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DEVELOPMENTS IN FM MULTIPLEX RECEIVERS

By Dwight Harkins
HARKINS RADIO, INC.
4444 E. Washington, Phoenix, Arizona

The use of multiplexed supersonic subcarriers by FM broadcast stations was authorized by the Federal Communications Commission in the spring of 1955. During the past four years over 60 stations have been put into commercial operation of multiplexing.

The actual use of multiplexing has enabled the development of the transmitting and receiving processes to take place on the firing line rather than by theoretical reasoning.

It is not the scope of this paper to detail the technical methods used in resolving the transmitting problems. The whole problem at the station revolved around eliminating cross-talk interference of the main channel modulation products getting into the subcarrier. Some of the things occurring at the transmitter were:

1. Multipliers created phase distortion resulting in cross-talk.
2. Improper coupling between stages caused cross-talk.
3. Regenerative amplifiers caused cross-talk.
4. Any mistuning caused cross-talk.
5. Any condition in the radiating system that presented a reactive load to the transmitter as indicated by high VSWR would cause cross-talk.

During the years 1955 and 1956 these and other situations were one by one discovered and rectified. During the course of installing multiplex exciters and modifying over 35 transmitters throughout the country all possible transmitting problems were encountered and corrected.

The mysteries of cross-talk no longer existed and the station operator had clearly defined corrective measures he could apply if the economics of the situation permitted it. The multiplex station monitor we developed had proven to be an excellent tool.

Now let's turn to the receiver which must detect and reproduce this correctly transmitted signal.

Based upon the requirements desired by background music operators and FM broadcasters in over 50 cities a set of minimum standards was arrived at as a goal. These operators wanted a multiplex receiver that would deliver:

1. Cross-talk below 60 db.
2. Sensitivity of less than 1 microvolt.
3. Built in antenna.
4. Freedom of service calls by eliminating tubes
5. Audio output to feed at least 100 speakers
6. Delivered price not to exceed $29.95 with long-term financing if needed.

At this time I make public admission of my failure to meet the requirements of the industry.

However, in turning from the fantastic to the practical we can set up some standards that are realizable.

1. Cross-talk 50 db. below subcarrier program peaks while modulating main channel 100% with any tone in audible range.
2. 10 microvolt sensitivity to insure operation within 50 microvolt contour.
3. Designed for continuous operation.
4. Drift free tuned circuits.
5. Audio response to 5000 cycles.
6. Priced no more than $150.00.

A little over two years ago measuring techniques were perfected that pointed up without doubt that the receiver was contributing cross-talk to the subcarrier signal. Using the same procedures as at the transmitter, the receiver measurements were 15 db. from the transmitter cross-talk figure of 50 db. This was the best obtainable with critically tuning of the I.F. strip. After regular alignment using meter tuning, the cross-talk figure in some cases was 25 db.

Background music customers were being served on a widespread basis with this level of performance. Commercially successful multiplexing became a reality. The receivers were out earning money. Coordination between engineering and management had brought about successful operation in many areas.

The following techniques were used. First, by holding back main channel modulation levels and by enforced gain riding and efficient peak limiting the main channel breakthrough was minimized. Subcarrier muting between musical selections was perfected. Sta-levels and unilevels were used on the subcarrier music to insure highest modulation level at all times. Volume controls and tone controls were carefully balanced at the locations served to keep the presence of cross-talk least noticed.

These and other similar techniques were considered par for the course. Coupled with the honest motive to make money with multiplex, a large segment of the new industry did do just that.

While all this was taking place there were many other stations and background music operators who wouldn't initiate the techniques that made multiplex usable. These parties not only used the deficiencies of multiplex as a reason for warding off F.C.C. rules pushing them in that direction but they knew from their own experience that something was not right in the whole system.

Since the signal transmitted was known to be correct, the weak link was isolated to be in the receiver.

The 10.7 Mc. I.F. strip was scrutinized closely. At the limiting grid, a recovery of main channel audio was discovered. This indicated an A.M. component on the carrier which wasn't there when the signal left the station. This amplitude modulation of the 10.7 carrier by the main channel music could be observed on a scope and its intensity changed by tuning various stages that preceded the limiter. The amplitude of the A.M. component observed correlated directly to the intensity of cross-talk heard in the subcarrier.

These observations led to the reasoning that unwanted conversion of F.M. to A.M. in the system produced a side product of intermodulation into the supersonic subcarrier of the unwanted audio products which started the whole process.

Since the subcarrier later went through complete limiting and clamping, the unwanted intermodulation product was in the form of phase shift or frequency modulation being induced into the subcarrier. This was observed on the oscilloscope when viewing the subcarrier.

A wide variety of 10.7 M.C. I.F. transformers were tried with only small degrees of improvement noted. The circuits which had cured the problem in the transmitter were found unsuccessful in the receiver I.F. because of too little gain to make them useful.

The problem resolved itself to one of amplifying the signal without introducing intermodulation.

About this time (which was in early 1957) I decided to shut down our receiver production line. During the eighteen months that followed, all effort was directed towards experimentation.

Setting the I.F. problem aside unsolved, we diverted our attention toward getting the most out of the subcarrier bandwidth. Looking at the situation closely we moved from 67 Kc. to 65 Kc. thus allowing plus or minus 10 Kc. deviation and still be within the allotted spectrum. By modifying the response curve of the audio pre-emphasis to the RIAA system used on LP records, together with a discreet 5000 cps. cut-off filter at the audio input of the unit, we made a startling advance on our problem.

By matching the pre-emphasis closer to the energy distribution curve, at least 6 db. more average energy was packed into the plus or minus bandwidth available for use. The additional de-emphasis after detection of the subcarrier equalized the system to flat response and gained us another 6 db. rejection of unwanted high frequency slop-over from the main channel cross-talk.

These techniques created new requirements for the filter used in the receiver at the entrance to the subcarrier amplifier. In order to handle the bandwidth of energy created in modulating the subcarrier plus or minus 10 Kc. with a tone of 5000 cps., the bandpass filter in the circuit had to be phase linear. Filters that appeared broad enough when measured by amplitude response methods failed to pass the signal without contributing phase distortion which completely disrupted the balanced side carriers causing unusable audio distortion.

Dropping to the 500 ohm level a filter was produced with six coils that did the job effectively.

A decision was made to incorporate these improvements into our system even though our old receivers would not permit its use. The newer approach had taken us out of the woods so much that it was worth the bold move making the old receivers obsolete.

Without improving the characteristics of the I.F. we had made for less critical multiplexing. While in the process of resuming receiver production we stumbled upon the answer to our I.F. problem. Using transformers at a frequency of 23 Mc. together with a balanced ratio detector we broke through the barrier, so to speak, and obtained measurements at the receiver that were the same as the transmitter showed.

At this time we junked the old receiver completely and designed a new chassis layout and cabinet and even switched from gray to green for its color. We incorporated such features as glass epoxy etched circuit boards for high stability as those used in guided missiles.

After testing the first 30 in half a dozen cities, we took the noise out of the automatic squelch circuit which showed up during the field tests.

At this convention last year a report was given by Mr. Bill Tomberlin, Chief Engineer of KMLA in Los Angeles. He told of the field tests in which he participated that took place during the latter months of the prototype development.

Eighteen of the first group produced were placed in service in the Los Angeles area. The music service to the Statler Hotel has been supplied by one of these new receivers since last April.

By last fall we had all the parts and equipment to go into production with the result that over 500 of the sets have now been placed in operation with uniform results.

This could be the end of the story but it isn't. The 23 Mc. I.F. coupled with full measure subcarrier width has performed as expected. Except in a few cases where trouble at the transmitter developed, cross-talk is just an ugly memory. A good receiver still requires a good transmission as it can't make corrections.

The experiences in the field the past six months have uncovered another receiver problem that is yet to be completely cured.

I speak now of individual location difficulties. At customer locations where the signal is weak, antenna location difficult, or where high local noise exists, a new set of problems must be solved.

Some actual case histories will best illustrate the problems to be faced. In San Francisco, trouble was experienced at a restaurant in the downtown area. The location was completely shadowed from the transmitter by not only five other buildings but Nob Hill. This very nice place was being served by a Simplex receiver successfully. The receiver was located near the cashier at the front entrance on the ground floor. From the receiver a twin lead transmission line went about 60 feet to the rear of the building, thence up 6 stories to the roof where it was stretched over to another building about 70 feet away that was a little higher where the 3 element antenna was mounted. This worked for the simplex receiver and the small amount of sizzle to be heard was easily masked by the tone control.

A multiplex receiver was substituted and was found unusable as the hash and sizzle was, for all practical purposes, just as loud as the music. The limiting voltage showed the signal to be in the 50 to 100 microvolt range. Several of the waiters volunteered to relay signals to the antenna for checking its orientation. Some improvement was made by aiming the antenna 90 degrees from where the transmitter was located on the other side of a group of taller buildings. Before reinstalling the simplex receiver we shifted the multiplex receiver to an unused FM channel and noted that the limiting voltage was about half as high as when tuned to the station. This indicated that the random pulses coming into the receiver generated by the multitude of electrical equipment in the vicinity were actually almost as strong as the desired signal.

According to theory the limiter should eliminate this condition.

Putting the receiver back to the regular station crystal we got out the oscilloscope and put it on the subcarrier for visual observation. Between musical selections the phenomena was readily visible. The noise bursts were frequency modulating the subcarrier just like the music did back at the station. Twisting every screw on the set made no change in the observed action. The Japanese waiters were quite impressed by the green faced little television set and the bartender sprung for a couple of free beers before we packed up and left. The simplex receiver was left in fine operation.

Plans were immediately put into motion for duplicating these conditions on a controlled basis at the home base in Arizona.

Several weeks later we had obtained a variety of noise makers such as electric shavers, Ford spark coils, and old neon transformers with which we could foul up the subcarrier. The same effect was observed visually and in the loudspeaker. The noise effectively frequency modulated the 65 Kc. subcarrier when the noise became at a critical level about one half of the signal strength.

The main channel still was usable just as it was at the San Francisco field test.

Time does not permit relating the facts gained from several dozen experiments and approaches that failed, - however, a summary of the findings to date might set the stage for somebody to come up with a complete solution.

1. The 23 Mc. I.F. was at least 10 db. better than the 10.7 I.F. in regard to impulse noise level heard in the subcarrier.

2. The limiting action definitely was functioning correctly and even a lightning bolt could hardly be heard in the main channel.

3. The receiver itself was allowing the noise voltages to frequency modulate the carrier and all of its components.

4. This unwanted modulation was also being imposed upon the main channel audio but was not heard out of the loudspeaker because the human ear does not have a built-in phase shift detector.

5. Visual observation of the wave behavior during noise bursts with audio tones showed the same effect on the scope with 5000, 10,000, 15,000 and 20,000 cps. modulation applied to the main channel. Various levels of modulation did not affect the amount of intermodulation by the noise. De-emphasis did not change the amount of phase shifts observed.

6. The degree of noise modulation increased directly as the modulating tone was raised in frequency. EUREKA! Here is a sudden explanation why several of our customers have observed less noise in the 26 Kc. subcarrier receivers.

7. Antenna location and lead-in treatment is important (that is until the receiver can reject the noise).

From this summary of facts related to the problem of noise we are very optimistic in expecting successful results.

In the San Francisco case earlier described, several steps towards relief are suggested. First, place the receiver on the rooftop near the antenna and feed the audio down the existing twin lead. Second, if this is not possible, use an antenna booster similar to the fringe area TV boosters that are mounted on the antenna mast and supplied 24 volts AC through the same lead in that is used for the R.F. signal. Third, replace the twin lead with co-ax. Any of these steps would give the receiver more signal and less noise.

I have now outlined how the cross-talk problem was eliminated, how the full use of subcarrier bandwidth and audio equalization provided improved performance, and stated the noise problem situation that is being worked on. Now I am going to tell you about an unusual application of multiplex techniques related to the regular multiplex system.

At KSL in Salt Lake City, Utah, a new situation presented itself. The KSL-FM transmitter was located on top of a mountain 9600 feet high. Along with the TV transmitter all program material came from the downtown studio 18 miles airline away via various microwave STL units, since not a single telephone line could be run up the mountain.

Adding two multiplex channels would require two more audio links from the studio. This was economically more expensive than the returns from multiplexing would warrant.

The existing 946 Mc. microwave STL system was rebuilt to enable successful operation of the system.

The STL transmitter proved simple to modify by the addition of phase angle modulation method at the 2nd tripler stage after the original reactance controlled oscillator. Our standard two channel subcarrier generator was placed next to the STL transmitter location adjacent to the TV studio control room in the city. This unit delivered the regular 26 Kc. and 65 Kc. modulated subcarriers to the STL auxiliary phase angle modulation point. Also injected was a 175 Kc. subcarrier from a custom built generator unit also installed at the studio.

The 175 Kc. subcarrier was designed to more than meet the Commission's standards for main channel operation since it was to carry that audio to the mountain.

The receiver end of the 946 Mc. STL requires more extensive rebuilding as it was guilty of serious intermodulation throughout. The original R.F. head was retained to convert 946 Mc. to 123 Mc. This signal was introduced into one of our regular multiplex receivers at the regular antenna terminals. After amplification and mixing the 123 Mc. was converted to 23 Mc. and thence to the I.F. strip and the balanced ratio detector.

The three subcarrier signals demodulated at this point were then routed as follows: The 175 Kc. went through a bandpass filter that allowed plus or minus 17.5 peak deviation without distortion after which it was amplified, limited, and demodulated. A low distortion audio amplifier following this fed the audio into the regular audio input terminals of the main channel exciter.

On the other hand, the 26 Kc. and 65 Kc. subcarriers appearing at the 23 Mc. ratio detector passed through filters similar to the regular ones used in our receivers and after two stages of class A amplification were applied at the auxiliary modulator of the exciter just as if the two channel generator was sitting there, as is the normal situation. The two channels were not demodulated before being applied to the main transmitter.

Metering was provided at the studio to enable supervision of all functions including measuring the frequency of the third subcarrier as well as the regular two. The original reactance control STL modulator can still be used as long as it is not pushed into the region that causes intermodulation into the three subcarriers. This occurred in the transmitter end and not the receiver part. Without disturbing the three supersonic channels a signal to noise ratio of 40 db. was obtained. This original channel is being used for a standby program loop as well as for a talk circuit.

The net result was obtaining four channels to the mountain from the modified 946 Mc. STL.

In summarizing I believe I have outlined the true nature of multiplex receiver developments and presented our engineering approaches in the hopes of more successful application of this unique form of communication allied with the broadcast industry.

Those of you already using multiplexing will vouch that it has been on a commercial level for some time. The management and engineer awareness of necessary operating techniques has earned money. To those of you who are contemplating the use of multiplexing, I hope this presentation has impressed you of the high level of performance that is now available if you desire it.

The major problems have been licked. The bugs are out. The way is cleared for the engineering of added refinements (such as the noise in weak signal areas). More excitement is in the near future with the forthcoming application of multiplexing to provide broadcasts to the public of a high fidelity stereo service.

Like all devout radio amateurs, I get great fun out of detailing the many lash-ups that didn't work. If some of this ham technique slipped into this presentation, it is only because the things that didn't work taught me the most and are therefore foremost in my mind.

"Vibration Problems in Tall Tower Construction"

by

J. Roger Hayden
Dresser-Ideco Company
Columbus 8, Ohio

This paper will be devoted to a fairly new set of problems which have arisen to plague a structural engineer. These may be stated simply as "Vibration Problems". I will try to show you some of the different styles of vibration and some of the methods which have been developed to control or to minimize this style of loading in the design and construction of towers.

Almost every structure designed by a structural engineer today is calculated to resist a static load with the structure being stationary with respect to the load. However, many loads today are dynamic in nature instead of static. Very simply a dynamic load is one applied to a moving structure causing the rate of movement to change. An engineer today transforms a dynamic load into a static load by applying an impact factor to a load and using the result or static load in the design. For example: a gusty wind is treated as a static load by multiplying the design load by a factor which is usually 1.3. This product then becomes the true design load and is considered as a static load. The moving load is transformed into a stationary load so that the structural problem may be solved.

However, this type of treatment may not always do the job. If the gusty style loading is repeated at a constant rate and is in tune with the natural vibration of the structure in question, the movement may tend to build up into dangerous or at least disturbing movements.

In tower construction the greatest movement has been observed in long guys having the same area throughout their length although some vibration has been observed in fairly long members in self-supporting structures. Any vibration in a member of a self-supporting tower is difficult if not impossible to predict but is easy to control by the use of additional members which shorten the span of the member so that the vibration is stopped. Shortening the span simply changes the period of the member as well as increasing the stiffners of the member.

Many times the rapid movements of a long slender member in a self-supporting tower are annoying because of the noise generated. A long steel member can sound like a parade of garbage cans with the right conditions of wind and member length.

This style vibration is not difficult to handle and as a general rule is not dangerous.

The vibration in a long guy must be handled in a different manner. The stiffness of a bridge cable cannot be increased by additional members nor can the span be changed very simply. The one thing that can be changed fairly easily is the load in the guy. This change in loading will prevent any constant increase in guy movements. Vibration in a guy will change the direction of any portion of the guy. If a device is attached to any portion of the guy which will resist a change in direction of the guy, this has the effect of adding a load to the guy wire.

Two different types of movement have been observed in tower guys. The most common is a high-frequency oscillation of about 30 cycles per second which has been observed in guy cables under a steady wind of 35 miles per hour or less. This style movement may be felt by placing a hand on a guy wire. As a general rule this type oscillation cannot be seen by the eye.

The second style movement is a fairly slow galloping of one cycle per second or less under a wind of 15 to 25 miles per hour. This style movement has only been observed in guy wires which have been coated with ice forming a different style shape and which has a different characteristic under a wind than the normal circular cable. This style movement is infrequent and is not regarded as dangerous by the structural engineer. However, this rather slow ponderous motion is disturbing to watch and should not be allowed to continue for any length of time.

A high-frequency vibration which continues over a long period of time can well cause fatigue in the metals and lead to failure. In a guy cable the failure can start in the small wires which make up the finished cable. Sometimes the vibrations from the guy wires cause movements in the tower proper with damage to equipment mounted on the tower. Since this style oscillation happens frequently, some means of controlling the movement should be used.

In order to control high-frequency vibration in the guys a number of different methods have been used but in general the principal was exactly the same. A weight having an inertia against any movement out of line with the guy wire is inserted in the guy assembly.

The first style dampener used in the guy wires of a tower were not regarded or designed as dampeners. They were AM tower guy insulators. The weight of the insulators plus the slight change in the stiffness of the insulator assembly over the guy wire stiffness added an inertia to the assembly which resisted any change in position along the guy wires. As a result of this secondary feature of guy insulators, the cables in an AM tower have not been inclined to oscillate to any great degree.

The first television tower over 1000 feet in height was constructed for WSB at Atlanta, Georgia and the guy wires were not insulated. The oscillation in the guys was considered in the design and rather long, heavy weights were attached to the guys at intervals to provide an inertia load which would resist movement.

At a later date another style inertia device was adopted. This device is known as a stockbridge dampener and consists of a pair of weights suspended from a guy cable by an arm giving the weight quite a bit of leverage to act against any oscillation of the guy. Once again, this is an inertia device resisting movement from a straight line.

All of the above style dampeners are used to reduce a high-frequency oscillation to a minimum. Since this style movement is fairly constant, this type control should be used on large guyed structures.

Some AM towers in the past have had guy wires that oscillate in a rotary or twisting fashion. This has never been objectionable nor has any record of failure of material developed from this style movement. However, if this were to develop, a stockbridge dampener could be suspended at right angles to the guy wire which would effectively resist a twisting motion.

A high-frequency oscillation in the tower bracing where the bracing is long and slender has been observed in a few instances. This is usually shown by a flutter in the member and is best controlled by increasing the stiffness of the member through the use of additional bracing. Brace rods used in pairs have been effected by wind turbulence or vortexes spilling off of the front or windward rod and caused vibration. This has been observed with rod or circular members only. The solution in this case is to tie the members together so that turbulence from one will not effect the other.

A low frequency galloping of the guy wires is a different style problem. The only records of this style of movement shows that this occurs when guys are covered with ice and a moderate even wind flows across the guys. A lift developes and the guys move in a rather large arc.

Fortunately, this happens at infrequent intervals when the ice coating and the wind velocities combine to produce this effect. Since the movements are slow and ponderous, the loads in the guy cables are not great and the tendency for fatigue stresses developing are slight.

To date, this problem has not been solved although the movement can be controlled by a number of different mechanical methods of attaching a heavy weight to the galloping cable.

We have found that a fairly heavy weight could be attached to the guy cable about 15 feet above the anchor and the movement could be stopped. However, it is not desirable to have this weight on the guy cables when a heavy wind storm is encountered. So the only recommendations to date are to control the movement when trouble appears.

In some instances the weight of a man has been sufficient to stop the movement of the guys. A tractor has also been attached to the guy wires and has stopped the movement.

A tower in Texas, built for WFAA-KRLD has a permanent means of controlling this style movement although this is mechanical and is not automatic. A concrete block was installed below each guy cable and a steel cable was attached to a chain hoist which was attached to the concrete block. This steel cable is slack at all times until icing occurs and the wind starts a movement in the guy cables. Then a man tightens the hoist until the movement is stopped.

Another method which has been tried consists of suspending a weight which increases when an upward motion is applied. This has consisted of a spring loaded device and has not been completely successful.

Still another suggestion is a suspended weight moving on an inclined plane with the incline increasing so that the force increases with an upward movement. This method is extremely expensive and has not been tried. The principle is the same.

This style movement is being studied by the American Institute of Electrical Engineers and further improvements in the art may be expected in the future.

I have two short movies showing examples of vibration. The first of these shows the cables of a tall tower moving under a moderate wind while covered with ice. This condition is the low frequency style vibration mentioned previously in this paper and was controlled by mechancial means.

The second movie shows the collapse of the Tacoma Narrows suspension bridge. This style movement is not a true galloping but has been described as a flutter plus a gallop. The wind through the Narrows bridge is extremely constant and moves at a uniform speed. This style movement has never been observed in any tall tower and is not expected to develop. The cause and result are from an extirely different set of conditions than that prevailing around a tower. However, I present this movie to show an extreme effect of a dynamic load on a structure as well as showing what is to me an exciting scene.

EFFECTIVE LIGHTING AND MARKING FOR RADIO AND TELEVISION TOWERS

Orrin W. Towner
Director of Engineering
WHAS, Inc.

March 1959

Effective Lighting and Marking for Radio and Television Towers

Introduction

In 1953 NARTB asked broadcast stations for suggestions concerning tower marking and lighting. WHAS, Inc. responded by setting up a program of experimentation and on October 6, 1954 authorization for initiating this program was received from the Washington office of the CAA. On February 16, 1955 an experimental system was installed on the 654' high WHAS Radio tower, Figure 1, located in rural surroundings two miles North of Eastwood, Kentucky (about 18 miles East of the center of Louisville.)

In setting up the criteria for this experimental installation, and in its continuing development, the requirements of aircraft pilots were given first consideration. Several members of the Engineering Department of WHAS, Inc. have been pilots and it has been their belief for some years that the existing requirements for marking and lighting of towers are inadequate. Ideally, a tower identification system should make a tower location evident to any alert pilot of an aircraft while he is at a safe distance. Theoretically this could be a system of electronic range finding designed to advise any aircraft when it approached within 5 or 3 miles of a tower. However, this presupposes electronic equipment to respond to this signal in all aircraft, which, of course, does not exist. It is, therefore, impossible from a practical standpoint to use radio equipment as an obstacle indicator. The need, therefore, is for aids to help V.F.R. pilots in good weather as well as under conditions of poor visibility. Indication of obstacles is vitally necessary for those pilots whose planes are without sufficient instrumentation (either due to equipment failure or the complete absence of it) and who through circumstance are caught by weather changes and are attempting to make the nearest airport or reasonable field, usually at a low altitude and with poor visibility. These requirements limit consideration to specialized lighting and other methods for increasing visual contrast, which do not require instruments for detection.

This developmental program has extended over four years and has resulted in the recommendation of the following innovations:

1. Multiple white beacons installed on the tower.
2. A white beacon located at each outer guy anchor.
3. One red beacon located approximately 50 feet above the tower base.
4. Use of two voltages on the beacon lamps controlled by a transmissometer.
5. All beacons synchronized.
6. Precise 30 flashes per minute.
7. Sun mirrors.
8. White marking on the ground.
9. Towers painted with black and white bands.

Lighting

The effectiveness of the pre-war rotating airways beacons, and the rotating red beacon which has operated on the WHAS transmitter building for the past 21 years, indicated that this type of high intensity beacon would be most effective. However, the selection of a red light source as is currently specified is most inefficient in view of the fact that the filter efficiency at the lamp source is only 10% to 15% of that of white light. As greater light output is required, it is, therefore, considered essential that the light source be unfiltered "white" light.

Four beacons are presently mounted on the tower. The bottom one is approximately 100 feet from the ground and the upper one is located on top of the tower structure, with the third and fourth located approximately equidistant between them. This bottom beacon is located to provide extra visibility for the low flying V.F.R. pilot caught with a very low ceiling.

The beacons, still in service, were especially manufactured by the Westinghouse Electric Corporation for this purpose, Figure 2. This beacon uses a mechanical occulting method in place of presently specified flashing light sources. This results in a much sharper contrast between ON and OFF than possible when using a flasher. These experimental beacons flash 30 times per minute with the candle power varying from 19,000 to essentially zero during the OFF period (as compared with 1800 CP maximum for the present flashing beacons.) The light source is a mercury vapor lamp with a rated life of 6000 hours and after three years of operation the only lamp which failed in service had operated 7138 hours.

Because the four beacons used on the tower are the only ones manufactured, smaller modified incandescent rotating units were installed at each outer guy anchor of this test installation so that the system aspects of this group of lights could be studied. A photograph of the 8 beacons near sundown is shown in Figure 10.

There was originally some question as to the comparative effectiveness of a red beam mixed with white. Because this beacon radiates three beams of light simultaneously while it rotates, it was possible to change the color of one beam by installing a red filter in front of it. Therefore, shortly after installation two of the beacons were temporarily modified to utilize 1000 watt incandescent bulbs in order to provide a source of red light. A pilot viewing the beacon would see in sequence white, white, red and then repeat. These two modified beacons were reinstalled on the tower for comparative purposes. The ineffectiveness of the third or red beam of the converted beacons was such that at reasonable distances or under poor visibility conditions it was of no effective value. At the end of approximately six months operation these two beacons were refitted with their original mercury vapor light source because of the very poor visibility of the red beam.

These experimental beacons have been controlled for over a year by a photocell which turns the beacons on whenever the North light intensity decreases below 500 foot candles. The effectiveness of the beacons and the sun reflectors overlap near sunset and after sunrise until the North light reaches approximately 1000 foot candles. It appears that this higher value should be used. To use the beacons only after the light has dropped to 50 foot candles would cause the loss of many hours of effective use. Figure 5 shows a typical case showing the part of the day that the beacons would be used during cloudy weather in the Louisville area.

Many people suggested the use of red neon tubing along the legs of a tower for identification purposes. In order to make a comparison between the capabilities of the two types of light, 200 feet of 15mm red neon tubing was installed on one leg of the tower while the experimental beacons were in service. During flight tests, at a distance of 7 to 8 miles, with visibility better than 10 miles, the neon tubes could not be seen without looking very closely while the light beams from the beacons were most obvious. After these tests had been made the neon tubing was turned off because it was so ineffective.

Throughout these tests the standard 100 watt red bracket lights have been in service. Due to their exceedingly small light output they are completely ineffective and not visible except at close range and, therefore, are considered unnecessary for a tower identification system.

A study of the effectiveness of these beacons indicated that considerably more impact with quicker perception would be possible by synchronizing the units. With all beacon lights visible to the pilot at the same moment the complete outline of the obstruction area is shown instantaneously as is illustrated in Figure 9, a photograph of a model of this lighting system. This removes the necessity for mental integration of the information coming from the lights, which would be required if they were visible at random times. Pilots comments have confirmed these results, and one commercial pilot, a veteran of over 20 years, said "the high intensity lights that are synchronized together give the complete outline of the tower and is the best obstruction lighting I have ever seen."

In order to obtain an approximate idea of the effectiveness of the tower lights, ground observations were made from September 1955 to April 1958 and general comments were recorded by the operating personnel of WHAS on their way to work at the tower location. The night shift, starting at 11:00 P.M., provided a convenient time for observations. Personnel arrived by means of a highway which has a clear view of the tower from a point 3.1 miles Southwest. The data also shows visibility as measured at Standiford Field, which although not necessarily accurate for the tower location is generally indictive of conditions. By

January 1, 1958, 753 night observations had been made, and of these 49 were made when visibility was reported as three miles or under. Of this group of poor visibility observations, 22 out of 23 indicate that the beacons were visible at our 3.1 mile ground check point when visibility was reported as 3 miles.

There has been much discussion of a condenser discharge warning light of sufficient intensity which might be visible under conditions of very low visibility. In order to determine if there was any practical application for the use of these multi-million candle power lamps, a modification was made to a lighting unit similar to the condenser discharge lights now being used at a few large airports. It was adjusted to flash 30 times per minute and was installed at the 400 foot level of the WHAS tower for a few months during the summer of 1958. The light was controlled from the Radio transmitter building near the base of the tower, and was turned on only when the visibility was reported to be under 3 miles. Ground observations were made during poor visibility conditions to determine the lights useful range. Although application of the Blondel-Ray formula predicted that its effectiveness would be poor, comments from aviation sources had indicated that it was promising. However, the experimental results were very disappointing so the unit was discarded.

Our final recommendations do not include the use of mercury vapor beacons similar to the experimental ones now in use for three reasons not easily corrected: First, the light intensity from the beacon is insufficient to meet the 3 mile meteorological range requirement. Second, an undesirable period of from five to ten minutes is required by the mercury vapor bulb after the power is momentarily interrupted, before light output is again obtained. Third, under certain temperature conditions the light output of the mercury vapor bulb has a greenish cast which is objectionable from a safety standpoint.

Marking

During days when the sun is out a tower requires either illumination with sufficient intensity to produce reasonable contrast with its background, or sources of reflected illumination to accomplish the same purpose. Rotating mirrors installed at the outer guy anchors and at one or two locations in the tower have proven satisfactory. Figure 3 shows the progressive development of these units. These units have mirror faces approximately 2 feet by 4 feet and in all but the first the reflecting unit is mounted in gimbals so as to allow rotation about two axes. The two latest units shown have mirrors that rotate at a speed of approximately 350 RPM, while the supporting frame rotates about 6 RPM, with its axis kept perpendicular to the sun by either a photoelectric servo system or a clock timer. Although full rotation of the mirror frame is not necessary in order to properly reflect the sun in all directions, it was considered more desirable mechanically than an oscillating movement. At the present time two reflectors are mounted on the WHAS tower and one on the roof of the transmitter building about 700 feet away. Flashes of light have been seen during flight tests of these units over 8 miles away. One model under life test on the tower operated 3210 hours continuously without servicing.

Near sunset or sunrise when a plane could be "flying into the sun" our experience has indicated that bright objects can usually be seen if they are located several diameters of the sun away from it. Due to the physical dimensions of a tall tower the reflectors would span a considerably greater distance than this minimum. For example, a 2000 foot tower might require an outer guy anchor diameter of approximately 3500 feet. A pilot would have to be approximately 70 miles away for a circle of this size to appear to equal the diameter of the sun. This would increase to about 20 times the sun's diameter when flying 3 miles away, thus there should be adequate separation of the mirrors. Even for 1000 foot towers with half these dimensions, the distance between the mirrors should be sufficient.

In order to aid in the identification of a tower after the reflectors have indicated its presence, a circular area of crushed rock painted white and 100 feet in diameter was constructed around the foot of the tower. This aids in its location under many visual conditions when the tower blends into the background. Investigation of further ground marking led to the installation of an annular ring of similar crushed rock approximately 800 feet in diameter and 12 feet wide. Under hazy conditions when the WHAS tower, painted in accordance with present requirements, was indistinguishable, this extra ground marking stood out well. The suggestion had been made by the AGA Ad Hoc committee that the annular ring should be divided into 16 segments with alternate white and international orange coloring. The rock was painted in this manner in one 90° sector and after test flights the obvious loss of contrast was so great that this proposal was immediately abandoned. This ground marking provides excellent identification when planes are high, and near the tower, as shown on the top photograph of Figure 4 which was taken from an altitude of 1200 feet, 1 mile from the tower. However, it is of less value when the pilot is flying at low altitudes as shown in the lower photograph of Figure 4 from an altitude of 450 feet, 1 mile away. Therefore, only the center circular area was considered useful.

A standard "HAZ" marker, as specified in the CAA publication, "Obstruction, Marking and Lighting - 1953," was constructed adjacent to one of the tower guy anchors. Its lack of effectiveness is obvious from the photographs, Figures 1 and 4 where it can barely be seen in spite of the fact that it was painted in accordance with the specifications. It is located at the break in the right near side of the white annular ring in Figure 4. This marker is of no value to low flying aircraft, as when it can be seen the pilot will be too close, or the aircraft will be too high to be concerned with the tower. In respect to this particular marker it was quite disturbing to discover that many pilots had no conception of its meaning, and because of its similarity to the station call letters, many asked when the "W" would be installed. When the "HAZ" marker was first constructed, neon tubing was installed to light it for night use. However, the same deficiencies applied at night as during the day.

No experimental painting of the WHAS tower structure was planned. Although the greatest possible contrast can be obtained by the use of black and white bands, the present international orange specifications are only a few percent less efficient. Weathered international orange paint was measured and found to have 13½ percent reflectance as against approximately 5 percent or less for black paint. International orange appears to be poor from an over-all visibility standpoint in this geographic area because the usual background does not provide maximum contrast.

Tests show that visibility of extremely long rectangular objects is greater than short ones, therefore it appears that the present specifications for narrow bands of international orange and white should be changed. We recommend that the present 1½ foot to 40 foot band width specification be replaced by 50 foot to 150 foot width bands with the greater dimensions being used on all towers over 1000 feet. It is also recommended that the bottom band be black, for contrast with the circular area of white crushed rock placed around the base of the tower. The top segment should also be black for maximum contrast with the sky.

Model Tests

During 1958, the difficulty of obtaining quantitative data resulted in WHAS, Inc. retaining Dr. H. Richard Blackwell, Director - Vision Research Laboratories, University of Michigan (now Director - Institute For Research In Vision, Ohio State University Research Center, Columbus, Ohio.) He proposed a series of psychophysical tests utilizing a scale model of a tall tower with marking and lighting, immersed in artificial fog.

An accurate model of the proposed 1860 foot WHAS television tower was constructed, using a scale of 1 to 400 and duplicating all important features. This model was painted with scaled 50 foot bands of international orange and white (the minimum dimension proposed) and was lighted by 6 minature lamps on the tower and 6 at the outer guy anchor locations. All of these lights were flashed together, 1 second ON and 1 second OFF (30 flashes per minute.) A scaled 100 foot diameter white circle was constructed at the base of the tower. The base was painted green, with a reflectance of 18%. The color was selected to approach summer conditions in this geographic area.

The model was taken to Ann Arbor, Michigan where Dr. Blackwell had his staff construct a "tunnel" shown on Figure 6. This consisted of a wooden framework approximately 8 feet wide and 10 feet high in cross section and 70 feet long, the entire structure being covered with translucent plastic sheeting. A small observation compartment was separated from the chamber containing the model by a plate glass window. Within the chamber, artificial fog could be generated with any density required, while in the observation room measurements of the fog transmittance were made by a photoelectric photometer as well as the measurement of contrast reduction by means of large black discs. Data were taken only on cloudy days when the illumination penetrating the fog would be uniform as is the actual case. No nighttime data were recorded as the daytime condition is more severe. The model was set on tracks so that its position could be changed in respect to the observation point with a scaled movement up to 5 miles.

After observations of the model were made through the fog Dr. Blackwell suggested that white radial strips would be psychologically helpful. These strips were scaled to 12½ foot width and were installed from the central circular area to each outer guy anchor. They were a definite aid in the location of the central circular area under conditions of reduced visibility, so they became a permanent part of the model for all of the visibility tests.

Due to the existance of aviation rules based upon visibility at 1, 3 and 5 miles (called meteorological range,) data were taken so as to obtain information under these three conditions. The first data were taken of each component of the marking system; the tower, the base circular area and the radial strips. Data for the unlit tower alone during daylight was determined to be as follows:

Meteorological Range In Miles (MR)	Visual Range In Miles (VR)
1	1.24
3	3.37
5	5.16

At 1600 foot altitude the circular area was visible at a distance of 1.3 miles under conditions of 1 mile MR and 3.08 miles for a 3 mile MR. The radial strips also at 1600 foot altitude were visible for 1.48 miles and 3.62 miles for 1 and 3 miles MR respectively. All of the above data were taken with the tower background brightness of 282 foot lamberts - the expected daytime value under conditions of reduced visibility.

These data show that when pilots know approximately where to look (in other words, dead ahead for a collision course) they could see important components of the tower marking complex during the day time at visual ranges beyond the MR without the addition of lights. Considering the entire tower marking configuration under conditions of a 5 mile MR, only the tower would be visible at 5 miles. For a 3 mile and a 1 mile MR the tower, center disc and radial strips would be visible at 3 and 1 miles respectively.

Superimposing on this complex the 6 rotating beacons on the tower, each producing 855,000 CP and 6 at outer guy anchor points, the VR (visual range) increases to the following values:

MR In Miles	VR In Miles
1	1.79
2	3.30
3	4.62
4	5.80
5	6.80

The above data are based upon an illumination safety factor of $2\frac{1}{2}$ created by the use of a background brightness of 730 foot lamberts in the calculations instead of the published average of 292 foot lamberts.

Under conditions of 3 miles MR with the beacon light output reduced to 142,500 CP the VR will be 3.08 miles. This candle power reduction is the result of installing red filters on the 855,000 CP beacon.

The proposed beacon providing 30 flashes per minute with a beam of 855,000 CP is a modified version of a 24 inch double drum aviation beacon such as the Westinghouse DGC-24 inch Double End Airport Beacon, Figure 7. The modifications include the use of a 1500 watt lamp, rotation increased to 15 RPM, with a synchronous motor and a lens system providing over 10° vertical beam spread while maintaining the 5° horizontal degree spread. Synchronized indicator circuits would also be added.

The use of this beacon permits its use 24 hours per day, replacing mirrors during sun lit hours. Assuming a maximum of 3,000 foot lamberts background brightness during daytime this beacon when operating at 50% light output or 427,000 CP would have a maximum visual range of 7.65 miles.

Standard aviation beacon lamps usually have a rated life of 500 hours, which has prevented their use for tower lighting in the past. This short life can be lengthened for use in lighting towers because fortunately the maximum output of the beacon is required only a small percentage of the time. On a clear night even a 600 CP flashing beacon is visible at great distances and during clear day light hours full output is not required as was indicated by the figures previously given. If the normal operating voltage on the beacon lamps is held to 95% rating the life is doubled while the output is reduced 15%. The data show that this leeway is available. Under good visibility conditions the beacon output can be reduced over half safely. Fifty percent output may be obtained by reducing the voltage on the beacon lamp to approximately 80% of the rated voltage. This reduction results in an approximate increase of 1300% in life making this lamp practical for tower lighting. Based upon Louisville data, where the visibility is 3 miles or less approximately 4% of the time, and is under 6 miles for less than 20% of the time, calculations show that for a 24 hour per day operation one lamp would last over 6 months or more than 4000 hours. Additional safety is available as the proposed beacons have automatic lamp changers, effectively doubling the length of the safe maintenance period.

The control required to make this voltage change would be a transmissometer which simply measures the received light at the bottom of the tower from a special source at the top. Calibrated for the equivalent of 5 miles MR the transmissometer would hold the applied lamp voltage to the lower 80% value until reducing visibility caused the control to drop out, thus letting the normally open contacts apply the higher voltage to the lamps. This would be a fail safe operation as any malfunction would cause full voltage to be applied to the beacons.

Operation over four years with the experimental beacons, still in use, indicates that the lighting of towers up to 1000 feet high, which are of concern primarily to V.F.R. pilots, should be sufficient to meet the visibility requirements of 3 miles under conditions of a 3 mile MR. Towers over 1000 feet high should meet the more severe requirement of 5 miles visibility under conditions of a 5 mile MR. This latter requirement can be met by the 24 inch double drum beacon, bottom, Figure 7, while the former requirement could be met by a smaller unit such as the Crouse-Hinds Type DCB-10 rotating beacon (upper picture, Figure 7.) It would require modification to provide a 1000 watt lamp, 15 RPM by means of a synchronous motor, a synchronizing device, side light shields and a lens system to increase the vertical beam spread to approximately 10°, and the horizontal beam spread to 5°.

The availability of high intensity beacons, with a light output which approaches that of the specular reflection from a mirror permits the use of either rotating mirrors or beacons, during the hours of sunshine, therefore the decision becomes an economic one. We, therefore, are recommending the use of mirrors with the small beacons (for towers under 1000 feet) and recommend the installation of only the large beacons operating continuously 24 hours a day on the higher towers. Individual situations affecting the economics of each installation will determine whether mirrors are justified or not.

We wish to acknowledge the many contributions of the Technical Department of WHAS, Incorporated. Special recognition should be given to Mr. W. B. Howard who was largely responsible for the construction of the light model and the very tedious construction of the scale model and to Mr. L. G. Hewitt who made all of the experimental beacon modifications and was responsible for the mechanical design of the many sun reflectors as well as their construction.

Recommendations

Towers 1000 Feet and Above

1. Install a minimum of four clear lens 24-inch double drum rotating beacons on the tower (similar to Westinghouse 24-inch Double End Airport Beacon, bottom, Figure 7.) These units to be equipped with 1500 watt bulbs, lenses to provide approximately 900,000 beam CP with 5° horizontal and 10° vertical beam spread, rotation at 15 RPM (30 flashes per minute) and synchronizing equipment.

   Locate the bottom beacon between 100 and 150 feet above the ground and the top one at the top of the antenna. The other beacons should be located approximately equidistant between them, but not exceeding 450 feet apart.

2. Install one similar rotating beacon, except with red lenses, located on the tower between 50 and 75 feet from the bottom.

3. All beacons to be synchronized and to operate continuously (24 hours per day) with 80% voltage applied to the lamp (approximately 50% light output) except that 95% rated voltage is to be applied to the lamp whenever the meteorological range drops to 5 miles or less.

4. Paint the tower with alternate bands of black and white, 100 to 150 feet wide, with the top and bottom bands to be black and 100 feet wide.

5. Construct a white circular area 100 feet in diameter on the ground with the tower base as the center. Extending from this area construct white strips 10 to 15 feet wide extending to each outer guy anchor. The width to be determined by multiplying width (in feet) times the reflectance of the surfacing material (in percentage) and this must equal 725. This surface can be obtained by using painted rock, white Portland cement, marble chips, etc.

6. Self-supporting towers would omit the ground radials and guy anchor beacons. If the antenna cannot support a 24-inch beacon at the top, a unit as specified below should be used with the highest 24-inch beacon being located not over 200 feet below. Figure 8 shows a vertical and horizontal view of a 1860 foot tower following the above recommendations.

Towers Under 1000 Feet

1. Install on the tower a minimum of three clear lens rotating beacons (similar to Crouse-Hinds Type DCB-10 rotating beacon - upper picture, Figure 7) modified to utilize a 1000 watt lamp, 15 RPM by means of a synchronous motor with a synchronizing device, side light shields and a lens system to provide approximately 5^{o} horizontal and 10^{o} vertical beam spread.

   Locate the bottom beacon between 100 and 150 feet above the ground and the top one at the top of the antenna. The other beacons should be located approximately equidistant between them, but not exceeding 300 feet apart.

2. Install one similar rotating beacon, except with red lenses located on the tower between 50 and 75 feet from the bottom.

3. All beacons to be synchronized and to be automatically turned on whenever the North light intensity is less than 1000 foot candles or by a sun light relay which would turn them off whenever the sun was shining.

4. Sun reflectors similar to those shown at the bottom of Figure 3 to be installed at each guy anchor and at two levels on the tower. These should be operated from sunrise to sunset.

5. Paint the tower with alternate bands of black and white, 50 to 100 feet wide, with the top and bottom bands to be black and 100 feet wide.

6. Construct a white circular area 100 feet in diameter on the ground with the tower base as the center. Extending from this area construct white strips 10 to 15 feet wide extending to each outer guy anchor. The width to be determined by multiplying width (in feet) times the reflectance of the surfacing material (in percentage) and this must equal 725. This surface can be obtained by using painted rock, white Portland cement, marble chips, etc.

7. Self-supporting towers would omit the ground radials, guy anchor beacons and reflectors.

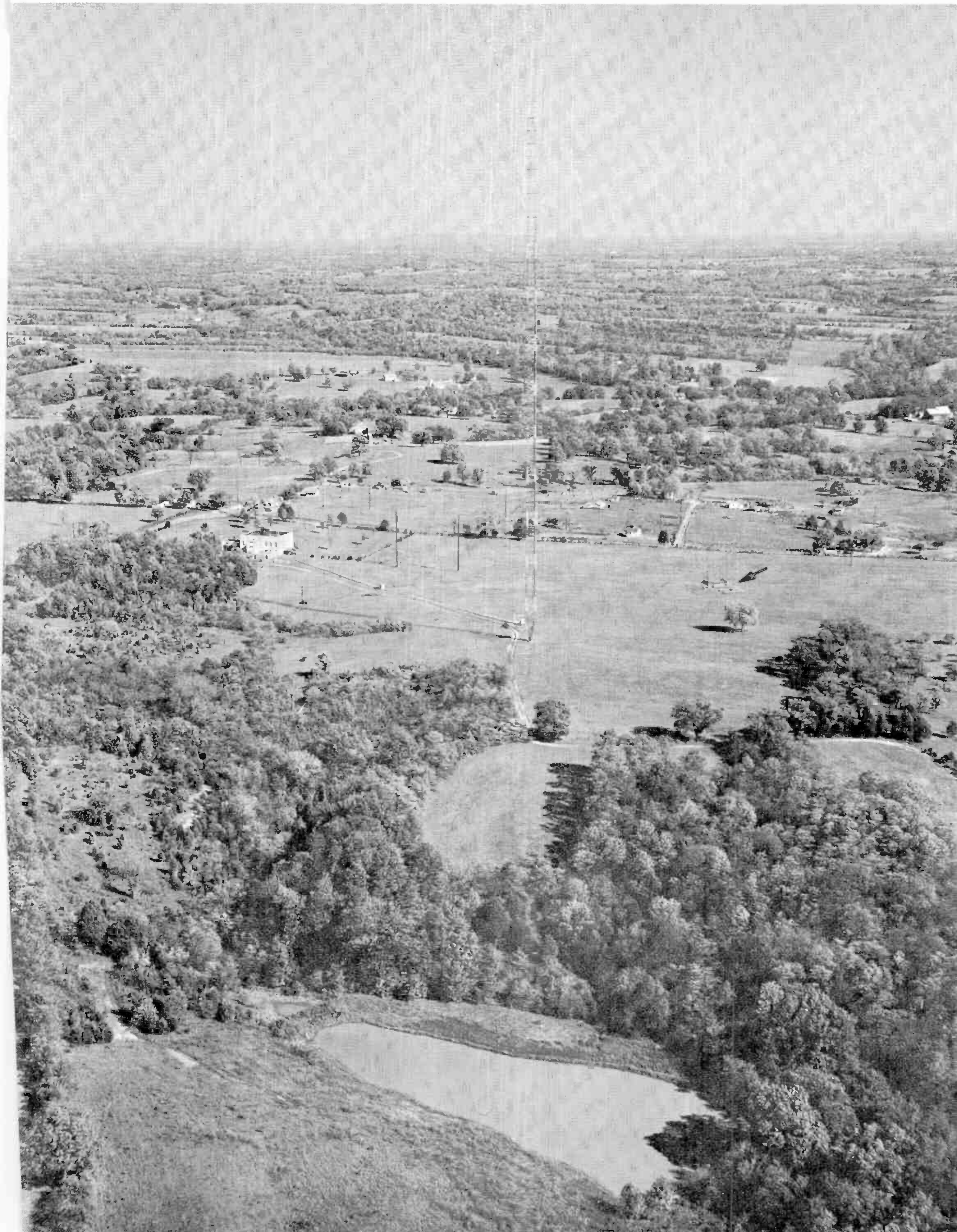


FIG. 1

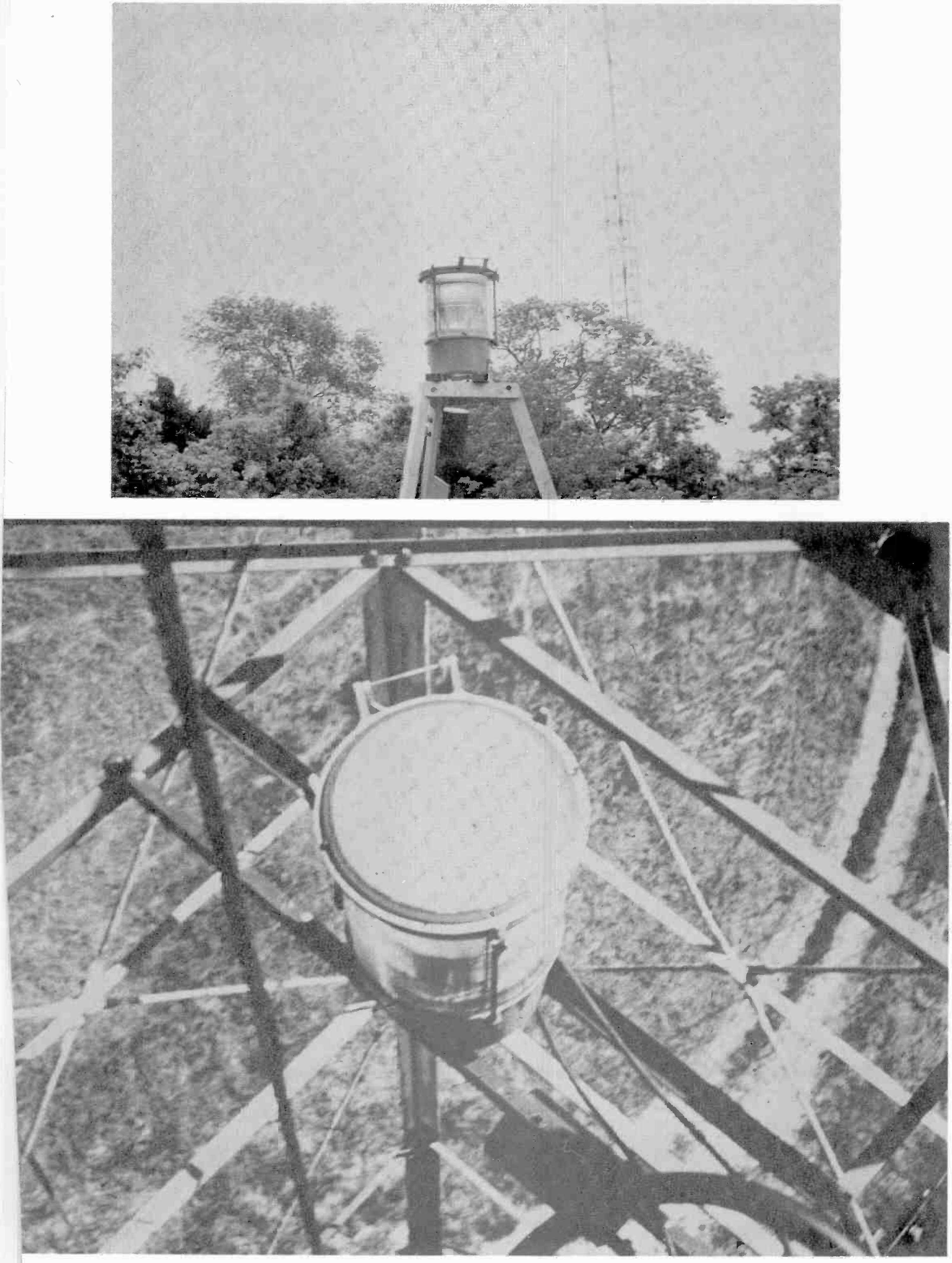
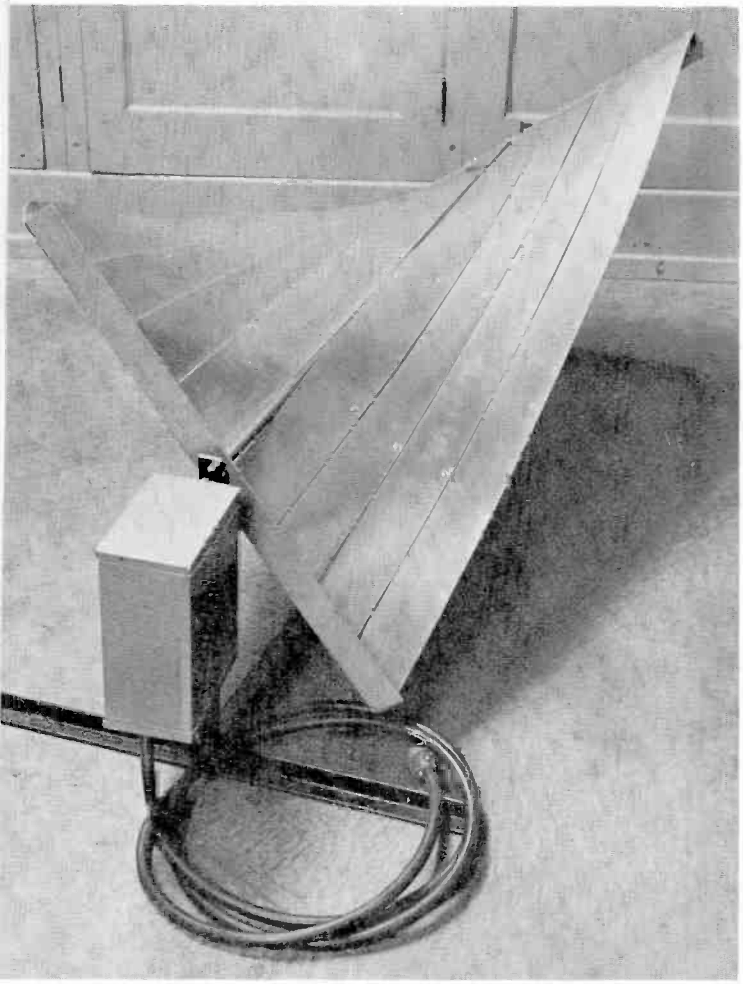
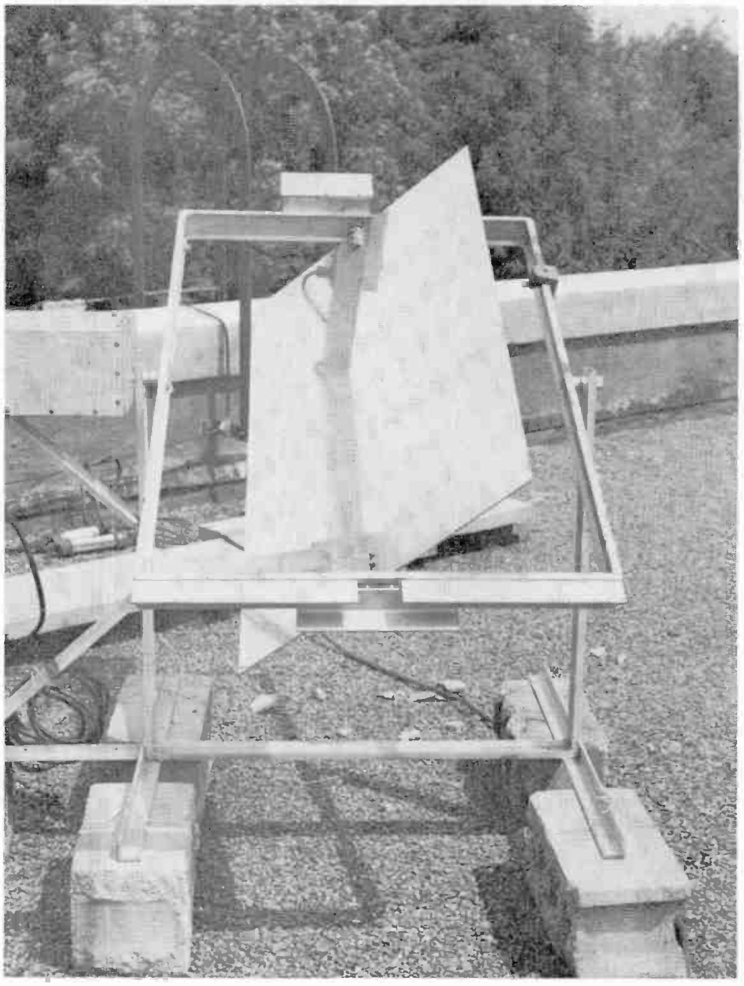
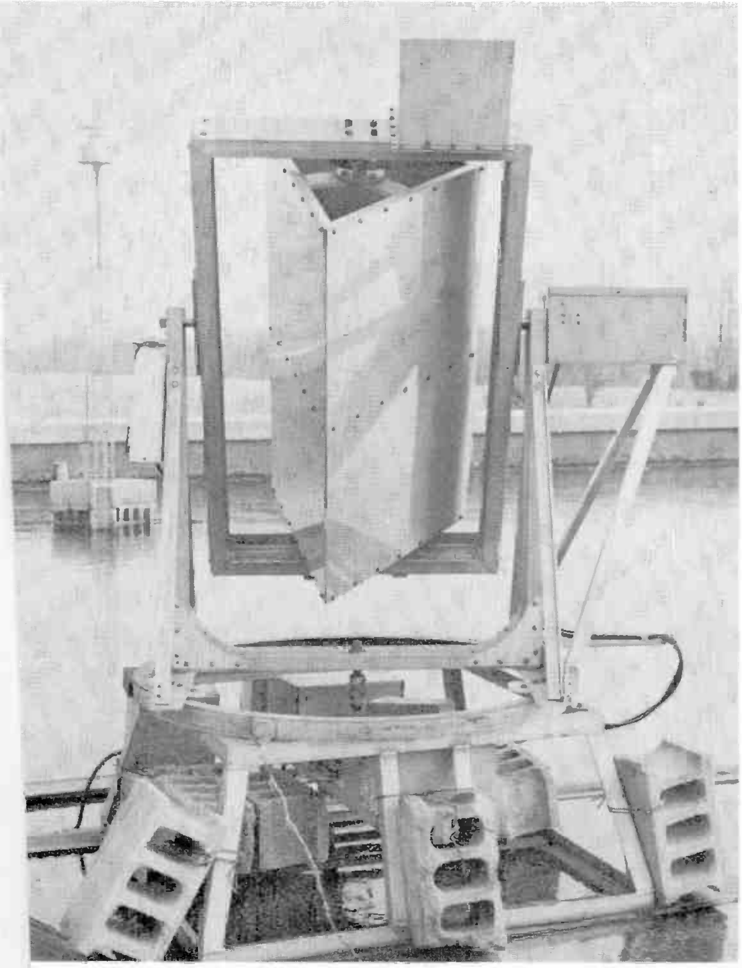
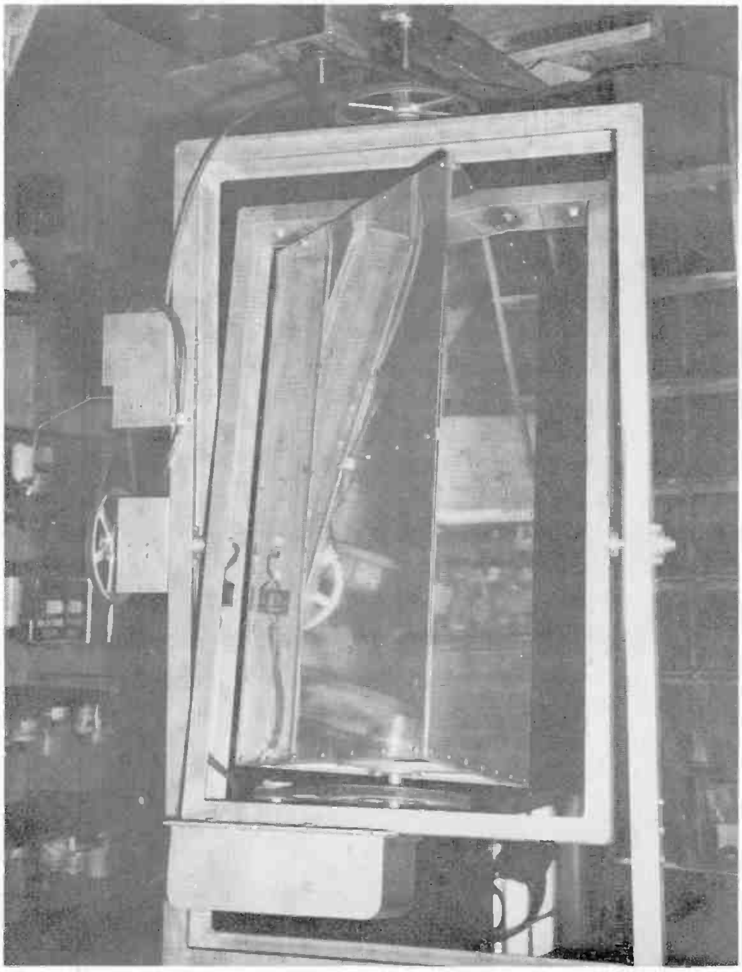


FIG. 2

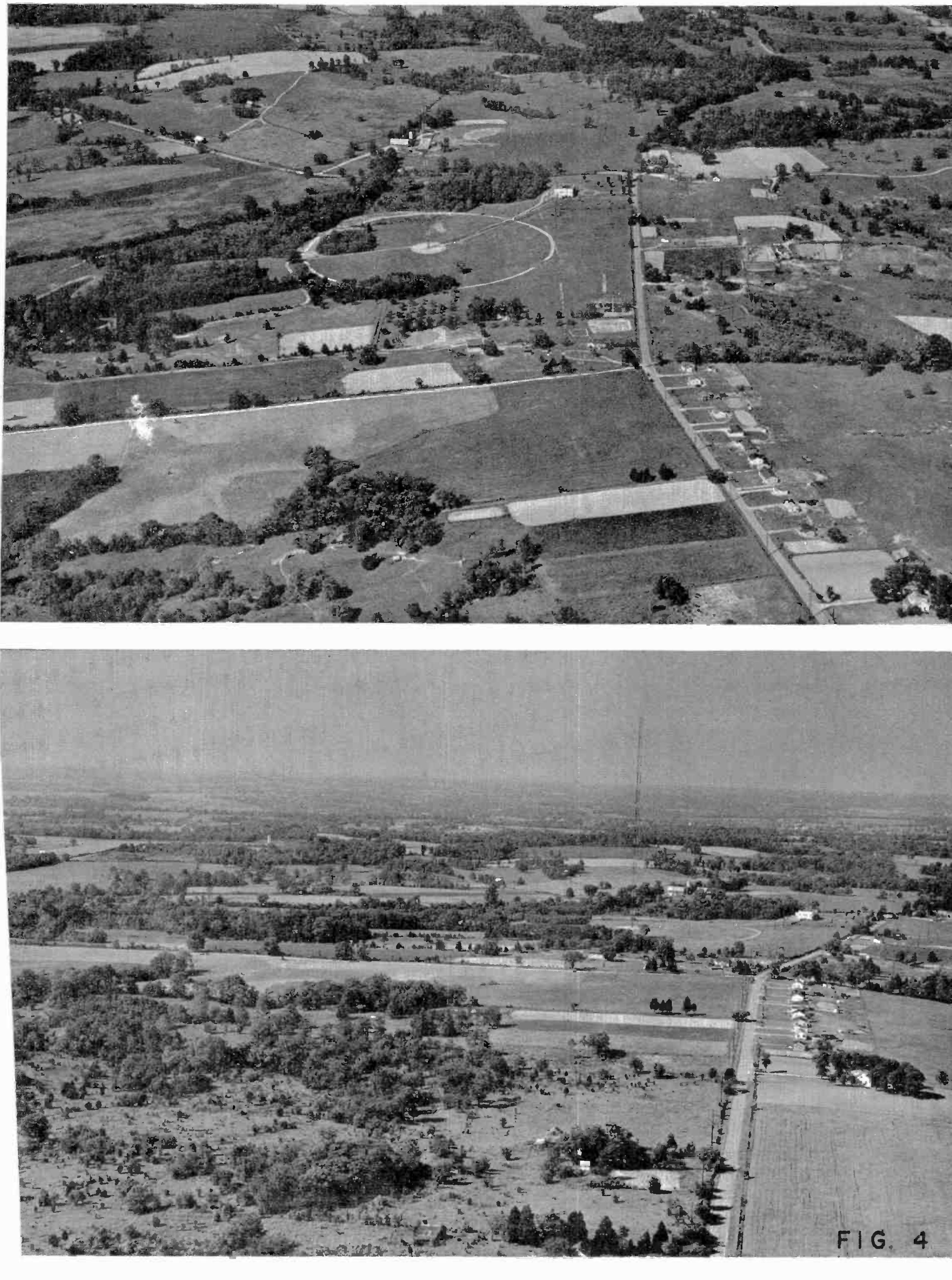


FIG. 4

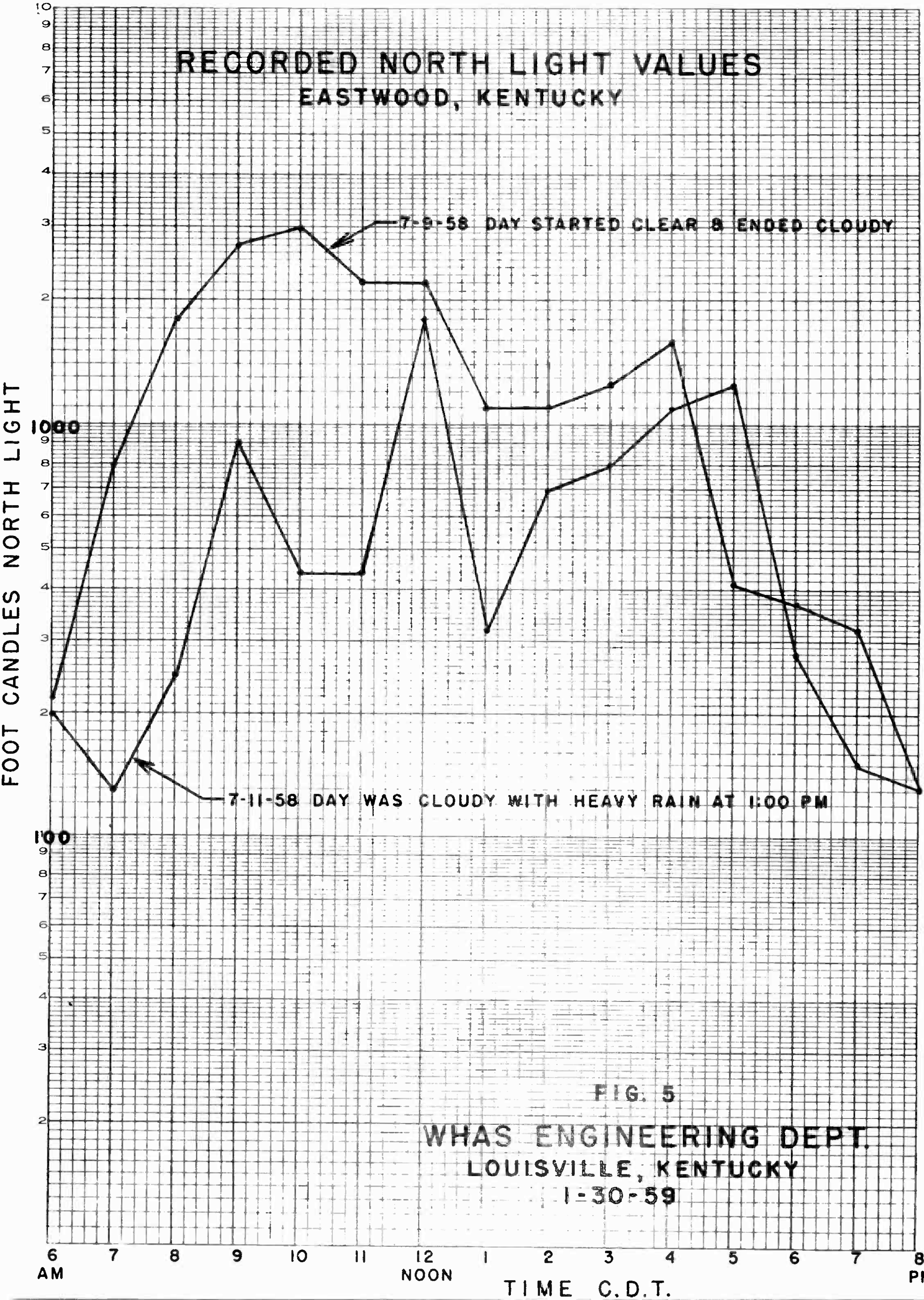
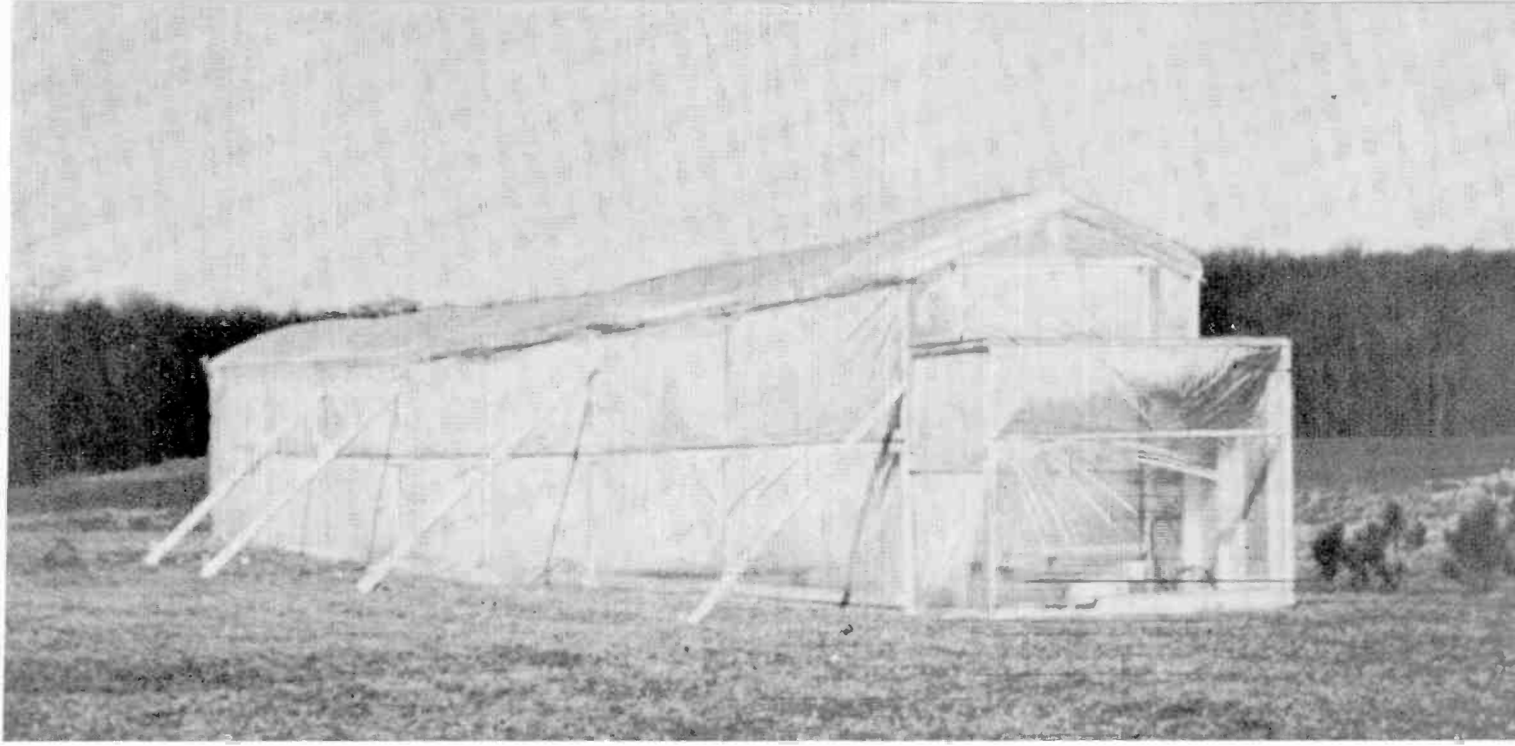


FIG. 5

WHAS ENGINEERING DEPT.
LOUISVILLE, KENTUCKY
1-30-59



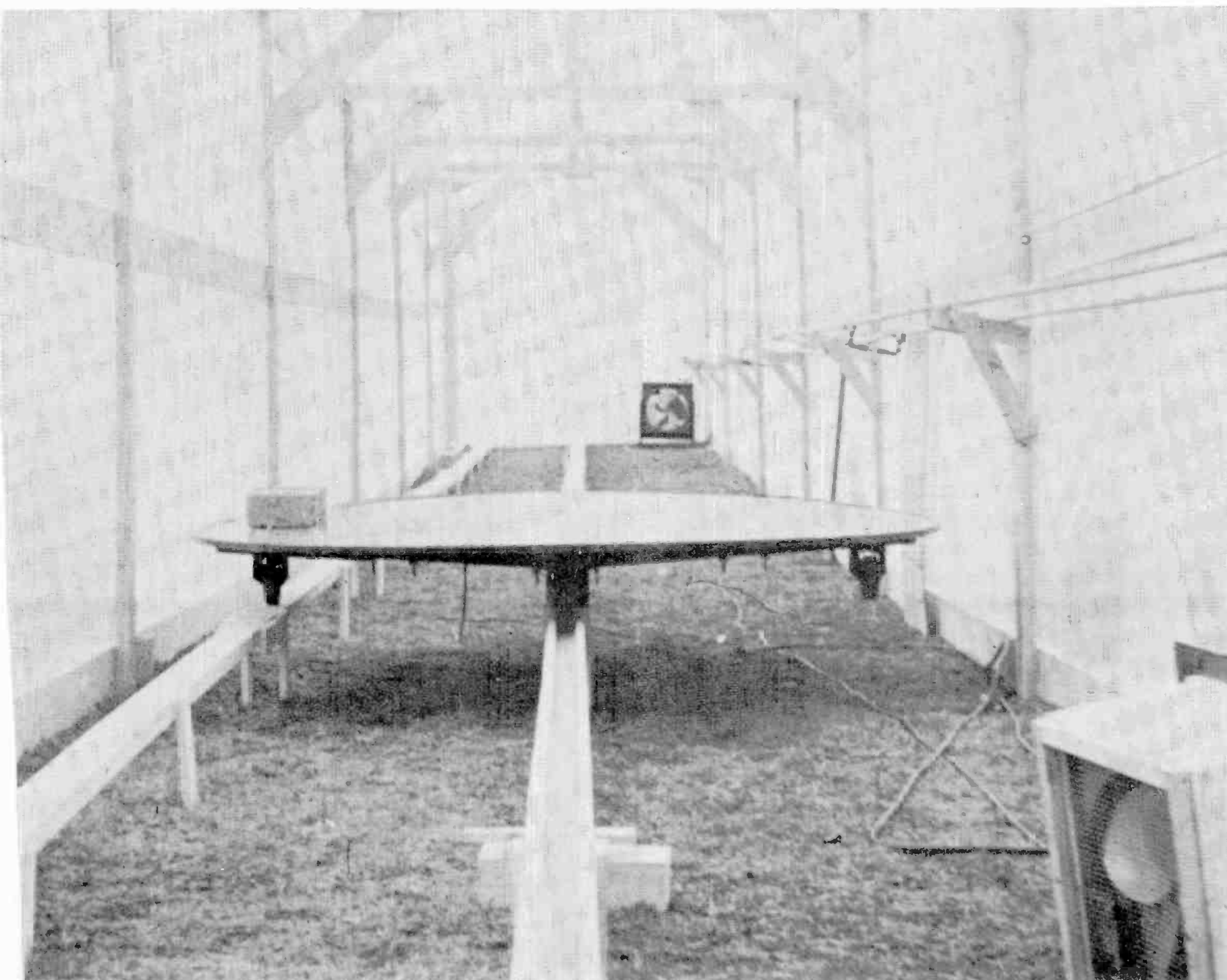


FIG. 6

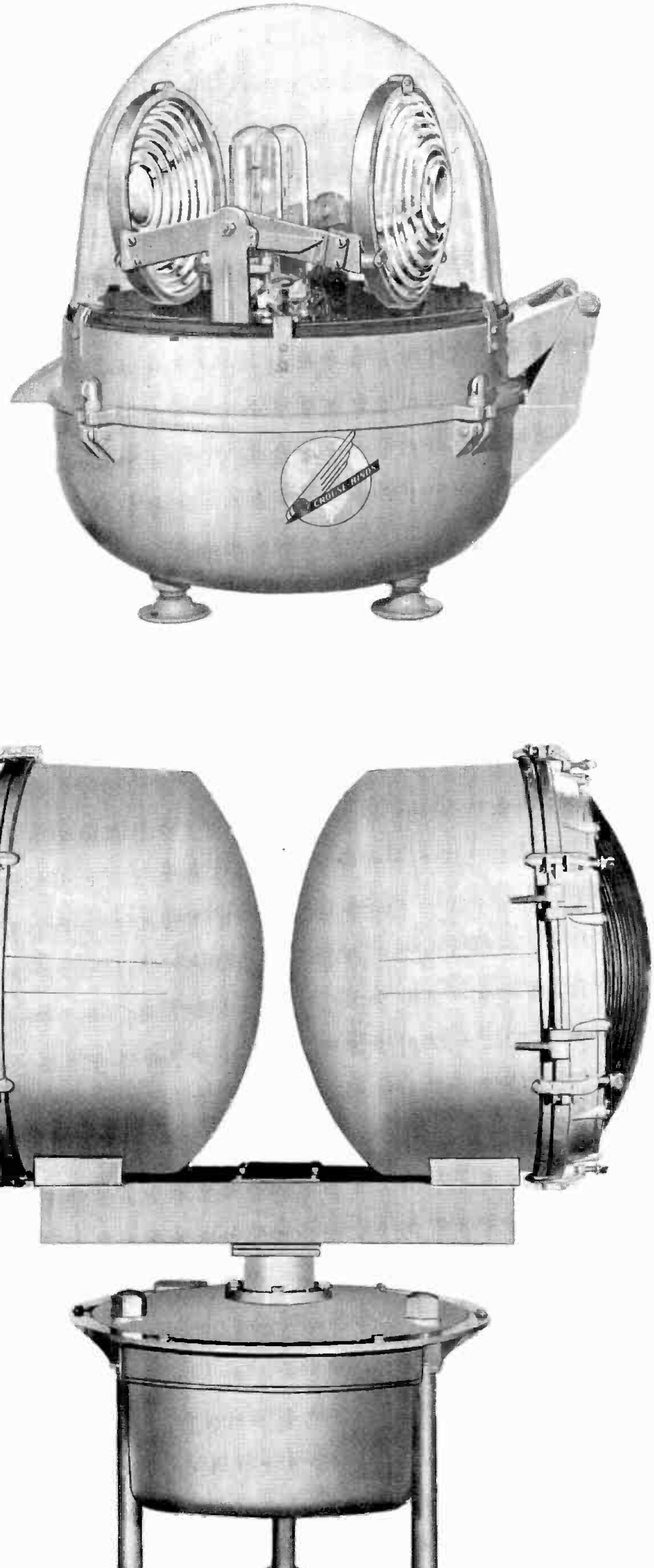
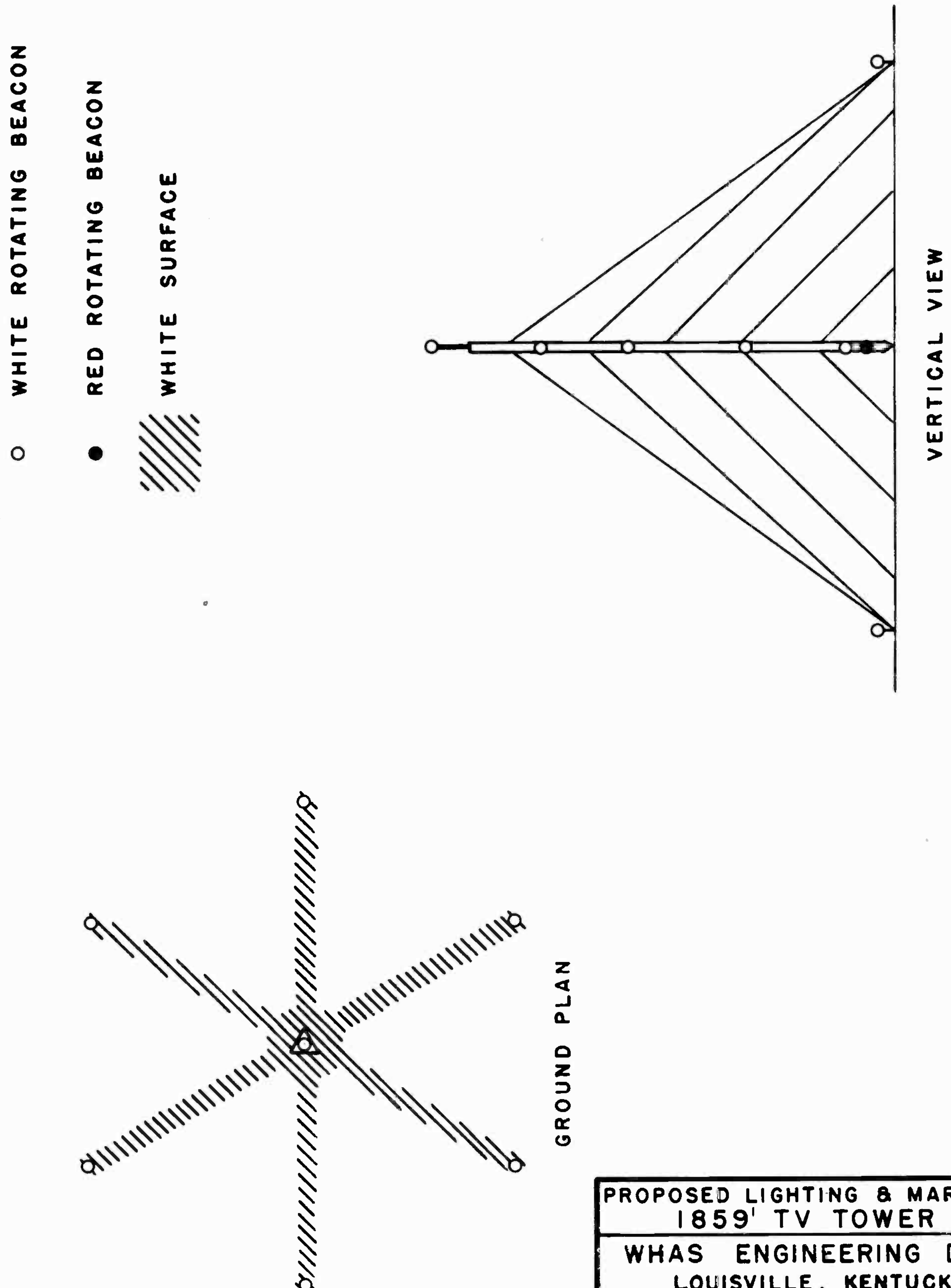


FIG. 7



PROPOSED LIGHTING & MARKING
1859' TV TOWER

WHAS ENGINEERING DEPT.
LOUISVILLE, KENTUCKY

ENGINEER O.W.T.	ASSOCIATED DWGS.
DRAFTSMAN A.C.H.	
APPVD. BY O.W.T.	
DATE 2-2-59	FIG. 8
SCALE NONE	

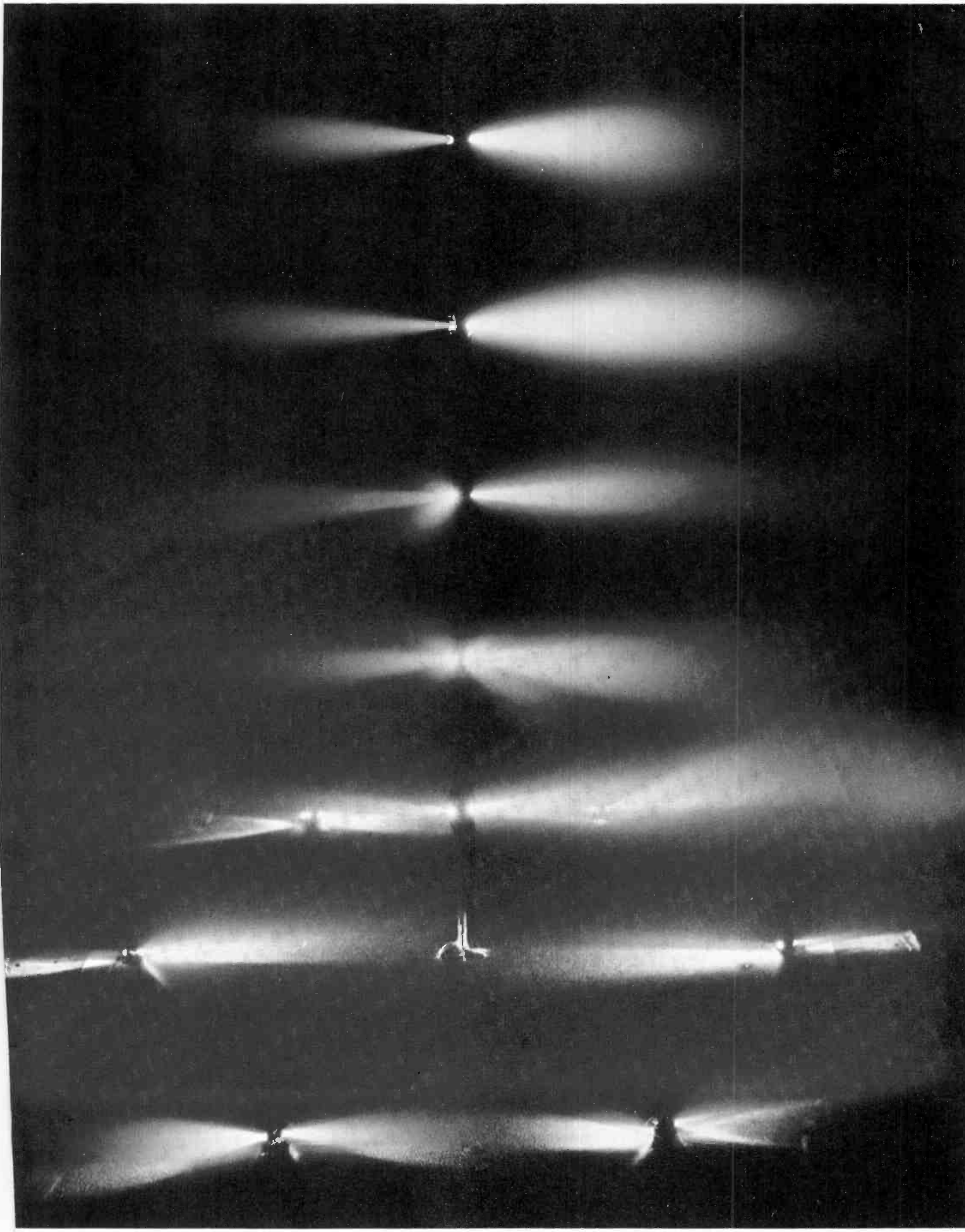


FIG. 9

Planning, Construction and Operation of a Reversible Inter-City Microwave Relay System with Automatic Fault Reporting Equipment

M. J. Minor, Transmitter and Field Engineering Manager

JEFFERSON STANDARD BROADCASTING COMPANY

ONE JEFFERSON PLACE CHARLOTTE 8, NORTH CAROLINA

WBT

WBTV

WBTW

Presented at the 1959 NAB Broadcast Engineering Conference

Jefferson Standard Broadcasting Company owns and operates two television stations - - WBTV in Charlotte, North Carolina and WBTW in Florence, South Carolina. The airline distance between the two cities is 94 miles. Charlotte, North Carolina, is a Metropolitan Area with a population of more than a quarter of a million people and is the largest city in the two Carolinas. Florence, South Carolina, has a population of approximately 26,000, however, there are more than 800,000 Carolinians within the Grade B contour of WBTW, which encompasses an area of some 12,292 square miles. Nearly 600,000 of these people reside on farms or in communities with populations under 1,000. Florence, with its population of only 26,000, is the largest community in the entire 12,000 square mile area served by WBTW.

The Florence station is completely equipped to originate local live productions. However, because of the small population of Florence itself and the wide dispersion of the communities it serves, WBTW has had real difficulty in securing the suitable and salable talent necessary for successful local live productions. Charlotte, with its much larger population, has an abundance of talent which has built up a very high degree of popularity in the Carolinas over WBTV during the past nine years. Florence needed television talent - - Charlotte had it - - the problem was how to make this talent available to WBTW at a cost which would be compatible with the station's rate card. Economics, of course, ruled out the use of common carrier facilities. Until recently, Part 4 of the Commission's Rules would not permit licensing of privately owned inter-city relay systems where common carrier facilities were available. In our case such common carrier facilities were installed and were available, thus, we were stymied until the Commission recently relaxed its rules so as to permit privately owned and operated inter-city facilities. We promptly applied for and received construction permits for the inter-city system. The system has been constructed and has been in operation since February 15 of this year. The system, which is designed to accommodate both color and monochrome programs, will also make available to WBTW the extensive color facilities installed at WBTV. The WBTV studios in Charlotte are equipped for the origination of local slide, film, opaque and live color or color video tape recorded programs. Origination of WBTW programs from one of the Charlotte studios enables WBTW to schedule local live color programs which is not feasible from the Florence studios.

The WBTV-WBTW inter-city system consists of two terminal stations and three repeater stations. (See Figure 1.)

The system was designed for remote control, reversible transmission, automatic fault reporting and the three repeater stations are unattended. A telephone line is used as the medium for switching signals and for reporting the status of each switched station as well as reporting faults existing at stations other than the controlling terminal. Separate private line telephone communication facilities are provided between all locations to facilitate maintenance and adjustments.

All transmitting and receiving equipment is housed in concrete block structures at the bases of the various towers. Plastic domed parabolic reflectors are mounted on these structures and are directed to passive reflectors mounted on the towers. The ground systems consist of 4/0 bare copper wire buried 15 inches and extends from the tower base to each guy anchor and is bonded to each guy wire as well as to a copper clad rod driven in the ground. A similar rod is used as a common point bond to all three ground wires, and connected to the tower and equipment racks to complete the system. A typical repeater installation is shown in Figure 4.

The transmission system is capable of monochrome or color television video signal transmission in either direction, with television audio contained within the channel as a diplexed sub-carrier signal. Audio diplexing is provided in both directions.

Automatic frequency control is provided at each of the repeater stations. Monitoring of the transmitter video modulation is also provided at each repeater, the RF signal being de-modulated by sampling the same cavity used in the AFC circuit. Thus the output of each repeater transmitter can be locally monitored as an aid to inspection and maintenance of the unattended equipment at the repeater stations.

Two RF channels are used in the system thus avoiding problems of cross-coupling between adjacent receiving and transmitting antennas and passive reflectors on the same tower. Sufficient frequency separation is used to provide adequate isolation between received and radiated signals. The use of two RF channels also minimizes possible problems of overshoot signals causing interference at subsequent receivers.

All of the equipment for this system was supplied by R. C. A.

In the design of a microwave relay system two types of fading must be guarded against if the system is to have a predictable and a satisfactory propagational reliability. These two types of fades are recognizable by their duration, and would be identified as due to what is called "inverse bending", or "multipath" reflection. A third type of fading - - due to actual attenuation of the microwave beam by rain or snow - - is generally negligible at 7000 mc and so will not be considered.

The inverse bending type of fade is prolonged. A fade of this type may last for from a few minutes to several hours, as atmospheric conditions change. It is caused by the fact that the trajectory of the microwave beam from transmitter to receiver is not actually a straight line, but is in fact curved, generally following a path similar to that shown in Figure 6. The path departs from a straight line because the dielectric constant of air generally decreases with altitude. If the atmosphere were perfectly homogeneous, propagation would be along a straight line. If, due to temperature inversion along the path the normal conditions become reversed, the beam may then have to follow an "inverse bend" trajectory which will result in its being blocked, unless sufficient clearance is provided.

The protection against inverse bending then is adequate clearance. Once this has been provided, the second type of fading, "multipath", may be considered.

Multipath fading, as the name implies, is caused by the signal arriving at the receiver by two different paths, which become out of phase 180° or nearly so upon arrival. In a multipath fade, one of the paths is, of course, the straight line antenna-to-antenna path. The second path may be from a ground reflection or from a layer of still air or maybe from a flat, low cloud base. The second signal, if it is of equal strength to the direct signal and in phase with it, could add only 3 db to the receiver input, however, if equal and out of phase, it could reduce the receiver input to zero. Fortunately, the reflected signal is generally weaker than the direct signal and so only reduces it by some 30 or 40 db when arriving out of phase. Protection against multipath fade is afforded by adequate clearance, plus providing sufficient fade margin to maintain the signal through those fades which come from reflections off atmospheric discontinuities. The multipath fade is always of short duration, only a few seconds at the most, but may take place in quick succession as a layer of air shifts so as to provide several reflections in sequence.

Proper clearance on the microwave path is assured by providing clearance for the beam during conditions of the maximum amount of inverse bending expected. This varies with the type of terrain, and with the generally prevelant weather conditions. Bending is always most severe over smooth earth, and in regions where the air is often still, and where temperature may vary widely in a short time.

These conditions are most condusive to the accumulation of layers of air in the path which can produce bending. On the other hand, a brisk wind blowing over a broken terrain will assure turbulence in the air which keeps it pretty thoroughly homogeneous, and the beam then tends to travel in a straight path.

For purposes of this paper let us say that sufficient clearance protection against both types of fading is provided by allowing full Fresnel Zone clearance over a 4/3 earth on the terrain covered by the WBTV-WBTW system. This clearance is generally equal to about 0.6 full Fresnel Zone over a true earth, depending on the distance involved. Figure 7 shows the required clearance for a microwave path.

Using this rule, antenna heights may be calculated for the case of terrain in which both ends of a hop are roughly equal. Antenna heights thus determined, provide line of sight clearance <u>above</u> all obstructions along the path equal to 0.6 of the Fresnel Zone diameter. In all cases it is of course advisable to plot all this on profile.

The Fresnel Zone is defined as a region bounded by a ficticious curved surface from which reflection traveling from transmitter to receiver will travel an extra 180° (one-half wavelength) compared to the direct path. Since there is 180° phase change upon reflection, any signal going from transmitter to receiver by this path will arrive as an <u>aiding</u> signal. A reflection from a point which penetrates well within the Fresnel Zone, however, will not have the benefit of the extra half-wavelength of travel and would arrive at the receiver as a cancelling signal. Figure 8 illustrates the Fresnel Zone and Radius vs. Path Length.

Proper clearance having been provided, it is now necessary to determine the fade margin for protection against those really unavoidable multipath fades which are statistically bound to happen.

In order to provide a fade margin, it is necessary to provide a non-faded input signal to the receiver which is considerably greater than that required for a usable or even noise free picture. The required fade margin for a given reliability varies with path length, and this is illustrated by Figure 9.

The fade margin may be defined as the amount by which the non-faded RF input to the receiver excedes the RF input which is needed to provide a minimum usable signal out of the receiver. The minimum usable signal is defined - - in view of the fact that expected fades are to be of short duration - - as existing when the S/N ratio is 28 db. This is a noisy picture - - the p/p signal will be 2.5 times the p/p noise but by subjective tests is tolerable for short periods (seconds) of time by an average viewer.

Figure 10 shows that the RF power to the receiver to produce this minimum usable signal is minus 99 dbw. Every db of power above this level is considered fade margin.

For example, let us take the Hartsville-Florence hop on the WBTV-WBTW system. The total free space loss on this 25 mile path is 141.5 db. Figure 11 serves to illustrate. Allowing 2.5 db for waveguide losses, the total loss is 144 db. The antenna-reflector combinations at each end of the link have gains of 42.5 db, or a total of 85 db. This makes the net loss between transmitter and receiver 144 minus 85 or 59 db, and the power into the receiver is minus 59 dbw (59 db below 1 watt). A fade margin of 99 minus 59 or 40 db has thus been provided. Figure 9, just displayed, shows that the reliability will be slightly greater than 99.99%.

A similar calculation on each of the other hops will also yield a reliability figure of 99.99%.

The overall reliability can be <u>conservatively</u> figured by assuming that none of the fades on the four hops will be coincident. Thus, if each hop is out for .01% of the time, the total will be out .04% of the time and the overall reliability will be 99.96%. Figure 12 shows the parameters of each path and the overall system between WBTV and WBTW, which is included in the published paper but not enumerated here nor shown on these slides.

A basic system diagram for a reversible, two-hop microwave system is shown in Figure 13. There could be "N" number of repeaters.

Comvor Data Transmission and Receiver Terminal equipments are utilized for reversing control and fault reporting. For fault reporting, the Indicon Coder and Decoder with Delay Timer are required.

Fault sensing is accomplished through the use of the Low Power/Low Signal Level Indicator, and the Video Presence Detector, while Receiver AFC disabling and automatic shutdown is provided for by the application of the AFC Radiation Switch.

From the Master Terminal, switching is accomplished through the activation of a Comvor Transmitter. A single Comvor Transmitter is required for reversing. It is arranged for the transmission of a carrier-on, mark or space signal. (Raise-OFF-lower operation.) A switching panel, arranged to suit the system contains activating controls for the Comvor Transmitter and an activating control for the local waveguide switch. Local fault indications appear on each of the units previously mentioned. An Indicon Decoder and Comvor Receiver are provided for the reception and display of remote faults and answer backs.

A Comvor receiver is provided at the unattended repeater to receive reversing information. This receiver is equipped with the Carrier Detector accessory, enabling the receiver to operate in the Raise-OFF-lower arrangement. The antenna reversing control provides a junction point for the Comvor receiver and waveguide switch wiring, as well as a remote and local answer back. It also contains a local reversing control switch. Various fault finding devices as previously mentioned are included. Remote contacts from the fault devices and the remote answer back contacts are fed to the Delay Timer. A closed circuit initiates the timing cycle and upon completion of the cycle, the Indicon Coder transforms closed circuits into coded pulses which key the Comvor Transmitter for reporting.

Fault sensing, reversing, and reporting from the final terminal is identical to that of the unattended repeater.

Switching control is shown at a master terminal with reporting to that same terminal. Modifications in arrangement and equipment are made to allow switching and reporting at both terminals.

Figure 13 is a block diagram of a basic reversible system with automatic fault reporting.

Operation of a reversing sequence is as follows:

1. To switch the system from that position shown (South-North), activate the system reverse switch at the attended master terminal to the N-S direction.

2. This turns <u>on</u> the Comvor tone generator terminal (Freq. F_2) and may cause it to transmit a MARK (or SPACE) signal. (RAISE)

3. This MARK (RAISE) tone is then transmitted over the wire line to all unattended stations.

4. The Comvor Tone Receiver (Freq. F_2) at each unattended station then receives the MARK tone. The output relay and Comvor (tone) detector device will then move to that corresponding position.

5. The output relays of the Comvor Tone Receiver are then fed to the Antenna Reversing Control.

6. This, in turn, activates the waveguide switch to the N-S position.

7. When the waveguide switch is placed in the N-S position the microwave receiver and transmitter waveguide connections are reversed. The receivers are then placed on the opposite antenna to that shown in Figure 13.

8. Similarly the transmitter antennas are reversed from the positions shown in Figure 13.

9. Also, on the waveguide switches, answer back contacts are provided to indicate the waveguide switch positions.

10. When the waveguide switches are activated by the antenna reversing control, the answer back contacts are fed to the Indicon Coders.

11. Taking first the unattended terminal, the answer back contacts on the Indicon Coder cause it to report.

12. When this Indicon Coder reports, the coded pulses out of it are used to key the Comvor Tone Generator.

13. These audio tone pulses are then transmitted over the wire line to the attended terminal.

14. At the attended terminal, the audio tone pulses are received by the Comvor Tone Receiver.

15. This tone receiver then keys the Indicon Decoder in sequence with the reporting coder. Thus, the answer back information is indicated on the decoder display. This answer back information tells what station is reporting and whether or not the waveguide switch is in the proper position.

16. At the unattended repeater, the answer back information is presented to the delay timer. After a prescribed time delay this station will then report just as the attended terminal did.

    It requires about 15 seconds for an Indicon Coder to transmit its pulses. To arrange that the next station does not report simultaneously, it is necessary to create about 20 seconds delay before the second station starts reporting. Similarly, if there is a third station, 40 seconds would be required at that location and a fourth station would require 60 seconds. This delay is provided by a delay timer at each location.

    Of course, all stations report in sequence with an arrangement such as this.

17. Thus, for a four hop system, approximately two minutes would be required to obtain a complete report from all stations.

18. Once all stations have reported, or allowing them to report twice, the reversing tone information is turned off. This is accomplished automatically by including a time delay relay in the system reversing control panel.

    When the reversing tone is turned off the antenna reversing control is deenergized which removes the answer back information from the coder. This prevents further transmission of answer back information, and eliminates excessive wear on the coder and decoder equipments.

19. Fault reporting is accomplished exactly as the answer back information.

    When a fault occurs, the coder is activated and sends out pulses. These pulses key a tone generator. The keyed tone is transmitted over a wire line, received at the attended terminal by a tone receiver. The tone receiver keys the decoder and the fault is thereby displayed.

    Delay timers are included to eliminate garbling of fault reporting should simultaneous faults occur at different stations.

The Indicon Coder is a precision electro-mechanical device capable of sending 15 digits of binary code for indication purposes. A total of 10 faults or indications can be coded. The first five digits of the binary code are used to identify the reporting station. One of these devices is required at each unattended station. Figure 14 is a photograph of the Indicon Coder unit.

Fault indications or other information is represented by <u>closed</u> relay contacts.

When any one or more of the fault indicating devices present a closed circuit to the coder, the coding cycle begins.

As the coder is activated, it searches all 15 positions to determine whether or not there is a closure on the circuit. The closures on the first five positions are permanent and are arranged such that a particular code is transmitted for each different station. For the other ten positions, if there is no closure, another type of pulse is transmitted. A pulse of 360 milliseconds duration (<u>long</u>) will represent a closure while a pulse of 90 milliseconds (<u>short</u>) represents no <u>closure.</u>

Assuming that faults numbers <u>1 and 5</u> occurred at station number 2, the sequence of pulses would be as follows:

short-long-short-short-short
long-short-short-short-long
short-short-short-short-short

These pulses are actually a series of switch and relay contacts which provide a closed circuit to ground for 90 milliseconds on a <u>short</u> pulse or 360 milliseconds for a <u>long</u> pulse. Approximately 15 seconds is required for the complete transmission of 15 digits. A transmission device such as an audio tone generator is then keyed providing a duration of audio tone equal to the length of the keying pulse, or zero audio tone if there is no pulse.

Once a fault has initiated the operation of the coder, it sends out the 15 digit code and then begins a timing cycle during which no code is transmitted. This timing lasts for ten minutes after which the coder again transmits the pulses providing the fault still exists. If the fault (faults) should disappear prior to the completion of the 10 minute cycle, only the station identification would be reported and the coder would then rest in the home position. So long as the fault exists, the pulses will be transmitted every ten minutes.

The decoder operates in response to incoming coded signals from the coder. A bank of five lamps are operated in response to the first five pulses of the coder pulse train for station identification. Ten other lamps operated from relays are used to display the received fault information. Figure 15 is a photograph of the Indicon Decoder.

A detailed functional description of the decoder is rather laborious. A simple explanation would be to say that when a long pulse is received a lamp is turned on and when a short pulse is received lamps are not turned on. Each pulse as it is received (long or short) causes an "impulse" relay to step; thus the 15 count sequence is retained. If the decoder should receive an improper number of pulses (15 exactly) as a result of a fault in the fault reporting system, then the information is cleared from the display of the decoder and it will await the second report.

As the fault information is reported, it is displayed on the decoder and the display is retained until another report is received. When the next report is received, the lamp display is automatically cleared before the new information is displayed.

The decoder is operated from closed contacts which are closed in sequence and for the same time duration as those of the Indicon Coder pulse output.

A tone generator, and tone receiver connected by wire line come between the coder and decoder. The tone receiver contains a relay in the output and this relay keys the decoder. A description of the tone transmitter and receiver would be time consuming and therefore would not be appropriate in this paper. However, Figure 16 shows a photograph and a block diagram of the Model 912T (transmitter) and Model 912R (receiver) used in this system.

In order to minimize field assembly and installation time for this relay system it was felt desirable to install all equipment in the racks, together with required inter-unit cabling, at the manufacturer's plant. Figure 5 is a photograph of one unit. This procedure made it possible to more rapidly and uniformly accomplish all wiring and cabling, and permitted complete system tests at a common location by engineering personnel familiar with system performance requirements. Thus, the equipment was delivered in this manner.

The equipment was given additional operating checks by measurement of video signal-to-noise ratio between transmitter and receiver pairs as they were to be installed in the actual system, after delivery in Charlotte and Florence. This check was performed to insure that all equipment was functioning normally after shipment; all equipment was, in fact, found to be functioning normally.

Upon completion of these checks the equipment was distributed to appropriate locations, antennas installed, and the waveguide plumbing connections between equipment cabinets and antennas made. The towers had been previously erected, passive reflectors installed and approximately oriented for path alignment.

Upon completion of all equipment, antenna and waveguide installation, alignment of the four paths was begun.

In general, the antenna and reflector alignment proceeded rather rapidly and smoothly, since antenna sizes were such that the beam widths are not unusually critical and the terrain traversed is not unusually prone to ground reflection conditions. Typical terrain is shown in Figure 3 which is a profile of the Pageland-Hartsville hop. The reasonably heavy stand of pine tree vegetation in this area, together with the slightly rolling terrain, is not as likely to aggravate the alignment problem with ground reflections as in some geographical areas. However, even under these conditions considerable care was necessary during alignment to distinguish between maximum observed from direct main lobe radiation and maxima which may be encountered due to alignment on reflections.

Upon completion of the overall system the performance was found satisfactory and program tests commenced on February 15, which carried educational programs for broadcast by WBTW for use in the public school systems of South Carolina.

The maintenance and technical personnel problem is of a twofold nature (1) regular preventive maintenance and (2) emergency repairs.

One complete set of tubes, crystals and fuses are kept at each station. A Lambda-Pacific Model 7100 Microwave Test Set, a Simpson Model 260 Multi-Meter, a vacuum tube voltmeter and a tube checker are carried by the maintenance technician on all regular checks.

A regular weekly visit is made to each station to check the performance of all apparatus at that location. A thorough inspection is made of all components to detect excessive heating or other defective functioning. Tubes that are suspected of improper operation are checked and replaced where necessary. A check of the ventilating system is made for proper functioning. A Lambda-Pacific Model 7100 test set is used to measure all pertinent characteristics of both transmitter and receivers.

Because of the use of fault reporting equipment loss of air time will be minimized. Personnel holding first class radiotelephone licenses are on duty at the terminal stations in Charlotte and Florence during all hours of operation of the system. In case of failure at one of the three unattended repeater stations it will not be necessary to search for the "needle in the hay stack" because the location of the repeater in trouble together with an indication of the type of trouble existing is automatically sent to the terminal control station and an engineer can be sent from the nearest terminal.

Acknowledgment: The speaker is deeply indebted to C. I. McDowell, C. A. Runyon and J. B. Bullock of R.C.A. and T. E. Howard for their valuable assistance in preparing the material in this paper.

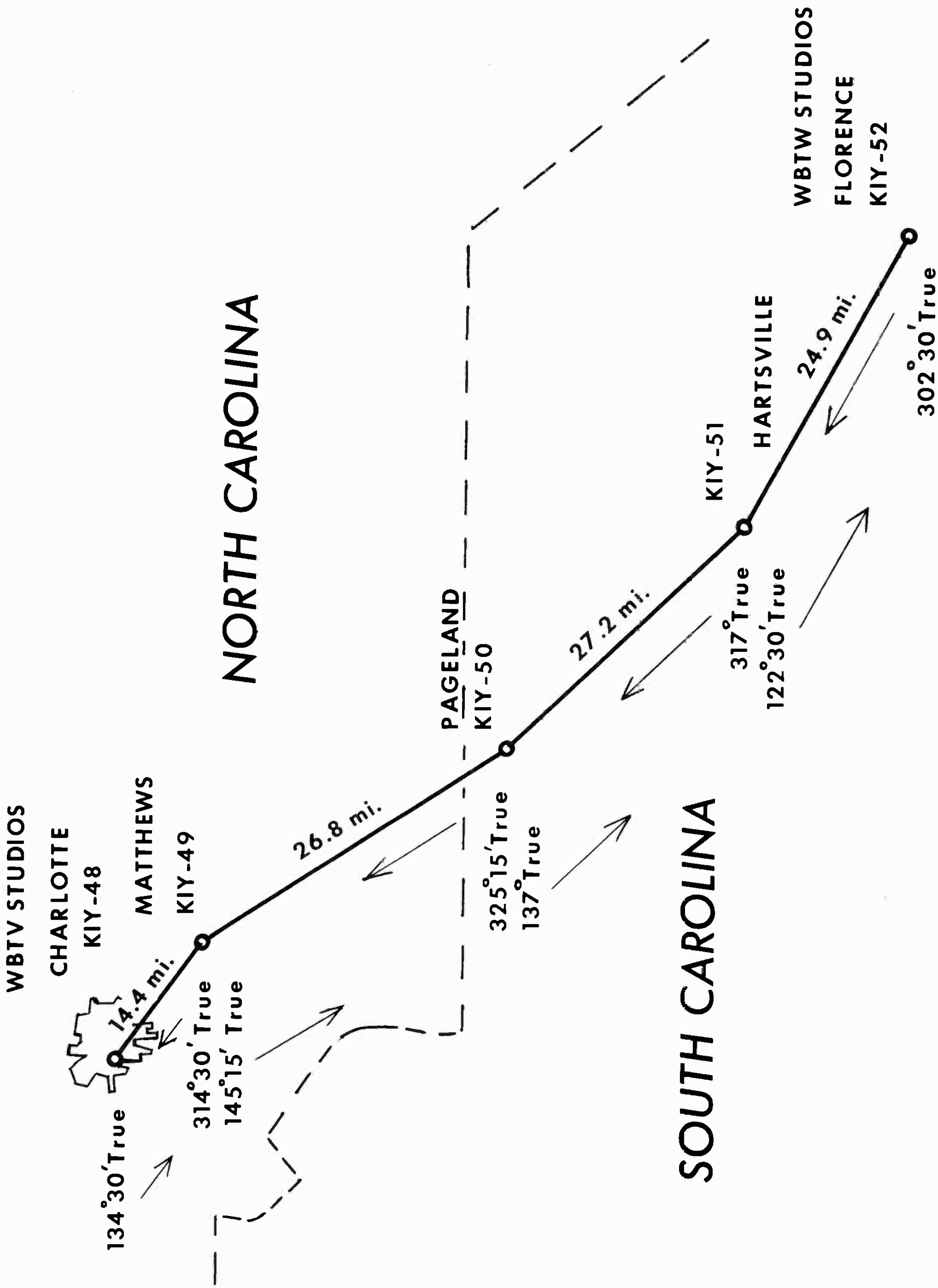
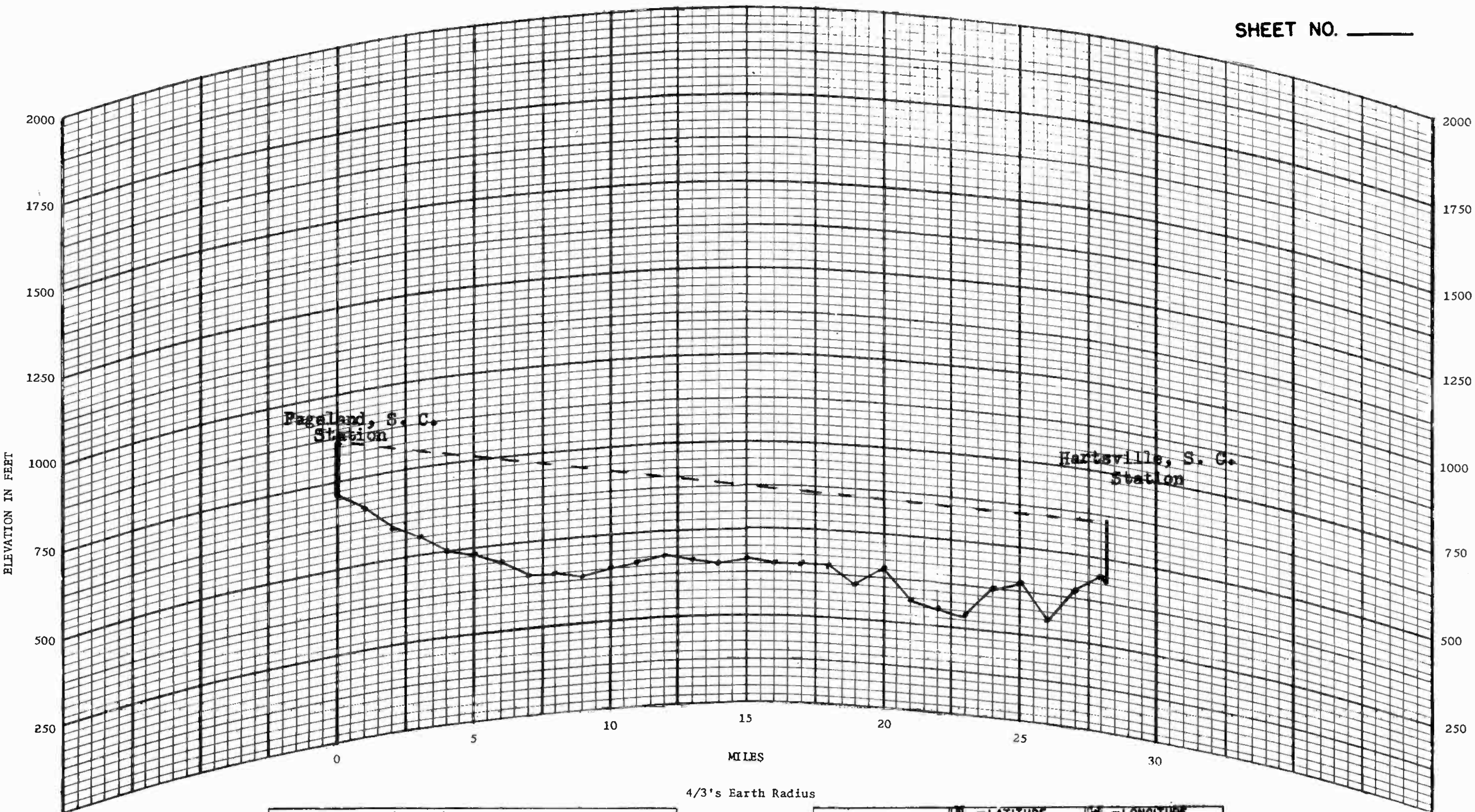

WBTV STUDIOS
CHARLOTTE
KIY-48
MATTHEWS
KIY-49
14.4 mi.
134°30' True
314°30' True
145°15' True
26.8 mi.
PAGELAND
KIY-50
325°15' True
137° True
27.2 mi.
KIY-51
HARTSVILLE
317° True
122°30' True
24.9 mi.
302°30' True
WBTW STUDIOS
FLORENCE
KIY-52
NORTH CAROLINA
SOUTH CAROLINA

Figure 1

SHEET NO. ______



JEFFERSON STANDARD BROADCASTING COMPANY

Television Inter-City Relay System
Charlotte, N. C. to Florence, S. C.

POINT TO POINT PLAN

LOCATION	N - LATITUDE D.	M	S	W - LONGITUDE D.	M	S
Pageland, S.C.	34°	45'	16.9	80	25	11.971
Hartsville,	34	27	54.15	80	05	15.207

BETWEEN Charlotte, NC AND Florence, S.C.

CONTOUR READINGS BY M. J. Minor DATE ______

Figure 3

Figure 4

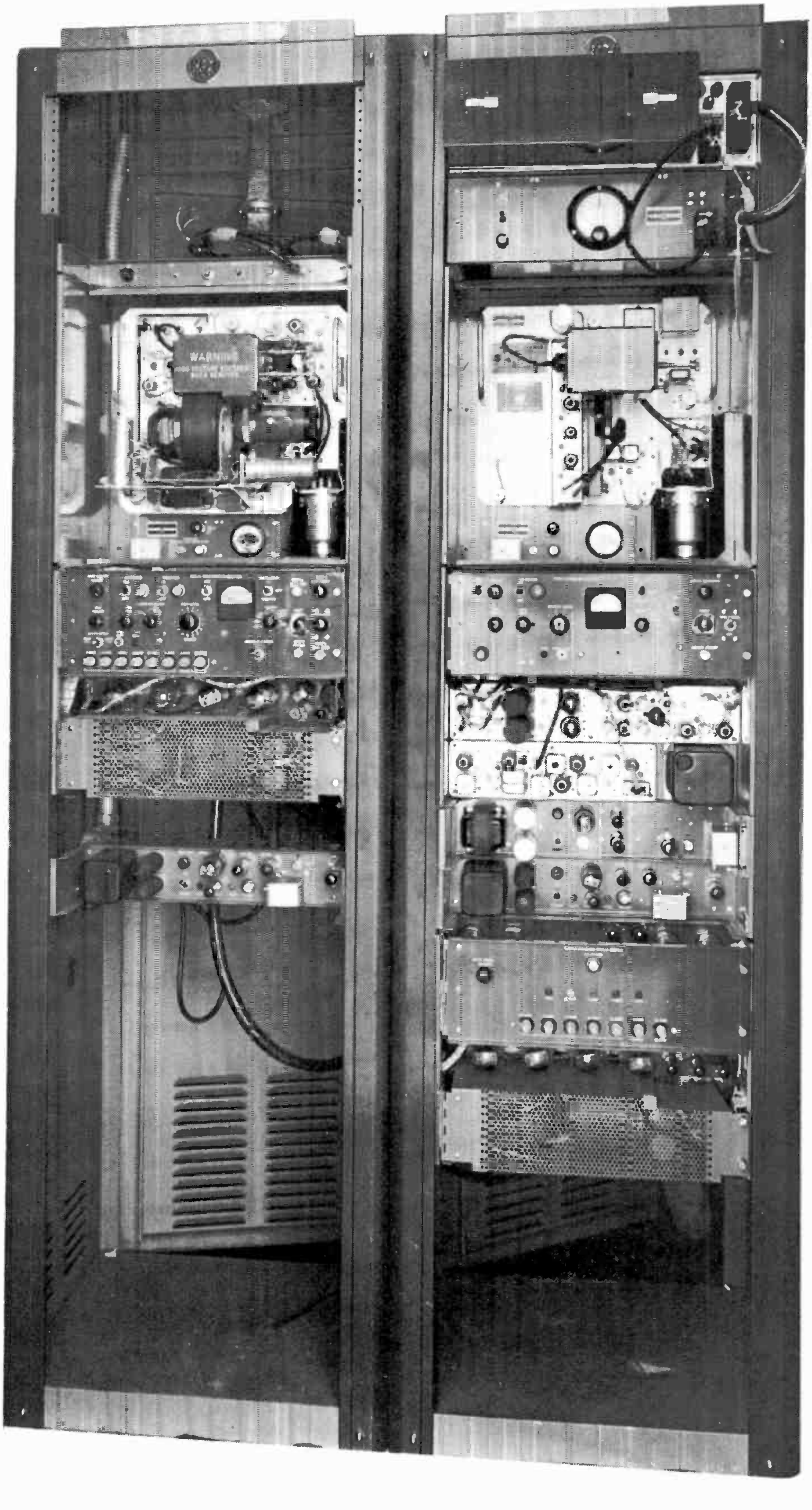
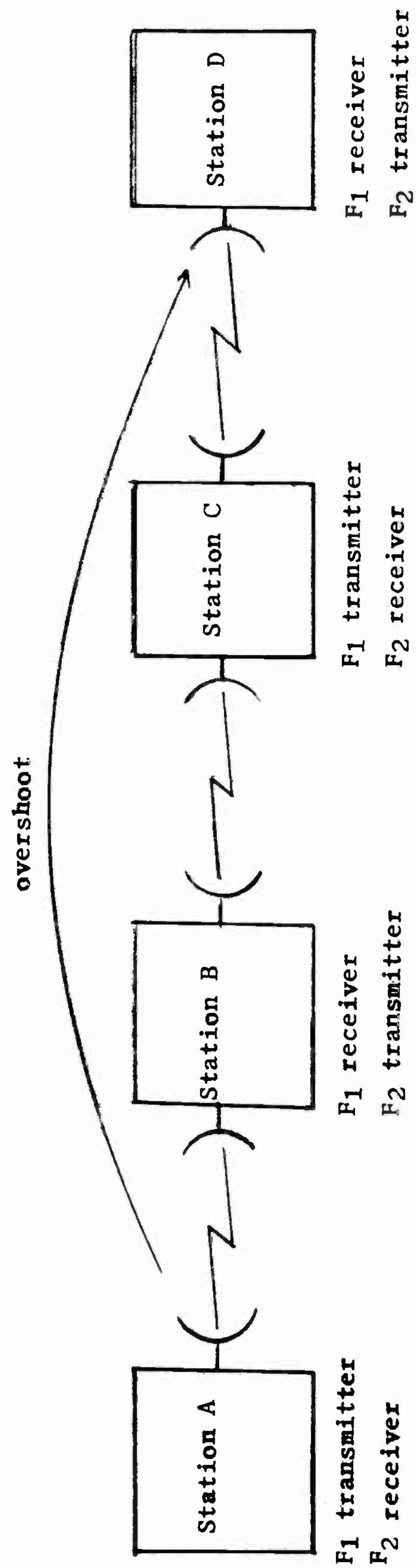
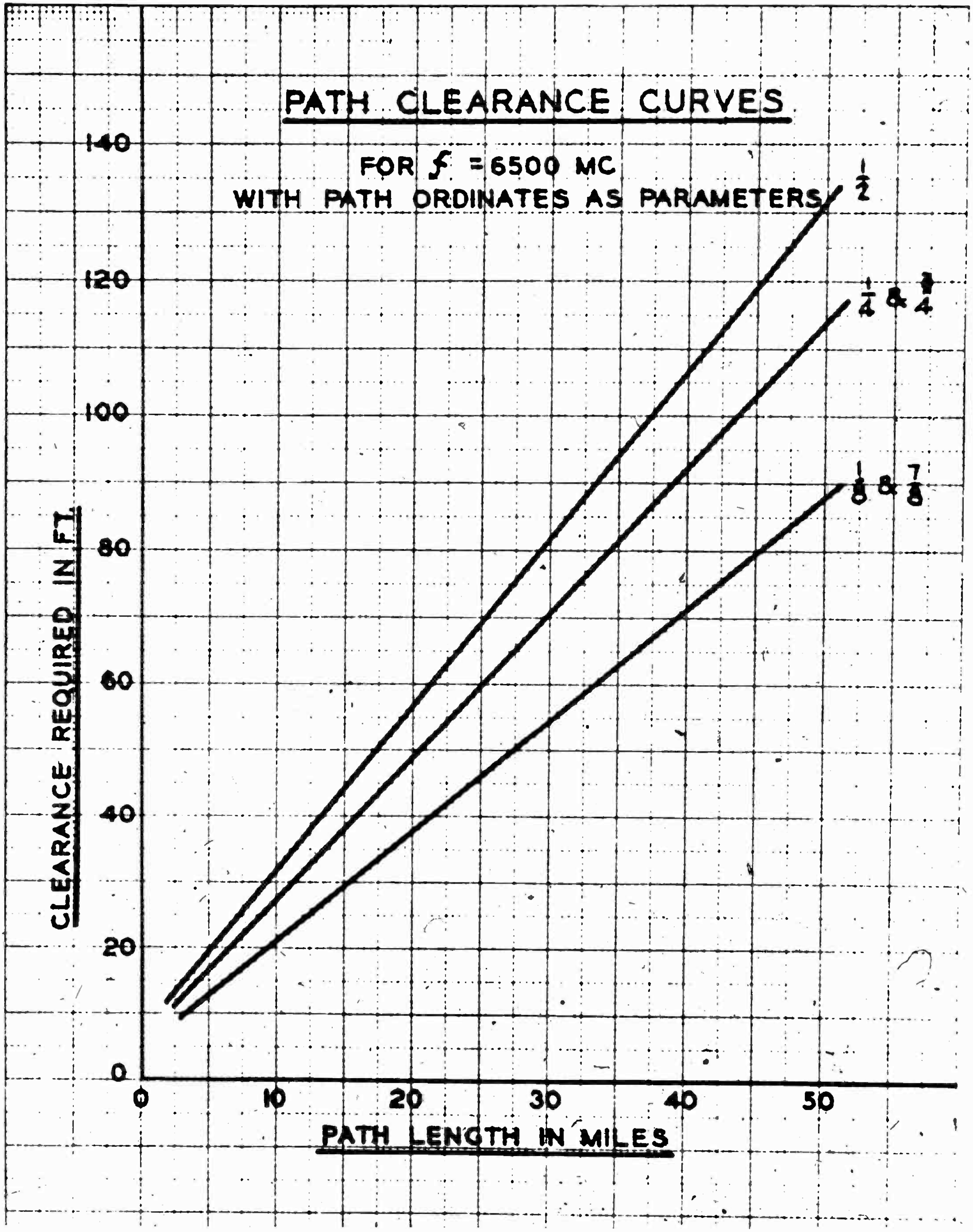


Figure 5



Station A
F_1 transmitter
F_2 receiver
Station B
F_1 receiver
F_2 transmitter
Station C
F_1 transmitter
F_2 receiver
Station D
F_1 receiver
F_2 transmitter
overshoot

Figure 6



PATH CLEARANCE CURVES
FOR f = 6500 MC
WITH PATH ORDINATES AS PARAMETERS
1/2
1/4 & 3/4
1/8 & 7/8
CLEARANCE REQUIRED IN FT.
0
20
40
60
80
100
120
140
0
10
20
30
40
50
PATH LENGTH IN MILES

Figure 7

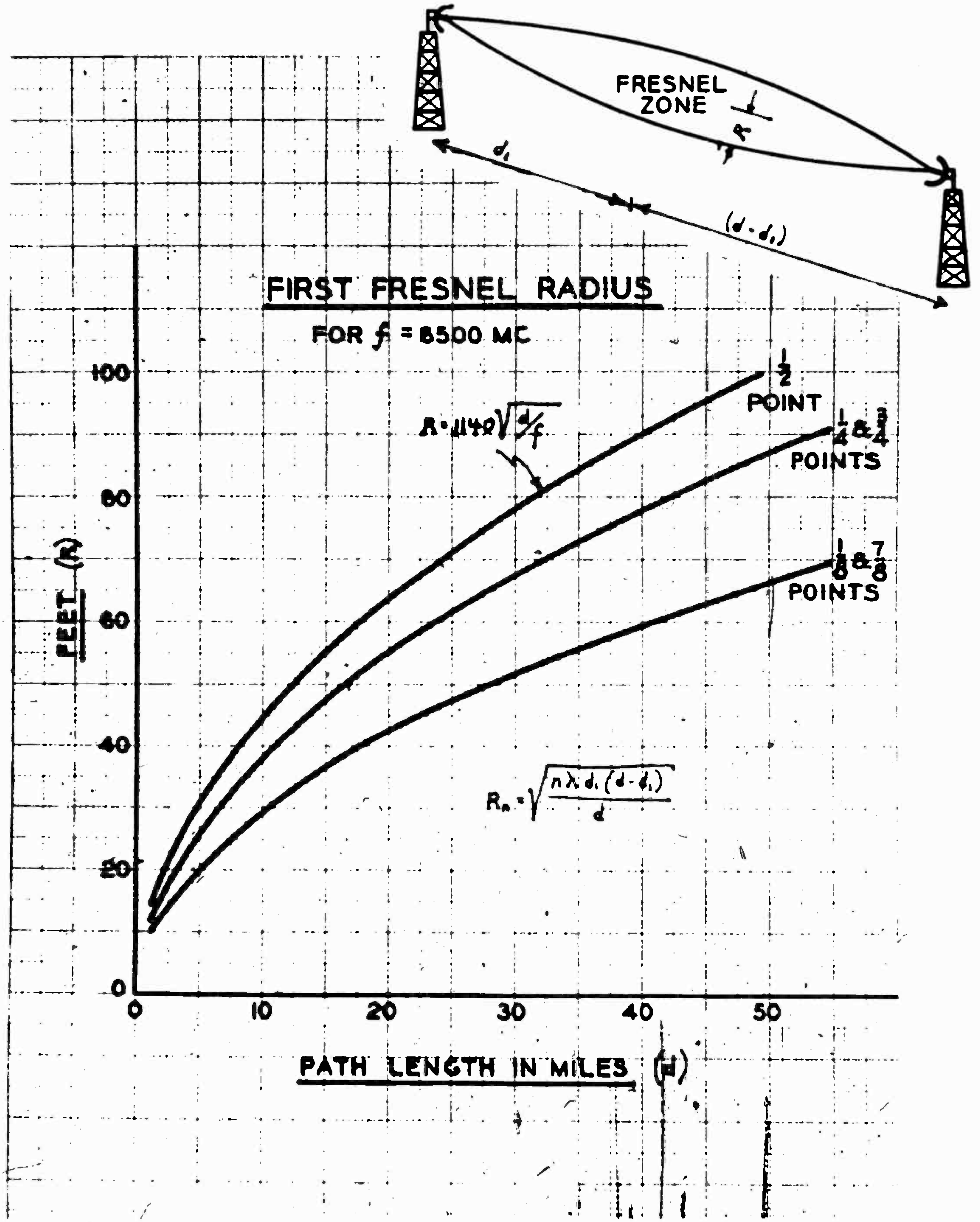

FRESNEL ZONE
R
d_1
$(d-d_1)$
FIRST FRESNEL RADIUS
FOR f = 6500 MC
$R = 1140\sqrt{d/f}$
1/2 POINT
1/4 & 3/4 POINTS
1/8 & 7/8 POINTS
$R_n = \sqrt{\frac{n\lambda d_1(d-d_1)}{d}}$
FEET (R)
0
20
40
60
80
100
0
10
20
30
40
50
PATH LENGTH IN MILES (d)

Figure 8

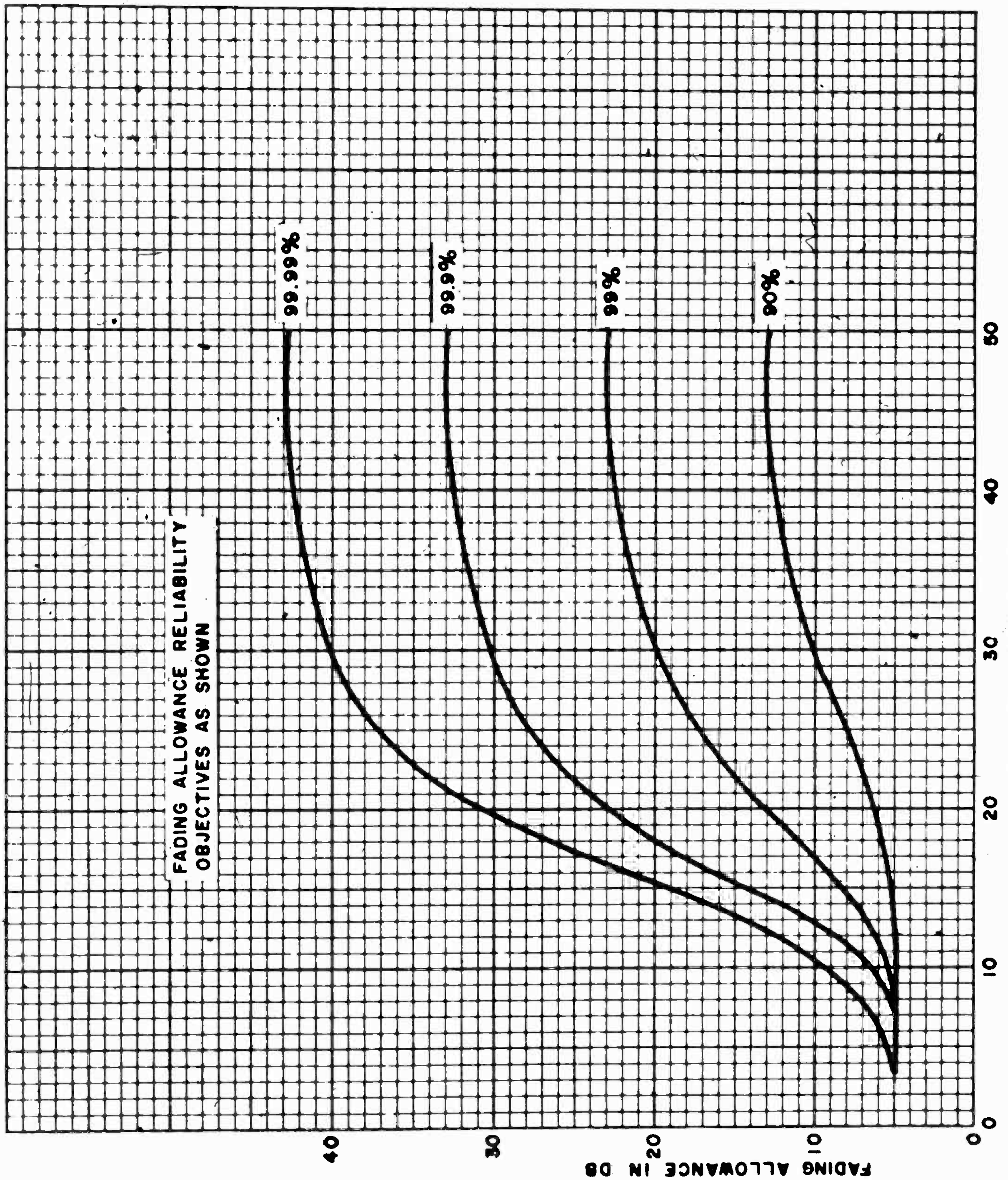

FADING ALLOWANCE RELIABILITY
OBJECTIVES AS SHOWN
99.99%
99.9%
99%
90%
0
10
20
30
40
50
PATH LENGTH IN MILES
0
10
20
30
40
FADING ALLOWANCE IN DB

Figure 9

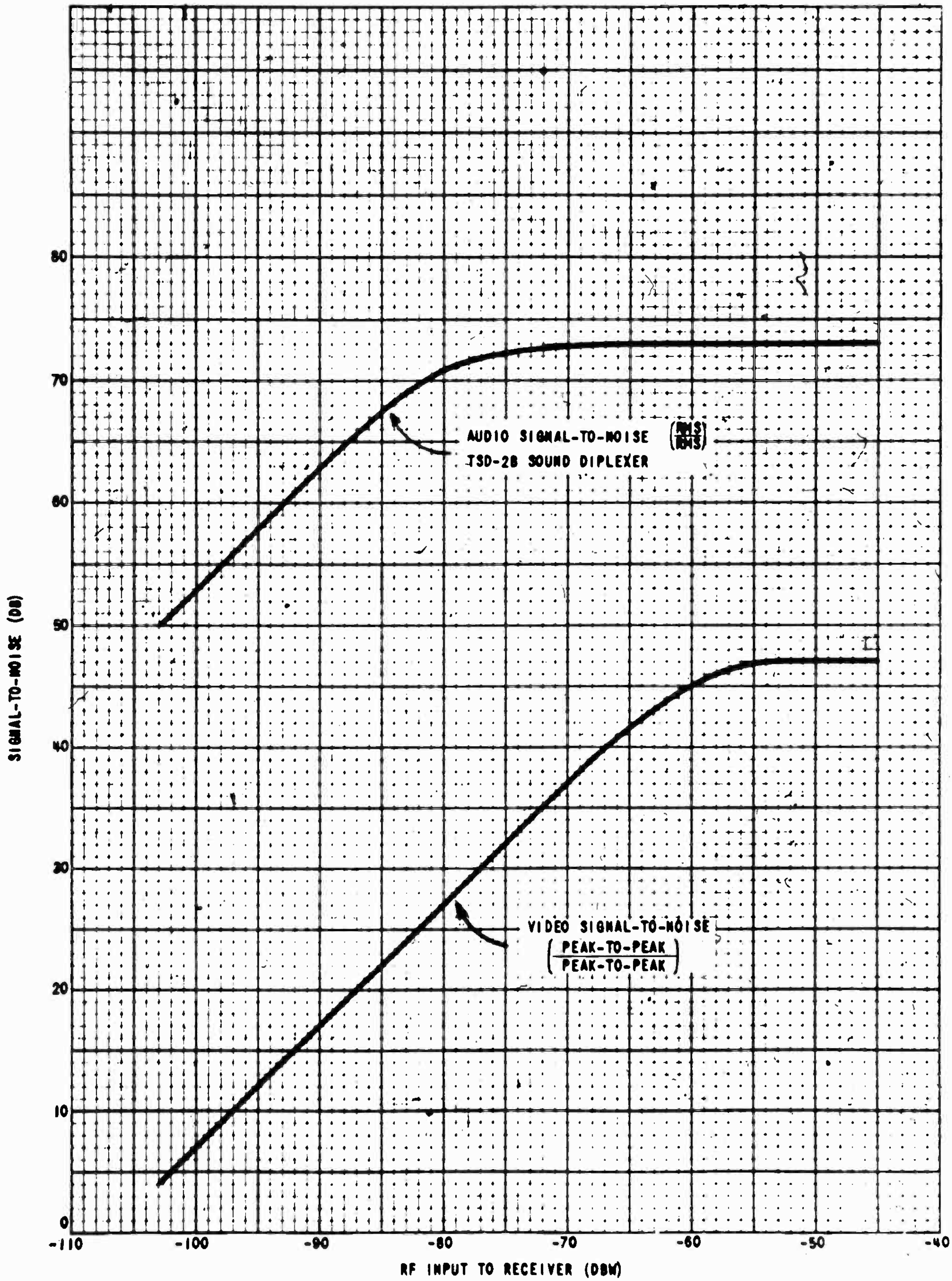


FIGURE 19C - SIGNAL-TO-NOISE RATIO

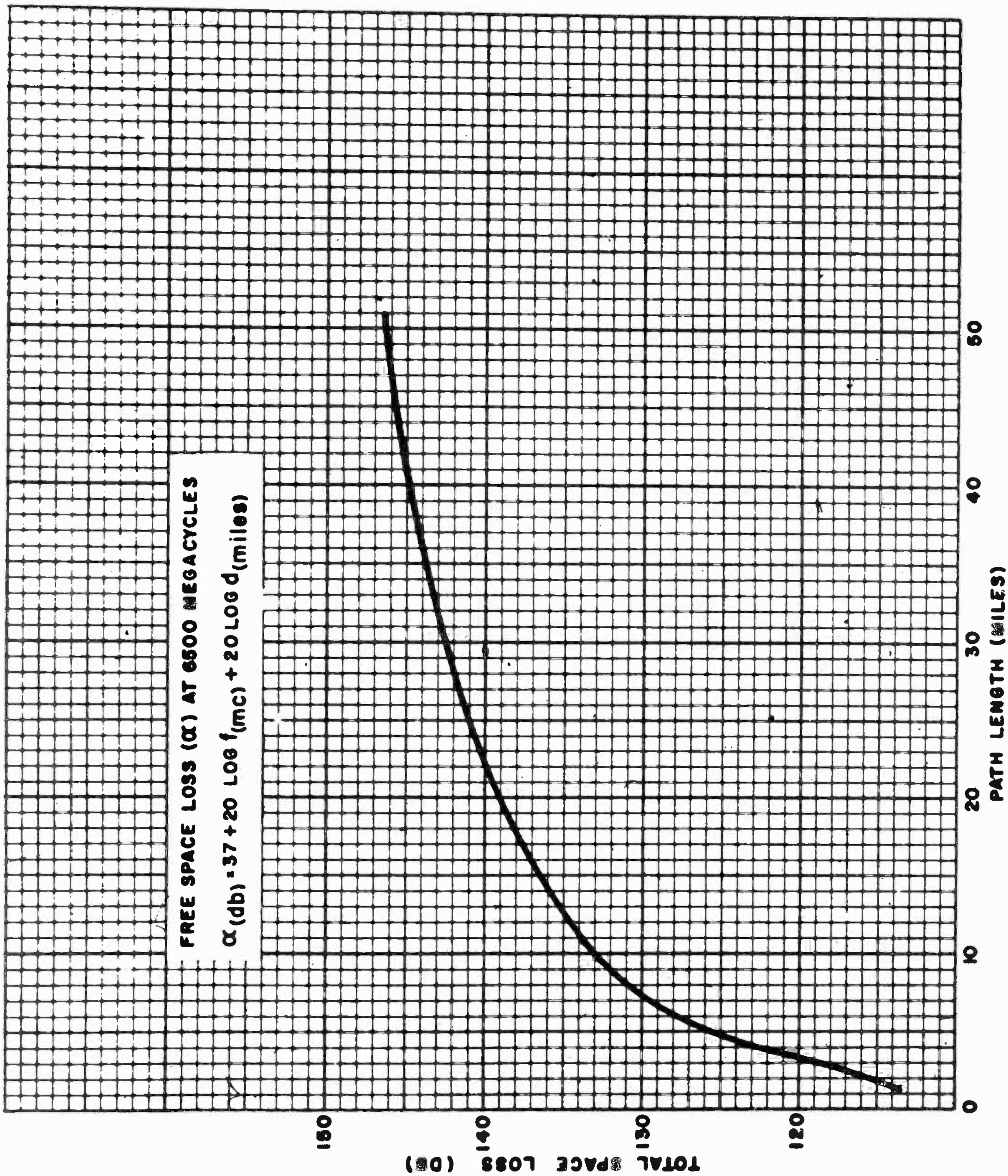

FREE SPACE LOSS (α) AT 6500 MEGACYCLES
α(db) = 37 + 20 LOG f(mc) + 20 LOG d(miles)
0
10
20
30
40
50
PATH LENGTH (MILES)
120
130
140
150
TOTAL SPACE LOSS (DB)

Figure 11

Path Calculations
WBTV 5 Station Microwave Relay System

Charlotte to Matthews

Free Space Loss, 14.4 miles		136.0 db
Waveguide Loss		2.5 db
	Total Loss	138.5 db
Antenna Gains		
4' dish and 8' x 12' Reflector, 160 ft.		39.5 db
4' dish and 8' x 12' Reflector, 150 ft.		39.5 db
	Total Antenna Gain	79.0 db
RF Input to Receiver		-59.5 dbw
Audio S/N ratio		73.0 db
Video S/N ratio		65.0 db
Fading Allowance		39.5 db
Predicted Reliability		99.99% plus

Matthews to Pageland; and Hartsville to Florence

Free Space Loss, 26.8 miles		141.5 db
Waveguide Loss		2.5 db
	Total Loss	144.0 db
Antenna Gains		
6' dish and 10' x 15' Reflector, 150 ft.		42.5 db
6' dish and 10' x 15' Reflector, 150 ft.		42.5 db
	Total Antenna Gain	85.0 db
RF Input to Receiver		-59.0 dbw
Audio S/N ratio		73.0 db
Video S/N ratio		65.0 db
Fading Allowance		40.0 db
Predicted Reliability		99.99% plus

Pageland to Hartsville

Free Space Loss, 27.5 miles		142.0 db
Waveguide Loss		2.5 db
	Total Loss	144.5 db
Antenna Gains		
6' dish and 10' x 15' Reflector, 150 ft.		42.5 db
6' dish and 10' x 15' Reflector, 150 ft.		42.5 db
	Total Antenna Gain	85.0 db
RF Input to Receiver		-59.5 dbw
Audio S/N ratio		73.0 db
Video S/N ratio		65.0 db
Fading Loss		39.5 db
Predicted Reliability		99.99% plus

Overall Predicted Reliability	99.96%
Overall Video S/N	59.0 db
Overall Audio S/N	67.0 db

Video S/N is P.P. Signal to RMS Noise) Random noise only.
Audio S/N is RMS Signal to RMS Noise)

Figure 12

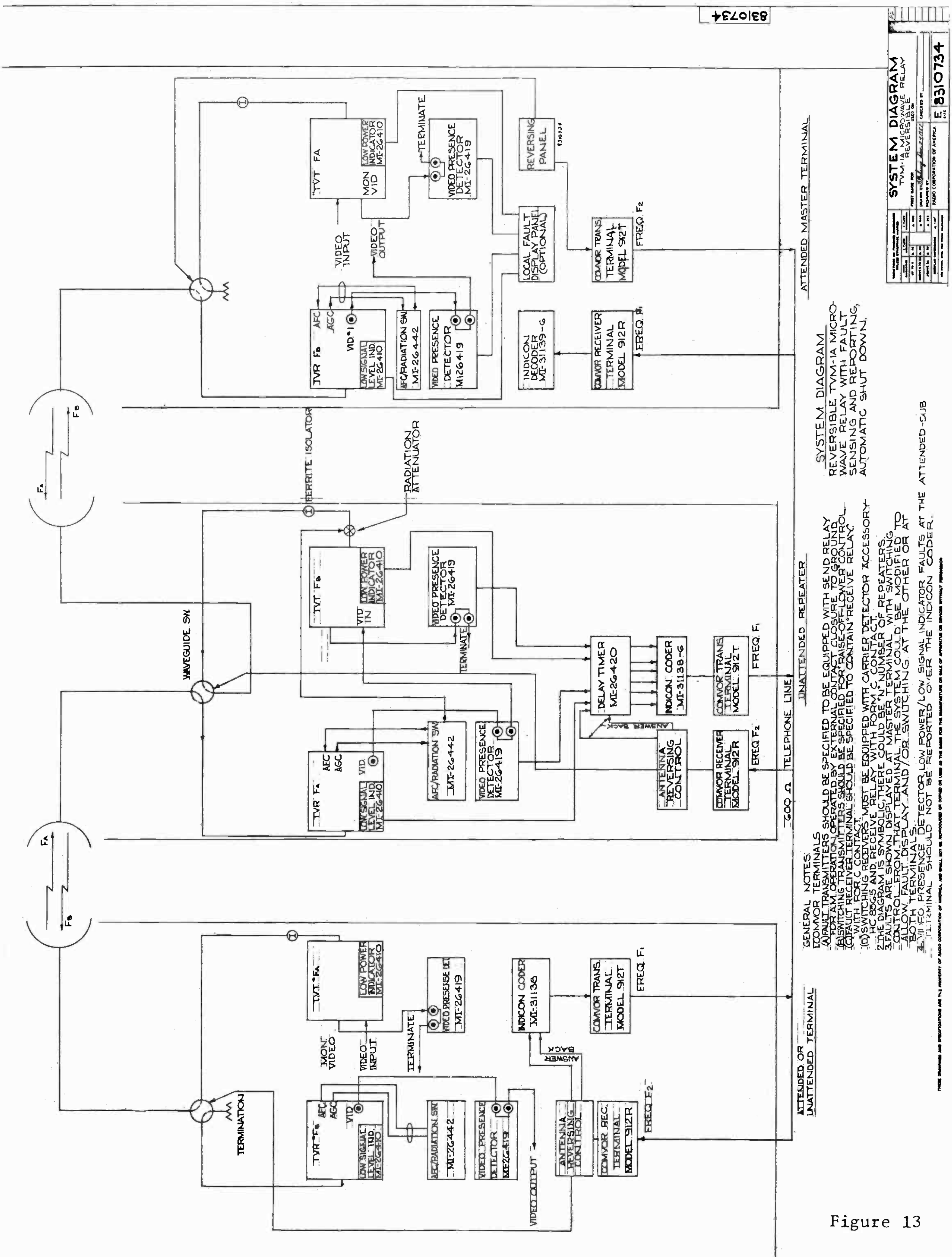

8310734
SYSTEM DIAGRAM
TVM-1A MICROWAVE RELAY
REVERSIBLE
RADIO CORPORATION OF AMERICA
E 8310734
TVT FA
MON VID
LOW POWER INDICATOR MI-26410
TERMINATE
VIDEO PRESENCE DETECTOR MI-26419
REVERSING PANEL
VIDEO INPUT
VIDEO OUTPUT
LOCAL FAULT DISPLAY PANEL (OPTIONAL)
COMMOR TRANS. TERMINAL MODEL 912T
FREQ. F2
TVR FB
AFC
AGC
VID #1
LOW SIGNAL LEVEL IND MI-26410
AFC/RADIATION SW MI-26442
VIDEO PRESENCE DETECTOR MI26419
INDICON DECODER MI-31139-G
COMMOR RECEIVER TERMINAL MODEL 912R
FREQ. F1
ATTENDED MASTER TERMINAL
FA
FB
FERRITE ISOLATOR
RADIATION ATTENUATOR
TVT FB
VID IN
LOW POWER INDICATOR MI-26410
VIDEO PRESENCE DETECTOR MI-26419
TERMINATE
DELAY TIMER MI-26420
INDICON CODER MI-31138-G
COMMOR TRANS. TERMINAL MODEL 912T
FREQ. F1
UNATTENDED REPEATER
WAVEGUIDE SW.
TVR FA
AFC
AGC
VID
LOW SIGNAL LEVEL IND MI-26410
AFC/RADIATION SW MI-26442
VIDEO PRESENCE DETECTOR MI-26419
ANSWER BACK
ANTENNA REVERSING CONTROL
COMMOR RECEIVER TERMINAL MODEL 912R
FREQ. F2
600 Ω TELEPHONE LINE
SYSTEM DIAGRAM
REVERSIBLE TVM-1A MICROWAVE RELAY WITH FAULT SENSING AND REPORTING, AUTOMATIC SHUT DOWN.
GENERAL NOTES:
1.COMMOR TERMINALS
(A)FAULT TRANSMITTERS SHOULD BE SPECIFIED TO BE EQUIPPED WITH SEND RELAY FOR A.M. OPERATION, OPERATED BY EXTERNAL CONTACT CLOSURE TO GROUND.
(B)SWITCHING TRANSMITTERS SHOULD BE SPECIFIED FOR "RAISE-OFF-LOWER" CONTROL.
(C)FAULT RECEIVER TERMINAL SHOULD BE SPECIFIED TO CONTAIN "RECEIVE RELAY" WITH FORM C CONTACT.
(D)SWITCHING RECEIVERS MUST BE EQUIPPED WITH CARRIER DETECTOR ACCESSORY HC 8565 AND RECEIVE RELAY WITH FORM C CONTACT.
2.THE DIAGRAM IS SYMBOLIC. THERE COULD BE "N" NUMBER OF REPEATERS.
3.FAULTS ARE SHOWN DISPLAYED AT MASTER TERMINAL WITH SWITCHING CONTROL FROM THAT TERMINAL. THE SYSTEM COULD BE MODIFIED TO ALLOW FAULT DISPLAY AND/OR SWITCHING AT THE OTHER OR AT BOTH TERMINALS.
4.VIDEO PRESENCE DETECTOR, LOW POWER/LOW SIGNAL INDICATOR FAULTS AT THE ATTENDED-SUB TERMINAL SHOULD NOT BE REPORTED OVER THE INDICON CODER.
TVT FA
LOW POWER INDICATOR MI-26410
VIDEO PRESENSE DET MI-26419
INDICON CODER MI-31138
COMMOR TRANS. TERMINAL MODEL 912T
FREQ. F1
MON. VIDEO
VIDEO INPUT
TERMINATE
ANSWER BACK
TERMINATION
TVR FB
AFC
AGC
VID
LOW SIGNAL LEVEL IND. MI-26410
AFC/RADIATION SW MI-26442
VIDEO PRESENCE DETECTOR MI-26419
VIDEO OUTPUT
ANTENNA REVERSING CONTROL
COMMOR REC. TERMINAL MODEL 912R
FREQ. F2
ATTENDED OR UNATTENDED TERMINAL

Figure 13

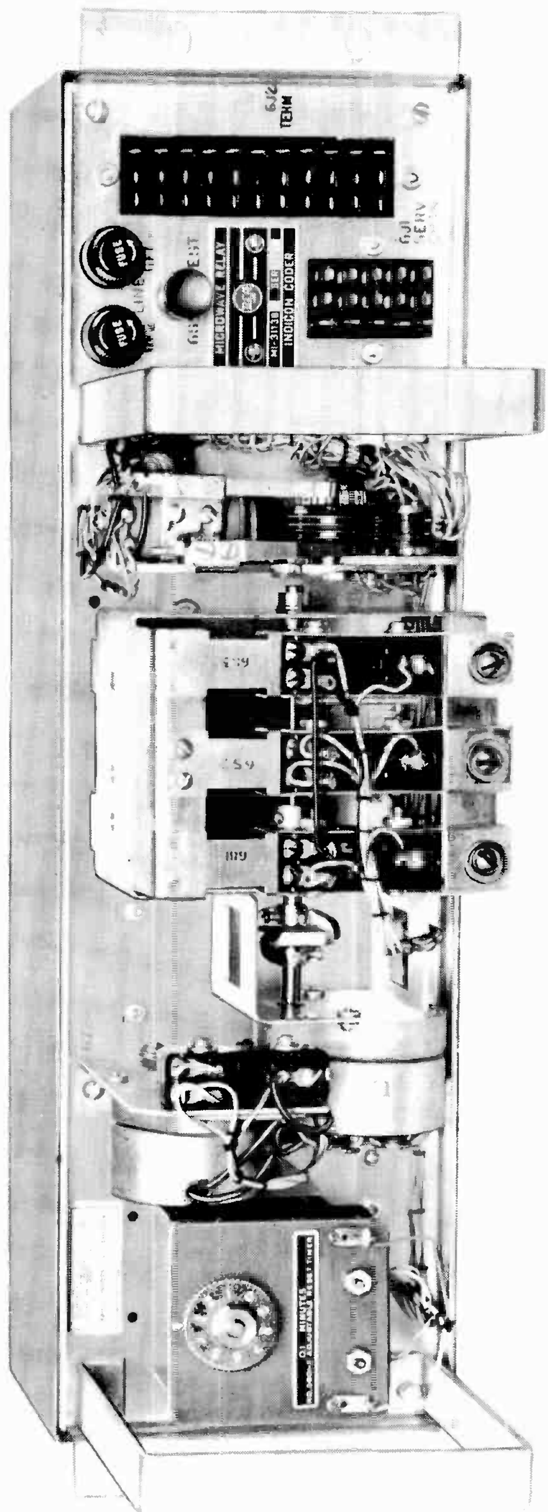


Figure 14

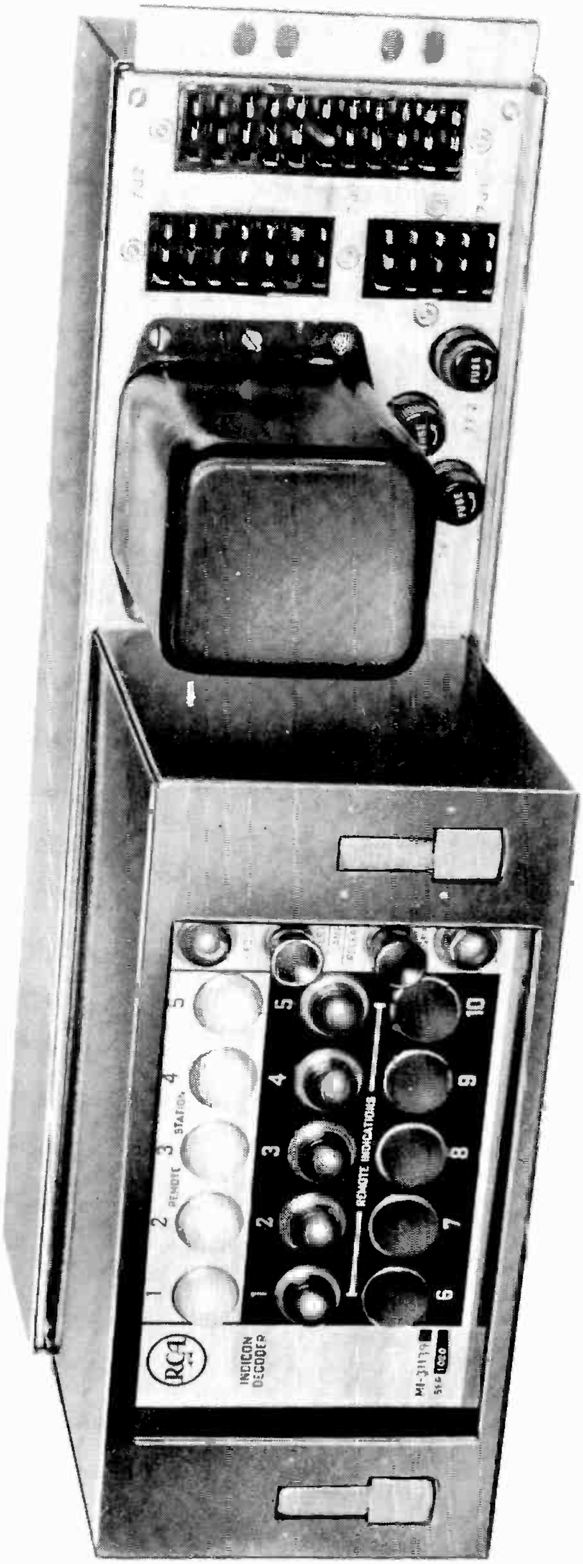
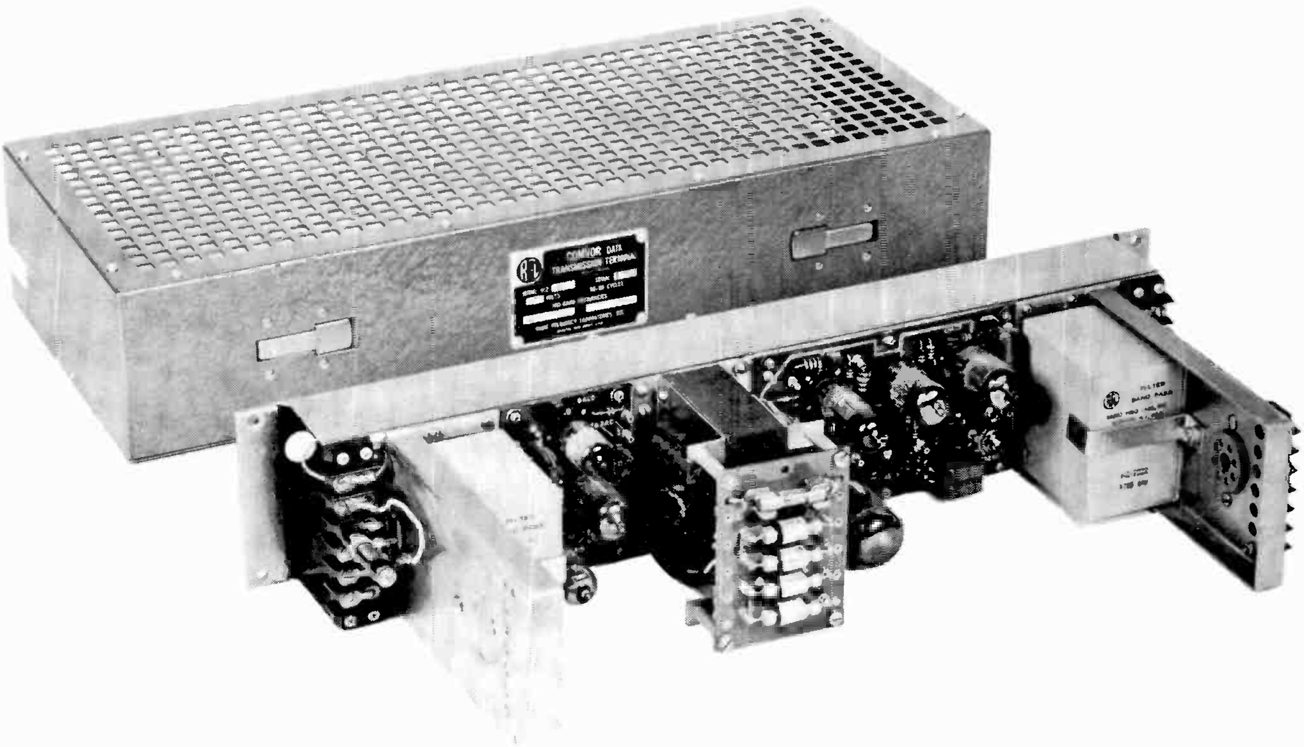
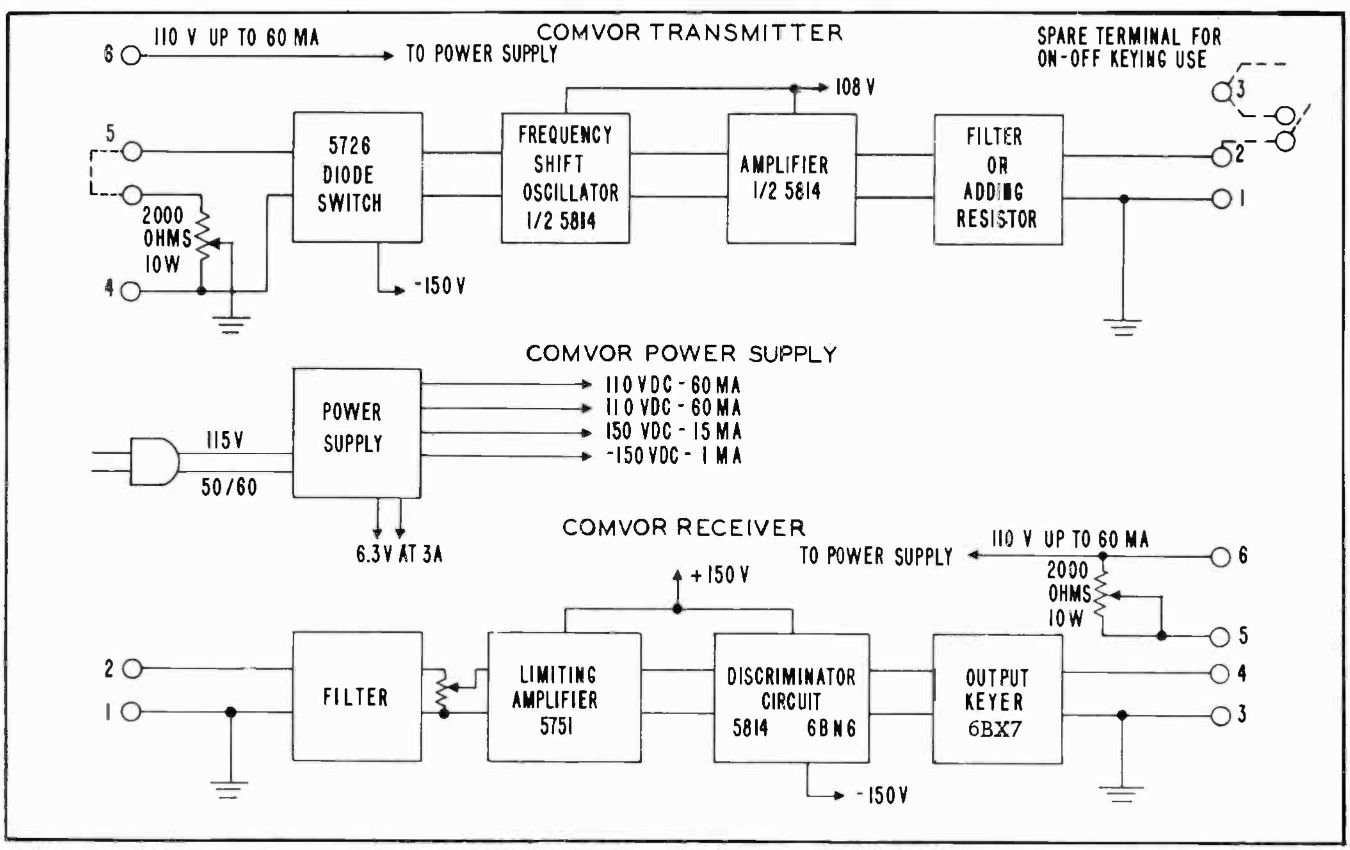


Figure 15





COMVOR TRANSMITTER
110 V UP TO 60 MA
TO POWER SUPPLY
SPARE TERMINAL FOR
ON-OFF KEYING USE
108 V
5726
DIODE
SWITCH
FREQUENCY
SHIFT
OSCILLATOR
1/2 5814
AMPLIFIER
1/2 5814
FILTER
OR
ADDING
RESISTOR
2000
OHMS
10W
-150 V
COMVOR POWER SUPPLY
POWER
SUPPLY
115 V
50/60
110 VDC - 60 MA
110 VDC - 60 MA
150 VDC - 15 MA
-150 VDC - 1 MA
6.3 V AT 3A
COMVOR RECEIVER
TO POWER SUPPLY
110 V UP TO 60 MA
+150 V
2000
OHMS
10 W
FILTER
LIMITING
AMPLIFIER
5751
DISCRIMINATOR
CIRCUIT
5814 6BN6
OUTPUT
KEYER
6BX7
-150 V

Figure 16

SEMI-CONDUCTOR TRANSMITTER PLATE SUPPLIES

New semi-conductor rectifiers developed in recent years have proved themselves to be excellent performers in transmitter plate supplies. As a result, transmitters can now be designed and manufactured that are more reliable and provide greater economy of operation.

The rectifiers under discussion are germanium and silicon types. These rectifiers have demonstrated many thousands of hours of satisfactory operation in General Electric transmitters. Silicon rectifiers have been chosen for use in the new Voice of America 250-KW transmitter. Customer acceptance of electrostatic precipitator power supplies using silicon diodes built by the General Electric Specialty Transformer Department at Holyoke, Mass. has been very good. Also, G. E. Holyoke has delivered a 40/20-kv, 20/40 ampere silicon power supply to a well known tube manufacturer.

Germanium and silicon rectifiers offer many advantages over previously used mercury vapor rectifier tubes. Power consuming filaments, and failures due to these filaments, are eliminated. No warm up period is required and these rectifiers can operate over extreme ambient temperature ranges without the need for heated buildings. High voltage transients due to arc back and arc starvation, common problems in mercury vapor tubes, are also eliminated. As a unit, a high voltage supply composed of quality germanium or silicon cells can be expected to last the life of the equipment in which it is installed, provided the cells are applied within their rating and adequate surge protection is provided.

Germanium rectifiers are employed in the General Electric BT-50-A AM Transmitter. One of these transmitters has been in operation for over 18 months at Station XEAK, Tijuana, Mexico. Performance of the Germanium power supplies has been very satisfactory in the hot, dry climate of this region. The individual cells in the 9-kv, 15 ampere supply, have been checked at regular intervals and only a few random cells were replaced because of changed characteristics. Failure of individual cells is not serious since a sufficient safety factor has been built into the power supplies so that when some cells are lost, usually these are the weaker ones, sufficient capacity remains in the power supply to withstand the peak voltages involved.

When it was decided to use germanium rectifiers in the high voltage power supplies of the BT-50-A transmitter, little was known of the operation of germanium rectifiers under these conditions. However, from various tests that had been performed on these cells and their performance in low voltage supplies, there was every reason to believe they would perform satisfactorily in high voltage applications. However, to determine their characteristics under such service, arrangements were made to test the cells under actual operating conditions in a G-E 50-KW shortwave transmitter at Schenectady, New York. Three GL 857B mercury vapor rectifiers, one half of a three-phase, full wave rectifier circuit, were replaced with germanium diodes similar to those to be used in the high voltage power supplies of the BT-50-A. These cells have been operating in the short-wave transmitter for approximately three years with applied voltage 30% higher than in the BT-50-A. To date the operation of these rectifiers has been very satisfactory and only a few cells located at random points in the stacks have been replaced. This operation is also severe from the standpoint that one half of the circuit consists of three mercury vapor rectifiers which are subject to arc-back conditions. This serves to point out that the germanium rectifiers can really take it under severe conditions.

As a result of the favorable operation of the rectifiers in the 50-KW shortwave transmitter at Schenectady, it was determined that they could indeed be used in the 50-KW AM broadcast transmitter. Thus, the design was formulated, tested, and resulted in the 50-KW transmitter that has been previously mentioned as giving very satisfactory service at Tijuana, Mexico.

Approximately two years ago G. E. received a contract to build a single side-band tropospheric scatter communications system. A 50-KW klystron power amplifier was included as part of this system. It was specified that the power supplies of this klystron amplifier should use rectifiers. In view of our experience and satisfactory operation with the germanium rectifiers we had no qualms about taking on this job.

The outstanding feature of this klystron amplifier is its 35-kv power supply. The diodes are operated at 1/2 their peak inverse voltage rating and the current load per cell is 1/6 its maximum rated current. In addition, each cell has a surge current rating of 100 amperes for one second. This power supply can withstand, for several seconds, the short circuit current that can be delivered to the load by the high voltage transformers. This permits the use of relatively slow acting circuit breakers. It should be noted that the conservative design of this power supply was dictated by a desired equipment reliability of 99.99%.

Semi-conductor diode rectifiers have definite limitations in regard to the voltage that can be impressed across the cells and the peak currents that can pass through the cells. The peak inverse rating of a diode is the maximum voltage, including transient voltage, that can be developed

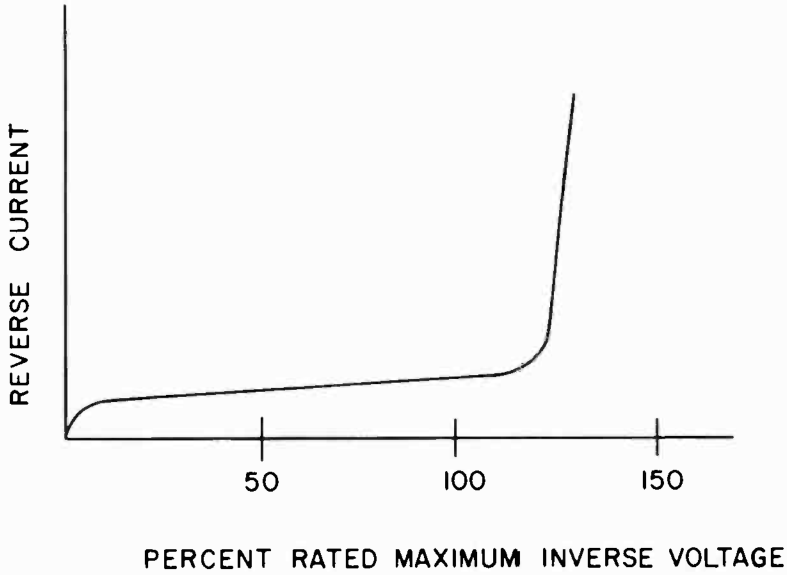


FIGURE 1

across the diode. FIGURE 1 shows the reverse characteristic of a typical diode. Notice the gradual increase in reverse current as the inverse voltage is increased until a value of voltage is reached where the current rapidly increases to a very high destructive value. Normally, the diodes are rated 20 - 25% below this breakdown point. The maximum diode rating must not be exceeded by any value of voltages. FIGURE 2 is a

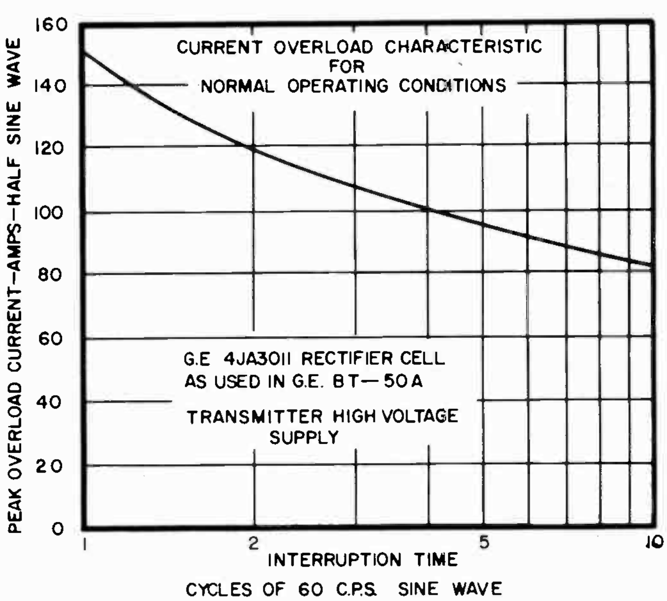


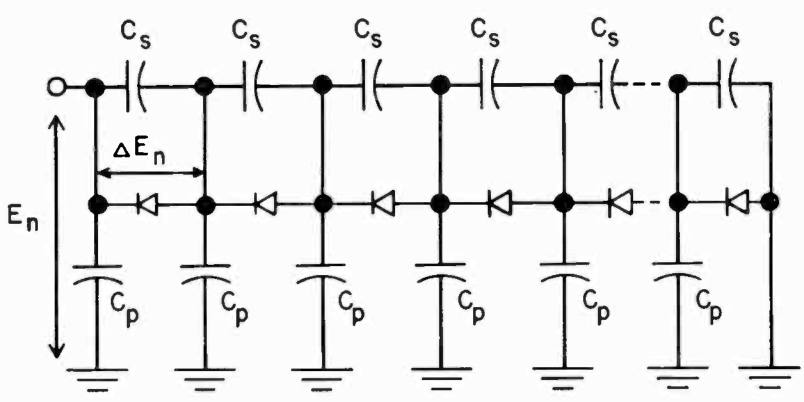
FIGURE 2

typical example of the peak forward current that can be passed thru a diode as a function of the number of cycles of their current. As more cycles of current are allowed to pass through the diode, the maximum value of current must be reduced. These characteristics are the dynamic characteristics of the diode and apply to the instantaneous values of voltage and current.

The power supply voltage determines the number of cells and also the cost. In addition the normal current load determines the cell size and cost. The cells should be operated as close to their maximum ratings as can be justified by good engineering practice and the diode manufacturer's recommendations.

One other very important factor that must be taken into consideration is the distribution of the inverse voltage across the individual series cells. The distribution of the inverse voltage is determined by the stray capacitance of the cells, in much the same way as the voltage distribution occurs across a string of insulators in high voltage AC power lines. The solution to the problem is the same in both cases, that is, the stray capacitance is swamped out with the addition of shunt capacity many times larger than the stray capacitance.

The extent of the inequality of division of the inverse voltage will depend on the number of series cells and the relative magnitude of the cell capacitance and the capacitance from cell to ground as shown in figure 3. Assuming the rectifier cells have a very high back resistance, and that the capacitance of the individual cells and capacitance between cells and ground are uniform throughout the string, Dr. R. deBuda of Canadian General Electric has shown that the peak voltage across the cell nearest the line, ΔE_n, can be expressed as shown in the equation in FIGURE 3 where:



$$\Delta E_n = E_n \sqrt{\frac{C_p}{C_s}} \quad \text{COTH } N\sqrt{\frac{C_p}{C_s}}$$

STEP FUNCTION INPUT VOLTAGE

N = NUMBER OF RECTIFIERS

FIGURE 3

E_n is the peak voltage across the entire rectifier leg.
N is the number of rectifiers in series per leg.
C_p is the capacitance between single cells and ground.
C_s is the series capacitance of a single rectifier.

As an example, if C_s is approximately 15 uuf and C_p is in the order of 1 uuf. Then, if a 50, 000 volt transient is impressed across 300 cells in series, the solution of the equation indicates that 12, 900 volts will appear across the rectifier cell furthest from ground. This means that approximately 25 percent of the transient voltage appears across the first cell. Semi-conductor cells available today would be destroyed by voltages of this magnitude. Proper solution of the equation will yield a value of capacitance that can be paralled with C_s which will force the inverse voltage across the individual cells to be within their rating.

Unequal distribution of the inverse voltage can also occur because of unequal inverse currents due to corona effects. Corona can be a serious problem when rectifiers are mounted in air, even at voltages in the order of 10 to 20 KV. Where corona appears, the air is electrically broken down and ionized so that it becomes a conductor of current. Corona forms at points of high voltage gradient, such as sharp corners, screw heads, and edges of rectifier fins. Thus, all available means of counteracting the effects of corona must be taken.

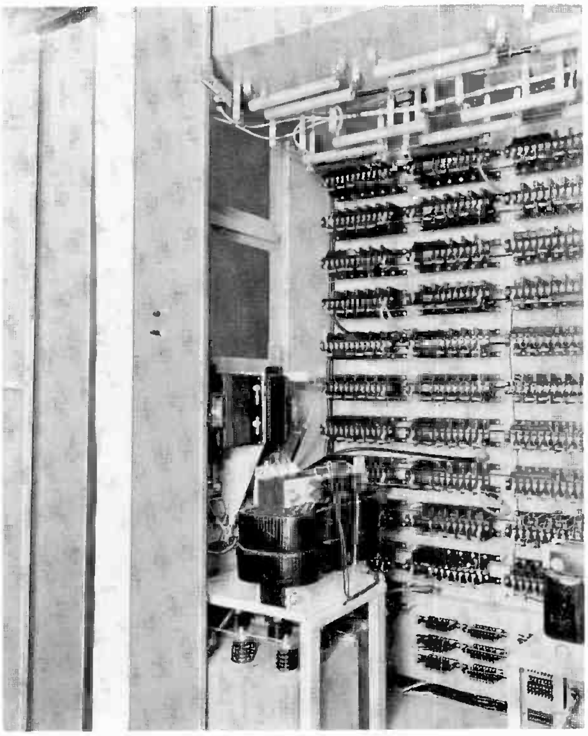


FIGURE 4

Shunt capacitors are used in the power supplies of both the BT-50-A and 50 KW klystron power amplifier. FIGURE 4 shows the rectifiers used in the BT-50-A, note the shunt capacitors across each cell.

The 35 KV klystron power supply is a three-phase, full wave bridge rectifier. One leg of the power supply is shown in FIGURE 5. It is the larger of the two shown, the smaller is one leg of an 8 KV supply. Each leg of the 35 KV supply consists of 216 diodes connected in series and mounted in a spiral. In this supply the capacitors are connected across each turn of the spiral rather than individual cells. The capacitors are not visible in this photograph because they are located inside the cylinder and mounted along its axis.

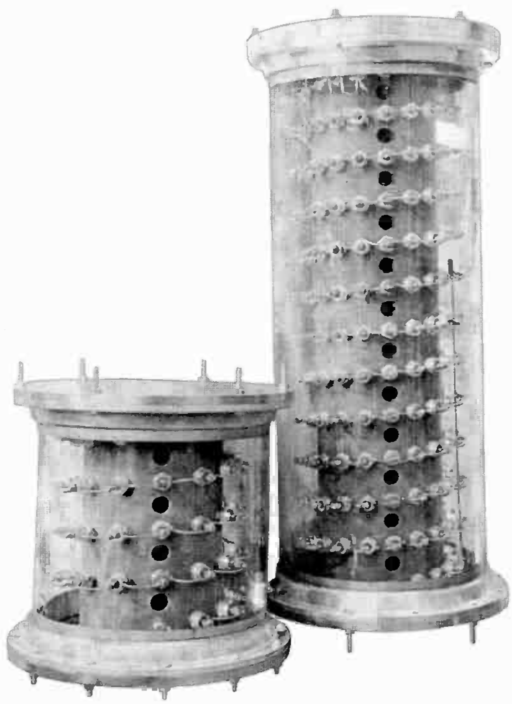


FIGURE 5

The operation and performance of this power supply has been outstanding. Three transmitters have been in operation in the field since February of 1958 and each transmitter has delivered approximately 8,000 hours of trouble free service. In addition, a fourth transmitter has been undergoing many tests in our factory floor. There has not been one single failure of this power supply since it was put into operation.

The inverse current of each rectifier leg is continuously metered, providing a means of monitoring the operating condition of the supply. Special tests were made under high voltage conditions where an increasing number of individual cells were shorted out with clip leads. It was demonstrated that the inverse current of the stack increased as the number of operating cells decreased. Over the course of a year's operation the inverse currents of the power supplies in all operating transmitters has not changed appreciably, indicating the rectifier stacks are as good as the day they were installed. As a matter of interest, it can be noted that the inverse current of one leg is in the order of 300-500 microamps.

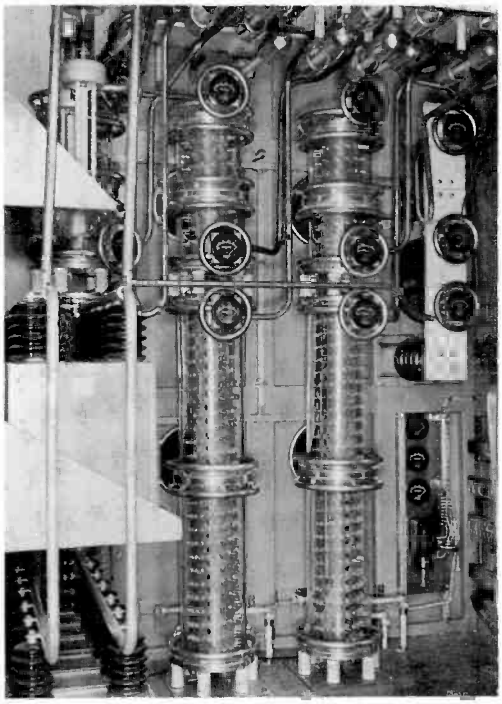


FIGURE 6

FIGURE 6 shows the 35 KV klystron rectifier. Note the method of mounting, inverse current meters and corona protection.

The operation of these transmitters has been unusually severe, from the standpoint of on-off cycles. The reason for this being that the transmitter used in our factory floor and those in the field were operated under test conditions. That is, the on-off cycles of the transmitters were many, many times greater than would ordinarily occur in a year of usage for communication purposes only. It is during the on-off switching that the worst transients occur.

The transmitter and the power supply have been put through severe environmental test and have come thru with flying colors. The environmental tests included prolonged operation with an equipment ambient temperature of 52° centigrade and operation under conditions of high humidity, including condensation. In addition the power supply was operated for an extended period at 130% normal voltage. No degradation in performance occurred either during the tests or in many tests made after this.

The choice as to whether to use germanium or silicon rectifiers is largely determined by the environmental conditions under which the transmitter will operate. If the transmitter is to operate under severe environmental conditions and wide variations of temperature, especially in high ambient temperatures on the order of 50° to 150°C silicon rectifiers should be specified. If however, the transmitter will operate in ambients lower than 50°C, germanium rectifiers can be selected. Such a choice may yield a somewhat lower initial cost and a little better efficiency. However, with the increasing use of silicon rectifiers in high voltage power supplies and the wide range of ratings available it is likely that the silicon rectifiers will become increasingly more popular.

Our experience has shown that germanium and silicon rectifiers do not have to be series matched. This is due largely to the sharp breakdown condition in their inverse characteristics. Thus, they can be selected at random, connected in series, and will provide satisfactory operation.

Practically every new job that we come across specifies that the power supply shall use silicon rectifiers. Thus, it can be seen that they are rapidly gaining customer acceptance and are being specified, especially in military contracts where extreme reliability is required.

One word of caution. There are many reputable manufacturers of germanium and silicon power rectifiers. Unfortunately, the power rectifier industry does not have uniform standards when it comes to rating rectifiers. Thus, until such standards are adopted it is very important that the circuit designer work very closely with the rectifier manufacturer.

In conclusion then, it can be stated that germanium and silicon rectifiers have proven to be good, stable, reliable performers in transmitter power supplies. Their use results in reliable, trouble-free transmitters which is what, you, the customer wants.

TELEVISION BROADCASTING ANTENNA SYSTEM IMPEDANCE REQUIREMENTS

Donald W. Peterson

Broadcasting high quality television pictures requires good engineering, quality manufacturing, and careful installation of the various portions of the TV system. This is no less true of the antenna system of Fig. 1 which has the special difficulty of requiring proof of satisfactory performance measured at a distance of a thousand feet or so from the antenna through a long transmission line.

Consider a television broadcasting system for which both the transmitter and the antenna have been well engineered. The electrical performance of these sub-systems can be fully described and technical specifications written which will convey to the broadcaster a satisfactory understanding of the expected performance. After delivery, installation, and test, the transmitter can be demonstrated to have fulfilled the electrical specifications. Similar proof of performance would be desirable for the antenna too. If we consider the entire antenna sub-system, specifications to assure the desired quality of performance fall into two natural areas. The first is related to the radiation characteristics of the antenna, an area beyond the scope of this paper. The second has to do with the antenna as the terminating impedance of a long transmission line and the performance of the line itself. In the belief that the present kind of antenna system specification has become inadequate, a new approach will be proposed which is capable of relating picture performance and specification simply, positively, and unequivocally.

How a Malfunctioning Antenna System Can Affect Picture Quality

Normally the only picture effect of the long line is the introduction of time delay of the echo voltage from the antenna. An abnormal line may introduce any of three effects. These are: (1) ghost images from discrete reflections with appreciable time delay; (2) smear from many reflections distributed along the line; and (3) misregistration of chrominance and luminance information in a color picture from envelope delay distortion. An electrical specification to assure that none of these effects will be visible in pictures is desirable for the antenna system.

The Antenna System Specification

An antenna impedance and transmission line specification should satisfy two simple requirements: (1) the quantities specified should be a measure of the picture quality of the signal which reaches the antenna; (2) success or failure in meeting the specification should be capable of proof.

The specification now in use sets a limit on the voltage standing wave ratio for components and sometimes also for the over-all system. The present VSWR specification is no longer capable of coping with changes and improvements of the TV system.

In seeking a satisfactory specification approach two possibilities have been considered. The first was to alter the present kind of voltage standing wave ratio specification to make it more effective. There are several reasons for alteration. Among these is the well known fact that a small line reflection near the transmitter can be less objectionable than the same reflection at a greater distance since the first appears as distortion in a brightness transition and the latter as a ghost image. This fact and others should be recognized in a proper specification. Nevertheless there is no doubt that a revised VSWR specification can be prepared which, when satisfied, will assure quality picture performance.

The difficulty is the inability to measure VSWR vs. frequency and distance. The voltage standing wave ratios that can be measured after installation of the antenna system are not a satisfactory measure of expected picture quality. It is difficult if not impossible to prove by VSWR measurement that the picture performance of a long line and its antenna termination will be up to standard. Neither can one always prove by this method that picture performance will be below standard. Systems which meet electrical specifications and perform badly and systems which fail to meet specifications but perform well are anomalies which can be expected even if highly refined VSWR specifications were to be used. Furthermore, trouble shooting by VSWR measurement in a system which is suspected of transmission line or termination trouble, can be quite baffling when there are several undesired reflections from line faults along with a multitude of normal reflections.

The Use of R-F Pulses in a Specification

On the other hand line faults of significant magnitude can be easily located and evaluated with r-f pulses. This suggests a second approach using pulses in the specification. Before trying to draft a specification based on pulses, let us review a few relevant facts about the antenna system.

Distortion of the radiated signal, which is introduced by either the transmission line itself or by reflection from the line termination, can be observed at the line input. The initial wave which propagates from transmitter to antenna through a normal line is virtually undistorted by the line. Reflected power from line discontinuities and the line termination introduce the only significant distortion. The reflected power propagates back to the transmitter, is partially reflected by the transmitter output impedance, and again propagates to the antenna to be radiated as distortion. Essentially the same r-f envelope exists at both the transmitter and the antenna terminals. This fails to be true when there are severe line discontinuities. As the reflection from a line discontinuity is increased from an invisible level, the first effect to be seen in the picture is the delayed image, followed at a much higher level by distortion of the initial wave.

The transmission line and its termination will have done their job very well indeed if the r-f envelope at the long line input is the same as the envelope when the modulated r-f is applied to a pure resistance equal in value to the line impedance. Modulation waveforms can be chosen to make such a test sensitive to all possible kinds of distortion. Since a faulty long line and its termination can introduce delayed ghosts, smears, and chrominance-luminance misregistration, tests for each effect will be described. The tests are given only as examples since many variations are possible.

A test can be made to see that ghost images from either the termination or line discontinuities will be below visibility. For this test the shortest r-f pulse which the system will pass can be applied to the input of the long line. The line will be terminated with the antenna impedance. The relative reflection voltage as shown in Fig. 2(a) returning from either the antenna or line discontinuities should be less than P% with the choice of P based on subjective tests with pictures. This will detect line faults which may occur during installation and show all that needs to be known about the antenna impedance.

There is a remote possibility that many discontinuities may be more or less uniformly distributed along the entire line length as a result of manufacturing or installation defects. These may be the result of accidental periodic dents, for example. Such line trouble will appear in the picture as a short smear of length equal to the round-trip propagation time T of the long line. This kind of distortion can be detected with a flat-topped r-f pulse slightly shorter than T. The flatness of the demodulated pulse, Fig. 2(b), in comparison with the test pulse observed with a resistance substituted for the long line, is a measure of the distortion. $\Delta v/V$ should be less than Q% with Q to be determined by subjective picture tests.

To learn if faults of the line will cause misregistration of color picture chrominance and luminance information, another r-f pulse test can be made. One approach here would be to modulate with a d-c pulse which has superimposed the color sub-carrier frequency as in Fig. 2(c). The misregistry time should be less than t microseconds. The time t will be so small that probably some other method of measurement will be necessary.

Another possibility is to do all three tests simultaneously with the modulating waveform of Fig. 3. The antenna relative reflection voltage is measured by the step at T microseconds. An accidental discontinuity of the line causes a similar step in a lesser time interval. The rise time is a measure of the envelope delay characteristic. Multiple distributed line discontinuities are evaluated by the flatness of the waveform between the initial rise and the step of the antenna. For this test the modulating pulse must be longer than T.

In terms of the tests which can be made to prove performance, the long line specifications to assure that ghosts, smear, and misregistration will be kept below acceptable limits are threefold. The following should be specified:

1. A maximum permissible relative reflection voltage P from line discontinuities and the line termination.

2. A required flatness Q of a test pulse slightly shorter than the round-trip propagation time of the long line.

3. The time delay t of color sub-carrier modulation frequency with respect to the d-c pulse on which it is superimposed or other suitable measure of envelope delay.

The critical numbers P, Q, and t must be chosen on the basis of subjective tests with a complete TV system and on the basis of theoretical considerations.

It should be recognized that a variety of factors will influence the actual specification numbers P, Q, and t. (1) The transmitter does not fully reflect the incident power returning from the antenna or line discontinuities so the relative reflection voltage from the transmitter output impedance will affect the numbers chosen as acceptable. (2) Reflected power must propagate through all or part of the long line two extra times so line attenuation is a factor. (3) Visibility of echo voltages in pictures depends upon detector linearity. There is a tendency with the usual envelope detector to compress low percentage black echoes and slightly stretch low percentage white echoes. (4) Another factor is that the linearity (gamma) correction introduced in the camera to pre-compensate for the kinescope light intensity non-linearity with input voltage obviously does not operate on echo voltages which occur in the system beyond the camera. Therefore kinescope non-linearity also tends to compress black and stretch white echoes. All of these factors combine to determine the acceptable relative level of echo voltages.

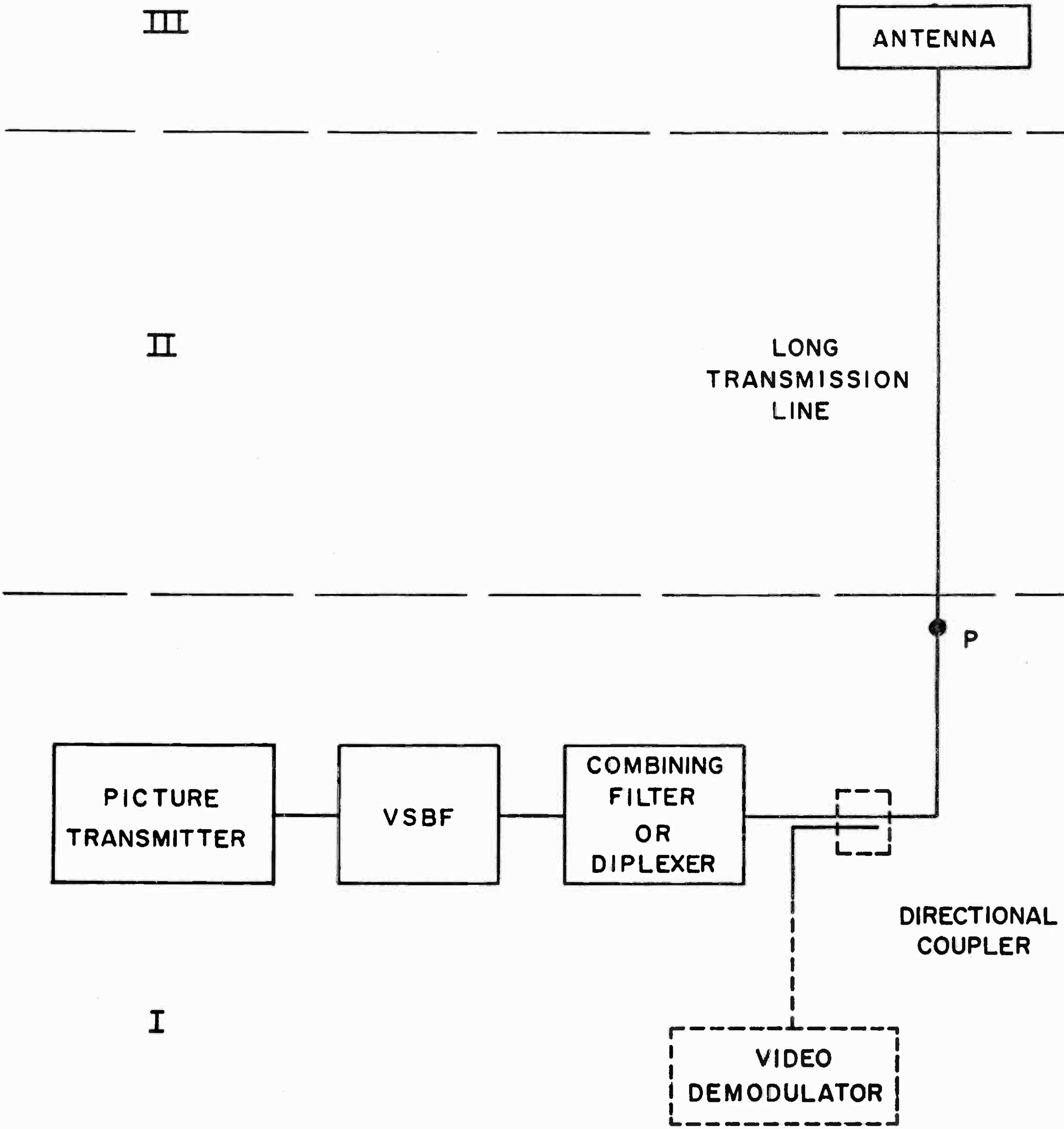
Experience with the new specification approach with our laboratory TV system, Fig. 4, has already shown great promise. This complete television system will be used for subjective tests for the purpose of choosing the necessary critical numbers for the specification. These will be chosen, we hope, with the cooperation of the TV industry. We want to demonstrate the new specification in the laboratory, test it in the field, and invite comment before we will be ready to make a recommendation.

Pulse Trouble Shooting

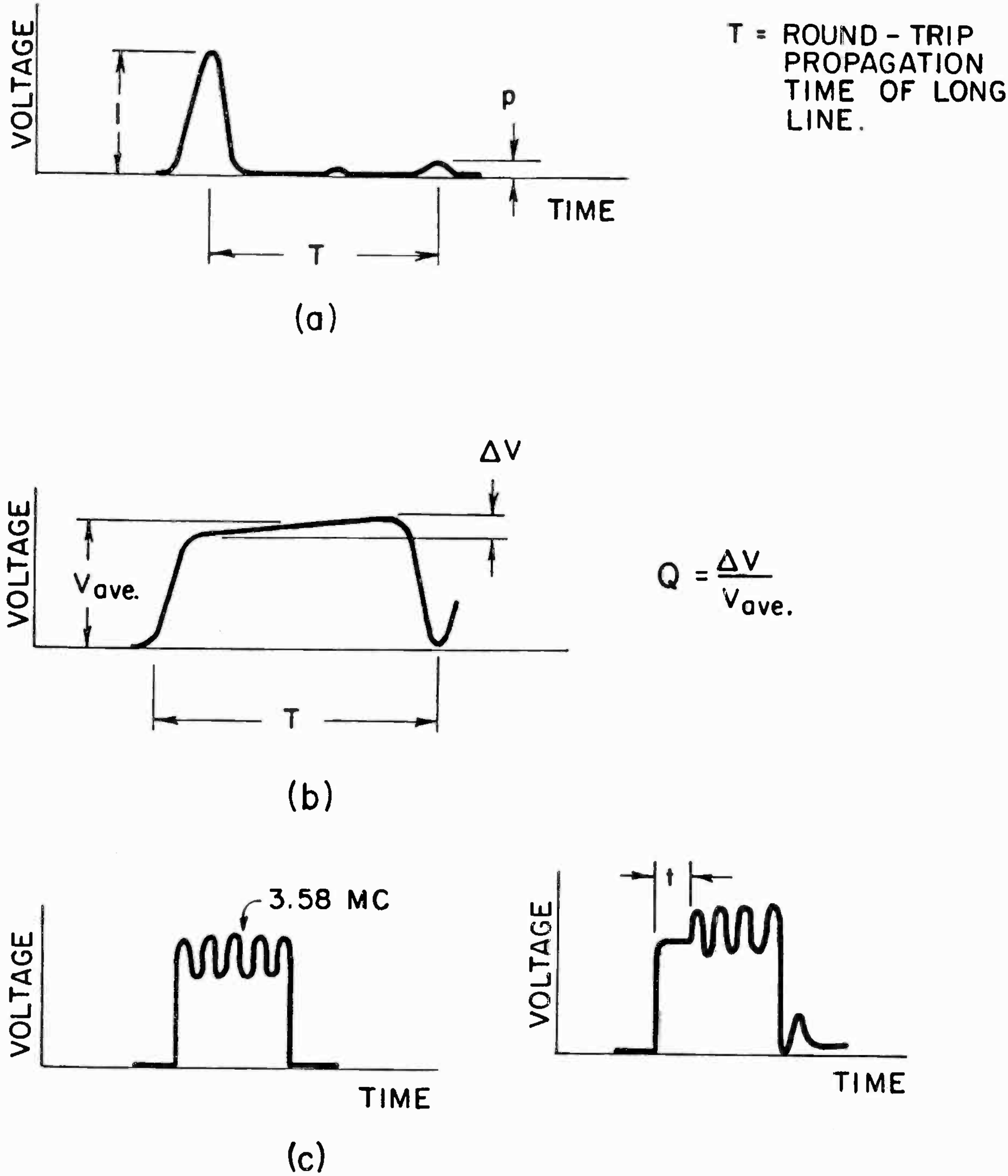
When performance of an installed system falls short of the specification, it will be necessary to find the reason. As already implied, this can be done with pulse tests as shown in Fig. 5. By the use of short r-f pulses (about 0.1 microsecond), line faults can be roughly located by viewing initial and echo pulses with a scope such as the Tektronix 545 at the line input. Then with 10 millimicrosecond d-c pulses such as generated with the EPIC 200A Square Pulse Generator the faults can be accurately located. The d-c pulse measurement is so accurate and sensitive that the causes of echoes well below objectionable level can be located within a few feet. Multiple echoes, which have caused considerable difficulty in diagnosis of line troubles by VSWR measurement, are no problem since individual echoes are displayed on a time scale which is linearly related to distance along the transmission line to the fault as shown in Fig. 6. Pulse trouble shooting is straightforward and can be done with readily available apparatus.

Conclusion

The proposed kind of pulse response specification is capable of clearing a lot of muddy water in the area of antenna system specification. In my opinion the broadcaster will benefit immeasurably by adoption of this new approach. In the long run the manufacturer must also gain because the approach is simple in conception and straightforward in practice. Not the least of the benefits to be expected will be better understanding of antenna system problems and improved system performance.

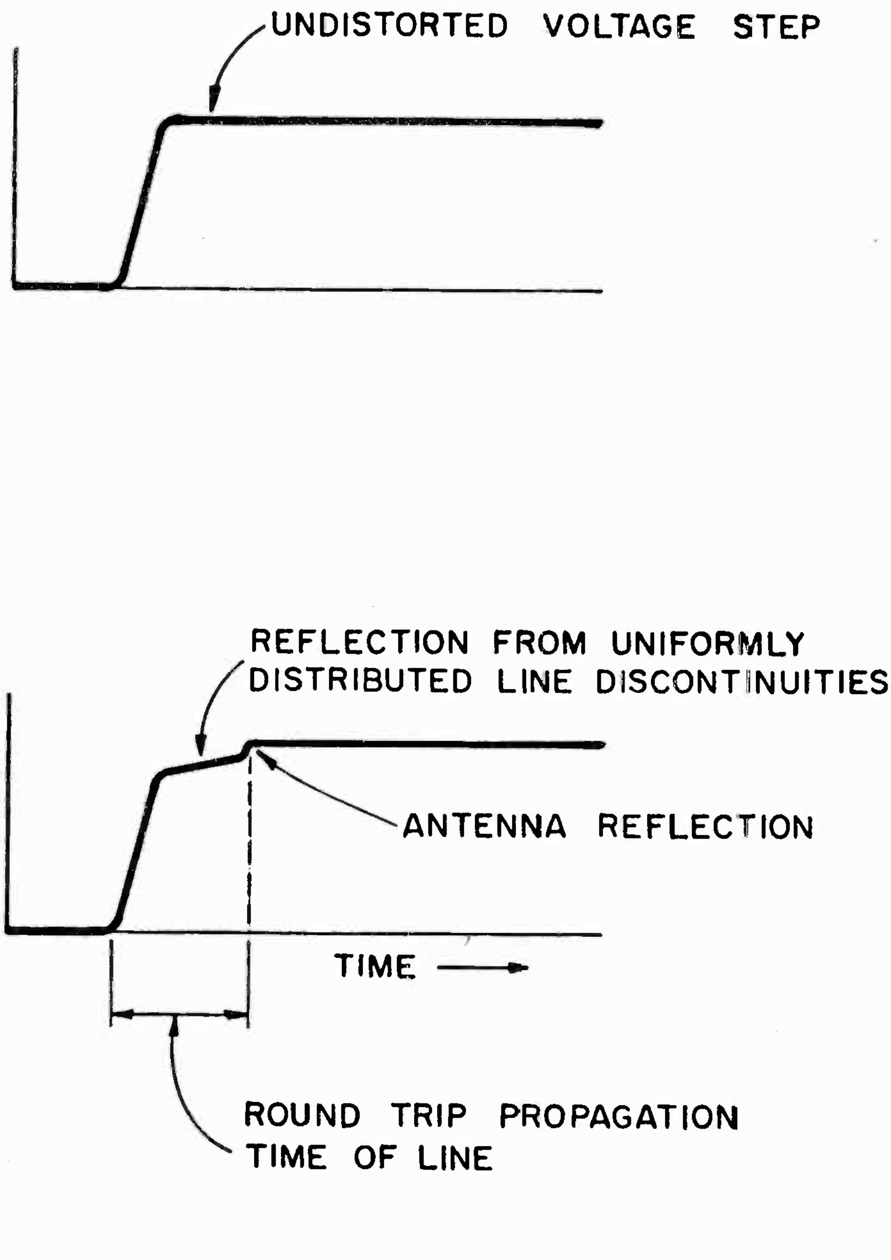


ANTENNA SYSTEM
FIG. 1



MODULATION WAVEFORMS FOR PULSE RESPONSE TESTS

FIG. 2



LONG LINE TRANSIENT

FIG. - 3

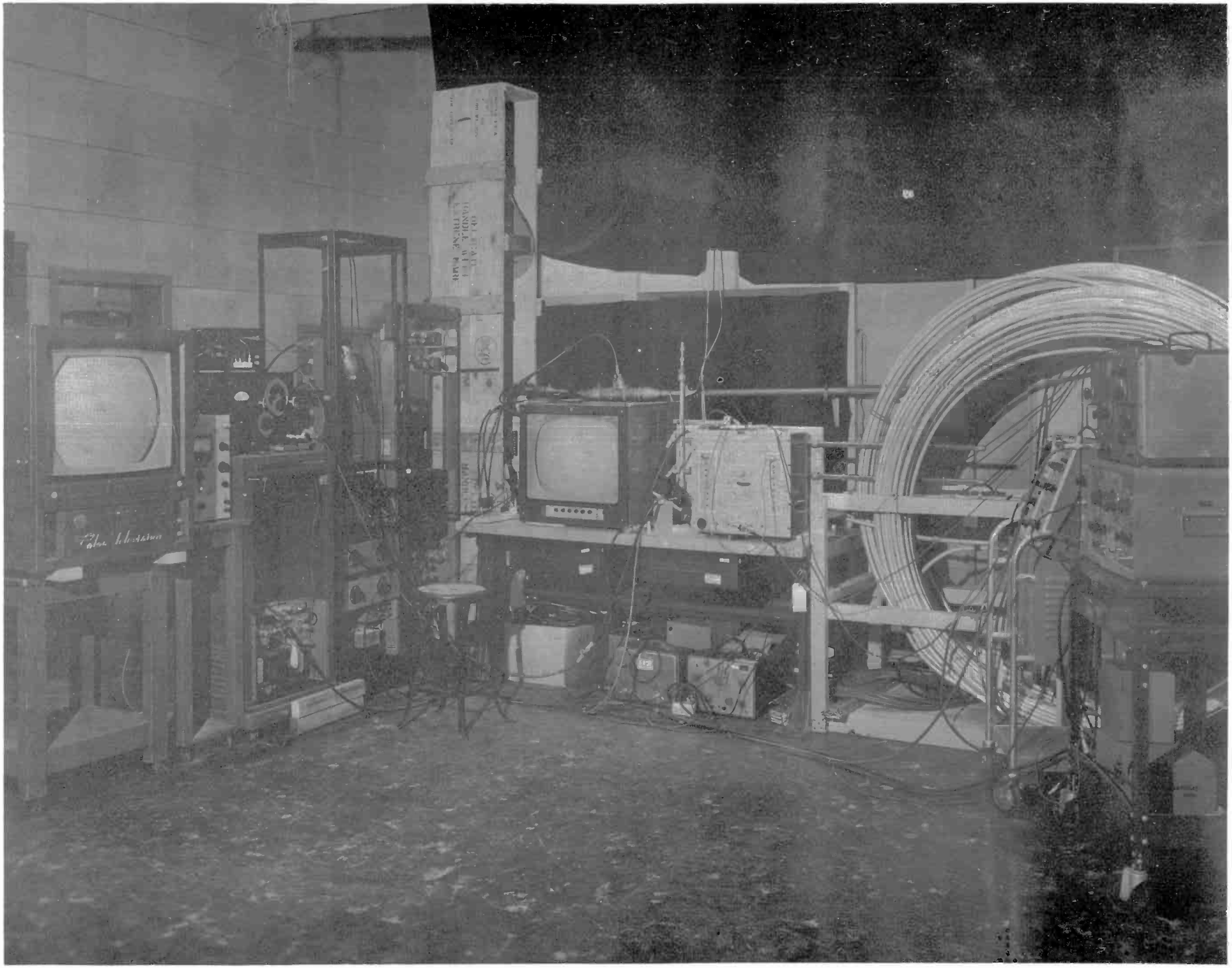
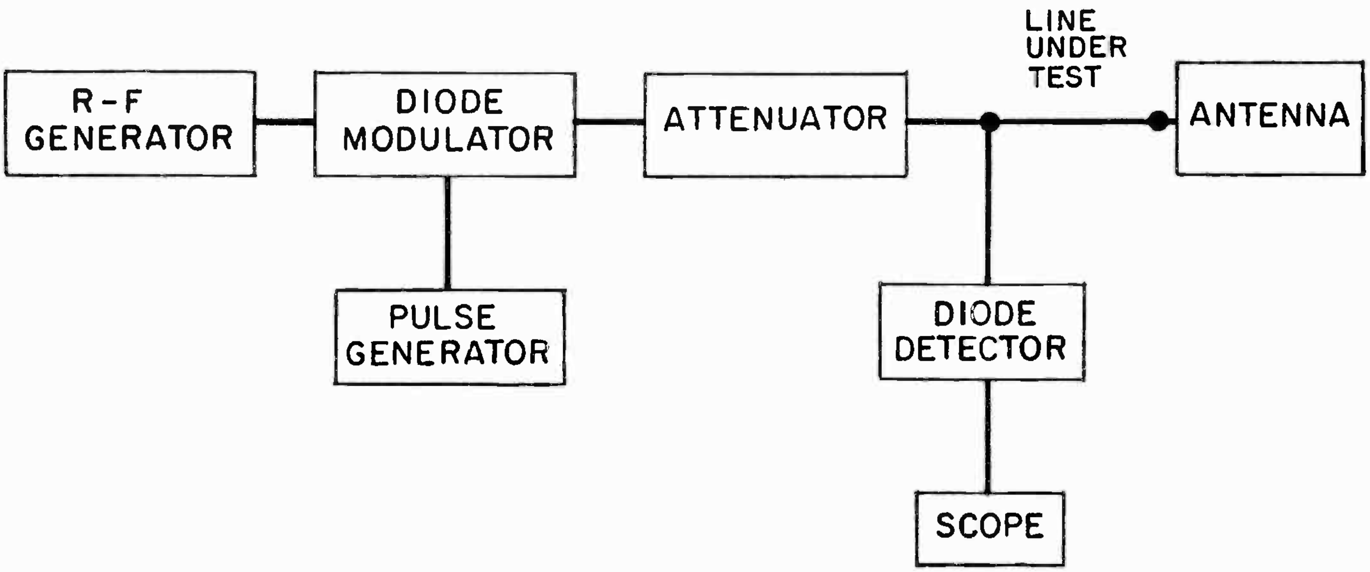
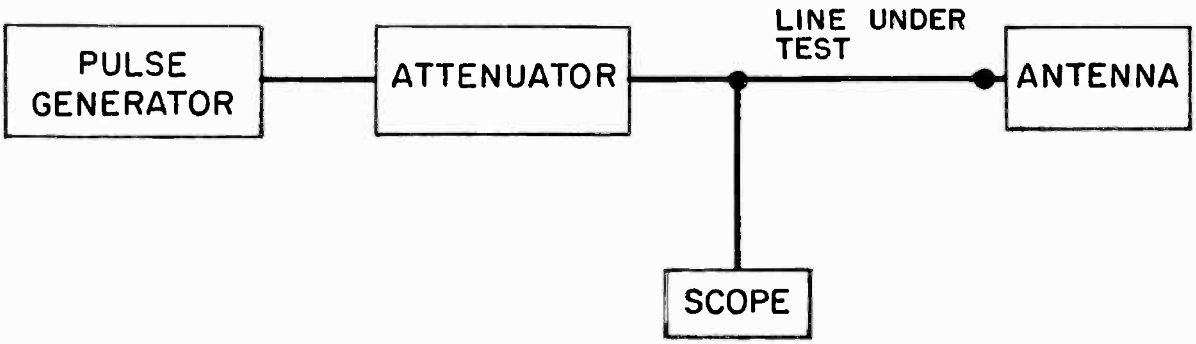


FIG. 4

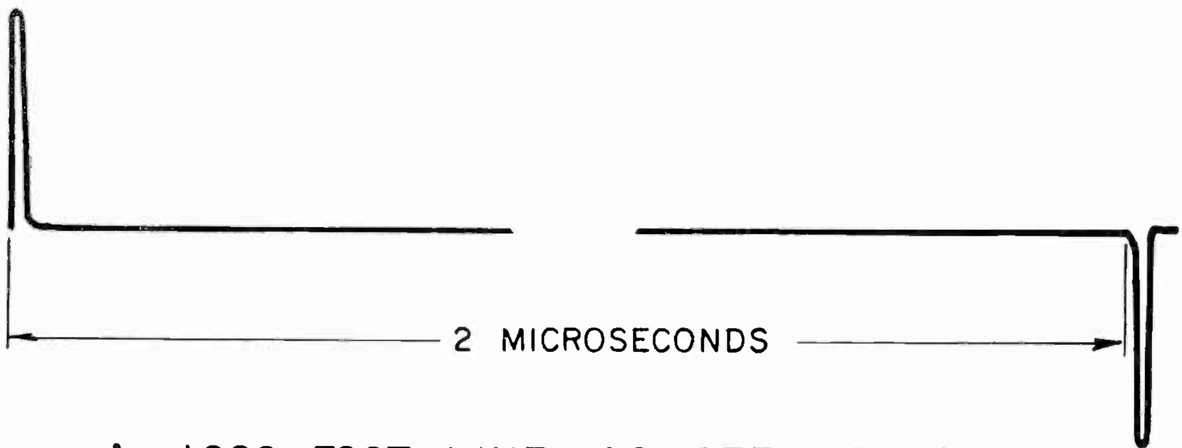


R-F PULSE TEST

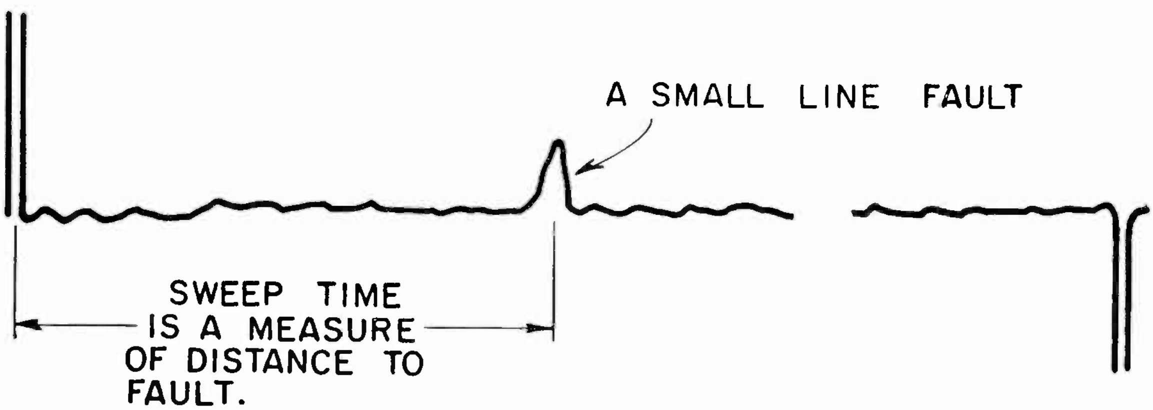


D-C PULSE TEST

FIG. 5



A 1000 FOOT LINE AS SEEN ON A SCOPE WITH D-C PULSE TEST.



THE SAME LINE WITH THE SCOPE GAIN ADVANCED 100:1.

FIG. 6

Stereophonic Broadcasting

By

Emil P. Vincent
Chief Audio Facilities Engineer
American Broadcasting Company

American Broadcasting Company owned Stations KGO, San Francisco, and KABC, Hollywood, have been transmitting stereophonic broadcasts by the use of the AM and FM channels. These programs transmitted for approximately nineteen hours a week have been eminently successful. The experience gained by these stations will be described.

In AM - FM stereo transmission, there is a question as to whether compatibility, insofar as separate channel listening is concerned, is necessary or desirable.

While AM - FM stereo transmission is the simplest method, at the moment, other presently considered methods will be reviewed.

There is a steadily increasing interest in stereophonic listening evidenced by the public in general. Many fine home record players and systems are available for purchase. Stereo records are appearing in great numbers. Soon stereo 45's will be available with "top ten" music. Still there is a great majority of people who would prefer to listen as they have in the past to recordings as played on the air by the local broadcasters.

Stereophonic reproduction is that which results from the use of two or more separate microphone channels to pick up the sound and two or more separate speaker channels to reproduce that sound. About 20 db electrical isolation between channels is normally considered as a target.

To better understand the requirements for broadcast playback of the stereo disc, it is appropriate to review the methods used in the production of those records.

In one case, the approach as applied to the recording of classical or even semi-classical music is generally that of the use of a miminum number of microphones, possibly only two spaced microphones for an overall pickup. These microphones are spaced to suit the record producer as he listens in the recording control room. These are either non-directional or highly directional microphones, depending upon the studio acoustics, set about 8 feet apart in front of the orchestra. The stereo effect results from level and phase or time difference as a function of the relative distance to various instruments from either microphone. Sometimes, this system produces the so-called "hole-in-the-middle" effect, in which case a third, center microphone is added and fed directly to both side channels. The center microphone now fills that "hole-in-the-middle."

A second system, more generally applied in the production of the popular or "gimmick" records, is one using a multiplicity of microphones.

This is a variation of the method used for making modern popular monophonic records where literally each orchestra section, rhythm, strings, etc. has its own closeup microphone. For stereo, however, certain of these mikes are called "right," others "left" and the remaining are called "center." These instrumental sections need not be physically located in the left, center, right positions with respect to each other. Actually, they are separated as far apart as required to retain some amount of acoustical separation. In this case, the so-called "center" mikes are mixed equally to both "right" and "left." On playback, the "left" instruments are heard on the left speaker, "right" instruments on the right, and "center" instruments directly between the two side speakers. Actually, this is a three-channel system and requires the use of a three channel audio console. The "center" in playback is, in essence, a phantom sound channel. This system depends only on difference in intensity or level. (See Figure 1.)

Another approach is in the use of two bi-directional microphones both located at the same position in front of the performers with the centers of the pickup pattern set at an angle of 90°. This system is quite generally used abroad and is called the "Stereosonic" system. A variation of this system called M/S or middle-side is also being used, whereby two microphones, one with bi-directional and the other with uni-directional or cardioid pickup patterns, are mounted together so that the uni-directional microphone faces forward, with the bi-directional microphone arranged so that its null faces forward. Because the microphones are mounted in the center and in front of the performance, there will be no such middle-hole effect as experienced with spaced microphones. The stereo effect with such systems results solely from intensity or level difference. (See Figure 2.)

From the foregoing descriptions of the various recording methods, we can conclude that the most important factor in producing the stereo effect is that of level or intensity difference from a sound source as recorded on the two channels. Phase difference is a secondary factor in one of the systems.

If we now understand how the stereophonic material is produced, we should have a clearer insight as to what must be done to provide the home radio listener with a proper presentation. The radio system including telephone lines is merely a link between the record or tape player and home speaker system. Fundamentally, we must playback and transmit a dual source via two isolated radio channels. The simplest presently available methods are to use a combination of TV-AM, FM-AM or even AM-AM. Either of the first two methods are available to many station operators, while the latter is a possibility with the cooperation of two local AM stations in one vicinity. Any of these systems will permit transmission of two sources with 100% isolation.

The most commonly used method is the FM-AM system, i.e., the FM transmitter is fed with the left side information while the AM transmitter is fed with the right side information. The left-right sequence for FM-AM transmission has become an accepted interim standard, and should be used. The two feeds can be supplied from information presently available on stereophonic discs or tapes. The broadcaster should, if possible, reproduce those recordings with no alteration of originally recorded level difference.

In order to play stereophonic records, a turntable must be modified to the extent that a good stereo cartridge is installed in place of the standard monophonic or single channel cartridge. There are, of course, many fine cartridges available for use. An additional pair of wires are added in the tone arm to connect what is in effect a dual cartridge to two pre-amplifiers.

These preamplifiers should be equal in equalization and in total amplification. To insure that the relative amplification between the two channels is held constant, the two preamplifiers should feed two sections of a dual fader or volume control. Each of the faders will in turn feed, via line amplifiers, the local radio lines to the respective transmitters. An operator, in gain adjusting, will therefore observe two VU meters, and maintain levels as before except that two channels are now varied at once, thereby retaining the originally recorded level difference. (See Figure 3.)

The two stereo channels are now handled at the transmitters in the same manner as for separate audio signals except that no further level adjustments should be made manually. Actually, each transmitter has as part of its system a limiting amplifier. A question could be raised as to what happens to the recorded level difference with two separate limiters operating, one on each channel. If the condition is one where both transmitters are at the same physical location, it is possible to modify the limiters so that the control voltages are tied together or ganged. In this manner, compression that results in one limiter will cause the same amount of compression in the other limiter, maintaining the original level difference.

In those instances where such ganging of limiters is physically not feasible because the transmitters are at different locations, it is recommended that the limiters be operated for a minimum normal compression and used only for the purpose of over-modulation protection. The same theory should apply to the use of the automatic gain control amplifiers such as "Sta-Level" or "Uni-Level."

We have discussed the essentials for putting stereo disc playbacks on the air. Obviously, if tape recordings are the source, the turntable is replaced with a dual channel playback machine.

Announcements can be handled in at least two ways, the simplest being to feed the output of the announce microphone to both channels. This should be done at a point in the system which is isolated from the turntable feed to avoid the possibility of electrically tying the two turntable feeds together, thereby removing the channel separation. This method guarantees equal announce audio level in both channels to satisfy the single channel listener. (See Figure 3.) A second and more sophisticated method would be to use two separate microphones and in this case separate faders. Announcing equally to both microphones would provide equal level announcements to both channels. The system leaves room for use by the announcer of two-channel announcements of the "gimmick" type. It would even allow the use of two announcers with many interesting programming possibilities. (See Figure 4.)

If it is planned to do live stereo broadcasts, a dual channel system with ganged microphone faders is necessary. For such a pickup, the simplest method for microphone placement would be the spaced microphone technique. Individual microphones L and R are fed to each side of a dual preamp-fader sequence. The center microphone is fed equally to both channels as is the soloist or announcer microphone. The system follows the same pattern as was discussed for turntable feeds. Two sets of field amplifiers could be used as an interim measure to provide a stereo output, in which case it would be desirable to gang faders by means of rubber bands or belt drives.

Another source of stereo is that which is provided by TV-Radio networks. The ABC LAWRENCE WELK Tuesday night show was transmitted to the ABC TV and Radio Networks on a stereo basis for an extended period. The WELK SHOW sound was transmitted via dual telephone company lines. Its primary purpose was to provide for the listener a TV-AM stereo source, in which case the TV system replaced the FM transmitter and in the home the TV set was located on the left side. ABC owned stations, KABC and KGO, transmitted the left side audio on FM as well as on TV. TV network audio and the radio network audio in this case were handled as remotes and mixed using dual faders.

It would be well to mention one of the problems inherent with network distribution of a pair of stereo lines. The most serious condition is that which involves the relative speed of transmission of carrier systems vs. landlines. If normal landlines are to be used they should be identical in physical length so that the both sides of the stereo audio channels arrive at the same time, or within certain maximum difference limits. Such a situation can be illustrated in the case of the LAWRENCE WELK SHOW. The normal TV audio channel is distributed to the network via telephone "K" carrier equipment. The time of transmission required for audio as part of a television show is that of maintaining "lip sync." For the distribution of the second channel, similar "K" carrier facilities were ordered. However, certain areas could not be cleared for a second "K" carrier line so that stubs of landline had to be included, with the total circuit set up to provide a maximum of delay difference of 10 ms between the TV sound and the radio network sound. The 10 ms requirement was arrived at as a result of tests made by ABC and Bell Telephone Labs indicating that the stereophonic effect is not appreciably disturbed when one side is delayed up to that value with respect to the other. That is now the telephone company specification for a pair of network stereo lines.

What about compatibility? There always must be full consideration of the single channel AM or FM listener. He does not receive the complete recording; he hears only the left or the right side and is therefore listening to a non-compatible signal. Will this cause the potential listener to tune to another station that is playing monophonic records.

The experience we have had at Station KGO-AM-FM, San Francisco, indicates no need for compatibility under the proper conditions. These conditions involve a somewhat careful selection of recorded material for playback, avoiding the obvious "ping-pong" or "gimmick" records. This conclusion is reached as a result of listener reaction evidenced in the letters of comment which have been received. As a point of information, KGO programs nineteen hours of stereo programming each week, including a half-hour period during the day for the local hi-fi dealers. The remaining programming is done in the evening and consists of show tunes, classical and semi-classical varieties of music. Similar programming is also being done at KABC-AM-FM, Hollywood, with much the same results.

There are at least two methods to make both channels compatible. Each is, and must be, a compromise of the true stereo effect. One method is as proposed by the Bell Laboratories to cross-feed both channels through 10 ms delay lines. This system is based on what is called the "precedence effect" which states that if in the case of two spaced sound sources equal in level, one source is delayed with respect to the other, the sound will appear to emanate from the earlier of the non-delayed source.

Another approach is to cross-mix the two channels using at least 6 db attenuation in the cross-feed. This system, of course, varies somewhat from our original specification of 20 db isolation between channels but is simple and satisfactory. (See Figure 5.)

The effect on the stereo reproduction of these compatible systems is that of moving the apparent sound sources closer together at the listening point.

While the method heretofore discussed, i.e., the use of two separate, isolated, transmission-receiving systems, is a simple presently available answer to the problem of stereo broadcast transmission, it seems certain that permanent and uniform methods will ultimately be adopted by the industry for use on AM, FM and TV.

A major stereo committee sponsored by the EIA, called the National Stereophonic Radio Committee, has been formed to evaluate stereophonic radio systems and will recommend one of the many proposed methods of providing stereo transmissions for each of the broadcast media.

It would be well to review various proposals. For AM, the following are some of those proposed methods:

1. The Philco System -- the system involves simultaneous modulation of the AM carrier, by both amplitude and phase modulation. From the two separate stereo channels the sum of the two signals, L + R or left and right, is used to amplitude modulate the carrier while the difference or L - R signals is used to phase modulate the carrier in quadrature. The sum signal can be received and reproduced by any standard AM receiver. A special adaptor connected ahead of the detector of the main receiver provides a second detector to recover the L - R difference signal which, when properly re-combined with the sum signal, will produce the two original separate stereo channels. One channel will feed the main receiver audio system while the second will feed an audio system contained in the adaptor unit. Stereo receivers can be produced to include all the necessary circuitry, and both speaker systems. The ABC radio station WABC, New York, plans to conduct tests of the Philco AM system if approval of FCC is received.

2. The Kahn Research Laboratories System -- as a result of previous development on a compatible Single Sideband adaptor for use with broadcast transmitters, Kahn Research Labs proposes the use of two such single sideband adaptors, one each for the upper and lower sidebands, in which case, effectively, one stereo channel is used to modulate the upper sideband and the other modulates the lower sideband. Two standard receivers, each tuned to separate sidebands, are used to reproduce two separate stereo channels. A single standard receiver can be used to tune to the carrier frequency for a reproduction of the combined signal.

RCA has indicated that they will announce a system in the near future and it is expected that further proposals will be made by other prominent broadcast equipment manufacturers.

For FM we have had two fundamental approaches for the transmissio of two stereo channels, both of which involve the use of the FM multi plex system. The Crosby system uses the L + R sum signal for modulation in the normal fashion of the FM carrier, with the L - R signal used to modulate the sub-carrier. A standard FM receiver will reproduce the compatible sum signal. An adaptor would be required to receive the L - R signal, which when combined with the L + R signal, will recreate the two original stereo channels.

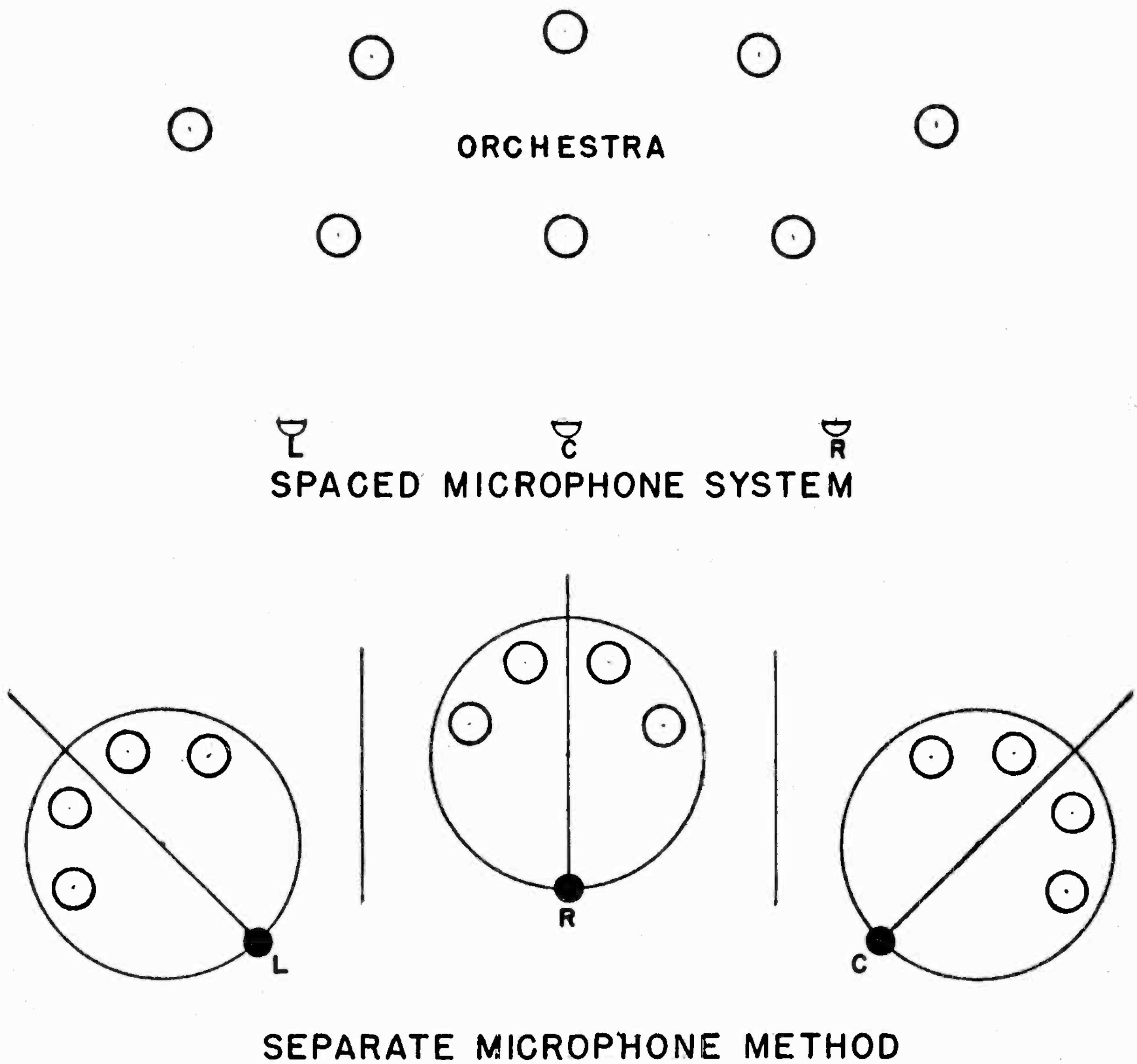
A modification of the Crosby proposal is the Calbest system which proposes to use the sum signal to modulate the main FM carrier and to use th difference signal, with a restricted audio range, 180 to 3500 cps., for sub-carrier modulation.

The Halsted system is one in which the left channel is used to modulate the main FM channel while the right channel modulates a sub-carrier. A special adaptor is required to detect the sub-carrier signal.

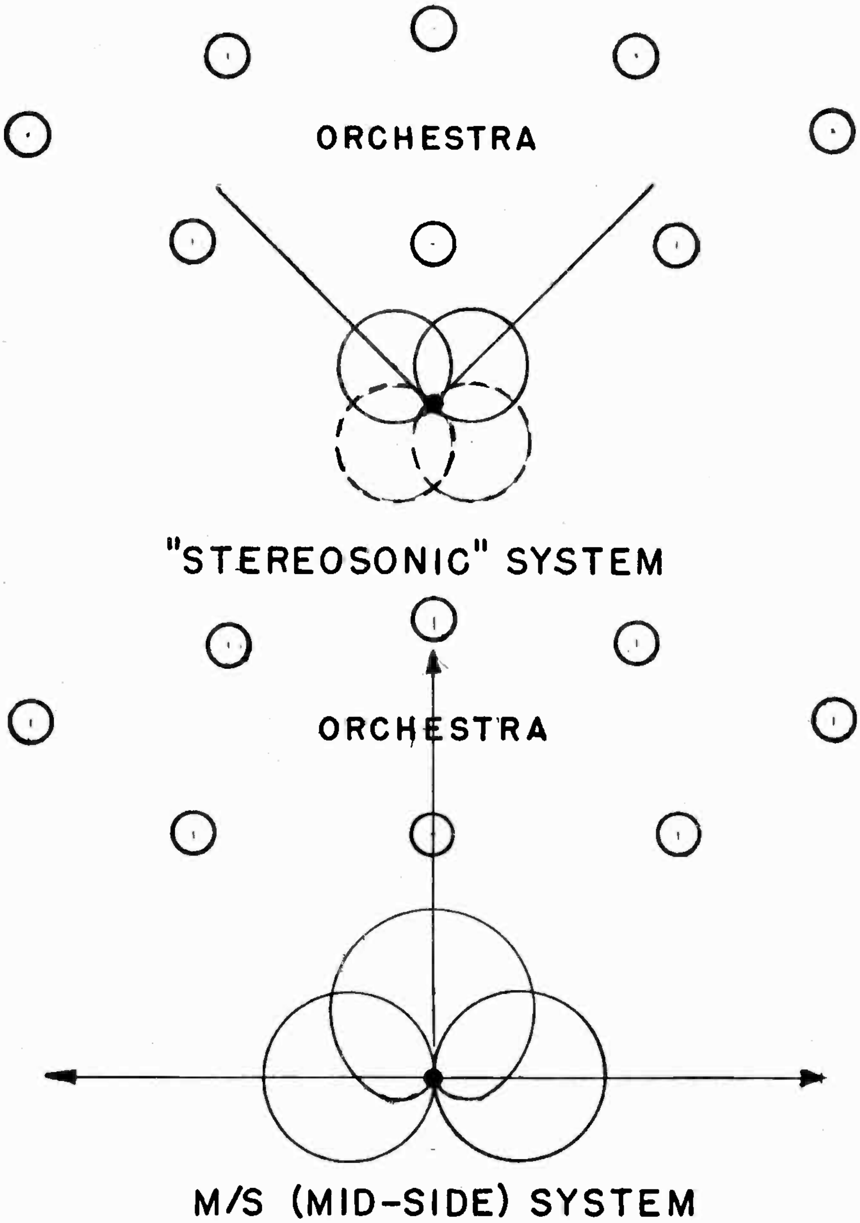
As this system was originally proposed, it could not be considered compatible. Halsted now proposes to make available a device which when used provides for compatibility. The device, called "Phantodyne", adds a difference signal to the left channel, and adds a second difference signal, 180° out of phase with the first, to the right channel. It is claimed that the left signal plus a difference signal is adequate for satisfactory monophonic listening, and when listening on a stereophonic basis, the two out of phase reproduced difference signals cancel.

A still different approach to the FM stereo transmission involves the use of the Percival system. The Percival system is one whereby it is claimed that the stereo information can be contained within a 100 cps bandwidth. The information within the 100 cps is that of relative level difference between the two channels which is encoded, then used to modulate a higher frequency (20kc) carrier and transmitted along with the combined stereo audio signal. The information, when received, controls the relative levels of the two channels to give direction to the sound. The combined signal can be reproduced by a standard FM receiver and therefore can be considered a compatible method.

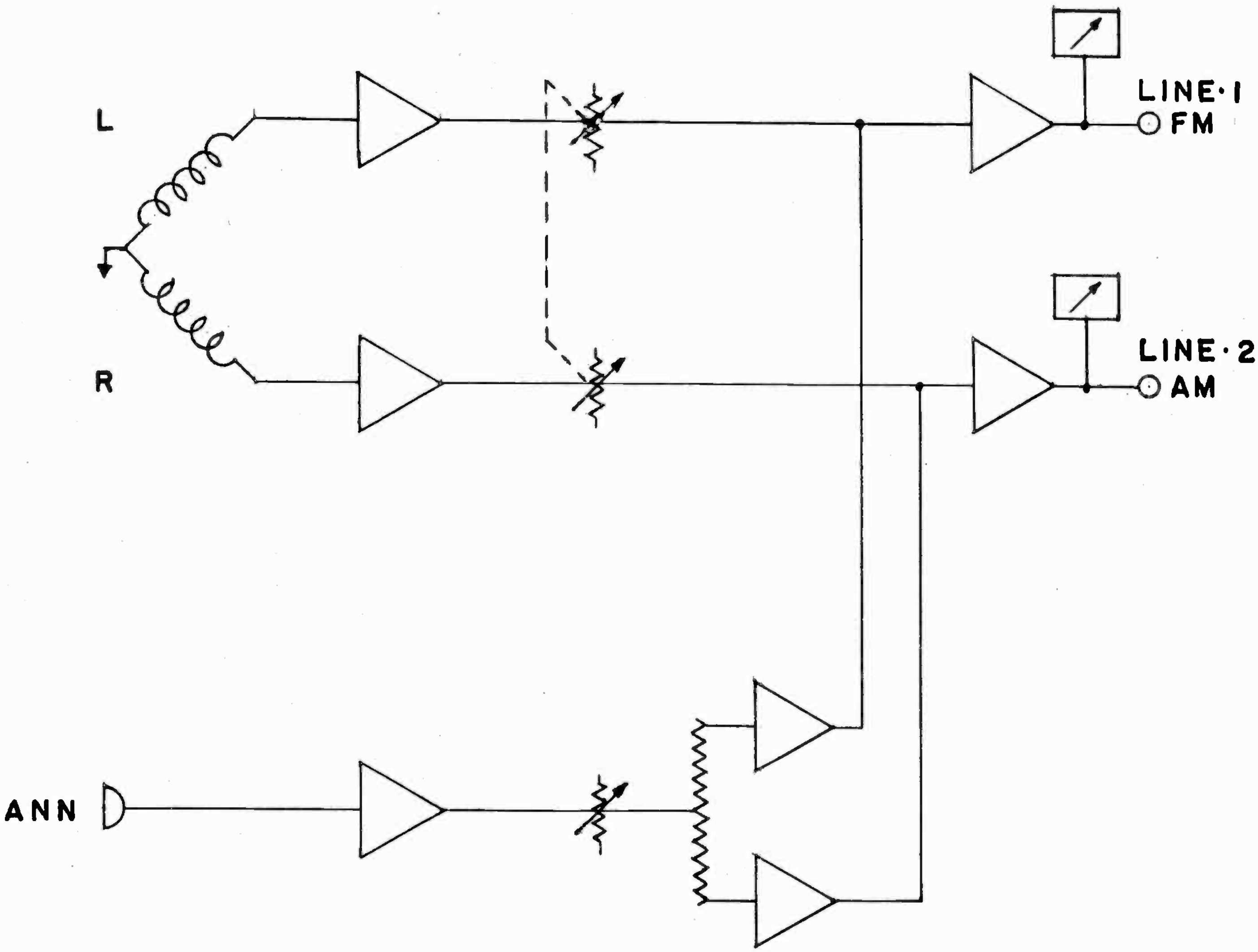
The present state of stereophonic broadcasting art leaves many questions unanswered as to the standard method of operation and standard facilities. Suggestions for standardization are: the use of one VU meter to properly measure two stereo audio signals, proper use of limiter and automatic gain control amplifiers for stereo audio signals, and specification of polarity requirements. It is hoped that not too much time will transpire before standards are proposed and then accepted. A major step in that direction is the formulation of the NSRC, National Stereophonic Radio Committee.



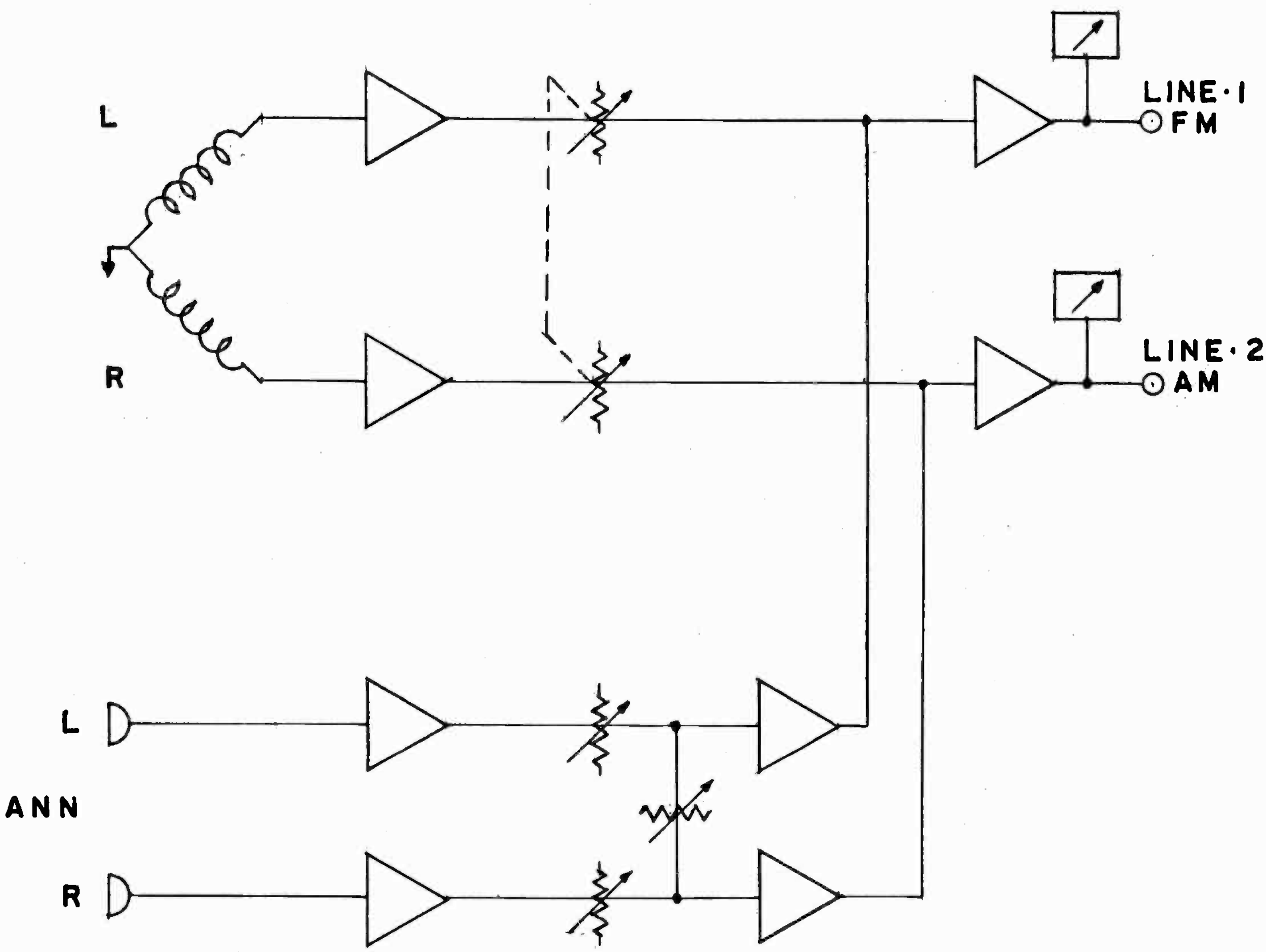
AMERICAN BROADCASTING COMPANY
ENGINEERING DEPARTMENT
FIG. 1



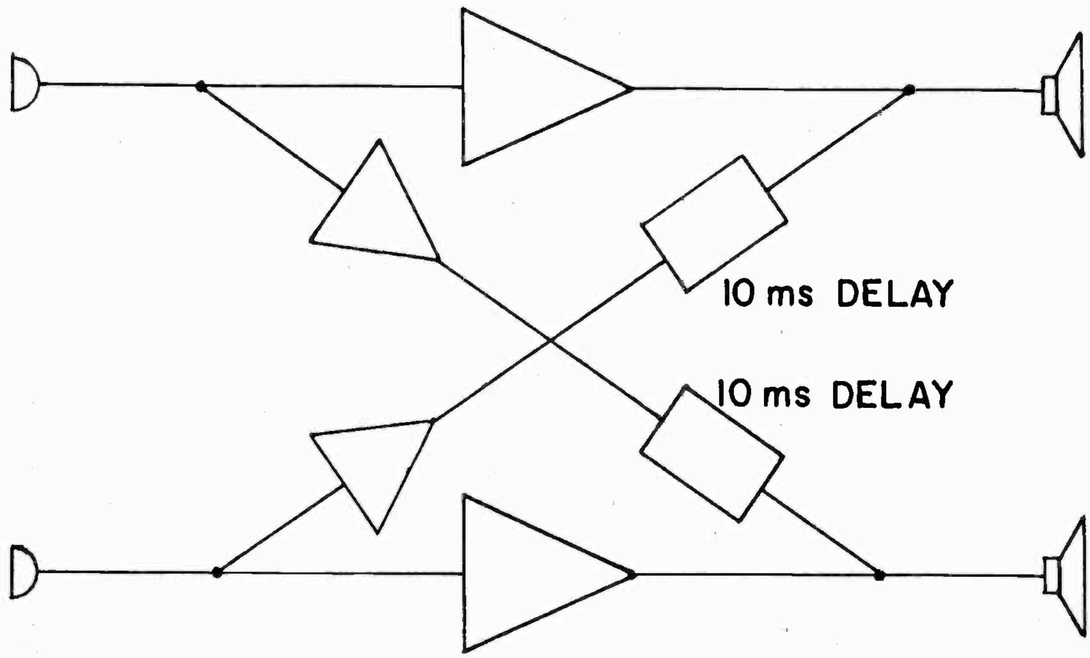
AMERICAN BROADCASTING COMPANY
ENGINEERING DEPARTMENT
FIG. 2



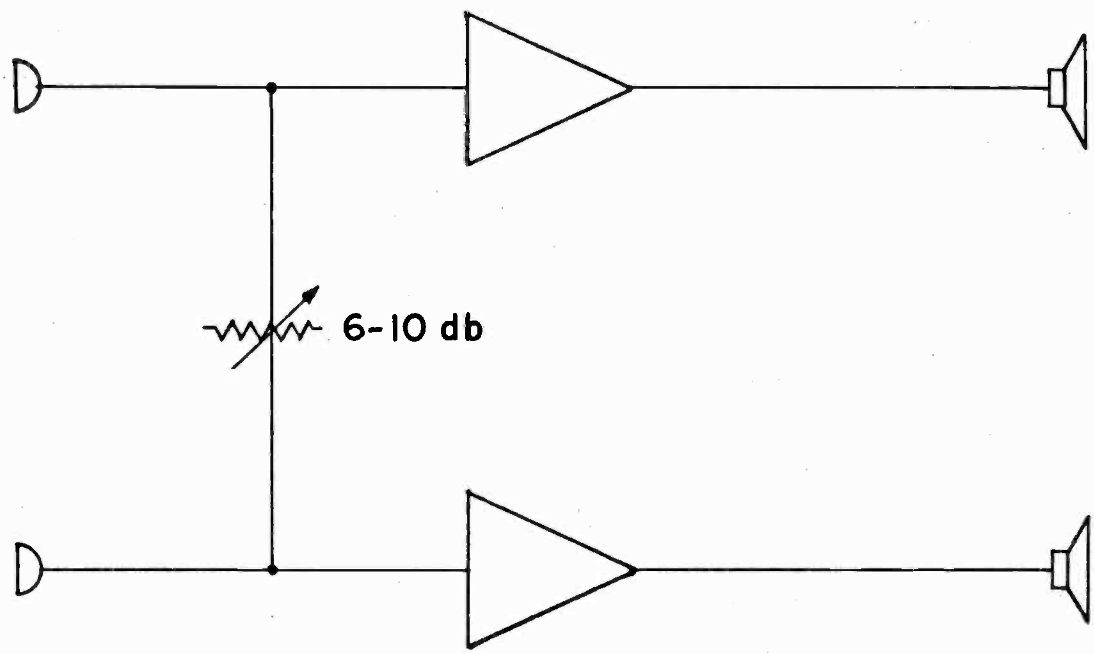
AMERICAN BROADCASTING COMPANY
ENGINEERING DEPARTMENT
FIG. 3



AMERICAN BROADCASTING COMPANY
ENGINEERING DEPARTMENT
FIG. 4



BELL LABORATORIES COMPATIBLE TRANSMISSION SYSTEM



SIMPLIFIED COMPATIBLE TRANSMISSION SYSTEM

AMERICAN BROADCASTING COMPANY
ENGINEERING DEPARTMENT

FIG. 5

General Offices: IVyridge 2-6000

WFLN 95.7 FM | 900 AM

8200 RIDGE AVENUE, PHILADELPHIA 28, PENNA.

PROBLEMS IN STEREOPHONIC MIXING

by Frederick Chassey, Chief Engineer

During the last decade, mixing consoles have changed very little. The changes that have been made were generally to expand the versatility of their operation. Style and appearance may differ from one console to another, but basically the design is the same.

But, even the most recent models prove totally inadequate to the demands of two-channel stereo mixing. Just as we have added a new dimension to the sound, we have added not one, but several dimensions to the job of mixing the various program channels.

From March of 1949 until July of 1958, WFLN was a good music, FM only station, concerned mostly with noise-free, high fidelity reproduction of music. But when, on July 23rd, 1959, we began duplicating our programming through a daytime AM transmitter, it became possible to broadcast AM-FM two-channel stereo. From the very first week of the two-transmitter operation, we scheduled some ten hours of stereo programming.

As the opening day of AM operation approached, we set out to devise a way of switching the line feeding the AM transmitter from the output of the main mixing console, as it would be used on monophonic programs, to a separate amplifier for use in broadcasting stereo programs.

Because the only satisfactory program material in stereo at that time was on tape, we purchased two Ampex 350-2 stereo recorder-reproducers. We decided to use the lower track of the tape machine to feed the AM line during stereo operation.

The Ampex 350-2 uses a 110 volt DC relay control for remote start and stop. Ampex sells a complete four-wire remote control unit for start, stop and record. In order to avoid the possibility of accidentally pressing the "record" button, we decided to build our own unite with two "start" buttons - one for "monaurel", the other for "stereo."

The second button - the "stereo" button is connected to a self locking relay which switches the AM line to the lower track of whichever of the two tape machines is on the air. On a separate circuit, of course, it starts the machine simultaneously. When the "stop" button is pressed, the AM line returns to the console feed. The output levels of the console and each of the two lower amplifiers on the tape machines are naturally adjusted to be equal. The two machines are connected to the line series, so that either one may feed the line when it's "stereo" button is pressed.

It is possible to play full-track and half-track monophonic tape on these stereo machines, of course. In this case, we use only the top amplifier, which feeds the regular mixing console. The regular "start" button is used to start the machine.

I should explain that our announcements on stereo programs are still broadcast monophonically from a single microphone in the control room.

For playing stereo tape, this system proved satisfactory and is still in use at WFLN. But, from the first, it became apparent that we needed something much more versatile. With this system, for example, it is impossible to fade both channels of a stereo tape in order to announce over music; the announcement is fed only to the FM transmitter. This system also makes no provision for stereo discs which, in spite of inconsistent quality and unreliable playback equipment at present, promise someday to provide a large share of our program material. True, we could expand our present set-up to include an independent power supply and two more switching relays for the stereo-disc amplifiers, but we feel this system is adequate only as a temporary expedient. So, from the very first, we have planned for a stereo mixing console that will handle two channel programs as easily as presently available equipment handles monaural material. It may sound easy, but unexpected problems develop- - as you will see.

These are the minium requirements for stereo-mixing equipment, based on our experience in some 400 hours of stereo operation.

First, there must be a sufficient number of inputs to mix the various program sources. For adequate operation, we at WFLN require two playback turntables with two inputs each; two tape machines with two inputs each; two announce microphones; two studio microphone set ups of two microphones each; and at least one set of two remote lines. This adds up to a total of 16 inputs - - unheard of in most monaural designs.

Second consideration is level control. If the number of inputs haven't already sent your console to the showers, this requirement will. Using the usual monaural console, this would call for operations like this one: fading down two tracks of a theme while opening the keys on two microphone inputs! Not having four-armed engineers - as yet - it is obvious we need some sort of dual control that will allow us to raise or lower the gain of two channels with one hand while we operate two more with the other hand. This can be handled with a ganged control. But, experience has shown that stereo tapes and records vary in level not only from one tape or disc to another, but from one track to another on the same tape or record. And, with a ganged control, we cannot adjust the individual channels to balance them for full stereo effect.

This brings up the third consideration: the addition of a balance control that will enable us to increase one channel as it reduces the other to maintain the correct balance that is so important to stereo. A fourth requirement is a phasing switch that will change the phase of one of the input channels to prevent cancellation. We have discovered that out-of-phase signals on some tapes cause a very strange result at some frequencies.

Fifth - and one of the most important considerations in stereo - is monitoring. Proper monitoring requires the use of two high quality distortion-free balanced amplifiers and two matched speakers. Under this same consideration, the stero console should provide a cueing circuit so that the input can be auditioned after the balance control so that is can be adjusted and the phasing reversed, if necessary. In addition, we might point out that in many stations this equipment will be operated long hours by personnel who are primarily concerned with announcing and have little or no technical training. It must be ragged, dependable, and so easy and logical to operate as possible. It may seem to many engineers that these are just too many functions for a broadcast console to perform. Drawing on our own experience at WFLN, we have designed a console which, we feel, fulfills all the considerations outlined here today. It is being built now by Industrial Transmitters and Antennas in Philadelphia. Besides the features we have mentioned, it incorporates push-button start and stop controls for our Ampex tape machines and Elektromessteknik turntables. The circuits we are presently using - - the ones pictured in the slide we have shown you - - are included in this console. But, when the "monaural start" button is pressed, both tracks are mixed into one channel, so that stereo material may be played monphonically. Based on our own experience, and on the current public interest in stereo, we feel that some form of stereo-casting will be a must for every station in the very near future. Adequate audio equipment, cantering around a stero console such as we have described, must be provided. Certainly any new equipment purchased now should not become obsolete in a few years because it cannot handle the requirements of 2-channel audio signals smoothly.

GATES

SPOT TAPE RECORDER

by

Jay Blakesley
Manager, Audio Sales
Gates Radio Company

A Paper delivered before the N.A.B. Engineering Conference:
Chicago, Illinois
March 17, 1959

MR. CHAIRMAN, LADIES AND GENTLEMEN:

The history of magnetic tape recording can be traced back to the original German Magnetophone, which was developed during World War II. The Magnetophone, while lacking in fidelity, launched the era of magnetic tape recording, and today, the magnetic tape industry is indeed, "big business".

It would be difficult to imagine a radio station without at least one magnetic tape recorder. It would be nearly impossible, to program todays' radio station, without a tape recorder. There are several reasons why tape recording machines are a prerequisite in radio and television stations.

First of all, the use of magnetic tape gives us the opportunity of frequent voice changes. The small station, with three or four voices, can mix these voices and come out sounding like the big market stations. The housewife after hearing one voice for a period of time, suffers from propagation hypnosis; commercials no longer send her scurrying to the market after the newest and finest ding bat. A change of voice is indeed necessary to break this monotony and satisfy the sponsor.

The second advantage of magnetic tape is that all announcers, at one time or another, "fluff". Fluffs can be eliminated when commercials are recorded and we thus eliminate embarrassment and irate sponsors.

The third advantage of magnetic tape is that programs and spots can be recorded at any time, for playback at a later hour, day or week. The Sunday program schedule is usually crowded with tape programs. In six days, God created heaven and earth, on the seventh day He rested. This was before the advent of radio and television broadcasting.

From the engineering point of view, it is easier to use magnetic tape for delay than any other method of recording. Magnetic tape offers a wide latitude in recording levels and diameter equalization is nonexistent.

Broadcast stations recording programs on tape have also used tape to an advantage in the recording of spot announcements. Earlier in this program, I discussed the advantages of using magnetic tape for recording programs. These advantages also hold true for recording spot announcements.

Double spotting is "old hat" to broadcasters. We have been doing this for several years. Spot saturation campaigns have led many broadcasters into triple and even quadruple spot announcements. Multiple spotting requires a change of voice and this, of course, brings the tape recorder into the foreground.

When spot announcements are recorded on magnetic tape, we are faced with the decision of recording one spot on each reel of tape or recording several spots on individual reels. Each method has inherent advantages and disadvantages. If several spots are recorded on each reel, we must exercise extreme care in selecting the correct announcement, from the multiplicity of announcements.

If we make the decision to record only one spot on each reel, we then have a large dollar investment in reels, as well as having a bulging tape library. Regardless of the decision, the normal announcer or engineer, that is working in a broadcast station still possesses two hands, two feet and one oral cavity.

If the radio station is using a combination announcer/engineer, to use the term loosely, the oral cavity is giving the time, weather forecast, station break, etc., at the same time, both hands are frantically changing reels of tape. If the station actually employs a control room engineer, the situation is basically the same except the oral cavity is now used for emitting four letter words.

The basic fault lies not in the use of magnetic tape or in the tape transport; the fault lies in the incorrect *use* of both magnetic tape and tape transport. We are asking a machine, designed to play for relatively long periods of time, to now play for a short period of time and still give us ease of operation and fast tape handling capabilities.

What we are doing is similar to the removal of a Phillips head screw with a flat blade screwdriver. It can be done if we take a long enough period of time and if we don't mind chewing up both screwdriver and the Phillips head. For every job we need the proper tool. Let's talk about the proper tool for spot recording.

The requirements for a spot tape recorder appear simple, yet until today, no company has been able to come up with the answer. All that is required is a machine that has the following capabilities:

1—The machine must have good frequency response, low noise and distortion. This requirement is the same as that called for in any commercial tape recorder.

2—The machine shall be of such physical size that it can be either rack or desk mounted.

3—The machine shall have a time capacity of over one minute for each spot.

4—The machine shall be capable of automatically cueing and rewinding each spot announcement.

5—The machine shall be capable of recording and reproducing over one hundred spots without removing the reel of the tape from the machine.

Now let's take a look at the specs on Spot Tape recorder as manufactured by the Gates Radio Company. The frequency response is from 30 to 8,000 cycles. The noise is 45 db down and the distortion is under 2%. These specs satisfy our number one requirement. Gates Spot Tape recorder requires only 8¾ inches of rack panel space. A cover is available if the unit is to be mounted on a desk. This satisfies the number two requirement.

Requirements three, four and five, until today, have been the toughest ones to meet. Gates Spot Tape recorder utilizes a band of magnetic tape, with a tape length of 90 seconds. This exceeds requirement number three by thirty seconds. This extra tape time, not needed by minute spots, can be used for themes, sound effects and mood music for dramatic programs.

Gates Spot Tape recorder satisfies requirement number four in a manner that is a little unusual. Instead of using adhesive foil and microswitches to accomplish tape cueing, two photoelectric cells accomplish both automatic rewind and tape cueing. The tape rewinds at the ninety second interval and automatically cues each spot to the correct starting point. I will discuss this feature a little more thoroughly later on in this program.

Gates Spot Tape recorder meets requirement number five, by using magnetic tape having a tape width of 13 inches. This tape width allows the recorder to accommodate one hundred and one announcements. The scale on the front of the machine is graduated into major divisions of one through ten. Each of these divisions is further subdivided into letters "A" and "K".

These scale divisions eliminate errors in program logging and the control room engineer has a simple timetable to follow. As an example, we might have a program log reading: Standard Petroleum Company #1C. The operator moves the pointer to #1C and the spot is ready to go. The front panel contains the necessary switches for accomplishing record/play functions, bias metering and volume indicating as well as the start-stop and manual rewind switches.

A little earlier we mentioned the automatic cueing and rewind facilities incorporated in Spot Tape. Let us assume that we have reached the 90 second limit of tape travel on any given track. At this 90 second time interval, a photoelectric cell reverses the drive motor and rapid rewind takes place. By eliminating adhesive foil, we no longer encounter tape stickage, print through and associated problems.

Automatic rewind of the tape is accomplished in 20 seconds. Bear in mind that manual rewind is possible at *any* time during the limit of tape travel. The manual rewind switch is located at a convenient place on the front panel. At the limit of tape reversal, a second photoelectric cell, reverses the drive motor and stops the tape movement. The same precise starting point is available for each of the 101 separate announcements.

With Gates Spot Tape recorder, the control room operator selects the proper track by following the program log. Changing reels of tape and the storage of these tape reels are no longer a problem. Themes with recorded intros are available at the fingertips of the operator. Station identification, time and temperature reports can all be recorded and are available for immediate playback.

Gates Spot Tape recorder is designed with the broadcast engineer in mind. I mentioned earlier that the frequency response is from 30 to 8,000 cycles. At ten thousand cycles, the response is only 5 db down. Good music reproduction is possible, since the wow and flutter is only two tenths of one per cent.

The power consumption of Spot Tape, including the drive motor is 75 watts. This power consumption is less than a single obstruction lamp on your tower. The tubes in Spot Tape are readily available anywhere in the country. Only six tubes make-up the tube complement of Spot Tape. Three of these tubes are of the same tube type.

Gates Spot Tape recorder will be ready to operate when received at the station. All tubes and transformers are supplied with the machine. Since Spot Tape will be connected to the station console in different ways, every engineering precaution has been taken to assure good performance under varying operating conditions.

The input impedance is either 150 ohms or bridging. Some engineers bring all recorders into a jack strip with bridging inputs, in this case, the low level circuits are amplified before reaching the jack strip. In some installation, this is not possible and it is necessary to use the high gain or matching input connection. Using the matching input connection, a microphone will drive the record amplifier to full output. The output impedance is 150 ohms and can be connected directly into the mixing bus of the console.

When desired, a remote control unit is available. This remote control unit duplicates the control functions of the recorder. The remote control unit can be mounted at any location desired by the operator while Spot Tape is mounted in a rack cabinet. Due to the low power consumption of Spot Tape, the rise in rack temperature is of no consequence.

For the first time, in the history of magnetic tape, a machine is now available for recording and reproducing, spot announcements; a machine that is designed for this specific function. We hope that you, as broadcast engineers, will personally inspect this machine in our display booth. Thank you.

71290

F.C.C. EXPERIENCE WITH REMOTE CONTROL OF AM AND FM BROADCAST STATIONS

BY: HAROLD L. KASSENS
CHIEF, AURAL EXISTING FACILITIES
BROADCAST BUREAU
FEDERAL COMMUNICATIONS COMMISSION

13TH ANNUAL NAB ENGINEERING CONFERENCE
CHICAGO, ILLINOIS

MARCH 17, 1959

As a result of the filing of a petition for rule making by the NAB, the Commission in January of 1953 issued a Report and Order amending its rules to permit stations using non-directional antennas and power of ten kilowatts or less to be operated by remote control.

At present over 1200 stations have obtained authority to operate in this manner. The emergence of remote control has been an important factor in the expansion of the AM and FM broadcast services during the past six years. It has provided an economically feasible operation in a great number of small communities which would otherwise be without a local broadcast facility.

In September of 1957, and again as a result of the filing of a petition for rule making by the NAB, the Commission further amended its rules to permit all AM and FM stations to operate by remote control -- without limitation as to power or type of antenna.

Since that time a total of forty-eight stations have taken advantage of the new rules and filed applications for remote control -- forty-four for operation with directional antennas and four for non-directional operation with fifty kilowatts. Twenty-three of the directional applications have been granted and we have confident hope that processing of the remaining twenty-one applications will be completed within the next two months. Of the fifty kilowatt applications, the three have been granted and approval of the fourth is anticipated in the near future.

Two difficulties have arisen which appear to be delaying implementation of remote control at many stations. The first is the requirement that stations with directional antennas and those with power in excess of ten kilowatts be equipped so that they may be operated on a CONELRAD frequency with power of five kilowatts or not less than fifty percent of the maximum licensed power. The power may be less however upon certification by the CONELRAD Field Supervisor that a lesser power will provide satisfactory service under CONELRAD. The rule does not require that a CONELRAD authorization be obtained, but does require that provision be made at the remote control point to permit the station to be operated on either 640 or 1240 kilocycles with the proper power. Further, installation of the equipment is not required until the commencement of operation under the remote control authorization.

The second difficulty of stations seeking remote control authorizations appears to be the requirement of submitting weekly readings of field intensity at each monitoring point for the preceding one-year period. This may appear to be unduly burdensome, but let me quote from the Commission's Report and Order in this matter:

"In response to the request contained in the Notice of Proposed Rule-Making, many parties submitted comments concerning the information

> to be supplied with the application for remote control of directional antenna stations as well as to what data should be supplied after remote control was authorized. We have carefully reviewed the comments filed and have concluded that applications for remote control will be considered upon a case-by-case basis and granted upon a satisfactory showing that the directional antenna system is stable and is in proper adjustment."

I'd like to reemphasize those last few words: "that the directional antenna system is stable and is in proper adjustment." This, then, is the basic information we are seeking. For many years the Commission has used as its criteria: (1) the maintenance of base currents or appropriate samples thereof within five percent; (2) maintenance of phase essentially at the values specified in the license; and (3) maintenance of monitoring point field intensities within the maximum values specified. Perhaps there are other criteria which may be substituted for these. But we feel that it is entirely reasonable to require new stations to submit monitoring point readings for a one-year period as a means of demonstrating, in part, the stability of the directional antenna system.

Many older stations complain that they are not required to measure the field intensity at each monitoring point. What they fail to recognize is that the license specifies the maximum field at each monitoring point, and there is no way they can tell whether this maximum is being exceeded unless measurements are taken at regular intervals.

Licensees are not precluded from filing applications for remote control and requesting a waiver of the one-year period of measurements, but they should be able to substantiate requests for waiver by the submission of other information to permit a determination "that the directional antenna is stable and is in proper adjustment." Of the twenty-three applications for directional operation already granted, eight applications contained less than fifty-two consecutive weeks of monitoring point readings. One contained readings each month for only ten months; another twenty-six weekly readings plus twenty-four months of quarterly readings; a third contained thirty-four weekly readings. In each case, however, consideration was given to other information available, such as technical logs from renewal applications, skeleton proofs-of-performance, and inspection reports. I'm sure you'll agree that if the inspector departed without leaving a violation notice the array was being operated properly!

Let us look now at the nature of some of the violation notices issued in connection with remote control.

The existence of a remote control authority does not in itself change the operator requirements. Stations with directional antennas and those with power over ten kilowatts are required to have on duty at the transmitter or at the remote control point an operator with a first-class license. Stations with non-directional antennas and power of ten kilowatts or less may use restricted permittees, but must have one first-class operator in full-time employ. And speaking of employment, it should be borne in mind that each operator, regardless of class of ticket held, must be an employee of the station. While this may sound fundamental, it has resulted in some difficulty for stations which use automatic programming and would like to have the remote control point at some all-night business establishment.

Section 3.39 of the Rules relates to the accuracy of the plate voltage and antenna current meters. It contains such specific details as: length of scale, total number of divisions, and accuracy figures. Meters at the remote control point to indicate these parameters are also expected to comply with the requirements of this rule. Meters having arbitrary scale divisions may be used provided that a calibration curve, showing the relationship between the arbitrary scale and actual meter reading is maintained at the remote control point. Further, the meter or meters at the remote control point must be calibrated once a week against the regular meters and the results entered in the operating log. If arbitrary scale readings are indicated in the station operating log, a copy of the calibration curve should be submitted to the Commission with each renewal application to enable the staff to properly correlate the readings given.

Section 3.67 of the Rules reads, in part, as follows: "A malfunction of any part of the remote control equipment and associated line circuits resulting in improper control or inaccurate meter readings shall be cause for the immediate cessation of operation by remote control." In simple terms, it means -- if anything goes wrong, fix it in a hurry!

A point to be remembered is that prior approval must be obtained whenever the location of the remote control point is to be changed. Remote control is permissible only from the location specified in the station license.

When operating by remote control, there are certain requirements concerning the logging of directional antenna parameters. Each half hour during directional operation, the Rules require the logging of common point current and remote readings of antenna base current. In addition, within two hours after the beginning of operation with each directional pattern, an operator with a restricted permit or first-class ticket must read and log, at the transmitter location, the common point current, base currents, phase monitor sample currents and phase indications. The purpose of this latter requirement is two-fold. First, it provides a means of determining that the phase readings are within the values specified, thus eliminating the difficult problem of providing a means for remote readings of phase. Secondly, it permits a physical inspection of the transmitting equipment to insure proper operation and to anticipate breakdowns.

One further requirement not to be overlooked is that of a skeleton proof-of-performance of the directional antenna system once each year during remote control operation. This is not a difficult requirement for it requires only three or four measurements on each radial used in the original proof. The points may be accurately spotted on a map in advance and the readings checked once each year. A comparison of these readings with those made previously should give an indication as to whether or not the directional array is in proper adjustment.

One advantage which accrues automatically to those who obtain authority to operate a directional antenna system by remote control, and one which should not be overlooked, is the Commission's practice of modifying the station license to require the taking of monitoring point readings on a monthly rather than a weekly basis. The theory supporting this practice is that once stability has been demonstrated, monthly readings are sufficient to indicate proper maintenance of the array. This relaxation is also available to those of you who, for one reason or another, do not desire to operate by remote control. It may be obtained by submitting an informal application supported by fifty-two weeks of monitoring point measurements and readings for thirty days of the directional antenna parameters. This information is the same as that required by paragraphs 3 and 4 of the remote control form.

An advantage which has accrued to FM operators who use remote control is the possibility of utilizing radio rather than wire lines for telemetering purposes. The control information is multiplexed on the studio-transmitter link and the meter readings are relayed back as multiplex modulation on the main carrier. Unfortunately no one has yet devised an acceptable means for relaying meter readings from an AM transmitter to the remote control point by radio. Perhaps investigation in this area will make remote control of AM transmitters even more attractive.

VISUAL ELECTRONICS CORP.
356 WEST 40TH STREET
NEW YORK 18 NEW YORK
PEnnsylvania 6-5840

product news

date :

Keeps You in View

A Paper Presented by:

JAMES B. THARPE, PRESIDENT
VISUAL ELECTRONICS CORPORATION

at 13th Broadcast Engineering Conference on March 17, 1959, at the NAB Convention in Chicago, Illinois

A BUILDING BLOCK TELEVISION PROGRAM AUTOMATION SYSTEM

A summary

A unitized electronic television program automation system is described which can be built up to provide varying amounts of station automation as required in the station development - from automating only the "panic" station break period to automation of the largest TV broadcast centers desiring to run completely automatic operations programmed by punched cards, punched tape or other means.

The system features maximum convenience and minimum confusion due to its "shift" storage and display system. All events which have been set into the equipment are continuously displayed to the operator in the order in which they are to occur. Changes or corrections can be made on any stored event at any time. When an event occurs, the indication describing it disappears from the top of the panel; all other indications shift up one position. Vacant positions at the bottom can be filled at any time either manually or by a punched card or tape device.

In order to provide ultra-reliability in this equipment, Beam Switching Tubes with 50,000 hour life expectancy are used for the heart of this system. Mercury-wetted contact relays rated at one billion operations are used for the shift function.

ll succeeding events again shift up one row to continue to provide at all times display showing the next upcoming event at the top and each scheduled succeeding vent in sequence reading down the panel. This continuous in-sequence display of pcoming events provided by the "shift" action of the storage/display panel provi- es clarity in operation not heretofore available in such systems.

ANUAL FEED-IN

nformation is fed-in and stored in the storage/display panel through a remote ontrol panel by the momentary grounding of a low voltage low current DC contact ssociated with the function desired for a particular event. When all functions for a iven event have been so set-in, the system automatically shifts this stored event p the panel to the last open event row. That is, an event is set into the bottom ow and automatically shifts up the board to fill the vacant row immediately follow- ng the series of stored events. Thus a complete sequence of events can be set-in rom the remote operating position and the event being set-in can be checked and orrected from the remote position and then released to shift up as described. In his manner the operator can load up the panel for a station break period by reading own the program schedule (log) and setting-in the desired events in sequence from single push button control panel - checking and correcting if necessary as he goes.

APE FEED-IN

he simplicity and straight forwardness of this shift display arrangement is evident or manual operations. The features provided also lend themselves ideally for ex- ansion from manual feed-in of information to feed-in from a punched tape or punched ard system. When using punched tape, as each event occurs, the stored information nifts up as described - leaving the bottom row empty. The tape is advanced one vent through the tape reader and read out. Its information is set-in the bottom ow.. As the next (top row) event occurs, the board will again shift up and the tape gain advances one event causing the tape reader to again fill the bottom row. Thus ne storage/display panel will provide storage and read out in depth for upcoming cheduled events which can be easily read, reviewed, and quickly corrected or changed f necessary prior to going on air - thus eliminating the inflexibility of the tape ystem alone which cannot be easily read or changed.

RD FEED-IN

ie unique feature provided wherein an event set in at the bottom row will automa- .cally shift up the panel to the open position immediately behind already scheduled vents provides the ultimate in adaptability for punched card fed systems. For in- ance, if a station adopts a punched card system it would not use a card for each vent - it would likely use a single card to schedule a commercial spot - this might ll for a sequence of several events - say 4 slides plus a film clip, etc. This .rd could carry accounting and other information: account name, spot identification, ntract #, frequency discount, etc. When this card dropped in the card reader, so med that several events were open at the bottom of the storage/display panel, its ent-function information would be automatically set-in in sequence and each shift the board in turn, stacking in the several events called for by this card, for is spot, these being set-in in sequence and immediately following the last pre- ously set-in event.

PROGRAM AUTOMATION SYSTEM

INTRODUCTION

This paper describes a unitized Television Program Automation System which can provide a simple manual preset for handling the "panic" station-break period and can be expanded step-by-step as station automation develops to provide complete automatic operation of all master control switching and related functions for the largest television broadcast center through punched cards, punched tape, or other pre-programmed storage devices. The system incorporates unique features to make its operation clear and straight forward and to allow for any last minute corrections or changes. In case of any unforeseen happening this automation system can be controlled by an operator to take care of the special situation rather than have the operator be forced to shift to "manual" operation at a most difficult time. As system reliability must be of the highest possible order, "50,000 hour" life potential components have been used for the key portions of the system. Construction is modular and so arranged that the system can be easily tailored to provide for the initial requirements of any station and expanded at will. All modules are plug-in thru "blue ribbon" connectors - even the key resistor and condensor groups are plug in! If trouble does occur in one of the modular units the faulty portion of the system can be by-passed by patching and serviced later. The limited servicing and maintenance required can be easily accomplished.

GENERAL

The storage-display panel holds a series of preset stored events. (Each occasion something is to happen is an "event" - what is to happen is a "function"). The system will store a number of "events" scheduled to occur in sequence and each event will have stored the video and audio "functions" which will go on the air at that occasion. Thus a number of events is preset into the storage/display panel - each of which specifies the particular video and audio function to occur at that "event." These events are stored and displayed on the panel from top to bottom in the sequence in which they will occur. (set in the panel here shown is sequence to occur as follows - event #1 - video function --- audio function --- event #2, etc.)

CORRECTION

Change or correction of any function in any stored event may be quickly and easily accomplished by simply touching a front panel "correction" push button associated with that function group. The unit will rapidly sequence through the functions available in the group and the desired one may be set by releasing the push button as it appears. This procedure is rapid and quite satisfactory for making corrections or changes in previously stored information when necessary.

SHIFT

An outstanding feature of this system provides that when the upcoming event occurs (goes on the air) that event leaves the top row on the panel and all succeeding events shift up one row to provide again a panel display showing the next upcoming event in the top row and all succeeding events in their order of scheduled occurrence reading from top to bottom. When this next event occurs (goes on the air)

DISPLAY SUMMARY

Thus, this system provides storage and display in depth for a number of events, always displaying them in their upcoming order from top to bottom of the panel with the next upcoming event always in the top row. Events may be scheduled and fed-in manually from a single remote control panel position or may be fed-in in sequence from punched tape, punched cards or other similar systems. An event is fed-in the bottom and automatically shifts up the board to fill the next in-sequence open event position.

"TAKE-BUTTON"

In a simple manual preset system, the top row event may be made to occur by hitting a "take button" which will put it on the air. Thus, if a station break is preset as a series of events, each succeeding event may be put on by hitting the "take button." (as events occur and the stored schedule shifts up clearing the lower rows, additional events may be set-in.) A simple manual feed-in, manual take preset system will provide a great aid to any station large or small for relieving operator burden during "pressure" station-break periods as it allows him to think through, plan, and preset a sequence prior to the critical time - and to look at the preset sequence displayed in full before him for review, correction, or change prior to initiation.

TIME

Operation may be augmented by the addition of a "timed" system such that each stored event will occur automatically at a pre-scheduled time rather than by manual "take button" action. Timed systems are arranged so that when the time set-in for an event coincides with the time on the system "clock" or timer, that event receives an "operate pulse" and its designated functions are put on the air.

COUNT DOWN TIME

The simplest timed system is an elapsed time or "count down" system which would be provided by the addition of three additional time storage/display units for each event on our panel - one for units of minutes, one for tens of seconds and one for units of seconds. The "clock" in this system consists of a timer which is started by activating a "start" button at the desired beginning of a timed sequence of events. After starting, it advances in time in one second steps, counting down the top row event to time coincidence at 0:00. In our storage/display panel, events are stored in sequence each with the time interval from the proceeding event. For example: we may have first slide 1 for 10 seconds, then slide 2 for 4 seconds, then film 1 for 20 seconds, then net. We set-in 0:00 S_1

0:10 S_2

0:04 F_1

0:20 N At the instant of "start" of the sequence, the first stored event (S_1) 0:00 would occur. The next stored event (S_2) then shifts up to the top row and the advancing "clock" timer counts it down 9-8-7-6-5-4-3-2-1 to 0:00 and it goes on the air. Then the next scheduled event (F_1) shifts up to the top row is in turn counted down 3-2-1 to 0:00, etc. When zero time coincidence occurs for each event, that event is made to occur and remaining scheduled events shift up always maintaing complete in-sequence display from the top reading down.

COMPLETE TIME

A complete timed system would incorporate the following:

1. A "True" time master clock supplying a time base of one second pulses.

2. A second, electronic clock which normally follows the time master clock stepping at a one second rate - but which can be pulsed much faster to run ahead or stopped as described below.

3. A 10's of minutes time column (units of hours and 10's of hours may also be included - though not essential for most operations). In normal operation all events are set-in in scheduled sequence with their program log time, the electronic clock follows the time master clock and establishes time coincidence with the top row event at its designated time - thus causing that event's functions to go on the air automatically at that time.

In cases of failure to follow the exact preplanned time schedule of events stored according to log time, an "approximate" time base is used to maintain each event in its proper sequence time interval. For example, suppose we have a station-break all set-in scheduled to begin at 29:30 and unexpectedly the net leaves early at 29:13. As 17 seconds of dead air time is undesirable, the operator would push the the "approximate time TAKE" button which would feed a rapid sequence of pulses to the electronic clock causing it to rapidly advance to time coincidence with the first event putting it on the air. The electronic clock then reverts to one second steps and the system continues to operate on the "approximate time" of the now reset electronic clock.

Likewise, if the President speaks over 1:23 and the net is late leaving, the operator can press "approximate time HOLD" which will stop the electronic clock until released. Upon release (net leaves) the operator would switch from "approximate time HOLD" to "TAKE" as described above and pick up his preset log sequence of events at their proper intervals from the now reset "approximate time" condition. When such a break is completed, time may be shortened in any interval by rapidly advancing to the next interval by the "TAKE" or time may be increased in any interval by the "HOLD". Thus the operator may get back on true time as the opportunity arises in the same manner which he does today (without automation).

A control panel switch allows resetting of the electronic clock to the "TRUE" clock when desired to automatically reset to exact true time.

RELATIVE TIME

Another unique feature of this system allows for the electronic clock to be used to provide "relative time" as well as "approximate time". For example, if during a net show, the station were to be scheduled to take a one minute break to be on arbitrary cue rather than on specific time, the one minute break to come in at the unknown time on cue could be set up on "relative time" from 0:00 for beginning of cue. The electronic clock would be re-set to 0:00 and started in one second advances from the operator's pushing the "relative time START" button on cue. When the relative time sequence is completed, the electronic clock is re-set to the TRUE time clock. Special features in this system allow for intermixing the storage of TRUE and relative time events with the system automatically changing time base due to coding of the relative time events by having only 3 time digits displayed (10's of minutes indicator dark for relative time events).

ANTICIPATION

A time base system allows the incorporation of an additional very desirable feature of this system. Consider the matter of a film projector with a 4-sec roll time or a VTR with a 7-sec roll time. In the simple manual preset system, one manual operation is required to "roll" the projector, a second to "take" the projector.

In the timed system, there are 3 possibilities:-

1. to schedule projector "roll" and film "take" as two separate events 4 seconds apart. This takes up a lot of events.

2. to schedule projector "roll" only and through a 4 second fixed time delay relay associated with that projector circuit have film "take" occur after this fixed delay. This necessitates scheduling the event 4 seconds (or 7 seconds, etc.) ahead of the program log on-air time - which is confusing. It also loses control of the time of the "take" event (set for a fixed 4 seconds) unless special provision for override of each such fixed delay is provided.

3. Due to its storage in depth, the currently described system can be expanded to provide an "anticipate" circuit which, when events are scheduled at on-air time per the program log, will provide automatic starting of machines <u>at the correct interval before</u> the event. For instance, projectors 4 seconds before, VTRs 7 seconds before, etc. This tremendous advantage can be provided on elapsed or count down timed systems for any events occurring after the 1st seven seconds in the sequence and in the more advanced timed system described for all timed events.

This anticipate circuit operates as follows:

Time coincidence is established with the top row event of the storage/display board 7 seconds prior to on-air time. The storage/display panel operates in normal fashion; however, the selected event does not immediately go on the air as it leaves the top row but rather travels down a 7 second "anticipate delay line" in one second steps. This delay line stores the selected function in the same manner as the event functions on the storage/display panel but no display is provided (it is not necessary) and the selected function is advanced one position along the line each second by the incoming one second timing pulses from the master clock system. Thus, a selected function leaves the top row 7 seconds before air time and goes 7 - 6 - 5 - 4 - 3 - 2 - 1 - on air. Along this delay line, each function has tapped off at the appropriate step, the "machine roll" initiate information, i.e., when VTR reaches step 7 (the first following the top row) the VTR machine is caused to roll. VTR function continues down the line 6 - 5 - 4 - 3 - 2 - 1 - on air, going on air at the scheduled time - and exactly seven seconds after VTR was "rolled". A selected film function would leave the top row 7 seconds before air time, travel 7 - 6 - 5 - 4 (here the tap-off to that machine would cause it to roll) 3 - 2 - 1 - on air - film switching on air at the scheduled time - and exactly 4 seconds after the projector "rolled".

Note that two or more selected functions can be traveling down the "anticipate delay line" at the same time (in different sequence positions). Therefore, the system does not jam for the required start time of any machine.

For example:- sequence (1) leave net
sequence (2) 2 second slide
sequence (3) take film

In this case, events would be scheduled according to on-air time.

29	30	leave net, take slide
29	31	
29	32	leave slide, take film

but, due to the anticipate feature, the 29:30 event (slide) would leave the panel top row at 29:23 (7 seconds before air time) and start through the delay line. Likewise, the 29:32 event (film) would leave the panel top row at 29:25 (7 sec before air time) and start through the delay line. Thus they would progress through the delay line with film following behind slide by 2 steps (2 seconds).

29:22	slide at top row	film at second row
29:23	slide at 7	film at top row
29:24	slide at 6	film at top row
29:25	slide at 5	film at 7
29:26	slide at 4	film at 6
29:27	slide at 3	film at 5
29:28	slide at 2	film at 4 causing projector roll
29:29	slide at 1	film at 3
29:30	slide at on-air	film at 2
29:31		film at 1
29:32		film at on-air

BUILDING BLOCK

The building block modules comprising this system provide three events in a 7" high standard rack panel. Thus nine event storage requires three 7" panels, 12 events four 7" panels, etc. For each horizontal event row there may be 6 ten-function groups on a 19" wide standard rack panel, 8 on a standard 24" rack, 10 on a standard 30" rack.

Function groups are available in multiples of 10, 20, 36, and 100. 10 takes one horizontal module space; 20 takes two; 36, or 100 takes three horizontal module spaces. Function group indicators may be numerical Nixies, alphabetical Nixies, or Neon tally clusters. In our model here, the time was displayed by numerical Nixies and video-audio functions by neon tally clusters. Complete freedom of choice as to these display indicators is available to the station in this modular system.

RELIABILITY

The requirement to perform all of the vital functions concerned with putting a station's pictures on the air places a high premium on both visual and electronic error free operation. To provide for the highest order of reliability in this system, a study was made of the various ways that it could be built circuit-wise and an evalua tion made of the various approaches found possible. Mechanical stepping switches; relays, tubes, and transistors in both binary and and decimal arrangements; magnetic storage elements, etc., all could provide such a system. The most reliable combination of circuit elements was chosen from this evaluation and is incorporated in the present system. It consists of Beam Switching Tubes for storage and switching of group functions, Nixie or neon readouts, and mercury-wetted contact relays for trans of events. Since the heart of the storage/display system described consists primari of these components, they are discussed briefly.

BEAM SWITCHING TUBES

Beam Switching Tubes may replace twenty or more transistors, tubes, or other components since a single cathode controls an electron beam to any one of ten constant current output positions each with "automatic" memory and the most versatile switching imaginable.

Features:	LIFE:	Up to 50,000 hours
	RELIABILITY:	Simple circuitry, few components
	SHOCK:	375 G
	VIBRATION:	10 G, 0-2000 cycles
	TEMPERATURE:	-60° to $+150^{\circ}$ C

The Beam Switching Tube is a ten-position, high vacuum, constant current distributor. It consists of ten identical "arrays" located radially about a central cathode. Each array comprises (1) a Spade which automatically forms and locks the electron beam, (2) a Target output which makes the beam current available with constant current characteristics, and (3) a high impedance Switching Grid which serves to switch the beam from target to target. A small cylindrical magnet is permanently attached to the glass envelope to provide a magnetic field which, in conjunction with an applied electric field, comprise the crossed fields necessary for the operation of this tube. The tube may be operated in several distribution or switching modes such as (1) the tube may be in a clear or cut-off condition, (2) an electron beam may be formed in any one of the ten positions, (3) the electron beam may be switched sequentially, (4) the electron beam may be switched at random from any one position to any other position, and (5) the electron beam may be cleared and reset to the setting of the adjacent tube. The use of the tube in various portions of this system utilizes each of these modes.

Target Output: The output efficiency of the Beam Switching Tube is without equal as a multi-position current distributor. All of the beam current is put to work in the one selected position without any current being wasted in the other nine positions. Approximately 15% of the beam current is used by the spade to automatically lock the beam while the other 85% is available at the target output with the constant current characteristics.

Reliability: Beam Switching Tube reliability can be directly attributed to the principle of crossed electric and magnetic fields upon which its operation is based. Its stability does not depend on any gas or secondary emission principles which are difficult to control. Beam Switching Tubes have been tested thoroughly by many individual Government and commercial agencies. Limits have been established on almost all possible mechanical and operational parameters to obtain reproducibility and dependability.

Life: The Beam Switching Tube is one of the most reliable of vacuum devices, with a life potential of 50,000 hours. Experience has indicated that a circuit may be designed reliably around Beam Switching Tubes with an end point emission level of 85 per cent. This compares most favorably with other components. The lack of a close-spaced control grid inherently contributes to this factor. The currents and voltages used are many times less than those for which the cathode is rated. The particular beam shape and the bi-stable tube characteristic which locks the receiving spade at near cathode potential both tend to minimize the effects of ion bombardment.

The beam formation has the property of using a different portion of the cathode for each beam position in a manner which results in time sharing and minimizes the effects of poor emission.

Temperature: Beam Switching Tubes are noteworthy as being one of the electron devices least sensitive to either high or low temperatures. Operation with ambient temperatures of 100° C have been common. Tubes with special processing schedules have been successfully made for continuous operation at 200° C and higher. Every completed tube and magnetized magnet assembly goes through a cycle at 150° C to permanently fix the silicone cement which holds the precise magnetic field alignment. Random tests made with repeated cycling at these temperatures have shown negligible effects.

Shock and Vibration: With the increased interest in using beam switching tubes in aircraft and guided missiles for such applications as coding, radar, loran, and telemetering, many laboratories have made individual shock and vibration tests. As a result of these tests the vibration rating of the present tube has been established somewhat conservatively at 10 G, 0-2000 cycles. Design improvements have been incorporated to permit sample tubes to go the limit of existing test equipment, 20 G, 0-2000 cycles without failure.

Rugged Structure: The rugged box-like symmetrical structure is balanced and supported evenly at all points, both within the mica and to the glass envelope. It is firmly held through many tie points to the multi-lead stem. Finally, the tube floats within the "rubberized" silicon cement that attaches the glass envelope to the permanent magnet to obtain an additional protective effect.

NIXIE NUMERICAL READOUT TUBES

The Nixie is a gas-filled, cold-cathod, ten-digit ("0" through "9") numerical indicator tube having a common anode. It is an all-electronic in-line readout device and is an ideal method of converting electromechanical or electronic signals directly to readable characters.

This simple tube contains stacked elements in the form of metallic numerals. Application of a negative voltage to the selected character with respect to a common anode results in its becoming the cathode of a simple gas discharge diode. Only the selected information is visible in a common viewing area because the visual glow discharge is considerably larger than its metallic source.

The device is an unusually efficient electronic-to-visual converter since all of its electrical energy is converted into a neon glow of relatively narrow optical band width. The eye acts as a natural filter in distinguishing this glow in high ambient light.

The Nixie tube types exhibit the following characteristics: (1) All-electronic with a minimum of power required, (2) High-speed rate of change, (3) Simplicity, (4) Wide temperature operating range, (5) Uniform characteristics from tube to tube and number to number, (6) Human-engineered numerical design, (7) Comparatively low cost, (8) Small volume for number size (9) Light weight, (10) Rugged construction (11) Good readability for number size.

At the present time there are four distinct sizes of Nixie. The Type 6844-A which is 1" in diameter and clearly visible at 30 feet, has been selected as standard for this display panel.

Nixies are available in numerals 0 - 9, and with alphabet characters. On request, and combination of alpha-numeric characters can be supplied. The multiple group neon glow tally indicator functions circuitwise the same as the Nixie in-line indicator. It is provided as an alternate for the Nixies and can be used interchangeably with them as indicators. Generally, preference is to use the Numerical Nixies for time indication, the neon tally group for audio and video function indication of 10 to 20 functions, the combination of alpha-numerical pairs of Nixies for indication of 20 to 36 functions, and numerical or alpha-numerical for 36 to 100 functions.

MERCURY-WETTED CONTACT RELAYS

For the high speed switching device to provide accuracy and dependability of the highest order for the event transfer shift, mercury-wetted contact relays, manufactured by C. P. Clare and Company under license agreement with Western Electric, provide electrical and mechanical stability with extraordinary uniformity of performance over very long periods of time.

It is the mercury-wetted contacts which, together with gas under pressure and the small size of parts, give these relays their distinctive character. Electric contacts between solid metal surfaces can, and often do, cause trouble in various ways: they wear down, get dirty, stick by locking or welding, and chatter. These faults are avoided by using mercury contact surfaces instead of solid metal. In the Clare Type HG Relays, platinum contact surfaces are wetted with mercury by means of a capillary connection to a mercury reservoir below the contacts. The contacting medium is a mercury film supported on the solid metal surfaces. The wick-action keeps the mercury at the contacting surfaces continuously replenished. This minimizes the amount of mercury that has to be put in motion for operation, and permits the moving contact to be carried by a light armature, capable of high speed.

Electrical Features

Long Life - units have a conservative life expectancy of more than a billion operations when operated within their ratings.

High speed of operation - can be driven at speeds up to 200 operations per second, with consistent performance.

Uniform and constant operating characteristics - repetitive operation of an individual relay is such that operating time varies by only about 0.1 millisecond under constant drive conditions. The repetitive precision with which a given relay may be expected to operate is within one per cent of its minimum operating current. This precision is substantially independent of number of operations or ambient temperature.

Mechanical Features

Small chassis space

Convenient mounting - plugs in like a vacuum tube

High sensitivity

Requires no maintenance whatsoever

Operation unaffected by humidity, barometric pressure, or temperature changes

Completely protected against dust and dirt, corrosive fumes, and explosive atmospheres

No shelf deterioration

Contacts can not wear down, get dirty, stick by locking or welding, nor chatter

There is no possibility of change in adjustment after assembly is completed

Steel housing reduces magnetic coupling between relays

Tamperproof

PLUG IN CONSTRUCTION

The basic components, BST, Nixie, and mercury wetted relay, comprise 95% of the entire system and provide ultra reliable operation in the circuits used. They are arranged in plug in modules providing (1) complete flexibility as to "building-block" expansion (2) immediate "patch around" by-passing of any trouble spot that occurs (3) ease of changing any complete module which may be faulty and (4) ease of removing and trouble shooting a unit while it is still patched into the system and, therefore, receiving its normal voltages and pulses. "Blue ribbon" connectors with special covers are used throughout and all components (resistors, capicators, etc.) associated with each storage/display point are separate plug-in assemblies.

Due to the brief time necessarily allotted here, I have just been able to touch on some of the more obvious details of a system similar to that, which I feel sure, the majority of you will incorporate in your operation in the next two to three years. I hope that all present will take the opportunity to visit the exhibit hall and try the system for yourselves.

THANK YOU

AUTOMATION OF TECHNICAL EQUIPMENT

AT STATION WRC-TV, WASHINGTON.

Introduction

We are on the threshold of a new era in broadcasting. This is the era of automation. Automation is important to the broadcaster because it will help him increase his profits. It will do this by eliminating costly errors in operation, and by increasing operating efficiency.

NBC and RCA have been very active in automation over the past three years. I remember talking to some of you here in Chicago two years ago about automation devices. Since that time we have built, installed and have actually used automation equipment in practical operation in Buffalo and in Washington. The automation equipment in Washington has been working there for about 9 months, and since it was put into service, it has been used every day for most of the station's operation. It has proven to be a very practical operating tool.

The Washington plant itself is a brand new building containing a radio station, and a television station of three studios. The station's operational requirements are similar to that of most independent stations, but it must also fulfill some network commitments such as news programs, remote pickups, "Meet the Press" and so forth. The plant was designed from the ground up for efficient operation. We knew that to do color programming in a larger plant and still maintain our efficient operation, we must do something "extra" in the plant's design. The extra is automation.

In designing the plant we prepared for automation in several ways (see figure 1).

First, we laid out the equipment in one central operating space so there would be no island operating areas. We have placed in one central space all video control, transmission, film chains and projectors, transmitter, rack equipment, and audio and video switching control. Therefore, if tasks such as video control and projection can be simplified enough to permit their combination, we can take advantage of this simplification because the equipments involved are in the same room. Thus program requirements, not equipment layout, determine manpower requirements.

Second, we wanted to reduce the amount of loading and unloading of film and slides so we provided 5 movie projectors and 3 slide projectors. Films of similar types are spliced together into one reel and then are loaded in the projectors at the start of the day. There are enough machines so that reloading is required only at infrequent intervals.

Third, since we wanted to operate the switching by automatic devices, we employed remote control video switching. We used a relay switcher for this purpose. We wanted to control audio automatically too, so we provided relay controlled audio switching.

Next, to further reduce the amount of attention required at projectors, we equipped all projectors with automatic cue up and stop. This device detects a piece of aluminum foil which is stuck to the film by the film editors, and brings the projector to a controlled stop an exact number of frames away from the foil. By placing the foil at the proper spot, it is possible to have the stopping point be the proper cue up point for the next film section on the reel. Therefore, manual attention to the projectors is required only to load and unload reels of film.

To simplify the operation of film video and audio control, automatic gain control amplifiers were placed in the audio and video channels of the film camera chains.

Another very interesting and new idea which has been built into the plant is the idea of simplified manual operation. This idea philosophically is that the controls provided to perform an operation should be those which directly relate to the operation desired not to the technical equipment line up. To show you what I mean consider the normal controls provided to operate a multiplexed film projector. There are start and stop buttons for each projector, controls for the multiplexer or dowsers so that the projector can be made to show, video switching controls for the particular film camera involved, and an audio fader to open. With simplified manual, (shown in figure 2) preset controls would be provided for the projector involved. Presetting the projector would light its projection lamp and start its shutter motor, automatically set the multiplexer and dowsers to the proper position for show, connect the start button to the projector, operate a video relay to set up the proper film camera on a preset monitor so the roll can be previewed, and operate a similar audiot relay so that sound can be prechecked. After the projector is rolled, a common "take" button is used to put the film on the air.

Another aspect to simplified manual is that all redundant controls are eliminated. Thus for transmission equipment only one set of stab amp controls should be provided no matter how many stab amps there are because it is only practical to adjust one stab amp at a time. In Washington we have a monitor switcher at the transmission position. The monitor can be connected to the outputs of each of the 6 stab amps in the plant. The connecting of the monitor also connects the one set of controls to the proper stab amp. Gone is the possibility of adjusting the wrong knob.

This automation system was designed with as many good operating features as we could think to include. The result is a system with great flexibility.

It is applied in parallel with the manual switching controls. (figure 3). Since it is so applied, and the manual buttons are not disconnected, manual override is always possible. Information from the automation system rather than from the manual controls makes the video and audio presets, starts the projectors when required and then makes the transition. This automation system is capable of controlling all plan switching actions. Thus it can start film projectors, change slides, switch multiplexers, switch video and audio for film cameras, live cameras, network and remotes, and can pick up and drop channels. The system also allows automatic set up of special effects equipment, and the programming of dissolve and wipe transistions as well as the usual cut.

In the automation system the switching information is stored on punched paper tape. We chose paper tape for Washington because the equipment to handle it is relatively inexpensive and readily available and is compact. Figure 4 shows how information is stored on the tape. The tape we use is called 8-channel tape because there is the possibility of 8 holes across the tape. It takes one row of holes for each character. Note that it takes quite a number of rows to indicate a complete switching action or event. In the illustration, the tape says that at 9:29:50 we want a slide and no audio (since we are going to have an announcer read copy for the slide, and the announcer controls his own microphone.) The tape readers we use in Washington read only one row of holes at a time. Therefore, it is necessary in the central automation equipment associated with the reader to commutate each character of information into a memory storage so that the complete requirements for a switch can be read at once.

We punch information on tape either by using a tape punching electric typewriter such as a flexowriter or by using a special tape punch connected to the buttons of the operating console. We chose the codes to operate the equipment carefully so that they corresponded to flexowriter codes for letters of the alphabet. Thus the letter S stands for slide and that flexowriter code is used to operate slide projectors by automation. Since this was done, and since it is possible to get these typewriters modified so that only prearranged information is punched, it is possible to produce the control tape for the technical equipment as a by-product of typing the program schedule. This is shown in figure 5.

The other way of preparing tape is to have the technician on duty prepare it by using his operating console and a special tape punch connected to it. This is shown in figure 6. Here, the technician sets up on the manual control panel of the operating console, the switching condition he wants to punch into the tape. He also sets a clock to the time he wants this particular switch to take place. When he presses a punch button, the time and switching condition are scanned, encoded and punched automatically. Another way this punching system can be used is to use it during a dress rehearsal of a show, in those cases where the show is carefully rehearsed.

In this case, the clock is set to actual air time. The punch actuate button is connected to the take button of the operating console. At the beginning of the dress rehearsal, the clock is started. As the rehearsal progresses, each time a manual switch is made, the equipment scans the time and the switching condition and punches the information on the tape. Therefore, when the dress rehearsal is over, there is a complete record of it, and the tape may be used during the air show to duplicate the actions during the dress rehearsal.

Before getting into the system itself, some definitions of terms are necessary. There are several modes of operation of the switching equipment possible in Washington. These are illustrated by figure 7. First of course, the switching can be done manually. This mode is necessary to take care of unrehearsed live programs and for last-minute changes in the scheduled programs such as news events. Secondly, the events only mode is available. In this mode, the automation equipment presets each switching action but does not make the on-air switch. The automation system does not have any time sense in this mode. An operator must press a take button each time he wants a switch to occur. As soon as the take button is pressed, automation makes a new preset for the operator. This mode reduces the operation to the repetitive pressing of one button. We use the approximate time mode when a series of events are required whose internal time structure is known, but we don't know when this group of events is to begin. An example of this is a station break where the network schedules the break at an approximate time. The system, under this mode of operation requires a start impluse.

After this one cue, all other switches are taken in proper time relationships automatically. The real time mode of operation is fairly obvious. Here events are switched automatically according to clock times as scheduled. No manual control is required. In Washington no matter how an event is scheduled on the tape to be taken, it may be taken in any mode desired. It is merely necessary to press the appropriate button; manual, events only, approximate time, or real time and the event will be taken in that way. However, the way an event is taken can be scheduled on the tape and if it is, the equipment will automatically switch into the indicated operating mode. For example, if in the midst of real time events a group of approximate time events is scheduled, the equipment will switch to approximate time, wait until a start impulse is manually given, then do the approximate time break, and return to real time by itself.

Figure 8 is a system diagram of the automation equipment. There are two identical modules to the system. Each module consists of a tape reader, a decoder, distributor, error check, two memories, and an approximate time clock. The two modules share a real time clock. Codes from the reader are decoded and then commutated to the proper positions in either memory 1 or 2. Each memory has a position for mode, hours, minutes times ten, minutes, seconds times ten, seconds, video event, audio event, special effects set up, channel switching, and mode of transition, whether lap, or some special form of wipe effect. Because projectors require 3 seconds to stabilize, two memories have been provided so as to see ahead one event to allow one switch between the roll of a projector and the video switch to it. This permits a two-second slide to precede a film. The two memories are identical. Whenever a memory contains information calling for a movie projector, a pre-roll signal to that projector is given automatically 3 seconds before the scheduled time for that film to go on. Time coincidence checking circuits are connected between the clocks and the memories. A time coincidence between time in the memory and clock time causes a switching impulse to effect a transition to whatever source was preset by automation.

When an approximate time event is called for, the approximate clock is switched into the system and is automatically set to the approximate time scheduled on tape. The clock does not run, however, until the manual start signal is given. Then the clock begins to keep time from that point on as though it were actually the time to which the clock was set.

If a change is required in the program schedule, a second tape is made up of the new schedule covering only the period of change. This tape is placed in the second reader. At the proper time, the second reader and module will take over automatically, operate for the appropriate time and then give control back to the first system at the end of its schedule. Meanwhile, the first module would discard the erroneous information so as to be ready to take over at the right point in the program schedule.

The two automation modules were installed on switches so that any of three control positions could make use of them. The arrangement as shown in figure 9. Automation equipment was installed centrally, and the tape readers were installed in each control point. If a tape reader is plugged in at a control point and turned on, the automation module associated with that plug will switch to the reader, and to the associated audio and video equipment. There are two plugs at each control point. If tape readers are plugged into both plugs and turned on, the control point automatically has the means for making corrections.

The Washington system has proven to be extremely reliable in operation. Not a single failure has been reported to me in its operation since it went into service. It has permitted staffing the Washington operation with two technicians during standard film and station break activities excluding transmission work. Its value in reducing operating errors has been substantial. The Washington plant proves that automation has arrived as a practical tool for the broadcaster. The practical operating experience gained here will be invaluable in the design of future systems.

R. W. Byloff
March 1959

PREPARATION FOR AUTOMATION

1. PLANT LAYOUT
2. 5 MOVIE—3 SLIDE PROJECTORS
3. REMOTE CONTROL VIDEO SWITCHING
4. REMOTE CONTROL AUDIO SWITCHING
5. AUTOMATIC STOP & CUE ON PROJECTORS
6. AGC AMPLIFIERS
7. SIMPLIFIED MANUAL

Figure 1

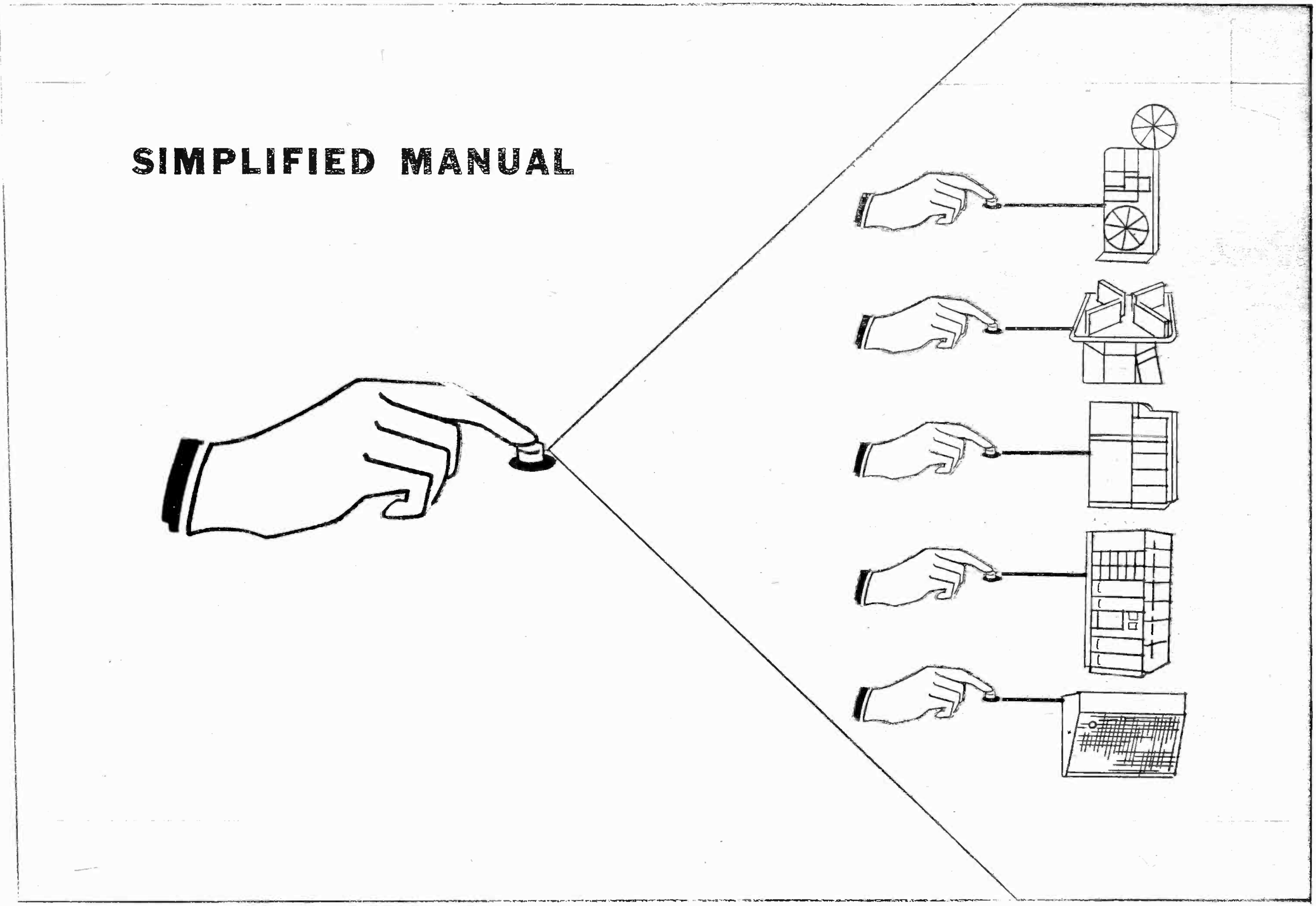


Figure 2

APPLIED IN PARALLEL WITH MANUAL CONTROLS

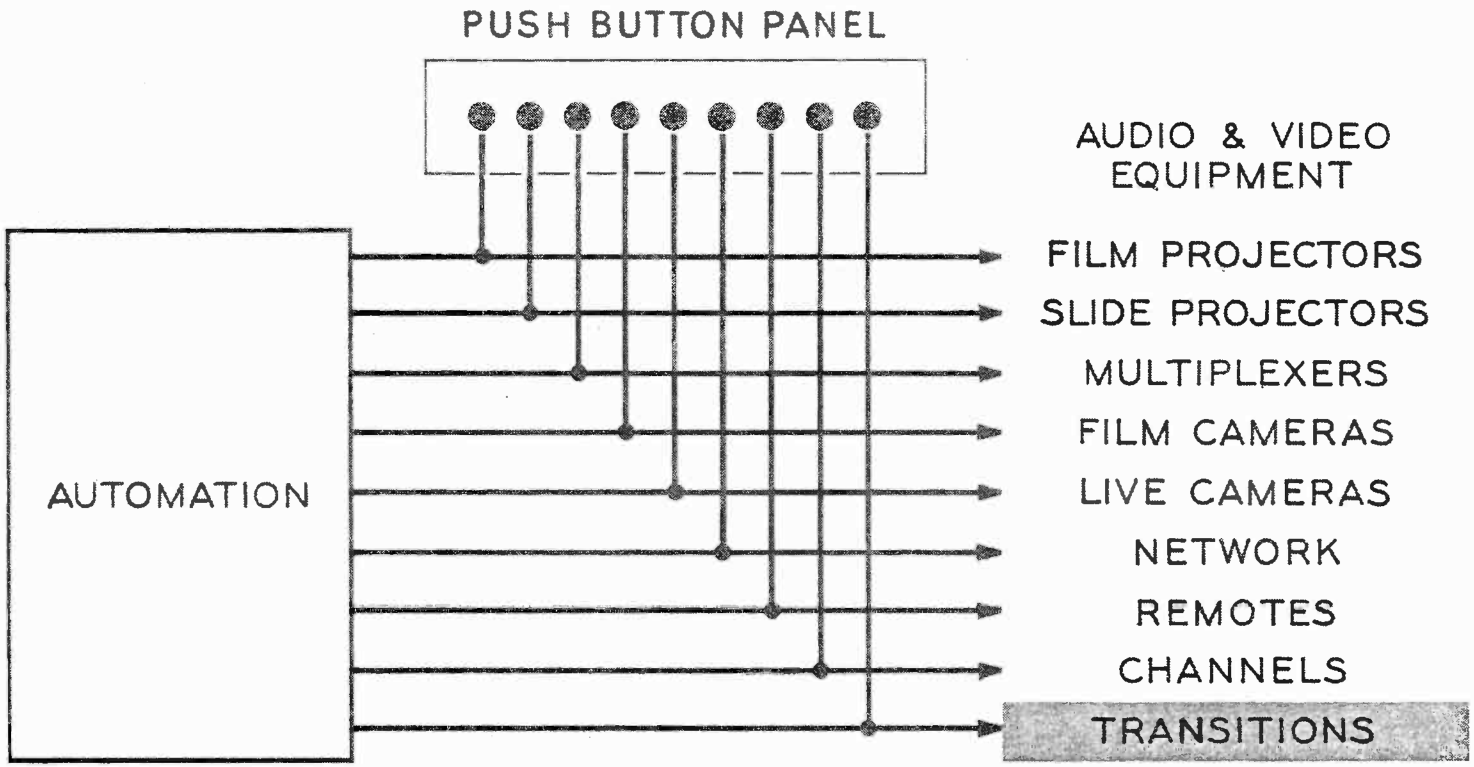


Figure 3

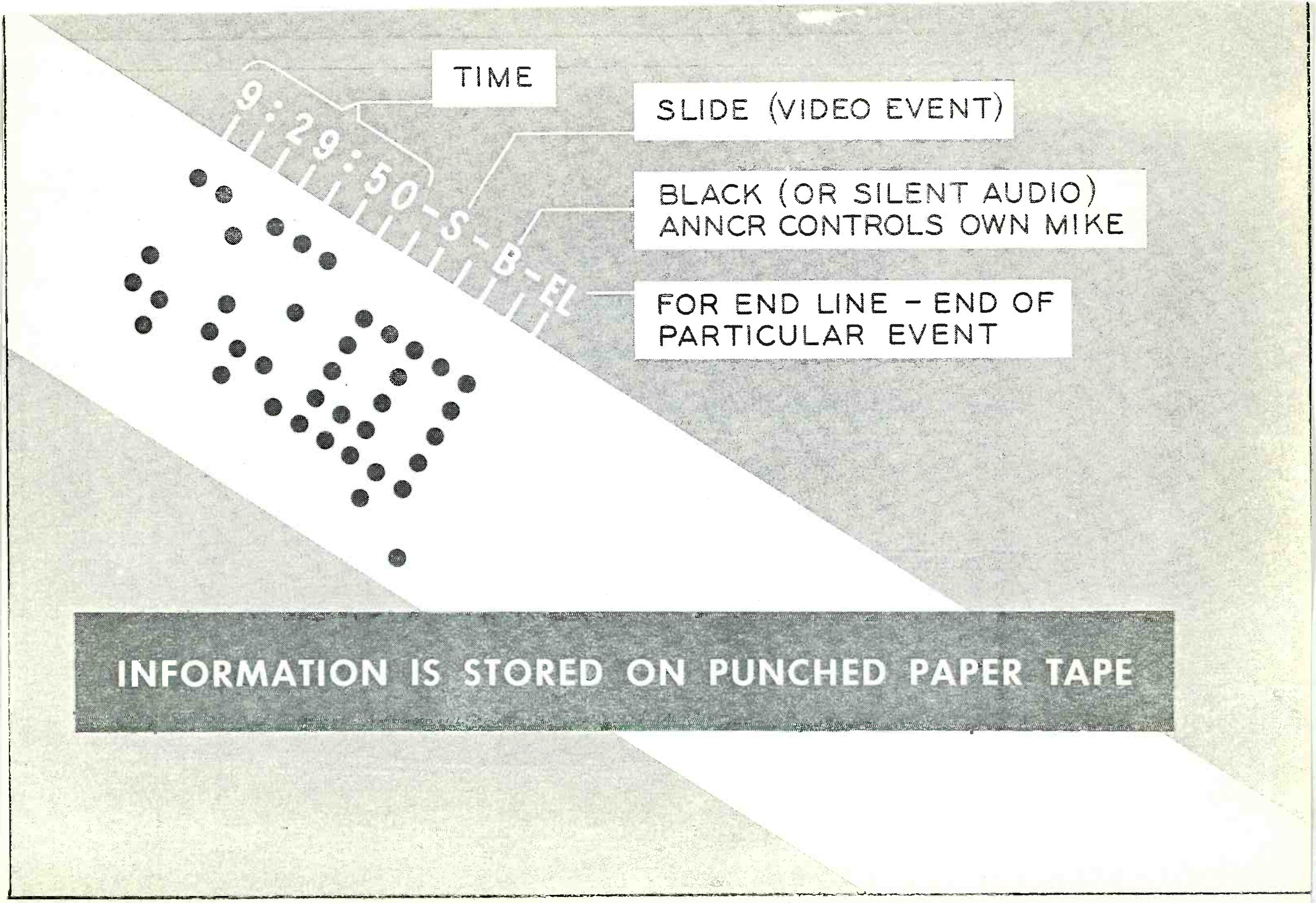

TIME
SLIDE (VIDEO EVENT)
BLACK (OR SILENT AUDIO)
ANNCR CONTROLS OWN MIKE
FOR END LINE - END OF
PARTICULAR EVENT
9:29:50-S-B-EL
INFORMATION IS STORED ON PUNCHED PAPER TAPE

Figure 4

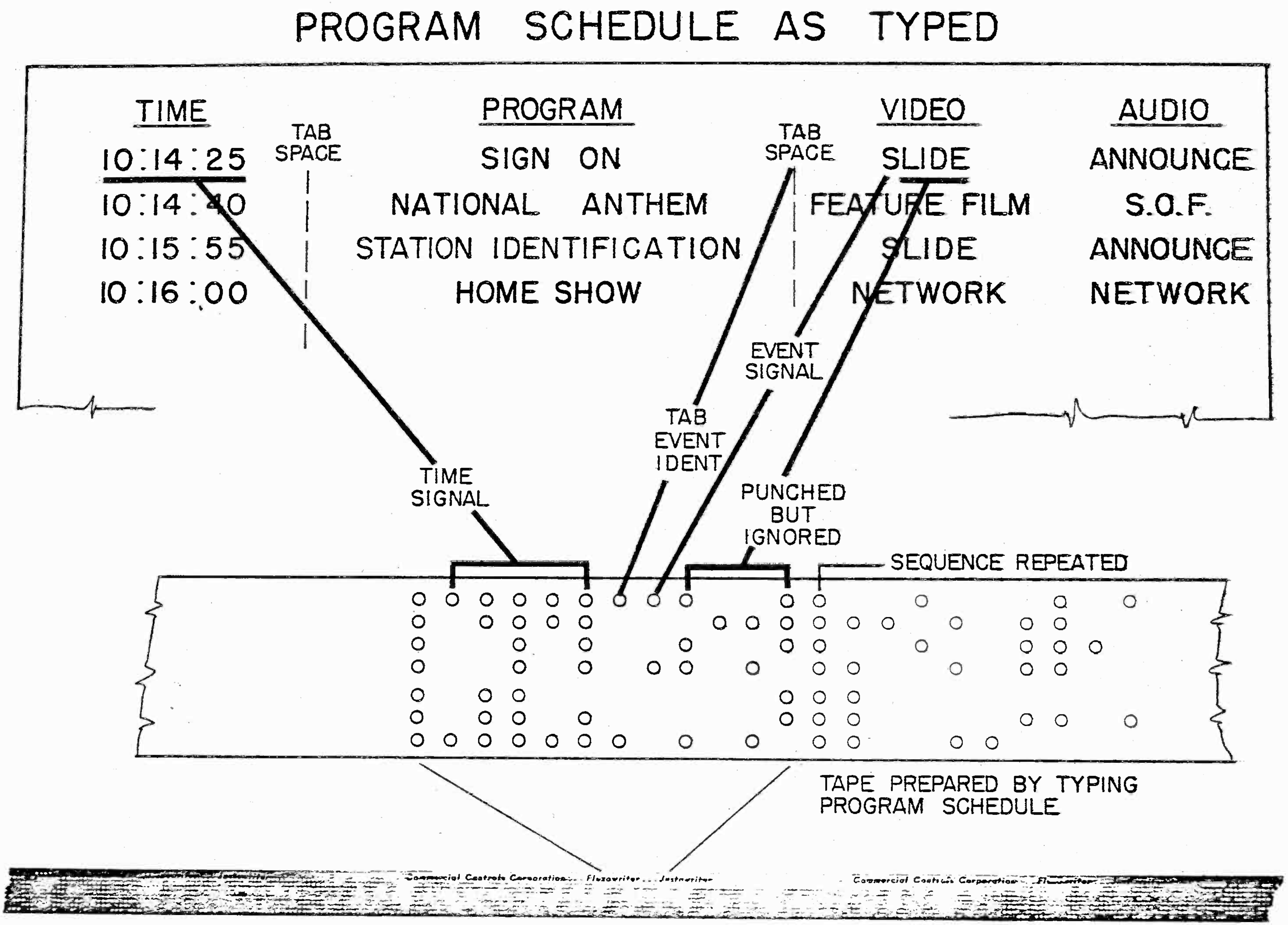

PROGRAM SCHEDULE AS TYPED
TIME
PROGRAM
VIDEO
AUDIO
10:14:25
SIGN ON
SLIDE
ANNOUNCE
10:14:40
NATIONAL ANTHEM
FEATURE FILM
S.O.F.
10:15:55
STATION IDENTIFICATION
SLIDE
ANNOUNCE
10:16:00
HOME SHOW
NETWORK
NETWORK
TAB SPACE
TAB SPACE
EVENT SIGNAL
TAB EVENT IDENT
TIME SIGNAL
PUNCHED BUT IGNORED
SEQUENCE REPEATED
TAPE PREPARED BY TYPING PROGRAM SCHEDULE

Figure 5

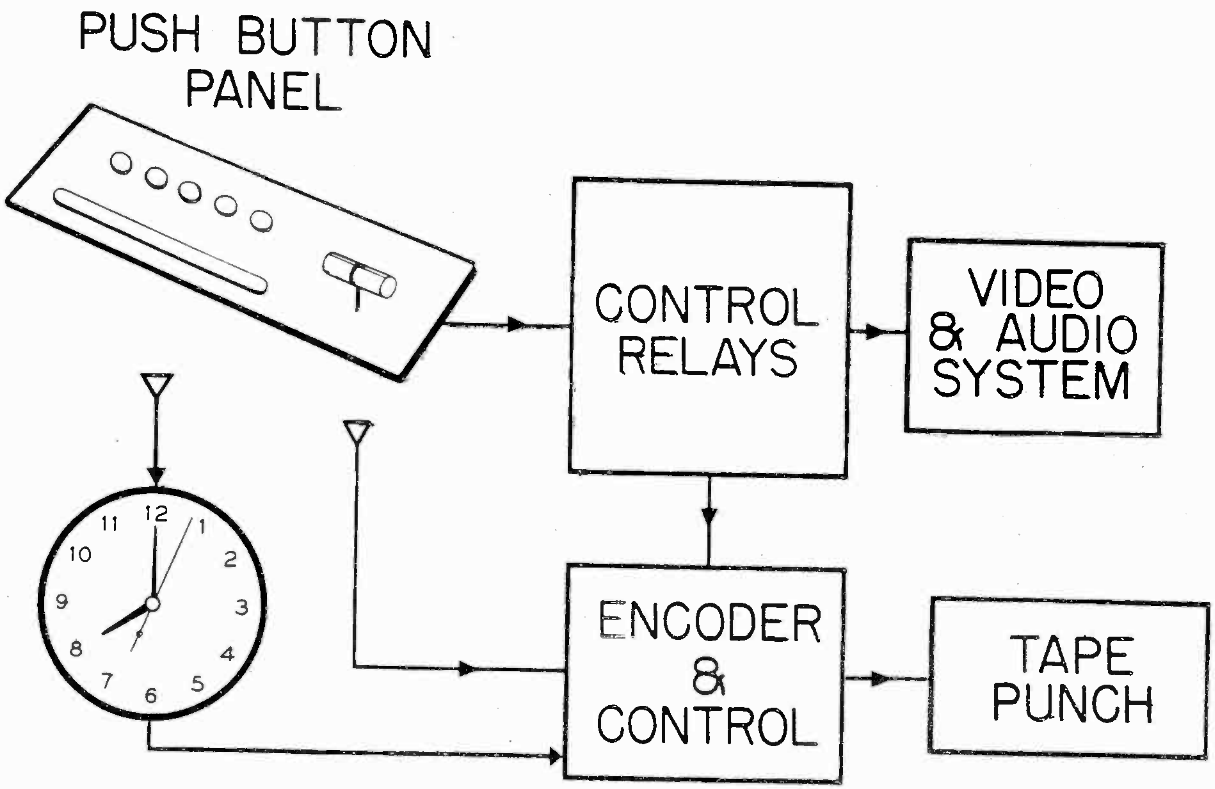

PUSH BUTTON
PANEL
CONTROL
RELAYS
VIDEO
& AUDIO
SYSTEM
ENCODER
&
CONTROL
TAPE
PUNCH

Figure 6

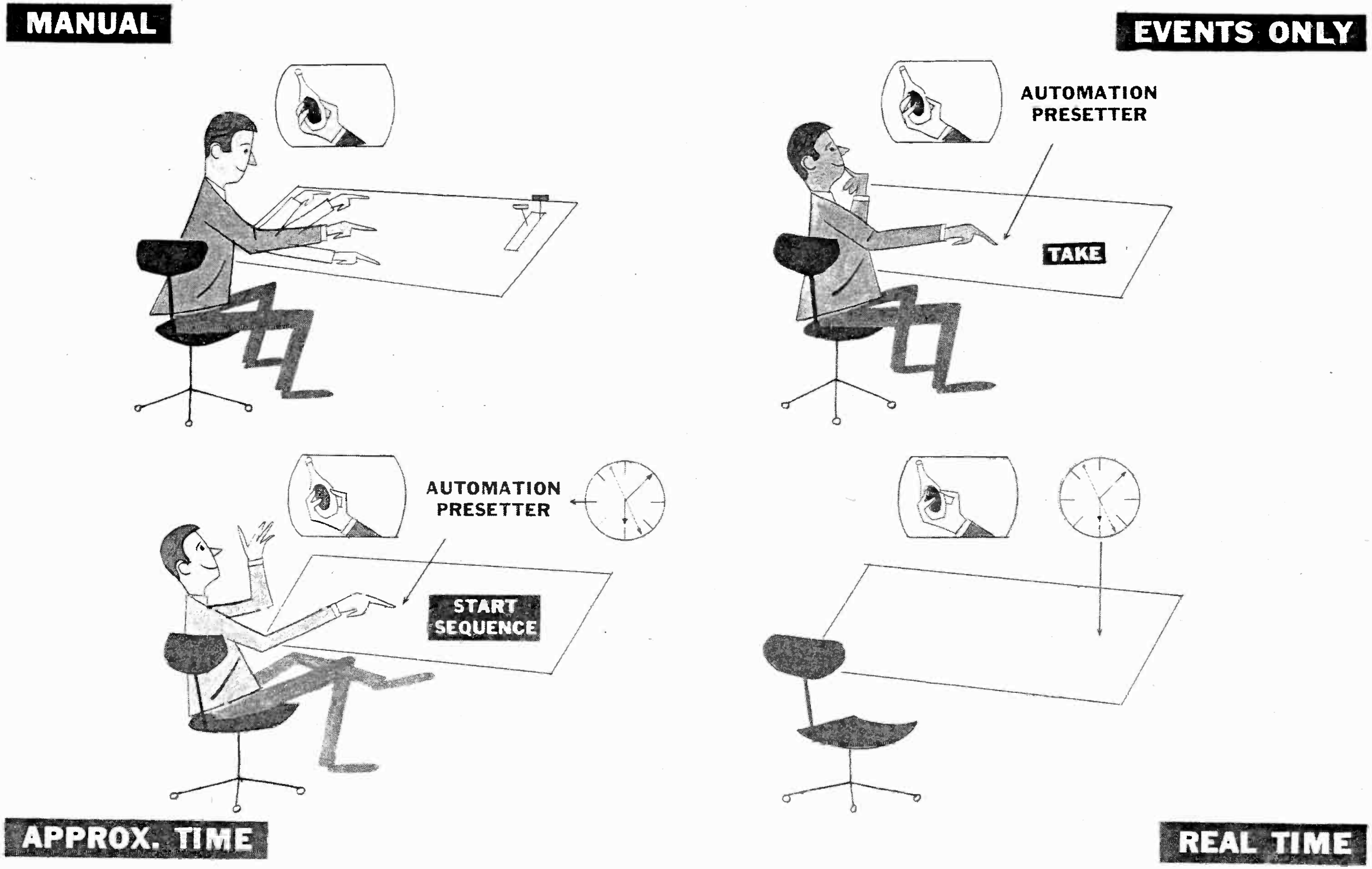

MANUAL
EVENTS ONLY
AUTOMATION
PRESETTER
TAKE
AUTOMATION
PRESETTER
START
SEQUENCE
APPROX. TIME
REAL TIME

Figure 7

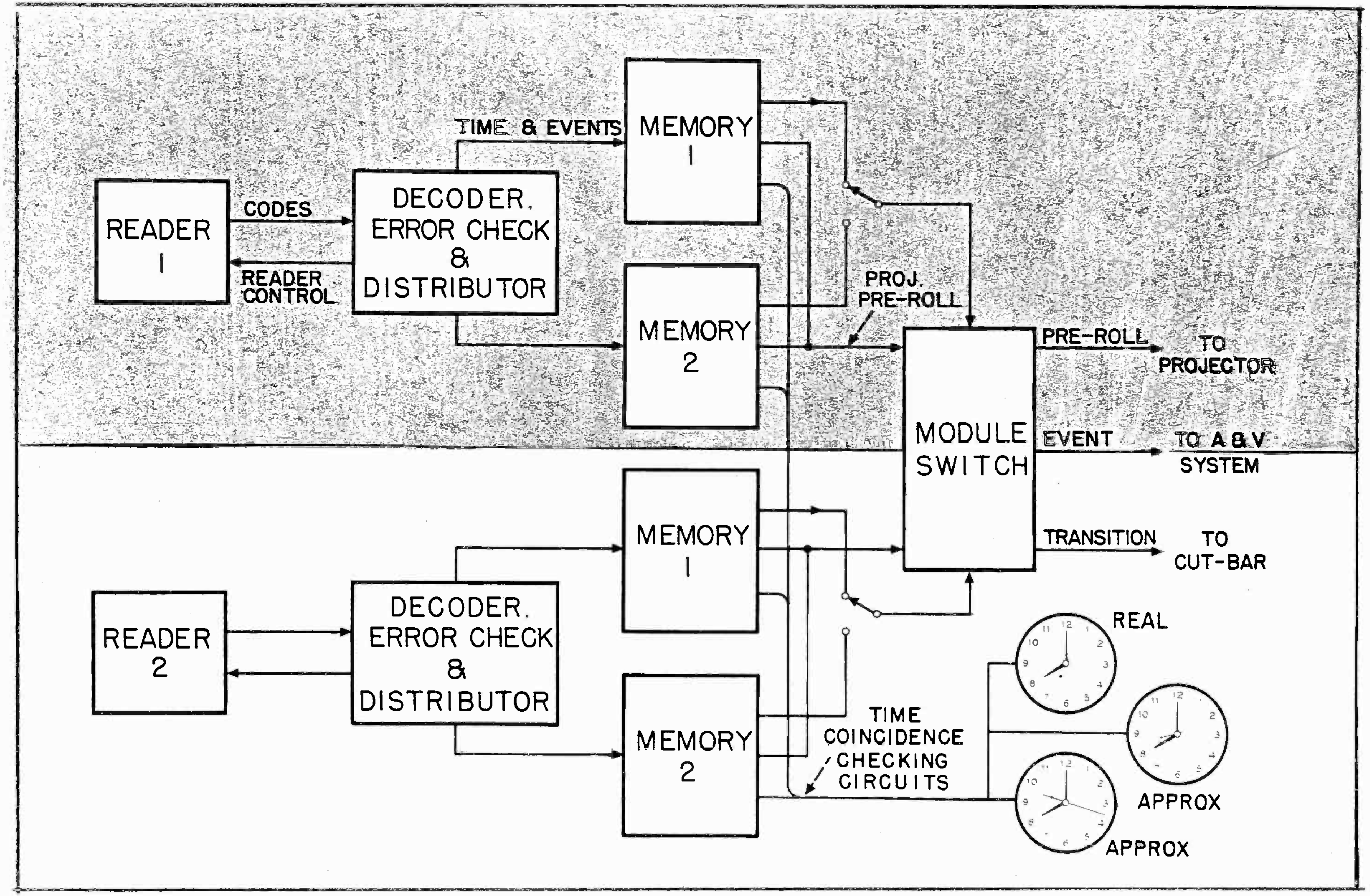

READER
1
CODES
READER
CONTROL
DECODER,
ERROR CHECK
&
DISTRIBUTOR
TIME & EVENTS
MEMORY
1
MEMORY
2
PROJ.
PRE-ROLL
MODULE
SWITCH
PRE-ROLL
TO
PROJECTOR
EVENT
TO A & V
SYSTEM
TRANSITION
TO
CUT-BAR
READER
2
DECODER,
ERROR CHECK
&
DISTRIBUTOR
MEMORY
1
MEMORY
2
TIME
COINCIDENCE
CHECKING
CIRCUITS
REAL
APPROX
APPROX

Figure 8

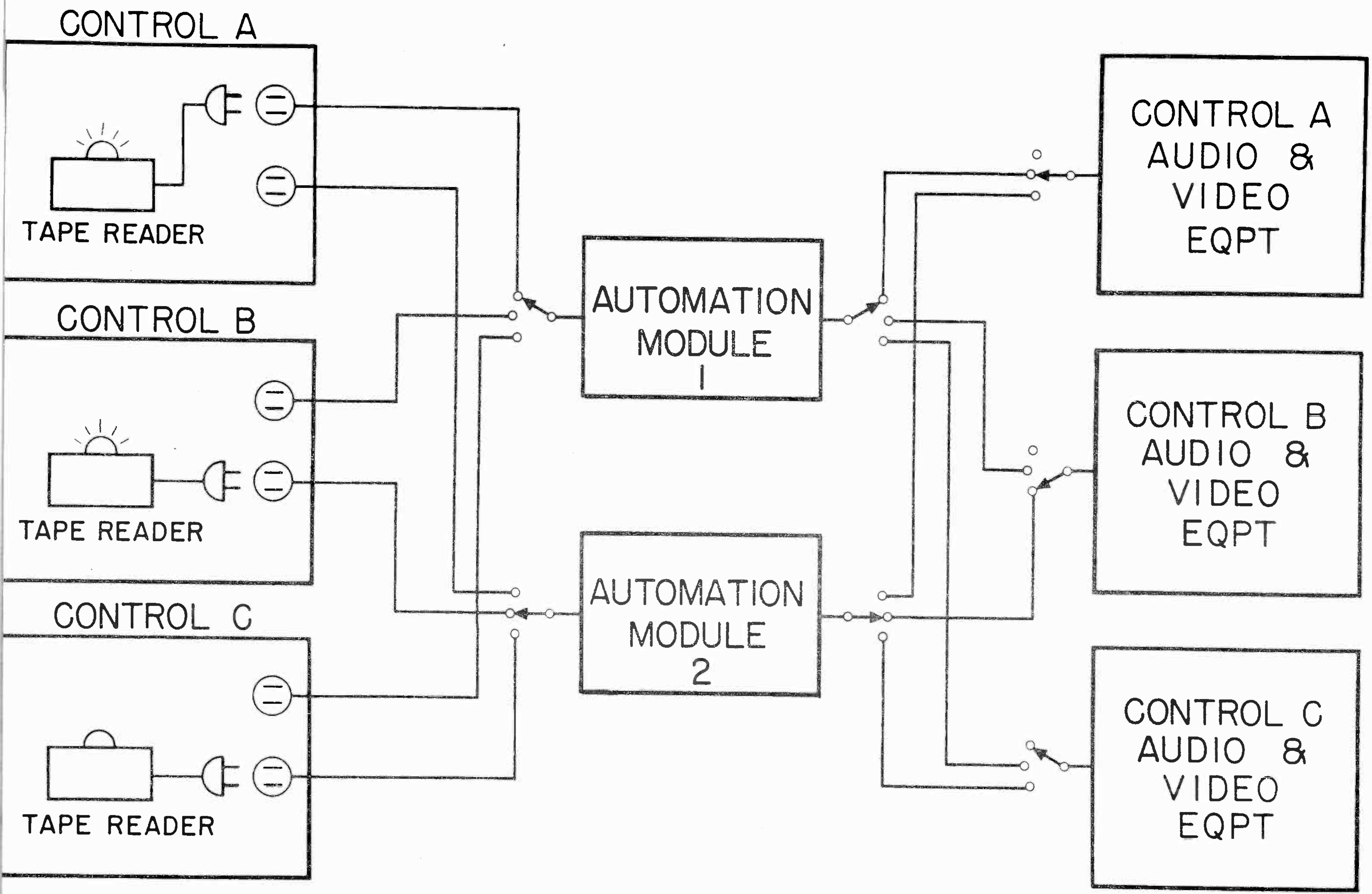

CONTROL A
TAPE READER
CONTROL B
TAPE READER
CONTROL C
TAPE READER
AUTOMATION MODULE 1
AUTOMATION MODULE 2
CONTROL A AUDIO & VIDEO EQPT
CONTROL B AUDIO & VIDEO EQPT
CONTROL C AUDIO & VIDEO EQPT

Figure 9

THE TRANSISTOR - A NEW FRIEND FOR THE BROADCASTER

by: R. N. Hurst and J. W. Wentworth

Broadcast and Television Equipment Division

Radio Corporation of America

Prepared for presentation
at the 13th Annual Broadcast
Engineering Conference

National Association of Broadcasters
Chicago, Illinois

March 17, 1959

The Transistor - A New Friend for the Broadcaster

by: R. N. Hurst and J. W. Wentworth
Broadcast and Television Equipment Division
Radio Corporation of America

Introduction

Broadcast engineers who make no attempt to become acquainted with transistors will very rapidly find themselves unable to participate in some of the liveliest technical conversations in the industry. The transistor, scarcely more than ten years old, has been refined and developed to the point where it is a fast-rising contender for many of the circuit functions required in broadcast equipment, both audio and video. It is not such a miraculous device that it will obsolete tube-type equipment overnight, but it offers enough advantages that we can confidently predict a steady trend toward transistorization in all categories of broadcast equipment. Reputable manufacturers and wise broadcasters will be careful to see, however, that transistorized equipment fully measures up to broadcast requirements before it is offered for sale or pressed into service. The novelty value which helps to sell transistorized consumer products is useless to the broadcaster, who must demand reliability in all equipment involved in the handling of his highly perishable product - broadcast time.

The purpose of this paper is to introduce the broadcast engineer to the transistor in such a way as to initiate a lasting friendship between the two. The paper is intended, of course, only for those broadcast engineers who have not yet had the opportunity to become acquainted with transistors through education or actual experience with them. The authors feel qualified to make an appropriate introduction, because we have had the privilege of getting to know both broadcasters and transistors through our professional activities extending over several years. We appreciate that broadcasters are not professional physicists, so we shall avoid the conventional approach which attempts to describe transistor behavior in terms of "holes", electron flow, energy levels, and other aspects of semi-conductor theory. We shall assume that transistor designers have done their job well, so the transistor may be introduced to the broadcaster as just another basic component, like the resistor, capacitor, inductor, or diode, that can be called upon to do specific jobs in electronic circuits. We shall present a brief summary of the "personality traits" of transistors, and a description of their typical behavior. We shall explain how they may be put to work in a few typical circuits, and shall conclude the paper with a few observations on handling precautions that will help to keep transistors and broadcasters on friendly terms with each other.

Advantages

The major advantages of transistors in comparison with hot-cathode tubes have been so widely publicized that only a brief summary is required here. The small size of transistors, coupled with their very low power input requirements, makes possible substantial reductions in the size and weight of electronic equipment. These advantages will be appreciated by broadcasters not only for portable field equipment, but also in cases where new facilities must be added to broadcast plants without increasing the floor space in control rooms. The reduced heat dissipation will not only add to operator comfort in crowded locations and reduce the power bill for technical equipment, but will also increase the life expectancy of nearly all circuit components (which always age less rapidly at reduced temperatures). The transistor, itself, enjoys a much longer life expectancy than its vacuum-tube cousin, provided it does not meet an untimely death from over-exposure to unfavorable conditions. There is considerable evidence that many transistor types have a life expectancy of the order of 70,000 hours (about 8 years) of continuous service if used under conservative conditions. This long life contributes, of course, to greater reliability in transistorized equipment. The absence of heated cathodes reduces substantially the warm-up time required for transistorized circuitry. Still another trait that is winning friends for the transistor is its versatility. It can be constructed in a variety of forms, many of which will do jobs that could never be done reasonably with tubes. Two transistors can be made as "mirror images" of each other for use in balanced or symmetrical circuits, for example, and it is even possible to make a transistor which behaves exactly the same whether it is hooked up "backwards" or "forwards".

Present Limitations

These obviously friendly remarks about transistors should not lull the reader into the false assumption that transistors are paragons of virtue. They have their faults and limitations, and broadcasters would do well to become acquainted with these less favorable attributes of transistors right from the beginning, so as to make proper allowances for them. Fortunately, many of the limitations of transistors are not of major concern to equipment users provided the equipment designers understood them and took them into account.

At the present state of the art, transistors are definitely limited in either frequency response or power-handling capability. Types have been developed which handle substantial amounts of power for such applications as series regulators in power supplies, but these types are generally useful only for frequencies below a few thousand cycles per second. At the other end of the scale, types can be obtained which operate up to hundreds of megacycles, but their power-handling capabilities must be measured in milliwatts or microwatts. This problem is a basic one, resulting from the fact that the transistor action actually occurs in a tiny active region within a pellet of semiconducting material. Because of the submicroscopic spacing between the "elements" of a transistor, its input and output capacitances tend to be quite high unless the active area is kept very small. When the active elements of a transistor are made large enough to handle appreciable amounts of power, and are thermally coupled to heat-dissipating structures, the capacitances become so great that operation at high frequencies becomes impossible.

A transistor may be regarded superficially as a sophisticated type of nonlinear impedance, implying that it does not follow Ohm's Law when voltages or currents are applied to its terminals. It should not be surprising, therefore, that inherent nonlinearity must be counted as one of its limitations in many circuit configurations. An ingenious circuit designer can get around this problem in a variety of ways, but nonlinearity prevents the use in high quality broadcast equipment of many simple circuits that look like obvious approaches to the transistor novice.

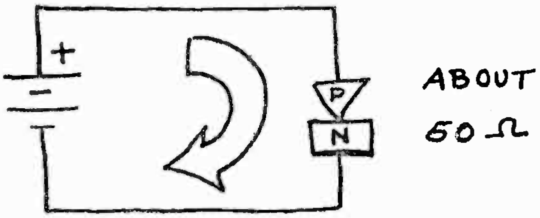
The relatively low impedance characteristics of most transistors may be either good or bad, depending upon the application. Broadcast engineers who have been "brought up" on tube circuits will probably find it difficult to break away from the habit of ignoring input impedances. A tube normally has an input impedance of several megohms, which can safely be ignored when shunted across the load impedance of the preceding stage. A transistor, however, has an input impedance that may vary from a very few ohms up to perhaps 100,000 ohms, depending upon the transistor type and the circuit configuration. In almost all cases, the transistor draws significant current from the preceding stage, so its input impedance must be taken into account when analyzing or designing circuits.

Two transistor traits of great significance to broadcasters are temperature sensitivity and rapid response to conditions of over-stress. Transistor performance characteristics definitely vary with temperature, although a competent circuit designer should be able to provide stable performance over a reasonable operating range. There is a temperature threshold, however, above which transistors may not be operated without suffering irreversible damage. For most germanium transistors, this critical temperature is about 85° Centigrade at the active region. When due allowance is made for normal temperature rises within the transistor cases and within confined equipment spaces, we find that about 55°C (131°F) is about the practical upper limit of ambient temperature for transistorized equipment using germanium devices. Silicon transistors will operate at substantially higher temperatures, but are considerably more expensive and are limited in some other performance characteristics. Until the temperature problem is overcome, broadcasters would do well to mount transistorized equipment in relatively cool locations.

The transistor cannot compete with its cousin, the tube, when it comes to tolerating occasional abuse "beyond the call of duty". While a tube is quite vulnerable with respect to its mechanical structure, it is surprisingly tolerant with respect to severe over-rating conditions applied to its internal elements on a momentary or accidental basis. An accidental short of a grid circuit to +B may cause a tube to glow red very quickly, but it can be restored to its normal condition if the over-stress is not continued too long. Not so with the transistor. If it is pushed well beyond its ratings in any respect even momentarily, it just quits in less time than a human hand could possibly take corrective action. Usually there is no flash, no red glow, no puff of smoke, not even a little "pop" - the transistor just dies, in silent protest against the intolerable conditions imposed upon it. Broadcasters need not fear transistors for this reason, but should use appropriate caution when poking around in "hot" transistor circuits.

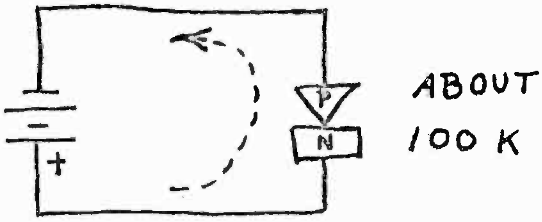
The Transistor as a Relative of the Diode

The transistor is a very close relative of the familiar semiconductor or "crystal" diode. A diode is formed at the junction between two electrically dissimilar materials when they have the property of conducting freely in one direction but not the other. In most practical diodes, the basic material is usually highly refined germanium, but minute quantities of impurities are added to control its electrical properties. Germanium which has been "doped" properly to serve as the anode of diode junction is called "p-type" germanium, and germanium doped to function properly as a cathode is called "n-type" (p and n stand for positive and negative respectively). When the "p" side of a junction diode is connected to the positive terminal of a battery, the diode conducts freely, and behaves like a relatively low impedance (commonly about 50 ohms).



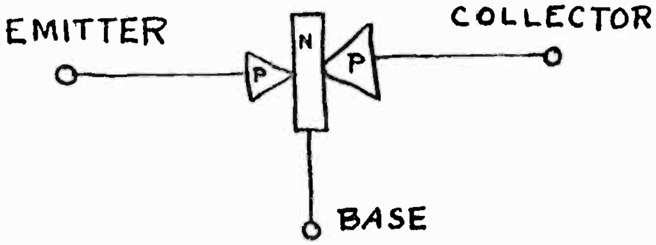
(1)

When the battery is connected in the reverse direction, however, the current flow is impeded, and the device appears to have an impedance of the order of 100,000 ohms or more.



(2)

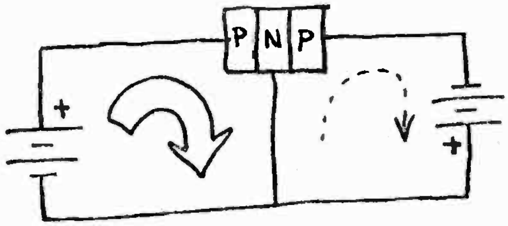
A junction transistor consists, in essence, of two diode junctions in series, with the same very thin piece of N-type material shared by both diode junctions.



(3)

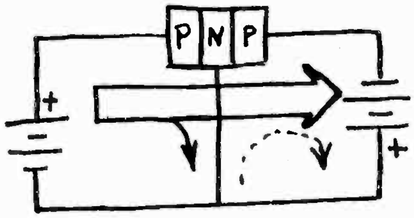
The three elements of the transistor are connected to separate leads, and are labeled emitter, base, and collector, as shown. In a few transistor types of symmetrical design, the emitter and collector have identical properties and may be freely interchanged, but in most transistors the collector junction has a larger area than the emitter junction, leading to differences in electrical characteristics.

In the majority of practical transistor circuits, the emitter junction is biased in the forward direction (i.e., in the direction of easy current flow), while the collector junction is biased in the reverse direction. If the transistor really behaved like two independent diodes in series, the operating currents would appear thus:



(4)

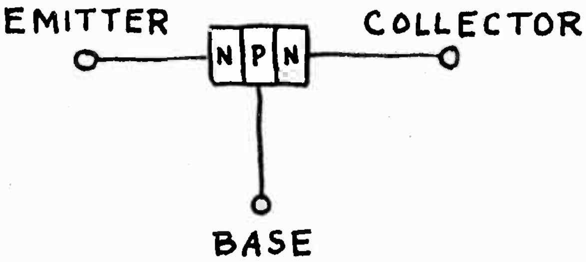
The current through the reverse-biased collector would be very small compared to the emitter current, and the base current would be almost equal to the emitter current. Actually, the situation is almost the reverse:



(5)

The forward-biased emitter draws current freely from its bias supply, but instead of flowing down through the base, the great majority of this current flows straight through to the collector (where its flow is aided by the added "push" of the collector supply battery). In a typical transistor, only about 2% of the emitter current will appear in the base lead. This apparently strange behavior is the very key to transistor action. As noted earlier, it is vitally important that the emitter and collector junctions are very close to each other (on a microscopic scale), and that they share the same base material. While a complete description of the action which takes place in a transistor is beyond the scope of this paper, the matter may be covered superficially by the statement that the current-flowing activity in the emitter junction so alters the characteristic of the immediately-adjacent collector junction that it is able to pass the emitter current rather freely. Of great significance is the fact that a deliberate change in either the emitter current or the base current will cause the same <u>percentage</u> change in the collector current. Considerable gain is made possible by the fact that a change in the relatively small base current can control the much larger collector current.

The above sketches indicate that a transistor, in its simplest form, may be thought of as a "sandwich" of N-type "meat" and P-type "bread". When constructed in this manner, it is called a PNP transistor. However, perfectly good transistors may be constructed by reversing the "bread" and the "meat":



(6)

This arrangement is known as an NPN transistor. The major difference between the two types lies in the fact that the various voltages applied to a PNP transistor must be reversed for an NPN transistor.

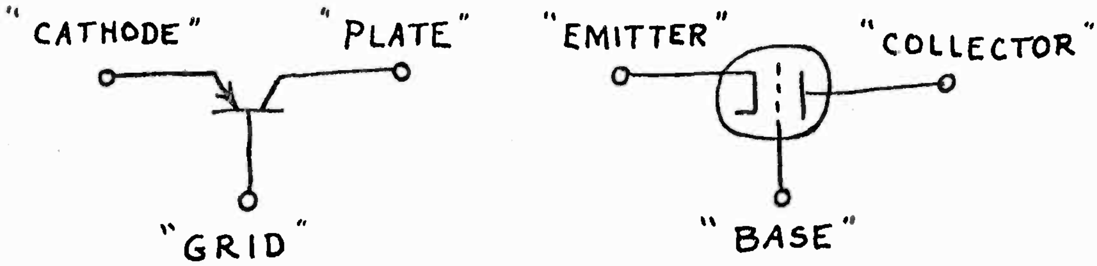
In schematic diagrams, NPN and PNP transistors are identified by the following contrasting symbols:

(7)

In both cases, the element symbolized by the arrow-head is the emitter, and the direction of the arrow-head indicates the direction of easy current flow.

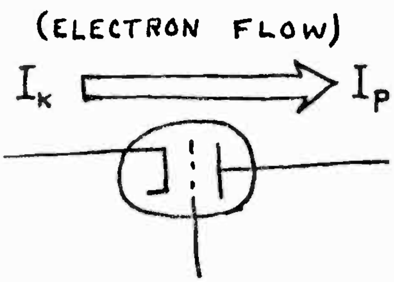
The Transistor as a Relative of the Vacuum Tube

The transistor, being an amplifying device, bears a resemblance to the vacuum tube in that the three "elements" of a transistor correspond (approximately) to the three elements of a vacuum tube. Equivalent functions are performed, for example, by the vacuum-tube cathode and the transistor emitter. The same may be said for the base and the grid, and the collector and the plate, respectively. These equivalences can be used to produce the following equivalent symbols:



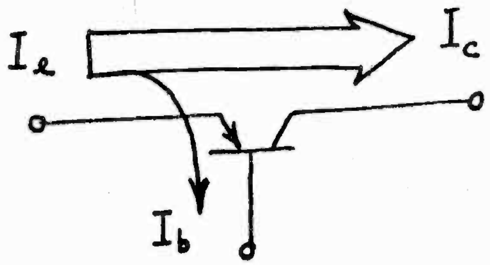
(8)

One should not infer, however, that these equivalences are anything but approximate. For example, consider the difference between a grid and a base. A grid, in normal negative-biased operation, draws no current. The total cathode current flows in the plate circuit:



(9)

It was stated above, however, that the emitter current in a transistor divides between the collector and the base, so that the base has an appreciable current flowing in it:



(10)

Since the current that flows (for a given voltage) is an indication of the impedance of a circuit, the fact that the base draws current while a grid does not leads to the conclusion that the impedance seen looking into a base would be very much smaller than the impedance seen looking into a grid. The conclusion is correct: a typical vacuum tube, it is well-known, has a grid impedance of several megohms, while a typical transistor may have a base impedance of less than 2,000 ohms.

Definitions of Alpha and Beta

Two transistor parameters that have an importance in transistor circuits comparable to the importance of transconductance (g_m) and amplification factor (μ) in tube circuits are those designated alpha and beta.

Alpha is the ratio of the collector current to the emitter current, and is typically of the order of 0.98 for small transistors at low frequencies. Alpha is always less than unity, and indicates the current-gain capabilities of the transistor when operated as a common-base amplifier. (The common-base circuit configuration will be described presently.)

Beta is the ratio of the collector current to the base current, and is related to alpha by the following expression:

$$\beta = \frac{\alpha}{1-\alpha} \qquad (11)$$

For a typical small transistor with an alpha of 0.98, the beta is .98/.02 or 49. Beta indicates, in a general way, the current-gain capabilities of a transistor in the common-emitter configuration to be described presently.

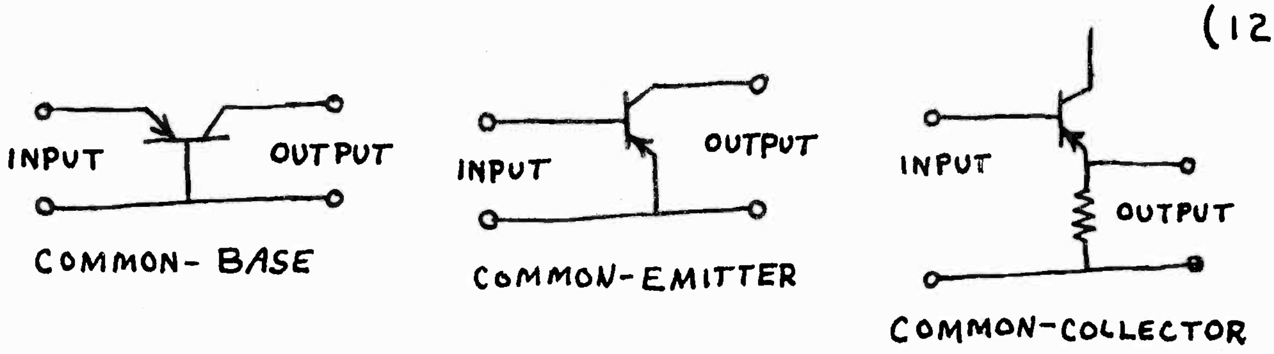
Unless indicated otherwise, alpha and beta describe a transistor's behavior for small signal-current swings at low frequency around the no-signal operating point; values for alpha and beta determined by d-c measurements alone may differ somewhat from the a-c or signal values. Both alpha and beta tend to decrease with frequency. The alpha and beta cut-off frequencies commonly listed in transistor specification sheets represent the frequencies at which alpha and beta, respectively, decrease to 70.7% of their low-frequency values. In general, beta decreases much more rapidly with frequency than does alpha.

The Three Basic Circuit Configurations

As in the case of tubes, transistors can be used in a wide variety of circuits, designed to function as amplifiers, oscillators, clippers, modulators, regulators, dividers, and other specialized devices. There are, however, three basic circuit configurations which are encountered very frequently, and which should be mastered by the transistor novice as a pre-requisite for understanding the more complex configurations. Within the limited scope of this paper, we can examine the three basic configurations only in the relatively simple forms in which they are found in straightforward amplifier service.

The three basic circuit configurations are usually designated common-base, common-emitter, and common-collector, and may be symbolized in simplified form as follows:

(12)



These three basic configurations are superficially equivalent to the vacuum-tube configurations commonly known as grounded-grid, ground-cathode, and cathode follower, respectively.

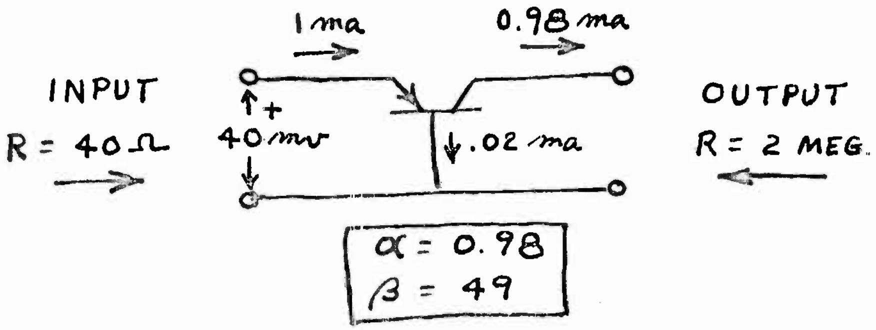
Transistors are similar to tubes in that certain power supply voltages (or currents) must be applied to establish reasonable operating conditions before the devices can handle signal voltages or currents in a useful fashion. As noted earlier, the great majority of practical transistor circuits involve a forward bias (in the direction of easy current flow) in the emitter junction and a reverse bias in the collector junction. The voltages required for transistor circuits are relatively low compared to those employed for tubes. In many transistorized devices, the highest voltage encountered is only about 20 volts. The fact that transistors require no special supplies or wiring for heaters is a definite advantage which helps to keep transistor circuits simple and compact.

Instead of describing each basic circuit configuration in detail before going on to the next, we shall discuss in parallel the major aspects of all three types, so that their differences will be more readily apparent. We shall begin by considering typical input and output impedances. Then we shall continue by describing practical bias arrangements, and conclude this section of the paper by examining typical behavior for a-c signals. For the sake of simplicity, we shall consider only PNP transistors, and shall confine our attention to low-frequency behavior. For the practical illustrations, we shall assume the use of a single transistor type with reasonably typical values of alpha, beta, input impedance, and output impedance. We shall also assume that the same alpha and beta values hold for both d-c and a-c conditions.

Typical Input and Output Impedances

The broadcaster who is only mildly interested in the principles of semi-conductor physics which account for transistor behavior will often find it helpful to think of transistors in terms of the equivalent impedances represented by the input and output circuits, just as he has found it helpful to think of diodes as equivalent to either very low or relatively high resistances, depending upon whether the diode is forward-biased or reverse-biased. For the present discussion, we shall assume that practical bias arrangements have been provided to keep the emitter junction in a freely-conducting condition, and the collector junction in a reverse-biased condition.

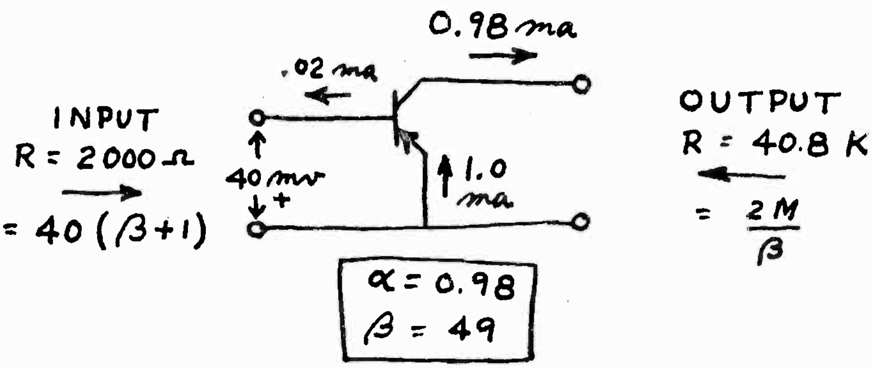
Typical input and output impedances are easiest to visualize in the case of common-base circuits, where the forward-biased emitter appears as the equivalent of about 40 ohms (in a typical case), and the reverse-biased collector appears as about 2 megohms.



(13)

The voltages and currents shown represent small changes superimposed on the steady-state bias conditions. The very high output impedance implies that the operating currents are quite independent of the collector voltage - even a wide change in collector voltage would cause very little change in the collector current. A voltage change of only 40 millivolts on the emitter, however, would cause a 1-milliampere change in the emitter current, leading in turn to current changes of 0.98 and 0.02 milliamperes in the collector and base, respectively.

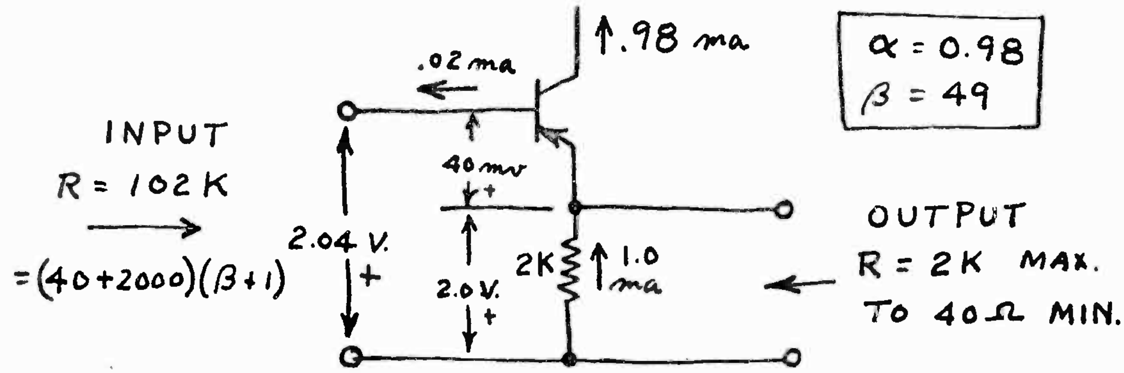
If the very same transistor is operated in a common-emitter circuit, however, the input and output impedances are substantially altered, as follows:



(14)

In this case, as before, a 40-millivolt change in the base-to-emitter voltage results in current changes of 1.0 ma, 0.98 ma, and 0.02 milliamperes in the emitter, collector, and base, respectively, but the resistance looking into the base is $E/I = 40/.02 = 2000$ ohms. Note that this is exactly $\beta + 1$ times greater than the resistance looking into the emitter, by virtue of the fact that the emitter current is $\beta + 1$ times greater than the base current. The output impedance is reduced by a factor of β relative to the output impedance of the same transistor in a common-base configuration. This reduction occurs by virtue of the fact that the very small reverse-bias current that flows as a result of the collector supply voltage (normally negligible when superimposed on the much larger current flowing into the collector as a result of the forward bias in the emitter-to-base junction) is also drawn through the emitter-to-base junction, resulting in its amplification by a factor of beta. Hence, a given voltage change on the collector of a common-emitter stage will cause a collector current change beta times as great as in the case of a common-base circuit.

When the same transistor is used in a common-collector circuit (often called an emitter follower because of its similarity to the cathode follower), the input and output impedances are both significantly influenced by the value of the load resistor. Let us consider the case where the load resistor has the reasonably typical value of 2,000 ohms.



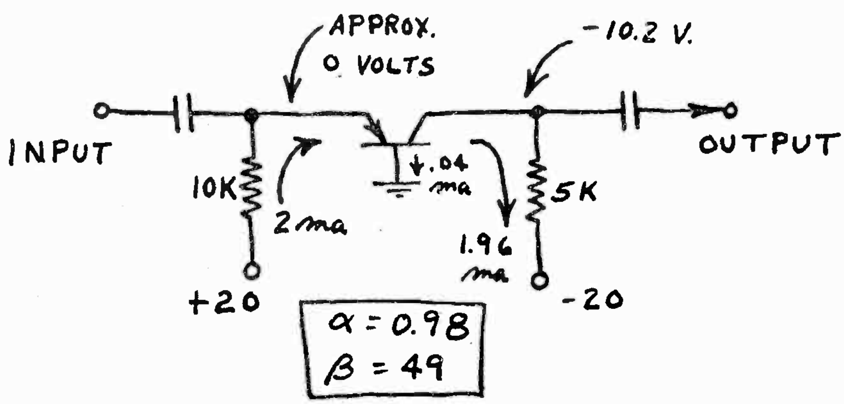
(15)

The collector, in this case, must be connected to a source of suitable supply voltage, but does not directly influence the circuit behavior. As in the two previous cases, it still requires a 40-millivolt change in the base-to-emitter voltage to cause current changes of 1.0, 0.98, and 0.02 milliamperes in the emitter, collector, and base, respectively. Because of the inherent feedback resulting from the presence of emitter resistor, however, the input voltage must be changed by 2.04 volts to realize a 40 millivolt change in the base-to-emitter voltage. By Ohm's Law, the input resistance is E/I = 2,040/.02 = 102,000 ohms. Note that this is β + 1 times greater than the sum of the load resistance and common-base emitter resistance of the transistor itself. If the external resistance in the base circuit is very high, the output impedance of the emitter follower is nominally equivalent to the load resistance. If, however, the base is driven from a very low-impedance source, the IK load resistance is shunted, as far as the output is concerned, by the emitter-to-base resistance of the transistor itself, and thus the output impedance may fall to slightly less than 40 ohms.

Practical Bias Arrangements

Let us now consider the problem of providing practical biasing arrangements to achieve reasonable d-c operating conditions. For the sake of consistency in our practical illustrations, let us assume that we are to handle fluctuating emitter currents of the order of 1 milliampere peak-to-peak. To achieve reasonable linearity, we must arrange conditions so that the d-c emitter current at the zero-signal operating point is of the order of 2 milliamperes. We must also see that the collector always remains at least a few volts negative relative to the base to assure a proper reverse-bias condition. Let us assume that we have stabilized sources at + 20 and - 20 volts available. (These are reasonably typical values for transistorized circuits.)

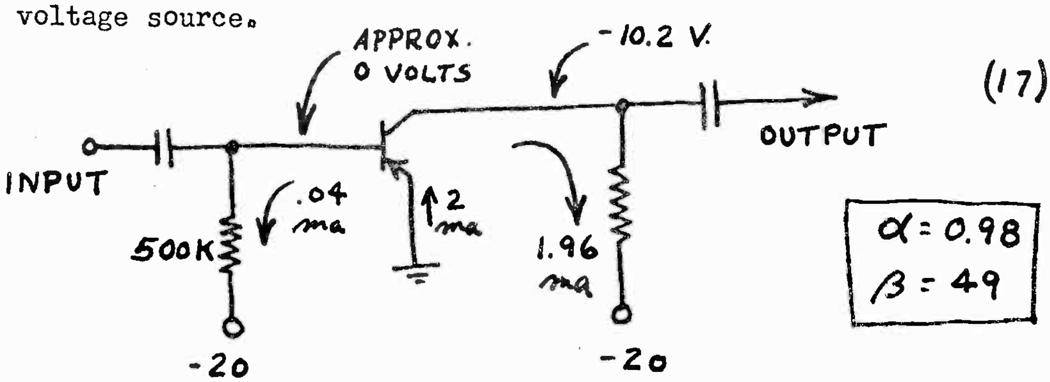
The simplest bias arrangements for common-base circuits are quite straightforward, consisting of the collector load resistor plus an emitter bias resistor.



(16)

Since the emitter input resistance of only 40 ohms is negligible in series with the 10K bias resistor, the emitter bias current is determined by dividing the bias supply voltage (20) by the resistance (10K), giving 2 ma. If the transistor has a d-c alpha of 0.98, the collector current is 1.96 ma, and the collector voltage is equal to the supply voltage (-20) less the drop across the load resistor (9.8 volts), giving -10.2 volts. The actual value of the load resistor is normally determined more by considerations of gain or bandwidth than by bias considerations.

Unfortunately, the simplest type of bias arrangement for the common-emitter configuration is a very poor one for practical amplifier circuits, but it is worth reviewing as an illustration of several aspects of transistor behavior. This simple, though impractical, bias arrangement requires only two resistors and a single voltage source.

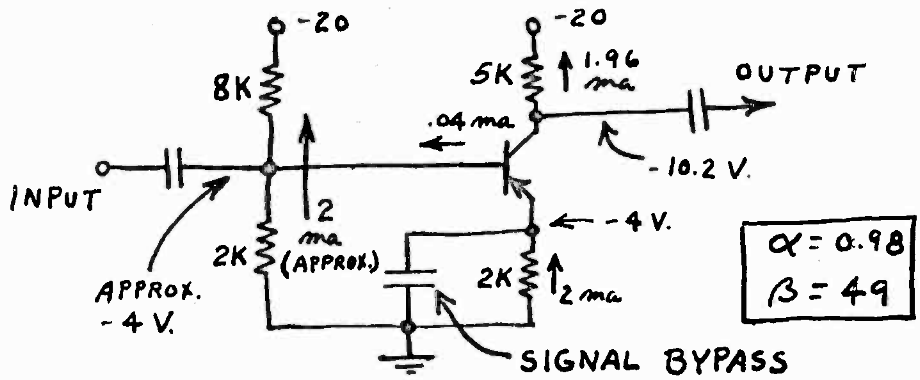


(17)

Since the 2,000-ohm input resistance looking into the base of the transistor is negligible in series with the 500K bias resistor, the nominal bias current is determined by dividing the supply voltage (-20V.) by the bias resistance (500K), giving .04 ma in the direction indicated. The collector current is beta times as great, or 1.96 ma, and the collector voltage is determined by subtracting the drop across the load resistor from the supply voltage.

The two major deficiencies of this simple, but impractical bias arrangement are: (1) it is unduly sensitive to variations in the beta of the transistor, and (2) its operating point tends to vary excessively with temperature. When the alpha of a transistor falls from 0.98 to 0.97 (causing only a slight variation in the performance characteristics of a common-base circuit), the beta falls from 98/2 = 49 to 97/3 = 32.3, a change of almost 35%! This change would seriously affect both the d-c operating point and the a-c gain of the simple common-emitter circuit shown above. The temperature sensitivity of the circuit results from the fact that substantially all of the reverse-bias current (i.e., the current that flows through the collector diode even when the emitter is open) must pass through the emitter-to-base junction, where it becomes subject to the current-amplifying action of the transistor. This current varies exponentially with temperature, and may become large enough to cause a significant shift in the d-c operating point.

The usual approach to the stabilization of a common-emitter circuit to avoid these problems involves (1) lowering the external impedance of the base circuit and (2) raising the external impedance (at least for d-c) in the emitter circuit. It is interesting to note that these actions make the circuit behave more nearly like the common-base circuit described earlier, which is a very stable circuit. A practical arrangement is shown below:

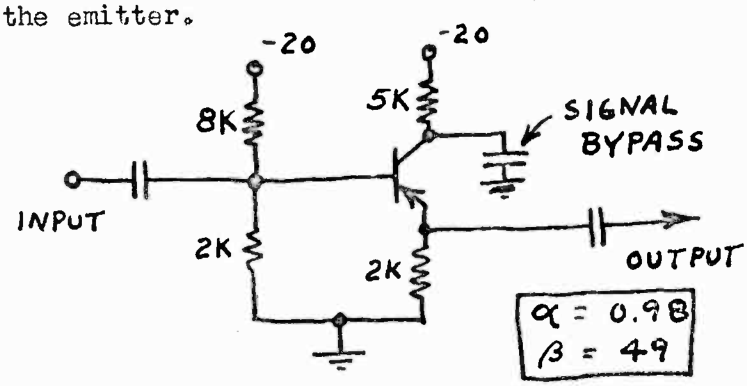


(18)

Because of the 2,000-ohm emitter resistance, the d-c resistance looking into the base of the transistor is 102,000 ohms, just as in the case of Figure (15). This high resistance is negligible when shunted across 2,000 ohms, so the current in the voltage divider in the base circuit is nominally equivalent to the supply voltage (-20) divided by the total resistance (10K), or 2 ma. The voltage on the base is therefore approximately -4 volts. Because the voltage drop across the forward-biased emitter-to-base junction is negligible, the voltage at the emitter must also be about -4 volts, implying that 2 milliamperes must be flowing through the 2K emitter resistor. If the alpha and beta of the transistor are 0.98 and 49, respectively, the collector and base currents must be 1.96 and .04 milliamperes, respectively. The collector voltage is determined by subtracting the drop across the load resistor from the supply voltage. For a rigorous analysis, the small, .04-milliampere base current should be taken into account in the determination of the actual voltage on the base, but since it is only 2% of the nominal current in the bias network, it may safely be ignored for a practical, approximate analysis.

This practical version of a common-emitter circuit provides less current gain than its simpler counterpart, and also has a lower input impedance because of the shunting effect of the bias network in the base circuit. These handicaps are outweighed, however, by the greatly reduced temperature sensitivity and decreased dependence on beta. Reasonable current gains can still be achieved (as will be shown later) provided the emitter resistor is bypassed to avoid the inverse feedback that would otherwise result.

A practical version of a common-collector circuit (or emitter follower) can be obtained by using exactly the same circuit constants shown in Figure 18, except that the bypass capacitor should be moved to the collector circuit, and the output taken from the emitter.



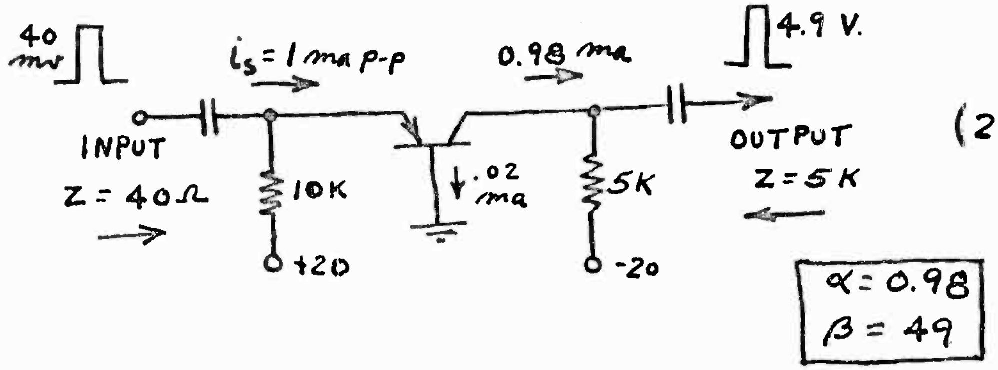
(19)

If the same transistor type is used, the d-c operating conditions are exactly the same as in the preceding example, and the analysis need not be repeated. The only function of the bypassed resistor in the collector circuit is to reduce the collector dissipation by decreasing the effective supply voltage. In many practical circuits, the collector resistance and its associated bypass capacitor would not be needed. Because a reasonable degree of stabilization is provided by the load resistor in the emitter circuit, the impedance of the bias network in the base circuit could safely be increased in many practical applications where a higher input impedance is required, but this action would tend to make the circuit increasingly sensitive to temperature.

Low-Frequency Performance of Typical Practical Circuits

In considering the performance of a practical transistor circuit for low-frequency a-c signals, it is necessary to take into account the source impedance of the preceding stage, because the input impedances of transistor circuits are generally so low that their loading effects on the preceding stages cannot be ignored (as in the case of tubes). Keeping this factor in mind, let us examine the low-frequency performance characteristics of the practical circuits previously described.

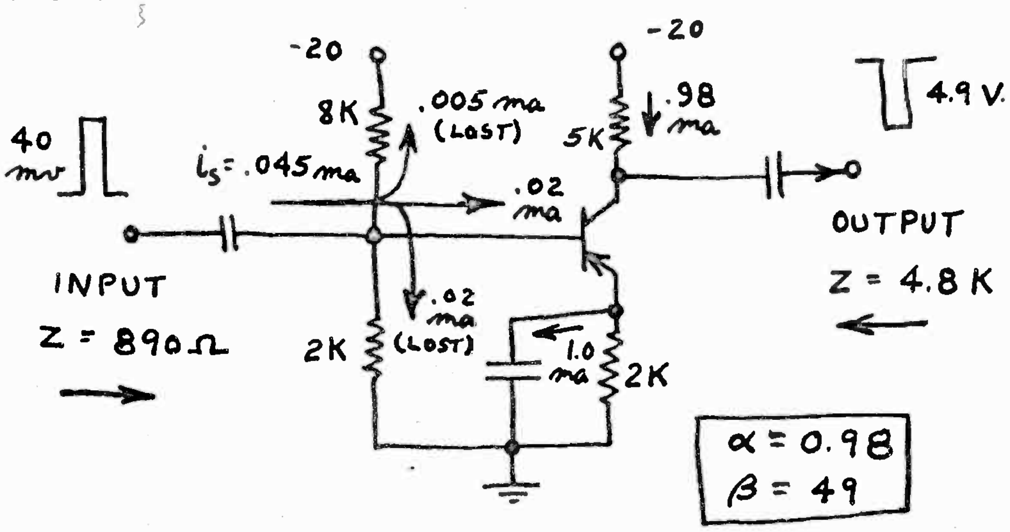
The current gain of a common-base amplifier is always less than unity, because some of the input signal current is always lost in the base, but the voltage gain may be quite appreciable if the load resistance is much larger than the input resistance of the circuit.



(20)

This figure illustrates the basic performance characteristics of common-base amplifiers, which may be summarized as follows: (1) low input impedance, nominally equal to the input impedance of the transistor alone, (2) relatively high output impedance, nominally equal to the load resistance, (3) no polarity inversion, (4) current gain only slightly less than unity, and (5) the possibility of considerable voltage gain, approximately equal to the ratio of the output impedance to the input impedance. It is interesting to note, however, that it does no good to cascade two or more common-base amplifiers if voltage gain is the objective - the voltage gain in each stage is effectively cancelled by the loading effect of the following stage, unless an impedance-matching transformer is used.

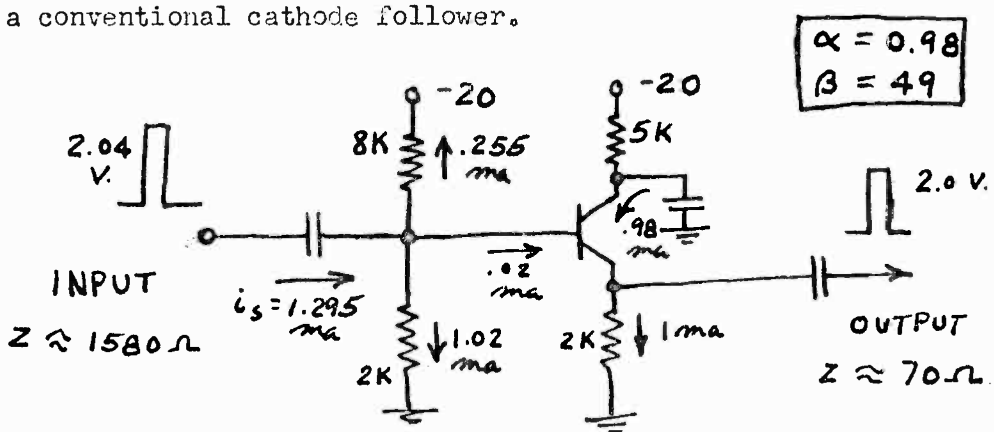
The performance characteristics of a practical common-emitter circuit are illustrated below:



In summary form, the key features of this circuit are: (1) a current gain of about 22, which is less than the beta of the transistor primarily because of the loading effect of the base bias network, (2) a voltage gain of about 122, assuming that the output is not loaded down appreciably by the following stage, (3) a reversal in the polarity of the signal, (4) an input impedance appreciably higher than that of a common-base amplifier, but considerably lower than the 2,000 ohm input impedance of the transistor alone because of the loading effect of the base bias network, (5) an output impedance that is slightly less than value of the load resistor because of the shunting effect of the output impedance of the transistor itself. The shunting impedance is somewhat higher than the 40,000 ohms indicated in Figure 14, because not all of the reverse-bias current that is involved in the determination of the transistor's output impedance is drawn through the emitter-to-base junction in this practical circuit - some of it is drawn directly from the base bias network. The output impedance of the transistor alone turns out to be of the order of 200,000 ohms in this case, which is intermediate between the 2 megohms expected of a common-base circuit and the 40 kilohms expected of a common-emitter circuit with very high impedance in the base lead. It should be noted that the analysis performed here is only approximate, based on several simplifying assumptions, but the characteristics indicated should hold within about 5%.

The common-emitter configuration finds wide applications where either current gain or voltage gain is required. In general, it provides more gain than the common-base configuration, but its frequency response for a given transistor type is more severely limited.

As shown in the following figure, the common-collector circuit behaves very much like a conventional cathode follower.



(22)

The important characteristics of this circuit are: (1) a voltage gain only slightly less than unity, (2) a current gain slightly less than unity (This is not necessarily typical of emitter followers, but results from the use of relatively low bias resistors. Note that the current gain of the transistor itself is $\beta + 1$, a value which could be approached in the complete circuit by the use of very high bias resistors, at some sacrifice in temperature stability.), (3) no polarity inversion, (4) a moderately high input impedance, and (5) a relatively low output impedance, consisting of the output impedance of the transistor shunted by the load resistor. The impedance characteristics of this circuit could be changed substantially by altering the bias network. For example, if the two resistors in the base circuit were increased 10 times to 80K and 20K, the input impedance would become about 13,800 ohms, the output impedance would go up to about 305 ohms, and the current gain would go up appreciably.

Handling Hints and Precautions

We hope that we have succeeded thus far in introducing the transistor as a potential friend and ally of the broadcaster. As in the case of any good friend, the transistor has a right to be treated with a reasonable degree of consideration and respect. The rules of etiquette when dealing with transistors are really quite simple, and should not interfere with the smooth working of the broadcaster-transistor team.

The most important rule to remember is that the transistor is a tiny little fellow with little capacity to absorb heat - he does his best work when kept cool, and commits suicide in protest when his junction temperature is raised above a safe limit. He appreciates the delicate touch of a pencil-type soldering iron, applied only sparingly to his leads - a big 200-watt bruiser can make him very unhappy, even if it is only held near his case. It's a good idea to use a transformer-type soldering iron, because many 110-volt types pass enough leakage current through their tips to damage a small transistor.

There are many potential hazards in the servicing of electronic equipment that can cause a transistor to fail, usually from a momentary thermal over-stress. In the case of equipment employing socket-mounted transistors, it is important to remember that, unlike tubes, transistors can easily be inserted in their sockets the wrong way, possibly resulting in the application of excessive voltages. A few minutes spent in gaining familiarity with transistor basing arrangements and socket connections will pay big dividends in avoiding frustrating accidents. It is wise to adopt the general rule that power should always be removed before inserting or removing a transistor from its socket; a brand-new transistor may lay down its life in vain if it is expected to absorb a charging surge for a capacitor, or if its bias is suddenly altered by the removal of a circuit-mate in an adjacent socket. If the broadcaster finds it absolutely necessary to poke around in a "hot" transistor circuit, he would do well to use well-insulated test prods and miniature test leads. As noted earlier, a transistor gives no visible or audible warning when it has become the victim of an accidental short circuit - it just doesn't feel like working any more.

One of the attractive features of transistors is the ease with which they may be tested, at least superficially, with an ordinary ohmmeter. It is important, however, that only the R x 10 or higher scale be used - the R x 1 scale on most ohmmeters can deliver enough power through the test leads to destroy a small transistor. Resistance measurements between emitter-base and collector-base pairs should both show a very low resistance in one direction and a relatively high resistance in the other; that is, the test should indicate that there is an active diode between either of these pairs. The direction of easy current flow (low resistance) depends upon whether the transistor is of the PNP or NPN type. Resistance measurements between the emitter and collector leads should always indicate a high resistance in both directions. If a transistor passes all of these ohmmeter tests, chances are very good that it is an operable unit.

The authors hope that those broadcasters who have first become acquainted with transistors through this paper will enjoy a long and happy association with them. Further information can be obtained from "An Introduction to Junction Transistors" by R. N. Hurst, appearing in the October, 1958 issue of Broadcast News. We wish to acknowledge the generous and constructive assistance of Mr. Arch C. Luther, Jr. in the preparation of this material.

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Broadcast Engineering Conference
National Association of Broadcasters
Chicago, Illinois

March 17, 1959

PROGRESS REPORT ON VIDEOTAPE STANDARDS

Robert M. Morris
American Broadcasting Company

A year ago at the Society of Motion Picture & Television Engineers Convention in Los Angeles the Society initiated action to formulate standards for the rapidly developing magnetic videotape recording art. A Committee was formed known as THE VIDEOTAPE RECORDING COMMITTEE with Howard Chinn of CBS the Chairman. Members of the committee include representatives of the two present manufacturers of videotape recording equipment, Ampex and RCA; the three major networks; the principal manufacturer of videotape, Minnesota Mining & Manufacturing Company; Westinghouse Broadcasting; a liaison representative of the SMPTE Television Committee; and, representative of all interested broadcasters, A. Prose Walker of NAB.

The committee has met regularly since its initial meeting in June of last year. Efforts have been made to expedite agreement on those standards and practices necessary to facilitate the full interchangeability of tapes between different points of recording and playback. Specific subjects for standardization have been assigned to members of the Committee who function either individually or as Chairmen of subcommittees.

The committee has completed a proposed standard for tape dimensions which is now being processed by the Standards Committee of SMPTE. The proposal specifies a two-inch maximum width tape with a lower tolerance 0.004-inches less. The tape thickness is specified as a maximum of 0.0015-inches, with no minimum specification. This provides for the future development of thinner tapes which in other respects meet the necessary requirements, while providing for a satisfactory tape at the present state of the art.

A proposal for standard videotape reels has been prepared which is under consideration by the committee. This proposal in its present form provides for four standard size reels as follows:

a 6" reel for 6-1/2 minutes of tape;
an 8" reel for 22 minutes of tape;
a 12-1/2" reel for 74 minutes of tape;
a 14" reel for 96 minutes of tape.

The 10-1/2" reel, which has had limited use, is not included in this proposal.

There has been much discussion in the committee relative to track standards. It is in this important factor that there has been a major difference between the preproduction units of the two equipment manufacturers. Both manufacturers, it is understood, have agreed that units produced hereafter will be compatible with respect to track standards. Tapes recorded on equipment of one manufacturer will therefore be reproducible on other equipment. It appears likely that track standards, with respect to spacing, size and position, will soon be agreed upon. It is desired by several members of the committee that there be a second audio track which would be placed adjacent to the control track. This second aural track, which would be only slightly narrower than the Number 1 track, could be used for cue purposes or as a second channel for stereo reproduction or for other aural requirements which may develop in future use of videotape.

Desire was expressed in the committee for visual footage marks on tape to aid in identifying and rapidly locating recorded material in a reel of tape. Study of this problem has indicated that a satisfactory solution appears difficult. No method is available which will provide reliable sensing with photoelectric devices and not cause interference with the recording. It appears likely that some magnetic marking and coding system may ultimately be the best means of high speed location of desired material in a reel of tape.

At the present time recording characteristics, with respect to frequency deviation, and pre-emphasis in the modulator section of the recorder, differ for black-and-white and color recording. The amount of deviation or modulation of the carrier applied to heads differs between organizations and even sometimes between units within one organization. This, of course, makes for non-uniformity in reproduction with respect to level, signal-to-noise ratio and probably video frequency characteristic. An effort is being made by the committee to establish standards of deviation and frequency characteristic in the recording process.

A method of measurement recommended and used by several members of the committee for determining the deviation of a recorded carrier on a tape may be of interest in this connection.

If the output of an adjustable oscillator covering the frequency range of approximately 4 to 8 mc is applied to the demodulator simultaneously with the feed from the preamplifier while reproducing a recorded tape, it will be found that a "beat" will be observed on the signal in the wave form monitor. This beat will be seen as a fluctuation in amplitude which will occur at various levels of the video signal as the frequency of the oscillator is varied.

This beat is, of course, an indication of the carrier frequency corresponding to that particular level of modulation. For example, a "beat" may be seen to occur at the tip of sync with a frequency of 4.8 mc, at the blanking level with a frequency of 5.2 mc and at the "white" level with a frequency of 6.2 mc. Another recording may have different frequency values for these levels. Measurement is facilitated if a stair-step or window signal is used as the recorded signal.

Data is being collected using this method to determine the amount of variation in deviation standards at different points and to aid in the recommendation of an acceptable standard.

A proposed recommended practice has been prepared and is now being processed for "Patch Splices on Magnetic Video Recording Tape". This proposed practice specifies the position of splice with respect to the "Field" or "Edit" pulses and the angle of splice with respect to the guided edge. This practice, it is believed, will unify and improve techniques in the splicing of tapes and improve performance in the use of such tapes.

A proposed standard has also been prepared and is being processed for "Specifications for Videotape Leader". This provides for a standard tape leader with tone beats at one-second intervals and visually recorded identification and numbers similar in manner and purpose to those incorporated in the "Academy" leader for motion picture film. It is intended that both manual and automatic methods of cueing for start be facilitated by a standard leader.

Consideration is also being given to the specification of a standard test tape, and to standards for the audio track characteristics of videotape.

It is believed that the SMPTE Videotape Committee has made a good start during the past year on providing a better understanding of and in some cases a solution to problems of interchangeability in video recording. The Chairman and the Committee are making every effort to expedite the work while at the same time endeavoring to avoid the formulation of standards that would inhibit future development.

"Advantages and Limitations of Video-Tape in Programming"

Opening Remarks by

Bill Michaels
Vice President & Managing Director
WJBK-TV, Detroit, Mich.

I realize that it is generally regarded as bad psychology and bad speaking m to begin with an apology, but if you will bear with me for a moment, I'm going take that liberty, for a couple of reasons. First of all, it is my understanding that purpose of these various meetings is to exchange information of potential value one another in a manner as close to "person to person" as practical, rather than ng formally lectured by people who probably know less about your business than ı do. It was only in the interest of conserving your time and keeping us panel mbers from wandering on indefinitely that we were asked to prepare these remarks written speech form for delivery, rather than informal conversation, which most ıs prefer. And secondly, I think we can get away with classifying these preliminary narks as "explanations and qualifications" rather than apologies. And in that case conscience doesn't bother me a bit, for I have spent a good part of my managerial listening to "qualifications" and "explanations" from chief engineers when I ıght all I was asking for was a few "simple facts". (Or does that sound familiar ou fellows?)

Well, anyway, what I am trying to get at is this: Any of us may strive e objective on a given subject, but the truth is that our so-called objective con- ions are necessarily based only on the facts and experiences with which we have sonally come in contact or of which we have been apprised. And there are rtainly a lot of facts and potentialities concerning video tape available from her stations with which we haven't been brought in contact, of just as much lue as the observations and conclusions which I will endeavor to bring to ur attention. Mine of necessity are going to be essentially based on the stallation and operation at one television station in one city. So to that extent ese remarks may be considerably removed from the objective category and into e realm of being subjective. And while we have tried to keep them unbiased, ey are not presented as being indisputable or axiomatic, but merely conclusions which one station has come in its few brief months of usage.

I can remember it as though it were yesterday three years ago re in Chicago when CBS scheduled a television affiliates meeting as it did s year immediately preceding the NAB convention, and Bill Lodge just about oke up the meeting with his surprise demonstration of video tape to the iliates attending what most of us felt was going to be a routine, possibly dull, gineering session. Most of us were much more anxious to get back to what considered the most pressing business at hand -- talk of a potential recession t kept cropping up stubbornly, and fall program plans to stave off NBC and ABC. ll, the first thing we knew, after a brief introduction from Bill, we were looking pictures of ourselves on the monitors not only taken just seconds before, but of uality that was hard to realize was actually electronically duplicated and not ve". It took a few seconds before we realized the significance of what we had n, and then, for all the world like a football crowd cheering Doak Walker or by Layne trotting off the field after the winning touchdown, the entire audience e to its feet and applauded spontaneously.

Now, probably most of you were introduced to video tape recording der less dramatic circumstances, but to engineers and non-engineers alike, ur first look must have been impressive. And video tape continues to be one the most dramatic and potentially useful and profitable pieces of equipment the industry. But therein lies a potential pitfall for all of us whether we be ıtion operators, program people, or engineers, and because of that, I make : following statement based on conclusions from several months of use:

There is simply no question the value of video tape as a wonderful ɔl for television broadcasters, with many known uses and many other still ɟeveloped uses which will come to light as they always do as the industry ɔgresses. But station operators should not make the mistake of erroneously nping to the conclusion that video tape is the answer to all problems of ɔgramming, manpower, engineering and operating expense simultaneously d up into a neat little package. For it is not, and is not claimed to be. Our ff's experience at WJBK-TV in Detroit has shown that its principal assets : in enabling the station to accomplish these things:

1. To do a number of things on the air which are impractical or even impossible to produce live.

2. Produce both commercials and certain programs better by editing or re-doing at once.

3. To better allocate work loads and alleviate the pressures and hazards of peak production periods, frequently cutting down on overtime.

4. To better demonstrate and present to potential advertisers

all types of availabilities and presentations, thus creating new business. (Such new business, as we all know is frequently, though justifiably, accompanied by additional work load, rather than less, offsetting the payroll saving in (3.)

Now these four categories of use are probably far from complete, t I do respectfully submit that even if they did comprise all of the potential es of video tape it is an imposing enough list without fallaciously classifying as the panacea for all of our daily operating aches and pains. And to substantiate statements, again we have to revert back to the first person and talk about first-nd examples at our own station.

Case 1. A local gasoline advertiser had been interested for many eks in doing an institutional type commercial, or series of commercials from new refinery. Live commercials were physically and financially impractical. ind-on-film was not judged desirable by the account for various reasons. With eo tape we were finally able to get the commercials produced for the advertiser, thus do them better and cheaper than live.

Case 2. The same advertiser had been using out of town talent for imercials on its sports broadcast commercials, resulting in travel expense, onvenience, and fresh risk every time a new commercial went on, as well as ing a crowded studio problem for us on many occasions due to other studio imitments. Use of video tape solved several problems simultaneously. ther, it freed up the out of town talent for other performances and resulted nore potential income for him.

Case 3. Furniture accounts have repeatedly found television effective th demonstration type commercials. These are fine for use on completely onsored shows, but it is physically impractical and financially impractical to use d strike furniture sets for 60-second "wild" spots. With video tape we were le for the first time to effectively produce and use such spots, and thereby oduce a considerable amount of additional revenue.

Case 4. A national advertiser with budget definitely allocated for e market, was still flexible in regard to the type of programming to be purchased, d desired a variety of availabilities. It was not practical for him to visit our y and spend a day or two auditioning talent and shows, so we took the "mountain Mohammed". A cross-section panorama type audition was prepared on tape and nt to the client for audition (both Chicago and New York). Result: A sale.

Case 5. Free-lance talent turned up with a dual commitment for the me evening, in which case at least one client was due to be pretty bitter about s whole business of television versus a nice simple newspaper ad. Solution: taped, talent made other commitment.

Case 6. Sunday daytime during football season is a pandemonium of ivity in our studios, though normally they are quite adequate. Due to league strictions we are not permitted to carry Detroit Lions home games, but neverthe- s we are committed to: A) Handle the remote with full crew at Briggs Stadium; originalte live studio commercials for feeding upstate for two different clients the games; C) Continue our own on-the-air activities over and above the football nmitments in one large and one small studio (and one staff!). Pre-recording some of our on-the-air studio activity smoothed out the peaks considerably.

Case 7. A news personality whom we considered outstanding was
ıysically unavailable during the time segments we desired to use him on an
ıalysis program, due to previous commitments at a local university. Rather
an abandon the program, we were able to tape record his commentary earlier
the day and protect the programming.

Case 8. Many times well known individuals very worthy of on-
e-air exposure are in and out of Detroit and can spare a few minutes at their
nvenience, but not ours. The logical solution: Tape record them when they
e available, play back when we are.

These instances are not presented as examples of extraordinary
nius on the part of our station, for by now similar examples are being
peatedly utilized around the country almost to the point of being commonplace,
ther than exceptional. We have dozens more in our files, there are hundreds
ɔre available from other sources. They were chosen particularly to illustrate
: four general advantages of the equipment which we have found and itemized
eviously. They were also chosen because they are fairly typical examples of
: type of use to which we regularly put the equipment, and which also lend
mselves as typical illustrations of the "limitations" in the subject title on which
as asked to expound.

The limitation which I feel is important to stress along with its
'antages is this: Our video tape machine is already enabling us to do many
v things; as portability comes closer and closer to regular application, more
/ potentials in the area of outside news coverage also come closer and closer;
it is enabling us to do many of the old things better. These are the major
antages. On the other hand it is <u>not</u> primarily a vehicle for doing the same

l things with less people and for less money. As a matter of fact, our engineering yroll has gone up due to the use of our video tape. But it has gone up due to e in constructive, income producing directions. Further, due to the other oduction efficiencies and new areas of exploration the machine produces for the vertisers, there is seldom reluctance to pay reasonable recording fees to help capture engineering costs and depreciation expense on the machine.

What is important to remember is a basic fact that all of us know: ien you put a three-camera show on tape, you're still using a three-camera ew some place . . . PLUS a video tape recorder and an engineer recording. fore you are saving money by production, it must be saving you overtime me place else due to the convenience of re-scheduling. More often, you are to find you are doing a job you would otherwise not be doing at all, with its companying income, and its accompanying additional expense. But it's the ne sort of expense you add when you buy a film show and re-sell it at time s film to an advertiser. It's the type of expense we enjoy adding, if there is h a thing.

Actually, a good deal of thoughtless conversation and publication our own trade which fail to recognize these basics have inadvertently caused as operators and chief engineers a good deal of labor difficulty which is not stantiated by the actual conditions. These quite premature (in my opinion east) predictions of imminently cut staffs, tape automation, etc., have painted some pictures in the minds of some of our own employees and union officials are causing us many hours at the bargaining table that we could be spending h better in other directions than alleviating or attempting to bargain away s rather than discussing facts.

Among other facts you may find of interest among our local experiences is that we have found that while one tape machine is certainly better than none, operation of a single machine poses numerous limitations and we will have a second in operation very soon. Again, some of these limitations are obvious, others not so easily apparent. With one machine, we obviously could not record and play back simultaneously, and as usage increases, such needs crop up more frequently. Maintenance, even minor, was frequently a problem if the machine was needed in service. Recording or playback of programs in excess of one hour was not practical, etc. But probably the most serious problem we ran into in Detroit was this: Advertiser A enthusiastically produced five or six one-minute spots taking two days to perfect, and into which he poured literally thousands of dollars worth of talent and production. When he finished, what we had was five or six original cuts, period. No duplicates. No file copies. No way to make them, except to send our tape to New York or Chicago for duplication. The dangers of damage or wear from continued usage were obvious. With the second machine, duplicates can be made either simultaneously with the original, or dubbed immediately.

In closing, there is one other major programming asset and there is one other limitation on which I would like to touch briefly. The asset is a subject for more detailed discussion on the panel by Ed Benham, but it should be given recognition here, for it is important. Specifically, there is an already growing source of program material available from syndicators and other stations which will be available only on tape, at least in the indefinite future, and without a video tape machine, the program source itself is not available to the station. And that is certainly a factor which concerns all of us as program people and station operators.

The limitation which still greatly restricts one of the major tential uses of the machine in programming is the fundamental legal restrictions der which stations still operate in the matter of video tape delays of network ograms as contrasted with the policies under which we became used to operating r audio tape delays. This is neither the time nor the place to argue the merits the situation, for I am sure that there are many problems from the network's andpoint, and there are certain circumstances under which stations today can cord and play back network programs through a formal clearance procedure der exacting conditions. So it may well be that this will work its way out over period of time. But for the time being at least, this certainly must be considered the area of "limitations" insofar as programming by video tape is concerned.

Thank you very much.

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Comments on SMPTE Proposed Video Tape Standards

By

J. L. "Lee" Berryhill
KRON-TV, San Francisco

NAB Technical Session
March 18, 1959

When I was asked to comment on how the proposed SMPTE Video Tape Standards would affect the operations of an independent station, my first thoughts were how these Standards would improve our present operation. More than 85 percent of the 300 hours of video tape presently aired on KRON-TV per year is produced on one of our two machines. No serious problem exists in maintaining compatibility between these machines. The only non-compatibility problems, not within our control, would exist on machines located elsewhere producing the remaining 15 percent of our video tape programming. Since this 15 percent of programming requires the re-alignment of our machine only two or three times each week, we would, with adequate standards, eliminate the need for occasionally re-aligning one of our machines to make it compatible for tape produced by others.

Iowever, the importance of adequate Standards becomes imperative to me in the independent station if I look to the future. There are in excess of 150 tape recorders in use by the television industry now. Each of these machines is potentially a supplier of tape programming for playback on the KRON-TV machines. The syndicator and the commercial spot producer are showing increasing interest in the use of tape as a means of distributing their program material. Within two years I can expect KRON-TV to be playing tape at the rate of 1000 hours per year, much of this in short segments, some of it spliced head to tail, many occurring consecutively.

Now if my video tape machines are to be truly operational, each must be capable of being loaded and adjusted with no more effort than the familiar film chain and its associated projectors and must be capable of playing back all tape, from whatever source with a minimum of readjustment.

look forward to a typical day's operation beginning with a thorough alignment of each machine using a standard tape to properly adjust the tip projection, the female guide block assembly, video and audio levels, resolution, control track level and position and gray scale. Only minor adjustments should be necessary throughout the remainder of the day. The machine operator would have only to load tape on the machine, briefly check the alignment signal portion of the VTR Standard Test Leader and run the tape through to the starting cue prior to the playing of each tape.

feel that adequate Standards will materially help attain this operational goal that I have outlined above. However, I would like to comment on several specific points: The Standards for the control track characteristics as proposed, describe several interlocking events which must occur and be recorded with precision in order to attain the accuracy necessary to compatibility between machines.

he control track in video tape recorders of current manufacture have the control track recording head spaced .7825 inches to the right of the rotating video head. At any given moment the control track is spaced ahead of the video track by slightly more than three television fields. Current practice is to superimpose an edit pulse on the control track coincident with the vertical interval to serve as a guide for splicing. The edit pulse is so positioned that t ape can be cut and spliced between the head tracks containing the vertical sync interval. Making splices under these conditions has been reasonably successful.

understand that there have been proposals advanced to the SMPTE Standards Committee hat would modify the placement of the edit pulse so that it would appear on the tape coinci- lent with the last head track containing the vertical interval information. Splicing would, herefore, be made between the last head track having vertical information and the first head rack having no vertical information beginning a television field. This would be at the top of he picture.

think the SMPTE Standards Committee should consider adopting this control track Standard o that any discontinuities caused by splicing will occur following the vertical interval. Any plice discontinuity that may occur should only affect the field within which it occurs, 1/30th f a second, and not affect the vertical sync system of the receiver. This change can be made y lengthening or shortening the lead time of the control track. Lengthening the lead time can asily be done on existing machines. Shortening the lead time may require some mechanical hange in the control track record head mounting but would give the additional advantage of ninimizing the effects of tape stretch.

'igure 1 is a pictorial time versus amplitude presentation of both the visual and audio portions f the proposed SMPTE Video Tape Leader. Time is represented by the horizontal ordinate, nd amplitude by the vertical ordinate. The top display is video and the lower audio. It was roposed that an alignment signal consisting of test patterns or multiburst, accompanied by an udio tone between 400 cps to 1000 cps, occupy the first five minutes. An identification slate ontaining the program title, an identification number, recording date, running time and pro- ucing studio would follow for ten seconds. No audio would accompany the identification slate. ext would be a ten second period containing the cueing signals. It was proposed that the audio onsist of a 400 cps to 1000 cps beep of 1/5th second duration, occurring at 7, 6, 5, 4, 3, and 2 econds ahead of the program including a steady state - 20 db tone starting with the first beep nd concluding with the beep occurring at time minus two seconds. A visual cueing signal such s "window" would occur concurrently with the period occupied by the audio tone. Program ync (or sync and setup) would only be recorded during the two second interval preceding the rogram.

Figure 2, I have detailed the changes that I feel the Committee should consider incorporating specifications for a video tape leader. These changes are:

(a) Require that a minimum of 32 seconds (40 feet) of tape preceed the alignment signal for machine threading.

(b) Reduce the duration of the alignment signal to a minimum of 40 seconds (50 feet). This will permit producers of spots to supply only 153 feet of tape in addition to the program material rather than 478 feet. The 40 second alignment signal can be re-played when more test time is required. Adjustments requiring more adjustment time should not be made on an alignment signal. A test tape should be used. Many tapes have been supplied KRON-TV produced on machines other than our own. We have experienced little difficulty with these tapes. Minor quadrature and female guide block positioning errors have been experienced. We feel these problems will diminish as we and the industry gain experience and better standards and standard tapes are used.

Our experience has also shown that once the final female guide block adjustments have been made, it is undesirable to stop the machine since minor variations can exist each time the guide snaps into position. Therefore, there should be no interruption between the recording of the alignment signal, slate, cue signal or program. A five minute and twenty second delay while the video tape leader is being produced could cause excessive production delays, but a one minute delay could be tolerated.

(c) Considerable variation exists in the VTR pre-role time desired by different operations. KRON-TV has standardized on a five second pre-role cue. This conforms to our film operation. I, therefore, feel that the visual cueing signal should be reduced to sync (or sync plus setup) between the 6th and 5th second and the 4th and 3rd second preceding programming. This will provide a choice of starting cues between two and seven seconds prior to the start of programming. Cue starts less than five seconds are seldom used. Because improvements may be forthcoming in future equipment, I believe it advisable to include this information now.

(d) Sync (or sync and setup) should only be transmitted during all periods not otherwise occupied by visual cueing signals within the ten second period preceding the start of programming.

(e) A minimum of ten seconds (12 1/2') of sync (or sync and setup) should conclude each separate video tape recording. This should be sufficient black to preclude any noise from getting on the air because of slow switching.

(f) A minimum of twenty seconds (25') of tape to insure tape wrap around the storage reel after the conclusion of playback shall be provided after the ten seconds of sync (or sync and setup) concluding a recording.

(g) All recording, from the beginning of the alignment signal to the conclusion of black should be continuous and from the same sync source. If improvements in the accuracy of positioning of the female guide block assembly can be expected from the equipment manufacturers in the near future, it then could be permissible to interrupt recording between the alignment signal and the slate or between the slate and the cueing signals.

Every effort should be made to set a standard for tip projection. The standard should be the minimum practical so that minimum tape wear will be realized.

Some statement that promiscuous playing of VTR program material for test purposes should be discouraged might well be included in the Standards. The test leader should get this additional wear, not the first part of each recording.

In conclusion, I should like to commend the Standards Committee on the excellent work they have done and urge that they conclude their work at the earliest possible time so that we in the industry can quickly enjoy the benefits of their work.

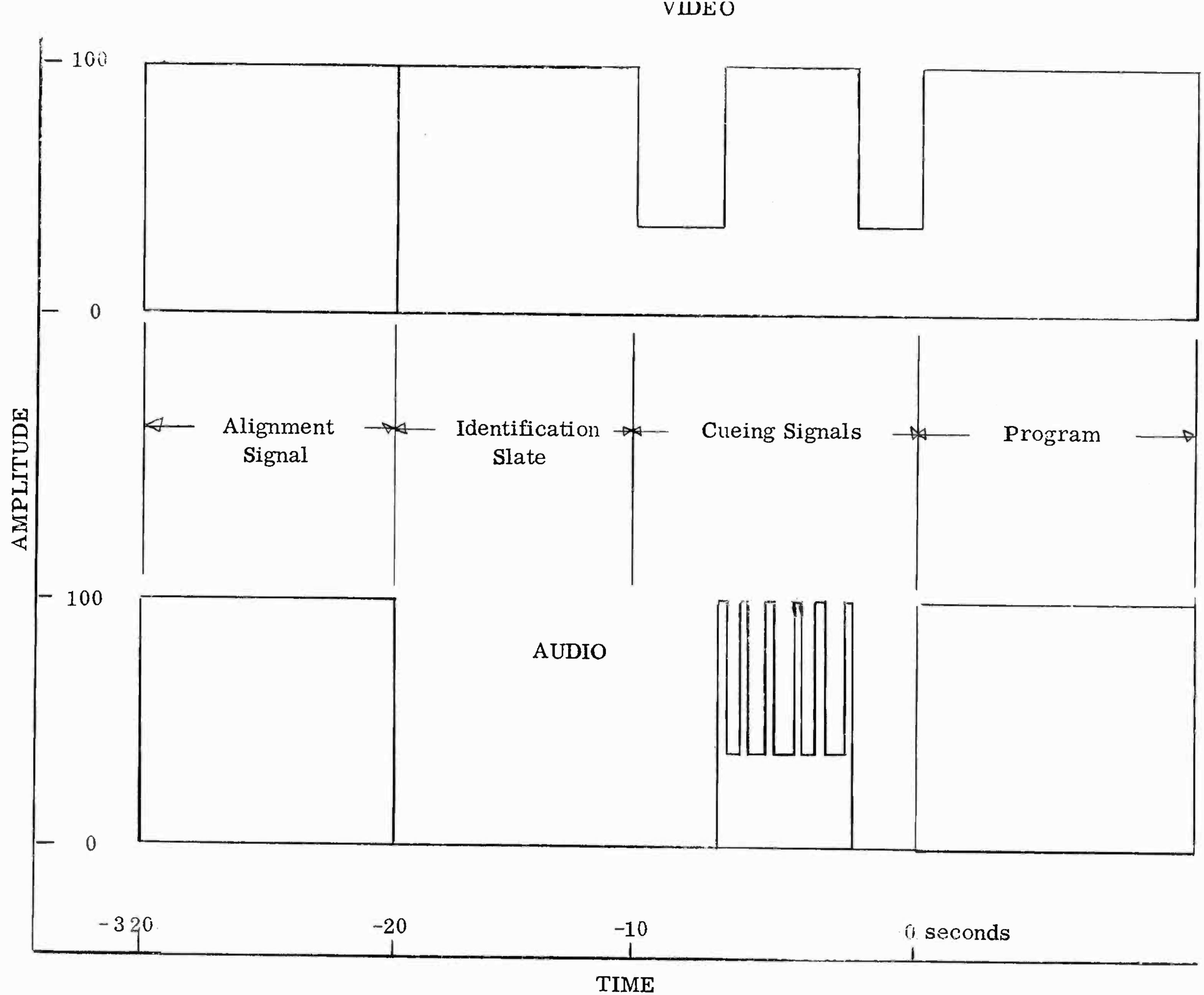

FIGURE #1

PROPOSED SMPTE STANDARD
SPECIFICATIONS FOR VIDEO TAPE LEADER

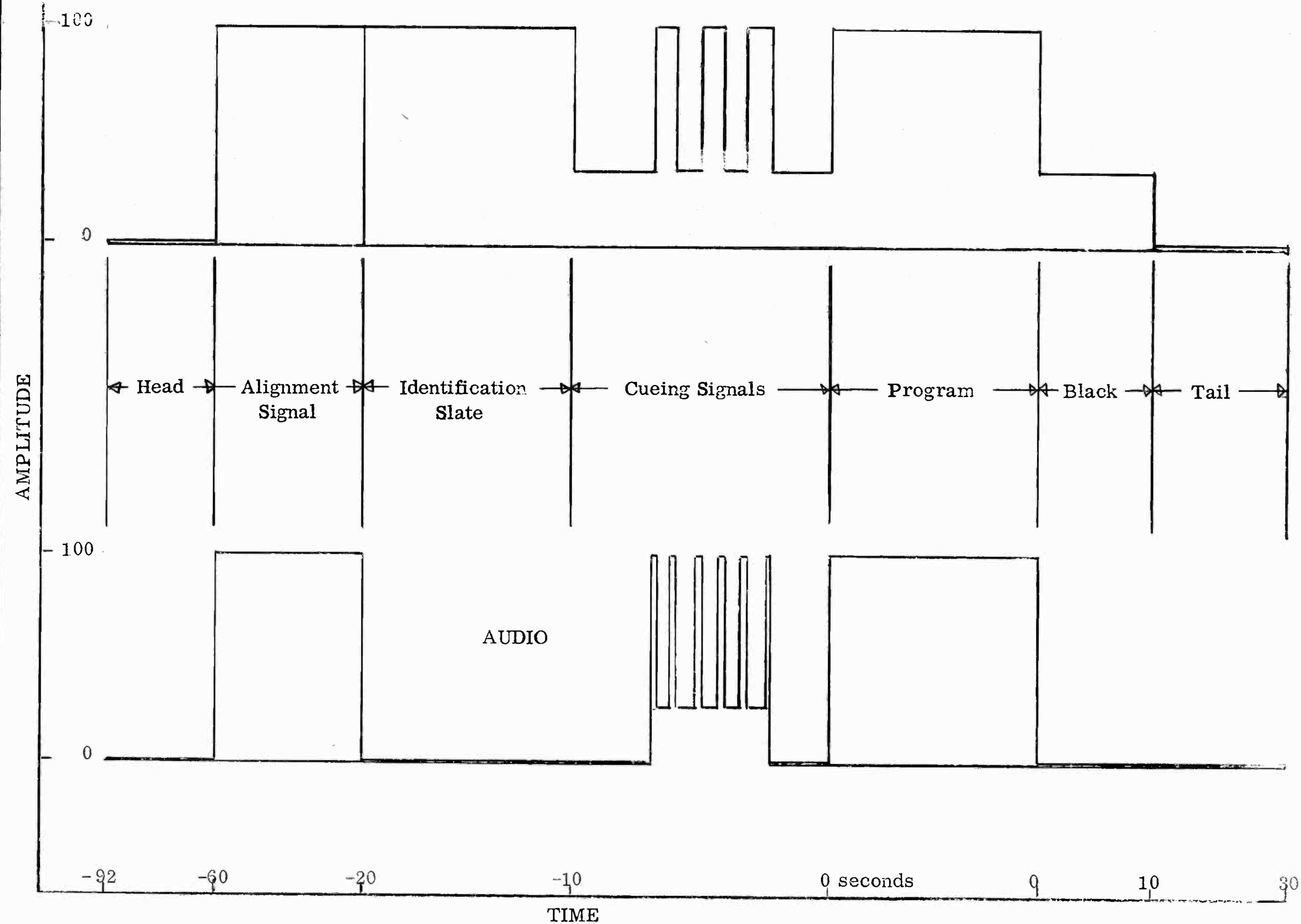

FIGURE #2

SUGGESTED MODIFICATIONS TO PROPOSED SMPTE STANDARD SPECIFICATIONS FOR VIDEO TAPE LEADER

MAINTENANCE, ADJUSTMENT AND OPERATING ECONOMICS OF VIDEO TAPE EQUIPMENT

Presented to the National Association of Broadcasters
Engineering Conference,
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March 18, 1959

Virgil D. Duncan
Chief Engineer
WRAL - Television
WRAL - AM and FM
Raleigh, North Carolina

MAINTENANCE, ADJUSTMENT AND OPERATING ECONOMICS OF VIDEO TAPE EQUIPMENT

Maintenance is that function necessary to maintain continuity of peration and involves test, cleaning, adjustment, and parts replacement.

Adjustment includes those functions necessary to proper operation of he equipment during record and playback.

Operating economics is simply, "What does it cost to support video ape equipment?"

(Slide #1, Showing the location of the video tape equipment with respect to Master Control, looking across Master Control.)

In our operation, the Ampex video tape equipment is located to the eft of Master Control, while our two film centers are located to the ight. This space was allocated for the video tape during planning and onstruction of our new studio building. An engineer operates the video ape equipment, but a remote control position located at Master Control, akes operation from that point possible.

(Slide #2, Showing close-up of Master Control position)

The remote control feature is usually used for playback only. It has een our experience that an engineer must be in full control of the video ape equipment during the recording sessions. On playback, an engineer imply loads the tape machine, checks the tape, and cues it up for playback. e Master Control Operator does the actual playback by remote control.

(Slide #3, Slide showing the cleaning equipment)

Maintenance of the video tape equipment can be boiled down to one ajor function. "Keep it Clean!"

It has been our experience that the recording head should be cleaned 'ter each tape pass. Be it recording or playback for five minutes or one ur. For this purpose we use a baby's toothbrush and petroleum ether. troleum ether is the only cleaning fluid we use.

To clean the female tape guide, we use the same toothbrush and troleum ether. The audio head, erase head and their supports are eaned by using "Q" tips or "Cotton Buds" dipped in petroleum ether.

The control track head can be cleaned by use of a tooth pick with a tton tip, dipped in petroleum ether.

For filtering the air in the vacuum system, we use milk strainers. ese seem to work very well in keeping the red oxide out of the vacuum stem.

Maintenance adjustments are standard for the power supplies, processing plifiers and the drive amplifiers for the capstan motor and the head motor.

Two units that do require considerable attention are the Master ontroller and the Head Switcher.

(Slide #4, Showing the Master Controller close-up.)

The Master Controller requires daily adjustment. The video tape ecordings will be no better than the adjustments on the Master Controller. pproximately three-fourths of our outages with the video tape equipment ave come from troubles or improper adjustment of the Master Controller.

Good ventilitation must be provided for all the video tape equipment. t must not be permitted to overheat. If this happens, as it did in our ase when the air conditioning failed, the solid state power rectifiers nd the diodes in the many different pieces of equipment will be damaged nd must be replaced.

(Slide #5, Showing special tools)

A spare parts list, tools and test signals are necessary to back up program of maintenance. Outside of the normal run of tools, resistors, ubes, condensers, etc., a few special items are necessary, such as a et of adjustable extension Allen Wrenches, Transistor type bypass ndensers, diodes and power rectifiers. We replace all 500 ma. cartridge ower rectifiers with type 750 ma. cartridge units. To date this has mproved reliability of the power supplies as prior to the change we lost everal of the 500 ma. type rectifiers.

(Slide #6, Showing the waveform at H rate of the stairstep signal taken from the scope.)

For test signal, we recommend the simple stairstep. We use ten teps of equal amplitude, composite, 1 volt peak to peak. At the present ime we do not have the color adaptor and all of our video tape programming s in black and white. Should we go to color in video tape programming, his same test signal with 3.58 megacycle superimposed on each step and ncluding burst would still provide a very good test signal.

(Slide #7, Showing tape wrinkles.)

For maintenance of the tape, keep tape in reel boxes, store vertically, l keep it clean. If there are any reels about 1 hour long, we recommend hat they be reversed, the inside to the outside. We have found that the rge reels tend to develop wrinkles near the inside where the tape is not equently used. Care should be taken to avoid wrinkling the tape as rop-outs" will develop along these wrinkles. Small plastic reels are satisfactory for continued use. The thick flanges cause misalignment of pe as it enters the tape guide.

(Slide #8, Slide of operating position showing recording set-up.)

An engineer handles the adjustment during recording sessions. One jor adjustment is the video level. The audio level does require some justment but in most cases the control of the video level is more portant. If the level is too low, banding and noise show in the playback

.cture. If the level is too high, there is considerable washout of
ie whites due to clipping. For after it has been recorded, there is
ery little you can do to make a good picture. We try to put our best
'fort in making a good recording. If we do this, the playback will
ike care of itself.

The control track must be recorded at proper level and the record-
ig currents from the four heads must be metered to ascertain the equipment
operating satisfactorily. A record must be made for each spare head of
ie recording currents. These recording currents will change some with use
id wear of the heads.

(Slide #9, Showing Daily Maintenance Sheet.)

Prior to our first recording session each day, we have a check list
iat must be "run down" on the video tape equipment. We have found that
ich a list saves many outages by helping to point out abnormal variations
fore they become "break down."

This check sheet is handled by the operating engineer. Included to
checked is a section devoted to cleaning. Instead of Ampex head cleaner,
use petroleum ether which does an excellent job of cutting the caked
:ide.

In the second part of the check list are listed the operating adjust-
nts. These are called "operating adjustments" since they are concerned
th the immediate program material and machine operation.

One thing I might point out under adjustments, is that we do not
timize recording heads each day. This is done only when it is felt
cessary by the operating engineer as would be indicated by noise and
nding.

(Slide #10, Showing Chart of cost of operation.)

Under operating economics are the things which we consider in our
st of operating video tape equipment.

To start with, it required additional engineering personnel. Also,
sent our Television Studio Supervisor to the Ampex Plant in Redwood City,
lifornia for one week training program on the video tape equipment. He
w handles major modifications on the equipment and some specialized
justments. The additional personnel and the cost of the Studio Supervisor's
ne is $212.50 per week.

I might add here that these cost figures are based on recording and
ring approximately 20 hours of program time per week. Also, this is
rough the month of November, 1958. Since that time, we have increased
e number of program hours and commercial spots on video tape.

Head cost for 20 hours program time per week is $43.80. This was
rived at and based on use of three heads for an average life of 137
urs each and a repair cost of $300.00 each. This comes to $2.19 per
ur, and this is the actual running time of the head.

In most of the video head failures, the failure was in only one ' the four tips. This was indicated by high noise and banding.

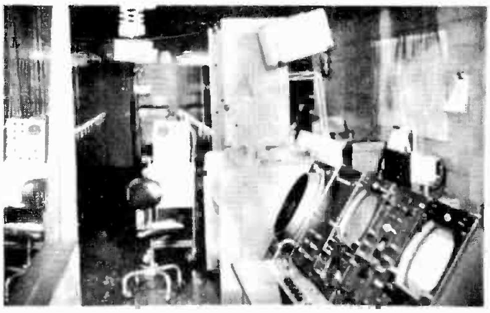
For 20 hours program per week, our tape cost is $31.20. This is ısed on the tape used for a six month period and 20 reels of tape. ıis amounts to $1.56 per pass per hour. Included in this is one reel ' tape which we lost due to mechanical failure in the machine.

Our average cost per week for tubes, rectifiers and diodes is ;9.20. This is based on 2,970 hours of operation and the total cost ır that period of time. Also, along with the tubes, rectifiers, and .odes, are the small repair parts. Our cost will average $15.00 per ek for small repair parts and about $10.00 per week for major items. has been necessary to buy two or three major components for repair ' the equipment.

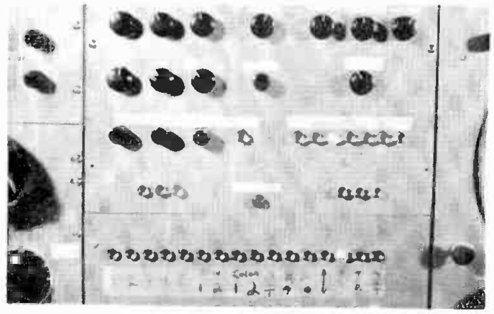
Last, but not the least amount, is depreciation. For this we .arge $200.00 per week.

Our total operating cost per week is $551.70 or an annual operating st of $28,688.40 and we believe it to be worth every penny.

I wish to express my thanks to my co-workers at WRAL-TV, Durwood use and John Buck for their major contribution to this data.



Slide 1



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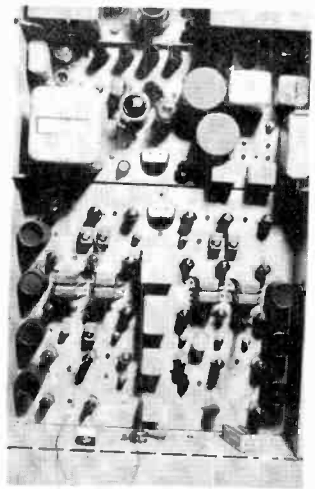
Slide 3



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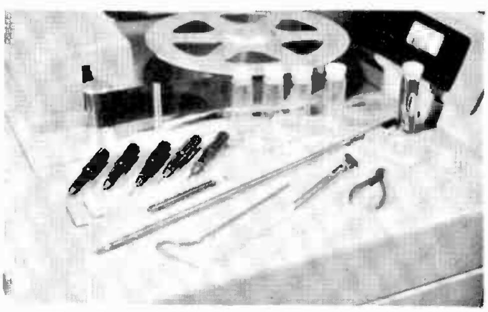

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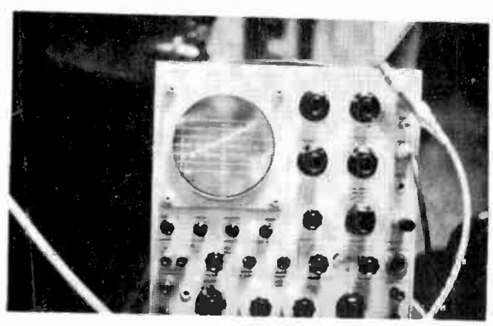
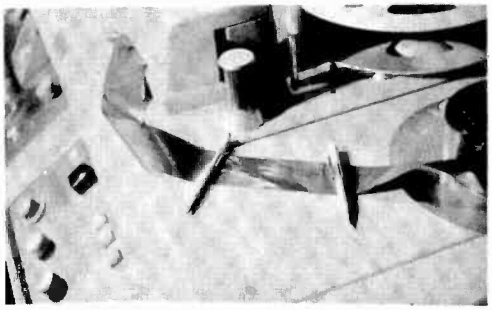
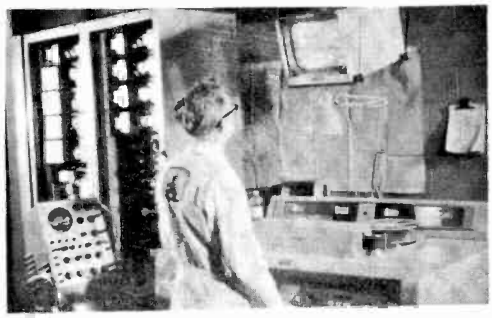


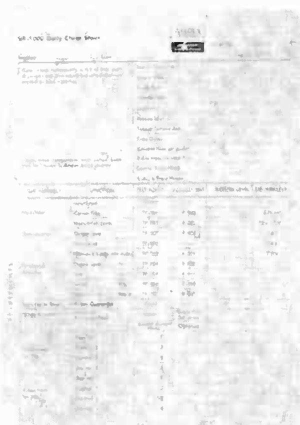
Slide 6



Slide 7



Slide 8



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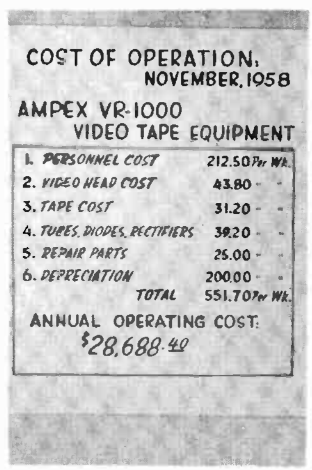

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3/5/59

VIDEO TAPE IN PROGRAM SYNDICATION

Edward E. Benham
KTTV Inc.
Los Angeles, California

Up to the present time, the syndication of video tape has been more theory than practice. As yet there are not too many programs actually in syndication. Most of KTTV's syndication experience has been gained in the distribution of a one-hour program entitled DIVORCE COURT. This program, which is produced by KTTV and distributed through Guild Films, is presently playing in 15 markets. Recently KTTV placed in syndication through National Telefilm Associates a one-hour program titled JUKE BOX JURY.

From a technical standpoint, when any discussion of syndication arises, the questions which are most often asked seem to be, "Is any difficulty found in playing tapes on the different machines after the program is distributed?" and, "Is it practical to make duplicates from the master recording?" I would like to make a straight forward answer to both of these questions and then enlarge upon them in detail. The answer to the first question is that the existing production video tape machines are compatible and there is no difficulty in exchange of video tapes due to different machines performing playbacks. The answer to the second question is that at KTTV we make duplicates which we call "prints" from our masters. In almost all cases, it is extremely difficult to distinguish the print from the master.

There are still many unknowns in video tape distribution, for instance, economics. KTTV produces DIVORCE COURT at a cost which is considerably less than would be practical on film. This is a one-hour version, which when prepared for shipment weighs approximately 18-20 pounds. This compares to a one-hour 35mm film packed for shipment of 40 pounds and a 16mm of ten pounds. The relative costs of shipment, therefore, will be in almost this exact ratio.

In most areas, the use of 35mm film has not been particularly heavy. It is, therefore, important to compare these costs in general to the 16mm. We believe, however, that in most instances the quality of a video tape reproduction will be higher than the reproduction of 16mm film. The reason for this is the lack of precision equipment for 16mm film. Conversely, good 35mm film compares favorably to video tape. We should be able to off-set a certain amount of cost by virtue of obtaining a better picture quality. This is an intangible, and, where picture quality is not a critical item, the station operator may not agree that this is an important factor.

I understand from the SMPTE studies of film prints that the life expectancy of a 16mm print is somewhere on the order of twenty plays. The processing of a half-hour 16mm print costs about $40.00. Dividing this by twenty plays, we obtain a figure of $2.00 per play. A half-hour of video tape tested and processed as a print costs on the order of $275.00. Let's assume that we obtain only 100 plays from such a print. We then have a cost per play of $2.75.

As you can see, video tape at this point is at a slight economic disadvantage from processing and shipping. However, there are additional advantages in that if you find it unnecessary to run the total number of plays on any given episode, the print can be returned and the stock reused to process a print of a new episode. This advantage, coupled to the potential of obtaining more than the 100 plays, will in the near future off-set the cost advantage of 16mm.

The question of machine compatibility or the ability to exchange tapes by way of syndication must be considered in terms of degree. If we make a good master and a good print, I have yet to find a machine which failed to reproduce the program. There are certain adjustments which must be made in order to obtain high quality playbacks. This is true in our operation of film or audio transcriptions. We have operating adjustments which we must make as standard procedures and these are no more difficult in video tape.

There is bound to be a variation in the video level after demodulation from one video tape recording print to another, and, certainly from one station to another. We make every effort to control the depth of modulation as closely as possible but we also are always attempting to obtain the highest modulation to avoid signal-to-noise problems. Adjustment of output level can be considered a normal operating function, although the antagonists of syndication may claim this as incompatibility.

Another and probably more important adjustment is that to eliminate scalloping. As you know, scalloping is the bowing of the 16-line intervals which have no automatic compensation such as that used to control skewing. The reason scalloping appears from machine to machine I believe is the lack of adequately controlled standard tapes. At KTTV we have made the vertical adjustment of the female guide a normal operating procedure by attaching a fixed knob and screw assembly to each head, so that, in the event of scalloping, a simple turn of the knob provides correction. I am sure we will soon have the degree of control necessary in standard tapes, which will eliminate even this minor problem of adjustment.

This is not to say that every print shipped is perfect. There is always a degree of degradation either in the master or the duplicate, but, for practical purposes, by expending the necessary time, these factors can be controlled and a completely acceptable compatible release print can be put into distribution.

In the making of duplicates, there have been various systems used. KTTV has experimented with both the rf to rf method, as well as machine to machine at the video level. We feel at this time that the rf method has theoretical advantages, however, we have not acquired enough experience to produce consistant quality in our duplicates by the use of this method. We normally use the video to video method, coupled with a careful adjustment of the pre-emphasis network in the modulator. In making duplicates, this is probably the most important factor that we have found. The pre-emphasis network, which operates much like an aperture control, tends in duplicating to overpeak and particularly increases the noise unless carefully controlled. It is important to know the characteristics of all machines involved in duplicating and provide the necessary compensation to produce a good print.

At the present time, there are several companies in Hollywood anticipating entry into the video tape syndication field. Some of these companies are not broadcasters. As you well know, the technical phases of production are only a part of the overall problem. Video taped syndication will require access to a great number of creative people in order to provide salable product. The availability of video tape equipment makes every broadcast station a potential producer. However, a salable item requires more than merely a video tape machine and production facilities. As we have always been taught, "the play's the thing." In addition, the problems of distribution still require the services of an organized distribution company. These are problems which, as more product becomes available, will certainly be solved, so, the next step in video tape syndication seems to be the availability of product which can be sold.

WEATHER RADAR

for

TELEVISION WEATHER FORECASTING

by

R. CRAIG CHRISTIE
Radio Engineer

Collins Radio Company Cedar Rapids, Iowa

Approximately a year ago a weather radar system was installed at WFAA-TV in Dallas, Texas for the purpose of showing the viewing audience an actual picture of the current weather. This weather presentation enjoyed rather wide acceptance by the Dallas viewing public. Because of this acceptance many other Television Broadcasting organizations have looked into and are installing weather radar systems.

This growing interest in weather radar aroused many questions among broadcast engineers. Some of these questions concerned theory of operation and associated installation problems. Other questions were in regard to weather radar interpretation and how this could be effectively presented to the viewing audience. This paper will endeavor to answer these questions.

GENERAL DESCRIPTION:

The primary function of a weather radar system is to present a weather map of the general sky area 360 degrees around the base of the antenna and at distances up to 150 miles. The weather map is displayed as a PPI visual presentation on a range azimuth indicator unit, which shows the location of cloud formations in terms of distance and azimuth with respect to the antenna location. Cloud formations which have heavy rainfall gradient or hail will appear as bright returns as compared to harmless formations which will appear much less bright.

The Collins WP-101, Weather Radar System, consists of five components (See Figure 1). These are the 374A-1 R-T Unit, 776C-2 Synchronizer Unit, 493A-1 Range Azimuth Indicator, 537F-3 Antenna and 561G-1 Control Unit. In addition to the above units a 1 KW source of 115v, 400 cps power and a 1 amp. 27.5 volt DC power supply is required.

SPECIFICATIONS:

Careful consideration was given to all system parameters in the design of the WP-101 system. Important parameters such as frequency, power output, pulse width, pulse repetition frequency and beam width have been optimized to give maximum interpretation to thunderstorms and other frontal conditions. A short summary of these parameters are as follows:

CHARACTERISTIC	DESCRIPTION
Frequency band	C band
Transmitting and receiving frequency	5400 mc ± 30 mc
Power output	75 kw peak, minimum
Pulse width	2.1 microseconds
Pulse repetition frequency	400 cps (nominal)
Intermediate frequency	60 mc
IF bandwidth	2 mc at 3 db, 60 mc center frequency
Overall video bandwidth	200 cps to 2 mc at 3 db points
Antenna scan	15 rpm, 360 degrees (nominal)
Antenna manual tilt	+ 10 degrees, - 15 degrees
Antenna beam width	$5\frac{1}{2}$ degrees
Sweep ranges	20, 50, 150 miles
Range mark intervals	5, 10, 25 miles
Power input requirements	115v AC ± 5%, 380-420 cps, 665va for a two indicator system; + 28v dc at 1.0 amps.
Presentation	PPI type range - azimuth information on a 5-inch cathode ray tube.
STC (sensitivity time control)	Continuously effective up to 25 miles
Iso-echo (contour) operation	Optional operation from 561G-1 control unit
Magnetron protection	Load isolator 16 db isolation; insertion loss less than 1 db.

THEORY OF OPERATION:

Your attention is invited to the block diagram (See Figure 8). It will be noted that the 400 cycle source previously mentioned is used to establish the pulse repetition frequency of the system. Using a non-resonant a-c charging scheme, a thyratron switch tube and a pulse forming network, a 2.1 microsecond pulse of large amplitude is generated and applied to the magnetron. The magnetron is a high-powered type of oscillator, and operates at approximately 5400 mc. Energy is coupled from the magnetron to the antenna via the load isolator, duplexer-mixer and interconnecting waveguide.

The load isolator is a device which transmits r-f energy with little attenuation in one direction, and a maximum attenuation in the opposite direction. The duplexer is an r-f energy switch which prevents the high energy of the transmitted pulse from entering the receiver (mixer), and directs the returned echo signal into the mixer. In the mixer the received echo signal is heterodyned with the local oscillator producing an i-f signal which is amplified and detected. The transmitted r-f energy is fed to the antenna through waveguide and is disbursed from slots in the antenna feed at the focal point of the parabolic dish. The parabolic antenna directs the energy into a $5\frac{1}{2}$ degree beam.

The antenna rotates at 15 rpm, scanning 360 degrees. Cloud formations, rain storms and solid objects reflect a portion of the transmitted energy. This returned energy (or echo) is received at the antenna and travels through the waveguide to the duplexer-mixer. Here the received signal is mixed with a signal from the local oscillator which is operating 60 mc above the magnetron frequency. A difference frequency of 60 mc is detected by the crystal rectifier and this signal is fed into the i-f amplifier. The i-f amplifier is highly selective and is tuned to a frequency of 60 mc with a bandwidth of 2 mc. After several stages of amplification, the signal is detected by a crystal detector. The output video signal is amplified in the indicator unit and impressed on the control grid of the indicator CRT, thereby causing the echo signals to be displayed as bright spots or areas on the face of the tube.

A pulse is derived from the thyratron switch tube and is used to synchronize sweep traces and range marks for the indicator. This gives the viewer a means of measuring distances of received echoes. Selector modules provide the appropriate sweep and range markers for each of the three ranges (20, 50, and 150-miles). The sweep currents are applied to the magnetic deflection coils (yoke) which encircles the neck of the CRT. Range markers (along with the video signals) are applied to the control grid of the CRT.

The azimuth drive system consists of a closed loop servo and an open loop servo. The closed loop servo includes a servo amplifier in the synchronizer unit, and a servo motor and synchro transformer in the range-azimuth indicator unit. The open loop includes an azimuth synchro transmitter which is geared to the azimuth gear drive of the antenna. The open loop transmits a signal to the closed loop, causing the servo motor (in the indicator unit) to rotate the deflection coils around the neck of the CRT in synchronism with the antenna.

Two sources of power are required for the operation of the radar system. These are 28v dc for relay operation and 115v ac primary power source. The power requirements of the radar system are divided into three loads. These loads are supplied from the three phases of a three-phase generator, or they may be supplied from the same source if single phase power is used.

CONTROL:

Operation of the system is accomplished by various controls located on both the 561G-1 Control Unit, and 493A-1 Indicator (See Figure 2). These controls and their function are as follows:

561G-1 CONTROL

CONTROL	FUNCTION
OFF-STBY-ON	System power control switch.
OFF	Turns equipment off.
STBY	Holds system in standby condition.
ON	Operating position after four minute time delay (high voltage applied).
ANT TILT	Varies tilt of the antenna 10 degrees up and 15 degrees down.
LO-HI GAIN	Controls r-f amplification of received signals.
CONTOUR-NORMAL	Controls iso-echo circuit.
NORMAL	Signal returns from targets are displayed as bright areas on the indicator.
CONTOUR	Signal returns above the contour threshold are displayed as shaded or dark configurations surrounded by brighter areas.

493A-1 INDICATOR UNIT

CONTROL	FUNCTION
DIM	Varies the panel illumination of the indicator unit.
INT	Adjusts the brightness of the sweep trace and range marks.

CONTROL	FUNCTION
VIDEO	Adjusts the contrast between the echo return and screen background.
RANGE	Selects range of operation and the corresponding range marks.
20MI	Selects 20-mile sweep and 5-mile range marks.
50MI	Selects 50-mile sweep and 10-mile range marks.
150MI	Selects 150-mile sweep and 25-mile range marks.

INTERPRETATION:

After proper adjustment of the controls has produced the most readable scope image, the task of interpretation of the weather front still exists. As an example (See Figure 3) let us look at a front on the 150 mile scale which extends in azimuth from 30 degrees right to 120 degrees left of the 0 degree reference. Bright returns within the shaded area denote the presence of rainfall in the weather front. The echoes are very intense and sharp-edged, indicating active, turbulent areas. Note that the farthest return is displayed approximately 25 degrees right of the 0 degree reference at a distance of 100 miles.

Next let us look at this same front on the 50 mile scale (See Figure 4). Notice that the closest portion of the front is displayed approximately 85 degrees left of the 0 degree reference at a distance of 20 miles. The display shows the extent in azimuth of an active turbulent storm but gives us no information relative to areas of heavy rainfall or degree of turbulence.

Let us now operate the contour switch on the control unit to the contour position (See Figure 5). Notice the difference between this display and the previous one. An area of heavy rainfall is displayed at 0 degrees/35 miles. Smaller areas of lighter rainfall are shown 15 degrees left of the 0 degree reference at a range of 30 miles and at 85 degrees left of the 0 degree reference at a range of 22 miles. The rainfall gradient changes rapidly from bright to dark at the 0 degree position indicating extreme turbulence around the contour of the black hole. The gradients at the 15 degree and 85 degree position do not change as rapidly; turbulence may exist but is not so extreme as at the 0 degree position.

Let us now look at this same front on the 20 mile scale with the nominal contour switch in the nominal position (See Figure 6). The bright intense echoes indicate active turbulent areas. No information is presented, however, relative to areas of rainfall and degree of turbulence. The closest portion of the front has advanced to approximately 8 miles at an azimuth of 45 and 80 degrees left of the 0 degree reference.

With the contour-nominal switch placed in the contour position the display changes (See Figure 7). Heavy rainfall is now denoted by black areas within the bright return at 0 degree/18 miles; 15 degrees left of the 0 degree reference at a distance of 13 miles; 60 degrees left/8 miles; 85 degrees left/12 miles; 90 degrees left/15 miles; and 105 degrees left/ 15 miles. Extreme turbulence exists in the areas surrounding the contour of the black holes at 0 degrees and at 15, 60, and 85 degrees left of the 0 degree reference. The portion of the front extending in azimuth from 90 to 120 degrees left of the 0 degree reference produces a light fuzzy return thus indicating little turbulence exists.

INSTALLATION:

Installing a weather radar system at a Television station can be accomplished with ordinary station personnel at minimum expense. As an example I have some pictures of the weather radar installation at WMT-TV Cedar Rapids, Iowa.

In coordinating the weather radar installation with their operational requirements WMT chose to mount the control unit and one indicator in a console in the news room (See Figure 9). This allowed the news forecaster to adjust and view the indicator continuously during thunderstorm periods. Another indicator was mounted in the studio in front of a fixed camera. This made possible the transmission of the actual weather to the viewing audience. Although some users place a weather map overlay over the indicator, WMT has adopted the practice of superimposing the radar picture on a false indicator which has been enlarged (See Figure 10).

The antenna is mounted on a circular pedestal located on the roof (See Figure 11). The height of the pedestal was chosen such that the protrusions from the studio building would not be in the beam width when scanning in a horizontal plane (See Figure 12). A plexiglass radome was placed over the antenna to protect it against weather.

The wave guide and power-control cable are fed through the roof to the RT Unit, Synchronizer and junction box which are located directly below the antenna (See Figure 13). Notice that the RT Unit, Synchronizer and junction box are mounted on a table for ease of installation and maintenance. Both the RT Unit and Synchronizer are mounted on shock mounts which allows easy removal when maintenance is required (See Figure 14). The wave guide is coupled to the shock mount through a 3 foot length of flexable wave guide.

Notice that all the cables from the system components are terminated in a common junction box (See Figure 15). This allows interconnection between units to be accomplished at a common place in addition greatly simplifying initial testing and routine servicing.

115 volt, 400 cps power for this system is supplied by an American Electronics 1.8 kva single phase motor generator (See Figure 16). 27.5 volt dc is obtained from a 6 amp transformer-rectifier power supply located on the second shelf of the table. The power input circuits are remotely controlled from the news room for convenience.

It is believed that the installation of weather radar system in television stations has greatly increased the interest in the "weather show". In addition TV weather radar allows the television industry to provide a great public service in offering actual first hand weather reports on approaching dangerous weather.

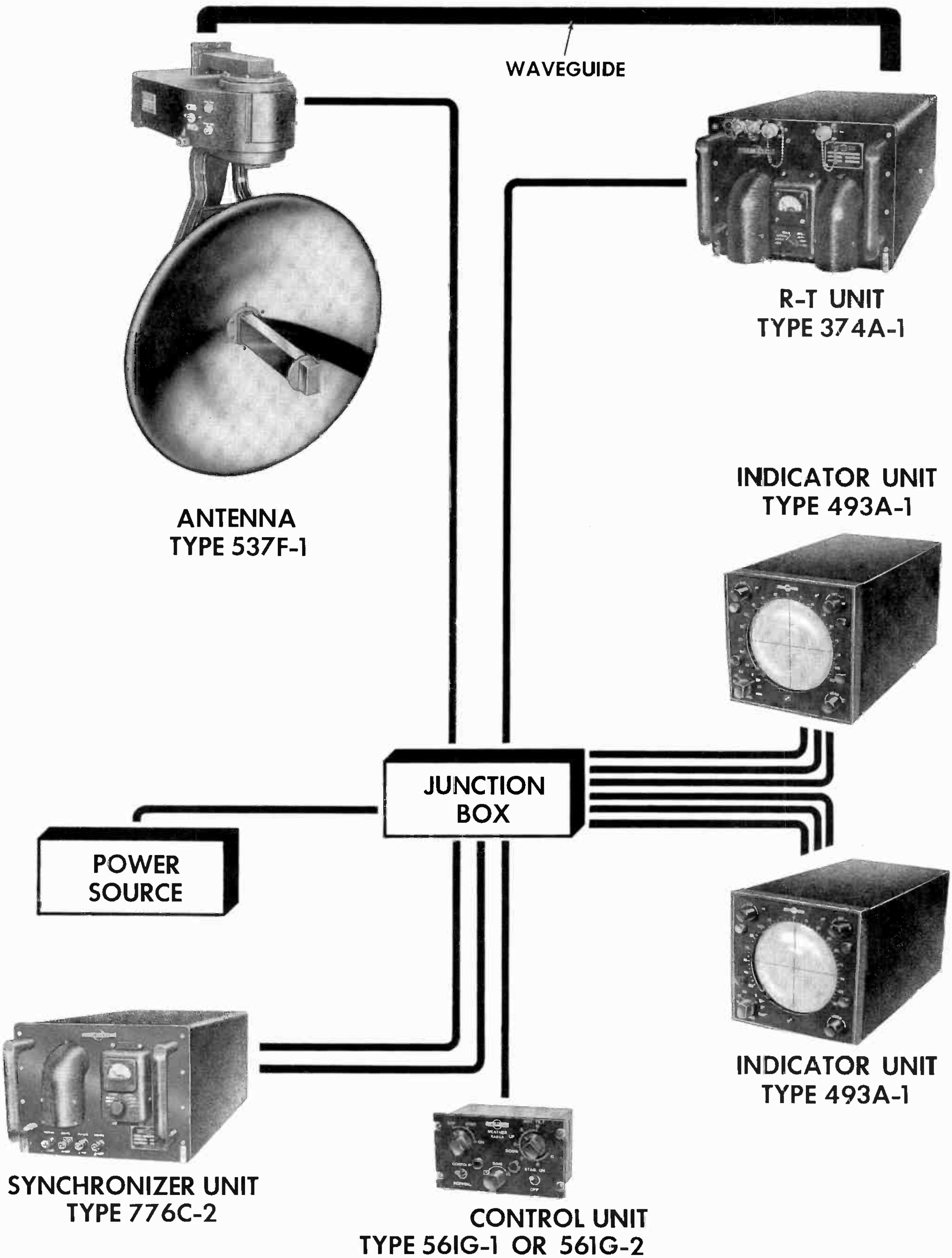
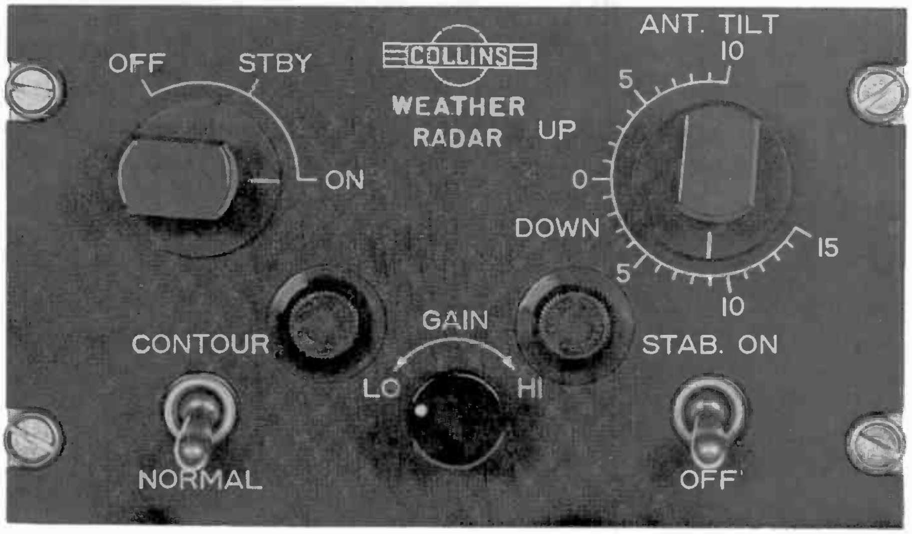
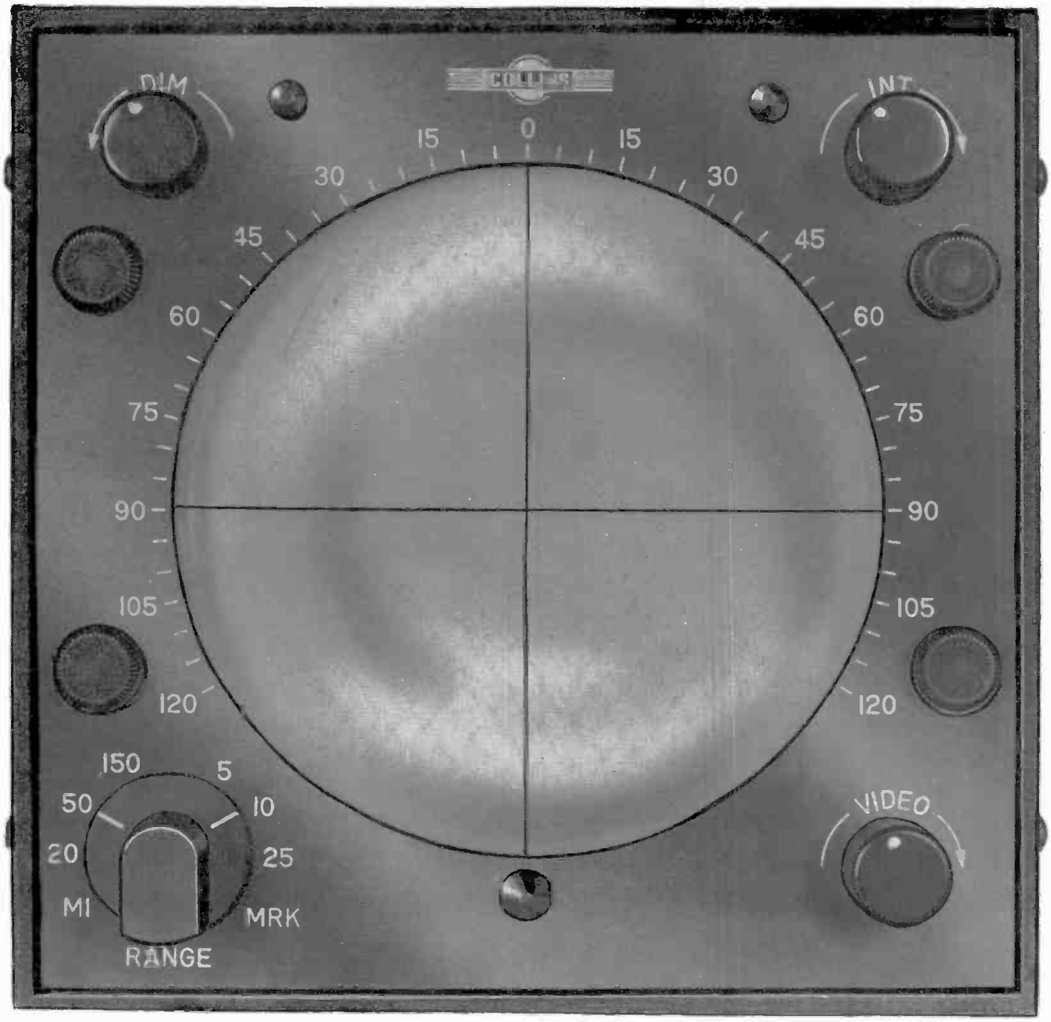


Figure 1. Units of the WP-101 Weather Radar System.



561G-1 or 561G-2 Control Unit, Front Panel



493A-1 Indicator Unit, Front Panel

Figure 2

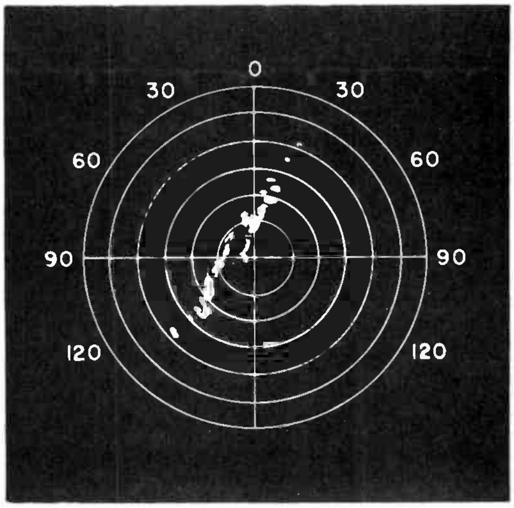


Figure 3. Indicator Display, 150 Mile Range, Initial Detection

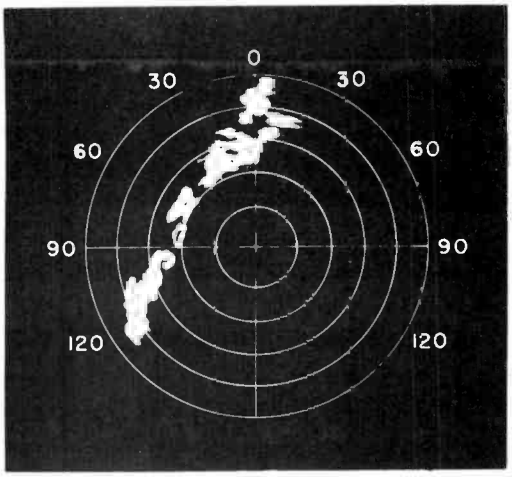


Figure 5. Indicator Display, 50 Mile Range, Contour

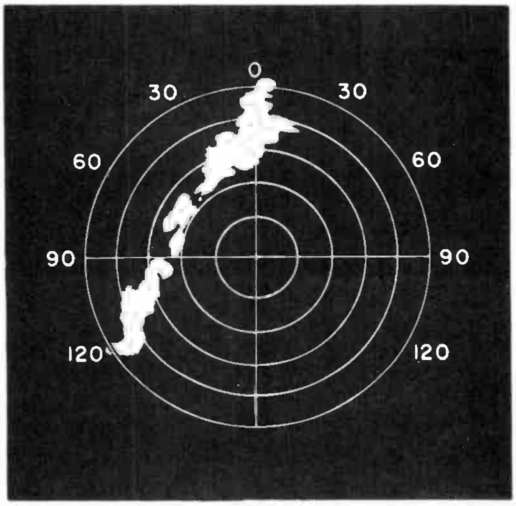


Figure 4. Indicator Display, 50 Mile Range, Normal

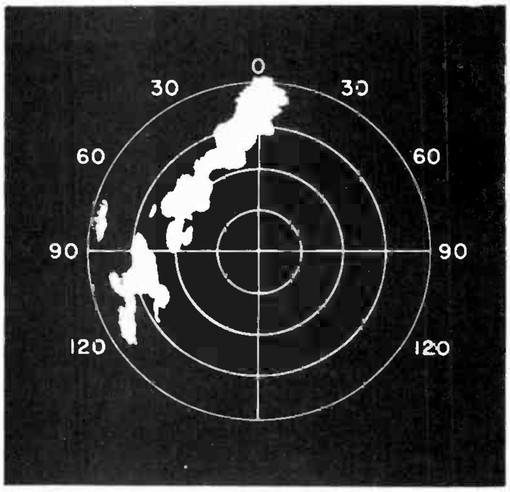


Figure 6. Indicator Display, 20 Mile Range, Normal

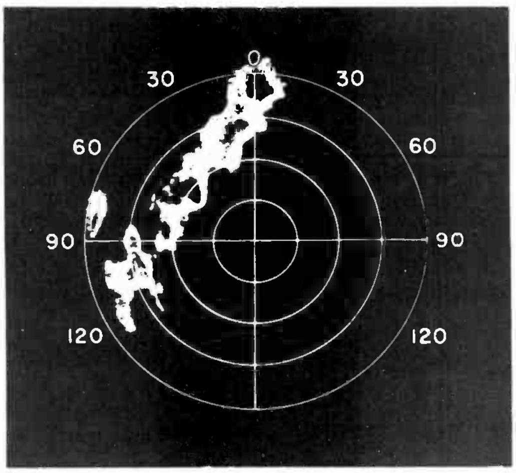


Figure 7. Indicator Display, 20 Mile Range, Contour

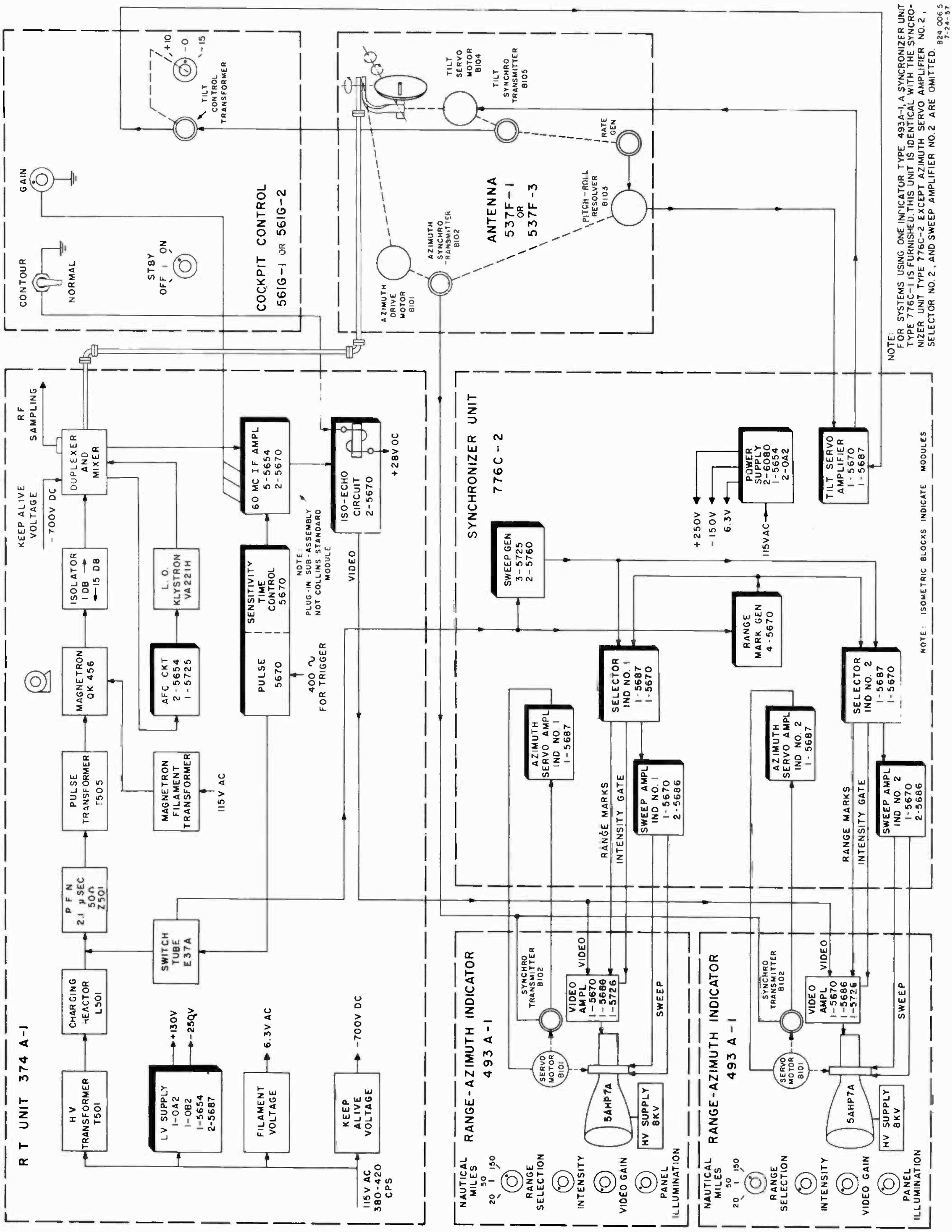


Figure 8. WP-101 Weather Radar System, Block Diagram

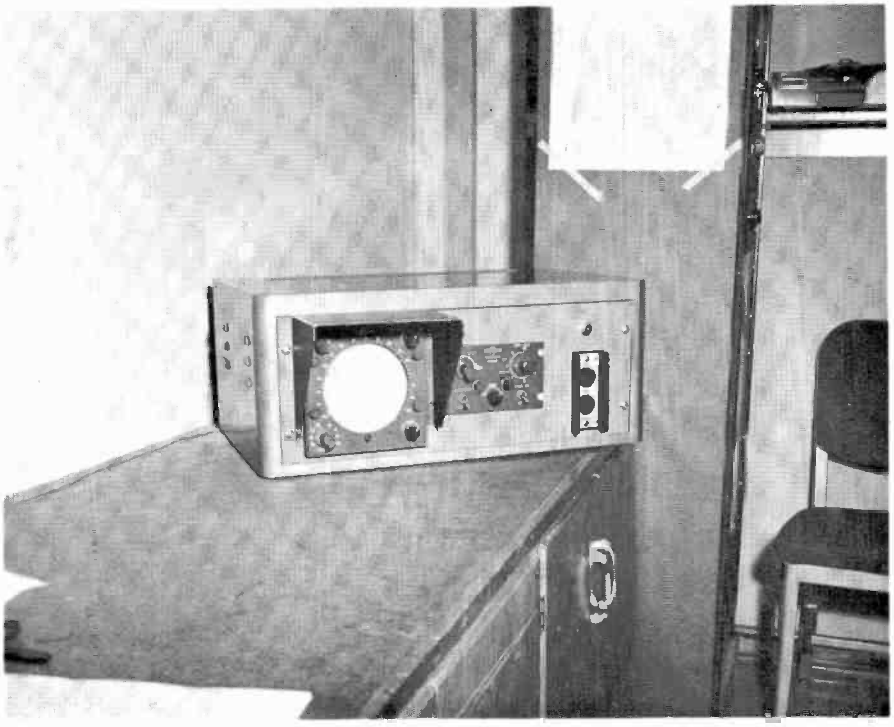


Fig. 9

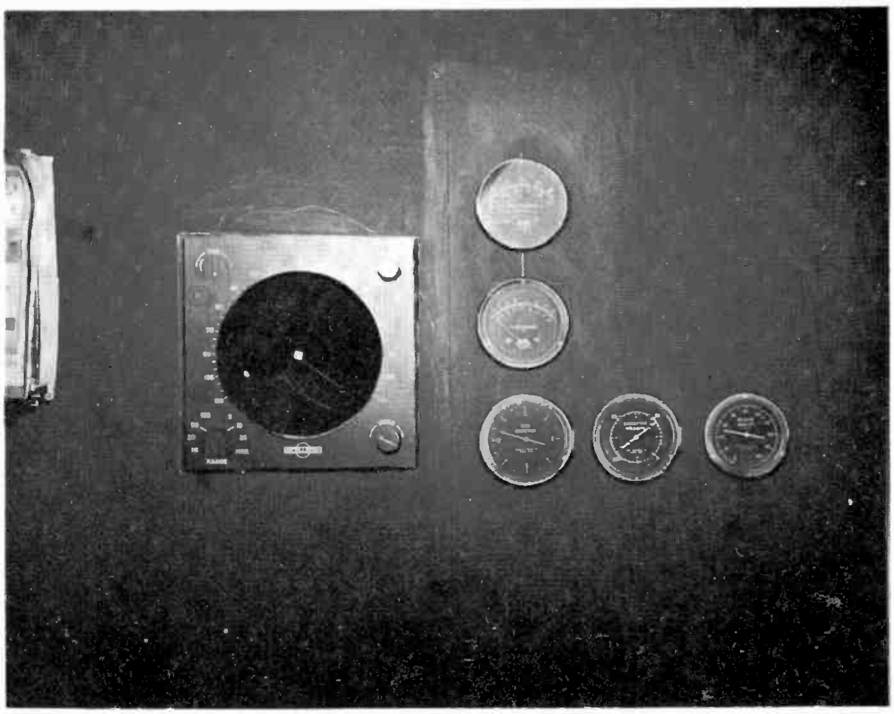


Fig. 10

Fig. 11

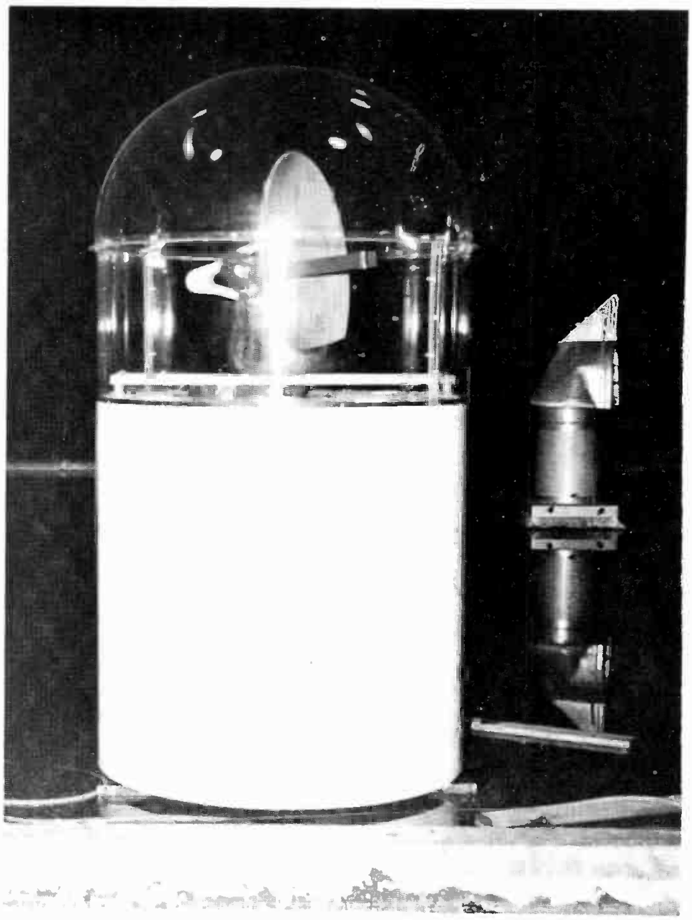


Fig. 12

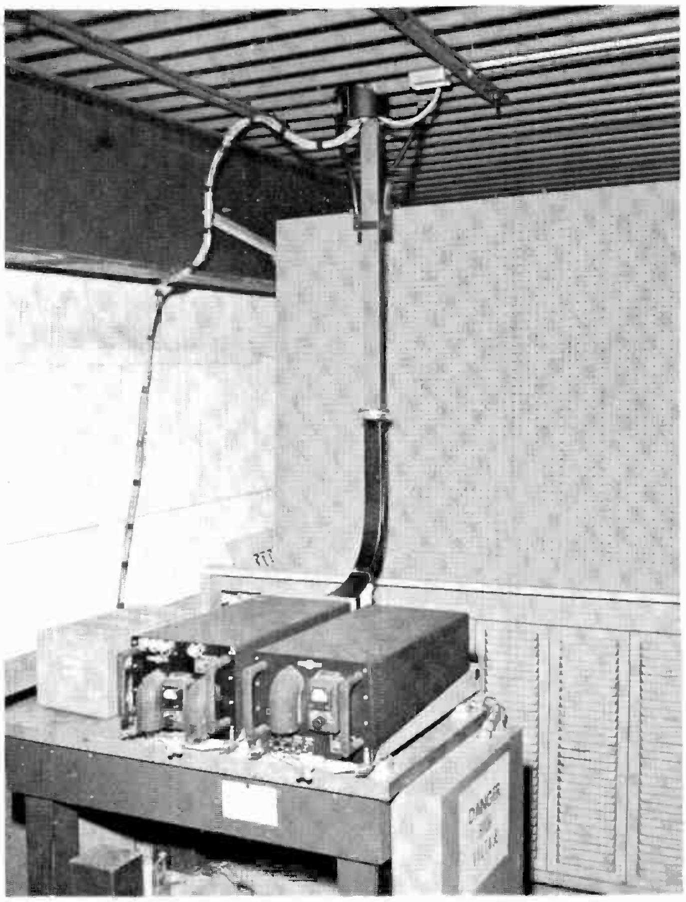


Fig. 13

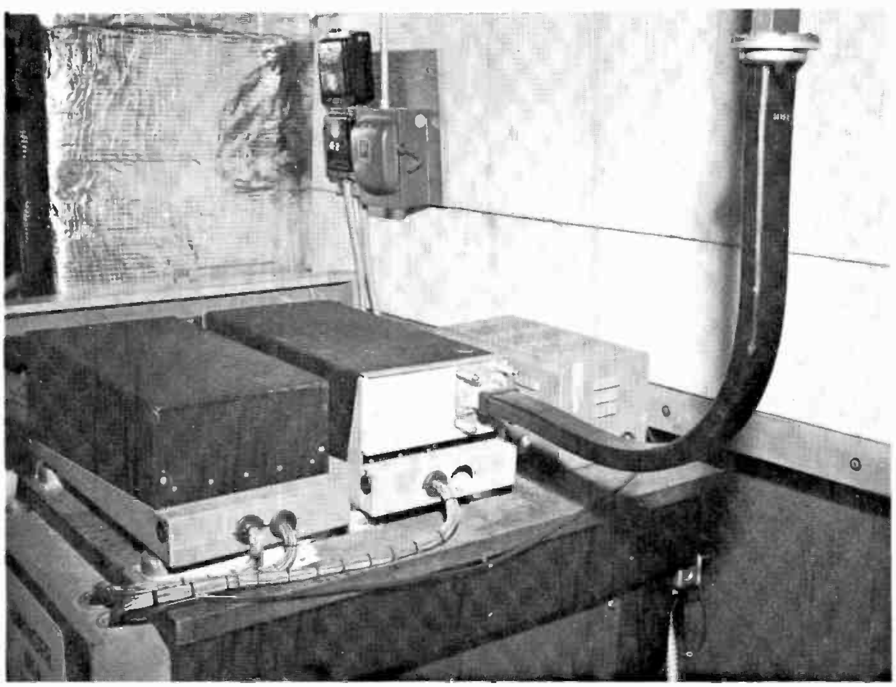


Fig. 14

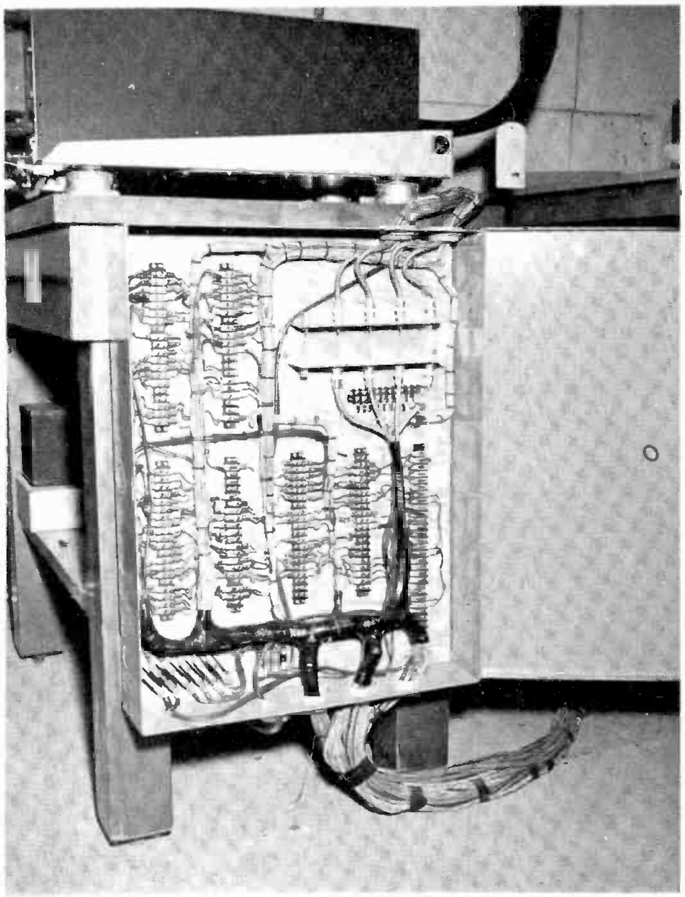


Fig. 15

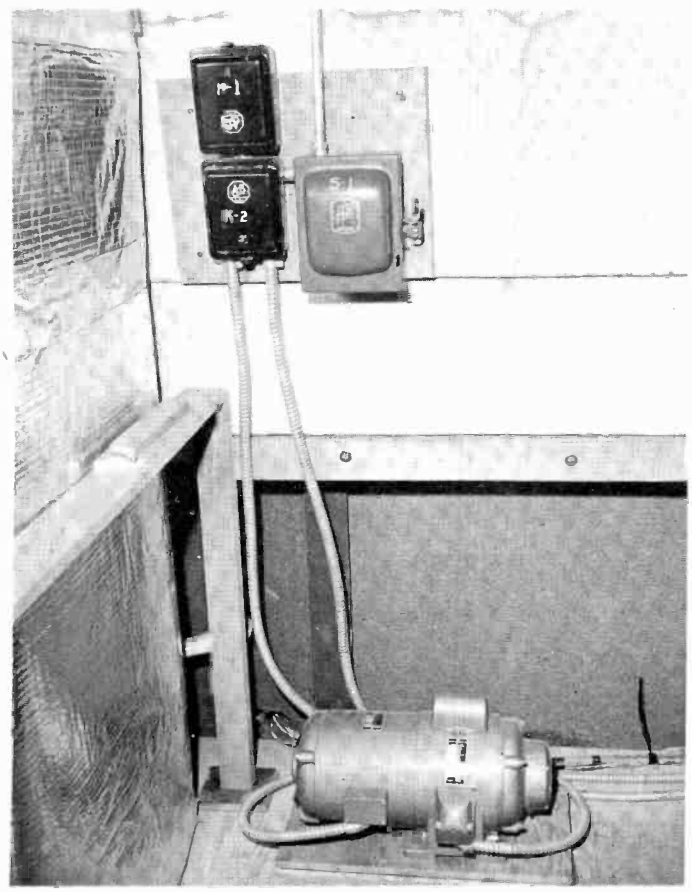


Fig. 16

PATTERN SYNTHESIS - SIMPLIFIED METHODS OF ARRAY DESIGN TO OBTAIN A DESIRED DIRECTIVE PATTERN

by

George H. Brown
Radio Corporation of America
Princeton, New Jersey

Summary - Mathematical methods of determining the magnitude and phase of the current distribution over an extended linear antenna aperture in order to obtain a desired directive radiation pattern are described. It is shown that the radiation pattern and the current distribution form a set of Fourier Transforms, thus yielding a ready solution to the problem. By adding a pattern in an imaginary zone to the desired real pattern, many current distributions or array configurations are found, all of which give the same desired pattern in the real zone.

I. Introduction

During the war, the writer and his colleagues were many times confronted with the task of designing large-aperture antennas to produce critically shaped beams with minimum side lobes and with specific rates-of-change of the main beam. The work of Dr. Irving Wolff[1] in applying Fourier series to relate the radiation pattern to a linear array of point sources of radiation led us to the infinite Fourier integral and to a ready solution to many problems by forming a set of Fourier Transforms to relate the desired directive pattern and the necessary current distribution.

- -

[1] Irving Wolff, "DETERMINATION OF THE RADIATING SYSTEM WHICH WILL PRODUCE A SPECIFIED DIRECTIONAL CHARACTERISTIC." Proc. I.R.E., vol. 25, No. 5, pp. 630-643; May, 1937.

- -

P. M. Woodward[2] has published a powerful method of dealing with the problem in which he combines graphical and analytical methods. Careful reading of his paper reveals that he was fully aware of the Fourier integral relationship and that he realized the value of sometimes proceeding into the imaginary angular domain. It is felt that this paper may supplement his exposition and assist in clarifying some of the obscure points.

- -

[2] P. M. Woodward, "A METHOD OF CALCULATING THE FIELD OVER A PLANE APERTURE REQUIRED TO PRODUCE A GIVEN POLAR DIAGRAM," Journal of The Institution of Electrical Engineers, Vol. 93, Part IIIA, No. 10, pp. 1554-1558; March-May, 1946.

- -

II. The field intensity when the current distribution is an even function.

When the currents in an array are specified as to magnitude and phase angle, the calculation of the resulting radiation pattern is not usually a very complicated operation. The converse operation, that of specifying the field pattern and then determining the current distribution, is quite another problem.

In Fig. 1, we have a sheet of current with the current distributed symmetrically about the center as an even function, that is, $i(z) = i(-z)$. The field due to the two small current elements shown in Fig. 1 is:

$$dE = 2Ki(z)\cos\left(\frac{2\pi z}{\lambda}\sin\theta\right) dz \qquad (1)$$

where $i(z)$ is the current per unit width. The current at all points in the sheet is of constant phase.

The total field due to the entire sheet is:

$$E(\theta) = 2K \int_{z=0}^{z=\frac{W}{2}} i(z)\cos\left(\frac{2\pi z}{\lambda}\sin\theta\right) dz \qquad (2)$$

where the sheet is of width W. Equation (2) may be written as:

$$E(\theta) = 2K \int_{z=0}^{z=\infty} i(z)\cos\left(\frac{2\pi z}{\lambda}\sin\theta\right) dz \qquad (3)$$

with the understanding that $i(z)$ in the integral is zero when z has a value greater than half the width of the sheet.

We are in general interested in the field variation over a range of angles from $\theta = -90^\circ$ to $\theta = 90^\circ$. Thus if we substitute $x = \sin\theta$, we will be interested in the field in the interval between $x = -1$ and $x = 1$. Then (3) becomes

$$E(x) = 2K \int_{z=0}^{z=\infty} i(z) \cos\left(\frac{2\pi z}{\lambda} \cdot x\right) dz \tag{4}$$

Now in (4) let us substitute a new variable, $v = 2\pi z/\lambda$.

$$E(x) = \frac{\lambda}{\pi} K \int_{v=0}^{v=\infty} \cos(vx)\, dv \cdot i(v) \tag{5}$$

It is readily seen that in this case where we have chosen $i(v)$ to be an even function of v, $E(x)$ is constrained to be an even function of x.

III. The field intensity when the current distribution is an odd function.

Let us now consider an arrangement where we have negative symmetry in the current distribution. Then the current distribution is an odd function of z and $i(z) = -i(-z)$. In addition, $i(z)$ is constant in phase for all values of z. The field intensity distribution is then:

$$E(x) = j\frac{\lambda}{\pi} K \int_{v=0}^{v=\infty} \sin(vx) dv \cdot i(v) \tag{6}$$

It is seen that E(x) is an odd function of x. In addition, E(x) leads the current distribution, i(v), by 90 degrees.

IV. The Fourier integral relationship.

A single-valued continuous function, E(x), that exists in the interval from $x = -\infty$ to $x = +\infty$ may be expressed in terms of the infinite Fourier integral,

$$E(x) = \frac{1}{2\pi} \int_{\beta=-\infty}^{\beta=\infty} E(\beta)\, d\beta \int_{v=-\infty}^{v=\infty} \cos v(\beta - x)\, dv$$

$$= \frac{1}{2\pi} \int_{\beta=-\infty}^{\beta=\infty} E(\beta)\, d\beta \left[\int_{v=-\infty}^{v=\infty} \cos(v\beta)\cos(vx)\, dv + \int_{v=-\infty}^{v=\infty} \sin(v\beta)\sin(vx)\, dv \right] \quad (7)$$

If E(x) is an even function, that is, E(x) = E(-x), the last term in (7) disappears and E(x) is given by

$$E(x) = \frac{2}{\pi} \int_{\beta=0}^{\beta=\infty} E(\beta)\, d\beta \int_{v=0}^{v=\infty} \cos(v\beta)\cos(vx)\, dv$$

$$= \frac{2}{\pi} \int_{v=0}^{v=\infty} \cos(vx)\, dv \int_{\beta=0}^{\beta=\infty} E(\beta)\cos(v\beta)\, d\beta \quad (8)$$

Then equating (5) and (8),

$$\frac{\lambda}{2} Ki(v) = \int_{\beta=0}^{\beta=\infty} E(\beta) \cos(v\beta)\, d\beta \quad (9)$$

Thus, if E(x) is an <u>even</u> function, (9) gives the necessary current distribution to produce the desired field distribution.

When E(x) is an odd function, that is, E(x) = -E(-x), the first term in (7) vanishes and E(x) is

$$E(x) = \frac{2}{\pi} \int_{v=0}^{v=\infty} \sin(vx)dv \int_{\beta=0}^{\beta=\infty} E(\beta)\sin(v\beta)d\beta \quad (10)$$

Equating (6) and (8), we find

$$j \frac{\lambda}{2} Ki(v) = \int_{\beta=0}^{\beta=\infty} E(\beta)\sin(v\beta)\, d\beta \quad (11)$$

So, if E(x) is an <u>odd</u> function, (11) gives the necessary current distribution to produce the desired field distribution.

Equations (9) and (11) show an integration on β from zero to infinity. Since x or β lies between -1 and 1 for real values of the angle θ, we can say that for all values of x outside of this interval, the field shall be considered to be zero. This however is not a necessary restriction. It will be seen later that it may indeed be desirable to specify E(x) in this imaginary domain.

If the desired field pattern is neither even or odd, (Fig. 2a), an even function to be used in equation (9) may be obtained by the method shown in Fig. 2b. Similarly, an odd function to be used in equation (11) may be obtained as shown in Fig. 2c.

V. A pattern with constant field intensity within a restricted angle.

As an example of the application of the above equations, we shall examine the case where the desired field pattern is constant within a given angle and is zero at all other angles. In this event,

$$E(\theta) = 1 \text{ when } -\theta_1 < \theta < \theta_1$$

$$E(\theta) = 0 \text{ when } \theta > \theta_1 \quad \text{or } \theta < -\theta_1$$

so

$$E(x) = E(\beta) = 1 \text{ when } -x_1 < x < x_1$$

and E(x) is zero for all other values of x, as shown in the upper right corner of Fig. 3. Since E(x) is an even function, equation (9) is appropriate to the problem and it becomes

$$\frac{\lambda}{2} Ki(v) = \int_{\beta=0}^{\beta=x_1} \cos(v\beta)d\beta = \frac{\sin(vx_1)}{v} \qquad (12)$$

At $x=0$, $i(0) = x_1$

and

$$\frac{i(v)}{i(0)} = \frac{\sin(vx_1)}{vx_1} = \frac{\sin(\frac{2\pi z}{\lambda} \cdot x_1)}{\frac{2\pi z}{\lambda} \cdot x_1} \qquad (13)$$

The relationship of equation (13) is shown in Fig. 3. It may be noted that as x_1 becomes small, the current distribution spreads out along the array and a larger antenna is required.

In deriving equation (13), no constraint was placed on the value of x_1. If a constant field is desired for all values of θ between -90° and $+90^\circ$, x_1 may be chosen at any value greater than unity. Thus a variety of current distributions, however impractical they may be, will all give the same constant field pattern in the real region.

Because of the inter-relationships of Fourier transforms, we could expect that a field intensity distribution of the shape of the current distribution shown in Fig. 3 would yield a new current distribution which was constant over an aperture and then became zero. For instance, if we desired a field intensity distribution where

$$E(x) = \frac{\sin(Bx)}{Bx} \quad \text{for all values of } x, \text{ out to infinity,}$$

equation (9) would yield a current distribution such that

$$i\left(\frac{2\pi z}{\lambda}\right) = 1 \quad \text{when } -B < \frac{2\pi z}{\lambda} < B$$

and

$$i\left(\frac{2\pi z}{\lambda}\right) = 0 \quad \text{when } \frac{2\pi z}{\lambda} < -B \text{ or } \frac{2\pi z}{\lambda} > B$$

If, however, we desire this same field intensity distribution in the region of real angles $(-1 < x < 1)$ and assume that $E(x)$ is zero for all values of x greater than unity or less than minus one, equation (9) becomes the sum of two sine-integral functions,

$$\frac{\lambda}{2} Ki(v) = \frac{1}{2B} \left[Si(B+v) + Si(B-v) \right] \qquad (14)$$

a solution which differs materially from the constant current over a finite aperture which results when the field pattern is considered to exist in both the real and imaginary regions.

VI. An exponential field distribution.

As another example, we shall examine the case of an even distribution of field where the field drops off on either side as

$$E(\theta) = \varepsilon^{-a \sin\theta}$$

or

$$E(x) = \varepsilon^{-ax}$$

Fig. 4 shows this field intensity distribution for a specific value of a equal to 0.5 and the field distribution extends to values of x greater than unity. At some value of $x = x_1$ the field drops to zero and remains at zero for all values of x greater than x_1. Then equation (9) yields

$$\frac{\lambda}{2} Ki(v) = \frac{a\left[1 - \varepsilon^{-ax_1}\cos(vx_1)\right] + v\,\varepsilon^{-ax_1}\sin(vx_1)}{a^2 + v^2} \qquad (15)$$

Fig. 5 shows three current distributions with $\underline{a} = 0.5$ and $x_1 = 1$, $x_1 = 2$, and $x_1 = \infty$. Here are three separate current distributions all of which yield the same field intensity distribution in the real region. It is evident that the case where x_1 is infinite yields the most conservative current distribution.

VII. A tilted-beam pattern without side lobes.

Equations (9) and (11) have been very useful in developing large antennas with narrow single beams and for lobe-switching antenna systems. This has been done by contriving even and odd functions of field intensity which are readily integrable and which fit each other.

A useful even-function field distribution is

$$E(x) = \cos^2\left(\frac{\pi}{4}\frac{x}{x_1}\right) = \frac{1 + \cos\left(\frac{\pi}{2}\frac{x}{x_1}\right)}{2} \qquad (16)$$

from $x = -2x_1$ to $x = +2x_1$ with E(x) equal to zero for all other values. When $x = x_1$, the field intensity is one-half of the maximum value. A corresponding odd function is

$$E(x) = \cos^2\left(\frac{\pi}{4}\frac{x}{x_1}\right) \sin\left(\frac{\pi}{4}\frac{x}{x_1}\right) \tag{17}$$

between $x = -2x_1$ and $x = 2x_1$ with E(x) equal to zero for all other values.

Curve A of Fig. 6 shows the even function of equation (16) plotted as a function of the angle, θ, while Curve B shows the odd function of equation (17), where $x_1 = 0.5$. Curve C is the sum of the two field patterns. The same set of curves have been replotted as a function of x in Fig. 7.

Figs. 8 and 9 show the corresponding family of curves where $x_1 = 0.2$. Successful lobe-switching antennas have been designed where the current distribution yielding Curve B has been rapidly reversed in phase.

Fig. 10 shows the total field distribution for a very narrow beam, where $x_1 = 0.04$.

When equation (16) is substituted into equation (9), we find

$$\frac{\lambda}{2} Ki(v) = \int_{\beta=0}^{\beta=2x_1} \cos^2\left(\frac{\pi}{4}\frac{\beta}{x_1}\right)\cos(v\beta) = \frac{\sin\left(\frac{4\pi z}{\lambda}x_1\right)}{\frac{4\pi z}{\lambda}}\left[\frac{1}{1-\left(\frac{4zx_1}{\lambda}\right)^2}\right] \tag{18}$$

At the center of the array, $z = 0$, the current density is

$$\frac{\lambda}{2} Ki(0) = x_1 \tag{19}$$

so the current density distribution is obtained by dividing (19) into (18).

$$\frac{i(v)}{i(0)} = \frac{\sin\left(\frac{4\pi z x_1}{\lambda}\right)}{\frac{4\pi z x_1}{\lambda}} \left[\frac{1}{1 - \left(\frac{4 x z_1}{\lambda}\right)^2}\right] \tag{20}$$

This function is plotted in Fig. 11 as i_s and is equally applicable to the field distribution of Fig. 7 or Fig. 9.

When the odd function of equation (17) is substituted into equation (11),

$$j \frac{\lambda}{2} Ki(v) = \frac{x_1}{2\pi}\left(\frac{4zx_1}{\lambda}\right) \cos \frac{4\pi z x_1}{\lambda} \left[\frac{1}{\left(\frac{1}{2}\right)^2 - \left(\frac{4zx_1}{\lambda}\right)^2} - \frac{1}{\left(\frac{3}{2}\right)^2 - \left(\frac{4zx_1}{\lambda}\right)^2}\right] \tag{21}$$

To normalize this odd function of current density, we divide (21) by the current density of the even function at $z = 0$ and obtain

$$j \frac{i(v)}{i(0)_s} = \frac{1}{2\pi}\left(\frac{4zx_1}{\lambda}\right) \cos\left(\frac{4\pi z x_1}{\lambda}\right) \left[\frac{1}{\left(\frac{1}{2}\right)^2 - \left(\frac{4zx_1}{\lambda}\right)^2} - \frac{1}{\left(\frac{3}{2}\right)^2 - \left(\frac{4zx_1}{\lambda}\right)^2}\right] \tag{22}$$

The odd-function current-density distribution of (22) is plotted as the unsymmetrical distribution labelled i_u in Fig. 11.

It should be noted that the current distribution of (22) lags that of (18) by 90°. Then the total current distribution and the corresponding phase angle to obtain the pattern C of Figs. 7 and 9 are given in Fig. 12.

VIII. A beam-tilted cosecant-theta pattern.

A tilted beam with a cosecant distribution over most of the positive real angle has been of some interest. The total field distribution is shown in Fig. 13a.

$$E(x) = 0 \quad \text{when } x < 0$$

$$E(x) = x/x_1 \quad \text{when } 0 < x < x_1$$

$$E(x) = x_1/x \quad \text{when } x_1 < x < 1$$

To find the even and odd distributions to use in the Fourier integrals, we follow the procedure demonstrated in Fig. 2. Then for the even function, shown in Fig. 13b, we obtain

$$E(x) = \frac{x}{2x_1} \quad \text{when } 0 < x < x_1$$

$$E(x) = \frac{x_1}{2x} \quad \text{when } x_1 < x < 1$$

and the even-function distribution of current density is

$$\frac{\lambda}{2}\,Ki(v) = \frac{1}{2x_1}\int_{\beta=0}^{\beta=x_1} \beta\cos(v\beta)\,d\beta + \frac{x_1}{2}\int_{\beta=x_1}^{\beta=1} \frac{\cos(v\beta)}{\beta}\,d\beta$$

$$= \frac{x_1}{2}\left[\frac{(vx_1)\sin(vx_1) + \cos(vx_1) - 1}{(vx_1)^2} + Ci(v) - Ci(vx_1)\right] \qquad (23)$$

The odd-function distribution of field is

$$E(x) = \frac{x}{2x_1} \quad \text{when } 0 < x < x_1$$

$$E(x) = \frac{x_1}{2x} \quad \text{when } x_1 < x < 1$$

while the odd-function distribution of current density is

$$j\,\frac{\lambda}{2}\,Ki(v) = \frac{1}{2x_1}\int_{\beta=0}^{\beta=x_1} \beta\sin(v\beta)\,d\beta + \frac{x_1}{2}\int_{\beta=x_1}^{\beta=1} \frac{\sin(v\beta)}{\beta}\,d\beta$$

$$= \frac{x_1}{2}\left[\frac{\sin(vx_1) - (vx_1)\cos(vx_1)}{(vx_1)^2} + Si(v) - Si(vx_1)\right] \qquad (24)$$

IX. Conclusion

Mathematical methods of determining the magnitude and phase of the current distribution over an extended linear antenna aperture in order to obtain a desired directive pattern have been described. It has been shown that the radiation pattern and the current distribution form a set of Fourier transforms, thus yielding a ready solution to the problem. By adding a pattern in an imaginary zone to the real pattern, many current distributions or array configurations are found, all of which give the same desired pattern in the real zone.

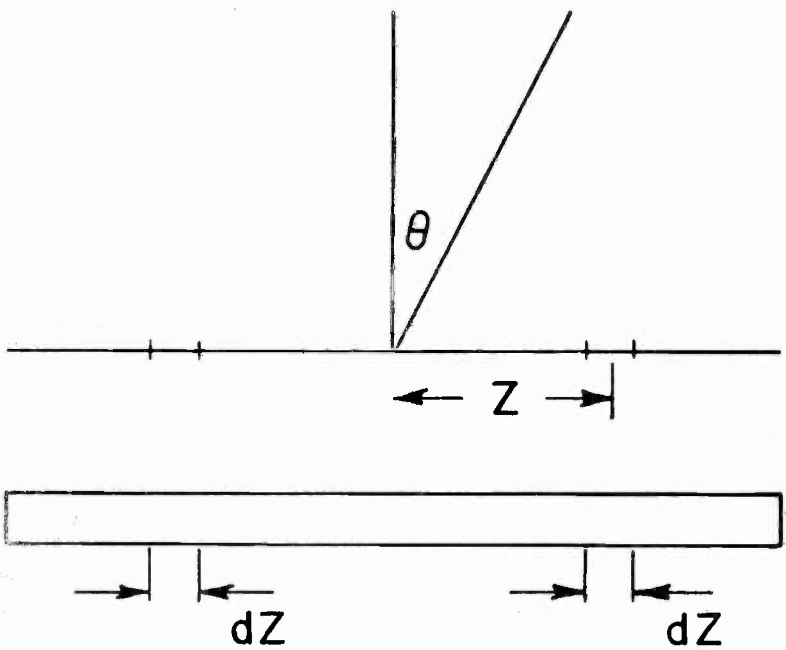


FIG. 1

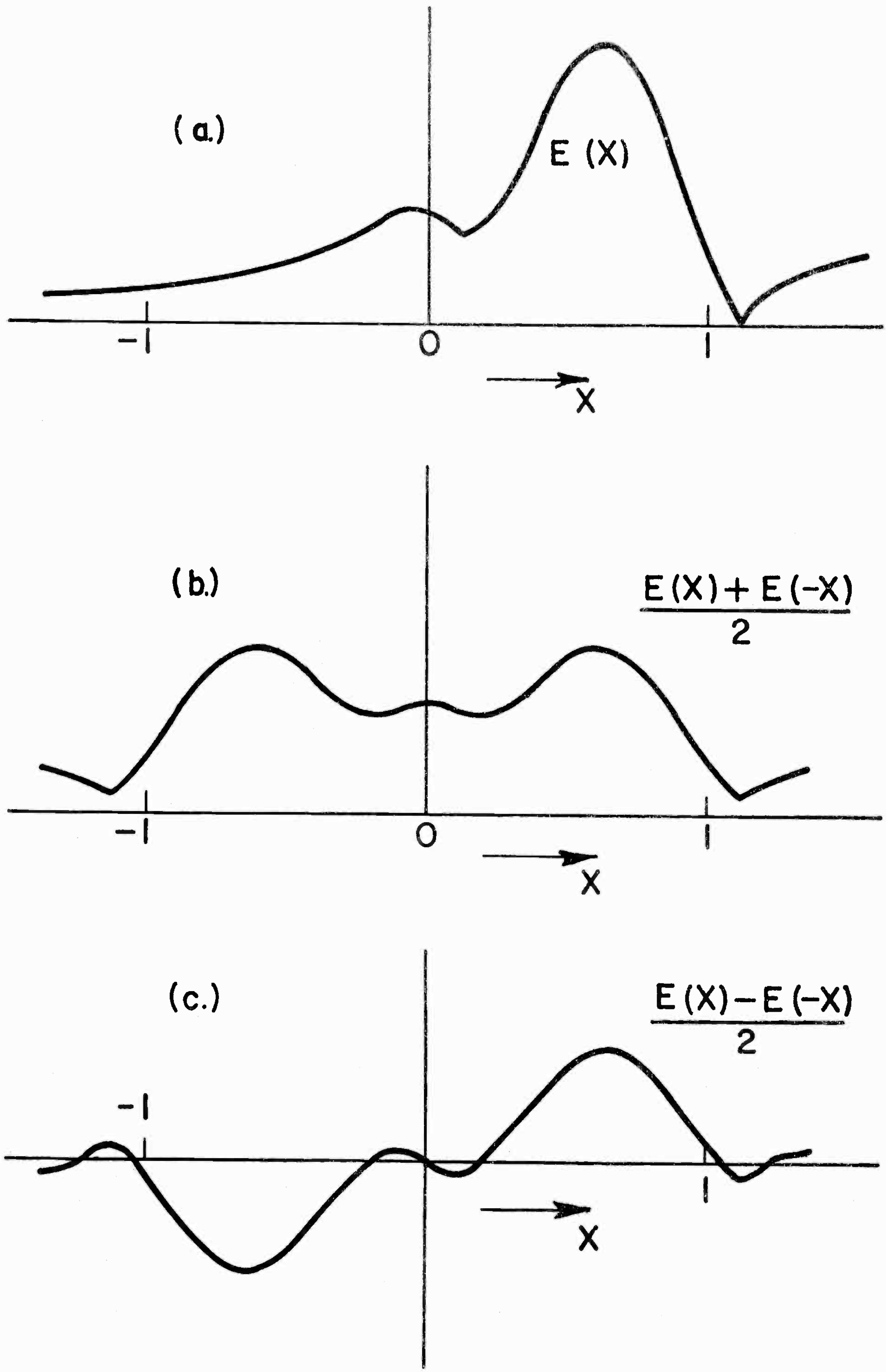
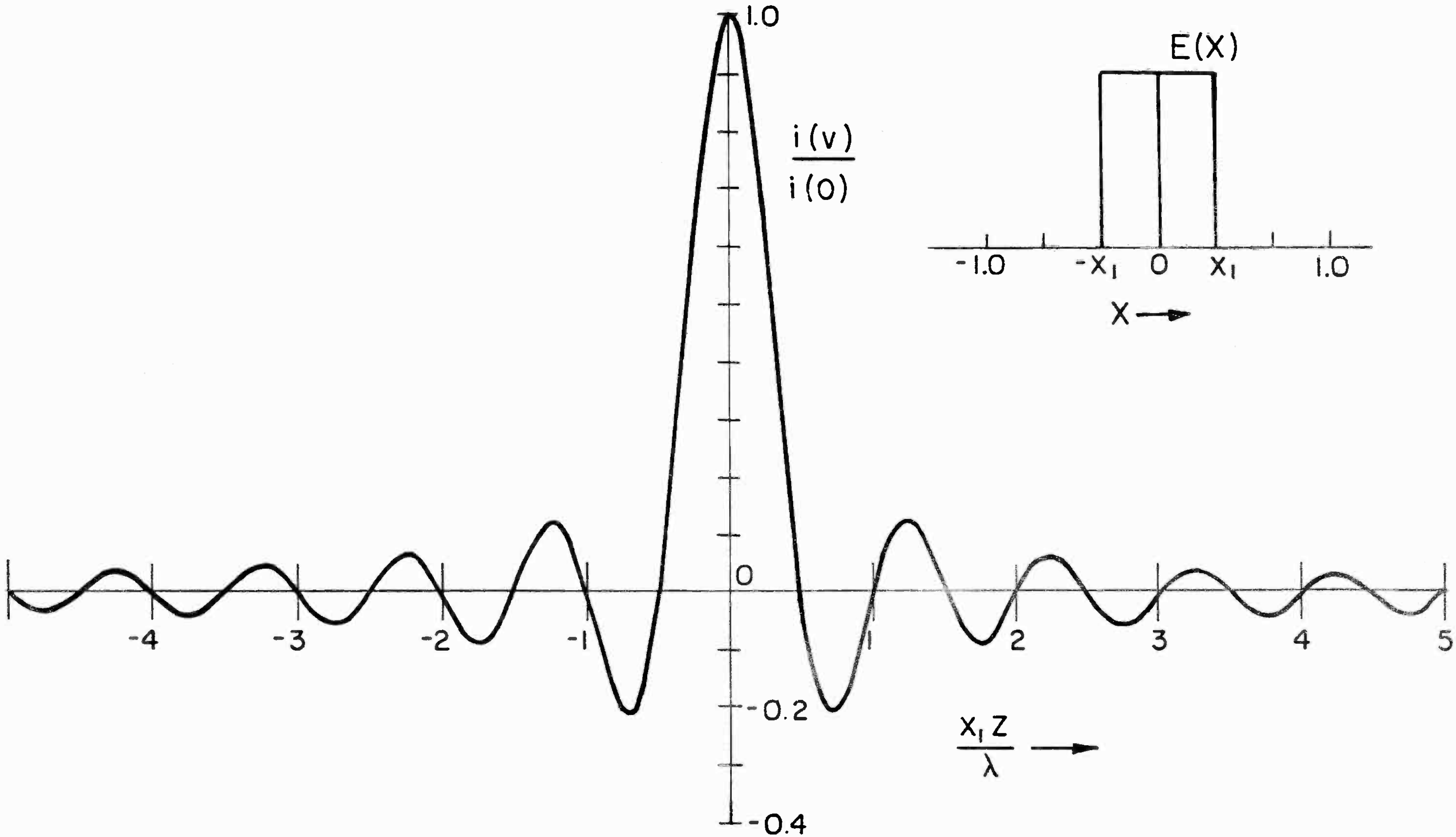


FIG. 2


1.0
i(v)
i(0)
E(X)
-1.0
-X1
0
X1
1.0
X
0
-4
-3
-2
-1
1
2
3
4
5
-0.2
-0.4
X1 Z
λ

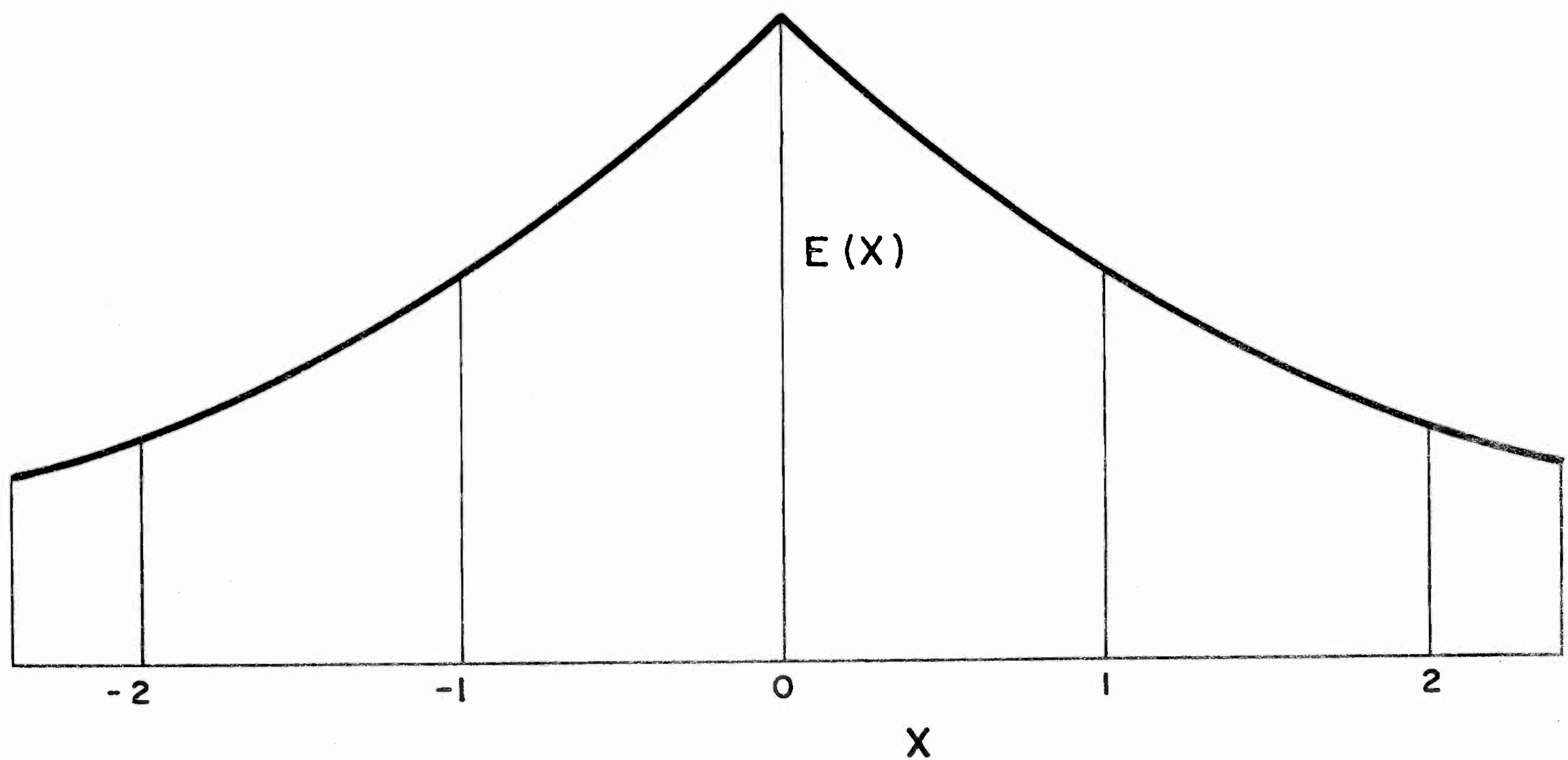


FIG. 4

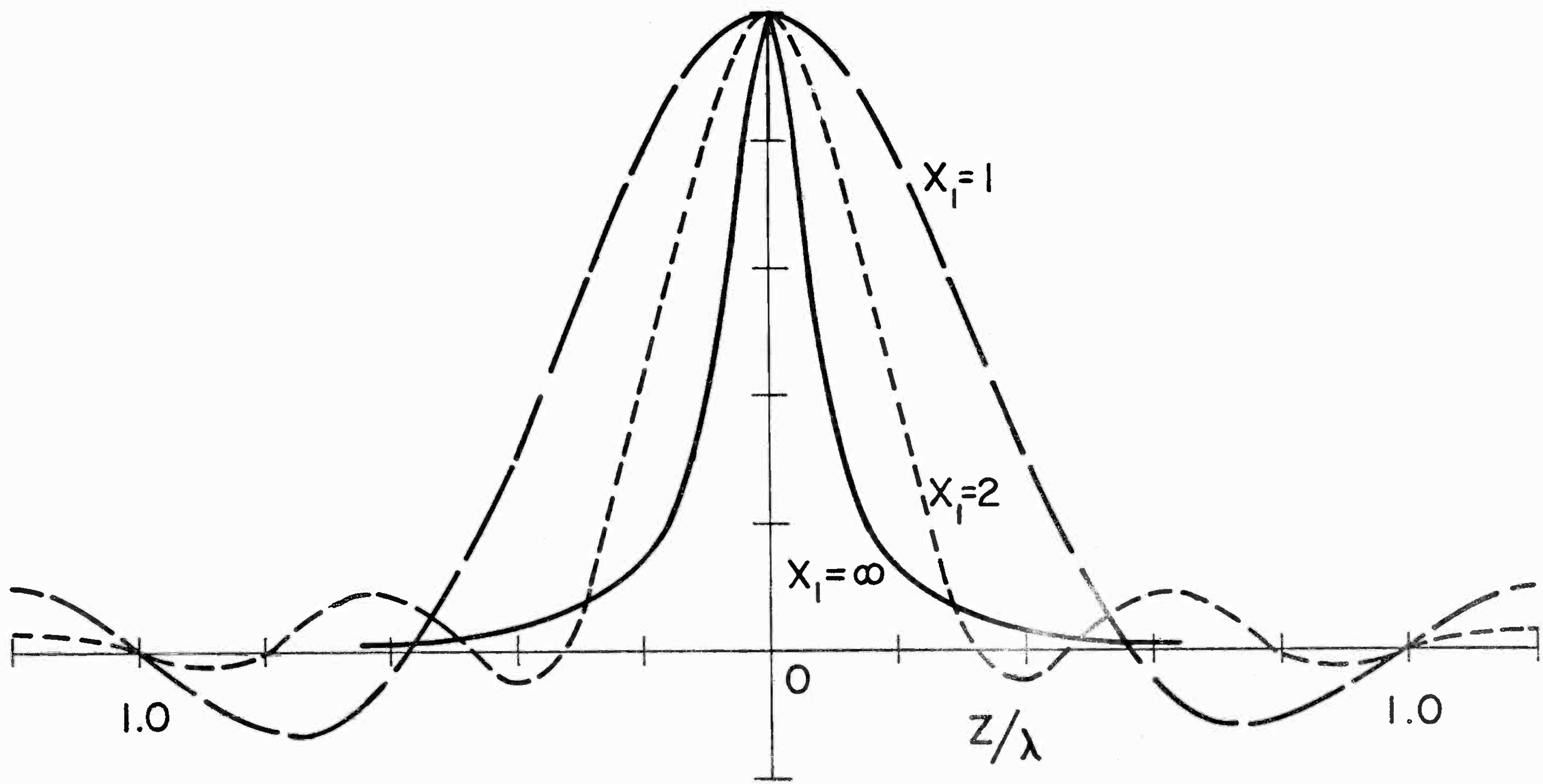


FIG. 5

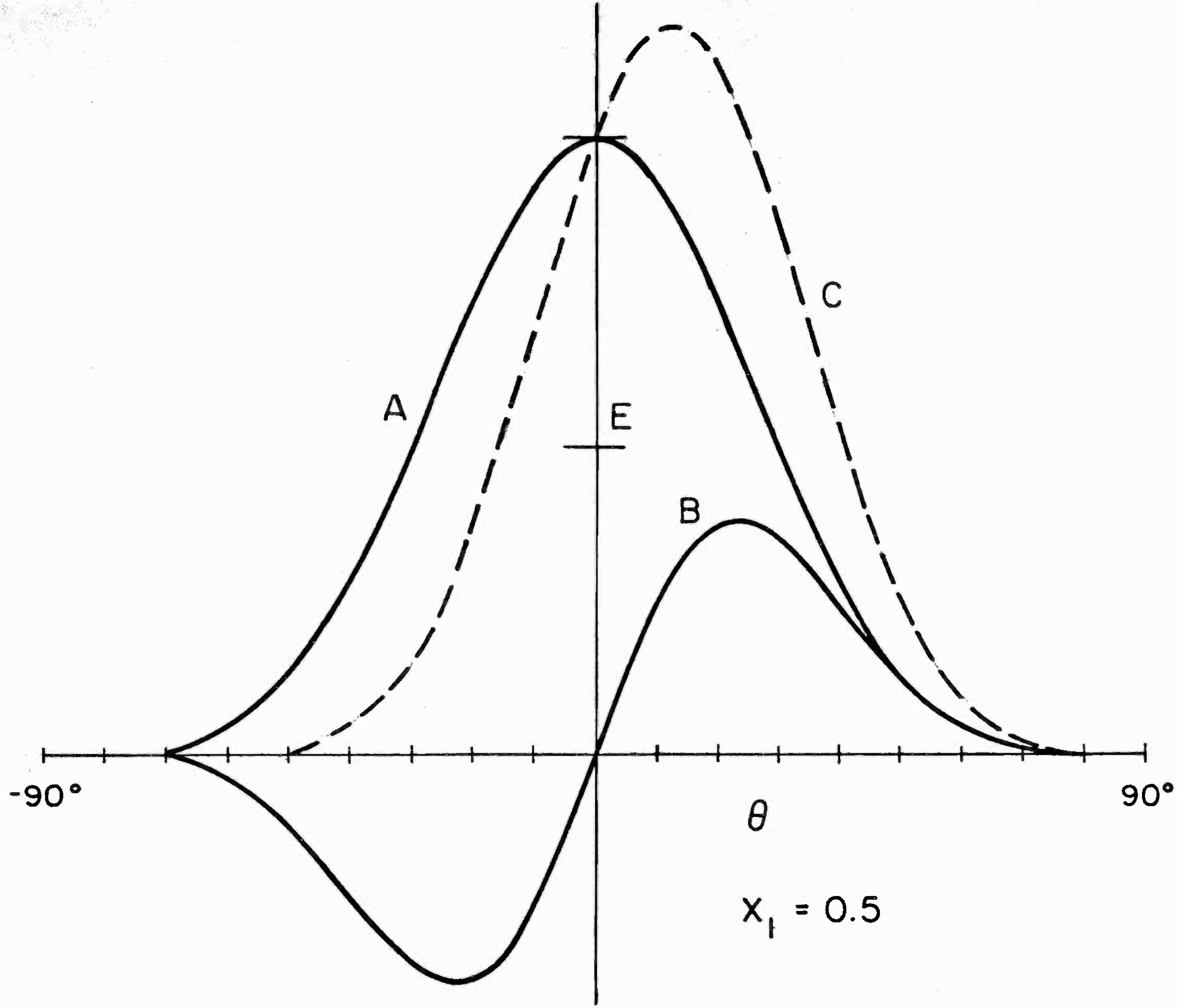


FIG. 6

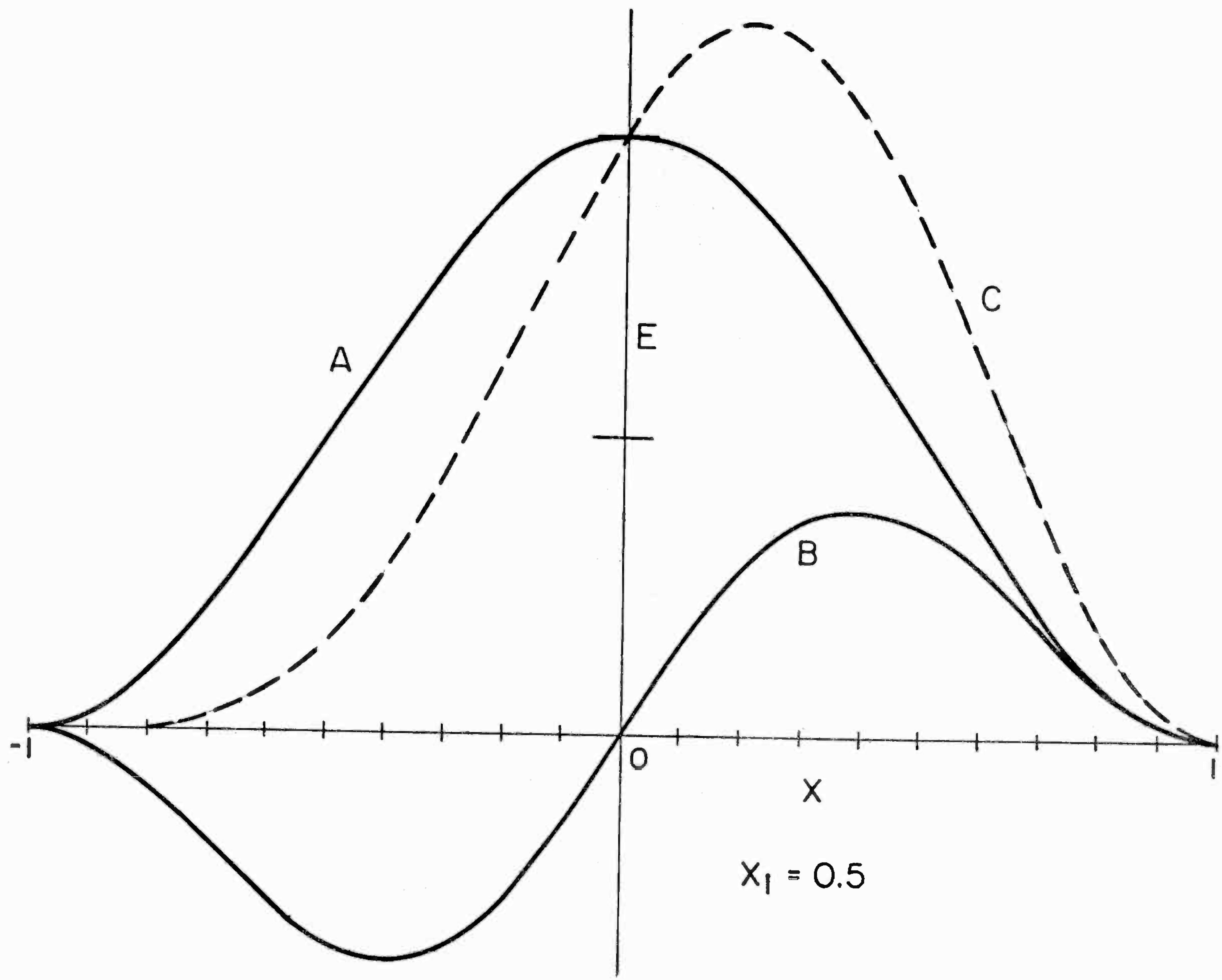


FIG. 7

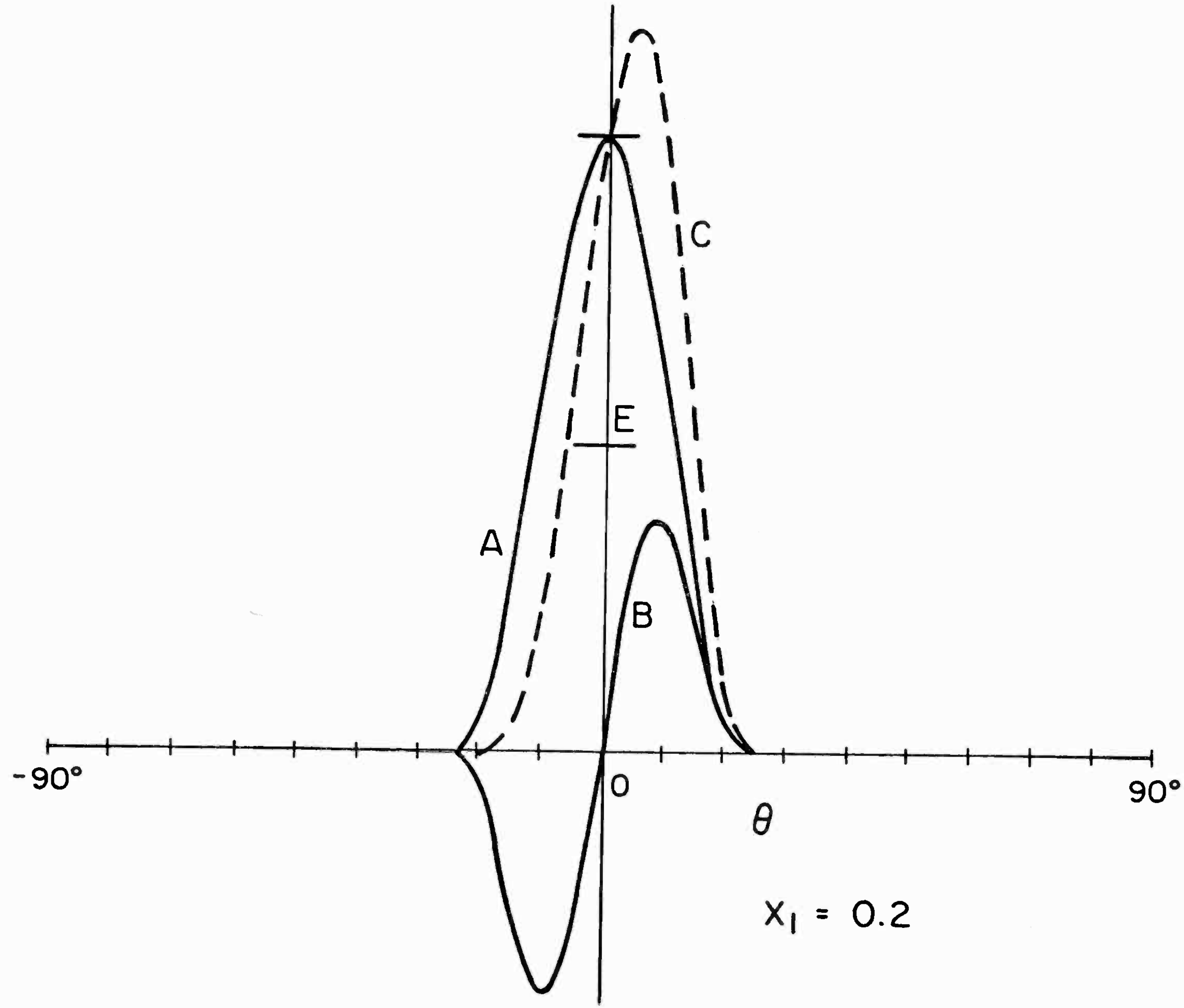


FIG. 8

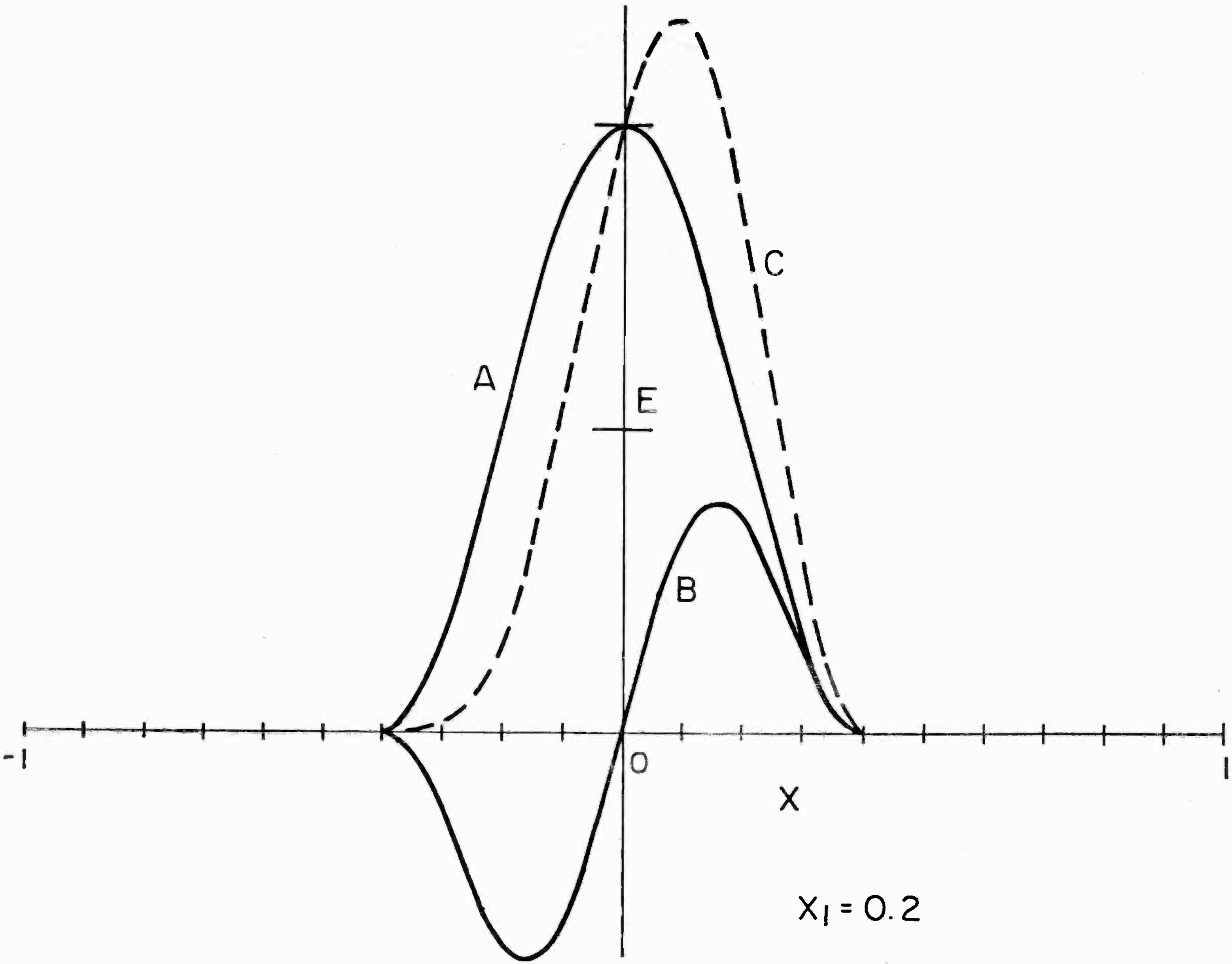


FIG. 9

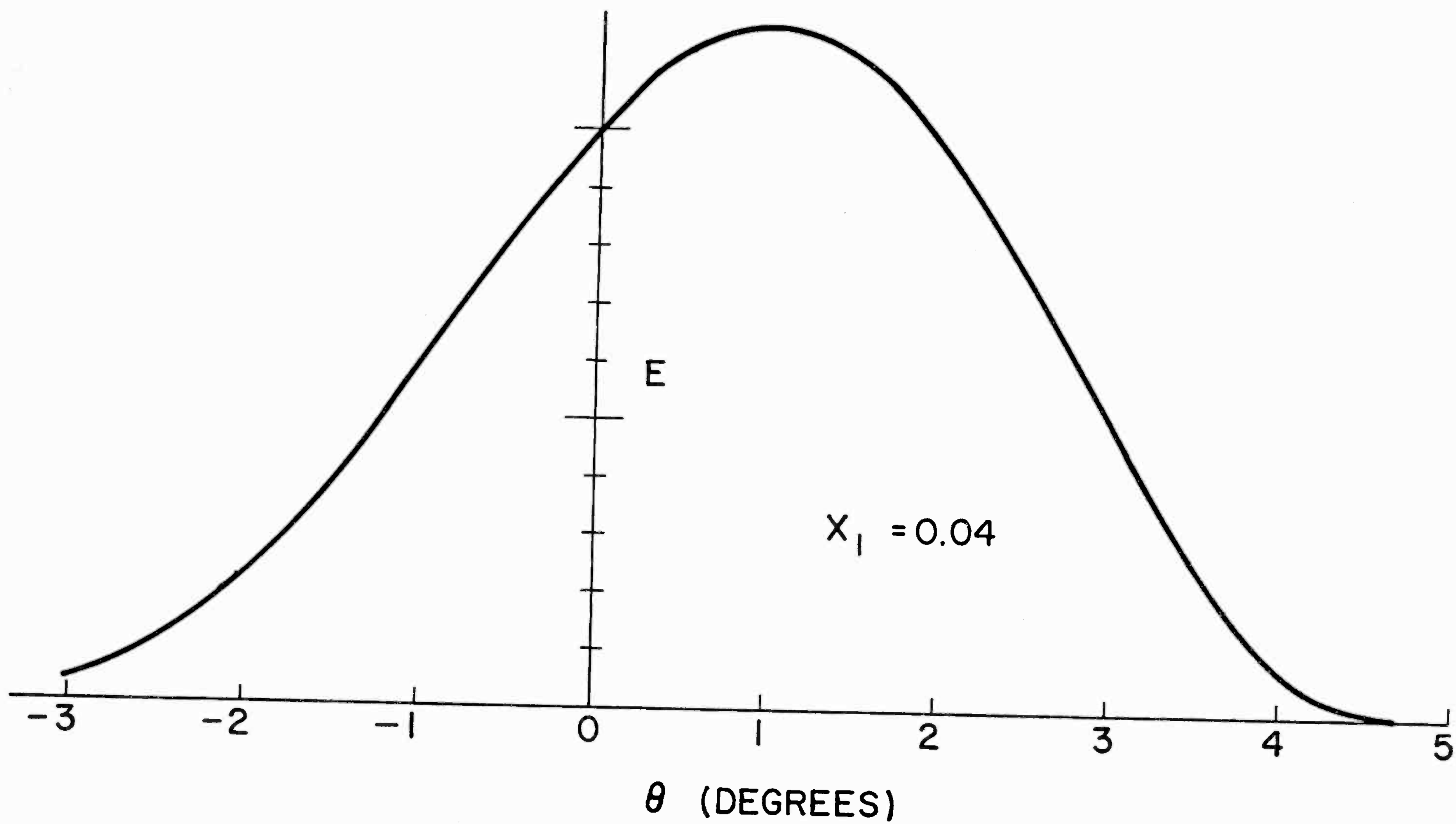


FIG. 10

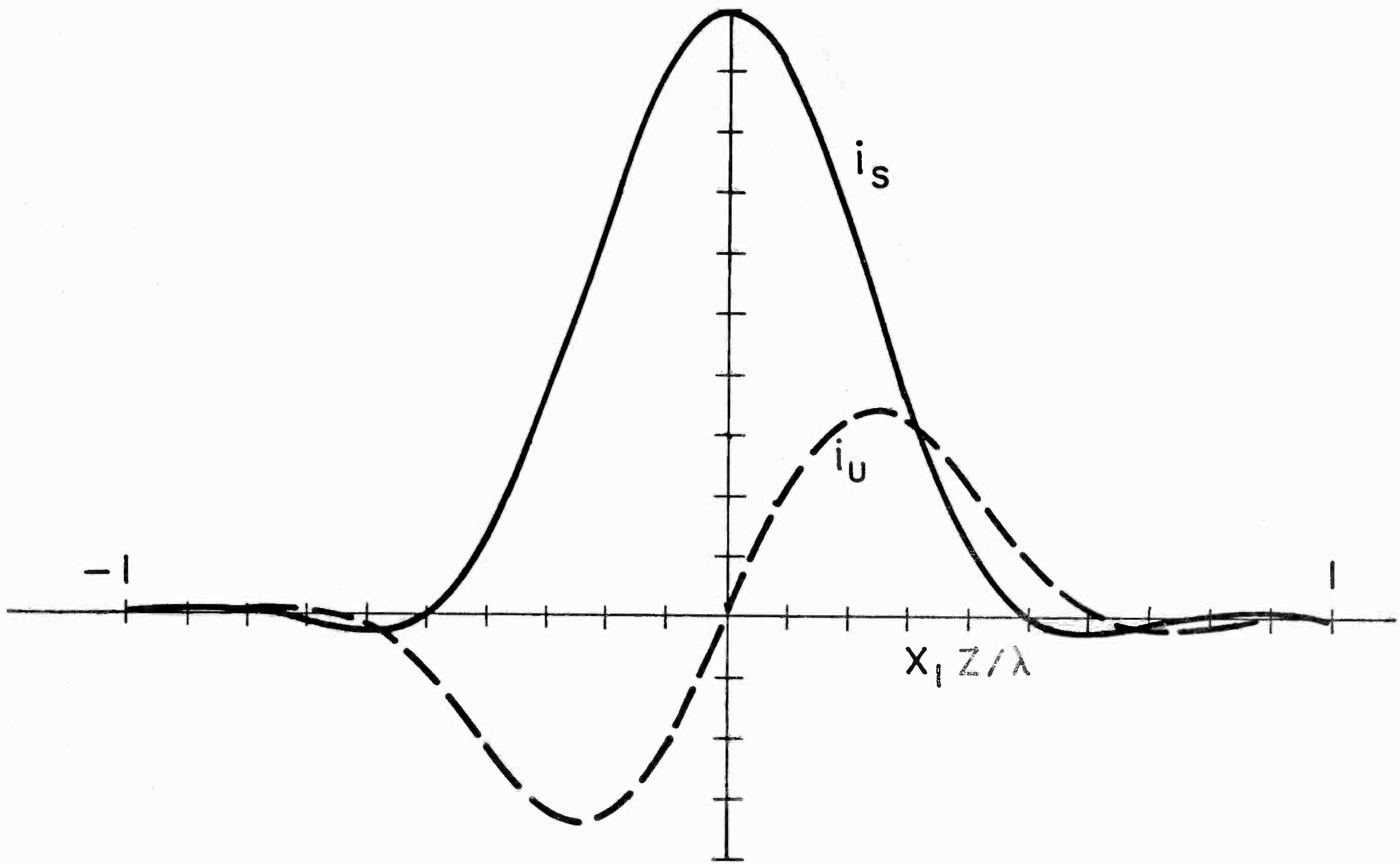


FIG. 11

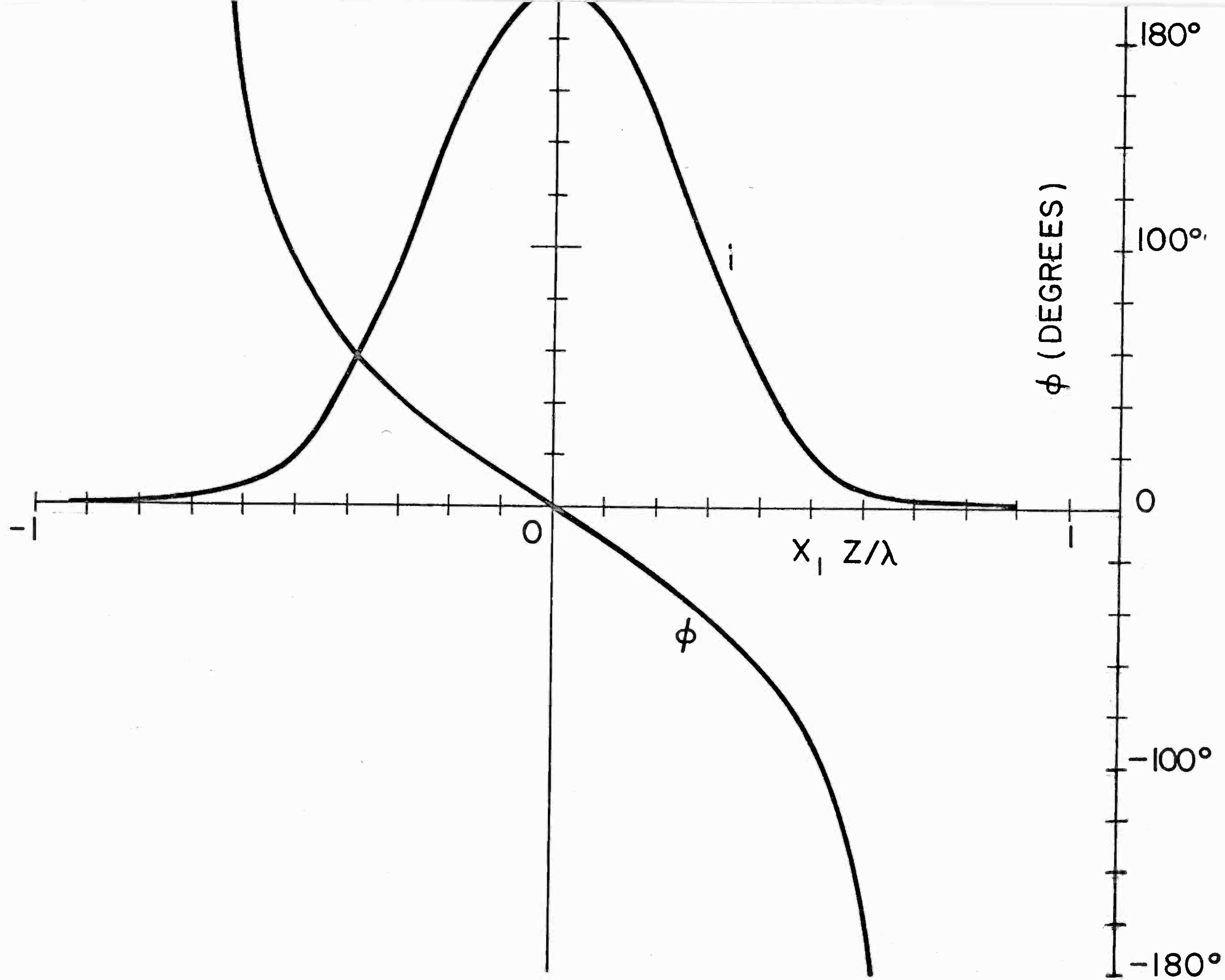


FIG 12

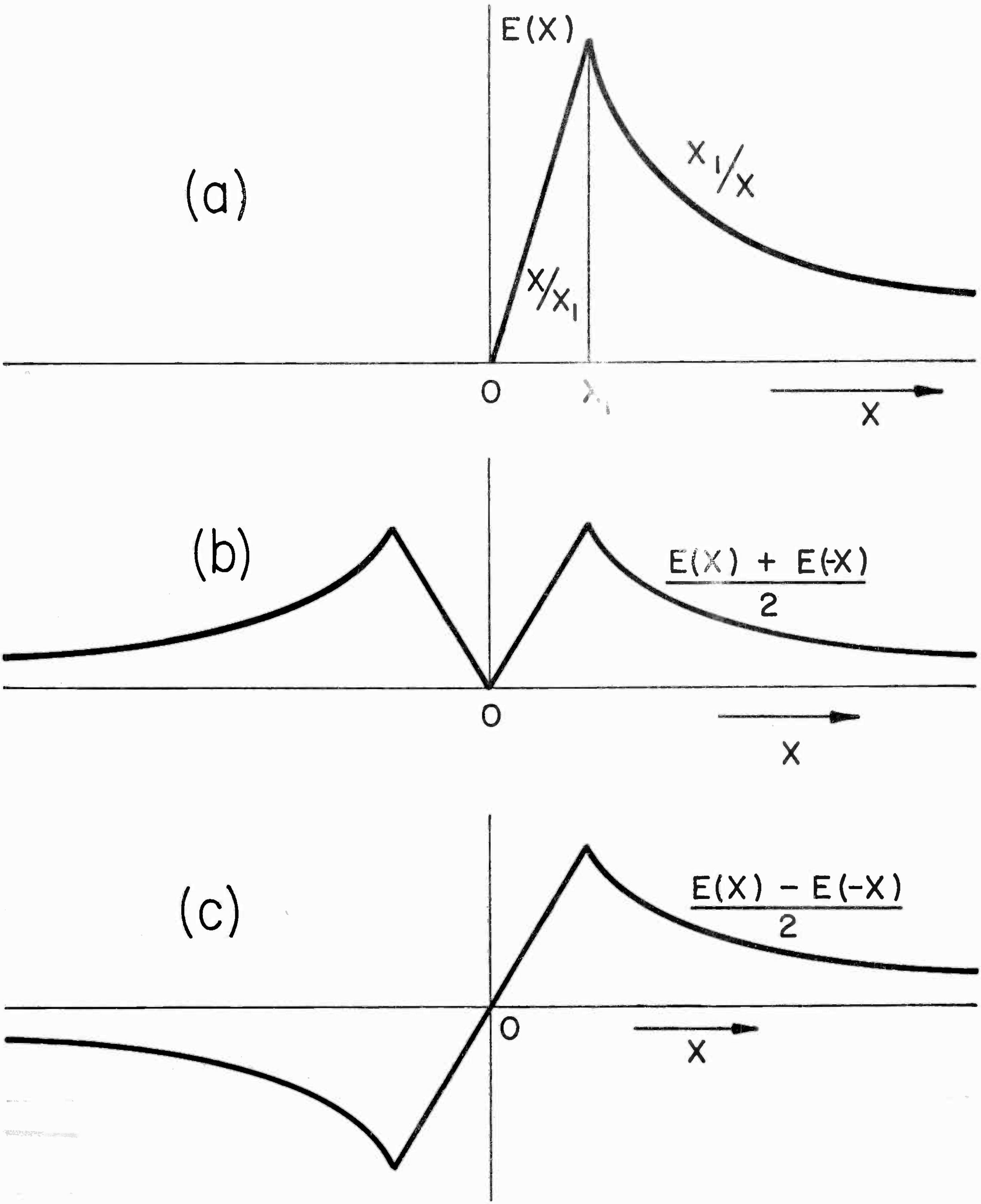


FIG. 13

CAPTIONS FOR FIGURES

Fig. 1 A radiating current sheet.

Fig. 2 A procedure for resolving an arbitrary field intensity distribution into an even function and an odd function.

Fig. 3 Current distribution which will give a constant field intensity over a prescribed angular sector.

Fig. 4 An even function of field intensity distributed exponentially. $(a = 0.5)$

Fig. 5 Three current distributions which yield the field distribution of Fig. 4.

Fig. 6 A distribution of field useful in lobe-switching antenna systems, plotted as a function of θ. Curve A is the even function of field, Curve B is the odd function, while Curve C is the composite field. $(x_1 = 0.5)$

Fig. 7 The field distributions of Fig. 6 replotted as a function of x, $(x = \sin\theta)$.

Fig. 8 Lobe-switching antenna patterns similar to Fig. 6. $(x_1 = 0.2)$

Fig. 9 A replot of Fig. 8 as a function of x.

Fig. 10 A very narrow tilted beam. $(x_1 = 0.04)$

Fig. 11 The odd and even functions of current distributions to obtain the field intensities of Figs. 6 to 10.

Fig. 12 The current distribution of Fig. 11, shown in terms of total current magnitude and phase angle.

Fig. 13 (a) A cosecant field distribution.
(b) The even-function component.
(c) The odd-function component.

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