Technical Papers

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ENGINEERING DEPARTMENT

NATIONAL ASSOCIATION OF RADIO AND TELEVISION BROADCASTERS

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NEW 50-KW AM TRANSMITTER DESIGNED AROUND MODERN COMPONENTS

A Technical Paper Written By

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For Oral Presentation

To

National Association of Radio-Television Broadcasters

Chicago, April 8, 1957

A NEW 50-KW AM TRANSMITTER DESIGNED AROUND MODERN COMPONENTS

Within recent years components have been perfected which permit many improvements and advancements in the design of AM broadcast transmitters. Following is a review of the design considerations for General Electric's new 50 KW broadcast transmitter, the BT-50-A, and examples of the application of some of these new components.

In considering the design of any new product the designer should ask the following questions. 1) What will serve the customer best? 2) What does he want and need? To establish the design objectives for the BT-50-A, we at General Electric asked ourselves and Broadcasters these questions and came up with the following answers: (Figure #1)

(1) Reliable operation;

(2) A transmitter easy to adjust and maintain;

(3) A high quality signal, non-critical to operating variables;

(4) A transmitter designed for remote operation;

(5) Low tube cost;

(6) Low power consumption;

(7) Small size;

(8) A reasonable price.

With judicious selection and careful application of today's components, it was decided that an outstanding job could be done in all of these areas.

The first component we will consider is Germanium Rectifiers, which are used for all DC power supplies in this transmitter. Some people have asked, why we selected Germanium instead of Silicon? The answer to this is that if ambient temperatures are going to approach 85 degrees centigrade (185 degrees Farenheit) there is no choice, since these temperatures are approaching the maximum safe junction temperature for Germanium.

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However, at lower temperatures either Silicon or Germanium perform very well and selection is usually based upon the availability of units for the particular current and voltage requirements of the circuit. Germanium does have one advantage over Silicon, however, and this is the lower forward voltage drop which results in slightly higher rectifier efficiency.

As shown in figure 2, Germanium rectifiers of this type are used for all d-c power supplies. General Electric medium-current-rectifiers are used for the high voltage power supply while our low-current-rectifiers supply all other d-c requirements of the new transmitter.

These germanium rectifiers offer many advantages over previously used mercury vapor rectifier tubes. For example, there are no filaments to consume power. This results in overall rectifier efficiency and, obviously, there can never be lost air time due to filament failure. Another example, no warm-up period is required for these rectifiers, thus the neccessity of keeping spare rectifiers on heat is eliminated. And, their ability to operate over a wide temperature range permits use in unheated buildings, even in extremely cold climates. This makes possible additional reductions in operating costs. In addition, arc-back and arc-starvation cannot occur, thus another common problem of mercury vapor tubes is eliminated.

Because of these advantages, it was decided that germanium rectifiers would improve our new 50 KW transmitter. Steps were then taken to measure performance under actual operating conditions.

FIG. 2

In General Electric's 50-KW short wave transmitter at Schenectady, New York, three of the six GL 857B mercury vapor rectifier tubes were replaced with germanium rectifiers, similar to those used in the high voltage supply of the new 50 KW AM broadcast transmitter. These rectifiers are being operated under conditions 30% to 40% more severe than will be encountered in the new transmitter.

After nearly a year of operation at Schenectady, rectifier cells of the exact same type as used in the new transmitter, have a survival rate of 100%. Of course, a year's operation on units we expect to last for many years, does not provide the convincing proof of reliability that we desire. So we have done more than to merely operate these rectifiers.

At regular intervals, we have carefully measured and recorded the operating characteristics of each individual rectifier cell. One of the characteristics measured is reverse current as a function of reverse voltage.

Figure #3 shows a typical curve for these rectifier cells. Any deterioration in a cell causes a change in the slope of this curve. Since there has been no significant changes in the characteristics of these rectifier cells after prolonged testing, we can confidently predict reliable operation for many, many years.

Like any other component, Germanium rectifiers must be properly applied if maximum reliability and long life are to be obtained. In addition to working within the manufacturers voltage and current ratings for given operating conditions, consideration must also be given to the protective circuits, so that circuit faults can not increase the junction temperature beyond safe limits.

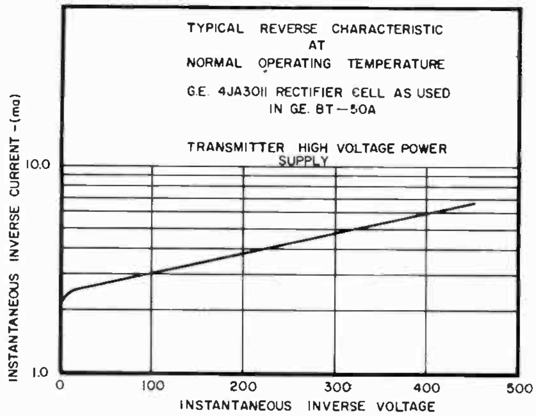


FIG. 3

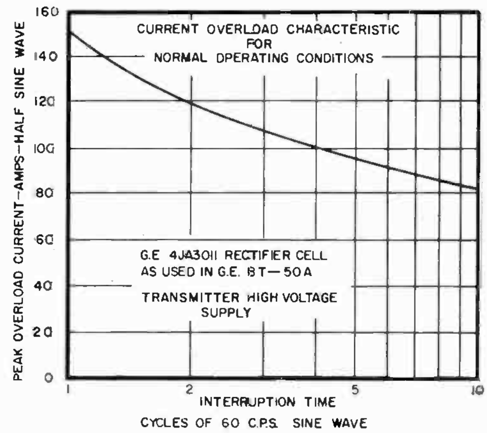


FIG. 4

Figure #4 illustrates the safe overload current as a function of interruption time for the medium-current-rectifiers, Type 4JA3011, as used in our transmitter. You will note that with one, or two, cycle interruption, this rectifier will safely handle peak overload currents of 150 amperes. Current limiting reactors can be used to control the magnitude of fault currents, and also to control the duration of time that fault currents flow can be controlled by the type of overload protection used. Since any impedance used for current limiting increases the output voltage regulation, a reasonable margin between operating current and permissible fault current should be allowed. In our new transmitter, fault currents cannot exceed 10 times full load current.

Operating Germanium cells in series actually improves transmitter reliability. By adding a few extra cells, voltage safety factor is built-in, which will allow normal operation even if some cells should fail. If a rectifier cell of this type fails, it always shorts, and thus merely reduces the number of series cells in a given leg. However, it is necessary here to assure:

(1) Good distribution of normal reverse voltage; and

(2) Control of transient voltages.

Proper distribution of normal reverse voltage is obtained by actually selecting all cells in a given leg which have like reverse characteristics. This is not difficult to do, since this characteristic is always checked during manufacture. This, it becomes merely a matter of selecting and of marking the individual cells. Once selection has been made, the cells, when connected in series, tend to share voltage in accordance with their ability to withstand reverse voltage.

Control of transient voltages involves both the reduction of transients and the equal distribution of any remaining transients. Our evaluation of transients during the design of this transmitter has shown that, without surge suppression, transient voltages several times the value of operating voltages may be produced with sudden changes of current though reactive components.

Regardless of the type of rectifying element used, adequate surge protection will prolong the life of all components and greatly increase transmitter reliability. Thyrite and surge suppression resistors used in the BT50A reduce transients to considerably less than 50% of operating voltages.

As an added precaution, capacitors have been connected across individual rectifier cells in the high voltage rectifier to assure equal distribution of any remaining transients.

By operating Germanium rectifiers conservatively, and by providing proper protection against voltage and current surges, as has been done in the BT50A transmitter, exceptionally long life will be obtained.

A desirable feature available today in all transmitters is rapid circuit protection, in the event that circuit faults develop. Fast interruption of fault currents greatly reduces stress and strain on all components.

Vacuum switches are an excellent device to obtain this fast interruption. In addition to extremely fast operation and rapid arc extinction, their mechanical action is very simple, being a straight push-pull action with movement of less than 1/4 of an inch.

As shown in figure #5, the RH4G vacuum switch, marketed by Jennings Radio Manufacturing Company, is particularly adapted for contactor service in broadcast transmitters. Three of these are suitable for handling 150-KVA at 480-volts. On a 2400-volt, three phase system, three of these switches will conservatively handle 750-KVA. Current-limiting-reactors limit fault currents to values less than 1/3 of the current which these switches will safely interrupt. With this type of coordinated protection, power will be quickly and safely removed, even if a severe fault should occur.

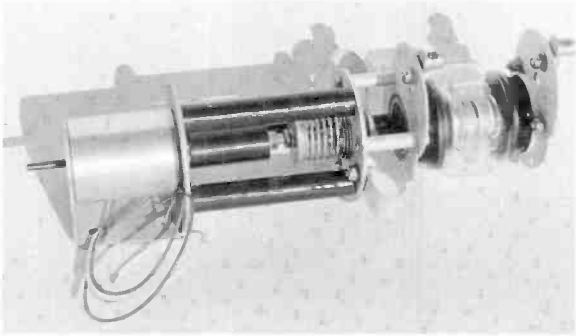


FIG. 5

Test data obtained during eight years of concentrated testing and actual operation in 60 cycle power switching indicate that, as applied to this transmitter, these switches will operate for many years with very little maintainence. Contacts operating within a vacuum remain clean and retain their inital condition for hundreds of thousands of operations.

Figure #6 shows some components that change dc power into rf and audio signals. This is the Machlett type ML-6427 tube which is used in the final rf amplifier and in the modulator. The model shown here illustrates how easy it is to handle these new Machlett tubes. Figure #7 shows even more convincingly the amazing lightness of this tube. Both the ML-6427 and the 893AR, shown on the low end of the tester board, have an anode dissipation rating of 20 kilowatts.

FIG. 6

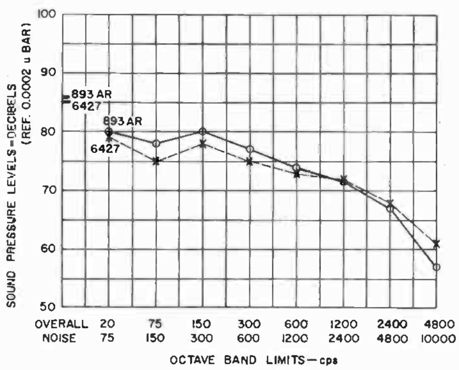
FIG. 7

The co-axial construction used for these new tubes permits precise, fabrication, thus providing improved electrical, thermal, and mechanical characteristics.

Thoriated filaments in these tubes are even more rugged than the filaments used in the ML-5681's which are giving from 15,000 to 20,000 hours in our television transmitters. Since the operating conditions in higher frequency service are somewhat more severe, we expect that the ML-6427's will last much longer in the AM Broadcast Service.

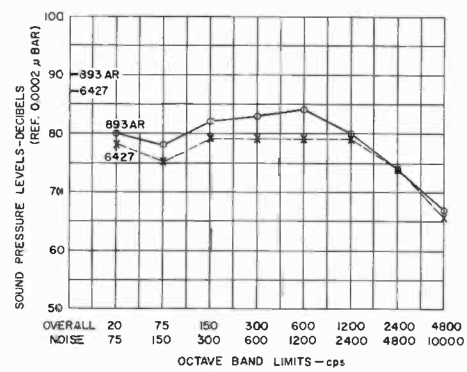
Air flow across the fins of the ML-6427 is horizontal, as compared to the conventional vertical flow used in the past. By using a uniquely-designed air distributor, cool air is passed across the fins in many short parallel paths so that as the air becomes heated, it is quickly removed. This feature, combined with the high velocity of air over the fins, achieves a cooling efficiency approximately twice that found in present broadcast transmitters.

What about air noise? Figure #8 shows measured noise for the ML-6427 and for the 893AR with their normal air flow for 15 kilowatts and 13 kilowatts dissipation respectively. Note that in each frequency octave, the noise from the ML-6427 is lower than for the 893AR.



COMPARISON OF AIR NOISE CHARACTERISTICS UNDER THE FOLLOWING CONDITIONS:
ML-6427, 15 KW: 580 cfm AT 2.6" WATER STATIC PRESSURE
893 AR, 13 KW: 1000 cfm AT 1.1" WATER

FIG. 8



COMPARISON OF AIR NOISE CHARACTERISTICS AT RATES OF AIR FLOW FOR MAXIMUM ANODE DISSIPATION:
ML-6427, 20 KW: 1000 cfm AT 7.7" WATER STATIC PRESSURE
893 AR, 20 KW: 1800 cfm AT 3.2" WATER

FIG. 9

Figure #9 similarly compares the two tubes with normal air flow for twenty-kilowatts dissipation. Again the noise from the ML-6427 is lower. This high efficiency cooling system not only requires less duct space in the transmitter cubicles but it also decreases installation expense. The smaller blower requires less power, thus permitting additional savings to the broadcaster. Since air is sucked through the tubes directly into the exhaust air duct, tube seals and all other compoents operate much cooler than with conventional air systems.

Figure #10 shows some ceramic capacitors which are typical of units now available. On the right is a 4000 mmf. capacitor having an operating voltage rating of 15 kv. Inherently, ceramic capacitors are extremely reliable due to their simple construction and the absence of organic compounds. Being both small inphysical size and relatively inexpensive, they can be applied in transmitter circuits operating at a fraction of their permissible voltage and current ratings. This type of capacitor is used for rf coupling and dc blocking in this new transmitter.

FIG. 10

FIG. 11

Referring to figure 11, you will probably recognize these vacuum variable and fixed capacitors made by Jennings. Perhaps they should not be classified as a new components, since they have been quite widely used in transmitters for several years. However, these capacitors are modern in every respect and cannot be overlooked when one is concerned with size of equipment and, at the same time, wants reliable operation with a wide range of atmospheric conditions. Like any other component, these capacitors must be properly applied. We mention this because, with a unit sealed in vacuum and unaffected by most external conditions, there is a temptation to apply them close to their maximum voltage. To allow for unexpected surges and to still assure reliable performance, it is our policy to use vacuum capacitors at not more than 2/3 of their voltage rating.

Now that we have outlined some of the more important components which enable us to meet our eight design objectives, let's consider the circuitry for a modern 50 kilowatt AM Broadcast Transmitter.

For low power consumption, a high efficiency circuit is necessary. There are at least three such circuits to consider. There are High Level, Doherty, and Chireix, or phase-to-amplitude types. After careful consideration, it appeared to us that the high level system using Class B modulators was best suited to meet our eight objectives. This system, being conventional, is well known by the operators and excellent fidelity is obtained without critical adjustments.

The new tubes described here, help to make the economics of the high level system very comparable with that of the other two high efficiency systems.

With increasing demands for Automation, no transmitter can be considered modern unless it is ready for remote operation. In our new transmitter, remote metering resistors are included in all important circuits. Voltages developed across these resistors are then wired to terminal boards for external connections. These voltages are suitable either for operation of remote control equipment, or for operation of continuous recorders. The use of continuous recorders could eliminate the need for manually logging transmitter meter readings and would be a progressive step in the operation of broadcast transmitters.

The control circuits of this transmitter have been specifically designed to work with the General Electric Ultracon or with other available remote control equipment. All provisions have been made for energizing the transmitter, monitoring operation, and shutting it down, from a remote location. In addition, equipment for remote crystal switching and remote power output control are built into the transmitter.

With increasing use of the radio specturm, excessive radiation outside of the operating frequency band cannot be tolerated. It is anticipated that new requirements will be released soon by FCC which will limit harmonic and spurious radiations from 50 kilowatt transmitters to about 80 D.B. Because of this, a three section low pass filter has been built into the transmitter to assure that these anticipated requirements will be met.

Another requirement for a modern broadcasting station is a reliable lightning trip circuit to momentarily interrupt r-f power should an arc occur in the tower gap, transmission lines or phasing networks. We have, therefore, included with this transmitter a trip circuit which uses rectified r-f signals to operate a balanced dc relay. A fault will cause this relay to trip and momentarily remove r-f drive.

Normally, voltage is supplied from two points in the r-f network. If, due to the characteristics of a particular directional array, voltages are needed from additional points in the system for complete protection, other units can be easily added to the circuit.

A somewhat different approach to the application of Audio feedback has been used in our new transmitter. Since feedback from the plates of the modulator tubes reduces the apparent impedance of the modulation transformer, this type of feedback actually increases any hum that may be present in the final r-f amplifier tubes. Therefore, at low frequencies (up to 1000 cycles), feedback voltage is obtained from the r-f amplifier, and above 1000 cycles, conventional feedback from the modulator plates is used. These two feedback signals are combined at the input to the first audio stage to give an effective overall feedback of approximately 10 D.B.

One of our design objectives was a high quality signal non-critical to operating variables. Figure #12 shows response measurements plotted in accordance with RETMA specifications. Note that response is well within RETMA limits and yet attenuation is rapid at very high and very low audio frequencies. Response at other percentages of modulation is e essentially the same as shown for 50% modulation.

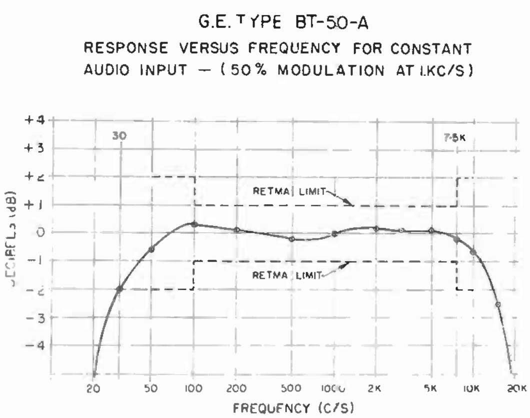


FIG. 12

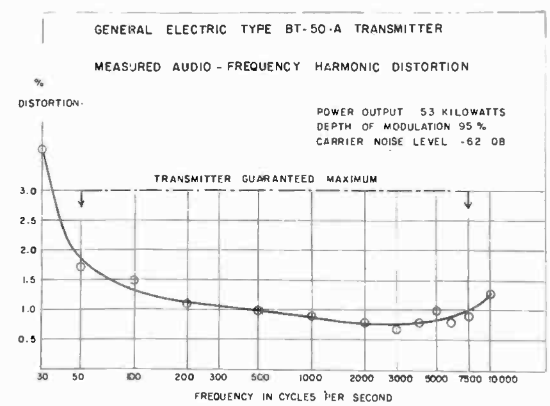


FIG. 13

In figure #13 you will note that our feedback system is very effective. This type of performance can be repeated without readjustment following tube changes. There are no critical adjustments to be maintained.

Note that these measurements were made with 53 kilowatts output. Carrier noise is 62 D.B below 100% modulation level. Carrier shift introduced by the transmitter is 2%. This includes regulation of the plate transformers and current limiting reactors.

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Figure #14 shows how the 50 KW transmitter with an auxiliary 5 KW transmitter can be readily accomodated in a building 24 feet by 20 feet. The three cubicles, which are seven feet high, occupy a floor area of only 13 1/2 feet by 4 1/2 feet. The use of these modern componenбs outlined here has permited us to design this space saving transmitter and yet provide exceptional accessibility.

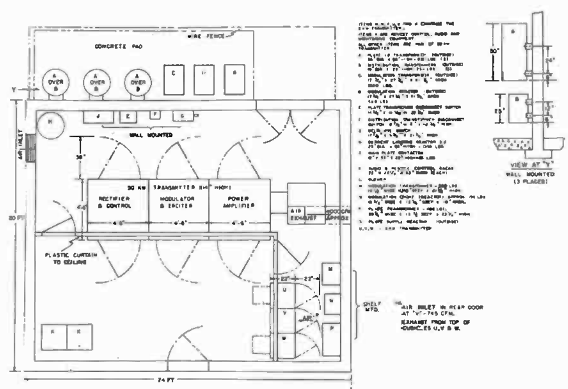

FIG. 14

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Progress Report on Remote Control Petition

And Automatic Recording Project

Presented by: A. Prose Walker

Manager of Engineering

N.A.R.T.B.

Monday, April 8, 1957

11th Annual NARTB Engineering Conference

Chicago, Illinois

Gentlemen, if there is one subject upon which I really feel incompetent to speak, it is the current status of the remote control situation at the Commission.

I think the best way to handle this particular subject would be for me to introduce about six FCC people sitting over here in a row. I would like do that, and I would like to ask them to stand up so that you can see who they are. If you don't get the right answer from me, go over and buttonhole them.

Chief Engineer of the Federal Communications Commission, Ed Allen. (Applause)

Sitting alongside him is that great, big, fellow whom many of you have met and talked to before, Wally Johnson. (Applause)

Next to him I see Bud Weston, who has only recently made a change in his position with the Commission from one of an engineering nature in the Rules and Standards Division, and who is now Engineering Assistant to FCC Commissioner Robert E. Lee. (Applause)

Next to him is one of the men you want to be sure to get hold of, because I think he has already done some work on the remote control problem. I know you want to meet him anyway, whether or not you talk to him about remote control. Harold Kassens. (Applause)

If any of you people recently had any problems before the Washington Airspace Panel, as well as other problems of a television nature, you will recognize Dan Jacobson. (Applause)

If you don't hear what you want to hear from me, these are the men to talk to, because I am not going to pretend to speak for them, and I am sure when you get hold of them they will say, "I can't speak for the Commission, but--".

There are three other people in this room whom I suspect you have met at least once before; they are the three boys who have handled the CONELRAD situation for some time. The U. S. Supervisor for CONELRAD for some years, as you know, has been Mr. Ralph Renton. Ralph recently decided that he wanted to get back into more technical aspects of broadcast engineering and other phases as well, so he went over into the Technical Research Branch of the Commission to replace Bill Bosely, who decided that he had worked for the government long enough, and the man who took Ralph's place is the fellow whom I have known for many years, and who I am sure many of you also know. He is a good friend of ours, and I would like to have you meet him. Mr. Ken Miller.(Applause)

I will introduce the two other boys back there with Ken simultaneously because by and large, they handle most of the United States insofar as the CONELRAD program is concerned. Ernie Thelemann, the central supervisor--and don't be misled by the term "central", because it goes all the way from the Atlantic to Texas and New Mexico and practically all over the country. Ernie Thelemann, from the central part, and Bob Linx, from the Western zone. (Applause) So, if you have any problems on CONELRAD, those are the boys to talk to.

I see by the program that I am to give you a progress report on the remote control petition, and that I am also to say something about automatic recording.

You will recall that last year we brought you the information that we had filed our petition with the Commission on February 15, 1956. Here it is, another year rolled around, and I would like to tell you as much as I can about the status of the situation.

As you know, opposition was filed to our petition on remote control principally by representatives of the labor unions--and of the labor unions I would say the chief opposition came from the IBEW, from NABET and from the American Communications Association.

In my humble opinion, the only oppositions that were filed that had any meat in them whatsoever were the ones that were filed by IBEW. They at least made a pretence of taking our petition apart, chopping it up in small bits, and throwing it back in our face.

We took the comments of IBEW and analyzed them very carefully, and we found that in our judgment the things that were pointed out as formidable and horrible forebodings of disaster were, in the main, things such as 0.5 of the current value, or one degree of phase, and things of that nature.

Whenever oppositions are filed to petitions before the Commission, the petitioner has the opportunity to submit reply comments to the opposition that has been filed, and we filed our reply comments with the Commission on October 22, 1956. Officially, the record on this proceeding has been closed, and it has now been at the Commission as a completed record since October 22 of last year.

Anyone who scans the trade press from time to time knows that the Commission has had before it a great many problems, primarily those relating to television, and the Commission has been beset from many quarters by those who have required a lot of their time not only at the Commission level but also at a staff level in all the departments of the Commission.

We have recognized that the Commission has been busy, and consequently we have attempted to act in a gentle, manly manner in regard to going over and swinging clubs and saying, "Look, fellows, how about it?" I am speaking facetiously, I am sure you realize.

We believe, however, that after a year perhaps the Commission may begin to do the necessary work to bring it before the seven Commissioners who have to take action on this matter. Let me say that Harold Kassens is probably a little closer to this situation than perhaps the rest of them, although I may be wrong; Bud, maybe it's you, I don't know, but I understand that some work has been done on it.

You see, the process is that the staff has to take a matter of this nature and write it up and place it on the agenda of the Commission. When it reaches the agenda stage of the Commission, that is the point where the seven FCC Commissioners make their decision. I understand that some work has been done at the Commission toward getting it in the sort of shape that it must be in in order to be placed on the agenda of the Commission.

May I express my own personal opinion for just a minute. Biased as I might be, I believe my opinion is based on some sound facts. I have sufficient confidence in the position and the data and the reply comments that we have submitted so that in my opinion there is good reason to be optimistic about the eventual outcome of this matter. As I said, this is my own personal opinion, but I base it on what I consider to be sound information and data that we submitted.

I am not attempting in any way, shape or form to quote anyone from the Commission with whom I have talked, but I do think our position is sound. I don't believe the IBEW or NABET or anybody else has submitted to the Commission one good, valid reason why our petition should not be granted, which we have not completely refuted. I am so confident of the submissions which we have made that I personally am very optimistic about the end result of this matter.

As to when, I know that is the question you all want to have answered. If there is one thing I have been asked here at this meeting more than anything else, it is this: "When are we going to get it?"

A lot of broadcasters--and I mean this sincerely--need it, and they need it badly. I don't know when. I can be hopeful that it is not going to take much longer, but I hope that during the course of the convention here you will have an opportunity to talk with the people from the Commission, and I hope they might be able to give you a little bit more information than I have been able to do.

The logical extension of remote operation is something we have been interested in for some time, and so have a great many other people. I want to briefly mention it, because we have an excellent paper to be delivered by Gus Ehrenberg, of Minneapolis Honeywell, on this particular subject of automatic logging.

Some of you people have done a limited amount of it for some time. It is nothing new. You are accustomed, of course, over the years, to make field intensity recordings with the old Esterline-Angus recorder, and that of course would be one way to make a record of any of the parameters of a transmitter or antenna system.

We have been conducting some experiments with a few stations. The experiments that are in progress at WFIL will be described in some detail by Mr. Ehrenberg. The same sort of experiments are going to be extended at Station WTOP in Washington, and I am sure Mr. Ehrenberg will make reference to these particular experiments in his paper.

We also have experiments running at the present time at another station, which is headed in the technical field by Phil Hedrick. I am sure you all know Phil, and he will be glad to talk to you about anything he is doing. He has some recorders that are made by Texas Instruments which are more or less along the line of the old Esterline-Angus recorders, and at the present time he is recording plate voltage, plate current and common point current.

In addition to that, as one of the requirements for his directional antenna, he has a field intensity pick-up in one of the nulls of his DA, and that value is piped back to the transmitter house. I think he is now recording also that particular value. So, you might talk to Phil to get more details of that particular work

The use of recording instruments of this type is authorized at the present time by the Commission in Section 3.39 (h), and I won't take time to read all of it. It states in general that recording instruments may be employed in addition to the indicating instruments, to record the antenna current and the direct plate current and plate voltage of the last radio frequency stage, and so on. So, this is something that is really permitted at the present time under the rules.

We would like to perhaps extend that rule a bit further and maybe, as the end result, get over into a philosophical separation of those things which we believe are rightfully within the province of the Commission and those which are rightfully within the province of the licensee of the station.

When it comes to allocations functions, the assignment of frequencies, the assignment of the tolerances, the power output, including the characteristics of the antenna, the classification of the station, as to whether it is 1, 2, 3 or 4, and anything which might affect the over-all allocation of those, of course this is rightfully within the province of the Commission.

When it comes to the operating details of the station, assuming the allocations requirements are met, then these, we believe, are within the province of the licensee of the station to do as he sees fit. That, in the end result, is what we hope to accomplish by what we are engaged in at the present time.

The specific details on automatic recording are extremely interesting. I have had the pleasure of discussing them already with various people; Gus Ehrenberg is one of them. I am not going to steal any of your thunder, Gus, so I will stop now.

Thank you, gentlemen.

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AUTO-RECORDING OF THE CRITICAL PARAMETERS OF A DIRECTIONAL ANTENNA SYSTEM AND A STANDARD BROADCAST TRANSMITTER

MINNEAPOLIS-HONEYWELL REGULATOR COMPANY
BROWN INSTRUMENTS DIVISION
PHILADELPHIA 44, PENNSYLVANIA

G. Ehrenberg
4/8/57

All tedious repetitious activity should be relegated to machinery to allow men to concentrate on work that requires reasoning and judgment. Manual logging of data is just such an activity and can easily be eliminated with a gain in both reliability and accuracy.

Over a single pair of telephone wires, twenty-four independent variables can be telemetered and recorded on a multipoint strip chart recorder with only a few seconds interval between points. The system and equipment have been in general use in process industries for many years. Since a remotely controlled broadcast transmitter is designed for semi-automatic operation - and the equipment is available - make it so!

Of the thousands of recording instruments in operation today in industrial processes, few have been applied to the radio broadcast industry. This is understandable. There was no demand for recording instruments until the FCC authorized the use of remotely controlled omnidirectional transmitters up to 10 KW power. It is now becoming apparent that these multipoint recording instruments are essential, from both a technical and economic standpoint, to the satisfactory operation of remotely controlled broadcast stations.

We are going to discuss the technical aspects of the system and its components in this paper. A preliminary test installation of the Minneapolis-Honeywell Regulator Co., Brown Instruments Division system, without the telemetering section, was made at WFIL broadcast transmitter at Whitemarsh, Pa. The tests were conducted with the cooperation of Henry Rhea, Engineering Manager. The computer servo used to give tower amplitude ratios, and the recording instrument operated satisfactorily.

At WFIL we are recording the first four of the following parameters. The fifth is a well proven measurement, therefore we omitted it.

1. Final Plate Voltage
2. Final Plate Current
3. Common Point Current Amplitude
4. Current Amplitude Ratios between towers
5. Tower Light Conditions

From the best information available the above are essential. Other parameters may be recorded at the discretion of the station engineers. (Refer to Figure 1 for a general system diagram.)

Transducers change the various measurements into low millivoltage direct current for application to a telemeter transmitter. A stepping switch at the transmitter, operated by tones from the telephone pair used for the measuring circuit, sequentially transfers the various input quantities to the telemeter transmitter. The instrument records the various measurements, in sequence, on a 12-inch wide chart. The position of the numbers on the chart indicates the value of the measured quantity, and the number identifies the parameter.

We will discuss the system in approximately the order as described above.

TRANSDUCERS

FINAL PLATE VOLTAGE (Refer to Figure 2.)

The transducer used for the Final Plate Voltage is a voltage divider built into the transmitter. This transducer actuates an indicating voltmeter. A manganin wire dropping resistor is placed on the ground potential side of the indicating voltmeter, and in series with it. (Note: Manganin wire is used because of its very low temperature coefficient.) The dropping resistor has a filtering capacitor and is protected by a Thyrite unit. To attain the calibrated millivoltage to the telemeter transmitter, a highly accurate, manganin wire variable rheostat is placed across the dropping resistor.

FINAL PLATE CURRENT

The Final Plate Current is measured by an indicating meter built into the transmitter. A very low resistance manganin wire dropping resistor is placed in series with the indicating meter and its associated overload relay. The dropping resistor has a filtering capacitor and is protected by a Thyrite unit. This circuit is almost a duplicate of the one used for Final Plate Voltage measurement described above. To attain the calibrated millivoltage to the telemeter transmitter, a manganin wire variable rheostat is placed across the dropping resistor. (Refer to Figure #3.)

COMMON POINT CURRENT AMPLITUDE & CURRENT AMPLITUDE RATIOS BETWEEN TOWERS

The Common Point Current Amplitude transducer is a loop placed adjacent to the transmitter's common conductor. The tower amplitude sampling loops are placed at the towers. The RF is brought back from the towers on coaxial cable and rectified by diodes. A very high impedance take-off is used from the coaxial cable. It does not affect the phase monitor readings. (Refer to Figure #4 for typical circuits for individual tower and common current sampling.)

TOWER LIGHT CONDITIONS

The transducer used to indicate Tower Light Conditions is a thermal converter which transforms a-c power into d-c millivolts. This thermal converter applies heat to the hot and cold junctions of a thermocouple (T/C). The circuit and mathematics shown in Figure #5 prove the reduction of a-c power to d-c millivolts. Note that by reversing either the a-c current or voltage of the thermal converter input, the hot and cold junction of the T/C are reversed, and the d-c millivoltage output reverses polarity. Due to the flashing beacon, an integrating network will be placed across the output to give an average value. The thermal converter is relatively insensitive to ambient temperature since both junctions of the T/C are heated. With a thermal converter on the lighting line to each tower, a 3% voltage change is easily detected on the recording instrument chart.

$$\frac{\text{100 watt bulb}}{\text{3000 total watts to a tower}} \times 100 = 3\%$$

PRINCIPLES OF OPERATION

COMPUTING SERVO

A computing servo is used to read current amplitude ratios between towers. (Refer to Figure #6.)

The circuit consists of an applied voltage from one tower to one side of a sensing amplifier, and an applied voltage from the second tower to the slidewire of the motor driven servo. The amplifier will seek a null point, adjusting the servo until the effective length of the slidewire produces an output equal to the voltage from the first tower. If the tower currents are changed in proportion, the servo will not move. Therefore, the servo position indicates current ratio. If another slidewire is "ganged" to the computer slidewire, it can be used to retransmit the servo position to a recording instrument, or telemetering transmitter. The retransmission circuit has no electrical connnection with the ratio circuit.

TELEMETERING TRANSMITTER

For transmission of various parameters to a remotely located recording instrument we can use a continuous balance telemetering system. The system consists of a servo that is almost identical to the one used for ratio, except for circuit modifications. The telemetering circuit is shown in Figure #7.

The output current of the transmission line passes through a fixed calibrated series connected resistance. The voltage drop across this resistor opposes the incoming voltage and is proportional to the current flow. The amplifier between them seeks the nullpoint. Should the transmission line resistance change, altering the flow of output current, the voltage across this resistor would change; the amplifier would immediately readjust the power supply voltage to give a current flow equal to the incoming potential. This readjustment would compensate for the resistance change. The same type of action would occur if the power supply voltage varies.

<u>The only thing that can affect this telemetering system is line leakage.</u> This is of no consequence in shielded telephone pairs, particularly when a sizeable 50 to 100 milliamperes is transmitted. Any microampere leakage would be insignificant. Other types of telemetering systems are available for use on excessively bad lines. (This was not considered in this paper as it is expected most applications will be converted by the above system.)

PARAMETER SELECTOR

To select sequentially the various parameters, audio tones are applied to the telemeter transmission line. A stepping switch designed for low level current and voltage operation is installed at the remote point to place the various parameters in sequence on the input to the telemetering servo. The stepping switch has gold plated contacts. It is a plug-in type of unit and operates under oil. This type of switch has performed satisfactorily under very adverse ambient temperature and atmospheric conditions. The selector switch in our instrument at the receiving point is used to give pulses. It pulses the stepping switch in sequence with the printed points on the chart by energizing a tone momentarily as transfer is made from point to point by the instrument. At the end of the sequence of points a second tone is momentarily energized to "home" the stepping switch to be sure it is in its "home" position. Thus, the stepping switch is synchronized every revolution, with the identifying points of our recording instrument. If any pulse should fail to advance the remote stepping switch, only one set of readings could be in error. Erroneous readings are readily recognized on the chart since they would be "out-of-line" with the readings before or after the erroneous cycle.

RECORDING INSTRUMENT (Refer to Figure 8.)

The recording instrument is a null balance type of potentiometer. The composite schematic is shown in Figure 8. It has an accuracy of $\pm 1/4$ of 1% and a reproducibility (repeatability) of 1/32 of 1%, which is greater precision than the usual 2% error indicating meters generally applied for broadcast transmitters. The precision records are easily read on a 12 inch chart.

AMPLIFIER

The instrument applies a standardized millivoltage to a slidewire which is servo operated by a motor driven from a sensing amplifier. The millivoltages of the servo operated slidewire must be equal to the incoming millivoltages. If the amplifier senses a difference between them, the slidewire is moved by the motor until the null point is reached.

PRINT WHEEL AND STEPPING SWITCH DRIVE

A print wheel carriage is also driven by the servo motor. The print wheel is actuated to print parameters on a chart.

An automatic mechanism is connected with a synchronous chart drive every thirty (30) seconds. This mechanism steps the print wheel one position, making a new print wheel point available. Simultaneously, the stepping switch is pulsed to its new position. This connects the next parameter to the remote telemetering transmitter and the instrument will be driven to its new position. The new parameter is measured in this new position, and is printed on the chart. The position of the print mark on the chart indicates the value of the measured parameter.

OPERATION OF THE SERVO MOTOR BY THE NULL-BALANCE SEEKING AMPLIFIER (Refer to Figure 9.)

A synchronous vibrator is used to "chop" direct current into pulses going through an input transformer that is center tapped to produce alternating current (ac). The ac is applied to the grid of the first voltage amplification stage. Note that this ac is in phase with the 115V line supplying current to the transformer of the power amplifier.

The synchronous vibrator has a small permanent magnet that is operated by an electro-magnetic coil that is energized by the power transformer filament winding. The amplifier consists of three (3) standard resistance, capacitance coupled, voltage amplification stages. The output stage is actually a phase discriminator. The grids of the two sections of the output tube are tied together and are operated from the output of the last voltage stage. The plates of the tube are supplied with a-c power. The cathodes of the tube are connected to the end of one winding of a two-phase motor. The other end of this winding connects to the center tap of the transformer supplying the plate voltage. The second winding of the two-phase motor is energized from the 115V line supplying power to the amplifier. This winding is in series with a capacitor. The capacitor shifts the phase of the current in this winding by 90°. This 90° current phase shift is needed for operation of a two-phase motor. One field should be 90 electrical degrees from the other. The phase of the current coming from the amplifier will be either in phase with the power line current, or 180° out of phase because the synchronous vibrator remains in phase with the power line. Refer to the wave form diagrams in Figure #8.

1. If there is no voltage input to the amplifier, the grids of the output tubes will not be energized and the output tubes will pass current, since they are not at cut-off. However, this current will be 120 cycles dc as shown. The servo motor will then tend to move in opposite directions for each half-cycle, and will not move.

2. If the input to the amplifier is plus - minus, the grids of the output stages will be plus (+) when one tube fires, and minus (-) when the other tube fires. Therefore, the output will look similar to the second wave form since one set of waves has grown, and the other set has diminished. The motor will move in the direction designated by the large waves.

3. If the input to the amplifier is minus - plus, the grids of the final output stage will be positive (+) when the opposite tube plate is positive (+), or when the other half-cycle appears. Therefore, the output wave will be similar to the third diagram shown, or 180° from the first set of half-cycles. The motor will turn in the opposite direction.

There is a capacitor in parallel with the winding of the motor energized by the amplifier. This capacitor tunes the circuit to 60 cycles, and instead of half-wave pulse, the oscillations will give a full 60 cycle a-c sine wave which can be seen on an oscilloscope. The capacitor, in series with the other motor winding energized by the 115V power line, tunes this winding for minimum impedance. This winding draws 11 watts to 15 watts (approximately) from the power line. The winding energized from the amplifier draws approximately 1 watt to 2 watts. This is sufficient to supply a rotating field to the motor. The amplifier has an amplification factor of one million. About three microvolts across the input will start turning the servo motor.

CONCLUSION

The Minneapolis-Honeywell Regulator Co., Brown Instruments Division system for remote recording of essential broadcast station parameters is a direct means for converting these parameters to low millivoltage dc through use of transducers. The millivoltages are applied in sequence through a stepping switch to a telemeter transmitter and are sent over a single pair of telephone wires to a remote studio. There they are automatically recorded with high accuracy on a recording ELECTRONIK Potentiometer.

Looking another step forward, the complete automatic control of a transmitter could be made available. It is only an application problem, and a simple one at that. Standard options to the Class 15 Brown ELECTRONIK instruments allow operation of alarm switches, process controllers, give digital conversion, and give various combinations of these options.

Information about instruments, and what they can do, is available through Minneapolis-Honeywell branch offices. Each office has an efficient service organization at the customer's disposal. Branch offices are located in almost every sizeable city in the United States, and in almost every country in the world.

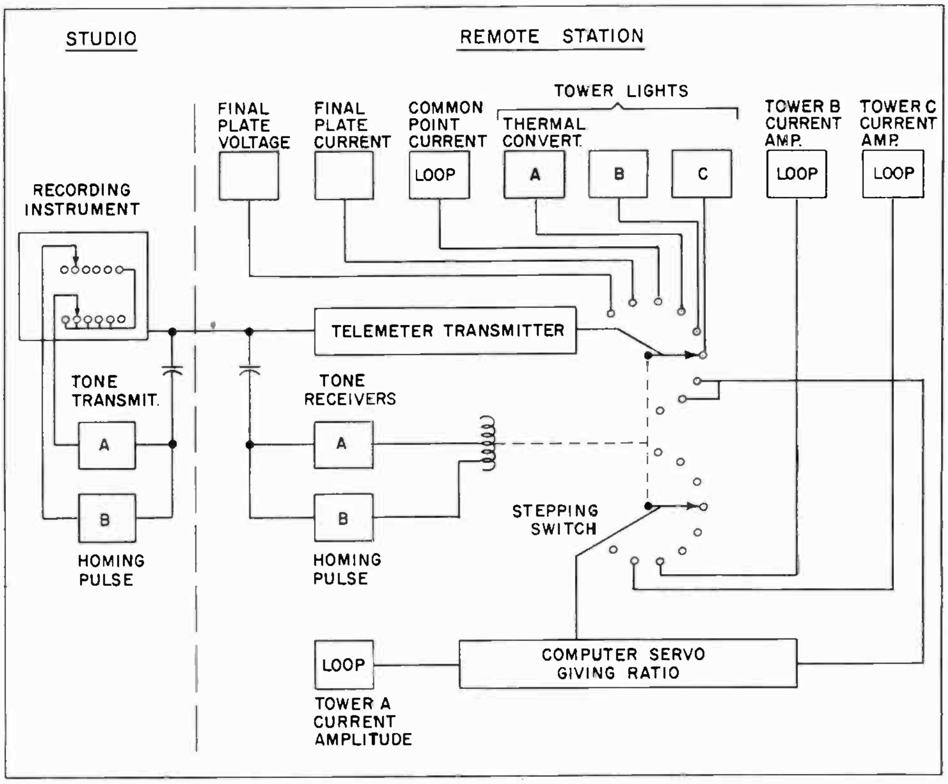


FIGURE 1

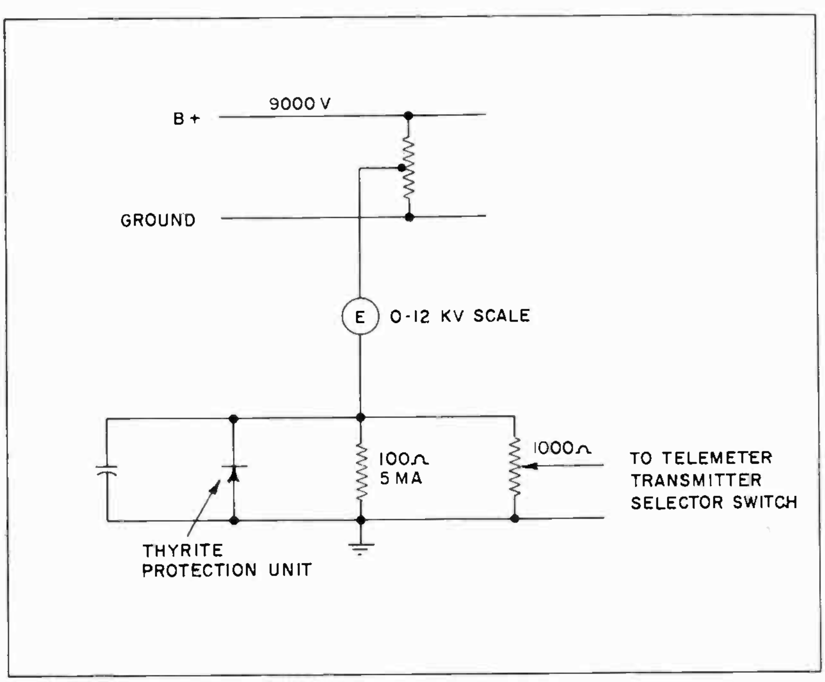


FIGURE 2

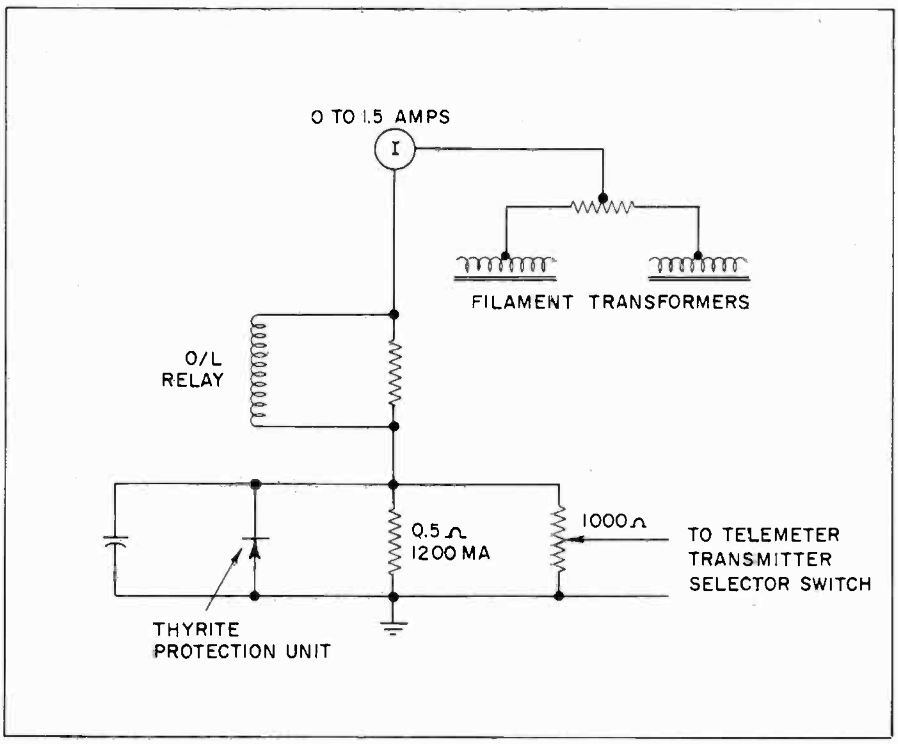


FIGURE 3

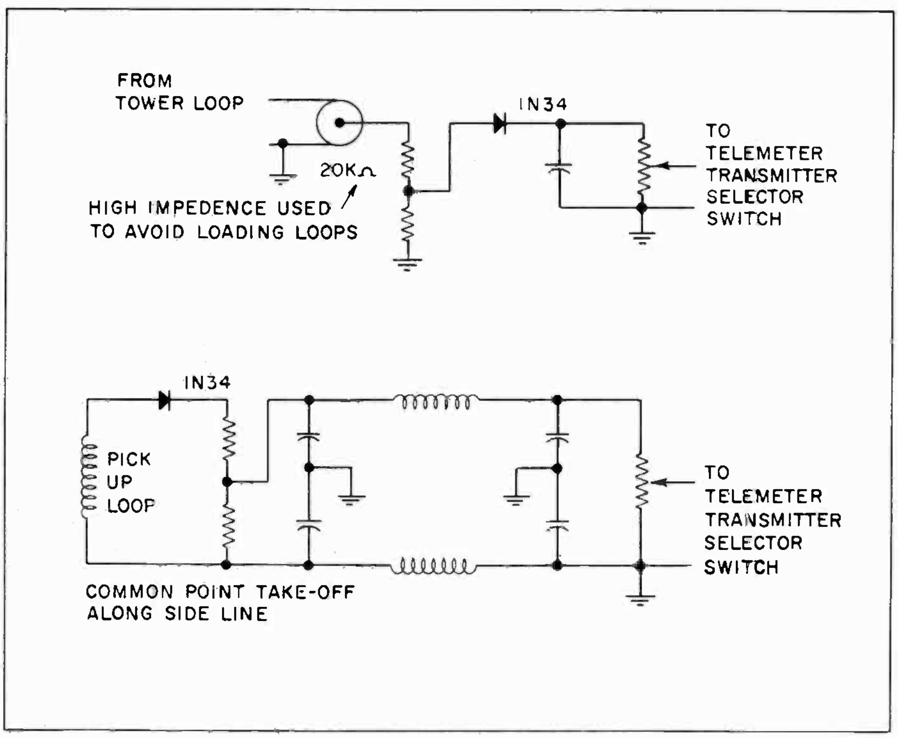
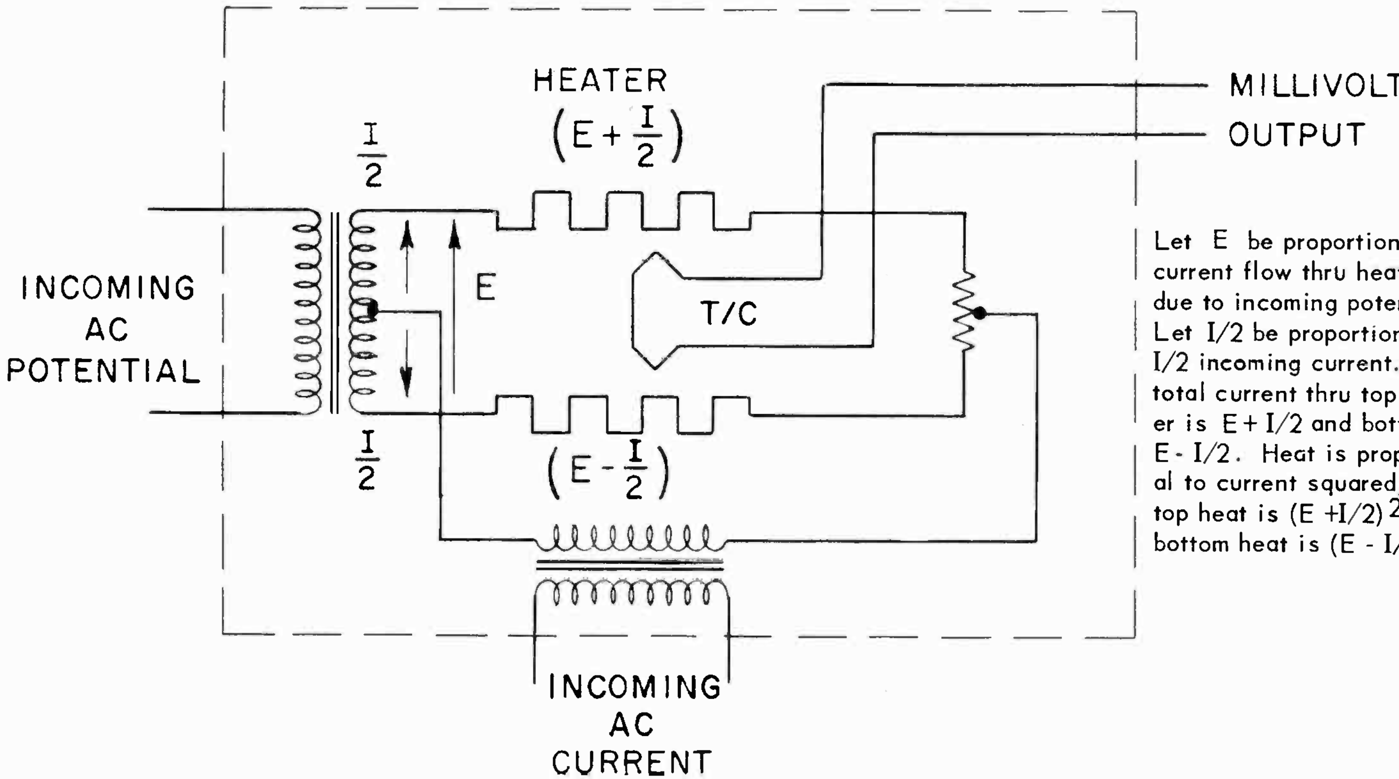


FIGURE 4

1/2 POLYPHASE THERMAL CONVERTER



Let E be proportional to current flow thru heaters due to incoming potential. Let I/2 be proportional to I/2 incoming current. Then total current thru top heater is E + I/2 and bottom is E - I/2. Heat is proportional to current squared, so top heat is $(E + I/2)^2$ and bottom heat is $(E - I/2)^2$.

Thermocouple output is proportional to difference in heat between junctions or

$$\frac{\begin{array}{l}(E^2 + \frac{2EI}{2} + \frac{I^2}{4}) \\ (E^2 - \frac{2EI}{2} + \frac{I^2}{4})\end{array}}{+\,2EI}$$

Therefore, thermocouple output is proportional to E I which equals power.

FIGURE 5

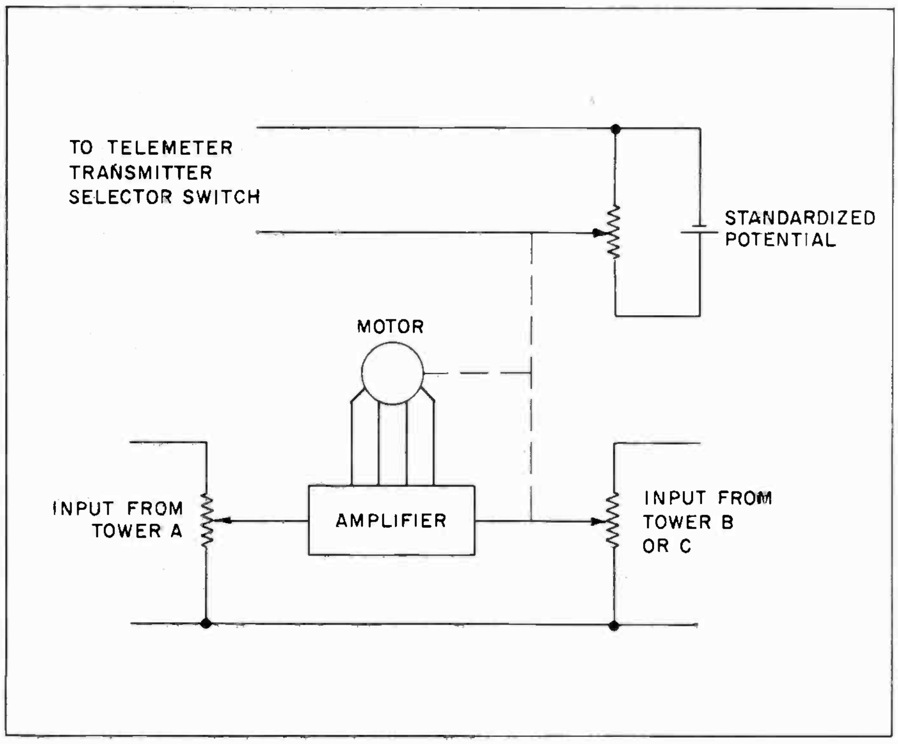


FIGURE 6

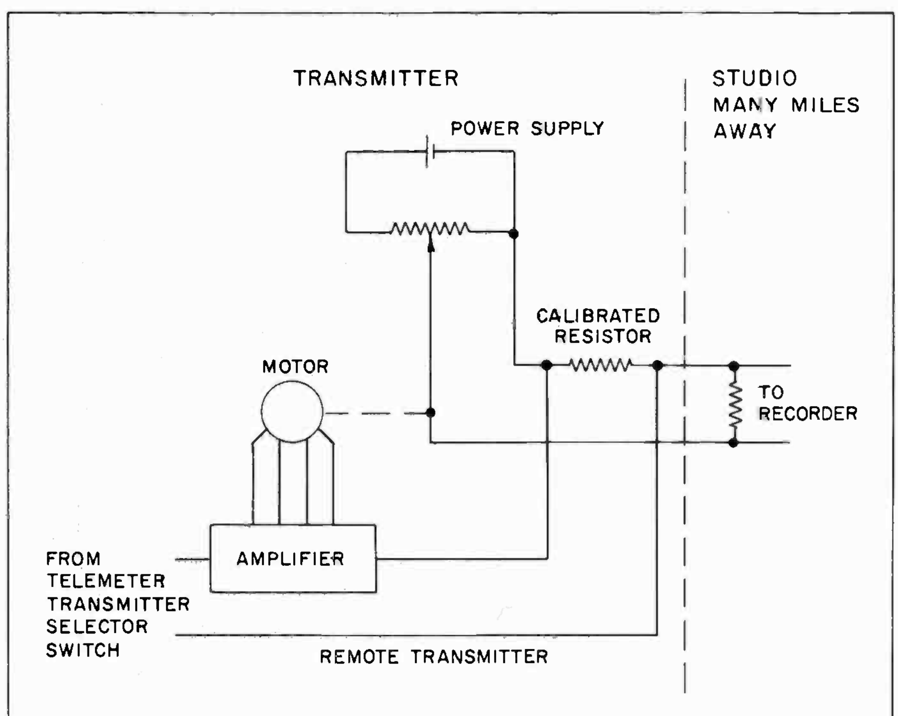


FIGURE 7

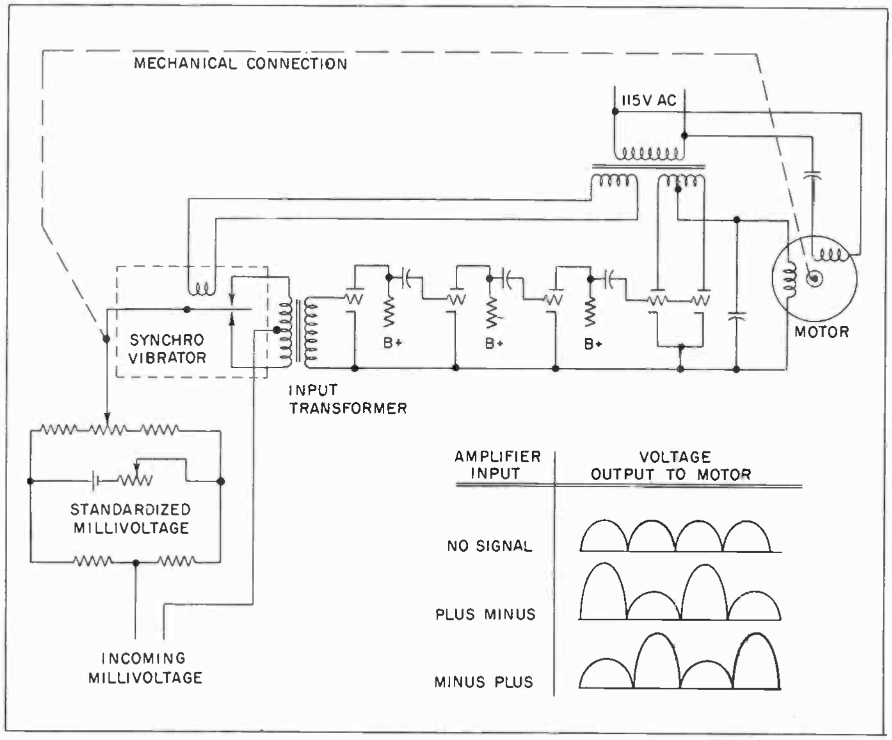


FIGURE 8

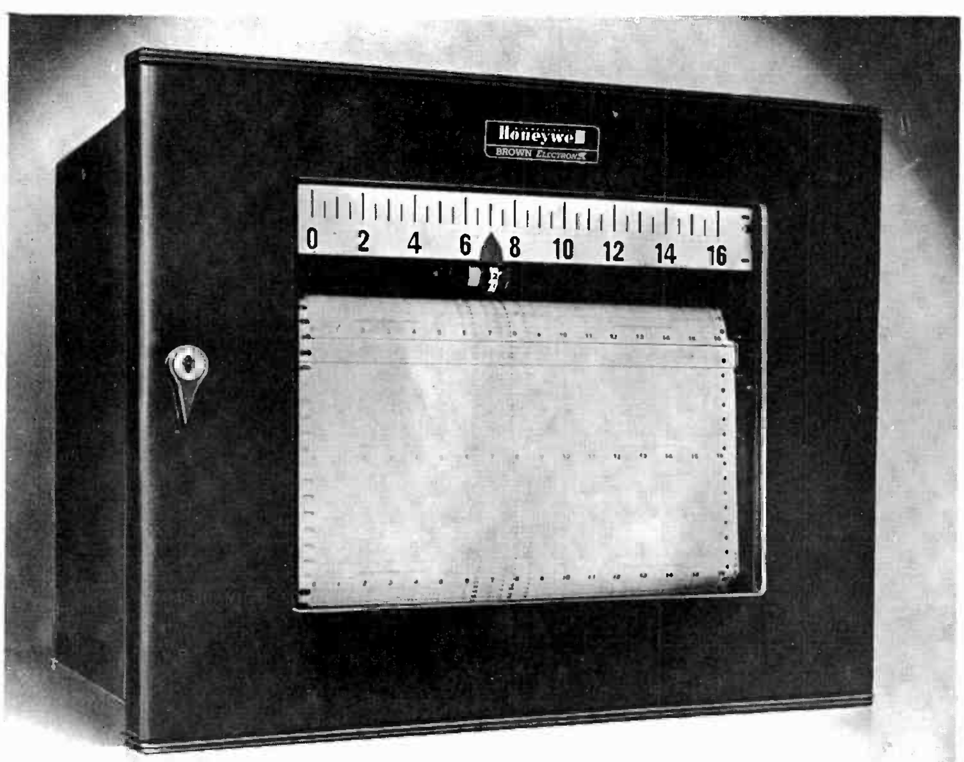


FIGURE 9

THE RADIO STATION OF THE FUTURE

John M. Haerle

Collins Radio Company

I. THE PAST

SINCE THE VERY BEGINNING OF COMMERCIAL RADIO BROADCASTING, THE PROBLEM HAS BEEN ONE OF SUPPLYING ACCEPTABLE ENTERTAINMENT AT LOW COST. THE ABILITY OF THE RADIO INDUSTRY TO FIND WAYS AND MEANS OF PRODUCING SUCH PROGRAMMING ON A LIMITED BUDGET HAS BEEN THE KEY TO ITS SUCCESS.

BROADCASTERS HAVE CONTINUALLY BEEN FACED WITH SITUATIONS LIKE THAT OF THE MIDDLE THIRTIES, WHEN THE MUSICIANS BEGAN RAISING THEIR RATES. INASMUCH AS MUSIC WAS RESPONSIBLE FOR APPROXIMATELY SEVENTY PER CENT OF THE DAILY PROGRAM CONTENT, THE BROADCASTERS WERE FORCED TO FIND A SUBSTITUTE FOR THE LIVE MUSICIAN OR GO OUT OF BUSINESS.

THE MECHANICALLY REPRODUCED PHONOGRAPH RECORD, OF COURSE, PROVIDED THE SOLUTION TO THIS PROBLEM. ITS LOW COST AND LONG LIFE WON UNIVERSAL ACCLAIM. AND, THE MUSICIANS WHO MADE THE RECORDINGS INITIALLY STILL COLLECTED THE ROYALTIES WHEN THE RECORDS WERE BROADCAST, BUT THE COST TO THE STATION WAS A MERE FRACTION OF THE COST OF PRODUCING THE SAME MATERIAL LIVE.

DURING THE WAR YEARS, ANOTHER PROBLEM WHICH FACED THE STATION OPERATOR WAS THE SHORTAGE OF PERSONNEL CAUSED BY THE CALL TO SERVICE OF SO MANY QUALIFIED PEOPLE.

PRIOR TO THIS EMERGENCY, THE AVERAGE STATION WAS STAFFED WITH A FULL COMPLEMENT OF OPERATING OR TECHNICAL PERSONNEL. EVERY PROGRAM ON THE AIR INVOLVED A STUDIO ANNOUNCER, A STUDIO CONTROL OPERATOR, PERHAPS A MASTER CONTROL OPERATOR AND AT LEAST ONE ENGINEER AT THE TRANSMITTING SITE.

AS A DIRECT RESULT OF THE WAR EMERGENCY, THE FIRST PERSONNEL CUT RESULTED IN THE REMOVAL OF THE MASTER CONTROL FUNCTION, WITH THE STUDIO OPERATOR ASSUMING THESE DUTIES. THIS MEANT THAT ONE MAN NOW OPERATED TURNTABLES, CONTROLLED ALL OTHER PROGRAM SOURCES AND WAS RESPONSIBLE FOR FEEDING THE TRANSMITTER.

MANY STATIONS ALSO ELIMINATED THE STUDIO CONTROL OPERATOR BY COMBINING THE DUTIES OF ANNOUNCER AND CONTROL ROOM OPERATOR INTO ONE JOB.

IT IS NOW RECOGNIZED THAT, AS THE DIRECT RESULT OF AN EMERGENCY WHICH FORCED SUCH CHANGES UPON THE BROADCASTER, THE NEW STREAMLINED OPERATION PROVED ITS PRACTICAL WORTH AND REMAINED AS A PERMANENT FIXTURE.

NEXT CAME TV AND STILL ANOTHER DEMAND UPON RADIO STATION PERSONNEL. SINCE IT WAS, FOR THE MOST PART, THE RADIO BROADCASTER WHO FOUNDED AND BUILT TV, IT WAS MOST NATURAL FOR HIM TO DRAW UPON RADIO STATION PERSONNEL TO STAFF TV. OF COURSE, STUDIO PERSONNEL IN MANY STATIONS HAD BEEN REDUCED TO THE MINIMUM.....BUT THE TRANSMITTER ENGINEERS STILL REMAINED. IN THE SEARCH FOR TECHNICAL TV PERSONNEL, IT WAS REASONED THAT, IF IT WERE POSSIBLE TO REMOTELY CONTROL AND METER TRANSMITTING EQUIPMENT FROM THE STUDIO, FROM ONE TO THREE SKILLED TECHNICIANS COULD BE MADE AVAILABLE FROM EACH RADIO STATION TO ASSUME TV DUTIES.

SENSING THE TREND, SEVERAL MANUFACTURERS SOON DESIGNED AND BUILT EQUIPMENT WHICH MET THE REQUIREMENTS AND UNATTENDED OPERATION OF TRANSMITTING PLANTS BECAME A POSSIBILITY.

THE FEDERAL COMMUNICATIONS COMMISSION THEN LICENSED A FEW EXPERIMENTAL INSTALLATIONS AND, UPON RECEIVING PROOF OF RELIABILITY, ISSUED GENERAL REGULATIONS AND LICENSING REQUIREMENTS FOR ALL NON-DIRECTIONAL STATIONS UP TO TEN KILOWATTS IN POWER.

II. THE PRESENT

TODAY, APPROXIMATELY ONE THIRD OF THE EXISTING RADIO STATIONS ARE OPERATED BY REMOTE CONTROL.

THE MANUFACTURERS HAVE CONSTANTLY IMPROVED REMOTE CONTROL EQUIPMENT UNTIL IT HAS REACHED AN ADVANCED STAGE OF DEVELOPMENT. RELAYS AND STEPPING SWITCHES HAVE BEEN DESIGNED FOR MORE POSITIVE OPERATION AND HAVE BEEN PROVIDED AS SEALED UNITS. METERING ERRORS HAVE BEEN REDUCED TO NEGLIGIBLE PROPORTIONS WITH MORE SENSITIVE METERS AND MORE ACCURATE CALIBRATION METHODS.

IN THESE AND MANY OTHER WAYS THE MANUFACTURERS HAVE CONSTANTLY IMPROVED REMOTE CONTROL EQUIPMENT UNTIL IT HAS REACHED A STAGE OF DEVELOPMENT COMPARABLE TO THAT OF THE TRANSMITTER ITSELF. THE RESULTING DEPENDABILITY AND PRACTIBILITY OF THIS OPERATION LEADS NATURALLY TO THE NEXT LOGICAL STEP......REMOTE CONTROL FOR DIRECTIONAL AND HIGH-POWERED STATIONS.

IN ATTEMPTING TO ARRIVE AT REASONABLE CONCLUSIONS REGARDING APPLICATION OF REMOTE OPERATION TO HIGH-POWERED TRANSMITTERS AND DIRECTIONAL STATIONS, A MEETING WAS HELD IN WASHINGTON ON SEPTEMBER 21, 1954. THOSE WHO ATTENDED REPRESENTED CONSULTING RADIO ENGINEERING FIRMS, CERTAIN RADIO STATIONS WHICH ALREADY INITIATED EXPERIMENTAL OPERATION, MANUFACTURERS OF REMOTE CONTROL AND BROADCAST EQUIPMENT AND THE NARTB.

DURING THE MEETING, VARIOUS IDEAS AND SUGGESTIONS CONCERNING THE APPLICATION OF REMOTE CONTROL TO DIRECTIONAL ARRAYS AND HIGH-POWERED STATIONS WERE EXPLORED. THERE WAS UNANIMOUS AGREEMENT ON FOUR POINTS........AND HERE WE QUOTE:

1. "THE APPLICATION OF REMOTE CONTROL TO HIGH-POWERED TRANSMITTERS IS NO DIFFICULT PROBLEM; IN FACT, IT CAN BE ACCOMPLISHED WITH LESS DIFFICULTY THAN WITH LOWER-POWERED TRANSMITTERS BY VIRTUE OF THE AUTO DEVICES NORMALLY BUILT INTO SUCH TRANSMITTERS."

2. "AS A CLARIFICATION OF THE USE OF THE TERMS 'REMOTE CONTROL' AND 'REMOTE OPERATION,' THE FORMER IS CONSIDERED TO APPLY TO THE REQUIRED FUNCTIONS OF A TRANSMITTER. 'REMOTE OPERATION' APPLIES TO REMOTE READING OF THE PERTINENT VALUES OF AN ARRAY AS WELL AS TO SWITCHING BETWEEN PATTERNS, INCLUDING SIGH-ON AND SIGN-OFF PERIODS. ACTUAL CONTROL OF THE ARRAY, THAT IS, ADJUSTMENT OF THE PHASING AND CURRENT VALUES IS NOT CONTEMPLATED IN THE REMOTE OPERATION OF A DIRECTIONAL ANTENNA SYSTEM.

3. "ALTHOUGH EACH DIRECTIONAL ARRAY PRESENTS A SEPARATE PROBLEM SHOULD BE CONSIDERED INDIVIDUALLY, ADEQUATE INDICATION OF THE CORRECT OPERATION OF THE ARRAY WOULD BE OBTAINED BY REMOTELY READING THE BASE CURRENT OF EACH TOWER IN THE ARRAY. IT WAS CONCLUDED THAT THE <u>PHASE MONITOR</u> READINGS SHOULD BE OBSERVED WEEKLY BY A FIRST-CLASS LICENSED OPERATOR."

4. "ASIDE FROM THE PARTICULAR PROBLEMS WHICH MAY BE ENCOUNTERED IN EACH ARRAY, IT WAS INDICATED THAT IT WOULD BE MOST DESIRABLE TO HAVE EXPERIMENTAL DATA CONCERNING NOT ONLY THE GENERAL REMOTE OPERATION OF AN ARRAY, BUT INCLUDING SUCH FACTORS AS FEASIBILITY OF SWITCHING REMOTELY FROM NON*DIRECTIONAL TO DIRECTIONAL OPERATION, AND SWITCHING FROM DAYTIME TO NIGHTTIME PATTERN, INCLUDING SIGN-ON AND SIGN-OFF PERIODS."......UNQUOTE

BEGINNING AT THIS MEETING IN 1954 AND CONTINUING TO THE PRESENT, INDIVIDUAL STATIONS, CONSULTING ENGINEERS, MANUFACTURERS AND THE NARTB HAVE WORKED TOGETHER ON THIS PROJECT. NUMEROUS DIRECTIONAL AND HIGH-POWERED STATIONS HAVE BEEN OPERATED EXPERIMENTALLY BY REMOTE CONTROL FOR MORE THAN TWO YEARS. MUCH EVIDENCE HAS BEEN COLLECTED AS PROOF OF THE PRACTICAL NATURE OF THIS PROPOSED OPERATION AND SUBMITTED IN THE FORM OF EXHIBITS TO SUPPORT THE NARTB PETITION OF FEBRUARY 15, 1956, LOOKING TOWARD AMENDMENT OF PERTINENT SECTIONS OF THE COMMISSION'S RULES RELATING TO REMOTE CONTROL.

THE PROPOSAL IS IN THE HANDS OF THE COMMISSION. IT IS NOW ONLY A MATTER OF TIME UNTIL WHAT IS OPTIMISTICALLY ANTICIPATED AS A FAVORABLE DECISION IS FORTHCOMING.

ANOTHER FACTOR AFFECTING ECONOMICS OF OPERATION IS (OR WILL BE) AUTOMATIC PROGRAMMING, WHICH IS DEVELOPING SLOWLY. FOR TWO YEARS EQUIPMENT HAS BEEN COMMERCIALLY AVAILABLE WHICH, THROUGH THE USE OF TONES ON TAPES, WILL KEY PROGRAMS AUTOMATICALLY.

BASICALLY, THERE ARE FOUR GENERAL SYSTEMS:

FIRST, THERE IS THE "SEMI-AUTOMATIC" SYSTEM, IN WHICH AUTOMATIC RECORD CHANGERS AND TAPE MACHINES ARE PRE-LOADED AND SUBSEQUENTLY KEYED MANUALLY BY A SET OF PUSH-BUTTONS. THESE PUSH-BUTTONS KEY SUCH FUNCTIONS AS "PRE-SELECTION," "CUEING," "REJECTION," "SEQUENTIAL OPERATION" AND "AUTOMATIC FADE-IN." PROPONENTS OF THIS SYSTEM POINT OUT THAT THE RULES REQUIRE AT LEAST ONE MAN TO BE ON DUTY AND THAT THIS MAN CAN OPERATE THE SYSTEM, ALLOWING THE FLEXIBILITY AND THE PERSONAL TOUCH OF CONVENTIONAL OPERATION BUT PROVIDING BETTER PRODUCTION.

NEXT, THE FULLY AUTOMATIC "TAPE AND RECORD" SYSTEM PLACES THE COMMERCIAL ANNOUNCEMENTS ON TAPES WHICH, THROUGH THE USE OF SUPERIMPOSED TONES, THEN KEY AUTOMATIC RECORD PLAYERS. IT IS CLAIMED THAT, IN LITTLE MORE THAN THE TIME REQUIRED TO RECORD THE ANNOUNCEMENTS, SEVERAL HOURS OF UNATTENDED PROGRAMMING CAN BE PROVIDED.

THE THIRD METHOD IS THE FULLY AUTOMATIC "TAPE ONLY" SYSTEM. THIS SYSTEM OPERATES VERY MUCH IN THE MANNER OF THE "TAPE AND RECORD SYSTEM," EXCEPT THAT THE MUSIC IS ENTIRELY ON TAPE.

FINALLY, THE "PUNCHED TAPE" SYSTEM USES A PRE-PUNCHED PAPER TAPE TO PROVIDE THE NECESSARY INTELLIGENCE FOR UNATTENDED SEQUENCING OF PROGRAM MATERIAL EMANATING FROM VARIOUS SOURCES.

ANOTHER ITEM RECENTLY DEVELOPED AND ALREADY WIDELY USED IS THE "CONSTANT LEVEL" OR "AVERAGE" LIMITING AMPLIFIER, USED AS A COMPANION TO THE PEAK LIMITING AMPLIFIER. THIS UNIT IS VERY EFFECTIVE IN PROVIDING A CONSISTENTLY FULL LEVEL OF MODULATION TO THE TRANSMITTER, RESULTING IN MAXIMUM FRINGE AREA COVERAGE.

USED ELSEWHERE IN THE STUDIO, THE CONSTANT LEVEL AMPLIFIER CAN ALSO PROVIDE AUTOMATIC FADING OF RECORDS TO A LEVEL SUBSTANTIALLY BELOW THAT OF THE OVER-RIDING VOICE ANNOUNCEMENTS.

THE CONSTANT LEVEL AMPLIFIER, AUTOMATIC PROGRAMMING, REMOTE CONTROL AND AUTOMATIC LOGGING <u>ARE</u>, OF COURSE, A PART OF TODAY'S PICTURE, AS ALREADY SHOWN..... BUT IT IS IMPORTANT TO REMEMBER THAT THESE ARE <u>NEW</u> DEVELOPMENTS, THAT MANY OF THEM ARE BY NO MEANS PERFECTED, AND THAT THEY ARE INSEPARABLY INVOLVED IN THE

FOLLOWING AND FINAL PART OF THIS DISCUSSION.......THE RADIO STATION OF THE FUTURE.

III. THE FUTURE

PROBABLY THE FIRST DEVELOPMENT OF IMPORTANCE IN THE FUTURE OF MANY RADIO STATIONS WILL BE THE ANNOUNCEMENT BY THE FEDERAL COMMUNICATIONS COMMISSION OF A DECISION REGARDING REMOTE CONTROL OF DIRECTIONAL AND HIGH-POWERED STATIONS. AS PREVIOUSLY MENTIONED, THOSE WHO WILL BE AFFECTED HOLD HIGH HOPES FOR A FAVORABLE DECISION.

LOGICALLY FOLLOWING REMOTE CONTROL OF DIRECTIONALS, IT IS OBVIOUS THAT AUTOMATIC LOGGING IS A NATURAL COMPLEMENT TO REMOTE CONTROL OPERATION. THERE IS NOTHING OF A TECHNICAL NATURE THAT CAN BE ADDED TO MR. EHRENBERG'S MOST INTERESTING AND COMPLETE DISCUSSION, BUT IT WILL ADD TO THE PURPOSE OF THIS DISCUSSION TO EMPHASIZE THAT AUTOMATIC LOGGING WILL SURELY PLAY AN IMPORTANT PART IN THE RADIO STATION OF THE FUTURE. IT SHOULD BE REALIZED, TOO, THAT RULE CHANGES WILL BE REQUIRED, JUST AS IN THE CASE OF REMOTE CONTROL. THIS MEANS THAT NARTB, AS THE BROADCASTER'S REPRESENTATIVE, MUST BE SUPPORTED BY CONSULTING ENGINEERS, MANUFACTURERS AND STATION OPERATORS IN THE DESIGN, MANUFACTURE AND EXPERIMENTAL OPERATION OF SUCH EQUIPMENT..... SUCH ACTION WOULD APPEAR TO BE MUTUALLY BENEFICIAL TO ALL CONCERNED.

THE TRANSMITTER OF THE FUTURE MAY ALSO UNDERGO MANY NEEDED CHANGES. ACCESSIBILITY WILL CONTINUE TO BE STRESSED. THIS FEATURE WILL BE GREATLY IMPROVED THROUGH MANY INTERESTING AND RADICAL CHANGES IN MECHANICAL DESIGN.

WOULD IT BE BEYOND THE REALM OF POSSIBILITY TO ENVISION A TRANSMITTER BUILT IN OPEN FASHION ON THE WALLS OF ITS OWN BUILDING?......THE ENTIRE TRANSMITTING PLANT COULD BE SHIPPED TO THE SITE, THE WALLS BOLTED TOGETHER IN TYPICAL PREFAB FASHION AND THE VARIOUS CIRCUITS JOINED BY TERMINAL BOARDS. RIDICULOUS?......TODAY, POSSIBLY......NOT IN THE RADIO STATION OF THE FUTURE.

MONITORS COULD BE HEADING FOR OBSOLESCENCE......TRANSMITTER CRYSTALS HAVE BEEN IMPROVED TO THE POINT WHERE IT IS ACTUALLY TRUE THAT SOME MODERN TRANS-MITTERS ARE MORE STABLE THAN THE COMPANION FREQUENCY MONITORS. IF THIS CONDITION CAN BE GENERALLY ACHIEVED, WHY NOT REPLACE THE FREQUENCY MONITOR WITH A SMALL ECONOMICAL UNIT CONTAINING A ONE HUNDRED KILOCYCLE OSCILLATOR AND A TEN KILOCYCLE MULTIVIBRATOR FOR USE IN PERIODIC COMPARISON CHECKS AGAINST WWV?

AGAIN, TO EFFECT A CHANGE OF THIS NATURE, A RULE CHANGE IS REQUIRED. THOSE CONCERNED MUST TAKE THE INITIATIVE......THEIRS IS THE BURDEN OF PROOF. THEY MUST CARRY THE IDEA THROUGH DESIGN, CONSTRUCTION AND TEST AND, IF THE IDEA IS SOUND, THEY MUST WORK THROUGH THEIR REPRESENTATIVE ORGANIZATION IN ASKING FOR THE CHANGE......REMOTE CONTROL BECAME A REALITY IN JUST THIS FASHION.

THE MODULATION MONITOR MAY ALSO FIND ITSELF OUTMODED. IMPROVEMENT OF THE CONVENTIONAL PEAK LIMITING AMPLIFIER AND ITS USE IN COMBINATION WITH THE "CONSTANT LEVEL" TYPE OF LIMITING AMPLIFIER PROVIDES MODULATION OF THE TRANSMITTER WHICH IS OFTEN MORE CONSISTENT IN THE ABSENCE OF OBSERVATION OF THE MODULATION MONITOR THAN THAT ACHIEVED WITH THE SINGLE PEAK LIMITER AND CONSTANT OBSERVATION OF THE MONITOR.

THE EVENTUAL ELIMINATION OF THE MODULATION MONITOR WILL BE A PART OF THE PICTURE OF THE RADIO STATION OF THE FUTURE.

IN A DISCUSSION OF THE RADIO STATION OF THE FUTURE, CERTAINLY FM MUST BE CONSIDERED.

THE GROWTH OF HI-FI AND THE RESULTANT INCREASE IN THE NUMBER OF GOOD FM RECEIVERS HAS GREATLY BENEFITED FM.

THE ADVENT OF MULTIPLEXING, WHICH ALLOWS SEVERAL PRIVATE SUB-CARRIERS TO RIDE "FREE" ON THE MAIN CARRIER, IS PROVIDING MANY FM STATIONS WITH ADDITIONAL REVENUE FROM "BACKGROUND MUSIC" FOR HOTELS, "STORECASTING" SERVICES ETCETERA.

THE EVER-INCREASING NIGHT-TIME INTERFERENCE PROBLEM LEADS MANY TO WONDER IF CERTAIN MARKETS AND CERTAINS CLASSES OF STATIONS WILL NOT EVENTUALLY BE FORCED TO SWITCH TO FM.

ONLY TWO YEARS AGO, USED FM EQUIPMENT WAS A DRUG ON THE MARKET. TODAY, SUCH EQUIPMENT IS HARD TO FIND AND THE PRICE HAS SKYROCKETED.

IS FM "DEAD"?......NO, NOT QUITE......IT MAY VERY WELL BE AN IMPORTANT FACTOR IN THE RADIO STATION OF THE FUTURE.

LAST BUT NOT LEAST, THE RADIO STATION OF THE FUTURE WILL EVENTUALLY USE SOME FORM OR SOME ADAPTATION OF AUTOMATIC PROGRAMMING.

MANY POINT TO THE OPERATOR WHO IS REQUIRED TO BE ON DUTY AND TO THE POSSIBILITY THAT A SO-CALLED "ROBOT" OPERATION WOULD RESULT IN PROGRAMMING DEVOID OF PERSONALITY. PERHAPS A COMPROMISE WILL BE THE SEMI-AUTOMATIC OPERATION, IN WHICH THE OPERATOR ON DUTY CAN SELECT OR CUE ANY DESIRED RECORD BY PUSHING A BUTTON.

IT IS WITHIN THE REALM OF POSSIBILITY THAT SHELVES IN THE RECORD LIBRARY OF THE FUTURE RADIO STATION WILL BE REPLACED BY BANKS OF "ONE HUNDRED PLAY" AUTOMATIC RECORD CHANGERS. THE RECORDS WOULD NEVER BE TAKEN FROM THEIR SHELVES, BUT WOULD BE SELECTED AS REQUIRED BY PUSH BUTTONS OR BY AN AUTOMATIC SEQUENCER OF SOME KIND.

SURELY, THE MANY GOOD MINDS NOW BEING DEVOTED TO THE SUBJECT OF AUTOMATIC PROGRAMMING ARE GOING TO DELIVER AN EVENTUAL ANSWER WHICH WILL MEET WITH GENERAL ACCEPTANCE.

IV. AUTOMATION

IF ALL OF THE AUTOMATIC EQUIPMENT THUS FAR DISCUSSED......EQUIPMENT WHICH WILL SURELY PLAY SUCH AN IMPORTANT PART IN THE FUTURE......WERE TO BE DESCRIBED IN A WORD, THAT WORD WOULD, OF COURSE, BE......AUTOMATION.

AUTOMATION IS SYNONOMOUS WITH THE FUTURE OF AMERICA. IT IS MERELY A CONTINUATION AND A PROJECTION OF A FAMILIAR PROCESS WHICH, THROUGHOUT THIS CENTURY, HAS MADE THIS COUNTRY DIFFERENT AND BETTER THAN ANY OTHER IN THE WORLD.

INEVITABLY, SOME WILL BE ALARMED BY THE WORD "AUTOMATION"......IT MIGHT BE WORTH A GOOD LOOK TO DISCOVER THAT SUCH FEARS ARE GROUNDLESS.

CONSIDER, FOR EXAMPLE, THAT MANY STATIONS HAVE REDUCED PERSONNEL TO INCLUDE ONLY ONE FIRST-CLASS LICENSEE......AND THAT EVEN THIS LICENSE MAYBE HELD BY AN ANNOUNCER WHO RECEIVED IT FROM A "LICENSE MILL" BUT WHO REALLY DOESN'T KNOW A TRANSISTOR FROM A TRANSFORMER.

IS THIS THE MAN WHO WILL INSTALL, MAINTAIN AND SERVICE SERVOS, TRANSDUCERS AND SEQUENCERS?........OF COURSE NOT.

IS THERE AN OVER-ABUNDANCE OF QUALIFIED BROADCAST ENGINEERS?........ DEFINITELY NOT. LOW SALARIES AND COMBO MEN HAVE FORCED MANY GOOD MEN INTO OTHER INDUSTRIES. THOSE QUALIFIED MEN WHO REMAIN NEED A SALARY RAISE AND, CERTAINLY, MORE PRESTIGE FOR THEIR JOBS......AND AUTOMATION CAN PROVIDE THESE BENEFITS.

FOR THE QUALIFIED ENGINEER IN THE RADIO STATION OF THE FUTURE, THERE IS NO DIRECTION BUT UP.

V. IN SUMMARY

AND SO IT HAS BEEN SHOWN THAT, FIRST THE MUSICIANS, THEN THE WAR AND FINALLY TV FORMED A PATTERN OF CHANGE THAT LED THE BROADCASTER CONSTANTLY IN THE DIRECTION OF SIMPLIFIED, ECONOMICAL OPERATION.

IT HAS BEEN SHOWN THAT THE PRESENT IS SYMBOLIZED BY THE ARRIVAL OF MANY FEATURES OF AUTOMATION WHICH WILL BE PERFECTED AND USED IN THE RADIO STATION OF THE FUTURE.

FINALLY, IT HAS BEEN SHOWN THAT AUTOMATION IS THE WORD. IT IS AN INEVITABLE PART OF THE RADIO STATION OF THE FUTURE......WELCOME IT......LET IT WORK FOR YOU.

SUMMARY

"Keeping Standard Broadcast Transmitters Up To Date"

Henry Hulick Jr
Chief Engineer
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Raleigh N C

Standard broadcast transmitters may be up-dated by keeping abreast of new developments in the art with an eye as to how they may be used in improving your own operation. Thought should be given to the initial cost and operation against money saved in the years to follow.

Newer tubes can be used in transmitters designed years ago to improve the overall operation at a lower cost. By discussing such changes with the manufacturers the modifications may be done by station engineers without the expense of outside engineering.

Old type transmitters may be cleaned up by improvements in reduction of harmonics and other spurious radiations so that they become in most respects modern broadcasting systems.

"Keeping Standard Broadcast Transmitters Up To Date"

The Westinghouse 50 HG transmitter in use at WPTF was installed in 1940. At that time, the transmitter operated with a pair of 849A's as audio drivers, two WL893's as modulators, and a pair of WL-895's in the P.A. Six 881's were used as rectifiers. Since then all the types mentioned have been replaced by tubes of later design.

One of the first changes made was the substitution of 857-B rectifiers for the type WL881 tubes. The 881 was declared obsolete and discontinued. The 857-B has given consistent long life - average of about 20,000 hours - and trouble-free operation. This change was made by the Atlanta division of Westinghouse.

The second change was the 849A tubes in the audio driver stage, connected as cathode followers. These tubes averaged only about 4,000 hours before beginning to limit the percentage of modulation. Since we were using two 833A tubes in the RF driver, it was decided to replace the audio 849A tubes with the 833A. The 833A has equivalent characteristics and all that was necessary was to change the sockets and adjust the filament rheostats. The 833A's give reliable service without limiting for twenty-five to thirty thousand hours and cost less than half the price of the 849A.

We found that the 828 stage was not operating at minimum distortion with the 1250 volt plate supply provided for it, so we rigged up a 1700-volt supply for these tubes consisting of a pair of 866A rectifiers. This move lopped a couple of percentage points off our distortion measurement.

We had been following the tube life of the RCA thoriated filament 5671's at KDKA and WBZ, and in 1952 we decided to make a change in the modulators and PA stages. This decision was brought about by trouble encountered with the Westinghouse WL893R used in the modulator. These tubes, although running past the guaranteed hours, were averaging only four thousand hours per tube. The WL895R, used in the power amplifier, was running much better mileage but it was thought that if one was to be changed, it would be better to change both - replacing with the RCA 5671 in both cases and thereby reducing the spare requirement and making it possible to interchange tubes from modulator to power amplifier.

After lengthy discussion and checking the circuits involved with the manufacturer, it was apparent that the electrical characteristics of the 5671's made them suitable for both the modulator and the power amplifier without a major modification except for providing the lower voltage, higher current supply for the filaments. This made it necessary to provide filament transformers to supplant the multi-phase transformers used for the 893 and 895 tubes. Here the first hitch developed. The company selected to provide the transformers either failed to follow specifications or else never received the right ones. In any case, the transformers were delivered without the center taps and were also wound to provide terminal voltages adjustable from eleven to twelve volts instead of the required ten to eleven volts. However, RCA provided small chokes with center taps which were wired across the transformer secondaries to carry the plate current of the tubes. RCA also provided two step-down transformers for reducing the filament bus voltage to 207 volts, thus making it correct for the transformers and producing the voltage range from ten to eleven volts at the secondary terminals.

The 50-HG is provided with spare positions for both the modulators and the power amplifier tubes. Our project called for converting the spare positions during off-the-air time until complete, then shifting to the new tubes in the spare sockets while converting the remaining positions.

The old filament transformers weighed approximately three hundred pounds and were mounted on the overhead of the transmitter cubicles with bolts spot-welded to the outside top of the cubicle.

Tubes, motor tuning controls, blocking condenser, neutralizing coil and all miscellaneous wiring were removed and the spot welding cut loose.

Saw horses were built to stand front and back of the cubicle with a two by ten plank suspended from horse to horse through the front window and out the back door by rope block and tackle falls.

The three-hundred pound transformers were eased onto the plank and lowered away and replaced by the lighter transformers for the new tubes. Special motion picture projection cable, silver soldered to large lugs, was used to carry the 285 amperes from the new transformer secondaries to the tube filaments.

One and one-quarter inch pipe was set into a hole in the floor of the cubicle for the air supply to the seal of the tube. This was brought to bear on the tube seal by means of a curved automobile radiator hose.

New filament voltage meters with scale to accommodate the lower voltages were installed.

The power amplifier was re-neutralized for the new plate-to-grid capacitance. This required only a slight change in inductance.

Power amplifier filament transformers were Scott connected to equalize the load on the supply line and reduce hum.

Modulators were connected so that both tubes operated off the same phase in order to take advantage of hum cancellation.

A mechanical whistle with a frequency of about six hundred cps was produced by the new tubes due to passage of air over the cooling fins. In the power amplifier this was eliminated by removing the tube lifting jackets. In the modulator, where four tubes are grouped in close proximity, removing the lifting jackets only reduced the whistle and it was necessary to install a partition down the middle of the cubicle to eliminate the whistle entirely.

Since converting to the 5671's, we have noted power consumption reductions amounting to twelve hundred dollars per year and a saving of thirty-four hundred per year on tube costs. To date, we have had no outright failures of the 5671 tubes although two of them have developed low emission characteristics after about eight thousand hours; however, they can be used as emergency spares. The other six have been in use for upward of 25,000 hours and to date have given no indication of any decrease in efficiency. Six out of eight is a pretty good batting average.

The 5671 conversion was made when the 93's and 95's were on the short end of their expected life and an expenditure of $5,000 was upcoming. By so timing the change-over, less tube life-hours were wasted and the $5,000 was applied to the cost of 5671's.

RCA did lend us one 893 to meet the required spares but it was never put in the transmitter.

All work on this project was done between 12:30 and 5 AM by our own personnel and no program time was lost due to the conversion.

Overall feedback was installed in the 50-HG by Westinghouse in addition to the two feedback loops in the audio section of the transmitter. This was done to compensate for the noise generated by the 895 and 893 tubes. This noise consisted of a combination of a number of frequencies. However, upon installing the RCA 5671 single phase thoriate filament power tubes, we found that the composite hum frequency generated by the new tubes was of a single frequency, 240 cps. We devised a 240-cycle generator to produce .3 volts at 240 cps with controls for varying the phase and contour of the wave. This was fed into the audio input in inverse phase and effectively cancelled out eleven decibels of the filament hum. The hum bucker consists of a double doubler operating from the 60 cycle supply line using selenium rectifiers and tuning to the ripple frequency. No vacuum tubes are involved. Use of this device allows the discontinuance of the overall feedback loop and its associated linearity compensating network.

Second harmonic radiation was one of the original faults of the 50-HG. As originally installed, a parallel resonant circuit was connected between the center tap of the P.A. tank and ground, tuned to the second harmonic. This arrangement was very ineffective and subject to detuning with heat. We replaced it with a series resonant circuit across the transmission line using a large inductance and a small capacitance. This arrangement effectively short-circuited the second harmonic without dissipating excessive power.

Another spurious radiation plauged us when in the early days of television it became apparent that we were radiating an interferring signal at an extremely high frequency which caused serious TVI in the circuits of nearby TV receivers. After much experimenting, the cause was found to be corona at the top of our two 375-foot quarter wave towers used for nighttime directional operation. The condition was eliminated by the installation of corona rings projecting a few inches above the top of the beacon lamp on top of these towers.

In 1949 we erected a 525-foot self-supported tower for FM and possible TV. This tower is also used as the daytime non-directional radiator for AM. The coax lines and lighting conduit are suspended on messenger cable and insulated from the tower. By bonding these leads to the tower at the quarter wave point, harmonic radiations from this arrangement are practically nil. A 1-KW station, 30 miles west, operating on our second harmonic can be clearly heard without interference one-quarter mile from our transmitter.

At WPTF we spot check the proof of performance run regularly and have found that this procedure pays off. Noise, distortion and frequency response will change from time to time, and, without these checks, would not be corrected prior to the regular yearly performance run.

I would like to thank RCA, Westinghouse and Allied Electronics for their cooperation on the 5671 conversion and give credit to Sam Liles, Transmitter Supervisor at WPTF, who was the workhorse on this project.

OPERATIONAL CONSIDERATIONS OF THE AMPEX VIDEOTAPE RECORDER

by Charles P. Ginsburg
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Introduction

Ampex videotape recorders have been in operation on the air for four and a half months. Network users who by now have had a lot of experience with the machines know that development is still continuing and will continue for some time to come. In spite of this, the machines are not only entirely practical but also allow the users to realize even at this time the benefits inherent in a suitable videotape recording system.

The object of this paper is to give the broadcasters a better understanding of the recorder, considering it as a piece of television station gear. With proper maintenance and set-up procedures being followed the machine is very reliable and is extremely simple to operate.

General Description

The Ampex videotape recorder is based upon the use of a set of four magnetic heads mounted on a drum which rotates with a peripheral velocity of about 1500 ips. (Slide 1.) The magnetic heads, which serve for recording as well as playing back, lay down on a tape magnetic track only .010 inch wide. The tape is two inches wide and is cupped to conform to the curvature of the drum. The magnetic tips protrude a few mils past the edge of the drum and maintain a very positive contact with the tape. The tape is made to conform to the shape of the drum by means of a curved guide whose radius of curvature is approximately the same as the radius of the drum. The protruding tips of the rotating heads actually ride in a groove cut into the curved guide. Thus, as the tape passes the drum it is stretched by the tips, which force the tape into the groove. Adjustment of the position of the guide in the plane perpendicular to the axis of the drum controls the amount of information which is written or read out per unit of arc of the head sweep. For example, if we assume that a recording has already been made and now merely consider the playback process, we would find that moving the guide in 2 mils closer to the drum would result in a shortage of information read out of approximately 2 microseconds during an interval of $1/960^{th}$ of a second, that is, during the time it takes a given head to describe an arc of 90 degrees. Conversely, backing the guide 2 mils away from its nominal operating position would cause an excessive amount of information to be read out during the same interval. More will be said about these effects and the regulation of them later in this paper.

Slide 2 shows the layout of components on the tape transport. The tape is fed from the supply reel on the left, around an idler and self-aligning tension arm, past the rotating drum. From this point, the tape is passed over two stacks of fairly conventional stationary magnetic heads. These heads, as shown on the slide, are the audio erase head at the top of the first stack, the audio record/reproduce head at the top of the second stack, and the control track record/reproduce head at the bottom of the second stack. The tape proceeds from this point past the capstan and capstan idler, to the takeup idler, around the idler arm, and to the take-up reel. Adjustment of a lead screw positions the female guide with respect to the drum shaft, thereby regulating the amount of tape stretching in the locus of the head sweeps.

Slide 3 shows the magnetic pattern on the tape. As the tape passes by the rotating heads the video tracks are written completely across the width of the tape. After passing the stationary control track and audio heads, the transverse tracks remaining occupy a distance of approximately 1.8". The control track signal occupies roughly the lowest $1/10^{th}$ of an inch of space on the tape while the audio track occupies approximately the top $1/10^{th}$ of an inch. The drum diameter has been chosen so that the 1.8 inches of video information represents 90 degrees of arc plus about two lines of picture information. Thus, if we consider two adjacent recorded magnetic tracks, we will find there is a redundancy of two picture lines in this pair of tracks. The purpose of this is to insure that during the playback process the read-out of information will be continuous. Because of variations in tape dimensions as a function of temperature, humidity, and lateral tensions, it is impractical to attempt to record and playback a continuous signal without such an overlap of information.

The Video System

Slide 4 is a block diagram of the complete video system. An incoming composite video signal at standard level is applied to the input terminals of the modulator unit. The modulator circuit itself consists of a multivibrator to whose grids is applied the composite video signal. The modulator is clamped to peak of sync and the deviation of the multivibrator frequency is entirely in the upward or high frequency direction as a linear function of the whiteness of the picture. The deviation corresponding to peak white is about 1.2 megacycles. The free-running frequency of the multivibrator, that is, the frequency without any modulating signal applied, is generally set at about 5 megacycles. Thus, the multivibrator will vary from about 5 megacycles to about 6.2 megacycles. Certain high frequency peaking which is used in the video amplifiers preceding the modulator actually cause the multivibrator, under certain transient conditions, to hit peak frequencies of 7 megacycles or higher.

The output of the modulator unit is applied to four record driver amplifiers; separate gain controls are used for these amplifiers, for reasons which will be discussed later. The four outputs are applied to constant current amplifiers which drive the heads during the record process. Signals are coupled to or from the rotating heads by means of brushes and slip rings. During playback the signals picked up by the rotating heads are applied to four separate preamplifiers. The signals picked up from the tape come off at the millivolt level. The four outputs from the preamplifiers are applied separately as input signals to the switcher, whose function is to pass the output of only one head channel at a time. Switching from channel to channel is accomplished by use of a 240 cycle signal generated by a photocell which receives a light source reflected from a disc mounted on the drum shaft. This disc is one-half reflecting and one-half non-reflecting so that a 240 cycle square wave appears at the output of the photocell. Although this 240 cycle signal is the basic timing signal for the switcher, an additional feature is incorporated in the switching process. This consists of switching not merely during the period of information overlap which exists between adjacent tracks, but of switching during a horizontal blanking interval which falls in the information overlap. To accomplish this the switching circuits employed are coincidence gates, with a short rise time derivative of the 240 cycle photocell signal constituting one of the pulses and the horizontal sync pulse of the head to be switched from constituting the second pulse. This horizontal sync pulse is obtained from the demodulated signal at the output of the machine.

Therefore, at the output of the switcher we have an essentially continuous frequency-modulated wave. This signal is applied to the demodulator unit, which consists of suitable amplifier and limiter stages, an fm detector and video amplifiers. The signal appearing at the output of the demodulator is composite video, with objectionable amounts of carrier and twice-carrier components present, notably in the black regions of the composite video waveform. This is because the multivibrator is operating at its lowest frequency during peak of sync.

The purpose of the last unit in the system, the processing amplifier, is mainly to improve the signal-to-noise characteristic during blanking and sync without sacrificing the bandwidth inherent in the system. By use of suitable techniques not only are the objectionable carrier and twice-carrier components eliminated, but in addition the signal-to-noise ratio, considering only the noise source constituted by tape dropouts and occasionally by switching transients, is made to conform with commercial television broadcast requirements.

Optimizing the Head Currents

In any ring type magnetic recording head a certain phenomenon associated with wavelength occurs which is especially significant in this system (Slide 5). The curves are plots of recording current versus playback voltage at various wavelengths. If the object is to get as much playback voltage as possible at all frequencies, then although the record current is not critical with respect to long wavelengths, it gets more and more critical at shorter and shorter wavelengths. In the video tape recorder the long wavelengths actually represent the high video frequency, since we are using a modulation system. Therefore, the effect of using too much record current at all frequencies would be a relative peaking at high video frequencies, or more precisely an attenuation of the low video frequencies with respect to the highs. Under some circumstances this built-in aperture correction might seem desirable, but unfortunately we must also consider the matter of signal-to-noise ratio. Any decrease in the rf playback amplitude at, let us say, 6 megacycles will result in a decrease in signal-to-noise ratio at the dc video level corresponding to that frequency.

Let us now complicate the situation by considering the fact that the depth of the magnetic gap plays a prominant roll in determining the wavelength response of a particular head. To make things still worse, it is completely impractical to try to hold dimensional tolerances close enough so that four randomly selected heads, when driven from identical impedance sources with identical currents, will reproduce the information with a sufficiently similar response. In the high resolution system with which we are dealing, comparatively small differences in signal-to-noise characteristics and in response characteristics will create a very objectionable banding effect. Under such conditions the reproduced picture may appear to be segmented into horizontal sections of about 16 picture lines each. Fortunately, it turns out that the whole problem is made trivial by supplying a separate gain control in the record amplifier driver associated with each head, and by equipping the user of the equipment with instructions which allow him to optimize a complete set of heads in about ten minutes. Having overcome some problems associated with the brushes and slip rings, as well as with the heads, which were encountered when the machines were first installed in the field, there has been no difficulty in reaching and exceeding the 100 hour head life predicted some time ago. In the worst case, the optimizing procedure should be used at the time of installation of a new head subassembly, and then at infrequent intervals, perhaps once a week. This necessity exists only if the user desires to get the absolute maximum in performance from the machine. On the other hand, assemblies have been replaced in the field and subjectively excellent pictures made without even taking the time to go through the optimizing procedure. In short, the head current optimizing procedure is at the worst a very simple matter.

Switcher, Blanking Switcher, and Processing Amplifier

Periodic routine maintenance of the switcher, the blanking switcher, and the processing amplifier is desirable in order to avoid the necessity of having to make any vernier adjustments while the machine is on the air. Specific checks are recommended on circuits whose function is to handle or process various timing signals, mainly in order to make any minor adjustments necessary to compensate for changes of component values as a function of aging, temperature, etc. The three units mentioned all break down into easy-to-follow functional block diagrams.

Perhaps the most complex unit is the processing amplifier, which cleans up blanking and sync. The nature of the circuitry used to accomplish this function is, in general, familiar to those who are already concerned with standard television equipment.

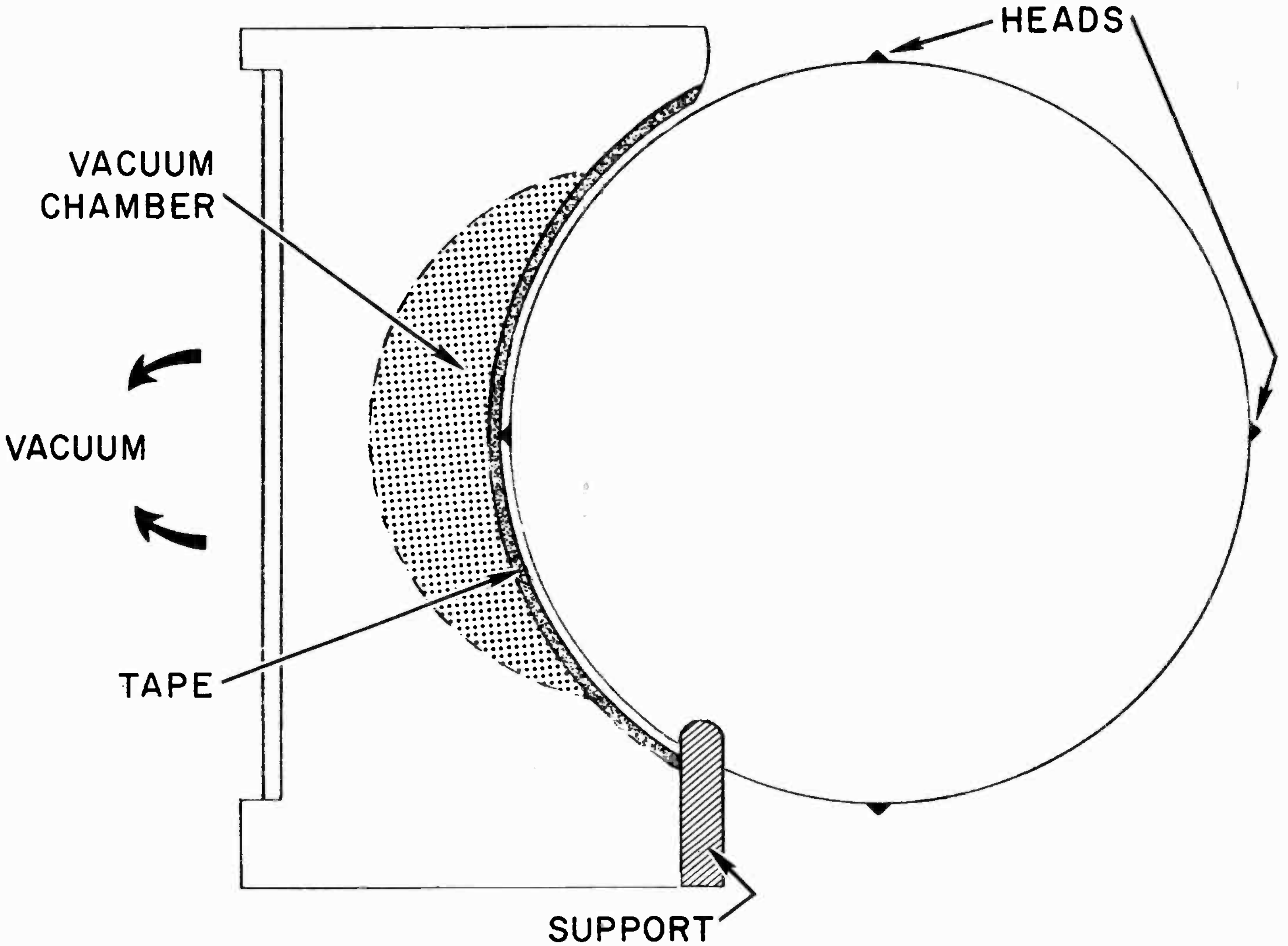
In order to allow the processing amplifier to achieve the most effective suppression of the switching transients and thus to avoid any unpleasant results from the action of stabilizing amplifiers in the case of the presence of such transients, they should be located at a recommended position on the back porch of the horizontal blanking signal. Since the first machines were put into the field, several changes have been made in the circuitry of the switching and processing units in order to minimize these effects as well as to make the adjustments less critical. By now the proper adjustment of these units poses no special problems.

Control System

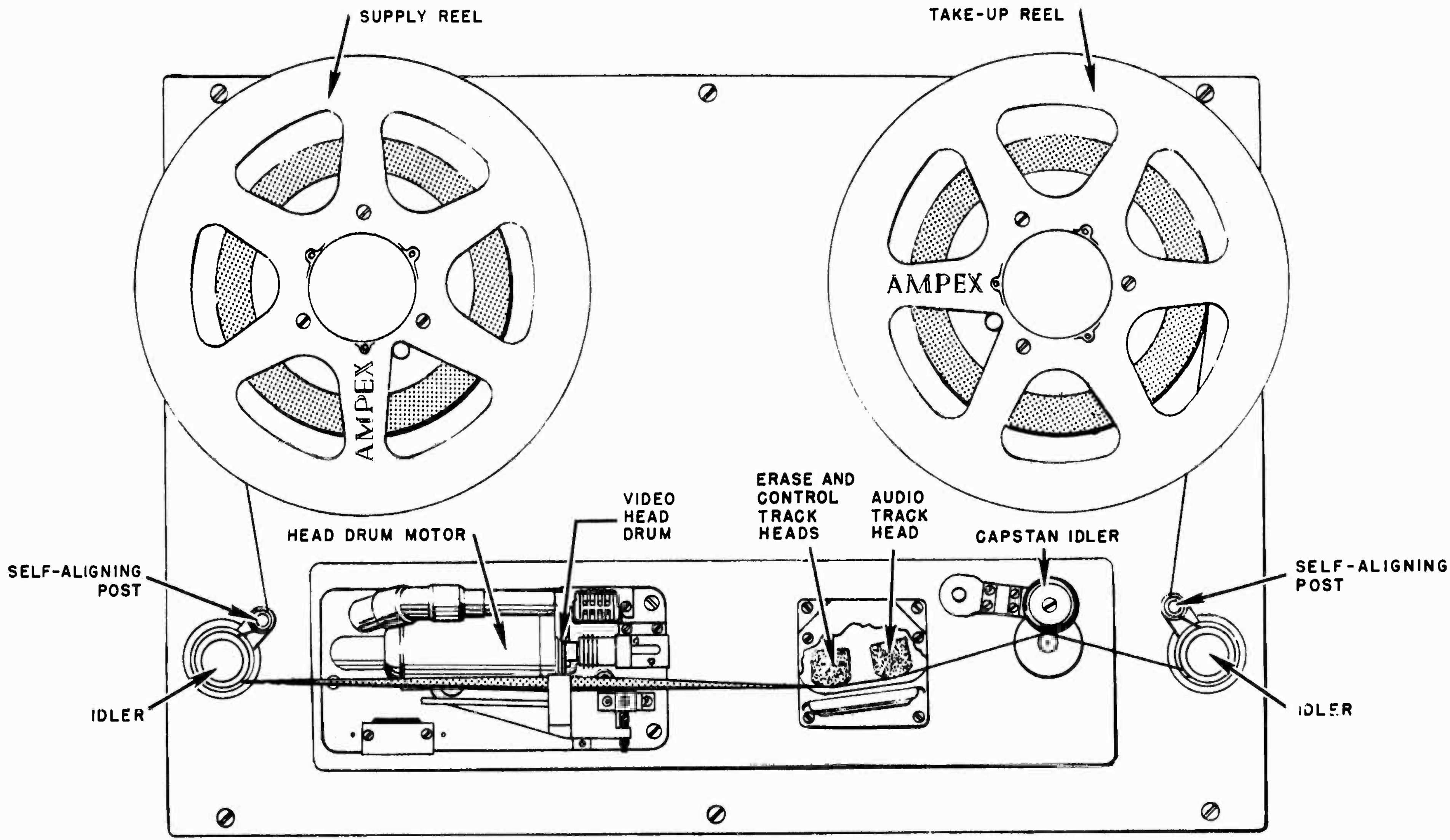
Slide 6 is a simplified block diagram of the control system. As mentioned previously, the photocell generates a 240 cycle square wave which corresponds to the rotation of the drum. This 240 cycle output is divided down to 60 cycles, which in the recording mode is applied to the input terminals of a power amplifier which drives the capstan motor. The 240 cycle photocell signal is also used as the input to the control track record amplifier, which drives the control track head during recording. This head thus writes a 240 cycle signal on the lower edge of the tape. During playback the control track head is switched to the input terminals of the control track playback amplifier whose output constitutes one of the two inputs to a phase comparator. The other input to the phase comparator is the 240 cycle photocell signal. The phase comparator generates an error signal which is a function of the phase difference between the two input signals. This error signal biases a reactance tube whose output circuit is one of the frequency controlling elements of a Wien bridge oscillator. The latter has a free-running frequency of about 60 cycles, which in the playback mode is applied to the input terminals of the power amplifier which drives the capstan motor. The polarity of application of the error signal to the reactance tube grid is such that a phase lag of the tape signal, with respect to the photocell signal, will cause the Wien bridge oscillator to advance in frequency or phase until the two input signals to the phase comparator are again in step. Conversely, any phase lead of the tape signal will cause the phase of the Wien bridge oscillator to be retarded. This action causes the capstan motor to speed up or slow down as required. Thus, the correspondence between drum rotation and longitudinal tape position which prevailed during recording is maintained during playback.

A single knob control is located on the operating panel of the console in order to make any vernier adjustments in tracking that might be necessary during playback. It has been found in the field that this control requires very little attention.

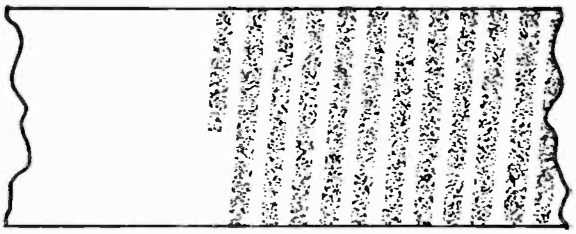
For several reasons it is desirable to run the drum during recording in synchronism with the composite video signal (or with the 60 cycle power line, in the case of a program originating locally). In addition, it is also sometimes desirable to run the drum motor during playback in synchronism with either the local sync generator, the power line, or a remote incoming video signal. The drum servo amplifier accomplishes these objectives and also acts very effectively to reduce a natural tendency toward torque angle oscillation of the drum motor. Before the introduction of the drum servo amplifier, some rather unpleasant manifestations of this hunting could be seen on certain types of receivers, and the effect has been most fittingly referred to as "raster wobble". Composite video or 60 cycle line is fed to the drum servo amplifier, whose 240 cycle output is applied to the input terminals of the power amplifier which drives the drum motor. Test points are liberally supplied at appropriate locations in the circuits of the control system. These units have been made sufficiently immune to drift problems so that routine maintenance checks on voltages and waveforms are sufficient to insure the degree of reliability required in daily operation.



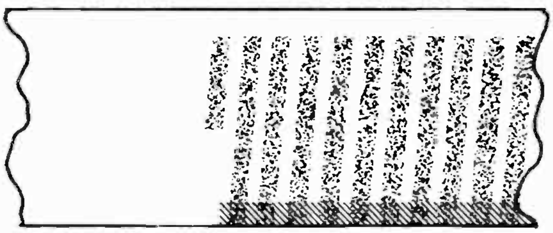
Cross - Sectional Diagram of Rotary
Heads & Vacuum Guide



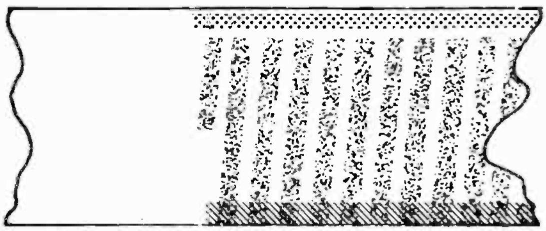
Layout of Video Tape Recorder Transport Mechanism.



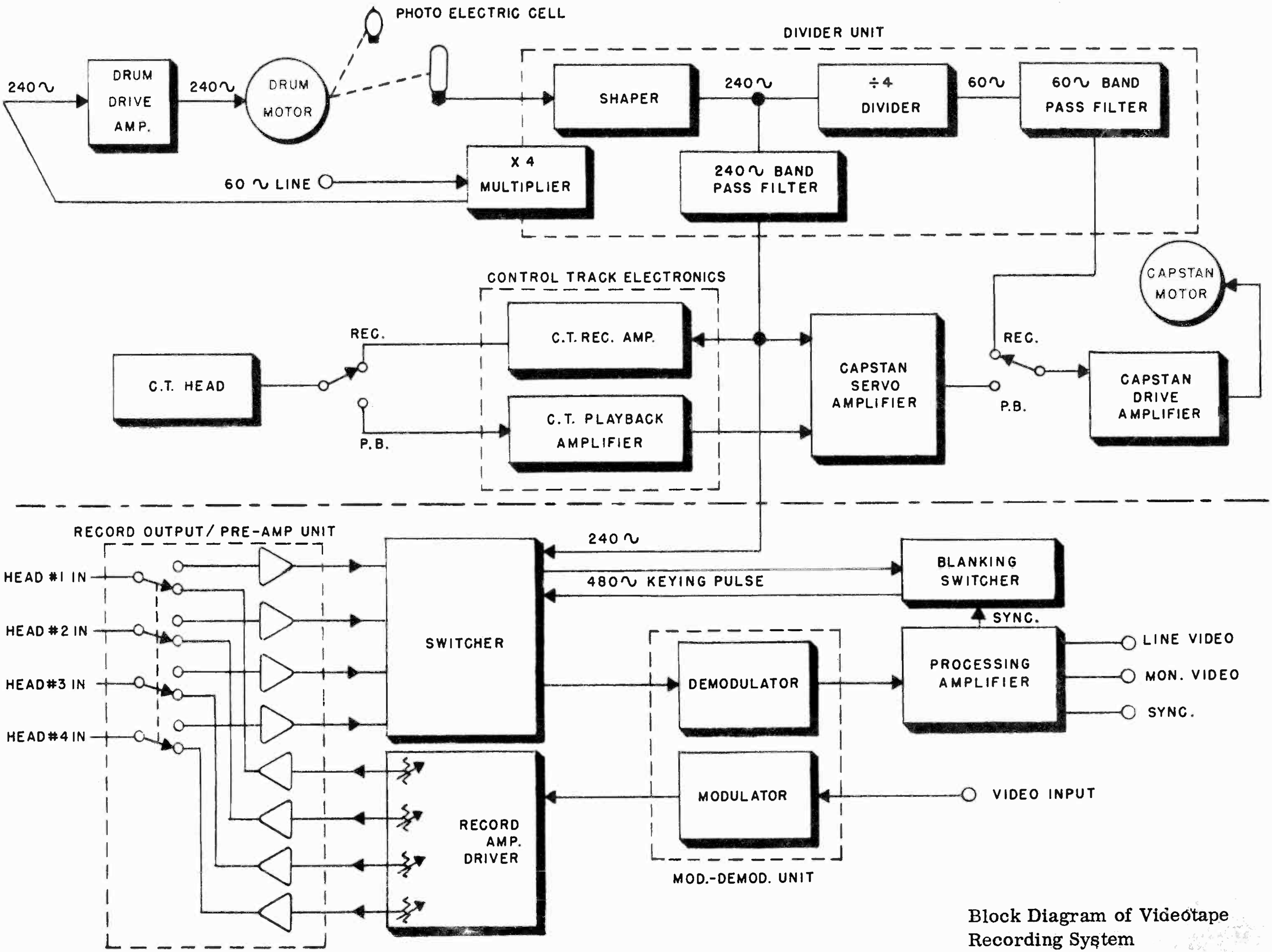
SIGNAL PATTERN AFTER PASSING VIDEO HEAD DRUM.



SIGNAL PATTERN AFTER PASSING PAIRED AUDIO ERASE AND CONTROL TRACK RECORD HEADS.



SIGNAL PATTERN AFTER PASSING AUDIO RECORD HEAD.



Block Diagram of Videotape Recording System

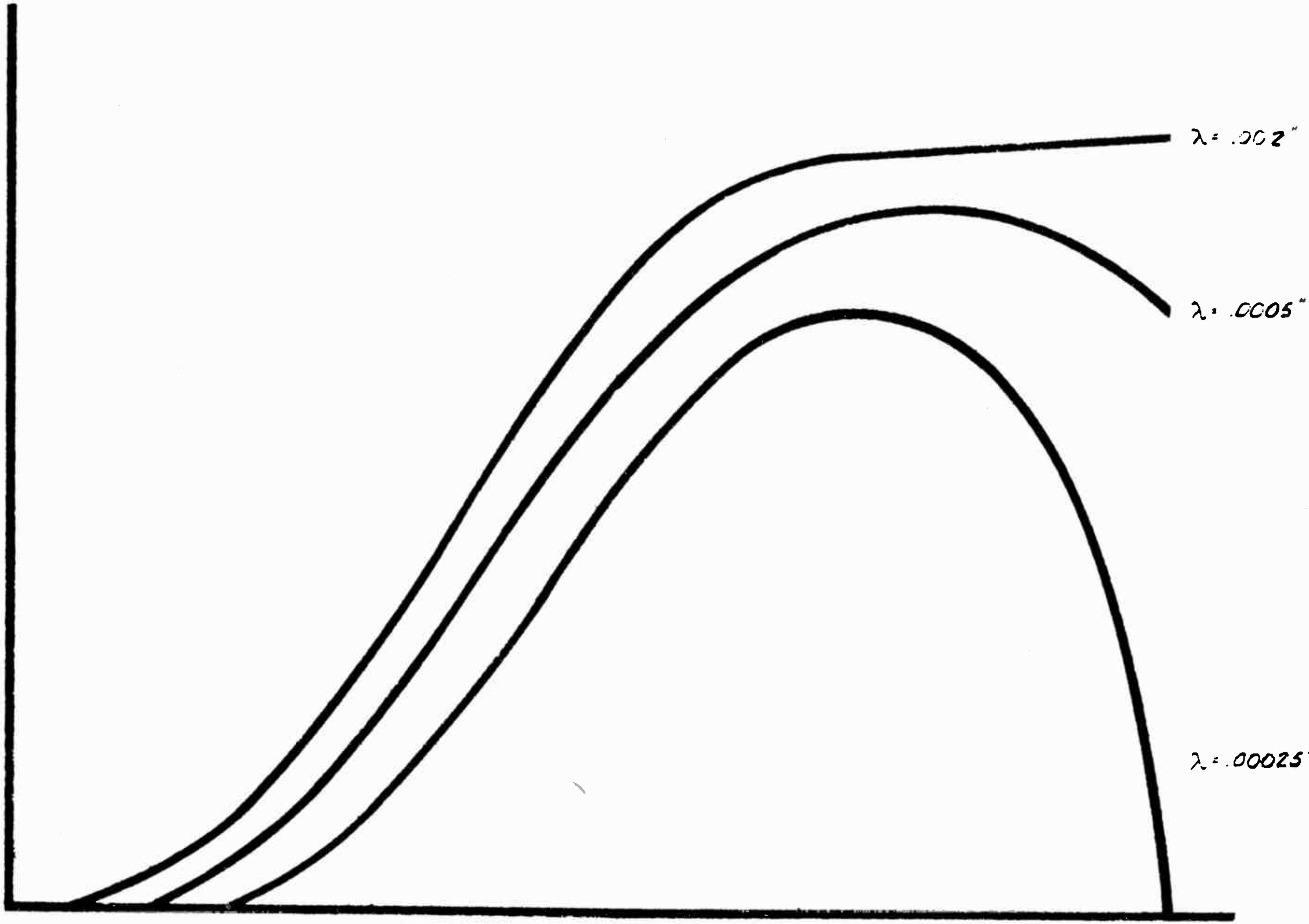
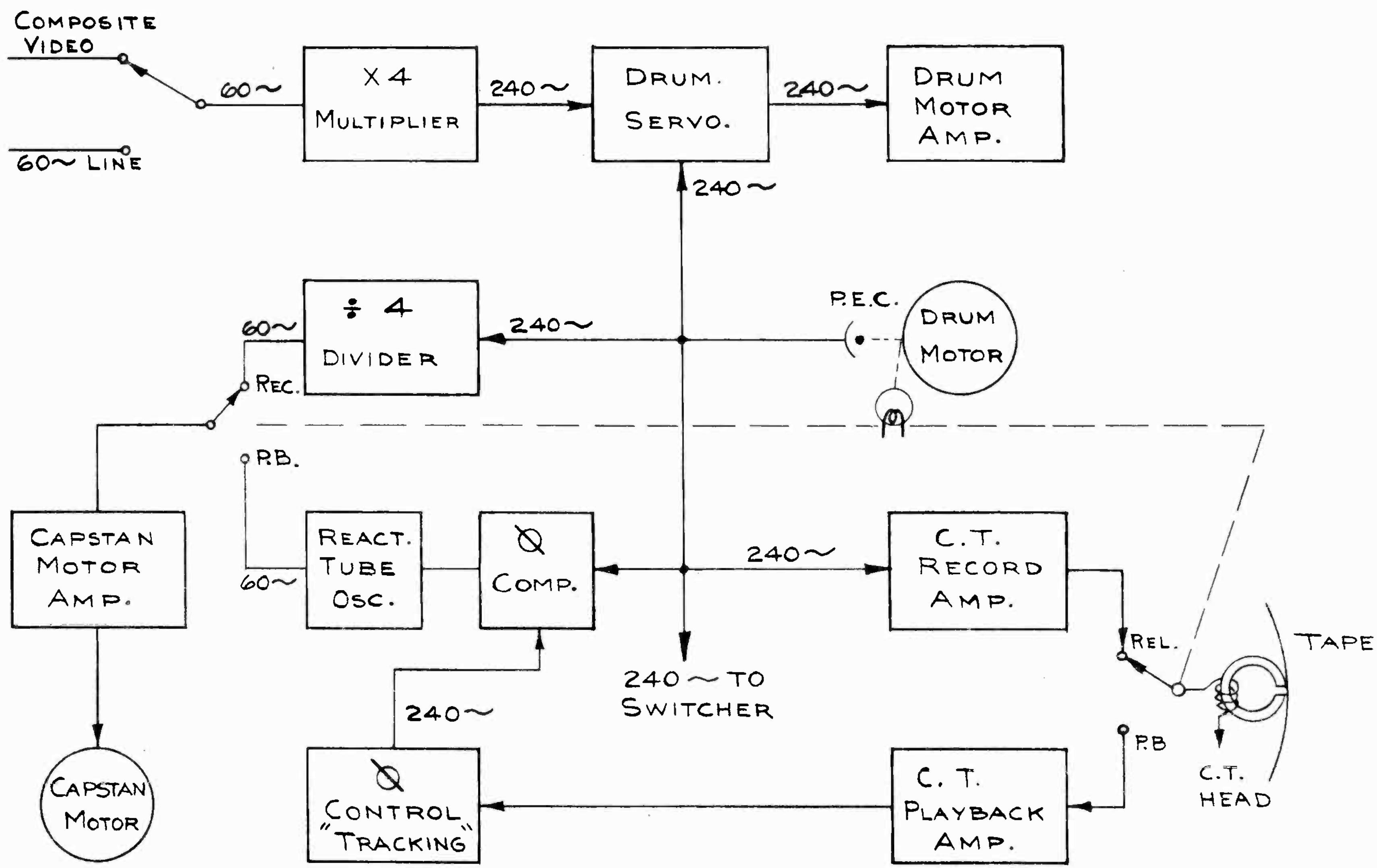


FIG. 5 FAMILY OF CURVES ILLUSTRATING SELF-DEMAGNETIZATION EFFECT.



CONTROL SYSTEM
— VIDEO RECORDER —

FIG. 6

8

Engineering Department Publications

CBS TELEVISION

Five Months Experience With Video Tape

by Howard A. Chinn

(Presented at 35th NARTB Convention, Chicago, Ill., April 8, 1957.) *E2116-A*

FIVE MONTHS EXPERIENCE WITH VIDEO TAPE

Howard A. Chinn

Last November, it was CBS' good fortune to be in a position to inaugurate the use of video tape recorders on a regular basis for the first time in the history of television broadcasting. In the intervening five months we have gained a fair amount of experience with video tape recording (VTR) and we are just as enthusiastic about the process as ever. In the following material we shall relate some of our experiences to-date in three general areas, namely, (a) in technical operations, (b) with the tape itself, as a recording medium and (c) with engineering design problems.

Video Recording Operations

The first broadcasting application of video tape recording was for time-zone delay. Specifically, it was (and is still being) used for delaying the daily 15-minute DOUG EDWARD'S NEWS program for two hours for the benefit of the CBS Pacific Network audience. After a week or so of trial runs early in November 1956, we finally took the plunge by recording the show in duplicate on video tape and backing this up with both 16mm and 35mm TV recordings. On playback, all four recordings were run synchronously - obviously, we were not taking any chances!

After several successful and uneventful weeks of this operation, we tackled a weekly 30-minute show, namely, GODFREY'S TALENT SCOUTS. Next we undertook a 45-minute program and then a one-hour program, in both cases, Ed Murrow's SEE IT NOW. Finally, we undertook a 90-minute program, in this case, CINDERELLA. Some of these shows were backed up with television film recordings (TVR) and to the credit of the Ampex VTR equipment, it is to be noted that on no occasion was it necessary to resort to a TVR backup. By now, of course, we no longer made TVR backups except in those instances where, for one reason or another, we have need for a film print.

While these air shows were being handled CBS also carried on a much more extensive daily recording and playback operation for personnel training and for equipment shakedown purposes. Complete programs were re-recorded and played back daily on a regularly scheduled basis. In playback however, the program material never got any further than a 75 ohm terminating resistor in the video jack field. Actually we made no effort to expand our broadcasting schedule because of our wish to first overcome certain technical problems which will be mentioned shortly. We were fortunate in having the full co-operation of our management in following this "slow-but-sure" procedure.

In due course, as you might expect, we were asked to record some programs that were to be delayed several weeks instead of for only two or three hours. Both GODFREY and BOB CROSBY programs were involved - the former because of Godfrey's absence from the country and the latter because of pre-emption of regular studio facilities at broadcasting time by a SHOWER OF STARS color program. This operation posed a small problem not present with time-zone delay operations.

It will be recalled that the prototype machines which we are using were not designed to permit the recording of a tape with one head assembly and playing it back with another. Thus, if between the time we made a recording and the time for its playback, the head were to wear out (or otherwise become unusable) all would be lost. The solution to the problem is simple, of course. You merely store the head assembly used to make the recording together with the tape itself and hope there are enough spare heads on hand to carry on your regular operations until the captive head assembly can be released. This problem will disappear, of course, when production machines become available, since free interchangeability of tapes among machines is promised by the manufacturer.

Currently, we are making preparations to handle a rather ambitious delayed-broadcasting schedule during the Daylight Saving Time months. Briefly, the plan contemplates the recording in TV City (Hollywood) of 40 network shows per week. All of these programs will be played back once and some of them twice. One playback entails a one hour delay and is for the benefit of midwestern stations on Central Standard Time. The other playback is with a two or three hour delay for stations in the Pacific Daylight Saving Time zone.

Our Daylight Saving Time schedule calls for 25 hours of recording and 30 hours of playback each week. Since we undertake all recording operations in duplicate, this amounts to a total of 110 hours of machine time per week. Since we have only five machines on hand, we have had to do some careful planning in order to handle this schedule with available facilities while maintaining full backup recording and a spare machine for emergencies.

Fig. 1 shows a portion of the current VTR installation in TV City. Three of the five available VTR machines are seen in the photograph together with their supporting rack-mounted equipments. Fig. 2 is a close-up view of one unit and shows the audio and intercom rack on the left, next, the rack which contains a waveform monitor, magnetic-head switching amplifiers, a modulator-demodulator chassis, a processing amplifier, and associated power supplies. The right hand rack contains a picture monitor, incoming video line and monitor switching circuits, frequency divider, drum motor oscillator, servo systems for capstan and drum motors, and their associated power amplifiers. In the background are three racks containing the audio and video terminal equipment for the entire setup.

The appearance of some of the queer effects that can be obtained with improperly operating VTR equipment may also be of interest. Fig. 3 shows the effect obtained when one of the four heads (or its associated amplifier channel) becomes defective. Since 16 television lines are recorded (or reproduced) for each sweep of a head across the tape and since the scanning lines are interlaced, a total of 32 lines as shown, are effected when a head goes bad.

When the timing of the head switcher is incorrect, an effect such as shown in Fig. 4 is obtained. Here the switching between heads is not taking place during horizontal blanking and the switching transient may be seen on the left side of the picture.

If the pressure with which the heads ride against the tape is not properly adjusted, an effect such as shown in Fig. 5 is obtained.

Finally, when an attempt is made to play back a recording with a head other than the one with which it was made, an effect such as shown in Fig. 6 may be obtained. In this, as in the preceeding examples, the discontinuities occur as 32-line intervals.

Before leaving the subject of video tape technical operations, special mention should be made of one of the many conveniences that VTR (or tape) affords over TVR (or film). If, upon reviewing a regular and backup video recording, it is found that one copy is unsatisfactory, a new backup can be obtained by re-recording from the one good copy. Thus, assuming time permits, both a regular and a backup recording can be for simultaneous playback by air time even though one of the original recordings may be defective. This procedure is no novelty to those accustomed to handling magnetic sound recordings, but it is a feature not normally available when handling delayed programs with "hot" TVR's because of the time element and potential degradation involved.

Video Recording Tape

As of the moment, the establishment of sources of supply for video tape has been a bit of a problem - to put it mildly. Since, from time to time, we have had several superior samples of tape, we naturally expect every square inch of all tape to be just as good as the best. It is a pleasure to be able to report that the tape manufacturers are sympathetic to this slightly radical viewpoint and have been coating tapes at all hours of the day and night in an effort to reproduce, on a production basis, the very best samples they ever turned out experimentally.

The three attributes of video tape which are of prime interest are (a) the output signal level, (b) the absence of dropouts and (c) the wearing properties. These subjects will be discussed in turn.

The need for adequate output signal level from the tape is obvious - it is required in order to obtain a satisfactory signal-to-noise ratio. At the same time, the amount of drive necessary to modulate the tape fully must be kept within reason. Finally, the "bandwidth" of the tape determines the maximum frequency deviation that can be employed for the FM modulation system that is used in the Ampex VTR equipment. As is usually the case, in the final analysis one must chose between signal-to-noise ratio and bandwidth or resolution. Peak signal-to-rms-noise ratios of 38 db with 320-line (4 Mc) resolution seems to be in the cards and there is every reason to expect improvement in this respect as time goes on.

Dropouts, or rather the elimination thereof, has been a very plagueing problem for the tape manufacturers. As you know, dropouts are generally caused by pin holes, impurities, scratches or scuff marks in the magnetic coating. One of the most frequently asked questions is "What do dropouts look like in a TV picture?" When they are less than one line in duration, they simply look like ignition noise as shown in Fig. 7. Although the dropouts illustrated were actually considerably less than a full line in duration, they are exaggerated in the vertical direction because of "blooming" of the picture tube and in the horizontal direction because of transients (which are discussed later).

The appearance of two kinds of dropouts on the surface of a tape is shown in Fig. 8. This illustration is a photomicrograph of a small portion of a video tape recording. The distance between centers of the video-modulated magnetic tracks shown is roughly 1/64 of an inch. Thus the area of tape shown in this illustration is about 5/8 by 11/16 inches. Since the full width of the tape is 2 inches and 16 television lines are recorded on each of the tracks, a full television line is recorded in 1/8" of track length. Thus in the 11/16 inches of track length shown, there are recorded about 5-1/2 television lines. The video modulation is visible along each track.

The 240 cycle control track pulses that are recorded longitudinally on the tape are shown at the left of the illustration. Here, the effects of the individual laminations in the recording head is clearly visible.

Scuff marks on the surface of the tape, which can cause dropouts are seen in the left portion of the illustration. A scratch, is seen in the right portion of the photograph.

In Fig. 9, which is at a still larger magnification, the video modulation may be seen somewhat more clearly. In this instance, the area of tape shown is about 1/8 by 3/16 inches. Most of the surface irregularities visible are merely loose dirt on the tape at the time the photomicrographs were made and is of little consequence. A minute scratch which can create a dropout may be seen, however, on the upper right side. Incidentally, we are indebted to Reeves Soundcraft for these last two illustrations.

We shall leave it to the tape manufacturers to tell, someday, the steps they had to take to meet video tape requirements. Meanwhile, it is obvious that they have had to undertake extreme steps in creating a practically sterile working atmosphere, to exert rigorous control every step of the way and to handle the tape with something a good deal better than kid gloves.

The third important characteristic of video tape is its wearing qualities. The tape for an hour's recording costs about $200. If the tape is good for 100 recordings and 100 playbacks (or a total of 200 passes through the machine) the cost per hour is only $2.00, (assuming one playback per recording). On the other hand, if the tape is only good for 10 recordings and 10 playbacks, then the hourly cost jumps to $20 per hour. We have had tapes whose life ranged between these extremes. Naturally, we hope that eventually the life of all tape will exceed the best we've had to-date !

The life of the experimental tapes that have been made available to us have been a function of three basic characteristics of the tape - only one of which is usually controlling in a given roll of tape. Some tapes fail because of a soft coating that clogs the magnetic heads. Other tapes fail because of excessive scuffing of the tape. Finally, some tapes seem to have a coating that is so brittle that the recording heads chip off particles from the surface. We are confident, however, that by the time production video recorders are available that the tape manufacturers will have ample supplies of satisfactory video tape.

Engineering Design Problems

In common with just about every new piece of video equipment we have ever acquired, the video tape recorders required considerable de-bugging. Among the problems encountered, all of which now seem to be under control, were (a) the question of head life, (b) a phenomena we call head-hunting, (c) head de-magnetization circuits, (d) the elimination of transients, and (e) the minimizing of dropouts in the reproduced picture.

The question of head life is an exceedingly important one since it can have a great influence upon the operating costs. For example, if a head lasts 150 hours and the cost of overhauling it comes to $300, then its contribution to the overall operating cost amounts to $2 per hour. But one hour of recording together with its playback amounts to 2 hours of head life, or a total of $4. This is more than the tape cost which, on a 100-recording and 100-playback basis, comes to $2 per hour. At the moment, we are not in a position to forecast the probable life of the recording heads because, among other things, it will depend upon the nature of the surface of the magnetic tape that is finally adopted for video recording use. However, a 200 hour life does not seem to unrealistic.

Next, the head-hunting problem. Everyone is familiar with the detrimental effects of turntable, sound-picture projector and magnetic sound reproducer wows. Since the magnetic head assembly in the Ampex VTR machines is a rotating device, it, too, is subject to wows or, what we have come to call, "head-hunting." The result of hunting of the head assembly is a lateral shifting back and forth of the reproduced picture which, in motion picture parlance, is called "weave." Depending upon the nature of the horizontal sync circuits in the receiver or picture monitor, the weave resulting from a given amount of head-hunting may or may not be severe. Obviously in any commercial television application, one must anticipate the most unfavorable situation and correct for it. It was the head-hunting problem in the original machines that caused us to limit their application to broadcasting service as mentioned earlier. A servo amplifier with a high degree of feedback has now been made available by Ampex and head hunting among the natives is now practically non-existant.

For some reason that I have never been able to understand, nearly everyone concerned with television broadcasting (including engineers, operating personnel and program directors) become so captivated with the picture that they often completely ignore the sound. Early in the game this led us (and others) into a neat trap. In the Ampex VTR machine the video information is recorded transversely or across the width of the tape while the sound track is located longitudinally along one edge. Thus, on playback, the video reproducing heads cut across the sound track at a 960 cps rate. If the video heads take on sufficient permanent magnetization, they can record a 960 cps buzz on top of the audio track. Because of a temporary failure of the automatic head de-magnetization circuits, we managed to so modulate the sound track of a recording by the simple process of not listening to the audio when reviewing the picture. The moral is plain - even video recording engineers cannot afford to ignore the audio portion of a program.

The existence of circuits that tend to create transients by ringing are probably more obnoxious in video tape recorders than elsewhere in a television system. This is because of their tendency to exaggerate dropouts as illustrated in Fig. 7. Here, instead of a dropout appearing as a short white streak, it oscillates back and forth alternately making white and black streaks. To minimize this pheromenon, we have redesigned the modulator-demodulator chassis originally supplied with the machine to reduce transients. The redesigned chassis has also resulted in better picture quality.

Other modifications that we have found beneficial include (a) the development of a dropout minimizer circuit (dropouts now appear gray rather than white), (b) rearrangement of the top deck of the machine to permit the use of 1-1/2 hour reels rather than the 1 hour ones originally planned, (c) the installation of improved cascode preamplifiers to provide a better noise figure, (d) modification of the recording amplifier output stage to permit higher modulation amplitude, and similar improvements.

Summary

To summarize, almost every week new specific applications for video tape are suggested and when more machines become available, we anticipate very widespread use of video tape recording. Its impact upon the television broadcasting industry will be just as great as was the introduction of sound magnetic tape on radio broadcasting - if one can remember back to the time when there was no audio tape recording.

The VTR installation made by CBS in Television City has been in regular daily service for over five months and we have yet to experience a program failure even though we are using prototype machines. Credit for this excellent record goes (a) to the Ampex engineers, under Charles Ginsberg who, I am sure, have aged considerably during the past year, (b) to our operating personnel at TV City under Les Bowman, and (c) to Blair Benson, Price Fish and Will Whalley of the CBS-Television Engineering staff in New York.

Fig. 1. Video tape recording installation at TV City.

Fig. 2. Close up of one video tape recording equipment group.

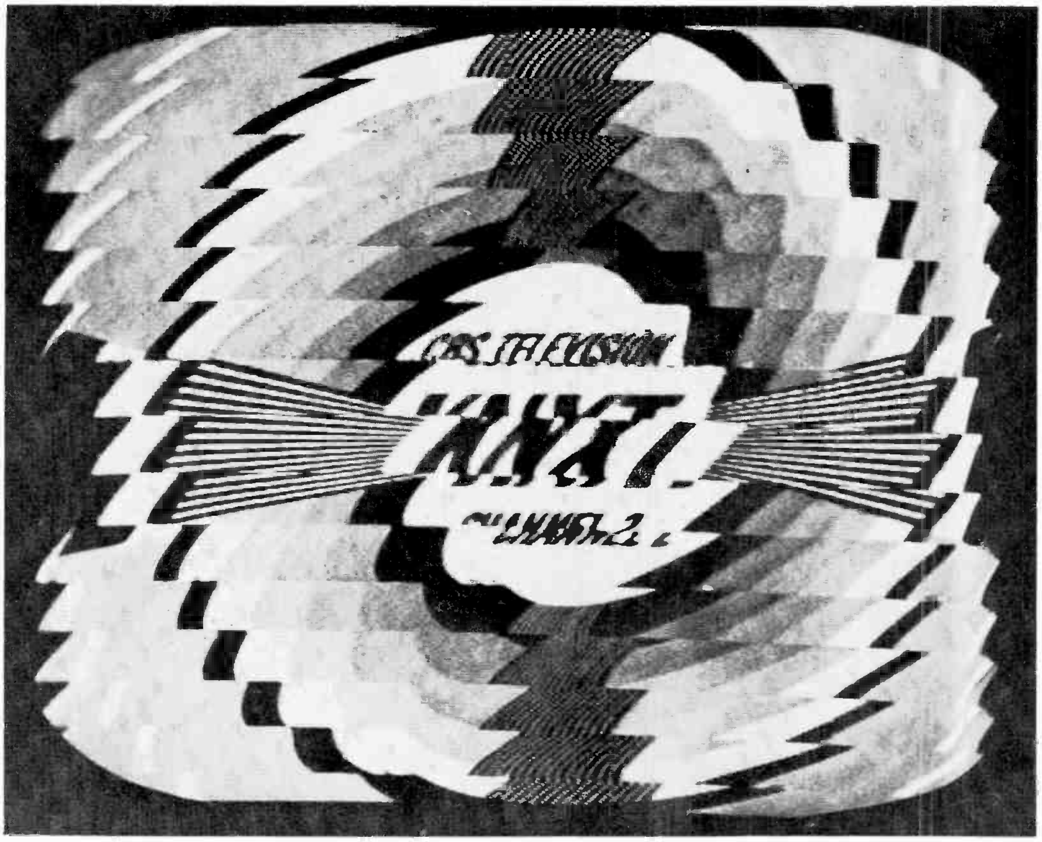


Fig. 5. Picture degradation caused by improper head-to-tape pressure.

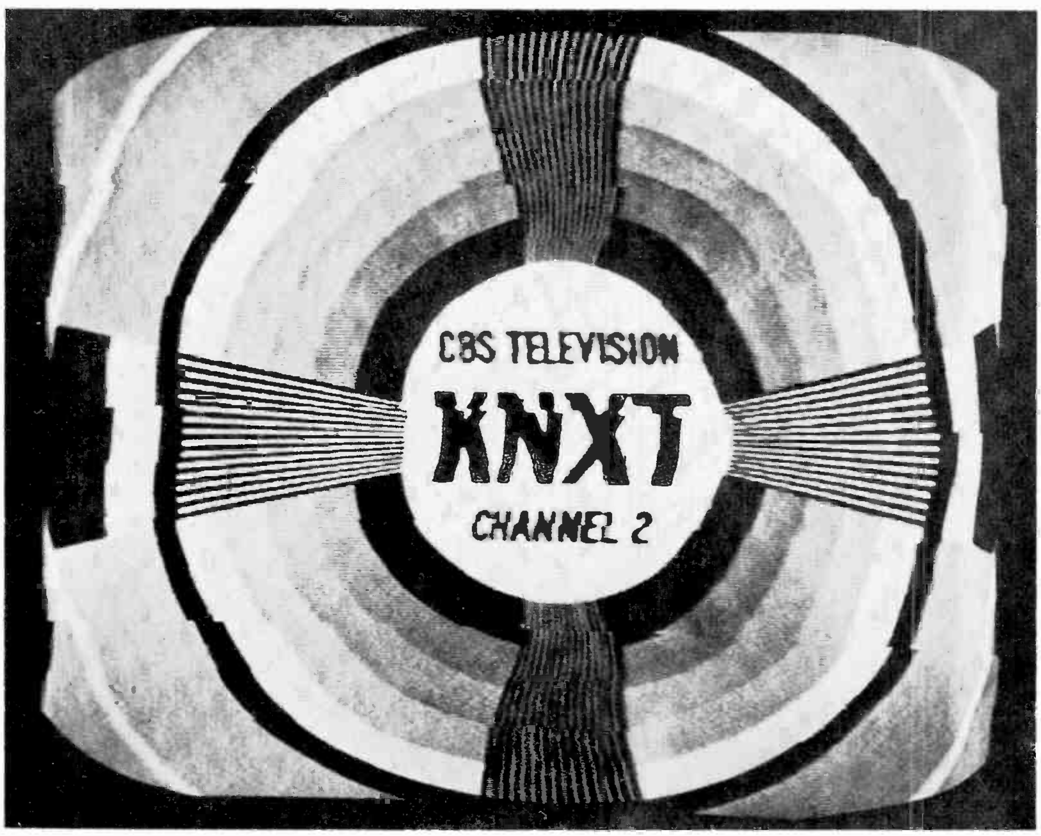


Fig. 6. Picture degradation caused by playing tape back on different head than used for recording.

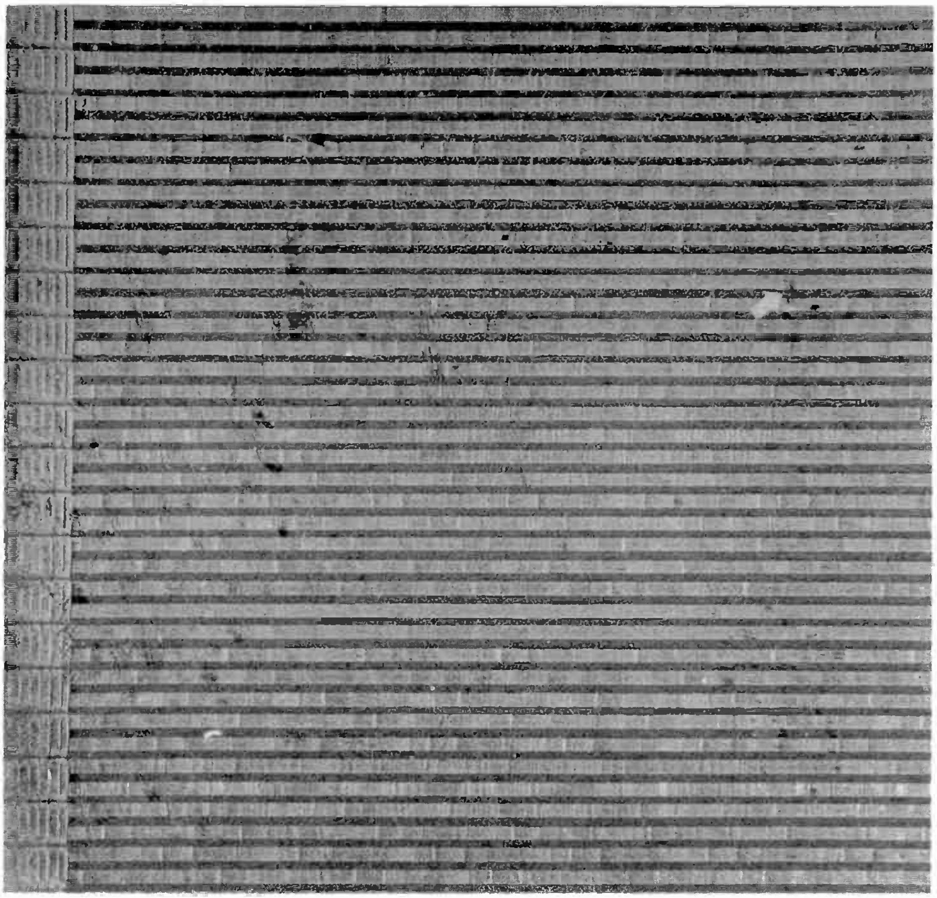


Fig. 8. Photomicrograph of a 5/8 x 11/16 inch area of video tape showing video and control tracks. (Courtesy of Reeves Soundcraft)

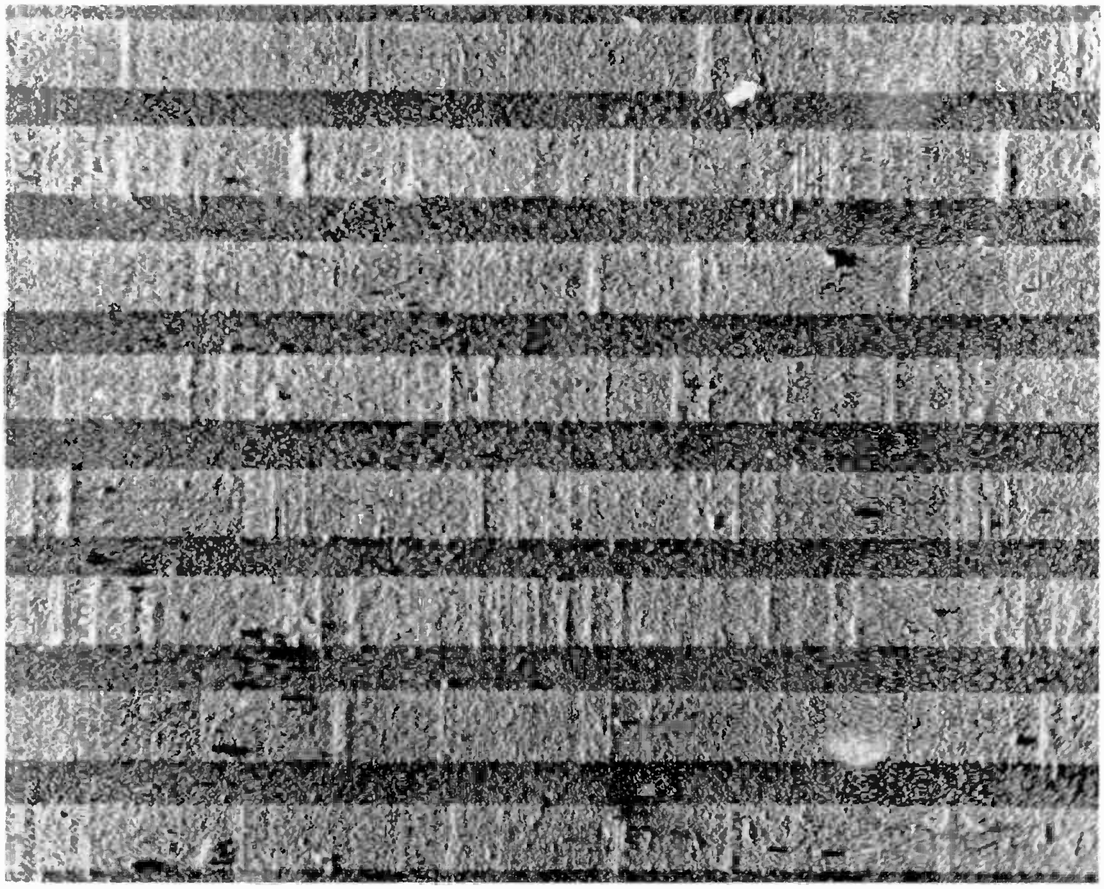


Fig. 9. Photomicrograph of a 1/8 x 3/16 inch area of video tape showing video modulation. (Courtesy of Reeves Soundcraft)

CONTROL OF COLOR APPEARANCES

IN T.V. STUDIO LIGHTING

By

ROLLO GILLESPIE WILLIAMS
Manager, Color Lighting Department

Before considering developments in the use of studio lighting to control T.V. color appearances, it may be helpful to briefly review the layout and types of equipment in general use.

So far the lighting layouts for Color T.V. Studios have mainly followed the same pattern as for Black and White studios except that lighting intensities are much higher. Normally color requires 350-400 foot candles of base lighting with accent lighting intensities ranging up to 800 foot candles. These higher intensities have required greater use of 12" 2000 watt, and 16" 5000 watt Fresnel Spotlights and sometimes 1000/3000 watt Ellipsoidal Reflector Spotlights.

CONNECTOR STRIP LAYOUTS

Overhead connector strips with pigtails continue to provide the most popular method of connection for the lighting units. These strips are usually spaced about 5 feet apart with pigtails at 2 - 3 foot centers. This follows much the same pattern as Black and White except that many of the circuits are 50 amp rather than the 20 amp. The proportion of 20 amp to 50 amp circuits varies but is often in the ratio of 5:1. It is normal for each 20 or 50 amp pigtail to be wired on a separate circuit. A typical connector strip layout for a 40' x

60' T.V. color studio is shown in FIG. 1. It will be noticed that in addition to overhead strips, there are also some 20 amp and 50 amp wall receptacles. However, there are new developments in studio lighting equipment involving color change lighting that require multi-circuit connections and the extensive use of this type of apparatus will require positioning of a suitable number of multi-circuit receptacles.

INCREASED LOADS FOR COLOR

Where color T.V. studio lighting is based on the use of white lighting from incandescent filament lamps, the lighting equipment mainly comprises scoops and Fresnel spots. With a representative Black and White equipment setup, 6" and 8" Fresnel spotlights might approximately equal the number of Scoops and together represent 90% of the lighting units. The remaining 10% might include a few 12" 2000 watt Fresnel Spots plus some Striplights and 750 W Ellipsoidal Reflector Spotlights. With Color T.V. Studio lighting the proportion of Fresnel Spots might be the same but the majority would be 12" 2000 watt and 16" 5000 watt. Ellipsoidal Reflector Spotlights where used would normally be of a larger size.

A comparision of the size of lighting units for a typical layout on a variety set of 1000 square feet is shown in FIG. 2. It will be seen in this case that the use of the larger units for Color only involves about twice the watts shown for Black and White. FIG. 3 shows a similar comparison for a dramatic set of 450 square feet. Here again the wattage for Color is shown as approximately double that of Black and White.

However these two setups do not include the lighting of cyclorama backgrounds and other scenic arrangements and the total wattage for Color is likely to be higher. It is usual to plan for a total load of 75 watts per square foot for Color Studio area compared with 25 watts per square foot for Black and White. (Color figures may range from 60 - 90 watts per foot.)

SPECTRAL QUALITY

The color temperature of incandescent filament lamps has remained much the same except when colored light sources are employed for special effect or background purposes.

Fluorescent lamps are not usually favored as sources of white light for Color T.V. work because the spectral quality of their light is different from that of incandescent filament lamps and there are unavoidable differences of color rendition from the two types of sources. However, fluorescent lamps can be used for certain forms of color lighting as will be discussed later in this paper.

Perhaps the most important advances in Color T.V. Studio lighting concern the use of colored instead of white light. Before discussing its applications, available color lighting equipment will be briefly reviewed.

COLOR FILTERS

Colored light can be obtained by the use of filters, colored light sources or by blending of lights in an additive color system. Also by other means such as Electroluminescence which it is not necessary to discuss in this paper.

Color filters provide an inexpensive and convenient form of providing colored light from incandescent filament lamp units. However, with the size and type of lamps normally used in color T.V. Studios, the life of gelatine filters is short. Cellulose acetate filters such as Cinemoid provide longer life and there is a wide choice of colors. If permanent filters are required it is necessary to employ glass. Unfortunately the range of colors available in glass is very limited and it is often difficult to find anything close to a desired color or tint.

ADDITIVE LIGHTING SYSTEMS

However glass filters are available which enable 3-color additive systems to be used when the lighting distribution from this type of equipment is suitable. Additive systems usually employ three primary colors, RED, GREEN AND BLUE, either with or without a fourth circuit of white (or sometimes YELLOW). For color blending purposes it is not always necessary to use red, green and blue and when high intensity tints rather than deep colors are required, the use of YELLOW, PEACOCK-BLUE, and MAGENTA as basic colors is often better. Such an additive system however will not produce separate red, green and blue hues and the deepest degree of saturation will be that of the single basic colors.

Colors produced by blending in an additive system usually require a greater wattage than a single light with filter. However the advantages of a wider range of color plus facilities to adjust to exactly the required hue and saturation frequently outweigh the higher load.

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COLORED LIGHT SOURCES

Colored light sources can be used instead of filters in certain types of strip-light, but until now the color range has been very limited and often the distribution characteristics of the lamp differ from those of the equivalent white lamp and there is lack of accurate color consistency. However new developments are pending in this field and there is reason to hope that soon a wide range of incandescent filament lamps will be available in hundreds of consistent colors without any appreciable distortion of normal lighting distribution. It is doubtful however if this type of development will apply to spotlight bulbs -- at least in the foreseeable future.

Colored fluorescent lamps have a very high lumen output in certain colors and can be usefully employed under certain conditions for the lighting of background or scenic surfaces. Green is the most efficient fluorescent lamp color, and gives approximately three times the light output of the blue, pink and gold lamps. The output of red light however is poor and represents about 5% of the green output. Hot cathode fluorescent lamps of the 40 watt 48" Rapid Start type can now be dimmed to low brightness values by suitable control systems. Two of the systems in use will reduce the light to 1/80 and 1/500 of full intensity respectively.

MULTI-COLOR LIGHTING UNITS

A wide choice of striplights is available arranged for either single or multi-color lighting. Batteries of multi-color floodlighting equipment can be created

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by mounting a number of Strips side by side on a common framework. Alternatively a number of individual lighting units can be grouped and arranged for multi-circuit lighting. It is necessary to have overlapping illumination from at least two units per color if sharp "cast" color shadows are to be avoided. The resultant illumination from a number of lighting units is more easily adapted to floodlighting than to narrow angle directional lighting. However the latter can be arranged by the proper choice of units providing there is space to accommodate the equipment.

A single directional four-color 9000 watt (maximum) unit was recently developed that combines several light sources per color in a unit 30" square by 36" deep. This unit gives up to 250 foot candles ≠ 10% depending on the selected blend of color -- over an area approximately 9 feet in diameter at a distance of 15 feet.

APPLICATIONS OF COLORED LIGHT

Colored light may be used in Color T.V. Studio lighting in numerous ways, as for example:

a) to provide Color on White or Gray areas.
b) to delineate form by modeling in different colors of light from different directions.
c) to accentuate certain colors or to help harmonize a group of colors.
d) to create mood values.
e) to create dramatic and pictorial effects.
f) to reproduce effects of nature.

When color is provided by the use of colored light instead of pigments important advantages become available which revolutionize the possibilities of color. For example the color can be changed in HUE, SATURATION (chroma) and BRIGHT-

NESS (value) in front of the camera and a new dimension of VARIABLITY is provided. Color then ceases to be static and becomes as mobile as music -- allowing a flow of color compositions that express both harmony and rhythm. Another important feature of colored light is its LUMINOSITY which imparts a new quality to Color and greatly expands the opportunities for its use.

CONTROLLING COLOR SHIFTS

However apart from artistic possibilities a new use is being made of colored light which will have far reaching effects on color rendition techniques. It is known that undesirable color shifts in the appearance of objects can be remedied by viewing them in front of properly selected color backgrounds so that the factor of "Simultaneous Contrast" is utilized to bring about the desired color appearance. It is often a lengthy process to find the desired color relationship by changes of colored papers or paints, and the final setup is, of course, static.

Simultaneous contrast effects can be much more easily obtained by the use of colored light as the background, since the hue, saturation or brightness of the colored light can be varied to a much greater degree than with pigments. Furtheremore high brightness values can be obtained without losing a desired degree of saturation. Color changes and adjustments can be produced immediately by using an additive color lighting system in conjunction with suitable controls. These color background effects can be provided either by projecting colored light onto a suitable surface or by transmitting light through the background so that it glows with color.

NEW COLOR VALUE WALL

A recent development is a COLOR VALUE WALL which provides a luminous area of diffused color that is variable at will. The equipment takes the form of a wall with a depth of 12" having one side made of special seamless translucent material. The translucent seamless surface can be any size up to 75 feet by 35 feet. The COLOR WALL can be free standing or mounted against a surface. A four-color lighting system is contained within the 12" depth and provides surface brightness of color up to 275 foot lamberts. The lighting load is very moderate, and working loads normally vary between 15 and 63 watts per square foot. Thus for a luminous surface 12'6" wide and 8 feet high, the working loads would normally range between 1500 and 6300 watts.

COLOR RELATIONSHIPS

It is sometimes believed that scientific and artistic factors concern different fields of interest, and the subject of color is not exempt from this belief. However, the relationships of different colors of light in T.V. Color work are governed by rules that are both scientifically artistic and artistically scientific. The writer is aware of no rule of harmonious and discordant color relationship that cannot be explained on a scientific basis.

Thus FIG. 4 illustrates a color circle based on scientific factors concerning the blending of red, green, and blue primary colors of light.

Complementary colors will be found at opposite ends of a straight line through the centre. There is sometimes a misunderstanding concerning the exact meaning of the word "complementary" when applied to color. Complementary colors are not "harmonizing" colors in the normal sense of the word but are exact opposites. In an additive system they represent two colors that together will make a blend of white light. Complementary colors are always very striking but are not necessarily a pair of harmonizing colors.

In the color circle under consideration a pair of harmonizing colors would be found by making the color nearest to yellow lighter than the one nearest to violet. Thus orange and turquoise would harmonize if the former were a pale orange and the truquoise a deep color. Conversely a deep orange and pale turquoise would represent a discord.

COLOR LIGHTING CONTROL SYSTEMS

The use of color lighting as discussed above necessitates dimmer control equipment of a type that not only provides flexible color mixing facilities but also makes complex color changing relationships possible.

Many Color T.V. Studios are provided with excellent Electronic preset control systems, as for example the installation shown in FIG. 5

A recent development in control systems that utilize either Thyratron tube or magnetic amplifier type dimmer units is known as C-lectrochrome System. This employs a principle of harmonized color contrasts, whereby different sets of four-color lighting equipment may be instantly caused to provide either a selected color blend or various contrasting colors that harmonize with this selection. The operator does not have to calculate these harmonizing colors but simply presses the load switch for a four-color set of lighting in the reverse direction to obtain contrast rather than a selected color. Thus if there are five sets of four-color lighting equipment illuminating an acting area from five different directions, one can set up a mixture corresponding say to Pale Pink and by pushing a single 3-way load switch for each set of lighting upwards, obtain that color, or by depressing the switch obtain a harmonizing color. Each of these five switches could provide a different color to the others.

FIG. 6 illustrates a C'lectrochrome control panel for a four-color installation involving 15 sets of four-color lighting equipment with a total load of 100 KW. In addition to the color contrast facilities described below, it will be seen that this is a five scene preset installation, with separate facilities for presetting both the contrast switches and the color mixing controls. The latter include five adjustors for each set, i.e. one each for intensity adjustments of red, green and blue primary color circuits, one for the degree of saturation and one for the overall brightness of each mixture.

FIG. 7 shows the bank of magnetic amplifier control apparatus operated from the control panel.

This paper was presented on April 8, 1957 at the 11th Annual NARTB Engineering Conference at the NARTB Convention at Chicago, Illinois by Rollo Gillespie Williams, Century Lighting Inc.

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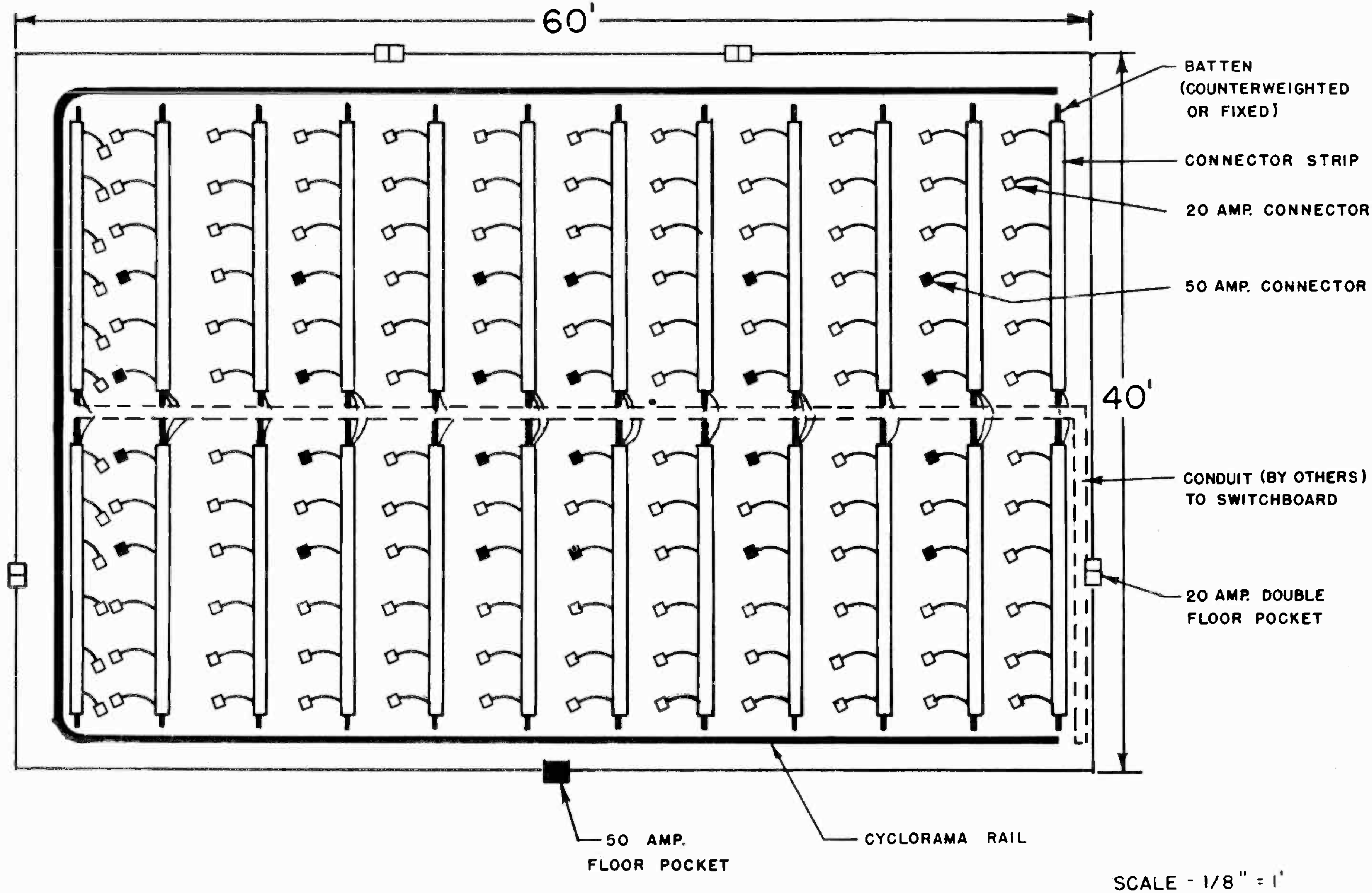

FIG. 1 Typical connector strip layout for a 40' x 60' T.V. Color Studio.

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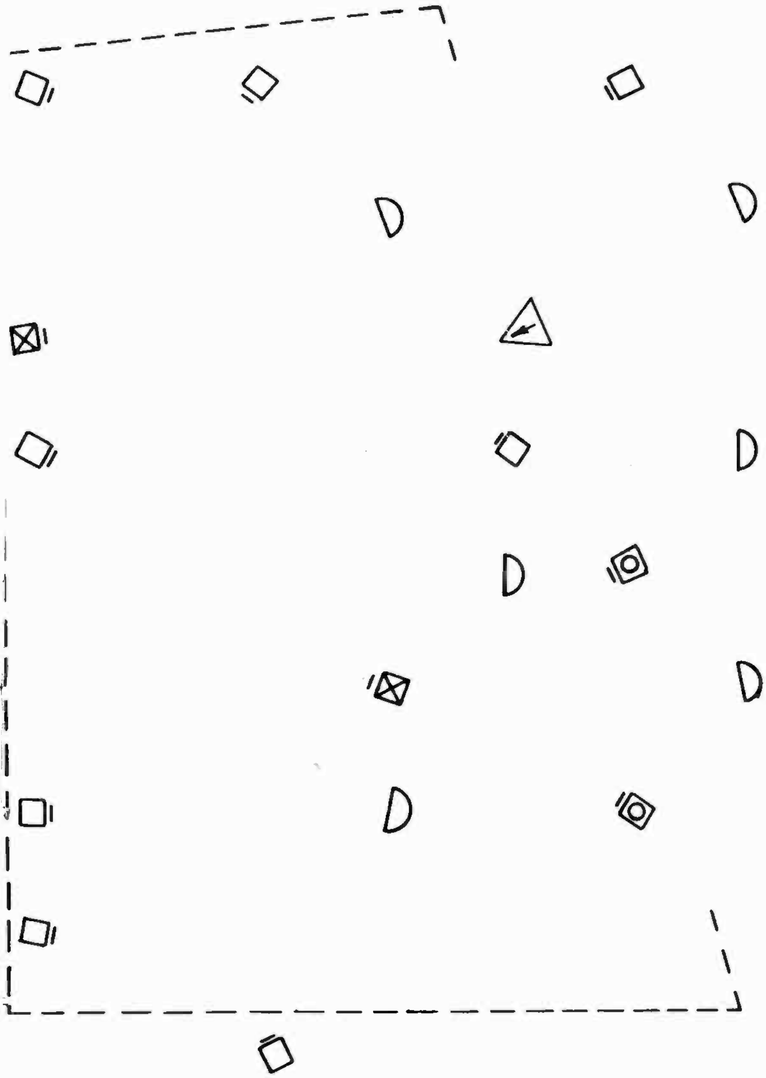
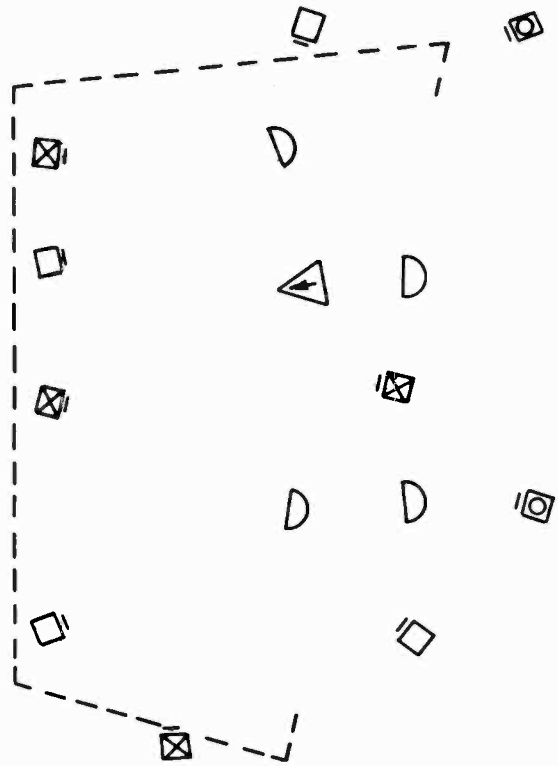
SYMBOL	COLOR PLAN	BLACK & WHITE PLAN
	NO. 526 8" 1000-1500 W FRESNEL	NO. 520 6" 250-750 W FRESNEL
	NO. 572 12" 1000-2000 W FRESNEL	NO. 526 8" 1000-1500 W FRESNEL
	NO. 576 16" 5000 W FRESNEL	NO. 572 12" 1000-2000 W FRESNEL
	NO. 1315 16" 750-1500 W SCOOP	NO. 1315
	NO. 1568 8" 1000-2000 W LEKO	NO. 1581 TV 4 1/2" 250-750 W LEKO



(VARIETY)

SCALE - 1/8" = 1'



(DRAMATIC)

SCALE - 1/8" = 1'

FIG. 2 A lighting equipment layout for a 1000 Sq. ft. variety set, showing comparison between lamp sizes for COLOR and BLACK and WHITE.

FIG. 3 A lighting equipment layout for a 450 Sq. ft. dramatic set, showing comparison between lamp sizes for COLOR and BLACK and WHITE.

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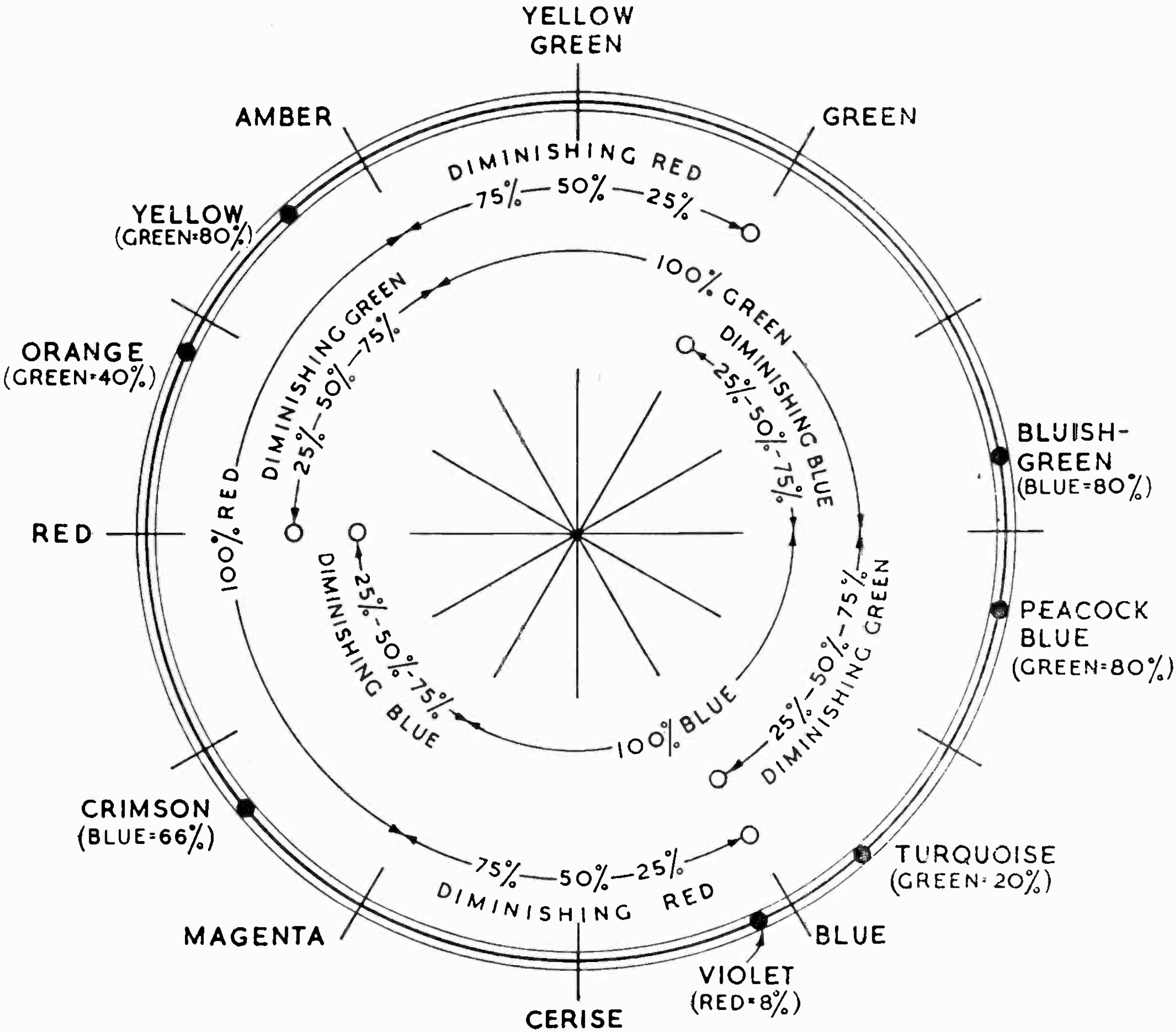

FIG. 4 Color circle showing range of lighting hues produced from red, green, and blue primary colors of light.
(**Lighting for Color and Form** by Rollo Gillespie Williams, Pitman Publ. Corp. 1954)

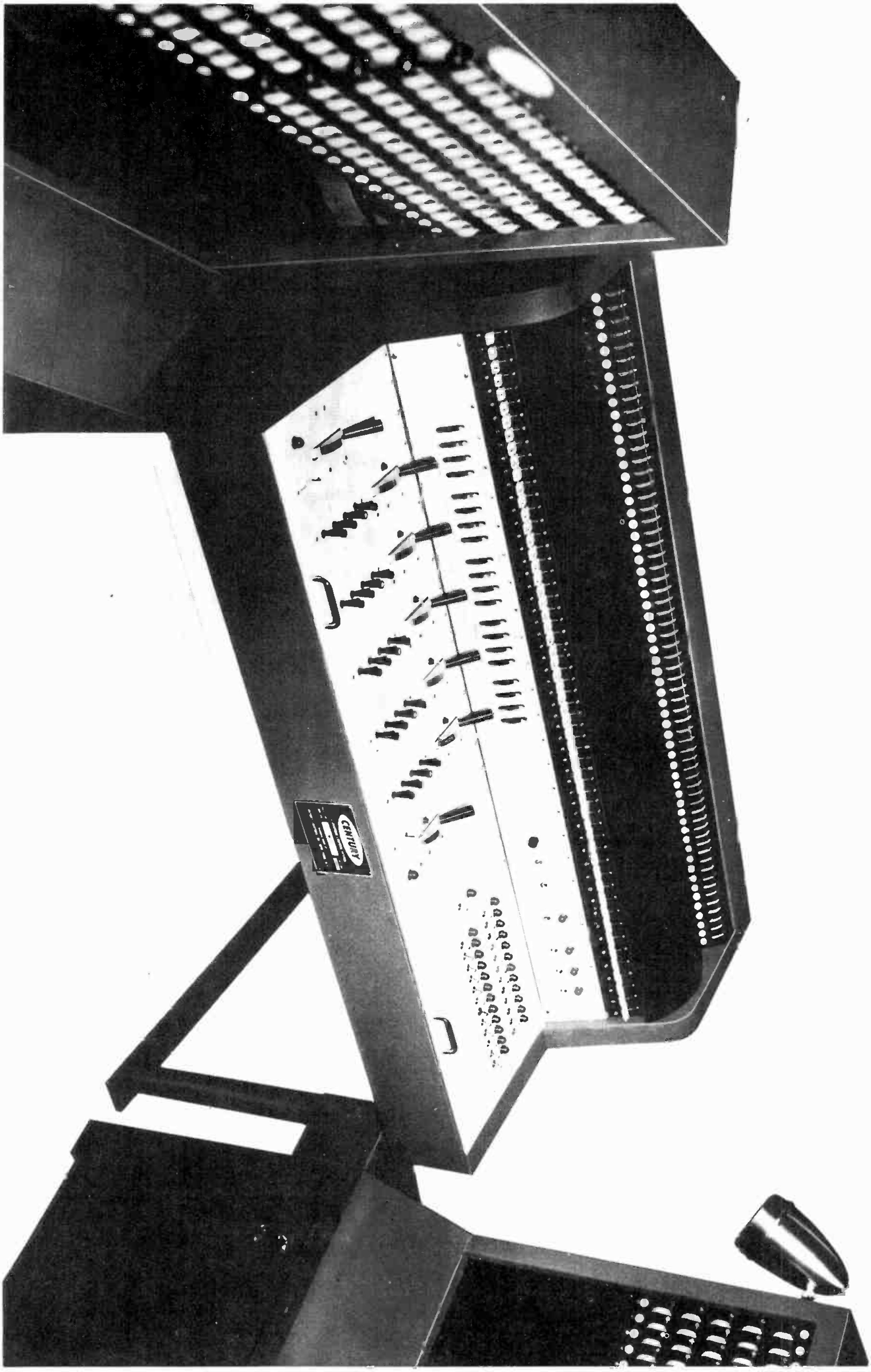

FIG. 5 View of control console for C.I. Electronic Dimmer Control System showing ends

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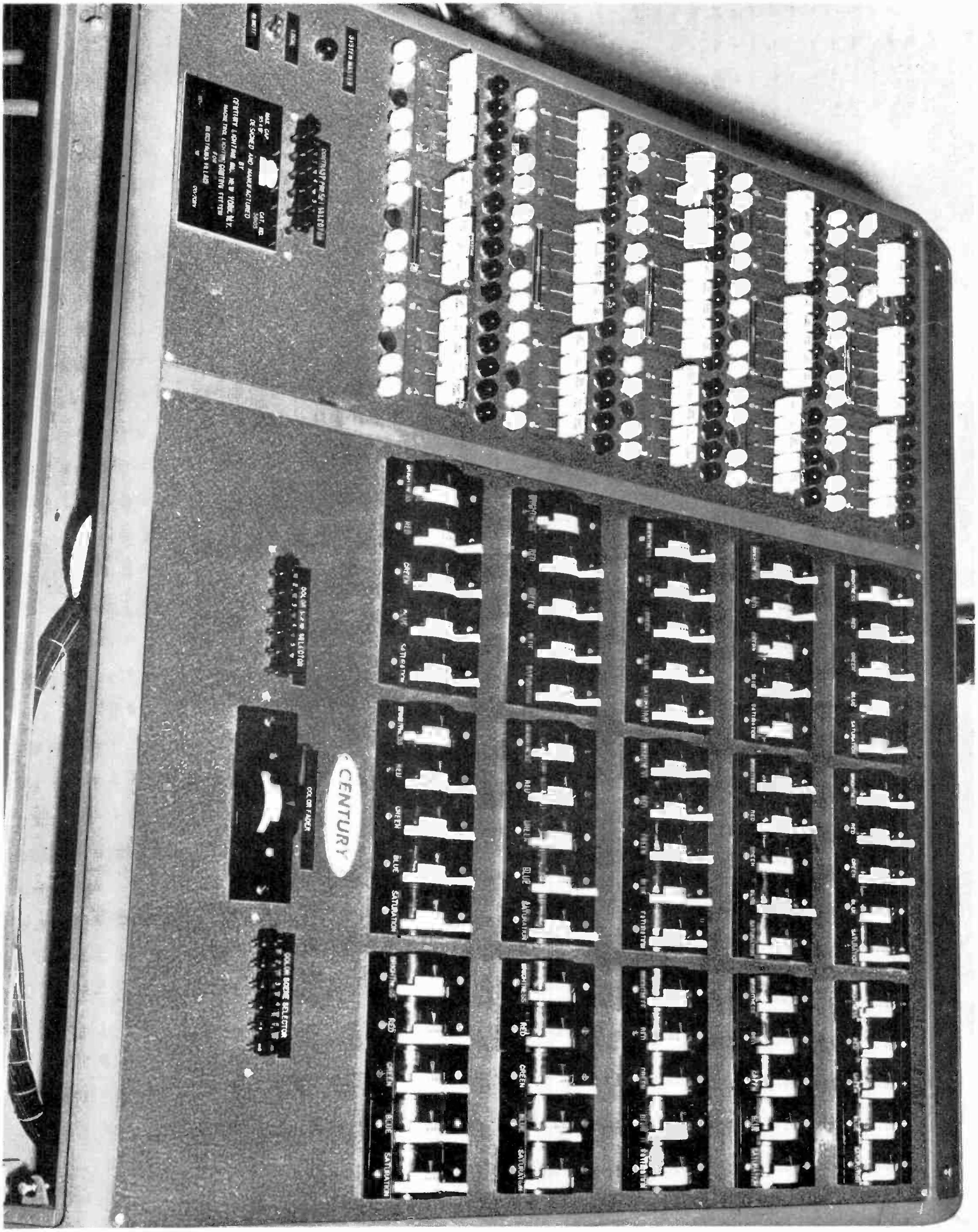

FIG. 6 Five-scene preset control panel for C'lectochrome magnetic amplifier four-color

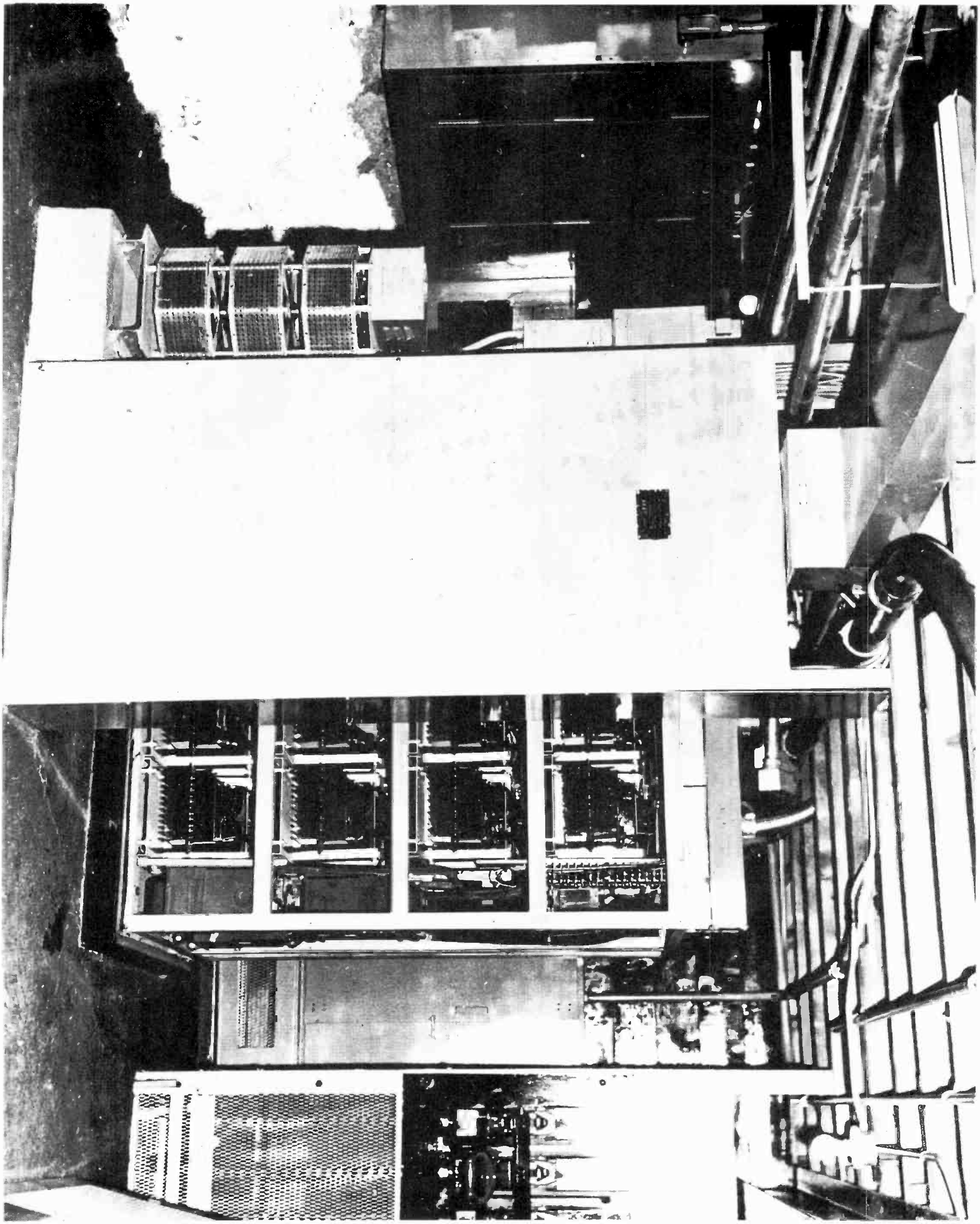

FIG. 7 Bank of magnetic amplifier dimmer units operated from control console shown in Fig. 6.

Color Test Signals Panel Discussion

Featuring

George M. Nixon, NBC

Richard S. O'Brien, CBS

Robert M. Morris, ABC

John Thorpe, AT&T

John W. Wentworth, RCA

Edward W. Allen, FCC

J. R. Popkin-Clurman, Telechrome

Moderator: Carl G. Nopper, WMAR-TV

Monday, April 8, 1957

11th Annual NARTB Engineering Conference

Chicago, Illinois

CHAIRMAN NOPPER: This afternoon we are happy to present a group of engineers who will tell us of the new operational techniques which permit the transmission of certain video test signals on a continuous basis during a normal program transmission time.

With more and more stations being equipped to transmit color, it is becoming evident that a network color test signal is needed. Several such systems have been proposed, with each system having special merits which warrant full consideration.

It is the purpose of this panel to discuss the relative advantages and disadvantages of the various color test signals, with emphasis on their practicability, effects which might be introduced into the system, integration into our present operating system, and the use of such signals in receiver servicing. Many other aspects of color test signals will be thoroughly discussed in the light of a workable and desirable system.

The members on the panel this afternoon are George Nixon, NBC, Director of Engineering Development.

Richard S. O'Brien, Assistant Director for Audio and Video Engineering of CBS Television network.

Robert M. Morris, Radio Facilities Engineer, American Broadcasting Company.

J. R. Popkin-Clurman, President, Telechrome Manufacturing Corporation.

John W. Wentworth, Manager of TV Terminal Equipment Engineering, RCA.

John Thorpe, Customer Services Engineer, American Telephone and Telegraph Company.

Edward W. Allen, Chief Engineer of the Federal Communications Commission.

Now that we have all the members of the panel on the platform, I think it is wise to start right in from the left and call on our first speaker, Mr. George Nixon, who will tell us some of the problems and some of the interesting items connected with the NBC version of this test signal.

MR. NIXON: Television broadcasting involves the transmission of video signals through a number of elements which comprise the transmission path between the program source and the ultimate destination - the picture tube of the receiver in the home of the viewer. The technical quality will be dependent in large measure on how well all these elements, whether they be amplifiers, interconnecting circuits, or the radio transmitter, are adjusted prior to program transmission, and how well these adjustments are maintained during program transmission. The home viewer makes his determination of the technical quality of the picture subjectively - by what he sees - and so to a large extent do those of us concerned with television program origination and and transmission.

Subjective measurements, however, are not of sufficient repetitive accuracy to be other than generally useful in the transmission problem of concern except that they can be made presently during the transmission of the program.

Instrumentation of familiar forms such as signal generator, oscilloscopes and similar test equipment are in general use for system alignment, detection and correction of defective elements, but usually are most effective when the system or an element of it is not in actual use. Network broadcasting presently uses "station break" time for the transmission of "frequency multi-burst","stair step" and "window" signals to inform the recipient of the transmission conditions at the moment. But some seconds or minutes later the source of the program and much of the circuitry transmitting the program may be radically changed with the result that you know how you were but not how you are.

Some form of stable and reliable reference signal, if transmitted continuously with the program, would permit a suitable index of circuit conditions to indicate whether adjustments in video level should be made, whether stabilizing amplifiers should be readjusted to provide a proper ratio of sync to picture, corrective equalizers to be adjusted, or what action should be taken.

Engineering development work was undertaken at NBC to determine the feasibility of transmitting such a reference signal without interference with the transmission of program material or affecting adversely home receivers regardless of age.

Vertical blanking time in a standard black-and-white or color television signal is between 1168 and 1335 microseconds in duration and is provided for the transmission of interlace equalizing pulses and vertical return pulses. There are approximately eleven lines in each field separating the second set of equalizing pulses and the start of the picture portion of the signal which are used to provide time for retracing of the scanning beam from the bottom to the top of the picture. It appeared that some of this "unused time" would be useful for the transmission of a suitable reference signal for evaluation of the performance of the television system during program transmission time. Further, such a reference signal would not be apparent to the home viewer as it would be concealed by the picture tube mask.

The reference signal developed consisted of three pedestals on each of three horizontal lines in each field separated from the picture area by one line, as is shown diagramatically in Figure 1. The separation from the picture area by one line is desirable to insure against interference with the picture area. The first pedestal is at 50 IRE units, the second at 0 IRE units, and the third at 100 IRE units. This arrangement places the "brighter" portions of the signal at the sides of the picture tube. These pedestals permit measurement of video level by reference to the 50% pedestal which corresponds approximately to the average a-c axis of program material and that portion of the signal least susceptible to distortion. The correctness of color burst amplitude may be made by comparison with the superimposed 3.58 megacycles on this second pedestal. The superimposition of 3.58 megacycles on each pedestal suitably phased in the case of color television program transmission with respect to burst frequency, provides an indication of differential phase and also differential gain response of the system. The 3.58

megacycle frequencies were superimposed on the first pedestal at a peak-to-peak amplitude of 40 IRE units phased 180 degrees with respect to burst frequency; on the second pedestal of the same amplitude but at a phase corresponding to magenta; and on the third at a phase corresponding to cyan. The 3.58 megacycle information in the case of the third pedestal is "depressed" within the pedestal so that the peak-to-peak amplitude does not exceed 100 IRE units, thereby permitting its transmission by a satisfactorily adjusted television transmitter.

Its appearance on a vector display device is shown diagramatically in Figure 2.

Figure 3 shows essentially the same information as Figure 1, except that it is a photograph of a cathode ray oscilloscope display.

Figure 4 in like manner is a photograph of a vector display device in which the reference signal is quite apparent during program transmission.

Figure 5 shows a photograph of a cathode ray oscilloscope display of the signal after passing through a high pass filter to indicate differential gain distortion. In this case the filtered frequency groups on the pedestals are of the same amplitude; consequently, differential gain distortion of any consequence is absent.

The tests conducted by NBC of the reference signal described during test transmission time and during commercial program time indicate that no difficulties will ensue so long as the signal is confined as regards time close to the start of picture time. It is planned to conduct additional tests within the broadcast plant and over the network with this signal and certain others under consideration in the immediate future.

It is apparent that there is considerable interest in some form of reference signal and general acceptance of its use as indicated by the eight papers on the subject at the recent IRE convention in New York. The afternoon session devoted to this subject included discussion of a number of types of reference and test signals for continuous, intermittent, or sequential transmission and other possible uses of the presently "unused" space in vertical blanking time. It is suggested that the reference signal selected finally be one which provides maximum utility to the user with least complexity of equipment for generation of the signal and its incorporation in the broadcast plant. It is believed the reference signal is presently of prime concern and other uses of the presently unused vertical blanking time should be allowed to develop gradually in an evolutionary manner.

The tests conducted on the air with the reference signal described have indicated its utility within the broadcast plant and for network service, and the feasibility of transmission of such a signal appropriately placed in vertical blanking time without adverse effects.

Due credit should be given to Mr. Ralph Kennedy of NBC for the development of this reference signal described.

CHAIRMAN NOPPER: Thank you, George.

Our next speaker is Dick O'Brien, of the CBS Television network, who will tell us about some of their interesting problems with this test signal as far as the CBS network is concerned.

MR. RICHARD S. O'BRIEN (CBS Television): Thank you, Carl.

Ladies and gentlemen, an important engineering objective at CBS and, I am sure, at the other networks, is the continuing effort to improve the quality of picture signals and audio as delivered to the viewer's home.

One of the most persistent problems that has been encountered in providing improved picture quality over the years is the matter of controlling the level of video signals through the transmission system. This is true whether the signal is a monochrome or a color signal.

In normal operations, a camera control operator at the point of origin sets the levels of the signal based on his interpretation of the scene that is being transmitted. However, depending on the particular scene, whether it is derived from film or black and white, whether it is filmed or live, color, black or white, the signal may or may not contain components which reach reference white or reference black level.

This ambiguity of the signal content makes for a certain amount of trouble along the network and at all the transmitters down the line, and the operators try to read the level and set the video gain of their portion of the system as it should be.

As a remedy for this longstanding problem CBS feels that a reference signal is by far the most important and the most urgent component of the various test signals which have been proposed recently for insertion during the vertical blanking intervals.

It is worth noting that within a centralized plant it has been CBS's practice in recent years to provide a rather elaborate calibration system. In this system monitor calibration pulses derived from a common source are accurately controlled and distributed to all monitoring points within the plant. The recently completed Chicago studios have such a system.

This works fine when it is within a plant. The obvious next step is to build a calibration signal right into the video signal so that it may be used not only within a central plant but may be used for control of transmission on through the network and to the transmitters.

Along the line of making use of this vertical blanking area that is rather going to waste at the present time, experiments were performed about 1950 in connection with inserting gray scales to use in connection with the control of television recording processes. This did not get into any widespread use, but it does now appear to us that the time is ripe to make use of a signal or signals in this vertical blanking interval for purposes of control.

(Slide) The slide shows in very abbreviated form the general nature of the signal that CBS would like to see adopted as an industry standard. Basically, it would occur on perhaps three lines during the vertical blanking interval, and it would consist of two components. One is a reference signal, white reference pulse working up from a black reference level, so you have both extremes, and secondly an area that could be used for the insertion of optional test signals as needed for specific test conditions. It may prove sufficient to use only two lines during vertical blanking, but this will be subject to the outcome of some field tests.

The reference pulse, which is a full white signal, is kept as far as possible toward the end of the scanning lines on which it occurs so that the curvature of the tube mass and receivers will help hide it from the viewer who really, I am sure, doesn't want to see it. Also, a couple of guard lines are left at the end of the vertical blanking to aid further in keeping these special signals out of sight of the viewer.

This subdivision of the three lines, the vertical blanking, into two areas, test and reference signal areas, is quite analogous to the division in interest among the different people who are going to make use of these two types of signals.

First of all the operating personnel will make almost constant use of reference signals throughout the network from the camera control point at which they may be inserted, on through the furthest transmitter in the system. Incidentally, it is rather obvious that one could key an automatic gain control amplifier to a discretely placed signal of this sort to some advantage in many cases.

The other group of people who will make use of signals inserted during vertical blanking are the maintenance people, and their primary concern will be with the area designated as "available for optional test signals". The signals that could be inserted during this period would include those of the type now used by the various networks, sandwiching them in between programs as time is available, and including such things as multiburst, modulated step waves for differential phase and gain measurements, perhaps sine pulses, and, those perhaps interested in color, perhaps color bars.

This functional division into reference pulse and test signal areas further lends itself to the practice organization of technical facilities in a program center. The reference pulse, being rather simple, easily generated and easily inserted, is the one which would be inserted at each point of origination, perhaps into each camera control. The special test signals could be inserted with special equipment at a central point, such as a master control, where the requisite degree of precision in their adjustment and utilization could be exercised.

One further practical advantage in separating the reference signal from the test signal part of the allocation here is that it may be possible to achieve industry standardization somewhat more easily on the relatively simple reference signal, whereas it might take quite a bit longer to reach an agreement on the more complex special test signals.

To summarize, it is proposed by CBS that a portion of the vertical blanking interval be used for test and reference signals, and that this be done on the basis of an industrywide agreement standard.

It is further proposed that the reference and test signal portions be handled separately, to better conform to their differing functional use, to the practical nature of studio installations, and also to facilitate the achievement of a standard at an early date.

In closing, I would like to acknowledge the considerable help of Mr. Will Whalley of our department in preparing these comments.

Thank you.

CHAIRMAN NOPPER: The third panel member is Mr. Morris, of ABC, who will discuss some of the activities they have done with regard to the test signal.

MR. MORRIS: We all, I believe, are acquainted with the video test signals used during the last two or three years for checking video equipment and network circuits. These are the familiar stair step, multi-burst and windows signals which all three networks have used in frequent over-all circuit checks.

Recently consideration has been given to the use of these and other test and control signals on a continuous basis in which they are transmitted simultaneously with program for one or more lines in the vertical interval.

The vertical interval consists of approximately 19 lines within which period the vertical synchronizing pulse is transmitted.

This interval was designed to be long enough to provide adequately for the necessary equalizing pulses before and after the vertical synchronizing signal as well as the time required for receivers of whatever design or manufacture to return the scanning beam from the bottom to the top of the picture. With improved deflection yoke design most receivers it is believed no longer require as large a part of the 15 to 16 lines existing after the start of the synchronizing pulse.

In the light of this situation and with the help of return trace blanking it becomes possible to transmit information at levels between black and white, (between $7\frac{1}{2}$ and 100 on the IRE scale), without having the information shown on receivers during retrace. Information so transmitted would be covered by the receiver mask just above the top edge of the picture or blanked by the return trace pulse.

Test signals inserted in the vertical interval, of course, consistute a variance as compared to the FCC Standard Television Signal Specifications. Such transmissions were, however, authorized for test purposes upon notice to FCC on October 11, 1956. This authorization has recently been extended.

I am sure that all who have given serious consideration to this technique have seen the possibility of utilizing signals within this interval for any of several purposes including:

1) The transmission of technical test signals for circuit and equipment checks.

2) The transmission of standard or reference video levels.

3) The transmission of control signals for remotely controlling some operating function related to the television program.

4) The transmission of cue signals for the guidance of personnel at remote points.

5) Transmission of coded communication such as teletype in a manner similar to time division multiplex

It may prove desirable to use the vertical interval for any or all of these things. I believe it is too early to predict what the future may hold in this respect. I do believe it is worthwhile and important to make a start in the application of this technique to the advantage of the TV broadcast service. I believe that the use of the level reference signal and the test signals for frequency and amplitude response will be those most useful initially.

The use of the amplitude reference signal is believed important as an aid to TV broadcast service since it would, if inserted at the point of program origination, serve as a fixed level reference for black and white, which would be transmitted simultaneously with the picture signal and under identical circuit conditions. It also would be visible on the standard wave form monitor or "A" scope and would therefore serve for the correct setting of gain or level at other transmission control or monitoring points without the addition of special equipment.

A photo of an "A" scope presentation of a 4-line window type reference signal keyed into a TV picture is shown in Figure 2. This produces a black reference at the left and right sides of the picture with white reference level in the center It is believed a better reference signal would be as shown in Figure 3. In this the white reference level is at the left and right sides of the picture where it is in the most favorable position to be masked off in the TV receiver. A photo off the kinescope of a picture to which this reference signal has been added is shown, without masking, in Figure 4.

These figures show the reference signal transmitted for 4 lines. Tests, however, have indicated that adequate visibility can be obtained on a standard wave form monitor with only 2 lines of reference signal. It is believed desirable to use the signal shown in Figure 3 without the addition of any chroma signal in order to assure maximum visibility for level reference. It may, however, prove to be possible to include chroma reference signals in this space when the majority of wave form monitors include the new IRE luminance signal "roll-off" which attenuates 3.58 megacycles more than 20 db.

It is believed the greatest immediate benefit can be derived from the use of this signal as a guide to operations personnel.

It should be evident, however, that by the use of synchronized keying pulses in equipment at points along the line of transmission it would be possible to use these level reference signals for the automatic control of level in equipment at such points. This should provide for substantially superior video level control as compared to that obtained by present methods.

The transmission and utilization of technical test signals in the vertical interval will probably require the use of specialized equipment at the receiving end. A usually available device for this purpose would be a triggered and delayed sweep oscilloscope such as the 524 type Tektronix. This would make possible the isolation and inspection of a single line of signal. The amplitude of the individual frequencies of a multi-burst or the levels of a stair step signal could then be determined and/or recorded.

The importance of this especially in network transmission is that the circuit condition may if desired be constantly monitored and even compensated during program transmission. This method of testing gives the video transmission engineer a new and important tool with which to facilitate and improve the results of his work.

It is probable that the best point in the broadcast system for introduction of reference and test signals is the point at which synchronizing signals are added to the picture signal. This is normally an important monitoring point whether it be the output of a camera chain or the output of a studio. Quality at other points would then be referenced to quality at this monitoring point in objective terms measured by changes in the test signal.

It is probable, however, that initially it will be necessary to provide for insertion of test signals into an existing circuit on what amounts to a temporary basis. A means for accomplishing this is provided in the Telechrome 1005 type test signal generator which incorporates means of adding a keyed test signal to a program line. The same type of keyed amplifier can be incorporated into the output stage of a program amplifier and the amplitude reference or other test signals can be inserted into this separate input. It is possible that two or more of these keyed signal adders will be needed to insert all of the reference, test and control signals desired.

A very preliminary proposal for allocation of time for the several functions which may be included in the vertical interval is shown in Figure 5. This would provide a total of 6 lines of space for the addition of signals, starting 2 lines after the end of equalizing pulses. It is believed this is approximately the maximum space which can be utilized although many tests will be required under the widest possible conditions to assure this is the optimum. This proposal would provide a constant amplitude reference at all times, and space within which to transmit test and control signals as desired. Flexibility for the development and test of new signals and uses is believed to be its principle merit.

The vertical interval signal technique offers new and challenging opportunities to the operations engineer for the technical improvement of television service.

CHAIRMAN NOPPER: Thank you, Bob.

Now we move on to the manufacturers, of whom there are two. The first is J. R. Popkin-Clurman, of the Telechrome Manufacturing Corporation, who will give us some of the interesting items about the manufacture of this portable as well as rack type of equipment.

MR. POPKIN-CLURMAN: One of the basic tools of television system maintenance engineers are specialized test signals. With such signals, all of the important characteristics of television networks can speedily be determined and easily monitored. Frequency response, non-linear distortions, differential gain and phase, overshoots, ringing, smears; all of these characteristics can be initially established and periodically monitored to detect gradual or abrupt changes. In these days of growing pains such as in color television, more stringent technical standards are required than ever before.

At present, test signals are generally used only when a facility is not being used for programming. This is a major restriction on their usefulness. Many of the shortcomings of present day test methods might be removed by transmitting test signals simultaneously with program material. This simultaneous transmission has many advantages, foremost of which is that network and facility characteristics may be determined at all times. Addition of such an "on-air" test signal must, of course, not degrade the program material in any way. Otherwise it would defeat its own purpose, which is to improve video standards.

It has been suggested that the logical place to add a test signal is during the vertical blanking period. Section A at the top of figure 1 shows one field of a standard composite video signal during vertical blanking time. No video information is normally sent during this time. Test signals have been added during this interval without degrading program material. Section B at the bottom shows the field of Section A, except two lines of a test signal have been added. The major consideration involved is the effect of test signals on the screens of studio picture monitors and also on home receivers if the signal is transmitted over the air.

Section A at the left of Figure 2 shows a typical home receiver vertical sweep circuit retrace for Field 1. The amplitude of the sweep is plotted against horizontal lines from the start of vertical blanking. Section B at the right shows a typical receiver mask. The horizontal lines occuring during vertical blanking for Field 1 are drawn over the mask. Again, the lines are numbered with respect to the start of vertical blanking. This picture shows that the first 12 lines or so should not be used to convey test signals. The signal information would be noticeable on receivers without retrace blanking and might interfere with normal viewing to some extent. It should be noted that the average American receiver does not have DC restoration and retrace blanking is almost universally used. All color sets do use retrace blanking. Lines 14 through 21 are at the top of the picture and are hidden under the receiver mask. This is true because it is standard practice to overscan receiver screens so that picture edges will not be visible, as circuits drift with time and under low voltage conditions. Tests have shown that test signals added during these lines apparently do not degrade the picture information and a home televiewer would not be aware of the test signal's presence. Note also that because of the shape of the mask, signals at the beginning or the end of a line are substantially better hidden than at the middle of a line. Therefore, a test signal should be constructed as far as possible so that its white peaks, the most noticeable parts, occur at the beginning or end of a line and not at the middle.

The number of horizontal lines required for a test signal depends on the method of observation of the signal. A test signal which is viewed on an A scope presentation can be sent for as little as one or two lines in each field. Tests have also shown that a test signal which contains color phase information may require three or four lines in each field to present a picture which can be easily observed on a chromascope or vectroscope.

Many different types of special test signals are being used. In present day practice, many broadcasters have standardized on the multi-frequency burst or multi-burst, the stairstep modulated with 3.58 megacycles, the white window (50% APL), and color bar signals. It would seem desirable for vertical interval signal use to draw upon those signals as far as possible and to modify and add, to enhance their usefulness. The following figures show these four test signals modified for vertical interval use.

Figure 3 shows the multi-burst signal. This is the same as the standard one except the white bar is at the right side. This change permits vertical interval test signals to have a peak white reference at the extreme right. Several variations should be considered. The white reference bar may have a notch added to it, shown dashed on the slide. This gives a 55% peak white reference which is useful under conditions of white compression. Other signals to be discussed later use a 50% peak white reference for the same purpose. For uniformity between signals, consideration should be given to modifying the multiburst signal so that the AC axis of the sinusoids is at 50% peak white. This is done by adjusting the peaks of the sinusoids to be at 90% peak white rather than 100%. The multiburst signal is used to obtain an instantaneous response curve of amplitude versus frequency. It also permits detection of frequency selective distortion.

Figure 4 shows the stairstep signal with a 3.58 MC subcarrier superimposed on the steps. Note that the 3.58 MC subcarrier brings the peak of the signal to 110% of peak white. The dynamic range of the signal will shift with variations in average picture level (APL) of the program. An immediate measurement of APL may be made by using an oscilloscope which has AC or DC coupling. Switching from one coupling to the other will give a vertical shift proportional to the APL. This signal also gives precise measurement of color subcarrier differential gain and phase. The stairstep alone permits a sensitive gray scale or transfer characteristic check.

Figure 5 shows the $sine^2$-square wave signal. This is a substitute for the window signal and emphasizes the one characteristic that cannot be tested by a vertical interval test signal, low frequency phenomena. However, this may be obtained from the vertical interval itself. The $sine^2$ pulse permits a sensitive check of transient response, and envelope delay. It is especially valid for "spike" evaluation. This method of testing is used extensively in England, is being used in Canada, and is becoming more widely known in the U. S. The main advantage of the $sine^2$ pulse is that its frequency spectrum is limited compared with that of a square wave and, therefore, does not respond as much to disturbances outside the band of interest. It is also more sensitive to disturbances within the band. The square wave at the right of the $sine^2$ pulse is the same as the horizontal portion of the window except that it has sine square transitions. The square wave may be modified to have a notch added to it, shown dotted on the slide to obtain a 50% peak white reference.

Figure 6 shows a vertical interval color bar signal similar to that used by R. C. Kennedy at NBC. This signal contains three color bars, Burst $\not\angle$ 180°, Magenta and Cyan. Each bar has an amplitude of 40 IRE divisions. The bars are superimposed on luminances of 50%, 0% and 80% peak white respectively. This signal permits a quick check of differential gain and phase, as well as alignment of encoders and color receivers and monitors.

Some of the specific advantages which may be otained from a vertical interval test signal are listed below:

1. A peak white reference is always present. This permits a very important level of a video signal to be determined. Black level changes are apparently less important as shown by the success of receivers which do not use DC restorers.

2. Deterioration or potential deterioration of video facilities is instantly indicated and corrective measures may be undertaken during program time.

3. The behavior of video facilities under dynamic signal changes such as varying APL and all other operating conditions is constantly shown. This indicates where technical improvement in present day facilities are required and will lead to higher quality and more reliable equipment.

4. Color or monochrome signals from different studios, cameras or encoders can be adjusted for the same operating conditions. This minimizes disturbances caused when scenes are switched.

5. Uniform conditions for video transmission may be established in terms of these test signals.

6. Permits off-the-air checking of the condition of TV facilities in accordance with established standards.

7. A useful by-product of system testing is in kinescope recording. A vertical interval stairstep can be added to monitor the transfer characteristic of the film. This permits continuous correction, if required, and results in a more uniform product on both recording and playback.

Figure 7 is a block diagram of the equipment on the demonstration table. This arrangement is typical of the way a test signal is added across any video line. The portable receiver has been modified so that the video from the detector is brought out at a low impedance level for signal handling convenience. This video line would be that connecting any two video equipments or facilities.

A composite video signal at standard peak-to-peak level is applied to the input of the Precision Sync Separator Unit. This unit has a high impedance bridging circuit and does not load the video line. The Sync Separator unit generates H and V Drive outputs. The leading edge of this V Drive pulse is very precisely determined by the edge of the first vertical sync pulse of the video signal and is used as the master time reference. The Sync Separator Unit need not be used when studio H and V Drives are available, as they are in many locations. However, the precision Sync Separator Unit makes the vertical signal equipment completely self contained, so that in its portable form it can be moved to any place where composite video signal exists.

The Vertical Signal Keyer Unit needs H and V Drive for proper operation. From these it generates precisely timed keying waves which controls the addition of a vertical interval test signal to the video line. The keying wave is applied instead of Blanking to the Blanking input of a normal test signal generator.

The test signal generator output should have a high source impedance so that it does not load down the video line, and it must be capable of developing the full vertical interval test signal amplitude when fed into half the line impedance. All test signal generators used by us meet this requirement by utilizing a plate driver output circuit. The generation of the test signal, is timed by H Drive.

Figure 8 shows a timing diagram with details of the keying process. Line A shows the last 3 lines of vertical blanking of the video signal. Line B shows the output wave form of the keyer unit adjusted for two test signal lines. Line C is the same as line A except that the test signal has been added. The duration of each keying rectangle is equal to the active picture time of one line. Thus the leading edge marked L of the keying rectangle corresponds to the end of the back porch. The trailing edge marked T corresponds to the beginning of the front porch. In this manner the test signal lines obtain standard picture blanking and sync intervals.

The lines during which test signals will be added have not yet been established by industry agreement. The present keyer unit permits the first test signal line to be varied from the 10th to the 20th line after the start of vertical blanking and the number of keyed in lines can be varied from 1 to 4 in each field. These numbers have been chosen primarily for evaluation and demonstration purposes and can be adjusted to meet any standards that experience proves desirable. In addition the keyer unit provides a special trigger for "one shot" scopes and a sweep sawtooth for observing the test signals.

The use of vertical interval test signals is readily extended to check individual portions of a facility. It is practicable for a vertical interval test signal to be inserted at the earliest possible point in a camera chain and then deleted at any point by deleter equipment. A new clean test signal can be added again to the video, applied to the next link in the network and deleted later. This procedure can be carried out as many times as desired. In this manner, individual equipment or portions of networks can be monitored so that when deterioration or failure occurs, the responsible facility may be instantaneously determined. The facility being tested can be determined more easily by having its test signal coded for identification.

To accomplish removal of the test signal, the video line passes through a unit called a deleter. This unit keys out the test signal lines. If a new test signal is to be added later, the keyout is done precisely, on a line-to-line basis, so that the new test signal will not be contaminated by remnants of the old one. If it is only desired to remove the information, then a simpler unit called the "crusher" is used to "squash" the test signal rather than remove it completely.

Thus far, we have discussed only the generation of the test signal and its addition to the composite video signal. Unfortunately, no one test signal provides all the information that is desired. Therefore, different test signals are applied at different times. Manual switching may be used to select between test signals. An automatic programmer which controls a predetermined sequence of signals, say, multiburst for 2 minutes, stairstep for 2 minutes, etc; may be as readily used.

A device such as the multi-signal generator being demonstrated lends itself to such an application. Because only one signal is required at a time, some vacuum tubes may be used in common for all signals. A minimum size power supply is used since B- is shut off from all signal circuits not in use. This design procedure has resulted in a portable lightweight unit which may be used to provide automatic sequencing of test signals in remote locations.

Figure 9 shows another method of sequencing test signals which is to have different signals on successive lines of the same field. If we assume that three lines are available for test signals in each field, then for Field 1 we may insert a multi-burst for the first line, a stairstep for the second line, and a $sine^2$ square wave for the third test line. For Field 2 we may send a color bar signal for all three test lines. This will be satisfactory if intensifying pulses from the keyer are used to enhance the presentation. A procedure such as this is very straightforward but requires considerably more equipment to accomplish. However, it has the great advantage that all characteristics explored by the test signal are available at all times. Many other combinations of test signals may be used instead of the one proposed above.

With vertical interval test signals being transmitted, it is interesting to speculate on how their usefulness may be extended. One application would be automatic control of various video and network characteristics. A good example of this which might be appreciated by TV engineers would be automatic control of peak white level. A relatively simple circuit would accomplish this. More complicated circuits could control equalizers which would automatically adjust frequency response, differential gain and phase, chroma level and other characteristics which are important in maintaining the quality of TV transmissions.

Another important use of the vertical interval test signal would be for cue and network control purposes.

Figure 10 shows one line of a test signal which is an elementary application of this idea. The line is divided into 5 time sectors. Each sector may be assigned 5 voltage levels, including zero. The number of symbols which may be obtained by using different combinations of voltage levels and sectors is five to the fifth power or 3,125. Different symbols might be sent for many different purposes such as to:

1. Identify point of program origin or identify point of test signal insertion in network or local station.

2. Indication of trouble.

3. Program switching, manual or automatic.

4. Replacement of cue marks during program portion of video.

The future of vertical interval test signal techniques appears to be very good since it promises to give great assistance in providing better standards, improved reliability and higher quality of program facilities for the public, as well as minimizing arguments between sources of programs, the common carriers, and affiliated stations. Perhaps we will no longer hear "It is leaving here fine; don't understand why you are getting such a poor picture there!"

CHAIRMAN NOPPER: Thank you very much, sir. It seems we have acquired two new names in our vocabulary, a "crusher" and a "deleter".

Our next speaker is John Wentworth, who will tell us about some of the activities RCA is doing with reference to this matter.

MR. JOHN W. WENTWORTH (Radio Corporation of America): Gentlemen, I think you have gained the impression from each of the speakers whom you have heard this afternoon that there is something worthwhile in this reference signal technique. That is certainly our point of view in RCA's broadcast engineering activities.

I wish to make a couple of matters clear about our position, however. The first is that we do not at the present time have equipment for sale. We regard this technique as something that is still in the field test period. We are willing to work with people who want to work with us on a requisitioning engineering basis to provide special equipment for field test purposes, but we feel it is a little premature to announce commercial equipment to generalize a signal which has not yet been standardized by any official body.

Also, I wish to make it clear that we are aware, that, as equipment manufacturers rather than users, we cannot afford to be opinionated in this particular area. We recognize that this reference signal technique is primarily for the benefit of the users of television equipment, and they are the final judge and jury in this whole matter.

A technique which does not satisfy the needs as recognized and as seen by the operators will have very little chance for success; so, we cannot afford to be opinionated and insist that we have the final word on any of these techniques.

We are, however, I feel, quite justified in expressing a point of view--and we do have a point of view.

Our particular point of view in this area, which we put forth for your consideration at this time, is that at the present time we favor the concept of coming up with one signal which will cover the widest possible variety of objectives. We go back to the objectives of the test signal and try to accomplish as many as we can with one signal which we hope ultimately will be standardized, consistent with the requirements for a reasonable degree of simplicity in the generation of equipment and the process of integrating it into the system.

I believe Mr. Nixon made the comment that the operational people generally have pretty well accepted the point that a desirable objective here is to strive for maximum utility for the user of this signal consistent with a reasonable degree of simplicity in the generating equipment.

We have a particular proposal which goes a little beyond any of the others presented here, in combining a number of objectives in just one signal wave form, so we throw it out at this time as a talking point, something we hope you will consider, and we hope we can explain enough about it so that you will understand essentially what it is we are driving at.

(Slide) This is a summary of the objectivesthat we see as good possibilities for this reference signal transmission. The reference signal has been cited several times this afternoon as probably the most pressing need for the industry at the present time, both monochrome and color. We certainly do not quarrel with that position.

Getting a reference white pulse added during vertical blanking time would be a major step forward in improving the operation of television systems. The checking of transmission facilities has also been covered by a number of the previous speakers. It is possible to add special signals which will do as thorough a job as you might like of checking out the transmission facilities, for such parameters as differential phase gain, levels, where there are cases of severe depression and distorted color that might be part of the picture signal anywhere along the line. There are a variety of things that can be done by suitable reference wave forms.

We feel it is possible to carry the basic technique a few steps further without introducing undue equipment complexity. We feel it should be possible to lean on this same technique through a standardized wave form to check out colorplexers, to check out all the information you need, both to set them up initially and give them a running check on their performance. We believe it is possible to check monitor and receiver adjustments in color to be sure your system is producing good color fidelity.

Finally, we see the posibility of this signal providing reference for several types of automatic controls in the future.

In addition to the reference level, which Mr. O'Brien mentioned in connection with his talk, it is possible to devise automatic circuits which will use certain other types of information contained in our proposed wave form for other types of automatic control circuits to more fully stabilize the operation of complete television systems.

(Slide) Let's look at this next slide, which shows a wave form sketch of a particular wave form that we are throwing out for consideration at the present time. We are not in an entirely different ball park from the other speakers you have heard this afternoon. There are a surprising number of areas of common agreement.

We all agree, for example, that somewhere in the reference signal there should be a reference white pulse, and the righthand side of the reference signal wave form seems to be pretty well agreed upon as a good place to put that reference white pulse, where you have the maximum masking effect from the receiver mask. So, you will note that our signal has such a reference white pulse over on the righthand side.

We propose that the signal might be divided into six intervals as you see sketched out here. The first two provide essentially a test of differential gain and phase as well as serve as a reference for burst phase to supplement the information normally conveyed by the color synchronized first, which is normally subject to certain kinds of distortion.

By transmitting information at the same amplitude and phase as the color sync burst, in colors Nos. 1 and 2, we have an objective reference inside picture times as far as the burst phases are concerned. Then we transmit the bursts during intervals 3 and 4. Then there is a green bar, followed by the reference white pulse.

In spite of the fact that this signal has six discrete intervals, it is very easy to generate.

(Slide) This shows the first step in the process of generating the signal. We propose that the timing information for inserting this signal can be provided by a fairly simple modification in the burst flag generator, already a standard item in virtually all color television studios.

We propose that the reference signal be added at each and every camera chain as close as possible to the point where the signal is actually generating. That applies to both color and monochrome cameras. In monochrome you would apply a slightly different version of the signal, but the timing information for all of these reference signals could be derived from the same wave form known as burst flag, which it is necessary to pipe around the color studio anyway, eliminating the need for piping around the studio an additional timing signal.

We modify the burst flag wave form by adding three additional pulses toward the back end of vertical blanking. The exact location is a matter subject to field test and industry agreement.

As this sketch shows, we have proposed adding the reference information at the very end of the vertical blanking period, in the last three lines. It may be desirable to provide one guard line, as some of the other speakers have indicated, and there is no particular problem in doing that. At any rate, in the burst flag wave form we add three additional pulses during the three lines where we want the test information to appear. These three pulses not only convey timing information to trigger off the rest of the wave form, but they also serve directly to operate the same burst gate in the colorplexer which provides the color synchronizing burst, to provide also the subcarrier component for test intervals at Nos. 1 and 2, so you can be assured that those test intervals match the color synchronizing burst at the point of origination in both amplitude and phase.

(Slide) This is a simplified block diagram of a possible circuit for a reference signal generator. We suggest that one of these units might be used for each and every camera chain. This little sketch shows that it might be simple in construction, consisting of six multivibrators in sequence, each one accounting for one-sixth of the total line period corresponding to one of the six intervals.

A practical unit to embody the basic approach illustrated by this simplified block diagram would imply approximately twelve to fourteen tubes, including the built-in power supply. It is a unit of about the same degree of complexity as the present color bar generator, rather widely used.

This unit is triggered off by separating test pulses pulled out of the modified burst flag wave form by the testing flag separator. This then triggers off the sequence of six multivibrators, whose outputs are fed to the color plexer. Note that the burst flag signal goes on to the colorplexer burst gate, which provides the subcarrier part of test intervals 1 and 2 as well as the standard color sync bursts.

Interval No. 1 requires a monochrome, provided by feeding a signal directly into the channel in the color plexer. The I and Q are provided by providing channels at the colorplexer. It next is fed into the green, and the final bar is white, in a 1 to 1 to 1 mixture.

(Slide) This shows the wave form sketch again, and we can talk for just a moment about what you can do with the various intervals. First of all, in setting up colorplexers you have all the information on this wave form that you need to make all the pertinent adjustments in a colorplexer or coder. You can check the relative phases of burst I and Q by looking at the three intervals, Nos. 2, 3 and 4. You can check the relative gains of the I and Q signals by looking for equality of the subcarrier intervals during intervals 3 and 4. You can check for over-all chroma gain, gain at subcarrier relative to the low frequency gain, by checking for tendency of the subcarrier component of the green bar at both the blanking level and the reference white level.

That green bar, by the way, is transmitted at an absolute level of 50/59ths maximum amplitude; a pure green bar of the maximum possible amplitude would have a monochrome component of 59, and a subcarrier component of 59 units peak, which means it would extend up to 118 on the IRE scale. We pull that down to roughly 84.7 per cent of the maximum possible amplitude in order to make the particular level of green which exactly fills the blanking to reference white range. That then proves to be an extremely useful signal for giving you a spot check of the gain and subcarrier frequency relative to the gain at the low end of the frequency response characteristic.

The reference white pulse gives you a good opportunity to check for white balance in the colorplexer. Since we have generated this signal by feeding the same pulse into the three channels of colorplexer, if there is any problem with the white balance adjuster, that will show as presence of subcarrier during reference No. 6. You can check carrier balance by the absence of subcarrier during this reference period.

You can check for the absence of any video component during intervals 3 and 4.

I think that covers the tests which those of you who are familiar with colorplexers recognize as being the significant ones in the process of setting up a colorplexer. It is very significant that our brethren on the East Coast can check the performance of our brethren on the West Coast. You do not have to be right at the colorplexer in order to take advantage of the monitoring points provided by this particular wave form.

Now let's talk about checking out the video transmission facilities, the video lines, transmission lengths or other gear you may be using.

In this wave form you have tests provided for differential gain and phase, first of all, intervals Nos. 1 and 2. You have bursts that start out with the same phase and same peak amplitude, one transmitted near white and the other near blanking. If there is any phase or amplitude difference between the two as measured at a receiving point, you know that something has happened during the transmission link. You can check absolute gain at 3.58 relative to the low frequency gain by means of the green bar. That is a very sensitive test for a particular parameter.

You have the reference level, which we all agree is very important and which will show as a dot in the conventional wave form monitor displays, as the other gentlemen have shown you in their slides. That gives you a rough idea of some of the things you can do for checking transmission facilities.

(Slide) This shows what you can do with this signal in order to check monitors and color receivers. The adjustment of a color receiver is a sufficiently sophisticated operation that there is some question as to whether the lay public will get much value out of this test, but certainly competent servicemen can do it, and I think a number of technically trained people among the lay public would have little difficulty making good use of the reference signal for this purpose.

To use this signal as an aid in making scientific adjustments of phase and chroma, in any color display device, to take the guesswork out of it, you will follow the very simple things sketched out here.

First, making the blanking bar visible by pulling in the deflection, by shrinking the deflection, or you can roll the vertical hold so you can see the blanking bar across the middle of the picture. Raise the background just enough to see some way out put out during the blanking interval. Then look at a pure red field. On a station monitor you can do this by means of a switch provided for that purpose; but in the case of a home receiver it is very easy to do this by viewing a monitor through a filter of such characteristic that it discriminates against the green and blue and lets you view only the red. It is very easy to obtain such filters, as many of you know.

Then you adjust the hue control for a match between the blanking interval and test interval No. 2. That match would appear where you see the dotted line marked "Hue Test" in this particular slide. You will find that is a fairly critical and sensitive test.

When the phase adjustment on the display device is correct, the interval No. 2 transmitted at burst phase should have zero output in the red channel feeding the color kinescope. When that adjustment is properly made, then if you have zero output you are neither at an interval brighter than blanking nor darker than blanking. You have just made a match, so that boundary actually disappears between the blanking interval and test interval No. 2.

Having made that adjustment, transfer your adjustment to interval No. 5, which is transmitted as a pure green bar. "Pure green" by definition is zero red and zero blue. Since that has zero red and you have already made a proper phase or hue adjustment, you now turn only the chroma control to achieve a match at interval No. 5. Thereby you have made a sensitive, objective adjustment of both phase and chroma in your color display device.

You then restore the obvious controls to normal operating position, and you should be in business.

You can make further checks by looking at the blue screen, and you should find a match in that No. 5 interval in the blue screen at the same setting where you get the match for the red. If not, you are either faced with a distorted signal or there is something wrong with the internal adjustments of your color monitor or display device. That gives you a rough idea of what you can do in setting up color monitors with the aid of this signal.

(Slide) This slide summarizes a couple of possible variations in the basic signal that you might use for special purposes. Some of you gentlemen are familiar with the so-called "black picture" problem which you encounter in color switching systems. It is possible to use a variation of this signal consisting of color synchronizing burst plus the complete monochrome component to the signal. That is a fairly sophisticated problem, and we will not take time to discuss it here, but there is a very nice solution to it.

(Slide) This shows a monochrome version of the signal which can be satisfactory for the addition to monochrome cameras to gain what benefit you can from the signal in strictly monochrome operation.

(Slide) This slide summarizes the problems we recognize must be checked out by field tests which are already under way. The basic practicality of the technique must be checked out. The possibility of spurious effects on receivers, while field tests to date have indicated there is no particular problem here, we must be absolutely sure of by further field tests.

We must check its usefulness for receiver servicing as well as for monitor setup in station operation. We must make sure it is fully practicable to integrate it into operating systems in a manner which theory indicates is possible, and we must of course explore its reliability for future automatic controls before we go off in a blind hurry and try to design such automatic controls before thoroughly having worked out the technique.

We are sure that with all the parties interested in this, the day is not far distant when a very satisfactory reference signal technique will be available for the benefit of us all.

Thank you.

CHAIRMAN NOPPER: Thank you very much, Mr. Wentworth.

Next we come to the AT&T representative here, who will fill us in on the AT&T comments with regard to these test signals and the activities of the various committees in the New York area. Mr. John Thorpe.

MR. JOHN THORPE (American Telephone and Telegraph Company): After listening to the previous speakers I have reached the conclusion that the television business is still as much an art as it is a science. As you know, we in the telephone company are vitally concerned, with you, in the transmission of good video signals from studio to viewer. I believe that we can state our goal to the effect that we wish the ultimate viewer in his home to receive a clear, steady and reliable picture at all times when he is located within a reasonable distance of the individual television station. This means that each of us must cause not more than his share of the distortion to the original picture. What this share is may be subject to a lengthy discussion and is not the purpose of this meeting today.

To illustrate the telephone company problem, here is a slide which shows the network facilities now in operation. This has grown from the original 900 miles in 1948 to about 78,000 miles, most of which are equipped for color transmission. You can see that for the average network transmission there must be literally hundreds of amplifiers in tamden. The relatively strict requirements for overall transmission distortion impose extremely rigid requirements on the individual building blocks. In order to operate this network and to assign responsibility for the testing and line-up of the facilities involved, we have divided the country into four more or less geographical sections with control offices located at New York, Chicago, Los Angeles and Atlanta. It is the responsibility of these offices, working with their sub-control offices, to make routine line-ups, to assign facilities for network use and to handle trouble reports. In addition to the individual line-ups, overall checks from coast to coast and between other extreme network points are made on a regular basis to insure that the built up channels will perform satisfactorily.

If by cooperative testing, and agreement as to objectives we can economically improve today's network transmission, we certainly wish to participate. In fact, we have been working very closely with the networks through VITEAC, which stands for Video Transmission Engineering Advisory Committee, and NTC, Network Transmission Committee, for several years. These groups were formed as a result of discussions between O. B. Hansen, then with NBC, Bill Lodge, CBS Television, and Frank Cowan, Line Lines Department, AT&T. The membership of the first includes the Chief Engineers of the three networks and appropriate engineering representatives of the telephone company such as Andy Hammerschmidt, Bill Lodge, Frank Marx, Frank Cowan, and Walt MacAdam. The NTC includes Howard Gronberg, Will Whalley, John Serafin and representatives of the engineering and plant departments of the telephone company such as myself. These groups have in the past worked out the form of the multiburst, stairstep, and window test signals which are commonly used today, and arranged for cooperative tests and visits throughout the country to discuss mutual problems. The regular transmission of these test signals on a daily basis has been most helpful in providing means of checking network performance and in analyzing difficult problems. Both television stations and telephone company test rooms have frequently been asked to take pictures of the various waveforms and to transmit them to a central point for analysis under such conditions. We shall be pleased to work out arrangements in this manner for trials of the vertical interval test signals which are proposed.

Actually, as long as the new signals do not differ too greatly from typical video information the possibility of transmission difficulty over our facilities is minimized, particularly because of the very small duty cycle involved. The employment of these signals for in-service adjustments would require study because it is our feeling that, if possible, basic trouble sources should be located rather than making compensations to hide the difficulty. Also our channels are lined up so that they may be switched to various sources and feeds and so should be independent as far as possible of any overall network layout. In working out a test program it would seem advisable to keep the signal as simple as possible yet indicative of the parameters which are important to observe. In this regard, there may be some difference of opinion between the color and the monochrome networks. In either case, a clear indication of black level and white level would be most useful in order to give all observers these important reference points.

I shall be pleased to discuss this further with any of you later on, if you wish.

CHAIRMAN NOPPER: Thank you very much, Mr. Thorpe.

And now for the last speaker on this panel. Mr. Edward Allen, who will fill us in on the various test signals used in the Laurel, Maryland, FCC Laboratory; secondly, the Commission authorization for the use of any test signals in the future; thirdly, the methods of implementing the test signal into the Commission's rules.

Mr. Allen.

MR. EDWARD W. ALLEN (Federal Communications Commission): I have listened with interest to the exhaustive talks on television test signals by previous members of the panel. It is my purpose here to tell you of the activity of the FCC in this matter, to describe briefly the kinds of test signals which we have found to be useful, and to make a few suggestions as to how such signals may be used with further advantage to the industry and to the FCC.

This problem has been under study at the Commission's Laboratory at Laurel, Maryland, since October, 1953 and we have been inserting such a signal in our television generating equipment for approximately one year. The particular signal used at our Laboratory consists of one line in each field and the material assigned to the line programmed sequentially at two-minute intervals by a mechanically-driven switch. The programmed material consists of a stairstep signal with color sub-carrier superimposed; a sine-squared pulse signal and window with sine-square sides, and a multi-frequency burst signal. Presently, the equipment is being modified to permit operation on more than one line, if desired, and to provide a short, three-step staircase in the early part of each test-line preceding the other material. The purpose of this abbreviated stairstep is to give a constant check on linearity and to provide a reference white signal. These signals are similar to those which have been described by previous panel members, and are used for similar purposes.

As in the case of any problem of widespread concern, it is being attacked simultaneously in this and other countries. During the Sixth Plenary Assembly of the CCIR, held in Geneva in 1951, conferences were held between the television study group of the CCIR and the transmission group of the CCIT relative to the transmission of television over long distances. As a result a study program was set up, which included proposed test signals of the kind described here. Continuous study has been made of this problem to date and, as a result, a rather complete specification of such a signal will appear in Volume 1 of the Documents of the Eighth Plenary Assembly, Warsaw, 1956. Substantially the same signal is described in a 1955 issue of the Journal of the Northwest German Broadcast System (Technische Hausmiteilungen des Nordwestdentschen Rundfunks, No. 7/8, 1955).

It is apparent that test signals of the type here discussed hold many possibilities for operational improvement and for the initiation of desirable measures which do not now exist. In television, many of the decisions, especially during the times of actual operation, are made on the basis of an individual's reaction to a picture viewed on a monitor. This situation is somewhat similar to that which we would have in the power field if we entrusted the decision for the maintenance of proper voltage to the power plant operator's personal decision as to whether the lights are too dim or too bright. Thus, while radio gave birth to the electronics field, and this in turn has resulted in the widespread application of automation in other industries, in communications we seem to have been much like the proverbial shoemaker.

In previous talks during this conference, Mr. Fellows, Mr. Walker and Mr. Ehrenberg have touched upon the subject of automatic logging in lieu of present day written logs. I believe that it is also apparent that a complement of properly selected test signals will permit automatic recording and adjustment of various transmission parameters. As to final selection, serious consideration should be given to a standard arrangement of the signals in a manner which would go one step further than so far discussed. The arrangement should be such that we could conveniently obtain a continuous record of certain of the parameters of interest. Recorders could then be installed to determine how the various parts of the system operate over various periods of time. By assigning certain definite lines and definite time periods along each line and definite times of transmission for insertion of each standard test signal, it would be possible to record the over-all operation as well as to see the degradations which occur throughout the system.

With this type of signal arrangement, it would be possible for the program originators, the common carrier, and the broadcasters to provide themselves with automatic recorders. The recordings could be reviewed periodically to determine the engineering quality of the product they are delivering or receiving, and should provide a means of determining the performance of both equipment and operating personnel. In addition to improved operation, the ability to keep a continuous check and to make adjustments during operating time should result in economies by reducing overtime tests, adjustments and maintenance.

One other thing which could be done would be to provide circuitry which would enable the test-line signal information to be viewed on ordinary meters rather than on an oscilloscope. For example, the frequency multi-burst signal could be processed to give a meter reading for each frequency. This form of presentation may be found useful when considering the problems of operating personnel for whom meter reading may be more desirable than interpretation of oscilloscope patterns.

The field personnel of the Commission have a similar interest in a standard test-line signal. In many cases, difficulties in TV transmission can be positively identified only by operation after the end of the broadcast day, which may mean working into the early morning hours. A standard test-line signal would enable the field personnel to make observations at more convenient hours, as well as to make many useful observations and measurements not now practical. However, this is but one of the many reasons for which the Commission is interested in such test signals and wishes to see progress in this field.

In order to permit television stations to broadcast test signals, the Commission has taken several actions to date and undoubtedly will continue to grant such waivers and authorization as are required, which at the same time protect the picture from observable degradation. In the case of the request for the transmission of the "green stripe", it was felt that the proposed signal was within the video interval of each line and that no waiver or rule change was required. More recently, in October 1956, the requests for the transmission of the line test signal during the field blanking period were granted by waiver of the pertinent rules. (FCC 56-986). This waiver expired on January 15, 1957, but has now been extended for an additional year by the Commission's action of April 3. On that date the Commission issued a Notice of Proposed Rule Making (FCC-57-346) and a Public Notice (FCC-57-342) in the matter, calling for comments by September 1, 1957, and extending the test period until April 3, 1958.

We have heard and seen on this panel so far the advocacy of various kinds of test signals. It would appear that all of them have their usefulness and have various forms of utility, and I am not here trying to appear as an advocate for any one.

In view of this rule making which has been issued by the Commission, we will maintain an open mind on these signals and will be interested in seeing what tests can be made and what recommendations are made to the Commission during the course of this rule making proceeding.

Thank you.

CHAIRMAN NOPPER: Thank you very much, Mr. Allen.

Well, this seems to about sum up the panel discussion for the day, with the exception that the major item left is questions and discussion from the floor.

You have heard in essence what appears to be a progress report of the activities of the networks, the manufacturers, the telephone company group and the Federal Communications Commission. May I suggest that if you do have any questions in regard to operational problems, you address them to the respective networks. If you have any questions regarding equipment, address them to the manufacturers and to the telephone company, and questions for the FCC should be addressed to Mr. Allen.

VOICE: Mr. Nixon, are you now transmitting test signals on the NBC network?

MR. NIXON: We are not now transmitting. We expect to resume transmission in about a week. That may be a test of the signal that I described, which is developed by equipment that is capable of easy adjustment to get pedestals of different heights, different bursts, but not more than two or three.

VOICE: Could you tell us on what program that test line will be?

MR. NIXON: Initially it will probably be on most of the color programs, but whether on precisely 100 per cent of them or not, I don't know at this time.

VOICE: Has any thought been given to whether or not it is a compulsory signal or a voluntary one? Will this only be network, or should it be individual stations?

CHAIRMAN NOPPER: I think at the moment this would be, just to give you a progress report on what the networks have been doing in the New York area. The next step, I imagine, would be for the group to get together and see if, with the manufacturers and the FCC, they can come up with some type of equipment that would be in keeping with installation within an individual station, not affiliated with the networks.

MR. WENTWORTH: I might make a comment on that. Rather than talk about compulsory versus voluntary, you might talk about standardization.

In order to realize some of the benefits of the signal, such as the possible use of automatic controls, you do have to have its use standardized to the point where you can be assured that it will be there; otherwise your automatic control gimmicks may go completely haywire if you suddenly decide not to put it in.

So, I think the real value of that question, as to whether it ought to be used universally or not, is more a matter of what benefit you can derive from having it present all the time, versus the spot checks which you might make one minute out of every five or so, if you are using it exclusively for checking purposes.

VOICE: Have you given any thought to the use for your precise offset? Is there any possibility there?

MR. WENTWORTH: These two techniques are not directly related. There will be a paper later on the precise offset technique. That, among other things you will learn in the paper, requires the use of very precise crystal control of the scanning frequencies as well as of the carrier frequencies in your transmitters.

That means that it may be desirable to operate almost continually on a color standard basis, that is, logged to a color oscillator, so that you have that degree of precision in holding your scanning frequencies, which may make it a little easier to implement this technique on a universal basis; but there is no direct relationship between these two techniques.

CHAIRMAN NOPPER: I have a question.

Mr. Allen, did I understand you correctly, that if a station wished to carry on some method of test signal transmission along the lines indicated today, the Commission would give approval to conduct such a test in accordance with the FCC announcement of April 3 or 4?

MR. ALLEN: The public notice states: "Such test transmissions can be used for the purpose of developing and testing the feasibility of the method employed, and will be of assistance in the preparation of comments and data in such rule making proceedings as may be instituted. ... The Commission believes it would be helpful in the meantime if television stations are authorized without further specific authority to transmit test signals during programming."

In other words, as I read this--and Jim Barr can correct me because he is in on this, too--I understand this to mean that it is blanket authority to transmit these test signals if they do not degrade the picture.

MR. BARR: That was the intention.

CHAIRMAN NOPPER: Then, assuming the network would initiate the test signals to affiliated stations, and the network received blanket permission, would the receiving station be required to send a telegram to get FCC approval?

MR. BARR: They don't need any permission at all. They have it, by this notice.

CHAIRMAN NOPPER: Then that is clear. Are there any other questions?

VOICE: I would like to ask CBS when they plan to send this type of test signal, or what type of test signal they plan to send.

MR. O'BRIEN: I can't give you a date, but it will be in the relatively near future, and we will advise all the affiliates as soon as we know. We are definitely planning to go into some field tests on it.

MR. WILLIAM STRINGFELLOW (WSPD-AM-TV, Toledo, Ohio): I would like to ask Mr. Wentworth how he determines amplitude linearity with this test signal. I didn't quite understand that.

MR. WENTWORTH: To measure amplitude linearity, or differential gain, which is the modern way of checking that characteristic, you use the first two test intervals, one of which is transmitted up near white and the other transmitted down near black, and measure for a difference in gain at sub-carrier at those two levels relative to each other, and with a suitable phase measuring instrument you can also measure the phase at those two levels. We are only field testing this wave form. We are also building equipment which we expect will be field tested at NBC, which will provide a slightly more elaborate version of the signal which has eight intervals instead of six, which will include a burst at 50 per cent as well as at 80 and zero on the IRE scale, so you would make a more complete differential gain phase test.

VOICE: How do you determine the frequency response?

MR. WENTWORTH: You have a good spot-check at 3.6, where it is particularly important that you hold it very closely in that green bar, where you check for the correspondence of the peak-to-peak sub-carrier amplitude just filling the blanking to reference white blank range.

As far as reference throughout the frequency band is concerned, you have to fall back on transient test; if you total wave form is reproduced faithfully, you have the nominal assurance that there is nothing wrong with your frequency response characteristic. It does not check the frequency response characteristic, as does a multi-burst, for example.

We feel this represents a reasonable compromise between the several possible objectives we are trying to meet simultaneously. It does not do the same job as a signal designed just for that purpose.

VOICE: I would like to ask CBS whether in their signal there was a pulse at the 50 per cent level, or just one white pulse?

MR. O'BRIEN: As shown, we did not show a pulse at 50 per cent level. We would be very willing to go along with the inclusion of such a pulse, and perhaps the addition of a modified pure green bar, such as John Wentworth outlined. The two could be put together and associated with the reference white pulse so that you could use this coincidence of the types with the reference white as a quick check of chroma versus luminescence gain. We would go along with that definitely.

I might add that for those periods when we are transmitting color, we would think of including that signal, not during monochrome.

VOICE: I would like to ask the FCC representative a question. If this provision for inserting this signal is approved by the FCC, would it be on an optional basis, where the signal could be inserted in that portion of the vertical period if desired, but would not necessarily be required in all instances?

MR. ALLEN: That is one of the problems which has to be resolved in this rule making. Mr. Jacobs, I believe, addressed himself to the same problem as to the idea of whether it should be made compulsory or voluntary. That is part of the problem which will be decided in this rule making undoubtedly, which the Commission started last Wednesday.

CHAIRMAN NOPPER: As you indicated, I believe that will be generated in the industry and will be presented in September.

MR. ALLEN: The rule making was initiated by the Commission last Wednesday, and the deadline for comments now is September; but undoubtedly if the industry cannot address itself to comments by September, and give adequate comments on which a decision can be made, extensions will be in order as in any other rule making proceeding.

CHAIRMAN NOPPER: There you are, folks. Full cooperation of the FCC.

VOICE: I believe one of the speakers mentioned the fact that he felt that the black level reference wasn't as important as the white reference level. My feeling is that, at the far end of the long haul, the same thing can happen to black level as well as white level. I feel they are both important to each other, and that there is no differential.

CHAIRMAN NOPPER: Would you like the networks or the equipment boys to answer that question?

MR. NIXON: It wasn't I. I thought we should have three references--zero, 100 per cent and 50 per cent. Whether it be black level or picture black, that is something we are not so positive of.

MR. MORRIS: I might add a comment. I think the signal I discussed was one that contained black level as distinguished from blanking, and I can only say that I, too, with Harry Jacobs, think black level has serious significance in the correct reproduction and transmission of a television picture.

Unfortunately, much too little attention has been given to that, especially by the receiver manufacturers.

(Applause)

CHAIRMAN NOPPER: Any other questions from the floor, gentlemen?

MR. POPKIN-CLURMAN: I would like to correct the record. I was the one who said that the black level was not as important, but my text reads, " Some people apparently do not believe black level to be as important."

VOICE: Has any thought been given to deleting the middle space between the end of the white pulse and the start of the front porch, for evaluation of the transient response?

MR. O'BRIEN: I would say that our signal, as shown on the slide, did have about a 3 microsecond interval left there for that, and also to prevent any transient derived from the white pulse from upsetting any marginal receivers.

CHAIRMAN NOPPER: Are those all the questions? Thank you very much, gentlemen, for a very instructive panel discussion.

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A COMPATIBLE SINGLE-SIDEBAND SYSTEM DESIGNED FOR USE IN THE BROADCAST SERVICE

Leonard R. Kahn*

Summary

The Compatible Single-Sideband system[1,2] offers a means for reducing interference and fading distortion. Since it reduces the bandwidth of an AM signal by a factor of 2-to-1, CSSB provides a means for easing congestion on the standard broadcast band, as well as communications bands. This system, which allows the use of an adapter to modify any standard AM transmitter, is now being used by the Voice of America at their megawatt station in Munich, Germany. The first domestic tests are now being conducted at New York Radio Broadcast Station WMGM.

Use of the Compatible Single-Sideband system does not require the alteration of home receivers and the system also provides high fidelity sound in comparison with standard AM transmission. For a given signal fidelity, CSSB provides an effective two-to-one power gain.

Introduction

During the past few years, many communications companies have converted their AM facilities to single-sideband. The reasons for this swing to single-sideband are:

1. Spectrum economy.

2. Reduction in selective fading effects.

3. Signal-to-noise and interference gain.

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Since almost all engineers agree that any alteration of home broadcast receivers is impractical, single-sideband techniques have not been considered applicable to standard broadcast service. However, a number of years ago Mr. W. J. Bray[3], of the British Post Office, prepared a United Kingdom proposal which was submitted to the CCIR for the adoption of full carrier single-sideband high frequency broadcasting. British Post Office engineers argued that full carrier single-sideband signals, while offering spectrum economy and reduction in fading distortion, can be received on conventional AM receivers. In order to carry out this program, it would be necessary to replace almost all transmitters to be used for this service. In addition, careful examination of a full carrier single-sideband wave points up some rather serious defects. These defects appear to have been recognized by proponents of the full carrier system and are probably the reason for limiting the proposal to high frequency broadcasting.

Slide 1 shows a full carrier single-sideband wave modulated by a single tone under peak modulation conditions. It is seen that the envelope waveshape is far from sinusoidal and actually there is a little over 23% harmonic distortion.

Also, it should be noted that the fundamental term has a peak value of 67% relative to the d-c term. Therefore, the maximum effective modulation of a full carrier single-sideband wave is only 67%. It has been suggested that in order to reduce the large amount of distortion of this envelope, the sideband level should be reduced. It may be shown that though the distortion is reduced, the effective modulation is also greatly attenuated. When the distortion is reduced to 10%, which is normally considered to be barely tolerable for most equipment, though not quite acceptable for broadcast service, the effective modulation is 38%. Such a low level modulation value reduces the effective power of the transmitter by a factor of over 5.3.

Two proposals[4,5] have been made for reducing this distortion effect at the lower frequencies by transmitting double-sideband for low audio frequencies and single-sideband for higher frequencies. However, these systems require more spectrum and are more critical to selective fading than pure single-sideband systems. These systems also require the replacement of most existing transmitters.

Compatible Single-Sideband

We would like to propose a new system that does not have any inherent distortion at a 100% modulation. This system, Compatible Single-Sideband (CSSB), allows the use of conventional AM receivers and is actually slightly less sensitive to incorrect tuning than AM transmission. It may be best to examine a simplified block diagram of a Compatible Single-Sideband transmitter at this point. Slide 2.

In the Compatible Single-Sideband system, a full carrier single-sideband wave is produced in what may be a conventional single-sideband generator. This wave is then passed through a limiter wherein the phase modulation component of the wave is isolated. This phase modulated wave is then amplified by Class-C amplifiers, or for that matter any other class of amplifiers and finally fed to a modulated stage.

The full carrier single-sideband wave, at the output of the SSB generator, is also fed to a product demodulator wherein it is electronically multiplied by the carrier. The resulting output wave from the product demodulator is free of distortion. In other words, the spectrum components at the output of this demodulator are identical with those at the input of the single-sideband generator. This audio wave is then amplified and finally used to modulate the phase modulation component. If this modulation process is linear, the envelope wave at the output of the modulated amplifier is free of all harmonic distortion. This wave may then be demodulated in the conventional diode detector with theoretical zero distortion at 100% modulation.

Analysis and measurements show that the undesired sideband of this wave is approximately 30 db below the desired sideband. Even though the Compatible Single-Sideband wave looks exactly like an AM wave on an oscilloscope, the wave is single-sidebanded.

Advantages

The advantages of the Compatible Single-Sideband system are as follows:

1. Reduction of Adjacent and Co-Channel Interference

Since Compatible Single-Sideband systems concentrate energy in one sideband, CSSB transmission reduces adjacent and co-channel interference.

a. Adjacent Channel Interference

In the case of adjacent channel interference, the use of Compatible Single-Sideband can increase the spacing of adjacent sidebands by two times the highest audio frequency transmitted. This increased effective sideband spacing greatly reduces adjacent channel interference.

Adjacent channel interference comprises three main types; sideband monkey chatter, undesired cross-talk and carrier heterodynes. In the United States, the 10 kc separation between carriers tends to reduce this form of interference because of IF and audio fidelity, as well as the listeners aural limitations. The crosstalk effect is greatly reduced by masking, and except for extremely large undesired signal levels is relatively unimportant. The main source of adjacent channel interference is sideband monkey chatter wherein the desired carrier beats with the undesired sideband components. If CSSB techniques are correctly applied, the frequency of the monkey chatter would be sufficiently removed from the desired carrier to be above audibility. Thus, CSSB offers a means for greatly reducing adjacent channel interference.

b. Co-Channel Interference

If co-channel stations are equipped for CSSB operation, the listener, by tuning to the desired stations side of the carrier, can effectively reduce interference effects. The optimum tuning point appears to be 1-1/2 to 2 kc on desired sideband side of the carrier and conventional home receivers offer a signal-to-interference gain of from

5 to 8 db. If a listener, in a particularly poor region, purchased a special high selectivity receiver, he could obtain approximately 30 db signal-to-co-channel-interference gain.

In addition to the reduction of this type of interference, there is also a reduction in beatnote distortion, which in AM systems is caused by the "phase beating" of interferring carriers. This reduction in beatnote distortion is discussed in the next section on "Selective Fading Distortion Reduction".

2. Selective Fading Distortion Reduction

The second advantage of Compatible Single-Sideband operation is the reduction of selective fading distortion, offering an increase in night-time coverage. It may be shown that the main cause of fading distortion is incorrect relative phasing of the carrier and the sidebands. This condition may be demonstrated by eliminating the carrier from an amplitude modulated wave and then reinserting the carrier at different phase relationships.

It is then seen that when the carrier differs by 90° from its correct phase, the signal, demodulated in an AM detector, is completely distorted. This distortion is independent of the percentage of modulation.

Compatible Single-Sideband operation, by suppressing one of the sidebands, is much less sensitive to selective fading distortion. The relative phase of the components of the Compatible Single-Sideband wave is much less critical and tests have established the fact that Compatible Single-Sideband waves are relatively free of fading distortion.

It should be pointed out that this insensitivity to phase deviation is another reason for the reduction in co-channel interference. When the undesired signal has a carrier frequency approximately equal to that of the desired carrier frequency, the combined carriers will be phase modulated at a low frequency beat note rate. This wave will then go in and out of proper phase and there will be a form of beating distortion. Because Compatible Single-Sideband is less sensitive to phase discrepencies, CSSB is relatively free of this distortion.

3. Improved Fidelity

Because the Compatible Single-Sideband wave occupies one-half of the normal AM spectrum, the bandwidth of the IF and RF amplifiers of the receiver may be halved. Since the fidelity of most receivers is restricted by the IF bandwidth, Compatible Single-Sideband offers a means for appreciably improving the effective fidelity of existing receivers.

If desired, the future home receivers may be built for restricted fidelity service, and in this case, it will be possible to obtain a signal-to-noise improvement by the use of CSSB. For a given fidelity, the bandwidth may be halved, thus providing a 3 db signal-to-noise improvement. Such receivers could be made somewhat cheaper because more gain can be obtained in the narrower IF amplifiers than in wider units. Also, it will be easier to obtain improved selectivity with attendant reduction in co-channel and adjacent interference effects.

Discussion of Compatible Single-Sideband Installations

Compatible Single-Sideband Adapters have been built for adapting standard broadcast transmitters to CSSB service. Installation of these adapters does not require alteration of the standard AM transmitters and conventional auxiliary measuring equipment, such as modulation indicators and AM monitors, may be used. This equipment has been installed and tested with high level modulated transmitters and also low level Doherty systems.

So far there have been two installations of the Compatible Single-Sideband system outside of the Laboratory. The first installation was performed at the Voice of America's megawatt station in Munich, Germany. This station has been in regular operation with the Compatible Single-Sideband equipment since late last summer. The second installation has recently been completed at New York Radio Station WMGM and tests of this installation are now being performed.

Conclusion

It would appear that Compatible Single-Sideband systems offer the user reduction in interference, reduction in selective fading, and improvement in signal-to-noise ratios and/or higher fidelity performance. It is actually quite conceivable that, by the use of receivers with improved selectivity, a listener residing in an area where the signal strength from two co-channel CSSB stations are equal, will be able to enjoy programs from either station.

References

1. L.R.Kahn, "A Compatible Single-Sideband System"; Second Annual Symposium on Aeronautical Communications; Utica, New York; October 9, 1956.

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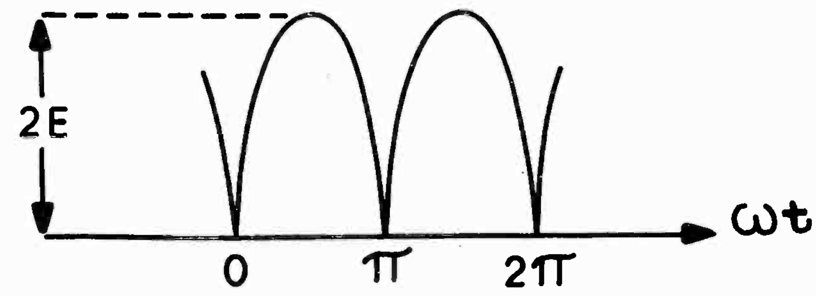
3. W.J.Bray, CCIR Question #62; Single-Sideband Broadcasting Study Group X, submitted by UK, July 1, 1953.

4. P.P.Eckersley, "Asymmetric-sideband Broadcasting", Proc. I.R.E., Vol. 16, p.1041, September 1938.

5. N.Koomans, "Asymmetric-Sideband Broadcasting", Proc. I.R.E., Vol. 27, No. 11., November 1939.

March 27, 1957

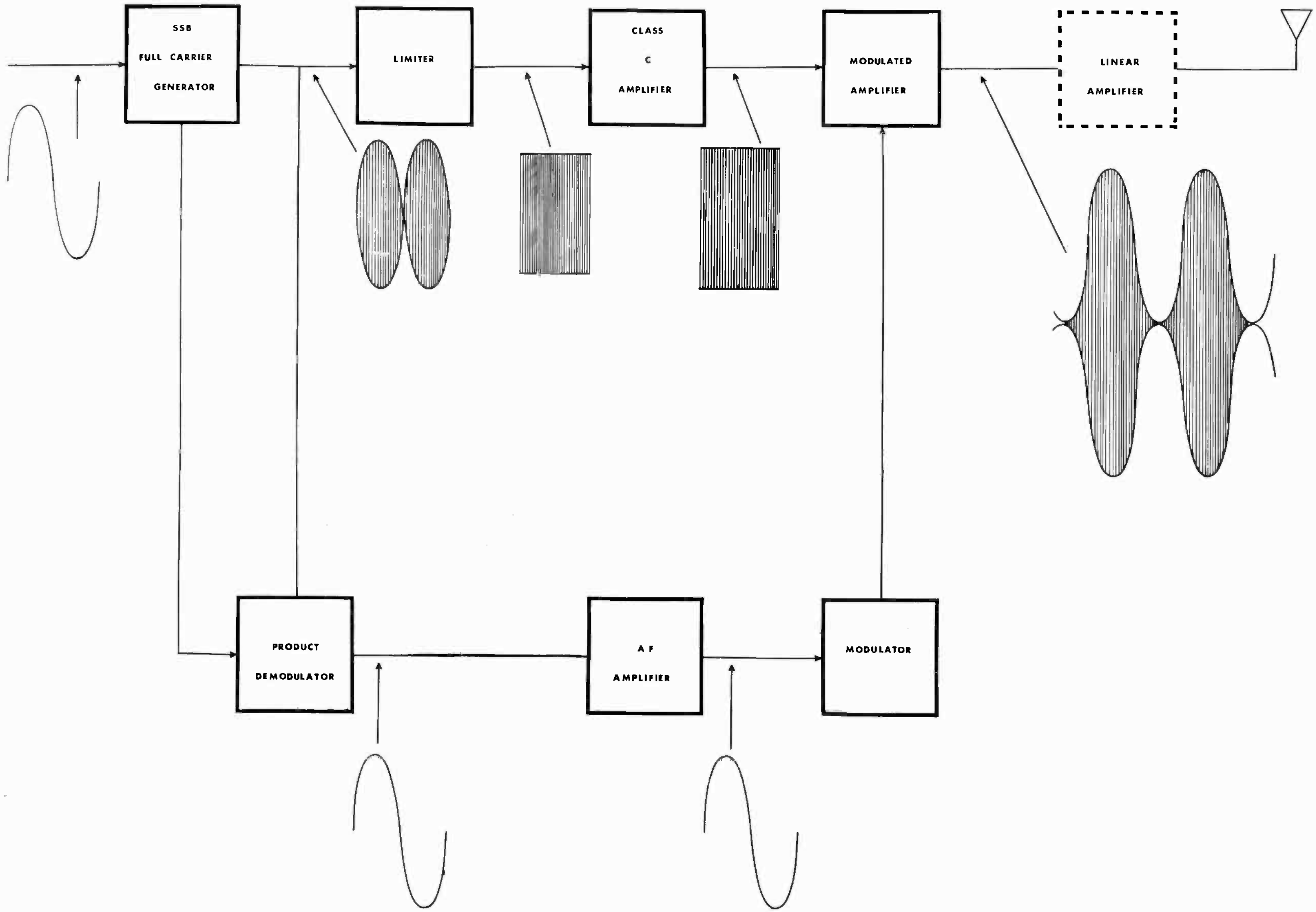


$$e = \frac{4}{\pi} E \left(1 + \frac{2}{3} \cos \omega t - \frac{2}{15} \cos 2\omega t + \frac{2}{35} \cos 3\omega t \ldots\right)$$

67% equivalent modulation approximately 23% distortion

For 10% distortion equivalent modulation 37.8%

SLIDE 1



BLOCK DIAGRAM OF BASIC COMPATIBLE SSB SYSTEM

"BRINGING RADIO TO THE PUBLIC"

Bringing Radio To The Public while certainly not a new subject, Bringing Radio To The Public - 1957 Style is bringing radio to the public in a manner that is different. Just a few short years ago we were concerned with the old, but not to be forgotten dance band remote, or the Saturday morning Amateur Hour from the auditorium of the local department store. Today it is not the aforementioned one-half hour dance band remote or the Saturday morning Amateur Hour, but the disc jockey who now occupies up to 5 hours of air time.

At WERE our programming structure is the block programming style of disc jockey around the clock. While many of you are responsible for stations which do not use this style of programming, I will endeavor to show you some of the types of equipment we use at WERE for disc jockey remotes lasting a minimum of 5 hours to all day operation from the field. Perhaps we use something which might be of value to you who do shorter programs of this type from the field.

While all our engineering planning for this type of remote is based on the use of technical personnel assisting the disc jockey, our system might also be adapted to the combo type of operation.

Our original attempt at doing the disc jockey remote came about in 1950 with the arrival on the Cleveland scene of our friend Television. In my mind, I compare our first attempts at this type of remote back to the old days of the carbon microphone with its companion, the storage battery. We, like many of you, went into the business of selling television sets with a real vengeance in 1950. A leading Cleveland dealer with stores on the east side and west side of Cleveland purchased sufficient amount of time to take our first 5 hour disc jockey remote to the field and I might add also, 5 days a week.

This meant taking a 70D turntable, a remote amplifier, a PA system, speakers and necessary small paraphernalia. In the few moments it takes to mention these items, it does not seem like a lot, but for those of you who have ever lifted a 70D turntable, you well know what I mean, when I say those days remind one of the carbon microphone and your storage battery era. After a 5 day period at one store all equipment had to be packed and taken across town. To those of you familiar with Cleveland, you know this was no simple task. A good half day's time was consumed in moving from east to west and vice versa. (Slide #1) This is a typical setup as used in those days. I might add at this point, all this effort was rewarded with success for both the sponsor and WERE.

We continued with the back breaking struggle for a few years with the studio type turntable. The popularity of this type of remote kept increasing until the need for more portable type turntables was almost a necessity. This type of remote was more and more in demand from restaurants and night clubs as an entertainment feature to supplant live entertainment.

The increasing popularity of better home record playing systems was a real blessing in disguise to us. Fairly decent turntables were available on the market. It did not take us long to start looking for something that would replace the 70D turntable. (Slide #2). As you can see in slide #2, we still had the remote amplifier plus an external PA system. We found that the PA system was almost as important a requirement as was the remote amplifier. At this stage of the game the back breaking element at least was eliminated. I might add at this point, we also were able to reduce overhead in doing this type of remote by utilizing WERE-FM to great advantage.

AT WERE, we never take any spot commercials to the field. All spots are played during these remotes from either a studio control room or master control, depending upon the time of day. Good FM tuners became available on the open market. Instead of purchasing a cue circuit from the telephone company, we utilize our FM signal as a PA feed for the audience watching our broadcasts. This gives the audience a complete feed of whatever is on our air. There is no reason why an AM signal cannot be used to just as good advantage. We happen to duplicate all programming on FM and there have been times when we have done these remotes from outlying areas where our AM signal is subject to night time sky wave interference. Hence, the use of FM.

Since WERE is a very alert station when it comes to promotion, we found that the disc jockey remote was one of the best promotional items we had. Not only were these remotes good for WERE, but these remotes were good for our advertisers. More and more of our disc jockeys were in demand to do their programs from the field. While we now had a light weight turntable, the whole operation was becoming too cumbersome. We needed better equipment. There was nothing available from any manufacturer that would supply our needs. What we needed was something that one man could handle with comparative ease.

We decided to build our own equipment and endeavored to put it into one package that was complete and still able to be handled by one man. After considerable deliberation and after many suggestions from members of the WERE engineering staff, we came up with a piece of equipment that we felt would certainly fulfill all requirements for this type of operation. We combined all the necessary facilities in one complete package weighing approximately 70 pounds. (Slide #3.) This unit has the necessary pre-amplifiers, line amplifier, turntable, PA system and all necessary controls. I might also add that we endeavored to make the operating controls correspond to all studio controls so that the operating personnel would be as familiar with field equipment as studio equipment.

This piece of equipment, which you have seen, fulfilled our fondest desires. It was, by comparison, light in weight and easily moved from location to location. We still are using this piece of equipment. In fact, I might add at this point, this piece of equipment is used as a part of a set in the closing shot of a TV show in Cleveland. We happen to do a 3 hour remote right from the studio of a local TV station. Our disc jockey is doing simultaneously a D.J. show plus commercials on a TV movie for the same sponsor. (Slide #4)

We are not alone in Cleveland in doing traveling D.J. shows. Our Manager, Dick Klaus, felt that we needed still something better. Certainly the type of equipment we had would not be adequate for all day operation from shopping center openings. We decided to equip a mobile studio on wheels, but our biggest difficulty was in finding the right vehicle.

We looked at all types of trucks, station wagons and trailers. We never could quite agree on what would really fill our needs.

One day, quite by accident, we came across an advertisement of a most unusual vehicle. I was dispatched to Illinois to look over this vehicle. When I first saw this truck, I knew we had found what we were looking for. I might add that this was one of those "once in a lifetime opportunities" to purchase a truck that would fulfill all our hopes and wishes for a mobile studio on wheels. We were very fortunate in that many basic needs were already in the truck.

Luckily this vehicle has been in the advertising field. An insurance company in Illinois had travelled this unit across the country to sell insurance. When we took possession of the truck, we naturally had to rebuild it to meet our requirements. The inner construction of the truck made it possible to allow for a studio and control room.

We decided to equip this truck completely to permit complete mobile radio independent of any outside facilities. While planning this truck to do a job for WERE, it became quite apparent to us that we could also do a job for the community. Here was an opportunity for WERE to do a "Public Service" job by combining the efforts of the Engineering Department and the WERE Promotional Department.

In planning the equipment for our mobile studio on wheels, we decided to equip the truck with as complete a setup as was possible.

We did our planning, keeping in mind other uses for this equipment besides actual broadcasting.

We did not want to limit our actual use of this truck. We started out by equipping the truck with a 5000 watt generator to supply all the necessary power for equipment, but also have sufficient power to light the truck on the inside and outside.

Our planning called for two turntables. Good turntables were now available and it was decided that we use 3 speed turntables so that we could play all types of records.

Our next problem was a console. Many of our equipment manufacturers had good small consoles available. One of our problems encountered in the field has been feedback. Therefore, it was deemed necessary that by using a small console we could take advantage of speaker relays to help beat this problem.

At the same time, space was a problem. We designed a special console table that would fit into the available space in the truck. The size of this console was such that we can remove it from the truck and use it also in the field at a semi permanent setup, such as an auto show where we might do a week's broadcasting. (Slide #5)

Some of our field pickups have come from areas where lines were hard to obtain. We added a 25 watt mobile FM transmitter so that we could go any place. There is a drawback to using mobile radio equipment. Low frequency response is poor on all available equipment. We use extended frequency response equipment, which gives us a very high quality voice channel. With our portable power plants, we can go almost any place.

We chose to use a directional antenna with our transmitter, figuring it was simpler to orient the antenna at the pickup point toward the receiver. So far this has proved a satisfactory way of doing mobile pickups from a fixed location.

I would like, at this point, to tell you of a mobile pickup we did from a ship on The Great Lakes. A new cruise ship called the S.S. Aquarama was brought to Cleveland last summer. The first night that this ship sailed from Cleveland was "WERE Night".

It was decided to also do our night disc jockey show while the ship cruised Lake Erie. In this instance we installed our transmitter and antenna aboard the ship on the bridge and did the actual broadcasting from one of the lounge areas. In this instance we did not attempt to play records aboard the ship. We used only a voice channel from the ship. We utilized our FM signal to feed the ship's PA system. I would like to say, at this point, that this was a very successful mobile pickup. We worked a range of 30 miles over water to our receiver. We had to keep a man on the bridge to rotate our transmitting antenna as the ship turned, but all our efforts were rewarded with a successful broadcast. (Slide #6) Incidentally, this broadcast covered a period of 4 hours.

In addition to the console, turntables and transmitter, we also equipped our truck with a tape recorder. We rack mounted all our equipment that was external to the console. (Slide #7)

The truck also has a 20 watt PA system with speakers mounted in the 4 corners.

All necessary switching equipment is readily available to the operator so that no connecting is necessary other than plugging in the microphones while out on location.

All equipment is set up to feed the studio by line or off the air pickups and simultaneously feed the truck PA, external PA systems and even, if so desired, a tape recording can be made. Likewise, the tape can also be used to feed the console or just the truck PA while the truck is in motion. I will go into this phase of our operation in more detail in a few moments. (Slide 8, 9, 10 & 11)

In putting radio on wheels, we have been able to serve two or even three masters. Not only do we provide the necessary technical equipment, but also a useful means to serve our Promotion Department and provide a real service to the public.

In addition to the technical equipment installed within the truck, we installed a theatre marquee type of sign on each side. We can advertise WERE or a civic venture. We use the same type of plastic letter with back-lighting as used by theatres on their marquees. This permits night time displays as well as day time signs. (Slide 12-exterior)

We have made this unit available to the City of Cleveland Police Department, Welfare Agencies, and Civil Defense Officials.

Last May a severe wind storm struck the West Side of Cleveland. Within an hour the unit was on the streets where severe wind damage took place, urging citizens off the streets because of fallen live wires. We were even requested to go to a district police station and supply power from our generators to light the police station.

We cruise this unit through the downtown areas supporting all civic drives such as Red Cross, March of Dimes, Community Fund. In these instances we make a tape with our air personalities interspersed with music urging citizens to support these worthwhile civic affairs. Not only do we help the community, but we are helping WERE at the same time.

I would like to quote you an example of how a unit of this type can help a station. The City of Cleveland was in dire need of having a Tax Levy passed. All media was striving to have this Levy passed, at a special election. I was sitting in an office of an advertising agency, going over some problems in connection with our baseball network and suddenly the sound of music came up from the street. The man said to me, "I hear you are out trying to get the Levy passed". Cleveland has come to expect WERE out on the streets to aid any worthwhile civic venture. This typifies how we use our generators, tape recorder and PA system while in motion.

The evolution of our equipment has followed closely, the evolution of the engineer's role in Bringing Radio To The Public - 1957 Style. Our job today is not only transmitters, antennas, control rooms, but how we can best adapt our tools to today's changing needs.

ml

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THE APPLICATION OF MODERN TECHNIQUES IN MAKING GOOD RECORDINGS

by

C. J. LeBel

Vice President

AUDIO DEVICES, INC.

PRESENTED AT THE NATIONAL ASSOCIATION OF RADIO AND TELEVISION BROADCASTERS ENGINEERING CONFERENCE IN CHICAGO ON APRIL 9, 1957

To their profound surprise many radio stations have found that radio is here to stay, and still more surprising to them, it is profitable. This suggests the need for improvement of audio facilities, and especially of recording facilities, due to the recent rapid progress of the art. We say "especially of recording facilities" because a well run station leans heavily on recording, and because much recording equipment is by now showing its age rather badly. For example, disc equipment is often six to twenty years old; and tape equipment is in too many cases five to eight years old, often wholly obsolete. Speech input facilities that feed the recording room are often ten to twenty years old. As a result, there is a serious lack of uniformity of results from one machine to another, as well as a need for general quality improvement. Finally, many combined FM and AM stations are considering the use of stereophonic broadcasting to enhance listener satisfaction. This is a new development which has aroused a great deal of listener interest.

DISC RECORDING

Let's start with the disc section of your recording room, for disc still has important advantages for the station; it is far from dead. Every station should use a heated stylus for lacquer recording, though too few do. This change offers a significant improvement in signal to noise ratio (up to 15 or 20 db), and a great reduction in change of frequency response with diameter. The latter is due in major part to the smaller burnishing facet which heat permits. If the station is using microgroove recording for economy, hot stylus is a complete necessity. Every phonograph recording studio has long since made the change, as have all conscientious transcription studios.

A further improvement in signal to noise ratio may be achieved by use of a more powerful recording amplifier. In too many cases older recording amplifiers overload before the cutting head does, so that the recording level is 4 to 10 db less than it should be or the distortion (on peaks) is far higher than it should be. Many older amplifiers can deliver only a small fraction of their rated power at low or high frequencies. This points in the direction of an amplifier able to deliver its full power of 75 to 100 watts from 40 to 15,000 cps. For protection of the cutting head, of course, a limiting amplifier must precede the power amplifier.

In view of the improved low frequency response of so many home high fidelity systems, it is highly desirable to reduce rumble. It may be reduced by 10 to 15 db through use of a recording lathe in which the motor and speed reducing mechanism are mounted separately from the turntable and carriage. In doing this with available equipment the carriage drive will also be better isolated from the turntable, so that audible rumble will be eliminated from the record. When getting the new lathe it would be desirable to specify variable recording pitch, which is very useful in microgroove work. Whereas 22 minutes is considered the maximum desirable microgroove recording time on a twelve-inch disc without variable pitch, the latter allows up to 30 minutes of music and up to 38 minutes (for speech only) without degradation of performance. Many phonograph records are made using this technique. Incidentally, the best modern lathes are rigid enough to handle even the heaviest of feedback type cutting heads.

This brings us to the most modern type of recording head -- that using negative feedback in conjunction with the driving amplifier. Increasing numbers of our better recording studios have adopted this technique because of the improved stability, wider frequency range and lower distortion that it affords. This method is essential if response is to be maintained uniform up to 15 kc, which is standard in the phonograph and transcription fields today. There are two methods of taking the feedback voltage from the cutter: in one, a feedback coil is mounted on the magnet structure; while in the other, it moves with the driving system. The first method linearizes only the magnetic characteristics, while the latter also takes care of mechanical nonlinearities. Feedback cutters are usually larger and heavier than nonfeedback types, and in fact, some are so large and heavy that they can only be carried on the largest and most costly lathe. Fortunately or unfortunately, it is these very heavy cutting heads which seem to offer the best characteristics available today.

The increased power handling capacity of the feedback cutter may be used to advantage in applying diameter equalization. It has been said that diameter equalization is undesirable when NARTB preemphasis is used. This may or may not be true, but it is certain that all leading recording organizations are using diameter equalization. The technique is more practical today because the use of hot stylus calls for much less diameter equalization than was the case years ago. It is general practice to compensate for a little of the reproducing diameter-effect, as well as for all the recording diameter-effect.

TAPE RECORDING

We haven't forgotten tape during this discussion - how could we? The radio station of today could not operate without tape, since even its disc recordings are made originally on tape.

Rapid improvement in recorder quality has left many stations with obsolete equipment, with 10 db poorer signal to noise ratio, double the percentage of wow which can be obtained today, and lacking the amenities necessary to secure uniform results from all machines of a group.

A newer recorder will in many cases raise signal to noise ratio from 45 up to 55 or 60 db, as referred to the NARTB standard 3% harmonic distortion level. Wow and flutter may be reduced from 0.3 or 0.4 percent to 0.15 or 0.2 percent. This is a very substantial reduction in terms of inaudibility to the listener.

The better machines provide for adjustment of bias current, which is essential to uniformity of results from all machines in the recording room. Uniform bias helps to assure the same distortion-free maximum recording level from all, and the frequency response remains more uniform from one batch to another.

If older machines are to be retained in use it would be desirable to correct the 15 inch per second equalization to the NARTB standard so that transcription tapes may be played properly. As yet, there is no official standard of 7½ inch per second equalization, though the Magnetic Recording Industry Association is working on the problem. Three different characteristics are presently in use.

The FM-AM station should consider adding a two channel stereo recorder so that the new stereo tapes may be played (the two tracks on separate transmitters) to full advantage. From the trend of industry discussions future standardization will probably adopt stacked heads, though both stacked and staggered recordings are presently available in most cases. If a great deal of commercial recording is being done, a three track machine (using half inch tape) will be found very useful, since the recording may be remixed before mastering. This is a technique which is just now beginning to come into use in the phonograph field. The three tracks may be used as follows: one track is reserved for the soloist or for solo instrumental passages, the other two tracks are reserved for different sections of the orchestra. These tracks are all combined into a single one by re-recording before disc mastering, and during this operation the balance may be adjusted with great freedom. This offers substantial advantages in the direction of saving time during the original recording. It allows for a great many afterthoughts to satisfy the artist.

In order to avoid unfortunate accidents and facilitate filing, it would be desirable to use commercially available colored reels for material of permanent value (such as master tapes); still more certainty would be provided by using commercially available colored tape. Several colors are available in the tape and quite a number of colors are available in the reels.

While we are discussing reels of permanent value, it might be well to take up the question of storage of historical material. Stations have always been rather good about keeping their lacquer discs of possible archival value, and this was found very helpful in preparing analytical material before, during and after World War II. Unfortunately, too many tapes of historical importance have been given to the news room for reuse. This is robbing many a station of a chance to build up a priceless historical record of the troubled times. Historical material, if on acetate base tape, should be stored in a temperature and humidity controlled vault. If on Mylar polyester base, the humidity control is unnecessary and the temperature control may be minimized. Frank Radocy, of our organization, presented an exhaustive study of tape storage problems before the Audio Engineering Society's Annual Convention in September 1956. This will be published in the Journal of the Audio Engineering Society, and reprints will be available.

OTHER AUDIO FACILITIES

If a great deal of studio recording is being done, a custom built mixing console will be found very advantageous. Leading studios prefer to put individual high and low frequency equalizers in each mixer position. These can both boost and attenuate in small steps. For some reason stations have not liked mixers of such complexity. Modernization of studio acoustical treatment might well be considered at the same time.

New turntables with rather low rumble content should be used with the new console; the signal to rumble ratio, as measured by the NARTB standard method, should be at least 50 or 52 db. Turntables of some years ago very seldom had a ratio better than 40 or 42 db. This change provides a very substantial improvement, perhaps 20 db in subjective effect. A change in turntables should be accompanied by a change in pickups.

Stations have made too little use of controlled reverberation. Added reverberation or echo, properly used, is a pleasant flavoring for much musical material (particularly the older records), and an effective spice for spot announcements. The simplest form of artificial reverberation has been produced by feeding the output of an ordinary type recorder back to the input; this has been done so often that it has palled on the listener -- a more intelligent approach is needed.

Of course, an echo chamber may be built which will be effective if large enough -- say, 10,000 cubic feet or more. The converted storage closet, with a volume of perhaps 1,000 cubic feet, has inherent acoustical faults which soon irritate the listener.

A more convenient method is the use of a commercially available magnetic tape loop reverberation generator, using five to eight heads (some movable on guides) and a reentrant electronic system with extraordinarily flat frequency response; thus very effective results may be secured. Reverberation should not be thought of as a patent medicine, to be added two drops at a time to each program. Properly controlled reverb has a definite personality of its own, and this personality should change to best fit the program. Some programs call for entirely natural character, while others benefit from a deliberately theatrical sound. Reverberation generators are much more flexible than the usual echo chamber, and in the four years or so that they have been in broadcast use the engineer has found it wise to use this flexibility to the utmost.

If live stereo programs are to be handled, a studio must be equipped with one of the larger standard consoles. These generally have two volume indicators and full provision for split channel operation, tho quality on the second channel is not always equal to that on the first. The same studio may be used for stereo recording as well.

CONCLUSION

By utilizing modern techniques the broadcaster may produce recordings of greatly improved quality. It is desirable to improve the performance of recording lathes, cutting heads and tape recorders. The use of colored tape and colored reels is desirable for identification purposes. More flexible consoles and tape reverberation generators are facilities which can improve the recorded product. In view of the importance of recording to the broadcaster, and the advanced age of many facilities, a systematic modernization program would be very desirable in many stations.

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SPECIAL EFFECTS IN COLOR PROGRAMMING

by

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Development of television programming techniques through the years has roughly followed the same lines as the motion picture industry. In the early beginnings only one camera was used. As soon as multiple camera setups were made, switching from one to the other became a necessity. After a while plain switching was considered undesirable and replaced by fading whenever conditions called for it. That, in turn, led to sustained use of the superposition of two pictures which can be considered as the first step towards more and more elaborate special effects. The often used and misused expedient of split faders goes one step further because it provides individual control of the levels of the two pictures in question. In order to eliminate undesirable effects of this technique often caused by improper level control, video keying of one picture into the other was developed. That, together with a large variety of wipes and inserts forms the available repertory of special effects in television programming. A large number of these are available and new ideas can be seen on the air quite frequently. Still, there are not nearly as many as we see produced optically on film but there is no doubt that we are still far from having reached the limit of the development of electronically produced effects in television.

The development as mentioned so far has mainly applied to monochrome television. There is no reason why color should follow a different pattern of progress. No doubt experience to date shows that it is going through the same steps. For good reasons, fading and special effects are being used more judiciously in color. These reasons are both artistic and technical. Some superpositions and other effects do not look good in color largely because additive mixing at times produces an undesirable final result. But even more important is the technical consideration because handling a color signal proves to be much more critical than monochrome. This mainly refers to the very strict requirements for maintaining the phase of all color subcarrier components which means extremely accurate delay equalization and phase linearity. This can be particularly troublesome in the case when a coded color signal is to be used for video keying in addition to the fact that it often is hard to produce a good keying signal from a video signal containing a large amount of color subcarrier. All these points have limited the use of special effects in color up to now.

Another important consideration is the difference in appearance between color signal sources. It often is a cause for complaint even in the case of straight picture switching. Moreover, in the case of split screens and similar effects, when portions of two separate pictures are viewed at full level for a sustained period of time, differences between color signal sources become much more apparent. A good way to minimize these differences is to use common equipment as much as possible. This can be done easily starting at the point where the individual signal amplitudes are in the range of .25V. This level has been accepted as an

approximate standard for the output of most primary signal sources. From that point on the signals originating from several different sources can be readily handled through the same processing chain including gamma correction, electronic masking, and color coding. Avoiding the duplication of all these units for each color signal source pays off not only in greater uniformity of the final signal but also in a considerable saving. Wherever different processing is required for various signals in the same overall system, this can be accomplished by relays actuated from the switching system.

Handling tricolor signals obviously introduces other problems. Triplication of some units of equipment must not become too cumbersome or expensive otherwise too many of the above mentioned advantages would be nullified. A good example of that is switching where the first tried approach of operating three remotely controlled relay switches in tandem proved to be completely impractical. Apart from the size and cost of the equipment necessary to do this job, switching could not be made sufficiently simultaneous. Only a switching system in which contacts for all three colors are operated by the same relay can possibly succeed. The Philco Video Relay Switching System maintains switch timing equal within one millisecond.

Since existing monochrome switching systems are available for use with fading and special effects, it became necessary to design units for these functions. The requirements for a mixing and fading amplifier are much stricter than for any design for one line. A main problem is producing good tracking between three amplifiers so that white balance will not be disturbed in the fading process. This, in turn, means that not only the transfer characteristic but also the fading control characteristic of the amplifier has to be highly linear. Since regular mixing and gating of two signals for special effects are two closely related functions, it was considered desirable to combine them in the same amplifier as long as this can be done without any undue complication.

Any unit meeting the above mentioned requirements will obviously also be up to the high standards of performance needed for use with color coded signals. This is essential because the switching system in conjunction with which the amplifier is designed to work also handles all kinds of color and monochrome signals.

Figure 1 shows a simplified block diagram of the Fade and Gate Amplifier indicating also the units to be used in direct conjunction with it. Considering the block labeled "Delay and Video Pickup" bypassed, both video signals first enter the gain control stages which produce fading. Leaving the gain controls, the signals are clamped and then fed to the gate amplifiers. The gated video signals are combined and pedestal is inserted and clipped to eliminate transients. The output amplifier pro-

vides dual source terminated outputs.

A few circuit details should be mentioned. A simplified schematic of the gain control amplifier is shown in Figure 2. In spite of the large number of tubes the circuit is straightforward and was mainly designed to meet the strict linearity requirements. V_1 and V_2 form a cascode amplifier and V_3 and V_4 are a single ended push-pull amplifier. In order to provide equal but opposite input signals for V_4 and V_5, the bottom of R_8 requires a video connection to the top of R_5. If this is done with a capacitor coupling into a large dropping resistor, undesirable changes in plate voltage of V_2 and bounce result. Therefore, the cathode follower V_3 is used to provide the necessary connection and at the same time keep the plate voltage of V_2 constant. The circuit is not sensitive to changes in tube characteristics within normal limits.

The right side of Figure 2 shows the trim potentiometers R16 through R21 and the main fader control R22. By proper adjustment of the trim potentiometers it is easily possible to achieve the necessary tracking of 3 channels to maintain the white balance of tricolor signals.

Figure 3 shows a simplified schematic of the dual gate amplifier and adder. Tubes V1, V2, and V3 form a cascode amplifier for Video 1, and V4, V5, V6 do the same for Video 2. The pair of triodes forming the upper half of each cascode are in parallel for video but in push-pull for the gate signal. Assuming a positive gate input, the plate of V2 goes negative and the plate of V3 goes positive. Current is drawn through the crystal diodes CR1 and CR2 and Video 1 is gated on. Similarly, CR3 and CR4 are cut off and Video 2 is gated off. The output is obtained by tying the junction points of the crystal diodes together. R9 is a DC balance control setting the crossover point of the two gates. Overall DC coupling facilitates balancing and eliminates problems due to changes in duty cycle.

At any given instant the amplifier will normally be used either for the gating or fading function. The unwanted function is made inoperative by having the amplifiers handling it turned on full. This is accomplished with relays operated from a control panel to be shown later. Should further studies show that desirable effects can be achieved by having both fading and gating functions operative simultaneously, this feature can be added without difficulty.

A simplified block diagram of the Montage Gate Generator is shown in Figure 4. Horizontal and vertical drive signals are used to produce triangle and sawtooth waveforms in conventional circuits. Relays K1 through K6 select the desired combination of waveforms. To produce horizontal and vertical dividing lines, both signals are individually clipped and then combined in an adder. To produce diagonal dividing lines,

the horizontal and vertical waveforms are first added and then clipped. This function is controlled by relay K7.

Horizontal and vertical drive signals are also added to provide a residual gating signal during the blanking interval at all times. This has no visual effect on the produced picture but maintains an AC signal through the whole chain even at the end position of the control when no actual gating waveform is present.

Video keying produces somewhat different problems and results. It is divided into two basic categories depending on the source of the video signal used for keying. It may either be one of the two signals making up the composite picture or a third signal, usually a simple geometric shape originating from a slide. These two cases are referred to as self keying and external video keying.

In either case the video signal to be processed is fed into the gate generator from video pickoff points in the fade and gate amplifiers. Three stages are provided to mix red, green, and blue signals, if required, but it will often be desirable to use only one or two of these signals. The signal is amplified and thru relay K9 applied to a clipper, the level control of which is set for best picture appearance. Through relay K8 and the other clipper it is possible to "wipe on" the video keyed effect in a horizontal or vertical direction or some of the other wipe patterns.

The stages the keying signal has to pass through produce a delay in the order of several tenths of a microsecond. In case of self keying it is required to have the keying signal and keyed signal coincident to avoid undesirable transients. Consequently, the video signal has to be delayed an appropriate amount.

The circuits described so far are merely the tools to produce the desired final result. The usefulness of the system depends largely on the control panel which has to coordinate a large number of functions in a small space with a logical layout making selection and identification easy.

Figure 5 shows the chart indicating possible wipes and similar transitions between pictures. This layout purposely leaves room for planned expansion and shows a number of effects not presently incorporated in the unit. These and many other additional effects, however, can be added in the gate generator without complications. Two rows of pushbuttons, one on top and the other one on the right side of the transition pattern selection chart, control the desired effect. Depressing one button in each of the two rows produces the transition indicated at the intersection of their coordinates. A lamp lights under the selected pattern for immediate identification. The two banks of pushbuttons just mentioned control relays K1 through K8 in the gate generator.

A picture of the control panel is shown in Figure 6. It contains the just mentioned series of pushbuttons for pattern selection, the transition control, and several other switches to be mentioned shortly. The wipe transition control is constructed in the form of a stick with freedom of motion in four directions. The potentiometers controlling the clip levels in the gate generator are operated by that stick through appropriate gearing. The direction of motion of the stick is logically tied in with the desired effect and the proper starting point is indicated on the transition pattern selection chart. If an accurate diagonal motion is desired, depressing the top of the control stick makes it engage into a diagonal guide.

A series of four pushbuttons can be seen near the upper righthand corner of the control panel. These buttons serve as function selectors to choose wipe, external video keying, video self keying, and fading. Each of them controls the proper relays in both the gate generator and the fade and gate amplifier in order to produce the wanted effect.

In the "wipe" position the banks of pushbuttons associated with the selector chart and the control stick are operative. In the two video keying positions the signal at the external video input or at Video 2 input is used to form the keying signal with the control stick determining the most desirable clipping level. In the "fade" position only the fader handles on the regular switch panel are operative while the gating function is disabled.

The features described so far are strictly applicable to monochrome use and do not pertain specifically to color. Only the two fairly inconspicuous rotary switches close to the control stick are unique for color operation. They both normally operate with video keying only, though the use of the righthand switch in connection with the wipe function can produce some interesting colored transition patterns.

The left switch selects which color component of a tricolor video signal is to be used to produce the video gating waveform. The possibility of selecting just one component of the tricolor signal ahead of the color coding process offers the distinct advantage of being able to have a video waveform available that has the right shape to be easily processed into a gating signal. The switch has enough positions to take care of any individual or combination of two or all three color signals.

The "gated channels" selector switch on the righthand side has identical labeling but is even more important for the production of special effects in color. It controls which color channel is to be used for mixing and gating. This feature makes it possible to control the color of the inserted video at will regardless of the original color of the object. This can be done with external video keying or self keying but probably is most effective in the latter case.

Although experiments with the system so far have been limited, indications are that the number of special color effects that can be achieved through it is strictly unlimited. The possibility of controlling the individual color components before they lose their basic identity in the coding process opens up a wide new area of special effects which are peculiar to color operation and which cannot be achieved with color coded signals. Obviously, more controls can be added to extend the scope of effects that can be produced. One of the first possible improvements is the replacement of the present "gated channels" selector switch with a combined switching and fading mechanism to allow smooth transitions between colors instead of abrupt changes.

The work on which this paper has been based is very recent and still in progress. Obviously, more ideas will be developed shortly to increase the possible scope of application and any suggestion will be highly welcome. The extreme flexibility of the system provides a fertile field for the ingenuity of operating engineers in working out new and different combinations of color effects but an experienced program director will most likely be able to think of many applications beyond the limits of the engineer's imagination.

No doubt the recent progress of color television has been disappointing to the whole industry. To reach the necessary degree of public acceptance it will have to provide entertainment values which monochrome television cannot supply. This paper is presented in the hope that the just described ideas on special color effects will make a contribution towards this objective.

ACKNOWLEDGEMENT

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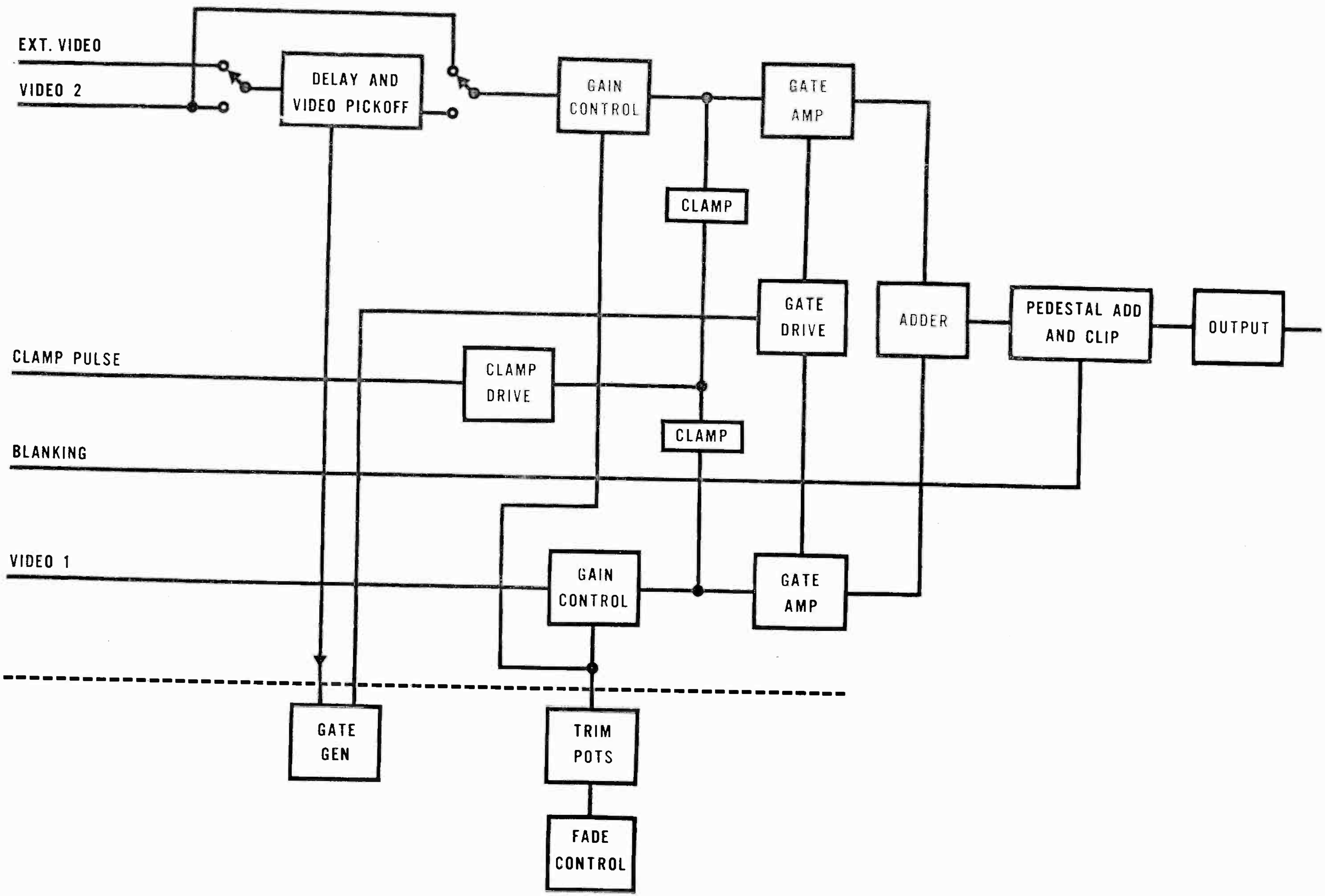

FIG. 1 FADE AND GATE AMPLIFIER

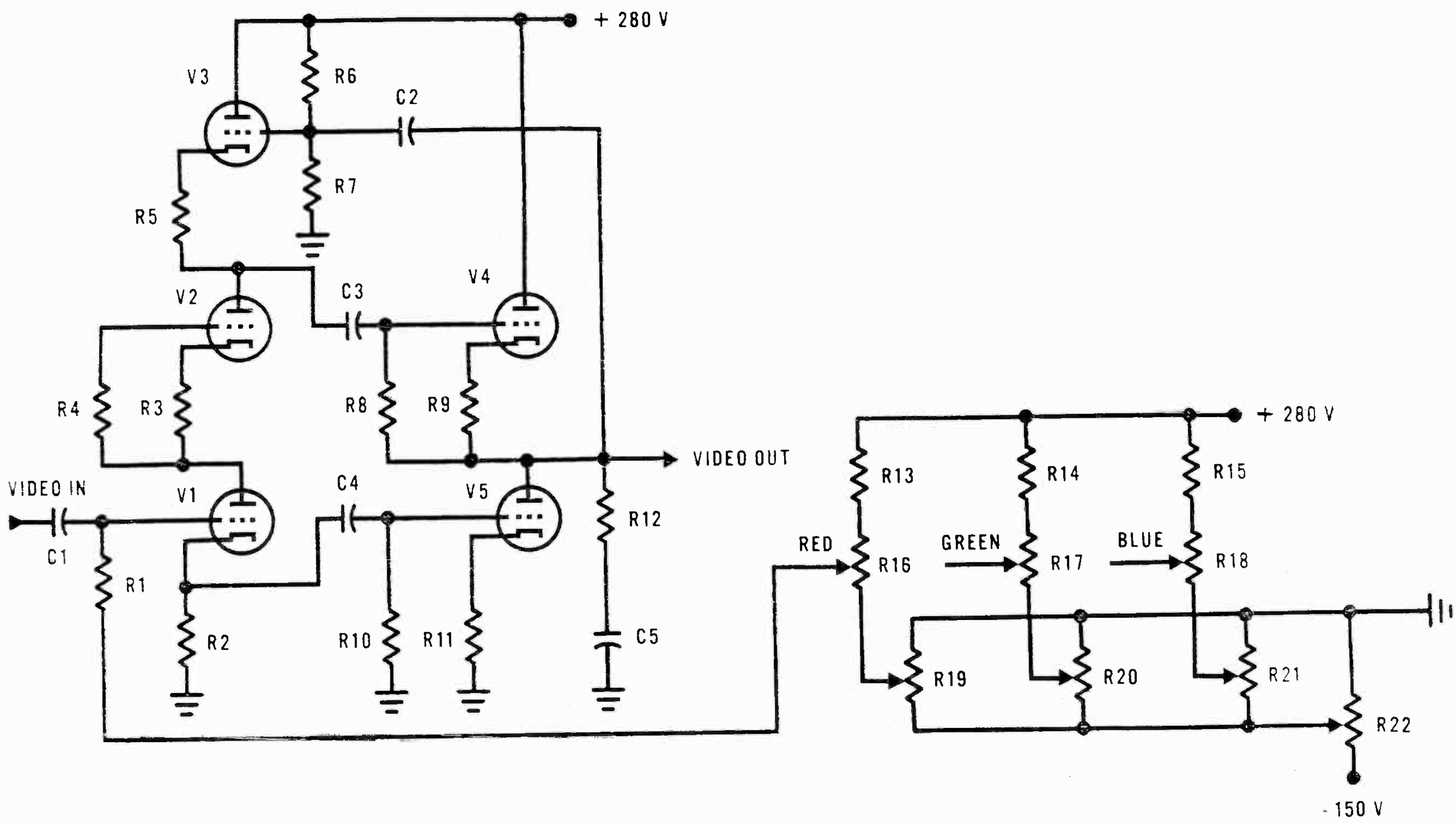

FIG. 2 GAIN CONTROL CIRCUIT

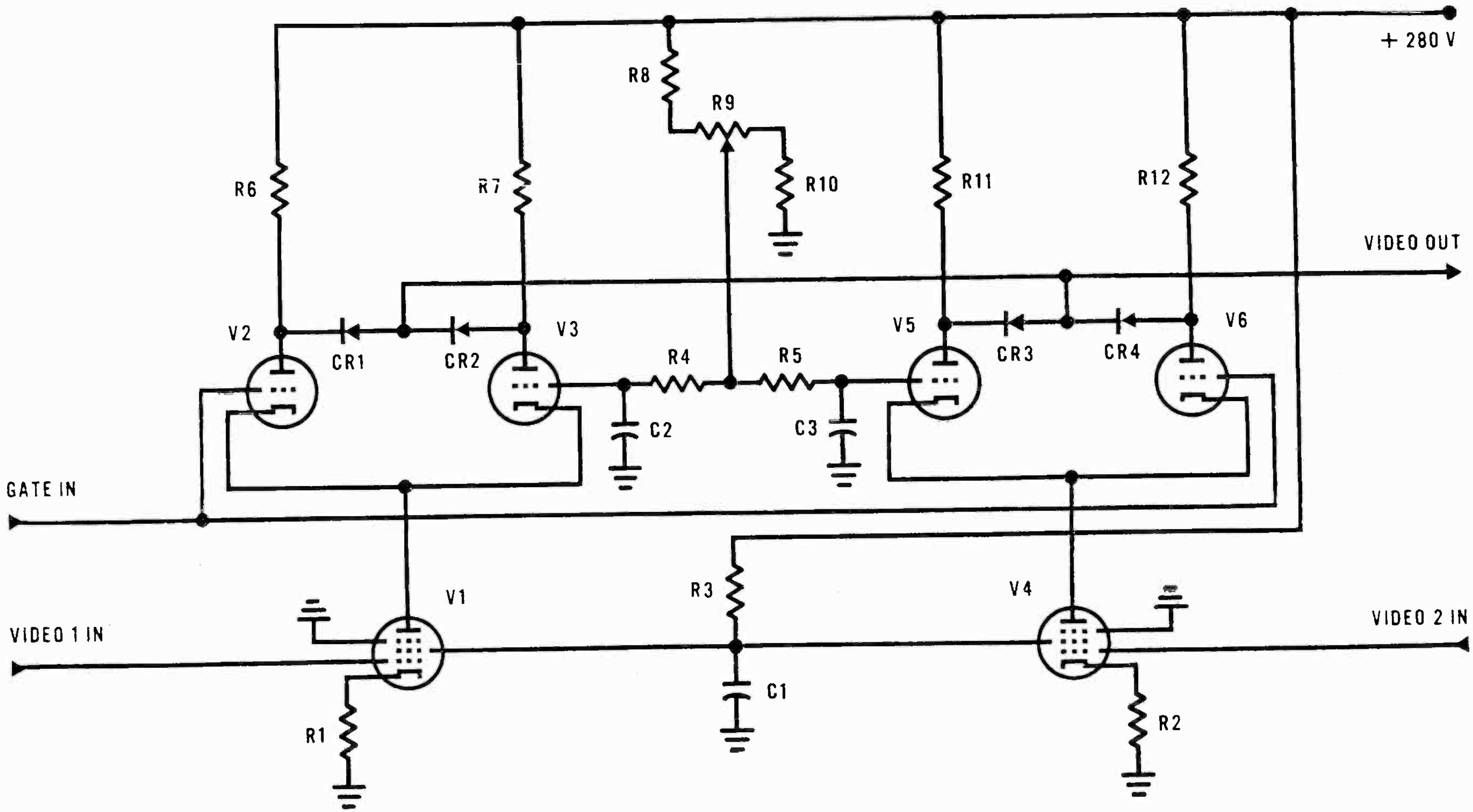

FIG. 3 DUAL GATE AMPLIFIER AND ADDER

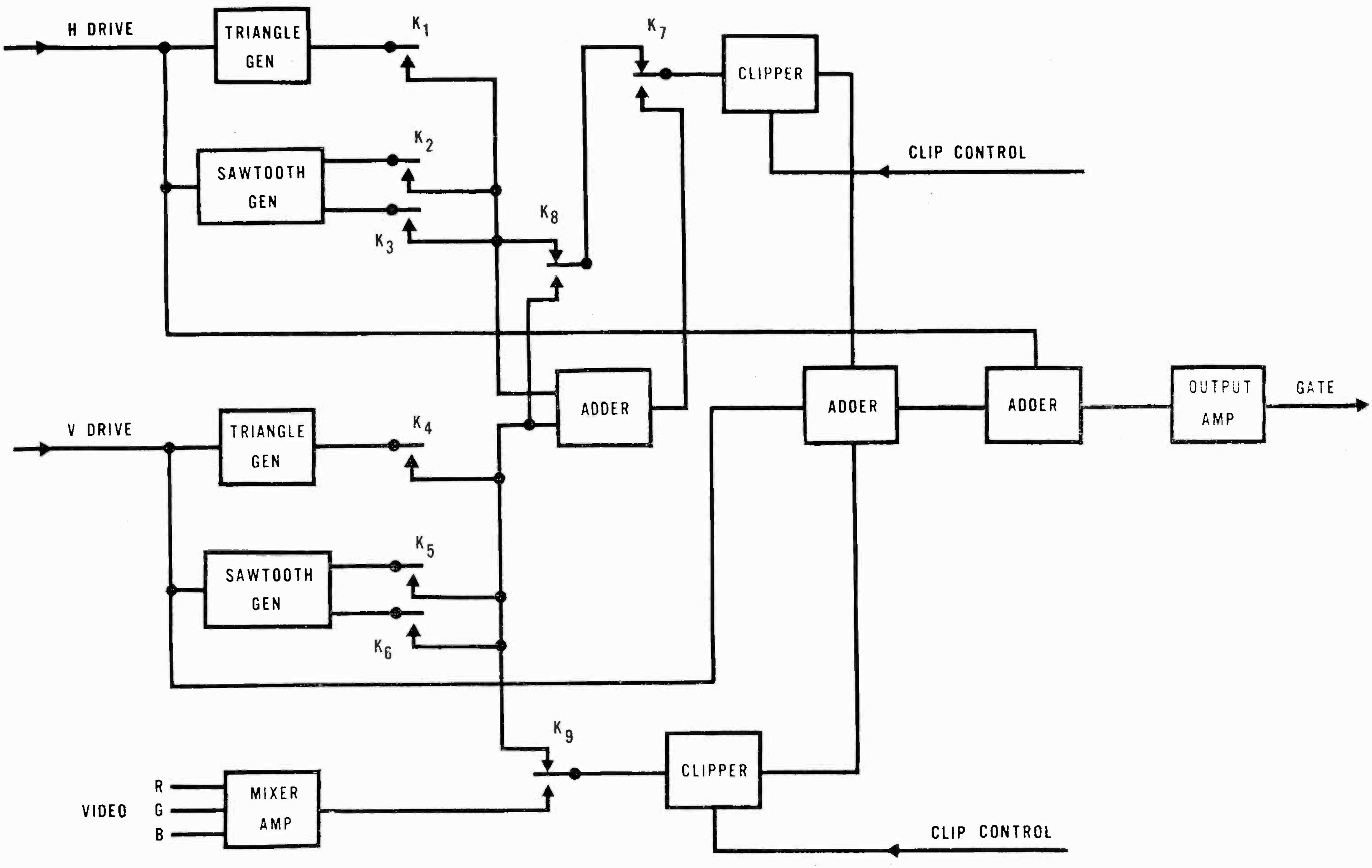

FIG. 4 MONTAGE GATE GENERATOR

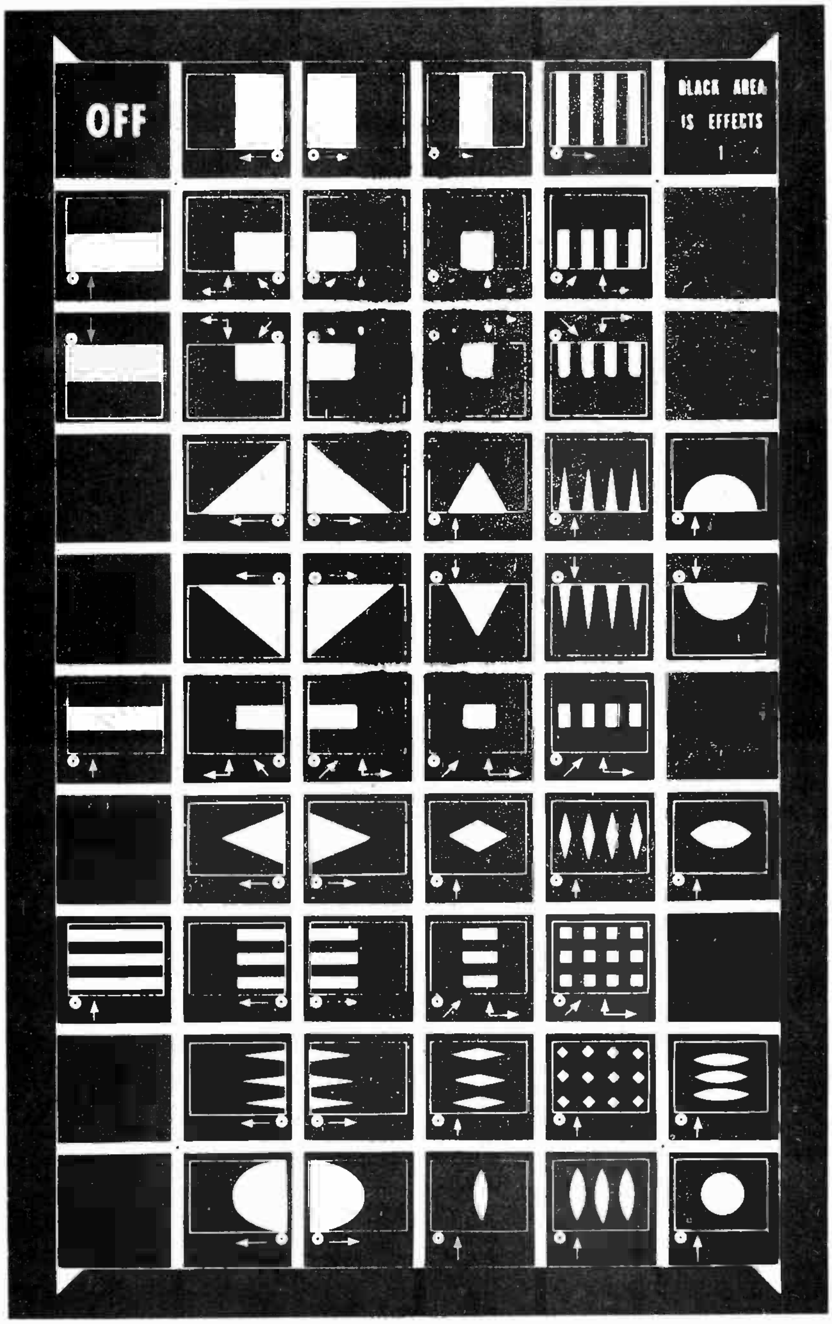

Fig. 5 Transition Pattern Selection Chart

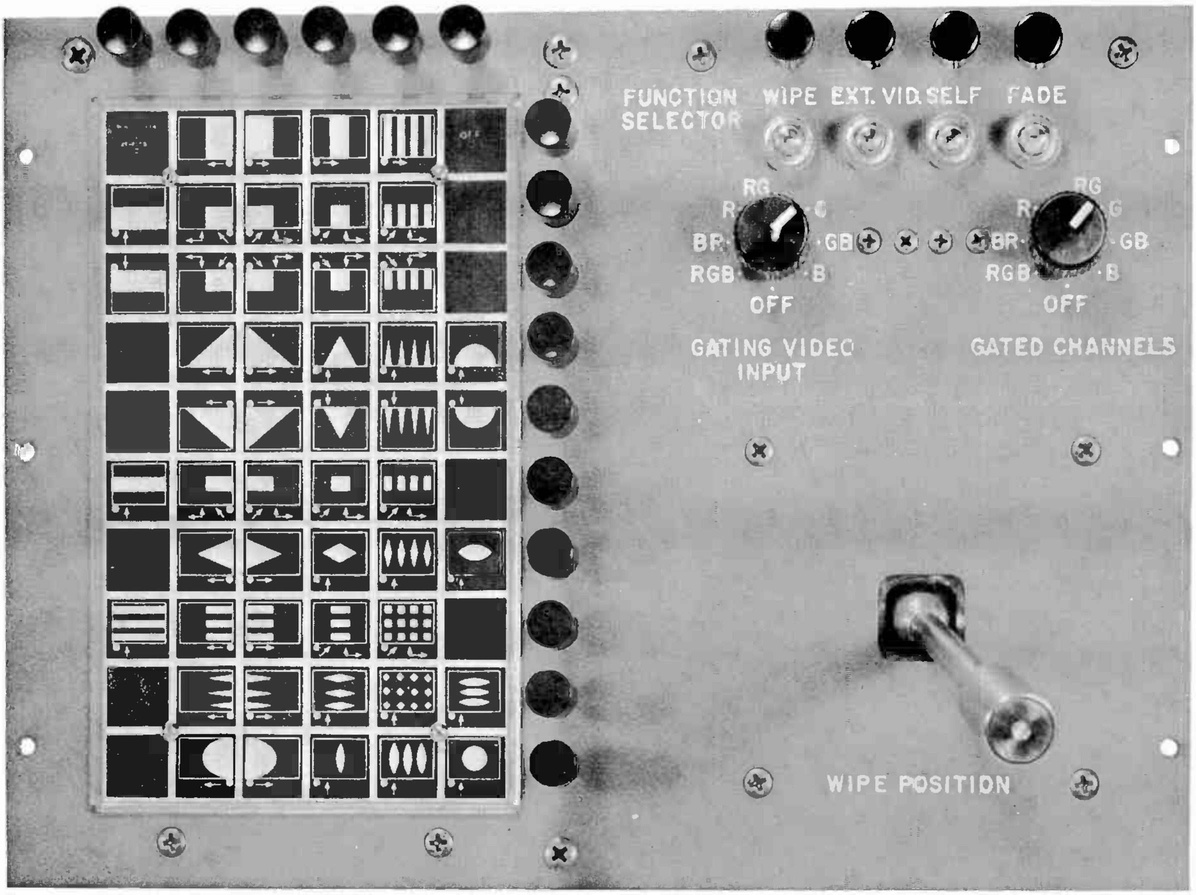

Fig. 6 Montage Control Panel

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A STUDY OF TECHNIQUES FOR MAKING FIELD INTENSITY MEASUREMENTS AT VERY HIGH AND ULTRA-HIGH FREQUENCIES

by

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APRIL 10, 1957

A STUDY OF TECHNIQUES FOR MAKING FIELD* INTENSITY MEASUREMENTS AT VERY HIGH AND ULTRA-HIGH FREQUENCIES.

by Howard T. Head, Partner, A. D. Ring & Associates
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A television industry sponsored group is currently undertaking, at the request of the Federal Communications Commission, studies of the engineering factors influencing television reception. These studies are being carried out by the Television Allocations Study Organization (TASO), jointly sponsored by the Association of Maximum Service Telecasters, the Committee for Competitive Television, the Joint Council on Educational Television, NARTB and RETMA. The Association of Maximum Service Telecasters, through the facilities of our firm, is conducting investigations into wave propagation problems in the television broadcast bands, with the ultimate aim of collecting field intensity measurement data in a number of the major television markets in the United States. These and other measurements will form the basis for new propagation curves and data to be made available to the Commission as a basis for future television allocations.

At the present time, no accepted standard measuring technique is generally recognized for the collection of field intensity data for this purpose. Several methods have been proposed, but only limited data have been taken and studied comparing the various techniques. The first step in a comprehensive measurement program, therefore, is the standardization of an accepted technique which will yield data suitable for the intended purpose.

The Commission's Radio Propagation Advisory Committee (RPAC), through its subcomittee on methods of measuring service fields, has listed five criteria to be met by a measuring technique. These criteria, which are intended to be applied primarily for measuring individual station service areas, are:

"1. They (The measurements) should indicate whether or not the transmitter and antenna system are performing in the manner predicted in the application for the facility.

"2. They should determine the extent and quality of service rendered by the operation, showing the areas not getting satisfactory service as well as those getting good service.

"3. At least some of the measurements should be suitable for technical studies and should add to the general knowledge of propagation conditions in the frequency bands involved.

"4. The measurements should be reasonably reproducible, so that they may be checked at a future date if desired.

*This work was sponsored by the Association of Maximum Service Telecasters, Inc.

"5. The techniques for making these measurements should not be too impractical or expensive."

As pointed out, these criteria are primarily intended to be applied to the taking of measurement data for the purpose of establishing the service areas of individual stations. In making measurements to be used as a basis for preparing general propagation curves, considerably more emphasis must be placed on the third criterion than would otherwise be the case.

Among the methods which have been suggested are:

a. mobile measurements in an airplane or helicopter;

b. continuous mobile measurements in a ground vehicle using a receiving antenna 30 feet above the ground;

c. similar measurements using an antenna approximately 10 feet above the ground;

d. short segments of mobile measurements at regular intervals along a radial route using a ground vehicle with a 30 foot antenna;

e. so-called "cluster" measurements; and

f. spot measurements in a prearranged pattern which is chosen to minimize correlation between measurements.

Most of the measurements on television service fields now available consist of continuous mobile recordings in a ground vehicle with a receiving antenna height of approximately 10 feet above the ground. Measuring routes have usually been chosen to extend generally radially outward from the transmitting antenna. A variety of receiving antennas has been employed by various engineers.

The principal objection to 10-foot mobile measurements is that a conversion factor is required to relate the field intensities measured at 10 feet above the ground to those actually obtaining at the height of typical home receiving antennas, which is presently taken to be 30 feet above the ground. Simple propagation theory, assuming a smooth spheroidal earth, indicates that for these receiving antenna heights, the field intensity should increase linearly with antenna height, or approximately 9.5 db from 10 feet to 30 feet. Experience has shown, however, that the actual relationship may vary substantially from that predicted by the simple theory, and in many instances the field intensity may actually decrease with higher receiving antenna height.

Mobile measurements with a receiving antenna height of 30 feet are impractical for the mass collection of data, since overhead wires and other obstacles are almost universally encountered along practically all major and minor roads. Short stretches, however, may be measured at a 30-foot receiving antenna height, and in the "cluster" and "spot" measurement techniques, individual measurements can be made at the 30-foot height, since the vehicle remains stationary while the receiving antenna is elevated. One of the most serious objections, however, to any technique requiring individual spot measurements at these frequencies, is

the wide variation in field intensity over very small distances (on the order of a wave length or so) due to high standing wave patterns which become increasingly more severe at the higher frequencies, especially in rugged terrain.

The purpose of this presentation is to describe experiments now being conducted for the purpose of comparing results using several of the techniques described. These experiments are still in process and the data are in no sense to be considered as complete or conclusive, but are presented at the present time as a matter of interest.

Our firm has equipped for the Association of Maximum Service Telecasters two mobile measuring units as field laboratories for the collection of field intensity data. The units are identical, and each unit consists of a Chevrolet station wagon containing the necessary equipment.

Figure 1 is an exterior view of one of the vehicles showing the receiving antenna mast in the retracted position for traveling. This mast was manufactured by the Thomas Mold and Die Company of Wooster, Ohio. It can be elevated in about 20 seconds time to a height of 30 feet by means of a hydraulic pump, and will support two receiving antennas at the 30-foot height; this is shown in Figure 2. This mast consists of five telescoping sections of aluminum tubing, and the mast is elevated by low viscosity oil forced in under pressure by a 1/4 h.p., 12 volt d.c. pump.

Figure 1 - MST Mobile Survey Unit No. 2. The hydraulic mast is shown in the retracted position for traveling.

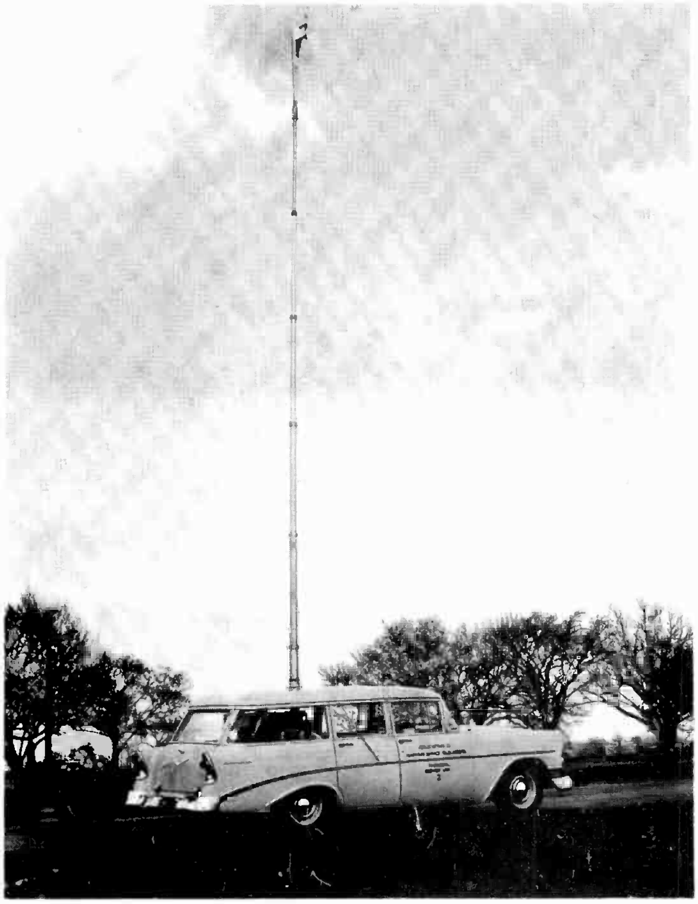

Figure 2 - Mobile unit with mast extended to 30-foot height. A UHF antenna is mounted on the mast.

Figure 3 is an interior view of the central portion of one of the units, showing the two field intensity meters, one for UHF signals and one for VHF signals. These meters are the RCA types BW-3A and BW-7A respectively, manufactured for RCA by Nems-Clarke, Inc., of Silver Spring, Maryland. These two field intensity meters may be operated simultaneously, and, by substituting meters, two VHF or two UHF signals can be measured if desired. For spot measurements, the meters may be read directly; for mobile recordings, two Esterline-Angus chart recorders are provided in the front seat position as shown in Figure 4. These recorders are driven by means of a connection to the car speedometer, and by means of changeable gears, a wide selection of chart speeds is provided.

Figure 5 shows the power supply for the equipment in the vehicle, consisting of four heavy duty 6-volt truck batteries. The batteries are charged in pairs in series by means of a 12-volt Leece-Neville heavy duty charging system, operated off the vehicle fan belt. They are used individually by means of the switching arrangement so that a single battery operates only one field intensity meter. The hydraulic pump and control relays are also shown.

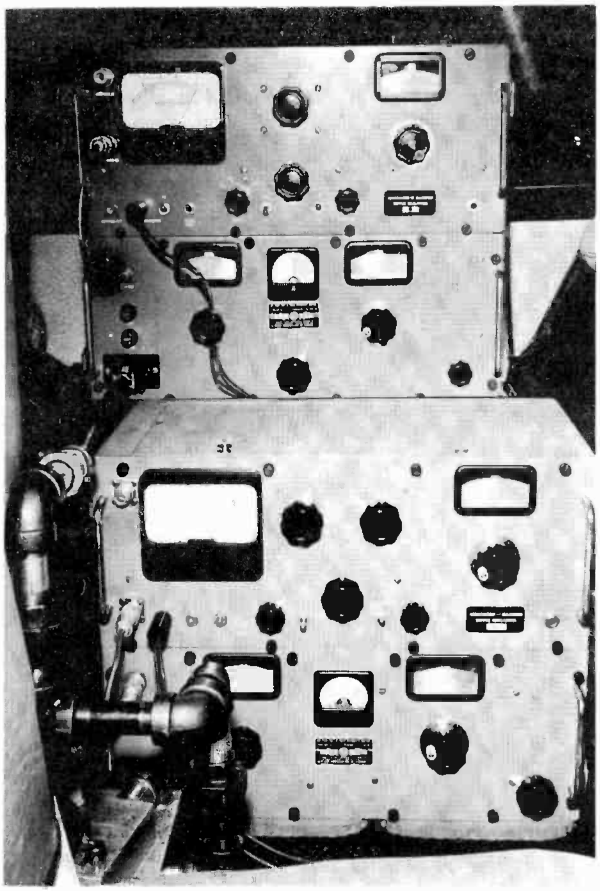

Figure 3 - Interior of mobile unit showing field intensity meters.

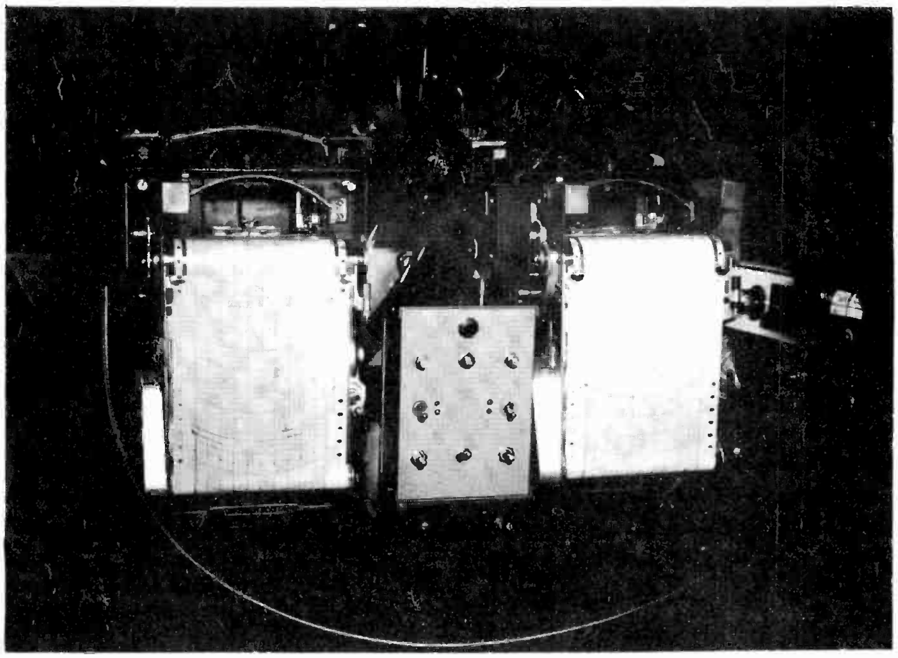

Figure 4 - Chart recorders for mobile unit.

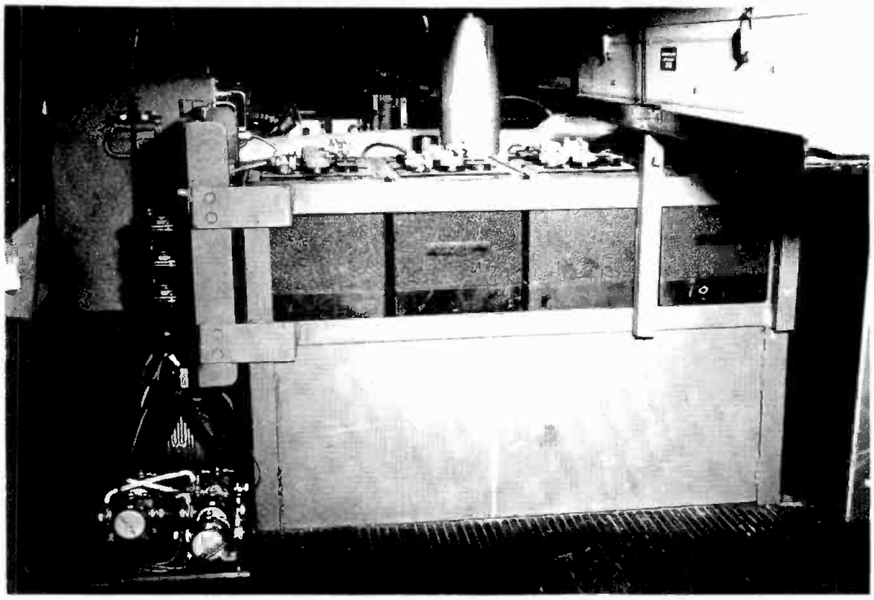

Figure 5 - Power equipment for mobile unit.

A number of accessories are provided, including a 200 watt ATR inverter to provide 115-volt 60-cycle AC for tube tester, soldering iron, or a portable receiver. A 17-inch RCA UHF and VHF portable television receiver is included for observing picture quality.

We have on hand and are preparing to install in each vehicle gyroscopes to be used in maintaining a constant orientation of the receiving antenna masts. The masts are equipped with motor operated rotating drive and the individual mast sections are keyed to prevent independent rotation.

At the present time, these units are being used in collecting VHF and UHF field intensity data for the purpose of comparing and evaluating techniques as previously discussed. Measurements have already been made in the areas of Salisbury, Maryland; Norfolk, Virginia; Harrisburg, Pennsylvania; and additional measurements are being made at the present time. The field techniques will be briefly described.

Around the transmitter being measured, major roads are selected which generally follow radial routes from the transmitter. Along each route mobile recordings are made with the receiving antenna at the 30-foot height for as many road segments as possible having a road length of 0.5 mile or longer. As soon as the recordings are made along each road segment for the 30-foot height, the segment is immediately repeated at the 10-foot antenna height. Spot observations of the field intensities at both heights are made when the antennas are raised or lowered. In addition to these runs of 0.5 mile or longer, an attempt is made wherever possible to secure at least one run of reasonable length at

both antenna heights every two miles. In addition, continuous mobile recordings at an antenna height of 10 feet are made over the entire measuring route.

The recorder charts for these mobile measurements may then be analyzed to show the results corresponding to each of the mobile measuring techniques described and, in addition, the results of cluster measurements can be evaluated by considering a very short mobile segment to be the equivalent of a cluster.

Some of the data which have been taken have been analyzed and some samples are available which may be of interest.

Figures 6, 9, 13, and 15 are graphs of mobile measurements made with a receiving antenna height of 30 feet. The circles show the median fields for the first 500 feet of each measuring sector.

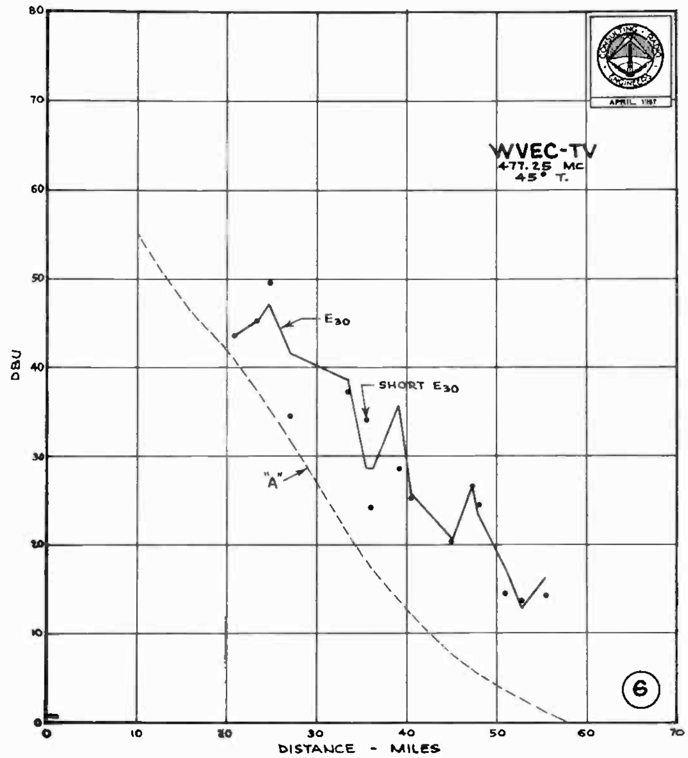

Figure 6 - Field intensity versus distance for WVEC-TV, Hampton, Virginia, on 477.25 mc (reduced to a radiated power of 1 kw) in the direction 45° True. The solid line joins the median field intensities for the long measuring sectors. The circles are the median field intensities for the first 500 feet of each mobile run. The line marked "A" is the median field intensity given by the Commission's TRR Report 2.4.16.

Each sector of the recorder charts was analyzed for the median fields at both the 10-foot and 30-foot receiving antenna heights and the height-gain factor was determined both for each complete run and the first 500 feet of each run. The solid lines of Figures 7, 10, 12, 14, and 16 show the distribution of the height-gain function for the complete runs, weighted according to the length of each run, and the dots show the distribution for the short 500 foot segments. It will be noted that the median height-gain factor is approximately the same for the short runs as for the complete runs, but is only about 6 db instead of 9.5 db as given by simple theory.

Figures 8 and 11 show the effect of applying the height-gain factors to the continuous 10-foot mobile recordings, as compared with the 30-foot mobile recordings. The solid line again is the analysis of the long 30-foot mobile recordings. The open circles are the values obtained from an analysis of the continuous 10 foot mobile recordings, in two mile sectors, adding a uniform height-gain factor of 6 db for the entire measuring route, as shown by the preceding figure. The crosses are the continuous 10-foot mobile measurements, with the median field at 10 feet increased by the individual height-gain factor measured nearest the sector being analyzed.

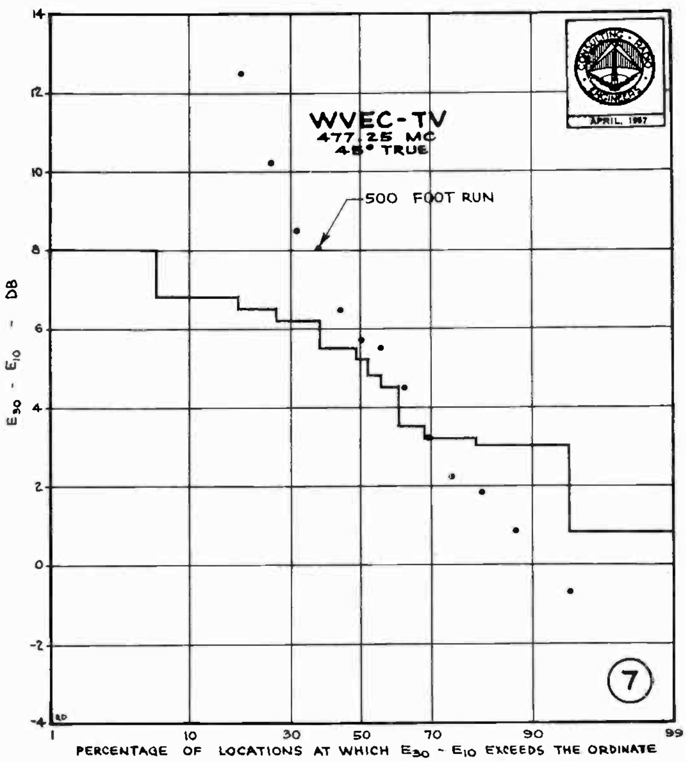

Figure 7 - Distribution of the antenna height-gain function E_{30}-E_{10} for the measurements of Figure 6.

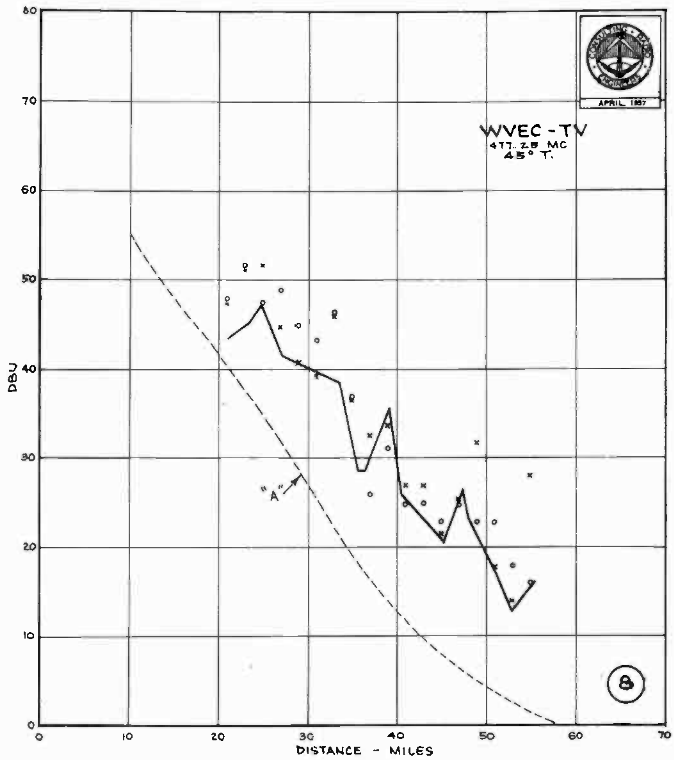

Figure 8 - Effect of applying height-gain factors from Figure 7 to continuous 10-foot mobile recordings. The circles are E_{10}+6 db, and the crosses are E_{10} plus individual height-gain factors. The solid line is the long E_{30} analysis shown in Figure 6.

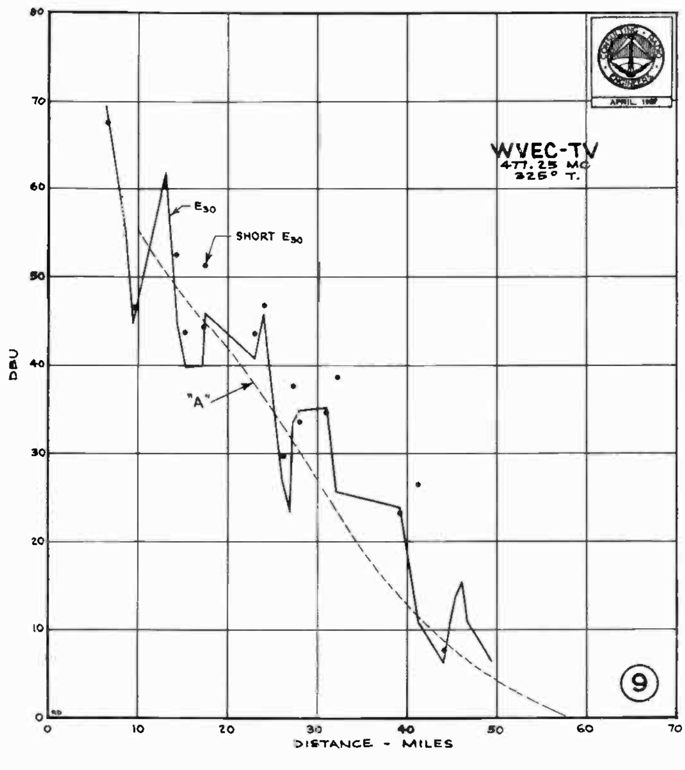

Figure 9 - WVEC-TV field intensities versus distance (reduced to 1 kw radiated) for the 325° bearing.

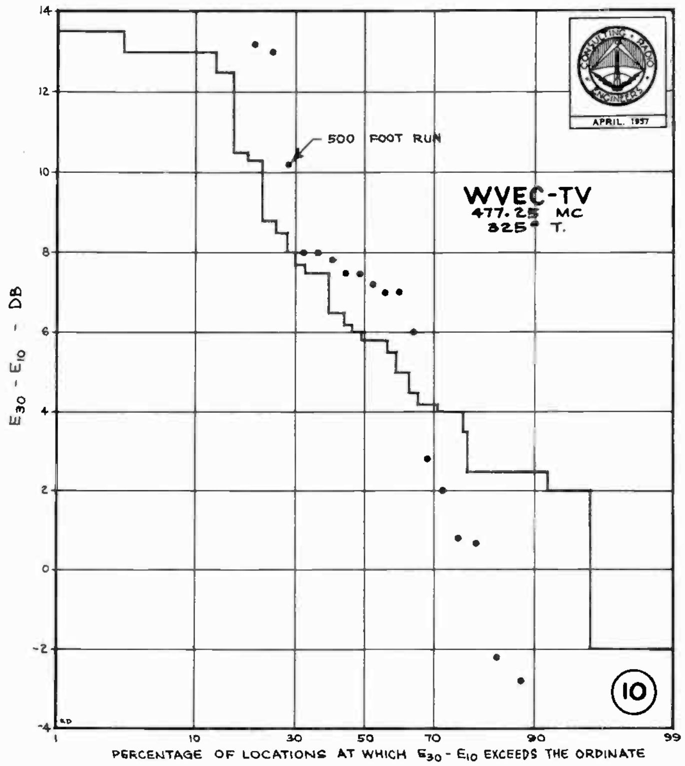

Figure 10 - Distribution of the antenna height-gain function E_{30}-E_{10} for the measurements of Figure 9.

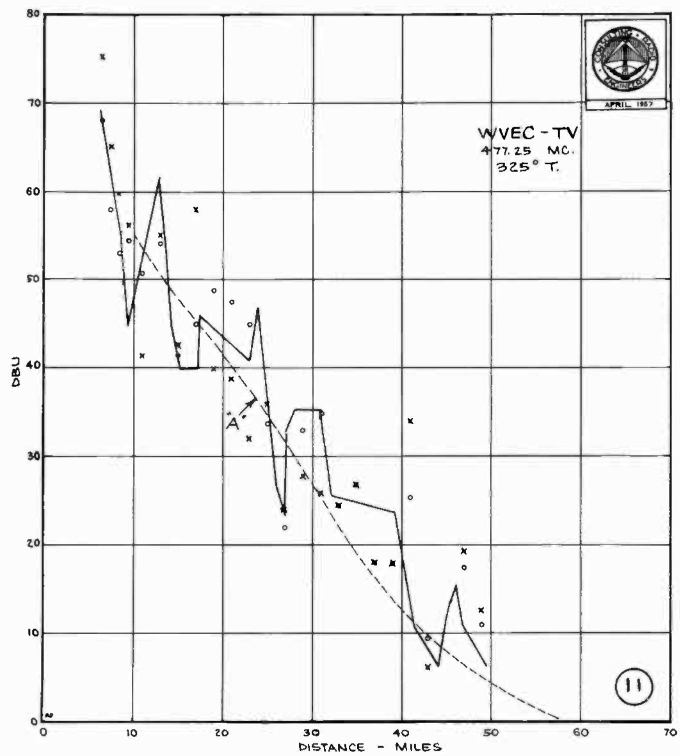

Figure 11 - Continuous 10-foot mobile measurements along the 325° bearing increased by height-gain factors.

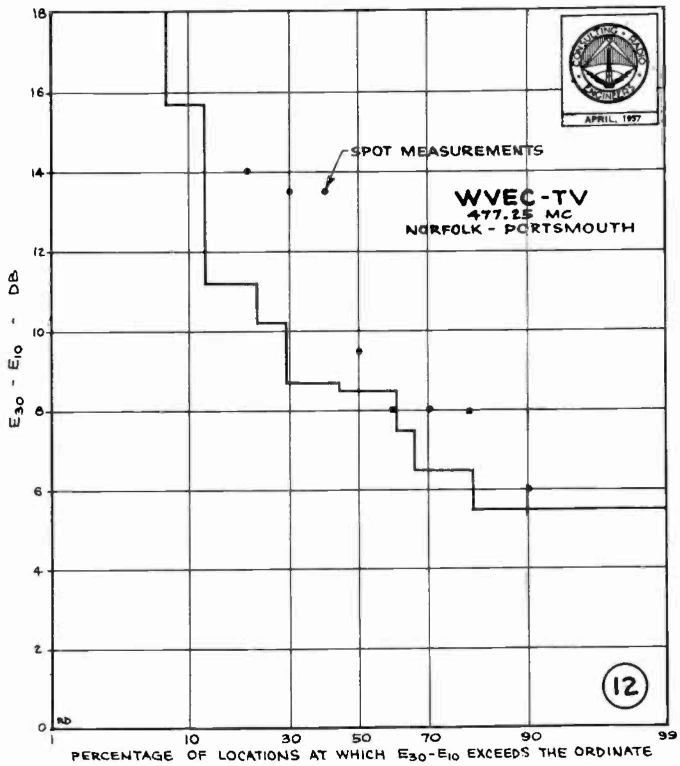

Figure 12 - Distribution of height-gain factor E_{30}-E_{10} in the cities of Norfolk and Portsmouth.

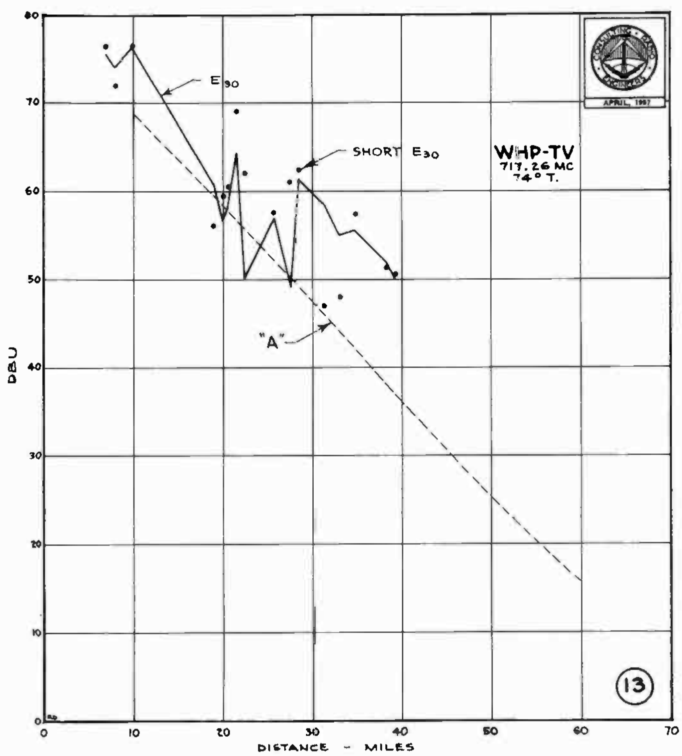

Figure 13 - Plot of 30-foot mobile measurements on WHP-TV on 717.26 mc reduced to 1 kw along a bearing of 74° True. The line marked "A" is from FCC Report 2.4.16.

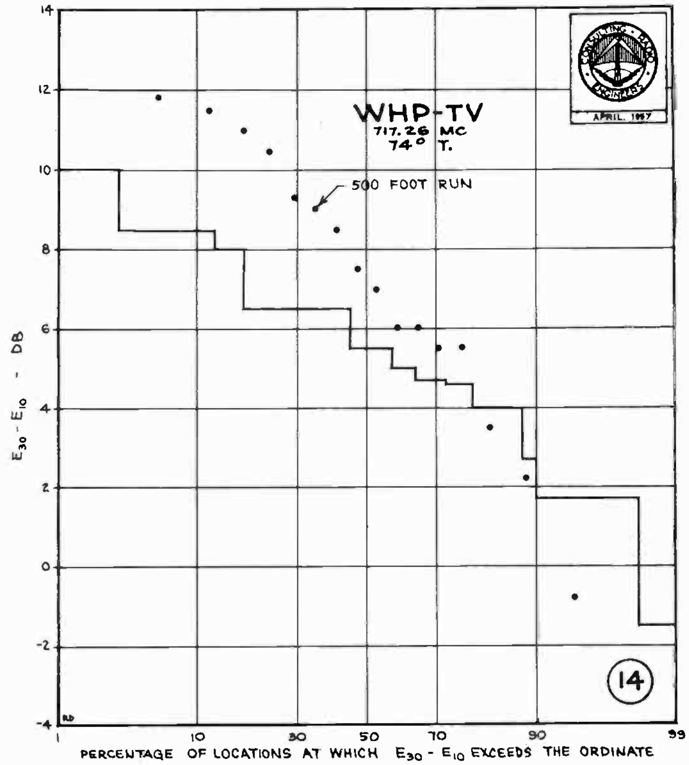

Figure 14 - Distribution of the antenna height-gain function E_{30}-E_{10} for the measurements of Figure 13.

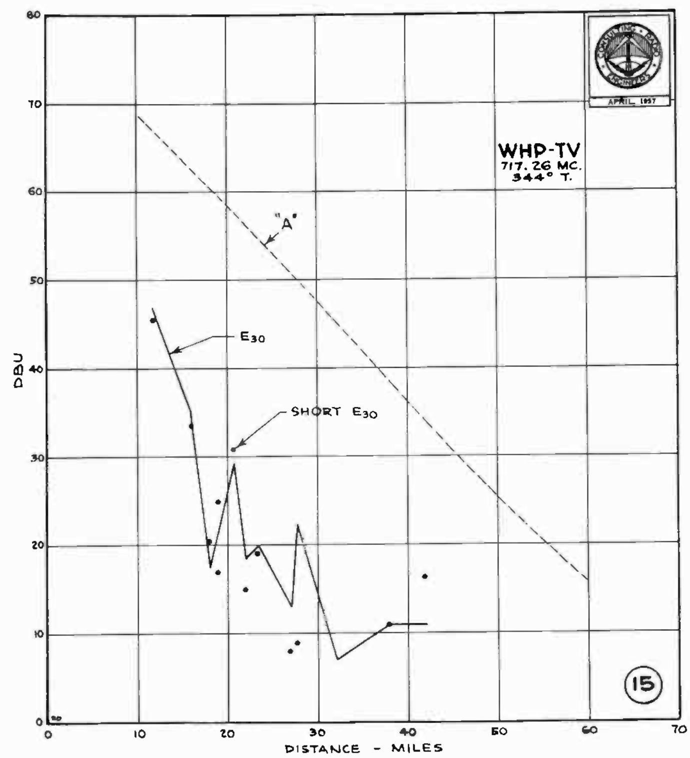

Figure 15 - Plot of 30-foot mobile measurements on WHP-TV on 717.26 mc reduced to 1 kw along a bearing of 344° True. The line marked "A" is from FCC Report 2.4.16. This is in very rugged terrain.

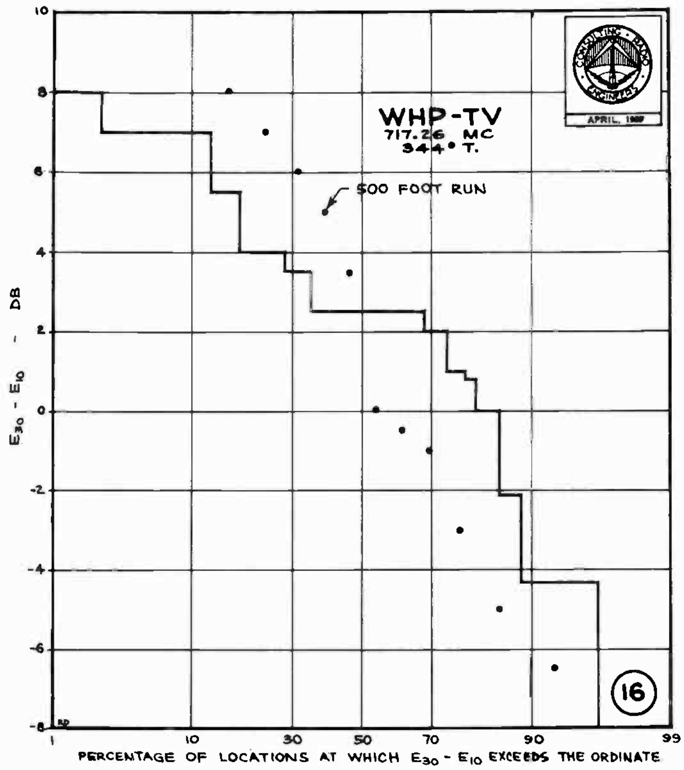

Figure 16 - Distribution of the antenna height-gain function E_{30}-E_{10} for the measurements of Figure 15.

THE APPLICATION OF VERY PRECISE FREQUENCY CONTROL TO MINIMIZE TELEVISION COCHANNEL INTERFERENCE

by

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Princeton, N. J.

The first television channel assignments made in this country utilized the separation between stations to provide the necessary protection against cochannel interference. The increase in the number of stations, together with the gradual increase in power of the stations, demonstrated that the original plan was not entirely adequate.

The search for a method to improve the situation resulted in our present system of allocations which utilizes an offset between visual carriers of cochannel stations. Experiments performed at that time demonstrated that the greatest amount of improvement is obtained when the offset frequency is near an odd multiple of one-half horizontal-line frequency of the television system. The greatest amount of interference occurs when the beat is an even multiple of one-half horizontal-line frequency. To make a practical system in which more than two cochannel stations are involved, it was necessary to make a compromise between these two values. The present system fixes one station on the nominal carrier frequency; the second station 10 kilocycles higher; and a third station 10 kilocycles lower. This makes the beat between the second and third stations 20 kilocycles which gives essentially the same improvement between each of the three stations.

At the time these early experiments were performed, it was noted that an additional improvement could be obtained for certain frequencies near the 10 and 20 kilocycles offsets, but the frequency tolerance required was so small that the existing methods of transmitter

frequency control made it impractical to try to utilize this additional improvement. An illustrative sketch showing this trend is illustrated in Figure 1. It will be noted that in addition to the maxima and minima occurring at multiples of one-half line frequency there is a fine structure superimposed. Recent advances in the art of manufacturing quartz crystals with long term stability, and novel circuitry for making crystal oscillators independent of circuit components other than the crystal, made a re-evaluation of the cochannel interference problem worthwhile.

The first step was a detailed investigation of the improvement to be obtained if the above mentioned fine structure could be utilized. A laboratory setup was made and statistical data obtained. Figure 2 shows the characteristics around 10,000 cycles and Figure 3 the characteristics around 20,000 cycles. These curves show the required difference in decibels between the desired signal and the undesired signal in order to obtain a tolerable picture for the offset frequencies shown. It can be seen that an improvement of at least 10 db can be obtained at each of the two offset frequencies. A more important observation is that in the region of maximum improvement the desired signal need be only 21 decibels stronger than the undesired to give a tolerable picture. This variation in interference is not unique for the frequencies shown. The curves are duplicated at frame frequency intervals and change slowly to conform to the variation related to line frequency as shown in Figure 1. This gives a clue to the basis for the improvement obtained. The interfering signal is not reduced but the beat pattern produced is related to both the television line and field frequencies in such a way as to interlace out or, in other words, to produce a fine-structure pattern which is less visible. This points out

a basic requirement for the proposed system: the offset frequency must be related to the television line and frame frequencies. Specifically, for the frequency domain being considered, the requirement is met by making the offset an even multiple of frame frequency. A simple method for providing the required stability of the field and frame frequencies is to lock the station synchronizing signal generators to a color subcarrier frequency crystal. This equipment is commercially available and already installed in many stations.

The indicated improvement can be used in two ways. If the separation between stations is unaltered, the use of precise frequency control would improve the pictures in areas where the quality is limited by cochannel interference. If present quality is considered adequate, the use of precise frequency control would allow stations to be moved closer together without creating increased interference in the cochannel limited areas.

An examination of Figures 2 and 3 indicates that the beat between the visual carrier frequencies should be maintained within ± 10 cycles to obtain the majority of the improvement possible. This allows a change of ± 5 cycles for each station. Thus it can be seen that the stability required varies from ± 1 part in 10^7 for the lower VHF channels to ± 5 parts in 10^9 for the upper UHF channels. The time during which this stability must be maintained without check or adjustment depends upon the period of time that is considered necessary for a practical system. A frequency check once a month is certainly not unreasonable.

Concurrent with the observational tests, work was started in the laboratory to produce crystal oscillators of the required stability. Perusal of the literature disclosed one approach that was basically different and offered promise of the required stability. A method of

implementing the basic circuit is shown in Figure 4. In this circuit it will be noted that the amplitude of oscillations is limited by a diode in the plate circuit, the plate circuit is decoupled from the crystal circuit by a transformer and the grid circuit is isolated from the crystal by a low value shunt resistor. This combination alone would make a reasonably stable oscillator.

The additional equipment allows the crystal to operate as a phase detector as well as in its normal function as an oscillator. A reactive change in the circuit would normally cause a change in the frequency of oscillation but with this circuit it will unbalance the bridge and produce a control voltage on the reactance tube which compensates for the original change. It is apparent that if a crystal can be provided which has good long-term stability, the circuit will be adjusted automatically in an appropriate fashion to make the frequency of oscillation very stable.

Stable crystal characteristics have been obtained by first utilizing a crystal that has been manufactured with the best techniques commercially available, and then this crystal has been placed in a good, constant-temperature oven. The oven also uses a bridge to obtain the control signal. One circuit with the desired characteristics is shown in Figure 5. Whenever the temperature of the bridge is below the balance temperature, a small AC signal is produced which is amplified and detected and used to control a DC supply which applies power to heat the bridge. If the bridge overshoots and goes too high in temperature, the phase detector prevents additional power from flowing into the bridge.

Two crystal oscillators were built. One was installed at WRCA-TV, the Channel 4 station in New York, and the other was installed

at WRC-TV, the Channel 4 station in Washington, D.C., and the system was tested for several months. When the units were first installed, one oscillator was arranged so that during color shows (when line and field rates were accurately controlled) the offset frequency could be changed with the snap of a switch from one of the best frequencies near 10 kc to one of the poorest frequencies near 10 kc. The signals were observed at several locations between New York and Washington and during many different shows. Due to propagation differences, cochannel interference was not always a problem. However, when cochannel interference could be observed there was never a time when changing to the desired offset did not either clear up the interference or materially improve it.

Regarding the relative stability of the crystal oscillators, almost daily checks of the beat between the two signals were made at the laboratory in Princeton. The results are shown in Figure 6. It will be noted that for the first forty days considerable aging is apparent since the beat changed by 5 cycles out of 67 million cycles. By this time the initial aging was essentially complete and the frequency was quite stable for the next 20 days. At the end of this period it was decided to readjust the beat frequency and change it to about 9950 cycles as shown. The next 15 days show an aging of only about one-half cycle. At this time one of the ovens became inoperative and although the crystal was kept oscillating, the unit was taken out of service. It was repaired and restored to service 135 days after the beginning of the test. For the next two months it can be seen that there is very little aging and the frequency held within $\pm$ 0.5 cycle. Operation continued for several

weeks beyond what is shown in Figure 6 with essentially the same results. This represents a relative stability of ± 4 parts in 10^9 for each oscillator for a period of two months.

To summarize, it has been established by laboratory tests that an improvement of the order of 10 db can be obtained by the use of precise offset frequency control. In order to obtain reduced visibility of the cochannel interference, it is imperative that the beat frequency between the visual carriers be related in a particular fashion to the line and field rates of the video signal. With the required conditions established, this means that the desired signal need be only about 20 db larger than the undesired signal to produce a tolerable picture. It also has been demonstrated in the field that the system is effective under actual operating conditions. Two crystal oscillators have been built and operated which have a relative stability more than adequate for the VHF television channels. The reduction in interference that is obtained can be used to move cochannel stations closer together or to improve the fringe area service of existing stations when they are limited by cochannel interference. It is interesting to note that in such areas if any station were to increase its service area by means of a power increase, additional viewers would be obtained at the expense of the cochannel stations. If the cochannel stations also increased their power by the same factor, the service areas would be back to the original condition. On the other hand, by application of precise frequency control, each station would obtain the same improvement as though it alone had increased its transmitter power.

References:

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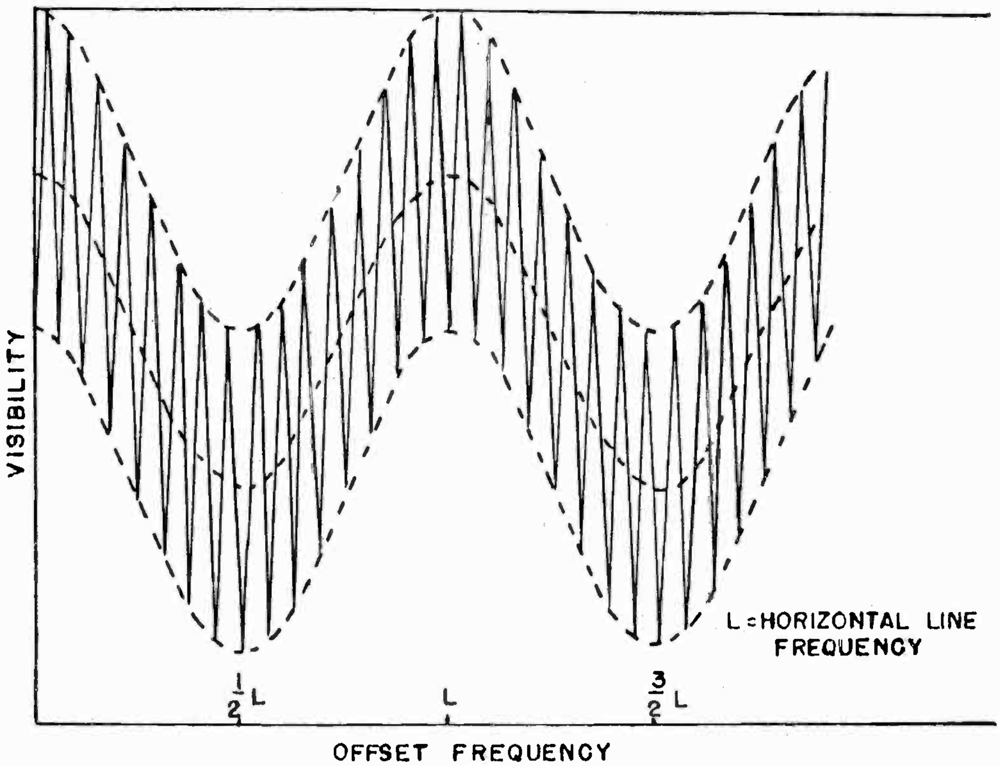
2. RCA Laboratories Division, "A Study of Co-Channel and Adjacent-Channel Interference of Television Signals, Part I," RCA Review, Vol. XI, p. 99, March, 1950.

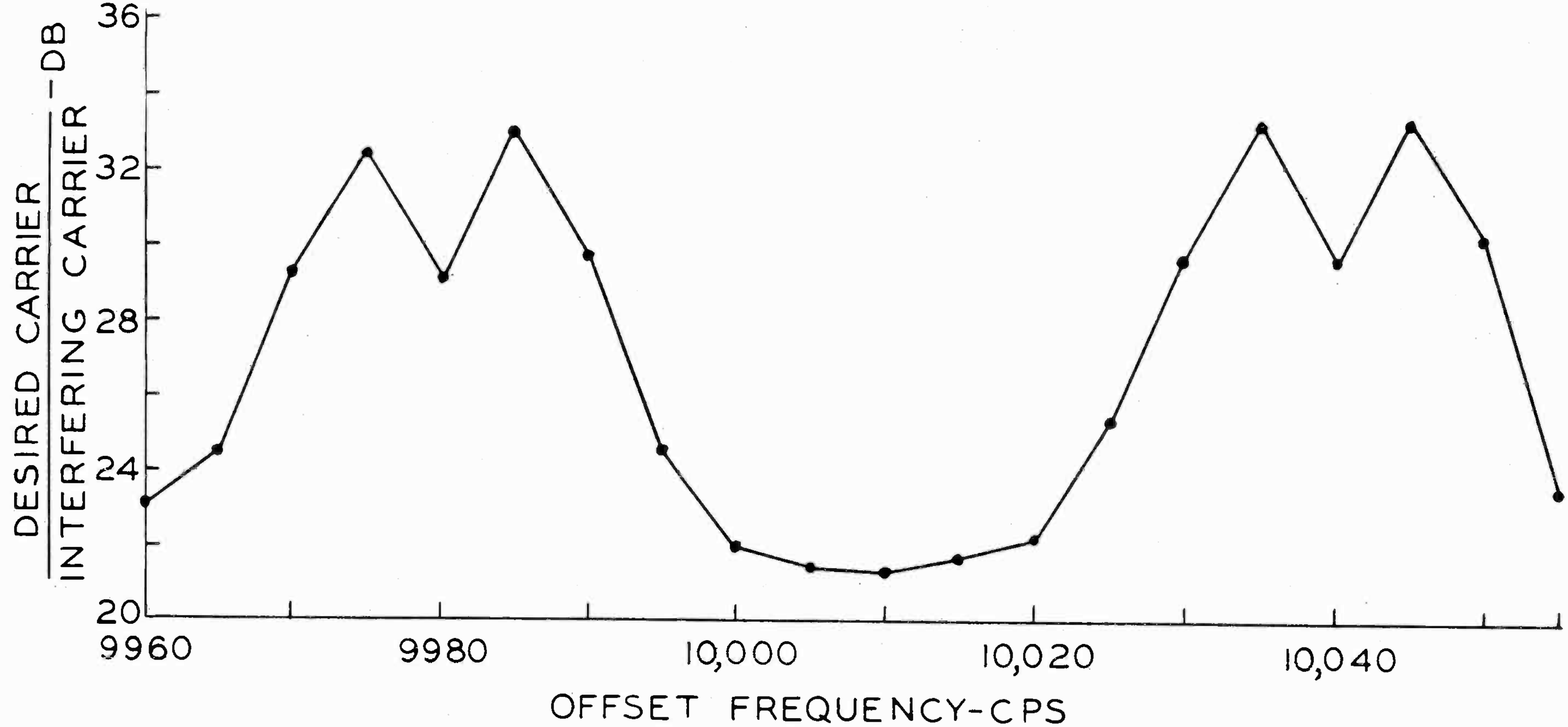
3. Norman Lea, "Quartz Resonator Servo — A New Frequency Standard," The Marconi Review, Vol. 17, p. 65, 3rd Quarter, 1954.

4. P. G. Sulzer, "High-Stability Bridge-Balancing Oscillator," Proc. I.R.E., Vol. 43, p. 701, June, 1955.



VISIBILITY OF CO-CHANNEL INTERFERENCE AS A FUNCTION OF THE OFFSET FREQUENCY.

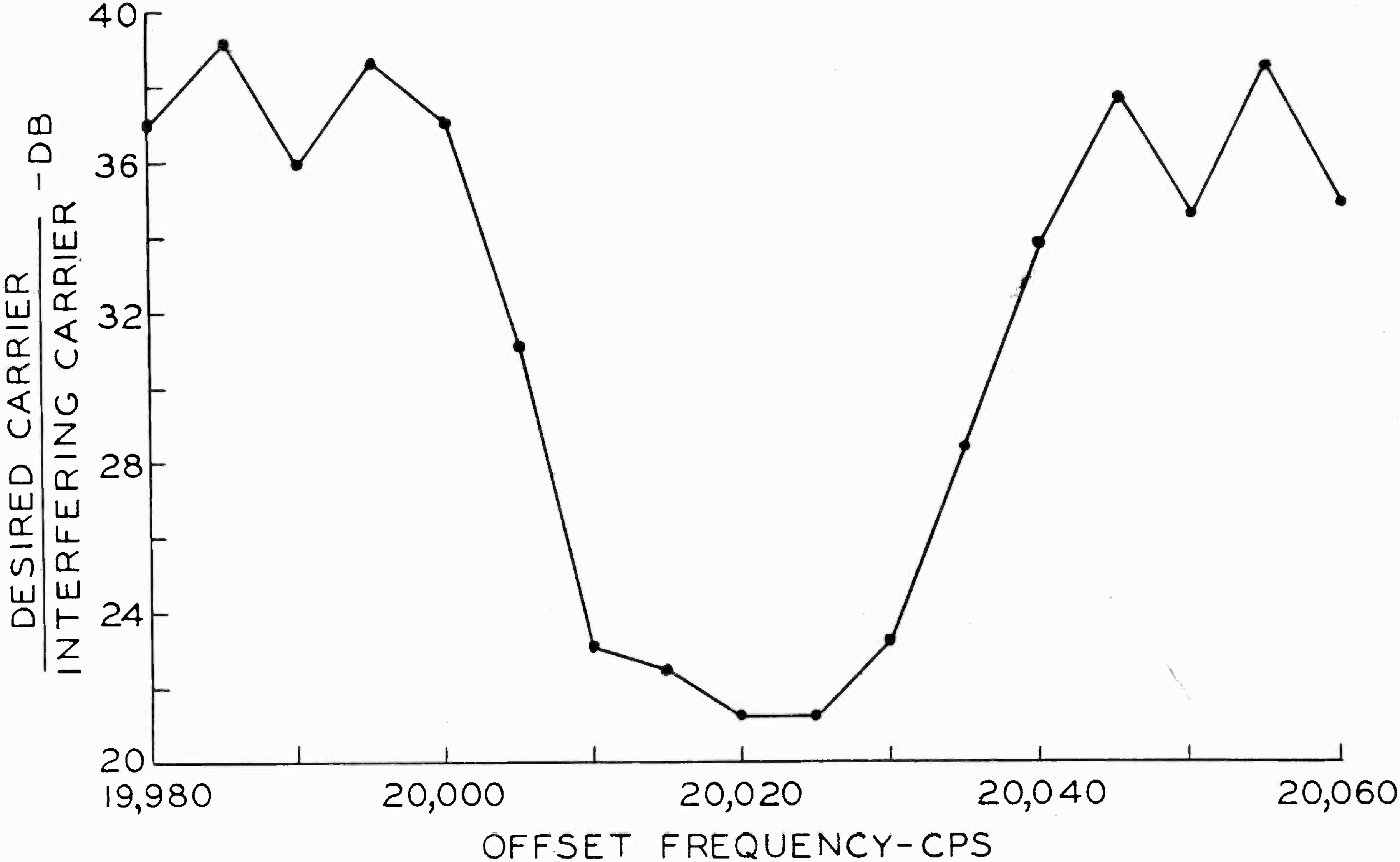
FIG. 1



AVERAGE-10 OBSERVERS
21" COLOR RECEIVER - SAIL'BOAT SCENE
INTERFERENCE - COLOR TEST CHART
8-1 VIEWING DISTANCE

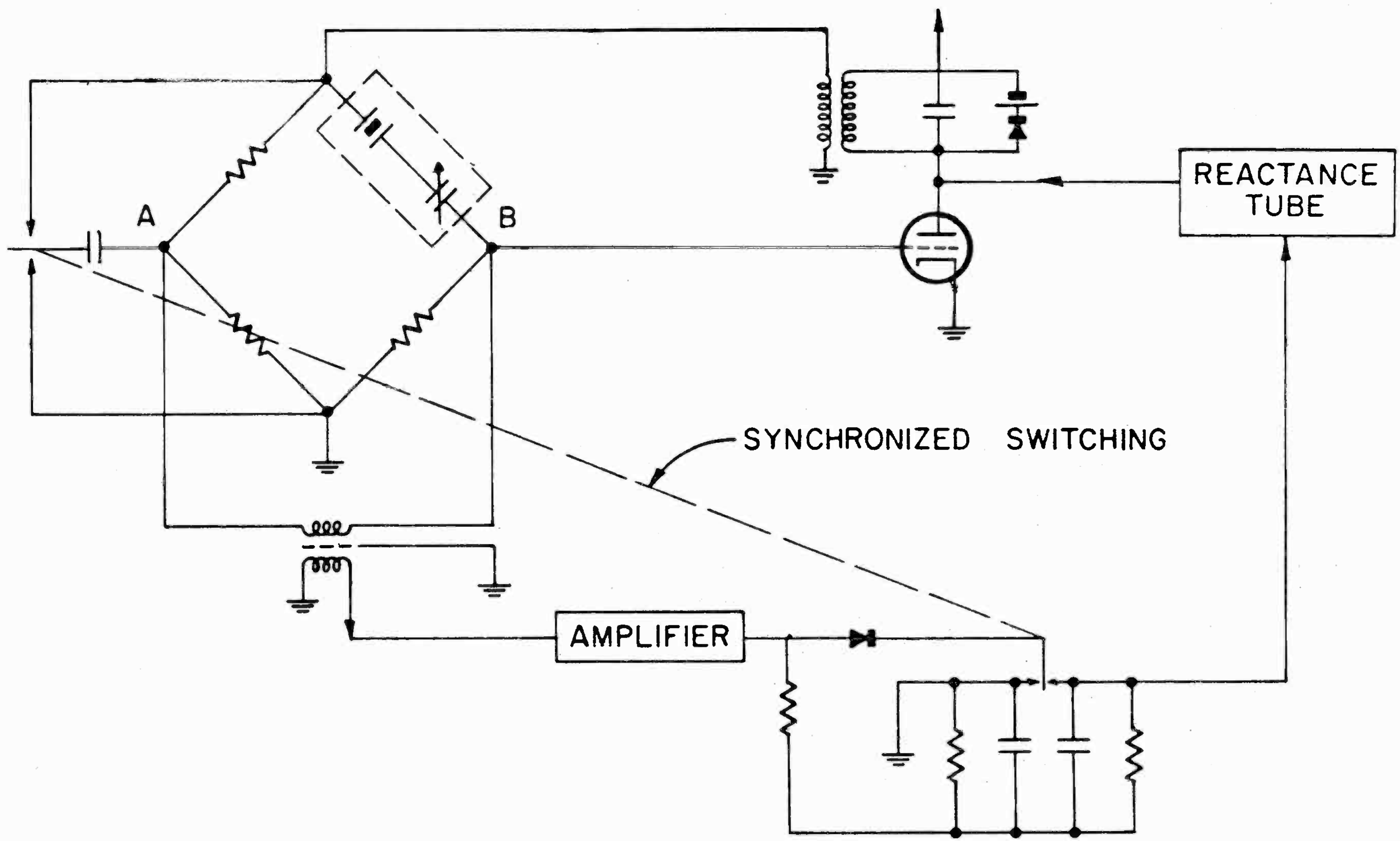
CARRIER RATIO FOR TOLERABLE INTERFERENCE

FIG. 2



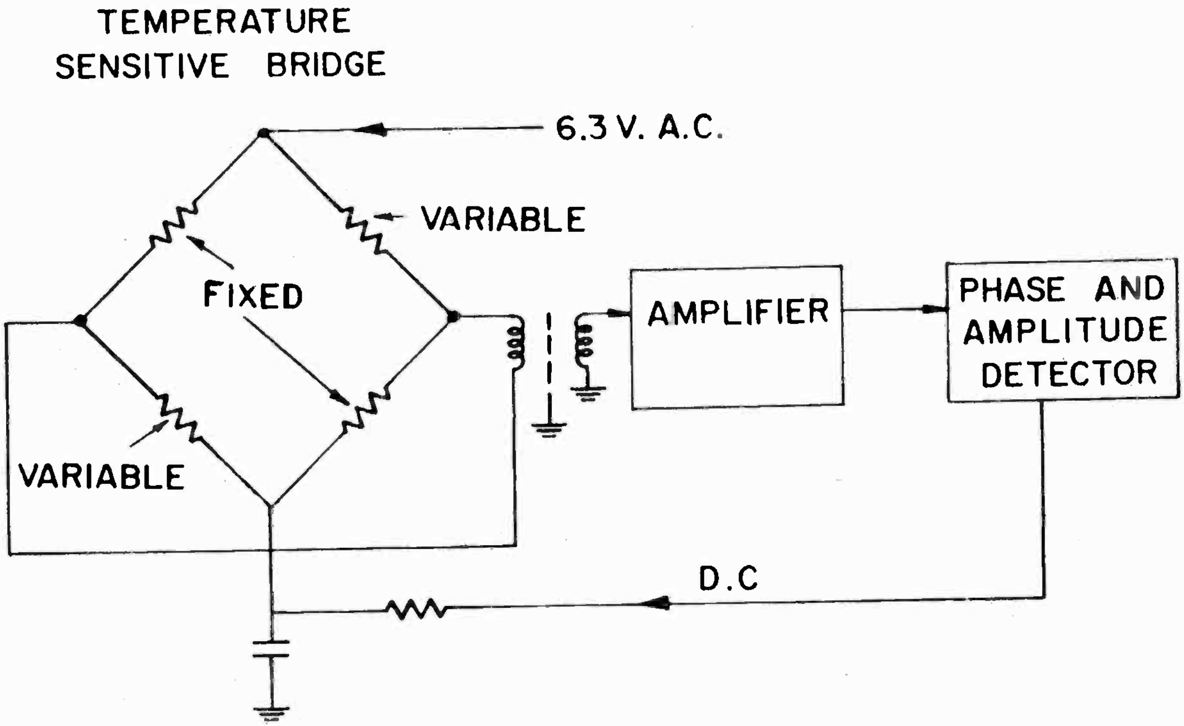
AVERAGE - 10 OBSERVERS
21" COLOR RECEIVER - SAILBOAT SCENE
INTERFERENCE - COLOR TEST CHART
8-1 VIEWING DISTANCE

CARRIER RATIO FOR TOLERABLE INTERFERENCE
FIG. 3



CRYSTAL OSCILLATOR

FIG. 4



METHOD OF CONTROLLING THE TEMPERATURE OF CRYSTAL OVEN.

FIG. 5

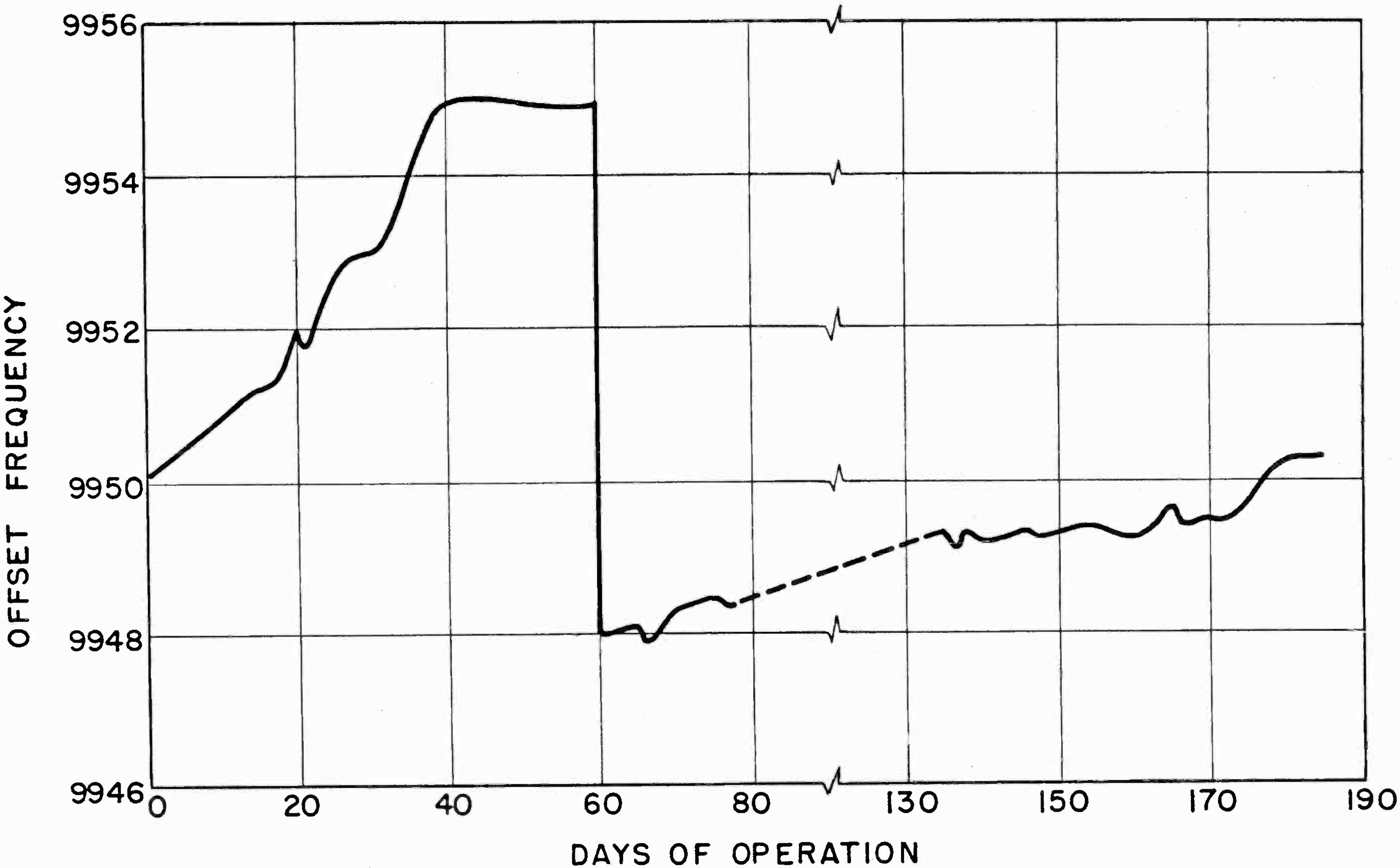


FIG. 6 CHANGE IN OFFSET FREQUENCY AFTER INSTALLATION IN TELEVISION STATIONS

43051

TELEVISION ENFORCEMENT PROGRAM USING A MOBILE MONITORING UNIT

by
Raymond L. Day
Engineer in Charge, Mobile TV Monitoring Unit
Federal Communications Commission
at the
Eleventh Broadcast Engineering Conference
National Association of Radio and Television Broadcasters
Chicago, Illinois
Wednesday, April 10, 1957

If you should happen to glance through a window of your transmitter building some day and see a big black truck pulling into the station driveway, it is probably the expressman delivering a box of tubes or a reel of cable. On the other hand, it could be that the FCC's Mobile TV Monitoring Unit has come to call. This could have happened at any one of approximately 100 TV stations along the Eastern Seaboard and extending as far west as Michigan and Texas which were visited by the Mobile TV Monitoring Unit during the past 18 months. The black color of the vehicle was not selected as an omen of bad tidings or to imitate our "Black Marias" which are undoubtedly well remembered by old time broadcasters of the late twenties. It just so happened that is the color it was when it arrived from the factory.

The Commission recognized some years ago that a need existed for a constructive, cooperative TV monitoring and enforcement program to insure an orderly growth of the TV industry within the framework of the engineering standards specified in the Commission Rules. As more and more stations with increasingly higher powers and more efficient antennas commenced operation, co-channel and other interference problems arose. The complexities of color TV added to the difficulties of the station engineering staffs in presenting the high quality pictures which the public had come to expect. The need for monitoring was further heightened by the fact that many of the stations were located in smaller cities where technical assistance and know-how are not always as readily available as in large metropolitan areas.

The necessity for a mobile unit for television enforcement will be understood by those of you who are familiar with the locations of our district offices and monitoring stations with respect to the television stations. Those TV stations situated near a monitoring station could very well be observed without resort to a mobile unit. A far greater number of the stations, however, would not normally be received well enough at Commission installations for even a frequency measurement to be made. Checks for compliance with any of the standards other than carrier frequency measurements require a signal strength comparable to that obtainable in the primary service area.

To provide a means for taking the measuring and monitoring equipment into the strong signal areas of the various TV stations, the Commission placed in service in 1955 a Mobile TV Monitoring Unit equipped with instruments and associated facilities for measurement of such features of a television signal as:

Carrier frequencies

Vertical and horizontal scanning rates

Video modulation levels

Pulse durations and rise times

Aural bandwidth

Color subcarrier frequency

Color phase relationships

Sideband attenuation

Ratios between visual and aural carriers

In addition, observations are made of pulse shapes, shading, smearing or streaking, ringing, etc.

The first slide shows some of the instruments with which the unit is equipped:

(Slide #1 showing rack-mounted equipment)

Oscilloscope

Panoramic receiver

TV tuner and IF amplifier

Monochrome and color monitors

Color phase meter

Transfer oscillator

High frequency receiver

Electronic counter

FM receiver and distortion analyzer

VHF and UHF signal generators

Oscillograph recording camera

In the next slide we see a block diagram of the measuring and monitoring equipment.

(Slide #2 showing block diagram of equipment.)

The usefulness of a good oscilloscope for analyzing a TV signal is well known. In the monitoring unit, as at the TV stations, the 'scope is used for checking video levels, blanking levels, sync height, pulse durations, rise times, and many other features of the composite video signal.

The IF amplifier used in the monitoring unit furnishes video signal to the oscilloscope as well as to the monochrome and color monitors. The amplifier was built by the Commission's Laboratory staff. Two amplification characteristics are available by throwing a switch. One approximates the theoretical ideal IF characteristic for a television receiver; the second provides a flat response.

The monitoring unit uses a modified commercial type tuner which covers all of the television channels. The tuner output can be connected to the Panoramic receiver, IF amplifier, or the FM receiver.

The Panoramic receiver displays carrier amplitude as a function of frequency.

(Slide #3 showing Panoramic display at 10 Mc sweep.)

When the widest possible sweep of 10 Mc is used the oscilloscope screen shows the two carriers of the TV station along with any nearby spurious radiations. The receiver is also used in the observation of sideband attenuation.

(Slide #4 showing Panoramic display at 4 Mc sweep.)

Narrower sweeps are used for more detailed observation of the visual signal and aural modulation.

(Slide #5 showing Panoramic display at 100 kc sweep.)

The picture monitors are used as they were supplied by the manufacturers except that jacks have been installed on the front panels where video is fed to the monitors and where vertical and horizontal synchronizing voltages and color sub-carrier are available. The vertical and horizontal synchronizing voltages are needed for frequency measurements, for synchronizing test signal generators, and for oscilloscope triggering. The color subcarrier is taken off for frequency measurement and it is also applied to the color phase meter.

The phase meter is basically a calibrated delay line which is used to determine the phase relationships between elements of a color picture.

The heterodyne oscillator and the electronic counter comprise the frequency measuring system of the monitoring unit. The counter is used by itself for measurements of frequencies up to 100 Mc. Beyond that frequency a harmonic of the oscillator is matched to the signal to be measured, and the counter is used to measure the fundamental frequency or a lower-order harmonic of the oscillator.

All of the instruments except the standard signal generators and certain portable test equipment are rack mounted. The panel space of three 6-foot relay racks is required and three additional racks are installed back-to-back with the first three. This arrangement is used so that the great depth of some of the equipment can be accommodated. The six racks are bolted together to form a solid unit which is shock-mounted on steel channel irons bolted to the frame of the vehicle.

(Slide #6 showing external view of monitoring unit.)

The vehicle is a $1\frac{1}{2}$-ton truck chassis with a panel delivery body. The original chassis has been supplemented by overload springs, dual rear wheels, and power braking. A lighter and more easily manageable vehicle would be desired, and it is hoped that smaller versions of the electronic equipment will some day make this possible.

The ultimate purpose of the monitoring and inspection program carried on by means of the mobile monitoring unit is to maintain the high technical quality of television and to recommend improvements where there is a weakness in the long chain of action between camera and home receiver. This includes improvement not only in the station's transmission facilities but also in the standards and rules under which television operates.

The Chairman of the FCC, speaking of television programs, has said ". . . . No group in our American society has a greater responsibility, as well as an opportunity, than you, the broadcaster of this country, to do that which is for the good of all the people . . . "1/ It seems that this statement applies equally as well to the technical aspects of television as to the programs to which Mr. McConnaughey referred. Careful adherence to the standards and improvement of some phases of your operations may be your contribution to "that which is good for all the people."

That better quality is the aim of the station staffs is indicated by the concern shown when certain discrepancies are pointed out. As competition grows keener, the monitoring unit engineers will probably continue to be asked even more often than now: "How does my station compare with the others?"

The monitoring and inspection program has already suggested a number of improvements which might be made in the interest of better TV service. A particularly troublesome link in a network distribution system became apparent recently when visits were made to a number of stations, some of which were served by that link and some which were not. Correspondence with the common carrier operating the troublesome link has brought assurances that the existing coaxial cable serving the area is soon to be replaced by a microwave system. No doubt several other areas are still being served by inadequate network circuit facilities which should be modified or replaced. There is room for improvement in transmitter frequency control and in frequency monitors. Nineteen percent of the VHF stations so far monitored by the Mobile Television Unit did not comply with the present Rule prescribing frequency tolerance. Eighty-five percent of

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1/At Boston, Massachusetts February 28, 1957 the UHF stations were measured out of tolerance. Deviations as high as 18 kc from assigned frequency have been measured; and 5 kc deviation is not uncommon.

Some station engineers have stated that they prefer to rely on the transmitter crystals rather than on the frequency monitor. This attitude is often justified by comparison of the frequency measurements made in the Monitoring Unit with the station frequency monitor log entries. As the number of stations, and the effective radiated power, continue to increase, better control of carrier frequencies will become an even more important concern.

The desirability of test lines transmitted simultaneously with program material was recognized early in the monitoring program. The continuous use of test lines inserted at the program source would be of assistance to the studio engineers where the program originates, to the common carrier and to the TV station transmitter engineers in checking picture quality and in locating sources of picture deterioration as it occurs along the transmission chain. Increased numbers of color programs seem to place added emphasis on the use of test lines.

I have touched briefly on a few of the major TV station technical problems which have been encountered by the Mobile TV Monitoring Unit. The discrepancies observed at individual stations and the condition of the stations cover the full range from very bad to very good. Following are several slides showing typical deficiencies.

(Several slides showing some conditions found.)

I am sure that none of you here today will recognize any of these conditions as being typical of your station. However, the problems illustrated do exist and some of them are rather common. It is gratifying to report that in most cases the station management and the engineering staff are quick to take corrective action when noted deficiencies are pointed out to them. The practice which has been followed of calling attention to observed discrepancies verbally rather than by more formal means has been well received and has produced the desired results with a minimum of inconvenience to everyone concerned. As the old saying goes, "A stitch in time saves nine (Pause) citations."

ADVANCED PERFORMANCE AND STABILITY IN COLOR TV FILM CHANNEL AMPLIFIERS

A Technical Paper Written By

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For Oral Presentation To
National Association of Radio-Television Broadcasters
At
Chicago, Thursday April 11, 1957

ADVANCED PERFORMANCE AND STABILITY IN COLOR TV FILM CHANNEL AMPLIFIERS

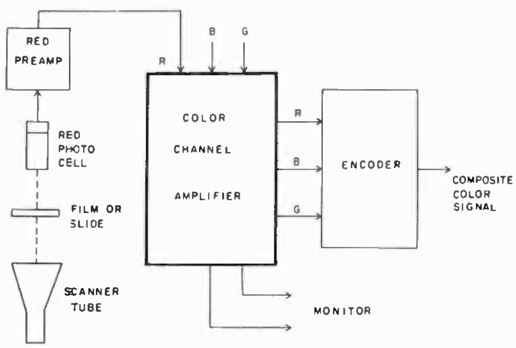
By

M. H. Diehl

One of the challenging problems of broadcasters who are now colorcasting or planning for color, is the complexity of pick-up equipment and the resultant attention required to produce consistent high-quality pictures.

Following is adescription of General Electric's TV-88-A Color Channel Amplifier. It incorporates such circuit advancements as an Automatic Video Gain Control; Precision Gamma Circuits; High-Level stable clipping; and Gain-Stabilized Monitoring Circuits which reduce to a minimum the attention required from operators.

Figure one shows a simplified block-diagram of the Film-Scanner System. We are concerned here with the channel amplifier "box," shown in heavy outline. The black box receives red, blue and green video signals from the photo-cell pre-amplifiers.



COLOR FILM SCANNER SYSTEM
FIG. 1

The Color Channel Amplifier, as shown in figure 2, performs the following seven operations:

1. Video Amplification;
2. Automatic Gain Control:
3. Phosphor Correction;
4. Blanking Insertion and Clipping;
5. Gamma;
6. Monitor Switching;
7. Calibration.

First five of the functions listed are accomplished on a small, six-tube, plug-in chassis, shown in figure 3. There are a total of three; one for each primary color. A fourth identical chassis is used when black-and-white preview is desired.

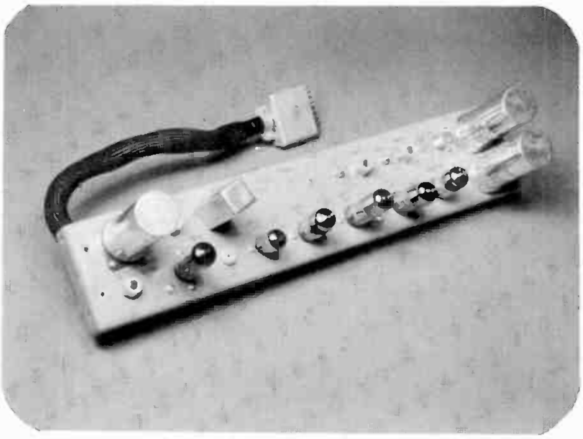


FIG. 3

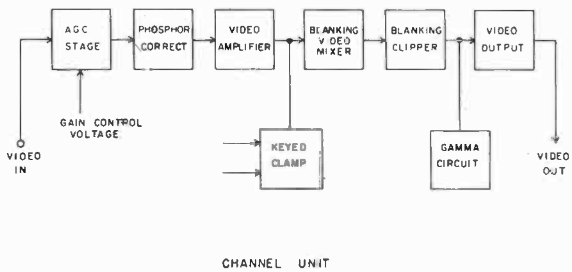


FIG. 4

Figure 4 shows a block diagram of the channel unit. The video input, at left, may be of widely different levels, due primarily to variations in film density. Levels commonly vary over a five-to-one range, or as much as ten-to-one in some instances. First, and probably most important, function of the amplifier is a wide-range video Automatic Gain Control circuit.

As is widely known, it is possible to lower the gain of a tube by reducing the DC plate current, which in turn, reduces the transconductance. In a single-ended stage, however, there will be severe differential-gain-distortion when handling large variations of a signal level. This results because the largest signal, which requires the most gain reduction, operates in the low G_m region where curvature of the tube characteristic is greatest.

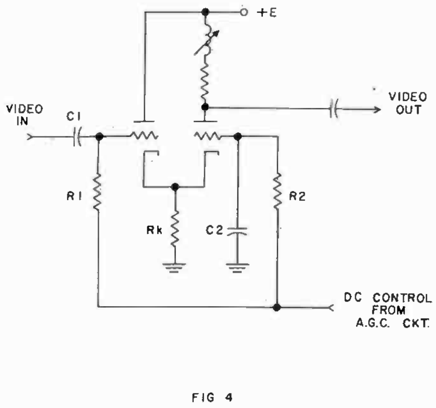


FIG. 5

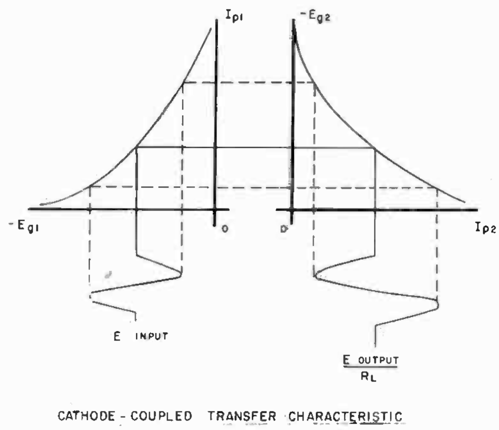


FIG. 6

This effect has been substantially reduced in this unit by using a cathode-coupled stage and applying the DC Gain-Control voltage to both grids, as shown in figure 5. The plate currents of both sections are then reduced to lower the gain. Signal currents are 180 degrees out-of-phase, and curvature of the $E_g - I_p$ characteristics tend to cancel, as shown in figure 6. The operation is similar to a push-pull stage.

The Cathode-Coupled gain control stage has another important advantage for color. It is very degenerative to the DC-Control voltage because of the large cathode resistor. Thus, it becomes easier to make three such stages "track," that is, to vary in gain together when a single DC gain-control voltage is applied to all three channels.

The Gain-Control voltage normally comes from the output of the AGC rectifier. By means of a front panel switch, it can be taken from the Master-Gain potentiometer which is used for Manual Gain Control.

The AGC rectifier is common to all three channels and is located on the main chassis. Equal parts of Red, Blue, and Green are taken from the 75-ohm output lines, added together, and then fed to a high-gain video amplifier, as shown in figure 7. Output of this amplifier is DC restored and fed through an isolating cathode-follower to the AGC rectifier. The rectifier, a silicon diode, is so biased that it does not conduct until the signal reaches a pre-determined "threshold" level. Above this level, an increasingly negative DC voltage is applied to the cathode-coupled gain stage described previously.

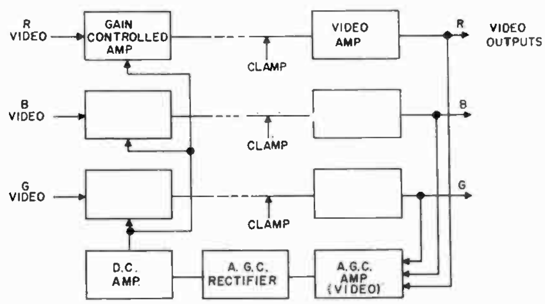


FIG.3

FIG. 7

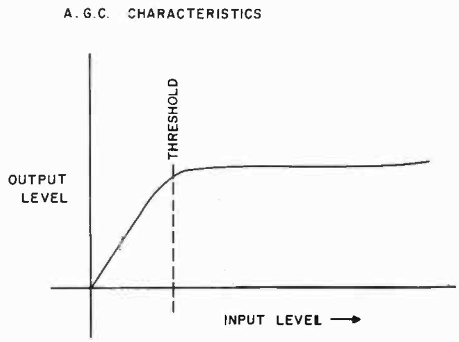


FIG. 5

FIG. 8

To increase the compression ratio, that is the flatness of the input-output curve, the rectifier is followed by a DC amplifier to increase the AGC loop gain. The input-output characteristic is shown in figure 8.

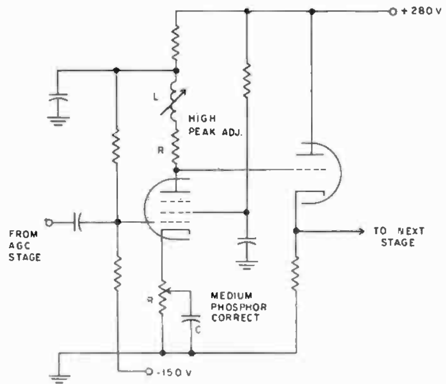
Above the knee or threshold, the putput increases by less than 10 per cent for a 1,000 per cent increase of input level. The entire AGC channel requires two tube-envelopes, plus two silicon diodes.

Attack time is also important when considering Video AGC systems. Objective here is usually very simple —— it should be as rapid as possible.

To make the attack rapid, however, requires that the filter time-constants following the AGC rectifier be short. If they are made too short, 60-cycle components resulting from the rectified field-rate components in the video signal are fed back into the video path. Up to a point, this unwanted signal can be removed by the Keyed-Clamp circuit, but this situation does set a limit on the attack time. The limit, however, is still much more rapid than can be achieved manually.

For this system, it is in the order of five-hundredths of a second. This overshoot is kept from exceeding 150 per cent of nominal output level by a white clipper, to be described later.

Phosphor correction is accomplished in the next stage, as shown in figure 9. The high-frequency peaking circuit consists of an R-L combination in the plate of the tube. By coupling directly to the grid of the triode section, used as a cathode follower, the stray capacity is reduced to a minimum. The resistive part of the peaker can then be made large enough, so that the gain at low frequencies is unity or more. The Medium time-constant peaker is an adjustable R-C circuit in the cathode of the pentode section.



PHOSPHOR CORRECTION CIRCUIT

FIG. 9

Since the amount of the cathode circuit peaking is dependant on the tube transconductance, a DC feedback loop is used to hold the plate-current (and therefore the transconductance) constant. The DC feedback voltage is taken from the decoupled point, and a large fraction of it applied back to the grid. The DC loop gain is high, thus a large amount of stabilization results.

A long time-constant cathode peaker is incorporated in the following stage. Here again, the pentode section is direct-coupled to the triode section used as a cathode follower. This reduces stray capacity and permits the use of a large load resistor for high gain, as mentioned previously. In addition. it is possible to develop a large peak-to-peak voltage swing with a relatively small plate current swing. Resultant benefit is good linearity with lower power drain.

Video level is about 10-volts peak-topeak at this point in the amplifier. This rather high level is necessary to insure stable operation of the black-clipper. In all vacuum tubes, the plate current changes erradically, even with all electrode voltages regulated and held constant. When referred to an equivalent grid-voltage change, the drift amounts to several hundred millivolts.

If this tube is the video-blanking mixer, the grid will be clamped during blanking to a fixed voltage. If, however, the video into this tube is but one-volt, a drift of some 20 per cent could be expected. With a 10-volt video level, and the same plate-current, the expected drift would be one-tenth of this, or about two per cent.

Measurements of clipping stability over an eight-hour period have borne this out. Relative drift between the three channels was found to be about plus or minus one per cent over an eight-hour period. This stability is obtained without uuse of feedback clamp systems, which in some cases, are plagued by video duty-cycle variations. To keep the video-blanking mixer-tube from becoming over-loaded by the 10-volt video signal, a large mount of cathode degeneration is used.

The Gamma circuit, shown in figure10, is a four-segment device designed to closely approximate an exponent of 1/2.2 over a thirty-to-one Brightness range. The video is black-positive at the input to the Gamma circuit; the level is four volts. When signal amplitude is at or near black level, the three diodes are biased so that they do not conduct, and the load on the clipper is R_1 only. As the signal becomes more and more negative, the diodes conduct and "switch in" the additional resistors across R_1.

- more -

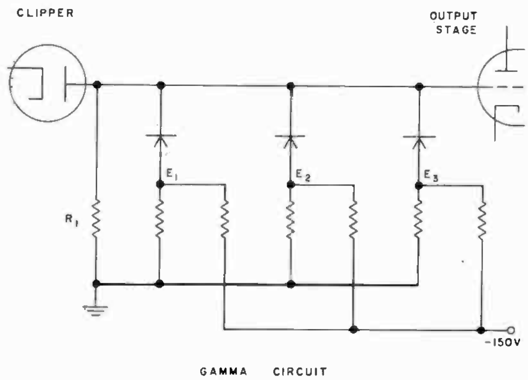


FIG. 10

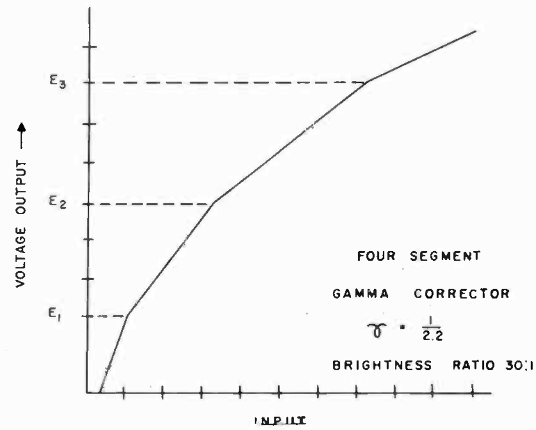


FIG. 11

Resultant transfer characteristic is shown in figure11. All resistors are stable, one per cent units. The diodes have a nominal forward resistance of about seven-ohms. Should the diode forward resistance change by as much as 100 per cent, the total resistance of the leg would change less than one per cent, since the diode resistance is very small compared to the fixed resistor.

The Gamma curve formed in this manner is very, very stable. Thus, it is possible to eliminate all adjustments and still maintain precise Gamma tracking between the red, blue and green channels.

Some high-contrast films require more black-stretching, however, so provisions have been made to switch-in a diode-resistor circuit to further increase the gain near black. The "break point" of this additional stretching is adjustable.

Correct operation of the Gamma circuit requires that the peak (white) level across it be four-volts. The output stage gain is then adjusted for a fixed gain of one-fourth, and the output level monitored at one-volt, in the usual manner. Output stage is direct-coupled from the clipper and Gamma circuits. This has the following advatages:

1. Zero bounce and practically no tilt on the output signal;
2. Output stage serves as White-Clipper, since a high-level white signal will drive it to cut-off;
3. Less stray-capacity across Gamma circuit permits higher impedance;

4. Extreme linearity not required, since slight curvature of output adds to Gamma curve;

5. Operation does not depend on video signal duty-cycle.

The Monitor Switcher section of the Color Channel Amplifier is common to all three video channels and is part of the main chassis assembly, as shown in figure 12. The chassis also contains the Clamp-Keyer, Blanking Buffer, +150-volt and -150-volt regulators, AGC rectifier, and a Calibration Saw Generator.

The Monitor Switcher section keys-in successive fields of red, blue and green, so that all three can be displayed on a single Waveform Monitor. The Monitor Switcher can be broken down into two functions —— the Keying-Generator and the gated-adder stage.

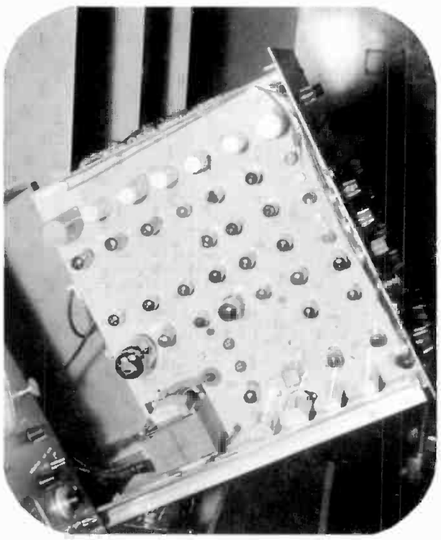


FIG. 12

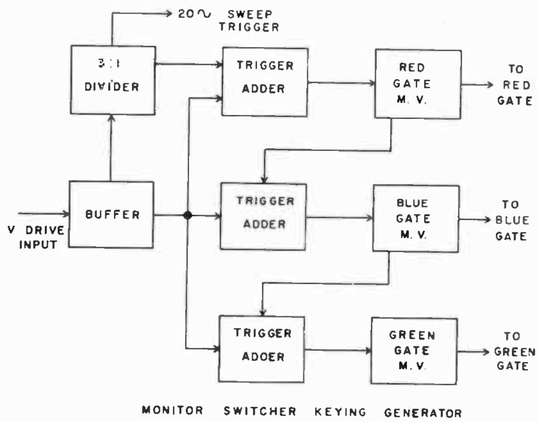
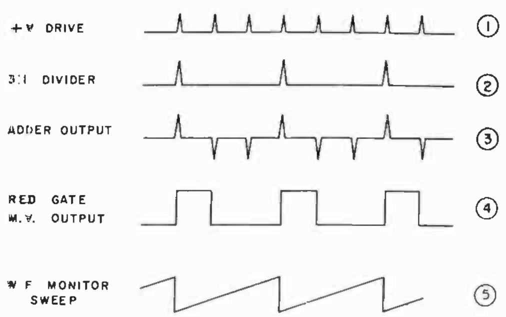


FIG. 13

The Keying-Generator is shown in figure 13. There is but one timing multivibrator in the entire circuit, which is the three-to-one divider. It is extremely stable and requires no adjustment.

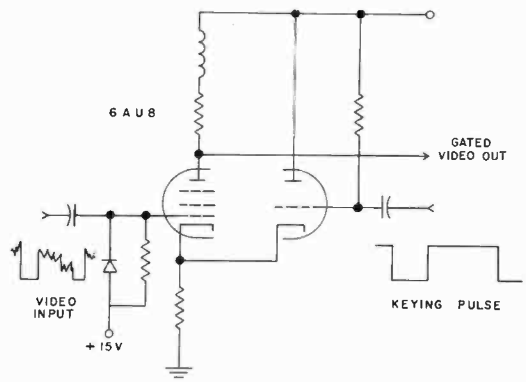
Most tubes will continue to count by three in this circuit even when the filament is dropped to 2.6 volts! The other multivibrators are simply ON-OFF devices and are not critical.

Figure 14 shows waveforms of the circuit. By combining wavetrain (1) and (2), the composite trigger (3) is obtained. First positive pulse turns the red multivibrator ON, while the first negative pulse turns it OFF. Succeeding negative pulses have no effect, since it is already in the OFF state. Output is the waveform at (4), which turns the red gate ON for one field out of every three. The blue channel operates in the same manner, except that the ON trigger pulse is taken from the trailing edge of the red gate. The green ON trigger is likewise taken from the blue gate. The entire Keying Generator, therefore, requires no setup or maintenance adjustment.



MONITOR-SWITCHER KEYING WAVEFORMS

FIG. 14



MONITOR SWITCHER GATE

FIG. 15

The Gated tubes are pentode sections of 6AU8's with the three plates tied together, figure 15. The Keying pulses are cathode-coupled through the triode section of the same tube. When the triode section is conducting, it raises the cathode voltage of the pentode section enough to cut off the plate current. When the triode section is cutoff by the keying pulse, the pentode section is biased to operate as a normal class A amplifier. This type of gate uses a large cathode resistor, thus is very degenerative to the video signal. Once again, the result is ahigh degree of gain stability. Redulting feedback of each channel is in the order of 20 DB.

Obviously, modern mass-produced vacuum tubes are not all alike, even though identical numbers are stamped on them. Even with 20 DB of feedback, the three Gated tubes will not have identical DC plate currents. Because of the gating operation, this unbalance would show up as a 30-cycle square wave in the output.

This unwanted output wave may be eliminated with balance pots. However, to keep the number of controls to a minimum, a special clamping waveform is used to clamp it out.

The clamp keying waveform consists of both H and V drive pulses, added together and clipped. The V-drive pulse is used to hold the clamp diodes ON for many lines following the field rate "step." This reduces the time required to charge --- or discharge --- the clamp coupling capacitor to several micro-seconds. With a conventional clamp, it may take 100 micro-seconds or more.

A small spike of a few microseconds duration resulting from the finite clamp speed is almost invisible on a 20-cycle sweep display, and will in no way interfere with calibration measurements or level monitoring. The red, blue and green outputs, therefore, can be checked directly, since it is not necessary to feed the commutated signal through a blanking mixer and clipper to remove the spike.

Provisions are made for easy and rapid calibration of the entire unit. A built-in Sawtooth Generator provides a calibration signal which can be switched into all three channels in place of the video input signals. If the output of the Monitor Switcher is observed at horizontal rate on the waveform monitor, the three waveforms will be super-imposed on one another, as shown in figure 16

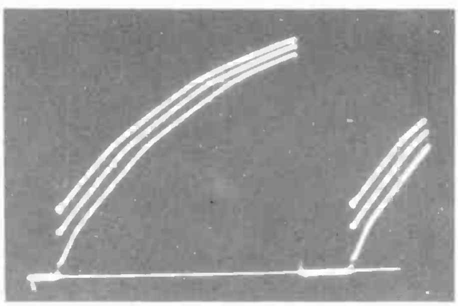


FIG. 16

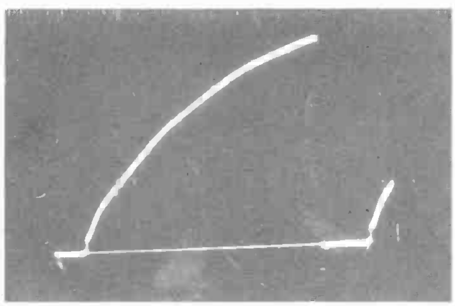


FIG. 17

Here the blanking controls have been purposely misadjusted. When they are correctly adjusted, the three waveforms appear as one, as shown in figure 17. This is a simple, yet accurate method of checking Gamma tracking of the three channels.

A front-panel switch is used to increase level of the calibration Sawtooth five times. This provides a simple means of checking AGC tracking.

Figure 18 shows the same commutated output with input level increased five times. The output level increased but a few per cent and, as you will note, there is no observable change of the Gamma curve.

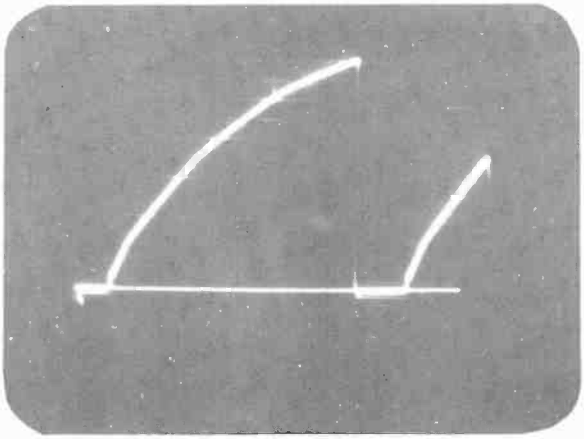


FIG. 18

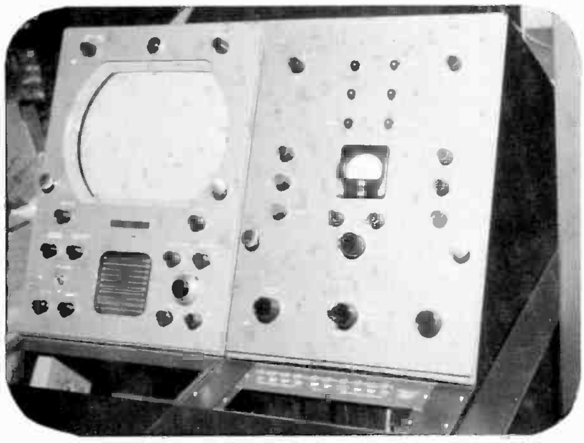


FIG. 19

In figure 19, a front-panel switch is used to select the input to the picture and waveform monitor —— through an isolation amplifier. Positions include red, blue or green output lines, encoder output, and one position marked "test probe." In this position, the waveform monitor input is connected to a flexible probe which can be used for calibration checks,or for a limited amount of trouble shooting in place of aregular oscilloscope. Complete calibrations of the device can be done in about five to 10 minutes. Routine calibration, which should be done about once daily, can be done in about two or three minutes.

Design objective for this unit is to make it stable and simple to operate, while mounting the high degree of performance required of color television equipment.

Stability objective has been met by the high-level clamp, resulting in blanking variation of two per cent, or less, over long periods of time, and by gamma circuits which are independent of active elements, such as tubes or diodes. All video stages incorporate cathode degeneration. Some have additional DC feedback. The monitor Switcher-Keyer requires no adjustment.

For simplicity of operation, the number of controls has been reduced to but half of the number required in former equipment. A built-in calibration signal and test probe permits easy and rapid setup of the equipment. A video AGC removes most of the gain-riding chore from the operator. In addition, a gain-reduction meter on the front panel makes the initial level setup a simple adjustment.

Each of the three channels provides a volt of video into a 75-ohm line with a 75-ohm source impedance. High-frequency response is flat to six-MC, and down less than two DB at eight-MC. Low frequency tilt is less than one per cent.

Phosphor correction circuits bring the center resolution to 600-lines, without overshoot or smear.

Stability of Gamma tracking is illustrated in figure 20. This photo was taken one week following that of figure 17. During this week of operation, no calibration controls were touched.

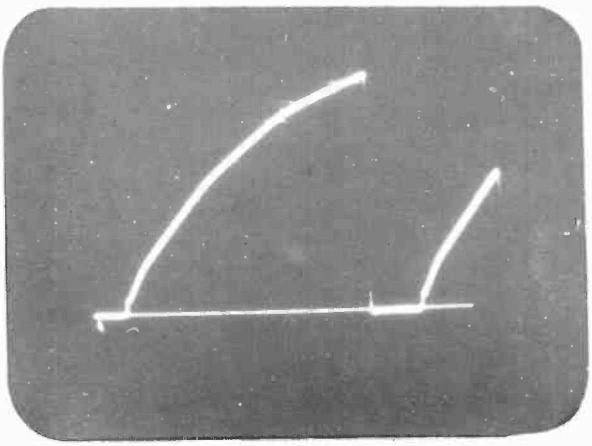


FIG. 20

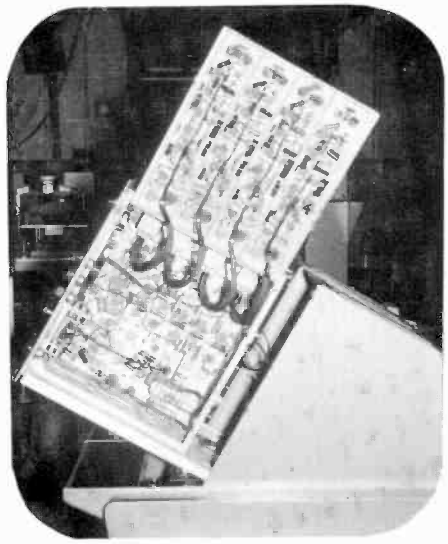


FIG. 21

The General Electric TV-88-A Color Channel Amplifier has a built-in +150-volt and a -150-volt regulator. All filament voltages are regulated for long tube life and stable operation.

For ease of maintenance, one side of the unit hinges up, as shown in figure 21.

22

VIDEO SWITCHING AT TELEVISION OPERATING CENTERS

A Paper For Presentation To

THE NATIONAL ASSOCIATION OF RADIO
AND TELEVISION BROADCASTERS

By

V. R. Hatch

VIDEO SWITCHING AT TELEVISION OPERATING CENTERS

Network television started in 1948 with a coaxial television circuit between New York and Washington. Since then, there has been rapid growth in the network facilities, and at the beginning of this year the Bell System had some 77,000 channel miles of video facilities, most of it equipped for color transmission. At the present time there are three major networks, one of which is shown in Figure 1. Switching of television programs involves two separate areas: sound, and video or picture. TV audio is transmitted over various Bell System program facilities similar to those previously built up for the networks primarily for radio purposes. Switching arrangements have been developed over the years for this part of the network, and either the Telephone Company or the broadcaster might make these rearrangements. The video links which make up the television networks are put together in various combinations of radio relay or coaxial cable circuit units as the needs of the broadcasters vary from hour to hour, and switching to accomplish this is usually done at Bell System operating centers known as Television Operating Centers, or TOC's.

Typical video facilities which might be furnished by the Bell System to one of the television networks within a typical city are illustrated in Figure 2. The local video facilities furnished to a network radiate from master control boards furnished by the broadcaster to each program originating point within the city and also connect between some broadcaster's studios. Some of these from the local studios of the network are used regularly for program origination. Others from miscellaneous local pick-up points such as the White House in Washington or Madison Square Garden in New York City are used less frequently. One or more circuits are furnished from the master control board to the transmitter of the local station affiliated with the network. The local video channels used to interconnect the television broadcasters' various locations within a city and to connect the broadcaster to the Bell System intercity network are being improved by the introduction of the new A2A video transmission system. The television operating center has interconnecting facilities to the TD-2 radio relay tower or coaxial termination serving the particular city. These may be in the same building or elsewhere.

In the early years of television when the networks were small, the necessary switches could be performed by coaxial patch cords or patch plugs. The first specially designed switch for making these network changes is shown in Figure 3. Each horizontal row of buttons has one input circuit associated with it and each vertical row is associated with an output circuit. Connection of an input to a desired output is made by pushing the button at the intersection of the two rows. A button which has been operated is protected by a green guard ring. A switch can be set up in advance by selecting the button which will be pushed and marking it with a red guard ring. These are referred to as preselected switches, and leisurely preselection in advance of actual switching tends to reduce operating errors. All other buttons are protected by white guard rings to guard against accidental operation. The switches themselves are mounted on the back of the panel and are operated directly by the push buttons. Switching with this equipment is done on a balanced circuit high impedance basis, and this is satisfactory as long as only one or two outputs are connected to an input. However, as additional outputs are connected to an input, special measures must be taken to reduce the high frequency roll-off effects caused by the paralleling of input capacitances. This is especially important for NTSC color transmission and creates operating problems which limit the flexibility of the switch.

The new video switch includes splitting pads, relay contacts, amplifiers and cables so designed that any input may be connected to any one or more outputs with negligible impairment of the video signal. Switching is on a 124 ohm balanced, constant impedance basis with the inputs terminated at the switching relays when not in use. Balanced rather than coaxial circuits are used throughout the video switch because many of the television operating centers are in locations where differences in ground potentials are to be expected due to nearby power, lighting or contact making equipment. Figure 4 illustrates the basic switching pattern for a video switch having 10 inputs and 12 outputs. Each input may be connected to any or all of the outputs by the operation of relays in the switch. Each input is terminated in a splitting pad having 12 output legs. Each of the 12 legs of an input splitting pad is terminated in one relay in each of 12 different 10 x 1 switches. There is about 54 db loss between any two output legs to prevent a momentary open on one leg from producing an appreciable transmission effect on circuits connected to other legs of the pad. This splitting pad is shown in Figure 5. Referring back to the previous figure, for each output circuit there is a 10 x 1 switch panel containing 10 wire-spring relays. Each of these 10 x 1 switches is capable of connecting any one of 10 inputs to the output associated with the 10 x 1 switch. The basic 10 x 12 switch units may be combined to form a 20-24 or 30 by 36 video switch so that each input may be connected to any one or more of the outputs as desired. This is accomplished by introducing splitting amplifiers with three identical outputs in the input and 3 x 1 switches at the output of the basic 10 x 12 switch units as shown in Figure 6.

The relays used throughout this switching system are wire-spring relays developed in recent years by the Bell Laboratories. To make these relays adaptable to automatic manufacturing processes, they have wire-springs mounted in a moulded assembly with precious metal double contacts welded on the ends of the springs, (Figure 7). This relay is faster and requires less power than the older flat spring type. The relays used in the video switch are standard models with no structural changes having been made other than to ground the non-circuit elements. In order to reduce crosstalk the link between the input and output is grounded when thru connection is not desired. Further crosstalk reduction is obtained by using two sets of transfer springs as a ground plane between the input and the output. In this application, the transmission paths of the wire-spring relays are connected by printed circuitry shown in close up by Figure 8. The two printed circuit multiple panels of a 10 x 1 switch unit are accurately spaced with respect to each other and permit reproducing with considerable accuracy the same capacity effect in the multiple wiring of all 10 x 1 switch units. Each input has a different length of printed wiring to the common output. This produces a variation in impedance which is compensated for by series inductances of different values.

The splitting pads at the input of a switching system introduce approximately 27 db loss into each connection between an input and an output. To make up for this loss, a receiving terminal amplifier such as is used in the A2A video system is inserted into each video switch output trunk circuit. This is a three stage video amplifier which for this application is constructed so that both input and output are balanced 124 ohms. It provides about 27 db gain with a nominal bandwidth of 4.5 mc. The gain frequency characteristic matches 10 to 50 feet of cable within .06 db out to 4.5 mc. The balanced amplifiers have several advantages, the most important of which are the reduction of distortion due to balancing out the even order distortion products of the electron tubes, and the reduction of longitudinal disturbances at the input of the amplifier. The outputs of the video switches are normally terminated in 124 ohm impedances which are automatically removed when connection is made to an output amplifier. Thus the impedance which an input "sees" looking into the video switch remains constant no matter how many outputs are connected.

In a large video switch such as this the components between input and output must be connected by several lengths of cable. (Figure 9) It is impracticable to provide individual equalizers for each length of cable. Accordingly, one equalizer is used for each incoming or outgoing connected facility. In this way one equalizer serves for several cables and associated components. All inputs and outputs are equalized to a common reference point as near as feasible to the switch contacts in the 10 x 12 switching unit. Since equalization tolerances are severe and all paths through the switch must be equalized alike, strict requirements are imposed upon the various cable lengths in the switch.

Switching in this system is controlled from a panel as shown in Figure 10. Incoming lines are represented by horizontal rows of lamps and outgoing lines by vertical columns. Each intersection of an incoming and outgoing line is indicated by two lamps, a white "preselect" and a red "execute" lamp. Each incoming line is controlled by a black push button and each outgoing line is controlled by a white push button near the bottom of each vertical column. Below the white push buttons a group of amber push buttons and lamps permit nearly simultaneous, or "salvo" operation of several switches at one time. Salvo operation permits one man to set up a number of switches in advance and then execute them in one operation, thus avoiding congestion at the panel during busy switching periods. It also allows the attendant's time to be utilized efficiently since the work of preselecting the switches can be spread out over the interval between busy switching times. After the preselection has been accomplished, it can be readily verified by the attendant's supervisor by merely looking at the lamps which are lighted.

To prevent the possibility of an unintended switch by an attendant accidentally touching one of the buttons the control panel is arranged so that the operation of a single button cannot cause a switch operation. Two buttons must be pressed simultaneously. To preselect a switch the operator presses the correct white and black buttons corresponding to the input and output to be connected. The white lamp at the intersection of the two lines indicates when this has been accomplished. Later, when the switch is made, the white button and one of the red execute or master buttons must be pressed simultaneously. When this is done the white lamp goes out, and when the buttons are released the associated red lamp lights to indicate that the switch has been made and that the outgoing line is in service.

As each connection is preselected on the panel it is automatically assigned to the top salvo row at the bottom of the panel, and the amber lamp corresponding to the associated output is lighted in that row. A preselected connection may be assigned to another salvo row by pressing the associated output button and the button of the desired salvo simultaneously. The amber lamp corresponding to the output will go out in the top salvo row and another amber lamp will be lighted in the new salvo row. All the switches assigned to any salvo may be executed simultaneously by pressing the master button and the desired salvo button. Two green annul buttons are located at the bottom of the panel so that if it is desired to nullify a preselection, this can be done by pushing the associated white outgoing line button and the green annul button.

In order to release outputs from service and make them available for testing, the lowest horizontal row of green and white lights on the main control panel is designated a "no service" row. When an output circuit is not in use it may be preselected and executed to this row in the same manner as to any one of the 30 input rows. As soon as the execute or green lamp corresponding to an output circuit lights in the no service row an "available" lamp corresponding to the output circuit will light in each test position (Figure 11). Control of the output circuit remains at the control panel so that it may be recovered for program service at any time. The operation of an output selection key on the test position also lights a "test in progress" lamp corresponding to the output circuit on the main control panel. These are located in a horizontal row just below the "no service" lamps.

Arrangements of crossbar switches are used to provide memory for the preselections and salvos and provide ground to operate the video switches and light the panel lamps. The common control equipment is provided in duplicate in such a way that should one set of common control equipment be inoperative because of a fuse failure or other troubles, switches could still be made using the duplicate equipment.

This new switching and control arrangement has been installed and is now in operation in the TOC's in New York, Los Angeles, Chicago and Washington. Similar installations are scheduled for 1957 in Atlanta, Dallas, Philadelphia, Cleveland, Richmond, Des Moines, Minneapolis, Buffalo, Columbus, Montreal, Toronto, and Calgary, and of course, additional ones are planned for other locations beyond 1957. This is part of a broad overall plan to furnish a reliable means of switching which will meet the exacting transmission requirements of modern television operations.

VRH:DA
3-20-57

VIDEO NETWORK PROVIDED FOR ONE BROADCASTING COMPANY

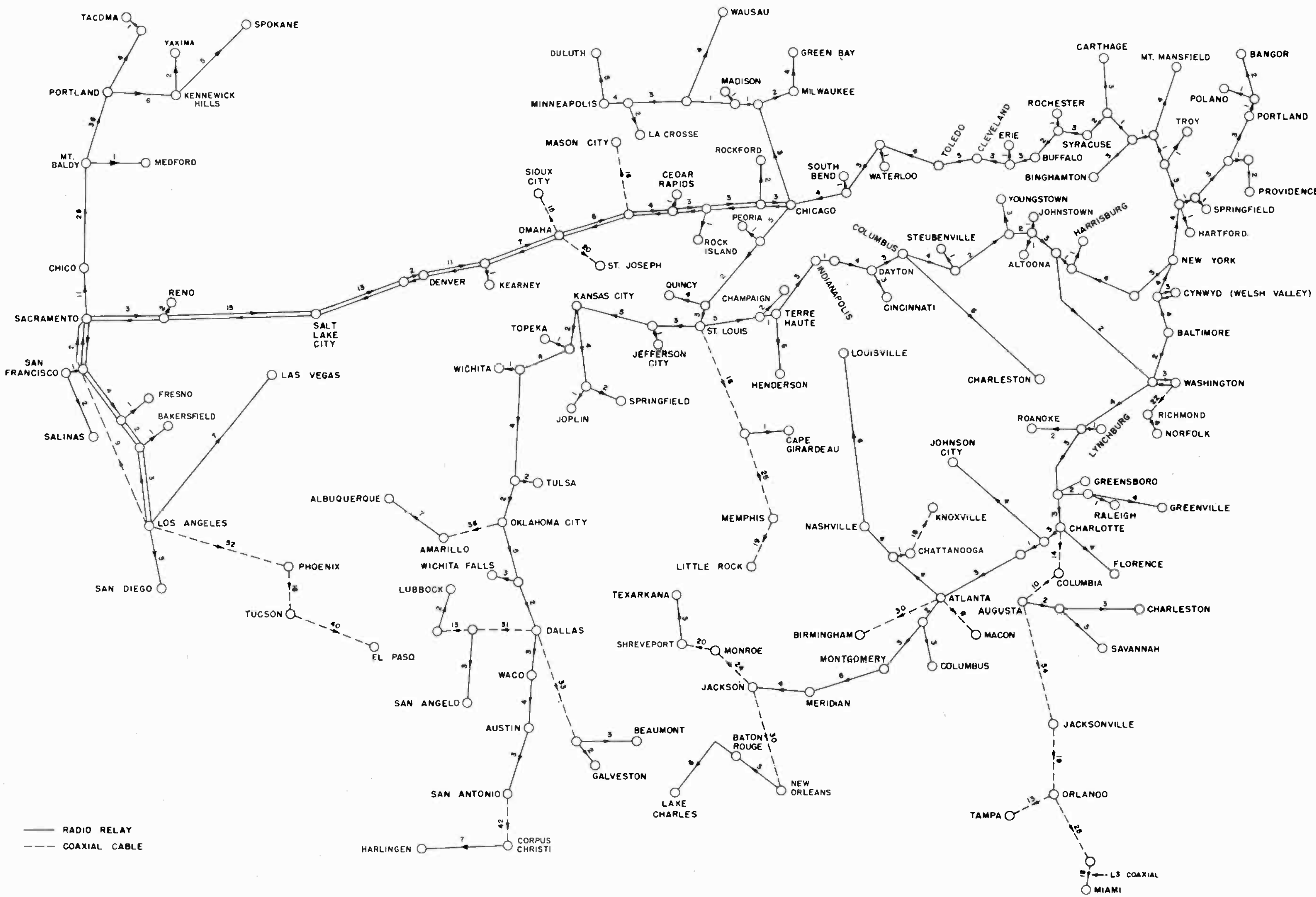
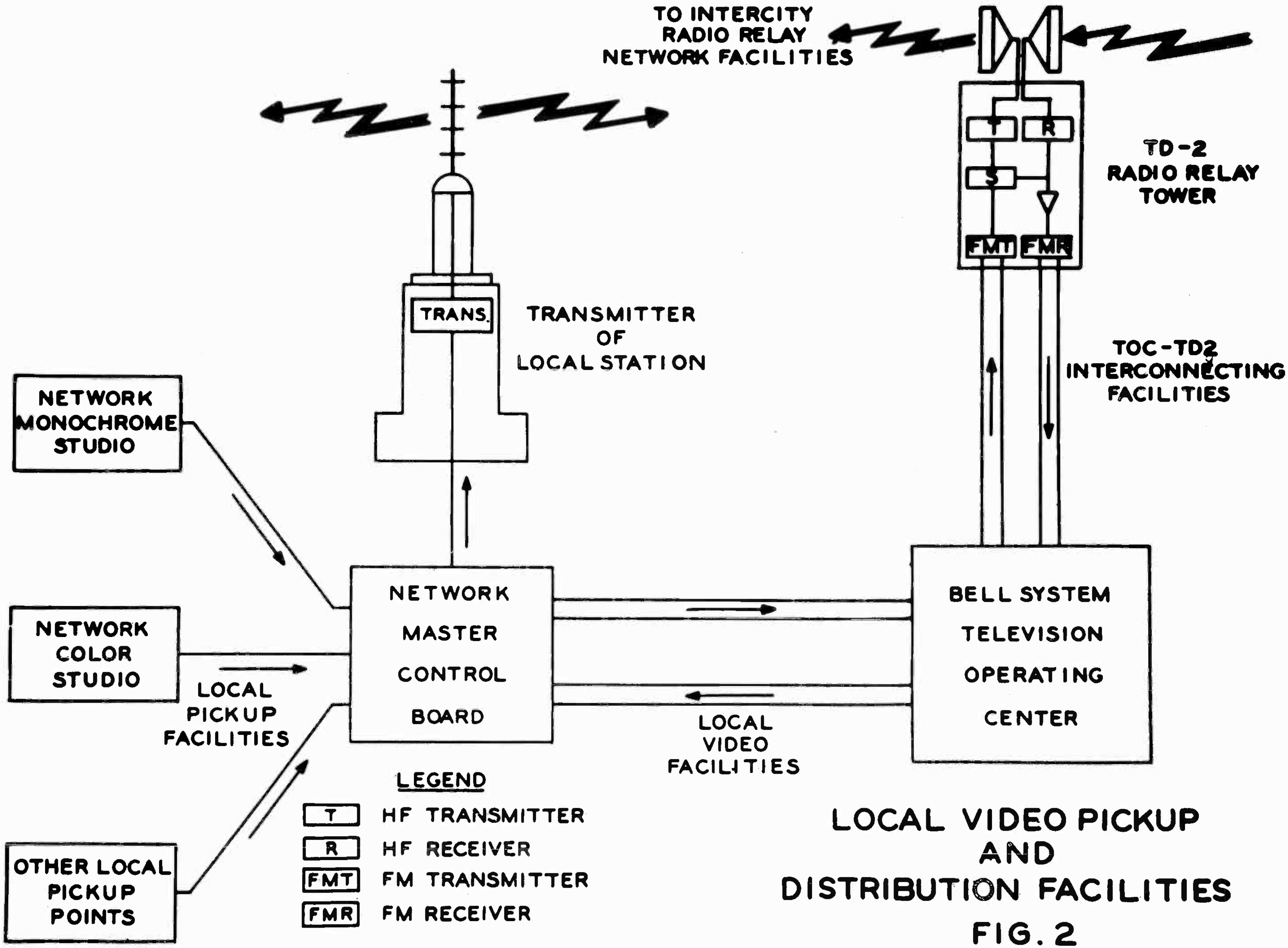
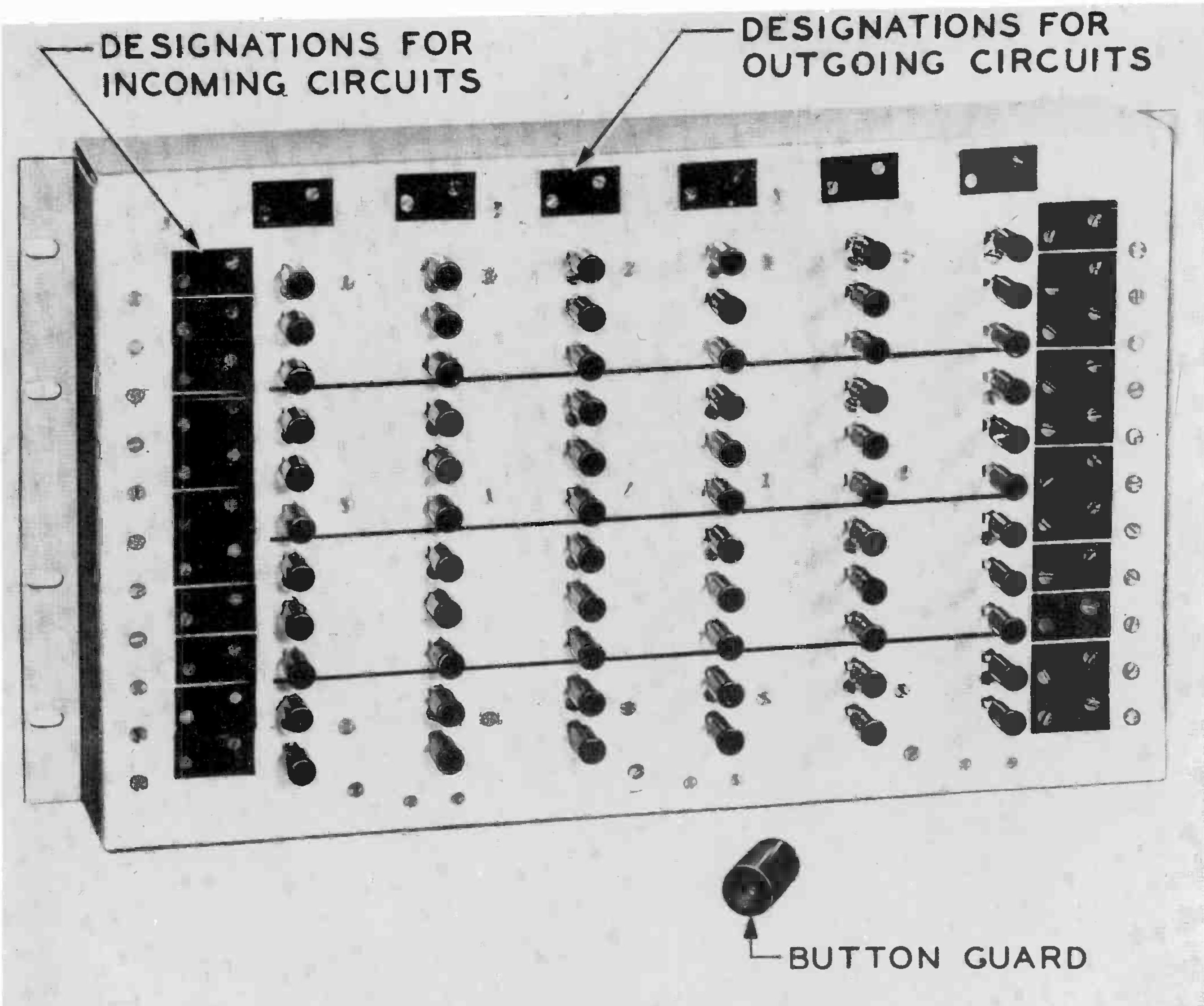


FIG. 1

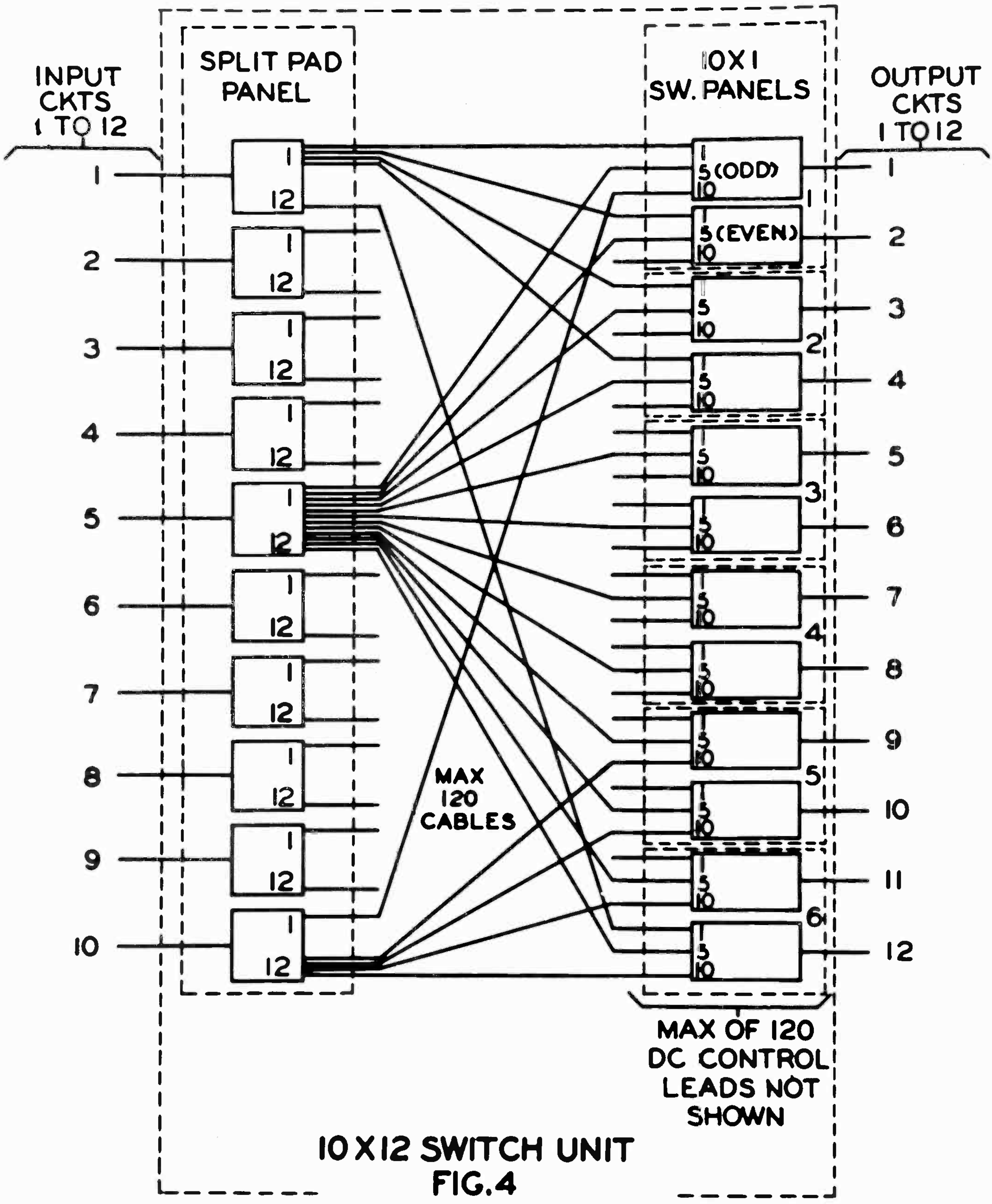
3-1-57



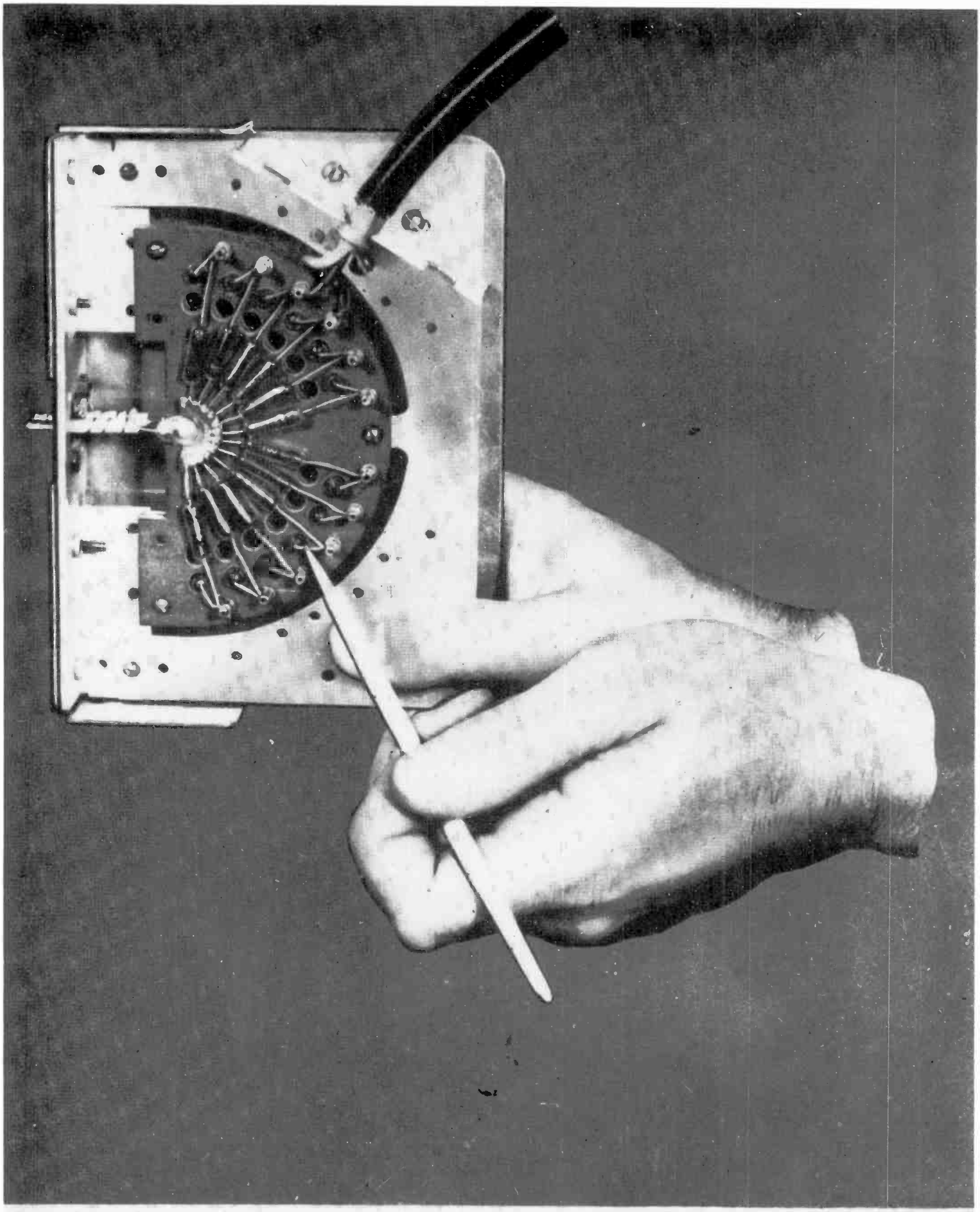
LOCAL VIDEO PICKUP
AND
DISTRIBUTION FACILITIES
FIG. 2



PUSH-BUTTON-TYPE
VIDEO-SWITCH PANEL
FIG. 3

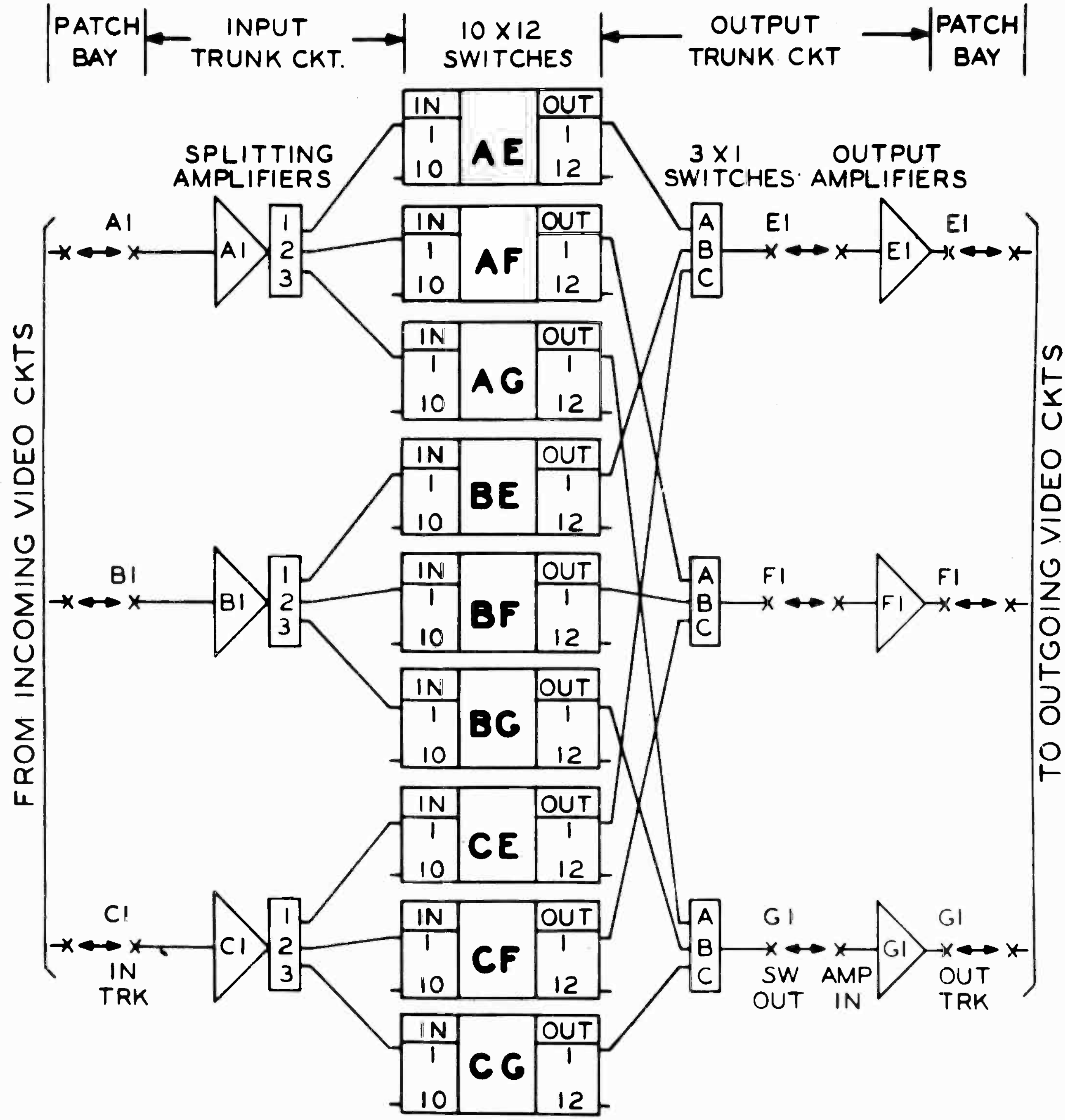


10 X 12 SWITCH UNIT
FIG. 4



1 X 12 SPLITTING PAD
FIG. 5

21-30 INPUTS TO 25-36 OUTPUTS



TYPICAL VIDEO SWITCH CIRCUIT LAYOUT

FIGURE 6

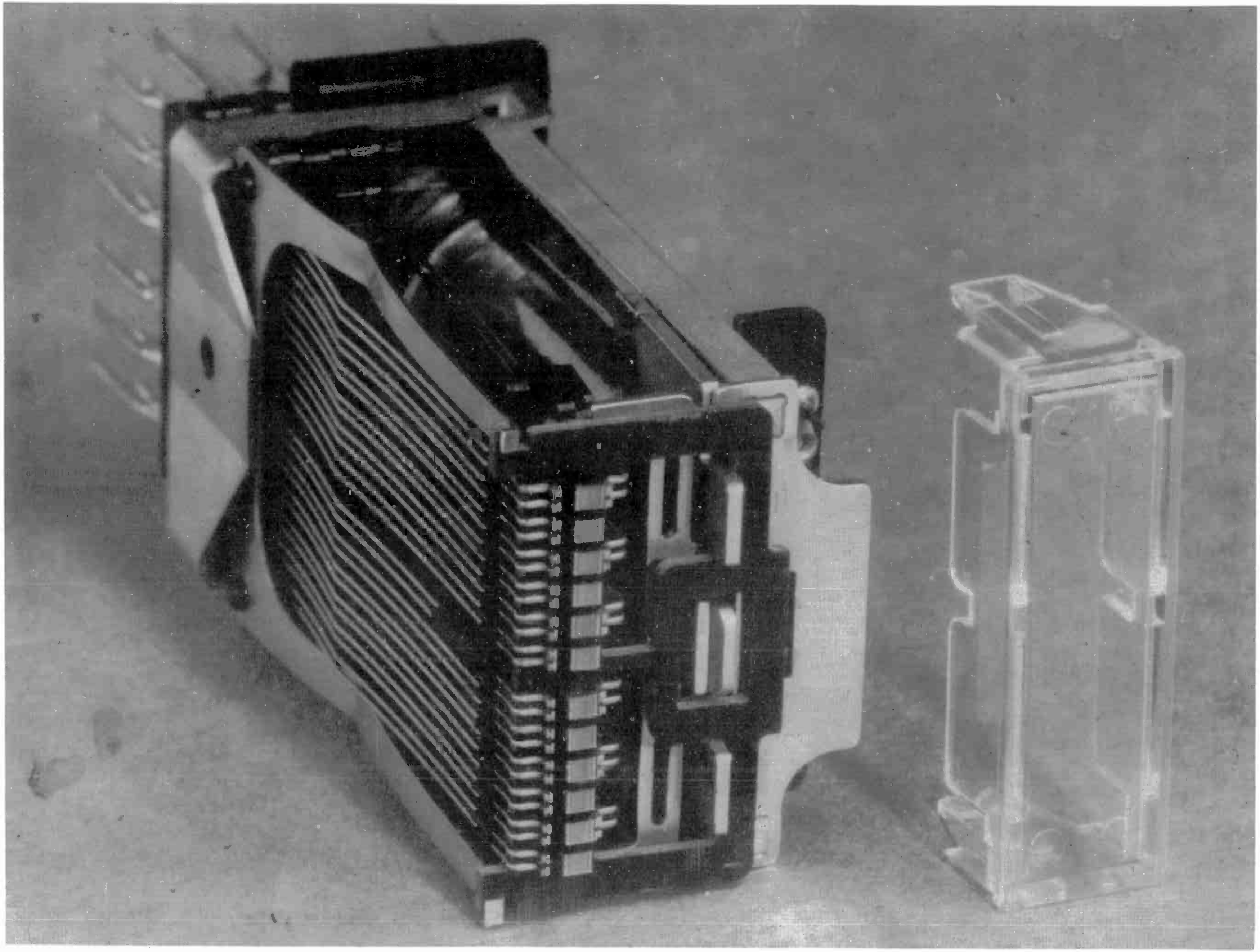
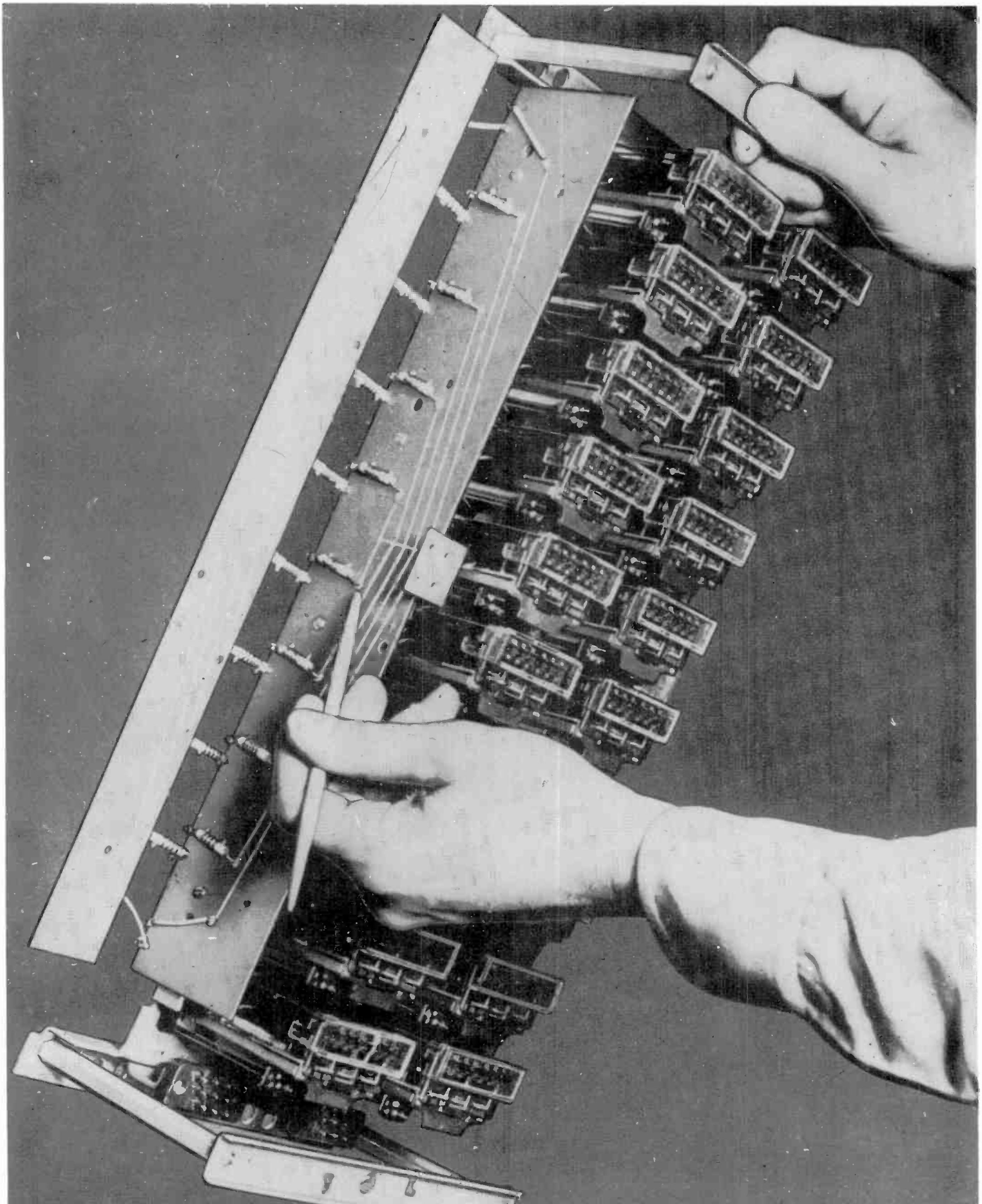


FIGURE 7



10X1 VIDEO SWITCH MULTIPLE WIRING

FIGURE 8

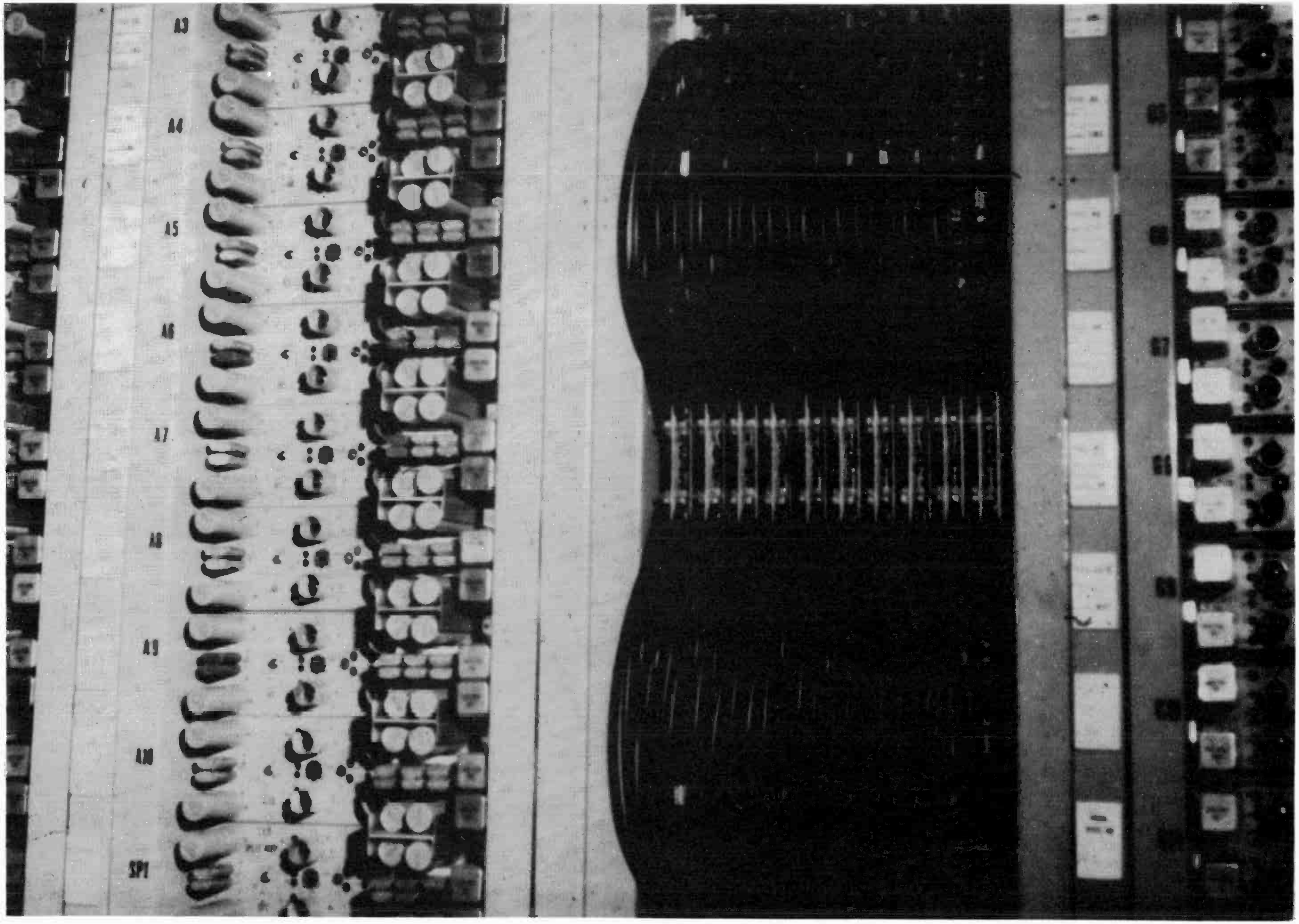


FIGURE 9

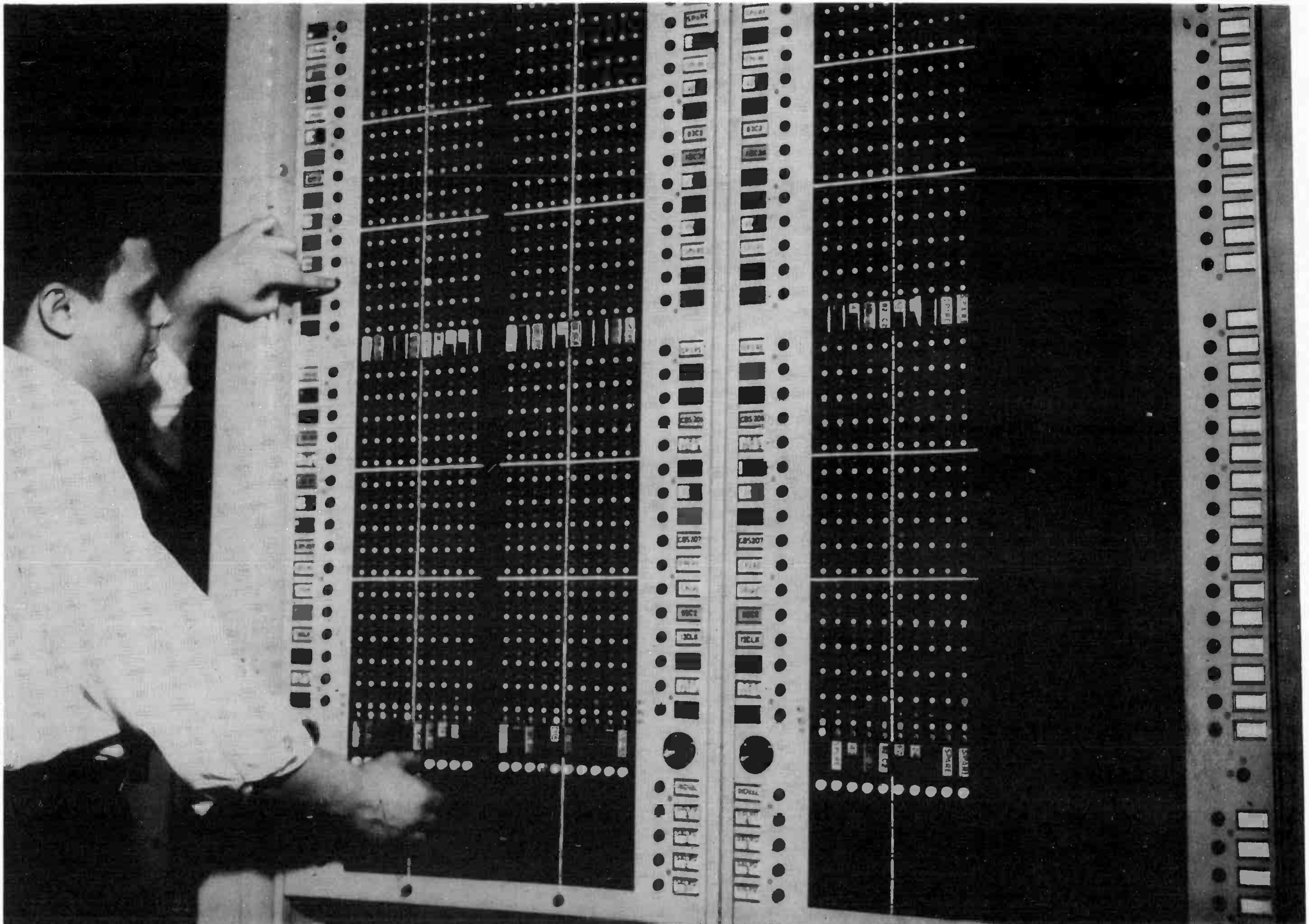


FIGURE 10

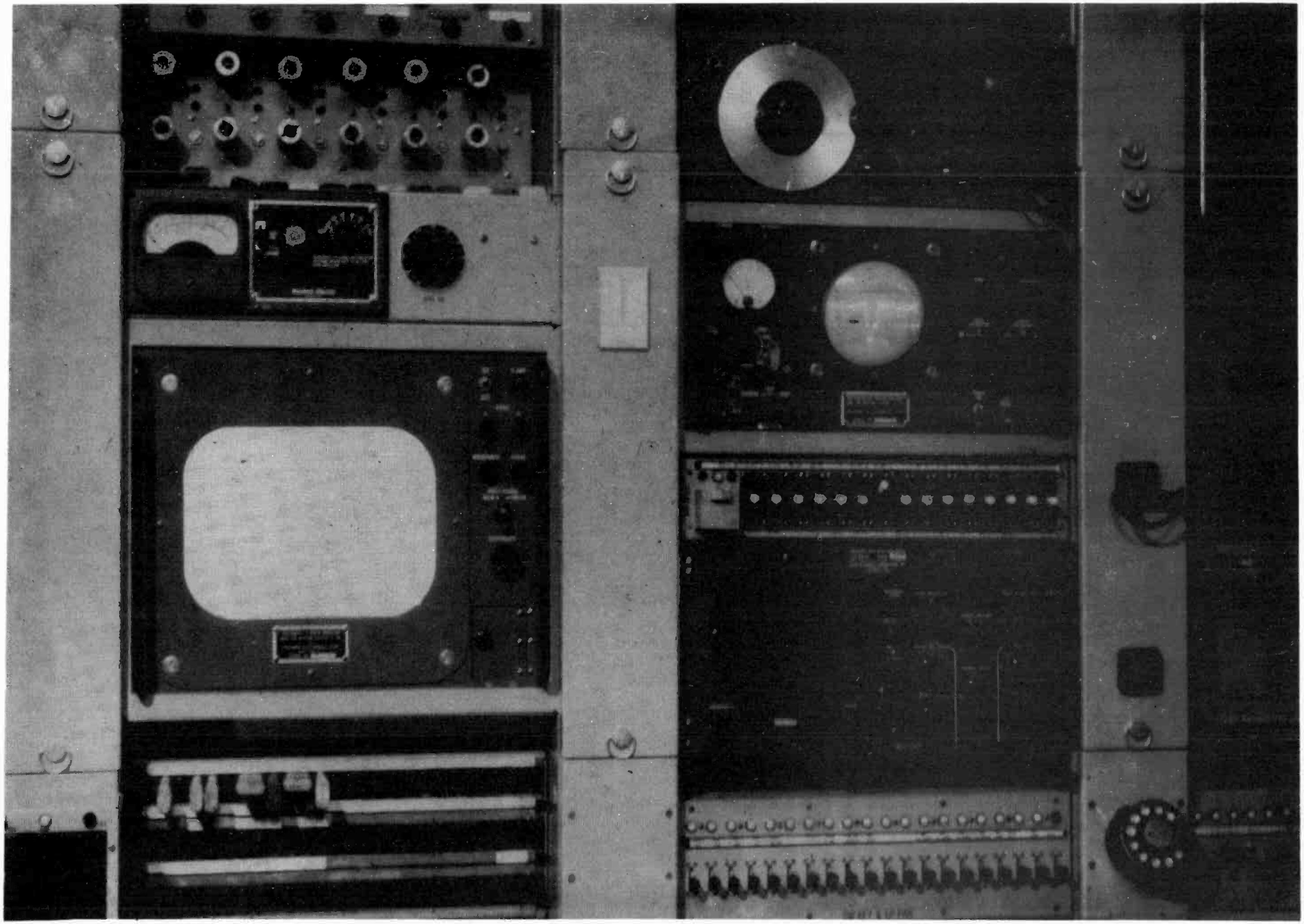


FIGURE 11

VIDICONS AND REMOTE CONTROL IN LOW POWER ECONOMY TELECASTING

by

R. T. Silberman, Vice President
KIN TEL (Formerly Kay Lab)

Thursday, April 11, 1957
10.00 - 10.25 A.M.

Eleventh Broadcast Engineering Conference
Chicago, Illinois

Several new developments in recent years have combined to create a demand for a reappraisal of telecasting techniques and installation procedures. The advent of the vidicon pickup tube has stirred the imagination of all economy minded engineers and operators. F.C.C. action authorizing so called low power operations provided impetus for the development of economical station components.

It has been found that the integration of simplified video equipment, practical remote control accessories and low power transmitters provide complete new concepts of operating efficiency and minimum area requirements for profitable station operation. The resultant techniques are not only suitable to the small or low power market but also to satellite operations and educational activities.

Expanded even further, the remote control vidicon operation will prove profitable to larger station operations, especially for early and late shift and remote requirements. The fundamental economy results from the utilization of low cost vidicon equipment and "human engineering" in station layout and equipment systems, minimizing operator and maintenance requirements.

From a new station point of view, several situations offer potential. In those areas which are not now served by direct coverage, interesting markets can be generated through studying the list of community antenna cities. These cities not only have a ready made market in the sets that have been attached to the community antenna systems, but also provide some insight into the feasibility of an off-the-air pickup. Finally, merchants in these cities are primed for TV advertising because they have been frustrated by the lack of a local media. Community systems bring entertainment without the parallel opportunity for commercial use.

A second class of potential markets for this type of operation includes those cities which fall under the umbrella of a major market situation but in essence do not have local service. In these situations the local area or suburban merchants cannot afford full coverage rates. Low power operations utilized in these areas can truly become TV's equivalent of AM's music and news outlets.

A third class includes those cities which now are served by one or two stations and which normally could not support a third large station, but might well fit the low power dollar formula. In this category there are many UHF areas which offer considerable opportunity.

Finally, educational stations of all categories should give close attention to the potentials of low power television, for simplified operation and minimum investment are compatible with the abilities of educational institutions. In this respect the use of low power video links as audio visual intercommunication systems for educational districts should not be overlooked. Considerable opportunity exists for providing a true adjunct to the normal teaching services by expanding the efficiency of teaching districts through the dissemination of training material from a central location. While in the sense of education for the public UHF stations in many cases are not practical, they are entirely feasible in terms of a link between educational institutions for student training purposes.

Some of these potentials exist today. Channels are available which can be utilized for low power operations. Other situations can be created through drop-in stations within the framework of the present allocations. Finally, the full potential of this type of service may reach fruition if, as time passes, directional antenna configurations are provided for within the framework of the Commission's regulations.

Present stations have found these techniques directly applicable to many operations for which image orthicon type camera equipment is now utilized. In particular, studio commercials, news casts, pickup of flip cards and so called commercial corner operations are readily adaptable to these techniques. Vidicons can be used for outdoor semi-remotes, for example in conjunction with automobile commercials.

Another application which is attracting increasing interest among station operators is the use of remote control equipment in conjunction with cameras for early and late operations, sign-off commercials, late hour news, and similar programming.

As mentioned, the key to economical station operations today is in part the result of the development of vidicon tubes. The fundamental simplicity of the tube itself and the required associated circuitry has made possible extremely rugged, simple to operate camera design. The present price of the broadcast quality, 16 millimeter vidicon is approximately one third that of the image orthicon. Since the vidicon uses 16 millimeter lenses, a wider aperture can be utilized for the same equivalent 35 millimeter field of view and depth of focus. Considering this apparent gain of the 16 millimeter lens system, vidicon sensitivity has proven to be within the factor of 10 db of the image orthicon.

The quality of tubes which are now manufactured, in terms of resolution and shading, is excellent and compatible with the highest broadcast standards. Consistent center resolution in excess of 600 lines is readily obtained, and corner resolution of 300 to 400 lines is practical.

This degree of corner focus can be obtained with the use of parabolic or dynamic focusing voltages. Shading of less than two or three percent per total scanned area results without the use of shading generators.

For indoor operation such as newscasts, flip cards, and commercial presentations, 150 to 200 foot candles of light are required. Experience has shown that vidicons for broadcast purposes have useful life in excess of 4,000 to 5,000 hours. In effect this means that the operating cost of the vidicon tube is on the order of 10 or 20 cents per hour.

Lag, or the apparent ghosting of images, which was prevalent in some early vidicon systems has been almost entirely eliminated through the use of (a) lower target operating voltage as a result of improved video amplifier design, (b) improvements in tube manufacturing techniques, and (c) utilization of better lenses.

An interesting phenomenon has been generally observed, that is, that after three or four hundred hours of operation the apparent lag in the vidicon tube is somewhat less than when initially installed, and as the tube ages there is essentially no noticeable change in the lag characteristic. Of real significant operating advantage is the fact that the vidicon has instantaneous warmup and images that are permanently focused on the conducting surface will not burn in. The combination of instant warmup and the elimination of burning problems makes the remote control of the units quite simple.

The gamma of vidicon tubes is somewhat less than one, averaging about .6. The application of vidicon tubes to film chains is, I believe, now accepted as a standard practice. For certain live applications in some quarters it is felt that a characteristic more like the image orthicon is to be desired. Many feel that the full grey scale of the vidicon provides more picture realism and fidelity. However, when vidicons are integrated with image orthicons in existing stations, or where in the new stations vidicons are used in competition with stations using image orthicons for live pickup, the employment of commercially available gamma correctors may be necessary as a "competitive equalizer."

Vidicon live cameras incorporate 8 megacycle plus amplifiers. By utilizing an amplifier with a bandwidth within 1 or 2 db at 8 megacycles and an aperture correction with maximum emphasis at approximately 6 megacycles, a good balance has been obtained between maximum resolution and best overall signal to noise ratio.

Video preamplifiers utilizing double cascode inputs allow for maximum sensitivity and make it possible to operate the vidicon tube at lower target currents. Typical target currents in the neighborhood of .2 microamps have been found quite satisfactory.

The vidicon cameras have generally been designed for minimum size. A typical design is such that the basic camera head is used inside a viewfinder housing for live pickup purposes when a camera operator is employed. The small size of the camera allows it to be attached to economical and reliable remote positioning equipment.

Viewfinder assemblies are now available incorporating rear control 4-lens turrets and nonlinear, side handle, lead screw focusing mechanisms. 16 millimeter lenses have a "short" focus. Operators must become accustomed to the differences in focusing technique, but readily obtain the feel of the mechanism. Tubes up to 7" are utilized and a complete camera viewfinder assembly typically weighs under 50 pounds.

Control units have been developed which are extremely compact. Low noise line videos incorporating keyed clamps and an aperture correction circuit are employed. System experience has shown that utilization of self contained power supplies in all components provides maximum flexibility. The electronically regulated power supply combined with feedback type deflection circuits results in extreme accuracy and stability in the camera control units.

The goal from an operational aspect in vidicon studio equipment has been to minimize the number of operating controls and minimize the number of tubes. It is important not to over-extend miniaturization techniques to the point that preventive maintenance cannot be simply and economically accomplished. However, good design practice has made it possible to house in one or one and a half racks all the necessary video control and sync generator equipment for a complete studio operation involving two live and one film cameras. Typically such a system will utilize 250 tubes as compared to the 425 tubes involved in similar image orthicon installations.

The basic philosophy from an engineering point of view has been one directed toward compromising only that performance which is not evident to the viewer for the sake of simplicity and reduced costs. One finds, however, that in operations of this type any operating excess or looseness can be eliminated without impairing the technical performance or the overall operating reliability. Remote control equipment has been specifically designed for small vidicon cameras. Some units are identical to those used in industrial and closed circuit applications. Others were first developed for broadcast uses.

The handiest remote accessory has been found to be the pan/tilt mechanism. Since vidicon tubes are not susceptible to burn-in, no wobbulating provisions are needed on the panning platform. Simple inexpensive pan/tilt mechanisms, providing a full 360° range of pan and ± 45° tilt angle, are now sold in the range of 300 to 500 dollars.

The remote control can be executed at considerable distance from the camera location. Remote iris and focus mechanisms are available. These units are designed in such a way that no permanent attachment to the lens is required. These units typically sell for $300 and can be readily attached to standard vidicon cameras.

A remote control 3-lens turret has been designed for use with 16 millimeter lenses. The vidicon camera is readily mounted on a focus platform. The camera itself is caused to move in respect to the focal plane of the lens to effect image focus. Any one of three lenses can be selected. The aperture of each lens may be individually adjusted and the adjustment of the iris of another lens does not affect those previously set. Consequently, lens stops for given programming conditions can be remotely preset. Turret assemblies are available for from $1000 to $1500.

Several high quality 16 millimeter, variable focus lenses are now available for approximately $1350. Typical lenses provide a focal range of 5 to 1, and an "f" stop of f/3.5. Remote control of focus, iris and focal length is provided. All lens accessories are readily mounted on the camera and may be utilized with the simple pan/tilt mechanism.

Remote control equipment can be utilized with simple programmers for automatically selecting lenses, camera position and focus to predetermine requirements. While in certain instances this may prove practical, it is felt that the mere feasibility of this technique does not make it per se in economy operations. The main audio video control position has been a key to reducing operating requirements. The application of simple human engineering techniques for positioning monitors, switchers and control equipment has proven very effective. In typical operations where one live camera is utilized, with an operator and a remote control camera film chain for commercials, one technical operator can handle both audio and video controls.

The video switcher employs both automatic and manual dissolves and laps. The master position also incorporates the camera electrical and mechanical remote control equipment. All monitors are fabricated in one piece construction.

Completely self-contained power supplies, integrated with basic equipment, increases operating reliability, since one power supply failure will not cause the downfall of a large number of units.

Interchangeability of operating units, simple patching and switching increase flexibility.

Experience has shown that 100, 150 or 500 watt transmitters, with antenna gain of 3 or 4, and an ERP of up to 1800 watts, provide coverage which is adequate for a large number of the potential markets.

A typical installation utilizing a 500 watt transmission on Channel 8, with an antenna height of 200' above average terrain, has given reliable coverage in a 25 to 30 mile radius. Signal levels at the end of the radius average between 100 and 500 microvolts.

In another instance, with a 150 watt transmitter, an antenna gain of 4, and an antenna height of 80' above average terrain, coverage of approximately a 15 to 20 mile radius is obtained.

Admittedly in this type operation one depends on the viewer's antenna for expanding coverage. However, in view of the advances in set design and the considerable advantage to the telecaster through the use of reduced transmitter power, this approach should be seriously considered. The public in many instances can have the advantage of live telecasting only through their willingness to cooperate with the station operator and by making the overall operation economically possible in smaller market areas.

New transmitter designs for 100, 150 and 500 watt operations have incorporated techniques which simplify the maintenance and initial adjustment, and minimize the total number of tubes. Through the utilization of more standard type tubes and lower cost tubes, the operation of these units becomes extremely attractive.

Physical considerations in the initial low power station layout are slightly different from those of a high powered station. In order to minimize initial investment one tries to find a compromise location which provides a natural antenna height, such as office building, hotel or other large structure.

It is also desirable to have the antenna located in the center of a population area to obtain minimum required city coverage with minimum waste power. It is almost fundamental that studio and transmitter sites be combined at one location. Typically, in one room we have installed film equipment, audio video master control, and all video and RF equipment racks. In a second room film editing, processing, teletype and traffic operations are laid out. The studio location is in view of the audio video control location and usually incorporates a permanent setup, commercial corner and minimum storage area.

By creating sets in a semi-circular fashion a central light bank can be utilized. Experience has shown that flat lighting is most effective since it will eliminate deep shades and give a more pleasing picture. This type of lighting may be provided through the use of fluorescent light banks, standard scoop and spot lights, or a recently developed system that uses standard household bulbs operated at near burn-out temperatures. While the life of the bulbs when operated under these conditions is rather short, this is no big problem since they cost only a few cents each and are available at any local store or market.

An entire lighting complement for a studio costs in the neighborhood of $1,100.

Provision should also be made for providing street level access for automotive commercials and other heavy commercials.

For 8-hour day operation the following minimum personnel are required, but are satisfactory:

Station Manager
Chief engineer
Salesman-announcer
Operating engineer
Secretary-receptionist-bookkeeper
Film man
Cameraman-maintenance engineer
Program production-traffic manager

It is found that areas with population of twenty to thirty thousand that are not now covered by television, and with retail sales of thirty million dollars annually, can consider low power operations.

Obviously one cannot generalize because all of the basic considerations of fringe area coverage, community antenna service and local economic conditions must be integrated into a formula to evaluate the feasibility of a particular operation. However, there are still certain areas of the country which, as previously mentioned, either now or in the future may logically qualify as potentially profitable low power markets.

Depending on the programming costs, which obviously is a separate subject, experience has shown that the "nut" of low power stations in markets of this size is between seven and twelve thousand dollars. Low power stations have gone on the air with initial orders in excess of the "nut" and several are conservatively making two to four thousand dollar profits per month.

Analyzing the strict low power station on the basis of a fifty to seventy-five thousand dollar investment, one sees that the return on the total investment is very interesting; but further, when one considers that credit can be extended for these situations the return on the actual investment is of extreme interest.

The application of simplified operating techniques and minimum cost equipment is bound to increase. Vidicon cameras are now manufactured by more companies and wider experience in operation and design garnered. Quite a few companies are engaged in vidicon tube development, and while today vidicons cannot be used for certain applications excellently covered by image orthicons, as time progresses the development of more sensitive vidicons is bound to come to pass. One would be somewhat remiss if he did not consider that in the not too distant future economical vidicon studio operations will be the rule and not the exception.

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THE COLOR TELEVISION SYSTEM

AT

THE WALTER REED ARMY MEDICAL CENTER

By: A. F. INGLIS

NARTB CONVENTION

APRIL 1957

CHICAGO, ILL.

Introduction

One of the most interesting and useful applications of closed-circuit color television has been its use for medical education. With the rapid growth in medical and surgical knowledge the education of doctors and medical technicians, both at the undergraduate and graduate levels, has become an increasingly critical problem in the progress of medicine. The most spectacular application of medical television has been its use in surgery where an unlimited number of persons may receive a close-up view of the proceedings in full color. To utilize fully the potentialities of television for medical education, however, it is necessary to produce complete programs using the techniques which have been developed for broadcast television. A complete television presentation for medical education would consist of an integrated program including such material as a lecture, clinical examinations, film and slide material and demonstrations.

If this more extensive use of television is contemplated it can be seen that the technical facilities required are very similar to those used by television broadcasting stations. For this reason it is believed that the color television facilities which have recently been installed at the Walter Reed Army Medical Center will be of interest to broadcast engineers. The Walter Reed installation is one of the largest color television systems in the country, and the technical problems which had to be solved were not unlike those which confront broadcast engineers who are planning facilities for color.

Location of Equipment and Facilities

An overall diagram of the Walter Reed installation is shown in Figure 1. The equipment is located in three separate buildings, the Armed Forces Institute of Pathology, the Walter Reed Army Hospital, and the Walter Reed Army Institute of Research. These buildings are all located on the Walter Reed grounds and are separated by distances in the order of 1,000 feet. As will be seen later these three installations all have complete audio and video interconnections so that complete interchange of programs is possible.

The largest installation and the control center for the whole system is located in the Armed Forces Institute of Pathology Building. In this building are located a medium sized studio, a TV film room, a camera control room and the master control room which provides switching facilities for all cameras located within the building and also facilities for switching between the various program origination points located in the other buildings. Also located in the A.F.I.P. building are color cameras in the autopsy room and on a microscope in the frozen section laboratory. An auditorium is provided with a 4-1/2' x 6' tele-mural projector which is used for displaying programs to larger audiences than can be easily accommodated with receivers.

The Walter Reed Army Hospital itself includes a camera installation in one of the operating rooms, a small studio to be used for patients too ill to be moved to the main studio and a small control room which serves the dual function of camera control and program control.

In the Walter Reed Institute of Research are included a studio and control room. In addition, a number of rooms have been provided with camera cable outlets which connect to the camera control through a patch panel. This permits one or more cameras to be moved from room to room as the need arises.

Photographs of the various rooms are shown in Figures 2 through 9.

Figure 2 is a view of the studio showing its use in teaching clinical procedure.

Figure 3 is a view of the film room showing a 16 mm projector and a 3-vidicon color film camera. Not visible in the picture are a 2" x 2" and a 3-1/4" x 1" slide projectors.

Figure 4 is a view of the camera control room in the A.F.I.P. building showing the rack-mounted camera control equipment.

Figure 5 is a view of the master control room showing the custom-built program director's console, the video switching position, and the audio console. The window at the left overlooks the main studio and gives the director a clear view of the proceedings.

Figure 6 is a view of the 3-V live pick-up camera located in the autopsy room. This camera is functionally similar to the standard TK-41 color studio camera but makes use of vidicon pick-up tubes rather than image orthicons. As a result its sensitivity is relatively low, and the applications of this camera are restricted to locations where adequate lighting (in excess of 1,000 to 1,500 ft. candles) is available. The viewing axis of the camera is directed downward by the mirror through a hole in the center of the lamp to the work area. The mirror is coupled to the lamp in such a way that the camera's field of view follows the lamp as it is moved by the surgeon. The mirror can also be panned and tilted by remote control independently of the lamp motion; this permits a vernier motion of the field of view as may be required. The camera is provided with complete remote control facilities including lens change, focus, light control and all necessary electrical adjustments. An overhead track arrangement permits the camera and light assembly to be swivelled through 360 degress and to travel several feet in either the north-south or east-west directions.

Figure 7 is a view of the 3-V live pick-up camera mounted on a microscope bench.

Figure 8 is a view of the 3-V live pick-up camera in a Walter Reed Hospital operating room. The camera, mirror, and lamp mounting assembly are similar to that installed in the autopsy room. A ceiling mounted camera is particularly desirable in the operating room since many anesthetic gasses are explosive, and safety codes require that any equipment which is not explosion proof must be mounted at least five feet above floor level.

Figure 9 shows the more modest control room in the Walter Reed Hospital which includes audio and video switching facilities and video control position for the 3-V camera in the operating room and the image orthicon color camera in the studio.

Technical Facilities for Program Origination

The most basic decision in the planning of the technical facilities for this installation was the choice of a compatible system of color television identical to that employed in television broadcasting. Among the reasons for this decision were the availability of standard network lines for intra-city and inter-city transmission of signals originating at the center, the desire to interchange programs with standard broadcasting stations, the desire to integrate both monochrome and color signals with a minimum of difficulty, and the ability to choose from the wide selection of broadcast studio equipment and home receivers which are so readily available on the market. As a result of this decision it was possible to follow, for the most part, standard broadcast studio design techniques and to make use of the wide range of broadcast products already available.

A simplified video functional diagram of the A.F.I.P. installation is shown as Figure 10. It will be noted that the most modern techniques of system design have been employed including centralized camera controls, relay switching, and the separation of the studio and video control functions.

In the overall system the installations at the Hospital and the Institute of Research have a function similar to that of studios B and C in a television station. Due to the wide separation between these locations and the A.F.I.P.

video control center, however, it was not practical to feed these locations from the same sync system because of the large delays involved. Accordingly, each of these locations has its own sync generator and pulse distribution system. In order to permit smooth switching between locations all sync generators are furnished with genlock facilities. This permits locking the entire system to the same generator. To provide this genlock facility sync signals are fed continuously from the A.F.I.P. installation to the Hospital and the Institute of Research, and local sync generators are locked to this sync. Since the A.F.I.P. sync is locked to the color subcarrier it is necessary also to send subcarrier signals to both the Hospital and the Institute of Research. A patch panel is provided at both of these locations so that the sync generators can be operated either independently or locked to the A.F.I.P. system.

It will be noted that a camera patch panel is used to increase the flexibility of the system. These patch panels are widely used throughout the entire installation to permit camera pick-ups to be made at a large number of locations, and using a minimum of equipment.

A simplified video diagram of the installation at the hospital is shown in Figure 11. Note that this system has its own pulse generators and distribution equipment as was previously mentioned. A similar diagram of the video equipment at the Institute of Reseach is shown in Figure 12.

A problem not ordinarily encountered in broadcasting stations arose in this system due to the long video cables joining the three buildings which varied in length from 1,100 to 1,600 feet. In order to reduce the amount of equalization, RG/34G cable was used. Special equalizers were provided which made it possible to make the frequency response of the lines essentially flat to 5 megacycles. The entire system was designed so that the overall frequency response and non-linear distortion will be maintained at values comparable with broadcast installations. The design objective was to make the overall frequency response of the normal signal path from camera output at either of the remote locations through the master control switching system at A.F.I.P. flat between ± 1 db at 3.58 megacycles. Similarly the design objective was to hold differential gain distortion to less than ± 4% and the phase distortion to ± 4 degrees. As an aid in reducing the non-linear distortion of video signal, levels are maintained at 1 volt composite.

The use of long unbalanced video lines between buildings led to some rather troublesome hum problems which were eliminated only after some difficulty. The lack of synchronism between vertical scanning and the power line frequency in the color system makes the reduction of hum a particularly important requirement, and the use of balanced lines in such an installation might well be desirable in many cases.

Although the audio and intercom facilities are less glamorous than color television, they are of equal importance in producing effective educational presentations. Accordingly this part of the system was planned with the same care, and in general, it was designed in accordance with standard broadcast practice. Small audio control consolettes were used at the Hospital and the Institute of Research, while a larger console was used at the A.F.I.P. studio control position. The master control audio switching function is handled by a custom built system employing interlocked relay switching. A feature not found in most broadcast installations is a talk-back system whereby, for example, a program moderator and a surgeon conducting an operation can discuss an operation as it progresses with the audience listening to both ends of the conversation.

Signal Distribution Facilities

The greatest departure from a standard broadcast system occurs in the signal distribution facility. Unlike a broadcaster who is concerned only with producing video and audio signals, the designer of a closed-circuit TV system must consider their distribution and display as well. Two basic methods of distribution are available; signals can be distributed directly as video and audio, or they can be used to modulate r-f carriers in the standard broadcast channels. R-f distribution has a number of important advantages: the audio and video for several programs can be handled on the same cable; the selection of programs can be made at the receiving location; standard receivers can be used without modification; equalization problems are much simpler. On the other hand, the modulation and demodulation process inevitably results in some deterioration in picture quality, the amount of this deterioration depending on the performance of the equipment. In the Walter Reed installation 3 r-f channels are fed to some 140 outlets, while direct video-audio connections are made to 15 outlets. These latter outlets are located in the auditoriums and other locations where it is desired to provide the best possible signal quality.

Summary

The installation at the Walter Reed Army Medical Center represents the first large-scale application of compatible television for medical education and is by far the largest such installation in the world. It represented a pioneering effort on the part of both the Army Medical Service and RCA. It should be a source of satisfaction to all of us who have been associated with the broadcasting industry for many years to see the equipment and techniques which we have developed used in an application which will be so valuable to the progress of the medical profession.

AFI:adb

3/29/57

35

THE USE OF A 100KW TRANSMITTER

TO

OBTAIN 316KW ERP

KGW-TV

CHANNEL 8 Portland, Oregon

A talk delivered by

James L. Middlebrooks

Vice President and Director of Engineering, Pioneer Broadcasting Company
KGW and KGW-TV, Portland, Oregon

and

Director of Engineering, King Broadcasting Company
KING, KING-FM and KING-TV, Seattle, Washington

before

The 11th Engineering Conference
National Association of Radio and Television Broadcasters
Chicago, Illinois - April 11, 1957

Pioneer Broadcasting Company, Portland, Oregon, was issued a permit to construct a new Television Broadcast Station (KGW-TV) in Portland, Oregon, to operate on Channel 8 (180 - 186 mc) with 316KW ERP at an effective antenna height of 1550 feet above average terrain. The date of this modified Construction Permit was March 27, 1956.

This paper will deal with the use of a 100KW Transmitter to obtain 316KW ERP. The twenty-five minutes of time allotted to this and other papers, limits the scope and detail in which subjects can be covered. Therefore, I will not attempt to discuss in great detail the circuitry of the individual transmitter units. Copies of the Manufacturer's Catalog covering the RCA TT-100AH Transmitter are available and cover this aspect very thoroughly.

Figure 1 shows in some detail the topography of the area surrounding Portland. A study of the terrain of Portland and the area around the city convinced us this was a location where low antenna gain and high transmitter output would be advantageous. The city of Portland varies in elevation from several feet to 1250 feet above sea level. Numerous receiving locations in the city proper are not in line-of-sight of any available TV Transmitter Sites and are in what could be termed "Shadowed Areas". About one third of the cities of Oregon are at elevations ranging from sea level to 250 feet, another one-third from 250 feet to 2500 feet, and the remaining from 2500 feet to 7000 feet.

KING Broadcasting Company, KING-TV, Channel 5 in Seattle, Washington, has had eight years experience in the use of low gain antennas covering similar terrain. KING-TV used a three-bay antenna with a 5KW Transmitter for five years. For the past three years it has used a 35KW Transmitter and a four-bay antenna, having a power gain of 3.8 to obtain 100KW ERP. The coverage results from this null-free broad vertical beam antenna have proven very desirable to us from a coverage standpoint, both close in and in fringe areas. This principle of using low antenna gain is not unique to our company but has been used by a number of broadcasters, who, because of surrounding hilly terrain or a unique coverage condition, prefer to obtain their granted ERP with a lower gain, wide-beam antenna and higher actual transmitter power.

Figure 2 is the vertical plane radiation pattern which we chose as best fitting our own coverage problem. You will note that the one-half field point is nine degrees below the horizontal, the minimum field is fourteen degrees below the horizontal and that there are no nulls indicated. The sketch in the lower left hand corner of this figure, shows the design parameters of the antenna which will produce the above described vertical pattern.

Figure 3 shows the installed antenna system which consists of two four bay superturnstile antennas, one located immediately above the other.

The station normally operates with the upper four bays as the visual antenna and the bottom four bays as the aural antenna. Suitable RF switches located in the transmitter room permit interchange of antennas, if desired; that is, the top antenna can be used for aural transmission and the bottom four bays for visual transmission. By means of suitable RF switching equipment, which will be discussed later, it is possible to operate during emergencies or when desired, with all eight bays operating as a combined visual-aural antenna with a power gain of 7.2. Or with either the lower or upper four bays separately operating as a combined aural-visual antenna, producing a circular pattern with one-quarter power radiated. The gain for each the visual and aural antennas, as they are used separately for normal operation, is 5.56 db (3.6).

Figure 4 is a block diagram of the antenna switching system. Switches "W-X-Y and Z" are motor operated, remote controlled, single pole double throw. RF co-ax switches, located just below the top of the tower. Co-ax switches "R-S-T and U" are located in the transmitter building.

During normal operation, each of the two four bay antennas (aural and visual) are fed through a single 6-1/8" transmission line to a power splitting TEE, located just below co-ax switches "W-X-Y and Z", where the power is divided equally between the N-S and E-W batwings. 90 RF electrical degrees time delay is introduced in the E-W feed line of each antenna after the TEE. Co-ax switches "W-X-Y and Z" are operated in Position 2 when the two antennas are operated as separate four bay antennas. Cross patches are available between switches "T and U", if it is desired to interchange the two antennas. Under emergency conditions, one half the aural and visual transmitter outputs can be fed to a conventional diplexer through Position 1 of co-ax switches "R and S". The combined signals (aural and visual) with their power divided in the multiplexer, can then be fed to the combined antenna through the two 6-1/8" co-axial transmission lines (which are normally used to feed separately, the aural and visual antennas) one of which is used to feed the upper and lower N-S batwings and the other the upper and lower E-W batwings. The combining of the two antennas is accomplished by operating co-ax switches in the number 1 position. Thus, with the loss of one-half of the aural or visual transmitter power 316KW ERP can be maintained. If either antenna fails, co-ax switches "R-S-T and U" are placed in Position 1 and co-ax switches "W-X-Y and Z" are placed in Position 2. The line feeding the defective antenna is removed at either switch "T or U" and a dummy load is substituted for the line feeding the defective antenna. This allows the station to remain on the air with 1/4 power radiated and a circular pattern.

Figures 5-A and B, are photographs showing details of remote controlled co-ax switches "W-X-Y and Z". Figures 5-C and D, show the mounting of the switches inside the tower. The switches are motor operated, gas tight and are fully interlocked against operation while RF is applied to the switches. The motor gear box oil, as well as the whole unit, is kept at a constant temperature which assures quick operation in sub-freezing temperatures. Indicating lamps in the transmitter room indicate the operation of the switches.

Figure 6 shows a photograph of the entire antenna and a close-up of the harness and feed lines on the antenna. Each antenna is fed by two 3-1/8 transmission lines from it's respective power dividing TEE, at the top of the tower.

In four months of operation, no additional gas has been required to maintain 15 lbs. pressure in the lines and antennas. The overall VSWR of the entire line, switches and antenna system is better than 1.1. The antenna and line system has been tested with over 120KW of power and no warm spots were noted. The amplitude of cross-modulation between the aural and visual transmitters was measured to be below -80 db; this is better than the -60 db requirement of the F.C.C. The total overall length of the two antennas is 45 feet 6 inches.

Figure 7 shows the floor plan layout of the transmitter building. The first floor contains approximately 2100 square feet and the blower room, which is above grade, contains 900 square feet. The building is constructed of reinforced concrete and is fireproof. The use of the space is indicated on the drawing, so therefore, will not be covered in detail.

Figure 8 is a sketch showing the line-up of the transmitter cubicles. Beginning from left to right are located the following units:

1. #1 - 30KW Aural Power Amplifier
2. - Access Door
3. #2 - 30KW Aural Power Amplifier
4. #2 - Control and Distribution
5. #2 - Rectifier and D.C. Switching
6. #2 - Regulator
7. - Aural RF Amplifier
8. - Aural Driver Chain
9. #1 - Control and Distribution
10. #1 - Rectifier and D.C. Switching
11. #1 - Regulator
12. - Visual Driver Chain
13. - Visual Modulated Amplifier
14. #1 - 50KW Visual Power Amplifier
15. - Access Door
16. #2 - 50KW Visual Power Amplifier

The entire transmitter is 56 feet 6 inches long. All units are completely accessible from front and rear and the four power amplifiers are accessible from four sides, as well as the top. Blowers for the drivers and power amplifiers are located in the basement, directly under the transmitter units.

Figure 9 is a simplified block diagram of the TT-100AH transmitter. The KGW-TV installation departs in only the two following minor respects, from this diagram. The visual and aural drivers can be operated from either the #1 or the #2 power supplies and a power dividing network, instead of a TEE, is used to feed the input of the #1 and #2 visual power amplifiers.

The RF section of the transmitter consists basically of one TT-10AH transmitter, used as a driver and the power amplifiers, rectifiers and power control equipment from two TT-50AH transmitters. The control system covering the entire transmitter is entirely new and affords the maximum degree of flexibility, in by-passing faults in individual units. Four rotary switches control a chain of relays, which allows for the following set-ups:

POWER SELECTION SWITCH		TRANSMITTER AURAL	TRANSMITTER VISUAL
Position	1	100 KW	100 KW
	2	50 KW #1 AMP	100 KW
	3	50 KW #2 AMP	100 KW
	4	50 KW #1 AMP	50 KW #1 AMP
	5	50 KW #2 AMP	50 KW #2 AMP
	6	50 KW #1 AMP	50 KW #2 AMP
	7	50 KW #2 AMP	50 KW #1 AMP
	8	10 KW Left Path	100 KW
	9	10 KW Right Path	100 KW
	10	10 KW Left Path	50 KW #2 AMP
	11	10 KW Right Path	50 KW #2 AMP
	12	10 KW Left Path	50 KW #1 AMP
	13	10 KW Right Path	50 KW #1 AMP
	14	10 KW Right Path	10 KW Right Path
	15	10 KW Left Path	10 KW Left Path

When operating under any of the above conditions, all units not used in the set-up, are removed from high voltage power and equipment may be worked on with a high degree of safety.

Figure 10 is a sketch showing the overall RF connections and RF switching system. A study of this drawing will show you the many RF paths that are available for by-passing units or changing the mode of operation. All co-ax switches are interlocked, so as to prevent a misconnection or attempted operation, other than that set-up for by the power selection switch position, referred to above.

The visual transmitter is an RCA-TT-100AH and has a maximum peak power output of 20dbk (100KW). It consists of a 10KW driver-modulator and two 50KW power amplifiers (referred to as Section #1 and Section #2), operated in parallel. The output power of the driver is divided in a conventional balun type power dividing network and one-half of the driver power is fed into the Section #1 power amplifier and the other one-half of the driver power, into the Section #2 power amplifier. The outputs of these two amplifiers are fed to their respective harmonic filters and then to separate sideband filters. The outputs of the two sideband filters are fed into a power combining network, where the maximum peak power output of the visual transmitter is available.

The #1 visual power amplifier receives its excitation 90 RF electrical degrees later than the #2 visual power amplifier. If the amplifier inputs are identical impedances, but do not exactly terminate their input transmission lines, the reflected components of the input power travel back through the input dividing network, in such manner, that it does not return to the exciter, but rather is dissipated in the dummy load. The driver, therefore, sees a constant impedance throughout the band pass.

The output RF power of the #1 visual power amplifier also is delayed 90 RF electrical degrees later than the output power of the #2 visual power amplifier. If equal, these powers then combine in the output combining network in such manner that the combined power reaches the RF output terminal and none is dissipated in the dummy load. If the two are not equal, some power is dissipated in the load, but the two amplifier output terminals are effectively isolated from each other.

At KGW-TV, we have not experienced any critical tuning requirements, in order to keep reject load power at a minimum; in fact, the drift in phasing or power ratios results in a loss of from 0 to 200 Watts, averaging about 100 Watts, or a power loss of .001% to .002%. The transmitter has been operated for the past four months without any retuning being required.

Visual power from this point, is fed to the antenna system by means of a 625 foot run of RCA-19387-1 coaxial transmission line (Teflon insulated) having an inside diameter of 6-1/8" and a calculated loss, when operating on Channel 8, of 0.391db. Section #1 and Section #2 power amplifiers are operated so as to deliver a combined power of 19.831dbk (96.1KW). For normal operation, since no multiplexer is used, the visual power delivered to the input terminals of the transmission line, is also 19.831dbk (96.1KW). Since the loss in the transmission line is 0.391db, the visual input power to the antenna, is 19.44dbk. Since the antenna gain for normal operation (four bays) is 5.56db, the effective visual radiated power is 25dbk (316KW).

The aural transmitter is an RCA type TT-10CAH and has a maximum peak power output rating of 17.7dbk (60KW). It consists of a 5KW driver-modulator and two 30KW power amplifiers (referred to as Section #1 and Section #2) operated in parallel. The output power of the driver is fed into a power dividing TEE. One-half of the driver power from the TEE is fed into Section #1 power amplifier and the other one-half of the driver power from the Tee, into the Section #2 power amplifier. The output of the two power amplifiers are fed separately into harmonic filters. The outputs of the two aural harmonic filters are then fed into a combining network, where the maximum peak power output of the aural transmitter, is available. Aural power from this point is fed to the antenna system by another 625 feet run of RCA-MI-19387-1 coaxial transmission line. The combined output of the aural power amplifiers for normal operation, are adjusted so as to deliver an output power of 17.591dbk (57.49KW). The input power to the transmission line is 17.591dbk. Since the transmission line loss and the antenna gain are the same as for visual operation, the effective radiated aural power is 22.76dbk (189KW).

Complete Proof-of-Performance Measurements, covering the overall equipment installation, have been made and submitted to the F.C.C. In every case the F.C.C. Standards and the manufacturer's specifications have been bettered, in most cases from 33-1/3 to 50%. In no case was a marginal measurement figure encountered which might tend to make continuous operation of the equipment critical.

Time does not permit a complete review of the Proof-of-Performance Measurements; however, the following few figures might be of interest.

Amplitude variation over one picture frame	Less than 2-1/2% of the Peak of Sync Level (Mfg. Spec. 5%)
Regulation of output	Less than 5% (Mfg. Spec. 7%)
Linearity (Differential Gain)	10% (Mfg. Spec. 15% max)
Harmonic Attenuation (Ratio of any single harmonic to peak visual or aural fundamental)	Better than 86db (Mfg. Spec. 60db)
Power input for average picture with 60% aural power	270KW

In conclusion, I would like to make the following observations:

1. When power tubes in modern transmitters are operated in accordance with manufacturer's specifications, tube life is not materially improved by operating them at less than rated power.

2. Operating modern transmitters at full rated power output does not increase component failures.

3. Increasing radiated power is not as costly as it might seem. For instance, the hourly 100KW transmitter power cost at KGW-TV is approximately 30 cents per hour over that for operating a 50KW transmitter.

4. Under certain conditions, low antenna gain and higher transmitter output power is desirable from a coverage standpoint. Engineers should carefully consider their own individual terrain and coverage problems, before resorting to standard type antennas, picked from the pages of a catalog. Often, so-called "Custom Built" antennas are not as costly as they might seem.

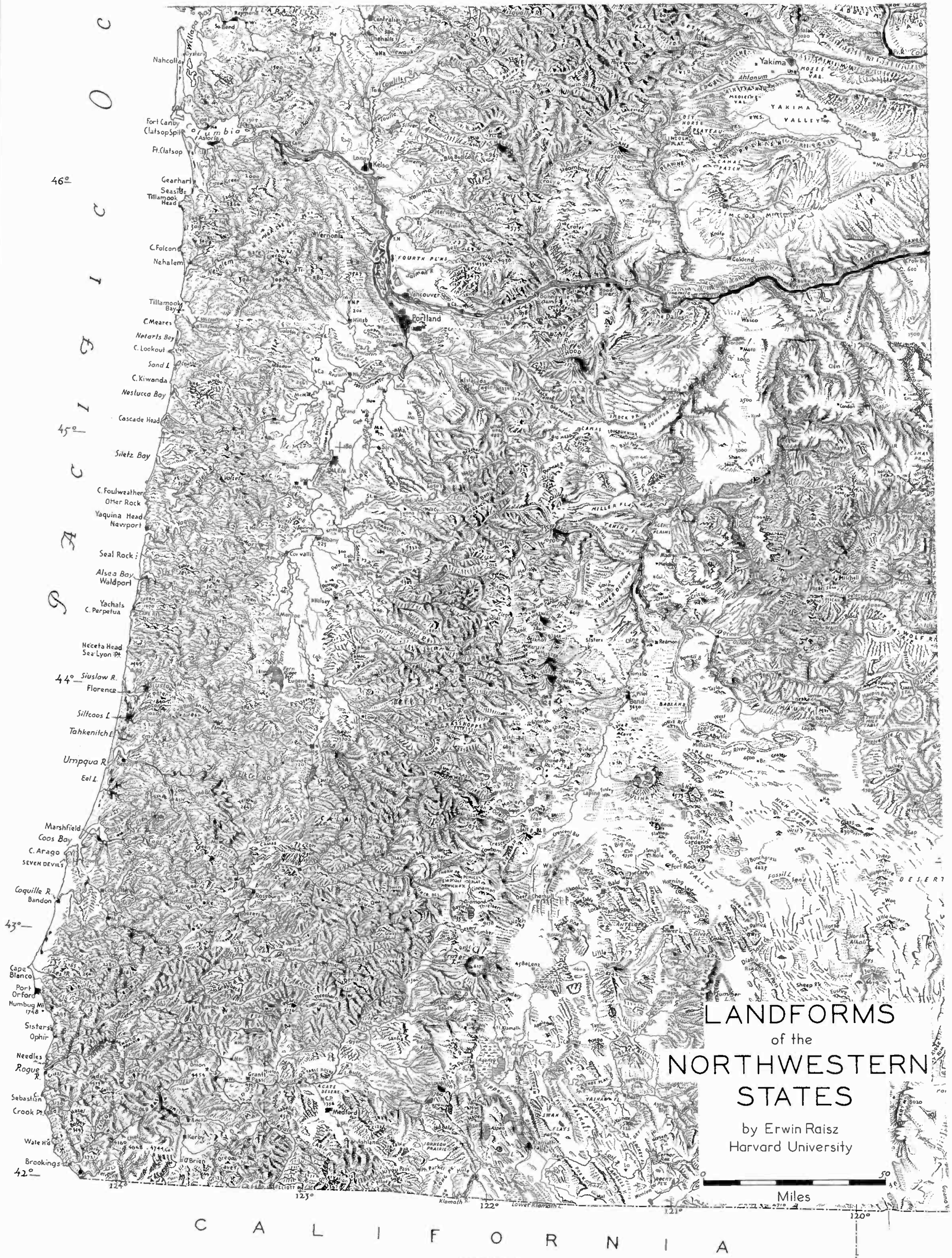
5. This new 100KW transmitter and antenna places in the hands of high channel VHF licensees, a power package insofar as the ratio of transmitter power to ERP is concerned, which in the past was only available to VHF Channels 2 through 6.

In closing, I would like to give credit to some of those engineers who contributed to the successful completion of this project.

First, Commander T. A. M. Craven, who during the planning stages was our Consulting Radio Engineer, (at the time, a partner in the firm of CRAVEN, LOHNES and CULVER, of Washington, D.C.) for his guidance and development of the basic engineering design. This firm, acting as our Engineering Consultants, prepared the engineering data which supported our Application for Construction Permit.

Mr. Noel Luddy, RADIO CORPORATION of AMERICA, who acted as overall coordinator between RCA and KGW-TV. And also, the many RCA Engineers who contributed materially to the overall equipment design and it's installation. The entire installation, from input equipment to antenna, was 100% RCA.

Special credit and recognition is due Clare Hanawalt, KGW-TV Chief Engineer; Gene Perusse, KGW-TV Transmitter Supervisor and last but not least, Robert Ferguson, KING-TV Chief Engineer, who contributed greatly to the planning of the installation.


LANDFORMS
of the
NORTHWESTERN
STATES
by Erwin Raisz
Harvard University
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50
Miles
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CALIFORNIA
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42°
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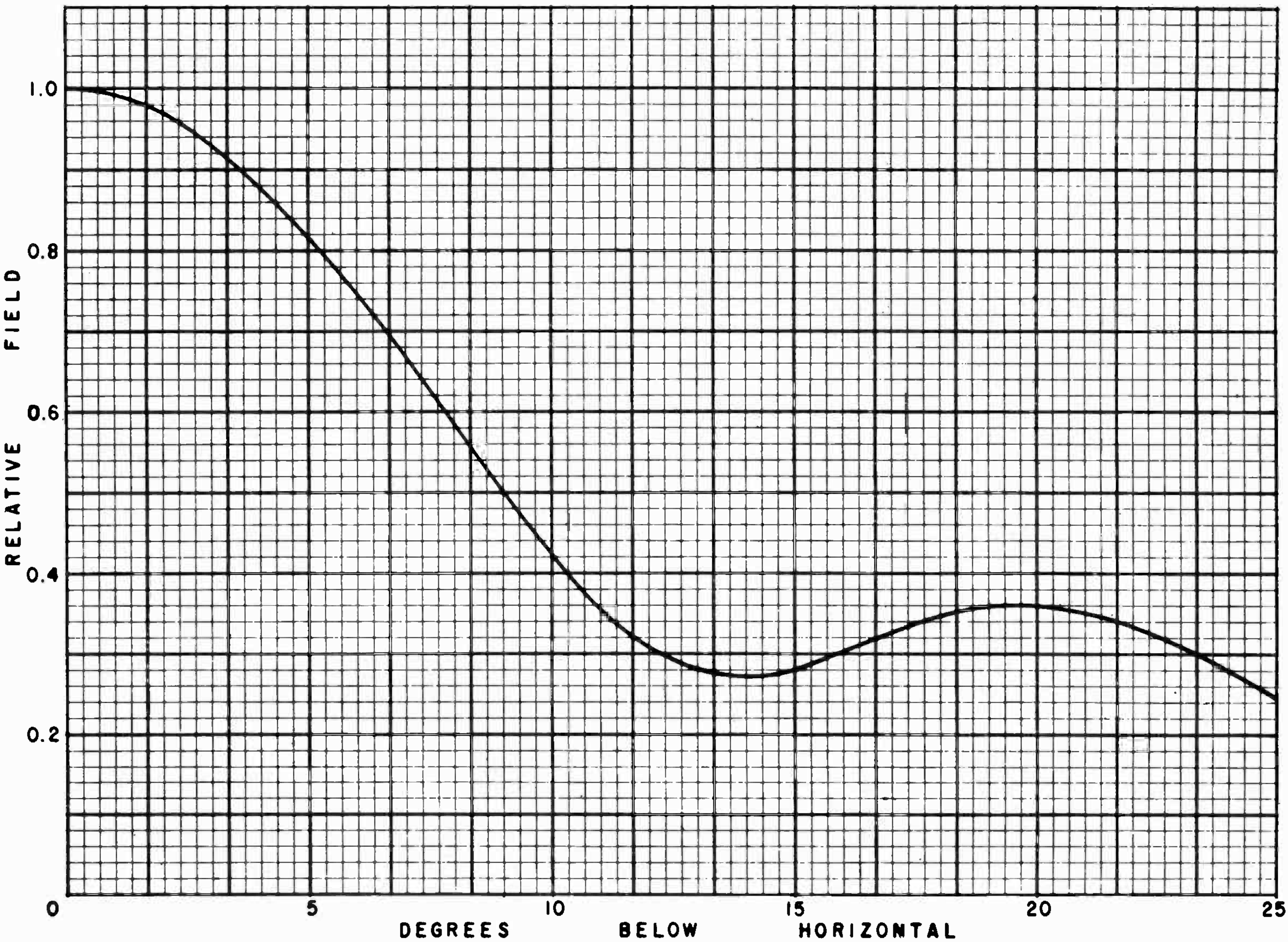
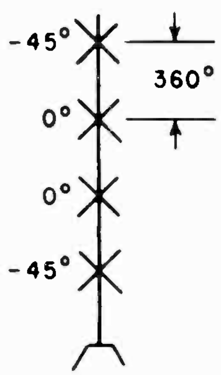
122°
121°
120°
Nahcotta
Fort Canby
Clatsop Spit
Astoria
Ft. Clatsop
Gearhart
Seaside
Tillamook Head
C. Falcon
Nehalem
Tillamook Bay
C. Meares
Netarts Bay
C. Lookout
Sand L.
C. Kiwanda
Nestucca Bay
Cascade Head
Siletz Bay
C. Foulweather
Otter Rock
Yaquina Head
Newport
Seal Rock
Alsea Bay
Waldport
Yachats
C. Perpetua
Heceta Head
Sea Lyon Pt.
Siuslow R.
Florence
Siltcoos L.
Tahkenitch L.
Umpqua R.
Eel L.
Marshfield
Coos Bay
C. Arago
SEVEN DEVILS
Coquille R.
Bandon
Cape Blanco
Port Orford
Humbug Mt.
1748
Sisters
Ophir
Needles
Rogue R.
Sebastian
Crook Pt.
Brookings
Yakima
Kelso
Vernonia
Vancouver
Portland
Bonneville Dam
The Dalles
Wasco
Goldend
Salem
Albany
Corvallis
Eugene
Redmond
Sisters
Bend
Roseburg
Medford
Ashland
Klamath
Lower Klamath L.
FOURTH PLAINS
YAKIMA VALLEY
SIMCOE MTS.
MILLER FLAT
LOWER DESERT
HIGH DESERT
FORT ROCK VALLEY
JOHNSON PRAIRIE

FIGURE 1





4 Section Superturnstile

360° Spacing

Channel 8

Gain - 3.6

Power Rating - 100 Kw

FIGURE 2

VERTICAL PLANE RADIATION PATTERN

(4 BAYS)

NORTH PACIFIC TELEVISION, INC.

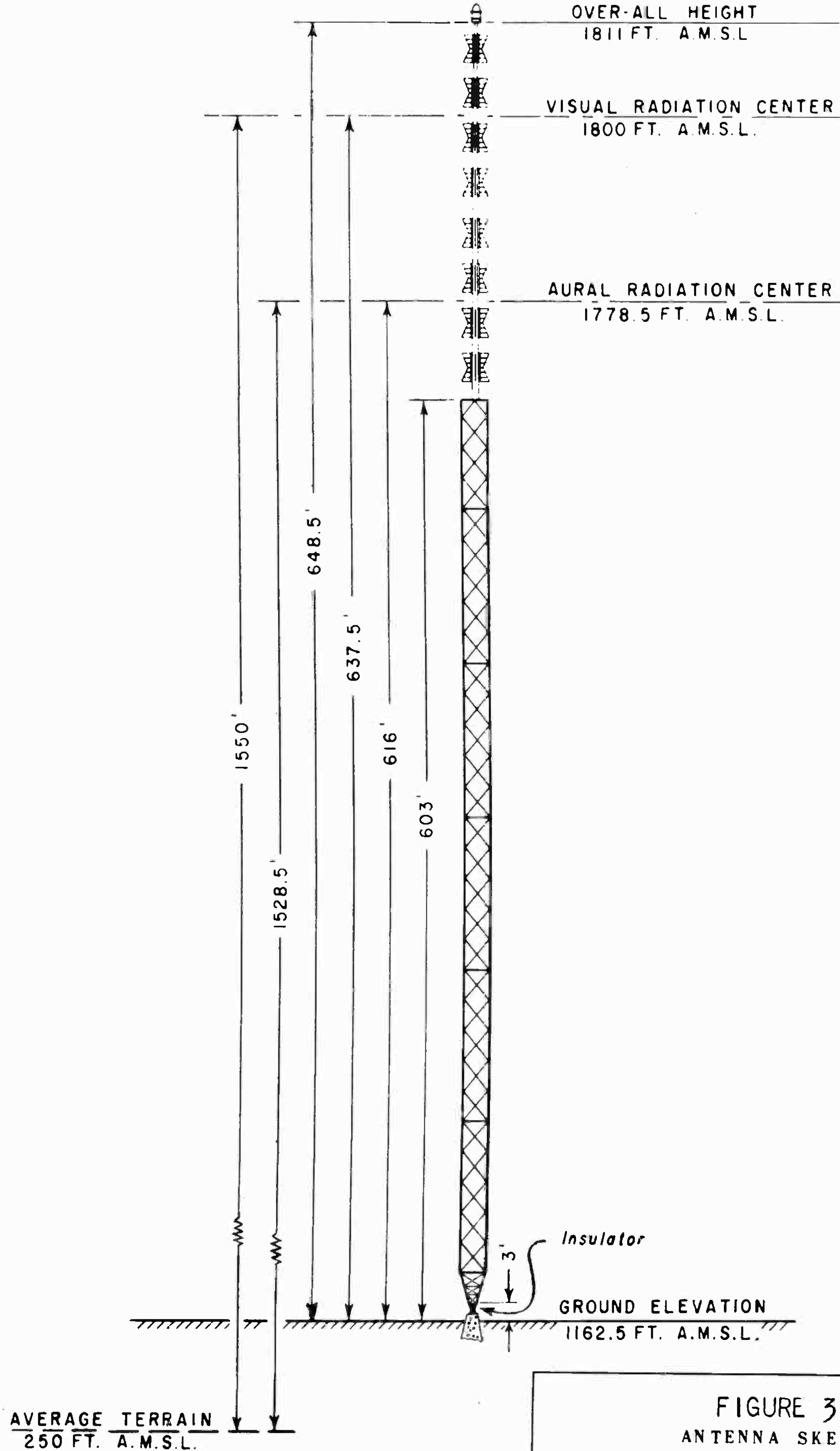
CHANNEL 8 316 KW-ERP

PORTLAND, OREGON

Prepared by

Craven, Lohre & Culver Washington 4, D. C.

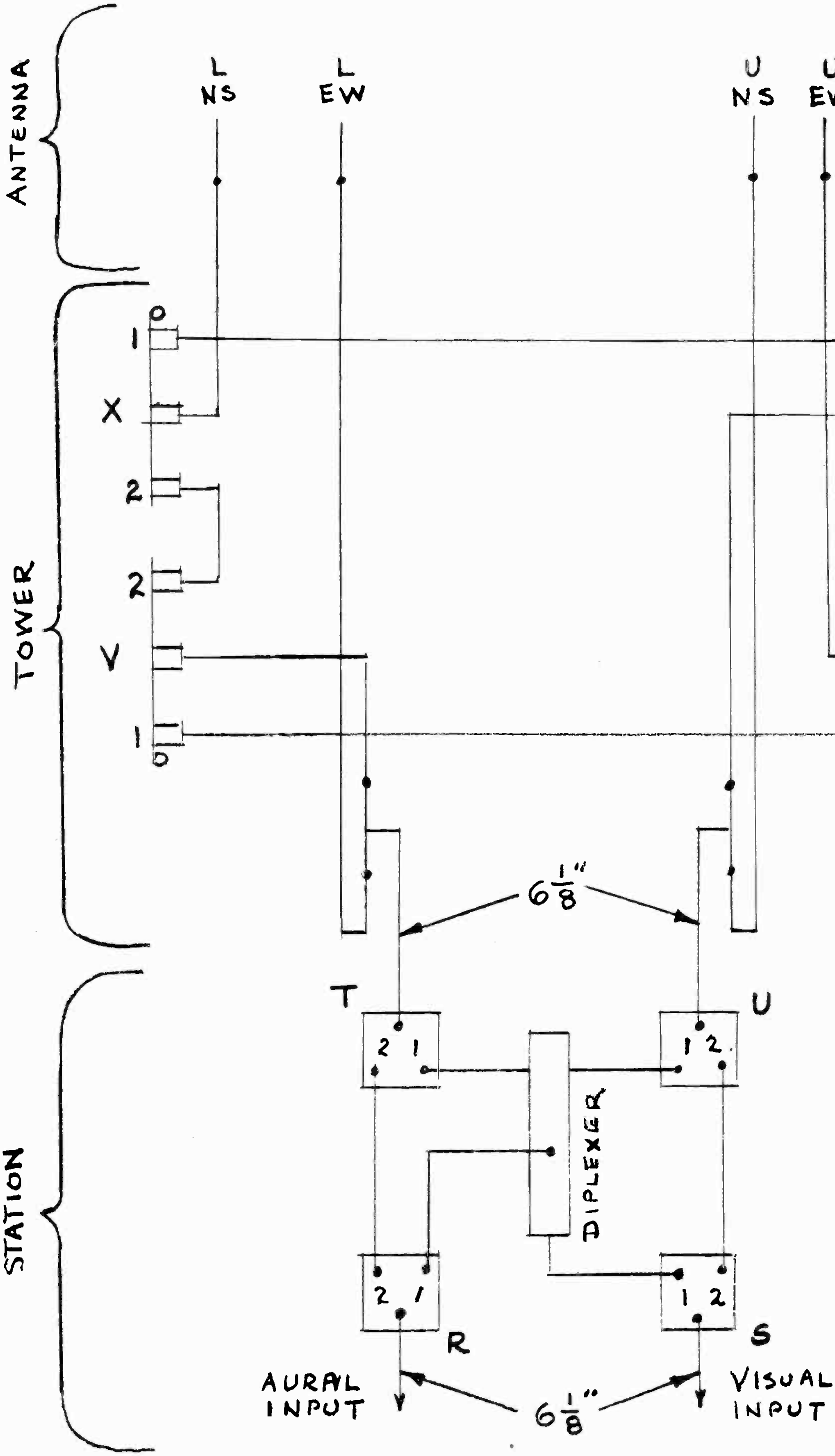
November 1955



North Latitude 45° 31' 22"
West Longitude 122° 44' 43"

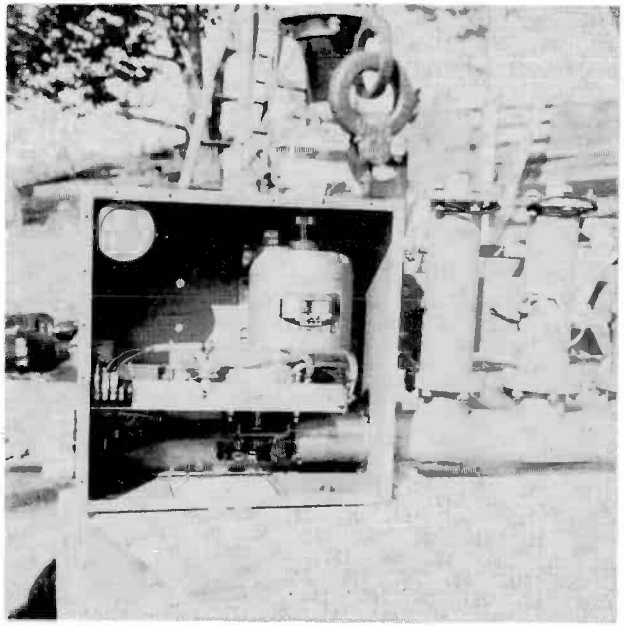
FIGURE 3
ANTENNA SKETCH
NORTH PACIFIC TELEVISION, INC.
CHANNEL 8 316 KW-ERP
PORTLAND, OREGON

Prepared by
Craven, Lohnes & Culver Washington 4, D. C.



KGW-TV
CHANNEL-8
PORTLAND, ORE.

FIGURE 4



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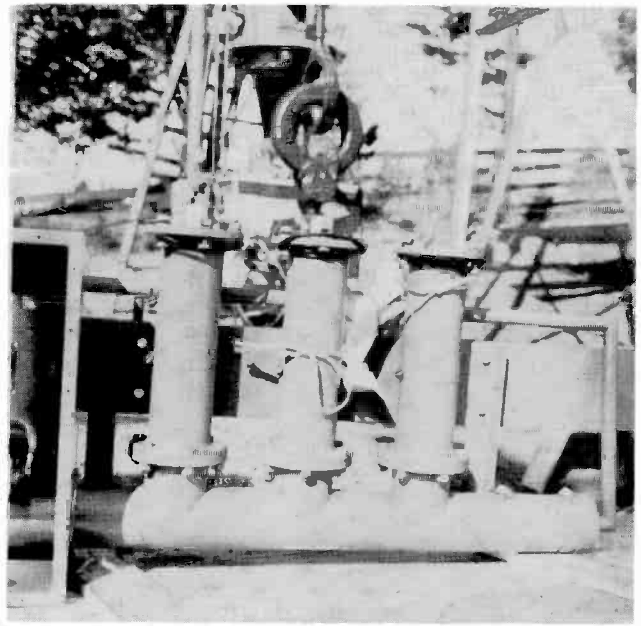

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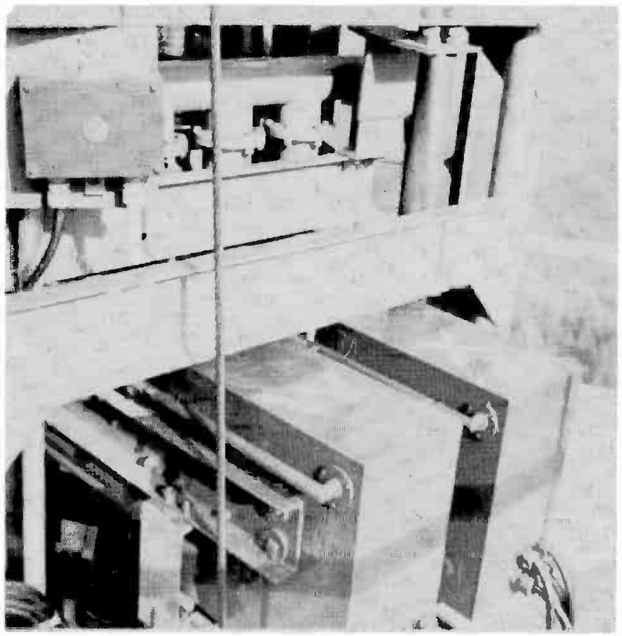

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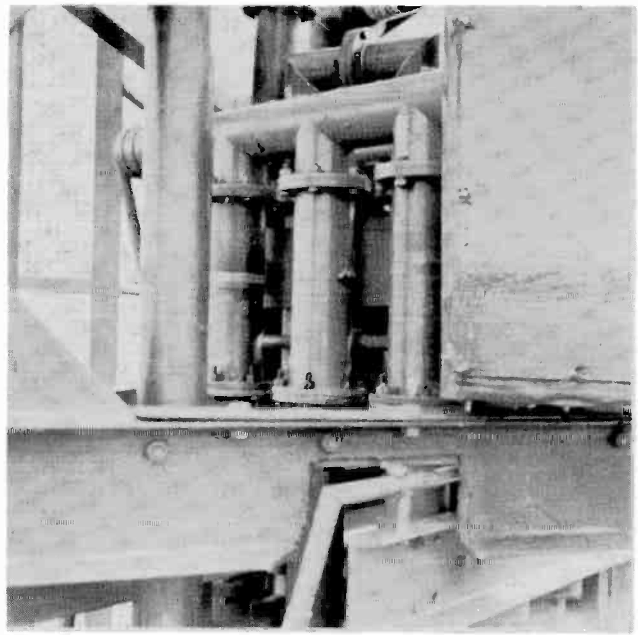

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FIGURE 5

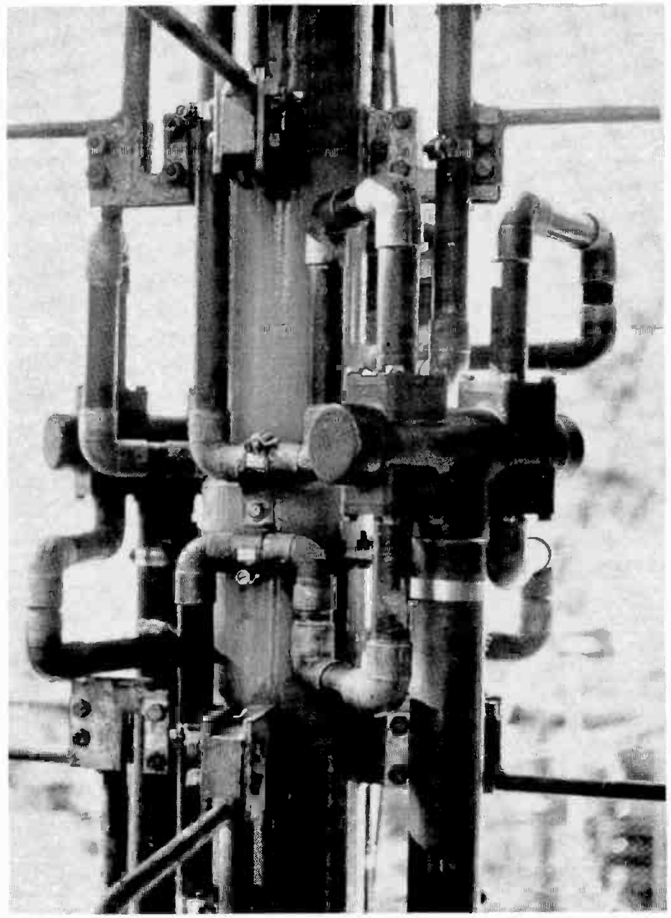
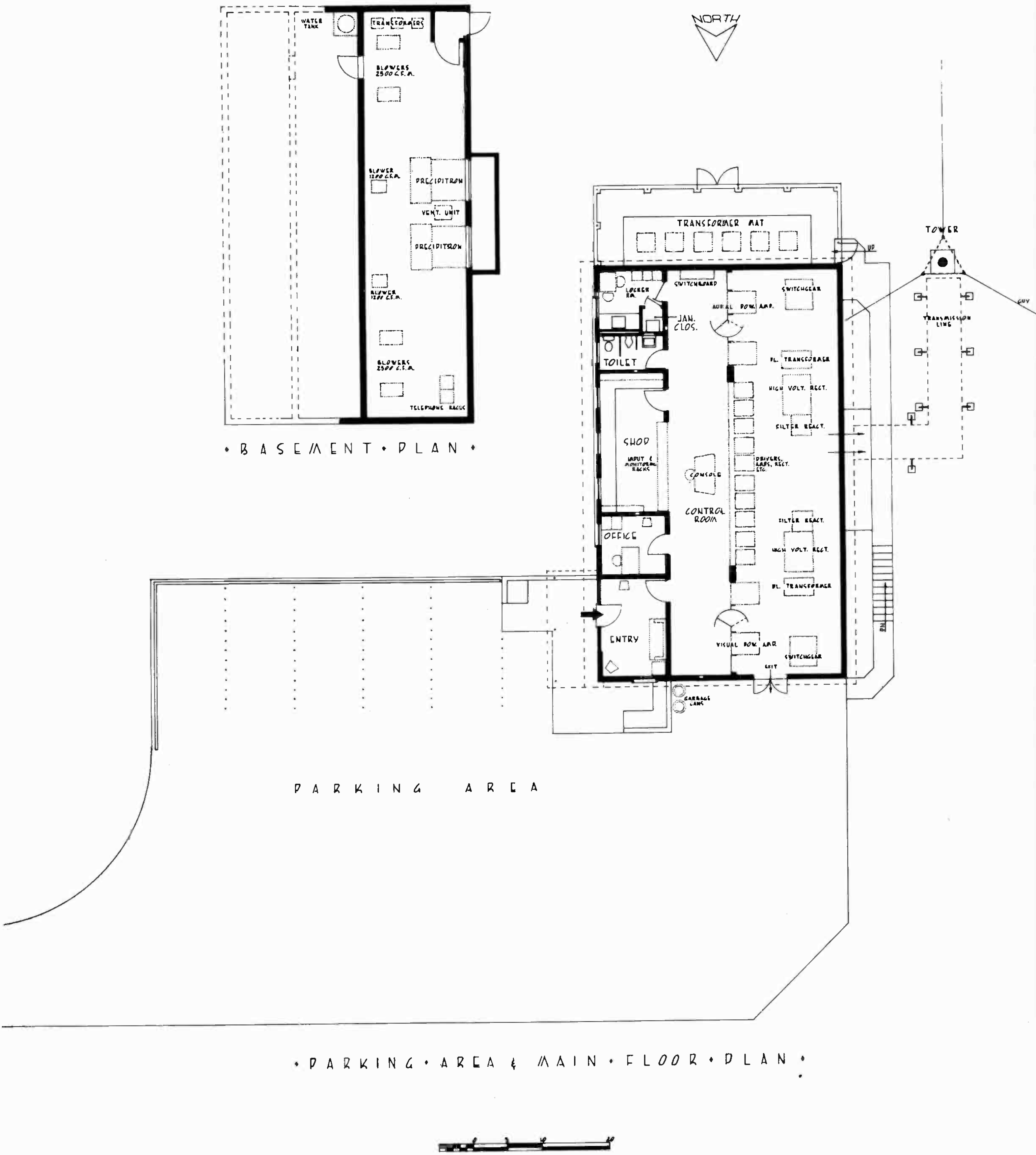


FIGURE 6



TRANSMITTER • BUILDING •

KGW-TV CHANNEL 8
FOR PIONEER BROADCASTING CO.
N.W. SKYLINE BLVD., PORTLAND, ORE.

ROI L. MORIN
ARCHITECT
202 HUGHES BLDG.
PORTLAND, ORE.
AIA

FIGURE 7

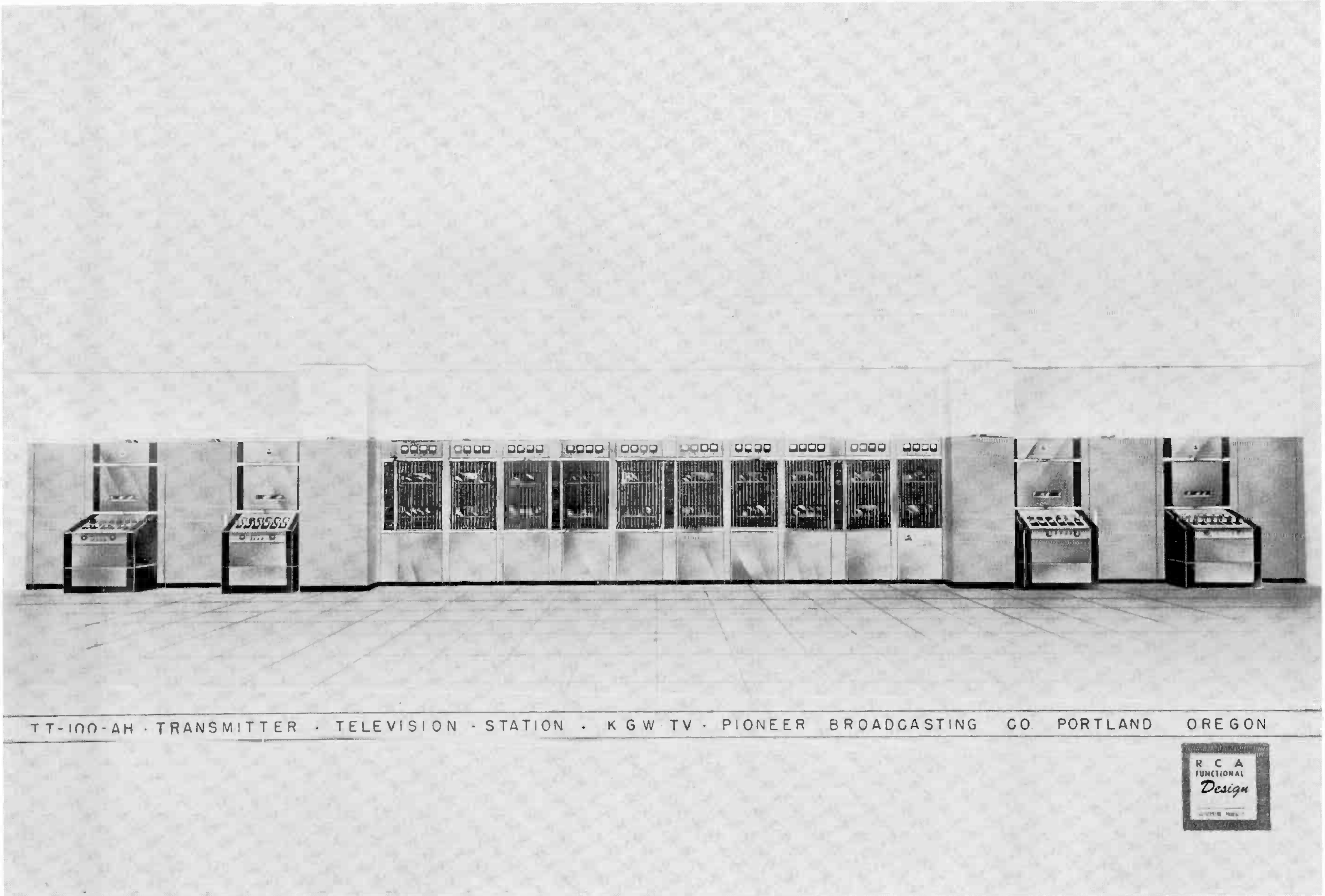

TT-100-AH · TRANSMITTER · TELEVISION · STATION · KGW TV · PIONEER BROADCASTING CO. PORTLAND OREGON
RCA FUNCTIONAL Design

FIGURE 8

Simplified block diagram of the TT-100AH Transmitter.

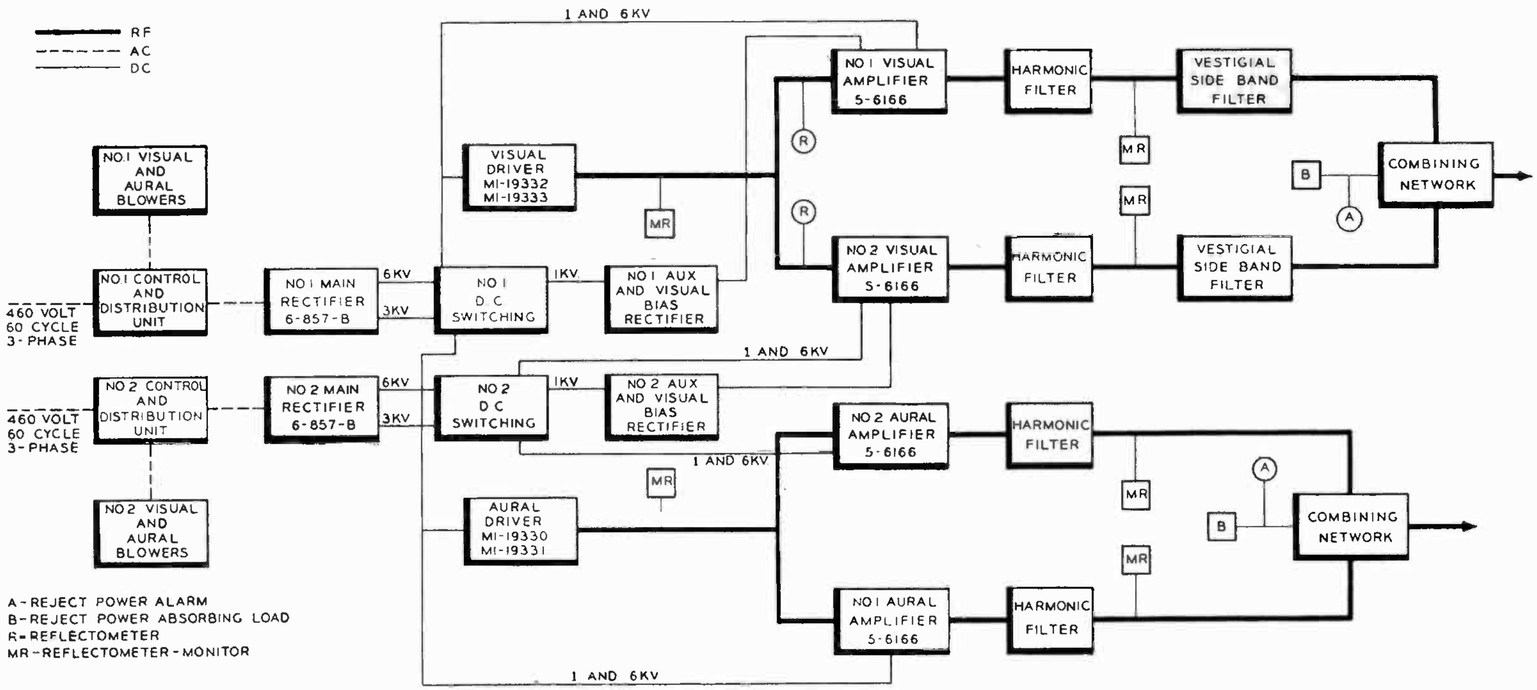
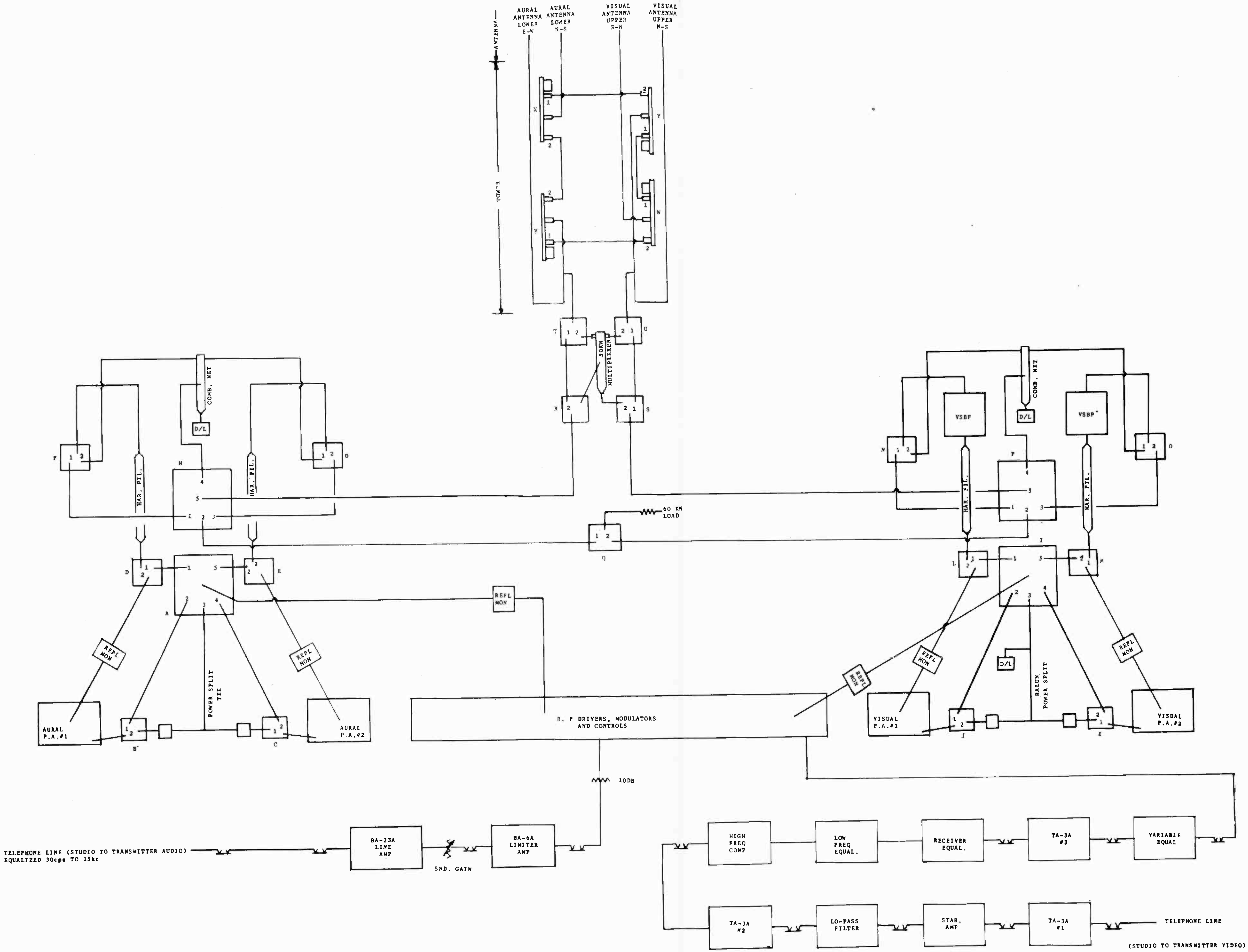


FIGURE 9



ANTENNA & TRANSMITTER SWITCHING SYSTEM
AUDIO AND VIDEO FUNCTIONAL DIAGRAM.

FIGURE 10

PIONEER BROADCASTING COMPANY
KGW-TV
CHANNEL 8 316KW ERP
PORTLAND, OREGON
JANUARY 1957

Paper Presented By:

F. CECIL GRACE, CHIEF ENGINEER,
VISUAL ELECTRONICS CORPORATION,

at 11th Broadcast Engineering
Conference on April 11, 1957,
at the NARTB Convention in
Chicago, Illinois.

A NEW LEASE ON LIFE FOR RETIRED IMAGE ORTHICONS

At the fall symposium of the Professional Group on Broadcast Transmitting Systems, Mr. John Wilner of WBAL presented a paper that aroused considerable interest. Entitled "A Method to Prevent Image Orthicon Burn-in", it described a system to oscillate the turret of an image orthicon camera slowly about its axis through a small angle. This causes the image on the photocathode to be constantly in motion even though the subject matter and the camera are stationary, and so minimizes burn-in.

Original test results at WBAL were extremely good and a patent application was filed. Visual Electronics Corporation has obtained an exclusive license to manufacture devices covered by this invention, and has designed a commercial version which includes vertical, as well as horizontal motion and correction.

The operation of the device is relatively simple. It consists of a mechanism to cause the lenses of a television camera to move in a small circular orbit. This causes the image on the orthicon photocathode to move in the same circular orbit. The orbit is only 9/64 of an inch in diameter, and the rate of the motion is approximately two times around per minute. This slight motion of the image on the photocathode of the tube has been found sufficient to prevent "burn-in" of the image, even when using an old, sticky tube.

There remains the problem of holding the transmitted picture stationary. This is done by introducing suitable correcting signals to the centering circuits of the TV camera. The correcting signals are sine and cosine functions obtained from a sine-cosine potentiometer. Each function is amplified by a small transistor amplifier and applied to the correct deflection circuit.

To provide the orbital motion of the lenses, it is necessary to replace the camera's original turret with the special turret shown in Figure 1. The lenses are mounted on a Lens Plate, which is free to move in the circular fashion indicated above, and carries all four lenses with it. This motion is with relation to the Spider, the X-shaped part which mounts on the camera turret arbor. The four arms of the spider each carry a chain sprocket, and each sprocket has an eccentric pin which drives the Lens Plate in its circular motion. The chain sprockets have two sets of bead chain sockets, one carrying the chain shown that assures all four sprockets will run in synchronism. The other set takes the chain that drives the system from a unit that mounts to the underside of the camera, called a Turret Driver.

At this point it should be explained that the model shown was designed for the RCA TK-10A camera, this make and model camera being chosen for our first model of the device because of the large quantities of this type camera in use. The equipment also fits the RCA TK-30A field camera. Equipments for other cameras are expected to follow shortly.

Of interest are the bearings that permit orbital motion without permitting any variation in the separation between the Lens Plate and the Spider, since any such variation would de-focus the lens. The problem may be divided into two parts: how to prevent the two parts from getting too close together, and how to prevent them from getting too far apart.

Figure 2, which shows the Turret dismantled, shows the four special ball bearings that prevent the two parts from getting too close together. Each bearing has but a single ball running in a hole milled in each part. Theoretically, a ball rolling between two flat plates would do the trick. If one plate were stationary and the other had the motion described above, the ball would roll about a circle with a diameter half the diameter of the circle of motion of the plate. In practice, it is necessary to prevent the ball from wandering gradually out of place, as well as to prevent it from dropping out if the pressure is removed. The milled holes, which have a diameter equal to that of the ball plus the diameter of the ball's circle of motion, accomplish this purpose. The friction against the walls of the holes is nil in theory and very small in practice.

In Figure 3, both the Spider and the Lens Plate have been turned over, as compared to Figure 2. The photograph shows the means used to prevent the Lens Plate and the Spider from getting too far apart. Once again, four assemblies are used, each consisting of a half sphere and a full sphere, joined by a long screw. The spherical surfaces work in spherically milled holes in the Lens Plate and the Spider, forming, in effect, ball joints. Since the motion of the Lens Plate is circular, the distance between the centers of the spherical surfaces does not change, so no spring take-up is required.

Figure 4 shows the Turret mounted on a camera, with the driving chain to the Turret Driver. The latter has its cover removed. Figure 5 is another view. Figure 6 shows the same, but with the turret rotated to a position between stops, in order to show what happens when lenses are changed. The sprockets simply roll rapidly along the slow-moving chain, turning as they go. This view also shows why two chains are necessary. Note that the bottom sprocket on the Turret has left the chain linking the Turret Driver, and is now entirely dependent on the shorter chain for its drive. The short chain also prevents the sprockets from getting out of synchronism when the turret is removed from the camera.

Another thing that happens during lens change is that the sprocket on the Turret Driver moves up approximately one quarter of an inch, being pulled up by the chain. This is because the Turret, when being rotated, is seen by the chain not as a single round sheave, but as a nearly square one. The Turret Driver is designed to accommodate this motion.

One more point about the chain drive system deserves attention. Since the correcting signal for the centering circuits is generated in the Turret Driver, it is necessary that the potentiometer in the Turret Driver be correctly phased to the Turret. It is also necessary that this phasing adjustment remain correct

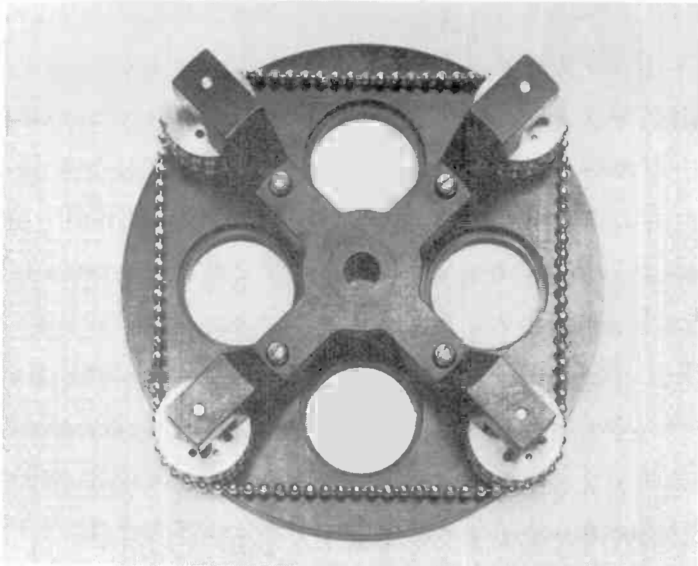


Figure 1

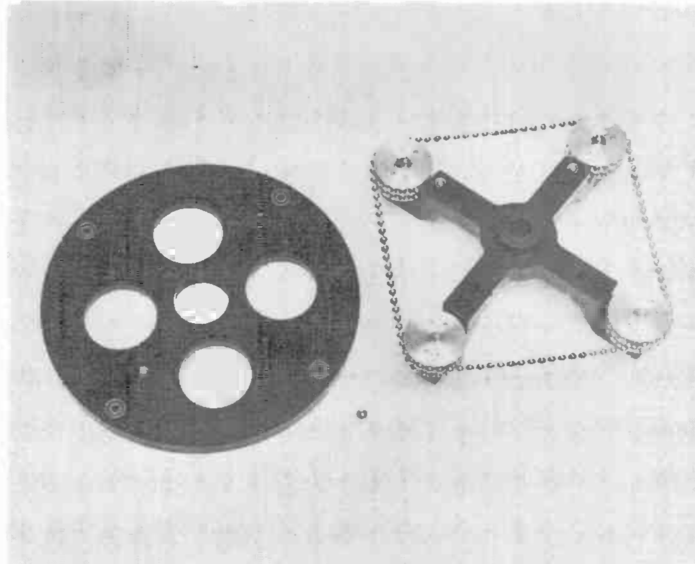


Figure 2

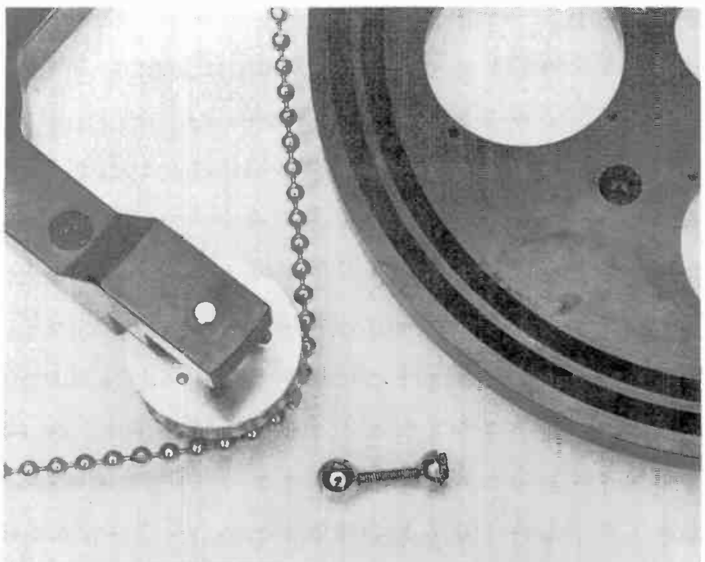


Figure 3

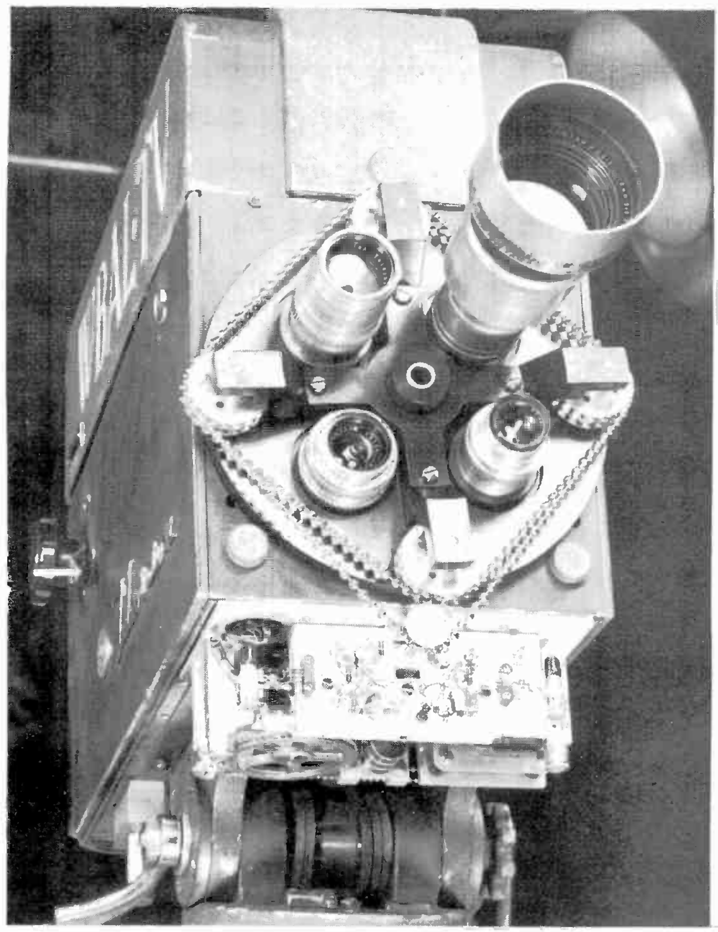


Figure 4

Figure 5

Figure 6

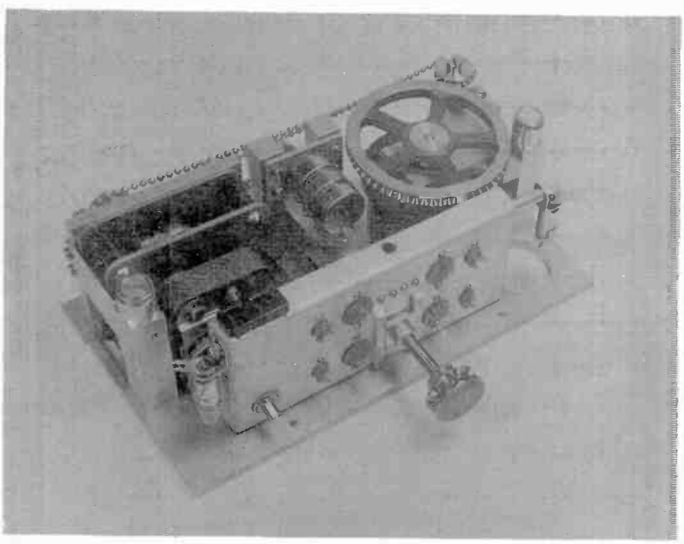


Figure 7

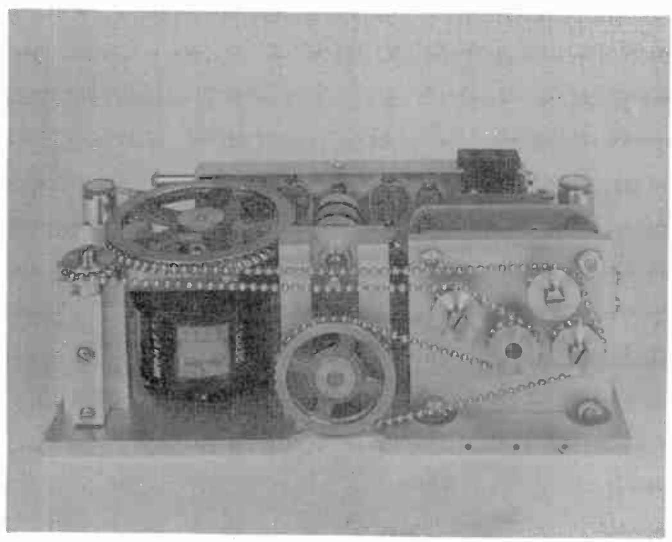


Figure 8

after a lens change. In other words, if the turret is rotated 90° to change lenses, and if this is done so quickly that the motion of the driving chain is negligible during the turret rotation, then the eccentric pins on the sprockets must occupy the same angular position that they had before the lens change. This will be achieved if the sprockets rotate a full 360° during the change. To provide exactly 360° rotation, the number of beads on that section of the chain which spans the space between sprockets must be just equal to the number of sockets in the sprocket. In this case, the number is twenty.

We now come to the other major unit in the equipment, the Turret Driver. Since in a two dimensional photograph the presence of wiring can greatly confuse mechanical details, we show in figure 7 a picture of this unit taken before it was wired. The unit screws to the underside of the camera, and operates in a position up-side-down from that in which it is shown here. In operation, it is enclosed by a cover, which is not shown.

The sprocket on the jackshaft protruding from the front is that which drives the turret. When the turret is rotated to change lenses, this sprocket must move vertically by a small amount, as previously explained. To permit this motion, the jackshaft is mounted in a housing which is pivoted at its rear end. The housing is loaded by a heavy spring to keep the chain tight during lens changes. An adjustable stop keeps the pressure of the spring off the chain during normal operation.

Figure 8 is a rear view of the unit. On the plate to which the gear motor is bolted, the sprocket in the center is driven by the motor; the other three are idlers. The larger sprocket in the center of the unit is on the back of the jackshaft; it transmits power to the turret. This sprocket tilts about a horizontal axis when the jackshaft housing moves about its pivot. However, since the points at which the chain from this central sprocket meet other sprockets is on the axis of tilt, such tilt will not alter the chain tension appreciably. Nor can the tilt twist the chain, since bead chain is not twistable. Any slight misalignment caused by the fact that the axis of the tilt is not exactly through the sprocket is easily handled by bead chain drives, since the cone-shaped sockets on the sprockets will collect the beads even though they may arrive displaced from the ideal position.

To the left in the picture may be seen the sine-cosine potentiometer which provides vertical and horizontal correcting voltages. This is driven by a very large sprocket, the ratios being such that it runs in synchronism with the turret. The sine-cosine potentiometer is a computer type, but since many broadcasters are not familiar with analog computers, a description of how these trigonometric functions are generated is in order. Figure 9 is by courtesy of the Gamewell Co., which manufactures this potentiometer. Resistance wire is wound on a square card, and a DC voltage is impressed across it. There is a voltage gradient along the card from the start of the winding to the finish, but, if the card is wound with many turns of fine wire, there is practically no voltage gradient at right angles to this direction, that is in a direction along the wires. This is because the resistance of a single turn of wire is small compared to the total resistance of the card.

Now suppose the card is fixed and a brush moves on it along the circular track shown. Simple trigonometry will show that the voltage picked off by the brush is proportional to the sine of its angle of rotation. This voltage is precisely what is required for a vertical correction signal. If a second brush is driven

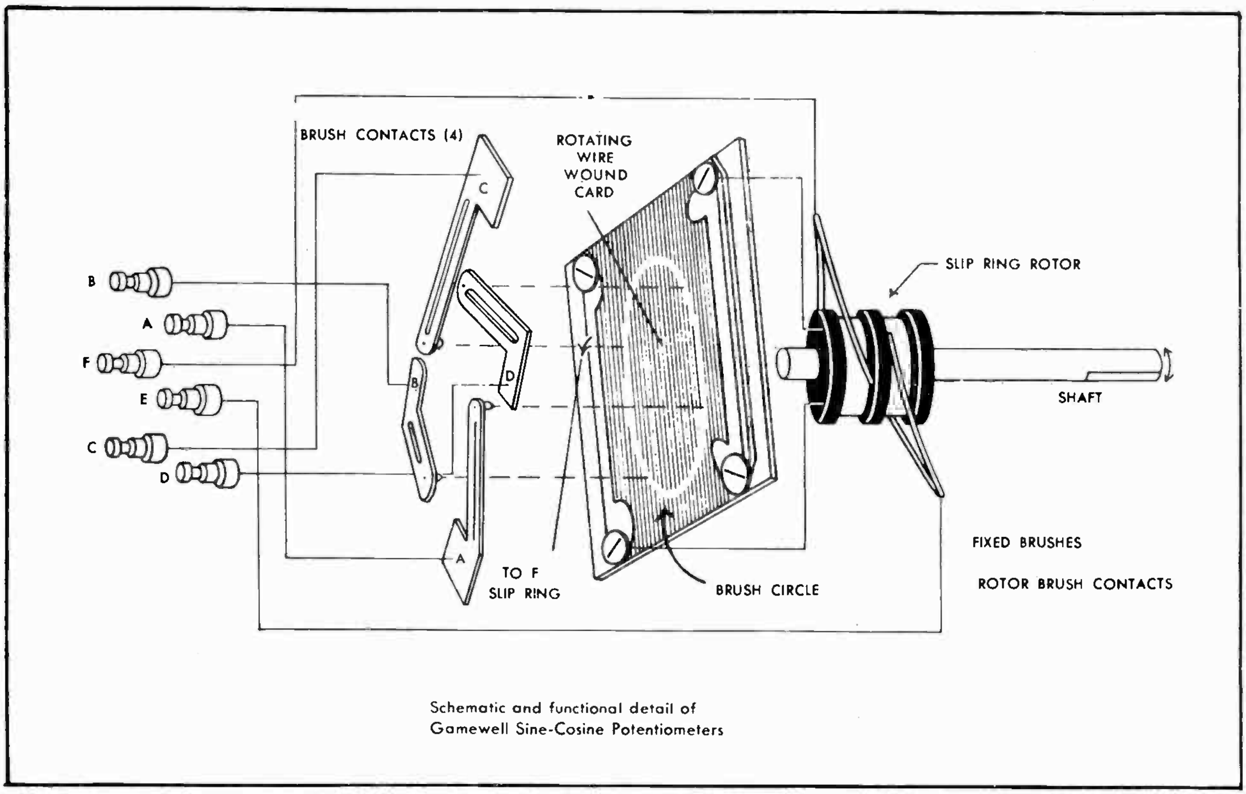


Figure 9

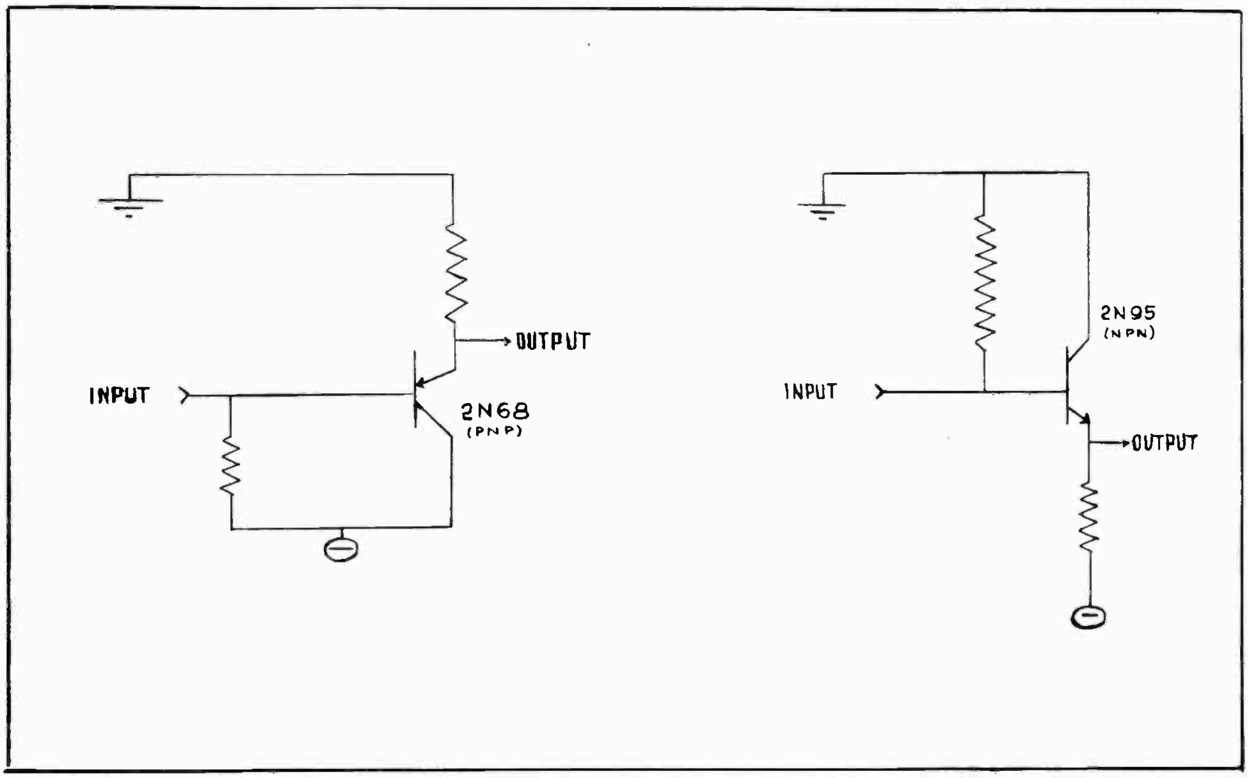


Figure 10

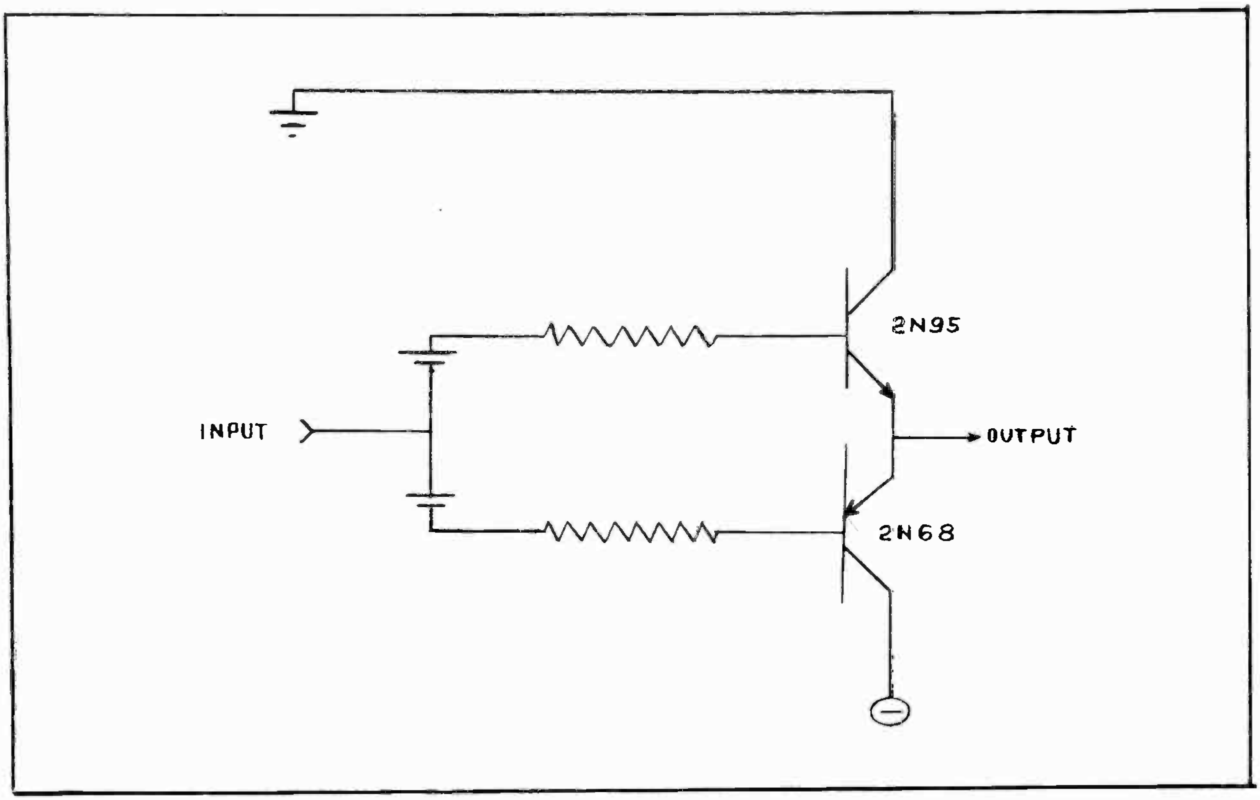


Figure 11

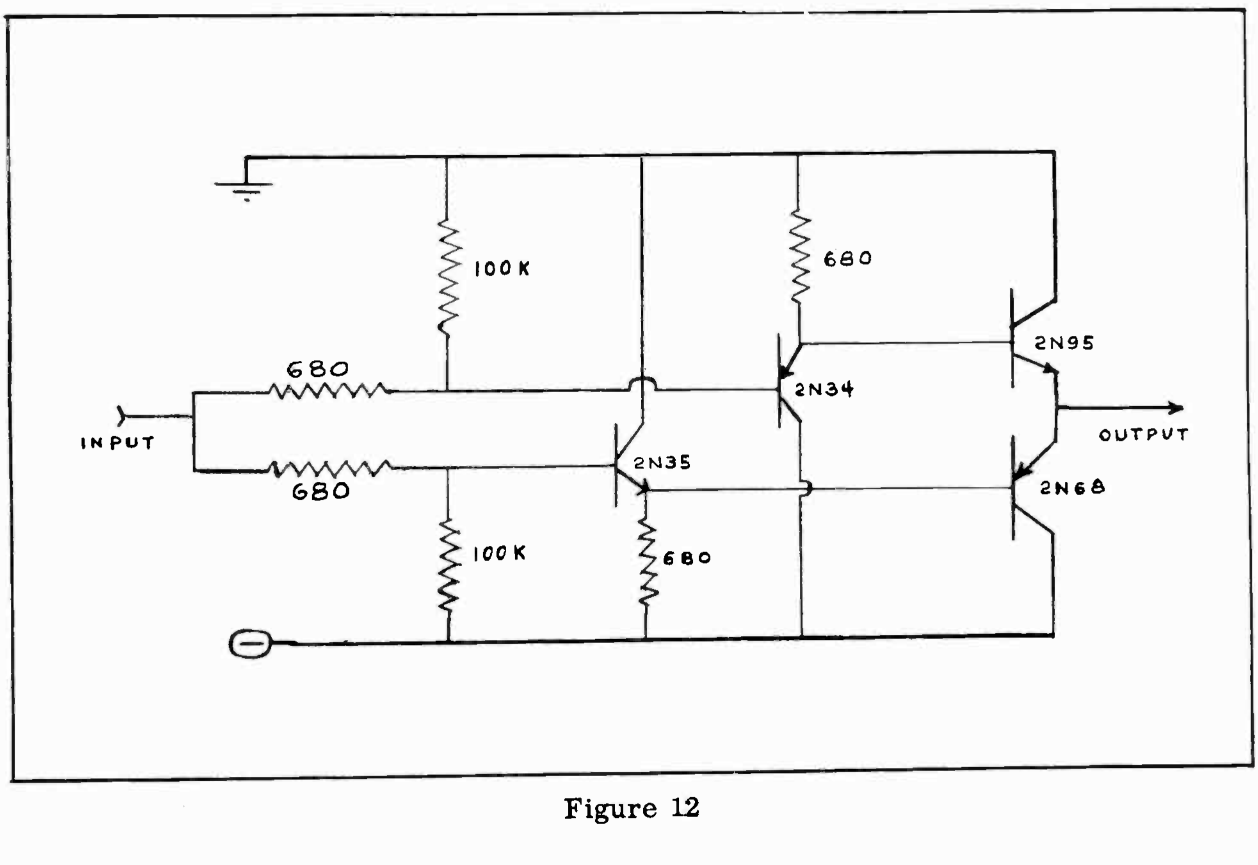


Figure 12

90 degrees out of phase with the first, it will generate a cosine signal, which is required for horizontal correction. The diagram shows two more brushes to generate a negative sine and a negative cosine function, but these are not required in the present application. Also, as the figure shows, the brushes are fixed and it is the card that rotates. This arrangement requires only two slip-rings; the alternative would require four.

Since these sine and cosine functions must drive the very low impedance centering circuits in the camera, it is desirable to have the resistance of the potentiometer as low as possible. Low resistance potentiometers are usually made by winding with only a few turns of coarse wire. This method cannot be used in this instance, however, for three reasons. First, the assumption of negligible voltage gradient along the card in the direction of the wire would no longer be valid. Second, the rough surface would reduce the brush life. Third, the correction would be in jumps rather than smoothly.

There is, however, one method of reducing the resistance without encountering these difficulties. This is to substitute for the usual nichrome, a wire having a lower resistivity. The potentiometer used in the Turret Driver is wound with wire made of a gold alloy, which has a resistance of only 80 ohms per circular mill foot, as compared with 650 ohms for nichrome. By this means a total resistance for the winding of only 2000 ohms has been achieved.

This still is much too high a resistance to connect directly in the centering circuit. Therefore a transistor circuit consisting of cascaded emitter followers is used as an impedance transformer. The emitter follower, or common collector amplifier, is the transistor equivalent of the cathode follower; it has the same properties of reduced output impedance, improved linearity, voltage gain less than unity, and increased input impedance. This last is quite important with transistors, especially in this case because we want to minimize loading on the sine-cosine potentiometer in order not to impair its accuracy.

Power for the transistors, as well as the voltage for the potentiometer, is taken from the camera centering supply voltage, which is negative to ground. Figure 10 shows two simple emitter follower circuits, both arranged to use a negative supply voltage. The one on the left uses a PNP transistor, type 2N68, while the one on the right uses its complementary, the NPN type 2N95. The emitter in the PNP circuit will come to a voltage slightly more positive than the base, while in the NPN circuit the emitter will be slightly more negative than the base. These conditions are necessary to maintain proper emitter current, just as in a cathode follower the cathode comes to a voltage slightly more positive than the grid, to maintain proper grid bias.

The two circuits of figure 10 can be combined into a single push-pull circuit that draws no more power from the power supply than either circuit alone, yet has greater linearity and lower output impedance. This is done by substituting, for the load resistor of either circuit, the transistor from the other. It is shown in figure 11. In this case, however, since the emitters of both transistors are connected together, there must be a difference in potential between the two bases, in order to maintain emitter current. Figure 11 shows a floating battery to establish this potential difference.

Figure 12 shows the actual circuit used. The bases of the 2N95 and 2N68 are driven, respectively, by a 2N34 and 2N35, also connected as emitter followers. These last two types also are complementary at low frequencies. Since the NPN power transistor is driven by a PNP input stage, and vice versa, the potential difference required between the input stage bases will be considerably less than that between the output stage bases. The potential difference that is required is produced, at a slight cost in gain, by the pair of voltage dividers shown.

This amplifier, when operated at a six volt potential, has an input impedance of approximately 5000 ohms. When the input is connected to a low impedance source, the output impedance is only about 2 ohms, rising to approximately 5 ohms when the input is open. For lower supply voltages, the impedances undoubtedly rise, but the equipment continues to operate normally.

Installation of the equipment on the camera is simple. A socket which replaces the convenience outlet on the camera makes all necessary interconnections, including AC for the motor. This AC is also brought to a convenience outlet on the Turret Driver, so that the outlet is not sacrificed when this equipment is added. On-air lights are also provided on the Turret Driver. This is because the lenses and lamps must be removed from those on the camera to accommodate the slightly larger special turret.

The last few slides show some results obtained at WBAL, where this equipment not only was tested but also has been used on the air. The pictures were photographed from a control room monitor. An old, sticky tube was used in the camera. Figure 13 shows a typical studio scene. With the motor in the equipment not running, the camera continued to pick up this scene for 1 1/2 minutes. Then a person seated himself in front of the desk, and immediately another picture, Figure 14, was taken. Note that the Gunther Beer sign is still visible, apparently right through the subject's body! After clearing the orthicon tube of retained images, the experiment was repeated. Again the camera viewed this scene for a minute and a half, but this time with the motor running. When the man seated himself again, Figure 15 was taken, and this time the human body has its expected opacity.

The next three picutres are similar, but this time a weather chart was used as background. Figure 16 shows the scene viewed by the camera for 1 1/2 minutes, first with the motor off, and then later for 1 1/2 minutes with the motor on. At the end of each period, a man walked up to write on the chart, and another picture was taken. Figure 17 shows the burn-in when the motor was off, Figure 18 the lack of burn-in when the motor had been running.

The last three pictures show the effect when the camera is panned. Figure 19 shows the scene that the camera observed in each case for a minute and a half, once with the motor off, once with it running. The camera was then turned to pick up another scene. Figure 20 shows the picture obtained with the motor off, Figure 21 with it on.

In conclusion, it is expected that this device will not only extend the average useful life of image orthicon tubes to a considerable extent, but also eliminate the "sticking" which is objectionable to the television viewer.

PROGRESSIVE STEPS TOWARD AUTOMATION

IN

TELEVISION PROGRAMMING

A. H. LIND

RADIO CORPORATION OF AMERICA

PROGRESSIVE STEPS TOWARD AUTOMATION IN TELEVISION PROGRAMMING

The word automation is being heard and is appearing in print very widely today. Although attempts to define it have been made by industry committees as well as individuals there remains a nebulous vagueness about it which can lead to confusion and misunderstanding. I don't intend to add to the confusion by making a general definition of the word, however, some comments may help explain the way in which it is used in this paper. Automation encompasses automatic devices. An automatic device is one having a self acting or self regulating mechanism that performs a required act at a predetermined point in an operation. Automatic devices have been used and found very practical for doing routine, tedious, repetitive jobs. Automation is an exploitation of automatic devices. One might say that the objective of an "automation effort" in broadcasting is to utilize automatic devices by the application of automation techniques toward unattended operation as an ultimate goal. Thus automation may be present in widely varying degress. It also follows that a plant can be "automated" to a high degree by planned progressive steps, each of which will be well worthwhile.

Why all the interest in automation?

Slide #1.

Why Automation?
1. Increase Profits
2. Eliminate Operating Errors
3. Increase Personnel Efficiency

Aside from many controversial social, political and labor considerations, there are these:

1. Automation can make possible increased profits for the broadcaster. The improved performance makes a station more appealing to viewers and sponsors alike.

2. Automation can eliminate operating errors. The confusion attendant to the station break or commercial insert "panic period", during which time most switching errors occur, can be drastically reduced.

3. Automation can permit more efficient usage of skilled personnel. Fewer technical people are needed. Thus it may be possible to afford high caliber people that are presently being attracted away from broadcast stations to more lucrative jobs in other areas of the expanding electronics field.

In a broadcast plant there are three types of TV signals or signal handling. First, there are signals derived from recorded programs. Such recordings include motion picture film, slide transparencies, positive prints or opaques, magnetic tape and disk records. Second, there are direct live pickup pictures. Third, from the standpoint of signal handling, there is the master control or program assembly function. In this case the signal arrives in "packaged" form via cables from either local or remote sources. In the first two cases there are control functions which must be performed in the process of generating the signals, both picture and the accompanying sound. In the third case it is a matter of switching the correct signals at the correct time.

TV programs can rather generally be classified into the following kinds:

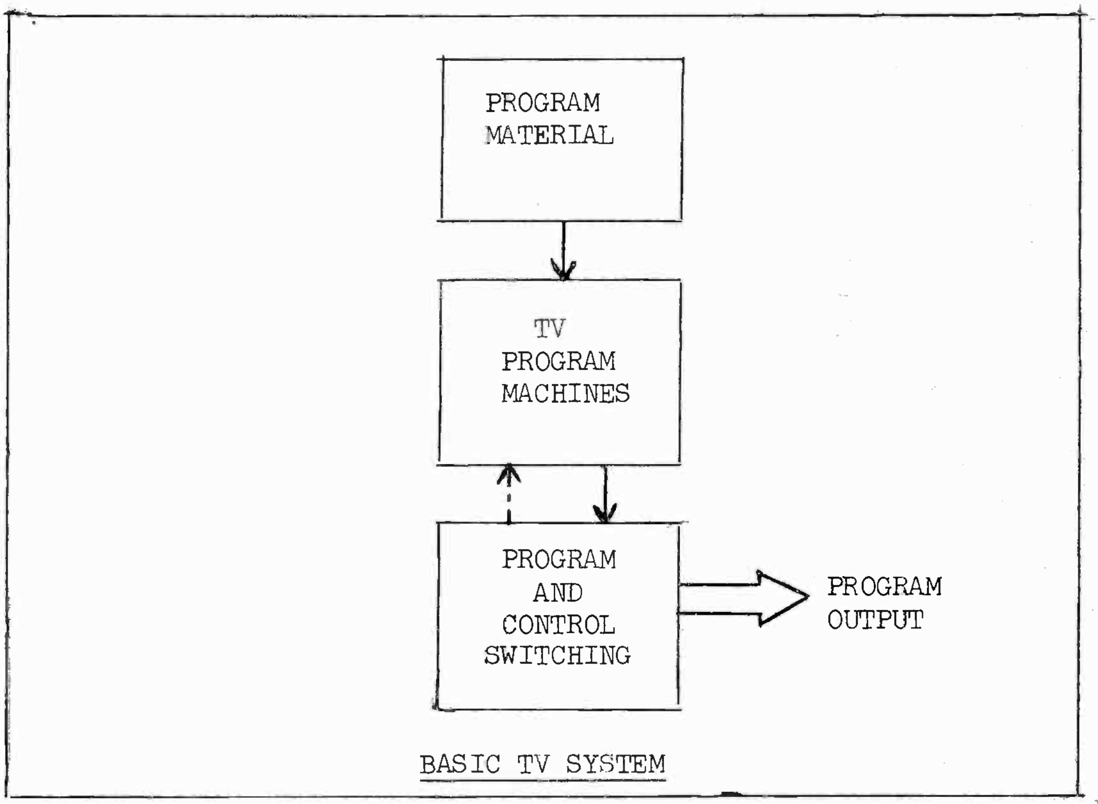
1. Short precisely timed sequences. These short sequences are station break or commercial inserts in the vast majority of cases. Short film inserts in live programming such as news scenes and slides for titles and program announcements are also used. Station break programs are the most rigidly scheduled with respect to clock time. The other types might be scheduled to occupy a precise time block but not so rigidly scheduled with respect to clock time.

2. Feature film. Motion picture films frequently provide programs of from several minutes to several hours duration.

3. Direct pickup live programming. This of course is a broad area of programming ranging from carefully planned and rehearsed studio pickups, through indoor and outdoor athletic events and a multitude of other unrehearsed events.

A program day is usually made up of a variegated mixture of these different kinds of programs. As indicated on the next slide

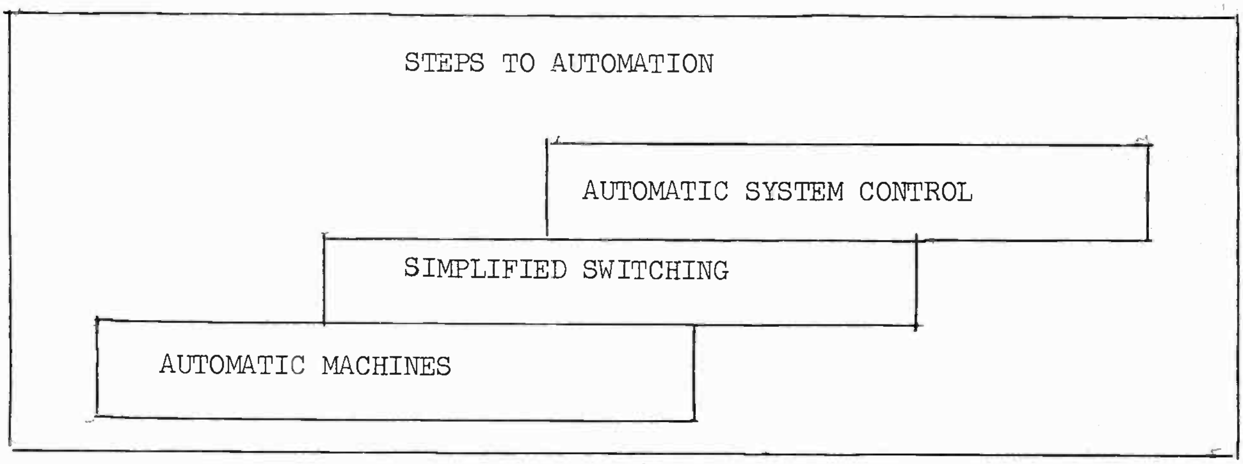
Slide #2.



the program material, live or recorded is transduced in appropriate TV machines into television picture and sound signals which are next subjected to program switching for signal selection to establish the program output. These are the picture and sound signals transmitted from the studio or plant. It is important to note that in addition to signal selection switching, machine control switching is required. This includes such functions as starting and stopping of motion picture projectors, changing slides, switching optical paths by means of an optical multiplexer, starting and stopping tape recordings and disc records. The pattern indicated here, in greatly simplified form, is representative of the basic television studio system as it is generally used today. Economics, well established labor practices, and well established programming techniques plus just plain human nature may make changes from present practice difficult and slow in coming.

It is logical to propose that automatic equipment be used to alleviate or cure shortcomings and to move forward in this era of automation. But where should one start? First, it is fundamentally logical to make every machine as automatic or self controlled as possible. This minimizes the amount of external control required. Once such machines are available in a broadcast plant they are of immediate use and benefit in that manual operation can be streamlined and simplified. Thus a second logical step is the introduction of simplified control. This step does not imply simpler equipment but rather a simpler control panel from the manual operators point of view. With automatic machines and simplified control available the third logical step is that of adding automatic system control. With the first two steps as background the automatic system control can be accomplished without becoming overwhelmingly complex. It can provide a system capable of unattended operation for brief or extended periods. Thus as is indicated in the next slide,

Slide #3



three logical, progressive steps to automatic programming are first, automatic machines; second, simplified switching; and third, automatic system control.

Let us look for a few minutes at the area of automatic machines. Since programming from recorded material lends itself most readily to automation this is where attention is first being directed. The next slide

Slide #4

AUTOMATIC TV MACHINES
AUTOMATICALLY CUED FILM PROJECTORS
AUTOMATICALLY CUED TAPE REPRODUCERS
AUTOMATIC TURNTABLES
AUTOMATIC SLIDE SELECTION
AUTOMATIC GAIN CONTROL
AUTOMATIC LIGHT CONTROL

lists six automatic machine functions several of which are available while the remainder are being developed and designed by RCA.

The cueing or positioning of motion picture film in a projector so as to insure that picture and sound will start at the instant the program schedule requires it is a problem that involves careful operating practice. Since the projector requires a finite period of time to accelerate to stabilized running speed, the frame placed in the gate of the projector must be well ahead of the first frame to be used. The amount of leader, of course, depends upon the start to stabilization time needed for a given projector. At present this operation is done manually. It requires that an operator be at the projector involved prior to every film sequence that is run. An automatic cueing facility can be added to the film projector to perform the cueing function by detecting the presence of a suitable cue mark on the film leader which will in turn actuate controlled stopping mechanisms that will bring the film to a stop with the specified frame in the gate. It now becomes possible to run through a series of film sequences spliced together on a reel with starting the projector at the proper time being the only operation required. This, of course, can be done remotely. Following the completion of a given sequence the program line is switched to another picture source but the projector continues to run until the cue mark for the following sequence is detected and the machine is brought to a controlled stop with that sequence cued for starting. Automatic cueing for RCA TP-6 and TP-35 Projectors will be available in attachment form in the future.

A second problem exists in motion picture film projectors. In addition to cueing the film for proper start, the start up time of the machine must be accommodated by starting the machine several seconds prior to switching its output to the program line. There are three interdependent functions that must be accomplished before satisfactory picture and sound can be obtained. The film and rotating parts of the machine must be accelerated to the 24 frames per second synchronized speed. Proper intermittent motion of film at the gate must be established. Second the light shutter must be rotating at the proper speed and locked in the proper phase with respect to the film intermittent. Third the film must reach stabilized, uniform motion at the sound take off point which by standard is 26 frames separated from the film gate where the film motion is intermittent. Availability of a machine that can produce a usable picture in a fraction of a second following its starting is probably a matter of years in the future. Thus it is necessary for automatic systems in the near future to accommodate a "roll cue" in advance of the "on air" picture switch.

The problem of cueing magnetic tape is similar to that of film with somewhat greater complication in that the tape cannot be cued by visual inspection. The addition of cueing tones that fall outside the program signal passband can provide marker signals to control the stopping of the machine with the next recorded sequence ready for starting. The cue tone frequencies can be filtered out of the program channel thus cue information can overlap program information in time if this is desirable for special reasons.

The RCA BQ-101 and BQ-102 Automatic Turntables are presently available. They provide means for storing a quantity of 45 rpm records and, when actuated, selecting a record either in sequence or in random order. The record is removed from the storage rack and placed on the turntable. The pickup arm is next positioned so that the stylus is in the lead-in groove of the record. The turntable platter is then deenergized and quickly braked to a stop. The machine remains in this ready condition until a start switch circuit is closed. Upon completion of playing a record the machine returns it to the proper place in the storage rack and goes on to ready the next record for playing.

Slide transparency projectors, such as the RCA TP-7A, are now available which have a substantial slide capacity. The TP-7A is a rugged, reliable projector designed for remote control service. The machine is basically sequential in operation. It is capable of showing a rapid succession of slides with very fast slide to slide transitions. If sequential operation through a series of slides will fit the programming desired the TP-7A will lend itself to automation immediately. A machine which will permit the selection of slides in random order makes for more flexible and efficient programming because slides can be used repeatedly without rearranging the loading of the drums. Such random selection facility is currently being developed for the TP-7. It will be designed initially for pushbutton manual remote control operation but it will be possible to readily integrate it into automatic control systems.

The need to keep the transmitted signal levels within proper bounds is, of course, always present. Automatic gain control amplifiers such as the

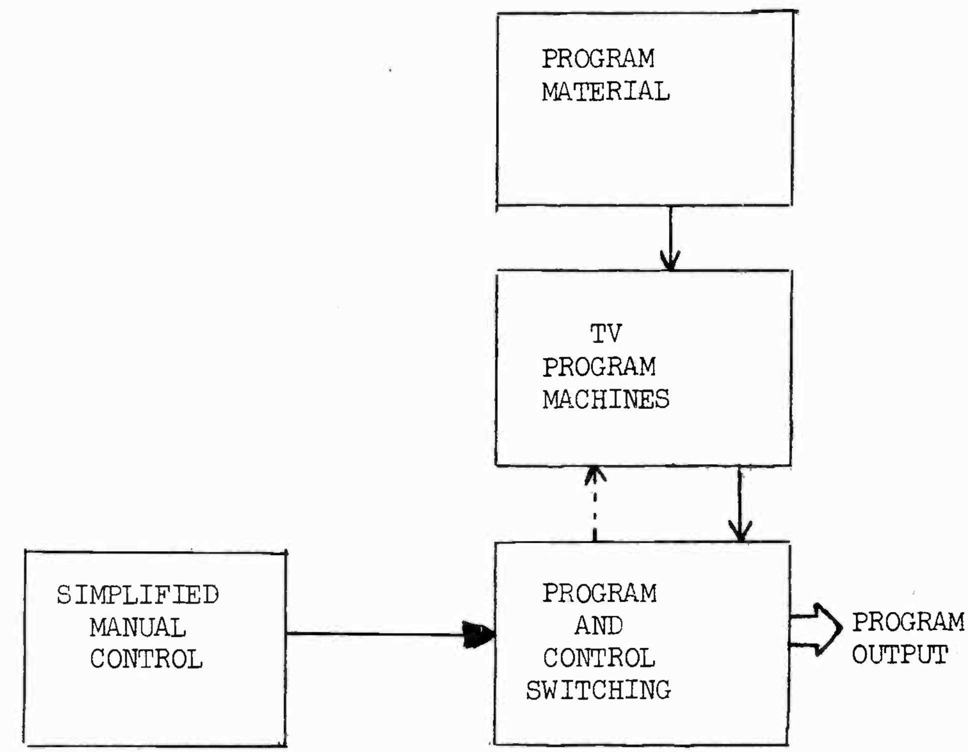
RCA BA-6A and BA-25A for audio and the RCA TA-21A for video are available. They are a beneficial help in relieving operators of much of the gain riding that otherwise may be necessary. Such amplifiers are essential to satisfactory unattended operation.

It is a well established fact that optimum operation for vidicons in film cameras obtains when the highlight brightness of the optical image on the photo surface of the tube is such that the signal electrode voltage is optimized and the beam just discharges the highlight. Excessive beam current will produce deterioration of resolution. If the sensitivity is varied to accommodate variations in the film image brightness by changing the signal electrode voltage, spurious effects can appear due to deviations from field flatness, distortion of the transfer characteristic, and shifts in black level behavior. The present method of maintaining constant highlight brightness at the vidicon by manually controlling the position of a neutral density filter disk in the projector light path works very satisfactorily. Development work is currently being done to make the neutral density light control automatic. A servo loop including the vidicon camera chain, a level measuring and error detecting amplifier plus power amplifier and servo motor to drive the neutral density filter disk can reduce the need for manual operation. This in the future automatic light control will be available.

A word of caution is in order about both automatic gain control and automatic light control devices. It is not practical, at least at present, to build into such servo equipments the kind of subjective judgement that can be exercised by a human operator. Thus some extremes in pictures and sound may not be aided, in some instances may even be deteriorated, because the automatic device uses a very objective judgement with limited IQ instead of an aesthetic subjective judgement.

Once automatic machines are available fewer control switching functions are required. As indicated in the next slide,

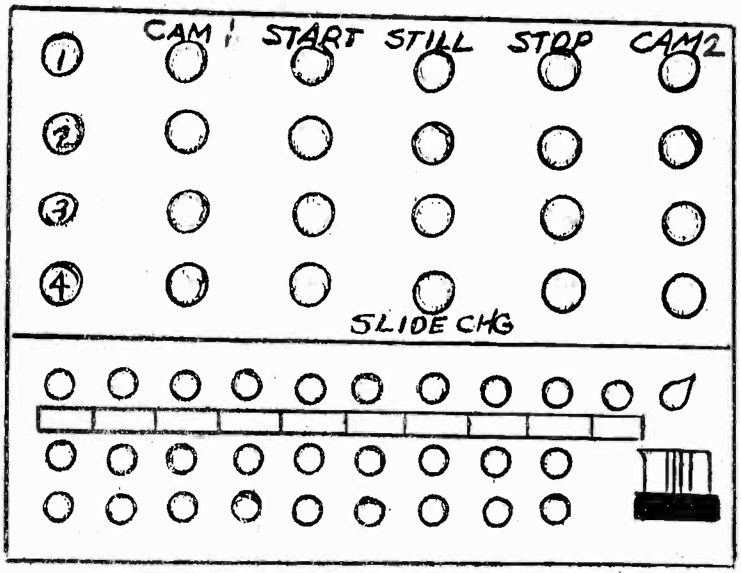
Slide #5.



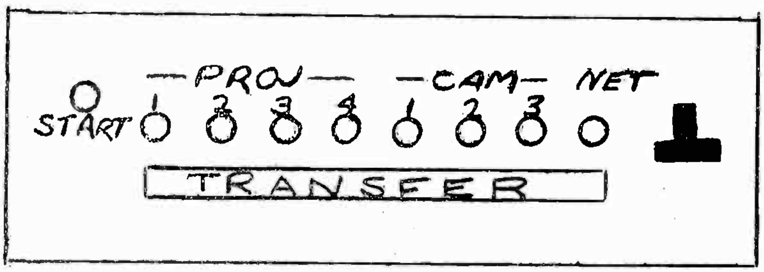
SIMPLIFIED CONTROL TV SYSTEM

a simplifed manual control can be added to the basic TV system. This is the second step toward automatic programming. To illustrate what might be done assume that a studio contains three live cameras, an incoming network line and a vidicon film chain which includes two vidicon film cameras, two motion picture film projectors, and two slide projectors in an RCA TP-15 multiplexed arrangement. It is quite probable that two picture monitors, one a preview monitor, the other a program monitor would be used. As shown in the next slide

Slide #6.



PRESENT MANUAL SWITCHING



POSSIBLE SIMPLIFIED SWITCHING

a TP-15 remote control panel and an RCA TS-11 Switcher are used at the control position. It is evident that the operator has quite a number of switches to keep track of and operate. He can start, stop or still project either film projector plus switch the projector output to either of the two vidicon film cameras. Similarly either slide projector can be started, stopped or slides changed plus projected into either film camera. The video switcher has three rows of pushbuttons or "busses" each capable of looking at the same video input lines. The top row selects the signal displayed on the preview monitor. The bottom two rows, Bus A and Bus B feed the program line under the control of the mixer-fader levers on the right. The control thus available is good, versatile and time proven. However, in the course of previewing, starting and switching a projector a number of buttons may have to be pushed in sequence.

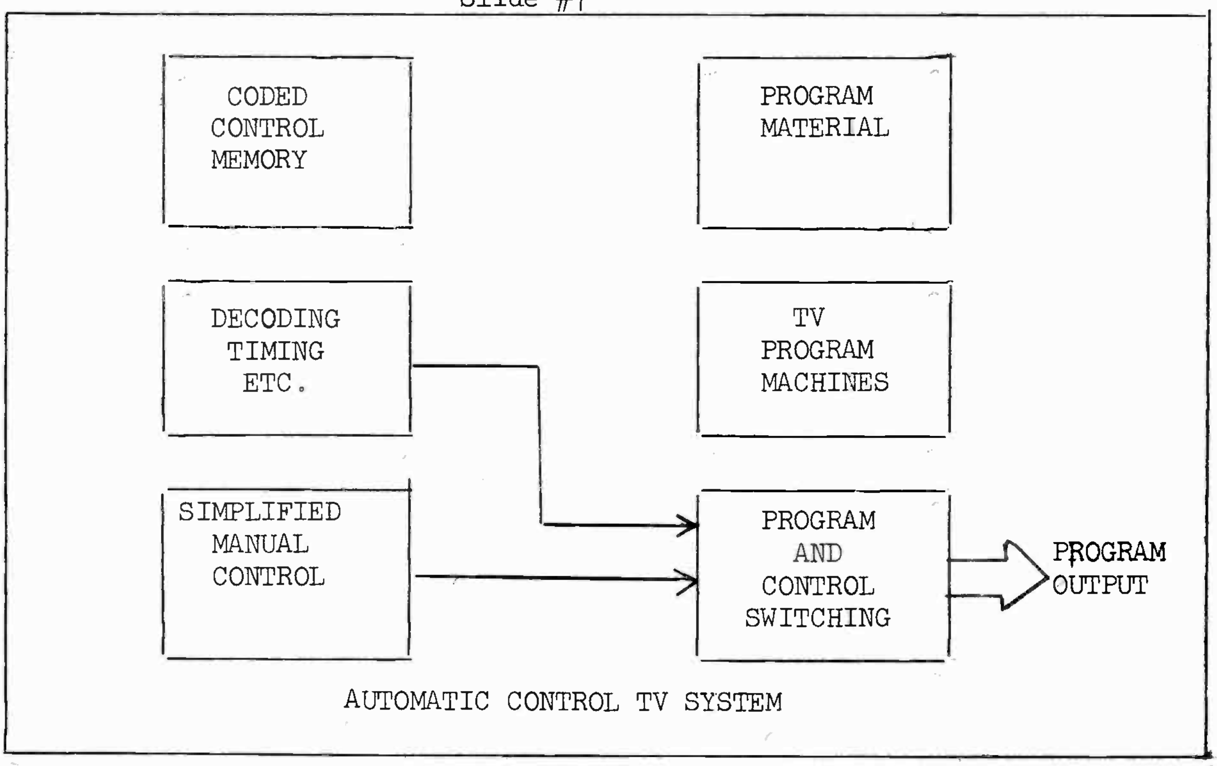
In the case of the simplified switching panel the pushbuttons select the signal which appears on the preview monitor. When a transfer from one signal on the program line to the next is desired the transfer bar is depressed. This causes the program line to be switched from the current input line to the signal which is punched up on the preview monitor. Mixing is accomplished between the program bus and the preview bus. When a signal initially on the preview bus is faded onto the program bus transfer switch action occurs at the end of the fader lever travel which frees the preview bus for further preview and presetting. One of the vidicon cameras would be normally used for the preview picture while the other used for program. When fading to the preset signal which is on the preview bus the role of the cameras will be interchanged.

Presetting a film projector will place the machine in still projection. The automatic cueing function will insure that the film is properly cued. Prior to switching this projector onto the program bus the start button must be pushed. This switch will always start the projector which is punched up on the preview bus. In the case of slides, after presetting the projector on the preview bus the first actuation of the transfer bar will place it on the program bus. If the projector remains punched up on the preset bus each succeeding actuation of the transfer bar will cause a slide change to occur. When tailored to a specific installation the operators job of control can thus be simplified. Because of this need for tailoring due to the great variety of studio systems this control portion of a simplified switching system at present must be a custom built equipment.

The third step may be a big one. It is the addition of automatic system control. The magnitude of this addition depends upon what is to be accomplished. The programming operation may be as simple as selecting the sequence in which the automatic machines are started. The switching actions may be program actuated, i.e., at the end of a given sequence the machine in use transmits a signal which causes the next machine to start. On the other hand the automatic system control may be very complex. The control memory may store accounting and logging as well as equipment control and signal switching and timing information. The control system may run on clock time or relative time or both. Relative time is used when an accurately timed insert is introduced in a program on a program cue basis rather than a scheduled clock time cue.

The next slide

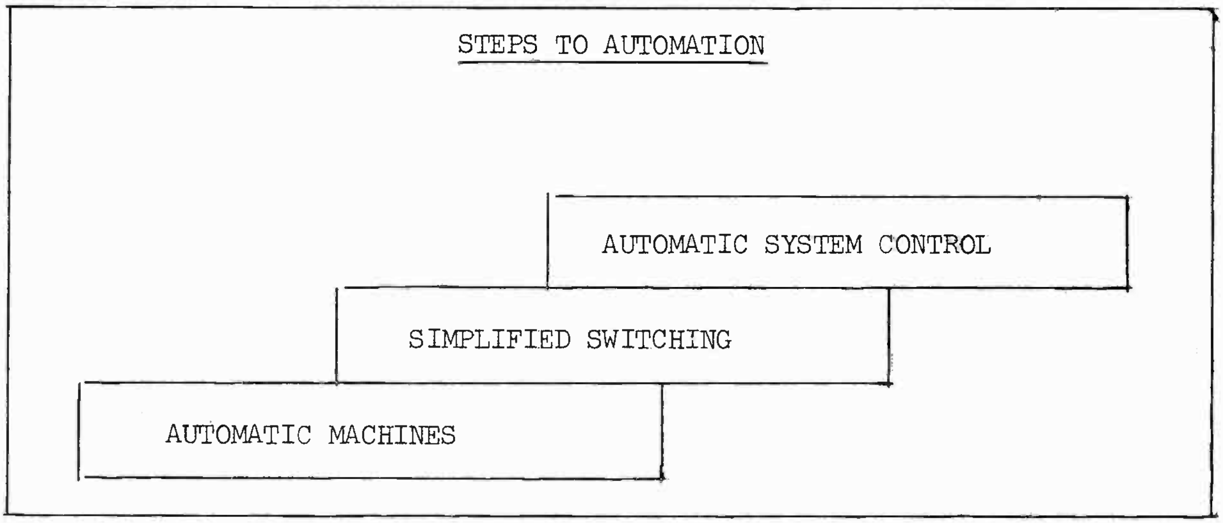
Slide #7



indicates the addition of coded control memory and decoding plus timing controls to complete the basic automatic programming system. Various means are available to accomplish the coded control memory, decoding and timing functions. Questions of whether the coded control memory should be based on punched tape, punched cards, magnetic tape or something else can only be answered when the operating system requirements are known. Studies made within RCA have explored many approaches. The most practical and realistic conclusion at present is that, because of the extremely wide range of system requirements, an automatic control system must be custom tailored to the operational needs of the TV station.

To recapitulate, a logical approach is

Slide #8

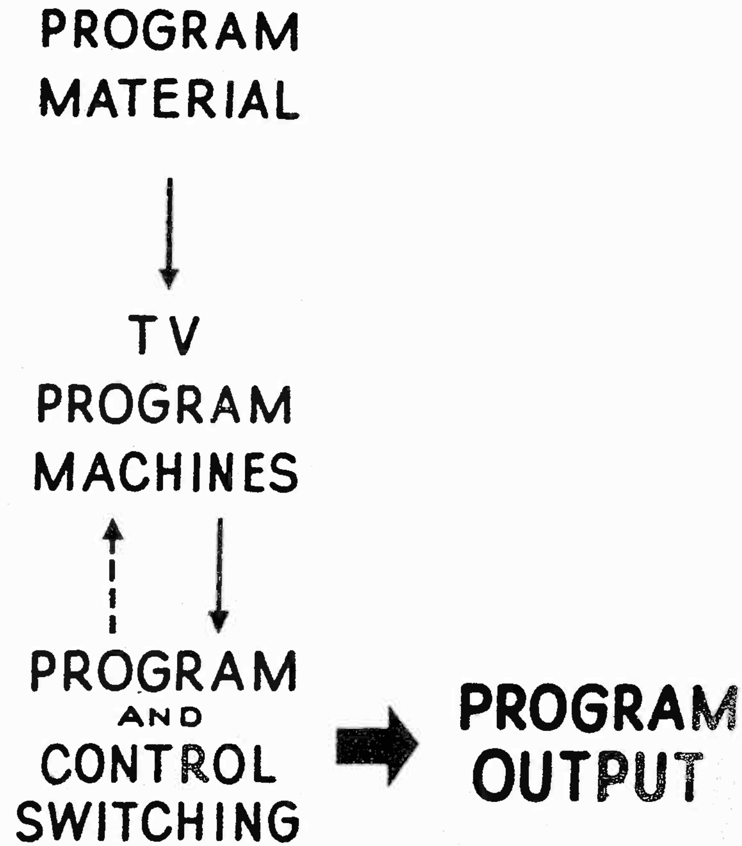


to build toward automatic programming by first taking the step of obtaining individual basic equipments that are automatic or in some instances modifying existing equipments to make them automatic. Second, take further advantage of the automatic machines by simplifying the manual control to ease the human operating problem. Third, based on the foundation of the first two steps add automatic system control and achieve the goal of automatic programming through system evolution.

WHY AUTOMATION ?

1. INCREASE PROFITS
2. ELIMINATE OPERATING ERRORS
3. INCREASE PERSONNEL EFFICIENCY

BASIC TV SYSTEM



STEPS TO AUTOMATION

AUTOMATIC SYSTEM CONTROL

SIMPLIFIED SWITCHING

AUTOMATIC MACHINES

AUTOMATIC TV MACHINES

AUTOMATICALLY CUED FILM PROJECTORS

AUTOMATICALLY CUED TAPE REPRODUCERS

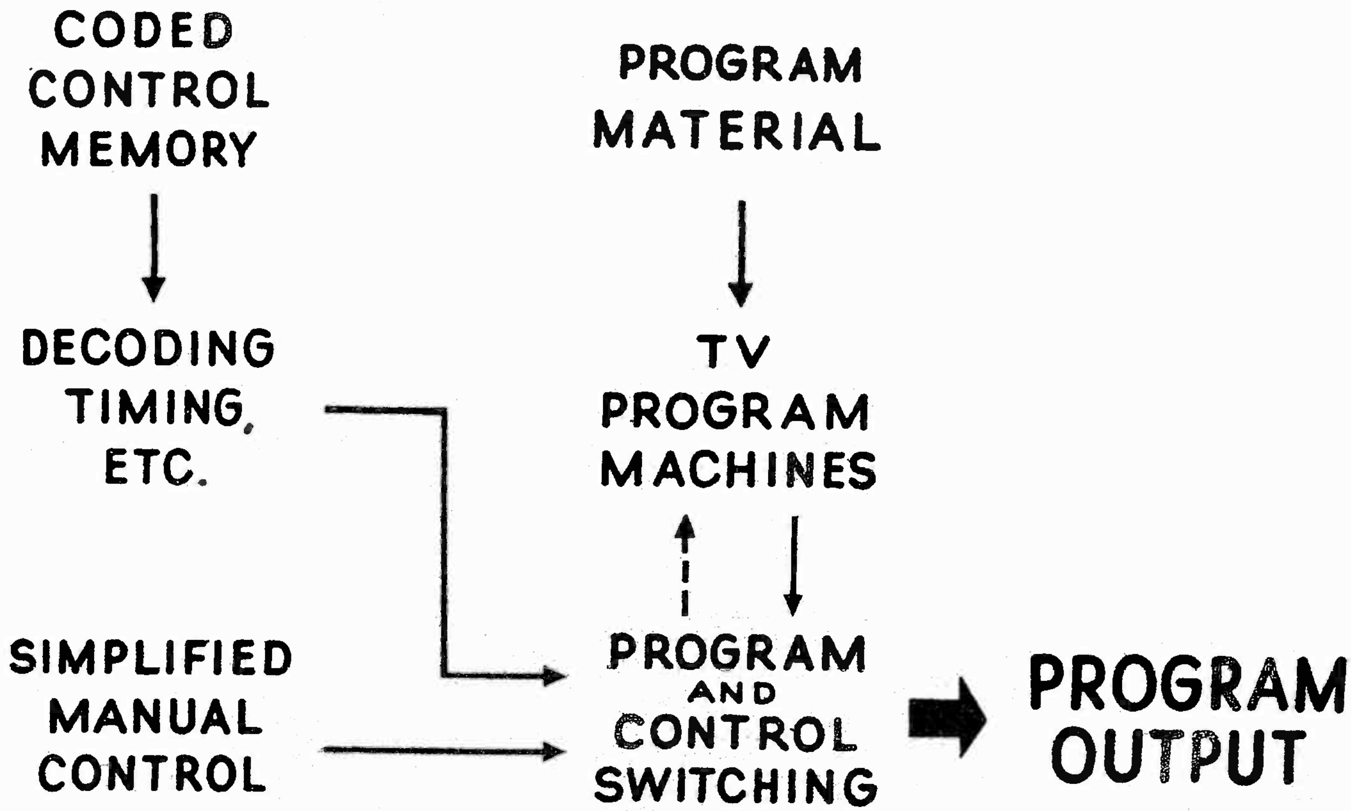
AUTOMATIC TURNTABLES

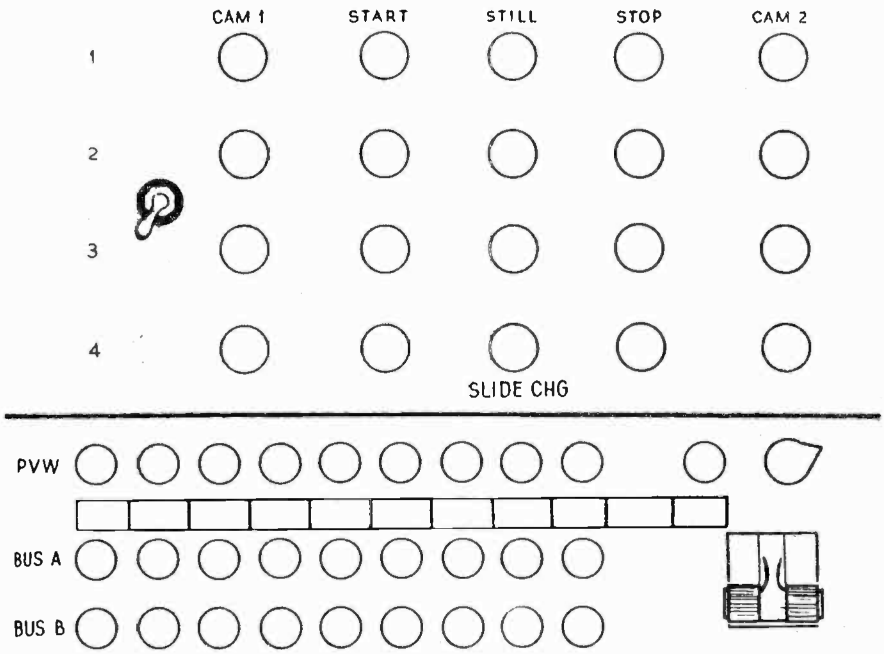
AUTOMATIC SLIDE SELECTION

AUTOMATIC GAIN CONTROL

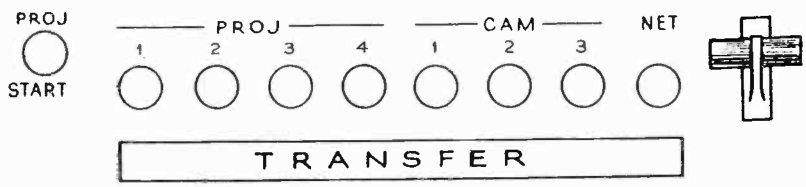
AUTOMATIC LIGHT CONTROL

AUTOMATIC CONTROL TV SYSTEM



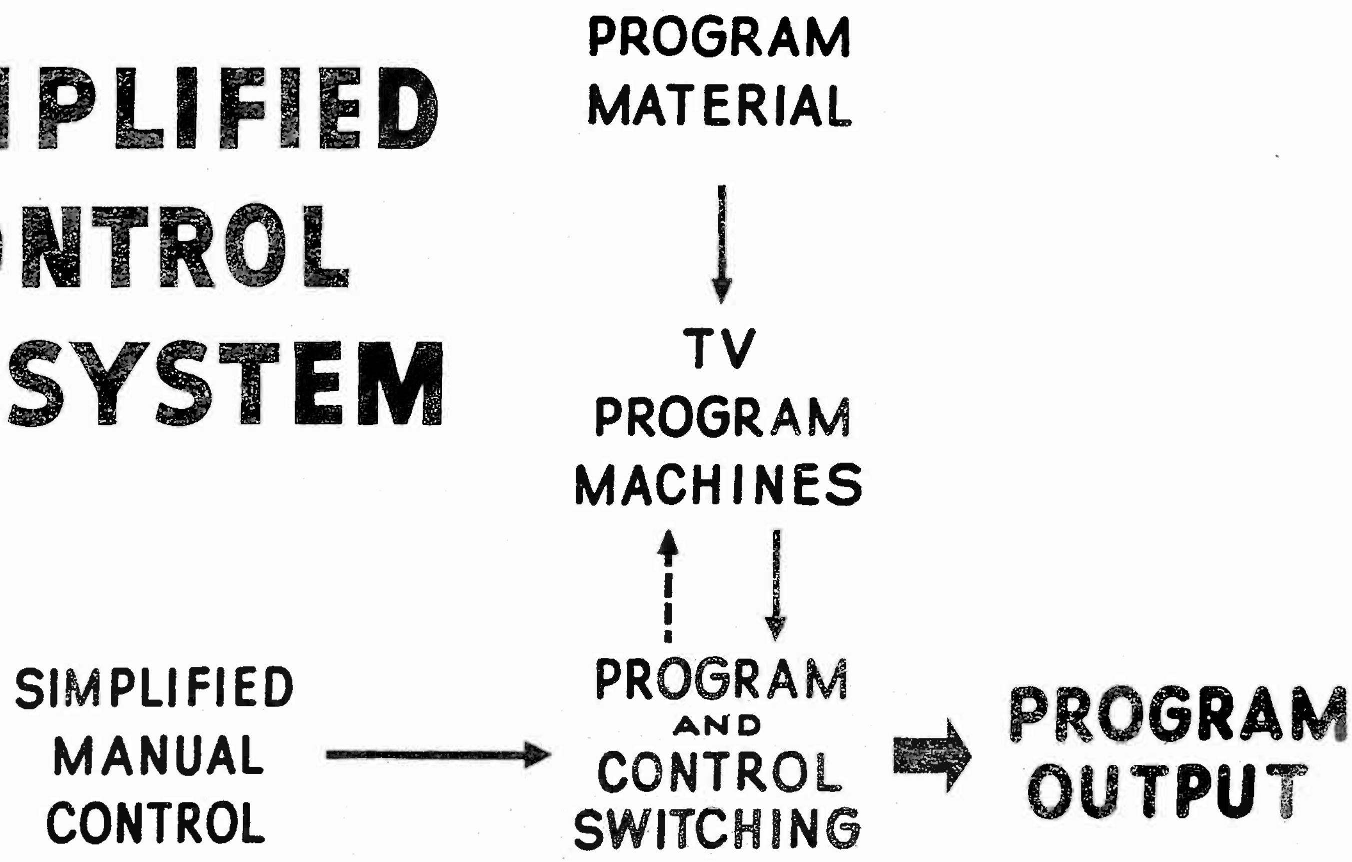


PRESENT MANUAL SWITCHING



POSSIBLE SIMPLIFIED SWITCHING

SIMPLIFIED CONTROL TV SYSTEM



TOWER DESIGN, CONSTRUCTION AND MAINTENANCE

Text of a talk to be presented at the 11th

Annual NARTB Broadcast Engineering Conference

Chicago, Illinois, April 7-11, 1957

by J. Roger Hayden
Product Sales Manager - Towers
Dresser-Ideco Company

Orville Pelkey
Chief Tower Design Engineer
Dresser-Ideco Company

First let me express my appreciation to the NAB and to Prose Walker for the opportunity to talk to you about towers and the reasons for their existence.

Towers today represent a big percentage of the money involved in equipment. This is true of a small AM structure or a very complicated multiple use TV tower.

The design considerations, construction and field work, involved in a tremendous structure like the Hill Tower Co. job in Dallas, Texas are very similar to the same considerations in a much smaller job such as an AM or a micro-wave tower.

This we will attempt to show you by talking a little of the design work, the construction in a manufacturer's plant, the construction in the field and the maintenance.

In order to proceed with the design of a tower or to select a standard tower to do the job the manufacturer must be given a few basic facts concerning the installation.

The Purpose For The Tower.

This may seem elementary but many times this basic piece of information is overlooked. A tower serves to act as a support for a TV antenna, an FM antenna, a micro-wave reflector or dish, a radiator for AM broadcasting, Police, communications or a combination of all or any of the above uses.

Physical Dimensions.

The physical dimensions involved are such apparently simple things as the height of the tower and the size of the property available to install the structure.

The height of the tower may be given to the tower manufacturer in many different manners instead of simply being a figure of so many feet. For example the height of an AM radiator should be stated as height in feet above the base insulator with the height of the base insulator above ground given. However the height of the tower may also be stated in wavelengths or degrees of the frequency in question.

The height of a tower supporting different types of equipment is frequently given in terms of effective heights of the equipment above ground. Many times a television structure is described to a designer by giving the overall height above ground and the top antenna type number.

The style and shape of the property available determines the type of tower to be used. Obviously the tower used on a small portion of a building roof must be self supporting. This is equally true of a tower located on a restricted mountain top or a small building lot.

The shape of the ground, general terrain and the soil conditions under the ground affect the design and the cost. A designer should receive maps and results of a soil investigation below the surface.

Equipment On The Tower.

The equipment to be supported by the tower has a great deal to do with the design and the style of the structure.

An AM tower is fairly simple. The tower supports its own weight and the lighting equipment. Nothing else unless the owner wishes to advertise by a sign showing the name of the station to the world.

An FM tower is also fairly simple. The equipment consists of the antenna and the transmission line.

A micro-wave tower frequently has limitations concerning deflection, twist and sway. The size dishes with their feed lines or the size reflectors must be known.

The equipment on a TV tower consists of the antenna, the transmission lines, the de-icer circuits, de-icer control circuits, and micro-wave facilities.

In addition to the above pieces of equipment many towers also support items such as elevators, telephone circuits and power circuits.

Any or all of the above items may be combined on one structure. A good example of this use is the tower which is operated by WHO at Des Moines, Iowa. This is one of the most complicated structures which we ever built. This tower is used as an AM radiator, is sectionalized at the center, fed as a Franklin antenna by a six inch transmission line, top loaded by a loading coil at the center, carries a tremendous FM antenna and has a TV antenna on the top. Also the AM power is a good healthy 50 KW.

Live Design Loading.

All of the preceding items are what I would term as dead load. This exists at all times on the tower. Now we come to an intermittent or momentary load on the structure which I would term the Live load. This loading is the wind loading, ice loading or some similar type load.

The wind loading on a tower is stated in pounds per square foot and is a factor which the tower designer is well equipped to select or to recommend. Many tower manufacturers have over 30 years experience behind their selection of a proper wind loading. Weather bureau records are also a good source of information on the subject of the correct wind load to use.

The location of the tower, the loss of revenue due to a wind storm accident and the hazard to the public are all factors to be considered in selecting a wind pressure to be used.

Obviously it would be ridiculous to design an AM tower sitting in the middle of an extensive ground system with no buildings nearby for extreme tornado conditions. Equally it would be ridiculous to put this same AM tower in a heavily populated area where hurricanes are a yearly occurrence.

A TV tower supporting an extremely expensive antenna which keeps a high hourly rate of money flowing into a station should have a much greater safety against storms than simpler style structure.

At the present time the RETMA standards committee covering towers and antennas is considering issuing a recommended minimum standard loading for structures in different parts of the United States. This standard will be of help in selecting a reasonable wind load for a tower design.

So the facts a manufacturer requires to prepare a design may be summarized as follows:

1. Purpose For The Tower.
2. Physical Dimensions.
3. Equipment On The Tower.
4. Live Design Load On The Tower.

With all of the above facts in hand we go to work on the design as the first step in producing a structure to fill the needs of the installation in question.

I know of nothing better than asking a designer to tell you of the problems involved in working out a design to suit any installation. I assure you that I have asked this next speaker to fill many a requirement that has seemed impossible at the start. He has yet to fail me. So let's listen to Mr. Orville Pelkey talk about the design problems involved in different type structures.

The design of any tower must begin at the top in spite of the fact that the customer wants to start foundation work immediately upon placing the order. The designer realizes that the foundations are the first step in field construction of the tower, but he must completely design the tower itself before he knows how much load the foundations will have to carry.

The loads acting on a tower are essentially the same as those on buildings and other structures and may be placed in three main classifications; namely: live, dead and erection. The major difference between live loads on towers and other structures is the effect of the wind. Wind is by far the most critical load encountered in the design of towers and is of such importance that the RETMA specifications does not allow the customary increase of 1/3 in unit stresses for loads from this source.

The design wind load is usually set up from references to U. S. Weather Bureau reports and maps for each specific locality. This varies from a recorded 132 MPH in Miami to 49 MPH in Los Angeles. The velocity is converted into pounds per Sq. Ft. in accordance with accepted formulas taking into account the increase of wind velocity with height. The RETMA loads of 20# for small towers in open country and 30# for towers in heavily populated areas or for those above 600' are applicable in general.

Recently, however, more and more customers are specifying 40# or heavier loads.

No attempt is made to design a tower to resist a tornado as the chance of direct hit is remote and there is no assurance that even a fantastically heavy structure would survive.

Ice load is another live load of importance. While its occurrence is not as frequent as high wind, a so-called ice storm or freezing rain can be very disastrous.

Very high winds, very seldom, occur at the same time as heavy icing. On the other hand, fairly strong winds with light ice and moderate winds with heavy ice are common. Ice from $\frac{1}{4}$" to 2" thick is the usual range used for design in the Continental United States. RIME ice with a thickness of 12" or more occurs in some isolated spots. Naturally the presence of ice on tower members increase their projected area exposed to the wind and the weight of the ice adds to the dead load.

Earthquake load must be considered in some localities, particularly on the West Coast. This load is considered as acting horizontally and is a function of the weight or mass of the structure. Although earthquakes occur infrequently, their threat cannot be ignored.

Other loads which may be classified as live loads are those from curtain antennas and elevators.

Dead loads include the weight of the tower members, antenna, micro-wave equipment, transmission lines, ladders, platforms and elevator equipment.

Erection loads are important, especially in the case of guyed towers. Wind on the tower in some stages of erections can subject certain members to loads greater than they will receive in the fully erected condition. Loads from very large and heavy gin poles also add to the hazards of erection. After the design loads have been determined the next step is to apply them to the tower. In order to do this the designer must calculate the projected area of the members acted on by the wind, and multiply this by the wind load per Sq. Ft. The shape of the tower and of the individual members in the structure must also be considered. This is known as the shape factor. The RETMA specifications, based on wind tunnel tests, state that the total wind load shall be based on the projected area of 1½ tower faces for laced triangular towers and on 1 3/4 tower faces for square towers. The RETMA also specifies that the wind on round members may be considered as 2/3 of that used for flats. Thus the load on a 3" rod will be equivalent to the load on a 2" flat bar or angle. The direction of wind is liable to be from any point on the compass, so the designer must assume the wind from those directions which give the maximum loads in each individual member of the tower. For instance, the maximum leg load on a triangular tower occurs when the wind is blowing perpendicular to one face and the maximum web stress with the wind parallel to one face. On a square tower the maximum leg load occurs when the wind is 45° to one face or across the corners, while the maximum web stress occurs when the wind is perpendicular to two faces and parallel to the other two. In addition to the exposed area of the tower legs and web, there are usually other attachments to consider.

Antennas, transmission lines, micro-wave discs or screens and conduits for carrying lighting, power, de-icing and telephone all add wind area and dead weight. The antennas, which are usually mounted on top of the tower, vary from a small police type communication antenna, 20' long and weighing 60# to the huge 12 section low band TV antenna, 232' long and weighing 80,000#. Supergain antennas which have been stacked as high as 185 feet also present a large surface area to the wind.

Transmission lines are usually in the form of coaxial cable 3/8" (diameter) to 6 1/8 (diameter) or rectangular waveguide 3½ by 7" to 7½ by 15". In some installations the exposed area of the transmission line comprises as much as 47% of the total wind area.

Large parabolic micro-wave discs and screen reflectors induce a torque or twisting load to the structure in addition to the direct load. Thus it becomes apparent that it is very difficult to standardize any particular tower design to perform all the above functions economically.

In the design of towers as with many other structures, the sizes of the various members are first assumed, the wind and other loads applied, and the stresses calculated. Each individual member is then designed to carry the caluculated loads and the size checked against the assumed size. If the sizes do not check, a new member is assumed and the process repeated.

The allowable unit stresses to be used in the design may come from any one of various codes and sometimes a combination of codes. (The term "allowable unit stress" means the number of pounds per square inch the member will carry safely.)

The RETMA-TR116 specifications is the code generally accepted for towers in most parts of the country. Most large cities have their own city codes which for the most part are patterned after the AISC. Many times the city codes conflict with the RETMA. In such cases the city codes must be followed or the owner cannot get a building permit. All codes contain provisions for some safety factors.

The term safety factor or factor of safety is a much misunderstood and sometimes misleading term. Generally, the term is intended to mean the number obtained by dividing the ultimate or failure unit stress of the material by the allowable unit stress. Thus mild steel having an ultimate of 60,000 psi in tension would have a factor of safety of 3 if an allowable stress of 20,000 was used. A more realistic definition of the term would be the relation between the elastic limit of the material and the allowable unit stress. The elastic limit of the material is that stress below which the material will not take a permanent set or deformation. In other words, it will return to its original shape. Rubber is a good example of a material with a high elastic limit. Obviously if a material is repeatedly loaded above the elastic limit, it will fail at a load far below the ultimate. Thus mild steel with an elastic limit of 33,000 would have a factor of safety of 1.65 in tension if the allowable stress is 20,000 psi. Materials which have no definite elastic limit, naturally show the ultimate stress to the allowable for the safety factor. Tower guys fall into this category. Guys with a factor of safety of 2½ indicates that the breaking strength of the guy is 2½ times the working load. With the allowable unit, stresses of the materials determined, the design may proceed.

In the case of self-supporting towers, the loads may be determined either analytically or graphically. Towers having a uniform cross section and vertical legs are more easily calculated by the analytic or algebraic method. If the tower is tapered with sloping legs the graphic method, using a stress diagram is more appropriate.

In the design of guyed towers the analytic method is used almost exclusively. For a balanced guyed tower design, many factors must be considered. A guyed tower is esentially a continuous beam in a vertical position supported by the guys. The portion between the guys must also be considered as a column. The slenderness ratio of the tower is determined by the relation of the length of the tower between guys and a function of the face width. This slenderness ratio is limited by codes and the allowable unit stresses are limited by column formulas. Slender towers with a small face width require more guys for this reason. In general, the face width also determines the type construction. Towers small enough to be shop welded and light enough to be easily handled by shop equipment, may be fabricated entirely of round members. This allows the shape factor for rounds to be applied and also facilitates the erection by eliminating most of the field bolts.

The guyed tower depends entirely on the guys to hold it vertical. The design of the guys is therefore of prime importance. As the ability of the guys to resist horizontal load varies inversely with the slope of guy, it is economical, design wise, to provide adequate guy distance. For a tower with one set of guys, an angle of 45° with the horizontal is good practice. For tall towers with multiple guys a little steeper angle is used for the top guy. This is to permit the attaching of several guys to one anchor and still keep the angle of the lowest guy in the group from being too flat.

Design of towers with very steep guys is undesirable because of the increased deflection and greater vertical tower load induced by the guy. At the time of erection, a pre-determined intial tension is placed in the guys. As the wind blows on the tower, the windward guy becomes taut, the tower moves and the leeward guy becomes slack. It is the problem of the designer to determine how much residual tension remains in the slack guy: This is combined with the wind load on the tower to determine the size of the taut guy and the vertical tower load. The movement of the tower is a function of the angle of guy slope the amount of initial tension in the guy and the construction of the guy. Most larger tower guys are of galvanized bridge strand. This strand is made of high strength steel and the manufacture is such that the stretch of the finished guy is minimized. Pre-stressing at the factory also helps eliminate this stretch. Forged or cast steel sockets are attached to the ends of the strand to provide a means of fastening it to the tower and anchors. These sockets are usually factory attached with molten zinc and then proof loaded to test their holding power.

There is yet another problem connected with guy design which the designer must face. Under certain climatic conditions and wind velocities, vibration develops in the guys. Cast iron weights, stock bridge and hydraulic type attachments are some of the means used to dampen the vibrations. The guys are anchored to the ground by reinforced concrete dead men. The main tower body also sets on concrete. To design these foundations, the engineer must have the loads from the tower and guys and the safe soil pressure allowed on the ground at the site. The soils on which towers are set vary widely for different localities.

Soils may be roughly divided into three categories: poor, such as swamp; normal, such as sand, gravel and clay; and good, such as shale or rock.

For poor soils, the foundations must be spread over a wide area or supported on piles. Piles are either wood, steel or concrete depending on site conditions and availability. Wood piles are cheaper but cannot be used unless they are permanently below the water table, and will not carry as much load per pile as the other two types. For guy anchors in poor soil, batter or sloping piles may be used to resist the sliding action of the foundation. For normal soil, a value of 4000 pounds per square foot is an average safe load.

In the case of self-supporting towers and guy anchors, the foundations must be able to take uplift in addition to downward thrust. This is accomplished by either using a large mass of concrete for dead weight or by using a smaller anchor buried deep in the earth. In the latter case, the weight of the earth helps to hold the anchor down. For foundations on rock, the concrete may be set directly on top of the rock if no uplift is present. Otherwise the uplift must be counteracted by the weight of the concrete alone, concrete combined with earth or patented rock anchors. The latter are inserted into holes drilled in the rock and hold by a mechanical wedging action. The foundation design completes the design engineer's work on the tower and it is ready to be detailed and fabricated.

Towers are usually constructed of steel and shop welded or punched for field bolts. A few small towers have been constructed of other materials such as aluminum, magnesium and wood but steel is still the most economical in the long run.

Most codes specify that ASTM-A7 steel be used and this is more or less standard for the industry. Recently, alloy steels of greater strength than A7 are becoming popular for tower design. As some welding is usually required in fabricating a tower, the alloy must be readily weldable. Manten, Mayari and T1 steels all fall into this category. Towers can be made from structural angles, formed plates, solid rounds and tubes or combinations of these sections. Angles and plates are more easily fabricated but being flat offer more area to the wind. Solid rounds and tubes must have plates welded to them in order to make field bolted connections.

The shop fabrication of round legs must be a precise operation. If the design calls for direct contact bearing between two legs, the rounds must be cut to accurate length and the ends milled square. The legs are then placed in a jig which holds the legs and their corresponding end plates and gussets in their proper position for tack welding. The assembly is then removed from the jig and the final size welds applied.

Electrodes of the proper chemical properties and strength must be used for each type of steel. Only top certified welders are used for this important work. All welds are continuous so that the joint is sealed to exclude water.

Continuous welds are particularly desirable if the leg is galvanized to eliminate acid pockets.

Rod diagonals are also jig welded to hold the length to accurate tolerances. Angle girts and other members are punched in the conventional manner. If the tower is to be galvanized, all fabrication is done before the zinc is applied in order to be sure that all raw edges and welds are protected.

All steel is then dipped in sulphuric acid. This operation is called pickling. The steel is then dipped in a neutralizing tank as the final preparation for galvanizing.

Galvanizing consists of an application of molten zinc to the steel. The zinc is kept at a constant temperature of about 800° by gas burners. The steel is dipped in the tank and left submerged the proper length of time to assure a uniform coating.

The final operation before shipping is a treatment with copper-sulphate to prepare the bright zinc surface for field painting.

Now back to Mr. Hayden for a discussion on tower erection and maintenance.

The construction work involved in putting a tower in place is not extremely complicated and consists of a very few different steps. The greatest hazard and the most unpredictable is the weather. The steps involved in constructing a tower consist of transferring material from a railroad siding to the tower location, sorting and checking completeness of the shipment, assembling the material into convenient sections, painting the various sections the proper color coat, hoisting sections into place, plumbing tower, installing equipment and cleaning up the location. This seems very simple. Let's describe a few of the steps involved.

The first step is to receive the material. In almost every instance the construction contractor acts as the receiving agent for the broadcaster. All material is unloaded, hauled to the tower location and the material is checked against a shipping list. Any shortages should be reported. Any damage caused by the shipping agency should be reported. Since many jobs are sold FOB factory the material is now the property of the broadcaster and the construction contractor is watching out for the interests of the broadcaster in this part of the work. This start is important and should not be neglected.

The next step is to assemble parts into convenient sections to hoist into place. Tower sections are usually 25 to 30 feet in length which has proven to be the best size to handle in the air. Longer lengths have been tried but not very successfully. Platforms are assembled on the ground and hoisted into place.

Almost all towers are painted on the ground and any places marred in construction are touched up after erection. The weather has a great deal to do with the painting. Freezing weather makes painting impossible.

These preliminary steps seem to take a lot of time and many times the broadcaster is puzzled in seeing so little seeming activity and is disturbed when steel does not start up in the air immediately.

The most useful tool in the construction of a tower is a "gin pole." This is nothing more than a long sturdy pole which is attached to a tower and extends above the work in progress. As work is completed the pole is hoisted up the tower and the pole extends above the work. This extension is the useful part of the Gin pole.

When towers for the broadcast industry first appeared telephone poles and even trees were used as gin poles. Many a tower was erected in the Thirties using an automobile for power, Manilla rope for hoisting and a tree for a gin pole. I remember one job in Tennessee where the construction foreman was especially elated at two things in connection with the job. One of these was finding a wooden pole with a kink in the top which fitted the tower very neatly and as well as though an engineer had designed the pole to fit the structure.

Today each construction company has gin poles of their own design with some of the poles being quite elaborate. Many of the poles have top heads or crossarms which are designed to bring the load up the outside of the tower into the correct vertical position and rotate the load into position on the tower. Some poles have small booms on top which swing loads into position.

The gin pole is carried up the tower in a series of jumps filling in tower steel as the work progresses...something like lifting yourself by your bootstraps.

A self supporting tower is pretty wide and the gin pole is swung within the tower by means of cable slings which permits swinging the pole from side to side.

A guyed tower is usually of a small cross-section and the gin pole is lashed or clamped to the side of the tower and carried up the outside of the tower.

As work is hoisted up the tower a line holds the work away from the tower. This line is called a tag line and is controlled from the ground. Also these same tag lines give the man in the air some help in aligning steel into place.

At times steel proves to be the most stubborn and obstinate of materials. Many times steel sections have been assembled into place in a manufacturer's plant with every piece put into place, matchmarked, disassembled and shipped to the tower location. On the job these very same pieces resist being put together with all the obstinacy of a mule.

A construction worker in the air has only his own weight, the leverage of a rather short spud wrench and the help of a tag line to force a stubborn piece of steel into place.

When a very heavy tower is being installed the hoisting equipment becomes very elaborate. The best of these hoists are regular oil field draw-works with a number of large drums which will hold and control a number of cables. The problem of lifting a heavy string of drill pipe or tools a long distance out of the ground is the same as hoisting a heavy load a long distance into the air.

A heavy load must be positioned very exactly in the air and a great many of the hoists have a torque converter type control which will start a load very gently and stop just as gently. Also this type of control permits a very precise positioning of the load in place. This eliminates the old jerky starts which made the job of handling heavy loads very difficult.

Guy cables can prove to be a tremendous job to install with some lifts being as much as 10 or 12 tons. When sizeable loads of this kind are encountered then the work of installing the guys must be done very carefully. Guys should be pulled into place in such a fashion that loads on the tower are equalized. In other words, all guys at an elevation should be pulled into place simultaneously. Loads on the tower should be balanced as much as possible.

If a heavy wind is blowing the problem of equalizing the loads during the installation of the guys becomes impossible. Work of this nature should be done during calm weather.

With the advent of FM and TV came the problem of installing antennas and transmission lines correctly. This problem is one of communication. The man who has the talents to design the antenna and the lines does not have the time to install each job nor does he have the climbing muscles nor does he have freedom of motion in high places which is necessary to install work of this kind. Further, the structural ironworker who has spent his working life developing a disregard for high places does not have the time, talent or inclination to devote to the technical reasons for many features of antennas or lines. So the man with the technical knowledge must communicate his ideas by means of drawings. The construction worker must use these drawings. Hence clear drawings are a must.

So with the construction of big and complicated structures came the need for a final inspection by a qualified climbing engineer. This need still exists and has not been entirely solved. A man who combines all of the talents of a structural engineer, an electrical engineer, a construction man and some of the best characteristics of a monkey has not been developed.

Maintenance of a Tower.

Towers should be inspected at regular intervals. The length of time between inspections depends on weather conditions. If the tower is located in a section of the country where windy seasons have a pretty regular cycle then inspections of the tower should also have the same cycle. Just as a general rule I like to see a yearly inspection record on file.

The first step in any inspection is to climb the structure from top to bottom and check the connections. Almost all towers have bolted connections with some means of locking the nuts of the bolts in place. These various style connectors are almost proof against movement but a check for tightness is important.

During this climbing inspection the paint should be observed. If the tower is galvanized the paint is for color marking only and the quality of the color coat is not too important. However, if the tower is painted only then the paint should be watched for signs of rust. If rust appears this means that a two coat job of paint might be in order.

If lighting equipment is working I would suggest looking at junction boxes to see that the connections are sealed with paint to prevent moisture entering the circuit.

The condition of the guys should be observed. Practically all guys are made of galvanized strand and experience indicates that the life of the guys without protective treatment is very long. I know of some jobs which are over 30 years old with no signs of distress. However, if signs of rust appear then a protective treatment may be used. The manufacturer has various types of protective coatings which may be used to protect the guys.

The initial tension in the guys is set at the time of construction pretty exactly. The guy connections are locked in place by various means. The setting of the guys is quite difficult to change. In view of these facts I would suggest that the guy setting be left alone.

One of the best ways to check the guy tensions is to put a transit on the tower to see if it is straight and plumb. If this is true, then it is almost a certainty that the guy setting is correct.

However, if the tower is not straight and plumb the tower manufacturer should be consulted. The style connection in the tower may permit slippage in the joints and this point should be checked first.

A shift in the foundations could cause movement of the tower. Fortunately, this is very unlikely if the foundations were properly designed at the start.

One of the best of rules if trouble is suspected is quite simple. CONSULT YOUR TOWER MANUFACTURER.

ChromaCHron

Developed by KRON-TV under the supervision

of William J. Wagner, art director.

ChromaCHron is a palette designed to assist scenic and graphic artists working in color television.

A palette consists of the necessary basic colors with which the artist can produce his art work. The ChromaCHron palette allows the artist maximum freedom in regard to color moods and harmonies. Like all palettes, ChromaCHron limits the number of basic paints needed and reduces the number of variations of these colors for the sake of simplification. These limitations add to its effectiveness and do not restrict the artist in color selections or in creativeness. These are beneficial limitations in the respect that they make ChromaCHron easy to use and to understand. The number of paints and formulas for intermixing these paints are few, making ChromaCHron a practical and economical approach to painting for television, whether it be for color or for black and white.

These are the problems which brought about the development of ChromaCHron.

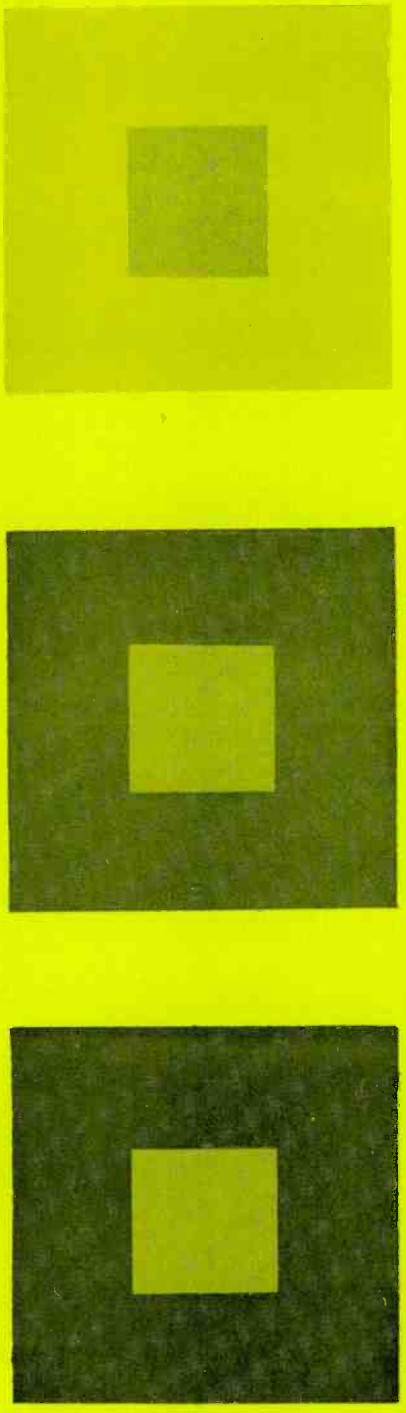
Most artists, at some time or another, have produced color art with adequate color contrast but lacking in brightness contrast. This error is not obvious until it is previewed. It televises well in color but results in a poor, if not completely unusable, black and white picture. This has occured in networks as well as in small stations. Correcting this type of unpredictable error can be costly and/or embarrassing. There is also the possibility of exceeding the color system's light ratio limitations, which can result in color changes in the color picture. The black and white picture then has too much contrast; both color and black and white pictures are not acceptable to the system.

Other factors are incorporated in ChromaCHron.

Economy is vital to the art departments which work on limited budgets. Errors must be avoided, for redoing any art is costly in man hours and materials. The paints selected must be versatile and inexpensive. Paints are subject to waste and a large selection of paints only adds to the waste.

The artist was the main concern in the development of ChromaCHron.

Although most artists are capable, few have had any training in art for television, let alone color television, and are at a loss when it comes to understanding what the twenty to one light ratio limits are. Very few, if any, are equiped with the tools by which to measure light reflection in order to determine the difference between the most reflective and the most light absorbing colors. There is no human way of predicting the gray equivalent of any color other than by the results of past experiences.



The artist asks himself, "What is the gray equivalent of a color when viewed on a black and white television receiver?"

A GRAY IS ONLY THAT GRAY DEPENDING ON THE SURROUNDING COLORS OR OTHER SURROUNDING GRAYS.

If a medium gray is surrounded by darker values, then it appears lighter; if the same medium gray is surrounded by lighter values, then it appears darker. This is noticeable in the three squares on the left of this page. Only one value of gray is being surrounded. However, the values of the surrounded gray appear lighter or darker depending on the surround.

The value, as experienced by the eye, of any gray is dependent on its environment. If surrounded by color, the gray appears to contain the complimentary hue of the surround. This brings up the term, "chromatic induction," which elaborates on this visual experience.

ANY COLOR IS ONLY THAT PARTICULAR COLOR DEPENDING ON ITS SURROUND.

The surround can induce brightness and/or grayness or chroma, or it can induce darkness and/or grayness or chroma. That is, depending on the surround, a color or gray appears to change in value and/or to have a foreign color mixture.

Nevertheless, regardless of the change which takes place in the human eye, both the colors and the grays are physically the same in color and value or light reflection, but they do not appear the same to the eye.

This makes it difficult to answer the question pertaining to the gray equivalent of a color, since the value can appear different to what it really is. This alone is enough to confuse the artist, who must produce color art work for a system with light reflection limitations and also have good gray scale in compatible black and white. A piece of art containing five grays can appear to have great contrast or can appear not to have enough contrast, depending on how the grays are arranged in the picture. It can appear to be within the system's limitations or appear to exceed the system's limitations. Only a camera preview can give him the answer.

The preview is possible only after the art work has been produced. If the art work is wrong, then it must be redone. ChromaCHron proposes to assist the artist in visualizing the black and white picture which in turn reduces error.

Every color and color variation is recorded in the ChromaCHron master palette with its gray scale equivalent. By knowing the physical gray scale of each color, the artist is assured of contrast. The light reflection also is determined by ChromaCHron in order that, besides having proper gray scale contrast, the picture is not exceeding any limitations and is staying within brackets of safety. This gives the artist great assurance that his black and white picture will be as successful as his color picture.

ChromaCHron does not teach the artist how to paint or tell the artist what colors to use in his painting. Color choice is a personal thing which must be left entirely to the artist. ChromaCHron cannot tell him if his color selection is in good or poor taste. It will only tell him that the colors will telecast as they were selected and if their gray scale equivalents have proper contrast. When the artist begins his mental process of selecting colors, it is possible that the result will be completely acceptable for color as well as the black and white picture. But by checking the ChromaCHron charts, it is verified that his original color choice will work. If he had selected one or more colors which have color contrast but are of equal brightness, the black and white picture then would be incompatible. This would not mean that he must completely change his selection of color, but it would mean that he must make minor changes in the saturation of one or more of the colors.

The color mood or harmony would not necessarily be affected by the corrections, and these changes would meet the requirements of the engineering departments.

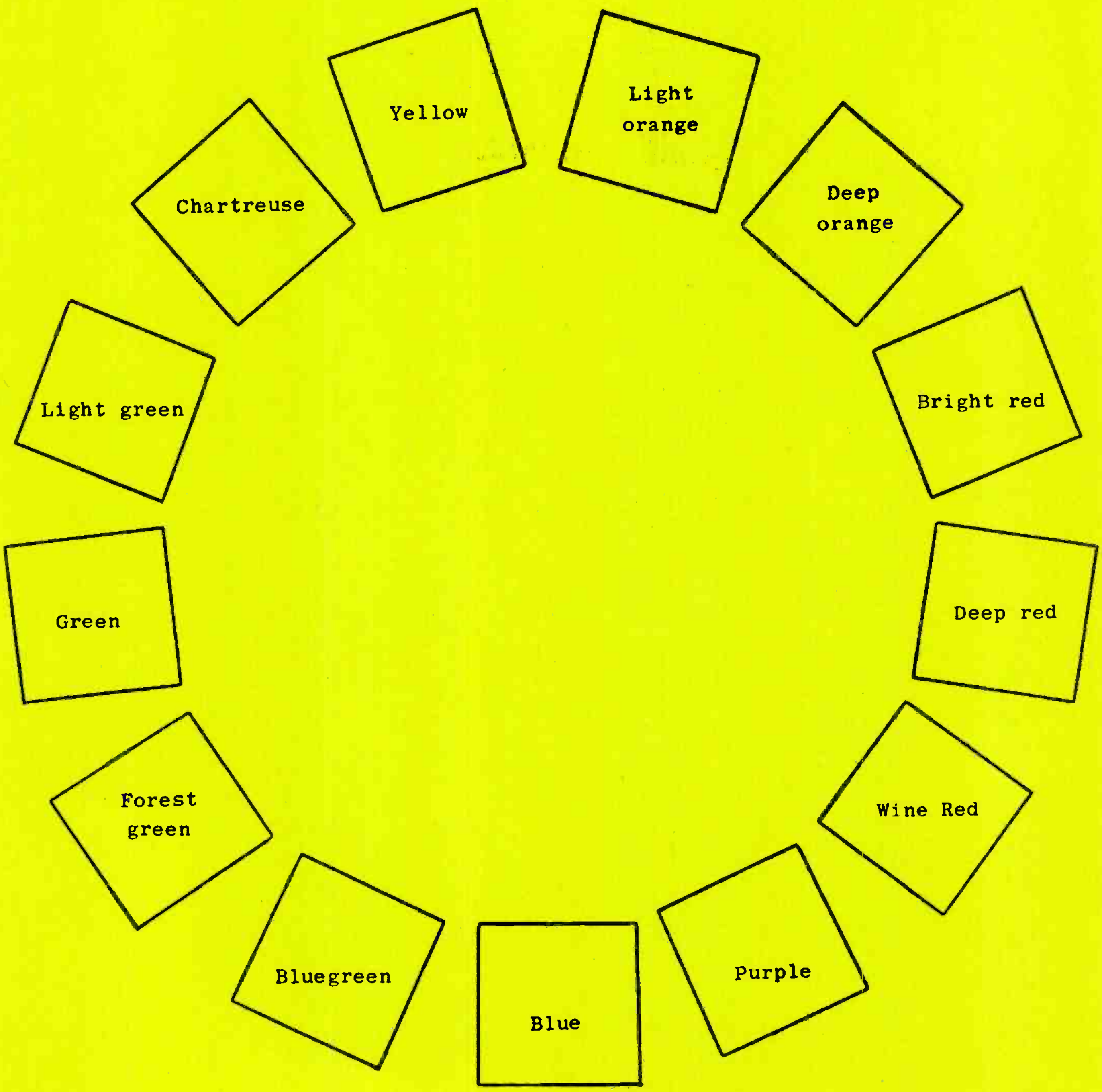
ChromaCHron differs from other palettes, systems, and theories in the respect that it has been designed specifically for television. Colors were chosen because they are readily available and have been manufactured for a number of years. These are inexpensive paints which may be used for both scenery and graphic art. If special colors were to be manufactured for

ChromaCHron, the cost would make it impractical. A compromise was made on the selection of paints. Due to the limited number of parent or basic colors, there is very little waste in this paint. Both color and black and white originating with color and/or black and white equipment are aided by ChromaCHron. Stations not telecasting in color may use it to improve the gray scale in their present art work. It also gives them a library of color art which will have proper color selections when color equipment is installed.

ChromaCHron requires seven water soluble paints; five are chromatic and two are achromatic. These paints are suitable for both scenic and graphic art. The chromatics are neither primary colors nor primative sensations. They are five basic colors which intermix to produce an adequate palette of thirteen common hues.

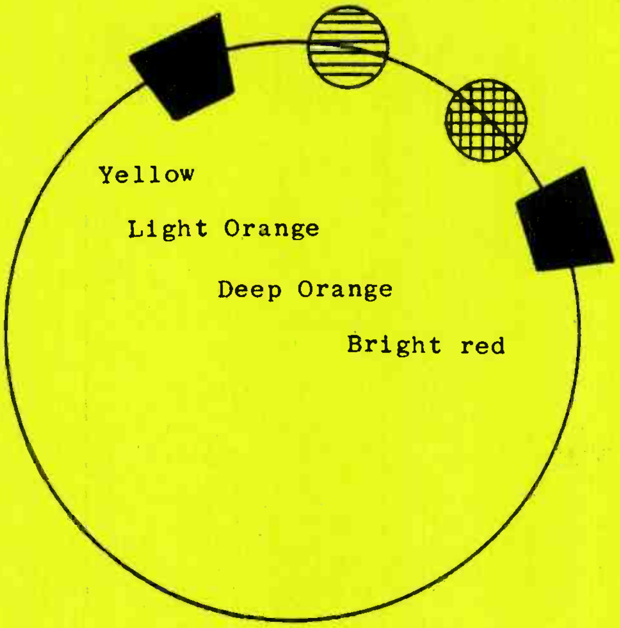
In ChromaCHron the term "hue" does not correspond to primaries or binaries. Instead it describes the five basic colors and the eight mixtures of these colors. Hue does not contain white and/or black. To the artist, hue is the purest color possible using the ChromaCHron basics. These five basics are called yellow, bright red, deep red, blue, and green.

There are thirteen hues in the ChromaCHron palette. In all diagrams they are placed so that they form a circle with yellow on top. Moving clockwise they are called yellow, light orange, deep orange, bright red, deep red, wine red, purple, blue, bluegreen, forest green, green, light green, and chartreuse.

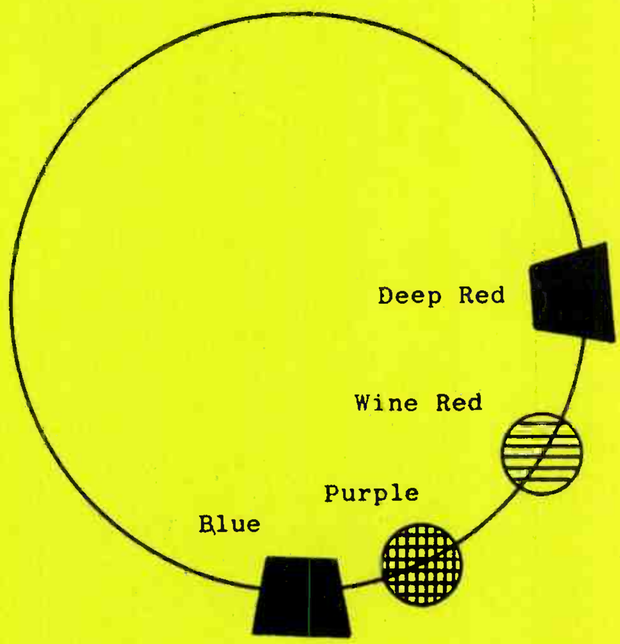


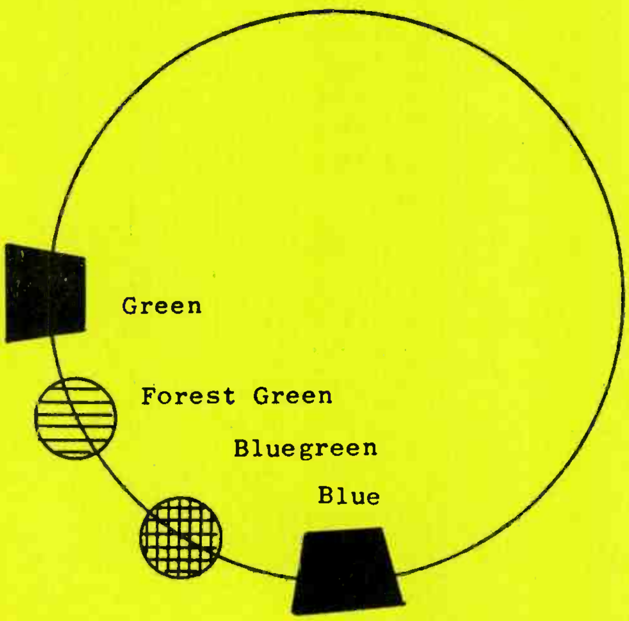
The thirteen hues are achieved in the following manner:

Mixtures of yellow and bright red produce light orange and deep orange.
Formulas:
8 yellow plus 1 bright red = light orange
8 yellow plus 7 bright red = deep orange

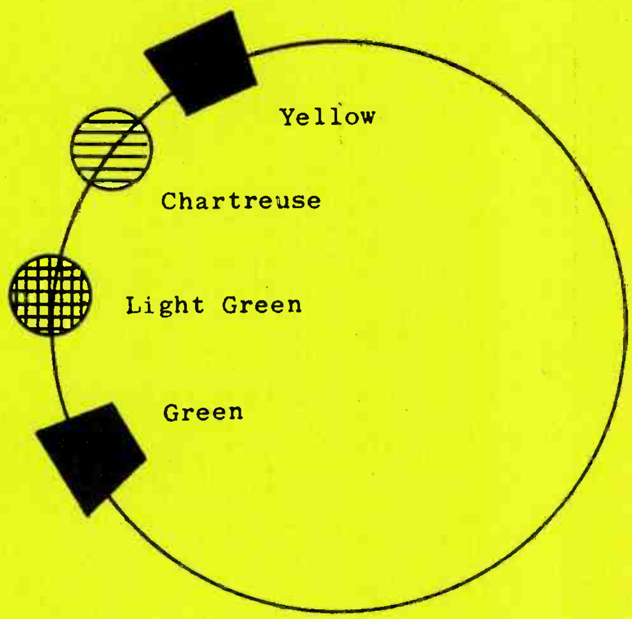


Mixtures of deep red and blue produce wine red and purple.
Formulas:
3 deep red plus 1 blue = wine red
1 deep red plus 1 blue = purple





Mixtures of blue and green produce bluegreen and forest green.
Formulas:
5 blue plus 2 green = bluegreen
5 blue plus 6 green = forest green



Mixtures of yellow and green produce light green and chartreuse.
Formulas:
6 yellow plus 4 green = light green
16 yellow plus 1 green = chartreuse

The following terms are popular with those who work with color. This language is applicable also to ChromaCHron.

Hue is pure color.

Saturation is the degree of hue in mixed color. Desaturation is described in the following terms:

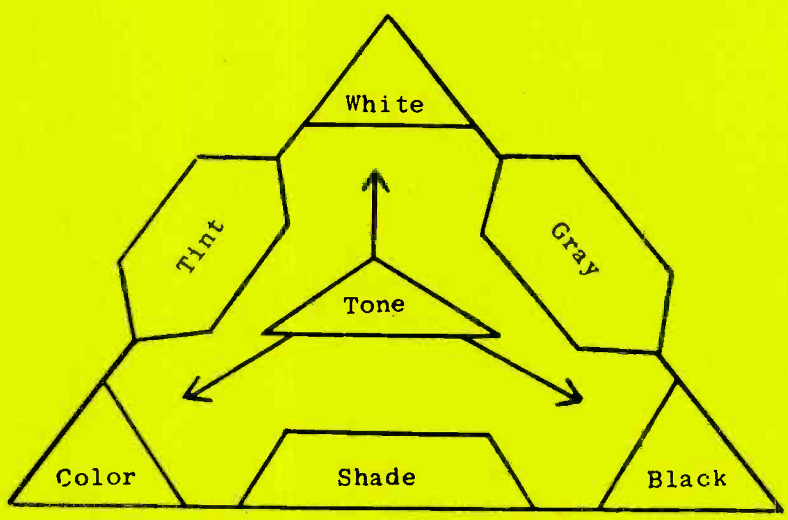
Tint - Hue diluted with white.

Tone - Hue mixed with gray (black and white).

Shade - Hue darkened with black.

Brightness refers to the luminosity of hue, tint, tone, or shade. Brightness or luminosity of a color or color mixtures corresponds to its value or to its position in the gray scale.

In common terms, tint is pale color, tone is grayed color, hue is vivid color, and shade is deep color, and the brightness of these is their gray scale equivalent.

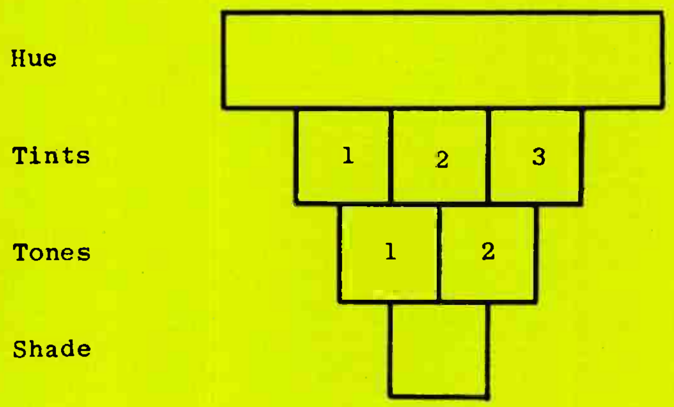


Color plus white equals tint.

Color plus black equals shade.

Color plus black and white equals tone.

In ChromaCHron each hue has three tints, two tones, and one shade. This gives each color seven variations, or there is a total of ninety-one color mixtures in the palette. Each color appears in the master palette as shown in the diagram:



Formulas:

Shade	15 hue plus 1 black
Tone 1	20 hue plus 15 white plus 1 black
Tone 2	10 hue plus 5 white plus 1 black
Tint 1	1 hue plus 5 white
Tint 2	1 hue plus 1 white
Tint 3	5 hue plus 1 white

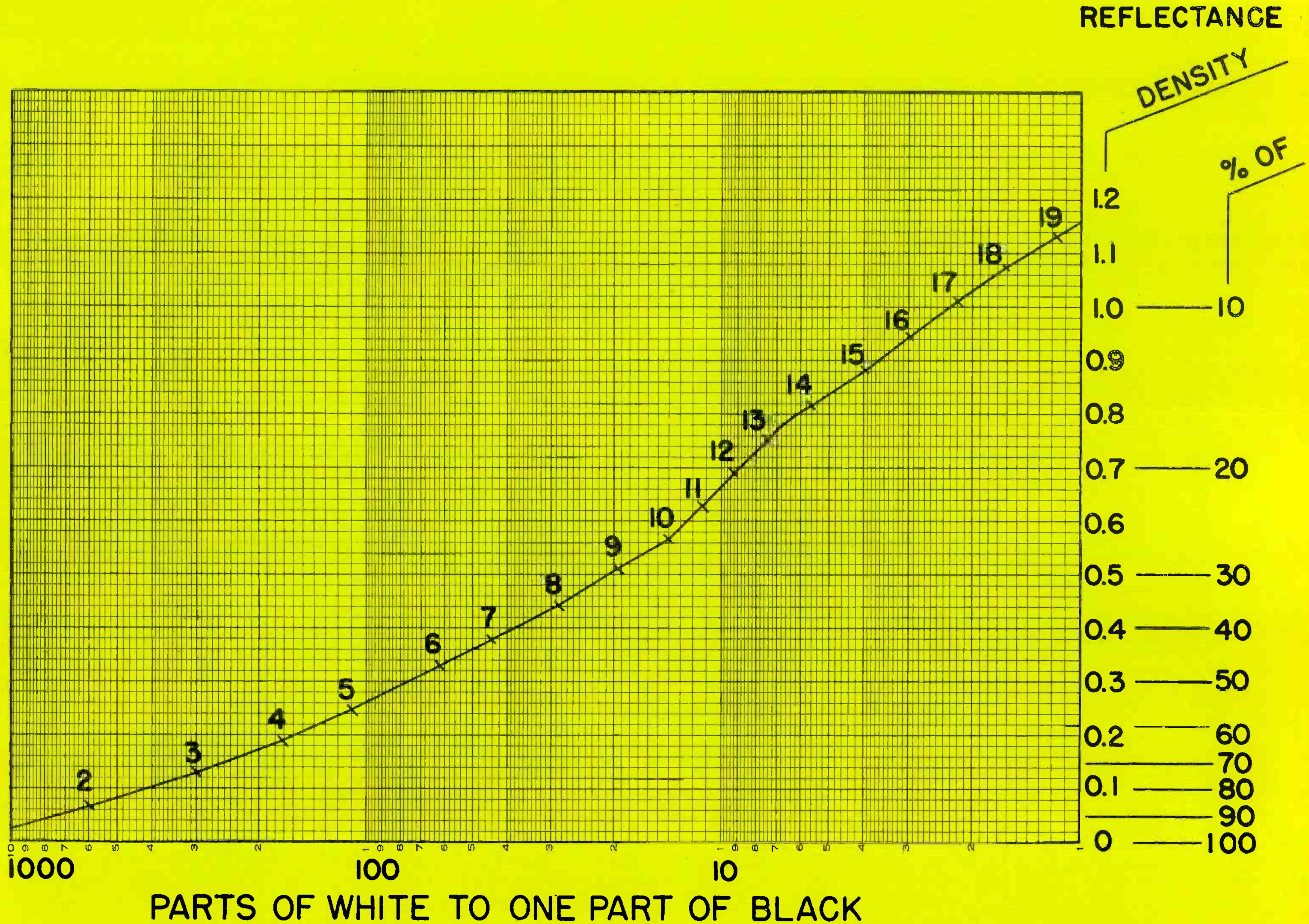
The most important thing in ChromaCHron is knowing the gray equivalent of a color. The hues, tints, tones, and shades as arranged in the palette have little, if any, meaning in regard to painting for television. Along with the ChromaCHron palette, a gray scale is essential.

ChromaCHron's selection of gray scale is based upon the measurement of reflectance of ChromaCHron's white and black and the division of this range into nineteen equal parts in terms of reflectance density, thus achieving twenty steps including white and black. White is step number one and black is step number twenty.

The ChromaCHron paints are in a paste form and must be diluted with water. In order to assure uniformity in the amount of pigment, a test is made and checked with previous results. In the case of the grays, if the test gray was darker than previous tests it meant that the black was not properly diluted and more water was added to the black pigment. Once the paints are balanced, the artist can proceed in making his color mixtures with the assurance that his tints, tones, shades, and grays will not vary to any great degree. There also will be some mixtures which will be slightly lighter or darker than the anticipated value; however, the shift in value will be insignificant.

Due to the importance of the gray scale, special precautions are taken to assure its accuracy. Color mixtures can be accurately matched by eye with the ChromaCHron palette as a guide.

The following page lists the reflectance density of each gray in the scale and the formulas by which to achieve each of the twenty steps.



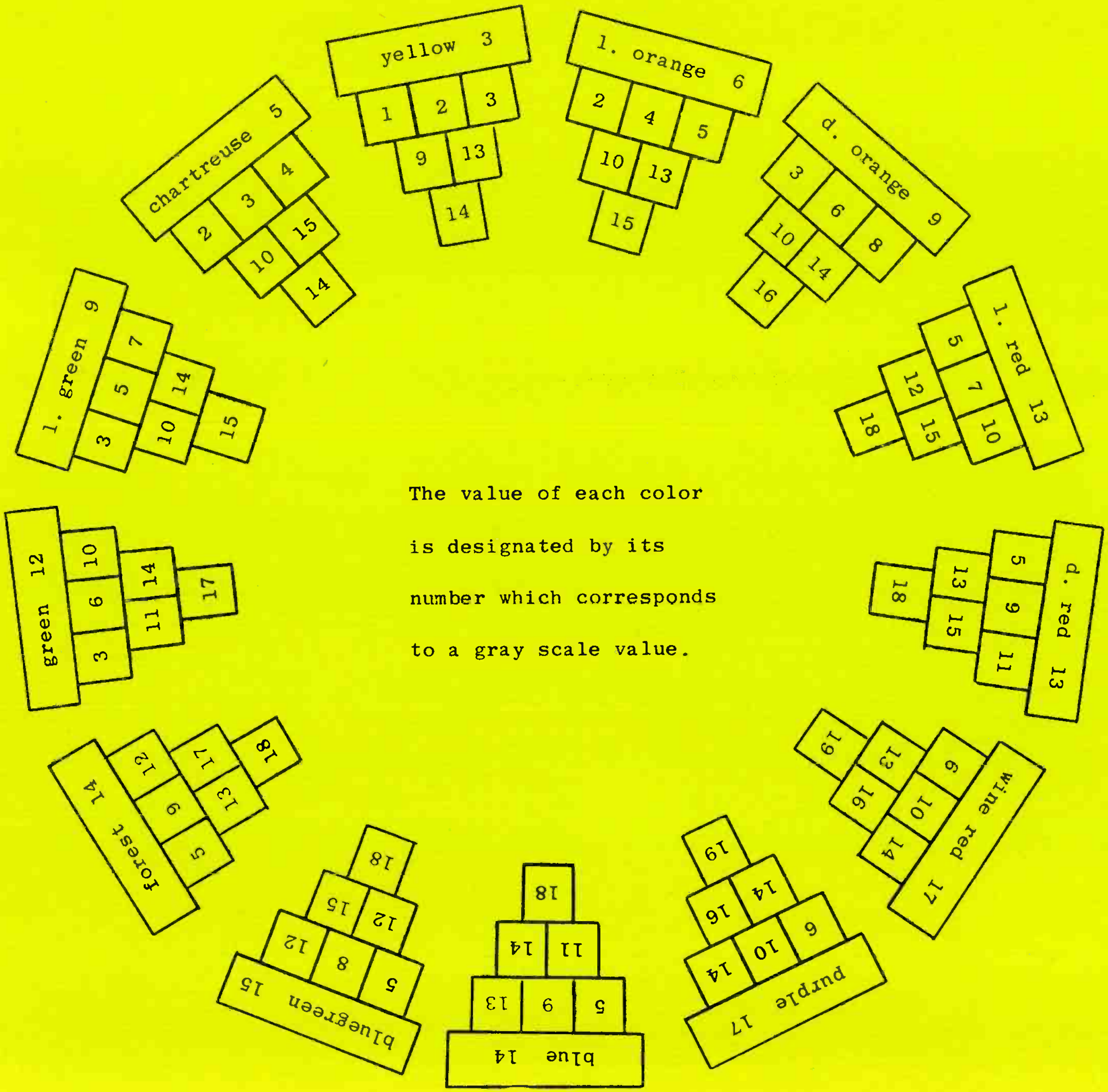
REFLECTANCE
DENSITY
% OF
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
10
20
30
40
50
60
70
80
90
100
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
1000
100
10
PARTS OF WHITE TO ONE PART OF BLACK

After the ChromaCHron gray scale was established, all colors were illuminated with 300 foot candles, 3200 Kelvin, at a 45 degree angle. They were viewed through a color camera on a black and white monitor and also on a tektronix oscilloscope. The color camera was balanced against a known value of gray in order to obtain a minimum chrominance modulation out of the color plexer. Amplitude of colors of approximate value was compared to the value of gray used in the setup. First, the lightest or those colors with the most brightness were compared to ChromaCHron white (gray #1). There was a rebalancing after each step of gray. This produced minimum modulation for each gray value.

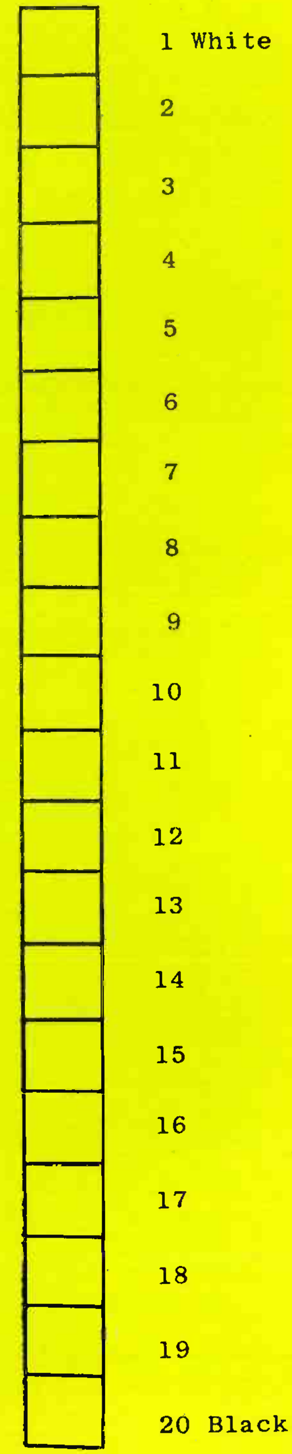
Every color in the ChromaCHron palette was tested and its gray equivalent listed. The following page contains the complete ChromaCHron palette, along with its gray scale. The number within each color chip in the palette corresponds to the number of the value in the gray scale. Merely by looking at this palette in full color the artist becomes aware of the approximate gray scale equivalent of each color. He can use the ChromaCHron palette as a guide for determining the grays of colors which may not be incorporated in this palette.

ChromaCHron Palette

Gray Scale



The value of each color is designated by its number which corresponds to a gray scale value.



All graphic ChromaCHron testing was done on illustration board. Although all the paints were tested on the same type of card, some cards with slight difference in surface reflectance were intermixed for the sake of comparison. The opacity of the paint and its texture completely overruled the reflectance surface of the card. In the case where the paints were tested on scenery canvas, the slight texture of the material was not enough to effect or alter the gray equivalent. However, this does not mean that these paints will always render the same gray regardless of the surface they cover. Had a coarser canvas been used the gray scale would have shifted evenly in any one direction. ChromaCHron is more successful when used on surfaces of similar reflection. That is, if card is going to be incorporated with scenery, the reflectance of canvas and of the card must be similar.

Under flat lighting conditions it is impossible to exceed the twenty to one light ratio limitations with the use of ChromaCHron paints. The brightest and darkest pigments or any mixtures of these pigments are well within the brackets of safety. It would not be possible to produce art work using any color combination on standard illustration board or on canvas and exceed the system's limitations. ChromaCHron under uniform lighting and painted on uniform textured surfaces will not exceed the twenty to one ratio.

This does not mean that the twenty to one ratio cannot be exceeded with the use of ChromaCHron. The mode of lighting or variety of lighting in one scene can alter the ChromaCHron gray scale. When the angle of light varies, the luminosity of the color varies. If ChromaCHron paints are used on surfaces such as combed plywood whose characteristics of light reflection cannot be altered by a coat of paint, then the ChromaCHron gray rendition is not accurate.

Incorporating other things with ChromaCHron also can effect the twenty to one ratio. A specular light source such as the reflection from jewelry, glass, chrome, foil, etc., can throw ChromaCHron off and make it exceed the system's limitations.

In general, to maintain a twenty to one relationship one should determine the lighting contrast on the set and divide this contrast figure into twenty to determine how many steps of gray value can be used safely. When persons of average complexion are incorporated with ChromaCHron, it is advisable to stay in the middle range (5 to 15) of the gray scale.

ChromaCHron must be used wisely. It is effective when used properly. ChromaCHron is easy to use.

This concludes the pigment phase of ChromaCHron but by no means does it stop here. Other phases will be incorporated, such as the testing of the various colored cards and papers presently used by graphic artists. ChromaCHron will catalog the gray scale of those card materials which are the most practical for color television graphic art work. At the present a great deal of graphic art is converted into color transparencies. The ChromaCHron palette will be converted into color tranparencies to determine the gray scale after it has been through the photographic process. The most popular color films available will be used in this experiment and processing will be done under ideal conditions. KRON-TV is ready to co-operate with manufacturers of paints, draperies, paper manufacturers, and others who produce graphic and scenic materials for the purpose of giving the ChromaCHron gray scale equivalent of their product.

A HIGH GAIN, LOW COST
EMERGENCY OR AUXILIARY VHF ANTENNA SYSTEM

BY

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11th Annual NARTB Engineering Conference

Chicago, Illinois

April 11, 1957

SUMMARY:

Many TV stations have spare or duplicate studio and transmitter equipment, but very few have a spare antenna system. The reason for this appears to be the high cost of a standby unit compared to the economies of antenna system outage. With increasing broadcast charges and ageing antenna system components, there exists a definite need now and more so in the future, for an inexpensive auxiliary antenna system. This paper describes one such inexpensive VHF system that can be duplicated by the average station.

Station's requirements may vary when it comes to choosing an auxiliary antenna system. Factors involving cost, and gain are usually of paramount importance. The antenna system to be described has the following features:

1. The power gain of a single section non-directional system is 10 DB for the high channels from 7 through 13, and 5 DB on channel 2 and higher on channel 6.
2. It is light weight, being 104 pounds net for a single section on the high channels and 500 pounds for the low channels. Wind loading is negligible. It will handle iceing and wind loading as encountered by the average TV antenna installation.
3. The system with its own transmission lines presents the present standard 50 ohm impedance per line to the transmitter. Thus the auxiliary can be switched into the operation without re-tuning the transmitter.

4. Power capabilities are 5 KW for the high channels and 11 KW for the low channels.
5. Its design, construction and tower mounting are simple enough so that the average station's transmitter personnel can do the entire job.
6. The system is low in cost. As a rough yardstick, high channel units should be less than twice the station's class A hourly rate. Low channel units can be built for about 4 times the class A rate.

Several different types of antennas were investigated for an auxiliary system. Parasitic arrays, rhombics, curtains and other high frequency antennas while meeting gain and cost requirements, have serious limitations. The simple expedient of obtaining a single bay batwing, or turnstile, was discarded because of low gain and cost. It also presented mounting problems. VHF helical antennas presented a possibility but this too was dropped because of construction problems. It was felt that the average station could not duplicate a properly designed helical. A commercially available loop antenna for TV made of 1-5/8" co-ax was investigated. This, too, while being considerably lower in cost than some of the others, has very low gain per section.

It was apparent in our early thinking that the minimum power gain in the order of ten was called for in the average installation. This minimum design value was chosen for the KBET-TV channel 10 installation. It was felt that a 10 DB reduction in field voltage from normal operation would not be detected by the average viewer. In our particular installation, this conclusion was checked out as valid. For transmitters located within the principal city, much greater gain reductions are possible. The total gain factor can be tailored to the station's particular needs.

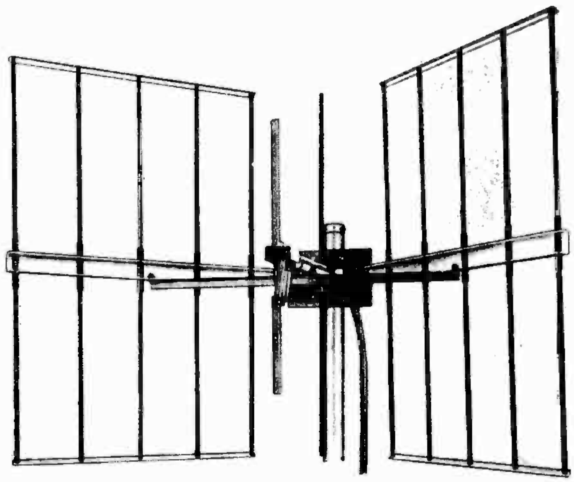
Figure 1 shows a basic corner reflector antenna, which is probably the most practical of all surface reflector systems. (1) It exhibits a preponderance of directivity in one plane, perpendicular to the direction of the driven dipole. In this practical form, it consists of two flat grid reflectors, making an angle of 90 degrees with each other. The dipole radiator is located parallel to the intersection of the corner and lying in the plane bisecting the corner angle. The practical power gains for a well designed and constructed corner reflector antenna runs between 8 and 13 DB for corner spacings of useable values and angles from 45 to 90 degrees.

The directivity, radiation resistance and the gain are all affected by the spacing of the dipole from the corner, or vertex. By choosing an appropriate dipole to corner spacing for a given corner angle, it is possible to realize a radiation resistance from 35 to 100 ohms. This permits a match to commercially available co-axial transmission lines.

The dipole is usually fed at the center and also supported at that point mechanically. When an unusual impedance results, that cannot be matched to available co-axial transmission lines, a quarter-wave matching transformer may be used between that dipole and the transmission line.

The length of the sides of the corner reflector should be at least .9 wavelengths long. The depth of the corner reflector, that is from the open end to the vertex, should be at least one and one-half wavelengths.

FIG. 1



These physical requirements should be met if the maximum theoretical gain and directivity are to be approached for a given corner angle.

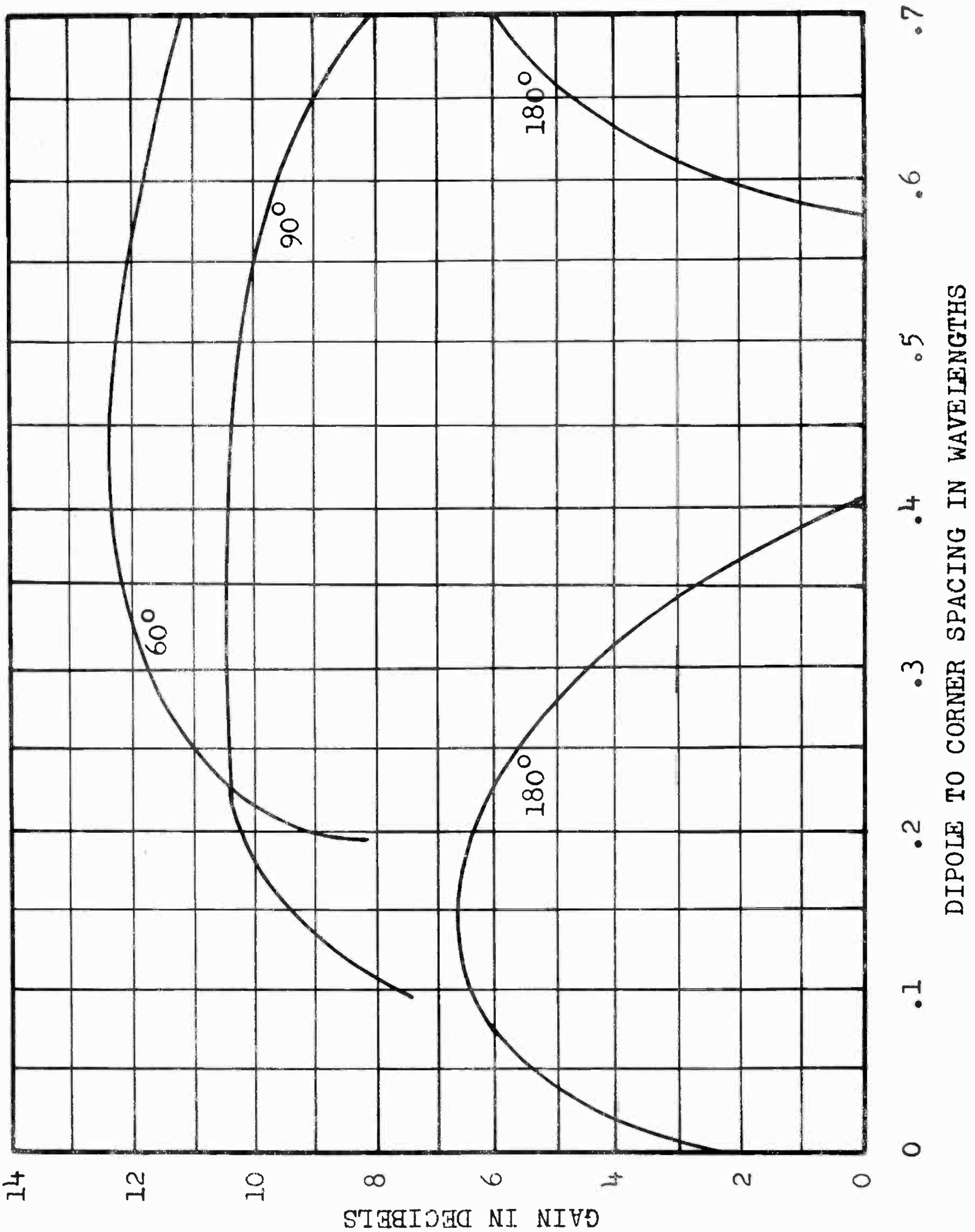
It is not necessary that the reflector be made of solid material. A woven screen of moderately small mesh may be used; or a grid arrangement consisting of close-spaced wire or rod conductors parallel to the dipole, is a favorite construction type of commercial and military manufacturers.

In order to understand this antenna system, let's look at some of the technical aspects. Assuming perfectly conducting reflecting sheets of infinite extent, the method of images can be applied to analyze the corner reflector antenna. Without going into deep math, let us examine the gain resulting from different antenna to corner spacings.

In a 60 degree corner, with antenna to corner spacing of about .4 wavelength results in greatest gain. Losses indicated by the drooped lines in Figure 2, result from low dipole radiation resistance at closer spacings, limiting the efficiency and thus the gain at this spacing. (2) Spacings of less than a quarter wave with 60 degree corners should be avoided. A small spacing also results in objectionable narrow bandwidth for TV operation.

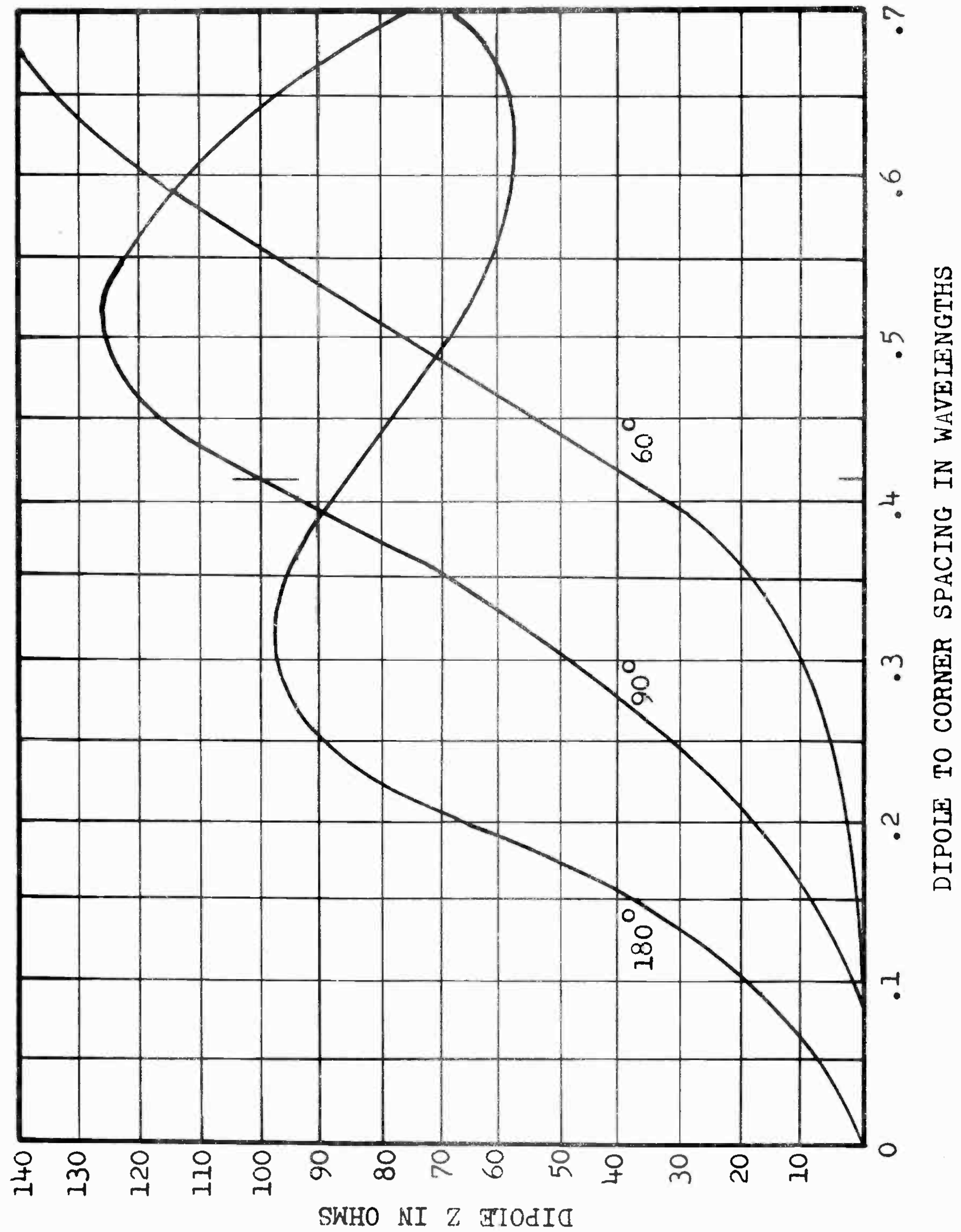
The radiation resistance as a function of antenna to corner spacings for three corner angles are shown in Figure 3. A spacing of .3 wavelength will give a radiation resistance of 50 ohms for a 90 degree corner, while a spacing of slightly over .4 yields a resistance of 100 ohms. In order to simplify matching problems without sacrificing gains,a spacing for design considerations of .42 wavelengths was chosen.

FIG. 2



GAIN IN DECIBELS
0
2
4
6
8
10
12
14
DIPOLE TO CORNER SPACING IN WAVELENGTHS
0
.1
.2
.3
.4
.5
.6
.7
60°
90°
180°
180°

FIG. 3


DIPOLE Z IN OHMS
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
.1
.2
.3
.4
.5
.6
.7
DIPOLE TO CORNER SPACING IN WAVELENGTHS
180°
90°
60°

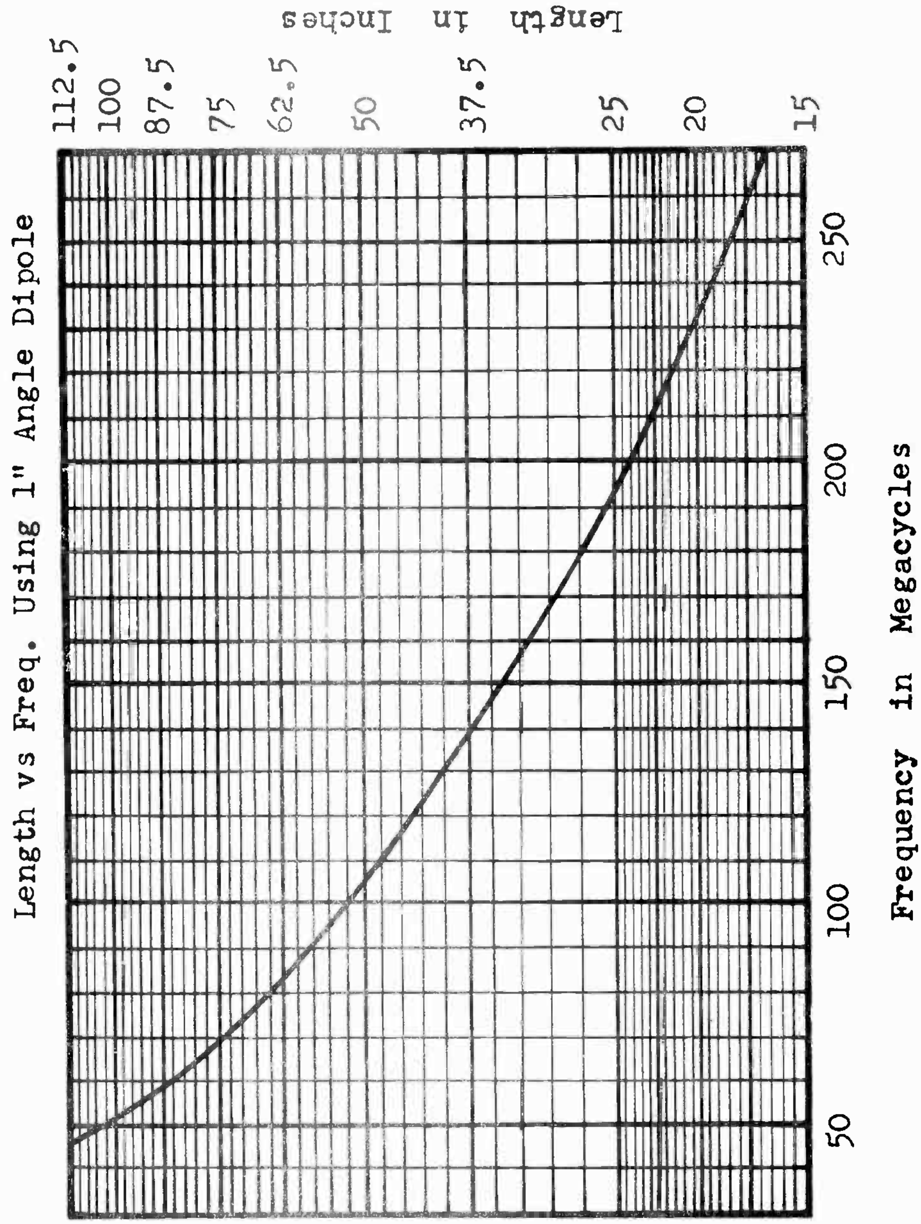
In the last two slides we have seen factors affecting gain and impedance of the corner reflector. Another important design parameter is the bandwidth of the driven element. The TV requirement is a low VSWR over a six megacycle bandwidth.

On VHF channel 11, a six megacycle bandwidth represents 3 percent of the carrier, while on channel 2, the same bandwidth is over 10 percent. Therefore some thought must be given to increase the frequency response of the driven element. This is most easily accomplished in a corner reflector antenna by increasing the physical cross sectional area of the antenna element.

By increasing the cross sectional area of the antenna element from a thin wire, to say a 1 inch diameter rod, the velocity factor is reduced. This has two important effects. It increases the bandwidth and decreases the physical length for resonance. This resonance may be as short as 75 percent of the thin wire free space value, depending on several factors. The physical length of the dipoles,having a dipole element made of 1 inch angle material, can be approximated by the nomograph, Figure 4.

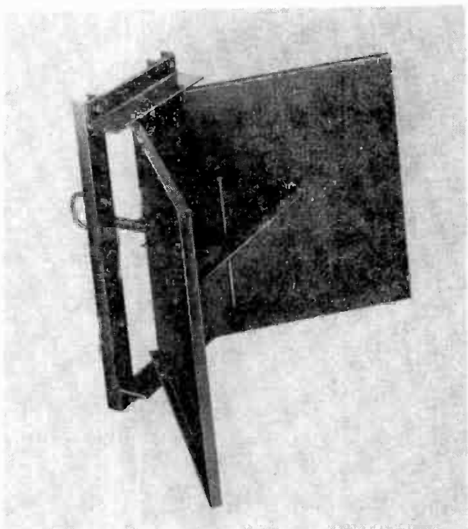
After the correct dipole length for the center of the visual channel has been determined, the element should be cut and tried out in a corner of the right angle and dipole to vertex spacing. By using a good grid dip oscillator, the resonant frequency may be determined, although some difficulty may be experienced. This lack of a sharp dip is caused by the low Q of the dipole. A better method is to make impedance and VSWR runs on the assembled antenna with an admittance bridge. The entire assemby should be at least 3 wavelengths away from metal reflecting objects and ground for the high channels

Fig. 4



Length vs Freq. Using 1" Angle Dipole
Length in Inches
112.5
100
87.5
75
62.5
50
37.5
25
20
15
50
100
150
200
250
Frequency in Megacycles

FIG. 6



and two wavelengths for the low channels.

It is not necessary for the station to actually build the entire corner reflector assembly. Corner reflector antennas covering the entire VHF band and UHF band are commercially available. The Andrew Corporation, Chicago, Illinois makes units that are excellent for TV modification. Figure 5 shows an Andrew model 3605 VHF high channel corner completely assembled. Its net weight is 26 pounds. Made of high strength aluminum alloy, it mounts easily on tower leg memebers whose diameter is from 2 to 4 inches. Dipole is made of angle aluminum, 1" to a side, supported on cone insulators. The Andrew model 3602 suitable for low band VHF has similiar construction except that the size is about two times the high band model.

The Andrew model 3606 should be suitable for an auxiliary system for the UHF channels. It appears that the same techniques used for VHF conversion could be applied to these UHF corners, to provide a worthwhile system. However, no work on a UHF unit was done by the author. This model 3606 is much smaller physically than the VHF models, being 15 inches high and wide, and 30 inches across the mouth. Made of solid sheet and braced to provide high strength, its weight is 19 pounds net. It is available in type N or 7/8" coupling flanges.

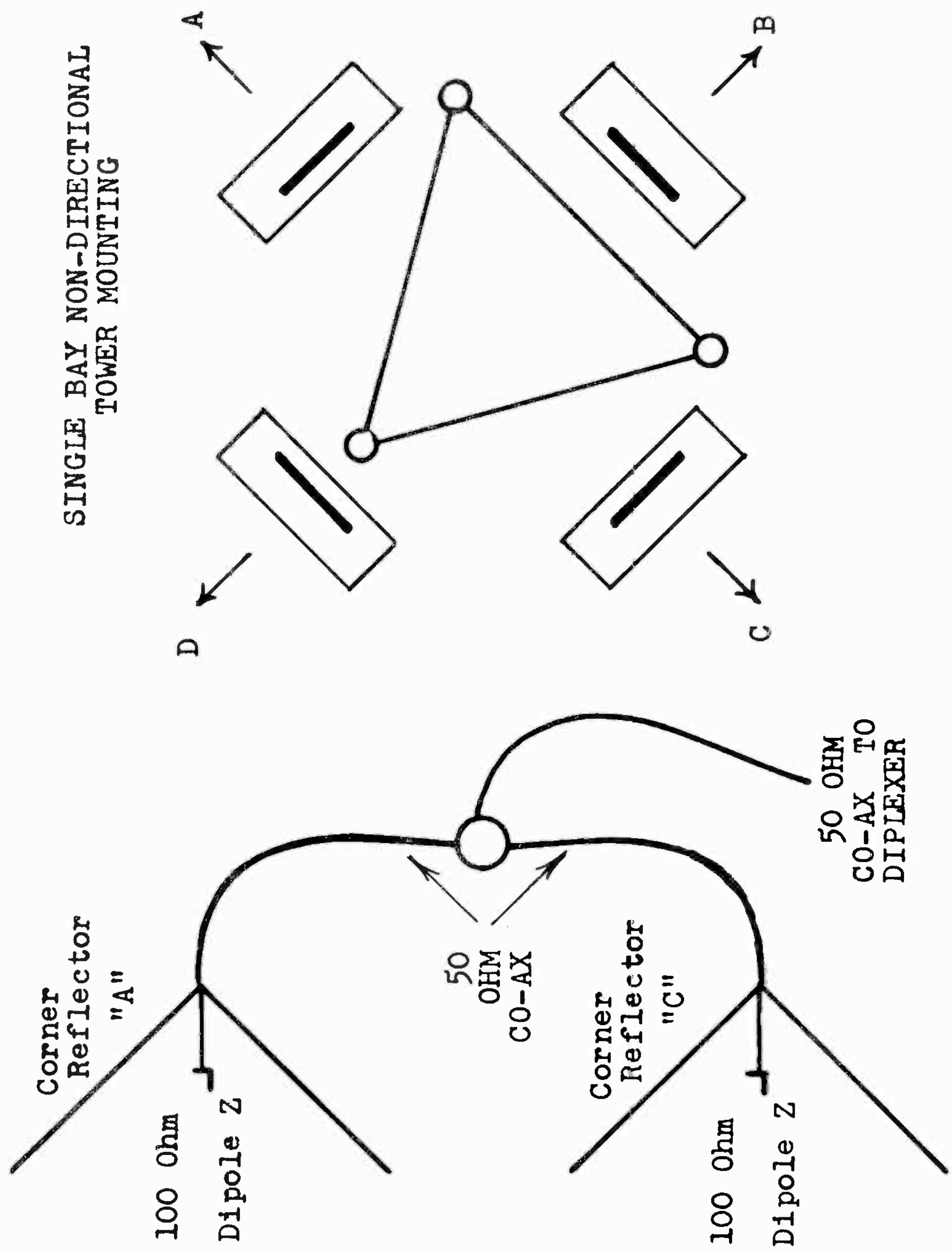
The Andrew corner reflectors, while originally designed for the communications fields were chosen for our use because of their availability, low cost and ease of modification for use as an auxiliary TV antenna.

So much for the single antenna elements. The $\frac{1}{2}$ power points from a single corner is about 60 degrees. By using 4 of these corners in a bay or section, a non-directional pattern may easily be had. The FCC does not have any performance specifications for auxiliary TV broadcast antennas. A non-directional pattern, as specified by the FCC for main TV broadcast antennas, is one wherein the power peaks and nulls do not exceed 10 DB. It is possible to achieve this non-directional pattern with corner reflectors since the peak power points are approximately 10 DB The nulls are about 4 DB, or a difference of 6 DB between peak and null. This pattern does not approach the pattern linearity of available standard TV broadcast antennas, but this is not too important in an auxiliary.

Feeding power into four corners, for non-directional operation requires feeding arrangements. It was previously recommended that these corner reflectors be made to have a 100 ohm nominal impedance. This may be achieved with a corner to dipole spacing of .42 wavelengths. It is apparent from figure 7 why this value was chosen. Here the two corner reflectors are fed together by short lengths of 50 ohm transmission line which is an integral of one-half wavelength at the design frequency. This feed line will have standing waves on it. The 100 ohm dipole impedance will be reflected to the feed junction which will thus be 50 ohms,since another 100 ohms hang on the other end. The matching harness length is short in wavelengths and the line efficiency is high. The loss due to this VSWR will be negligible.

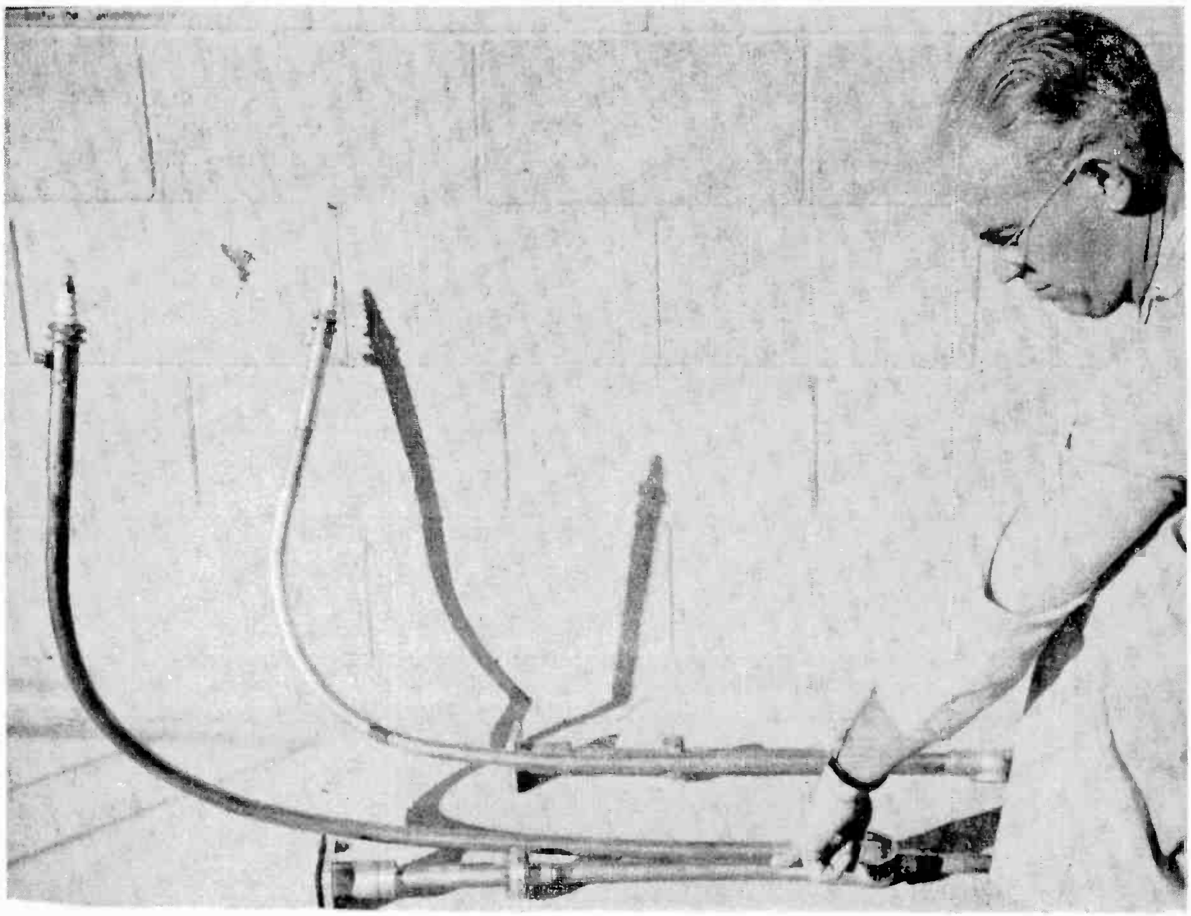
Feeding two corner dipoles is the co-axial matching harness shown in Figure 8. It is form shaped to be inserted in the backs of the corners. At its midpoint is an Andrew type 859-A Junction box, with a 13945 adapter to mate semi-flexible transmission line to the matching harness.

FIG. 7



SINGLE BAY NON-DIRECTIONAL
TOWER MOUNTING
A
B
C
D
Corner
Reflector
"A"
100 Ohm
Dipole Z
50
OHM
CO-AX
Corner
Reflector
"C"
100 Ohm
Dipole Z
50 OHM
CO-AX TO
DIPLEXER

FIG. 8



The matching harness is made from Andrew type S-450 7/8" co-ax. This line is available from the factory with dipole end terminals, using gas tight construction. The junction box ends of these lines may be cut and soldered on the job, depending on local measurements.

Figure 9 shows two assembled corner reflectors with feed harness in place. The terminals connecting the line to the dipole elements are shown, although the harness itself is hiding behind the aluminum braces of the corners. The two units interconnected, are shown lying on their sides. When mounted on a tower, they will be as shown in Figure 10. This picture shows four corner reflectors, pointing in two directions, approximately 90 degrees apart, on the KBET-TV tower. This particular configuration of the corner reflectors came about in an attempt to cover the two important viewing areas in the station's coverage. The principal city, Sacramento, lies on a bearing of 260 degrees and approximately 35 miles away. The other city is to the south, 90 degrees from the Sacramento bearing and 50 miles distant. The measured signal from the auxiliary antenna system compared to the known antenna gain of the main antenna , yielded a power of 12.5 times, or approximately 11 DB, at 35 and 50 miles. No tilt was used. The entire auxiliary system performed much better than expected. With co-axial switches, the 5 kilowatt driver may be switched from the 50 kilowatt amplifier, to the auxiliary antenna in 3 seconds.

These corner reflector antennas may be mounted in several different arrangements in order to give the desired coverage. For example, if the area to be covered from a mountain top transmitter consists only of the principal city in a valley, then four of the corners may be pointed in that one direction and fed in phase.

FIG. 9

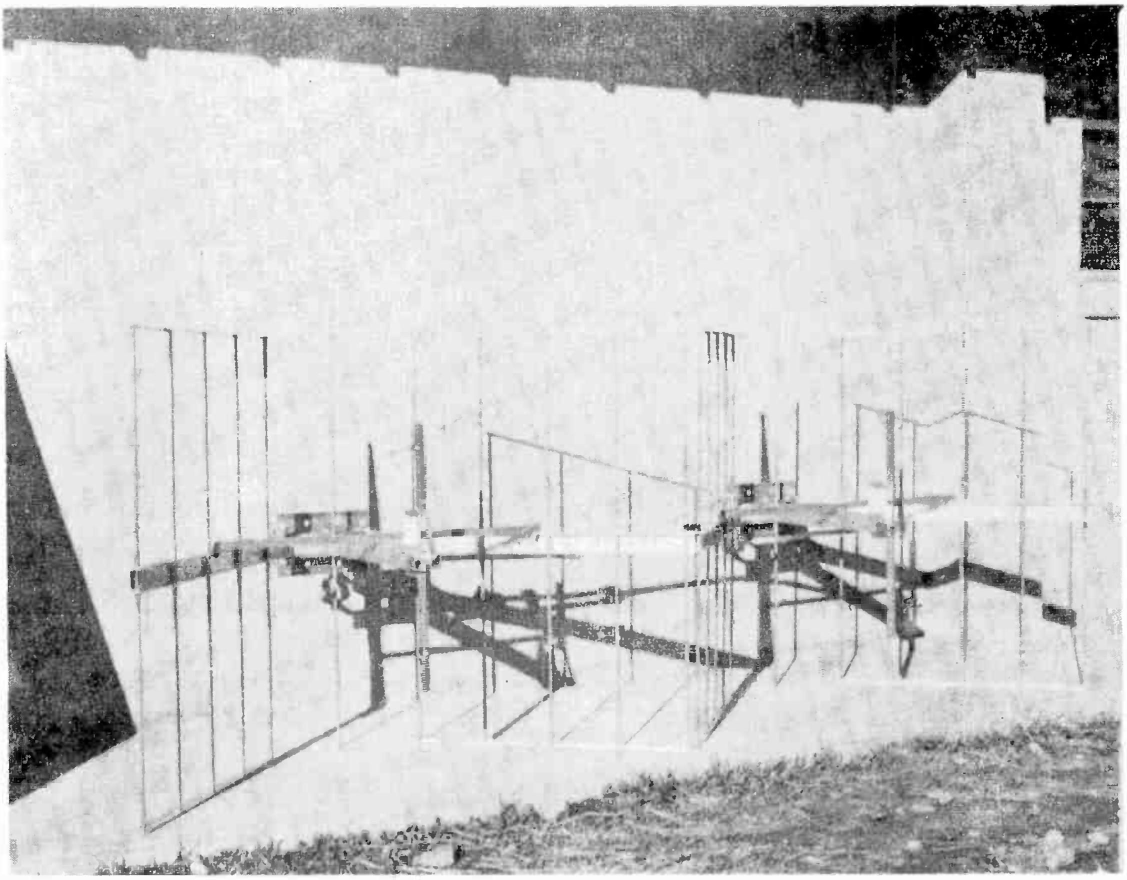


FIG.10

Theoretical gains of 16 DB or 40 times the input power may be realized. In this example, simple mechanical tilting may be called for. If in the above case, a simpler antenna is desired, only two corner reflectors may be used, without a matching harness. The visual transmitter is fed into one corner while the aural feeds the other, omitting the diplexer. The power gain would be approximately 10 for the high channels and 5 for the low channels. The dipole to corner spacing would have to be reduced to .3 wavelengths to match the 50 ohm transmission line.

If a non-directional pattern is called for, four corners must be mounted on the sides of a square, around the tower, and fed in 90 degree phase quadrature. The same type of matching harness shown would be employed. The transmission lines should be in turn fed from a phase quadrature type diplexer. This device mixes aural and visual power, yet isolates the visual from the aural transmitter. It also delays power by 90 degrees at one of its two output spigots. From the output of the diplexer, all transmission lines should be kept equal in length to maintain the proper phase relationship.

This auxiliary antenna system makes possible the following:

1. Complete emergency standby antenna system. Back up for:
   - A. Main transmission line failure
   - B. Diplexer or filterplexer failure
   - C. Antenna failure due to styroflex feeder failure
   - D. Junction box failures
2. Provide high gain to approximate normal high power operation, when the amplifiers are shut down for emergency repairs.
3. Provides an auxiliary, when the main antenna is being moved to a higher tower, or is being otherwise removed.
4. Provides a low cost high gain antenna system for low power installations, or satellites.

Shown below is the cost breakdown of a typical installation, for a high band channel. This installation was for a directional coverage pattern, but the cost of a non-directional would be essentially the same.

QUANTITY	ITEM	PRICE
4	Andrew type 3605 reflectors	$500
25 Ft.	Andrew type S-450 7/8" co-ax	50
200 Ft.	Andrew type 1-5/8" Heliax Co-ax lines	743
2	Andrew type 859-A Junction boxes	30
2	7/8" to 1-5/8" adapters	52
1	Diplexer, used	200
-	Rental, GR Admittance Bridge	25
Misc.	Terminals, clamp connectors, mounting hdwe.	100
	Total cost	$ 1,700

CONCLUSIONS:

It has been shown how a high gain antenna, such as a corner reflector, can be utilized to provide a standby antenna system at low cost to the average TV station. The advantages of having such an antenna system were also shown. Where high time rates are established by a TV station, and its existing antenna system has been weathered for several years, both station management and engineering management will do well to consider the installation of a standby auxiliary antenna system.

References:

1. John D. Kraus, THE CORNER REFLECTOR ANTENNA, Proceedings IRE, November, 1940.

2. John D. Kraus, ANTENNAS, McGraw Hill, 1950.

PREDICTING OPERATIONAL CHARACTERISTICS OF CLOSELY SPACED ANTENNAS ON THE SAME SUPPORTING STRUCTURE

By I. T. Newton, Jr.
Dr. M. S. O. Siukola

The period between the shipment of five antennas for a multiple antenna stacking installation on the Empire State Building in New York City, December 1950, and the completion of the Hill Tower candelabra installation in Dallas, Texas in 1956 has produced considerable activity in multiple station installations. The interest in such installations for technical and economical reasons has been augmented by recent aeronautical considerations which have led to an F.C.C. Proposed Rule Making which would encourage "farms" or multiple antenna installations.

This proposal, docket number 11665, was issued March 29, 1956, and deserves quotation in its entirety. In the interest of time, only a brief portion is quoted here.

> "With respect to the television broadcast service, in areas and communities where more than one such service is contemplated, there are distinct advantages to locating all transmitting antennas in the same general area; and this is true both from the standpoint of generally improving television reception as well as minimizing hazard to aviation. Every effort should be made, therefore, to group high antenna structures and to encourage the use of a single structure for supporting multiple antennas. The principal objective is, of course, to choose an area where the towers will not constitute a hazard to aviation.
>
> "In view of the foregoing, the Commission is proposing to amend its rules to encourage the grouping of antenna towers and the multiple use of structures for supporting antennas."

Antenna farms or multiple installations on one tower present the following advantages:

1. Reduction of hazard to air navigation
2. Minimizing receiver antenna orientation problems
3. More uniform coverage, eliminating areas of greater differential in signal levels than can be satisfactorily tolerated by receivers and receiving antenna systems
4. Economy in land requirements, installation cost, and maintenance cost in the case of multiple installations on a single tower
5. Multiple utilization of a unique site
6. Commercial assistance to educational TV.

RCA has supplied stacked or candelabra installations in eight U.S. cities and four locations outside of the United States. In addition to these, a number are in the planning stage or under construction. Vertical stacking of antennas is the most economical, however, the candelabra installation is to be preferred where the number of antennas and physical dimensions would result in inadequate height for the bottom antenna. Other individual problems may make the candelabra more desirable than the stacking approach.

Figure 1 shows several methods of physical arrangement for multiple antenna installations. On the left is a sketch of a supergain antenna for VHF and a Pylon for either FM or UHF. An example of this type installation is WSB in Atlanta, Georgia. The second sketch shows the use of a supergain antenna and a Superturnstile for VHF. Examples of this type installation are three stations on the Foshay tower building in Minneapolis; Oklahoma City and Tulsa, Oklahoma where educational channel antennas are combined with the commercial TV installation. The third sketch shows vertical stacking of Superturnstile antennas. The KTHV and KARK installation in Little Rock, Arkansas is an example of this type. We are currently fabricating antennas for a similar installation in Philadelphia for WRCV and WFIL. The fourth sketch shows the candelabra or side-by-side mounting. The only example of an existing installation is WFAA and KRLD in Dallas, Texas. Work is in process for a similar installation for three stations in Baltimore, Maryland and others are in the planning stage. The fifth sketch shows a possible stacking arrangement of the UHF Pylon and a VHF Superturnstile. The sixth sketch shows a Rectangular Slot Antenna which is designed for side mounting on the tower. This makes it feasible to employ stacking arrangements which permit the lower channel to be on top rather than the higher channel which is normally placed on top position. A number of towers that have been installed are designed to permit future additions of other stations by use of this side-mount antenna.

Exhaustive engineering tests have been made by RCA in both types of systems both in model work in Camden, New Jersey and in completed installations. We have found that either system may be properly designed to preclude any problems of cross-coupling between stations or substantial effect of one antenna on the coverage of another. Both types of approach permit a considerable degree of freedom in specifications of gain, power-handling capacity, pattern shaping and mechanical windload rating. Stacking systems have been designed and completed to withstand hurricane winds with a loading as high as 80 psf and the candelabra installation now in process for Baltimore, Maryland is designed for a windload of 70 psf.

A number of publications over a period of six years have fully documented the test and results obtained in vertical stacking. The only technical problem which might be presented by vertical stacking is possible excessive coupling of energy between antennas, leading to cross modulation and spurious radiations. The exhaustive tests in the past and the number of such installations have fully established that any combination of channels can be stacked without any more separation than dictated by mechanical requirements. The isolation in all such cases is at least 30 db or more. The candelabra approach is of more recent interest and not as fully documented except for articles in <u>Broadcast News</u>, October 1955, reporting the model test and installation in Dallas, Texas. Figure 2 illustrates the final installation.

Specifications for the Dallas antennas included, among others, specifications of plus or minus 3 db circularity and 26 db isolation between systems. These specifications were demonstrated in the RCA test yard at Camden with 8-to-1 scale models of the actual antennas, in addition to very extensive electrical tests of the final installation.

These scale models duplicated the actual Superturnstile antennas in every respect even to the actual scaling of the size of the individual feedlines as well as maintaining the correct impedance and match. The tests included separate impedances and pattern tests of the individual antennas to varify their correct characteristics and combine tests to determine mutual effects on horizontal and vertical pattern, impedances and cross-coupling. Figure 3 shows the model antennas in the course of horizontal pattern measurements.

Work is now under way for a candelabra installation in Baltimore, Maryland, which will include three antennas on Channels 2, 11 and 13. More rigid specifications have been prepared for this installation and, again, scale models will be used to demonstrate feasibility prior to the actual installation. Theoretical mathematical investigations have led to the development of analytical techniques to provide the necessary answers without the necessity of model tests. The validity of these analytical techniques will be determined by comparison of results with actual measurements on the work now under way. In the future, it should be possible to complete the planning of these installations with a considerable saving in time and cost by using mathematical analysis in lieu of model measurements.

The following discussion by Dr. Siukola will describe these techniques.

The preceding discussion has dealt with reasons for multiple antenna installations and mechanical methods and their achievements. The following discussion will relate to electrical considerations for candelabra installations.

On the side-by-side mounting, the antennas are in the main radiation field of each others. Therefore, electrical problems arise which are considerably greater than in other multiple antenna arrangements. The most important is the effect on the horizontal pattern of the antennas by each others. Another problem is the mutual coupling between the antennas. This is much less important because it can be changed by proper arrangements even after the construction of the antenna system. However, any appreciable change of the resulted horizontal pattern once the system has been built is exceedingly difficult.

To determine the magnitude of these effects calculations have been performed with methods which are explained in the following.

A. Horizontal Pattern Circularity

Let us first look in the horizontal pattern distortion. Figure 4 shows top view of the geometry which determines the formation of the horizontal pattern. The transmitting antenna is shown at left and at the distance b from it a reflecting object such as another antenna. The radiation from the transmitting antenna produces the main or primary field F_0, which is normally omni-directional. Part of this energy is being intercepted by the reflecting object and for the most part re-radiated forming the reflected field F_r. The magnitude of the reflected field is determined by the amount of energy being intercepted by the reflecting object, by the amount being absorbed by it and by the shape of the re-radiation pattern. The final radiation field is a vectorial sum of the primary field and the reflected field. The phase difference between the two fields at any specific direction is shown by the equation below the diagram.

The first term of the equation is the phase difference between the two signals because of different path lengths. It is a function of b in wavelengths and azimuthal angle ϕ. The second portion of the phase difference is determined by the characteristics of the reflecting object. In practice the first portion of the phase difference is greater, since the distance b is normally several wavelengths. This results in that the phase difference changes slowly by varying azimuthal angle ϕ at the general direction of the plane of the transmitting antenna and the reflecting object. The variation is rapid in the plane perpendicular to this.

The type of horizontal pattern obtained is illustrated by Figure 5. It shows the effect produced by a 1.3 wavelength diameter metal cylinder about 15 wavelengths away from a Superturnstile antenna. The heavy center curve is the undisturbed or primary pattern of the Superturnstile antenna which in this example has a circularity of plus or minus $1\frac{1}{2}$ db. By adding the reflected field, the rapidly varying diffraction pattern is obtained.

The effect of the shape of the re-radiation pattern is apparent from the differing magnitude of the diffraction pattern variation about the primary pattern at various directions. The slow change of phase difference in the plane of transmitting antenna and the reflecting cylinder as well as rapid change in the plane perpendicular to this is also indicated.

From the minimum and maximum values of the diffraction pattern, the overall circularity of plus or minus 3 db has been calculated. It can be seen, however, that if an envelope is drawn both inside and outside of the diffraction pattern and the minimum and maximum values of these envelopes are used in the circularity calculation, the result because of the rapid variation of the diffraction pattern is almost identical. Therefore, calculations can be made only for the envelopes of the diffraction pattern instead of for the whole diffraction pattern. The result is of course slightly conservative. The advantages of the calculation of the envelopes are: first, the phase difference between the primary field and the reflected field is very difficult to determine with adequate accuracy for the diffraction pattern calculation, and second, the amount of work is considerably reduced.

Theoretical Approach

To devise a practical method of calculation several assumptions have been made (Figure 6).

First, a plane wave incidence at the reflecting antennas was assumed. This can be done since in a practical case the effective radius a compared to the distance b between the transmitting antenna and the reflecting object such as another antenna is small.

Second assumption of the reflecting antennas being cylindrical and highly conductive has been made to simplify calculations and also to give a universal answer which can be used in different problems.

As the third assumption the second reflections have been neglected. This can be done if the first reflection from any supporting structure or antenna is small compared to the primary field of the transmitting antenna. Thus the second reflection would be negligible.

Fourth, reflections from the supporting structure have been neglected. This has been substantiated by previous model tests and also measurements of an actual constructed system.

In case of several antennas, that is, more than two being installed on the same supporting structure, it has been assumed that the reflection fields are all in phase in any direction. To obtain the total diffraction pattern envelopes the summation of all the reflection fields has been added to and subtracted from the primary field. This would be the worst case and give conservative results.

As the last assumption linear interpolation has been used when the antennas are of different lengths or at different elevations or when a reflecting antenna has large openings within its aperture. The latter is the case, for instance when a low channel Superturnstile antenna interferes with a high channel transmitting antenna since the low channel antenna has considerable openings between the sections for free passage of high channel radiation.

Based on the described assumptions equations shown on Figure 7 have been derived at. The outside envelope F_{max} of the diffraction pattern has been obtained by adding to the primary pattern F_o the summation G of the magnitudes of all the reflected patterns. The inside envelope F_{min} results from subtraction of the same patterns. For a Superturnstile as a transmitting antenna a simple adequately accurate equation for F_o is given.

The summation G of the reflected patterns is obtained by arithmetically adding the amplitudes of the scatter patterns F_s modified by proper factors. The scatter patterns F_s are the results of theoretical calculations of the re-radiation fields from highly conducting cylinders. The magnitudes of these scatter patterns have been modified by three factors. The first, K_m, is the linear interpolation factor. The second, $\sqrt{\frac{\lambda}{b_m}}$ takes into account the distance between the transmitting antenna and the reflecting antennas. The third factor, F_o, includes the effect of the primary pattern shape on the excitation of the reflecting antennas or objects.

These equations can be directly used for calculation of diffraction patterns in application where the reflecting objects are cylindrical such as supporting poles or UHF Pylons. However, in the case of interfering Superturnstile antennas proper effective radii and interpolation factors have to be found. Figure 8 shows the method used.

The sections of the Superturnstile antenna are assumed to form a set of cylindrical blocks. As the effective radius (a) of the blocks the average radius of a section of the Superturnstile antenna has been used since the horizontally polarized electric field is approximately perpendicular to the edge of the batwings. The height of the blocks (h) has been assumed to consist of the length of the batwings plus $\frac{1}{8}$ of the wavelength at the frequency in question on either side. This includes the additional shadowing effects by the top and bottom rungs of the batwings on the electric field parallel to them. The height (h) as compared to the distance between sections (L) has been incorporated into the interpolation factors.

Example:

The described theoretical method of predicting the circularity of the horizontal patterns in multiple anténna installations of this type has been applied on several occasions. However, to substantiate the method of calculations only one set of actual pattern measurements has been available. These measurements were made with scale models of the multiple antenna system of Hill Tower, Inc., Dallas, Texas. The results of the calculations are presented for comparison.

This multiple antenna system has a medium channel 6-section Superturnstile antenna mounted 75 feet from a high channel 12-section Superturnstile antenna on a triangular supporting structure. The horizontal primary pattern of the Channel 8 scale model is shown in Figure 9. The measured circularity of plus or minus 1.92 db has been used in calculations. By the method described above the pattern envelope shown in Figure 10 has been calculated. From the minimum and maximum values of the envelope, a circularity of plus or minus 2.85 db has been obtained. It should be somewhat conservative according to the assumptions which have been made.

In this example the maximum magnitude variation of the diffraction pattern is again toward the reflecting antenna and the minimum variation at the angles of about 70° on each side of it.

The actual measured horizontal diffraction pattern of the scale model is shown in Figure 11. It has a circularity of plus or minus 2.67 db which is approximately 6% less than the calculated giving an excellent correlation.

The measured pattern shows as the theory indicated that the variation of the field is slowest or the lobes farthest apart in the plane of the antennas and that the variation is most rapid in the plane 90° from it. The envelope of this pattern confirms that the maximum amplitude variation is toward the reflecting antenna and the minimum variation about 70° from it on each side. Comparison of the calculated and measured envelopes (Figure 10 and 12) reveals an excellent similarity between them, thus giving confidence to the theoretical calculations.

B. Mutual Coupling Between Antennas:

Now, let us look briefly at the mutual coupling between side-by-side mounted antennas. The equations employed in calculation of the decoupling between the antennas are shown in Figure 13. The upper equation holds when the antennas are separated far from each other. The theory has been developed based on the effective aperture principle of the antennas. The only assumption made is that the reflections from other antennas and structures have been neglected.

The close field equation is based on three assumptions in addition to this. First, the transmitting antenna is assumed to radiate all the energy horizontally. Second, the field is assumed to be uniform at the receiving antenna. And third, linear interpolation is used to include effects of different elevations and/or lengths of the antennas. By again using the effective aperture principle for the receiving antenna the close field equation has been derived.

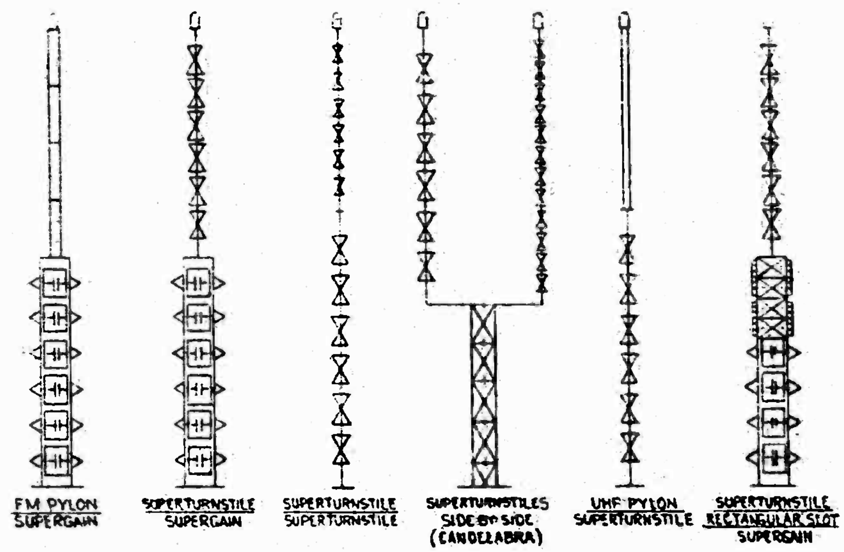
For any specific application, the calculations have been performed using both equations. By plotting the decoupling in db versus the logarithm of the distance between the antennas in wavelengths, the equations result in two straight lines (Figure 14). If the region of interest is between the validity areas of these two equations an adequately close approximation can be obtained by interpolation, that is, by drawing a curve between the straight lines.

In practice, this method is often difficult to apply, since some of the constants in the equations are exceedingly difficult if not impossible to determine. Fortunately, though, in most cases the results need only be used as guidance since even after the construction of the antenna system mutual coupling can be changed by varying the orientation of the antennas or by changing the feed system lengths of the antennas or in the worst case by placing proper filters in the feed systems. Any of these modifications will change the constants in the equations and result in a different decoupling value. However, these equations can be used to determine the worst possible case in any application without the modifications mentioned.

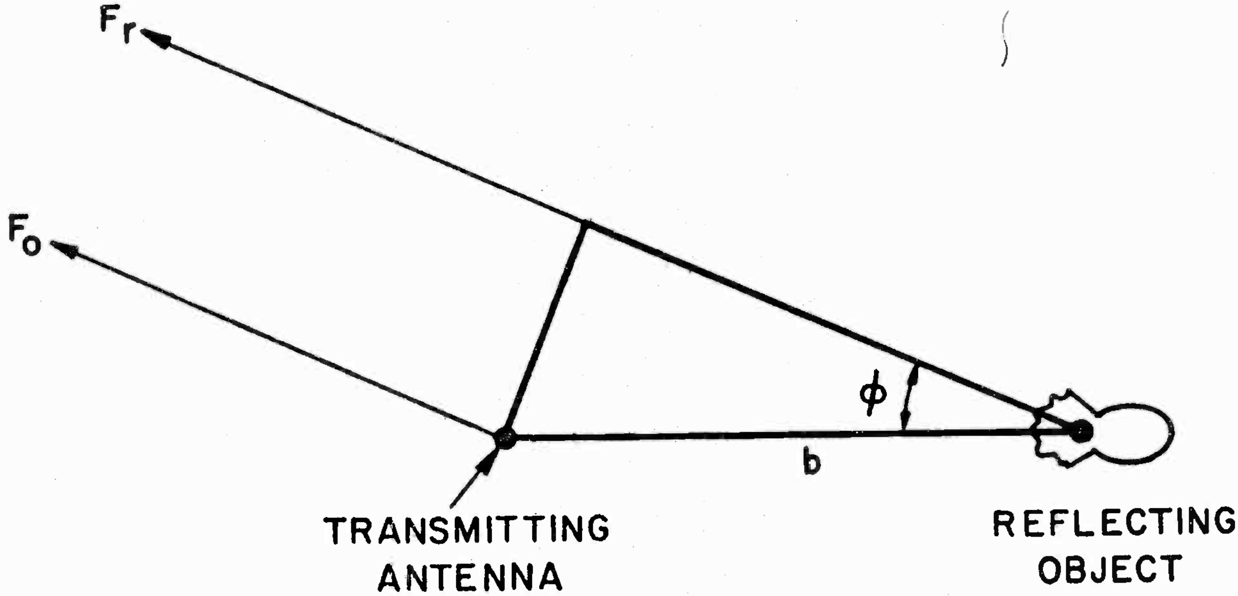
<u>Summary</u>

Both the calculations of the circularities and the decouplings have been applied in several occasions. However, at this moment the methods are not believed to be accurate enough to be firmly relied on. Therefore, in the near future experimental tests are planned. From these measurements further substantiation and/or modifications for the theoretical approach will be obtained. At present, scale models are being built for the investigation of these effects in the multiple antenna system of Baltimore, Maryland (3 Superturnstile antennas). Figure 15 is a picture of one of these models. By proper correlation of the measured and the calculated results, it is expected that at later date the effects can be solely determined by calculations. However, high accuracy of evaluation is mandatory especially in circularity calculations, since any appreciable change of circularity once the system has been built is extremely difficult.

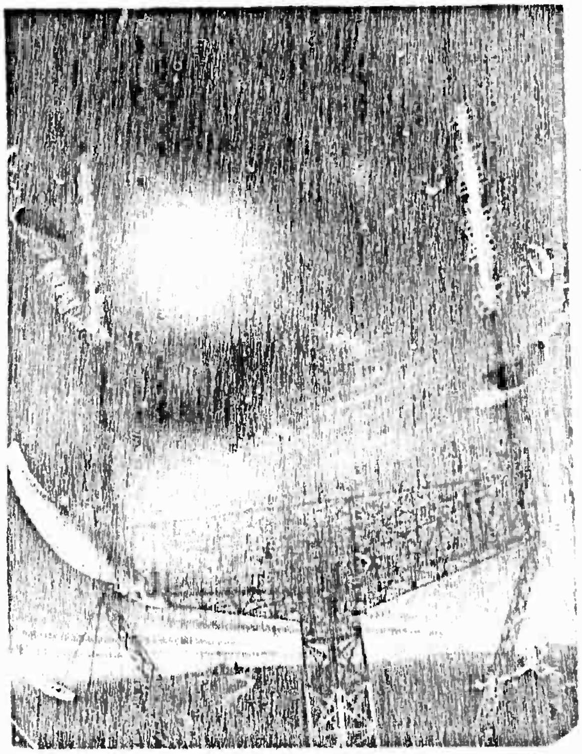
MULTIPLE ANTENNA COMBINATIONS

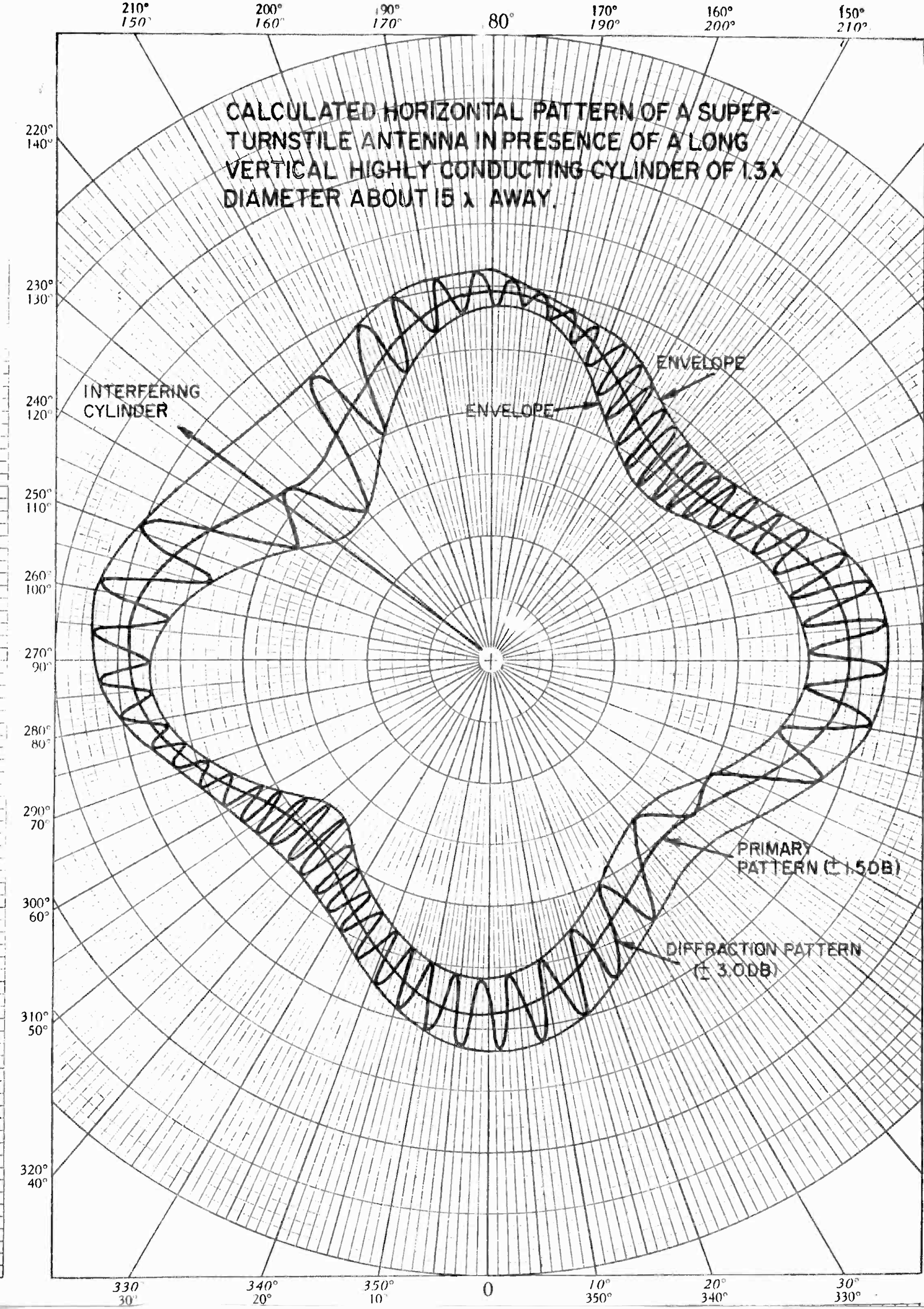


GEOMETRY WHICH DETERMINES HORIZONTAL PATTERN DISTORTION



$$\Delta \varphi = 2\pi \frac{(1+\cos\phi)b}{\lambda} + \varphi_r(\phi)$$




CALCULATED HORIZONTAL PATTERN OF A SUPER-TURNSTILE ANTENNA IN PRESENCE OF A LONG VERTICAL HIGHLY CONDUCTING CYLINDER OF 1.3λ DIAMETER ABOUT 15 λ AWAY.
INTERFERING CYLINDER
ENVELOPE
ENVELOPE
PRIMARY PATTERN (± 1.5DB)
DIFFRACTION PATTERN (± 3.0DB)
210° 150°
200° 160°
190° 170°
180°
170° 190°
160° 200°
150° 210°
220° 140°
140° 220°
230° 130°
130° 230°
240° 120°
120° 240°
250° 110°
110° 250°
260° 100°
100° 260°
270° 90°
90° 270°
280° 80°
80° 280°
290° 70°
70° 290°
300° 60°
60° 300°
310° 50°
50° 310°
320° 40°
40° 320°
330 30°
340° 20°
350° 10°
0
10° 350°
20° 340°
30° 330°

ASSUMPTIONS:

1) PLANE WAVE INCIDENCE AT REFLECTING ANTENNAS (a/b IS SMALL)

2) SCATTERING ANTENNAS CYLINDRICAL AND HIGHLY CONDUCTIVE

3) SECOND REFLECTION NEGLECTED (FIRST IS SMALL COMPARED TO MAIN FIELD)

4) REFLECTIONS FROM SUPPORTING STRUCTURE NEGLECTED

5) ALL REFLECTIONS IN PHASE OR OUT OF PHASE AS COMPARED TO MAIN FIELD (WORST CASE)

6) LINEAR INTERPOLATION HAS BEEN USED TO TAKE CARE OF PARTIAL SHADOWING EFFECTS OF ANTENNAS DUE TO

a) DIFFERENT LENGTHS AND DIFFERENT ELEVATIONS OF ANTENNAS, AND

b) OPENINGS WITHIN ANTENNA APERTURES

EQUATIONS FOR HORIZONTAL PATTERN CALCULATIONS ON MULTIPLE ANTENNA INSTALLATIONS

$$F_{max}(\phi) = F_o(\phi) + G(\phi)$$

$$F_{min}(\phi) = F_o(\phi) - G(\phi)$$

$$F_o(\phi) = 1 + A \cos\left[4(\phi - \phi_o)\right]$$

$$G(\phi) = \sum_{m=1}^{M} K_m \sqrt{\frac{\lambda}{b_m}}\, F_o(\phi_m) \left| F_s^{(m)}(\phi - \phi_m) \right|$$

$$F_s(\phi) = -\frac{1}{\pi} e^{i\frac{\pi}{4}} \sum_{n=0}^{\infty} \epsilon_n \frac{J_n'(ka)}{H_n^{(2)'}(ka)} \cos(n\phi)$$

$$\epsilon_n = 1 \quad n = 0$$

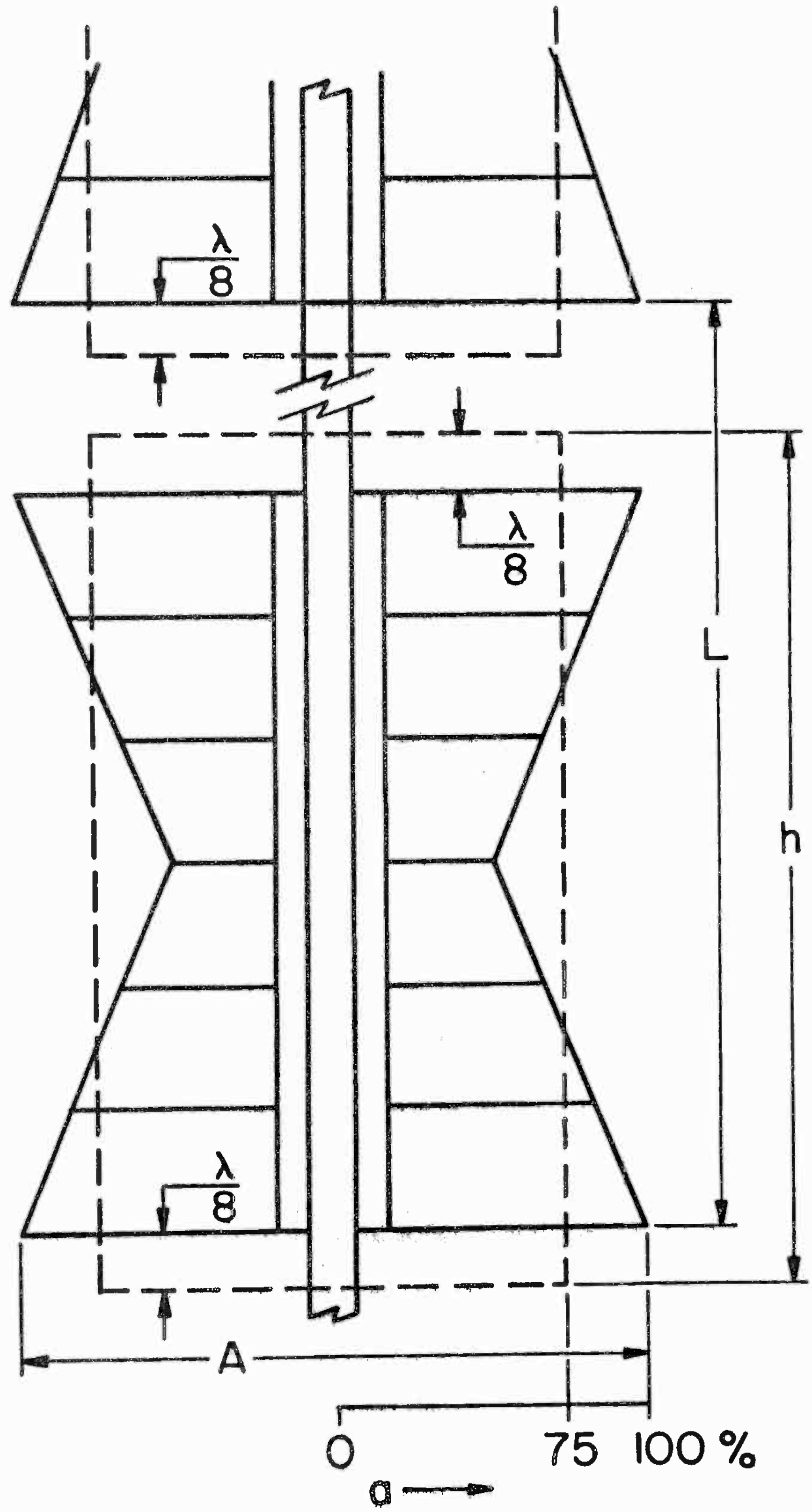
$$\epsilon_n = 2 \quad n \neq 0$$

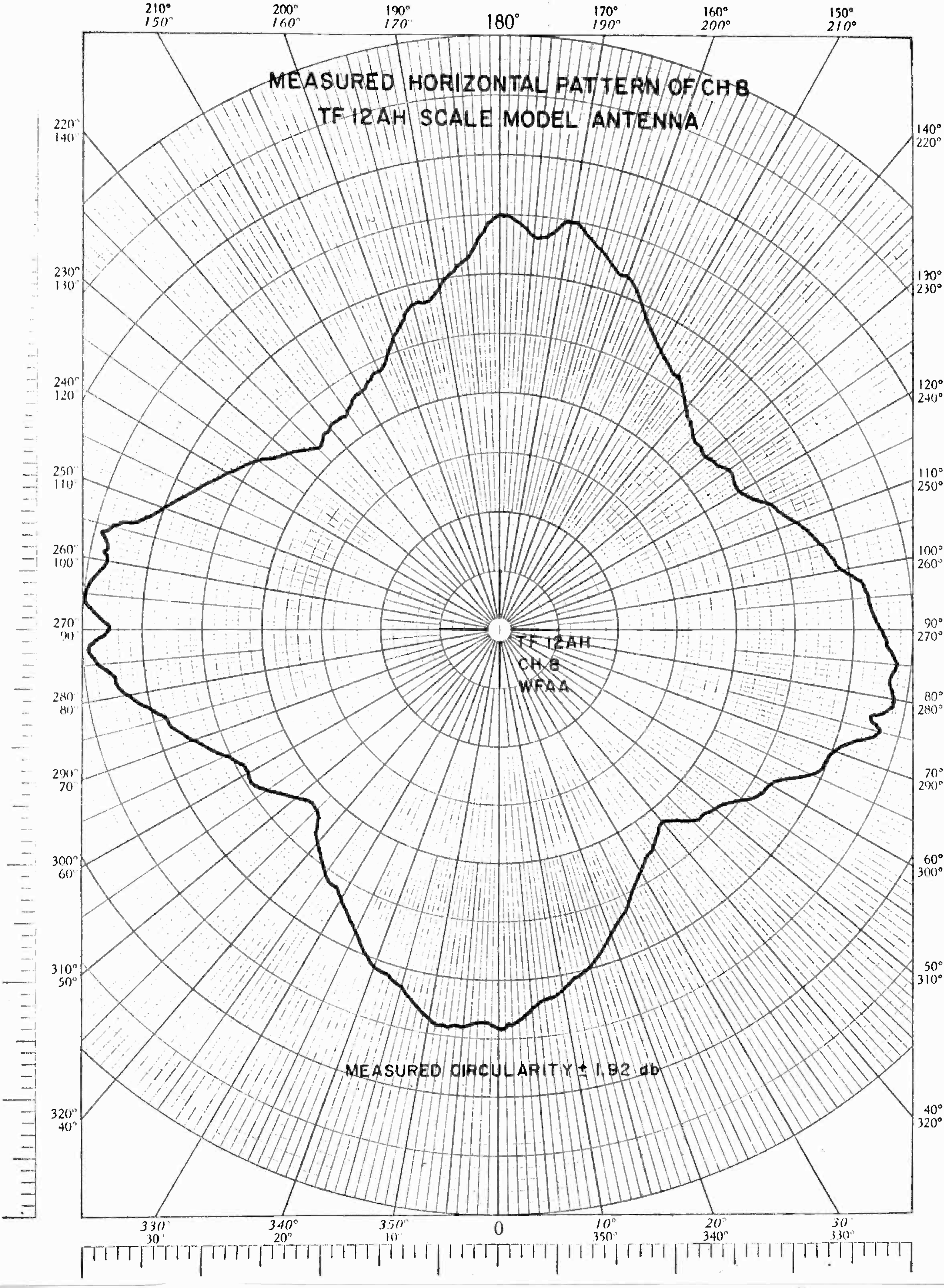
$$k = \frac{2\pi}{\lambda}$$

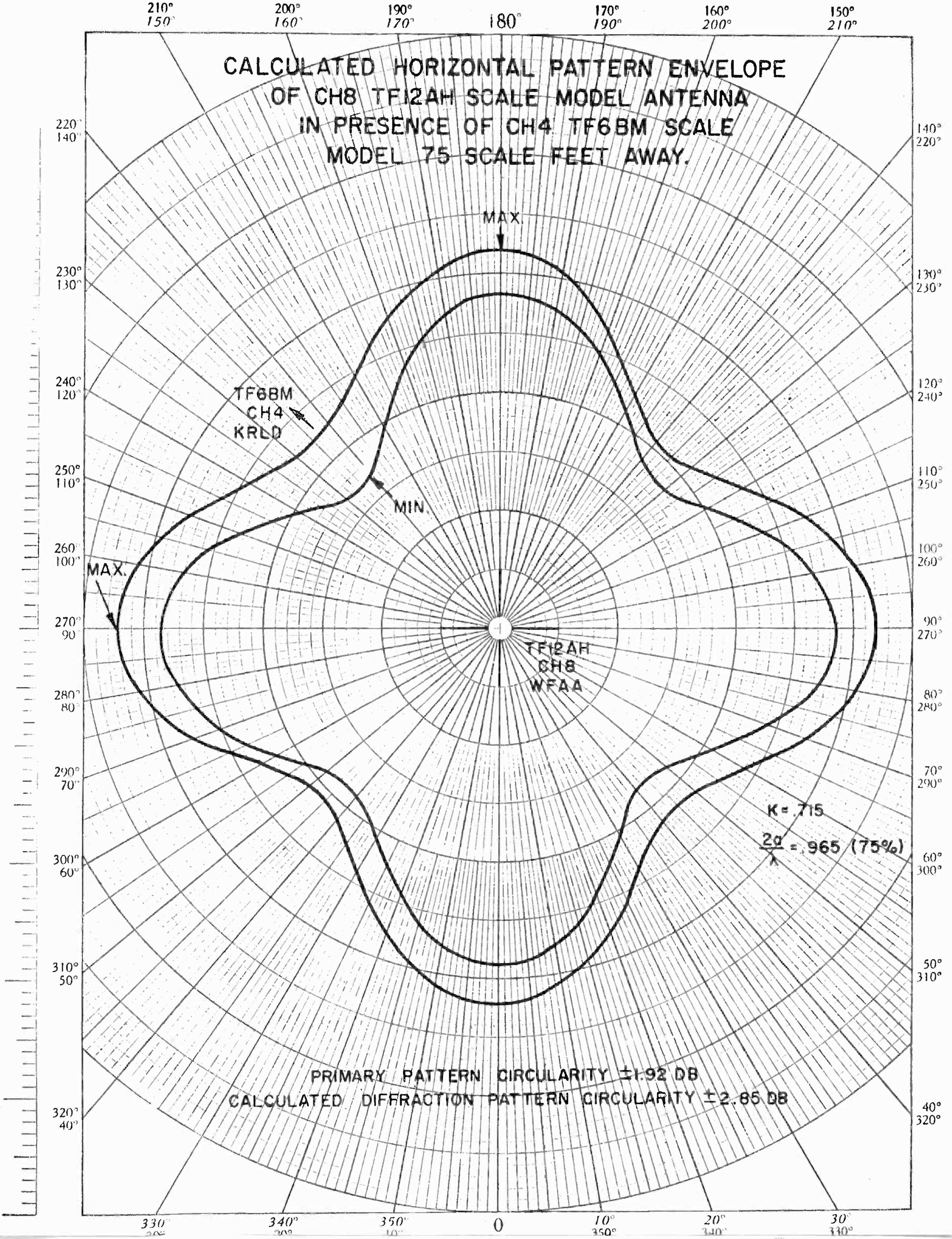
$$K_m \leqq 1$$

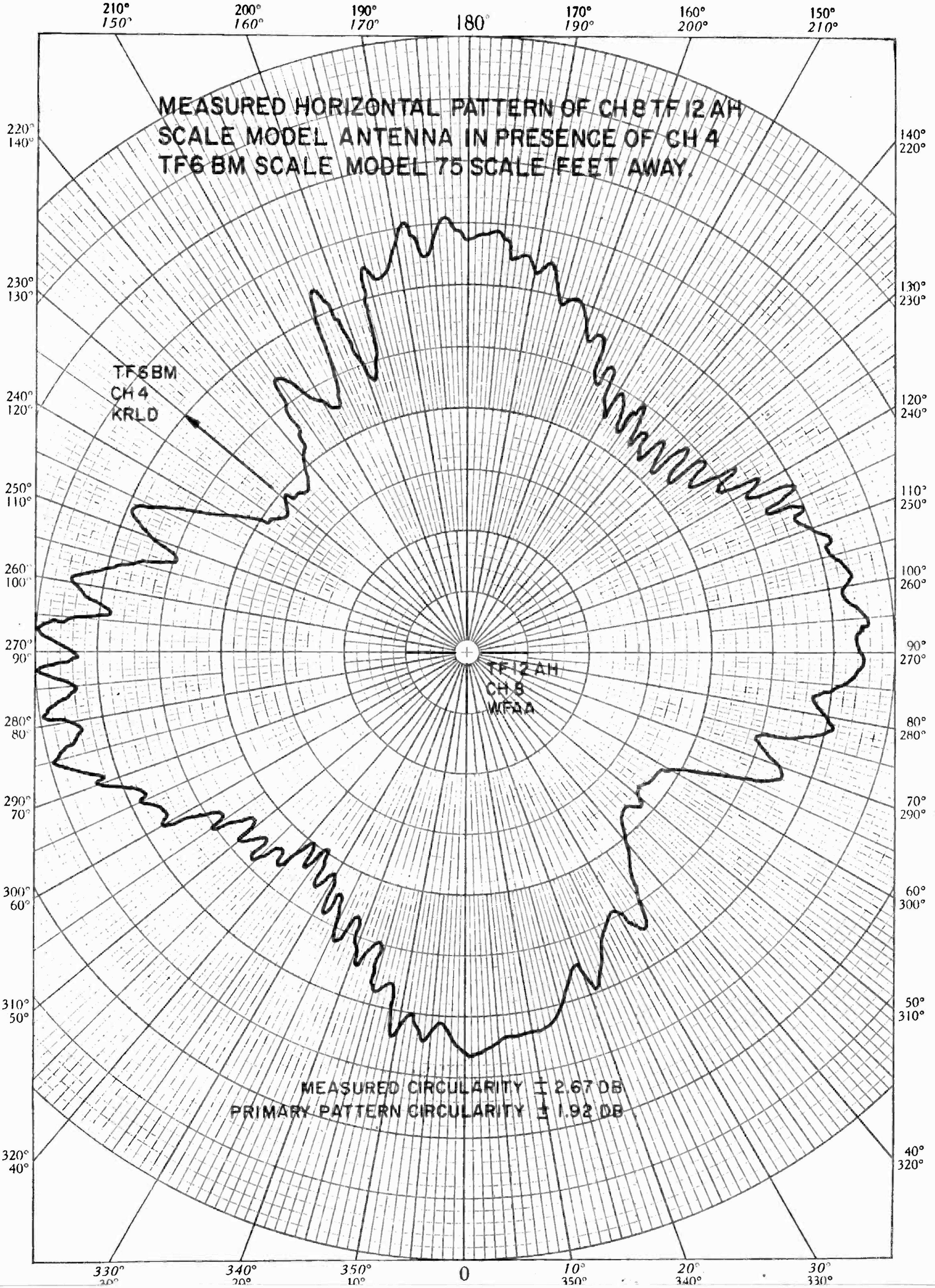
$F_{max}(\phi)$, $F_{min}(\phi)$	ENVELOPE OF PATTERN
$F_o(\phi)$	PRIMARY FIELD
$G(\phi)$	MAXIMUM FIELD OF REFLECTIONS
$F_s(\phi)$	SCATTER PATTERN
a	EFFECTIVE RADIUS OF REFLECTING ANTENNA
b_m	DISTANCE BETWEEN TRANSMITTING AND REFLECTING ANTENNAS

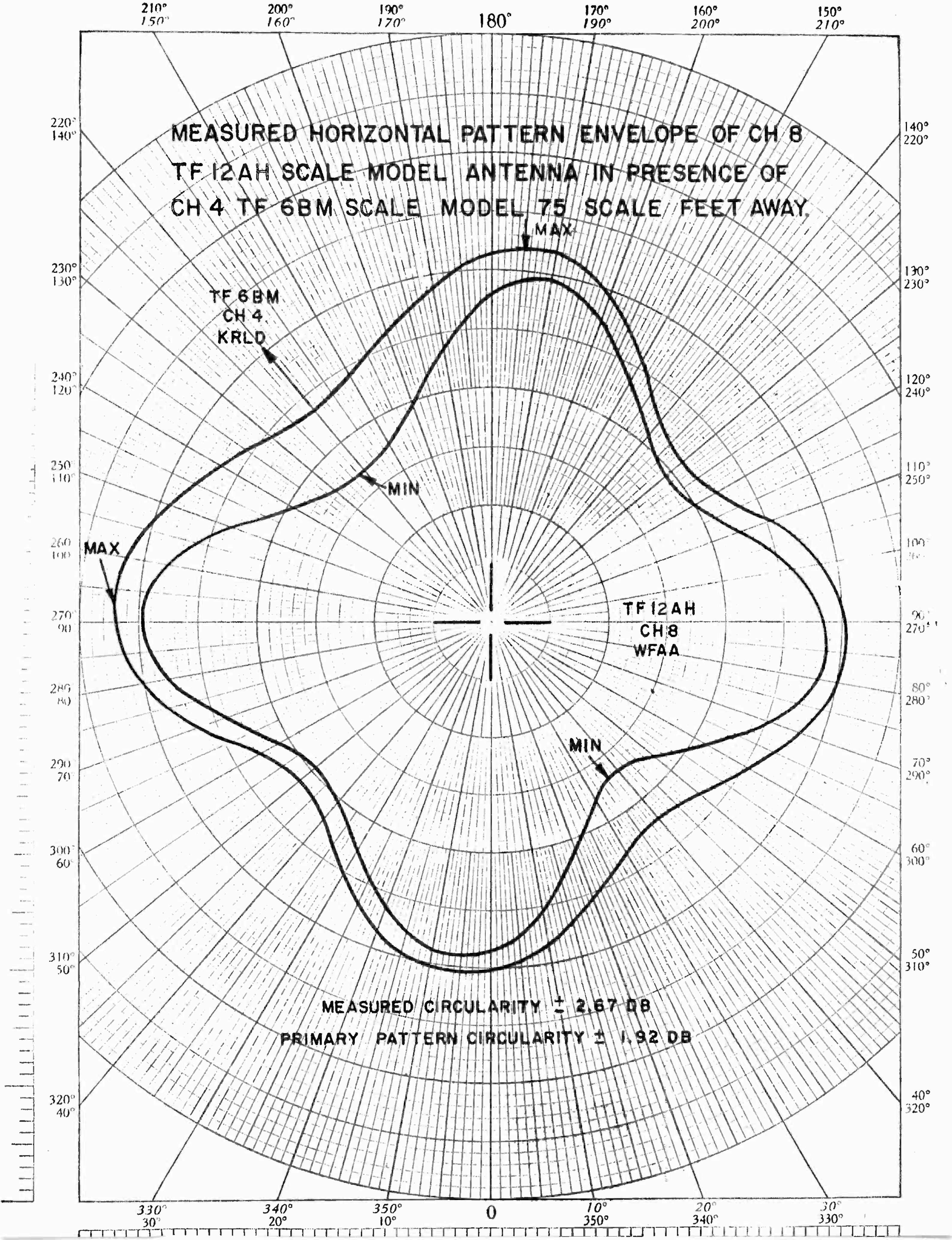
ERIVATION OF EQUIVALENT CYLINDER IMENSIONS FROM A SUPER TURNSTILE NTENNA FOR HORIZONTAL DIFFRACTION ATTERN CALCULATIONS.




MEASURED HORIZONTAL PATTERN OF CH 8
TF 12AH SCALE MODEL ANTENNA
TF 12AH
CH 8
WFAA
MEASURED CIRCULARITY ± 1.92 db
180°
0


CALCULATED HORIZONTAL PATTERN ENVELOPE
OF CH8 TF12AH SCALE MODEL ANTENNA
IN PRESENCE OF CH4 TF6BM SCALE
MODEL 75 SCALE FEET AWAY.
MAX.
TF6BM
CH4
KRLD
MIN.
MAX.
TF12AH
CH8
WFAA
K = .715
2a/λ = .965 (75%)
PRIMARY PATTERN CIRCULARITY ±1.92 DB
CALCULATED DIFFRACTION PATTERN CIRCULARITY ±2.85 DB


MEASURED HORIZONTAL PATTERN OF CH 8 TF 12 AH
SCALE MODEL ANTENNA IN PRESENCE OF CH 4
TF6 BM SCALE MODEL 75 SCALE FEET AWAY.
TF6BM
CH 4
KRLD
TF 12 AH
CH 8
WFAA
MEASURED CIRCULARITY ± 2.67 DB
PRIMARY PATTERN CIRCULARITY ± 1.92 DB
180°
0


MEASURED HORIZONTAL PATTERN ENVELOPE OF CH 8
TF 12AH SCALE MODEL ANTENNA IN PRESENCE OF
CH 4 TF 6BM SCALE MODEL 75 SCALE FEET AWAY
MAX
TF 6BM
CH 4
KRLD
MIN
MAX
TF 12AH
CH 8
WFAA
MIN
MEASURED CIRCULARITY ± 2.67 DB
PRIMARY PATTERN CIRCULARITY ± 1.92 DB
180°
0

EQUATIONS FOR CALCULATION OF ISOLATION BETWEEN OMNIDIRECTIONAL ANTENNAS ON MULTIPLE ANTENNA INSTALLATIONS

$$\text{DECOUPLING} = 10 \log \left[\frac{58.713}{k_{gr}\, k_{gt}\, \alpha_r\, \alpha_t\, D_r\, D_t} \left(\frac{b}{\lambda}\right)^2 \right] \text{ db}$$

AT FAR FIELD

$$\text{DECOUPLING} = 10 \log \left[\frac{48.144K}{k_{gr}\, k_{gt}\, \alpha_r\, k_t\, D_r} \left(\frac{b}{\lambda}\right) \left(\frac{H}{\lambda}\right) \right] \text{ db}$$

AT CLOSE FIELD

D_r, D_t	DIRECTIVITY OF THE ANTENNAS COMPARED TO $\lambda/2$ DIPOLE
α_r, α_t	EFFICIENCY AND MATCHING FACTORS OF EACH ANTENNA RESPECTIVELY
k_{gr}, k_{gt}	DIRECTIONAL FACTORS OF THE ANTENNAS
b	DISTANCE BETWEEN THE ANTENNAS
k_t	EFFICIENCY FACTOR OF TRANSMITTING ANTENNA
H	HEIGHT OF TRANSMITTING ANTENNA
K	INTERPOLATION FACTOR

DECOUPLING BETWEEN TWO ANTENNAS AS A FUNCTION OF THE DISTANCE BETWEEN THEM.