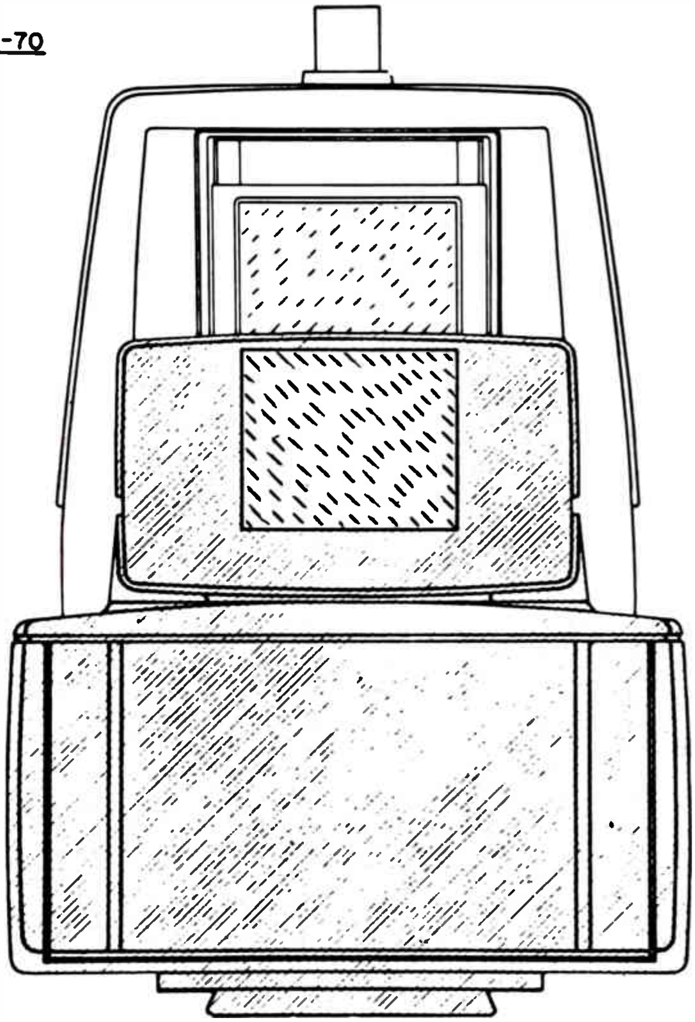


Fig. 11

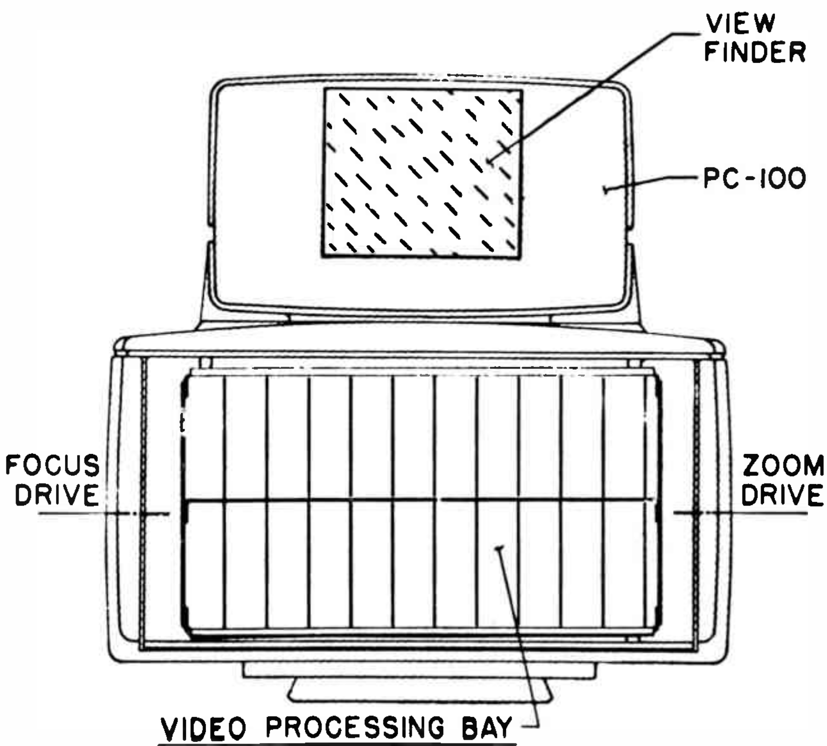
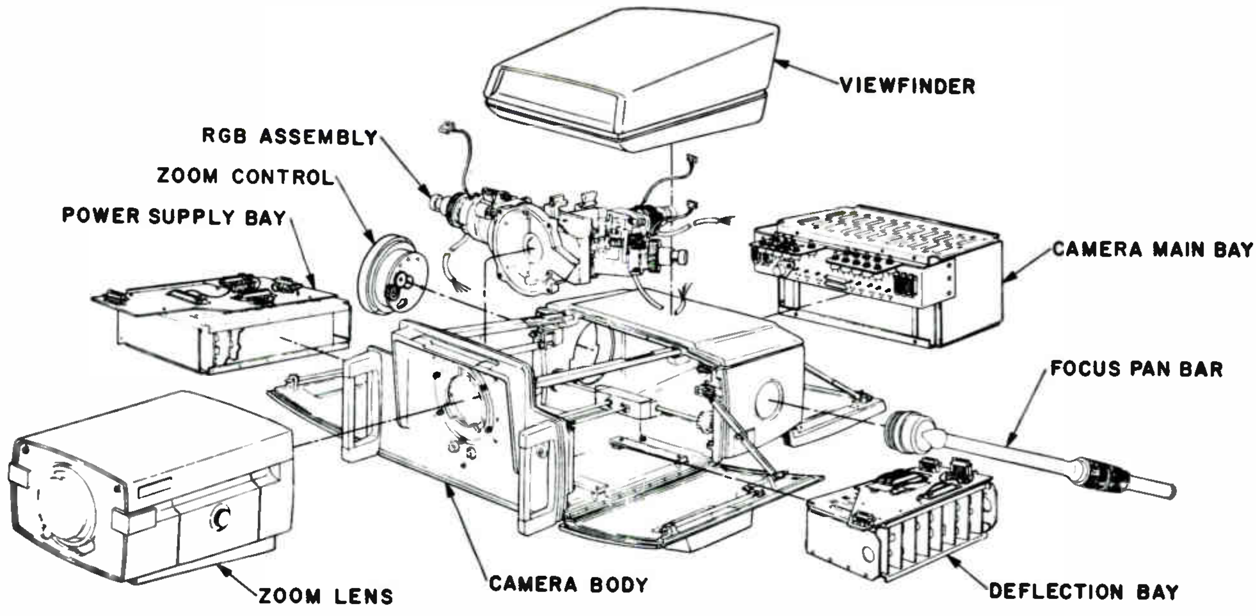


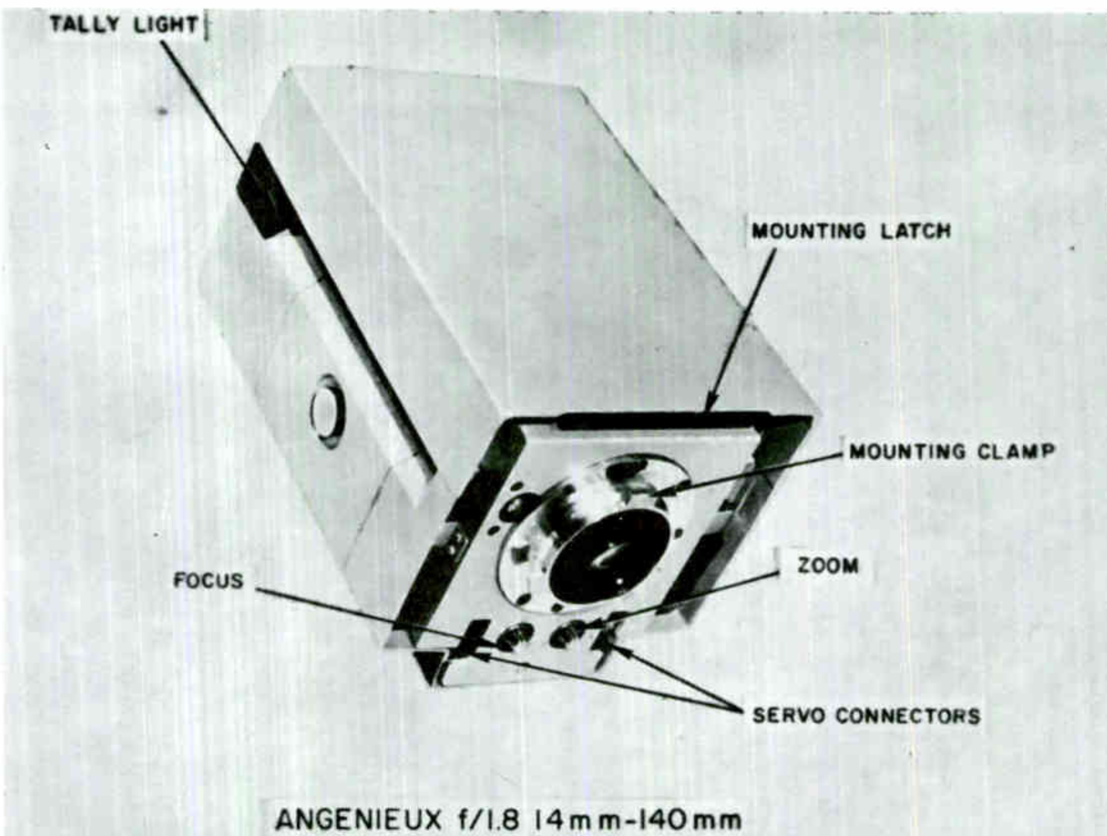
Fig. 10

(INTERIOR PC100)



PC-100 CAMERA (EXPLODED VIEW)

Fig. 12



ANGENIEUX f/1.8 14mm-140mm
ZOOM LENS

Fig. 13

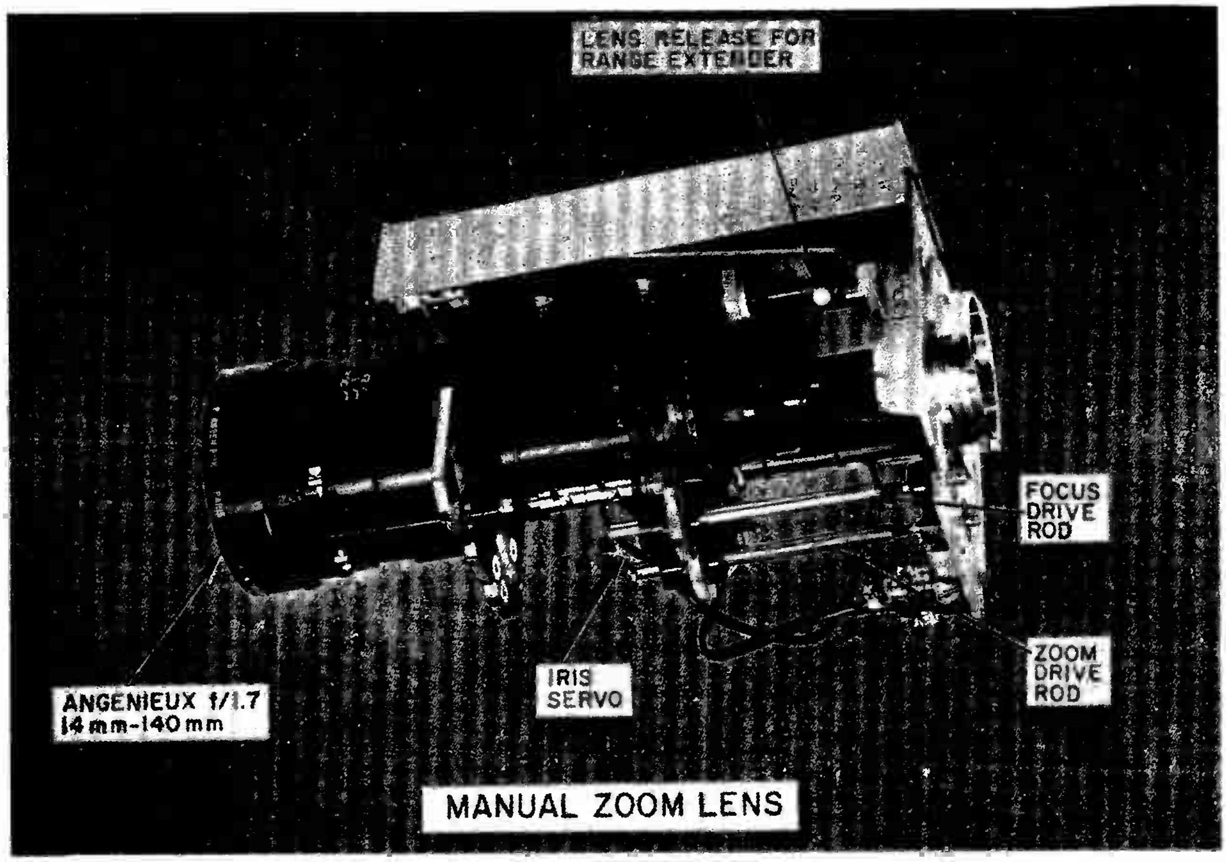

LENS RELEASE FOR
RANGE EXTENDER
FOCUS
DRIVE
ROD
ZOOM
DRIVE
ROD
IRIS
SERVO
ANGENIEUX f/1.7
14 mm-140 mm
MANUAL ZOOM LENS

Fig. 14

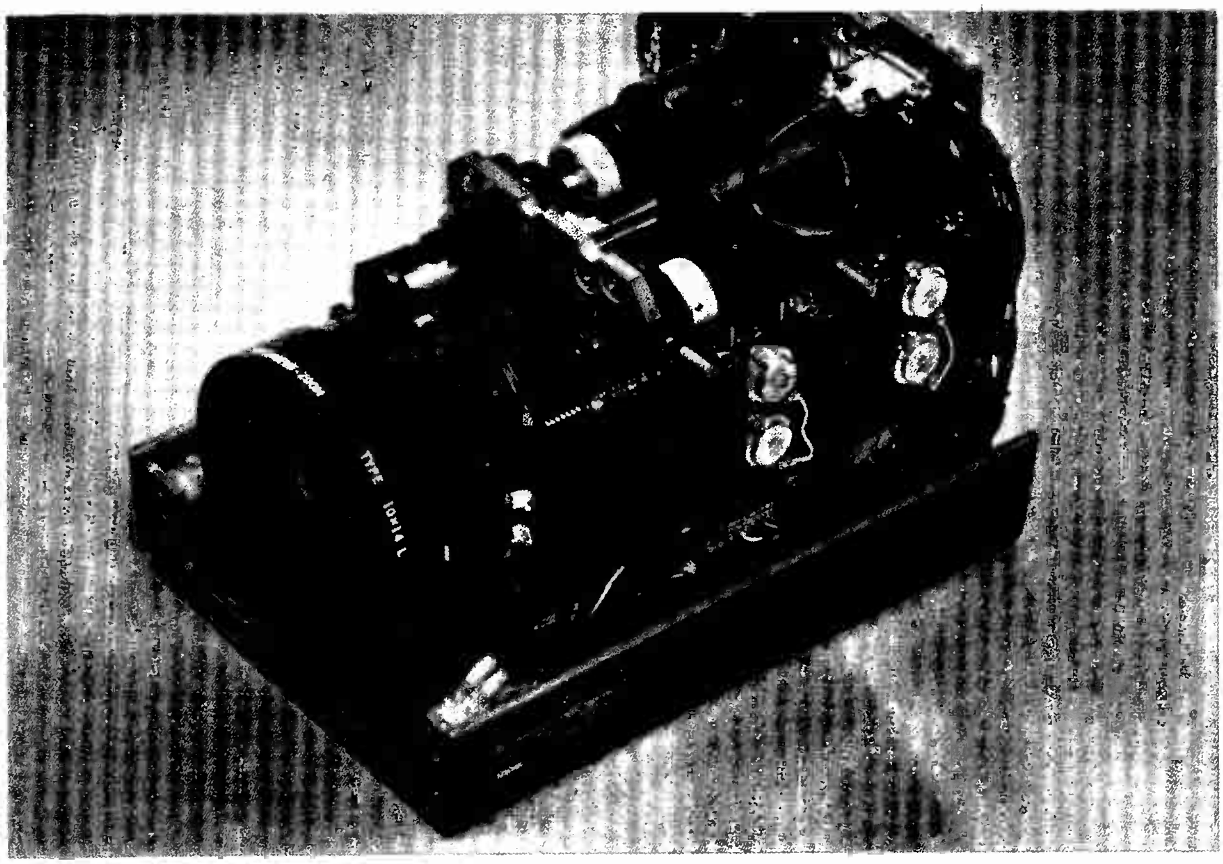


Fig. 15

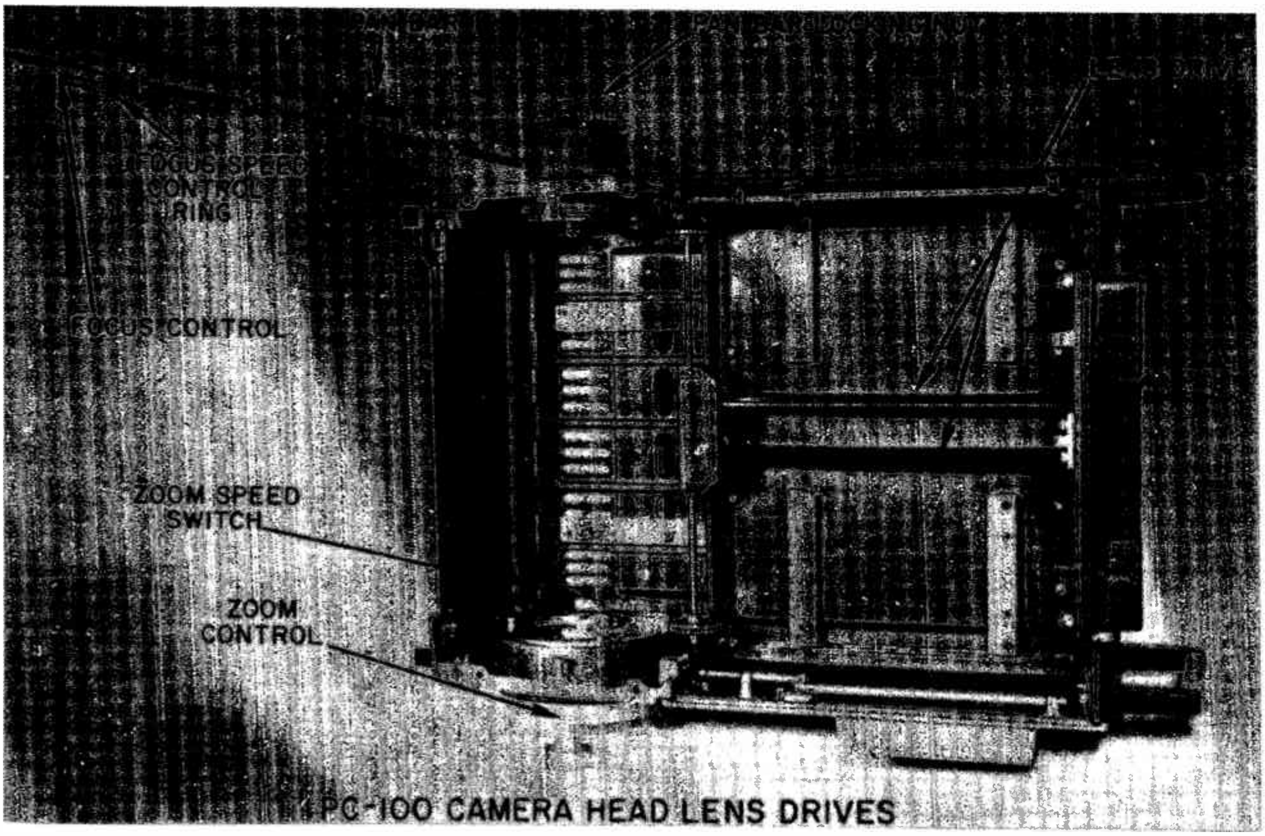

FOCUS SPEED
CONTROL
RING
FOCUS CONTROL
ZOOM SPEED
SWITCH
ZOOM
CONTROL
PC-100 CAMERA HEAD LENS DRIVES

Fig. 16

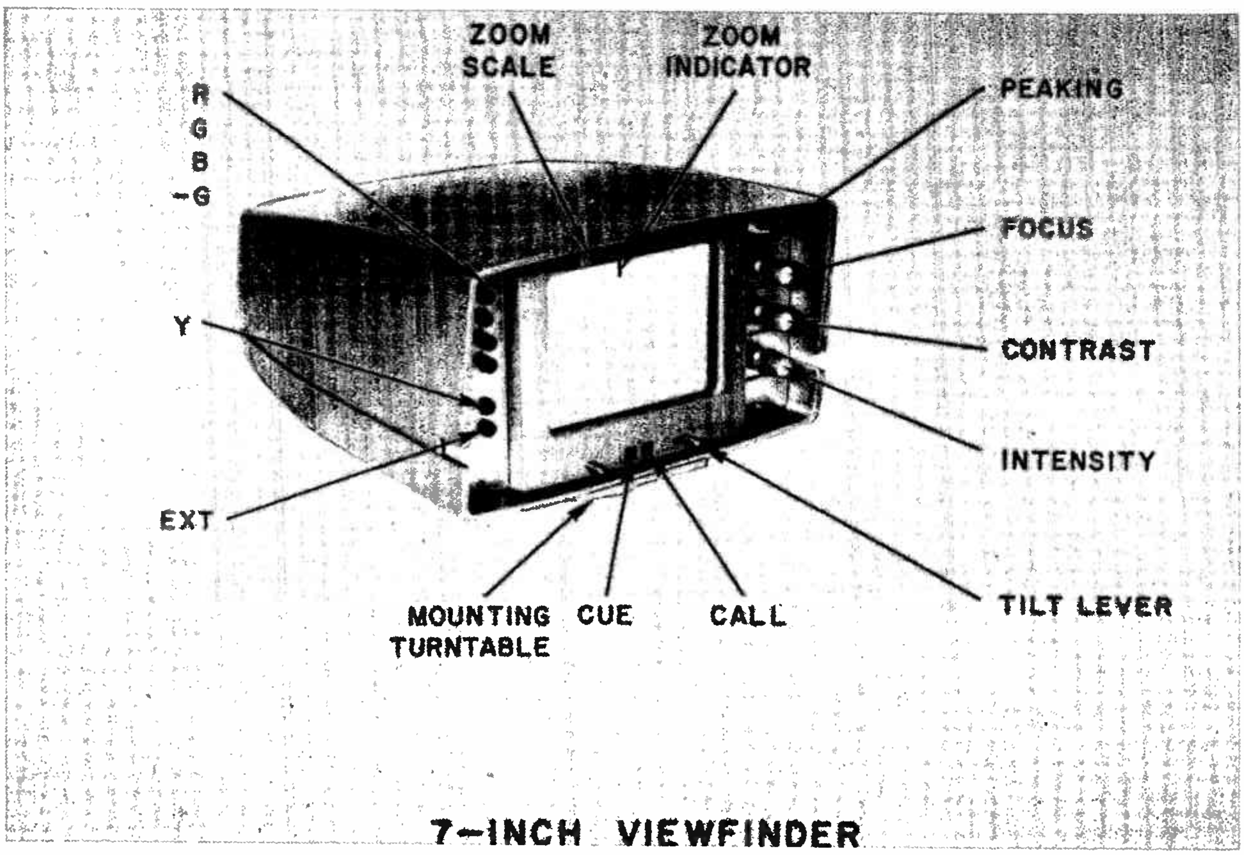
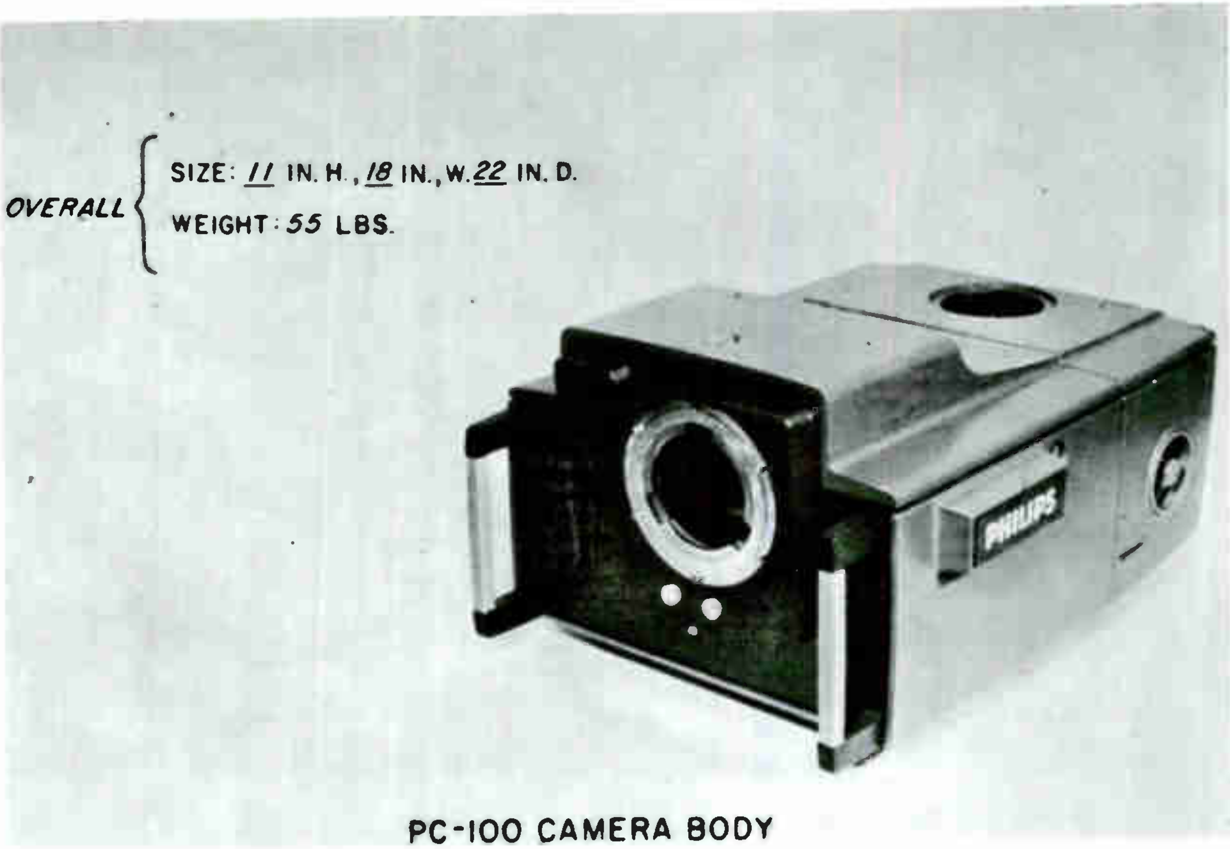
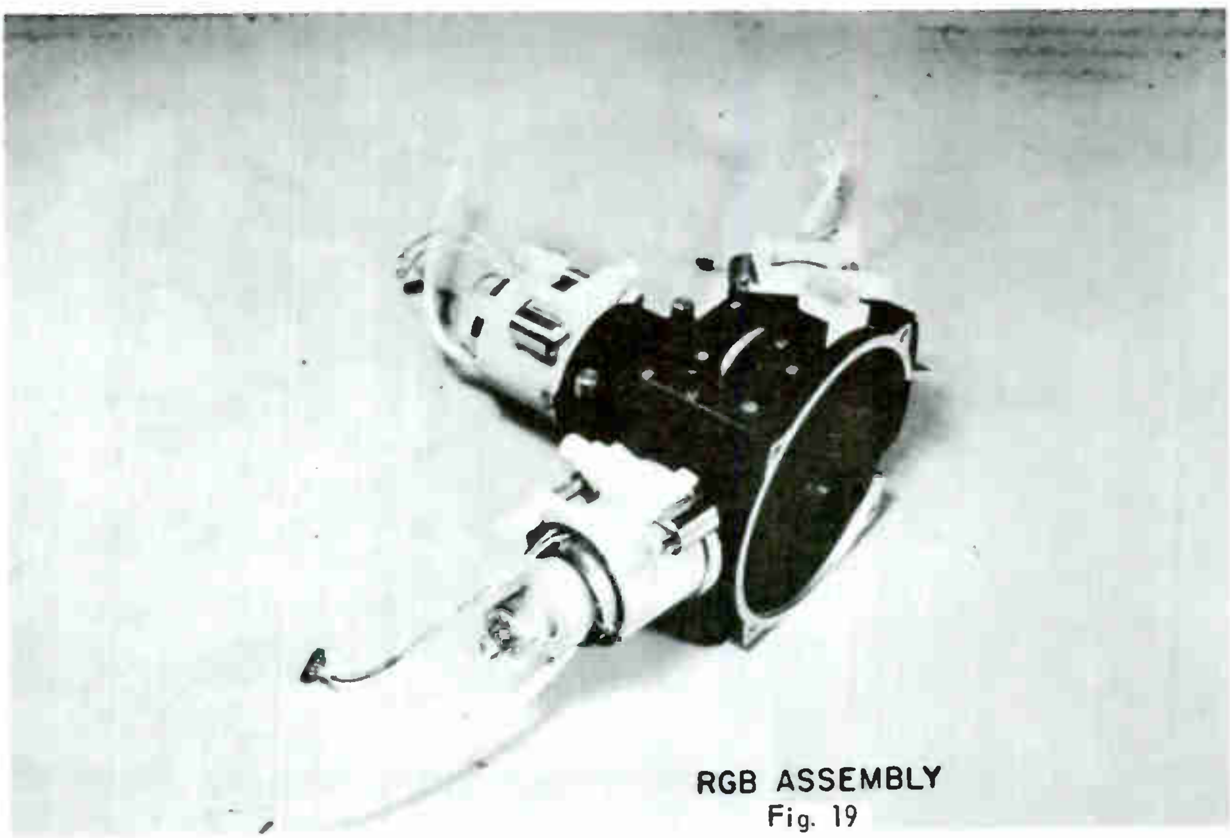

ZOOM
SCALE
ZOOM
INDICATOR
PEAKING
R
G
B
-G
FOCUS
Y
CONTRAST
INTENSITY
EXT
MOUNTING
TURNTABLE
CUE
CALL
TILT LEVER
7-INCH VIEWFINDER

Fig. 17



PC-100 CAMERA BODY

Fig. 18



RGB ASSEMBLY
Fig. 19

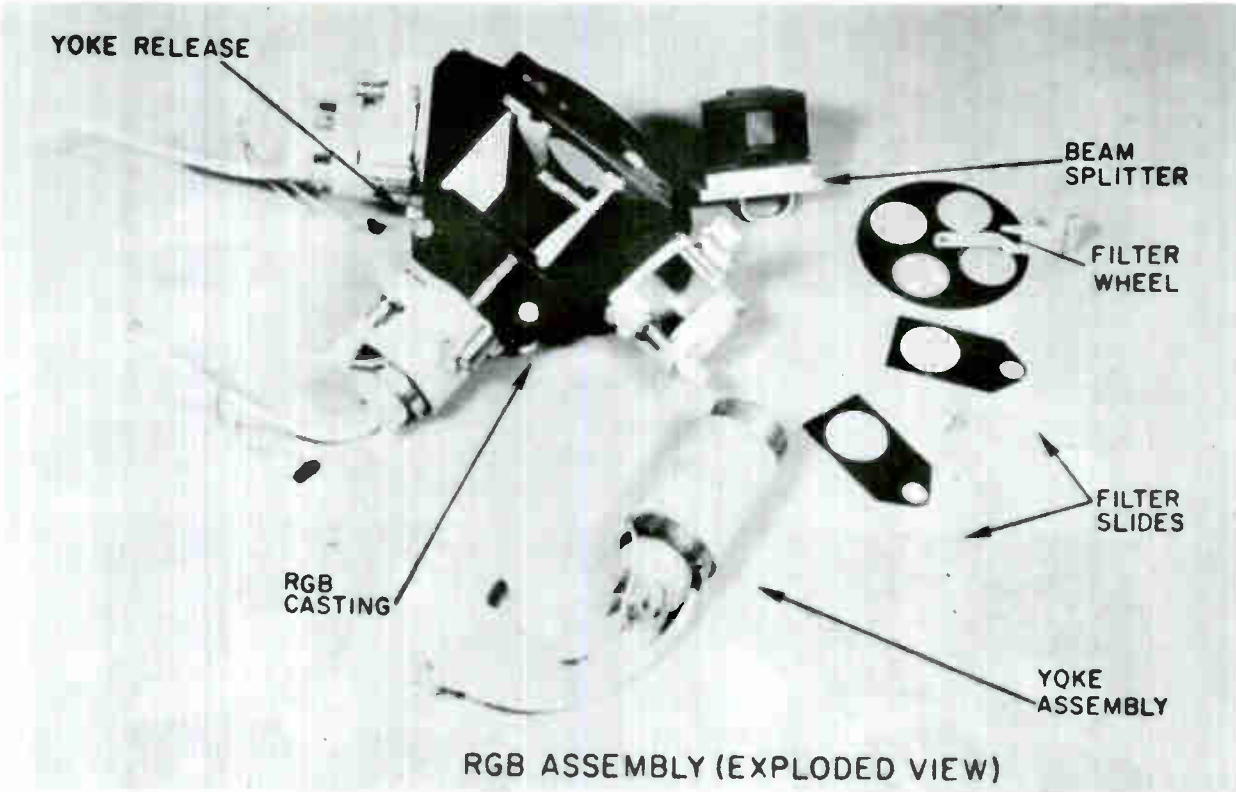

YOKE RELEASE
BEAM SPLITTER
FILTER WHEEL
FILTER SLIDES
RGB CASTING
YOKE ASSEMBLY
RGB ASSEMBLY (EXPLODED VIEW)

Fig. 20

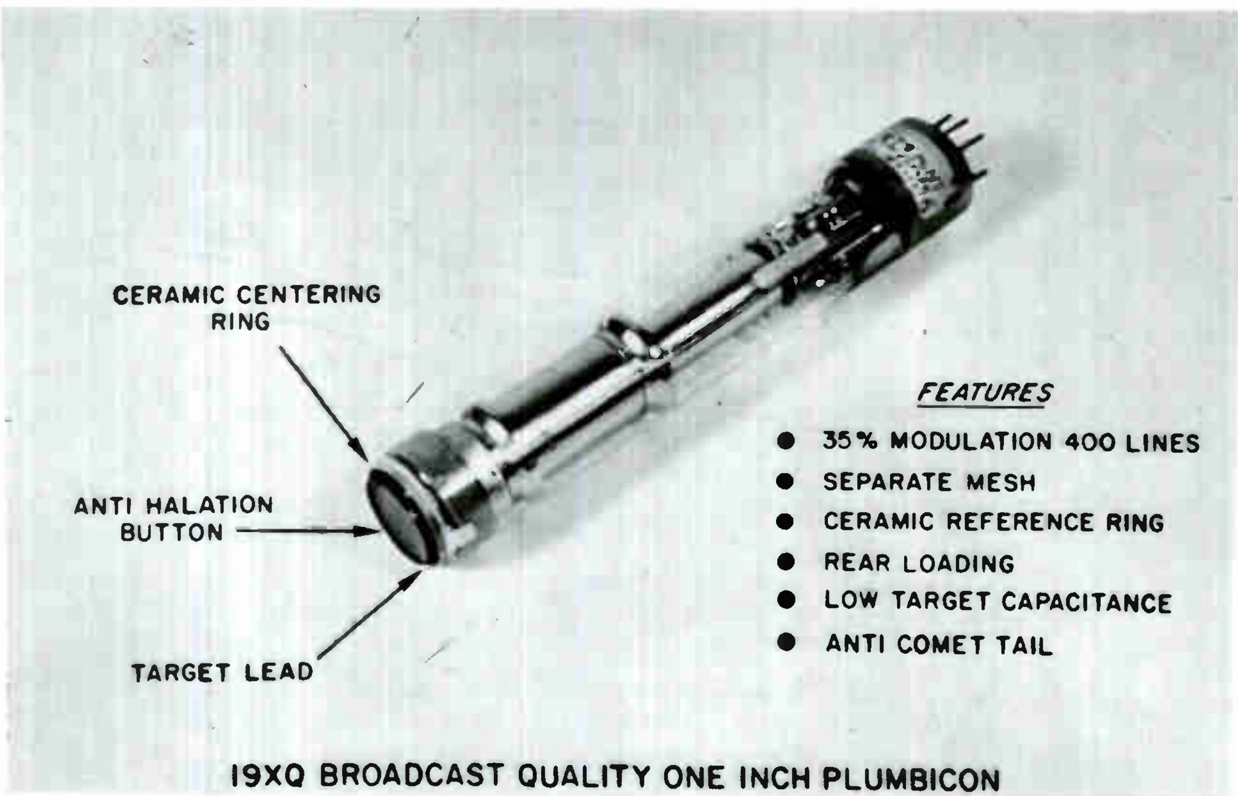
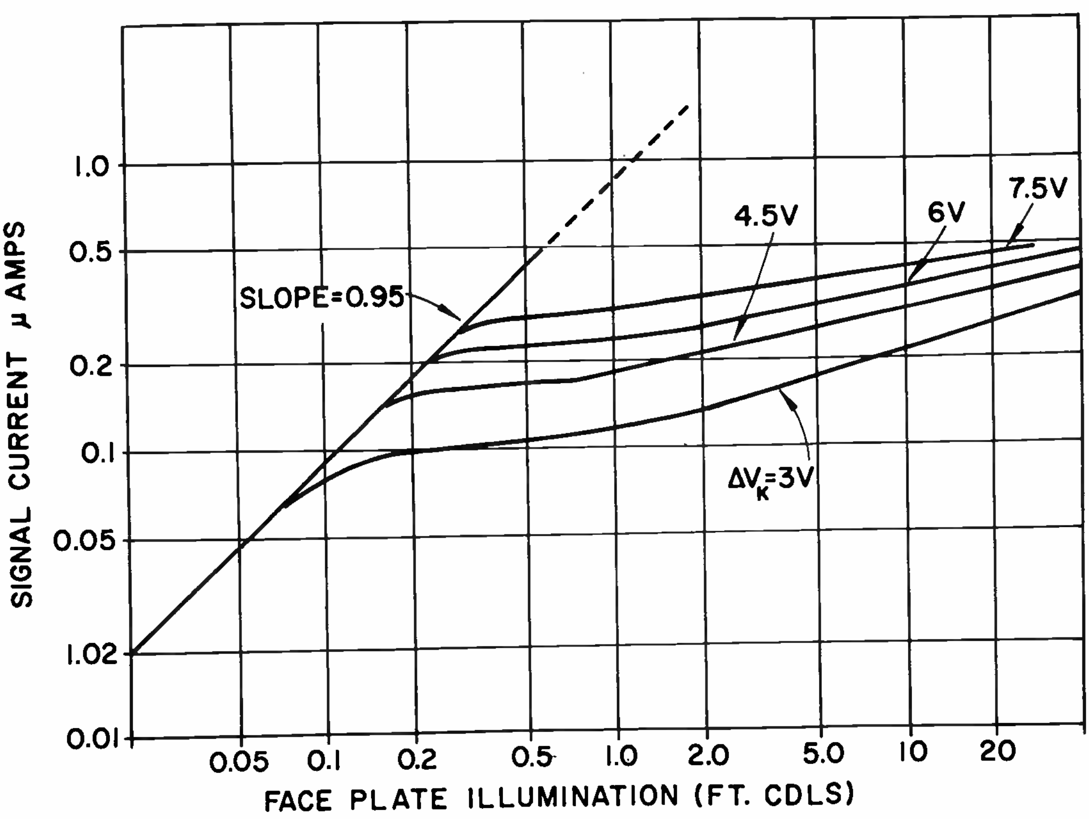

CERAMIC CENTERING RING
ANTI HALATION BUTTON
TARGET LEAD
FEATURES
● 35% MODULATION 400 LINES
● SEPARATE MESH
● CERAMIC REFERENCE RING
● REAR LOADING
● LOW TARGET CAPACITANCE
● ANTI COMET TAIL
19XQ BROADCAST QUALITY ONE INCH PLUMBICON

Fig. 21

Fig. 22



ANTI-COMET TAIL LIGHT TRANSFER CURVE

Fig. 23

ring. The capacity of the one-inch tube in its wire yoke assembly is approximately 6 pfd, as compared to 12 pfd for the 30mm tube. This reduction in capacity effects a 5 db signal-to-noise improvement. Signal to noise through the preamplifier is 50 db. The ceramic reference ring is mounted during the manufacture of the Plumbicon, and is positioned concentric to the electrical axis of the gun. The ceramic ring is then used as a reference point in the yoke, in lieu of the glass envelope.

Future versions of the tube will incorporate a radically new flyback highlight discharge gun. This gun increases the dynamic range of the Plumbicon. To demonstrate the performance of the (Anti-Comet Tail) A.C.T. Plumbicon, the word "Philips" was printed onto a standard 100-watt light bulb, and although it is difficult to see in Fig. 22 (Polaroid photos), taken from a 14-inch monitor screen, the word Philips can be seen through the illuminated lamp.

In the standard Plumbicon, highlight levels beyond approximately 1/2 foot candle on the surface of the tube cause "blooming" (comet-tailing). This occurs because the gun is unable to supply sufficient current to stabilize the target for extreme highlights. In the A.C.T. (Anti-Comet Tail) Plumbicon a light level saturation characteristic (knee) is imposed on the transfer curve (Fig. 23). Any excessive signals (highlights) are limited to those less bright, still stabilized elements in the scene. In essence, this allows the dynamic range of the Plumbicon to be extended by at least two orders of magnitude at the upper end, with no effect on the low light level part of the scene. Because of the action of the beam during flyback highlights of 20 - 30 ft. candles on the surface of the tube can be stabilized. Also evident is the ability to produce some grey scale in the highlights even though it is greatly compressed.

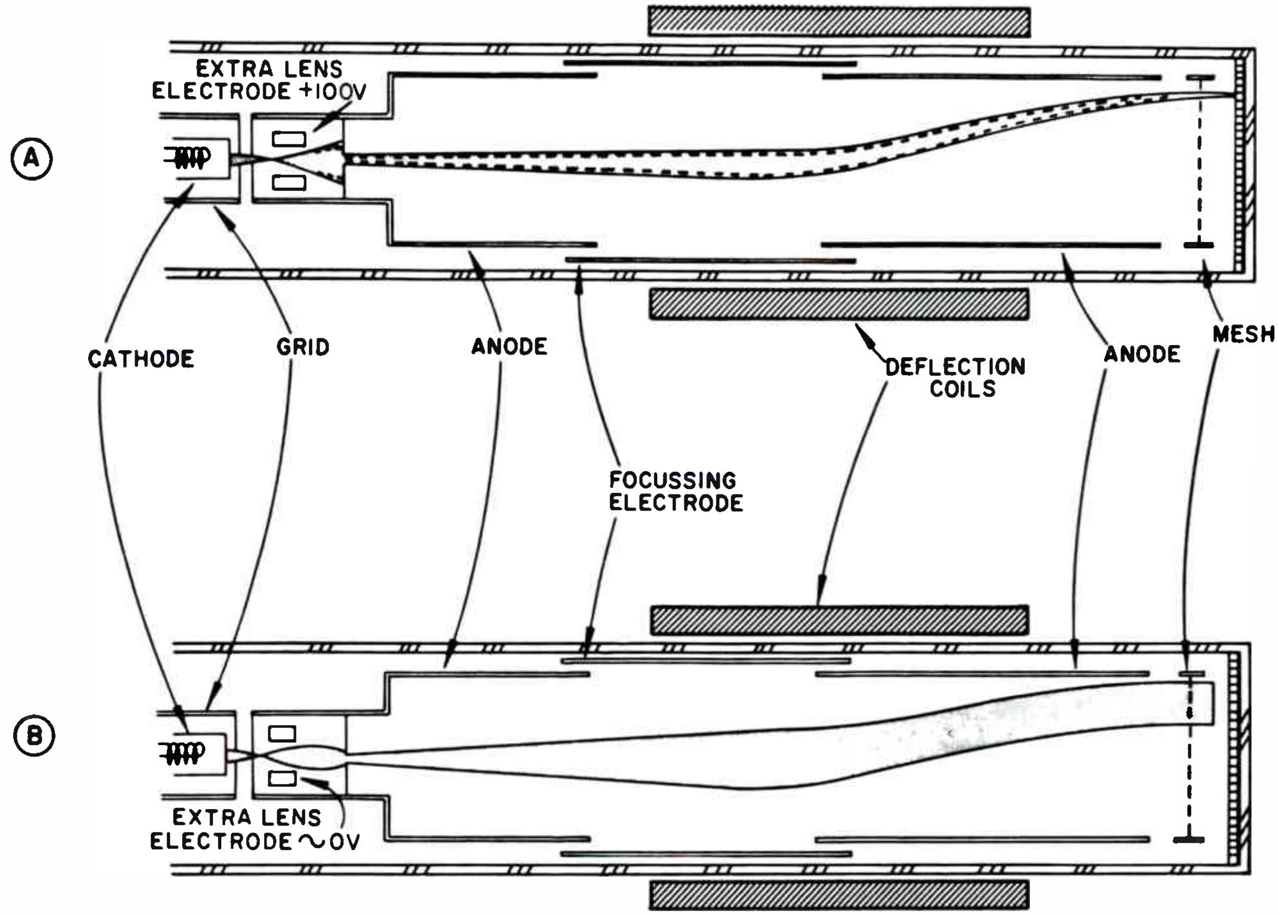
The gun structure of the A.C.T. Plumbicon is shown in Fig. 24. An extra lens electrode has been added. This electrode is pulsed during flyback to 0 volts, increasing the cathode current by approximately 50 times. This current is then available for auxiliary stabilization during flyback.

The yoke assembly (Fig. 25) consists of a precision wirewound coil housed in a spun mu-metal shield. The FET preamplifier is mounted inside the cylinder close to the Plumbicon target contact. Particular attention has been paid to shielding to minimize the effects of extraneous internal and external fields and spurious signals. The yoke mounting was specially designed for the PC-100. An external geared-type clamp is mounted on to the mu-metal shield for rotation in its holder. The tube ceramic ring mounts into a centering hole in the mu-metal cylinder and is clamped at the rear by a compression type nylon clamp.

The electronics (Fig. 26) are packaged into three bays. Three-by-five inch cards are used throughout the camera system. The cards plug into mother boards which are then interconnected through pendant type cables. The cards are multi-layer type to provide isolation planes and interconnect leads for the compact integrated circuits. Fig. 27 shows some of the representative circuit cards used in the camera.

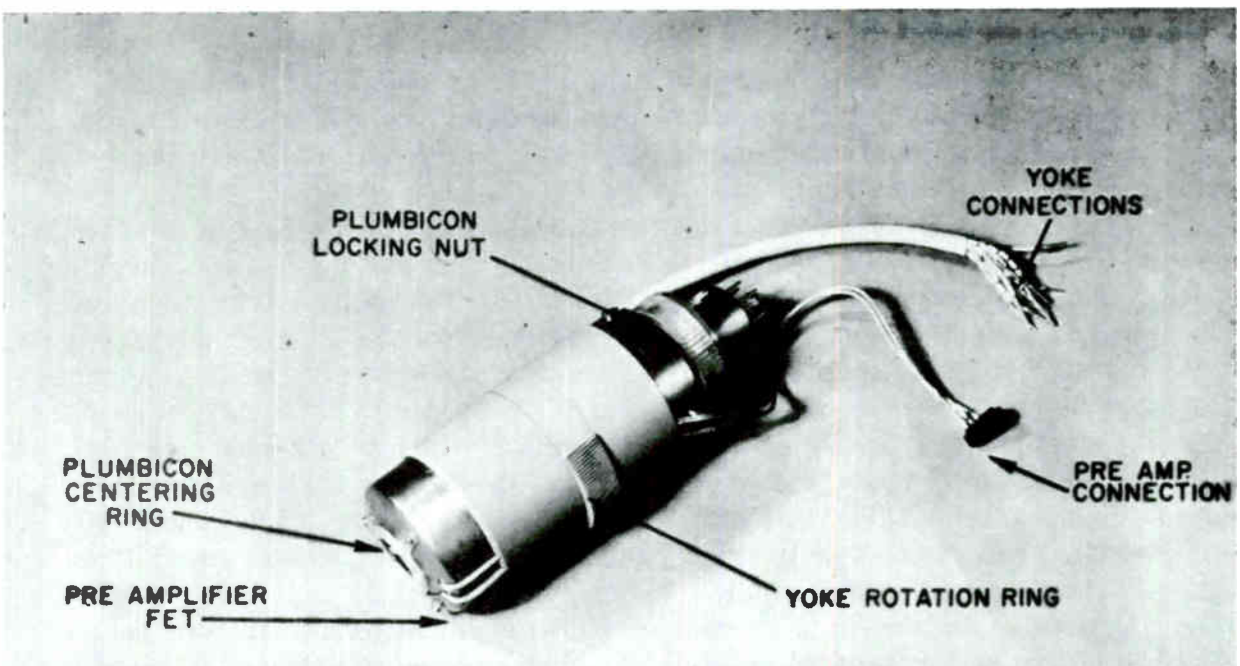
The electronics unit (Fig. 28) houses a two-level card bin on a 7-inch high rack as compared to the 15 3/4 high electronics unit of the PC-70. The card bin is mounted in a retractable, tiltable draw for ease of servicing. Coaxial and multi-pin connectors are mounted on the rear panel (Fig. 29). The camera triaxial connector is also mounted on this panel.

The registration and operations panels (Fig. 30) are mounted in a drawer assembly which can be racked into the cabinet. An overlay panel is provided to cover the registration controls after set-up of the camera. To aid in the set-up of the camera, switches and associated lamps are interlocked to reduce the number of man-



ANTI-COMET TAIL PLUMBICON

Fig. 24



BROADCAST QUALITY ONE INCH PLUMBICON YOKE

Fig. 25

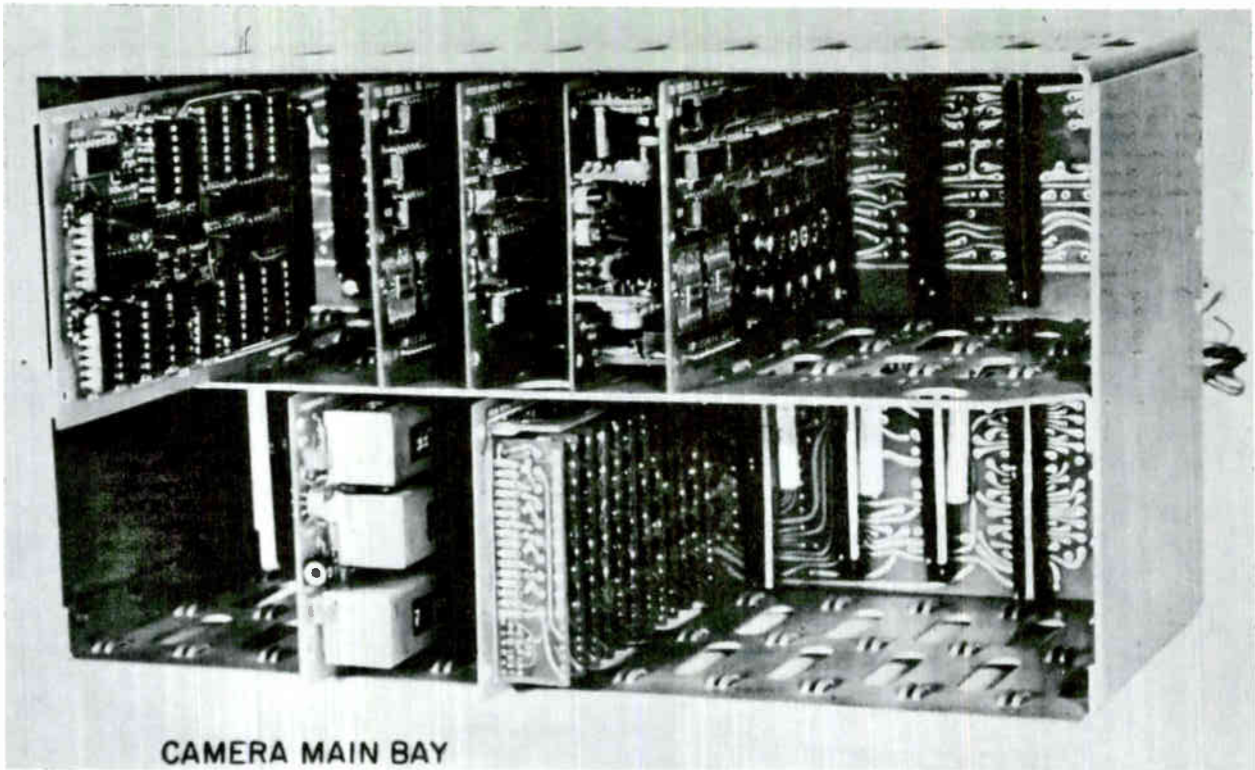
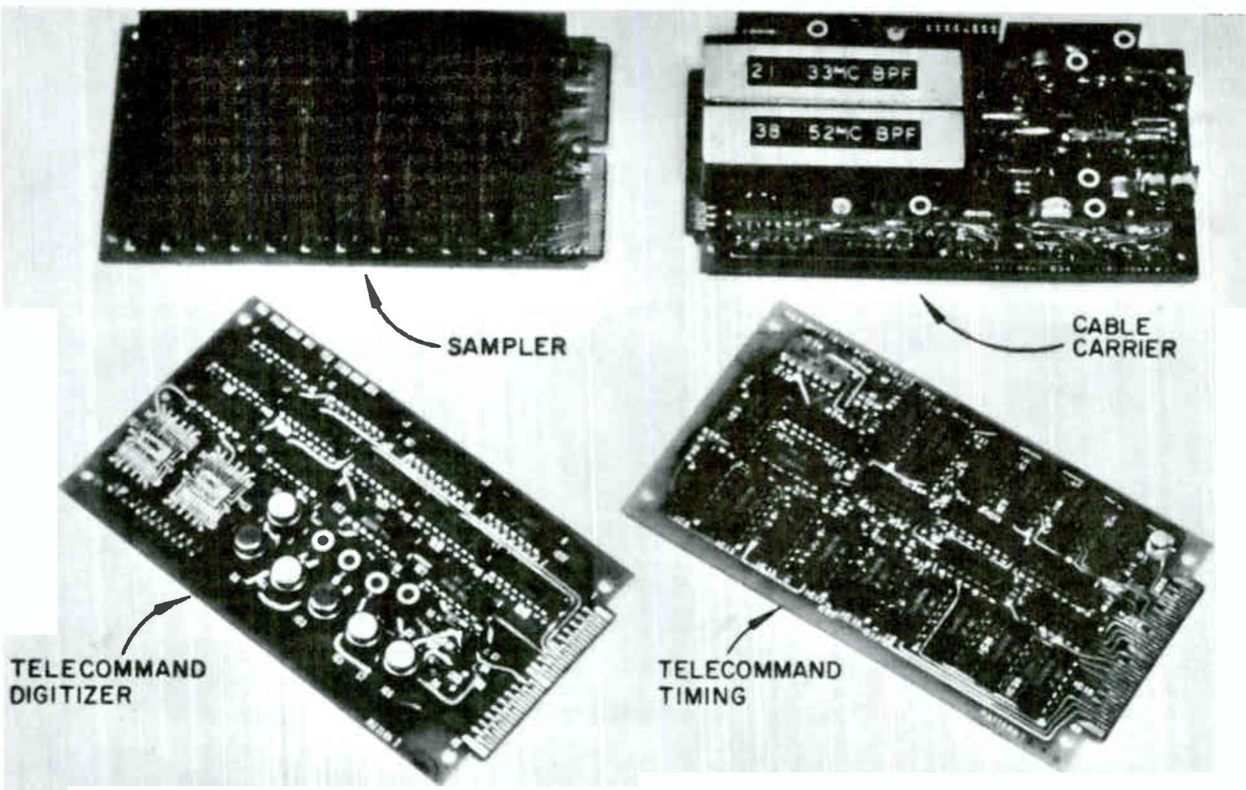


Fig. 26



3X5 INCH MULTI-LAYER PRINTED CIRCUIT CARDS

Fig. 27

Fig. 28

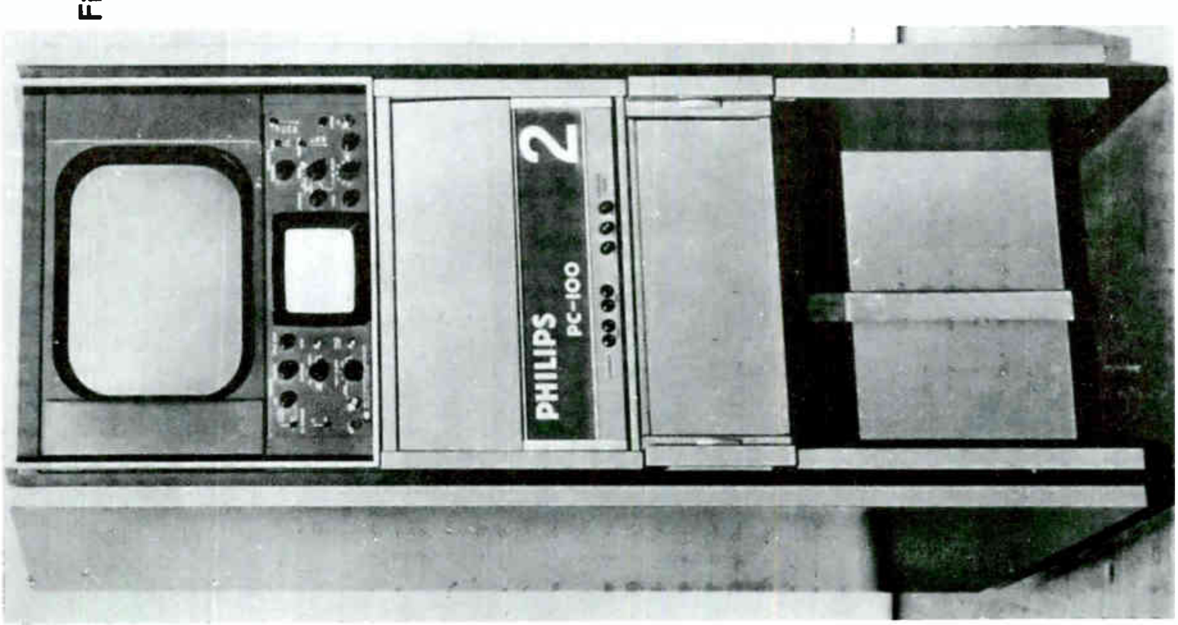
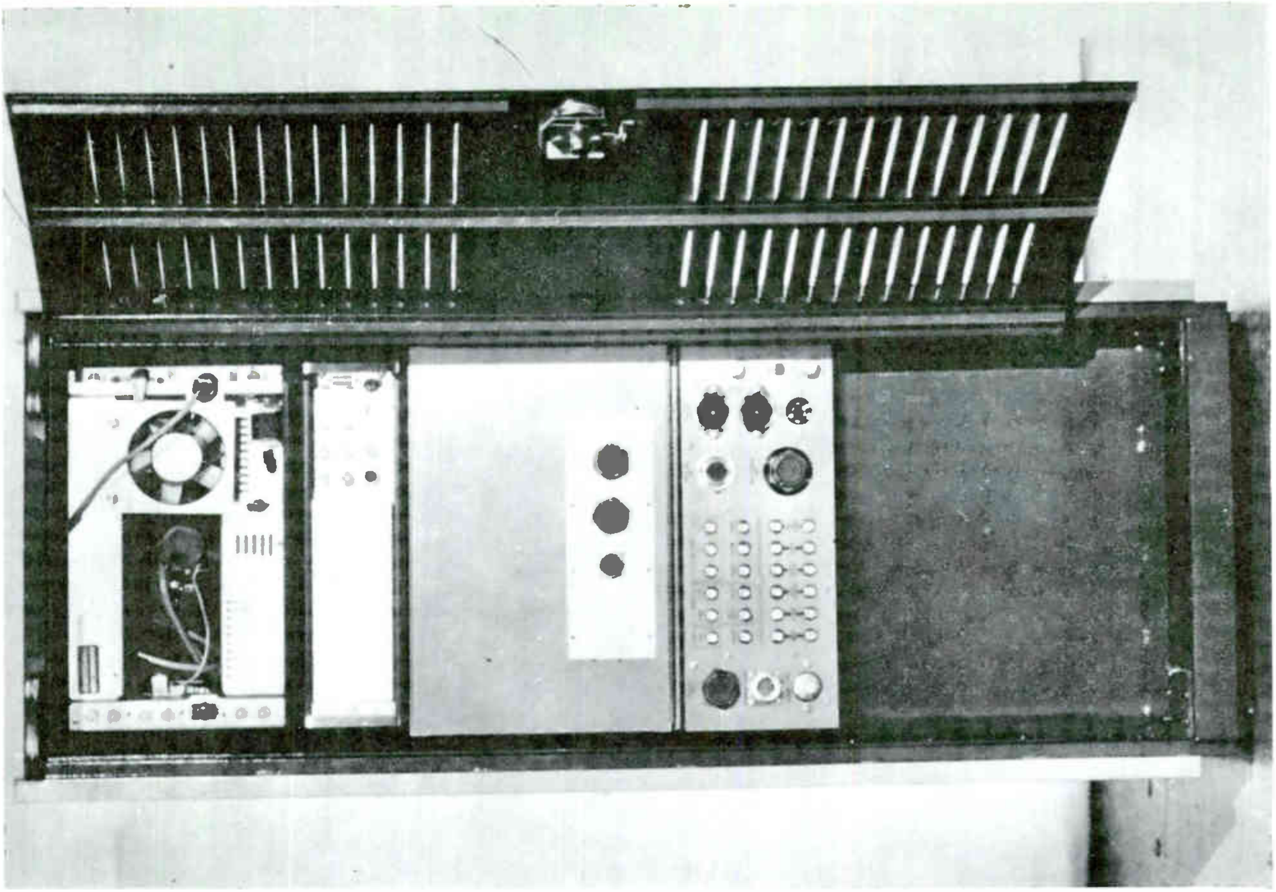


Fig. 29



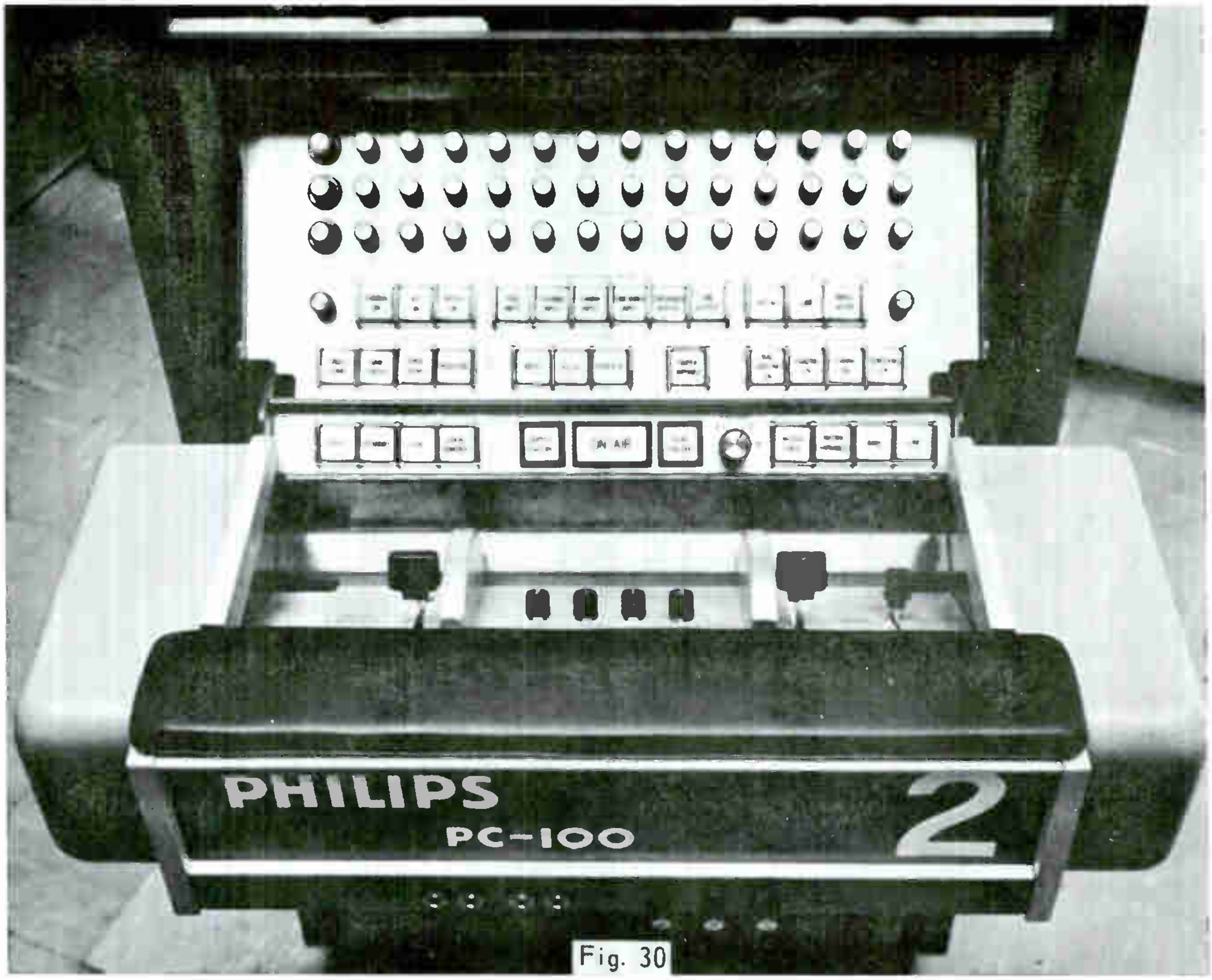


Fig. 30

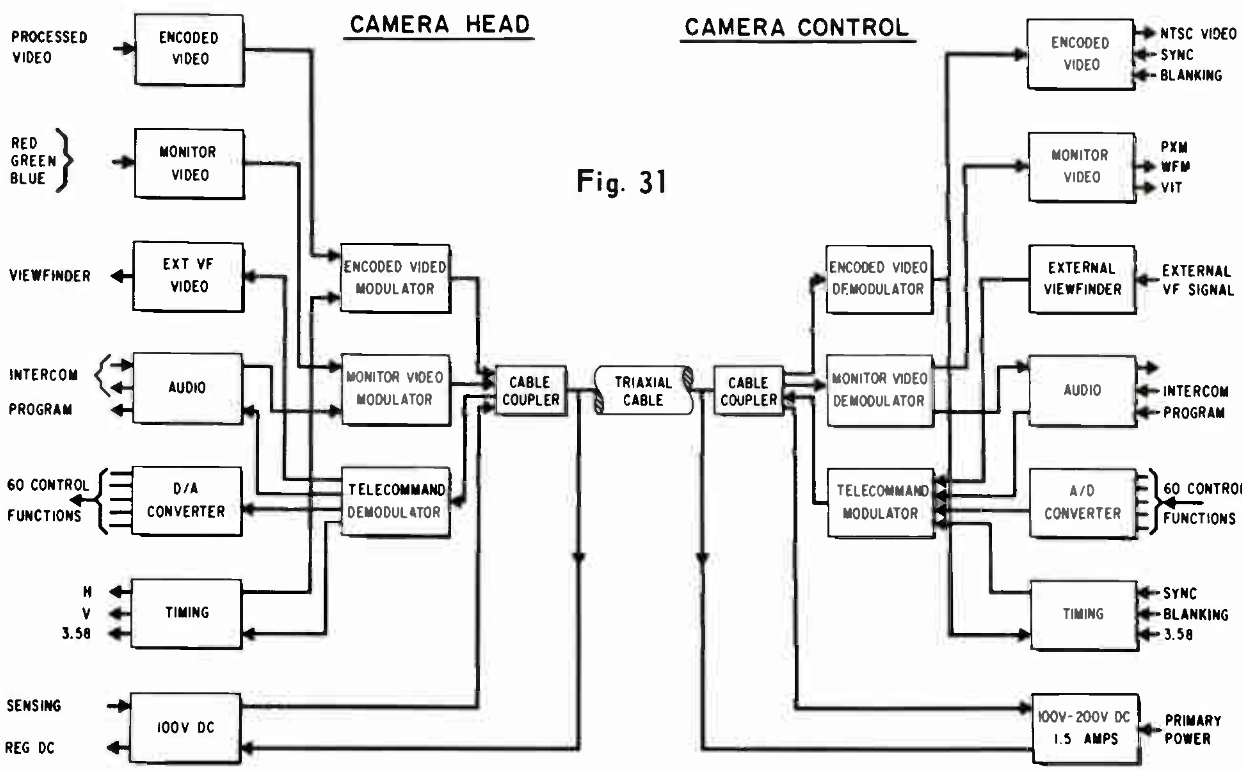


Fig. 31

PC–100 SIMPLIFIED SYSTEM DIAGRAM

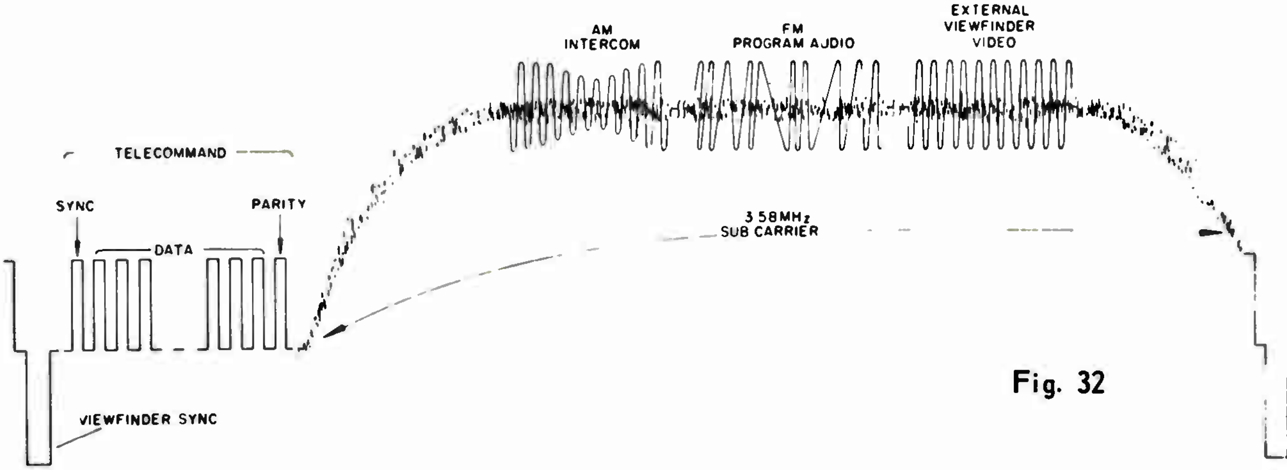


Fig. 32

TELECOMMAND CHANNEL

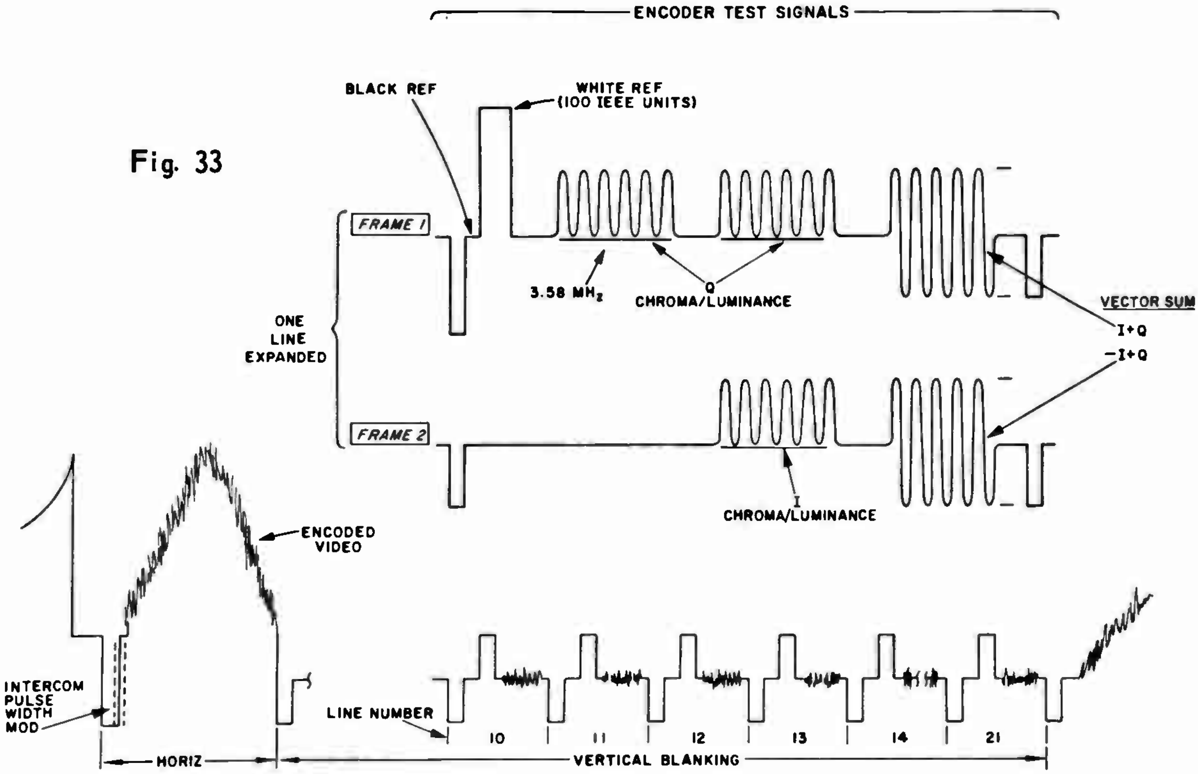


Fig. 33

VIDEO CHANNEL

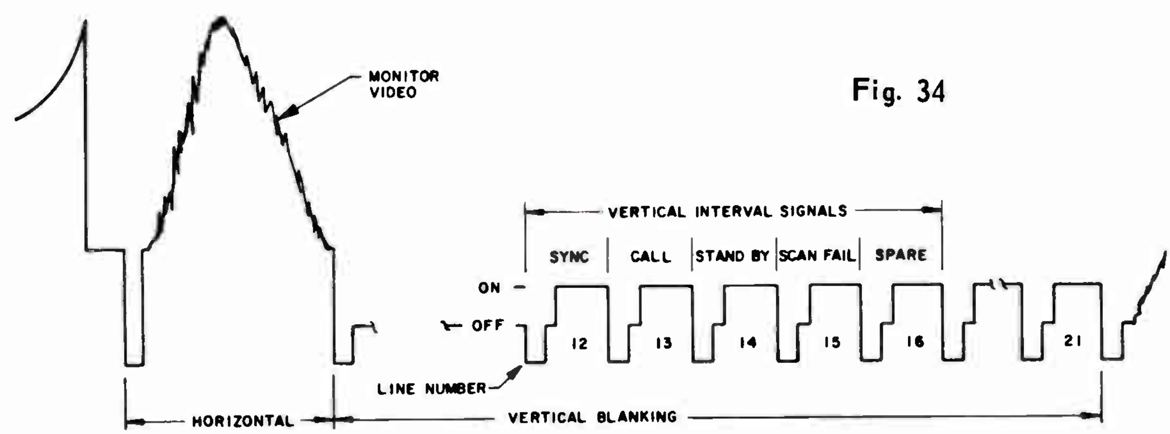


Fig. 34

MONITOR CHANNEL

ual operations required. As an example, a "Registration" pushbutton is provided which, when depressed, switches matrix and contours to off and encoder input signal to the waveform monitor. It also switches the waveform monitor to the RGB sequential mode and minus green video to the Picture Monitor.

Fig. 31 is a simplified block diagram of the PC-100, which illustrates the approach taken in the design of this camera. All the PC-70 features of monitoring and control at the CCU are provided in the PC-100. As can be seen, there are three channels of information multiplexed on the cable:

1. A telecommand channel for transmitting all operating, registration, and set-up signals from the control location to the camera.
2. A video channel for sending encoded video from the camera to the control location.
3. A monitor channel for sending monitor signals from various points in the video processing chain to the control location.

Telecommand Channel: The control system consists of an analog-to-digital converter at the CCU, and separate digital to analog converters in the camera. Control functions are normalized from 0 to 5 volts in both the CCU and camera. The information is transmitted in 8 bit digital form. Each function is sampled four times per field, or 240 times per second. A capacity of 60 8-bit channels and 60 one-bit channels is presently provided, leaving room for system growth.

The digital train (Fig. 32) is added to the composite signal containing the external viewfinder video and composite sync, taking the place of subcarrier burst. This signal is then modulated on an 11-MHz subcarrier. Since the subcarrier burst interval is used for data transmission, an alternate means is used to synchronize the camera subcarrier oscillator. This is done by adding subcarrier to the external viewfinder during the video interval. An AM subcarrier is used to modulate the color subcarrier to provide intercom from the CCU to the camera. Program sound is provided by a separate FM subcarrier (sub-subcarrier) on the 3.58 signal.

Video Channel: The video system produces an encoded signal (Fig. 33) which is modulated on a 27-MHz subcarrier. A timing pulse is included in the video blanking interval for horizontal timing. This timing pulse is extracted at the CCU location and compared with studio horizontal sync. A control voltage is then generated and transmitted through the data link to adjust camera phase such that the final output signal is in time with the studio. The timing pulse is removed at the CCU location in a video mixer, where studio blanking and composite sync are added. A line amplifier provides the required output drive capability.

Monitor Channel: Camera video signals (Fig. 34) are selected at various points in the chain by a video switcher receiving its commands through the data control link. Intercom signals are applied to a pulse width modulator, which is then added to the monitor video during the blanking interval. A vertical interval coder in included to provide data on camera performance status, such as power and scan, and for the call signal key. A fixed level on selected horizontal lines during the vertical interval is all that is added, since only one bit of information is required per channel for these functions. The monitor, audio, and vertical interval coder signals are then applied to a 45 MHz subcarrier for transmission to the Camera Control Unit. Fig. 35 shows the frequency bands used to carry the multiplexed information on the triaxial cable.

Fig. 36 illustrates the tremendous steps being taken in the components field today. The top of the photograph shows a breadboard of the circuit used to convert digital pulse trains from the camera control unit into equivalent analog voltages in

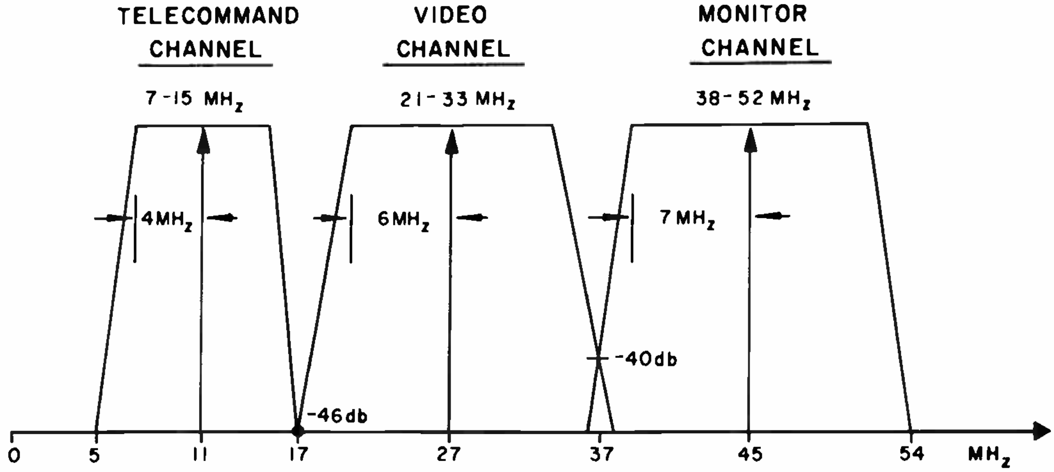


Fig. 35

PC-100 MULTIPLEX CHANNELS

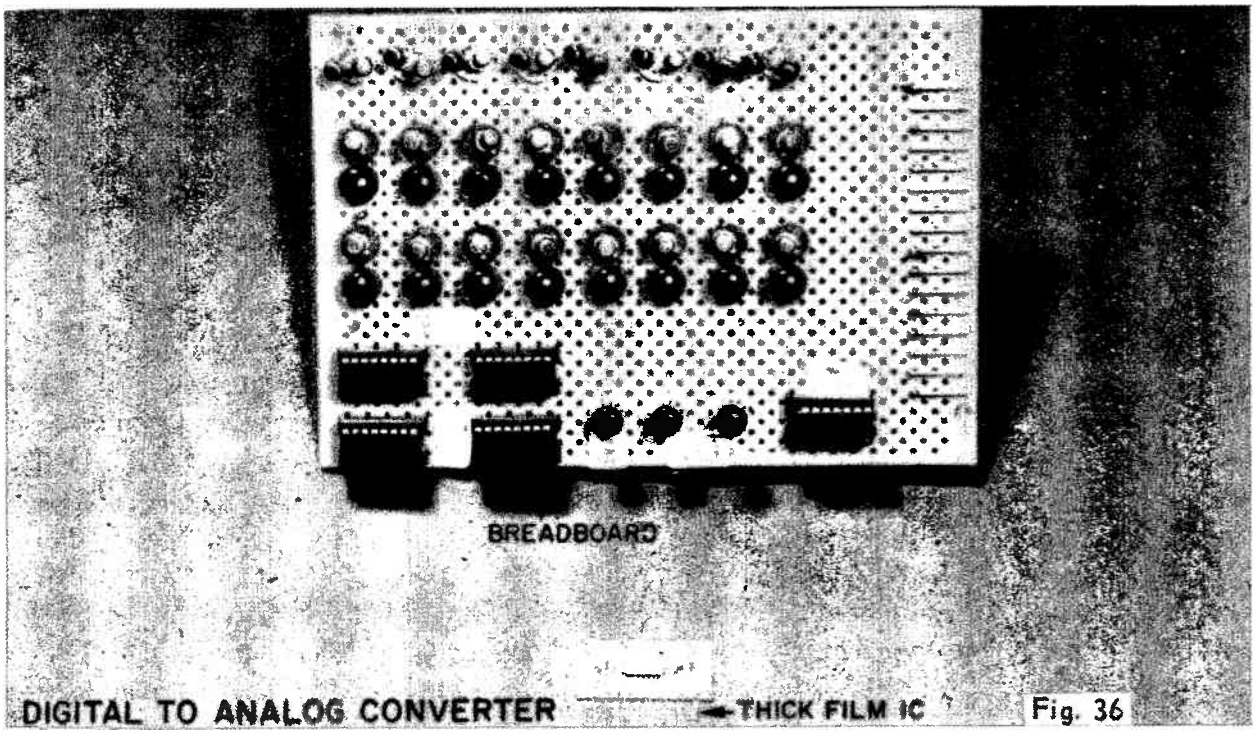


Fig. 36

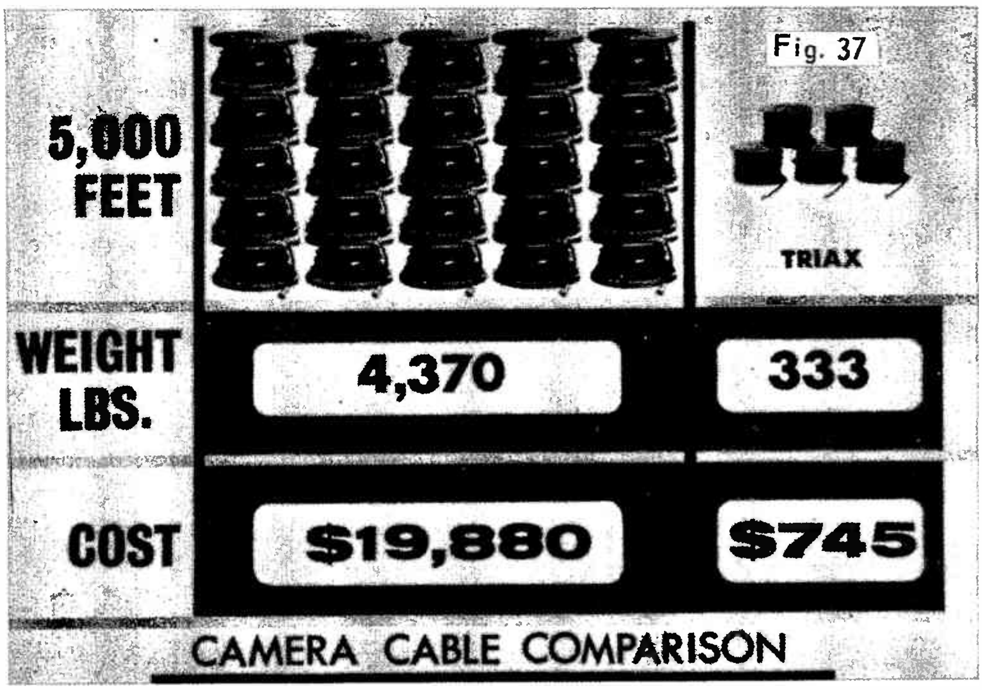


Fig. 37

the camera head. If you look closely, you can see that IC circuit elements were also used in the breadboard and, in addition, on the opposite side of the board a string of discrete leveling resistors are used. Some can be seen protruding over the top of the card. The thick film assembly below was produced to meet the specific design requirements of the PC-100 color camera.

Fig. 37 bluntly points out one of the major reasons for the design approach taken for the PC-100. It shows the difference in size, weight, and cost of 5,000 feet of TV-81 type cable compared to the Type 8232 triax cable used on the PC-100. As shown, 5,000 feet of TV-81 weighs 4370 pounds and lists for $19,880. The same length of triaxial 8232 weighs 333 pounds and lists for $745. This represents a weight reduction of more than two (2) tons, with a dollar savings of over $19,000 for a single installation. I understand that, conservatively, 10,000 feet of TV-81 type cable is used at a typical golf match remote pick-up. This would add up to approximately 9,000 pounds of cable, at a value of $40,000. Comparable lengths of triax cable would be 600 pounds, at a value of $1500. Here a savings of over $38,000 and a weight reduction of over 4 tons in cable weight would be realized by using PC-100 Systems in this typical remote pick-up. There will also be very substantial savings in installation, labor, and shipping cost. Costly failures due to multi-wire cables and connectors will be eliminated.

One last point about the PC-100 designs: The digital and multiplex system used has been so designed that remote automatic operation of the camera is possible through coaxial or a microwave link with some minor accessories and changes to the basic version you have seen. The maximum distance between the camera and CCU can be extended beyond 1 mile with proper accessories and local camera power.

Measurement of Nonlinear Distortions in NTSC Color Television

Charles W. Rodes
Tektronix, Inc.

Experience with Vertical Interval Test Signals in evaluating network transmissions has brought to many engineers' attention that variations in average picture level cause variations in the signal transmission and cause successive measurements made on a VITS basis not to be in agreement to the extent anticipated. Some operators have criticized the VITS technique as unreliable, not understanding that APL variations in program signal are the cause of the measurement uncertainties experienced. The fact is that the VITS only demonstrate that transmission quality does vary during a program.

Let's review for a moment the matter of APL as it has such a bearing on our problems of both transmission and measurement. APL has been defined as the average value of the picture signal, integrated over the time interval of a frame. APL differs from duty cycle in that it ignores the time intervals occupied by blanking (and sync). That is, it is a measure of the scene brightness. An all black scene, neglecting set-up, has zero percent APL. An all white scene has 100% APL. The IRE standard provides for testing television systems with test signals having an APL variable over the range from 10% to 90%. This corresponds to a very wide latitude in scene brightness, wider in fact than that normally encountered in typical program content.

APL variations can affect transmission quality at any point in the television system where the video signal is being amplified or modulating a carrier if the signal lacks its DC component. That is, whenever the video signal is AC coupled and not clamped or DC restored, variations in APL will cause the video signal to move over the dynamic range of the amplifier/modulator in question. As an example (Fig. 1), with a standard 140 IRE signal having 50% APL displayed on a waveform monitor with the DC restorer switched off so that blanking is at zero IRE level, a 10% APL signal will have its blanking at +30 IRE and a 90% APL signal will have its blanking at -31 IRE. Thus, the video signal which we think of as 1-volt peak to peak occupies not 140 IRE units, but 201 IRE units considering APL variations from 10%-90%. This corresponds to 1.4 volts peak to peak and any video amplifier must have an input signal dynamic range of at least 1.4 volts in such cases.

While the transmitter has DC restoration at the input to its modulator, video distribution amplifiers do not. DC restoration is not used at the video input of the FM modulators in the Telephone Company facilities. If such equipments were always tested with 50% APL test signals with the luminance signal at +3 db level, then we could expect such measurements to agree with the measurements made using a 1-volt signal with APL of 10%-90%. As a matter of fact, at least some television authorities in Europe carry out their tests of unclamped equipment such as radio relay lines with

+3 db level test signals. There is no need to provide the +3 db test signal level capability on test equipment which has the variable APL feature. The +3 db technique must not be used on circuits which have clamps.

Variable APL test signals are produced by time sharing a test stairstep or other test signal whose own APL is exactly 50% with an adjustable pedestal signal. With a 100 IRE pedestal on four out of every five active lines, time shared with a test signal having 50% APL, the average is 90%. When the pedestal is at blanking level, on four of five lines, the average is 10%. In Europe, they time share the pedestal at blanking or white level on three out of every four active lines, with the test signal line whose own APL is 50%. Thus, they obtain an APL range of 12 1/2% to 87 1/2%.

We are all familiar with the variations in program white reference level of VITS. What we are seeing is the variation in picture signal gain with APL. Similarly, we know that the blanking-to-sync amplitude varies too, and this is also attributable to APL variations. There two gain changes with APL are called dynamic gain (picture signal) and dynamic gain (sync). Frequently we will observe that the picture signal dynamic gain and the sync dynamic gain go in opposite directions with a given change in APL. Table I shows several measurements of dynamic gain on some typical round robbin facilities:

TABLE I

Facility	APL	Picture IRE	Sync IRE	Dynamic Gain %(P)	Dynamic Gain %(S)
Test #1	10%	96	42	-4%	+5%
	50%	100	40	0	0
	90%	102	39	+2%	-2 1/2%
Test #2	10%	101	37	+1%	-2.6%
	50%	100	38	0	0
	90%	95	40	-5%	+5%

$$\% \text{ Dynamic Gain (picture)} = \frac{2(E_{max} - E_{min}}{E_{max} + E_{min}} \times 100$$

Dimensions of E are in IRE units.

The measurement is simplified if the test signal is set to nominal amplitude for the 50% APL test. Then:

Picture: % dynamic gain = $E_{max} - E_{min}$

Sync: % dynamic gain = $E_{max} - E_{min} \times 2.5$

A practical problem frequently encountered in measuring dynamic gain in network transmissions is one due to transients on the white reference signal which are usually large because it represents a 100 IRE transition. That is, 4% overshoot on a 100 IRE pulse causes a 4 IRE amplitude uncertainty in the white reference level. The usual staircase test signal must not have the subcarrier component present for this test, and this is frequently not convenient to do.

Fig. 2 shows a new form of staircase test signal designed to permit both dynamic

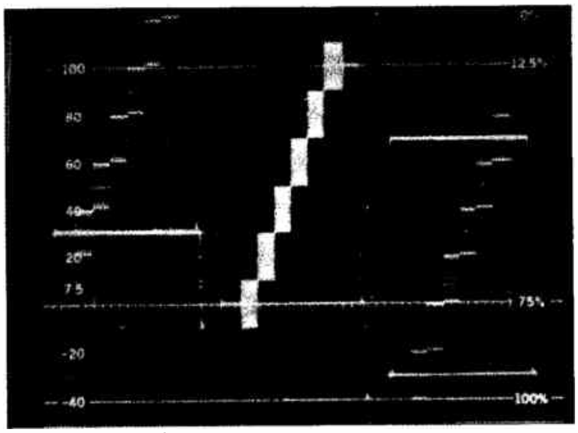


Figure I. Staircase signal, dc restorer off, left to right, APL: 10%, 50% & 90% blanking level shift is 61 IRE units for 80% APL variation.

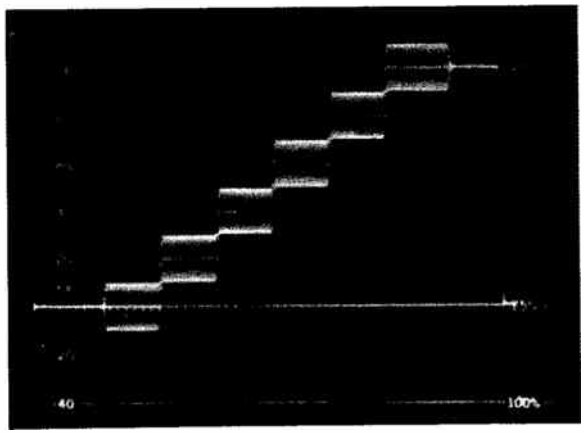


Figure II. TEKTRONIX staircase waveform. Note the white reference pulse following subcarrier, and blanking level preceding subcarrier, to facilitate dynamic gain measurements.

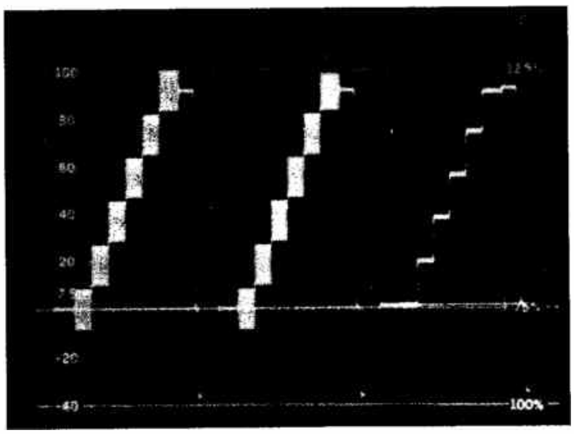


Figure III. Left: staircase signal. Center: subcarrier clipping, wideband. Right: same signal, subcarrier filtered to show axis shifting of last step.

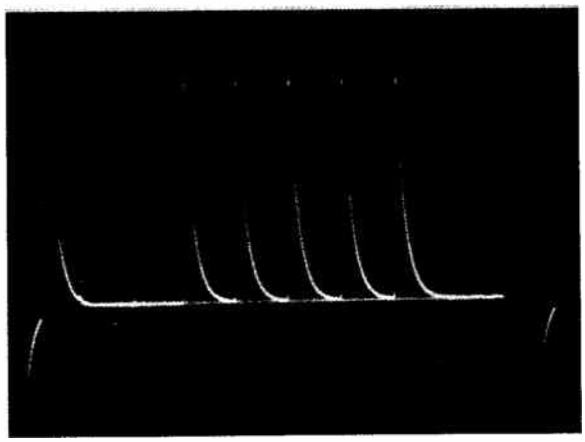


Figure IV. Staircase signal, luminance component only, differentiated and gain increased.

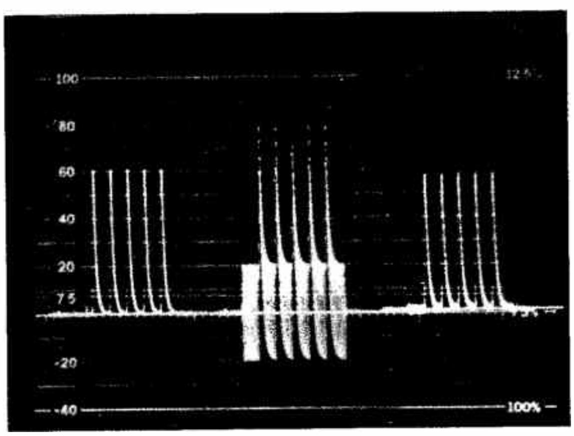


Figure V. Differentiated staircase signal. Left: no subcarrier present. Center: subcarrier present, accurate results cannot be obtained due to subcarrier in display. Right: IRE response reduces possible errors.

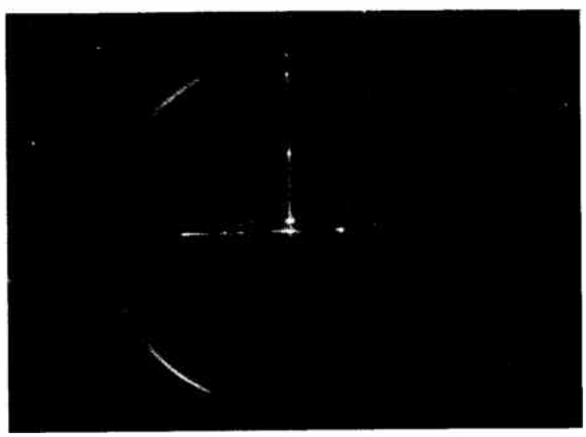


Figure VI. Vector display of complete subcarrier components of Variable APL staircase signal. Burst 180°, staircase modulation: 0°.

Three amplitudes of subcarrier, all at 90° occur on the variable pedestal lines when APL is variable. Pedestal ranges from 0-100 IRE.

gain measurement and differential phase and gain measurements. Much more will be said about it later, but for now please observe the white reference (100 IRE) without subcarrier following the 100 IRE step with subcarrier. This step is free of any transient effects and represents a very convenient level for dynamic gain measurements. A blanking level, free of subcarrier, precedes the start of the subcarrier modulation to give a convenient blanking level. The addition of both blanking and white reference pulses preserves the exact 50% APL of the test signal. Thus, with this signal there is no need to remove subcarrier to measure dynamic gain.

Filtering the subcarrier out in the waveform monitor may lead to incorrect conclusions about dynamic gain. Should there be amplitude nonlinearities in the system under test which affect the subcarrier, the axis of the staircase step so affected would be shifted. This effect is not in itself dynamic gain, because dynamic gain does not require a subcarrier to be present. However, in the new test signal shown, axis shifting will be quite evident between the white reference having subcarrier and that immediately adjacent and not having subcarrier. The same is true of the two blanking level references. This is shown in Fig. 3. Thus, this signal is designed to facilitate dynamic gain measurements and to detect any tendency toward luminance signal axis shifting caused by subcarrier rectification. If this type of test signal were adopted as a vertical interval test signal, it would seem attractive to use the subcarrier free white reference as a program reference white because of previously mentioned overshoots on the usual white reference pulse. The latter would still be needed up to the point in Master Control where the VITS are added.

The relationship between blanking level and APL, which is essentially linear, allows us to overcome the problem of determining the APL with VITS. With no input video signal, and the DC restorer of the waveform monitor off, position the trace +4.6 IRE. Now a 50% APL, 140 IRE signal will have its blanking level at 0 IRE, and a 10% APL signal will have a blanking level of +31.5 IRE. For a 90% APL signal, blanking will be at -32.7 IRE. As the relation between the 61 IRE blanking level change and the 80% APL change is nearly linear, interpolation is valid. Thus, with VITS, while we cannot control APL, we can measure it and include in our measurements the APL then present which will help make more useful the data gathered by use of the VITS.

Measuring the luminance signal amplitude, nonlinearity can be done with either of two methods. A 1-MHz sine wave might be used instead of the color subcarrier in the stairstep test signal. This is often done in Europe to test systems not yet colorized and, therefore, testing at the 4.43-MHz subcarrier would not be valid. A second method is to shape the staircase transitions, or step risers, with a low-pass filter so that each step has the same transient response and the cut-off frequency is chosen below the color subcarrier. Usually the filter gives sine squared response. Risetime of 260 nanoseconds seems appropriate for NTSC signals.

Differentiation of such a signal allows us to compare the amplitude of each step riser with the others on a common base line and, with increased gain, very small differences are easily measured. Fig. 4 shows the stairstep luminance signal differentiated and with gain increased x5 so that steps may be compared on a percentage basis. This test is valid only if the staircase signal is known to have been generated with identically shaped transitions as discussed above. As this test signal has a different form than others previously used, it can be recognized, and it is a specification of its innovator and manufacturer that the steps are generated with identical transitions to make this measurement valid. The same manufacturer also offers the differentiator commercially. A simple differentiator RC network

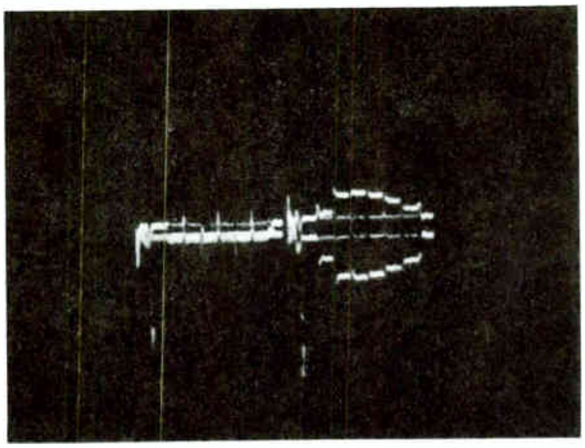


Figure VII. Differential phase display of staircase signal. Left display shows test signal only. Note burst and all steps are in phase null together. Right: distorted signal. While bursts are still nulled out, black level step now has a phase error as do all other steps.

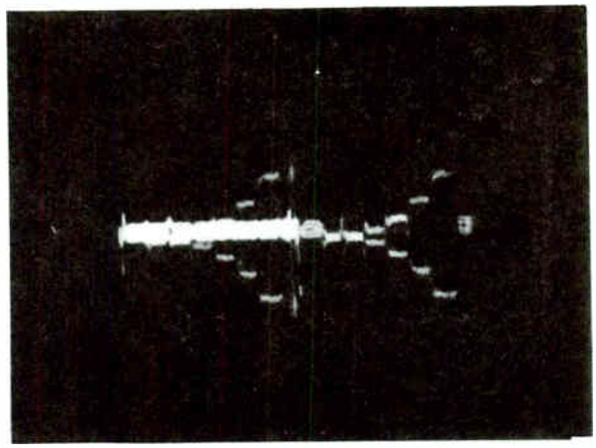


Figure VIII. Differential phase display of variable APL staircase. Left: bright base line obscures measurement. It is the four out of five pedestal lines. Right: pedestal lines shifted off screen by small 90° subcarrier signal.

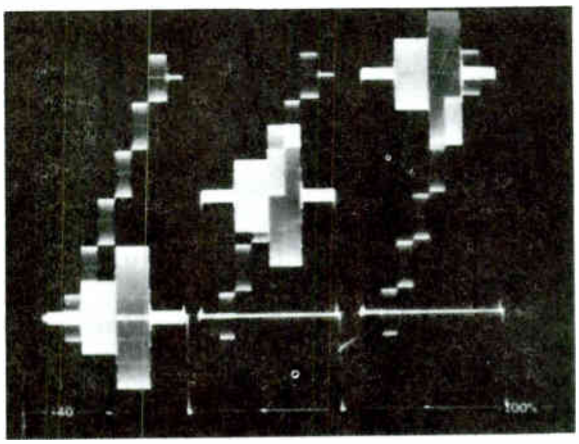


Figure IX. Complete variable APL test signal. Left to right, APL is 10%-90%. Largest subcarrier signal corresponds to amplitude of 75% RED color bar, intermediate subcarrier is half amplitude, smallest subcarrier is 30mV. Staircase subcarrier is 140mV, half of burst amplitude.

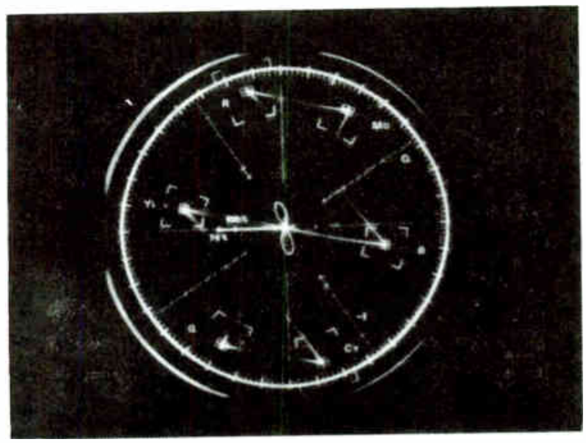


Figure X. Vector display of color bar signal. Transient response is under careful control in both R-Y and B-Y axes. Dot at 0° is vertical interval staircase signal.

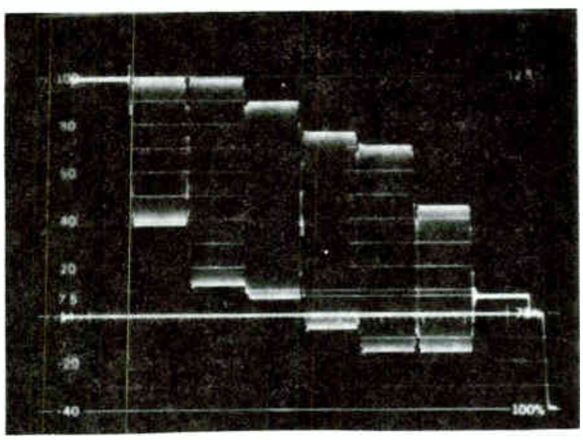


Figure XI. 75% amplitude color bars. Black reference bar follows blue at 7 1/2% set-up. Peak white reference bar precedes yellow bar.

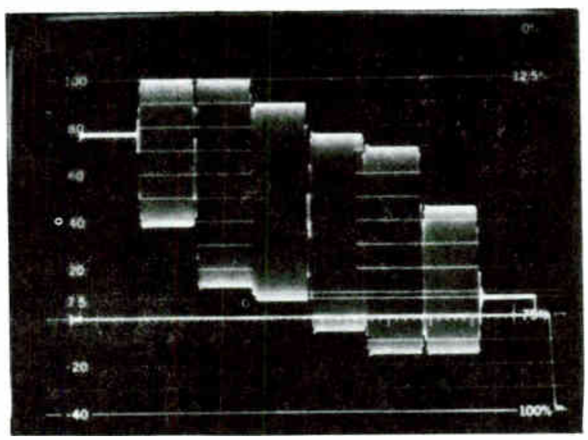


Figure XII. 75% amplitude color bars with the neutral reference bar preceding yellow bar also at 75% amplitude.

Set-up shown is 7 1/2%, but is selectable 0%, 7 1/2% or 10% without any recalibration.

proved unsuitable because of inherent 6 db/octave response accentuated noise present. The Tektronix staircase differentiator also includes an integrator RC network whose time constant is much shorter than the differentiator section; the combination has a bandpass characteristic centered at approximately 800 kHz and is suitable for use with the 260ns step transitions. It has a 75-ohm input impedance. Return loss is 34 db at subcarrier.

These measurements are made with the subcarrier off. Fig. 5 shows the display if subcarrier is present. For this reason, as a VITS, it might be desirable to provide two staircase signals, one with subcarrier and the other without.* The latter could be simplified, but the transitions ought not be too close together or the differentiator will give false indications.

Use of five risers allows a larger subcarrier which is useful in improving the signal-to-noise ratio which usually is significant in making differential phase and differential gain measurements because of the high gain employed in these measurements. Additionally, a five-riser signal may occupy less of a television line, making it possible to place additional test signals on the same line. As the color burst signal may be regenerated before it reaches the transmitter, it would be very desirable to have a positive means for measuring the phase at which burst is reinserted on the signal.

Fundamental to the test signal being described today is the concept that the subcarrier on the staircase signal is phased exactly 180° from the burst signal which is also generated in this unit. The same doubly balanced modulator stage is used to key both the color burst and the staircase subcarrier modulation, but with opposite polarity burst flag and subcarrier modulation gating pulses. Any phase error in burst reinsertion is evident on either the vectorscope or a color picture monitor. Fig. 6 shows the vector display of this signal. Fig. 7 shows the differential phase display on the vectorscope. Note that while the color burst nulled out, the stair-step signal is not nulled out at black level, indicating a burst phase error. This is not due to differential phase because both signals are at the blanking level.

Burst might also suffer phase modulation due to back porch keyed clamps which, in their keyed state, may present to the driving signal source a different reactive impedance load than is presented during the active line. Burst phase modulation, whatever the possible cause, may be easily checked with this phase locked test signal. Using a variable APL signal, four out of five lines do not carry the staircase signal. On the vectorscope, instead of doing something useful, they produce a bright baseline having no significance and obscuring the demodulated staircase signal as in Fig. 8.

A very small subcarrier signal phased at 90° may be added to the luminance pedestal signal so that, during these lines, the beam is deflected off the vectorscope screen when making differential phase measurements as shown at right in Fig. 8. On differential gain displays, this signal will not appear because the screen shows only the $\pm$10% range in subcarrier amplitude of the test signal itself.

Further exploitation is made of these lines in another test mode. Three different amplitudes of subcarrier, all at exactly 90°, are also available. Fig. 9 shows the waveform monitor display for 10%, 50% and 90% APL conditions and Fig. 6 shows the vectorscope display, showing that the three amplitudes are all at 90°, burst at 180° and the staircase subcarrier at 0°. As the luminance level of these lines is variable over the range from blanking to peak white, we can see whether a large chrominance signal suffers phase or amplitude modulation as a function of luminance level or APL variations. Furthermore, we may also test to see whether this large

*Some European nations now follow this practice in VITS testing.

amplitude subcarrier at any luminance level causes shifts in luminance level due to amplitude nonlinearities suffered by the chrominance signal. Due to the wide frequency separation between the chrominance signal and the bulk of the energy in the luminance signal, it is reasonable that either signal is capable of cross modulating the other signal. Cross modulation of the chrominance signal by the luminance signal is well known as differential gain. The opposite effect is also possible, wherein large amplitude chrominance signals affect the luminance signal. This is a serious condition in that it will degrade the monochrome picture as well as the color picture. Such cross modulation tends to increase the luminance of dark, strongly saturated picture areas and to decrease the luminance of bright, highly saturated areas. These distortions may occur in the color receiver itself or in any video signal obtained by demodulating the RF signal. Thus, such a signal should prove of some value in any off-the-air rebroadcast systems employing demodulation as opposed to frequency translation systems and, even then, the results would be interesting.

The amplitude of the largest subcarrier shown in Fig. 9 is the amplitude of 75% saturated red or cyan which, at the luminance levels, no greater than 70 IRE should pass through the entire system without distortion. Such is the situation with color bars.

While the staircase signal just described is indeed an elegant form of test signal containing several innovations over the usual signal, it still bears little resemblance to the color signals from the camera. Here one may speculate whether the color bar signal might not give results which better typify the real picture transmission capabilities of the system by better imitating the program signal. Its inability to be interpreted on a color picture monitor is an indication of this weakness. The obvious historical advantage of the staircase signal is its ease of generation with rather little error in phase or amplitude. The present state-of-the-art, to use a trite phrase, allows the generation of color bar signals having very great accuracy. The stability of the circuits available today is such that no trimming adjustments need be provided. In fact, the equipment in question will remain within stringent phase, amplitude, and carrier balance specifications over a reasonable range of ambient temperature for long periods of use. Fig. 10 shows the vector display of color bars.

This color bar generator can provide either 75% or 100% amplitude, 100% saturated color bar signals with black level set-up of zero, 7 1/2% or 10% without recalibration. The EIA standard color bar split field display is provided but, in addition, a full field color bar is provided with two new features. The neutral bar preceding the yellow bar or 75% amplitude bars may be at either 100 IRE; i.e., white, or at the proper value to represent 75% amplitude white. Following the blue bar, a black reference bar is provided to help adjust the picture monitor black level. It is felt that most applications of the EIA split field display are better served with this new full field display, at least when being monitored on waveform monitors where the split field display is somewhat difficult to interpret.

Fig. 11 shows the full field signal with 100 IRE white reference level and black level set-up at 7 1/2%. Particular attention is paid to the transient response in both the chrominance channel and luminance channels. The results are evident in the waveform shown. Timing of the chrominance signal, relative to the luminance, is held to very small errors, the criteria being that the 50% amplitude point on the chrominance envelope matches that of the luminance transition at its 50% point. The excellent transient response makes measurements more repeatable and, hence, more accurate. Fig. 12 shows the 75% amplitude neutral bar on the same bar signal which is valuable in checking the decoded signal as it forms a reference amplitude. On 100% amplitude bars, the neutral reference pulse is automatically 100 IRE (peak white). Thus, tests may be conducted with either the usual 75% bars or the more stringent 100% bars.

It is interesting to note that, in the United Kingdom, 75% amplitude color bars are not used. They feel that truly meaningful measurements can only be made with 100% amplitude bar signals. This is explained by their observations that some highly colored fabrics approach 100% color bar conditions. This is particularly noticeable on reds, I may add as a personal observation. However, it is also true that in the U.K. their color transmissions are on UHF 625 line transmitters which employ, like ours, negative modulation, but it is limited to 20%. Thus, they can radiate 100% color bars. They employ a 25% black level set-up on their color bar signal and thus avoid difficulties in the sync direction as well.

On the Continent, we find much greater correspondence with our own practices, because they use the same white modulation level as we do. They use the 75% bars, with the neutral bar at peak white. Black level set-up which was 50mV or 7 1/2% is being abandoned in many PAL countries. 75% amplitude bars have a rather low APL of 37 1/2%. 100% bars may have an APL up to 55% as shown in table II.

A very interesting feature of PAL color television theory has been exploited in the Tektronix NTSC Color Bar Generator. Quadrature phasing of the R-Y and B-Y modulators is checked to a very high degree of precision by letting the R-Y signal alternate in phase $\pm 90^{\circ}$ with respect to the B-Y signal on a line by line basis. In this mode, the signal generated is not NTSC, but PAL. If the two modulators are indeed accurately in quadrature, no 15-Hz flicker effects will be observed on an ordinary waveform monitor with the correct sweep speed and sweep repetition rate. Such a scheme will detect quadrature errors of less than 1° without question.

The color bar signal may be inserted in the vertical interval along with the variable APL staircase signal as a full field test signal and, thus, the color bar signal can have any desired APL from 10%-90%. Either 75% or 100% bars are available as a vertical interval test signal. Either the staircase or the bar signal may be keyed onto any line from 16-21 of either or both fields as desired. This capability affords the interesting opportunity to measure transmission systems in terms of the classical dynamic gain, differential gain, and phase and in terms of color bar transmission errors which would include burst phase errors.

The Tektronix Type 520 Vectorscope can make all of these measurements. The luminance signal, or the decoded red, green or blue color signals, that is Y plus either R-Y, G-Y, B-Y or Y alone, may be displayed with a 60 μsec time base. All of these signals are band limited, including the Y signal, with phase equalized low-pass filters to eliminate high-frequency noise and subcarrier to provide very clear waveforms. The display of the decoded R, G and B signals, in this way, would appear to be the most effective test of the transmission facilities. Errors in the encoded signal are negligible, and decoding errors in the vectorscope are likewise very small.

Particularly attractive is the possibility of testing with 75% bars in the vertical interval using line 17 or later on both fields. The display is clear and bright on picture monitors as vertical retrace is over by line 17 and use of both fields eliminates flicker and adds materially to the brightness so that the yellow bar appears yellow. Line 20 seems too near the top of the picture for comfort. With this test signal, picture monitors can be calibrated or checked accurately during program transmission. The vectorscope can measure the decoded signal in terms of IRE error on each color because, of course, proper decoding will place all bars at either the black or neutral reference level.

Figs. 13 to 16 show the Y only and the R, G and B displays without any distortion in the signal path. Fig. 18 shows the blue display with some chrominance attenua-

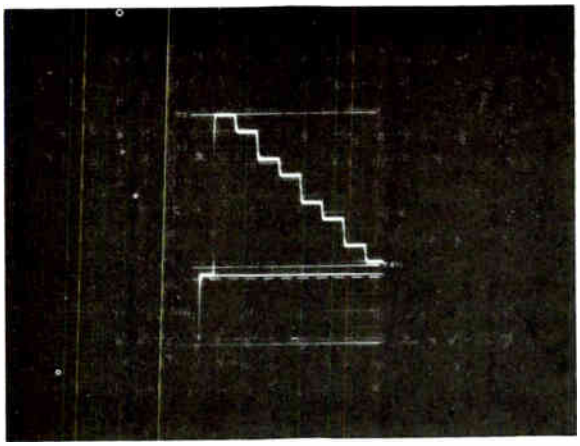


Figure XIII. TEKTRONIX Type 520 Vectorscope display of luminance component of color bar signal. Phase equalized low pass filter restricts display bandwidth to approx. 1mHz. Subcarrier is -34dB. Fast sync tip clamp removes hum, etc.

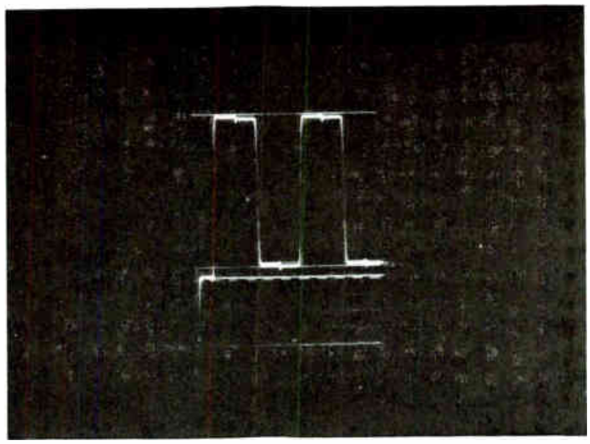


Figure XIV. RED video signal generated in the 520 Vectorscope by adding R-Y to the Y signal. Bandpass same in the Y display. Delay time in chrominance channels and luminance channel are matched.

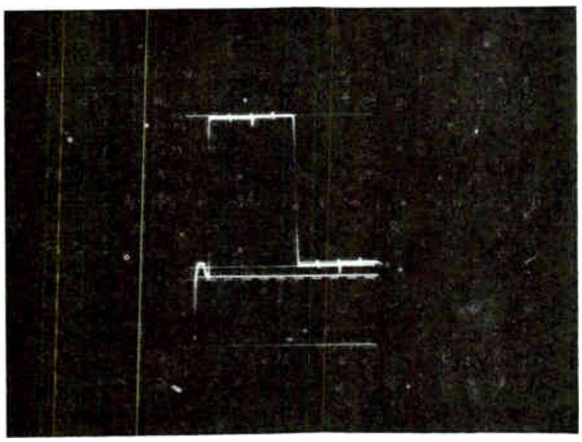


Figure XV. GREEN video signal display.

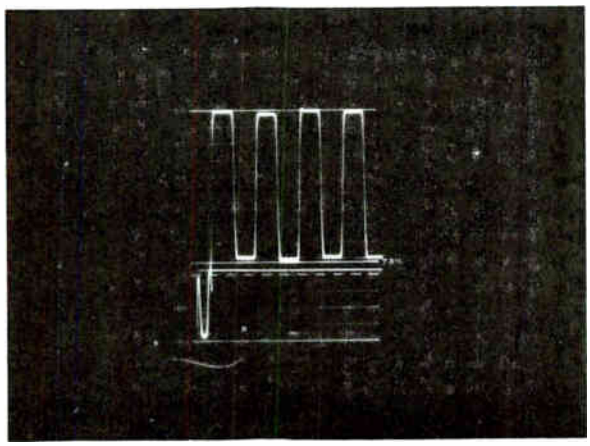


Figure XVI. BLUE video video display.

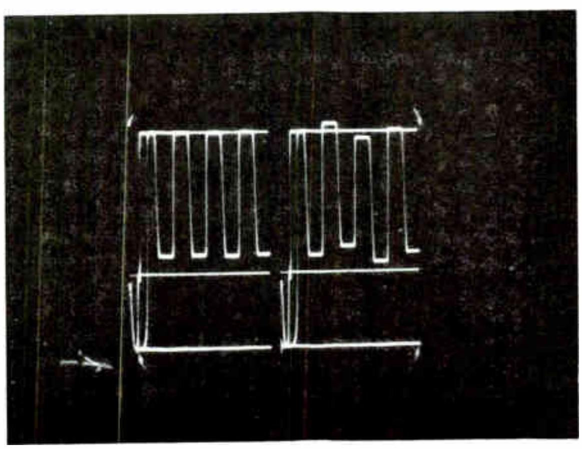


Figure XVII. BLUE BAR DISPLAY. Left: normal bars. Right: 3° burst phase error present.

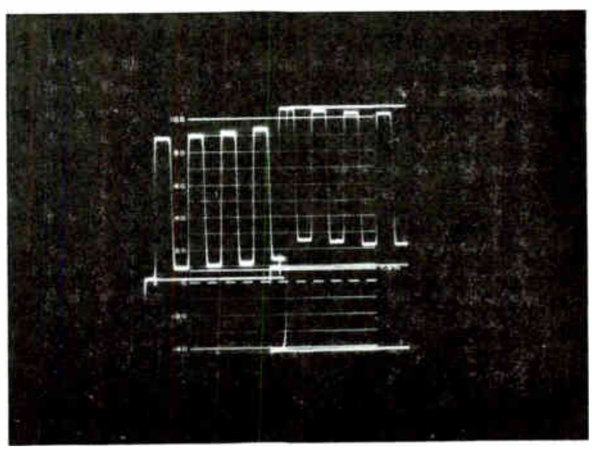


Figure XVIII. BLUE BAR DISPLAY. Left: luminance signal, relative to chrominance -7%. Right: luminance signal is 7% too large with respect to chrominance.

tion relative to the luminance level. Note similarity of the slope down to the right between this and the luminance only (Fig. 14). There was no phase error involved. Fig. 17 shows a differential phase error in the blue display. Independent control over the luminance gain allows the luminance to chrominance ratio of any signal to be corrected to observe what other defects there are. Fig. 18 shows chrominance/luminance gain error.

Analysis of transmission errors by means of the color bars is fairly straightforward. Phasing of the vectorscope can be verified with the red display as the burst is 90° from the R-Y phase. With the red display, the R-Y chrominance signal is added to the Y signal. Once the burst is nulled on the red display, the blue display should be selected as it is the most sensitive to phase errors in the transmission system. Phase errors produce what is sometimes called a crankshaft display in that some bars have increased amplitude relative to the neutral reference bar and the black bar. The other bars will be smaller than the reference bars. Assuming no phase errors, any error in the relative chrominance to luminance signal amplitudes results in slanted displays. Since the luminance signal slants downward to the right; i.e., descending luminance values, if the blue bar display also slopes down to the right, then the chrominance signal is too small, at least relative to the luminance signal. The Tektronix Type 520 Vectorscope is amplitude calibrated for the luminance signal to 1%.

The value of the color bar as a transmission test signal lies in the fact that it can be transmitted as a vertical interval test signal which indicates phase errors, luminance/chrominance gain errors and nonlinearities in the amplitude response of the luminance and chrominance channel signals, including any intermodulation effects in phase or gain. Dynamic effects are indicated as the blue bar display changes with picture brightness. The staircase signal can be used to analyze the chrominance channel and luminance channels for intermodulation and dynamic gain, but the combined distortions are what degrades the picture and these are not readily assessed by the stairstep alone.

Table II tabulates the average picture level calculated for a variety of NTSC color bar signals as generated in the Tektronix Type 141. The APL on color bar signals is thus seen to vary over a range from 36.7% to 55%.

TABLE II

Split Field Color Bars

100% Amplitude		
100% Saturation	APL	
0% Set-up	47.3%	
7 1/2% Set-up	49.7%	
10% Set-up	50.5%	
		Note (i)
75% Amplitude	APL	
100% Saturation		
0% Set-up	36.7%	
7 1/2% Set-up	39.8%	
10% Set-up	40.9%	Note (ii)

Notes: (i) Neutral reference bar preceding yellow bar at 75%
(ii) Conforms fully to EIA Standard RS-189

Full Field Bars W/Black Bar

100% Amplitude

Setup	APL
0%	50%
7 1/2%	54.25%
10%	55%

75% Amplitude

Setup	100% Neutral Ref. APL	75% Neutral Ref. APL
0%	37.5%	34.38%
7 1/2%	42.19%	39.30%
10%	43.75%	40.94%

The author acknowledges with gratitutde the contributions on dynamic gain made by Mr. Win Hurlford of Radio Corporation of America.

AM Light Line Modulation Monitor

Fred L. Zellner, Jr.
American Broadcasting Co.
(Chairman, NAB Aural Overmodulation Subcommittee)

J. L. Smith
Collins Radio Co.
Dallas, Tex.

Virgil D. Duncan
Consulting Engineer
Raleigh, N.C.

MR. ZELLNER: The rules and the regulations of the Commission require that standard broadcast stations, frequency-modulated stations, and aural TV stations, use a modulation monitor in their normal day-to-day operations. During the past few years, it has become apparent that a disagreement exists between the present-day modulation monitors and their associated peak indicators.

A committee was appointed by the National Association of Broadcasters and in conjunction with the Federal Communications Commission conducted three series of tests. Series 1 and 2 were conducted in Raleigh, North Carolina, and Series 3 at the transmitter facilities of WABC FM, Empire State Building, New York City. The first series of tests which were conducted at WRAL FM used modulation monitors of long standing and are a matter of record with the Engineering Department of the National Association of Broadcasters, NAB Building, 1771 N Street, Northwest, Washington, D.C.

In 1968 a new generation of FM modulation monitors had been developed by manufacturers and type-accepted by the Federal Communications Commission. Also at this time the Subcommittee of the National Association of Broadcasters dealing with this subject had been reconstituted with the purpose of reopening and continuing the work that had been started at WRAL FM in Raleigh. A series of tests was then set up, the first of which was conducted by Virgil Duncan, Consulting Engineer, Raleigh, North Carolina, at his laboratory facilities.

The purpose of these tests was to ascertain the accuracy of this new breed of monitors as to peak flasher capability and indicating meter capability. The results of these tests, will be reported on by Mr. Duncan later on in this presentation.

Upon completion of Mr. Duncan's tests, a second series of tests was set up at the WABC FM transmitting facilities in the Empire State Building, New York City. A monitor was chosen which was representative of all those tested at Raleigh. The Federal Communications Commission monitoring truck was simultaneously located at the WABC AM transmitter plant which is located in Lodi, New Jersey. The exciter used on this new FM transmitter was an RCA, operating on a frequency of 95.5 megahertz. The FM transmitter facilities used in this test consisted of a five kilowatt transmitter operating at a power output of 4.3 KW.

The antenna system is of RCA design and radiates a circularly polarized wave at a power output of 4.6 kilowatt ERP. This antenna also accommodates the FM transmission facilities of the Columbia Broadcasting System in New York.

The audio equipment consisted of the following: One Ampex 440 tape recorder, General Electric BA-7 limiting amplifier, and associated monitoring equipment.

The test tapes used are presently on file at the National Association of Broadcasters here in Washington and consisted of the following material:

a. The standard Ampex test tones.
b. High Noon from the Movie Themes from Hollywood, Dimitri Tiomkin and Orchestra, Coral Records, CRL-57006.
c. Live commercial, New York National Speedway.
d. Whistler and His Dog, Medallion Records ML-7501.
e. With Eddie Layton at the Hammond Organ, Epic Records ML-24246.
f. Holiday on Skis of Sound of Christmas, UA, P-6617 the record number.
g. The NAB standard Reference Loudness Recording.

During the experimental test period on the morning of December 5, 1968, nine tests were performed by playing the test tape through the system, observing the modulation and the in-line light meters, with the FCC field truck monitoring simultaneously at Lodi. As the program material was played, observers counted peaks at different levels of modulation using the peak flasher, the meter on the modulation monitor, and the in-line light modulation meters. Observers in the FCC field truck at Lodi, New Jersey, also simultaneously counted and recorded peaks in the same manner. The equipment used in the FCC field truck was a calibrated oscilloscope across a wide-band discriminator for FM.

A typical result is test number three. The audio setup as used in this particular test consisted of the Ampex tape recorder driving the BA-7 limiter with all limiting disengaged and with an 8 db pad on the audio input to the exciter. No filtering or other audio processing was used.

The modulation monitor meter indicated 47 peaks to 100 per cent. The modulation monitor flasher indicated 105 peaks. The in-line light meter indicated 295 peaks to 100 per cent or over. Now, the FCC truck simultaneously reported on section one, selection number one, seven peaks to 130 per cent; on selection two, five peaks to 130 per cent; on selection three, 13 peaks to 120 per cent; selection four, 24 peaks to 160 per cent; selection number five, six peaks to 110 per cent. The peak flasher on the modulation monitor used in the above tests had its variable control set in all cases to 100 per cent. It is to be noted that the peak count of the modulation meter peak flasher is lower than the peak count on the in-line light meter. This can be attributed to the time constant on the modulation flasher, which is three seconds.

With regard to the above subject test and the in-line light meter which was used, Collins Radio Company has a similar device under test and evaluation. Also in this regard the Collins Radio Company submitted a petition for a proposed rule making regarding the use of in-line light meters for the use of peak indicators on AM and FM transmitters for modulation checking. This petition was submitted to the Commission on October 12, 1967. The notice of proposed rule making was issued by the Federal Communications Commission on March 8, 1968.

The difference between the Collins unit and the in-line light meters is that the Collins unit consists of five lights which indicate peaks at the following levels of modulation: 25 per cent, 50 per cent, 85 per cent and 100 per cent, and a fifth light which is adjustable to all percentages of modulation, while the other units have lights from zero to 140 per cent in ten-per-cent increments.

The units which are displayed before you consist of, from your left to right, number one, the Collins unit; number two, the demod unit which is used to drive the three in-line light meters. The purpose of this demonstration is to acquaint you the industry with just what we are talking about regarding in-line modulation monitors using lights at various modulation levels as peak indicators instead of the conventional modulation meter which consists of a meter and an adjustable peak flasher. The test program material which will be used this morning will consist of the same material used in the Raleigh test and the Empire State test. It will be played on an Ampex 600 series tape recorder which feeds an amplifier and monitoring system.

The Hewlett-Packard radio frequency generator is operating at a frequency of one megahertz and is amplitude-modulated. The monitor speaker is bridged off the audio output of the driver amplifier before going into the Hewlett-Packard equipment. To further explain the operation and to demonstrate the two types of indicators, Mr. Virgil Duncan, Consulting Engineer, will present further information on his work in Raleigh and also explain the in-line light meter. Mr. J. L. Smith of Collins Radio Engineering Department will then explain the Collins five-light meter which was the basis for the subject petition filed with the FCC. Mr. Duncan:

MR. DUNCAN: Thank you, Mr. Chairman. Gentlemen. For some time now it has been apparent there existed a rather large margin of disagreement between the modulation monitor meter indications and the peak flasher. Over the past five years a number of tests have been conducted, which Mr. Zellner spoke of. Two of these were in Raleigh, North Carolina and was a joint effort of the Association and the Federal Communications Commission.

Some idea of the problem can be pointed out by an example of the early test in Raleigh, North Carolina. The modulation peaks were measured by the FCC field mobile unit parked nearby and a typical modulation monitor with a peak flasher set at 70 per cent. A short typical program was used to modulate the FM transmitter.

The results: The FCC mobile unit measured 85 peaks exceeding 100 per cent. The peak flasher set at 70 per cent modulation indicated 40 peaks. The percent of modulation meter indicated peaks only to 95 per cent modulation. In another test a popular short commercial spot was used. The FCC mobile unit measured peaks in excess of 140 per cent modulation. The modulation monitor with the flasher set at 70 per cent indicated no modulation peaks in excess of 100 per cent.

I would like to point out here the FCC mobile unit can be calibrated using an oscilloscope across a wide-band discriminator. This technique can provide very accurate measurements and the oscilloscope can be calibrated to an accuracy of about one per cent. Also I would like to point out these are modulation peaks, either positive or negative peaks, that are being measured. As you are aware, the FM monitor has a semi-peak indicating meter having an accuracy of plus or minus five per cent, also a peak flasher that is adjustable from 50 to 120 per cent modulation. There is no accuracy specified for the peak flasher.

An analysis of these early tests indicated the following conclusions:

It is quite evident that there is on many occasions a great disparity between the readings taken on many modulation monitors and those taken by the Federal Communications Commission field inspector force.

By 1968 a new generation of monitors had been developed. The Subcommittee decided it would be a good idea to see how this new generation of modulation monitors would compare using the same type of program material as was used in the earlier test.

All of the manufacturers of modulation monitors were contacted and agreed to supply monitors for the test. The broadcast industry in this country is indeed most fortunate to have the support and cooperation of equipment manufacturers such as these.

These tests were conducted in two parts. The first, in Raleigh, involved a comparative test of the monitors. The second part was at the Empire State Building in New York City and involved a comparison of the monitors at the Empire State Building and the FCC field inspection unit parked at the ABC transmitter site in Lodi, New Jersey. We are most grateful for the excellent cooperation we received in working with the FCC on the modulation monitoring problem.

Now let's look at an example from the Raleigh test. Program Test Tape Number One, the entire program: We used an 8 db pad on the input to the exciter, no limiting or audio filtering. The output level of the tape recorder was set by standard VU meter on the playback machine.

The results: Peaks over 100 per cent modulation: Monitor A—57, Monitor B—80, Monitor C—11, Monitor D—38, The peak line indicator—209. Results using the peak flasher set at 100 per cent modulation were as follows: Monitor A—84 flashes, Monitor B—91, Monitor C—72, Monitor D—86, The peak line light indicator had 209 again for 100 per cent or over.

You must remember that these monitors have the long-duration flashers which are three seconds or longer on-time.

So far we have laid the foundation for the purpose of this presentation. While I have been talking to you, you have noted the peak line indicators on the table. Lights are used to display peaks of modulation equal to or exceeding a reference level.

Several years ago, it became apparent the broadcast industry was in need of a modulation peak indicator which could be used as an operating tool and aid in the adjustment of transmitter modulation. With emphasis on peak flashers it was apparent one or more lights could make an excellent display of modulation peaks.

Over a period of time, tests were conducted with lights at 25 per cent intervals, then at 20 per cent intervals, then at 10 per cent intervals, and then at five per cent intervals. These were from zero to about 130 per cent. From these tests, we arrived at 10 per cent intervals to give a feel for program material and to provide a display resulting from control adjustment of transmitter modulation.

It was immediately apparent that modulation peaks were well beyond the 100 per cent modulation point. In the first model lights were indicated to 130 per cent at 10 per cent intervals from zero to 130 per cent. This was later increased to 140 per cent, as you see one of the indicators here today. Also, it was readily apparent program material fed to the lights could not display the very short time constant of transient peaks, so some form of memory or storage was required. This was accomplished by using a method of trigger and hold. This introduced a new problem of how long should the lights be on to be observable and how short to provide rapid display.

From the test conducted with the 15-light indicators, 150 milliseconds or less appeared to be too short, while 300 milliseconds or longer appeared to be overly long. The multi-light indicators in use here have an on-time of about 165 milliseconds. This time constant appears to give good correlation between control and readability.

I might add that the lamps used in the peak indicators are of the 50,000-hour type, and of the 15 or 20 units in use today it appears there is only one unit that has experienced a lamp failure in the past year. A peak indicator such as this made possible considerable improvement in measurement accuracy of modulation. The threshold of light on to light off is accurate to about one per cent at each indicator level.

A peak must equal or exceed an indicator level for the light to operate. The peaks are determined across a balanced 600-ohm line or any low impedance source. Therefore, the degree of accuracy in measuring positive and negative peaks is determined by the impedance match each side of the line to ground. To read a one per cent peak you must have a much better, accurately balanced impedance or resistance from each side to ground.

Here also involved is a bandwidth of the peak indicator. The multi-light peak indicators shown here have a bandwidth extending from DC to well over 100 kilohertz. Again, new problems were introduced as the result of the bandwidth. First and foremost is the DC offset on the output of numerous pieces of equipment. You must remember that an accuracy of one per cent is an error of about one millivolt and the output of numerous pieces of equipment, including test equipment, has a DC potential at the output, that can be either negative or positive, of from two to five millivolts. Now, this will give you an error of plus or minus five per cent and one per cent peak readings that are not possible with this DC offset. So for precise measurements, impedance and DC offset must be accurately controlled.

There is one other point I would like to make about bandwidth. The integrated circuits that are used in these indicators have an operating range of several megahertz. It was discovered that a short piece of wire on the input gave an indication of all of the local AM broadcast stations operating in the area. Needless to say, the bandwidth has now been restricted to 100 kilohertz. Even so, it is interesting to speculate about the possible peak modulation monitoring of the RF carrier directly of an AM station without demodulation. Or, for that matter, you may wish to include FM.

Of no small concern to each of us would be the prospect of having to replace the modulation monitor with peak indicators. The multi-light peak indicators shown here may be attached to any existing modulation monitor having satisfactory audio output. Preferred is 600 ohms, balanced to ground, with one-volt peak-to-peak 400 per cent modulation. A calibration control is provided on the rear chassis to calibrate the indicator. Therefore, this peak indicator may be used as a studio control indicator of peak modulation, transmitter input peak indicator, or on the output of an existing modulation monitor to indicate your modulation peaks. There is an AM demodulator and an FM demodulator available to drive the peak indicators. One interesting feature of the AM and FM demodulators is that the carrier level is maintained at a fixed point by an internal AGC system. Variations in the carrier level of plus or minus 20 per cent have little effect on the modulation level.

When the AM demodulator or FM demodulator is used along with the peak indicator, the two units make up a peak modulation monitor. By using a peak modulation indicator such as this the broadcast industry can monitor modulation levels equal to or better than the oscillographic technique now employed by the FCC field monitoring unit. Thank you.

Now Mr. Smith will make his presentation.

MR. SMITH: Thank you. I have been invited here to speak with you on the subject of why Collins chose five lights as the indicator device for their 900 El AM modulation monitor. And I will restrict my comments to this subject and will not take up your time to explain the features of the 900 El. We can perhaps save that for another time.

In making the decision of what type indicator we should use we came first of all to two realizations, the first one being that a modulation monitor is a device that monitors the results of the modulation of the transmitter. That is, it is a monitor device as opposed to a gain-riding device.

We certainly do not believe that a person could ride gain with only five lightbulbs. But we do feel that it is very useful in monitoring the results of riding gain. Second, we recognized that the use of the monitor falls into two general categories, the first category being the routine day-to-day operation of the transmitter, monitoring the depth of modulation.

The second category is what is termed special situations, and these are occasions where it is desirable to know some specific unique value of modulation. An example of this might be trying to trace down a point where you were having some modulation breakup or distortion at a particular level of modulation that did not happen to fall on one of these indicator lights that we have. We have to have some kind of way of interpolating between these lights for these special situations. So we have two general categories: The day-to-day where you just want to see how the transmitter is doing over there; and the other being the case of the special situations where you want to run a proof and things of this sort.

Now, let's consider first the day-to-day requirements. We reasoned that regardless of the type of indicator that you might have, when a human looks at this indicator he automatically categorizes the reading that he gets.

Let me explain that statement with a couple of examples. Imagine a hypothetical indicator of some sort that has infinite resolution; it can display all of the information to you, and at some particular instant a human looks at that indicator and the indicator reads 26.75 per cent. Now, what does that mean to the man? We asked ourselves this question. Do you think that the man looks at that and he says, Ah, I see that my peaks of frequent recurrence are 26.75 per cent? I hardly think so. I think the realization he comes to is the fact that his modulation is low and he should raise it.

On the other end of the scale, suppose that the instant that he looked at it, it was 115.23 per cent. Here again the numerical value, precise numerical value, is not the subject of interest. The fact is that the modulation is too high and he should lower it. So we reasoned then that when the human looks at this indicator, he is going to categorize these readings, he is going to place them in categories and take his action accordingly in his day-to-day operation.

So then the question comes up: Well, what categories does he place these readings in? Well, we thought he would put them in the category of low, medium, high, and too high, there would be four categories. So then it remained to be determined, if he is going to put them into these four categories, where do we draw the line for each category.

Well, it was easy to determine what too high was. We took 100 per cent for that one. And the mid-point wasn't real difficult to determine either, because that is 50 per cent and we took it in there. But then when we came to the other two categories of the low and high, we fell back on the rules and regulations for those two points.

As you know, you are required to make measurements in your proof at 25 per cent, and at 85 per cent also. And also your rules ask you to try to keep your average modulation or your peaks of frequent recurrence up around 85 per cent and not exceed 100 per cent. So we thought that we would choose these things to embody those fixed points which are of interest to the broadcaster in his day-to-day operation there. And so we chose 25 per cent, 50 per cent, 85 per cent and 100 per cent.

Now let's look at the other requirement of the modulation monitor; that is, special situations. We have taken care of his day-to-day operation now, but this doesn't fulfill all of the needs of the modulation monitor. And here it was necessary to measure an arbitrary depth of modulation, but it still isn't necessary, we feel, to measure it out to two and three and four decimal places. In the average use of the work, within a percent or so is plenty close enough. Therefore, we reasoned that if we put an additional indicator on the modulation monitor which carried an adjustable threshold that was adjustable between zero and 125 per cent, then the man could use that to get his intermediate values.

Now, in the event that you are presented with an arbitrary level of modulation and you want to determine what this is, you would take your peak flasher light or your adjustable light, turn it up to the 125 per cent mark and start backing down. And when you have gotten to the point where your light just came on, then that is the percentage of modulation that you are reading.

On the other hand, you may want to set up a desired value of modulation, in which case you simply set the knob to the value of modulation that you wish and increase the modulation from zero until the light comes up, and you are able to set up your percentage that way. So that kind of tells us why we came up with five lights: Four for the routine day-to-day operation and one to take care of the special situations. Now, your special-situation light is also useful if you would like to leave it set at some value other than your fixed ones. That gives you an additional point to have.

But the story doesn't end there, I'm afraid. I'm sure that there are people thinking: Well, if this is a minimum number of lights that we think we need, why not put some more on there; the mind is going to categorize these lights anyway, and we are not going to lose any information by putting lights up there. And I certainly agree. There is certainly nothing wrong with having as many lights as you want. They certainly do not subtract from the utility of the indicator. But we did not propose more than what we thought were the minimum number of lights when we filed our petition because we felt that there was a possibility that the Commission may write the rules in such a way that they would specify a minimum number of lights and if we included in the petition more than what we felt was the minimum and that eventually got into rule making, then every manufacturer would have to put that number of lights on the monitor.

Now, if a minimum number is specified—and I don't know how it is going to turn out—but if a minimum number is specified, I would imagine that an individual could buy and a manufacturer could offer a unit that had more lights and he could, each could suit his own preference that way. This is what we were hoping. Now, what is wrong with just going on and specifying additional lights? Really nothing. But it boils down to a problem of economics and cost. The more lights you add, the more it costs. And I know you are thinking, Well, gee, how much does a lousy lightbulb cost. And I am the first to admit that a lousy lightbulb doesn't cost very much. And a good one doesn't cost too awfully much itself. But there are other things that go with the lightbulb.

In the first place, you have got to put the thing into a socket, you have got to have a lampdriver to drive this lamp; you have got to add an additional comparator circuit for each lamp on your monitor; you have to increase the resistors in your precision voltage divider to pick off all of these different levels in there, you have to increase that by the number of lights that you have; your power supply then has to deliver more power to drive these additional lampdrivers and lamps and comparator circuits and things of this sort. Then you get these components and you have got to put them somewhere. So you put them on a printed circuit board and you either have to have a larger board or two boards in order to accommodate it all.

Then, of course, you have got to put all this stuff together. Your assembly time goes up. Your test time goes up. You have to set up each one of these modulation levels accurately and measure each one of your indicators. And in general the equipment ends up more elaborate perhaps than it really would have to be, and all the consequences that go with equipment that is more elaborate.

That sort of summarizes the reasoning that Collins went through in selecting the indicators that we have there. I know I probably took too long to tell you why there are five lightbulbs on a piece of equipment, but I have a habit of doing that anyway. If you would like to know more about the monitor, perhaps we could tell it to you some other time. Thank you very much.

MR. ZELLNER: Briefly the Collins unit has lights at 25, 50, 85, 100 and a variable which is set at 100 per cent with the adjustable control. The first unit, which would be on your left, of the in-line variety, has lights flashing at 30 per cent, 60 per cent, 90 per cent and 110 per cent. The second unit has lights at 20 per cent, 30 per cent, 60 per cent, 80 per cent, 100 per cent, and 110 per cent. The third unit on your extreme right has lights from zero to 140 per cent in ten-per-cent increments.

It is interesting to note at this point that the work which was going on in this regard at Collins Radio the Committee and the people involved with the Committee were completely unaware of. We began our first experimentation as far as the Committee was concerned about a year ago with the in-line light meter. We were aware of the Collins petition, but we just didn't know what it was. It is interesting to note that there were two groups of people progressing in the same direction unbeknownst to one another. Russell, do you want to start the test tape?

(Tape playback.)

TECHNICIAN OPERATING AMPEX: That's white noise.

MR. ZELLNER: This is white noise.

(Playback of NAB Reference Tape.)

On the Collins unit, or the five-light unit, in the absence of modulation there is no light lit. On the in-line light indicators, in the absence of modulation the zero light is lit. The last white light on the in-line meters is 100, and on the first two in-line meters, the last light or the red light indicates 110 per cent.

A MEMBER: What is the Collins set at?

MR. ZELLNER: 110 per cent. The discrepancy in the VU meter is about the same on this music as it was on the NAB Reference tape. One of the questions which this Committee is trying to answer in conjunction with the FCC regarding in-line light meters is just how many lights would be necessary on a modulation monitor of this type. The industry is invited to make comments to the FCC on this matter. Comments should be addressed to the Federal Communications Commission, 1919 M Street, Washington, D.C., and are to be referenced to FCC Docket Number 18063.

It is most important in this regard that comments be received from operators of broadcast facilities, as they are the people who use this type of equipment on a day-to-day basis and are confronted with the problem of controlling modulation using modulation monitors of conventional design. It is also very important in filing comments with the Commission that good reasons be given to justify their respective positions which they take. It is of absolutely no value in submitting comments to simply state that you like an idea or you dislike an idea. Your position has to be justified.

I would also like at this time to take the opportunity on the part of various members of this Committee to thank the Federal Communications Commission for their excellent cooperation, help and advice which they have given so that this Committee may perform the experimentation so necessary in order that we are able to sucessfully evaluate the project before us and make the necessary recommendations.

Are there any questions? (No response.) Thank you very much for your attention.

New Two-Tube Color Cameras for Broadcast Use

B. M. (John) Poole
Ampex Corp.

In a paper read at the 1968 NAB Convention, a portable color camera was described using two plumbicon tubes. A novel principle was adopted in the interests of reducing size and weight. One of the camera tubes was used as a luminance channel, and the other was used for time-sharing red and blue at field rate. The missing fields of red and blue were reinserted by means of a 262-line delay.

During the last 12 months many improvements have been made to the general system, resulting in greatly improved performance. The laboratory model studio camera shown last year has been redesigned, embodying these improvements, and is now a production item. Further development of the hand-held camera has extended its usefulness to include direct recording onto the VR-3000 portable video recorder. This arrangement makes it possible for a two-man team to originate recorded color program material.

This paper will describe some of the factors contributing to the present excellent performance, and introduce two new cameras. One is a "hand-held" camera (the BC-110) designed to operate either on cable or with a portable video recorder. The other is a studio camera (the BC-210). An integrated-system concept permits the use of only one type of camera control unit, with consequent possibilities for equipment-sharing in the interests of economy.

IMPROVEMENTS TO THE PERFORMANCE OF TWO-TUBE CAMERAS

Signal-to-Noise Ratio. Until recently the cascode type of preamplifier, using vacuum tubes such as the "Nuvistor," was still capable of giving the best signal-to-noise ratio. Attempts to transistorize always resulted in slightly degraded performance. The field-effect transistor which is analogous to a tiode tube can now be made with a high transconductance, 4000 microsiemens, and very low input capacity. With three field-effect transistors in parallel in a cascode circuit, a signal-to-noise ratio of 50 db can be realized with a 4.2-MHz bandwidth at a target signal current of 250 nanoamps. This is 4 db better than preamplifiers using junction transistors. The improvement gives a "margin of safety" for the color matrix which improves colorimetry at the expense of increased noise.

Red/Blue Filter Wheel. Earlier cameras used Wratten filters. Number 47 was used for blue with a peak transmission of only 50% at 450 nanometers. Number 24 was used for red with a sharp cutoff on the short wavelength side of 600 nanometers. The latest filter wheel is all glass with dichroic deposits. This results in a 2:1 increase in both red and blue signal currents, which is only partly due to a broadening of the red-taking characteristics.

Separate-Mesh Plumbicons. Changing over to separate field-mesh plumbicons made improvements to beam landing, corner resolution, and uniformity of lag characteristics. There is also an improvement in registration accuracy. This is because there is some rotation of the picture when a non field-mesh tube is set up with a good margin of beam current. The two-tube camera requires a new grade of camera tube which meets both red and blue specifications. This is evidently not a problem to the tube manufacturer who makes only a nominal selection charge.

Ultrasonic Field Delay Line. The 262-line delay shown in Fig. 1 uses an improved type of ultrasonic line. A piezoelectric transducer converts the electrical input to an ultrasonic torsional wave in a coil of special wire. The output transducer is magnetostrictive because this type can be made adjustable as a fine trimmer on the overall delay. The frequency response extends to a 2.2 MHz which is ample for the narrow bandwidth color difference signals. As the frequency response falls off below 400 kHz, a modulated carrier system is used centered at 1.2 MHz. The new lines have improved signal-to-noise ratio, and the wider bandwidth results in better transient response.

Colorimetry. In this type of camera it is necessary to matrix green from the Y signal, and also perform the color masking required to produce the correct negative lobes on the taking characteristics. Fortunately, the colorimetry of color cameras is now an exact science. The use of a computer facility greatly simplifies the actual running of the necessary colorimetric calculations. The computer's input data includes the kinescope primaries, spectral characteristics of the optics, and some index of the relative weighting to give signal-to-noise improvement compared to minimization of colorimetric errors. The set of computer programs takes the input data, goes through initial computation through an optimization program, and then prints out the matrix values to be used on the camera taking signals. Additional print-out includes colorimetric errors for a series of standard test color chips, and the specification of any optical filters to be used. The programs yield colorimetry data which is ideal to the limit of signal-to-noise compromise, the accuracy of the system elements, and the control of gamma. After setting up with the calculated matrices and trimming filters, the degree of success can be judged experimentally by viewing standard color chips of known spectral characteristics and measurement of the R G and B channel outputs. Fig. 2 shows a typical set of characteristics for the BC-210.

Single Control Three-Channel Gamma Correction. The gamma correction method used is a novel application of two integrated circuits. Fig. 3 shows the schematic. Three diodes on the same chip are used for the nonlinear shunt elements of the R G and B gamma circuits. A fourth diode senses the chip temperature. An operational amplifier controls the current through a transistor, also on the same chip, maintaining the temperature at 60°C ±1% with a warmup time of less than 20 seconds. The resulting circuit is highly stable.

Horizontal Image Enhancement. Fig. 4 shows a simplified schematic of the unit. The nine-section open-ended delay line preserves a flat frequency response in the normal condition. The output and input of the delay line are fed into a differential amplifier which passes only the picture transitions to a pair of biased diodes. Negative and positive clipping removes the baseline noise, after which only the transients are mixed in with the unmodified video signal. In this way edges are enhanced without visibly increasing the picture noise.

Test Waveform Generator. A staircase generator in the camera head provides ten steps of 10 IRE units. It is remotely controlled from the camera control panel, and can be switched into either luminance or chroma channels or both at once.

Chroma Key. It was generally believed that a restricted bandwidth red and blue

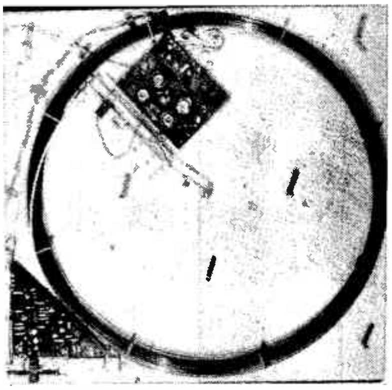


Fig. 1

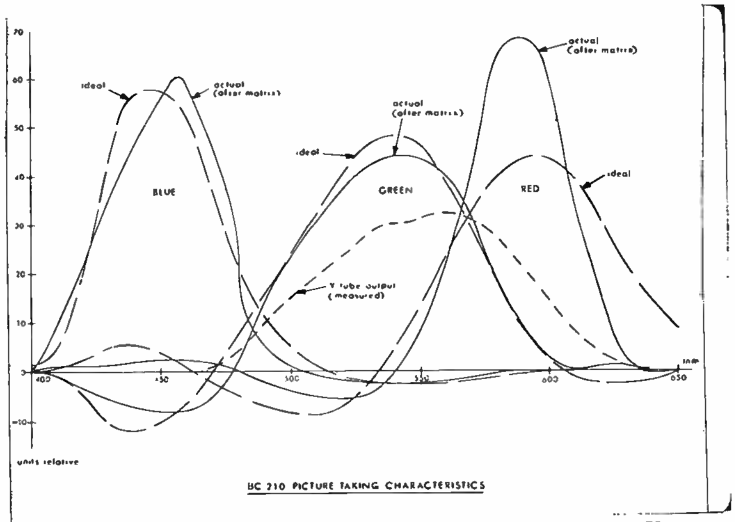


Fig. 2

```
LOAD
FROM: /V/

>RUN
                              PROGRAM  V
THE NUMBER OF SAMPLES IN SAMPLE FILE IS:
? 17

HAVE YOU RUN PROGRAM III ?
IF YES TYPE 1 IF NO TYPE 0 (ZERO)
? 0
TYPE INITIAL VALUES OF MATRIX VARIABLES
 0      ? 1.6
 1      ? -.6
 2      ? -.25
 3      ? 1.5
 4      ? -.09
 5      ? -.12

DO YOU WANT PRINT-OUT OF J.N.D. ERROR FOR EACH SAMPLE ?
IF YES TYPE 1 IF NO TYPE 0 (ZERO)
? 0

RESULTED-MASKING MATRIX
***********************

FOR RED
-------
RED            GREEN             BLUE
 2.1926986    -1.2373563       .4465766E-01
FOR GREEN
--------
RED            GREEN             BLUE
-.62997381     1.7443349      -.1143611
FOR BLUE
---------
RED            GREEN             BLUE
-.10259164     .5519812E-01    1.0473935

MEAN J.N.D. ERROR = 1.4734253

DO YOU WANT THE FINAL RED,GREEN AND BLUE CURVES
AS CORRECTED BY THE OPTIMUM MASKING MATRIX ?
IF YES TYPE 1 IF NO TYPE 0 (ZERO)
? 0
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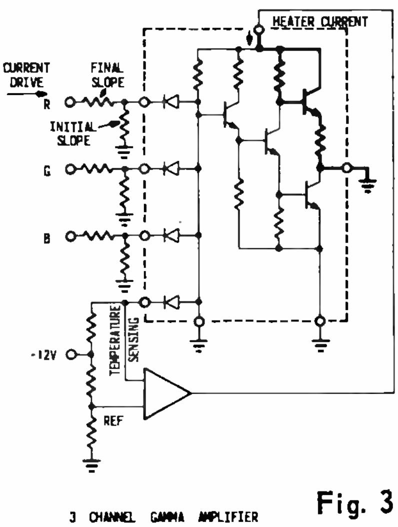

Fig. 3

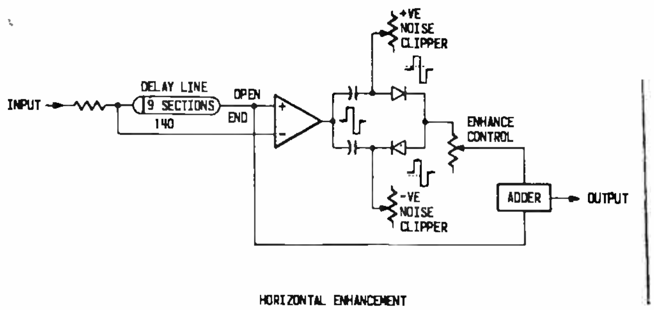

Fig. 4

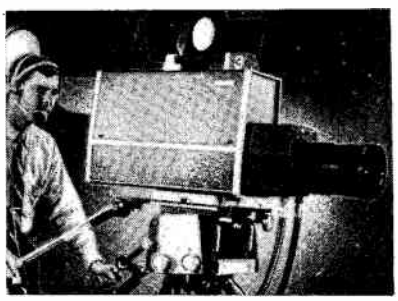

Fig. 5

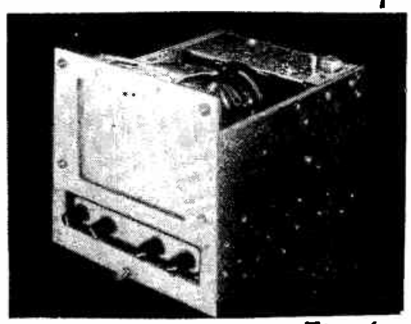

Fig. 6

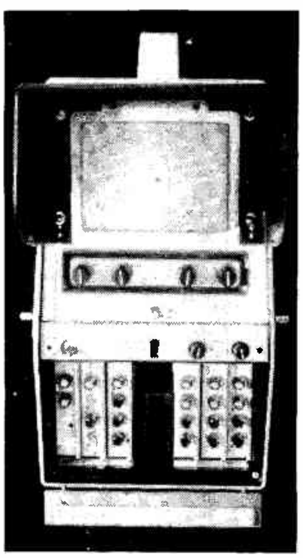

Fig. 7

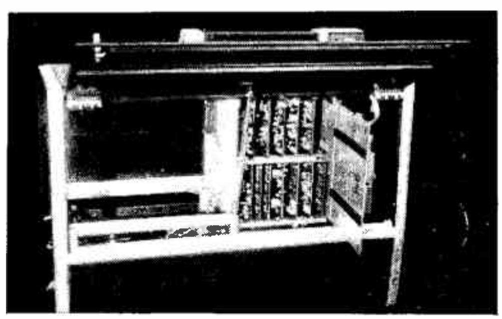

Fig. 8

signal would not be usable with chroma key. In the two-tube camera the red and blue signals at the encoder input have the same rise times as the wide bandwidth luminance. This is because the R-Y, B-Y signals are narrow-band and the Y signal is wideband. When Y is subtracted to produce R and B, the high-frequency content of the Y signal remains.

THE BC-210 STUDIO CAMERA

The design improvements described have been incorporated in this new camera system. The following is a brief description. The camera head (Fig. 5) weighs 50 lbs without the lens, which accounts for between 5 and 20 lbs; depending on choice of 6:1 f2.6 or 10:1 f2.2 lens with range extenders. The one-half inch diameter camera cable uses two coaxials for video, and 11 other wires for power, interphone, and remote control of iris, test signals, and sync generator phase. This arrangement is achieved without elaborate multiplexing or digital control system. Two main factors are responsible for this major simplification. Firstly, with only two pickup tubes the camera is easily registered by viewing luminance and chroma difference signals on the viewfinder. (A typical three-tube camera uses 40 wires for adjusting the deflection and beam circuits.) Secondly, the use of a micrologic sync generator in the camera, which eliminates the need for drive pulses and effectively deals with all problems associated with cable length, such as drive and clamp pulse timing. It requires only an audio pair for phase-locking the crystal oscillator in the camera to the station sync generator.

The Viewfinder (Fig. 6). The viewfinder is a plug-in unit using a 6-inch diameter rectangular picture tube. Brightness is over 200 footlamberts, and resolution is adequate for camera focusing or checking registration. A monitoring circuit feeding the viewfinder provides gamma correction and crispening with a switch on the rear panel (Fig. 7) for selecting luminance, chroma or difference signals. The viewfinder picture is also correctly blanked and clamped by the camera head processors.

Setting-Up Controls. The rear panel has a flap door which provides access to the setting-up controls. All of the modules are plug-in and will operate for maintenance purposes on extender cards. The side view shown on Fig. 8 shows the card rack for all of the circuits not requiring operational adjustment. These include the sync generator, power supplies and regulators, video processors, tube blanking, scan protection, and servos for the lens iris and the red/blue filter wheel.

Optical System. The optical system was described in previous papers.[1 2] Briefly, the two plumbicon yokes are at right angles with a beam-splitting prism. Fig. 9 shows the general arrangement. There are four positions on the filter turret, and in addition to the rotating red/blue filter there is a trimming filter for the luminance tube.

Control Panel. Fig. 10 shows the half-rack width control panel. The main controls are gain and black level for R G and B, master pedestal, and iris. A comprehensive push-button monitoring system is provided with multiplier switches so that all signals can be seen before and after gamma correction. Other controls include switching of color bars, burst, and parade generator, and choice of intercom modes. Under the flap cover are a master gain control, camera output gain and pedestal trimmers, and control of the test signal generator.

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1 Poole, B. M. (John), Two-Tube Color Cameras for Broadcast Application, International Broadcasting Convention, No. 46, Part 1, 3.25.1-.9 (1968)

2 Berry, Max, Poole, B. M. (John), A New Portable Color Camera, NAB Eng. Conference, No. T-148, 163-174 (1968)

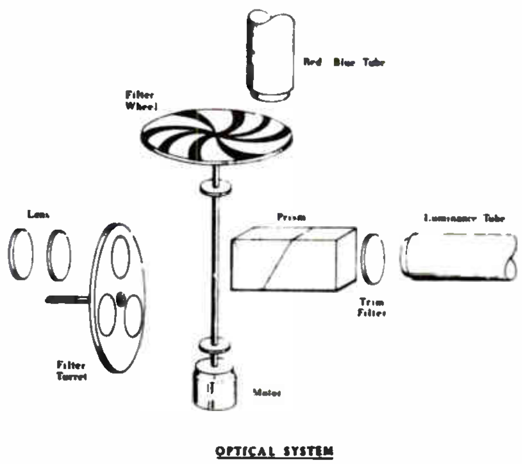

Fig. 9

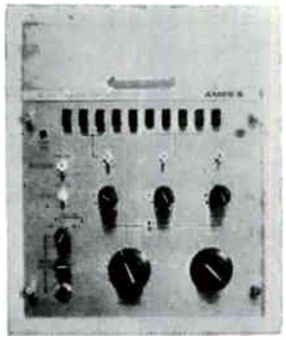

Fig. 10

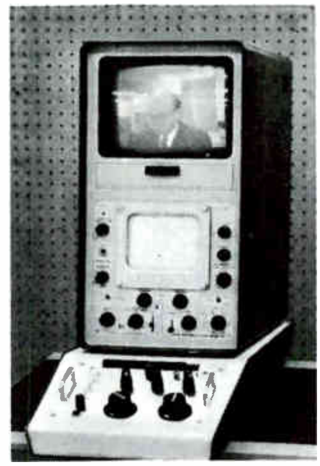

Fig. 11

Fig. 12

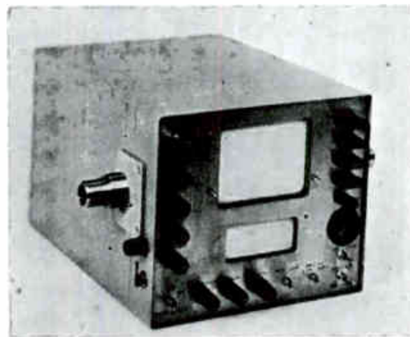

Fig. 13

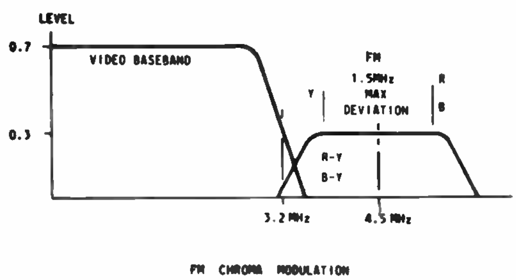

Fig. 14

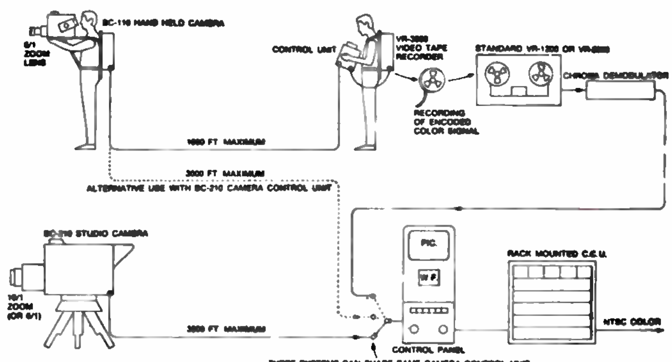

Fig. 15

Fig. 16

Picture and Waveform Monitor. Fig. 11 shows the now familiar picture and waveform monitor mounted on the control panel base.

Rack-Mounted Camera Control Unit. The principle elements of the rack-mounted camera control are cable length correction, remote gain and pedestal, field delay and switch, color matrix, gamma correction, sync phase comparator, horizontal and vertical aperture correctors, and color encoder.

Camera Performance. The camera meets its performance specifications at a light level of 100 footcandles at f2.8. Increased sensitivity is obtainable with the lens at f2.2, and an additional 6 db is provided by the master gain control.

DIRECT RECORDING FROM THE HAND-HELD CAMERA

The third part of this paper deals with a new application of the hand-held camera which can now be used for direct recording of color onto the VR-3000 portable video recorder.

BC-110 Portable Camera. This new camera, the BC-110, (see Fig. 12) is compatible with the BC-210 studio camera; i.e., it will operate using the same camera and camera control unit. Most of the PC boards in the camera head and back-pack are also identical to those in the BC-210. In this new configuration a smaller back-pack are also identical to those in the BC-210. In this new configuration a smaller back-pack is used reducing the total weight to under 40 lbs. The reduction is effected by leaving out the microwave transmitter, receiver, and multiplexing used on the BC-100. The viewfinder used has a one-inch picture tube, and the 6:1 zoom lens is fitted with servo iris control.

Recording Direct on the VR-3000. In an alternative mode of operating the BC-110 can be rigged for operation on batteries to record directly into VR-3000 portable video recorder. Five additional circuit cards are required, and also a small picture and waveform monitor with provision for remotely controlling the recorder (Fig. 13) and adjusting the camera iris to give correct recording level. Development of an FM chroma modulation system to improve microwave performance on the BC-100 has resulted in an excellent basic system which is readily adapted to the requirements of tape recording.

Referring to Fig. 14, the baseband video signal is rolled off above 3 MHz, and the sequential color difference signals modulate a subcarrier at 4.5 MHz. The bipolar signals deviate the carrier ±750 kHz. The recording is played back on a highband video recorder using a 5-MHz output filter to avoid cutting the chroma upper sidebands. Playback is passed through a demodulator which converts the signals back to Y and R/B for processing through the camera control unit and encoding to NTSC.

Overall System Concept. Fig. 15 shows the various ways in which the equipment can be used, and how a single camera control unit can be used in conjunction with a BC-110 on cable, a BC-210, or for playback of tapes recorded from the BC-110.

Tape Recording - Operational Aspects. Before setting out on a field trip, the camera receives a full line-up. Critical setting of color balance on gray scale is not important at this stage. On arrival at the location, a brief check is made for camera registration. A slight adjustment of centering is sometimes needed. Before taping, the camera is shown a gray-scale chart for about one minute. This is required during final playback. Approximate color balance can be checked by observing color difference signals on the waveform monitor. (Fig. 16 shows a field check in process.) When taping, the camera operator needs only perform the actual focusing and zooming required for picture composition. The video operator adjusts video level into the recorder using the portable picture and waveform monitor by remote control of the lens iris. He then checks the recording using the black and white playback facility of the VR-3000.

Playback. After returning from the field trip, the tapes are played back on a highband recorder. The Colortec and processor are bypassed, the output passing instead through the chroma demod accessory unit which separates the video signal into a luminance channel and a red/blue channel. These are now correct inputs for the camera control unit which processes the signals to provide color balance, aperture correction, and finally, encoding to an NTSC signal. It is interesting to note that the FM chroma system is free from hue shifts or banding effects due to velocity errors. This means that adjustment of guide height and tip projection on the portable recorder are not critical. When playing back the tape, the camera control unit can be used to make operational adjustments as if it were controlling a "live" camera.

Color Balance. The recorded leader of a gray-scale chart can, therefore, be adjusted for correct red, green, and blue tracking in the normal way by adjustments to the gain and pedestal settings of the three channels. When a camera is used under various lighting conditions, both indoors and outdoors, there are color temperature changes in the range of 2800 to 10,000 degrees K. Normally the camera would be set up at 3,200°K before taking it on a field trip. A filter would be used for daylight correction which would reduce errors caused by the higher color temperature, but the changes in channel outputs under varying lighting conditions are too great to be compensated properly this way. Even daylight varies from 4,800 K to 10,000 K according to weather conditions and time of day. ([3]) To obtain good flesh tones or to match up with previously recorded material the ability to "post paint" the recording is mandatory. In addition, special effects are possible such as night scenes.

Conclusion.. The camera systems that have been described are highly portable, and simplified by the use of only two camera tubes. The BC-210 studio camera will operate on up to 3000 ft. of small-diameter cable; its camera control unit can be shared with a small hand-held camera, the BC-110, operating on the same type of cable. In its other mode of operation, the BC-110 can be used on batteries for recording color directly into a VR-3000 portable video recorder, thus opening up a new field of usefulness for the television camera that was previously the exclusive domain of the film medium. By originating exclusively on tape, film processing is eliminated and all of the new electronic editing aids can be used to advantage.

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3 Wyszecki, Gunther, and Stiles, W. S., Color Science: Concepts and Methods, Quantitative Data and Formulas, 10 (1967)

FCC/Industry Panel

MODERATOR: Albert H. Chismark, Director of Engineering
Meredith Broadcasting Company
Syracuse, N.Y.

PANEL PARTICIPANTS:

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Broadcast Electronics, Inc.
Silver Spring, Maryland

Wallace E. Johnson, Assistant Chief
Broadcast Bureau
Federal Communications Commission
Washington, D.C.

Lloyd Smith, Supervisory Engineer
TV Branch, Broadcast Facilities Division
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Everett L. Dillard, President & Owner
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WDON
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Harold L. Kassens, Assistant Chief
Broadcast Facilities, Broadcast Bureau
Federal Communications Commission
Washington, D.C.

Benjamin Wolfe, Vice President for Engineering
Post-Newsweek Stations
Washington, D.C.

(Reprinted from the official transcript)

MODERATOR CHISMARK: I know we are running late, so in the interests of time, we will forego the biographical sketches. They are all experts anyway. And I will let each member of the panel introduce himself, and I will start on my immediate right. So would you start off, Wally.

MR. JOHNSON: Good morning. First of all, my name is Wally Johnson, Assistant Chief of the Broadcast Bureau.

Several things have happened to us during the Convention, of course. One thing is that you only come every four years to Washington and one of the things we do is try to get all of our engineers to attend as much of the Convention as they can because they do gain a lot of valuable information and a lot of good insight as far as the broadcast industry is concerned.

But one thing worried me this morning. One of our newer engineers came up to me and said he spent a lot of time down with the exhibits, talked to broadcast engineers and so forth. But he got a little concerned. He says, "You know, there are a lot of people out there who don't really like us." So I said, "I have been coming to these things for several years now and don't worry about it because Friday morning we will all regroup. So meet in my office at ten o'clock and we'll all get together."

As far as what I do...As the Assistant Chief of the Broadcast Bureau, I think that I get involved in some pretty impossible things. Sometimes, they come to some conclusion. One of the things I was involved with was the Mexican Agreement, the new Standard Broadcast Agreement; I helped in the negotiations, and it is pretty well concluded now.

The other thing that is of primary importance right now is the land mobile problem. We have two rule makings on land mobile involving UHF channels, and I am involved in that. And and another thing, various management functions that I perform relate to budget problems which involve very highly technical engineering at times. One of the more happy things that I do is approve Harold Kassens' leave. And also his requests for travel.

MR. KASSENS: I am Harold Kassens and I am Assistant Chief of Broadcast Facilities. Our Division processes all the broadcast applications that come in, except for renewals and assignments, so we have plenty to do.

We also worry about the day-to-day operation of broadcast stations. And, as you well know, I am sure, sooner or later you all have occasion to contact us on your day-to-day problems, and we are happy to take care of them.

MR. SMITH: My name is Lloyd Smith and I am the Supervisory Engineer for the Television Applications Branch. This Branch is responsible for processing applications for construction permits, modification of construction permits, and applications for licenses for television broadcast stations, translators, instructional fixed television services, and auxiliary facilities for all of the broadcast services.

MR. BEVILLE: I am Ross Beville. I am Chariman of Broadcast Electronics. We manufacture Spotmaster tape cartridge equipment and other audio devices which we fondly hope find their way into your hands.

MR. DILLARD: My name is Everett Dillard, I am the owner of radio station WDON and an engineering consulting firm, Commercial Radio Equipment Company. I sort of wear a dual hat. I guess I am up here in the capacity of industry and, of course, in both phases of this we deal with the boys on the other side of the table, and I have found them to be pretty nice guys.

MR. WOLFE: My name is Ben Wolfe and I am Vice President of Engineering for Post-Newsweek Stations in Washington.

MODERATOR CHISMARK: Gentlemen. Thank you very much. In the aisles are microphones; please feel free to use them if you have any burning questions.

Let's start with this question: The AM and FM rules specifically require proof of performance measurements. No such requirement is mentioned in the TV rules. Why?

MR. SMITH: The TV rules now, so far as the application for license is concerned, require a proof of performance, but require only that these measurements be submitted once. This is really a once-in-a-lifetime equipment requirement, and as long as we don't change certain things, then no additional performance measurements are required.

We have had many people question this, particularly in light of the relative cost of color receivers and this type of thing, why don't we require additional or periodic remeasurements of some kind, particularly the color performance measurement. I am not aware at this point of the historical background of our present requirements. However, it may be a case where we need to take a serious look at this type of thing and see whether or not certain remeasurements in connection with the entire proof of performance should be required.

MODERATOR CHISMARK: Do the members representing industry feel that we should have such a requirement?

MR. WOLFE: Yes; I do. I think you can go for ten years without measuring differential gain, differential phase, the visual linearity of a television transmitter while trying to make the NTSC color work. But I believe it is important that we have some regulations along these lines in the interest of not only our industry but I guess firstly the nation. I would like to have the Commission react to that.

MR. KASSENS: We're working on it.

MODERATOR CHISMARK: That's what we're afraid of. The second part of the question that was handed me is: What is the proper way to answer the proof question on the TV renewal application?

MR. SMITH: This does not apply.

MODERATOR CHISMARK: Could you clarify the new power output meter calibration rule for TV transmitters?

MR. SMITH: The Commission recently adopted new rules regarding the calibration of power output meters for television transmitters. This is something that came about very recently, I think around the middle of February, that we adopted these new requirements. Apparently—and I say "apparently" because I'm not in a rule-making area—we first decided to do this as a result of some of our field inspectors' complaint that in many cases the power meters were only calibrated at 100 per cent, or at the authorized power output of the television transmitter. Our rules have a certain prescribed tolerance. You can operate with not more than 110 per cent or not less than 80 per cent of the authorized power. The new rule requires that the power meters be calibrated at 80 per cent, 100 per cent, and 110 per cent.

There is, however, one exception to that. We did receive some comments regarding the fact that some of the older transmitters perhaps could not generate powers up to 110 per cent. So the new rules do provide for calibrating at between 100 and 110 per cent. Now, if you calibrate the upper limit at some value less than 110 per cent or somewhere between 100 and 110 per cent, any readings over this value will be considered in violation of the rules.

MODERATOR CHISMARK: In marking the meter would a chinagraph pencil be acceptable, or how would you like the marking shown?

MR. SMITH: Well, some type of adjustable markings, keeping in mind that there is a requirement that these meters be calibrated at intervals not exceeding six months. The upper and lower limits must be calibrated at this time and if there is any difference, it must be recalibrated and remarked.

MODERATOR CHISMARK: Thank you. Do we have any questions from the audience at this time?

A MEMBER: Are we required to redo our sign-off, sign-on, et cetera, to include megahertz and kilohertz rather than kilocycles?

MR. KASSENS: The answer, of course, is no. Some of us are still old-fashioned and, as Mr. Hathaway observed the other day, we feel much safer with kilocycles. But, along this line let me point out to you that a good many stations get on and give a rather long sign-on or sign-off spiel, even bringing us into the act. If you will look closely at the rules, you will find that this is not required, and we have been doing it for probably these 40 years: the Star Bangled Banner, the frequency, the power and so many other things. This is not required. The only thing you are required to do when you start and stop is give the call letters and the location.

MODERATOR CHISMARK: Thank you. Hal, a lot of people have been asking you questions. Would you like to ask industry a question?

MR. KASSENS: Yes, I've got one. Ross Beville is a friend of mine—and has been for a good many years. In fact he once thought so highly of my accomplishments that he made me Honorary Chief Engineer of his STL.

I am wondering about this question of noise in cartridge tape. Since he is an expert, I would like to know what we run into with, shall we say, playing spots too often and getting noisy cartridge tapes. Really the question I would like to direct to him: What would you think about the idea of running equipment performance measurements from tape output to transmitter output instead of what the rules now require, from mike input to transmitter output?

MR. BEVILLE: With that question, the way you put this, Hal, I'm not sure we are going to reappoint you. It's a several-part question and I assume that you are speaking of the noise generated by various devices, not only tape cartridge equipment but reel-to-reel tape, turntables, and various other pieces of audio equipment that are attached to a console feeding the program bus and the noise generated and hum levels generated by this.

Having had some background in the broadcast industry I sort of agree with the intent of your question. The only requirement so far as I know is that the performance measurements be made from the input of the microphone terminals to the output of the transmitter. And, of course, this leaves something to be desired in that there are an awful lot of stations that hardly ever open a microphone nowadays. A good 90 per cent of their program material is generated on other pieces of equipment. And the question arises then, I am sure, in your mind as to what are the performance characteristics of this equipment. And I would be the first to admit that in many broadcast stations some of this equipment would not meet the Commission's requirements. A lot of it I would suspect, though, is a matter of proper maintenance and proper installation at the time.

Generally, manufacturers are pretty persnickety about meeting their own specifications. There are enough very good engineering departments in broadcast stations and networks to check up on you, and they do. I don't feel qualified to speak for competitive equipment, but in our case I know that we do make our equipment meet the specifications that we advertise. I think, as a general statement, I could say that other manufacturers do the same thing. But equipment does deteriorate. Electrolytic capacitors dry out, tape in particular does degenerate as time goes along. And a spot, for example, that is made to be used possibly a thousand times over the course of a year, such as a station break or something of this sort, can also deteriorate and the background noise behind this program material can be quite high.

There was a second part to the question on whether or not there should be a requirement for making measurements and making all of the auxiliary equipment in the audio chain meet the requirements that the Commission now has laid down for microphone input. This might be a good idea. So far as I know, we are about the only country in the world that doesn't require this. Other nations around the world with broadcasting systems comparable to American broadcasting do require frequency response, noise, and distortion measurements on all of the other audio equipment.

I know, for example, in Australia that they require the audio measurements to include tape equipment, record playback characteristics, the console, other program equipment between the console and the transmitter, and the output of the transmitter, the Australian CAB, which is the equivalent of our FCC here, states that distortion cannot exceed three per cent at the zero VU recording level on tape. They further require that the distortion percentage not exceed five per cent 8 dbs above the zero VU recording level.

MODERATOR CHISMARK: Thanks, Ross. Next, I'll take a question from the audience.

A MEMBER: One thing that has concerned me for quite a while in TV is the poor audio response on the network lines. I don't know if anyone here can do anything about it, but we are on network far more than anything else at our station and the audio leaves a lot to be desired.

MR. BEVILLE: I would like to comment briefly on that. This is certainly true but it is not just the network programming or response characteristics of network lines. This is not the only contributor to these problems. The very recording that we do, a lot of us are more or less governed, in many cases, by what the news department wants to do. And the news department, if they can get an intelligible recording they will demand that this go on the air. This can have terrible noise behind it, no matter how well you maintain your equipment or how well you do it. The distortion percentage, the frequency response, and the noise levels of some transmissions on newscasts are pretty horrible.

There was a time, I can remember, when the engineering department had a little veto power on some of these things. But those days are pretty well gone. And the news department, if they want something on, it usually goes on. This results in high noise levels, poor response and the bad distortion percentages regardless of what happens in your studio equipment. It is not only true in these instances, but also in the network lines, and as well in some of the records and transcriptions you play that are done over and over again and develop high noise levels, and in some cases the recording characteristics on records are far from anything that you would think of as being reproducible in flat response.

A MEMBER: The FCC rules and regulations specify that in FM modulation there shall be no appreciable compression on music. What is the FCC's opinion as far as the use of records which have 10-20 db compression?

MR. KASSENS: Well, the Communications Act says we can't do anything about programming. You notice I still smoke cigarettes. I would suggest that maybe sometimes you will find records that have about a one db range. But what goes in from the program source unfortunately we sometimes can't do anything about. We would like to find a good dynamic range, except for a good music station, you probably don't find it.

MODERATOR CHISMARK: When will the AM freeze be lifted?

MR. KASSENS: We are in the process now of trying to come up with new AM rules. At this stage we don't know what the notice of proposed rule making will say, but we are actively working on it, and I would assume that within a couple of months the new rules will be out. When the freeze will be over, at this time, I think it is too early to tell.

A MEMBER: I wonder if the gentleman from the Commission would clarify the Commission's regulations in respect to levels for color programming. In monochrome the levels required by the Commission of not exceeding the 12 1/2 per cent modulation on white and setup on black are well established. Then along comes color with luminance values being the same. Adding the chrominance portion of the signal means that you are going to exceed the 12 1/2 per cent on the high side and setup on the down side. And the Commission's regulations are a little unclear as to what your intentions are with respect to levels for color programming.

MR. KASSENS: I would like to make this observation. You heard a very interesting talk yesterday about the JCIC. I am very fortunate to be an FCC observer on this Joint Committee. I think we should not take our color specs too lightly. I doubt that there is anybody in this room who is in color who hasn't run into all of these problems. I think it is a wonderful thing to say about engineers that we see a problem arising, a very serious problem, and one of the things, of course, they are considering is tightening up our specs on color so that you can go from station to station in town and even from network to network and get the same color twice.

MODERATOR CHISMARK: That Committee is doing a real fine job, I think. We should get something out of them soon.

A MEMBER: I have two questions, one unrelated to the other. Backing up a second to the noise and distortion that we have been talking about just a few minutes ago, I don't know if I am running into an unusual problem myself, but I am sure a lot of people are having this problem nowadays, in that I operate an FM station and the requirements are a 15-kHz upper limit on the frequency response. This is all fine until you get in with the telephone company. I have had the transmitter at our particular site since 1950. And up until last year they could supply a 15-kHz loop. Now, they say they can't do it because of change in facilities.

Now, do I have to change my transmitter site because the telephone company all of a sudden decides that they are degrading their facilities and will no longer supply a high-quality loop. Is there any pressure that can be brought through the Commission to help alleviate this problem?

MR. KASSENS: The answer is Yes. We would prefer, of course, that you do everything at the local level that you can. We have found in general that the telephone companies are usually very cooperative. Fortunately, we also have control over the telephone companies and, on occasion, when stations have had difficulty we have resorted to contacting the phone company to do what we can to get them to improve their facilities.

MEMBER: My second question has to do with remote control, and I am speaking of remote control now in AM and FM broadcasting and not in television. The rules very clearly state you have got two types of operation: attended transmitter where your operator is at the transmitter, or remote control. There is no interim policy on this and I was wondering if anything had ever been considered in the situation where a lot of stations nowadays are locating their studio facilities at the transmitter but due to noise conditions or physical plant layout the operators cannot be directly in view of the transmitter but very economically a complete control and direct-metering package could be placed at the operator's position. This would be all meter functions, all control functions at the operator's location, a direct-wired situation. Is there anything in the works or has anything been considered to allow this type of operation?

MR. KASSENS: This is a very difficult problem. It is one, of course, we have dealt with many times. We try to be reasonable, but in this business it is always necessary to draw a line, because if you try to treat every case on a case-by-case basis, that's all you would spend your time doing. If you said that you could have extension meters in the next room from the transmitter, of course this is reasonable, you can walk through the doorway and see the transmitter. Well, this is the line you draw. But when we were talking in these terms a few years ago, a fellow came to me and said I have a transmitter which is one floor below on the stairway, it's closer than if I went into the next room. This is an example of the type of line you have to draw. We find it convenient to draw the line and the rule is so written that you should be able to see the transmitter. If you can't see it, then it is too far away and you should have remote control.

MR. BEVILLE: It appears to me, Hal, that this rule is being applied in a place where it was never intended to be applied. The rule was written to permit broadcast stations with remote studios to control their transmitter unattended from a remote location. It was never really intended to apply to a situation such as this. But it turned out to be a handy rule that you could put your hands on when stations began combining their studio and transmitter operations. Let's take two ridiculous examples. Say we install a transmitter in the far end of the D.C. Armory, which is about 150 yards long, and the control position is at the other end. The operator can see the transmitter and he complies with all the rules. But on the other hand, if the same operator is located just on the edge of a partition where he would have to get up and walk two feet from his control position to see the transmitter, then he is not in compliance with the rules.

It seems to me that somewhere along the line that the Commission should be able to set up guidelines by which a decision could be made as to whether or not a man must apply for a remote control operation in order to truly remote-control his transmitter. I know of stations that are using a system of mirrors, and I know of one in particular that is using a camera chain to look at the transmitter. And this gets a little ridiculous because you really can't see anything. Back in the days when transmitters had big windows on the front of them and you had tubes that you could see, then perhaps looking at a transmitter to see if there was any smoke coming out of it or a tube was gone or something like that, perhaps that rule was a good one at that time. But today you can't even see inside of a transmitter. Besides that, the rule doesn't say whether you have to see the front of the transmitter or the back of the transmitter or the side or what.

MR. JOHNSON: Al, I don't think I can stand it much longer. I think there has been a very interesting development, particularly at this Convention, or else I am getting older. The thing that is bothering me is that our rules and standards were originally based on manually-operated equipment. We had rules, we had standards, and then we relied a great deal on good engineering practice. What I hear over and over again now and the trend, I think, in the past few years is: "Commission: Why don't you specify this, give us more specifications, give us more and more details about how we should be operating a station. We are getting away from the concept we started out with that we were basically interested in end results. We would prescribe the end within which we wanted the stations to operate. Then we relied on you as licensees and engineers to achieve those end results without our specifying one, two, three, four, down the line exactly what you had to do to achieve them.

I am concerned because we have lost a lot of experienced engineers at the Commission lately and even Kassens will be gone in the not-too-distant future. I think what we are going to end up with is a set of rules which is going to compare in size with Pike and Fischer. I am sure most of you are acquainted with them. The engineer at the station won't make a move unless he goes to the book and finds exactly what he has to do. As far as I am concerned, I think this is a kind of an unfortunate trend, to turn to the government and say we want more and more regulations. As engineers, we would prefer to have you determine how best to achieve the required end results.

Sometime come by my office and let me show you the rulebook that I had when I first came into the Commission in 1942. It's a book that is less than an inch thick and it contains the rules and good engineering standards. These were designed primarily to achieve end results. But since then—I would like to compare the rulebook that we have now. I'm not sure we weren't doing a better job in those days, relying more on the licensee and the engineer to achieve the end results that we thought were important.

I don't think you should come to us and ask us to put in our rules every operating practice which you as engineers should be doing to achieve end results. There is nothing that bothers us more than questions like "How far can I move my operator away from the transmitter?" "Is it one foot, two feet?" "What time do I sign my transmitter on?" "My license says six o'clock in the morning." "Can I sign it on actually at one minute to six, five minutes to six, quarter to six, or what can I do?" The whole trend is, "Commission: Draw the line and make it black and white. Don't fool with us, tell us exactly what we can do." I think that is a very questionable trend, and I would like to get back to the concept that the licensee is responsible for achieving end results that we want and only look to us for the required end results. Then as engineers we should all do more and more to look at the good engineering practices which we as engineers know that we should be complying with, instead of turning to us and asking us for a detailed specification, a detailed limit.

MR. DILLARD: Wally, it seems to me that the disparity between the thickness of the old rules and the thickness of the new rules really doesn't show up, because when you went to the fine print in the new rules you included so much more information that if you had had the same size print as you had in the original standards, it would be four or five times thicker.

I agree with Wally. But the thing which goes through my mind, from an industry standpoint, is that the standards were a general guide and you didn't have to set everything down in black and white. They were a general guide and you followed them. The minute we started making specific rules to cover specific instances for every instance of everything you can think of, then the rules began to grow and they have become so cumbersome that sometimes one rule will almost cancel another. It is just a case, I think, of confusion that has come about because of adding detail upon detail upon detail which we have had to explain in minute detail.

MR. WOLFE: I agree with Wally too. Our problem is that after reading over all the rules and regulations and after the initial proof of performance has been made of the television transmitter, what do you want the operator of the transmitter to watch? We make no measurements. What would you like him to watch? If he has to watch the transmitter, what does he watch on the transmitter?

MR. JOHNSON: One of our biggest problems, I think, that has developed is the problem we have with operators. I think that this whole trend of asking us to give more and more details for the actual operation of a station, every technical point in operating a station, is looking towards a completely automated station. I think what we are doing now is educating the operator through the rule-making process and I don't think we can ever achieve 100 per cent education of the operator that way.

I'm not sure that we aren't looking towards the day when we are going to have a completely automated transmitter with all the fail-safe devices and so forth necessary to control the operation of the transmitter within prescribed limits. Every year we make a plea that what we really need to do is to make a wholesale revision of our rules, go through all of our rules and come up with a new set of rules. We have asked for industry help on this, and I think that we would like to do that again.

We did this last year. But we are always too busy to get into the actual wholesale revision of rules. But I think we need to sit down with industry representatives and actually go through the whole philosophy of what our rules are intended to achieve and, I don't know, have a rule burning or something and start over again. So once again I would urge that, at least before Kassens and Lloyd retire, we do take a real good look at these rules and in some way get divorced from these day-to-day problems that we have and try to come up with a new set of technical rules that become meaningful again.

MR. BEVILLE: Wally, I don't think any of these people out here are looking for more rules. These questions come up as a result of citations.

VOICES: Yes.

MR. BEVILLE: And they then want to know what to do about it. It's not that we are looking for more rules to go by.

MODERATOR CHISMARK: Ross, are you saying that there isn't enough liaison between the field inspectors and Washington?

MR. BEVILLE: This sometimes is the case.

A MEMBER: They are nit-picking.

MR. WOLFE: I can't speak for the industry but I think that the industry would be most willing to help.

MR. JOHNSON: Well, I think we need that. But as far as the Field Engineers are concerned, I would like to answer that. I think the Field Engineers are operating, of course, as the arm of the Commission in Washington, and they are operating under instructions that they receive from Washington. So when you say that the engineer is nit-picking, I think that you have an opportunity to come back with your answer to the nit-picking, or however you describe it, through the response to the notice that he gives you and actually make an explanation of what you think the situation is. So that the process would be that modified instructions could come from Washington based on the response and on our field inspection. We in Washington, the responsible operating bureau and the field bureau, could get together and come up with a new set of instructions.

But I think when the inspector goes out to make his inspection, he is following the instructions that he has as to how he should conduct an investigation or an inspection. I think the Commission is responsible for that. What you need to do is come back to us and tell us what your problem is and see if we can resolve it. Maybe we will come up with a more detailed or even a tougher response to the particular citation. But I wouldn't pick too much on the inspector who is going out to your station, because he is following instructions and guidelines that we have set in Washington.

MR. DILLARD: I don't like to dwell on a very simple thing which seems obvious but for which we really haven't gotten a concrete answer. But again this question of visibility of the transmitter to the operator, there is a certain vagueness about this which almost makes it a silly rule. But let's go back to the purpose of the rule. What is the need for the operator to view the transmitter if he takes readings every 30 minutes? Now, all of these transmitters are automated enough to the extent that they will take themselves off the air, an alarm can be set up which would show that it was off. And the 30-minute readings of the important parameters, I would think myself that this would be sufficient to indicate that the transmitter was operating properly and not going into some defective mode of operation.

MR. JOHNSON: I hate to be dominating the discussion at this point, but many of the things that we do I think you can look at as "loading the dice," if you want to. There isn't a real good technical explanation for some of the things that we come out with, like whether the engineer should view the transmitter. But the thing that bothers us is that all of these stations, the AM stations in particular—well, televison also—have a lot of things that go into the station's allocation. You know what we go through in order to finally come up with a grant on some of our directional antenna operations. The allocation part of it is very tight and you sometimes wonder when the grant is made what would happen if the wind blows more than 20 miles an hour on that particular group of antennas that finally result.

What we are trying to do is to come up with operating requirements that some way assure us in some fashion that the station is going to continue to operate in accordance with its basic authorization. So when we say that we would like to have the operator at least in the vicinity of the transmitter, that does add a little bit in assuring that the transmitter is going to operate satisfactorily. If we don't say that he has to be near the transmitter so he can physically view it, the first thing you know, he's down the hall, he's down on the next floor; he's got all sorts of duties and it's lucky if he ever gets back to the transmitter. So to assure that the station operates in accordance with the basic allocation, to us at least, it is a little bit more insurance for us if the operator continues to view the transmitter in some fashion, physically view it.

The same problem with our operators. We get all sorts of questions raised. We require First Class operators in certain circumstances. Well, we have never said that a particular First Class operator is going to be qualified to operate your station. We won't tell you that the fact that we give someone a First Class license guarantees that he is going to be able to technically operate your station to your satisfaction. But what we are saying is that at least it gives us a little better insurance that that operator is going to have some technical knowledge. And the chances are that if we didn't have some sort of an operator requirement that we would have many more problems at the stations. You can take us apart on individual requirement, but if you take the total concept of what we are trying to do, the total end result, each one of these items helps us assure that the end results are going to be achieved. If there is some other way of achieving those end results without nit-picking on each one of these items that make up the whole, then I think that we need feedback from you.

MR. KASSENS: I would like to make an observation. This is not a one-sided picture. Maybe all the rich stations can send their high class engineers to NAB. This is a big business with 4200-and-some AM stations plus 2200 FM, plus 700 TV. Let me give you a few figures. This is for a six-months period from July through December of '68. This is FM only. 239 stations inspected—85 citations for improper power. Now, Ev, you say he reads them every half-hour. But why 85 stations that can't even set power properly? There has to be a reason here, and I think it's a lot deeper than we think it is. I could go on on this list: 105 citations for improper logging. I don't think it is all nit-picking. I think that you can go into a lot of stations and I suspect that if you have been around as our field inspectors have, you can run into a lot of stations and find a lot of problems. And these are the ones I think we are really trying to correct.

MODERATOR CHISMARK: We are running quite late, and I will entertain one more question from the audience.

MR. HOBART J. PAINE (Tuscon, Arizona): I would like to make one quick comment. I have been to these NAB conferences for many years and I would like to see a longer period of time for these panel discussions and eliminate some of the equipment papers. We can see the equipment on the floor. I would like to have about an hour and a half devoted to this type of panel discussion.

MR. KASSENS: I would like to make one observation on behalf of the Commission. The demonstration you saw this morning, a very excellent demonstration, was done at our request. As Mr. Zellner pointed out, we have a very serious problem. This Committee was started because the trucks were running around using high-priced equipment to check modulation, and the complaint was that we were being too critical. So we have cooperated at great length with this FM Committee of the NAB and we are very much interested in getting all the comments we can from all the engineers as to whether this is a feasible type of display to have to determine modulation. And thank you very much to the NAB.

MODERATOR CHISMARK: Just before we go, Wally Johnson has one more thing to say.

MR. JOHNSON: I can't quite read your name there, but I think we all appreciate what you said, because we feel very keenly about this, we who have been attending NAB conferences, that we benefit greatly from this give-and-take. As regulators we are not trying to be completely divorced from you who are being regulated, because I think we are all in this together. We are trying to do the best job we can on our side, and I think you are trying to do the best job you can on your side. But as far as talking to us, I think that we try to make ourselves as available as possible, even outside the NAB conventions. So you can call us on the phone or come by the office. We don't have a closed door or a closed telephone. We try our best to answer any questions that you have.

MODERATOR CHISMARK: With that, gentlemen, thank you very much. We will see you all next year.