NRL REPORT NO. R-3185

THE AN/ARC-19 (XN-1) AIRBORNE MULTICHANNEL COMMUNICATION SYSTEM

ITS DEVELOPMENT, EVALUATION, AND A PROPOSAL FOR AN IMPROVED SYSTEM

J. E. McGeogh, J. H. Dunn and
G. K. Jensen

Approved by:

R. M. Page, Superintendent, Radio Division III

Problem No. 36R01-05 October 27,1947

NAVAL RESEARCH LABORATORY
COMMODORE H. A. SCHADE, USN, DIRECTOR
WASHINGTON, D.C.

DISTRIBUTION

BuAer	
Attn: Code EL-92	(20)
Attn: Code TD-4	(2)
BuShips	(5)
CNO	
Attn: Code OP-413-B2	(5)
ONR	
Attn: Code N482	(4)
CO, ONR, Boston	(1)
Dir., USNEL	(2)
Cdr., NATC, Patuxent	(1)
CO, AMC, Wright Field	
Attn: TSELO	(1)
CO, AMC, Watson Labs., Red Bank	
Attn: WLENG	(1)
CO, AMC, Watson Labs., Cambridge	
Attn: WLCRD	(1)
SNLO, USNELO, Ft. Monmouth	(1)
OCSigO	
Attn: Ch. Eng. & Tech. Div., SIGTM-S	(1)
CO, SCEL	
Attn: Dir. of Engineering	(2)
RDB	
Attn: Library	(2)
Attn: Navy Secretary	(1)
Science and Technology Project	
Attn: Mr. J. H. Heald, Ch.	(2)

CONTENTS

CONTENTS (CONT'D)

CONTENTS (CONT'D)

ABSTRACT

The AN/ARC-19 (XN-1) Ultra High Frequency Airborne Communication Equipment was designed at the Naval Research Laboratory for use in Naval Aircraft. This equipment uses only seven crystals including one guard channel crystal and provides 876 channels spaced 200 kc apart throughout the frequency range of 225 to 400 Mc. The frequency stability is maintained within ±5.8 kc under all service conditions. All 876 channels are available to the operator at the control box and, in addition, provision has been made for any ten of these channels to be preselected without tools at the control box and made available on a preset basis. All ten preselected channels can be set up in less than three minutes. The power output of the transmitter is greater than 4 watts over the entire frequency range and the receiver sensitivity is 20 microvolts or less. The current drain from the 26.5-volt supply is less than 20 amperes.

This equipment provides many desirable features and with modification could be made suitable for use in Naval Aircraft.

PROBLEM STATUS

This report concludes the work on the AN/ARC-19 (XN-1) phase of Problem No. 36R01-05. Work is continuing on the XCU-1 phase of the problem.

PART I

Equipment Development

INTRODUCTION

The Model AN/ARC-19 (XN-1) is an airborne multichannel communications equipment operating in the frequency range of 225 to 400 Mc and providing 876 channels spaced 200 kc apart throughout this range. This equipment is the model developed from the initial proposals* for the design and development of an equipment of this type based upon the principles of the British TR 1407 multichannel VHF communications equipment (100 to 130 Mc).**

This report includes development information, results of tests conducted to determine the operational characteristics of the completed equipment, evaluation of the equipment, and a recommendation for an improved system.

The chief advantage of this multichannel system over former systems is the great reduction in the number of crystals necessary to provide the equivalent of crystal control on all channels in a multichannel band. The AN/ARC-19 (XN-1) provides complete coverage of all 876 channels in the band from 225 to 400 Mc plus the 25 channels from 220 to 225 Mc using a total of only seven crystals including one guard channel crystal. The other six crystals are used in the frequency monitor. A separate crystal was required for each channel in former systems.

Another advantage of this system over former systems is the ease with which preselected channels can be set up. The entire operation of setting up ten preselected channels requires less than three minutes.

The flexibility of this equipment is an advantage over former systems. The operator has all 876 channels available at the control box at all times and the ten preselected channel settings can be changed without tools at the control box while the equipment is in operation in the air. No adjustments or alignments are necessary in order to change preselected channel settings since all circuits are tracked and coupled to a common motor-driven tuning assembly.

The AN/ARC-19 (XN-1) is pressure sealed to overcome the difficulties of operation at high altitudes. This seal also provides protection **against dust, fungus, and humidity.** A porous cartridge containing a desiccant is mounted inside the case to remove moisture from the internal air.

* References d through n, page 150.

** References a, b, and c, page 150.

The AN/ARC-19 (XN-1) is the first equipment of its kind covering such a wide range of frequencies and the first of its kind in this frequency band; for this reason it was designed to operate only with equipments having a comparable stability and the same channel spacing.

The original design and construction of the pre-engineering model of this equipment was done entirely at NRL. The design and construction of the preproduction models was done at NRL with the exception of the r-f circuits, motor-driven tuning assembly, and control box, which were designed and built by Bendix Radio, Division of Bendix Aviation Corporation of Towson, Maryland, using the principles evolved at NRL. The case was constructed by General Communications Corporation of Boston, Massachusetts.

FREQUENCY TOLERANCE

The frequency tolerances of the various circuits and components influencing the overall frequency stability of the equipment are shown on Table I. For each item, the highest frequency involved, the tolerance at the monitor frequency, and the tolerance at the operating frequency are given.

The crystals for the crystal oscillators are temperature controlled by ovens. The ovens, crystals, and circuits are so designed that when the crystal has been initially trimmed to the correct frequency, its frequency thereafter will not change more than plus or minus 0.001 percent under Service Conditions. This tolerance includes drift due to tube changes and tube aging.

The crossover frequency of the discriminator may change due to four causes. The first cause is change in temperature. This change is listed in the table as "drift" and must be held within plus or minus 0.1 percent or plus or minus 32 cycles. The second cause is tube aging, circuit variation, or change in input level. This change is listed in the table as "shift". The third and fourth possible causes of change are initial adjustment and changing polarity. These two changes are lumped together and listed on Table I as "adjustment error".

The discriminator slot width is the range over which the master oscillator can drift in frequency before the monitor causes the tuning motor to return the master oscillator frequency back to a point that is within the control range of the reactance tube.

When all of the maximum deviations are added it is seen that under the worst possible conditions of drift the maximum error for one equipment is plus or minus 13 kc at the output frequency.

RECEIVER I-F SELECTION

In order to determine the receiver passband assume that both the receiver and transmitter have drifted to the maximum deviation of 13 kc in

TABLE I FREQUENCY TOLERANCES AN/ARC-19 (XN-1)

	Highest freq. involved	Percent	Maximum permissible deviation: Cycles at monitor freq.	Maximum permissible deviation: Kc at operating freq.
Reference Freq. Crystal	15 Mc	±0.001	± 150	±3.0
Harmonic Spectrum Crystal	5 Mc	±0.001	± 50	±1.0
I Total Crystal Drift			± 200	±4.0
Discriminator Crossover:				
Drift	32 kc	±0.10	± 32	±0.64
Shift	32 kc	±0.10	± 32	±0.64
Adjustment error	32 kc	±0.11	± 36	±0.72
II Total Discriminator Error			± 100	±2.00
III Total Monitor Error I plus II			± 300	±6.0
Discriminator Slot Width			± 350	±7.0
IV Total Frequency Tolerance			± 650	±13.0

opposite directions and that 4 kc modulation of the transmitter is used. The half bandwidth of the receiver at 6 decibels becomes the sum of 13 kc, 13 kc, and 4 kc, or a total of 30 kc. The total passband must then be 60 kc at the 6-decibel points.

Since the same oscillator is used for both the transmitter and the receiver, and the frequency of this oscillator is controlled by the monitor, all that is necessary in order to switch from transmit to receive is to change the crossover frequency of the discriminator in the monitor unit. The oscillator frequency must be changed by one-fourth of the receiver i-f, and this change can be accomplished in the discriminator only if the i-f center frequency is placed at a low enough value. Hence, it was found desirable to use a low intermediate frequency. The use of a low i-f precluded the accomplishment of any attenuation of the image response in the r-f section of the receiver and made it necessary to select an i-f which would cause the image response to fall between channels.

The i-f first chosen for the An/ARC-19 (XN-1) had a mid-frequency of 45 kc. This choice was a compromise to eliminate excessive microphonics at the low-frequency end of the passband and yet allow sufficient attenuation of the adjacent channels at the high frequency end of the passband. The image frequency existed between the operating channel and the adjacent channel. The i-f 6-decibel bandwidth was 60 kc to assure reception even under the worst conditions of drift of both receiver and transmitter. A model of this i-f was designed and constructed and tests were conducted to determine the performance characteristics. The frequency allocation is shown graphically in Figure 1 for this i-f. Tests indicated that an i-f of this low frequency is not practical for a unit of light weight and small size. This is discussed in detail in a succeeding section of this report.

In order to avoid the undesirable features of the 45-kc i-f it was decided to locate the i-f at a higher frequency such that the image would fall between the adjacent channel (n + 1) and the next adjacent channel (n + 2). This system has all the desirable features of the first system, and avoids some of the difficulties. The frequency allocation is shown graphically in Figure 2 for this system.

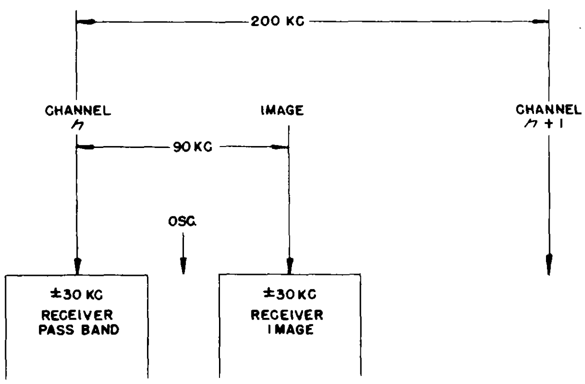


Figure 1.-Frequency Allocation for Receiver with 45-kc I-F

The center frequency of the i-f characteristic must be determined in such a way that a practicable attenuation ratio of the skirts is obtained. The attenuation ratio on each side of the selectivity curve is defined as the ratio of the absolute frequencies at the 6-decibel and 80-decibel points. Suppose, first, that the image is placed midway between channel (n + 1) and channel (n + 2). The image frequency will then be 300 kc above channel n, and the i-f must be 150 kc. The frequencies at the 6-decibel points will be 150 kc ± 30 kc which will equal 180 kc and 120 kc. The maximum transmitter drift plus modulation is plus or minus 17 kc, and the maximum receiver oscillator drift is plus or minus 13 kc. Since the channel spacing is 200 kc, the total space available for placing the image is therefore (200-17-17-13-13) kc or 140 kc under the worst possible conditions of drift of transmitter and receiver. Hence, the maximum 80-decibel bandwidth is ± 70 kc and the 80-decibel points on the i-f selectivity curve will thus be 150 kc ± 70 kc which will equal 220 kc and 80 kc The attenuation ratios in this case will be $\frac{220}{180} = 1.2$ and $\frac{120}{80} = 1.5$. Hence, the center frequency of the i-f is not symmetrically placed between the 80-decibel points so as to produce equal attenuation ratios on either side of the selectivity curve.

To determine the proper center frequency of the i-f so that the attenuation ratios are equal, the attenuation ratios must first be expressed as a function of the center frequency. The proper center frequency of the i-f

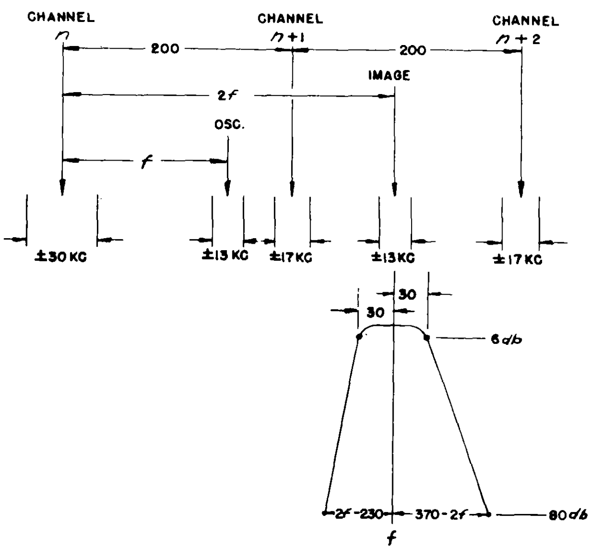


Figure 2.-Frequency Allocation for Receiver with 143-kc I-F

can be determined by equating the attenuation ratios. Refer to Figure 2 and assume that the receiver is operating on channel n. The image will be placed between channel (n+1) and channel (n+2). The center frequency of the i-f is designated as f; hence, the distance from channel n to the image is 2f. The oscillator frequency tolerance is plus or minus 13 kc at the output frequency. Therefore, the image frequency tolerance may be plus or minus 13 kc. The transmitter frequency drift plus modulation is plus or minus 17 kc. First, assume that a transmitter is operating on channel (n+1). The difference frequency between channel (n+1) and the image center frequency is (2f-200 kc). However, to allow for the 17-kc maximum drift plus modulation of the transmitter on channel (n+1) and the 13-kc maximum drift of the image, this frequency difference is reduced to (2f-200-17-13) kc or (2f-230) kc below the i-f center frequency. This must be the lower 80-decibel point of the selectivity curve. Since the 6-decibel points have been set at (f plus or minus 30) kc, the attenuation ratio of the low frequency side of the curve is $\frac{f-30}{f-(2f-230)}$. Next, assume that a transmitter is operating on channel (n+2). The difference frequency between the image and channel (n+2) will be (400-2f) which will be reduced by the maximum 13-kc receiver drift and the maximum 17-kc transmitter drift plus modulation to be equal to(400-2f-13-17) kc or (370-2f) kc. The upper 80-decibel point on the selectivity curve must then be f + (370-2f) kc, and the upper attenuation ratio will be $\frac{f+(370-2f)}{f+30}$. These attenuation ratios are set equal and solved for f, as:

$$\frac{f-30}{f-(2f-230)} = \frac{f+(370-2f)}{f+30}$$

$$f = 143.33 \text{ kc.}$$

This shows that in order to place the image between the adjacent channel and the next adjacent channel and maintain a practicable design of the i-f transformers, the center frequency of the i-f should be 143.33 kc.

FACILITIES PROVIDED

The AN/ARC-19 (XN-1) uses a total of seven crystals including one guard channel crystal and provides 901 preset channels spaced 200 kc apart from the lowest frequency channel (channel number 100) 220 Mc, to the highest frequency channel (channel number 1000) 400 Mc. The limits of the allocated frequency band are 225 Mc and 400 Mc. Hence, only 876 of these channels are within the allocated frequency range.

The channel numbering system is a decade system with channel 000 at 200 Mc. This system was chosen for simplicity and for convenience and speed in channel selection. The monitor was designed to cover all channels from channel number 000 (200 Mc) to channel number 1000 (400 Mc), but in this equipment channels below channel number 100 (220 Mc) are outside of the tuning range of the r-f circuits and a mechanical stop in the control box prevents the selection of these channels by the operator. A visible indication is given at the control box when the operator attempts to select one of these channels.

All 876 channels are available to the operator at the control box, and, in addition, provision has been made for any ten of the 876 channels to be set up by a channel preselector control. One of the ten preselected channels has been labeled G for guard channel transmission and one labeled M for manual selection of any one of the 876 channels desired.

A separate, fixed-frequency, guard channel receiver is provided to permit monitoring of the guard frequency while the main channel receiver is tuned to another frequency. A switch on the control box enables the operator to select either the guard channel or the main channel receiver separately or both simultaneously.

The sensitivity of the main channel receiver is 20 microvolts or less over the entire band.

An altitude gain control is incorporated to provide a continuous increase to six decibels in audio gain for a change in altitude from sea level to 30,000 feet. This control consists of two potentiometers which are adjusted automatically for changes in atmospheric pressure by means of a bellows. One potentiometer controls the input to the grid of the final audio amplifier in the receiver and the other controls the input to the grids of the driver stages in the transmitter modulator.

A table of dimensions and weights of all components is included in this report (page 107). The complete equipment is shown in Figure 3. This figure shows the complete equipment consisting of the transmitter-receiver unit, antenna, junction box, two headphone-microphone jack boxes, control box, microphone, headset, and all cables. The additional outlet on the junction box is for radio relay operation.

The transmitter-receiver unit is shown in Figure 4. The case consists of two parts: the head, containing the dynamotors, blowers, heat exchanger, power relay, antenna relay, transmit-receive relay, altitude gain control, and external plugs; and the cover, which covers the r-f assembly, motor drive, modulator, monitor, i-f amplifier and guard channel. The head and the cover are fastened together by means of four,self-locking, lever-action fasteners, and a pressure seal is obtained by using a rubber gasket between the two parts.

The cover is fabricated of sheet aluminum except for the lip where the cover and the head fit together. This lip is cast aluminum and is welded to the fabricated cover. This lip and the guide rails which hold the unit in place inside the case can be seen in Figure 5. This figure shows the complete transmitter-receiver unit with the cover removed. The r-f assembly, monitor, receiver i-f, modulator, and guard channel r-f unit are all separate sub-assemblies. These units are mounted on the main deck. Figure 6 shows the unit from the right side. The receiver i-f chassis is mounted on the main deck on this side by means of four Airlock fasteners, and a disconnect is provided for electrical connections.

Figure 7 shows the bottom of the main deck where the r-f circuits, motor tuning drive, modulator, and guard channel are mounted. These units are subassemblies and can be easily removed. All of the tuned circuits driven by the motor are mounted on the same casting with the motor and tuning drive assembly.

The left side of the unit is shown in Figure 8. The monitor unit is mounted on this side opposite the receiver i-f chassis. The method of mounting the monitor chassis is the same as that used for the receiver i-f chassis.

The top view of the unit is shown in Figure 9. This figure shows the edge of the receiver i-f chassis and the edge of the monitor chassis. These two chassis are mounted on opposite sides with the tubes to the inside. This was done to facilitate servicing and simplify cooling.

The main deck is mounted at right angles to a plate which is fastened to the head by four screws. This plate is provided with two disconnects. The four-terminal disconnect is for dynamotor voltages. The large discon-

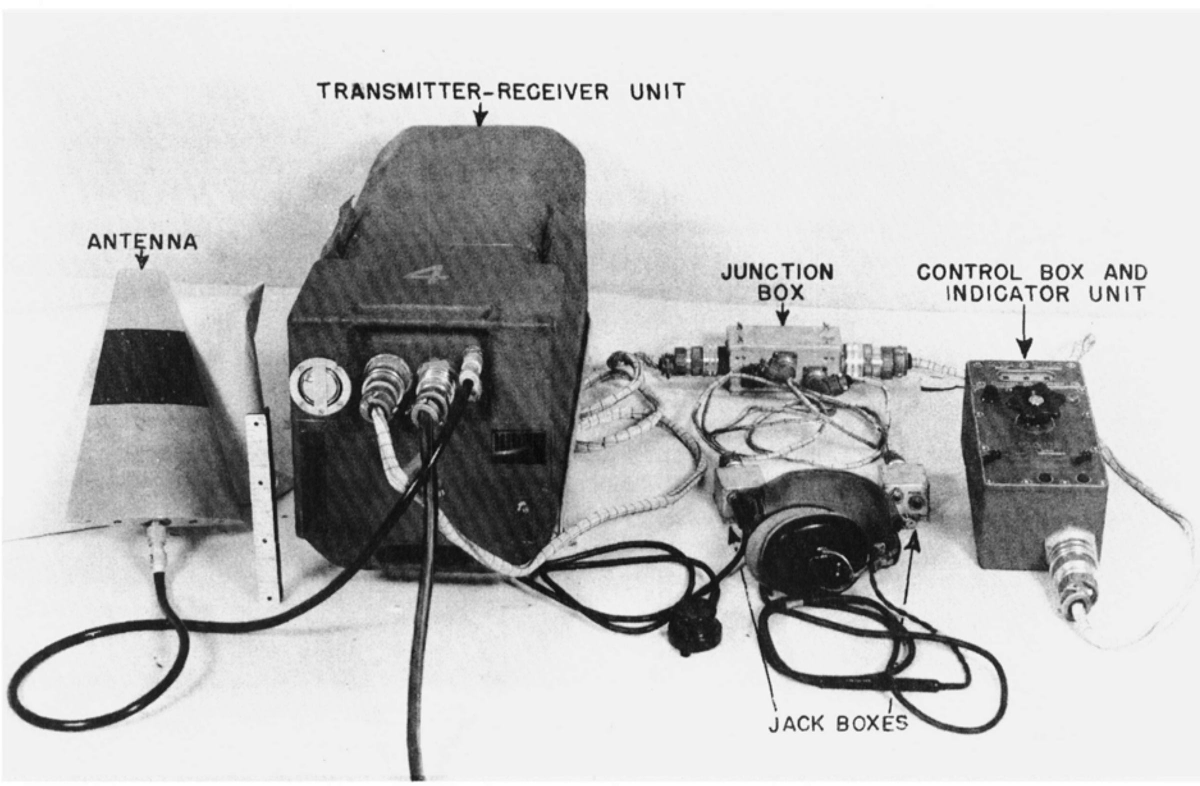


Figure 3.-Complete Equipment

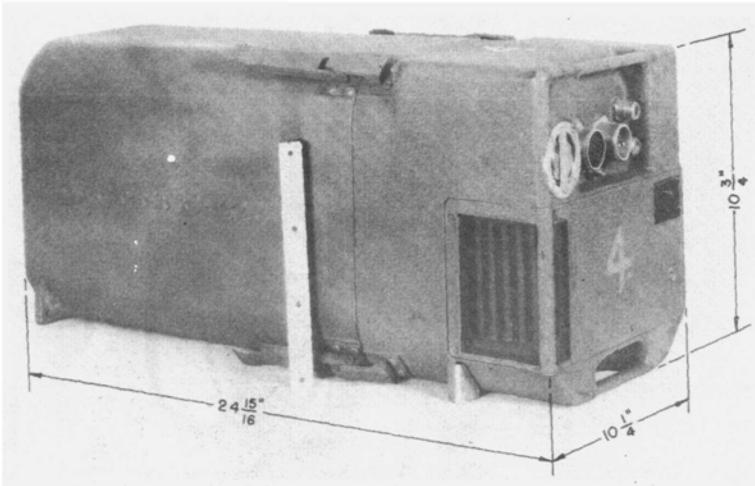


Figure 4.-Transmitter-Receiver Unit with Cover.

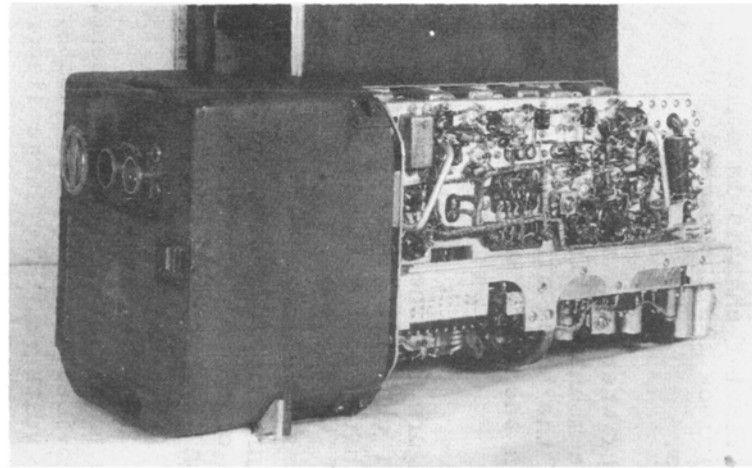


Figure 5.-Right Side with Cover Removed.

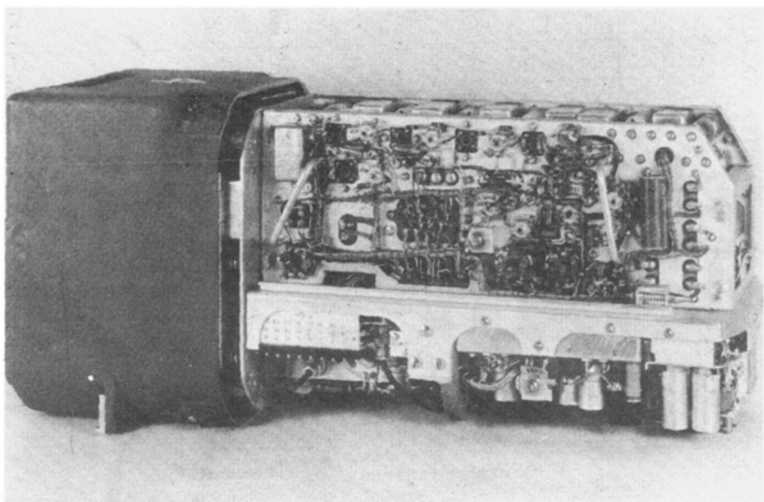


Figure 6.-Right Side with Cover Removed.

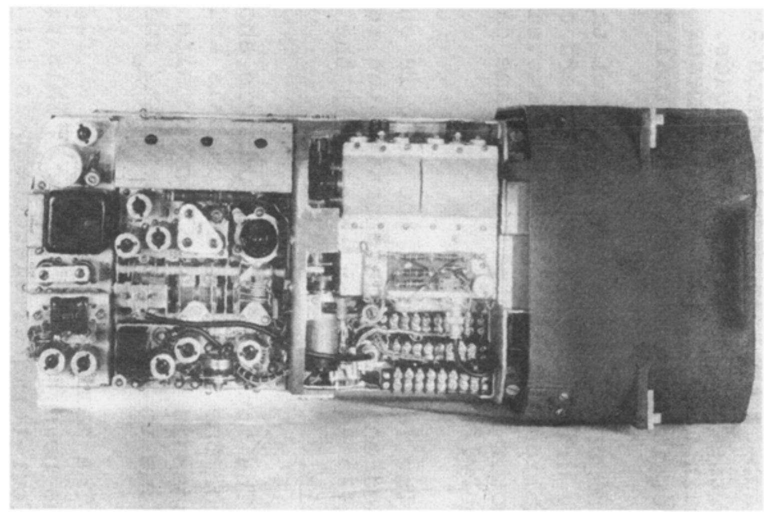


Figure 7.-Bottom View with Cover Removed.

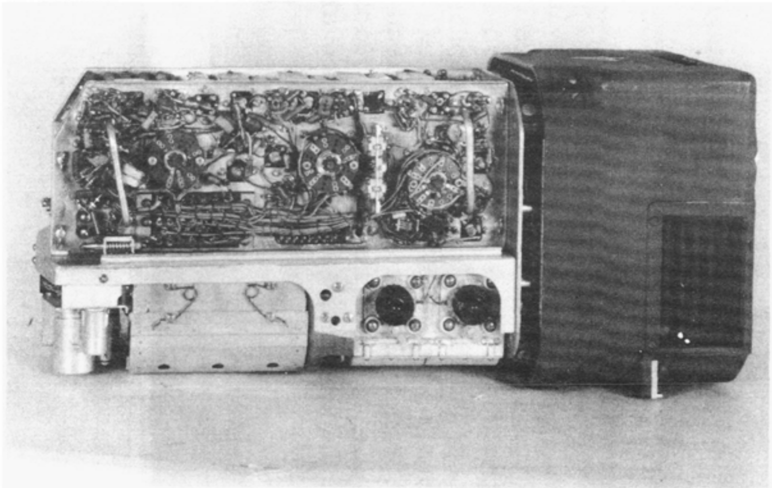


Figure 8.-Left Side with Cover Removed

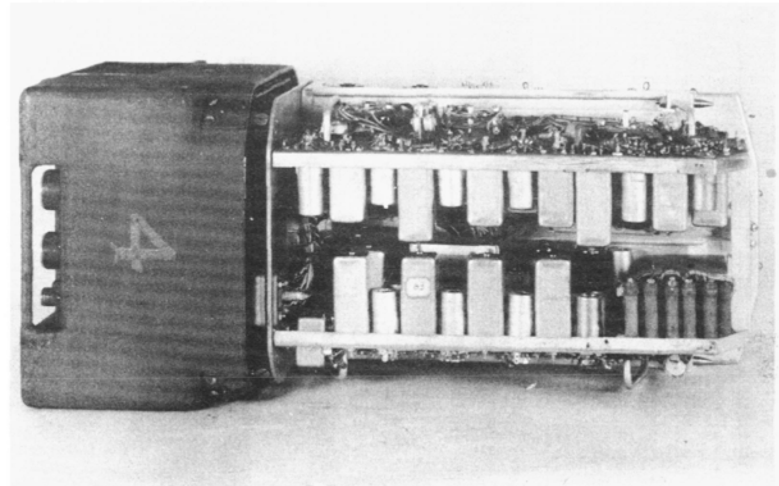


Figure 9.-Top with Cover Removed

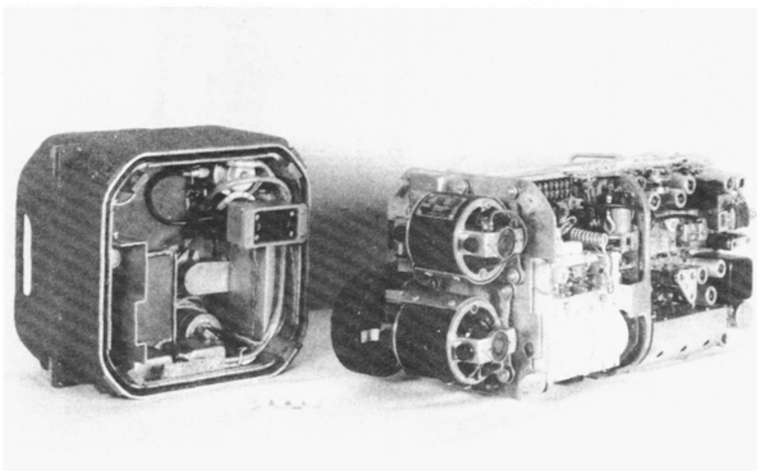


Figure 10.-Bottom with Head Removed

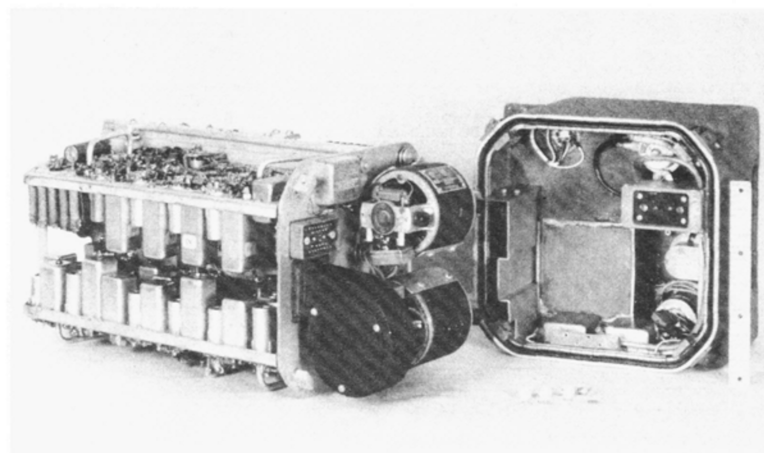


Figure 11.-Top, Head Removed

nect is for all electrical connections between the head and the main deck. The dynamotors are shock mounted on the bulkhead plate and the internal blower rotor is mounted on the receiver dynamotor shaft. This blower operates at all times that the equipment operates. Figures 10 and 11 show the head unit and the main deck separated to show the dynamotor disconnects and the method of mounting.

The heat exchanger is welded into the head unit. An internal blower circulates the air inside the case through the inner surfaces of the heat exchanger, while an external blower circulates the outside air through the external surfaces of the heat exchanger. The external blower is controlled by a snap-action thermostat mounted at the rear of the main deck. When the temperature of the air inside the case at the rear of the main deck reaches 40° C, voltage is applied to the external blower through the thermostat switch. The external blower and the external view of the heat exchanger are shown in Figure 12.

The altitude gain control is shown in Figure 12. This control is a plug-in unit and is held in place by a hinged strap which is fastened with a screw. A sensitivity control consisting of a screwdriver adjustment, is provided on the front panel. This control adjusts the screen voltage on the second stage of the i-f.

A power plug and the plug for connections to the control box are provided on the head. There are also two coaxial cable connectors provided. One of the coaxial connectors is for the antenna and the other is to permit the use of an AN/ARR-2 Homing Receiver on the same antenna. A filter is provided inside the head to prevent interference between the AN/ARC-19 (XN-1) and the AN/ARR-2 receiver. All plugs on the head are pressure tight.

A valve is provided on the head as a safety precaution to permit the release of any pressure inside of the case before opening the fasteners.

Figure 13 shows the interior of the head. The desiccant cartridge is shown in the air flow channel at the top of the figure. A filter box is shown mounted in the head at the bottom of the figure and housing is provided for the leads from the disconnect to the head and from the disconnect to the external plugs. The filter box is mounted by means of four screws. Individual filters are provided in this filter box for each external lead coming into the unit through the main plug. Separate filters are provided for the dynamotor input. In the lower right hand corner of this figure are the transmit-receive relay and the power relay.

The main channel receiver r-f circuits are shown at the top left in Figure 14.

Figure 15 shows the main deck with the monitor chassis and the receiver i-f chassis removed. There are two spring loaded guide pins mounted at the rear of the main deck which hold main deck in place when the cover shell is in position.

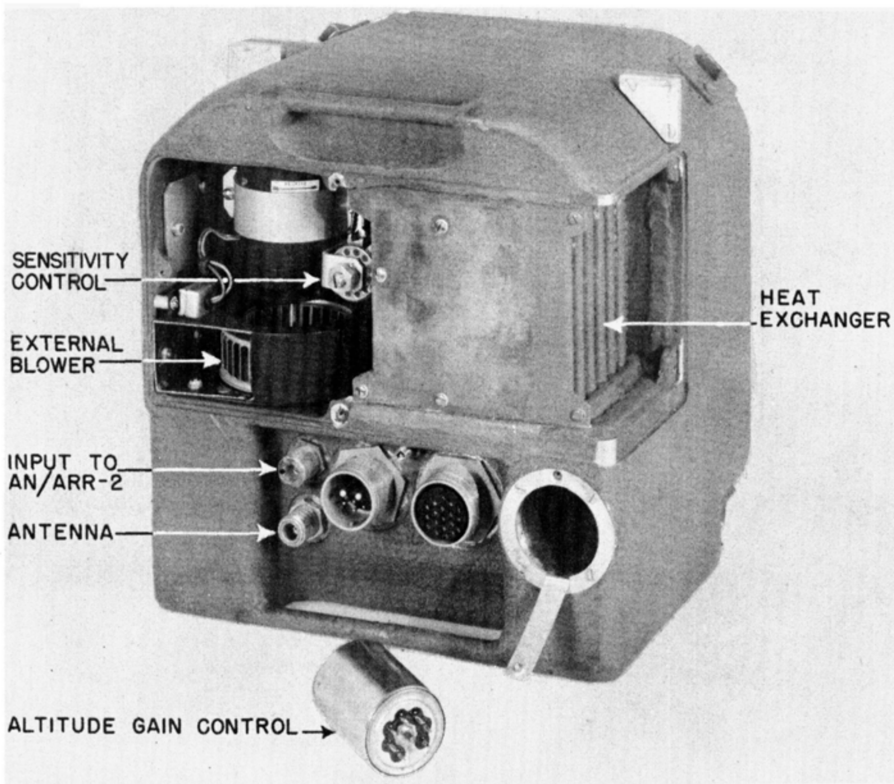


Figure 12.-Front View of Head Unit with Cover Plate Removed

Figure 16 shows the top view of the receiver i-f chassis. The disconnect is shown at the lower center of the chassis. Figure 17 shows a top view of the receiver i-f chassis with the relay box cover removed.

The wiring side of the receiver i-f chassis is shown in Figure 18. Handles are provided to facilitate removal of the chassis from the main deck. These handles also prevent damaging the components when the equipment rests on the wiring side.

The top view of the monitor chassis is shown in Figure 19. A similar view of the monitor chassis with the relay box cover removed is shown in Figure 20. The wiring side of the monitor chassis is shown in Figure 21.

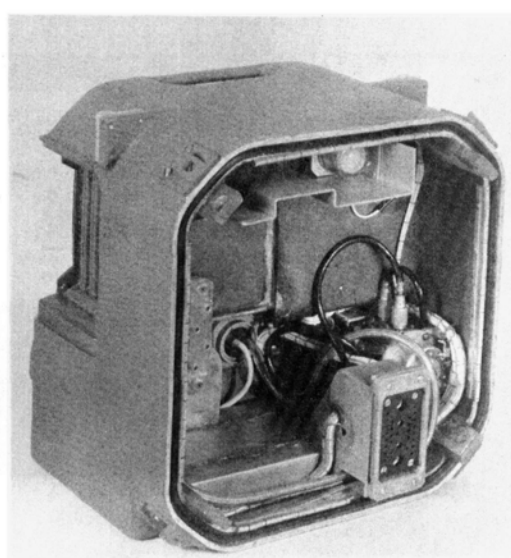


Figure 13.-Rear View of Head Unit with Cover Plate Removed

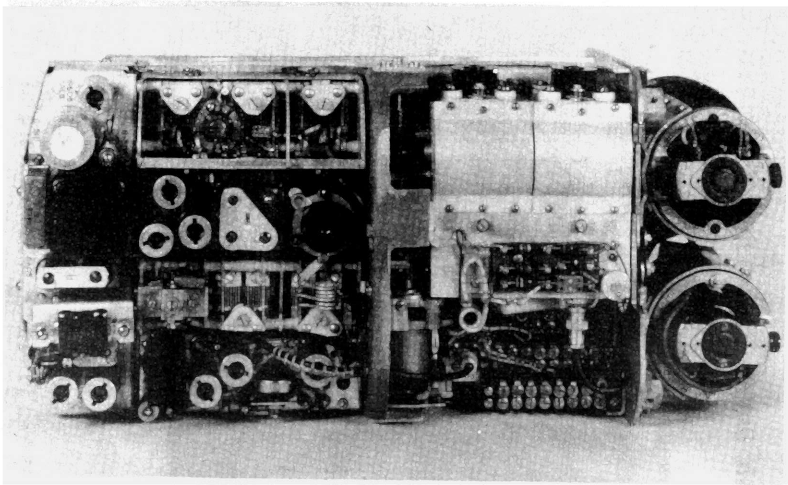


Figure 14.-R-F Deck

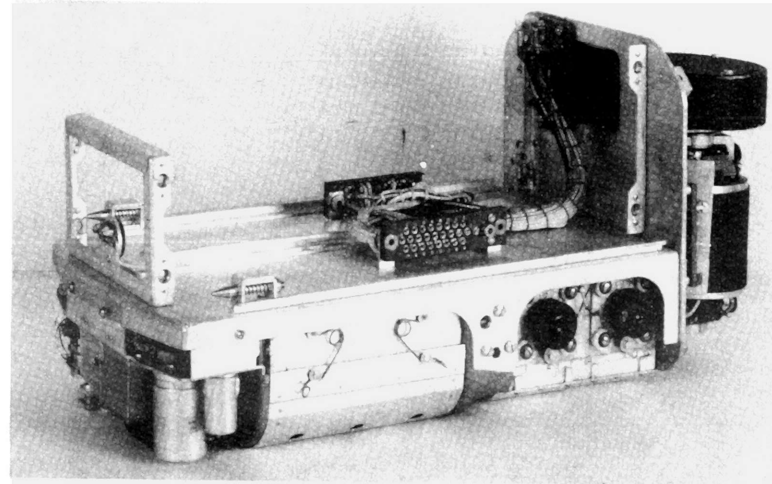


Figure 15.-Main Deck with Monitor Chassis and I-F Chassis Removed

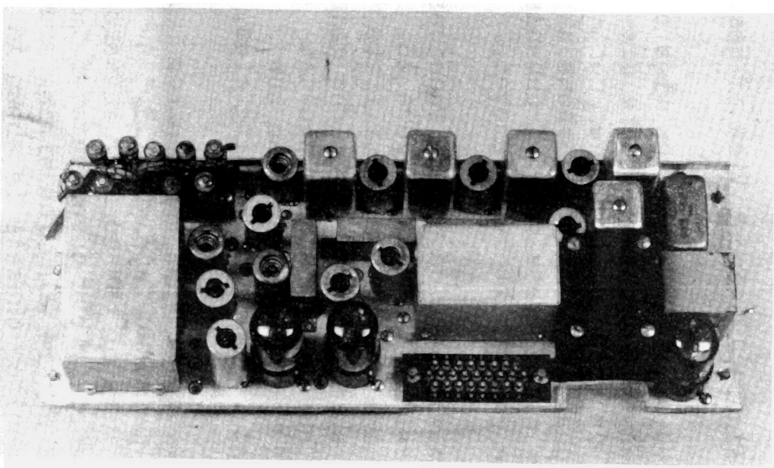


Figure 16.-Top View of I-F Chassis

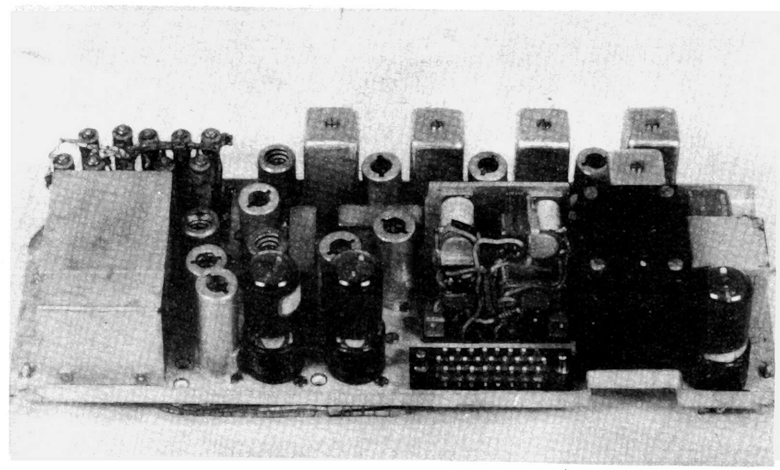


Figure 17.-Top View of I-F Chassis with Relay Box Cover Removed

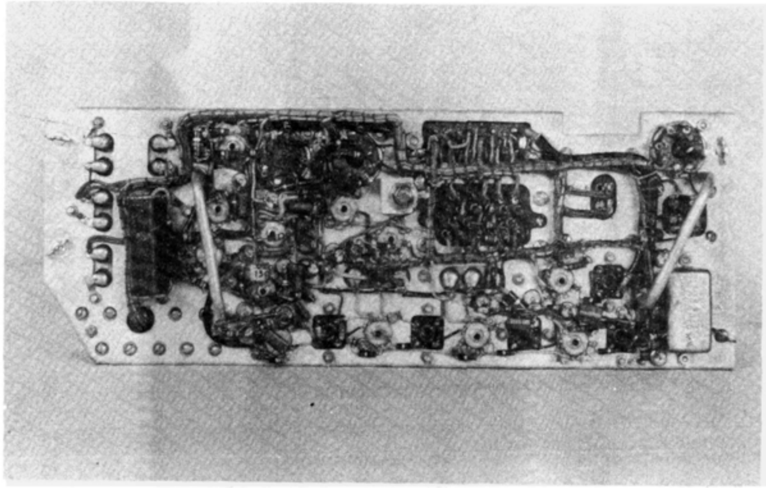


Figure 18.-Bottom View of I-F Chassis

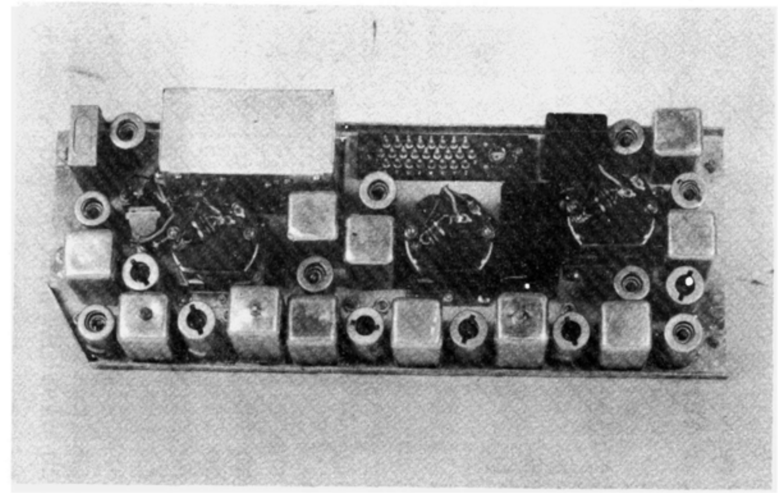


Figure 19.-Top View of Monitor Chassis

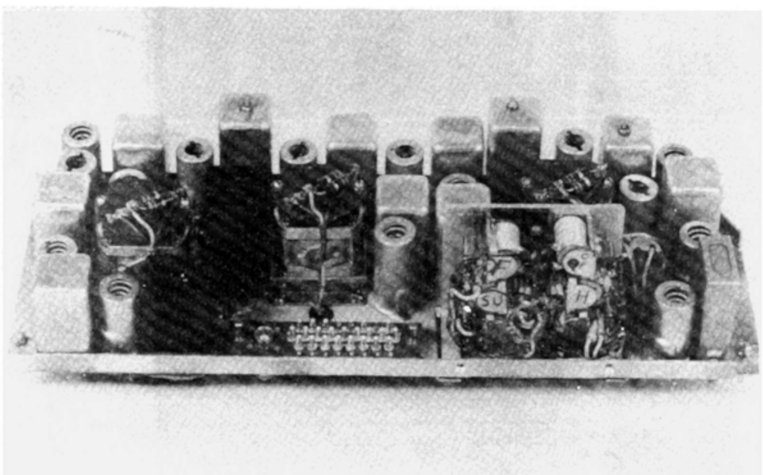


Figure 20.-Top View of Monitor Chassis with
Relay Box Cover Removed

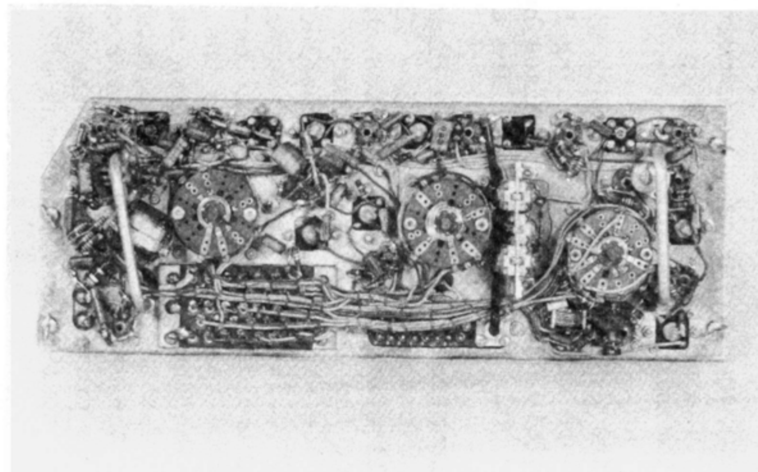


Figure 21.-Bottom View of Monitor Chassis

The guard channel and modulator are shown removed from the main deck in Figure 22. The guard channel is held in place by three screws. A sensitivity control consisting of a screwdriver adjustment, is provided on the guard channel. The modulator is held in place by four screws and is mounted at the rear on the main deck.

Figure 23 shows the main deck with the r-f circuits removed. The r-f circuits are mounted on the casting for the motor and tuning drive assembly. This complete unit is held in place by six screws. The underside of the modulator and the guard channel are shown in Figure 23.

The control box is shown in Figure 24 with the channel indicator attached. All 876 channels in the 225 - 400-Mc band are available at the control box at all times. Ten preselected channels are provided and may be selected by turning the knob until the number of the desired preselected channel appears in the window labeled "preselected channel." The actual channel number (100 to 999) is shown in the three windows of the channel indicator unit. A volume control is provided on the control box at the upper left hand corner. This control varies the input to the grid of the final audio stage in the receiver. The three-position switch at the lower left-hand corner labeled "main-guard-both" permits the operator to select the guard channel receiver output or the main channel receiver output separately or both simultaneously. A switch is provided to enable the operator to select voice or tone transmission or to turn the equipment off. A squelch disable switch and a ready

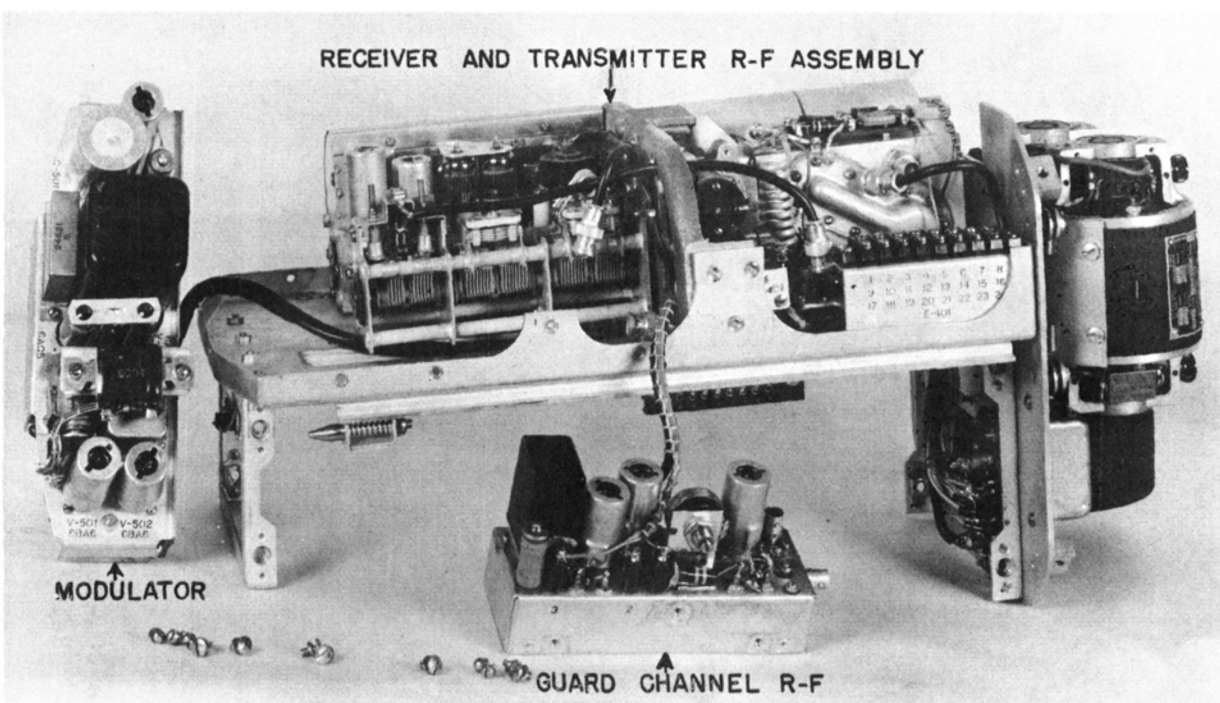


Figure 22.-R-F Assembly with Guard Channel Receiver and Modulator Unit Detached.

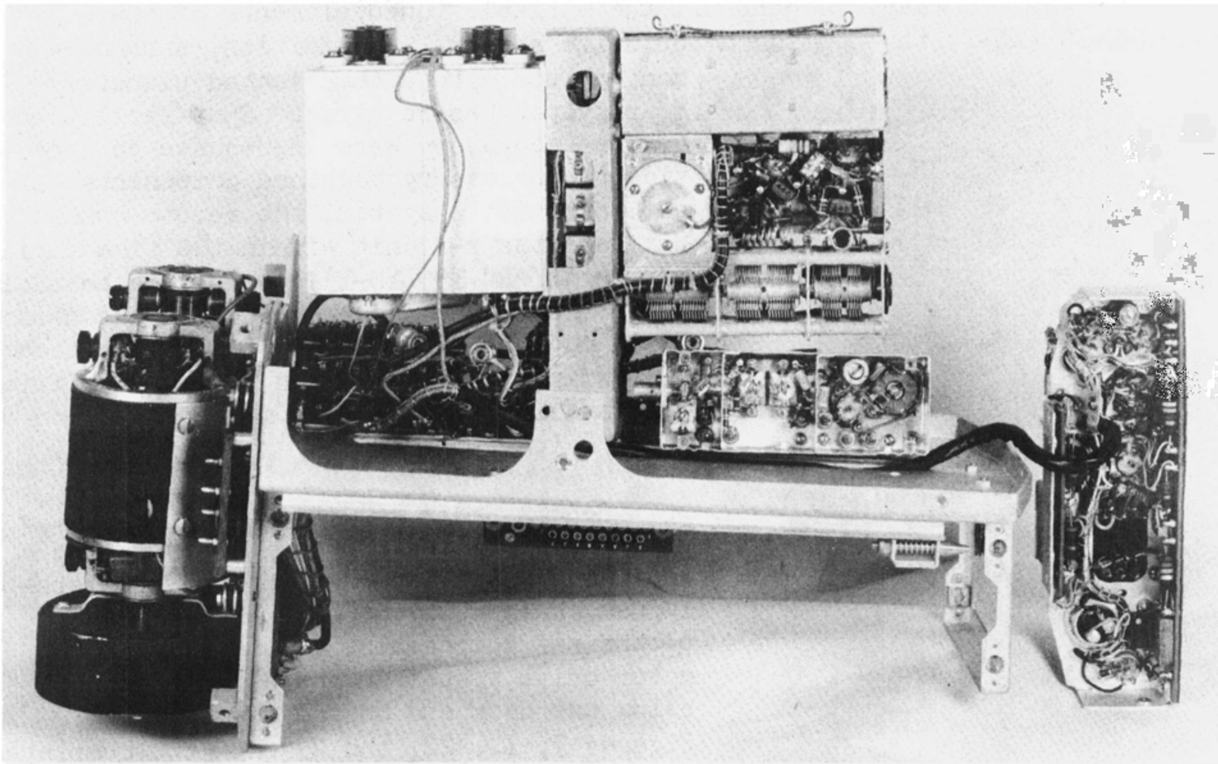


Figure 23.-Bottom View of R-F Assembly, Guard Channel Receiver, and Modulator Unit.

light test switch are provided.

The channel indicator is a separate unit and can be placed anywhere in the plane or several can be used at different positions if desired. Figure 25 shows the control box and the channel indicator unit separated. Both of these units were designed in such a way that they can be mounted in a console rack. The control box and indicator unit are pressure sealed and a desiccant cartridge is inclosed, see Figure 92.

TRANSMITTER DEVELOPMENT

The initial development of the AN/ARC-19 (XN-1) transmitter was conducted at the Laboratory and a unit was constructed breadboard style with each stage individually tuned. The original unit consisted of four stages: oscillator, first doubler, second doubler, and power amplifier. Lumped-constant circuits were utilized in the oscillator and first doubler stages, but cavity resonators were used in the second doubler and final amplifier stages.

The power output over the entire frequency band was well in excess of the specified minimum value. However, tracking problems had not yet been encountered since the circuits were individually tuned.

It was necessary to gang all the variable tuned elements of the AN/ARC-19 (XN-1) to a common motor drive system. In addition, a remote-control box with a complicated planetary gear system was required. Shop facilities of the Laboratory were inadequate to provide the necessary machined components of the motor drive system, the remote-control box, and the r-f unit within the time limit of the AN/ARC-19 (XN-1) development schedule. Hence, it became necessary to let a contract to an outside firm--Bendix Radio, Division of Bendix Radio Coporation, where facilities were available for the rapid construction of these units.

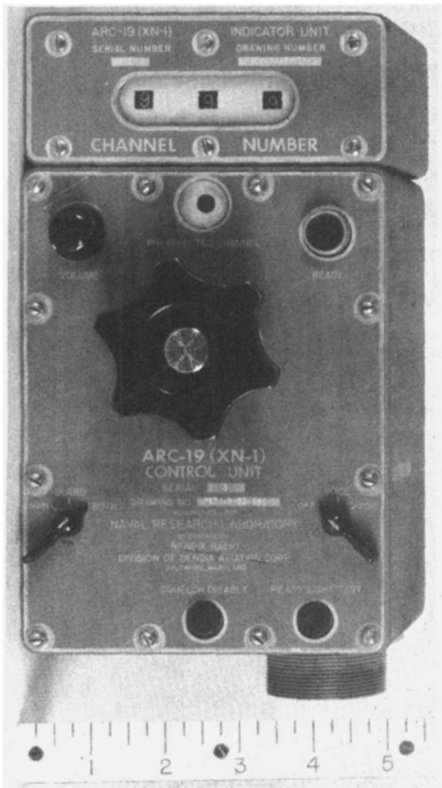


Figure 24.-Control Box and Indicator Unit

Bendix Radio redesigned the transmitter and constructed the variable condensers and the transmitter cavities. A completely new chassis layout was made to fit all of the r-f components, modulator, and the motor drive system in the allotted space below the deck and behind the bulkhead. Figures 7, 14, 22, and 23 show the completed r-f unit. The final design of the transmitter consists of the following r-f circuits and the corresponding tubes:

Master Oscillator	2 type 6C4's in push-pull
First Doubler	1 type 2C39
Second Doubler	1 type 2C39
Final Amplifier	1 type 2C39

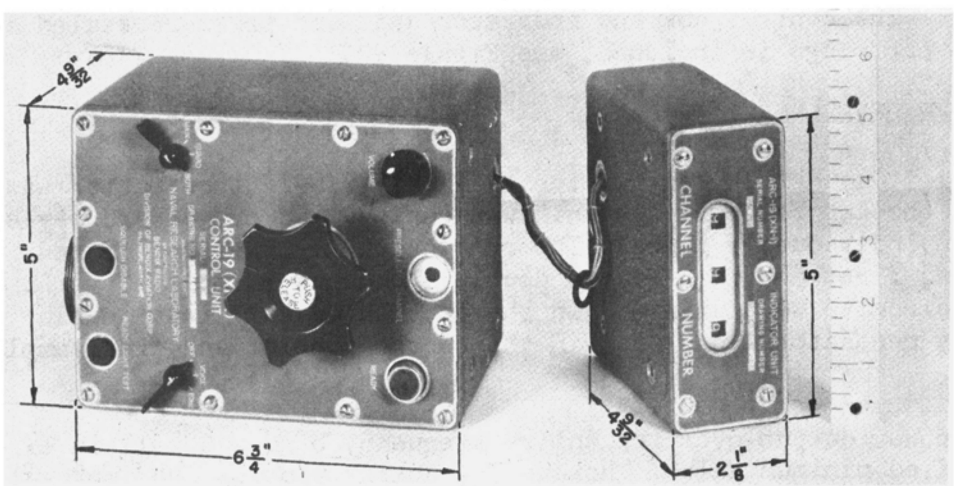


Figure 25.-Control Box with Indicator Unit Detached

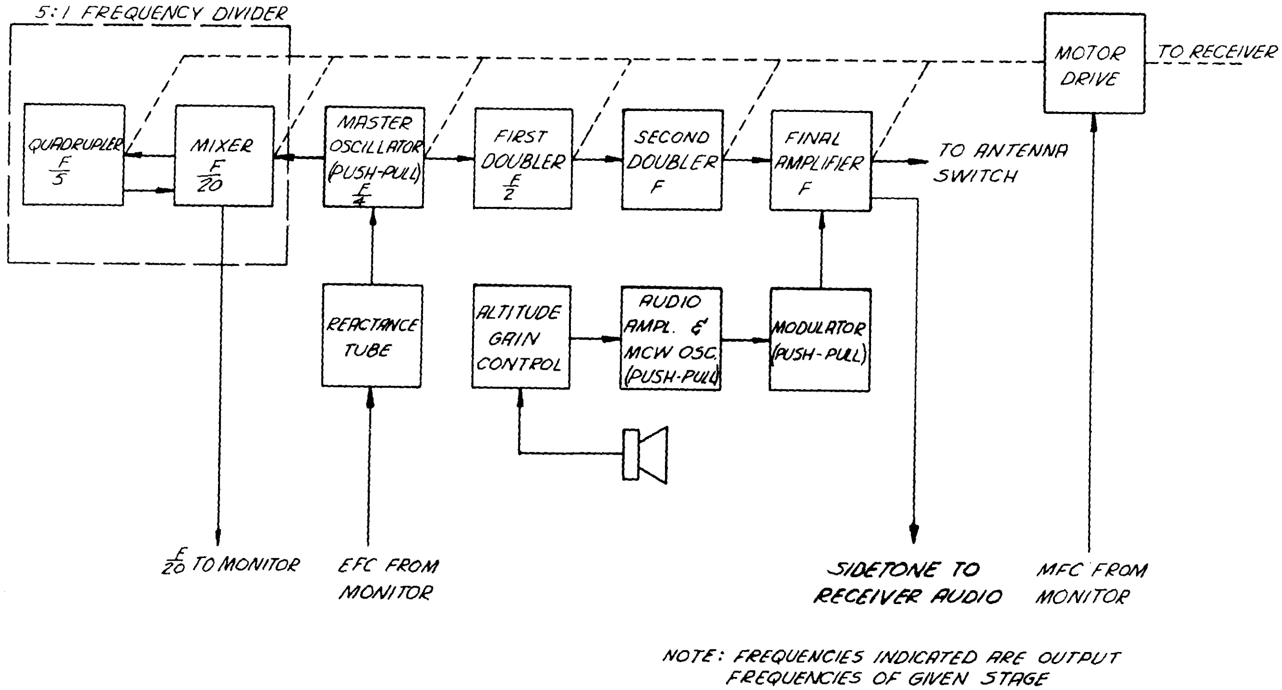


Figure 26.-Transmitter Block Diagram.

The modulator consists of the following circuits and tubes:

Amplifier (or tone oscillator)	2 type 6BA6 (in push-pull)
Modulator	2 type 6AQ5 (in push-pull)
Speech Limiter	1 type 6AL5

A block diagram of the transmitter is shown in Figure 26, and the schematic is shown in Figure 27.

The master oscillator and the first doubler circuits are tuned by a condenser gang having three dual sections. (The third section is used in the frequency divider circuit.) A separate condenser gang tunes the cavity resonators of the second doubler and final amplifier stages. Both variable condensers are coupled to the motor drive through a worm drive. The master oscillator is continuously variable by means of the motor drive, between 55 and 100 Mc, and the actual tuning is controlled by the monitor unit. A conventional push-pull circuit is used for the oscillator. Coupling from the oscillator to the first doubler state is obtained through a mica condenser. The first doubler is coupled by a coaxial cable to the second doubler which is mounted on another chassis. The output of the second doubler is loop-coupled to the cathode of the final amplifier which is loop-coupled to the antenna relay.

The modulator employs a push-pull amplifier and a push-pull modulator output stage. A double-diode connected to a secondary winding on the modulation transformer converts a small amount of the modulator output into a negative d-c grid bias for the amplifier stage. A positive delay voltage

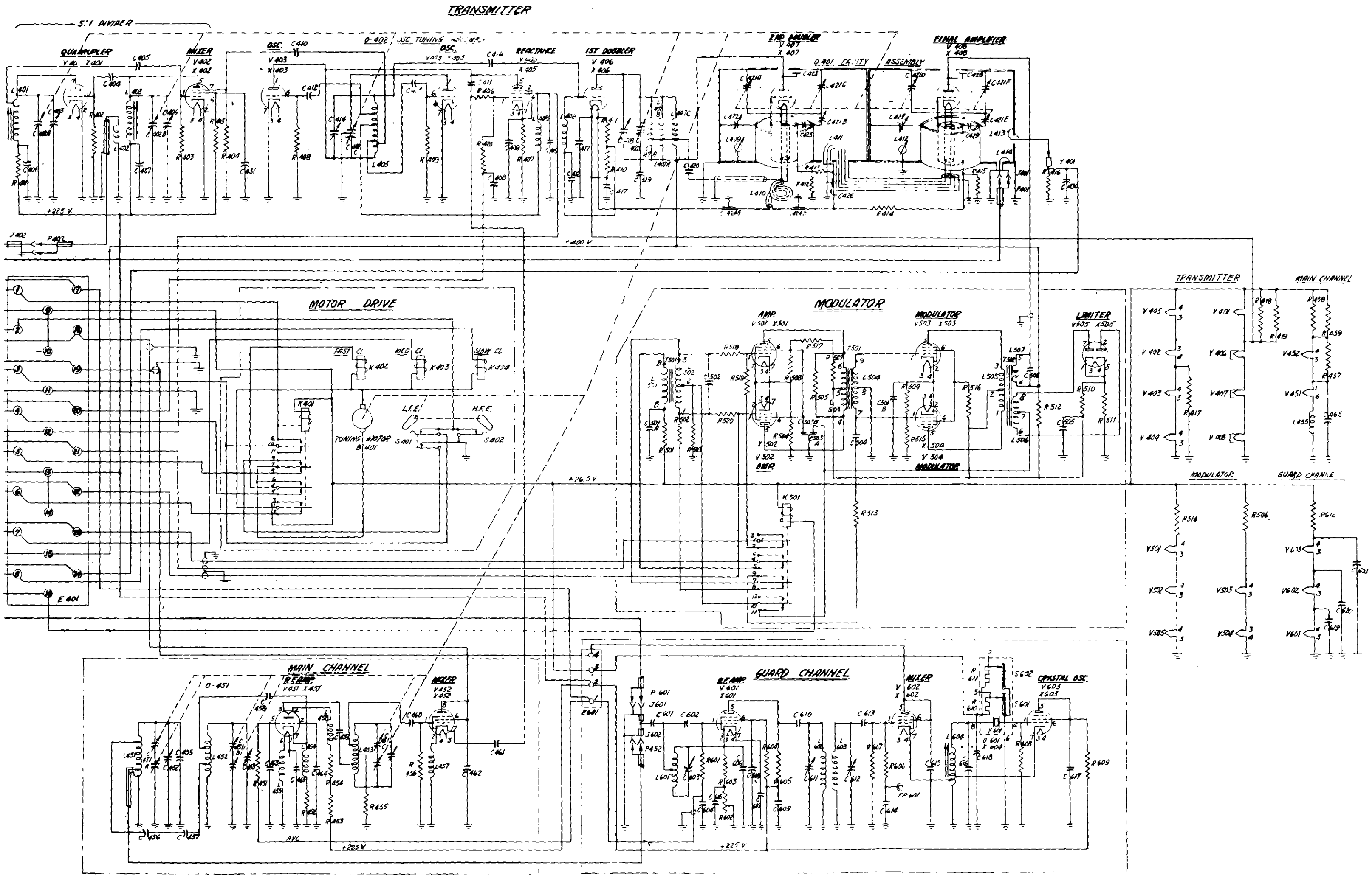


Figure 27.-Schematic Diagram of R-F Assembly

on the cathode of the rectifier was adjusted to a level which prevented a bias voltage from being developed until a predetermined modulation level was reached.

The above system permitted the use of a high gain modulator unit without producing modulation levels in excess of 100 percent. An aneroid control in the grid circuit of the modulator amplifier increased the amplifier gain with increase in altitude. However, the effect of the altitude gain control was greatest at low modulator input levels where the speech leveler had not yet caused reduction of modulator gain. The altitude gain control (Figure 12) is located in the head of the AN/ARC-19 (XN-1) unit where a change in external pressure will operate the bellows to produce a change in potentiometer setting.

RECEIVER DEVELOPMENT

The AN/ARC-19 (XN-1) equipment was designed to receive signals on any main channel, on the guard channel, or on both channels simultaneously. Tentative specifications required a sensitivity of 5 microvolts with a signal-to-noise ratio of six decibels when using a 30-percent modulated input signal. It was necessary to provide a flat receiver bandwidth of at least 60 kc while maintaining a 140-kc bandwidth at the 80-decibel level. It was possible to simplify the design of the monitor unit by using a low frequency i-f. Since with a low intermediate frequency no image rejection could be realized in the r-f circuit, it was decided to locate the image between the operating frequency and the next adjacent channel. This choice predetermined the center frequency of the i-f to be 45 kc as shown previously in this report.

An i-f amplifier was designed and constructed to meet the bandwidth requirements. Overall dimensions were 4" x 5" x 18", and the weight was 10 pounds. It consisted of three i-f stages coupled into a conventional diode detector. The detector was followed by a Wasmansdorf-type noise limiter, and audio filter. The additional audio circuits included a squelch tube and a power amplifier which fed into two 600-ohm headsets in parallel. A delayed AVC system was also included. The i-f stages were coupled with band pass filters composed of one and one-half sections of constant "K" and a half section of series "M" derived to hold constant input impedance over the pass band of 15 to 75 kc.

Operation of the composite i-f audio strip showed that inherent deficiencies would prevent its use in the AN/ARC-19 (XN-1) receiver. Microphonics presented a serious problem in the design of such a low-frequency i-f system. Distortion of the i-f carrier was severe since harmonics up to the fifth were passed without attenuation when the i-f carrier frequency was near the low-frequency end of the pass band. Carrier distortion was excessive even at 45 kc. Although the modulation distortion was not excessive, the effective modulation percentage was increased with increase in input signal through the i-f amplifier until a one-volt 30-percent modulated signal at the input became a 100-percent modulated signal with excessive distortion at the detector. The i-f carrier distortion began at about 5000 microvolts and became increasingly worse at higher input levels.

Since the i-f carrier could be as low as 15 kc it was imperative to include an audio filter to prevent this low frequency from overloading the audio amplifier. At such a frequency the filter components were physically large and the size and weight were prohibitive for a compact airborne unit of this type. Similarly, the components in the i-f filter units were large and could not be easily constructed in compact form.

The overall transient response was poor due mainly to the ringing of the complicated audio filter. However, the transient response of the i-f stages alone was fair and the i-f would pass a 300-cps square-wave modulated signal with very little distortion.

The many defects of the 15-to 75-kc i-f pass pand led to the choice of a higher center frequency where the defects could be overcome. Since the monitor design required that the i-f be kept at a low frequency, the next higher usable frequency was calculated to be 143.3 kc. The derivation has been shown previously. This frequency was determined as the one which will cause the image frequency to fall between the adjacent channel (n+1) and the next adjacent channel (n+2), yet maintain equal attenuation ratios on both sides of the i-f selectivity curve. It was again necessary to provide a bandwidth of 60 kc at the 6-decibel points and 140 kc at the 80-decibel points.

A model was designed and constructed. The circuits included three stages of i-f amplification, a diode detector, a delayed AVC, a noise limiter, a squelch, and an audio amplifier. All but the i-f stages were similar to the first model. The overall dimensions of this model were 2" x 3" x 14½", and the total weight was 2.55 pounds. The decrease in size and weight from the original model was appreciable.

The i-f transformers are triple-tuned. The transformer design lent itself to small size and the transformer could be conveniently mounted in a shield can 1½ inches in diameter and 2 inches high.

The operation of this i-f amplifier at high input levels was considerably better than the lower frequency one described previously. Here the i-f center frequency was high enough that under no condition could harmonics of the i-f carrier be passed by the amplifier without attenuation. This allowed operation with signal input levels of two volts without serious distortion of the modulation. The modulation percentage did not increase as rapidly as in the 45-kc i-f and would allow the operation of a clipping noise limiter in the audio circuit to function satisfactorily over a much wider range of inputs. The frequencies within the i-f bandwidth were considerably higher than the highest audio frequency and could be filtered at the detector with a simple resistance-capitance circuit.

The main cause of the poor transient response had been eliminated in this design; hence, the overall transient response was good.

Microphonics were eliminated since the i-f frequency was considerably above the lower frequency band in which microphonics were prevalent.

A model of the guard channel receiver was designed and constructed at the Laboratory. The entire r-f portion, including oscillator-tripler, doubler, mixer, and r-f amplifier was mounted on a chassis 1-3/4" x 2-3/4" x 7¼". A sensitivity of five microvolts was obtained with a signal-to-noise ratio of six decibels. The mixer stage was a push-pull circuit, but the other stages were conventional circuits. The primary difficulty was that of excessive radiation from the oscillator and multiplier circuits. Otherwise the guard channel operated satisfactorily.

Construction of the r-f section of the main channel receiver was not completed by the time a contract was awarded to Bendix Radio, Division of Bendix Aviation Corporation.

The r-f portions of the receiver were redesigned and constructed by the contractor under the contract which included all r-f circuits. The i-f, a-f, and voltage-regulator circuits were designed and constructed at the Laboratory.

The tube complement of the receiver is as follows:

Main Channel r-f Amplifier	6F4
Main Channel Mixer	6AK5
Guard Channel r-f Amplifier	6AK5
Guard Channel Mixer	6AK5
Guard Channel Oscillator	6AK5
Main Channel 1st i-f Amplifier	6AK5
Guard Channel 1st i-f Amplifier	6AK5
Second i-f Amplifier	6AK5
Third i-f Amplifier	6AK5
Detector and Noise Limiter	6AL5
First a-f Amplifier	6AK5
a-f Output	25L6
AVC Diode and Squelch Diode	6AL5
Rough Regulator	6J6
Squelch d-c Amplifier	6AK5
Squelch and Radio Relay	6J6
Gas Regulator (150V)	OA2
Regulator d-c Amplifier	6AK5
Regulator (150V)	25L6
Regulator (150V)	25L6

The receiver block diagram is shown in Figure 28, and the schematic is shown in Figure 29.

The main channel receiver is tuned by a three-gang condenser composed of three dual sections. Two of these were incorporated in the input circuit of the r-f stage while the other section was used in the input of the mixer stage. The mixer tube is a pentode but the plate and screen were connected together to provide triode operation. The mixer circuit is unusual in that subharmonic injection is used. The oscillator voltage is obtained from the master oscillator and applied directly to the mixer cathode across an r-f choke. The r-f signal input applied to the control grid is mixed with the

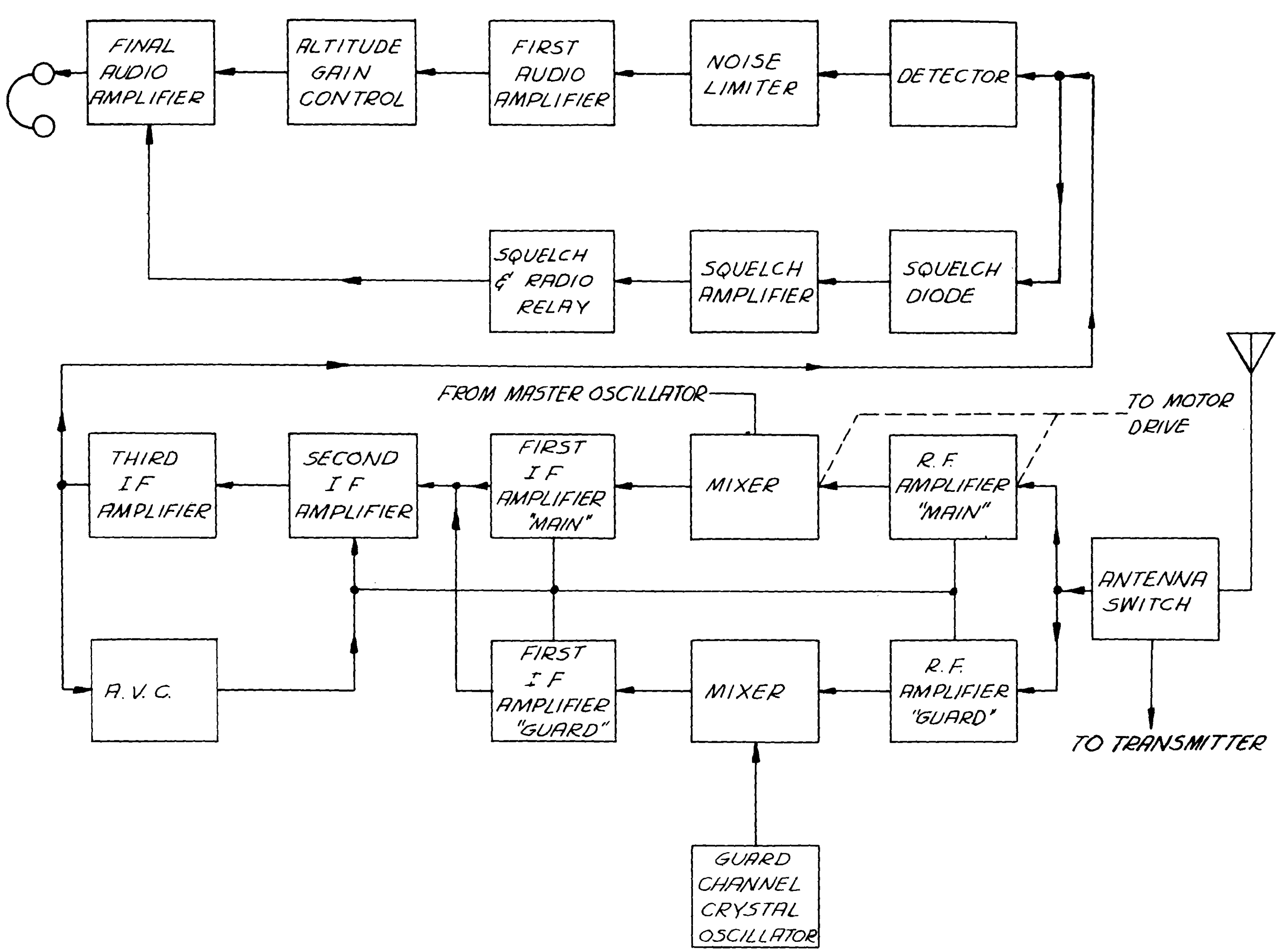


Figure 28.-Receiver Block Diagram

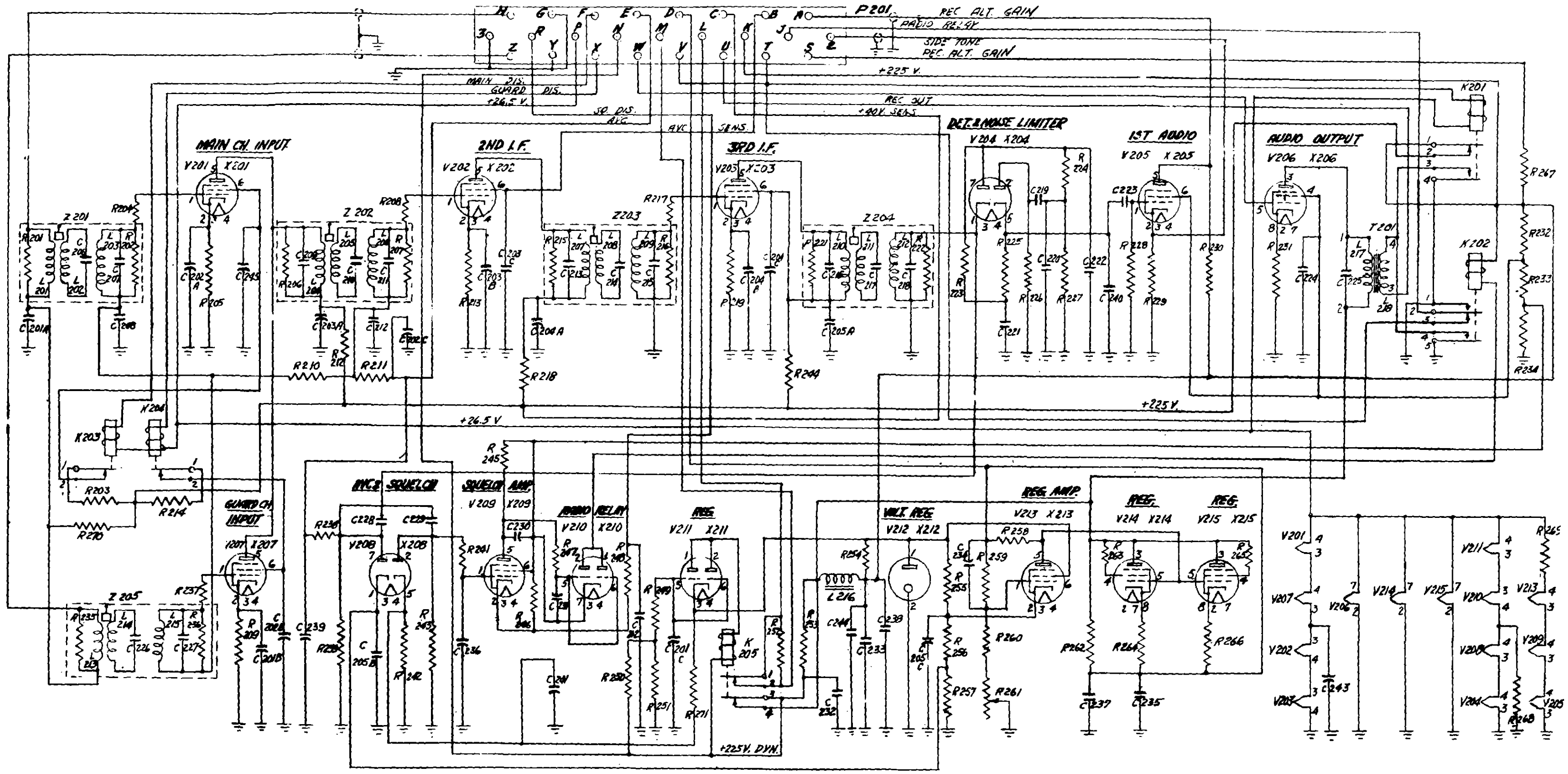
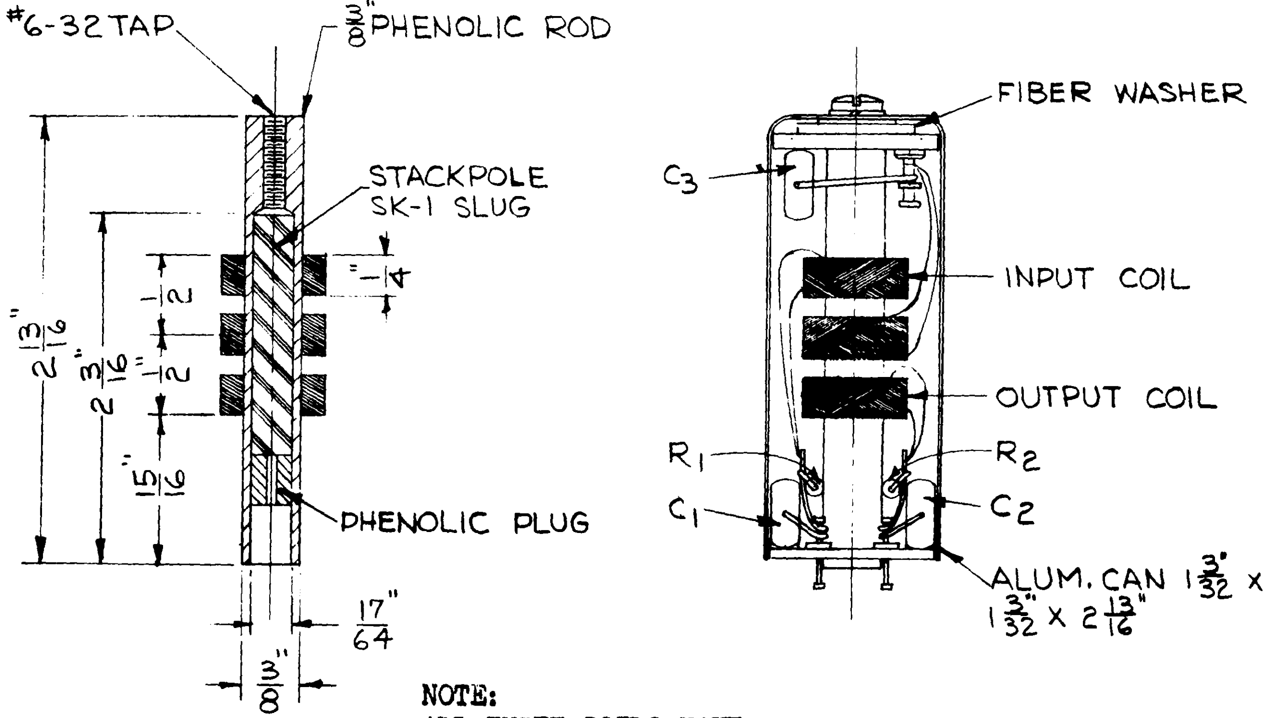


Figure 29.-Schematic Diagram of I.F. and Filter Assembly

fourth harmonic of the oscillator frequency to provide the i-f difference frequency. The fourth harmonic of the oscillator frequency may be above or below the channel frequency by the i-f of 143.3 kc, depending upon the channel number. Subharmonic injection was found to produce a better signal-to-noise ratio than when using a conventional mixing frequency.

The guard channel is fixed-tuned, but may be trimmed over the frequency range of 275 to 285 Mc by a screwdriver adjustment of trimmer condensers. It is necessary to use a crystal oscillator with a crystal oven to provide a sufficiently stable local oscillator signal to the guard channel mixer. The crystal must be changed in order to change the guard channel frequency. Subharmonic injection is used in a circuit similar to the main channel mixer, but the sixth harmonic of the crystal oscillator frequency is used in the mixing action.

Both main and guard channel mixer stages are coupled to separate first i-f stages through triple-tuned transformers. The i-f consists of three stages, the second and third stages being common for both r-f inputs. Triple-tuned transformers are used as coupling between i-f stages and as coupling from the last i-f to the detector. The coil construction as shown in Figure 30, is identical in each of the triple-tuned stages. The transformers were fixed-tuned before assembly, then covered with three coats of Glyptol baked on separately.



NOTE:
ALL THREE COILS HAVE
520 TURNS #39 SSE,
3/8" I.D., 1/4" CAM
3.4 MH WITHOUT IRON CORE

Figure 30.-I-F Transformer Assembly

A low frequency iron slug insures overcoupling of the coils and permits mounting in a small size shield can. The input and output transformers differ slightly from the interstage transformers. The input transformers have across the input coil a condenser of such size that the total capacity of the mixer output circuit, the cable, and the condenser will equal that value used on the other transformers. The output transformer differs electrically from the interstage transformers only in the resistor loading of the coils. The input and output coils of each transformer are loaded with one-half watt carbon resistors.

The i-f output stage is connected to three diodes. Coupling is made to the cathode of the detector tube, and to the plates of the squelch and the AVC diodes to divide the loading to each half of the modulation envelope.

The audio circuits which follow the detector consist of a Wasmansdorf series diode-type noise limiter, an audio amplifier, and a power amplifier. The output transformer is matched to a 300-ohm load which would be approximately equal to the load of two headsets in parallel. A pressure operated aneroid gain control forms a part of the plate load of the a-f voltage amplifier and causes a six-decibel increase in the voltage supplied to the grid of the power amplifier when the ambient pressure changes from that at sea level to that at 30,000 feet. The grid circuit of the power amplifier contains the audio volume control potentiometer.

The AVC diode is operated with a delay voltage of ten volts to prevent the reduction of receiver gain at the low input levels. To prevent feedback difficulties, the AVC circuit impedance was reduced. The AVC bias voltage is applied to the grid circuits of the r-f amplifier and the first and second i-f stages.

The output of the squelch diode is amplified through a d-c amplifier and fed to the grid of the squelch tube. If the grid voltage is sufficient to overcome the positive cathode bias voltage, the tube will be brought into conduction and the plate circuit relay will be energized. A squelch disable switch in the cathode circuit of the d-c amplifier opens the cathode and prevents the flow of current in this tube. In this case the squelch tube has sufficient positive grid voltage to cause the plate circuit relay to be energized. The relay has two functions; squelch action and radio relay operation. The low side of the audio output transformer is connected to one contact of a S.P.S.T., normally open set of contacts. The other is grounded. When the relay is energized the contacts close, the audio circuit is completed to ground, and the audio signal may be heard in the headset.

Radio relay operation may best be described by reference to Figure 31. When two AN/ARC-19 (XN-1) equipments are located in one aircraft, the radio relay may be used. It is required that four leads be coupled between unit # 1 and unit # 2 as shown in Figure 31. It is necessary that the remote boxes be set for voice operation and that unit # 1 and unit # 2 be on different channels. The radio relay may then serve as a link between two stations and increase the range of communication considerably over line-of-sight distances.

A S.P.D.T. set of relay contacts are used for radio relay control. Any signal of sufficient strength to cause operation of the relay will ground the radio relay lead. If the relay of unit # 1 is energized and the radio relay lead grounded, the T-R mic lead of unit # 2 will be grounded and this unit will transmit. The receiver unit # 1 audio output supplies the modulation for the transmitter (unit # 2). Once unit # 1 has received a signal and relay K202 has closed, unit # 2 will continue to transmit until the message has been completed and relay K202 of unit # 1 again is opened. The possibility of receiver noise closing the relay K202 in unit # 2 has been eliminated by removing the plate and screen voltages from the i-f amplifier during transmission. Hence, no irregular control operation is anticipated. The reverse operation is similar to above. Unit # 2 may receive a signal and cause unit # 1 to transmit.

R-F DIVIDER DEVELOPMENT

The r-f divider is incorporated in the equipment to reduce the oscillator frequency by a factor of five so that the master oscillator frequency range of 55 to 100 Mc becomes 11 to 20 Mc at the divider output. The divider consists of two stages which are ganged and tuned with the master oscillator. The tuning condensers are mounted on the same condenser gang with the master oscillator and first doubler stages.

The mixer tube of the divider circuit (V402) is Type 6AS6 and the master oscillator output is condenser coupled to the supressor grid of the mixer tube. The plate of the mixer is tuned to a frequency which is one-fifth of the master oscillator frequency by a circuit composed of inductor L403, tuning condenser C402B, and capacitive trimmer C406. Output from this tank circuit is capacitively coupled to the grid of a quadrupler tube V401 which is a triode, Type 6J4. The plate circuit of the quadrupler is tuned to four times the input frequency or four-fifths of the master oscillator frequency by inductor L401, tuning condenser C402A, and capacitive trimmer C403. This plate tank frequency is fed back to the control grid of V402 through C405. This input of four-fifths the master oscillator frequency combines with the master oscillator frequency to produce a difference frequency of one-fifth the master oscillator frequency. The divider output is obtained by link coupling to inductor L403. The coils of both mixer and divider plate circuits may be tuned by iron slugs for tracking and alignment purposes.

R-F DIVIDER, TRANSMITTER, AND RECEIVER ALIGNMENT

R-F Divider

The r-f divider must be properly aligned so that the tuned circuits track at one-fifth and at four-fifths the master oscillator frequency. Before the alignment procedure can be started on an equipment, the motor drive mechanism must be disabled. This is done by disconnecting the clutches which is done by removing the leads from terminals 4, 7, and 8 of the terminal strip, located on the r-f deck, and by unsoldering one lead from the motor. In addition, the EFC lead must be grounded. Before power is applied to the equipment the motor driven condenser gangs must be returned to the low-frequency end of the band in order to operate the low-frequency limit switch.

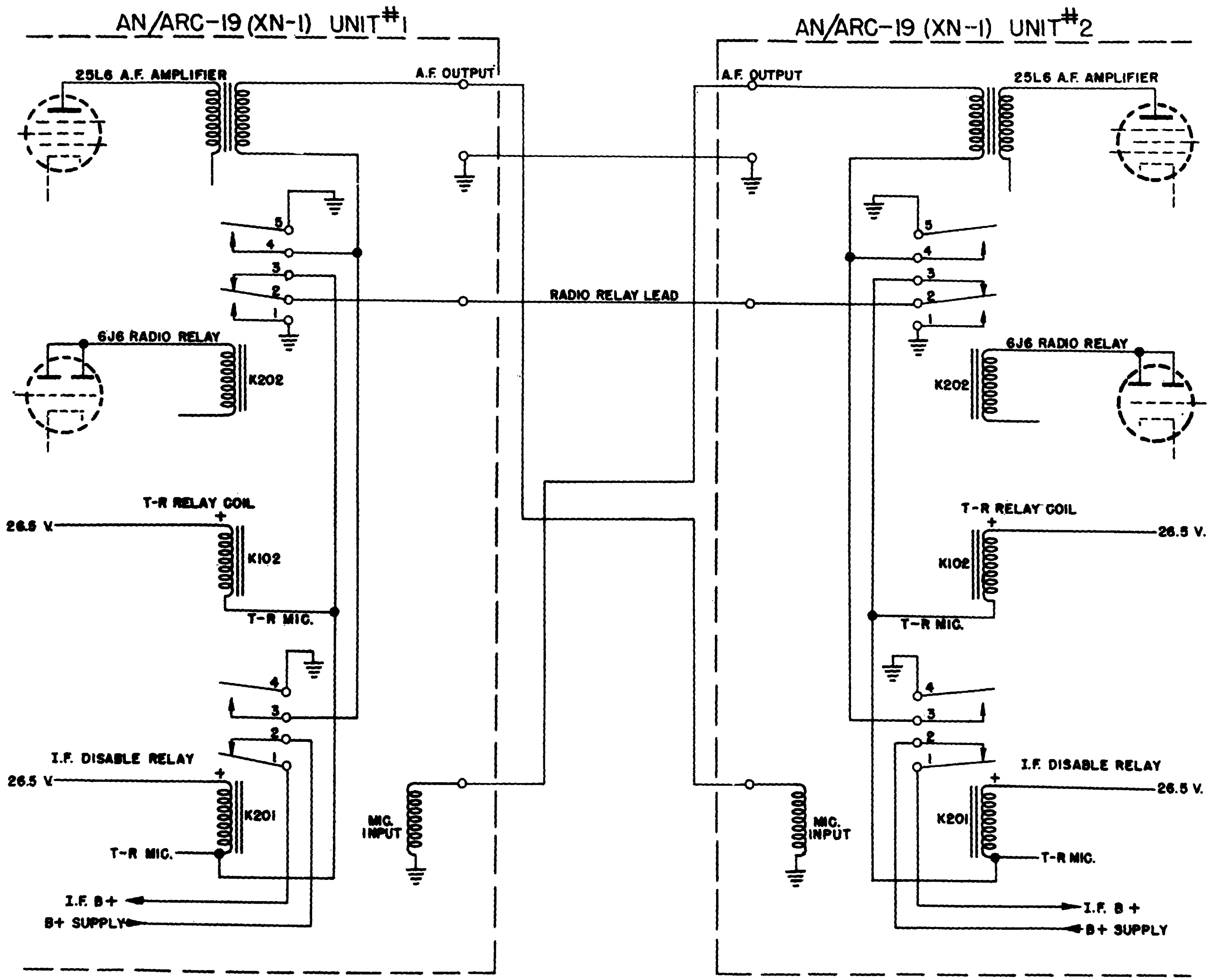


Figure 31.-Simplified Schematic of Radio Relay

A hand crank may be attached to the main shaft of the motor drive system for this purpose. Power is then applied and after tube warm-up the shaft is rotated to set all condenser gangs to the high-frequency end of the tuning range. Tuning the condenser gangs to the high-frequency end of the band after energizing the low limit switch will cause the H and T steppers in the monitor to step to their finish positions. The steppers must be in this position to cause voltage to be applied to the receiver i-f and to permit the transmitter dynamotor to be operated by the mic button. A G.R. Type 726A Vacuum Tube Voltmeter is connected to the link output coupling of the divider mixer stage, and an oscillograph is connected across filter Z310 in the monitor unit.

Adjustment of the capacity trimmers C403 and C406 is made for a peak reading on the voltmeter. The motor drive is then returned to the low-frequency end of the tuning range and inductive trimmers L401 and L403 are adjusted for maximum voltmeter reading. At this point the divider output is temporarily shorted to determine if the divider will go into operation the instant the short is removed. If not, the inductive trimmers must be readjusted until the divider operates the instant the short is removed. Next, rotate the motor drive shaft to tune through the entire frequency range and observe that the voltmeter reading remains in excess of 1.5 volts and that there is a signal present at all times on the oscillograph presentation. If the divider output drops out at any frequency in the range, it is necessary to make slight adjustments of the oscillator tuning to provide tracking of the oscillator and divider circuits. It might also be necessary to replace aged first doubler, master oscillator, or divider tubes to prevent loss of divider output.

Transmitter

Alignment of the transmitter may be made after the frequency divider and master oscillator circuits are aligned and tracked over the required range as previously described. The transmitter is first set to the high-frequency end of the band where the capacitive trimmers of the first doubler (V406), second doubler (V407), and final amplifier (V408) are adjusted in that order for maximum power output. The equipment is then cycled to a low-frequency channel where the inductive trimmers of the second doubler and final amplifier are tuned for maximum power output. It is necessary to observe the output at several intermediate points in the frequency band to insure that the tracking is satisfactory. If it is not, and low power output is observed at some intermediate point in the frequency band, the inductive and capacitive trimmers must be readjusted until the tracking is satisfactory.

Receiver Alignment

The antenna input, r-f amplifier grid circuit, and the mixer grid circuit of the main channel receiver must be aligned for proper operation. The i-f stages are fixed-tuned and require no adjustments. The only adjustment required in each r-f circuit is that of a single trimmer condenser. The equipment is set at the high-frequency end of the band. A signal generator is fed to the antenna input and tuned to the frequency of the receiver. The capacitive trimmers of the r-f tank circuits are adjusted for maximum receiver audio output. The signal generator output must be kept as low as practicable during the trimming procedure. The signal generator should be retuned and the trimming adjustments repeated.

Alignment of the r-f unit of the guard channel receiver is similar to the above method. The trimmers are in different circuits but the method of alignment is the same as above. However, it is necessary to adjust L604 of the crystal oscillator tuned circuit until maximum d-c voltage is read at test point TP601. Then L604 is adjusted to the gentle slope side of the resonance curve until approximately three-fourths of the maximum d-c voltage is observed at the test point. This completes all receiver adjustments.

POWER SUPPLY

A block diagram of the power supply system is shown in Figure 32. Two separate dynamotors, located in the head of the equipment case, provide supply voltages of approximately 225 volts for the receiver and monitor, and approximately 400 volts for the transmitter and modulator. Also located in the head of the equipment case are the main power relay and the T-R relay for operating the receiver dynamotor and transmitter dynamotor, respectively. All leads of the external cables are filtered before entering the bulkhead plug. A schematic diagram of the circuits in the head unit is shown in Figure 33. The output of both dynamotors is fed to a rough regulator which limits the output voltage variations caused by changes in the primary supply. The 400-volt supply is used directly from the rough regulator, but the 225-volt source is filtered before use in any circuits. A regulator system follows the 225-volt filter to produce an accurate regulated 150-volt supply for the critical circuits of the monitor unit. The voltage remains within three volts of 150-volts for all changes of primary supply voltage and for changes in load conditions caused by switching from "receive" to "transmit voice" or "transmit tone." A potentiometer is provided to adjust the re-

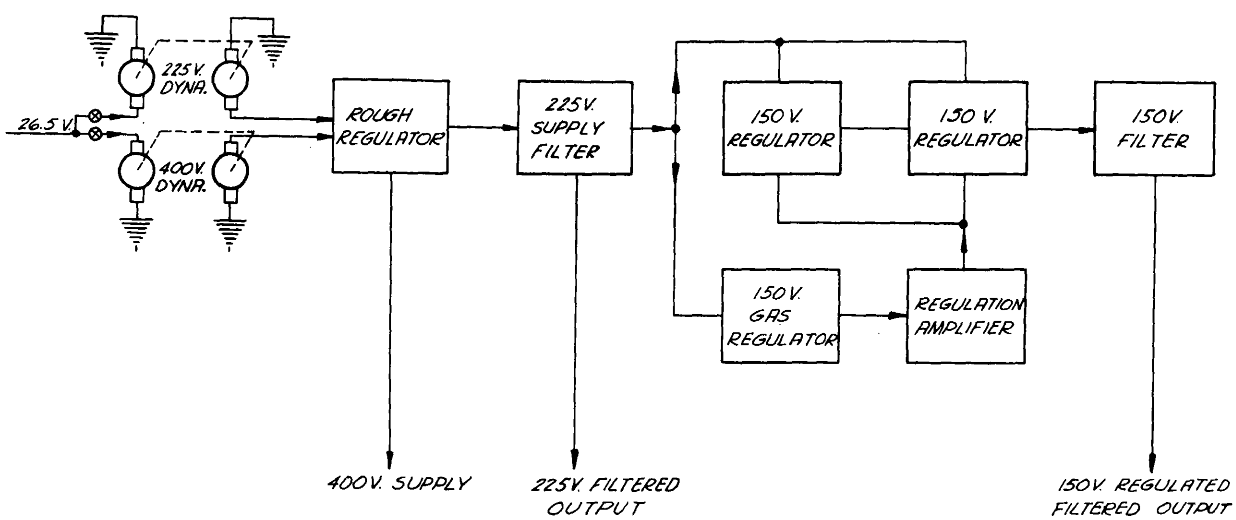


Figure 32.-Block Diagram of Power Supply and Filters.

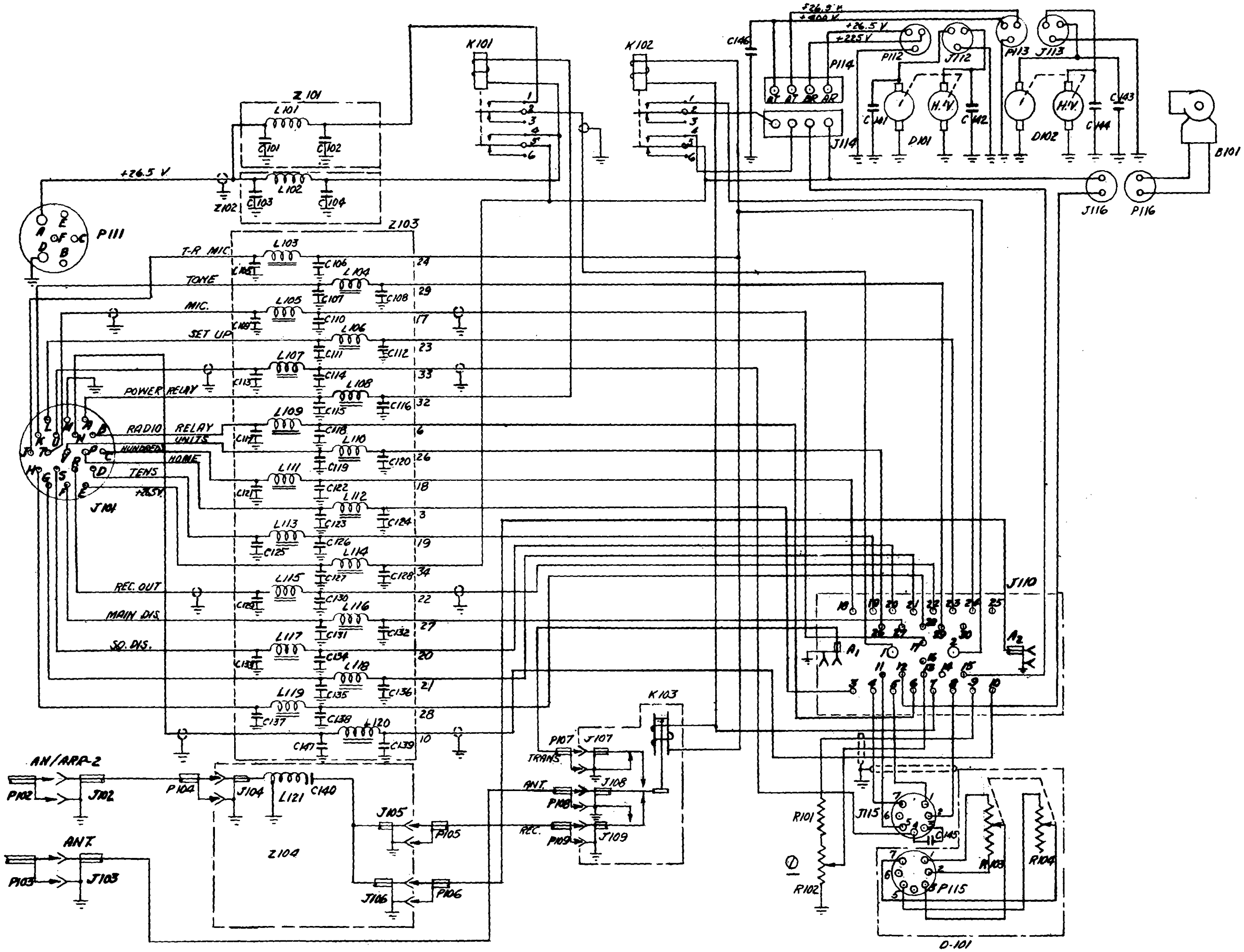
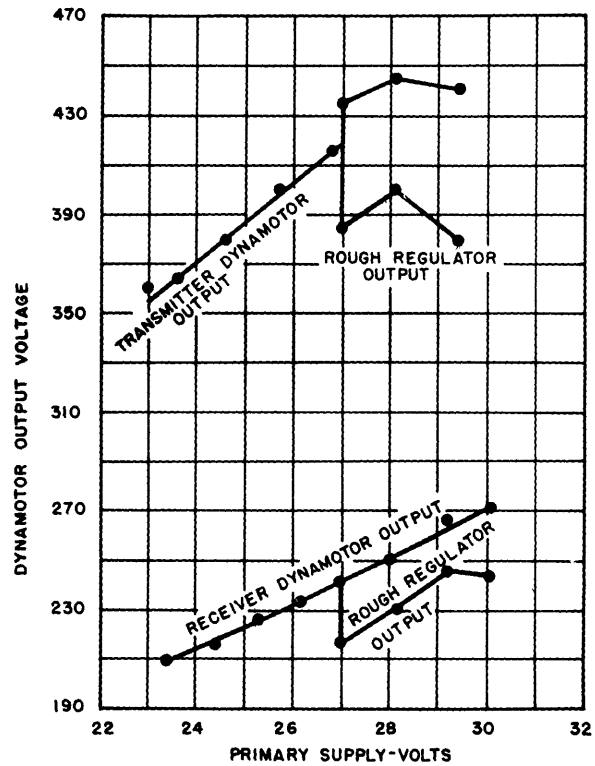


Figure 33.-Schematic Diagram of Head Assembly.

Figure 34.-Dynamotor regulation and rough regulator operation of AN/ARC-19 (XN-1), Serial No. 4, at room temperature and under normal load conditions.



gulated voltage to the desired voltage level during the initial adjustments of the equipment. The 150 volts is effectively filtered before use in the monitor circuits.

The rough regulator stage consists of a triode having a regulated 150 volts applied to the cathode, the 225-volt dynamotor output applied to the plate through a 6500-ohm, 10-milliampere relay, and a d-c supply on the grid derived from a voltage divider across the 225-volt dynamotor output. The position of the grid tap on the voltage divider determines the dynamotor voltage level at which the triode grid voltage will approach the cathode bias and cause the triode to conduct. When the primary supply voltage is increased, the dynamotor output voltage is increased. A point is reached where the triode plate current is sufficient to energize the plate circuit relay. Operation of the relay causes a 220-ohm resistor to be inserted between the 225-volt dynamotor and the load and an 82-ohm resistor to be inserted between the transmitter dynamotor and its load. The operation characteristic is shown in Figure 34. The current drawn from the receiver dynamotor is relatively independent of the receiver dynamotor voltage. The addition of the low value resistor in series with the receiver load causes the rough regulator output voltage to parallel approximately the dynamotor output voltage but at a lower level after the relay has been energized. The current load of the transmitter dynamotor is dependent upon the dynamotor voltage and increases with increase of voltage. At the instant the relay is energized, and the resistor is inserted in series with the transmitter dynamotor load, the dynamotor voltage is suddenly increased and the rough regulator output voltage is suddenly decreased. This is caused when the decrease in voltage at the transmitter reduces the current drain and less voltage drop appears across the dynamotor.

The 225-volt filter consists of a π section, low pass, L-C filter. The regulation of the filter was found to be such that the large currents drawn by the type 25L6 audio amplifier caused a ripple on the filter output of a frequency coinciding with the frequency of modulation. The plate supply of the amplifier was changed from the output to the input side of the filter and the filter operation was then satisfactory. The ripple on the input of the filter had negligible effect on the operation of the audio power amplifier.

The fine regulation of the 150-volt supply was accomplished by the use of a gas regulator tube in conjunction with a conventional voltage regulator circuit. The gas regulator provided a sufficiently constant 150-volt source to stabilize the screen voltage of the regulator amplifier. A 470,000-ohm plate load of the regulator amplifier develops the control voltage for the grids of the type 25L6 tubes which are connected essentially as triodes. The grid bias of the regulator amplifier is obtained from the regulated 150-volt output bus through a voltage divider. Any slight change in the regulated 150-volt output will cause a corresponding change in the current of the regulator amplifier which will then control the grid voltage of the type 25L6 tubes to counteract the initial voltage error (Figure 29).

MONITOR DEVELOPMENT

The monitor is the heart of the AN/ARC-19 (XN-1). It performs two vital functions. First, the monitor causes the transmitter-receiver to tune to the channel frequency selected at the control box. Second, after the transmitter and receiver are set on a channel, it minimizes any tendency of the transmitter and receiver to drift from the selected channel frequency. The monitor performs these two functions through its ability to control the frequency of the master oscillator. It exercises this control over the master oscillator by means of a motor-driven, three-speed, gear-reduction system, and a reactance tube. The first means constitutes a rough control over the master oscillator and is known as the Mechanical Frequency Control (MFC). The second means is a fine control over the master oscillator and is called Electronic Frequency Control (EFC). The system block diagram of Figure 35 indicates the electrical and mechanical connections between the receiver, transmitter, monitor, and the control box.

The master oscillator is a self-excited oscillator which tunes from 55 to 100 Mc. This oscillator provides excitation for the remainder of the transmitter and also provides a local oscillator injection voltage for the first mixer of the reciever. All r-f circuits in the receiver, transmitter, and divider are ganged and tracked on a common shaft and are driven by the motor gear-reduction system. Therefore, it is obvious that if the master oscillator is caused to be driven to a selected frequency by the monitor, all other r-f circuits will also be tuned to the proper frequency. It is in this manner that the monitor, through its ability to control the master oscillator, causes the transmitter and receiver to drive to the selected channel frequency. It is apparent that the accuracy with which the transmitter and receiver assume the selected channel frequency is dependent upon

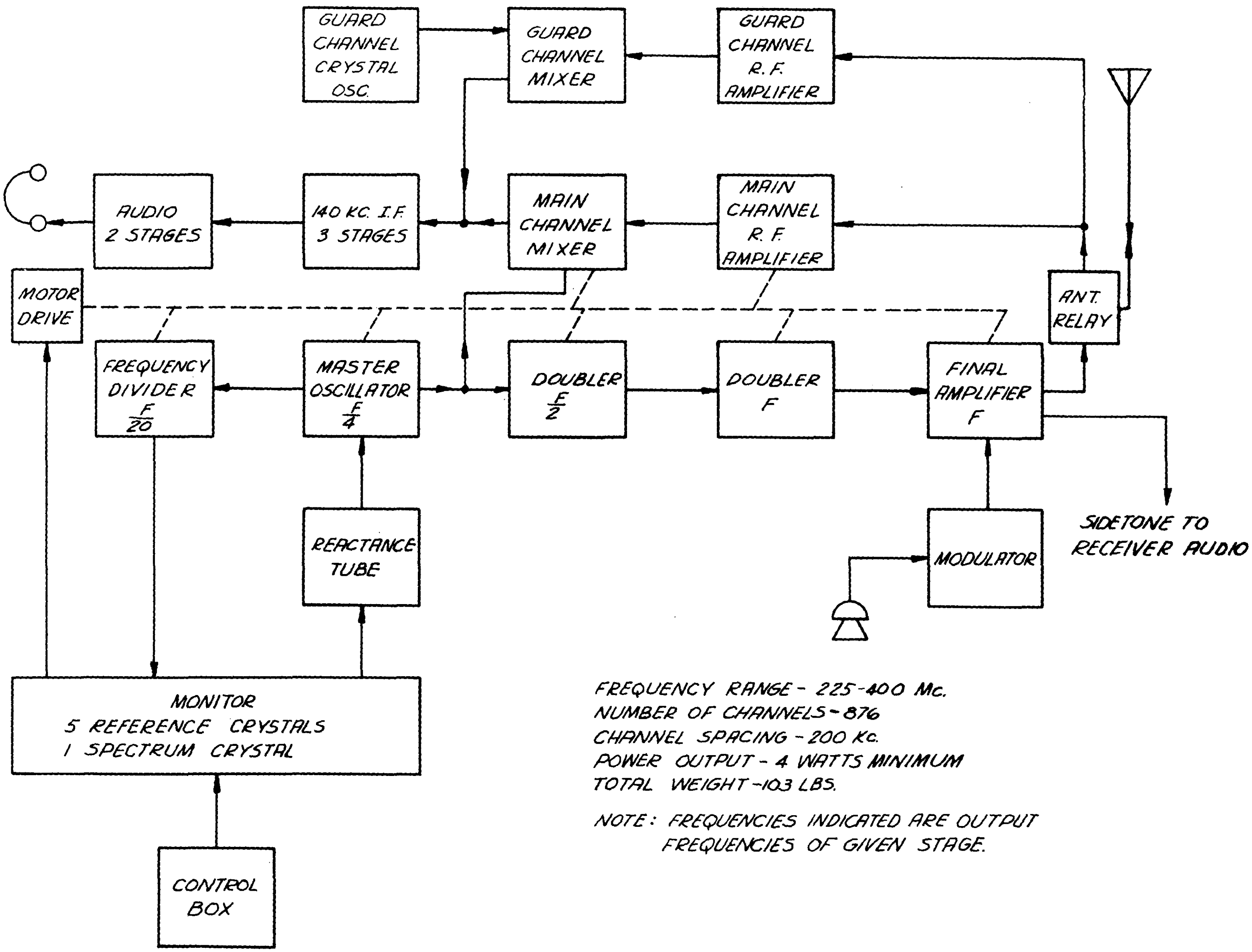


Figure 35.-Block Diagram of Complete Equipment.

the accuracy of the master oscillator frequency which in turn is entirely dependent upon the action of the monitor.

The precise method by which the monitor causes the transmitter and receiver to drive to the selected channel frequency, and the method thereafter by which the monitor causes the transmitter and receiver frequency to be maintained at the selected channel frequency within fixed narrow limits, will be outlined in the succeeding paragraphs.

The first function the monitor is called upon to perform is that of causing the motor to drive the transmitter and receiver from one channel frequency to any one of the 876 that might be selected. This channel change must be accomplished in a minimum of time and with the least complicated circuits. The number of quartz crystals employed is especially important. Preferably, the number of crystals should be reduced to a minimum and the crystals in all equipments should be identical so that they are completely interchangeable from one equipment to another.

The problem the monitor faces in carrying out its first function is to know where each channel is located within the band of frequencies covered by the transmitter and receiver. A logical solution would be to place markers at appropriate points in the band and count markers, beginning at a fixed starting point at one end of the band, until the selected channel is reached. A marker could be placed at each channel frequency, but the number of counts required to be registered for the higher channel numbers would be great. Therefore, a system involving fewer counts is more desirable. Since the total number of channels is less than 1,000, a three-digit, decade counting scheme would be suitable. With this scheme every hundredth channel is marked and after the proper number of hundreds have been registered, the hundreds-markers are removed and tens-markers are substituted marking every ten channels. In the same fashion the tens count and the units count can be registered. At the conclusion of the counting process, the transmitter and receiver have been driven to the proper channel by the motor drive, and the monitor is switched to the automatic frequency control (AFC) position. The monitor is then prepared to perform its second function, that of continuously monitoring the transmitter-receiver frequency and applying suitable correction to maintain this frequency within narrow limits.

The adoption of the decade counting system will reduce the maximum number of counts which must be registered from 876 to 27. This figure can be reduced to 18 by not counting units, but rather selecting them directly. Such a method will be described later. This arrangement shortens the channel selection time to a minimum. An example will illustrate how the channel counting system operates. First, assume that channel number 100 has been selected. Starting at the low-frequency end of the band, one hundreds-marker will be counted, no tens-markers will be counted, and the units digit selected directly. Second, assume that channel number 995 has been selected. Nine hundreds-markers will be counted, nine tens-markers will be counted, and the proper units digit will be selected directly. It should be pointed out here that the speed of the motor drive system is reduced ten to one between the hundreds count and the tens count so that the two counts will be made at the same rate. A further reduction of 25-

to-one in shaft rotation speed occurs between the tens count and the AFC position. This reduction is necessary to reduce the tendency of the motor to hunt.

The hundreds and tens counting is done with separate 12-positions rotary step switches. These switches are wired so that at the completion of any counting operation they always end up at the same position which is called the finish position. With this arrangement it is, therefore, necessary at the beginning of each counting operation to preset each rotary stepping switch a number of positions equal to 12 minus the number to be registered. The reason for establishing a finish position on each of the two rotary switches is to make it possible to do certain necessary switching at the completion of the hundreds count and also at the end of the tens count. A third rotary stepping switch is used in the monitor to select the units digit. This switch, however, is preset directly to the desired position.

The block diagram of Figure 35 shows that the output frequency of this equipment extends from 225 to 400 Mc. The master oscillator operates at one-fourth this frequency or from 55 to 100 Mc. The diagram indicates an r-f divider circuit between the master oscillator and the monitor. The master oscillator drives this divider to produce a frequency of one-fifth the master oscillator frequency supplying the monitor with a signal varying from 11 to 20 Mc. This reduction in frequency was provided to simplify the monitor design. It is therefore evident that the monitor operates on a signal which is exactly one-twentieth of the equipment output frequency. The channels are thus spaced 200/20 = 10 kc apart at the monitor operating frequency. Ten channels will occupy 100 kc of the band and 100 channels will occupy 1.0 Mc of the band.

Channel number 100 corresponds to 220.0 Mc at the output frequency and to 11.0 Mc at the monitor frequency. Since the channels are spaced 10 kc apart and channel number 100 corresponds to 11.0 Mc, all of the remaining channels will fall on integral 10-kc points throughout the band beginning at 11.0 Mc.

Figure 36 shows a simplified block diagram of the monitor. Only those circuits necessary for the hundreds count are indicated. The spectrum generator supplies two sets of markers. The markers in the first set are spaced exactly 100 channels apart and in the second set the markers are spaced ten channels apart, that is, 1.0 Mc and 100 kc apart, respectively. These markers begin at 1.0 Mc and 100 kc, respectively, and extend in frequency beyond five Mc. The spectrum and the signal from the r-f divider are fed to the first mixer. The output from the first mixer goes to a 15-Mc i-f amplifier and then to the second mixer. It is desired that the combination of the r-f divider output with either the hundreds or tens spectrum produce a 15-Mc beat frequency signal for every 1.0-Mc or 100-kc point in the range of 11 to 20 Mc when the divider output signal varies over the 11 to 20 Mc range. For example, if the r-f divider output is 11 Mc and the hundreds spectrum is switched on, the first mixer output will contain a series of beat frequency signals which are the sum and difference frequencies of the spectrum markers and 11 Mc. They are: 11 + 5 = 16 Mc, 11 + 4 = 15 Mc, 11 + 3 = 14 Mc, etc. to 11 - 5 equals 6 Mc. Since the i-f amplifier has a resonant frequency

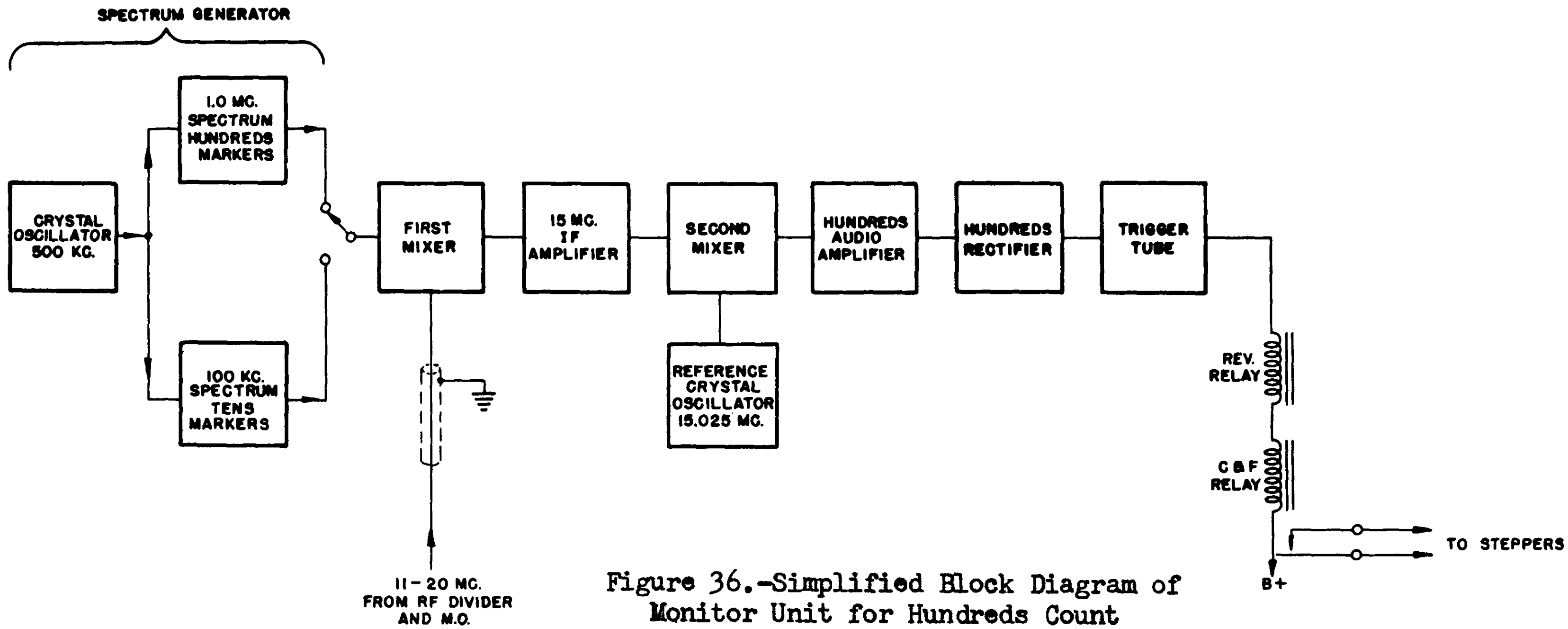


Figure 36.-Simplified Block Diagram of Monitor Unit for Hundreds Count

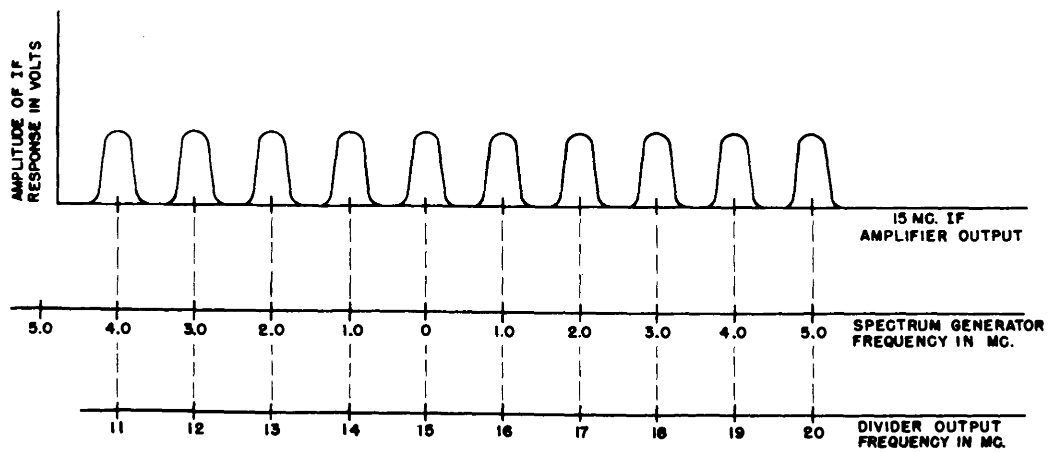


Figure 37.-I-F Response for Hundreds Count

of 15 Mc, the only signal to pass through this amplifier will be the 15-Mc beat frequency; all others will be rejected. Similarly, if the r-f divider output is 12 Mc, one of the beats will be 12 + 3 Mc or 15 Mc and will pass through the amplifier. Therefore, it is apparent that for every integral megacycle between 11 and 20 Mc, a beat will be produced in the mixer which will pass through the 15-Mc i-f amplifier. If the i-f amplifier has a bandwidth of 200 kc and the r-f divider output is varied from 10.5 to 20.5 Mc, the i-f response characteristic will be traced out at every integral megacycle point and the i-f amplifier output will appear as shown on Figure 37. This figure indicates the frequencies which add or subtract to produce the 15-Mc beat frequency which passes through the 15-Mc i-f amplifier. Every hundredth channel is therefore marked, and a response will be obtained from the i-f amplifier for every marker when the master oscillator is driven from one end of the band to the other.

The output of the i-f amplifier is coupled to the second mixer where this output is mixed with a signal from a reference oscillator. This oscillator is crystal controlled and operates at a frequency of 15.025 Mc, this frequency being one of five operating frequencies. The two signals mix to produce an audio output which varies from a high audio frequency through zero beat and back to a high audio frequency as Figure 38 indicates. The envelope of the audio response is identical to that of the i-f amplifier. The i-f amplifier output has not been converted to an audio frequency and a response will be obtained for each megacycle point in the band as the divider frequency sweeps from 10.5 to 20.5 Mc as shown in Figure 39. The audio signal is next amplified in the audio stage and then rectified. The rectified d-c voltage is applied to the grid of a tube which has two relays in its plate circuit. A set of contacts on one relay actuates the hundreds rotary stepping switch (stepper). Each closure of the pair of contacts causes the stepper to progress one position forward. Thus it is possible for each audio response to position the stepper one position forward and to register each hundreds-marker as the divider output frequency sweeps

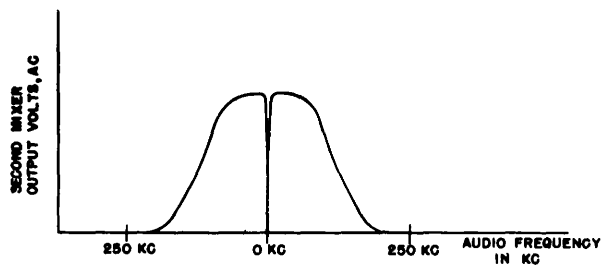


Figure 38.-Second Mixer Audio Output Response Characteristics

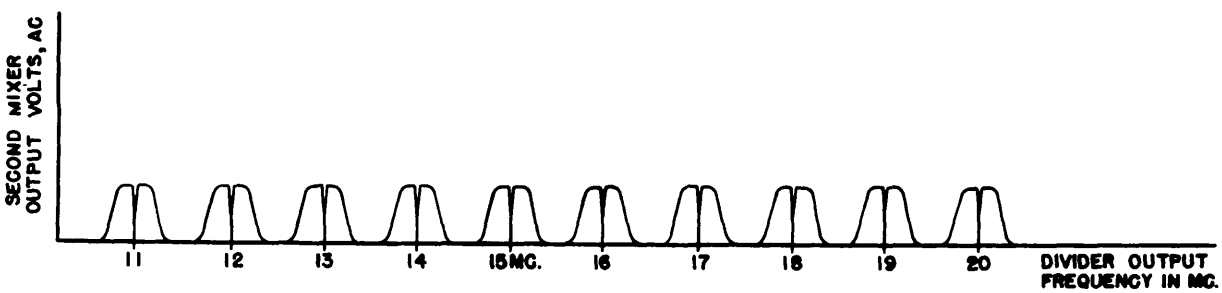


Figure 39.-Second Mixer Audio Output Response vs Divider output Frequency.

from the low to the high-frequency end of the band. The tube with the relays in its plate circuit (trigger tube) is biased so that the rectified audio signal must rise to about 12 volts before the relays will close. Figure 40 indicates the rectified audio signal that is applied to the grid of the trigger tube. The level at which the relays operate is also shown. Therefore, the cross-hatched areas are a measure of the length of time that the relays are energized.

The speed at which the markers are registered is important. This speed should be as high as possible with reliable counting so that the equipment channelization time shall be a minimum. The factor which limits the counting speed in this system is the steppers. The 12-position rotary steppers manufactured by Price Brothers Company have a maximum speed at about 20 positions per second when driving a load of two or three wafer switch stacks and when being energized by a 50-percent duty cycle. A decrease in the duty cycle of the stepper driving voltage or an increase in wafer load will reduce the positioning speed of the steppers. Therefore, the percent duty cycle should be kept as near 50 percent as possible and the wafer load kept small for maximum positioning speed. Since the steppers are the limiting factor in counting speed, the monitor must be designed around this limiting factor.

The i-f amplifier bandwidth determines the duty cycle of the audio signal which actuates the stepper because the amplifier bandwidth determines the length of time during which the audio response is present as each hundreds-marker is passed. Ideally, the amplifier bandwidth should be 500 kc. This bandwidth would result in a 50-percent duty cycle for the audio signal which then would be present for half the time as the r-f divider output frequency changed from one megacycle point to the next.

The speed at which the motor drives the master oscillator from the low-frequency end of the band towards the high-frequency end during the hundreds count must also be controlled. This speed must not exceed 20 megacycles per second at the monitor frequency or the steppers will not follow reliably. The gear reduction ratio between the motor and fast speed for the hundreds count can be determined with regard to this limitation. Assume the motor speed to be 10,000 rpm and that 180 degrees rotation of the master oscillator tuning condenser will include the total band of frequencies. Also, assume that instead of counting 20 markers per second, only 10 markers per second be counted to insure reliable counting even under adverse conditions of temperature and primary voltage. Ten markers will be passed for one-half

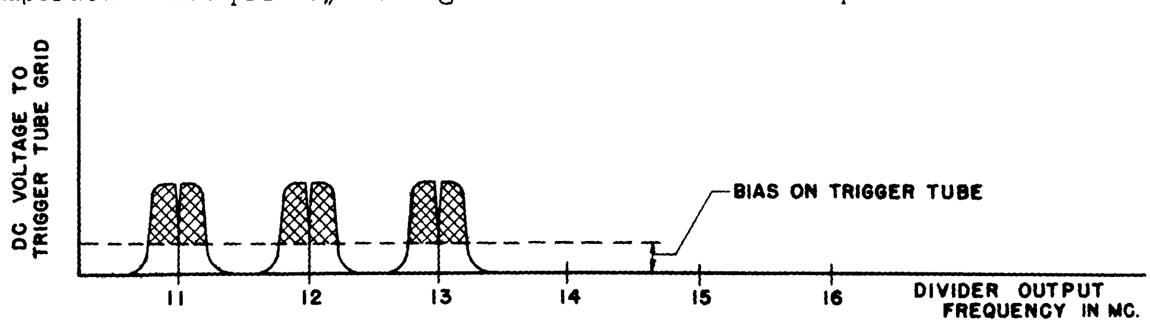


Figure 40.-Signals at Trigger Tube Grid.

revolution of the master oscillator condenser gang. Therefore, the gear ratio is $\frac{10,000}{60 \times \frac{1}{2}} = 333.$

This is the reduction in speed which must exist between the motor shaft and the master oscillator condenser shaft during the hundreds count to insure reliable counting.

At the completion of the hundreds count, the hundreds stepper has reached its finish position, and the necessary switching to conduct the tens count is done by the wafer switch stacks driven by the hundreds stepper. Figure 41 is a simplified block diagram of the monitor which shows the circuits necessary for the tens count as well as those used for the hundreds count. Before the tens count is begun the exact frequency in the band to begin this count must be determined. Since the audio signal generated by the hundreds counting process cannot give this information, some other means of determining this point in the band must be added to the system. A discriminator will fill this need. The crossover frequency selected was 25 kc. This low crossover frequency was chosen because a low discriminator frequency results in a small frequency drift in cycles per second for temperature variations. There also is another reason which will become apparent in the following paragraphs. The block diagram shows that a 50-kc low-pass filter, an audio amplifier, a 100-kc low-pass filter, and a discriminator have been added for the tens counting process. The discriminator is conventional except for a modification which causes it to develop a voltage far beyond crossover in either direction as shown in Figure 42. This result is obtained by rotating the axis of a normal discriminator curve as shown in Figure 43.

The transition from the hundreds count to the tens count cannot take place simultaneously with arrival at that point in the frequency band. Some anticipation of that event must occur such as slowing the rotational speed of the condenser shaft. Certain switching is also performed previous to the transition. The preparation for the transition occurs at the time the next to the last hundreds-marker is counted. The switching is done by the wafers driven by the hundreds stepper and takes place when the stepper is stepped to the position once removed from the finish position (Figure 41). Switches SW1, SW2, and SW3 are shown connected for the hundreds count. Switch SW3 is switched after the next to the last hundreds count in preparation for the tens count. The master oscillator condenser shaft rotation speed is reduced by a factor of 10 at the same time. This change in speed is brought about by a relay-operated clutch which changes the motor drive gear ratio. The audio signal from the hundreds count is now fed to the discriminator through the 100-kc low-pass filter. Figure 44 shows the hundreds count signals appearing at the trigger tube grid for a channel between channel number 300 and channel number 400. Since the channels are numbered from channel number 100 must coincide with 11.0 Mc. Also, since the channels are spaced 10 kc at the monitoring frequency, one hundred channels will occupy 1.0 Mc of the band and channel number 200 will therefore coincide with 12 Mc, etc. It is apparent from Figure 44 that for a channel number between 300 and 400, three hundreds-counts will have to be registered, the last hundreds-count being at 13.0 Mc. The d-c signal at the grid of the trigger tube for the first two hundreds-counts will be a rectified audio signal, and, at the

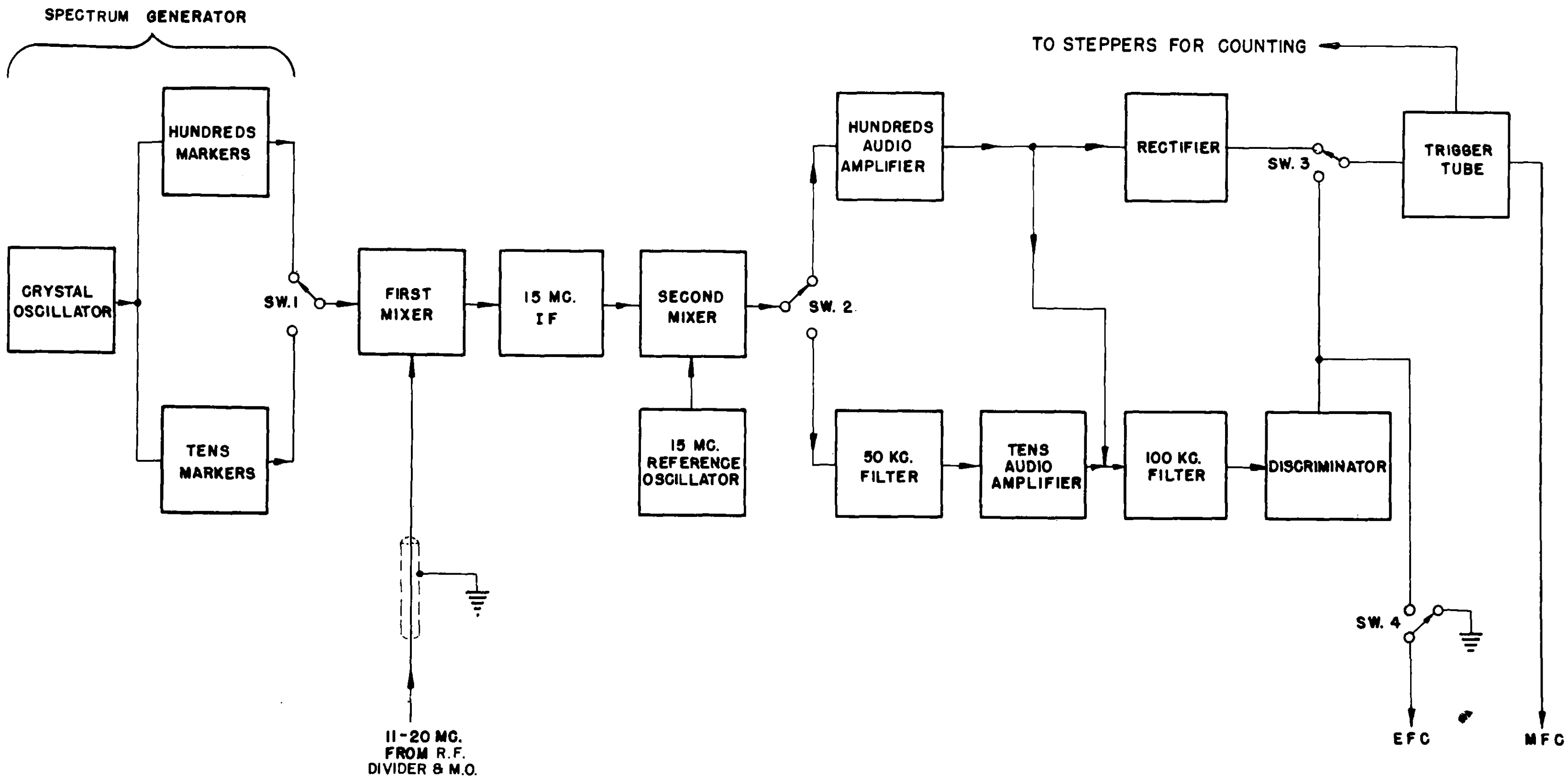


Figure 41.-Simplified Block Diagram of Monitor Unit for Tens Count

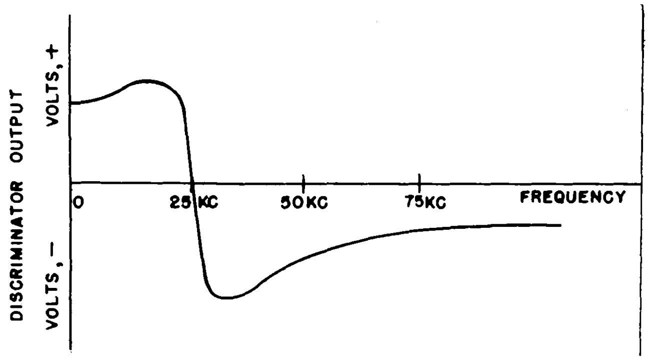


Figure 42.-Modified Discriminator Characteristics.

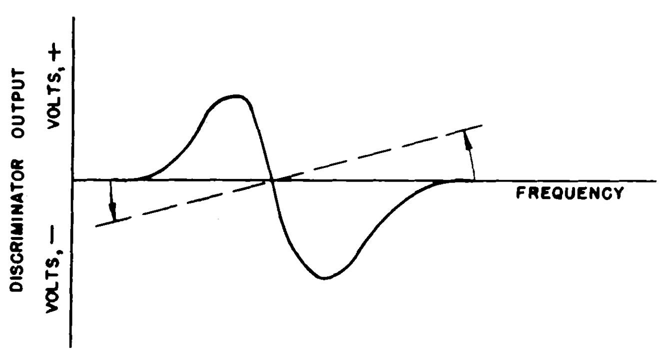


Figure 43.-Original Discriminator Characteristics.

finish of the next-to-the-last count, the grid will be switched to the discriminator output. The waveform shown for the last hundreds-count is the discriminator curve traced out twice. The curve is traced out twice because the audio beat note begins at a high audio frequency, 500 kc, passes through zero beat, and again increases in frequency. The bias voltage on the trigger tube is indicated on the diagram. The counting relay does not operate until the signal at the grid exceeds the bias voltage. The counting relay will close at points a, b, and c on the three counting impulses. The relay, however, is connected so that it de-energizes the stepper when a signal is present. The stepper is energized at the beginning of the counting and is de-energized only in the presence of a signal. Of course, at the completion of the counting process the stepper is again de-energized. This is done because the stepper positions the wafer stack only when power is removed. This fact is especially important at point c because sufficient time must be given the stepper to release and move the rotors of the hundreds wafers to the finish position so that the tens counting can begin at point d which is 13 Mc. The condenser shaft speed is reduced to medium speed at point b, but the tuning speed in kilocycles per second is still great enough so that the spacing between c and d must be an appreciable amount. The high frequency audio response is cut off at 100 kc by the filter preceeding the

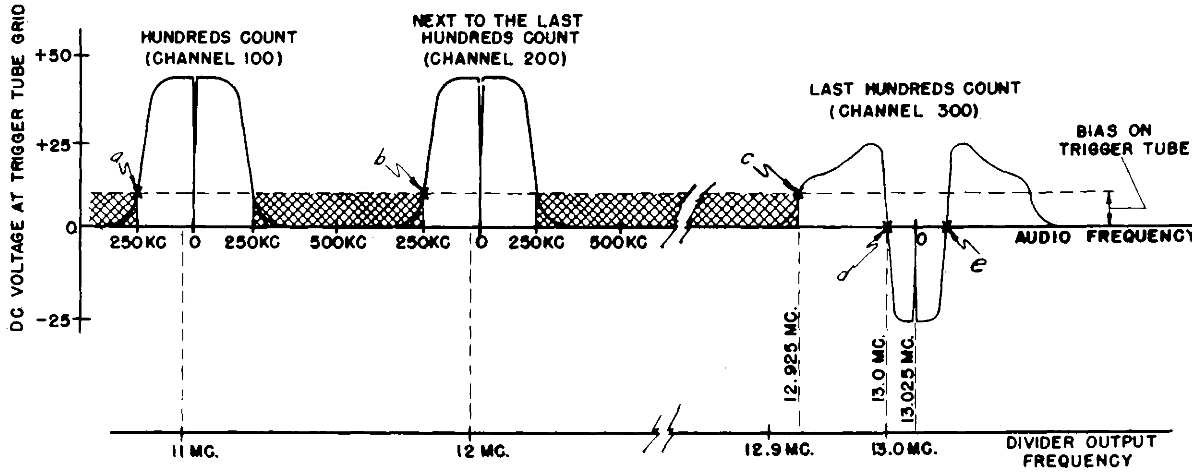


Figure 44.-Hundreds Count Signals vs Divider Frequency.

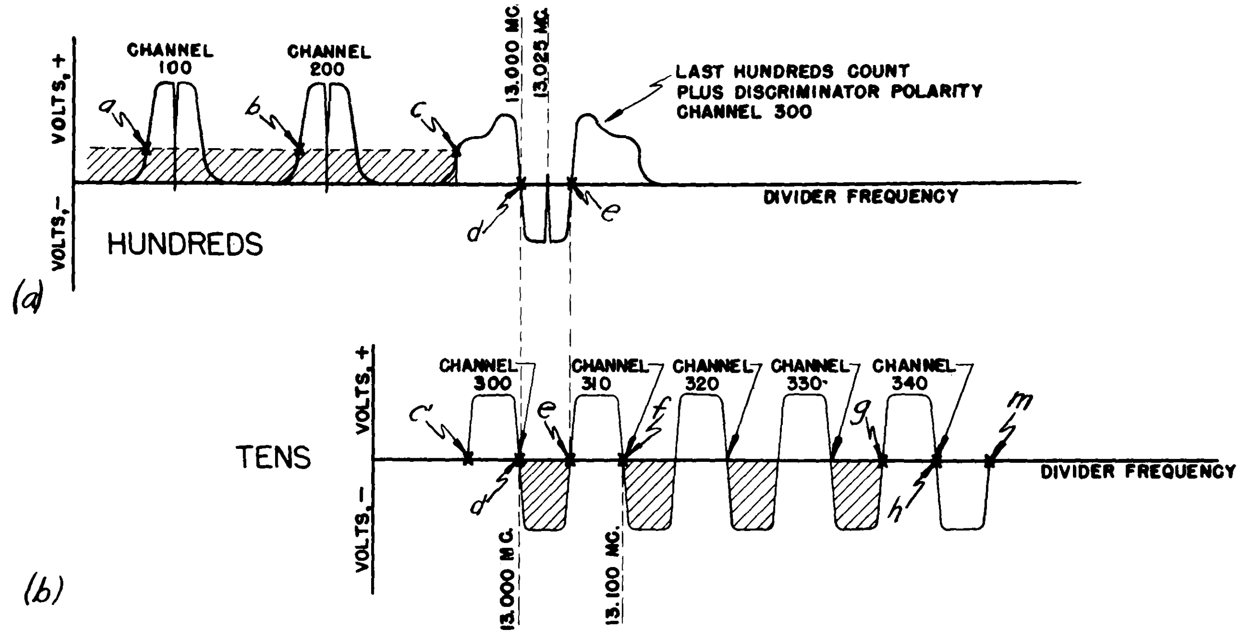


Figure 45.-Signals at Trigger Tube Grid for Hundreds and Tens Count.

discriminator. The filter therefore fixes the space between point c and zero beat at 100 kc and the distance between c and crossover at point d as 75 kc. The audio signal could have been fed through the 50-kc filter to the discriminator. The distance between c and d would then have been 25 kc. This was tried but resulted in miscounting because the hundreds stepper did not have sufficient time to step the last count to the finish position. The miscounting was particularly bad when even hundreds channels were selected such as channel number 300. When such a channel is selected, no tens are counted, and the monitor is switched directly to AFC when the hundreds stepper reaches the finish position. Therefore, if the hundreds stepper is not given sufficient time to operate, point e will be reached before the hundreds stepper moves and a miscount will occur.

When the hundreds stepper arrives at the finish position, SW1 and SW2 of Figure 41 are switched. This operation substitutes the tens-markers for the hundreds-markers and feeds the audio output of the second mixer through the 50-kc filter and then through the tens audio amplifier to the discriminator. Figure 45 illustrates the signals present at the grid of the trigger tube during the hundreds count and also during the tens count. The transition from the hundreds waveform of Figure 45(a) to the tens waveform of Figure 45(b) takes place shortly after passing point c. Therefore, since the tens waveform replaces the hundreds waveform, the points c, d, and e also may be transferred. Several audio frequencies will be present in the second mixer output due to the fact that the i-f amplifier has a bandwidth greater than 100 kc. The tens-markers are spaced 100 kc apart; therefore the beat frequencies from two or more markers will pass through. The 50-kc filter was placed at the input of the tens audio amplifier to reject all but the primary audio beat frequency. This beat frequency will vary from 50 kc through zero beat back to 50 kc, and this cycle will repeat for each tens-marker. The cycle actually begins at 25 kc, because when the divider output frequency and a marker frequency beat to produce an i-f signal of exactly 15 Mc, the audio output frequency will be equal to 25 kc and the discriminator will be at its crossover voltage or zero voltage. This condition, of course, was desired and was obtained by making the reference frequency 15.025 Mc. The complete cycle will be as follows: 25 kc - 0 kc - 25 kc - 50 kc - 25 kc. Point d on Figure 45(b) is the starting frequency for the first tens count. The audio frequency is 25 kc and corresponds to the divider output frequency of 13.000 Mc and channel number 300. One complete tens-count cycle will end at point f. This channel will thus be number 310 and will correspond to a divider output frequency of 13.100 Mc. The tens stepper is energized at the start of the tens count.

When the trigger-tube grid is driven positive in voltage the tens stepper is de-energized and the tens wafers positioned one step forward. The shaded area of each tens cycle indicates the time during which the tens stepper is energized. Point e is the frequency at which the tens wafer is moved one step forward. For example, if channel 340 were selected, four tens-cycles would have to be counted. The first tens count would be registered at point e and the fourth count at point g. The fourth count will bring the tens stepper to its finish position where appropriate circuits are switched to permit the monitor to automatically control the frequency of the master oscillator by means of a reactance tube and motor drive mechanism. The switch SW4 of Figure 41 connects the discriminator output to the reactance tube controlling the master oscillator and to the trigger tube. The motor leads are also switched to the two relays in the trigger tube plate circuit. One relay closes at 5.0 ma of current and the other closes at 6.0 ma. The trigger tube and relays are shown in the circuit diagram of Figure 46. The cathode bias of the tube type 6AK5 is adjusted so that at zero grid voltage the tube will draw about 5.5 ma of plate current causing the 5-ma relay to close and leaving the 6-ma relay open. From inspection of the motor circuit of the diagram it

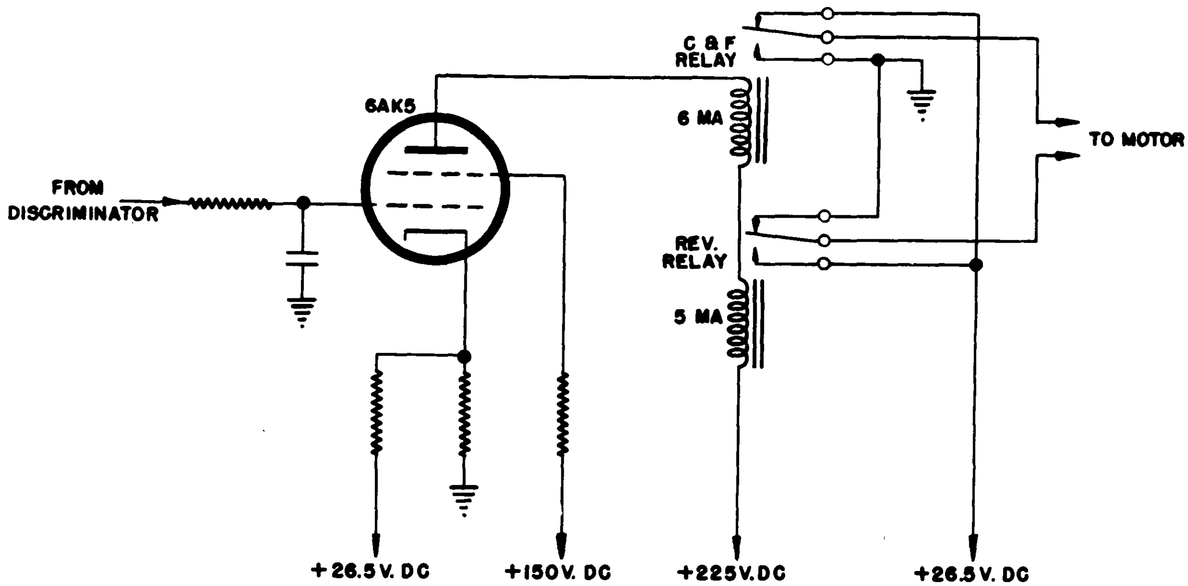


Figure 46.-Trigger Tube Circuit

is evident that if both relays close, the motor will drive forward, and if both relays open, the motor will drive in the reverse direction. However, if one relay remains open while the other remains closed, the motor will not be energized. The polarity of the discriminator output voltage thus governs the direction of motor rotation.

At the moment that the tens stepper reaches its finish position and switches the monitor functioning from channelization to AFC, the divider output frequency will be somewhere between point g and point h. The discriminator output voltage will be positive and will cause the motor and reactance tube to change the divider output frequency to point h or 13.400 Mc. If the divider output frequency should over-shoot point h and approach point m, the discriminator will produce a negative output voltage which will cause the motor and reactance tube to reverse and again return the divider output frequency to point h. The same action will occur if the master oscillator should drift off frequency. The reactance tube will return the master oscillator for small drifts in frequency. If the drift should be large the motor will aid in the correction. The monitor has been so designed that the automatic frequency control is stable at point h where the slope of the discriminator characteristic curve is negative. In other words, the master oscillator will be driven towards point h no matter where its frequency may lie if this frequency is anywhere between g and m. On the other hand, one-half cycle away at point m where the slope of the discriminator characteristic curve is positive the AFC control is unstable. The divider output frequency will always be driven away from this point, the direction depending on whether the frequency was above or below the point.

The process by which the monitor tuned the transmitter and receiver to any tens channel has been described. The process began with the motor drive returning the master oscillator to the low frequency end of the band where it reversed direction and drove the master oscillator up in frequency again. The counting procedure took place between the low frequency end of the band and the channel selected. However, the counting procedure allows only every ten channels to be selected. The process by which the units channels are selected will be described in the following paragraphs.

With the example previously cited where it was shown how channel number 340 was obtained, assume channel number 341 has been selected. Since channel number 341 is now desired, some means must be found to move the divider output frequency 10 kc higher. The units are not counted as were the tens and hundreds. This shift in divider output frequency can be accomplished by a change in the reference oscillator frequency. If the reference oscillator frequency is shifted, the divider output frequency must shift a like amount because the AFC circuits and discriminator demand that the audio beat frequency always be 25 kc. If the audio signal is not 25 kc, the automatic frequency is 25 kc. Figure 47(a) shows the fourth tens-count cycle of Figure 45(b) enlarged several times. Point h corresponds to channel number 340 in both figures. Channel number 340 was obtained with a reference frequency of 15.025 Mc. If this frequency is made 15.035 Mc, the divider output frequency will also have to shift 10 kc so that it will then be 13.410 Mc. which is channel number 341 and point j on Figure 47(a). The remaining units channels from channel numbers 341 through 349 can be obtained in a like manner by increasing the reference frequency in steps of 10 kc. The reference frequency oscillator is crystal controlled and the 10-kc steps in frequency are obtained by switching in new crystals. It can be seen that ten separate crystals will be needed for the ten 10-kc steps in frequency. This is an excessive number of crystals and the number can be reduced to five by an additional circuit. Five crystals ranging in frequency in 10-kc steps from 15.025 Mc through 15.065 Mc will allow channel numbers 340 through 344 to be selected. Now, should the discriminator output voltage be reversed in polarity as shown on Figure 47(b), the stable point will no longer be point h but will become point m due to the fact that the slope of the discriminator characteristic curve through these two points has changed in sign. This means that the stable point has been moved 50 kc up in frequency or five units to channel number 345 for a reference frequency of 15.025 Mc. If the same crystal reference frequencies are again used channel numbers 345 through 349 can be obtained.

In order to make the channelization process clearer, two examples will be given. If channel number 341 is selected, the units stepper will immediately be positioned so that it connects reference crystal number two, which is a 15.035-Mc crystal, to the reference oscillator and so that it also

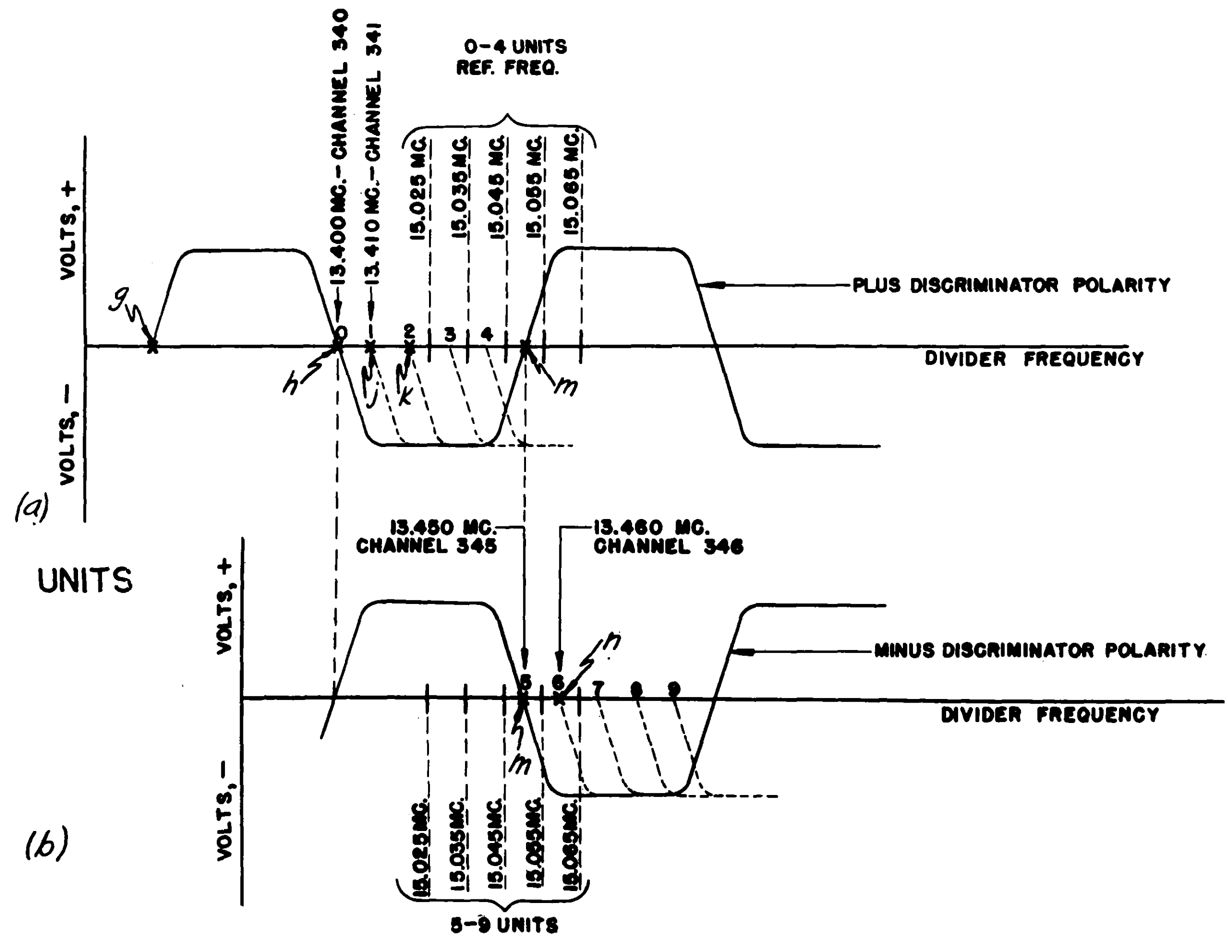


Figure 47.-Signal at Trigger Tube Grid for Units Selection.

switches the discriminator output to have a positive polarity. The tens stepper will be preset so as to have only four more steps to go to reach the finish position. The hundreds stepper will be preset so as to have only three steps left to the finish position. After the three steppers have been preset channelization takes place. The master oscillator is driven from the low-frequency end of the band to the selected channel. First, the hundreds markers are counted at high speed, second, the tens markers are counted at medium speed, one-tenth high speed, and then at the completion of the tens count the master oscillator arrives within 50 kc of the selected channel and the monitor is switched to AFC. The master oscillator condenser shaft rotation speed for AFC is reduced in speed by a factor of 25 from medium speed. If channel number 346 is selected, the same channelization process occurs. The only difference is that this time the units stepper reverses the discriminator polarity. It still selects the same crystal frequency.

The method by which the equipment is switched from transmit to receive will be described in the following paragraphs. The master oscillator is used for two purposes as previously mentioned. First, during periods of transmission, it is used to excite the remaining stages of the transmitter. Second , during periods of reception with the three final stages of the transmitter disabled, it is used to provide a local oscillator signal for the first mixer of the main channel receiver. When the master oscillator is used as the receiver local oscillator, it must be shifted in frequency by an amount equal to one-fourth the receiver i-f resonant frequency. The receiver i-f center frequency is equal to 143.3 kc; however, the master oscillator is shifted approximately one-fourth this amount or 35 kc because it operates at one-fourth the equipment operating frequency. No multiplier stages are placed between the master oscillator and the receiver first mixer in order to simplify the r-f circuit design. The first mixer, therefore, was designed to operate on the master oscillator fundamental frequency. It is evident that this has simplified the design of the local oscillator circuits. Since the i-f center frequency is approximately 140 kc, the master oscillator needs to be shifted only 35 kc. This amount of change is readily obtained by means of the reactance tube and monitor circuits . In the previous discussion it was pointed out that the master oscillator frequency is directly dependent upon the spectrum harmonic used, the absolute reference frequency, and the discriminator crossover frequency. If any one of these three changes in frequency, the master oscillator will be forced to change exactly the same amount. Two of these parameters were in fact changed to select the tens and units channels. Therefore, the master oscillator may be shifted the 35 kc for receive purposes in the same manner. Only, in this case, it will be more convenient to switch the crossover frequency of the discriminator. Because of the five-to-one r-f divider between the monitor and master oscillator, the crossover frequency will have to be moved only 7 kc higher in frequency to cause the master oscillator to shift 35 kc. The process of switching from transmit to receive is simple. All that is needed in the monitor is one relay to switch out fixed capacitors at the discriminator to change its resonant frequency. The monitor causes the master oscillator to shift frequency by means of the reactance tube; therefore, this shift occurs instantly. The transition from transmit to receive involves other switching as well as that in the monitor, such as de-energizing the transmitter dynamotor, antenna change over, and applying B plus to the receiver i-f stages. The frequency stability of the receiver will be practically identical to the stability of the transmitter since both are excited by the same master oscillator. However, the receiver i-f instability will also detract from the overall receiver frequency stability. The i-f instability for all causes will amount to about 300 cycles at the signal frequency. This is a very small part of the total frequency deviation allowed the receiver and for all practical purposes can be lumped with the instability caused by the master oscillator. The maximum permissible frequency deviation of either the receiver or the transmitter anywhere between 225 and 400 Mc is plus or minus 13 kc.

The relationship existing between the various frequencies present in the monitor can be better visualized by referring to Figure 48. This figure was constructed for the example in which channel number 340 was selected. The divider output frequency, which is the master oscillator frequency divided by five, will be 13.400 Mc for channel number 340. This signal mixes with the 1.600-Mc marker of the tens spectrum to produce a 15.000-Mc signal which passes through the i-f amplifier. The 15.000-Mc signal is in turn beat with the 15.025-Mc reference frequency to give the 25-kc audio beat frequency to drive the discriminator. In Figure 48 the tens spectrum with markers or beats spaced 100 kc apart is shown as a line extending between A and B. The spectrum begins at zero frequency at B and extends up in frequency to five Mc at A. The spectrum, of course, extends to the right of B as well as to the left. Point C represents the master oscillator frequency. It may lie anywhere between 11.0 and 20.0 Mc. In this example, it is assumed to be 13.400 Mc. Point B represents the 15.000-Mc resonant frequency of the i-f amplifier. The point D represents the reference frequency and the distance E the discriminator 25-kc crossover frequency. The diagram shows that the discriminator frequency and the spectrum serve as a tie between the reference and master oscillator frequencies. The master oscillator is free to move in frequency and its movements are governed by the monitor. Therefore, it may be called a disciplined oscillator. The reference frequency is fixed and it, therefore, serves as an anchor for the whole system of frequencies. The frequency of the master oscillator thus depends on how much of the spectrum is used, the absolute discriminator frequency, and the absolute reference frequency. The diagram makes it clear how the master oscillator frequency may be moved one channel or ten channels. Moving the reference frequency by 10 kc will cause the master oscillator to go one channel higher or lower and setting the master oscillator on one less spectrum marker will cause the master oscilla-

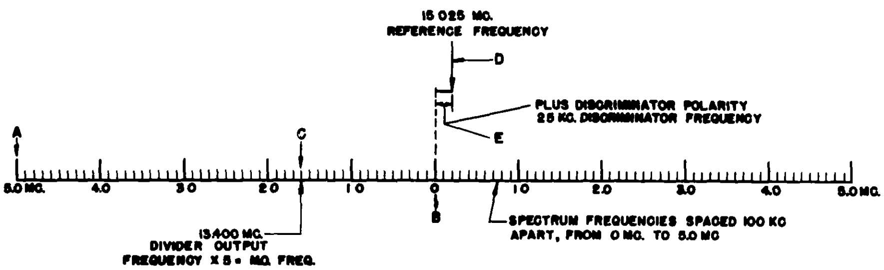


Figure 48.-Relationship between Frequencies in the Monitor for Channel Number 340

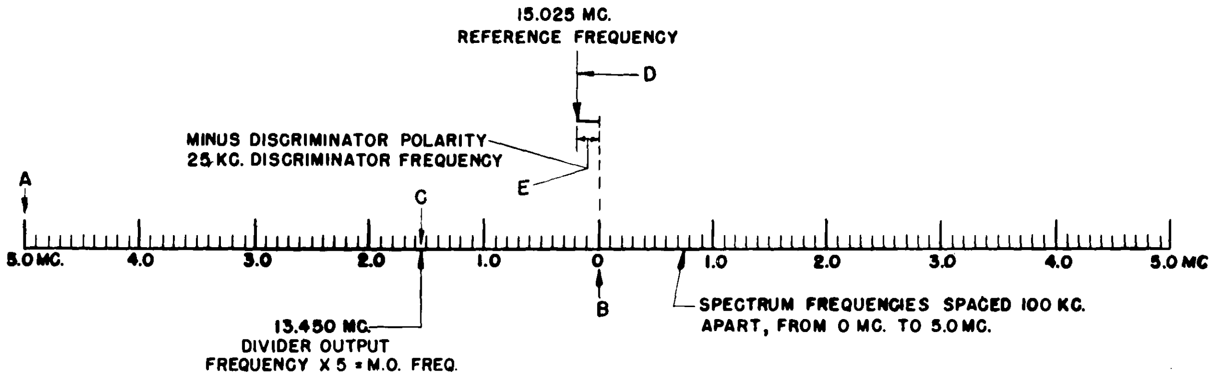


Figure 49.-Relationship between Frequencies in the Monitor for Channel Number 345.

tor to change 10 channels. Figure 49 illustrates the 50-kc shift in master oscillator frequency when the discriminator polarity to reversed.

Figure 48 also illustrates the factors which will determine the frequency stability of the master oscillator when the monitor is in the AFC position. Since the master oscillator is tied to the reference frequency by the spectrum and discriminator, the master oscillator stability will be a function of the stabilities of all three. Therefore, particular attention must be given to the design of these three circuits to insure an acceptable overall equipment frequency stability. The design precautions taken to insure acceptable stability of these three circuits will be pointed out when the monitor schematic is discussed.

The maximum frequency deviation permitted for either the transmitter or the receiver at its output frequency has been calculated and found to equal plus or minus 13 kc. This figure has been broken down and allocated to the three frequency stability determining parameters of the equipment. The maximum deviation at the monitor frequency will be plus or minus 13 kc divided by 20, which is equal to plus or minus 650 cycles. It has been assumed possible to hold the two crystal oscillators within plus or minus 0.001 percent in frequency. Therefore, since the highest spectrum frequency used is 5.0 Mc, the spectrum stabilizing crystal oscillator has been allowed a maximum error of plus or minus 50 cycles at 5.0 Mc. Likewise, since the reference crystal oscillator operates at 15.0 Mc, it has been allowed a total frequency error of plus or minus 150 cycles. This leaves a total of plus or minus 450 cycles out of the original plus or minus 650 cycles. This remainder is allocated to the discriminator and neutral position of the AFC controls. These allocations of maximum permissible frequency error include frequency errors due to all causes.

DESCRIPTION OF MONITOR CIRCUITS

The following paragraphs will describe the monitor circuits and the considerations that entered into their development. Figure 35 is a complete equipment block diagram which indicates the monitor's position with relation to the other components of the system. Figure 50* is a system schematic which shows all circuits of the equipment and their electrical interconnections.

*Figures 50 and 168 are enclosed in back cover of report.

The block diagram of Figure 51 indicates each component of the monitor and the schematic diagram of Figure 52 shows the electronic circuitry of these components.

The circuits of tubes V301 through V306 comprise the spectrum generator. The generator can supply markers spaced either 1.0 Mc apart or 100 kc apart extending in frequency to beyond 5 Mc. Switch S301 on the hundreds stepper determines which set of markers appears at the first mixer tube. A blocked-grid oscillator is used to generate both sets of markers. This oscillator consists of tube V305, transformer T301, and a means of synchronizing the oscillator at a repetition rate of either 1.0 Mc or 100 kc. Transformer T301 is critically damped. The coupling coeffieient, turns ratio, distributed capacity, and inductance of the transformer were so selected that the oscillator output pulse had a width of 0.15 μs at its base when a

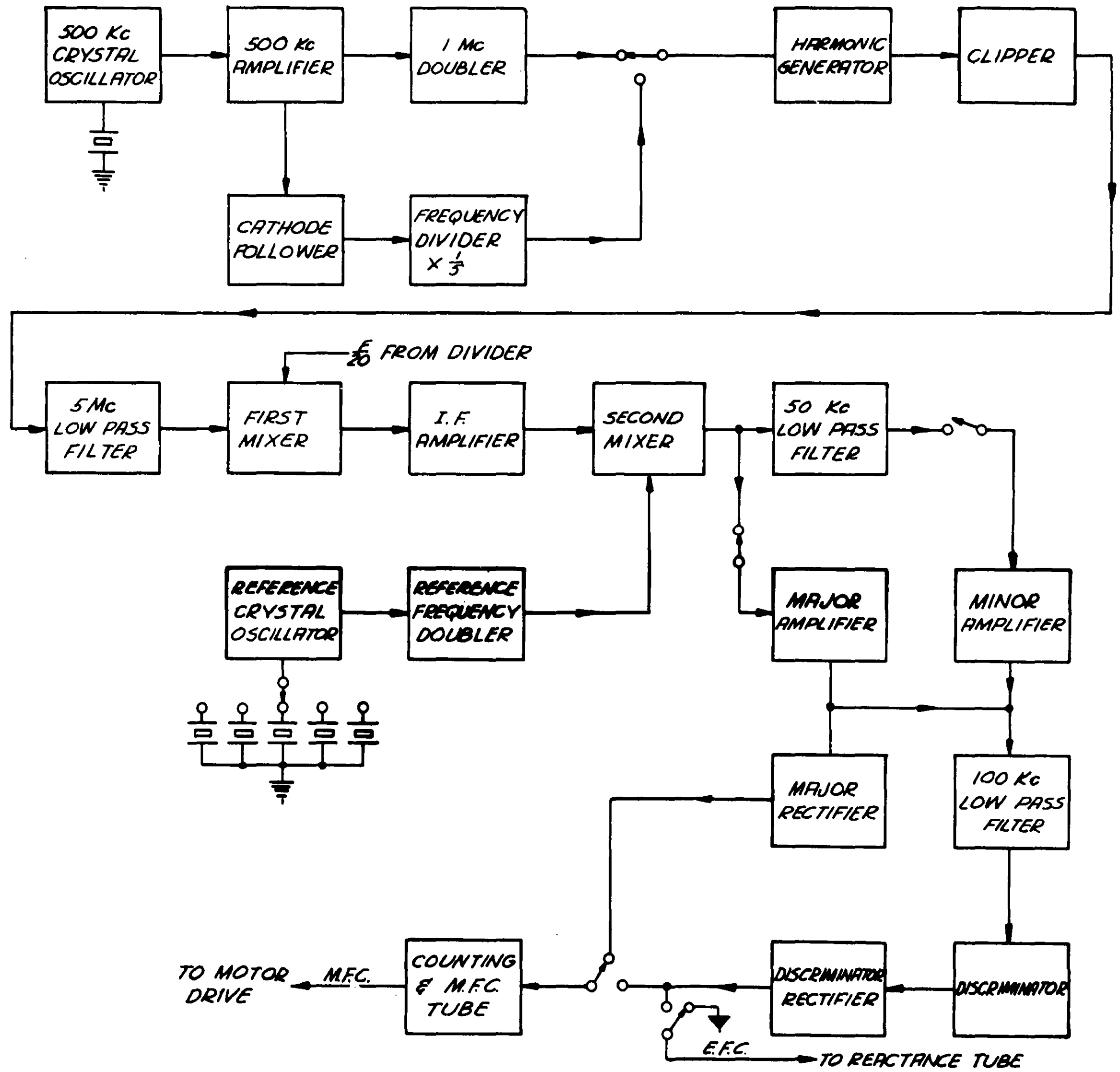


Figure 51.-Block Diagram of Monitor Unit.

plate voltage of 150 volts was applied. Under these conditions the amplitude of the positive output pulse of the oscillator is about 45 volts.

The repetition rate of the blocked-grid oscillator must be either 1.0 Mc or 100 kc. Since the precision of the spacing of the markers is a contributing factor in the overall equipment frequency stability, it is important that the two repetition rates, especially the 100-kc repetition rate, be held within predetermined limits. This limit, as mentioned previously, has been set as plus or minus 0.001 percent of the operating frequency. Since the blocked-grid oscillator is synchronized with an external signal, the stability of the oscillator's repetition rate will be equal to the frequency stability of the synchronizing signal. A logical source of a synchronizing signal, stable to better than plus or minus 0.001 percent in frequency, is a crystal-controlled oscillator. The frequency of the crystal oscillator could be either 100 kc or 1.0 Mc; however, either choice of frequency would necessitate a multiplication of ten or a division of ten to supply synchronizing signals at both repetition rates. Circuits that permit a multiplication or division by ten are not wholly satisfactory at these frequencies. Therefore, to improve reliability it is desirable that the multiplication and division factor be less than ten. A crystal oscillator frequency of 500 kc was selected as the best compromise. Crystal oscillators 500 kc and higher in frequency almost always oscillate readily with the application of supply voltages. This is not always true with oscillators lower in frequency. This fact is important because the crystal oscillators must always commence operating immediately without fail when the equipment is turned on.

The oscillator, including tube V301, is arranged so that the crystal operates at its series resonant frequency. The crystal is silverplated and wire mounted in a type HC-6 can. The crystal is a type CT cut with the nose of its temperature characteristic curve centered at 70° C. The crystal with holder is enclosed in a small oven which maintains the crystal temperature at 70° ± 5° C under Service Conditions. The small single-unit oven is shown in Figure 53 together with the larger five-unit oven for the five reference crystals. Figure 54 shows a disassembled view of the small oven. Both the single-unit oven and the five-unit oven were obtained under developmental contract from Sommerset Laboratories. When this project was started, no small crystal ovens with suitable characteristics were available, so a contract was let to develop ovens for this equipment.

Variable capacitor C312 allows the crystal oscillator frequency to be adjusted to exactly 500 kc. This adjustment is necessary to overcome the small differences in the natural resonant frequencies of the crystals as they come from the manufacturer and also the variations in oscillator circuit characteristics from one equipment to the next.

The selection of 500 kc as the crystal oscillator frequency requires that a division of five be made in frequency to synchronize the blocking oscillator at the 100-kc repetition frequency and a multiplication of two in frequency to synchronize the same blocking oscillator at 1.0-Mc repetition

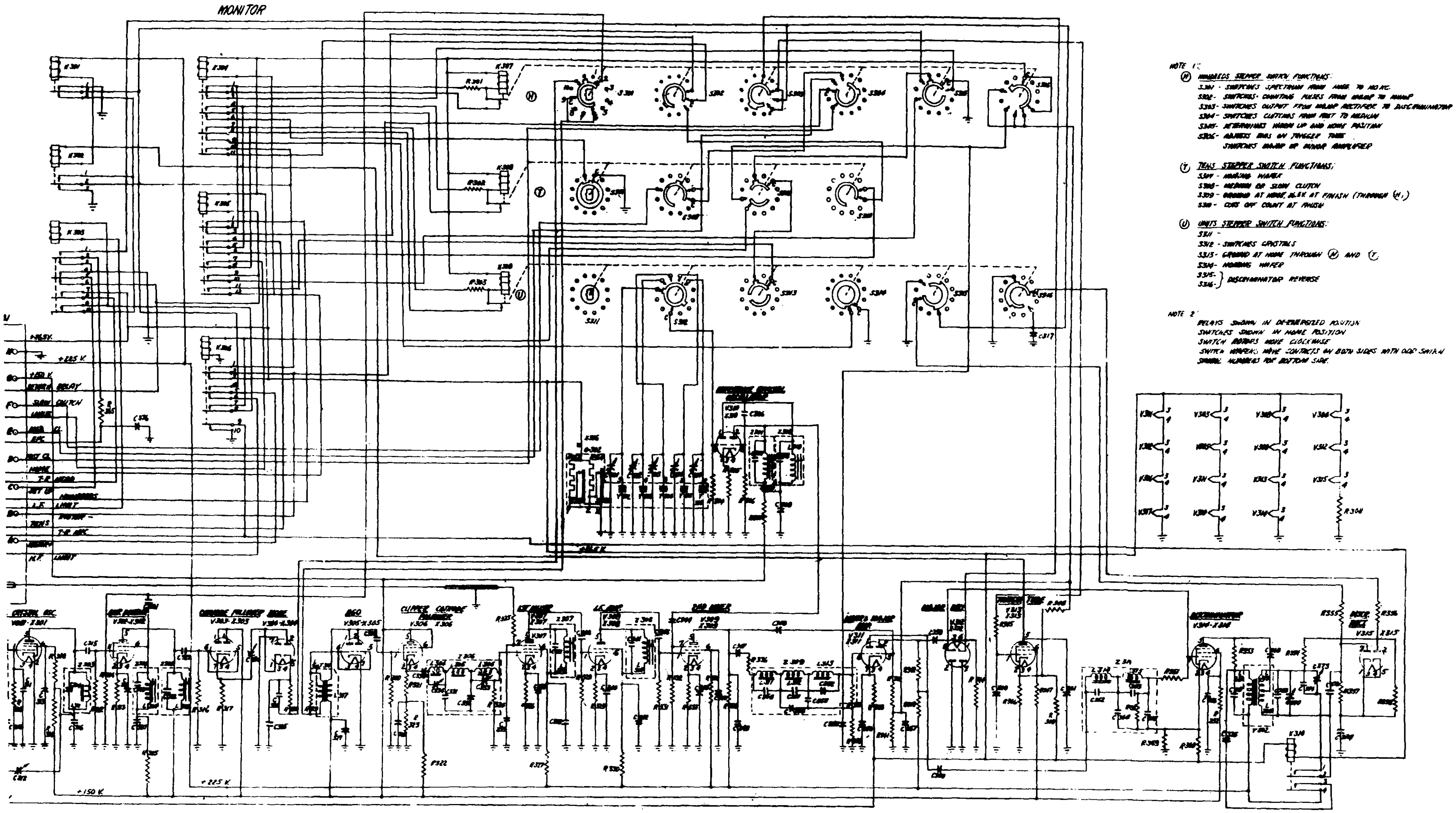


Figure 52.-Schematic Diagram of Stepper Type Monitor Unit

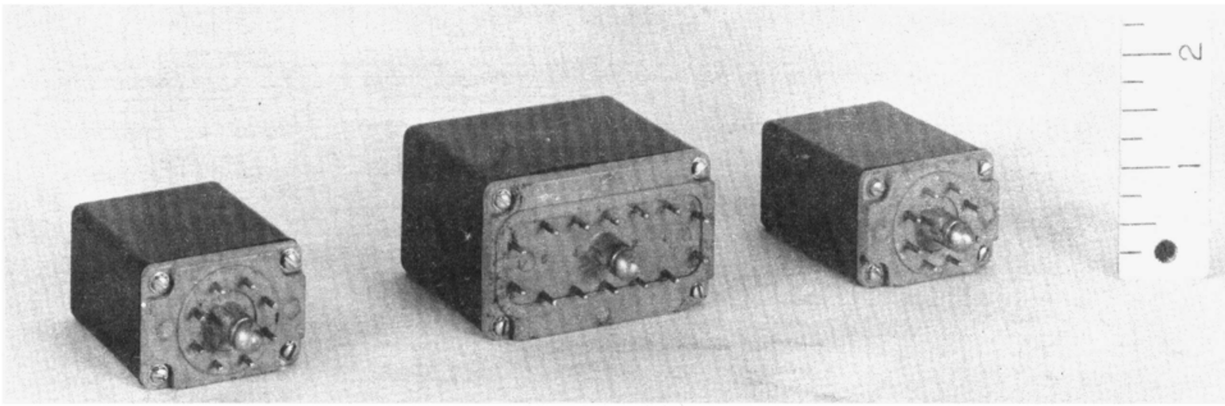


Figure 53.-Crystal Ovens

frequency. The circuits providing the two synchronizing signals are fairly simple as a result of the reduced multiplication and division factors.

Tube V302 is a combined amplifier and doubler stage. It also serves as a stage of isolation between the load and the crystal oscillator. Components L303 and C322, in the plate circuit of the amplifier, are resonant at 500 kc. Components L302 and C319, located in the screen of the amplifier, are resonant at 1.0 Mc. This circuit is the source of the 1.0-Mc synchronizing signal used at the blocking oscillator. The capacitor C321 couples the signal from the 1.0-Mc resonant tank circuit to the grid winding of the blocking oscillator through switch S301.

Stray capacitance to ground plus C321 and resistance R314 determine the natural repetition rate of the blocking oscillator. This repetition rate is set somewhat lower than 1.0 Mc so that the blocking oscillator may be synchronized at 1.0 Mc. The 500-kc signal at the plate of V302 is coupled to cathode follower V303 which drives the five-to-one divider tube V304. The divider has a relatively low input impedance. To insure reliable operation

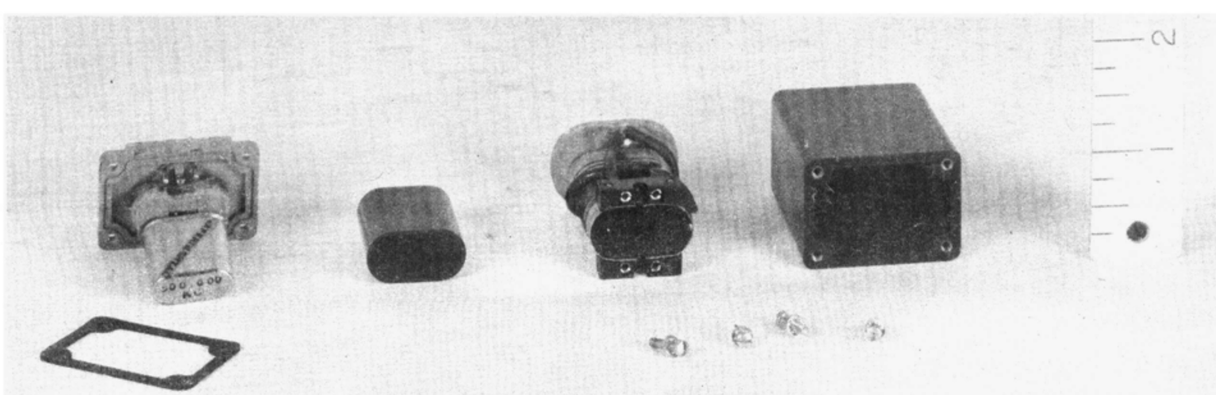


Figure 54.-Model 1 Crystal Oven - Disassembled.

of the divider it was necessary to match the high output impedance of V302 to the low input impedance of the divider with the cathode follower.

The divider circuit is conventional. Capacitor C326 and resistor R316 connected in parallel determine the natural repetition rate of the blocking oscillator when switch S301 connects the divider with the blocking oscillator. One end of C326 and R316 is tied to the high side of C325 and the other end is connected through S301 to the grid winding of the blocking oscillator transformer. The natural repetition rate is approximately 60 kc. When the blocking oscillator has fired, C326 will be charged negatively and the positive charge on C325 will be completely removed. However, the double diode prevents C325 from being charged negatively. During the quiescent period between pulses a positive charge is built up in progressive steps in C325. Each cycle of the input signal applied to the double diode, V304, adds to the positive charge on C325. The blocking oscillator will be triggered when the algebraic sum of the positive voltage in C325 and the negative voltage in C326 is sufficiently positive to cause V305 to conduct current. The ratio of capacity between C324 and C325 determines the number of cycles required to build up a sufficiently positive charge in C325. Hence, a very convenient control of the division ratio can be had if capacitor C324 is made variable. This capacitor is adjusted so that five cycles of the 500-kc input signal are required to trigger the blocking oscillator. Thus the repetition rate will be one-fifth 500 kc or 100 kc.

A positive 45-volt pulse 0.15 μs wide at the base is coupled from the blocking oscillator to the clipper-cathode follower tube V306. This tube is cathode biased so that a positive voltage in excess of 40 volts is required to cause the tube to draw plate current. Since the input pulse is essentially triangular in shape, the output of this stage will consist of a pulse considerably narrower than 0.15 μs with an amplitude of only a few volts. It is desirable that the 100-kc spectrum be as uniform in voltage amplitude as possible throughout the utilized range of 100 kc to 5.0 Mc. This range includes harmonics up to the 51st harmonic.

The amplitude of the harmonics in the spectrum decreases with increasing order of harmonic until this amplitude is reduced to zero at the end of the first loop. It is obvious that if the first 50 harmonics are to be reasonably uniform in amplitude they must constitute a small portion of the total number of harmonics enclosed in the first loop of the spectrum. The number of harmonics enclosed in the first loop is a function of the pulse width. The base width of the pulse output of the clipper-cathode follower is equal to approximately 0.03 μs. Thus the first loop will extend

$$\frac{1}{\text{pulse width in } \mu s} = \frac{1}{0.03} = 33.3 \text{ Mc or to the 333 harmonic.}$$

The pulses are capacitively coupled from the clipper-cathode follower to a low-pass filter, Z 306, with a cutoff frequency of 5.0 Mc. The characteristic impedance of the filter is 1000 ohms which necessitated the use of a cathode follower as a driver stage. The characteristic impedance was made as large as possible while maintaining practical values for the filter components. The filter consists of two m-derived half sections connected to the ends of a prototype filter section. Capacitors C334 and C333 are variable capacitors which allow the cutoff frequency of the filter to be accurately adjusted after the filter is connected in the circuit. The two capacitive trimmers were necessary since it was very difficult to estimate or measure accurately the various stray filter capacitances and also because the filter condenser values were only a few times greater in value than the stray capacitances. In any quantity production of this monitor the final capacity of the trimmers could, of course, be measured and fixed capacitors substituted. The output of the filter is loaded with a 1000-ohm resistance to eliminate reflections. The filter characteristic is shown in Figure 55.

There are two reasons for using this filter. It minimizes a spurious response in the hundreds-count signals and one in the tens-count signals either of which, if not suppressed, could cause the monitor to miscount and consequently tune the equipment to the wrong channel. The two spurious responses are due to spectrum harmonics above 5.0 Mc. Since the monitor utilizes spectrum harmonics only as high as 5.0 Mc, the filter was, therefore, designed to cut off sharply at this frequency. The spurious response occurring during the hundreds-count was due to the second harmonic of the divider output frequency mixing with spectrum harmonics above 5.0 Mc. For example, if the divider frequency is 10.5 Mc its second harmonic will be 21.0 Mc. This signal mixed with the 6.0-Mc spectrum harmonic will result in a beat frequency of 15.0 Mc which would, if not filtered, pass through the i-f amplifier producing an output identical to a normal hundreds-count response except for amplitude. The same phenomenon would likewise take place at 11.5 Mc, 12.5 Mc, and 13.5 Mc until at 14.5 Mc the spurious response has disappeared. The cause of the disappearance of the spurious response is apparent when it is remembered that the higher order spectrum harmonics diminish rapidly in amplitude. These spurious responses would cause the hundreds-counts to be registered every half megacycle instead of every full megacycle in the lower half of the band; however, the filter completely removes these spurious responses and the hun-

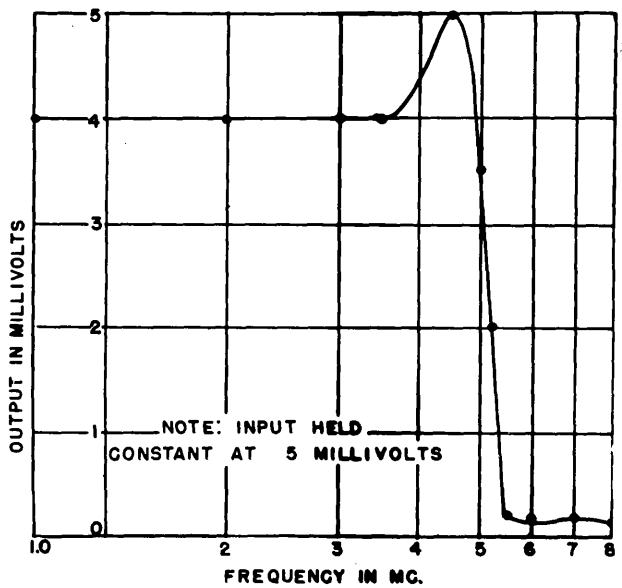


Figure 55.-5-Mc Filter Response

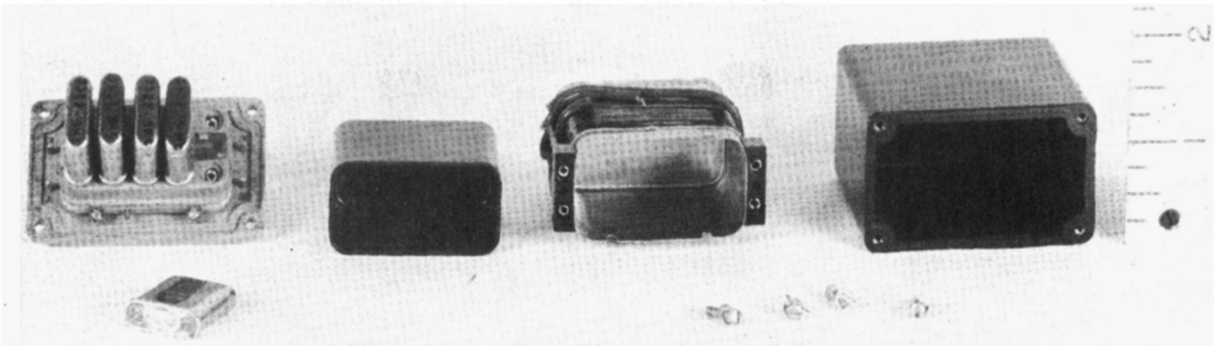


Figure 56.-Model 2 Crystal Oven, Disassembled

dreds counting is normal. The spurious response occurring during the tens count was due to the 15.0-Mc harmonic feeding through to the second mixer where it mixed with the reference frequency. An audio beat frequency would be produced which would cause an unvarying d-c voltage output from the discriminator. This was true if the spectrum and reference crystal oscillators were not exactly on the design frequency. The crystal oscillators are not necessarily on the exact design frequency since each may drift plus or minus 0.001 percent in frequency. The unvarying d-c voltage could cause premature counting and thus miscounting. Here again, filter Z306 attenuates the 15.0-Mc spectrum harmonic to such an extent that the spurious response is eliminated.

The output of filter Z306 is directly coupled to the control grid of the first mixer, V307. The level of the spectrum at this point is about 50 mv. The divider output frequency from the master oscillator is fed to the suppressor grid of the first mixer. The level of the signal is maintained at one volt rms over the band by the network of R366 and C335. The amplitude of this signal may change plus or minus 0.5 volt without undesirable effects. Components L307 and C337 in the plate circuit of V307 are resonant at 15.0 Mc. The first mixer is capacitively coupled to the 15-Mc i-f amplifier, V308, and this amplifier is likewise coupled to the second mixer, V309. The gain of the i-f amplifier was purposely reduced to prevent over-driving the second mixer. It was not possible to eliminate the i-f stage because the total monitor gain requirements were such as to make it desirable to obtain a portion of the gain at the i-f frequency.

The i-f signal is coupled to the control grid of the second mixer and the reference frequency is fed to the suppressor grid. The reference frequency is developed in tube V310, which is a double triode. One triode is a crystal oscillator and the other a frequency doubler. The drystal oscillator is conventional. Components L310 and C308 in the plate circuit of the oscillator triode resonate at 7.5125 Mc. There are five crystals, any one of which may be connected to the grid by S312 on the units stepper. The crystals vary in frequency in 5-kc steps from 7.5125 to 7.5325 Mc. The crystals are silver plated and wire mounted in modified HC-6 cans. The five crystals are plugged into a small five-unit oven shown in Figure 53. Figure 56 shows the internal construction of this oven. The oven maintains the crystal temperature at $70^{\circ} \pm 5^{\circ}$ C. under Service Conditions. The crystals are a type CT cut with the plateau of their temperature characteristic centered on 70° C. No precautions have been taken to temperature stabilize the frequency of this oscillator other than to oven control the temperature of the crystals. Separate trimmer capacitances in parallel with each crystal have been provided to allow each crystal, when connected to the oscillator, to be adjusted precisely to the design frequency. The reasons for the trimmers are the same as those set forth for the spectrum crystal oscillator. Components L309 and C307 in the plate of the doubler triode resonate at 15 Mc, which is twice the oscillator frequency. Both the oscillator and doubler tank circuits are sufficiently broad-banded that little loss in signal amplitude occurs from one crystal frequency to another. Tube V309 is cathode biased two volts positive. The d-c circuits of the control and suppressor grids are returned to ground. The signal level at the control grid normally is not large enough to cause a d-c back bias to develop. The signal level at this point is about 0.5 rms volts. This condition holds true for all divider output frequencies from 11 to 20 Mc. with the exception of 15 Mc. It is obvious that when the divider output frequency at the first mixer is 15 Mc, this signal will pass directly through the 15-Mc i-f amplifier, impressing a signal of approximately 5 volts rms on the grid of the second mixer. As a result, a back bias is developed on this grid which reduces the gain of the mixer for small signals, reducing the amplitude of the desired beat frequency.

This phenomenon is not serious enough to cause monitor miscounting under Service Conditions on the test bench. The cause of the difficulty, of course, is due to the fact that the i-f frequency lies within the range of 11 to 20 Mc. The i-f frequency could have been placed outside the band, but a spectrum of markers extending to 10 Mc would then have been necessary and very difficult to obtain. The selection of the i-f frequency was thus a compromise. There are several ways to minimize the back bias. One means is to reduce i-f gain. This was done and carried to a practical limit. The use of an AVC voltage is not a solution. The application of an AVC voltage to the i-f amplifier on first mixer will merely aggravate the condition because, in effect, the back bias on the control grid of the second mixer is an AVC voltage. Another solution to the difficulty would be to insert attenuation to 15 Mc between the r-f divider and the first mixer. The attenuation characteristic should be similar to that of the i-f band-pass characteristic. With this arrangement the 15-Mc signal would be attenuated by the same amount as it was amplified in the i-f and an essentially constant voltage of 0.5 volt rms would be fed to the second mixer for all divider frequencies from 11 to 20 Mc. The attenuation was not inserted because the harmful effects of the back bias were not serious enough to cause miscount of the monitor on the test bench.

The audio output of the second mixer is fed to Z309 and to one-half of tube V311. Capacitor C348 by-passes the i-f component of the output. Filter Z309 is a low-pass, m-derived, three-section filter with a cutoff frequency of 50 kc. Figure 57 illustrates the filter characteristic curve. The filter was designed to have a characteristic impedance of 27,000 ohms. Filter Z309 is directly coupled to the grid of the second triode section of V311. This section is the tens-count audio amplifier and the first section is the hundreds-count audio amplifier. Either amplifier may be cut off by switch S306 on the hundreds stepper by the removal of plus 26.5 volts d-c from the appropriate grid return. The cathode of the tube is tied directly to the plus 26.5-volt d-c primary power supply. Therefore, if the 26.5 volts is removed from the grid return, that amplifier will be biased well beyond cutoff.

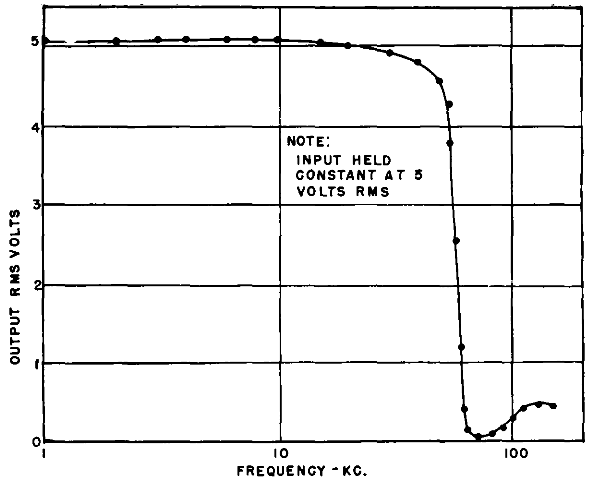


Figure 57.-50-kc Filter Response

The audio output of the hundreds amplifier is coupled to one-half of the double diode V312. The rectified d-c voltage from this diode is run to switch S303 on the hundreds stepper. A typical hundreds-count response appearing at the rectifier is shown on Figure 58. The response curve is identical to the i-f band-pass characteristic. The irregularities of the curve are due to Z309 changing input impedance with frequency. They cause no harm since they are well above the trigger tube operating voltage. Figure 59 shows the d-c voltage amplitude of each hundreds response in the band from 9 to 21 Mc. The 9-Mc and the 21-Mc responses have been attenuated by the spectrum filter Z306.

The audio output of the tens amplifier is coupled to Z310. The hundreds amplifier is likewise coupled to this filter because the discriminator must be driven by the hundreds amplifier during the last hundreds count and by the tens amplifier during the tens count and during AFC conditions. Filter Z310 is a low-pass, two-section, m-derived filter with a characteristic as shown in Figure 60. It has a characteristic impedance of 27,000 ohms. The

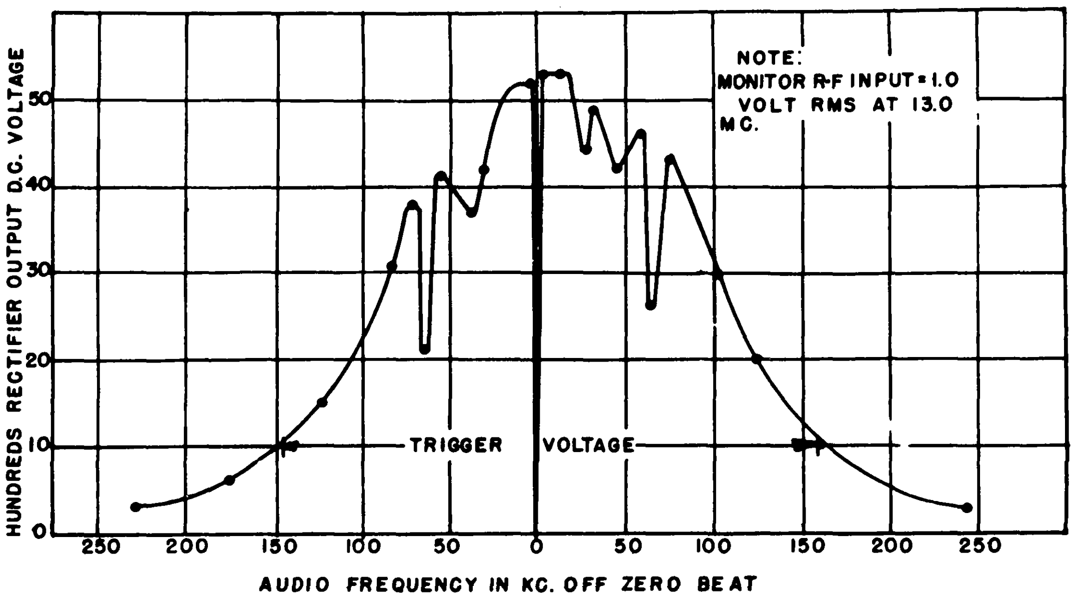


Figure 58.-Typical Hundreds Count Response

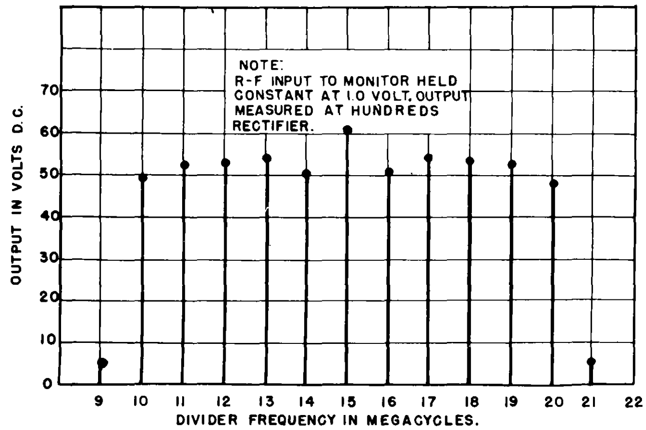


Figure 59.-Amplitude of Hundreds Audio Signal

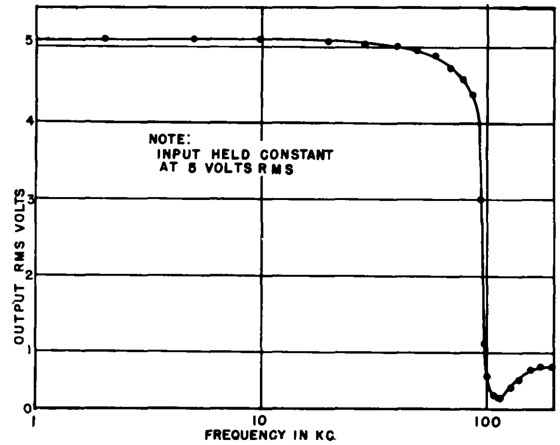


Figure 60.-100-kc Filter Response

filter output is directly coupled to the discriminator grid, tube V314, through resistor R351. The cathode of the second half of the double diode V312 is connected to the grid of V314. The cathode of the diode and the grid of V314 combine to clip or square the top and bottom of the input audio sine wave. The positive and negative points at which squaring occurs are determined by the cathode bias on V314. Resistors R359 and R360 fix this bias at plus four volts. Consequently, the audio voltage at the grid of V314 rises to 3.0 volts rms and thereafter remains constant for increasing audio output from Z310. The reason for sharply limiting the audio input to V314 is to prevent changes in the discriminator crossover frequency. Appreciable amounts of crossover shift in frequency were noted without limiting. With the limiting provided, the shift in crossover frequency has been reduced to less than 25 cycles for a variation of audio input of 3 to 15 volts rms. The normal level of the audio output of Z310 is ten volts rms. Figure 61 shows that this

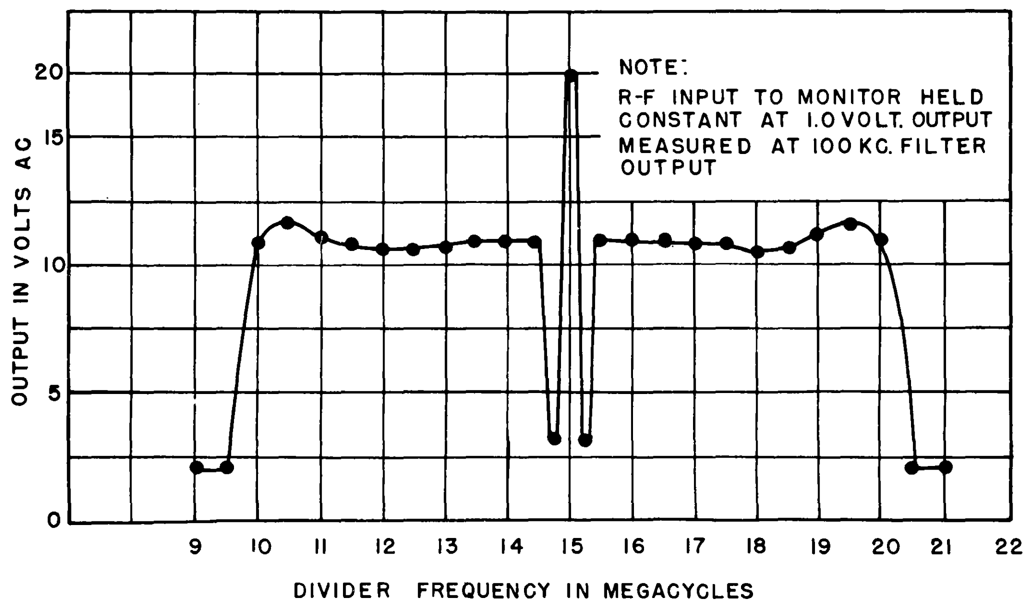


Figure 61.-Amplitude of Tens Audio Signal

level varies less than 1.5 volts from one end of the band to the other except at 15 Mc. Previously it was pointed out that it was desirable to maintain the spectrum reasonably uniform in amplitude for it is the spectrum which determines the magnitude of the audio signal. The audio signal must always be greater than three volts or serious crossover frequency deviations will result.

Since the spectrum, and thus the tens audio level, were found to be so uniform and more than three times greater than the minimum required voltage it was decided that it would be unnecessary to apply AVC to the monitor. Simplification of design resulted. The figure also indicates the effectiveness of the spectrum filter Z306. The tens audio response is cut off sharply below 10 Mc and above 20 Mc.

Tube V314, discriminator transformer T302, and dual diode V315 comprise the discriminator circuit. Components R354 and C372 cause the rotation of the characteristic curve axis. Figure 62 and Figure 63 show typical curves for a 25-kc crossover frequency and a 32-kc crossover frequency.

Relay K310 causes the master oscillator to be changed from transmit to receive frequency. It accomplishes this change by shifting the discriminator crossover frequency from 25 to 32 kc as previously mentioned. Capacitor C367 in the primary of T302 and C369 in the secondary tune the discriminator to 32 kc. Capacitor C370 is a trimmer capacitance in parallel with C369 to align the discriminator to exactly 32 kc. The relay parallels C375 with C367 in the primary and C371 with C369 in the secondary to tune the discriminator to 25 kc. Capacitor C373 is a capacitive trimmer to align the discriminator to exactly 25 kc. The primary of the discriminator is tuned to exactly one-half the secondary frequency. This was found necessary to eliminate crossover frequency shift with changes in input signal amplitude. This precaution was required in addition to limiting at the discriminator input. Both the positive and negative leads of the discriminator are brought to switches S315 and S316. These switches reverse the discriminator polarity making it

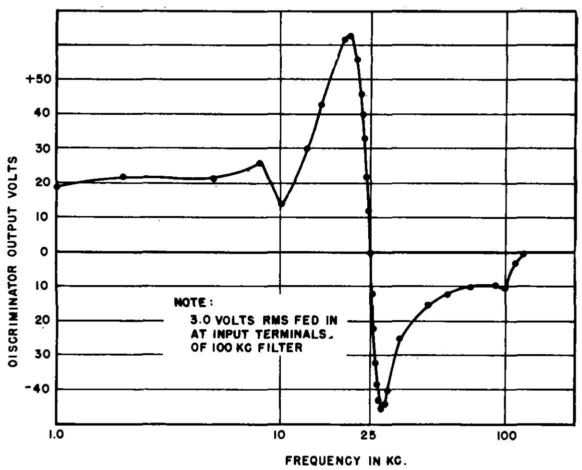


Figure 62.-Discriminator Response for 25-kc Crossover

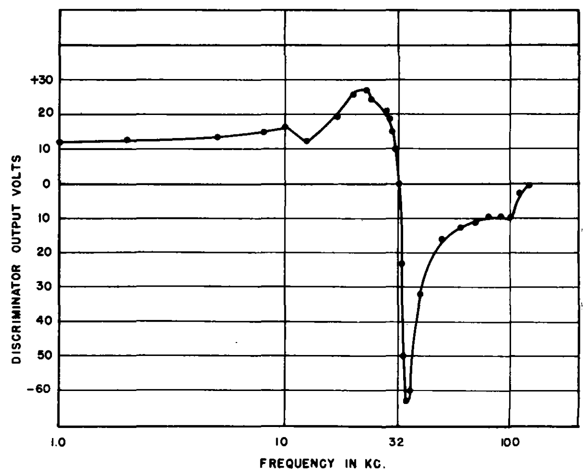


Figure 63.-Discriminator Response for 32-kc Crossover

positive for units digits 0 through 4. It reverses discriminator output polarity by grounding the appropriate discriminator lead and connecting the remaining lead to switch S303. Capacitor C317 by-passes the outgoing lead of S315 and S316 to ground. It effectively swamps out changes in switch capacity and wiring capacity from one switch position to the next. This measure was necessary to minimize discriminator crossover frequency shift when the output polarity is reversed. The shift in crossover frequency is large without by-passing. With by-passing it has been reduced to less than 25 cycles. The discriminator output voltage or EFC voltage is run from S315 and S316 to S303 and also through contacts 1 and 2 on relay K303 to the reactance tube in the transmitter assembly. Relay K303 disconnects the reactance tube grid from the EFC voltage and grounds it during counting. Switch S303 on the hundreds stepper connects the trigger tube grid, tube V313, to either the hundreds rectifier output or the discriminator output.

The trigger tube and relays K301 and K302 perform the same functions as the circuit previously described with the aid of Figure 46. Relay K301 is the reverse relay and K302 is the counting and forward relay. They cause the tuning motor to either reverse or run forward. However, K302 performs a second function. It also serves as the stepper-actuating relay during the hundreds and tens count.

TOLERANCES OF MONITOR COMPONENTS

All resistors and capacitors have a tolerance of plus or minus 5 percent or greater. All filter inductances are plus or minus 5 percent tolerance. The value of inductances in the resonant tank circuits must be close enough to the design value to bring the resonant frequency within the range of the capacitive or inductive trimmers. The six crystals must be near enough to the design frequency so that they may be pulled by means of a trimmer to the exact design frequency. The crystal tolerances have been set as plus or minus 0.001 percent in frequency. The monitor will operate normally with tubes operating within the JAN specifications for vacuum tubes.

MONITOR POWER REQUIREMENTS

The heaters of all monitor vacuum tubes are connected in groups of four in series from plus 26.5 volts to ground. They crystal ovens also operate from plus 26.5 volts. This voltage may vary plus or minus 10 percent without undesirable effects. The plus 150-volts supply is regulated and maintained within plus or minus 3.0 volts. It supplies plate voltage to all the spectrum generating circuits, the reference crystal oscillator and doubler, and to the screens of the discriminator tube V314 and trigger tube V313. The purpose of employing a regulated voltage on these circuits is to prevent any appreciable shift in the spectrum frequency, the reference frequency, and the discriminator crossover frequency. The plus 225-volt bus supplies the plate and screen voltage of the remaining tubes. This voltage may vary from plus 180 to plus 300 volts without harmful effects.

MONITOR ALIGNMENT

The monitor may be aligned with a test bench setup or in the equipment. The test bench setup is preferable and will be described here; however, the monitor may be aligned in the equipment by following the test bench procedure.

The test bench setup consists of a motor driven, reactance-tube-controlled, master oscillator operating from 10.5 to 20 Mc, a control box, a monitor, a power supply, and an electrical harness to connect all four units. Three test instruments are necessary: an oscilloscope, a vacuum tube voltmeter, and a signal generator to provide one volt rms of r-f signal at the divider output frequency of 10 to 20 Mc. This completes the test setup, and alignment may commence.

Since it is desired to align the monitor and not to operate the motor drive, the motor must be disabled by disconnecting one lead. Power then is applied to the setup. The first circuits to be aligned are the two crystal oscillator plate tank circuits. The procedure for trimming the crystals to their exact design frequencies will be described later. The 500-kc crystal oscillator has a fixed-tuned tank circuit Z303 resonant at 700 kc which does not need aligning. However, Z304 and Z305 in the doubler amplifier stage, V302, do require alignment. Circuit Z305, resonant at 500 kc, is peaked while observing the deflection obtained on the oscilloscope when it is directly coupled to the cathode of V303. Likewise, Z304, resonant at 1.0 Mc, is approximately peaked with the oscilloscope connected to the switch side of C321. It will not be possible to accurately peak Z304 at this point because the capacity of the oscilloscope lead is not isolated from the circuit as it was for Z305. However, Z304 will be accurately peaked later in the procedure. The reference oscillator tank circuit is aligned next. Any of the reference crystals may be switched into the oscillator. A vacuum tube voltmeter is connected to the grid of the oscillator and Z302, resonant at 7.5 Mc, is adjusted on the gentle slope side of resonance until the voltmeter reads two-thirds of the peak negative voltage. Resonant circuit Z302 is detuned from the peak reading to insure stable oscillator.

The next step of the procedure is to set the control box, if it is not already set, on a number several hundred channels high. This operation prepares the monitor to register a number of hundreds counts. Since the motor is inoperative it permits the hundreds wave forms to be observed at leisure with the signal generator replacing the master oscillator. The first mixer tuned circuit, Z307, the i-f amplifier tuned circuit, Z308, and the reference frequency doubler tank circuit, Z301, can now be aligned. The oscilloscope is connected to the output of the hundreds rectifier and the signal generator is tuned to an integral Mc point such as 12.0 Mc. It is tuned so that the audio signal at the hundreds rectifier is slightly off zero beat, about 100 cps to get a maximum scope deflection yet not be so far off zero beat to cause misalignment of the tank circuits. With this setup, Z307, Z308, and Z301 can be peaked for a maximum oscilloscope deflection. The d-c voltage at this observation point should equal about 50 volts. Next, the signal generator is tuned to 10.5 Mc and Z304, readjusted until the spurious response obtained at this frequency disappears. Resonant circuit Z304 is then aligned to exactly 1.0 Mc.

The spurious response will be obtained when Z304 is misaligned because the tank circuit then will not present maximum attenuation to the 500-kc signal on the plate of V302, and appreciable amounts of 500-kc signal will be present in the 1.0-Mc output. The blocking oscillator will tend to synchronize at 500 kc as well as 1.0 Mc, producing a spurious response at the half-megacycle points in the band. All the circuits involved with the hundreds count now have been aligned. The amplitude and wave shape of the hundreds responses at the hundreds rectifier can be compared with Figure 58 and Figure 59 to determine if the response is normal. The voltage at which the counting relay operates can also be checked. This triggering voltage should equal about 10 volts d-c.

The circuits utilized in the tens counting are aligned next. The signal generator is tuned over the band until a sufficient number of hundred-markers are registered to step the hundreds stepper to its finish position. The monitor is then prepared to count tens. The oscilloscope is connected to the output of Z310. The division ratio of the spectrum generator divider can now be adjusted by means of trimmer C324. The signal generator is tuned through one megacycle in frequency and the number of tens-count cycles which appear as the signal generator is tuned, are noted. If there are not ten cycles present in the one-megacycle tuning range, the divider must be readjusted until there are ten present in this range. Once the correct division ratio has been found, the limits of the capacitive trimmer setting can be determined by rocking the trimmer to either side and noting when the oscilloscope audio signal pattern begins to jitter. This trimmer can be rotated about ± 30 degrees before the five-to-one division ratio will be upset. The trimmer is set in the middle of the 60-degree range. Once this adjustment is made, the divider division ratio will not change under Service Conditions. Filter Z306 is next aligned. The signal generator is tuned to 9.5 Mc, and trimmers C333 and C334 are adjusted so that no signal appears on the oscilloscope. The signal generator is next tuned to 10 Mc, where the audio signal displayed on the oscilloscope should be of the same amplitude as the signal from 11 to 15 Mc. If it is not, the trimmers should be readjusted. The monitor has now been aligned for the tens count signals and the response at the output of Z310 should be as shown in Figure 61.

The discriminator must be aligned to 25 kc and to 32 kc. These two adjustments must be made with precision. The procedure will be described in subsequent paragraphs together with the procedure for trimming the spectrum and reference crystal oscillators.

The counting and forward (C and F) relay and the reverse relay connected in series in the plate of the trigger tube, V313, must also be adjusted. The operation of this circuit was described in conjunction with Figure 46. The output d-c voltage of the discriminator is fed to the trigger tube and also to the reactance tube V405 which is coupled to the master oscillator. When the equipment is in the AFC position the master oscillator is shifted either higher or lower in frequency in unison with the polarity of the discriminator output d-c voltage by means of the reactance tube and also by means of the motor drive controlled by the trigger tube. The reactance tube continuously forces the master oscillator frequency back towards the channel frequency whenever it drifts off. However, the reactance tube is unable to force the master oscillator back to the exact channel frequency because it does not commence to be effective until a voltage is applied to its grid. This voltage is not developed at the discriminator until a shift or error in the master oscillator frequency occurs. Consequently the reactance tube and discriminator always operate with a small error signal. The magnitude of this error signal is a function of the magnitude of the master oscillator drift. The greater this drift, the greater is the discriminator output voltage. The master oscillator may drift so far in frequency that the reactance tube becomes ineffective. It is the purpose of the trigger tube and motor drive to avoid this condition. This circuit should be adjusted so that the motor will retune the master oscillator to its exact channel frequency whenever the reactance tube becomes unable to return the master oscillator to within predetermined limits of the channel frequency. These predetermined limits in frequency are known as the monitor neutral position or monitor slot width. It is, of course, the range of frequencies in which the motor tuning drive is quiescent. The slot width of the monitor has been set as plus or minus 50 cycles which remains constant anywhere between 11 and 20 Mc. At the signal frequency, anywhere between 225 and 400 Mc, the slot width is 20 times greater or ±1000 cycles. It is apparent that the slot width should be as narrow as possible because it is one of the factors which determines the overall frequency stability of the equipment. The slot width is determined by the adjustment of the reverse relay and the C and F relay located in the plate circuit of the trigger tube. When the master oscillator is plus or minus 50 cycles off channel frequency the discriminator will develop plus or minus 1.4 volts of output. In this condition the master oscillator, discriminator, and reactance tube system are in balance. Since the reactance tube circuit is capable of shifting the master oscillator ±40 kc with ±1.4 volts on its grid, it stands to reason that under the above condition the natural master oscillator frequency must have been ±40,050 cycles off channel frequency and that the reactance tube forced it back to within ±50 cycles. If the natural master oscillator frequency should drift beyond ±40,050 cycles, the system balance point will exceed 50 cycles and 1.4 volts and the motor will retune the master oscillator. Figure 64 shows the trigger tube grid voltages at which the reverse and C and F relays open and close. When the grid voltage is more negative than 1.8 volts, both relays will be open and the motor will be energized driving the master oscillator back, or reverse, to zero volts. Likewise, when the trigger tube grid voltage exceeds plus one volt both relays will be closed and the motor will drive the master oscillator forward in frequency until the discriminator output voltage is zero again. The motor is quiescent only when the reverse relay is closed and the C and F relay is open as previously explained. It is obvious that this quiescent position is different depending upon the direction

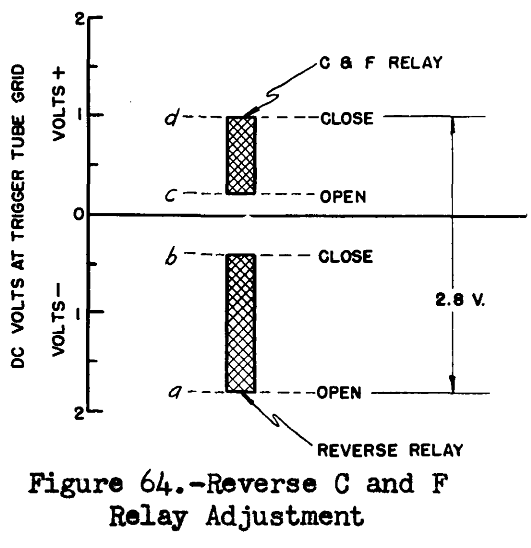


Figure 64.-Reverse C and F Relay Adjustment

in which the master oscillator approaches the frequency where the discriminator output voltage is zero. Point a is the grid voltage at which the reverse relay opens when the voltage is increasing in a negative direction. Point, b is the voltage at which this relay closes when the voltage is becoming more positive. Likewise point c is the decreasing positive voltage at which the C and F relay opens and point d is the increasing positive voltage at which this relay closes. Therefore, when the master oscillator frequency approaches the correct frequency from the negative voltage side of the discriminator characteristic the motor will cease running at point b and will not be re-energized again until point d is reached. Normally, the motor drive will not coast to point d, but will stop at about the zero bolt point on the diagram. Once the point b has been passed, the slot becomes the distance a to d instead of b to d because the reverse relay will be closed and the C and F relay will be open in this area. A similar condition exists when the master oscillator frequency approaches the correct frequency from the positive voltage side of the discriminator characteristic. The motor will be de-energized at point c and will be re-energized if point a should be reached. Once point c is passed, the slot width again becomes the distance a to d. The adjustment of the relays determines the slot width and the tendency of the motor to hunt. The opening and closing currents of the relays are set by adjusting spring tensions, armature gaps, and shunting the coils with resistance. The zero voltage axis is set midway between a and d by the appropriate cathode bias. Motor hunting is reduced by making the distances c to a and b to d as great as possible without sacrificing slot width. If hunting still persists it may be eliminated by increasing the slot width at the sacrifice of equipment frequency stability.

The slot width of the AN/ARC-19 (XN-1) is adjusted as shown in the figure just discussed. The slot width is equal to 2.8 volts or ± 1.4 volts which is equivalent to ±50 cycles or a total of 100 cycles. The actual frequency of the master oscillator is never in error more than ±50 cycles. In other words, the AFC and EFC circuits are responsible for only ±50 cycles of frequency error regardless of the amount of error introduced by the spectrum crystal oscillator, the reference crystal oscillator, and the discriminator crossover frequency. In previous discussions the slot width error is considered to be a part of the total discriminator frequency error.

There is one other slot width which may be considered and that is the mechanical slot width. Since the reactance tube pulls the master oscillator plus or minus 40,050 cycles back toward channel frequency before the motor begins to operate, the mechanical slot thus is 80.1 kc wide. This means that the natural master oscillator frequency can be anywhere in this range before the motor will retune it.

The procedures and considerations entering into the alignment and adjustment of all monitor circuits have been discussed with the exception of the method used to trim the spectrum crystal oscillator, the reference oscillator, and the discriminator to their design frequencies. This procedure requires a precise frequency measuring setup. This setup together with the aligning procedure will be described in the succeeding paragraphs.

FREQUENCY MEASUREMENT

In aligning the AN/ARC-19 (XN-1) monitor and determining its frequency stability characteristics, a precise method of measuring frequency is required. It is the purpose of this portion of the report to describe the equipment and methods used by the Laboratory for making the necessary frequency determinations.

There are three points in the monitor where frequency measurements must be made. These points are at the crystal controlled spectrum oscillator, the reference frequency oscillator, and the r-f divider output. The spectrum oscillator which operates at 500 kc is checked at the output of the blocking-grid oscillator which generates the harmonic spectrum. In order to facilitate frequency measurement, the 10-Mc harmonic of the spectrum is used. The five crystals of the reference frequency oscillator are checked at the doubled frequencies of 15.025, 15.035, 15.045, 15.055, and 15.065 Mc. At the output of the master oscillator divider, the frequencies to be measured range from 10.993 to 19.997 Mc. Since these frequencies are at one-twentieth of the output channel frequencies, they are spaced one-twentieth of the 200-kc channel spacing, or 10 kc apart. When the monitor is placed in the transmit position, the frequencies fall on integral 10-kc points 11.000 to 19.990 Mc; whereas, when in the receive position, the frequencies shift 7 kc below or above those points. For unit digits of the channel numbering from 0 to 4, the shift is below; for 5 to 9, above.

In order to obtain the necessary accuracy in measuring these frequencies, the method used by the Laboratory involves a Secondary Harmonic Frequency Standard which is constantly monitored against WWV. The accurately known frequency from the Frequency Standard is beat against the signal to be measured, and the resulting note is used to determine the actual deviation of the signal from the true frequency. By this method, high precision measurement is possible with a Standard of average stability. Accuracies within 0.00001 percent are readily obtained. The difference between this accuracy and that of WWV, which is held to within 0.000002 percent, is attributed mainly to instrumental errors. Besides allowing spot frequency measurements, the setup may also be used to provide a continuous record of frequency deviation such as required in a long duration temperature run of the equipment.

The block diagram for the frequency measuring setup is shown in Figure 65. It consists of a Harmonic Frequency Standard, two standard communication receivers, two electronic frequency meters, two Esterline-Angus Recorders, an interpolation oscillator, an audio mixer, and two low-pass filters. The Harmonic Frequency Standard delivers a spectrum of 10-kc harmonics which extends well above the highest frequency (20 Mc) to be measured in the monitor. Receiver Number 1 is a standard communication type receiver used for mixing the 5-Mc signal of WWV (This frequency was chosen for its stability of reception at the Laboratory location) and the 5-Mc harmonic (500th harmonic of 10 kc) from the Frequency Standard. Capacitor C_2, shown on Figure 65, is adjusted for an optimum beat note at the output of the receiver. A speaker connected to the receiver assists in this adjustment. Any modulation, including speech announcements made every hour and half-hour on WWV, is eliminated by means of the 0 to 200 cps low-pass filter, allowing a pure beat note to be fed to Electronic Frequency Meter Number 1 (Hewlett Packard Model 500A) which is set on the 0 to 200 cps range. Previous to measuring a frequency, the oscillator trimming condenser on the Frequency Standard is adjusted so that the 5-Mc harmonic is shifted to some frequency between 50 and 200 cps above WWV. This shift is indicated on Electronic Frequency Meter Number 1 and may be continuously recorded on Esterline-Angus Recorder No. 1. The actual procedure for measuring a frequency is divided into three cases which will be described subsequently. These three cases cover all the necessary measurements made on the monitor.

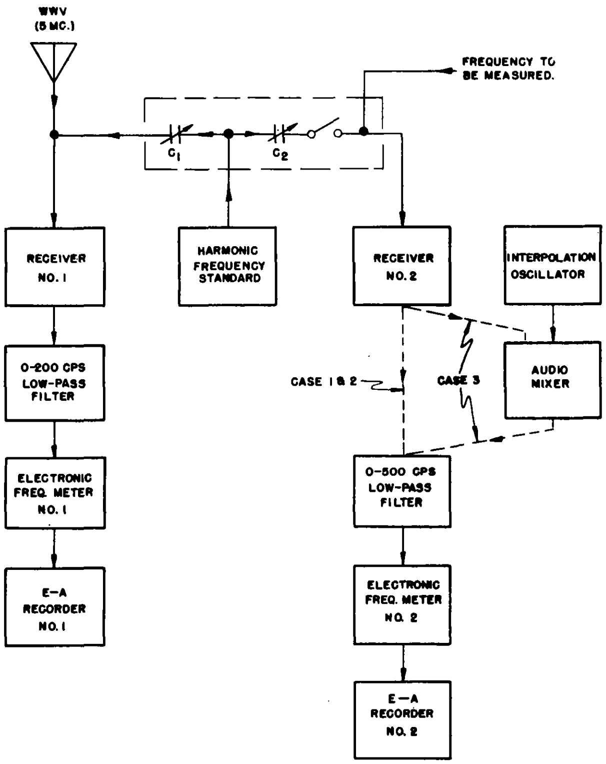


Figure 65.-Block Diagram of Frequency Measuring Setup

Case 1 - Measurement of Frequencies Falling on Integral 10-kc Points.

In measuring the frequency of a signal that falls on an integral 10-kc harmonic point, the particular set-up used is indicated as Case 1 on Figure 66. Two examples of frequencies falling in this category are: first, the channel frequencies from the r-f divider when the monitor is placed in the transmit position, and second, the output from the spectrum oscillator which is checked at the 10-Mc harmonic.

The signal to be measured is picked up in Receiver Number 2 by means of a loosely coupled probe. In checking the channel frequencies, the probe may

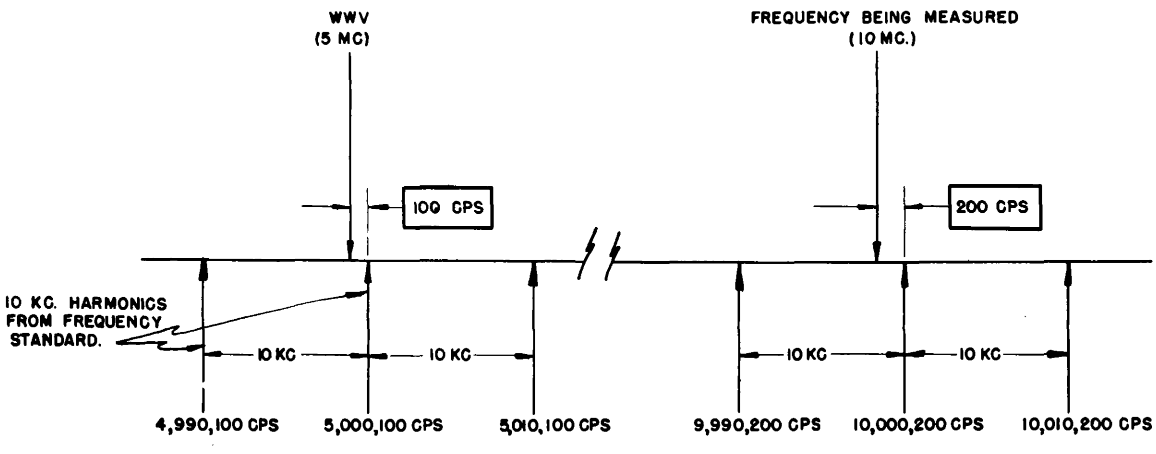


Figure 66.-Frequency Measurement, Case 1

be placed near the grid of the first mixer in the monitor where the output of the r-f divider is introduced. For checking the spectrum oscillator, the probe is placed near the plate of the blocking oscillator in the monitor. The signal thus obtained is mixed in Receiver Number 2 with the output of the Frequency Standard and the resulting beat note is fed through the 0 to 500 cps low-pass filter to Electronic Frequency Meter Number 2, set on the 0 to 500 cps range, and its corresponding Esterline-Angus Recorder Number 2. This range was found to be sufficiently wide for all measurements made on the monitor. Capacitor C_2, shown on the block diagram on Figure 65, is adjusted for an optimum beat amplitude from Receiver Number 2. To obtain the exact frequency of the measured signal, the beat note indicated on Frequency Meter Number 2 must be corrected by the amount the Frequency Standard has been shifted (as indicated on Frequency Meter Number 1) from the known frequency (i.e. WWV). The amount of correction depends on the frequency of the signal. For example, consider that the Frequency Standard is shifted so that its 5-Mc harmonic is 100 cps above WWV as indicated on Frequency Meter Number 1 and the frequency of the signal to be measured is exactly on 10 Mc. The 10-Mc harmonic from the Frequency Standard is then actually 200 cps above the true frequency or at 10,000,200 cps. This harmonic beating against the signal at exactly 10 Mc gives the 200 cps beat indicated on Frequency Meter Number 2. It follows that by assigning a negative sign to the reading on Frequency Meter Number 2, and adding it algebraically to the positive value on Frequency Meter Number 1, converted to the measured frequency (in this example, multiplied by 10/5 or 2) the actual deviation of the signal is obtained. The frequency relation of the above example is illustrated in Figure 66. From the example, it may be seen that for any frequency falling on integral 10-kc points, the following equation may be used for obtaining the frequency deviation:

$$F.D._{(1)} = (\Delta f_{F.S.})\left(\frac{f_s}{5}\right) - \Delta f_s \qquad \text{(Equation 1)}$$

where: $F.D._{(1)}$ = Frequency deviation in cps from f_s.

$\Delta f_{F.S.}$ = Frequency shift in cps of the Frequency Standard above WWV at 5 Mc as indicated on Frequency Meter Number 1.

Δf_s = Exact design frequency in Mc of the signal to be measured.

Δf_s = Beat frequency in cps between signal and harmonic from the Frequency Standard as indicated on Frequency Meter Number 2.

It may be noted that if the signal to be measured happened to be 10,000,400 cps instead of exactly 10-Mc, a 200 cps note would also result from beating with the 10,000,200-cps harmonic of the Frequency Standard. In order to verify that this is not the case, it is necessary merely to rotate the oscillator trimmer of the Frequency Standard back and forth and note the change in the beat frequencies from the two receivers. If the signal is on the proper (i.e. low) side of the harmonic from the Frequency Standard, the beat frequencies will vary in the same direction.

By using the Esterline-Angus recorders, a continuous frequency stability run may be made on the measured signal. Points may be taken from the two charts and by the use of Equation 1, graphs of frequency deviation against time may be plotted. In a similar manner, records may also be obtained for Cases 2 and 3 which are described in the ensuing paragraphs.

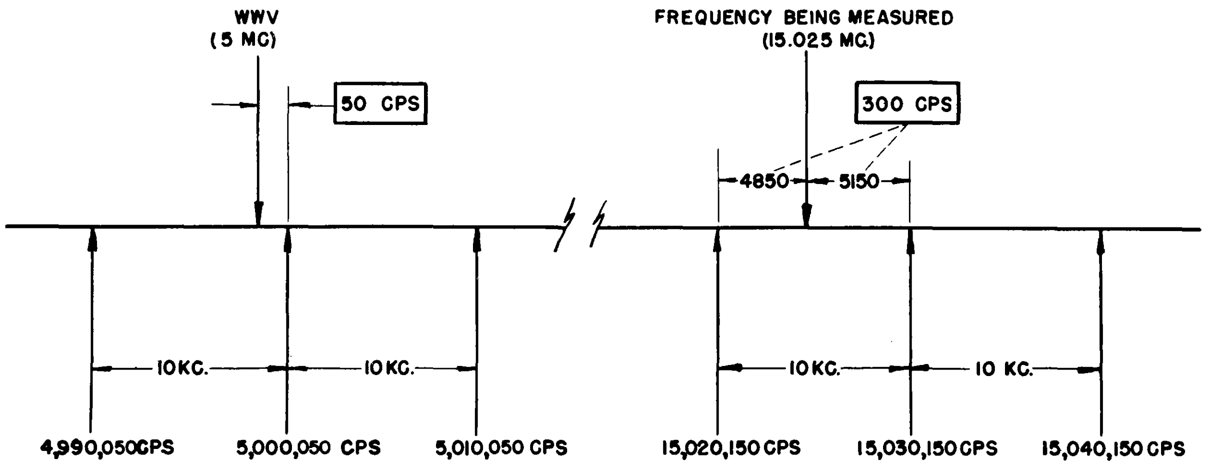


Figure 67.-Frequency Measurement, Case 2.

Case 2 - Measurement of Frequencies Midway Between 10-Kc Harmonic Points

For measuring frequencies midway between 10-kc harmonic points, such as the output from the reference oscillator, the same setup described in Case 1 is used. In this case, however, two beat frequencies of approximately 5 kc are produced between the signal to be measured and the adjacent upper and lower 10-kc harmonics of the Frequency Standard. The tuning of Receiver Number 2 is adjusted to allow these two beat frequencies to beat with each other to produce a third low frequency. The frequency of this beat is dependent upon the amount of shift of the Frequency Standard from WWV. For example, assume that the Frequency Standard is adjusted so that the 5-Mc harmonic is 50 cps above WWV and that the signal to be measured is exactly 15.025 Mc. Consequently, the harmonics beating with the 15.025-Mc signal are 15,020,150 cps and 15,030,150 cps producing 4,850-cps and 5,150-cps beats. These two frequencies in turn beat together to give the 300-cps low-frequency beat which is indicated on Frequency Meter Number 2. The higher audio frequencies are filtered out by the 0 to 500 cps low-pass filter, and therefore do not actuate the frequency meter. The frequency relationship of this example is shown in Figure 67. It follows that the frequency deviation of any measured frequency falling into this category may be found by the following formula:

$$F.D._{(2)} = (2\,\Delta f_{F.S.})\left(\frac{f_s}{5}\right) - \Delta f_s \qquad \text{(Equation 2)}$$

where: $F.D._{(2)}$ = Frequency deviation in cps from f_s .

$\Delta f_{F.S.}$ = Frequency shift in cps of the Frequency Standard above WWV at 5 Mc as indicated on Frequency Meter Number 1.

f_s = Exact design frequency in Mc of the signal to be measured.

Δf_s = Resultant low-frequency beat in cps as indicated on Frequency Meter Number 2.

In a manner similar to that described in Case 1, the trimmer on the Frequency Standard should be rotated to determine whether the beat frequencies from Receiver Number 1 and Number 2 vary in the same direction.

Case 3 - Measurement of Frequencies Between 10-kc Harmonic Points

In this case, assume a frequency 7 kc below or above the 10-kc harmonic points, such as channel frequencies from the output of the r-f divider when the equipment is in the receive position. As shown in Figure 68, the setup for measurements in this category requires, in addition to the existing equipment, an interpolation oscillator (G-R Type 617C) and an audio mixer.

The frequency to be measured is mixed, as in the previous cases, with the 10-kc harmonics of the Frequency Standard. In this case, beat frequencies of approximately 3 kc and 7 kc result from the signal to be measured beating with the adjacent 10-kc harmonics. Receiver Number 2 is tuned so that the approximate 3-kc frequency is predominant and is mixed with the exact 3-kc signal from the interpolation oscillator by means of the audio mixer. At the output of the mixer is a third audio note, the frequency of which is dependent on the deviation of the measured signal from the 7-kc points and on the initial shift of the Frequency Standard. For instance, if the measured signal is exactly 10.993 Mc and the Frequency Standard is shifted 100 cps above WWV at 5 Mc, the measured signal would then beat with the 1,099th harmonic (10,990,220 cps) of the Frequency Standard to produce a beat frequency of 2780 cps. Since this frequency is mixed with the 3-kc signal from the interpolation oscillator, the resulting beat frequency indicated on Frequency Meter Number 2 is 220 cps. The frequency relationship for this example is shown in Figure 68. Hence, the following equation may be used to determine the frequency deviation of any signal in this category:

$$F.D._{(3)} = (\Delta f_{F.S.}) \left(\frac{f_s}{5} \right) - \Delta f_s \qquad \text{(Equation 3)}$$

where: $F.D._{(3)}$ = Frequency deviation in cps from f_s.

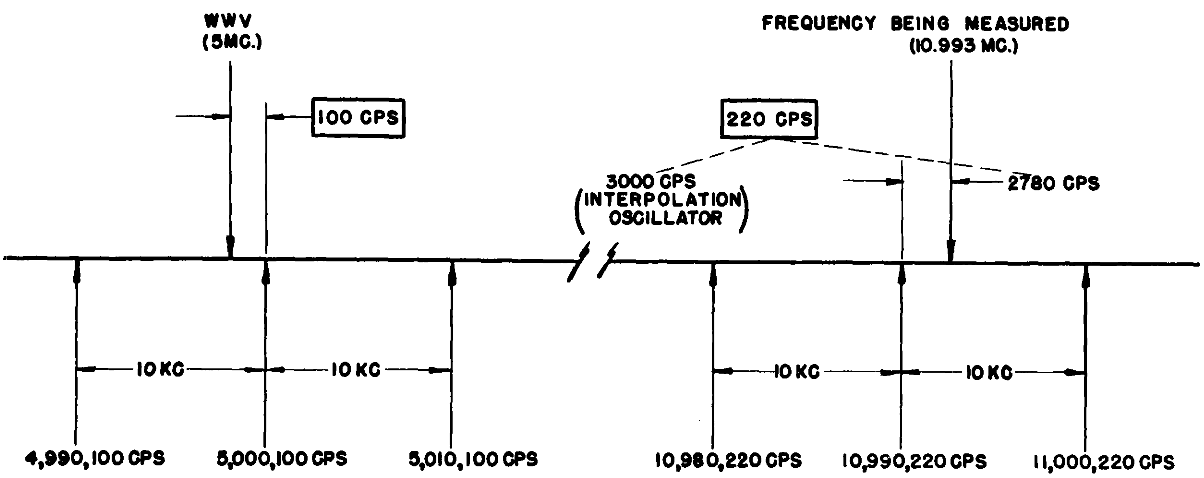


Figure 68.-Frequency Measurement, Case 3.

$\Delta f_{F.S.}$ = Frequency shift in cps of the Frequency Standard above WWV at 5 Mc as indicated on Frequency Meter Number 1.

f_s = Exact design frequency in Mc of the signal to be measured.

Δf_s = Resultant low-frequency beat note in cps as indicated on Frequency Meter Number 2.

As in Cases 1 and 2, the trimmer on the Frequency Standard should be rotated and the two frequencies indicated on Frequency Meters 1 and 2 noted for same direction of change.

ALIGNMENT OF THE DISCRIMINATOR AND SLOT WIDTH DETERMINATION

In the measurement of the channel frequencies with the equipment in the transmit and receive positions as described in Cases 1 and 3, it was assumed that the discriminator of the monitor had already been properly aligned. If this is not the case, the frequency measuring procedures described in these two cases may be used for discriminator alignment in the following manner. First, the spectrum oscillator and reference oscillator are set on frequency as described in Cases 1 and 2. Then, the monitor is placed in the receive position and a channel is selected at the control box. The deviation on Frequency Meter Number 2 is obtained as described in Case 3. Now, the master oscillator is slightly detuned by the slow introduction of some external capacity, such as the hand in the vicinity of the master oscillator tuning condenser. When sufficient capacity has been introduced to exceed the control range of the EFC, the motor is energized to correct for the frequency shift. At this instant, the reading on Frequency Meter Number 2 is noted while the frequency offset of the Frequency Standard is maintained constant at 100 cps as shown on Frequency Meter Number 1. Then, as the external capacity is slowly withdrawn, at a given point the motor will again recorrect. The reading on Frequency Meter Number 2 is again noted. The difference between this value and the one previously obtained is the slot width. For proper alignment, the 32-kc trimmer on the discriminator is adjusted so that the center of the slot lies 7 kc below or above (depending on the channel selection) one-twentieth of the channel frequency, i.e. the center of the slot is such a value on Frequency Meter Number 2 as to yield zero frequency deviation according to Equation 3.

To adjust the 25-kc trimmer, the monitor circuits are switched to the transmit position and the procedure described in Case 1 is used to obtain the frequency deviation. The center of the slot is again determined by a procedure similar to that used in adjusting the 32-kc trimmer. For proper alignment the center of the slot should be exactly on one-twentieth of the channel frequency according to Equation 1.

In a long duration stability run, the shift of the channel frequency within the slot width is normally not accounted for. However, by the attachment of a motor driven external condenser plate that momentarily detunes the master oscillator at regular intervals, it is possible to obtain a continuous record showing the position and width of the slot throughout the run. In this report, the channel stability curves showing the slot width were obtained by this means.

Use of Equipment for Measuring Other Frequencies

The frequency measuring setup described herein is not necessarily limited to determination of frequencies within the monitor. It may be seen in the description of Case 3 that by setting the Interpolation Oscillator to other values, it is possible to determine accurately any frequency up to the highest harmonic detectable in Receiver Number 2 from the Harmonic Frequency Standard.

Description of the Harmonic Frequency Standard

The Harmonic Frequency Standard consists essentially of a crystal controlled oscillator, two frequency dividers, and a harmonic generator. The oscillator operates at a frequency of 500 kc which is divided down to 10 kc by a 5:1 divider and a 10:1 divider. The crystal in the oscillator is temperature controlled to aid in its stability.

Photographs of the standard are shown in Figures 69, 70, and 71. In Figure 72 is shown the schematic diagram of the circuit. Tube VI is the crystal controlled oscillator, using a Type 6AK5 tube. The buffer amplifier V2, also a Type 6AK5 tube, follows to feed the Type 6J6 tube (V3) cathode follower. Following V3 is the 5:1 frequency divider using a blocked-grid oscillator which is keyed when the step voltage developed across the 20$\mu\mu$f condenser connected between the cathode and plate of V4 reaches the level to allow conduction in V5. This step voltage counteracts the cutoff bias voltage developed across the 1000$\mu\mu$ f grid condenser by a preceding cycle of operation. The positive voltage across the 20$\mu\mu$ f condenser is built

Figure 69.-Frequency Standard

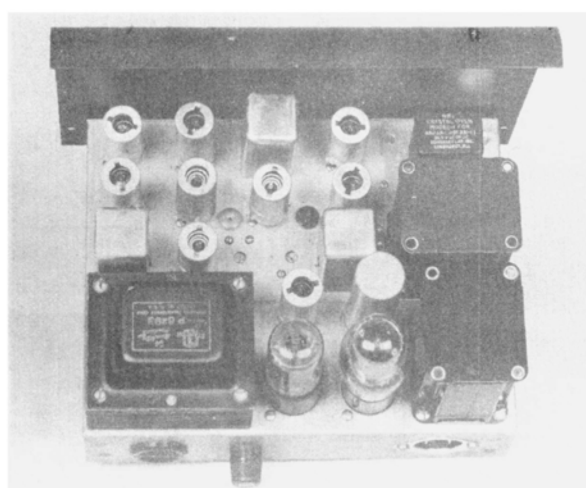


Figure 70.-Frequency Standard with Case Removed

up from successive charging cycles through V4, the Type 6AL5 tube. The frequency division ratio depends on the number of cycles of charging required before the blocking oscillator goes into conduction, and is adjusted by varying the capacity of the 3-45$\mu\mu$ f coupling condenser between V3 and V4. An oscilloscope connected between point A and ground will show the step voltage which should have 5 steps for proper operation. Since the crystal oscillator is operating at 500 kc, the frequency at the output of the first divider is 100 kc.

Following the 5:1 divider is a Type 6J6 tube (V6) cathode follower feeding the 10:1 divider (V7 and V8), a circuit similar to the first one. They differ in that the blocking oscillator of the 5:1 divider acquires its cut-off bias in the grid circuit whereas in the one for the 10:1 divider it is developed in the cathode circuit by the cathode current and a bleeder from the plate supply. The latter circuit results in a slightly better stability for the higher division ratio. The division ratio of the 10:1 divider may be checked by connecting an oscilloscope between point B and ground.

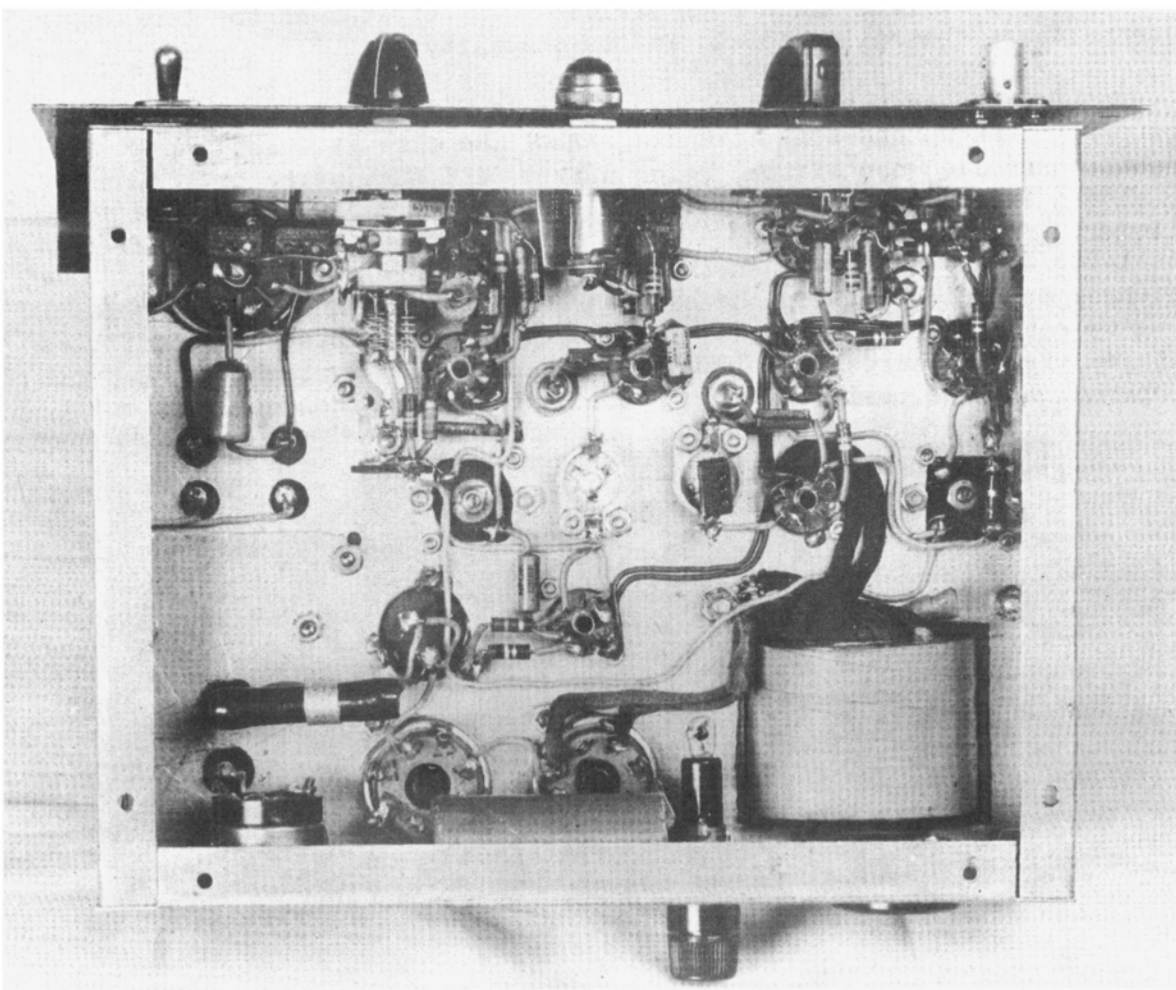


Figure 71.-Bottom View of Frequency Standard with Case Removed

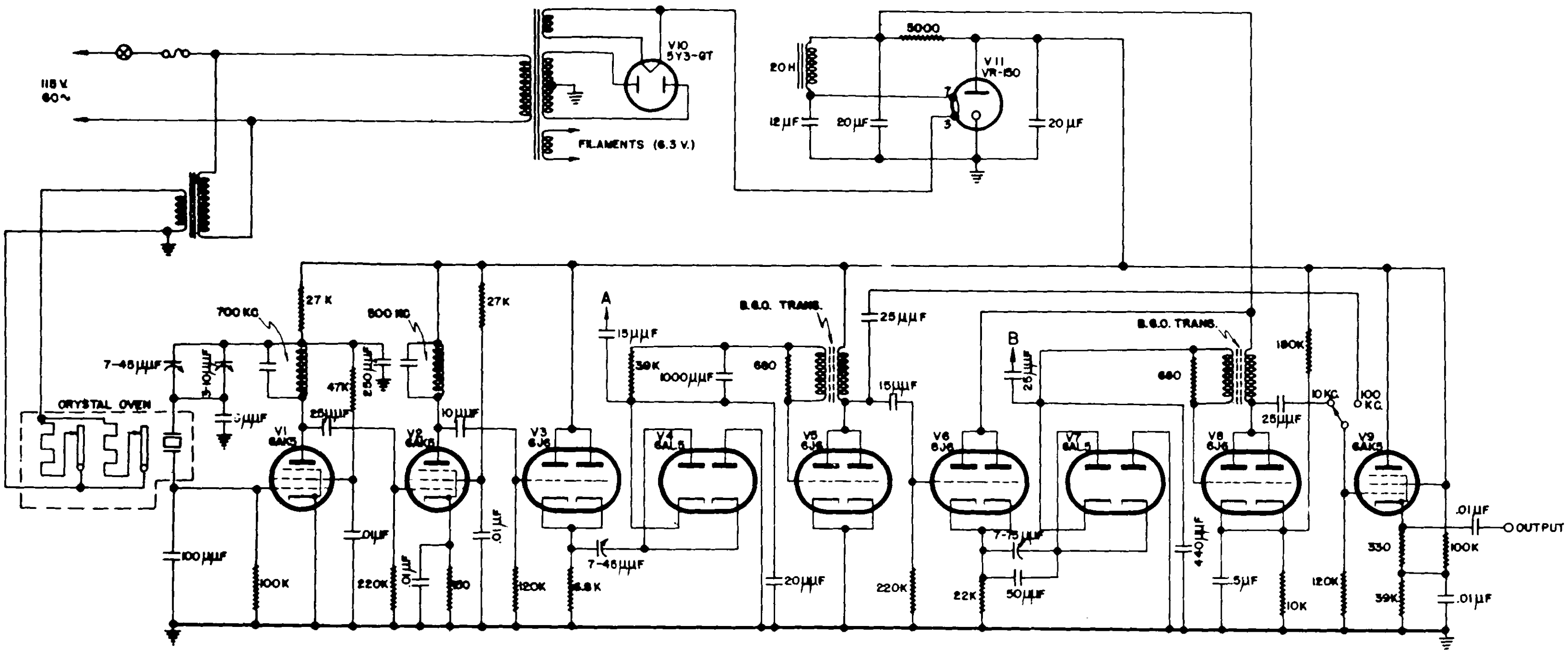


Figure 72.-Schematic Diagram of Frequency Standard

The output of the second blocking oscillator is a sharp voltage pulse recurring at the rate of 10 kc. By feeding this pulse to the Type 6AK5 tube (V9) clipper cathode-follower, a high order of 10-kc harmonics is realized at the output.

A single-pole double-throw switch at the grid of the clipper cathode-follower allows the selection of either the 10-kc or 100-kc spectrum of harmonics. The 100-kc spectrum is generated at the output of the first blocking oscillator (i.e. in the 5:1 divider stage). In measurements of the monitor frequencies, the 10-kc spectrum was used throughout.

Calibration of Instruments

In the frequency measuring setup described, it is necessary to calibrate some of the instruments in order to realize the high degree of accuracy desired. Instruments requiring calibration are the interpolation oscillator, the two electronic frequency meters and the two Esterline-Angus recorders. In order to calibrate the frequency meters and Esterline-Angus recorders, the interpolation oscillator is first calibrated at 220 cps by mixing that frequency with the 440-cps signal of WWV, when the oscillator is properly adjusted Lissajous figures of the two voltages on an oscilloscope should show a 2:1 ratio. After this initial calibration, the frequency meters and Esterline-Angus recorders are calibrated from the interpolation oscillator. When using the interpolation oscillator at 3000 cps as in Case 3, it should be calibrated close to this frequency. This is accomplished by adjusting the zero-set dial of the interpolation oscillator while the main dial is set to 3080 cps and the output compared on an oscilloscope with the 440-cps standard from WWV. The oscilloscope should give a 7:1 Lissajous figure when the proper adjustment is reached.

MONITOR FREQUENCY STABILITY

The monitor determines the overall transmitter and receiver frequency stability therefore, it was necessary to determine how the monitor reacts to non-standard conditions of voltage and temperature. For these tests the monitor was placed in a temperature chamber and the frequencies of the master oscillator, reference frequency oscillator, and the spectrum frequency oscillator were measured with the setup described in the previous paragraphs. All supply voltages were maintained at normal values. The temperature was varied from room temperature to -50° C then to $+50^\circ$ C and back to room temperature. A continuous record of frequency deviations was kept on the Esterline-Angus charts and plotted on the graphs for the cyclic temperature variation.

The first frequency stability run was made on the spectrum frequency oscillator of monitor Number 2. The results of this run are shown in Figure 73. Temperature is plotted in degrees and frequency deviation in parts per million. As can be seen the maximum deviation of this oscillator is 3.5 parts per million. It will be noted that the frequency deviates from zero beat only during periods of rapid temperature change. At other times it returns to zero beat. The oscillator was temperature compensated to obtain this effect. However, the temperature of the compensating condensers lags the temperature of other circuit components during rapid temperature changes, leaving bumps in the curve at points of rapid change. Capacitances C311 and C310 were changed from zero coefficient to negative coefficient capacitors to obtain the compensation. It is evident that the oscillator remains well within the plus or minus 0.001 percent frequency tolerance.

The next frequency stability runs were made on the reference frequency oscillator. Three runs were made, one each with crystals number 1, 2, and 3. Three runs were made to see if the crystal position in the five-unit crystal oven affected the stability of the oscillator. Figures 74, 75, and 76 show these three runs. No great difference is apparent between the three curves; therefore, crystal position is of little consequence in the large oven. The greatest frequency deviation obtained was 4.5 parts per million at -50° C.

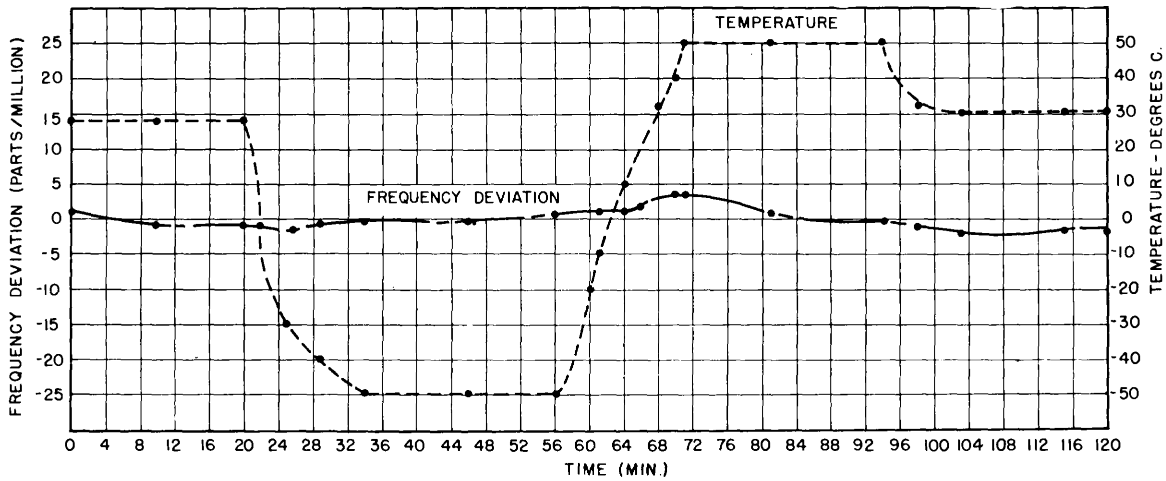


Figure 73.-Frequency Deviation vs Time during a Cyclic Temperature Run on Spectrum Crystal Oscillator of Monitor Number 2

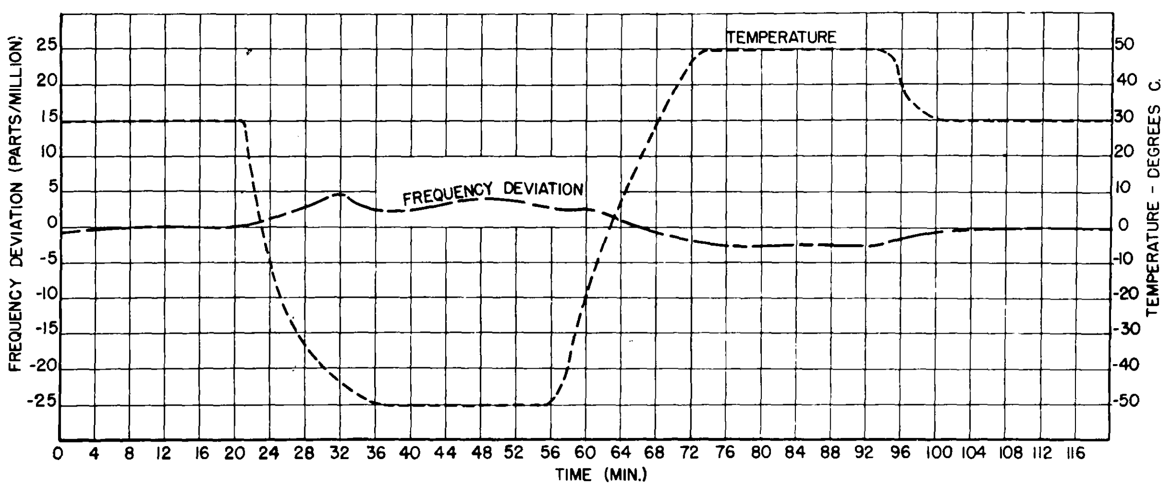


Figure 74.-Frequency deviation vs time during a cyclic temperature run on reference oscillator of monitor number 2 with crystal number 1 in position number 1.

This oscillator is again well within the plus or minus 0.001 percent frequency deviation permitted.

Four frequency stability runs were made on the master oscillator in the transmit position for channels number 100, number 105, number 550, and number 990. These channels were selected for the purpose of revealing the individual effects of each of the three frequency stability determining circuits on the overall equipment frequency stability, i.e., the master oscillator. On channel number 100, frequency errors of the spectrum frequency oscillator and the reference frequency oscillator subtract to make the master oscillator stability look better. Channel number 105 shows the effect of reversing the discriminator polarity. At channel number 550 very little of the spectrum is used so that the error introduced by the spectrum frequency oscillator at this frequency is neg-

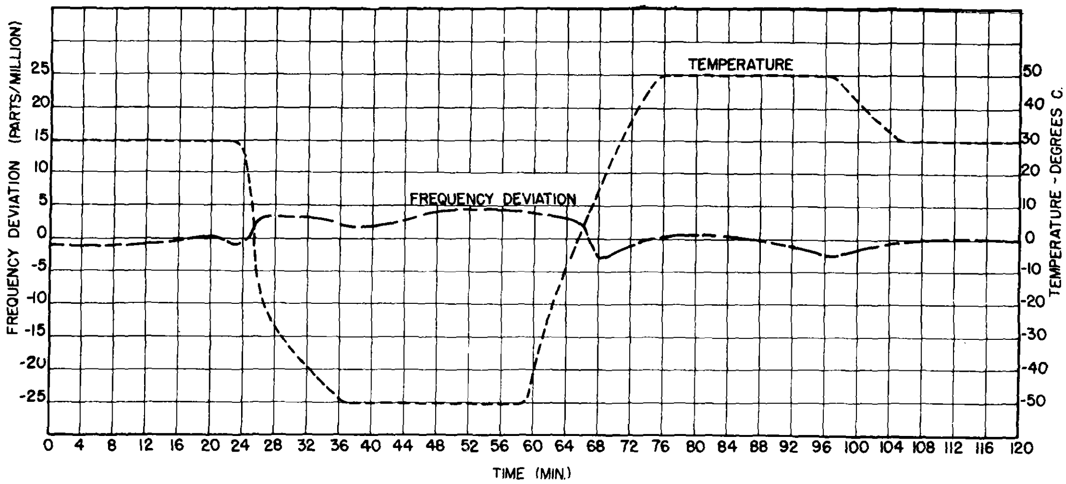


Figure 75.-Frequency deviation vs time during cyclic temperature run on reference oscillator of monitor number 2, with crystal number 2 in position number 2.

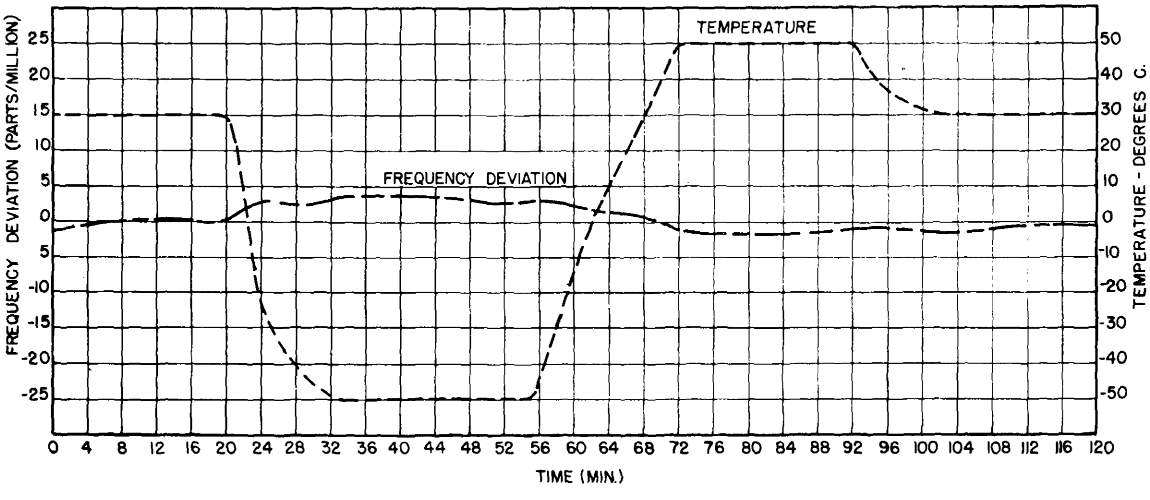


Figure 76.-Frequency deviation vs time during cyclic temperature run on reference oscillator of monitor number 2, with crystal number 3 in position number 3.

Table II Frequency Deviation of Channels 100, 105, 550 and 990 in the Transmit and Receive Positions for Monitors 1 to 5

Monitor No.	Channel No.	Channel Frequency Mc	Frequency Deviation			
			Transmit		Receive	
			Kc	(Parts/ Million)	Kc	(Parts/ Million)
1	100	220	+0.60	+2.73	+0.20	+0.91
1	105	221	+0.12	+0.54	-0.98	-4.44
1	550	310	+0.90	+2.90	+1.80	+5.81
1	990	398	+1.00	+2.51	+1.80	+4.52
2	100	220	-0.52	-2.36	-0.20	-0.91
2	105	221	+0.18	+0.81	+0.54	-2.45
2	550	310	-1.90	-6.13	+0.40	+1.29
2	990	398	-0.70	-1.76	+0.20	+0.50
3	100	220	-0.60	-2.73	-0.20	-0.91
3	105	221	+1.02	+4.62	+0.42	+1.90
3	550	310	-0.60	-1.94	-0.40	-1.29
3	990	398	+1.10	-2.76	-0.20	-0.50
4	100	220	-0.20	-0.91	+0.80	+3.64
4	105	221	+1.22	+5.52	+0.62	+2.80
4	550	310	+0.20	+0.65	+0.80	+2.58
4	990	398	+0.20	+0.50	+0.40	+1.00
5	100	220	+0.40	+1.82	-0.40	-1.82
5	105	221	+1.02	+4.62	-0.18	-0.81
5	550	310	+0.20	+0.65	+1.00	+3.23
5	990	398	-0.80	-2.01	-0.20	-0.50

Notes: (a) Measurements made at standard temperature and voltage.
(b) Frequency deviations in kc are at the channel frequencies.

ligible. On channel number 990 the frequency errors of the two crystal oscillators add. Figures 77, 78, 79 and 80 show the runs on these four channels for monitor number 2 of five which were built. The width of the slot is also indicated on these curves. The curves are plotted in parts per million which can be converted to the channel frequency by multiplying by the appropriate number of megacycles. The error will then be in cycles at the channel frequency. The maximum frequency deviation for each channel is as follows:

Channel number 100 - 2.0 kc
Channel number 105 - 3.3 kc
Channel number 550 - 2.7 kc
Channel number 990 - 2.0 kc

The above runs were made in the transmit position only. Table II shows spot checks of frequency deviation for the receive position of the master oscillator frequency as well as the transmit position frequency. These checks were made on the above four channels on all five monitors. The purpose of these checks was to determine if the master oscillator receive frequency was maintained with the same accuracy as the transmit frequency. The checks were made at room temperature. The ambient temperature was not cycled because the identical monitor circuits are used to maintain the master oscillator receive frequency as are used to maintain the transmit frequency. Therefore, the master oscillator receive frequency should be as stable over the same temperature cycle as the master oscillator transmit frequency. The table shows that the receive frequencies were maintained with an accuracy comparable

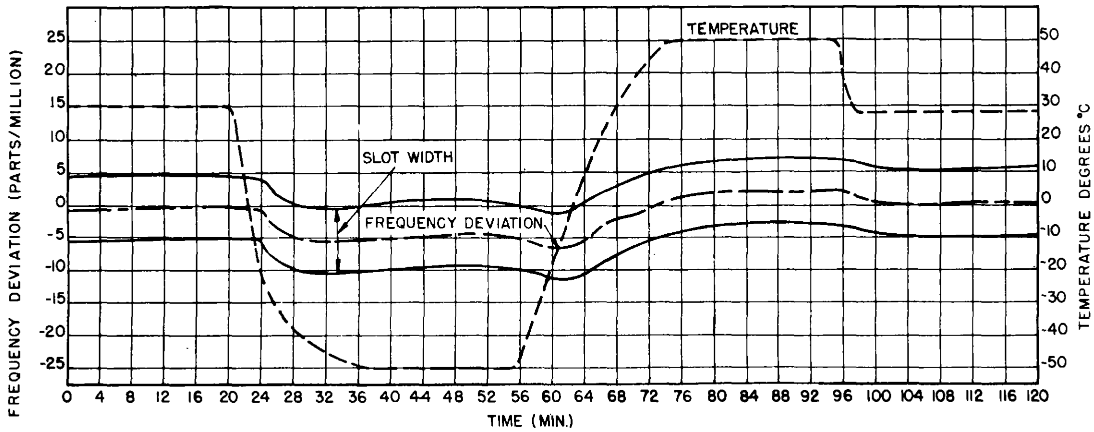


Figure 77.-Frequency deviation vs time during a cyclic temperature run at channel 100, on monitor number 2, with master oscillator at room temperature.

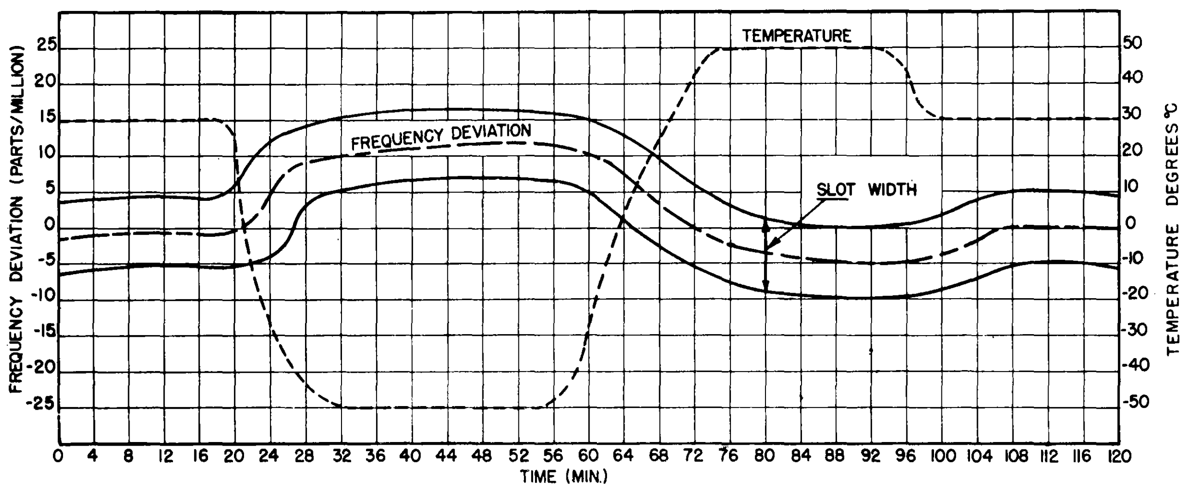


Figure 78.-Frequency deviation vs time during a cyclic temperature run at channel 105, on monitor number 2, with master oscillator at room temperature.

to that of the transmit frequencies. The greatest deviation from an allocated channel frequency was 1.9 kc at 310 Mc.

Five identical monitors were built. Figures 81, 82, 83, and 84 show the results of one run of frequency deviation vs temperature on each of the other four monitors. The frequency stabilities obtained for these four monitors are comparable to those of the first monitor tested. Thus the curves are evidence that it is possible to reproduce the temperature stability obtained with monitor Serial Number 2 without difficulty.

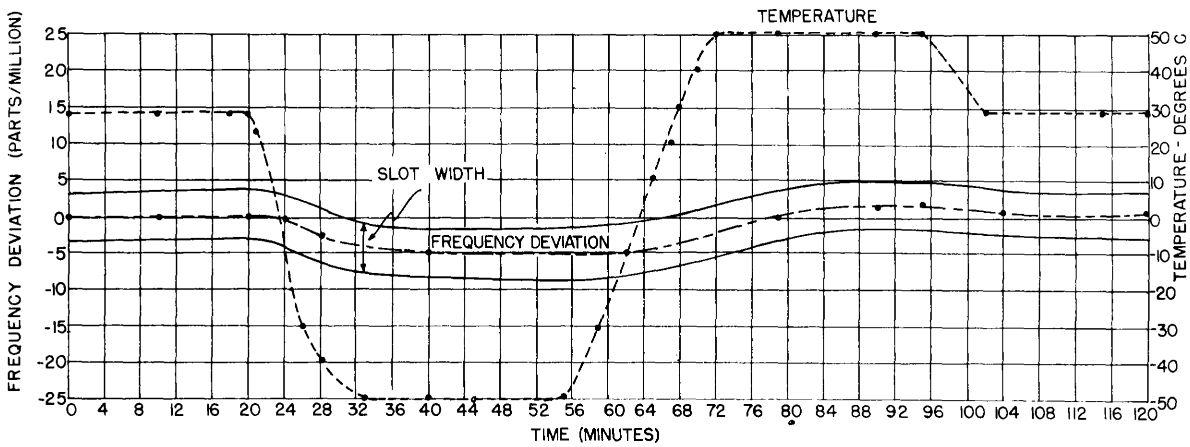


Figure 79.-Frequency deviation vs time during a cyclic temperature run at channel 550, on monitor number 2, with master oscillator at room temperature.

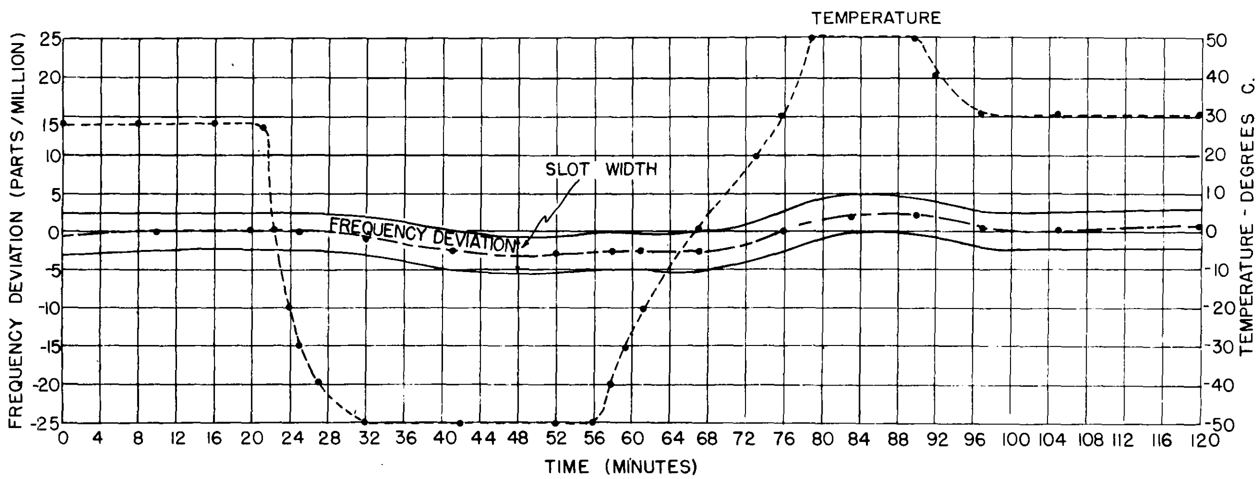


Figure 80.-Frequency deviation vs time during a cyclic temperature run at channel 990, on monitor number 2, with master oscillator at room temperature.

Monitor Number 2 was also tested to determine its frequency stability with variation of supply voltage. The tests were made at room temperature on channel number 100. Table 3 shows the results of these tests. First, the 26.5-volt filament and oven heater supply were varied plus and minus 10 percent with the other two supply voltages held normal. The monitor was allowed to stabilize for five minutes at each voltage before the master oscillator frequency was measured. No shift in frequency was noted. Second, the 150-volt regulated supply was varied plus and minus 10 volts with the other voltages normal. Here again, a negligible frequency shift occurred. Third, the 225-volt supply was varied plus and minus 20 percent with the other

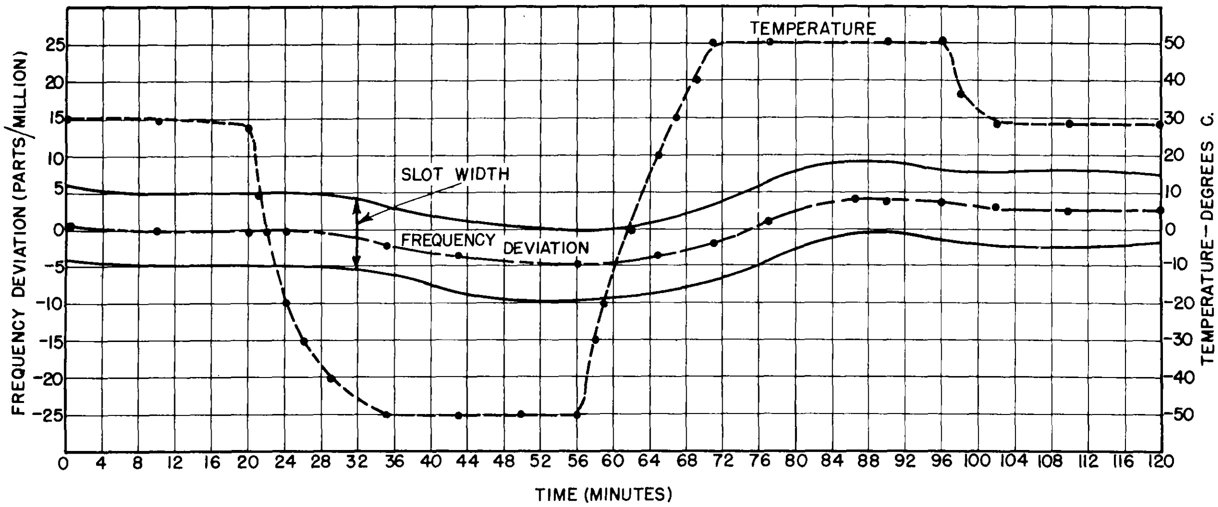


Figure 81.-Frequency deviation vs time during a cyclic temperature run at channel 100, on monitor number 1, with master oscillator at room temperature.

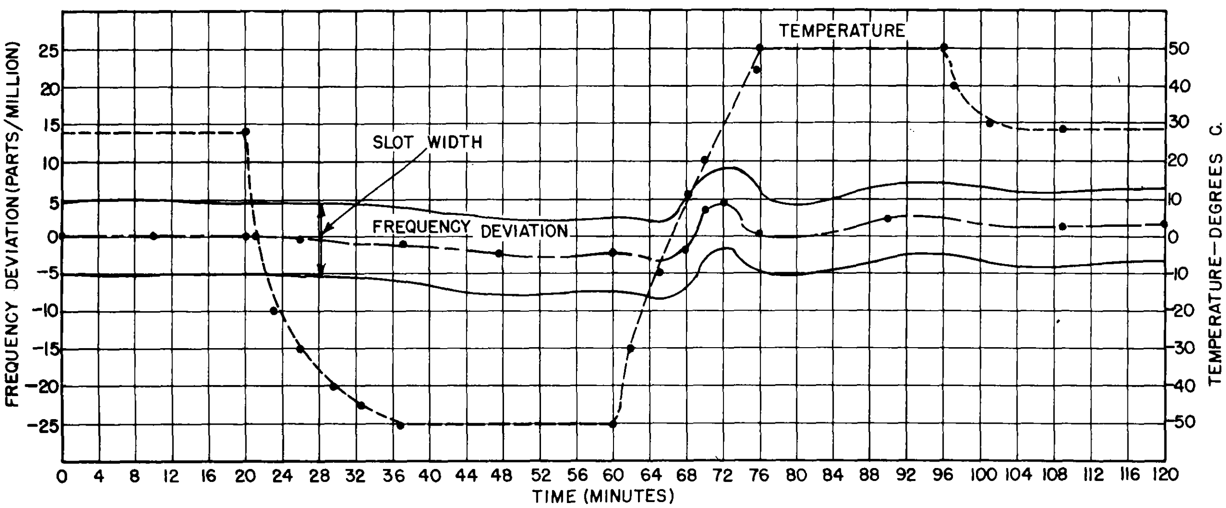


Figure 82.-Frequency deviation vs time during a cyclic temperature run at channel 100, on monitor number 3, with master oscillator at room temperature.

voltages held at normal values. In this case, the master oscillator did shift in frequency. The shift at 220 Mc was plus 0.64 kc and minus 0.84 kc. Finally, all voltages were varied in unison. The table shows that the frequency shift at 220 Mc for this condition was minus 0.90 kc and plus 1.80 kc.

Since the maximum frequency deviation which is permitted for either the receiver or the transmitter by the AN/ARC-19 (XN-1) specifications is ±13 kc, it is obvious that this monitor maintains the frequency well within specifications and will do so for all channels. Since the monitor determines the equipment frequency stability, these curves and tables are an excellent indication of the performance that can be expected of the equipment as a whole.

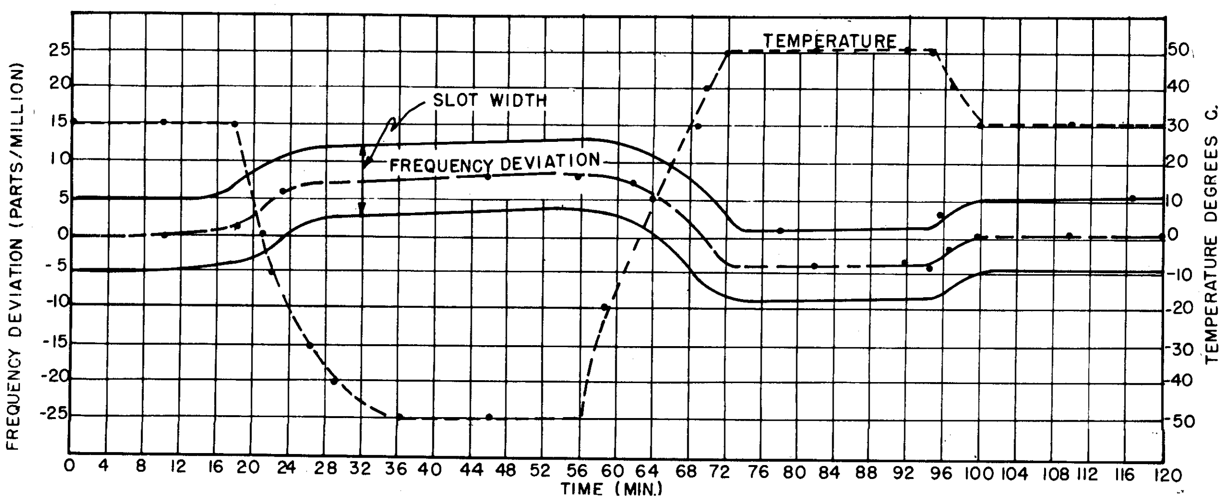


Figure 83.-Frequency deviation vs time during a cyclic temperature run at channel 105, on monitor number 4 with master oscillator at room temperature.

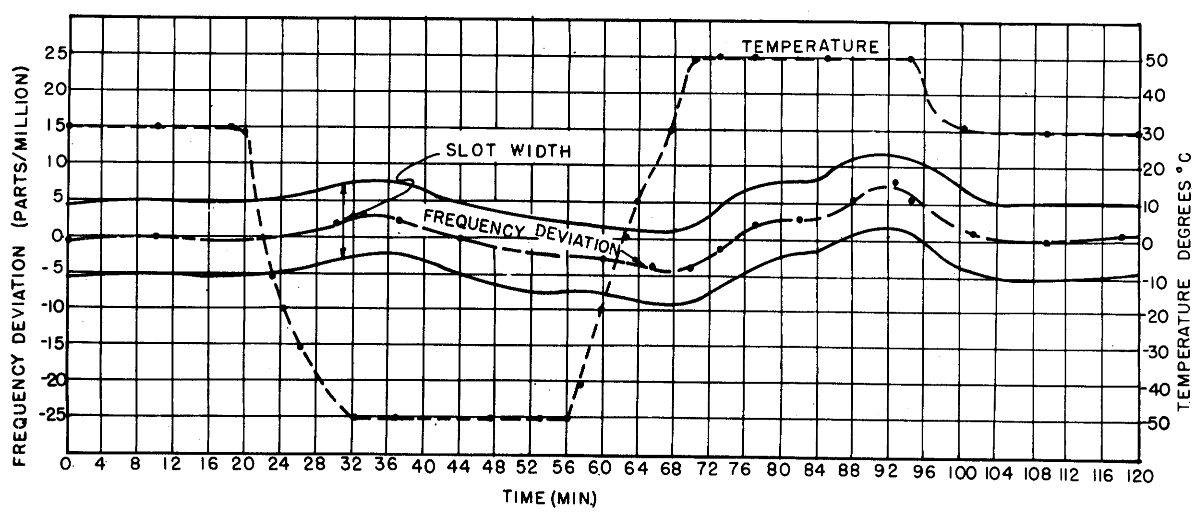


Figure 84.-Frequency deviation vs time during a cyclic temperature run at channel 100, on monitor number 5, with master oscillator at room temperature.

TABLE III Frequency Deviation of Channel 100
Due to Voltage Variation in Monitor No. 2

A. Variation of the 26.5-volt supply with the 150-volt and 225-volt supplies held constant:

Voltage (Volts)	Frequency Deviation (Kc)	Frequency Deviation (Parts/Million)
23.8	-0.20	-0.91
26.5	-0.20	-0.91
29.2	-0.20	-0.91

B. Variation of the 150-volt supply with the 26.5-volt and 225-volt supplies held constant:

Voltage (Volts)	Frequency Deviation (Kc)	Frequency Deviation (Parts/Million)
140	+0.06	+0.27
145	+0.04	+0.18
150	+0.04	+0.18
155	+0.06	+0.27
160	+0.04	+0.18

C. Variation of the 225-volt supply with the 26.5-volt and 150-volt supplies held constant:

Voltage (Volts)	Frequency Deviation (Kc)	Frequency Deviation (Parts/Million)
180	-0.84	-3.82
210	-0.36	-1.64
240	-0.04	-0.18
270	+0.36	+1.64
300	+0.64	+2.91

D. Combination of voltage variation:

Voltage: 26.5-volt supply (V)	150-volt supply (V)	225-volt supply (V)	Frequency Deviation (Kc)	Frequency Deviation (Parts/Million)
23.8	140	180	-0.90	-4.10
26.5	150	240	+0.20	+0.91
29.2	160	300	+1.80	+8.18

Notes: Frequency deviations in kc are at channel number 100 (220 Mc).
Measurements made at Standard Temperature.

METHOD OF MEASURING CRYSTAL OVEN TEMPERATURE

The crystal ovens developed under contract for the AN/ARC-19 (XN-1) were tested to determine if they complied with the temperature specifications of the contract. The specifications stated that the oven temperature should not deviate more than ± 5° C from 70°C under Service Conditions. The succeeding paragraphs will explain the temperature measuring setup used and the results obtained on two typical crystal ovens.

The equipment for testing the crystal oven temperature consisted of an audio oscillator, audio amplifier, recording milliameter, thermistor, and thermistor bridge as shown in Figure 85. The arms of the bridge were selected to limit the current through the thermistor and to provide greater recorder accuracy for temperatures of 70° ± 5° C, which are the operating limits of the ovens.

It was desirable to have the calibrating point of the bridge near the low temperature limit of the ovens; and, at the same time, it was also desirable not to use the bridge null because of the difficulty of properly setting the amplifier gain at the null. The bridge was initially balanced

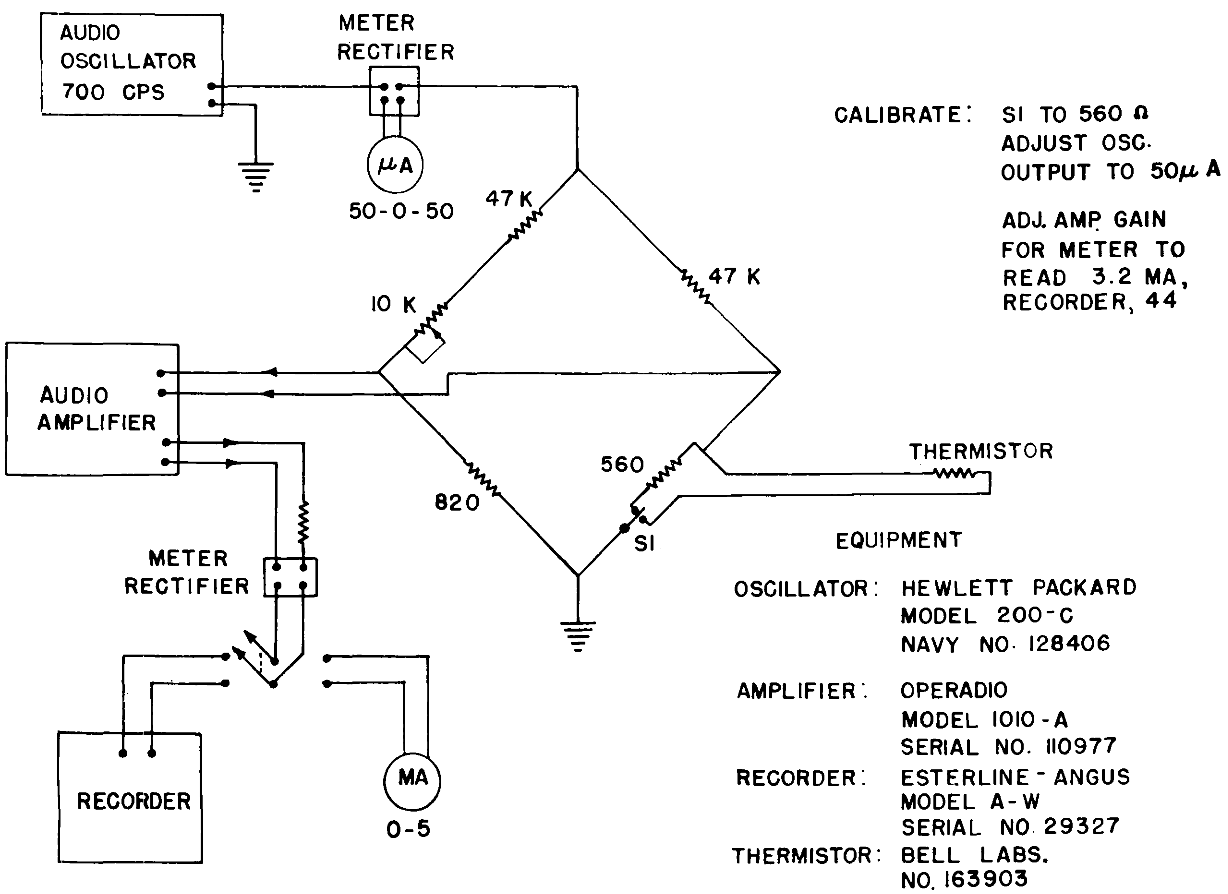


Figure 85.-Thermistor Bridge Circuit for Crystal Oven Internal Temperature Measurements

with a resistor equivalent to the resistance of the thermistor at 50°C. The calibrating resistor, 560 ohms, was selected to simulate the thermistor resistance at approximately 65°C. This calibrating resistor caused a definite unbalance of the bridge and allowed adjustments to be made to compensate for warmup of the amplifier. The input to the bridge was measured with the microammeter which permitted resetting the audio oscillator. To calibrate the setup, the 560-ohm resistor was switched in place of the thermistor, the oscillator output was adjusted to 50 microamperes input to the bridge, and then the audio amplifier gain was adjusted to give 32-ma d-c output. The thermistor and bridge were then calibrated by varying the thermistor temperature and noting the recorder reading (Figure 86). The thermistor was mounted in a crystal can and placed in the crystal socket of the oven. The curve of Figure 86 is accurate to within ± 1/2 degree.

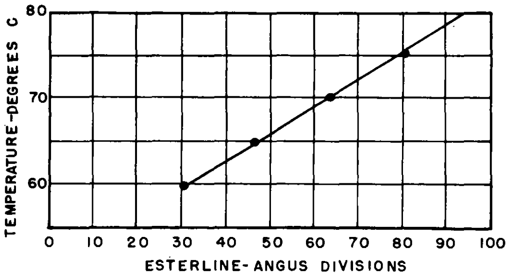


Figure 86.-Calibration for Thermistor Bridge

Curves for typical ovens are shown in Figures 87, 88, 89, 90, and 91. Figures 87 and 88 show the warm-up of the typical ovens at room temperature and also the variation in oven temperature with changes of ambient temperature. Figures 89 and 90 show oven warm-up characteristics in a plus 50°C ambient and warm-up in a minus 50°C ambient temperature. These curves also show

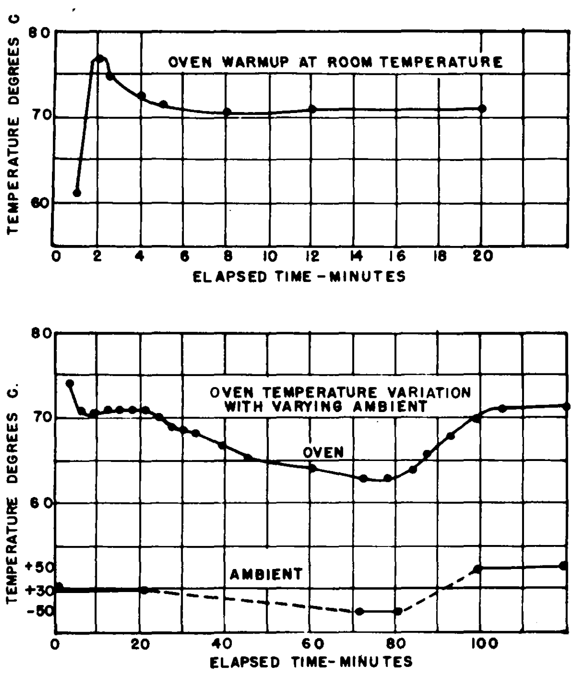


Figure 87.-Temperature characteristics of Model 1, single-unit crystal oven, serial number 8.

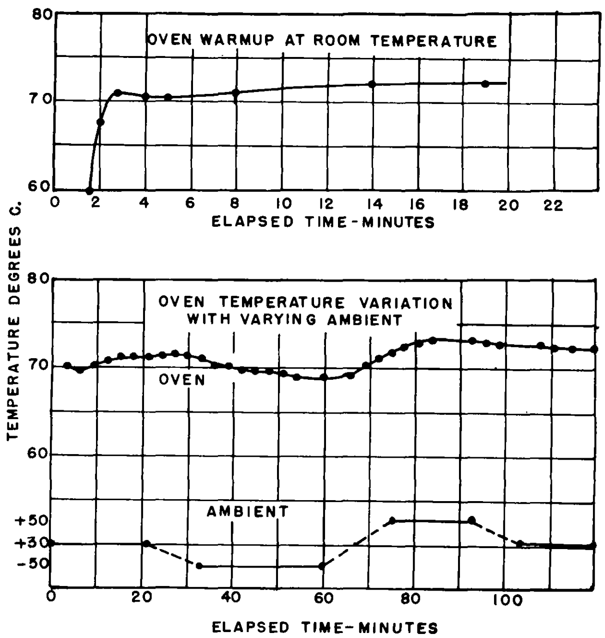


Figure 88.-Temperature characteristics of five-unit, model 2 crystal oven, serial number 8.

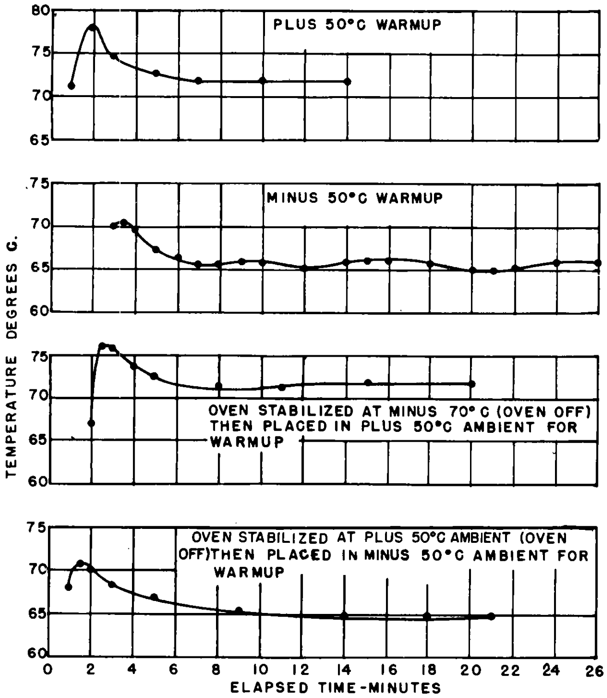


Figure 89.-Warm-up characteristics of single-unit, model 1 crystal oven, serial number 8.

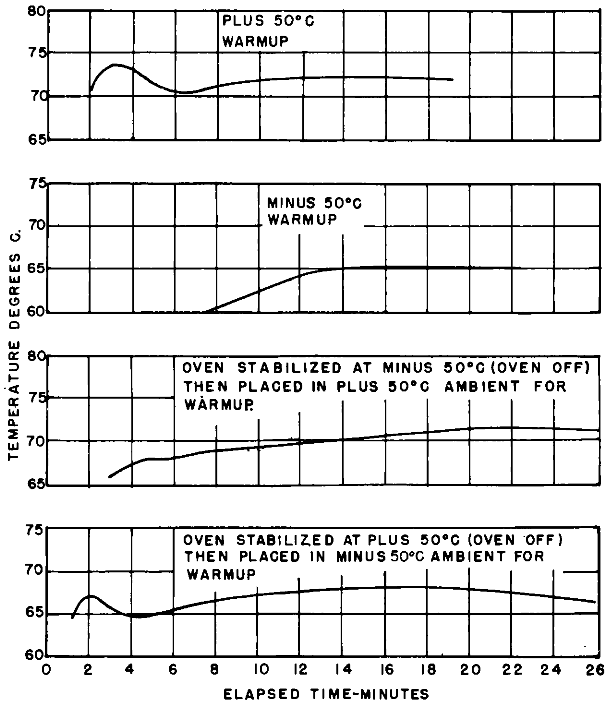


Figure 90.-Warm-up characteristics of five-unit, model 2 crystal oven, serial number 8.

the warm-up characteristic of an oven in a plus 50° C ambient temperature after being stabilized with the oven off in a minus 50° C ambient temperature. The last curve of Figures 89 and 90 shows the oven warm-up characteristic in a minus 50° C ambient temperature after being stabilized with the oven off in a plus 50° C ambient temperature. Figure 91 shows the variation in temperature with crystal position.

CONTROL CIRCUITS

Control Box Description

This portion of the report describes the operation of the control circuits. All controls necessary for operation of the equipment are located on the control box (Figure 24) and are as follows:

1) A rotary control for selecting any one of ten preselected main channel frequencies and also for presetting these ten channels to any of the 876 possible frequencies.

2) A three-position rotary switch for selecting reception on the main channel frequency, on the guard

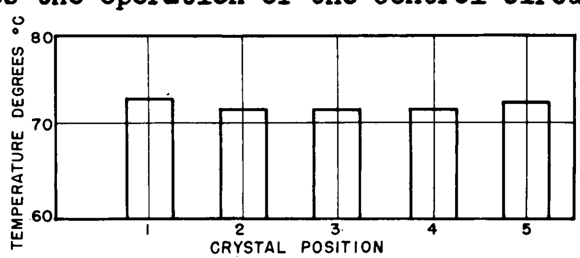


Figure 91.-Oven Temperature variation with change in crystal position for five-unit, model 2 oven, serial number 8, at room ambient conditions.

channel frequency, or on both the guard channel frequency and the selected main channel frequency.

3) A three-position rotary switch for controlling the application of primary power to the equipment and for selecting voice or tone modulation.

4) A ready light for indicating when the equipment is on frequency and ready for operation.

5) A volume control knob for setting the audio volume level to the headsets.

6) A ready light test button for determining the condition of the ready light bulb.

7) A push button which disables the receiver squelch circuits and permits receiver operation to be checked.

8) A visual indication to show which of the preselected channels has been selected appears at the "preselected channel" window on the control box.

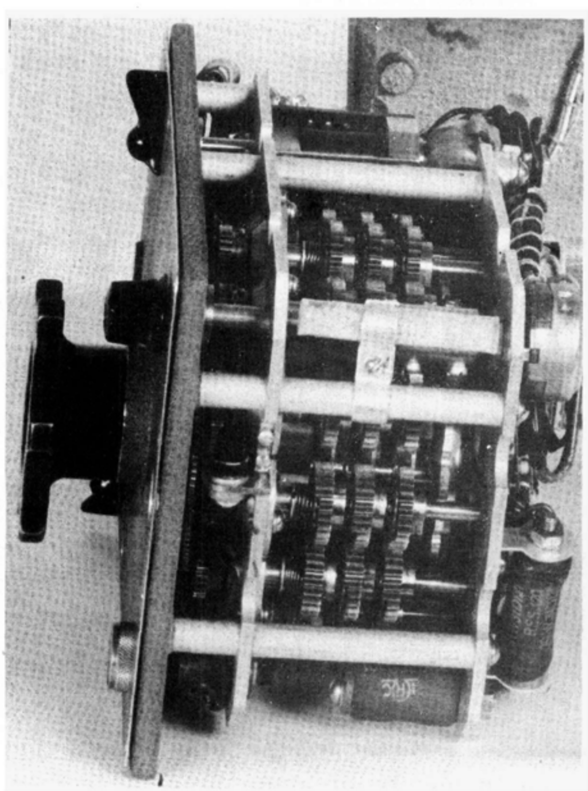


Figure 92.-Side View of Control Box with Cover Removed

The indicator unit is mounted in a rectangular box which is attached to the top of the control box. Windows are provided on the front for viewing the indicator dials which show the channel number to which the equipment is set.

Connections for all power, audio, and control circuits to the control box and indicator units are made through a single AN-28-11P receptacle mounted on the lower end of the control box. (Figure 3).

The combined overall dimensions of the control box and channel indicator unit including all projections are as follows:
Height, including plug receptacle (plug disconnected) 9-13/16 inches; width, 5 inches; depth, 5-7/16 inches.

The combined weight of the control box and indicator unit is 11.1 pounds.

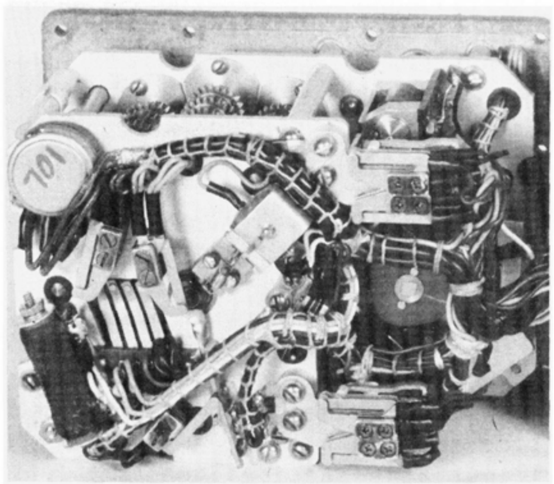


Figure 93.-Rear View of Control Box with Cover Removed

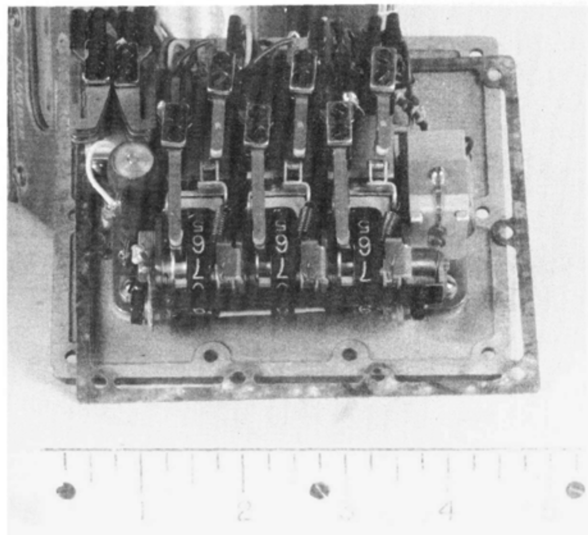


Figure 94.-Channel Indicator Unit with Cover Removed

<u>Control Circuit Operation of Control Box and Monitor</u>

The control box provides means for manual selection of any desired communication channel of the 876 channels. The actual channel number of the preselected channel is indicated by a number which appears in the channel indicator window when the equipment is on frequency. The channels are numbered consecutively beginning with channel number 125 at a frequency of 225 Mc. The preset channels are designated as G (guard) 1,2,3,4,5,6,7,8 and M (manual). In the small window above the frequency control knob appears the number of the preset channel which has been selected. To change from one preset channel to another, it is necessary only to rotate the knob until the desired preset channel number appears in the window.

In describing the manual operations required to change the frequency of a preset channel assume that it is desired to set preset channel number 1 on a frequency of 324.4 Mc. A frequency of 324.4 Mc is channel number 622. To set channel number 1 to this frequency the operator grasps the selector control knob, rotates it until number 1 appears in the preselected channel window, presses the lock release button in the center of the knob, and pulls outward. As the knob is pulled out from the panel, three detent positions can be felt. With the knob pulled out to the last of these detent positions, a rotation of the knob changes the hundreds digit which will appear in the left hand window of the channel number indicator when the equipment is operating on the channel. To set the hundreds digit on six, the knob, when in the last outward detent position, is rotated to the left against the stop, then rotated to the right to the sixth detent position. To set the tens digit, the knob is pressed directly inward to the center detent position, rotated to the left against the stop, and rotated to the right to the second detent position. The units digit is then set to two by pressing the knob inward to the units detent position, rotating the knob to the left against the stop and then rotating it to the right to the second detent position. The knob is then pressed in against the panel where it will be held by the electrical latch. The control knob shaft is marked with H, T, and U calibration circles which indicate which of the outward detent positions is engaged.

It is not necessary to change the channel number digits in any particular order; any digit or combination of digits can be changed in any desired order by pulling out the knob to the appropriate detent position.

The electrical latch prevents accidental change in frequency of the guard channel and the eight "numbered" channels, by preventing the knob from being pulled out unless the electrical latch is released. Due to the fact that the latch is electrically operated, power must be applied to the equipment before the latch can be released. Since both pull-out and rotational positions of the knob are detented and end-stops limit clockwise and counter-clockwise rotation, it is possible without looking at visual indicators to operate the knob by feeling the detent positions and end stops. Thus it is possible to reset the preset channels in the dark. Electrically and mechanically the position marked "M" (manual) is actually another preset channel. In the "M" position with power applied it is not necessary to press the release button in order to pull the frequency selection knob outward. It is expected that pilots will use the "M" position in cases where it is necessary to set up a channel during flight. If the pilot attempts to pull out the knob when it is in one of the first nine positions, he will be reminded by the latch release that he should switch to the "M" position so as not to disturb the other nine preset channels before attempting to set up on a new channel for some special use.

When all preselected channels have been preset and the selector knob pressed in to the operating position, the control circuits will automatically cause the master oscillator in the transmitter-receiver unit to be tuned to the correct frequency. The master oscillator is tuned to the desired operating frequency by a counting process. In selecting a new frequency the master oscillator tuning condenser is always returned to its lowest frequency position and then driven forward to the desired position.

The counting and crystal selecting switches in the monitor are driven by rotary stepping relays. An unmounted stepping relay is shown in Figure 95. The switches which are driven by the monitor stepping relays are twelve-position wafer-type switches. One terminal of each stepper relay coil is connected to the 26.5-volt circuit as soon as power is applied to the equipment. When the other side of the stepper coil becomes grounded, due to control circuit action, the stepper coil becomes energized and causes the relay armature and ratchet to advance against spring tension to the position

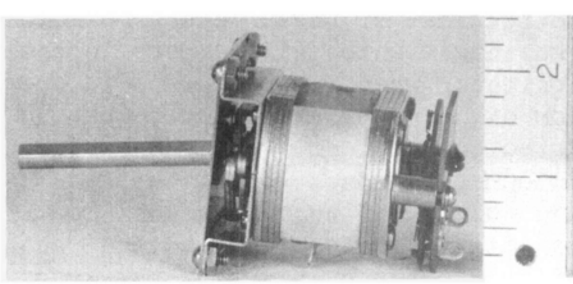


Figure 95.-Unmounted Stepping Motor

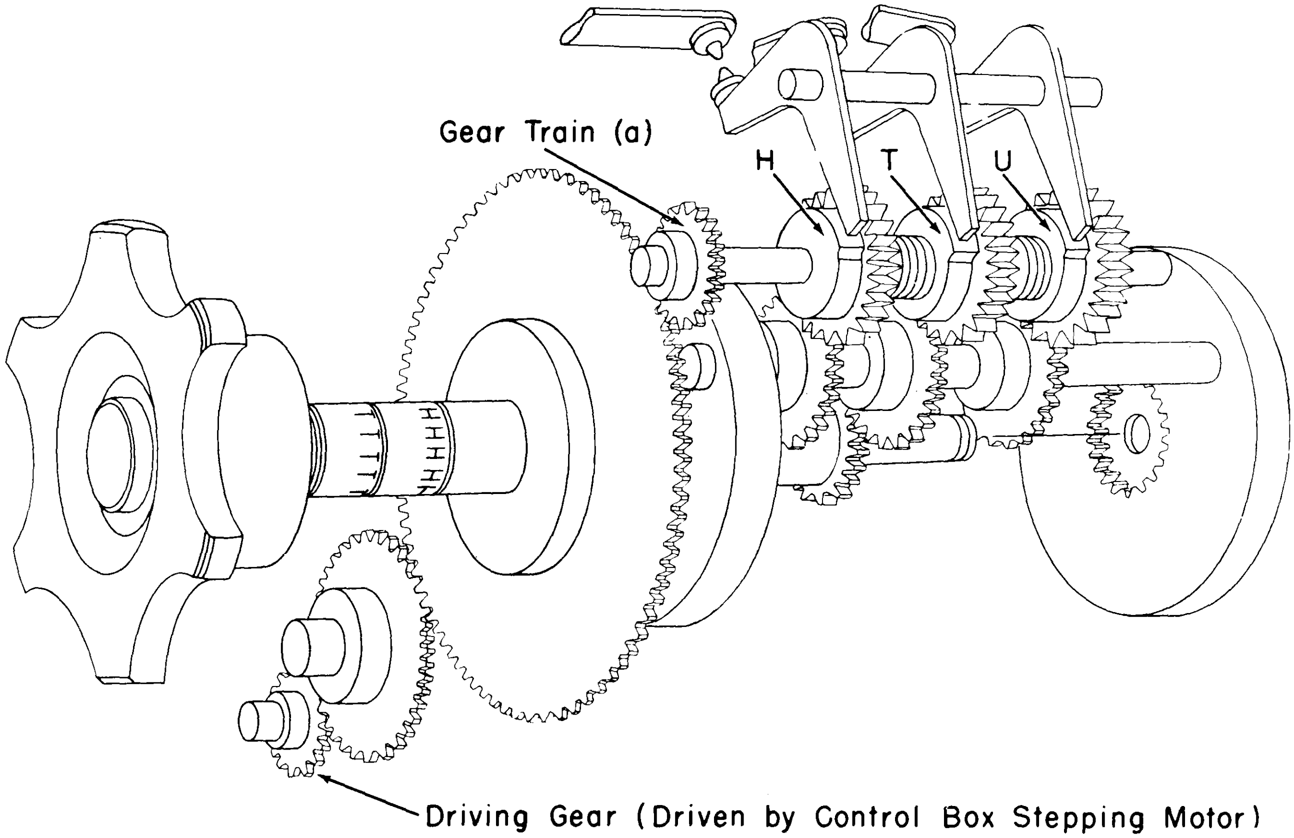


Figure 96.-Simplified Drawing of Control Box Planetary Gear System

of maximum armature travel. Due to the ratchet action, the switch wafer rotors do not move until the coil circuit is broken. When the coil circuit is broken the spring tension returns the armature and advances the switch rotor shaft one position. The switch wafers are of the twelve position type; therefore, the relay coil circuit must be made and broken twelve times to complete one 360-degree rotation of the switch rotor.

Three stepping relays of the type shown in Figure 95 are mounted on the monitor chassis and are referred to as the hundreds (H), tens (T), and units (U) steppers. A similar type stepping relay is used in the control box for transmitting setup pulses to the monitor.

The principle of operation of the mechanism by which the control unit remembers the preset channels is illustrated in Figure 96. It will be noted that three gears, designated as H, T, and U, are included on gear train (a). On the side of each of the three gears a cam has been machined integral with the gear. Gear train (a) contains gears for one preset channel only. As shown on Figure 92, a total of ten such gear trains, one for each preset channel, are mounted in a circle around the main driving gear. Setting up a preset channel in the control unit consists of rotating the channel-determining gears H, T, and U, on their driving shaft to a position dependent upon the channel desired. This preselecting process is accomplished by manually manipulating the channel selecting knob as previously described. It should be noted that the gears H, T, and U are rotated on a rigid mounting shaft during the presetting operation and driven by the same shaft as that which the control unit stepping motor cycles. This action is possible because a spring type friction clutch is mounted on the side of each H, T, and U gear. Gears H, T, and U are set at predetermined positions on their driving shaft in order that the gear cams will open contactors K715, K716, and K717 after the desired number of pulses have been transmitted to the monitor unit.

In Figure 97 is shown a simplified schematic drawing of a portion of the control circuits and is intended to serve as an aid in showing how the pulses from the control box set up or preset the counting switches in the monitor unit.

In describing the functions of the counting switches reference will be made to the home and finish positions of the switches. The home or zero position is indicated (Figure 97) by the downward position of the arrow. Succeeding positions are indentified as positions 1 through 11 in a clockwise direction. Prior to selecting a new channel the switches will return to the home position. The circuit design is such that when the desired number of hundreds and tens have been counted, the hundreds and tens steppers must have reached the finish position. For this reason, position number nine is referred to as the finish position.

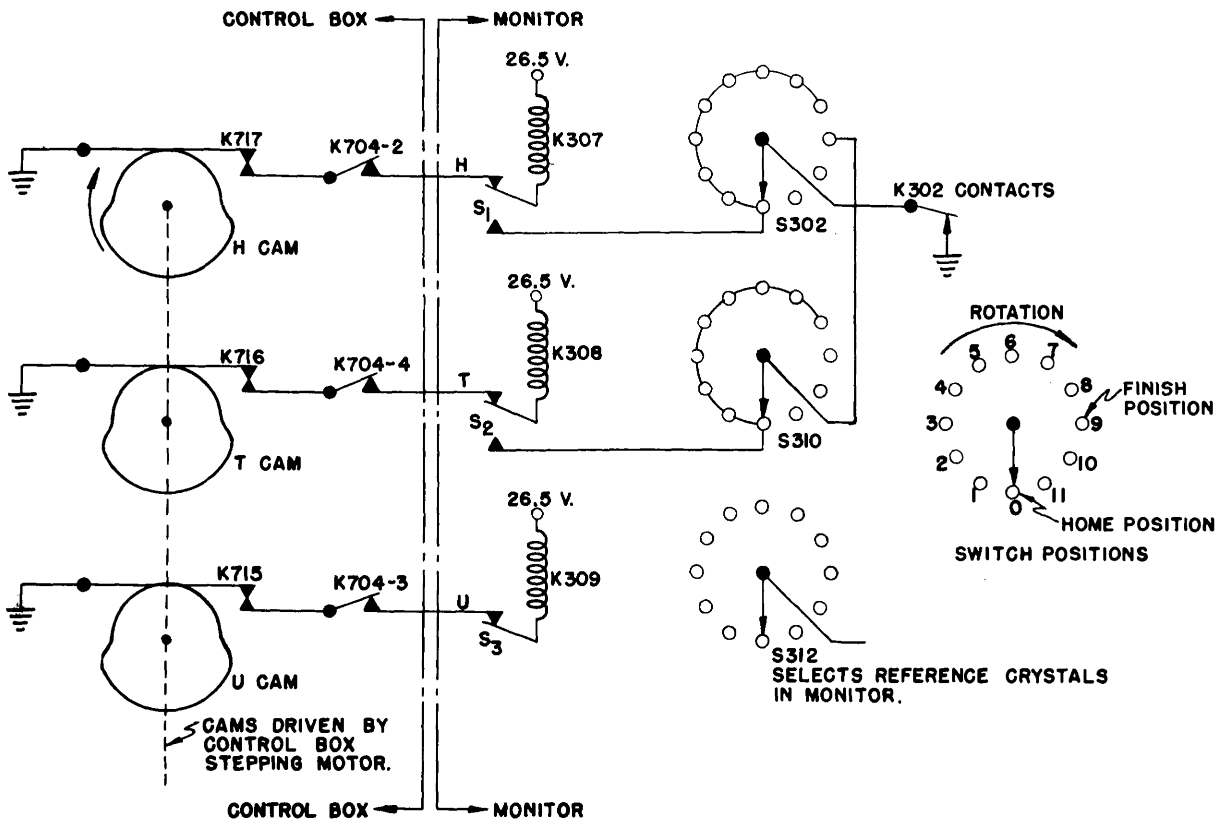
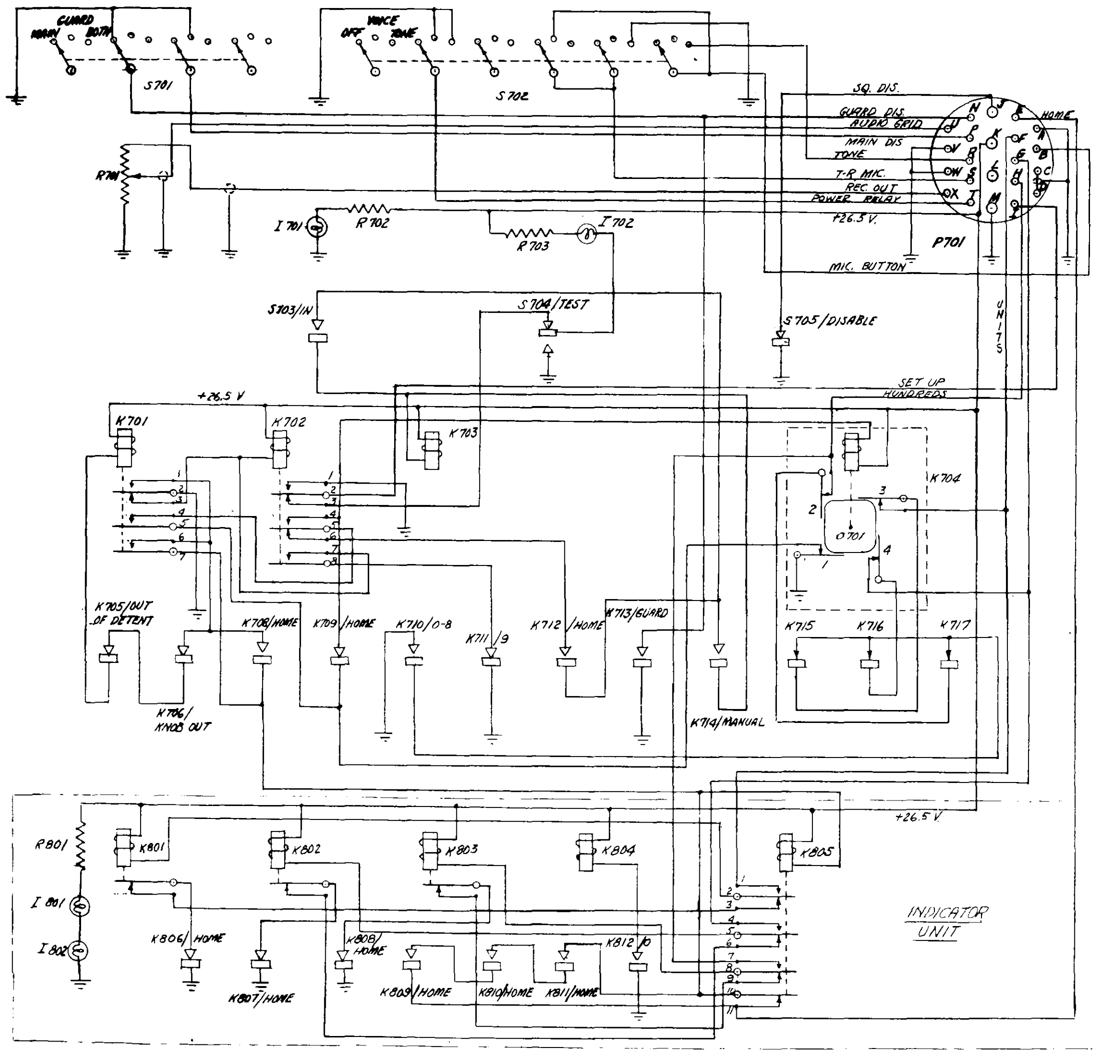


Figure 97.-Simplified Schematic of Setup Circuit

As an example, assume that it is desired to operate on channel number 622 which has a frequency of 324.4 Mc. At a final frequency of 324.4 Mc, the signal fed to the monitor from the master oscillator divider circuit will be one-twentieth of 324.4 Mc or 16.22 Mc. Since the first "hundreds" is counted at 11 Mc, this indicates that six "hundreds" and two "tens" must be counted in order to reach a frequency of 16.22 Mc. The H and T switches must reach the finish position when the equipment is on frequency. It can be seen that the control box pulses must preset the H switch to position number three and the T switch to position number seven. This will leave six "hundreds" and two "tens" for the monitor to count. For a frequency of 16.22 Mc, the units stepper must select the 7.5225-Mc crystal.

The H, T, and U cams shown in Figure 97 are the same cams that are shown in Figure 96. Preparatory to receiving setup pulses over the H, T, and U leads from the control box the monitor circuits are as shown on Figure 97. The setup relay contacts S1, S2, and S3 are closed, thus connecting the solenoids with the H, T, and U pulse leads from the control box. When power is applied to the equipment or a different channel selected, the stepping motor in the control box will complete one cycle of 24 steps. Each time the control box stepper makes a step (armature traveling to maximum position of travel and returning) the contacts K704-2, K704-3, and K704-4 are opened and closed by a cam on the control box stepper driving shaft. Each time the circuit is opened the control box stepper will advance one position. The cam gear H in the control box has been preset on the shaft in such a position that contacts K717 will be held open by the cam after three pulses (K704-2 opening and closing three times) have been transmitted to the H stepper in the monitor. The T cam has been preset to open K716 after seven pulses have been transmitted to the tens stepper in the monitor. The control box units cam opens K715 after two pulses have been transmitted to the units stepper in the monitor. The circuit design is such that the setup relay will become de-energized and power will be applied to the tuning motor as soon as the counting switches have been preset by the control box. The master oscillator tuning condenser is now driven forward and six "hundreds" are counted, thus advancing the H wafer switch to the finish position. It will be noted that, when the H switch rotor reaches the finish position, the circuit to the H stepper solenoid is broken and the circuit to the T solenoid is completed to ground. As the tuning motor continues to drive the master oscillator condenser forward, the 100-kc spectrum will produce beat notes causing the tens stepper to advance from position seven to the finish position. When the tens count is completed, the monitor is switched to automatic frequency control.

The above explanation of the setup and counting action was made with reference to Figure 97 in order to describe more clearly this part of the control circuit operation without confusion with other circuits. Complete control circuits are shown in Figure 50. A complete schematic of the control box and indicator unit is shown in Figure 98. Figure 99 shows in chart form the sequence of action of the relays in the monitor and control box with reference to time. The time of operation of the tuning motor is also shown in Figure 99. All relay contacts in Figure 50 are shown with the coil de-energized. The sequence of control circuit action is as follows. With the



NOTE 1 – RELAY FUNCTIONS

K701 – NEW CYCLE STARTS WHEN K701 RELAXES
K702 – OPERATES WITH K701 TO PROVIDE MEMORY FOR EITHER POWER FAILURE OR RELAXING OF K701
K703 – ELECTRICAL LATCH
K704 – PULSE TRANSMITTING MOTOR
K801 – UNITS REPEATER
K802 – TENS REPEATER
K803 – HUNDREDS REPEATER
K804 – BLANKING–FLAG RELAY
K805 – HOMING RELAY FOR THE REPEATER

NOTE 2 – CONTACTOR & SWITCH ABBREVIATIONS

•K705 – CAGE DETENT, NORMALLY CLOSED
K706 – CONTROL KNOB IN PLACE, NORMALLY CLOSED
K708 – HOMING LEAD CONTACTOR, OPEN EXCEPT AT HOME.
K709 – MOTOR HOME CONTACT, CLOSED EXCEPT AT HOME.
K710 – 0-8 GATE CONTACT, OPEN EXCEPT PULSES 0 THRU 8.
K711 – INTERRUPTING CONTACT FOR MEMORY RELAY, CLOSED EXCEPT AT POSITION 9.
K712 – LATCH HOME CONTACT, OPEN EXCEPT AT HOME.
K713 – GUARD POSITION CONTACTOR, OPEN EXCEPT IN GUARD POSITION.
K714 – MANUAL POSITION CONTACTOR, NORMALLY OPEN EXCEPT IN MANUAL POSITION.
K715 – UNITS CAM CONTACT.
K716 – TENS CAM CONTACT.
K717 – HUNDREDS CAM CONTACT.
K806 – UNITS HOME CONTACT, CLOSED EXCEPT AT HOME.
K807 – TENS HOME CONTACT, CLOSED EXCEPT AT HOME.
K808 – HUNDREDS HOME CONTACT, CLOSED EXCEPT AT HOME.
K809 – UNITS HOMING CONTACT, OPEN EXCEPT AT HOME.
K810 – TENS HOMING CONTACT, OPEN EXCEPT AT HOME.
K811 – HUNDREDS HOMING CONTACT, OPEN EXCEPT AT HOME.
K812 – ZERO ON HUNDREDS CONTACT, OPEN EXCEPT AT ZERO.
S701 – MAIN-GUARD-BOTH RECEIVER SELECTING SWITCH.
S702 – OFF-VOICE-TONE SWITCH
S703 – LATCH SWITCH, NORMALLY OPEN.
S704 – READY LIGHT SWITCH, NORMALLY OPEN.
S705 – SQUELCH DISABLE SWITCH, NORMALLY CLOSED.

NOTE 3 – ALL RELAY CONTACTS ARE SHOWN WITH THE RELAY COIL DE-ENERGIZED.

NOTE 4 – CONTACTORS ARE SHOWN IN THE NON-ACTUATED POSITION.

NOTE 5 – CONTACTORS ARE DESIGNATED BY CONTACT NUMBER AND THE ACTUATED CYCLE. THUS K709/HOME MEANS THAT K709 IS IN THE POSITION SHOWN, EXCEPT FOR THE "HOME" POSITION OF THE SCANNING PINION.

Figure 98.-Schematic Diagram of Control Box and Indicator Unit

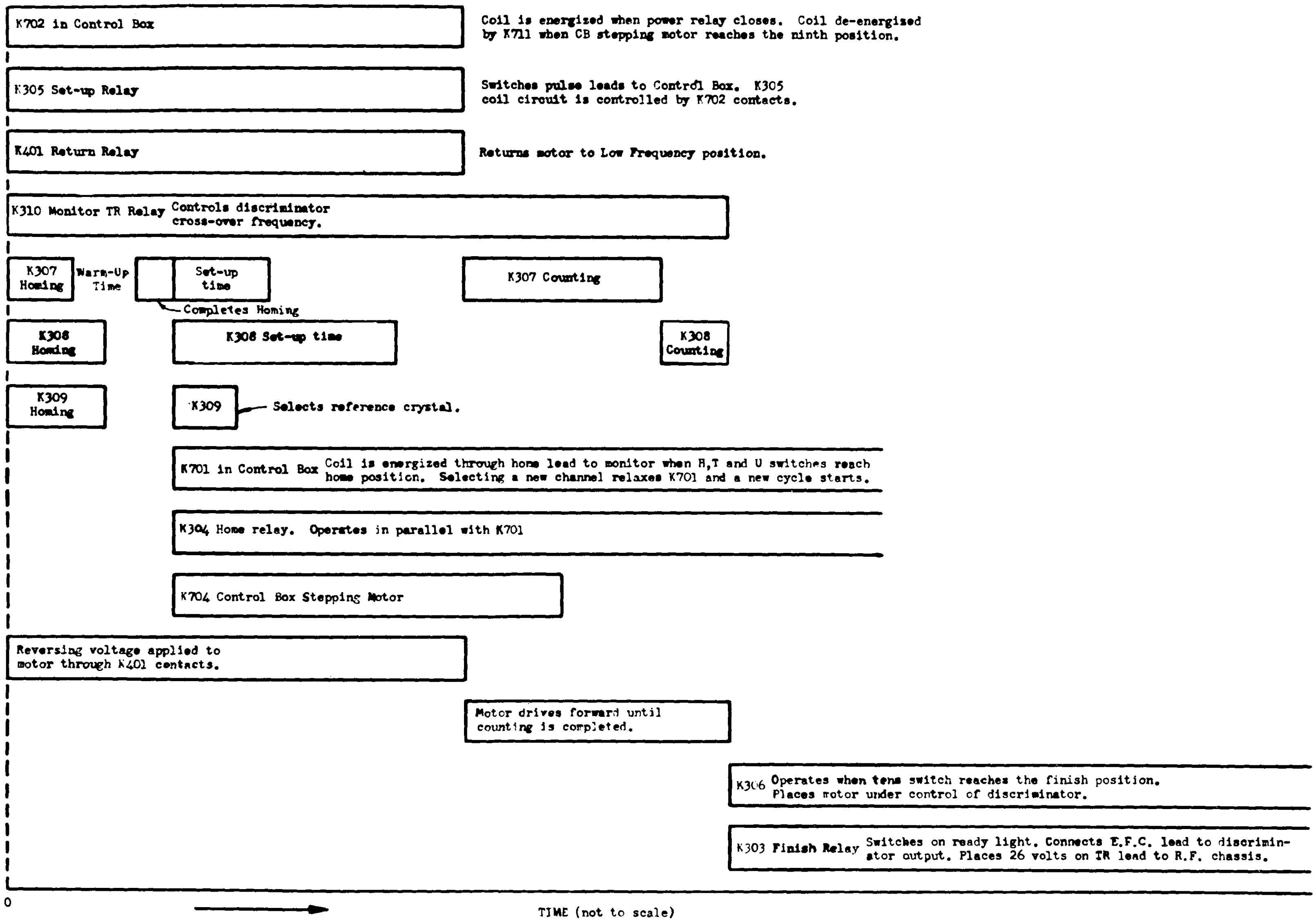


Figure 99.-Bar Graph of Time Sequence of Control Units

"off-voice-tone" switch in the "off" position all relay coils will be de-energized, and the monitor H and T stepping switches will be in the finish position. When the switch is thrown to the "voice" or "tone" position, power is applied to the stepping relays. The H stepper solenoid is grounded through its self-interrupting contact, the home relay (K304) contacts, and wafer switch S306, and will, therefore, advance to the warm-up position (position number 11). The H switch will remain in the warm-up position until the monitor tubes warm up and the plate current of the counter tube causes the reverse relay K301 to operate and ground the H stepper coil. The H stepper then moves to the home position. The warm-up feature of the circuit delays the setting-up and counting process until all tubes have reached normal operating temperature, thus preventing errors in counting. With application of power the T and U steppers also return to the home position. With the first application of power the coil of setup relay K305 in the monitor and the return relay K401 on the motor drive are energized through the contacts of K702. The direct current line voltage applied to the tuning motor terminals through K401 contacts is of the correct polarity to cause the tuning motor to drive the master oscillator condenser to the low-frequency position. At the low-frequency position, power is removed from the tuning motor by the low-frequency limit switch S401. Switch S401 is opened by a cam attached to the master oscillator condenser rotor. As soon as the monitor counting switches reach the home position, the home relay coil K304 in the monitor and K701 in the control box are energized through a setup relay contact and wafer switches S305, S309, and S313. The stepping motor in the control box now begins to cycle due to the fact that its solenoid circuit is completed to ground through contacts K702 and K701. The correct number of setup pulses are transmitted to the monitor as previously explained. The solenoid circuit of K702 is opened by contactor K711/9 when the control box stepping motor has completed nine steps of its cycle. The control box stepping motor solenoid circuit is opened by K709 when the control box motor has completed its setting-up cycle of 24 steps. The setup and return relay coils are de-energized when K702 is de-energized, since their coil circuits are opened by K702-1. When return relay K401 is de-energized its contacts reverse the direct current line polarity to the tuning motor and the tuning condenser is driven forward. The speed of the condenser shafts is controlled by three clutches, which provide a fast, a medium, and a slow speed. The shafts are driven at fast speed while counting all hundreds except the last. Wafer switch S304 switches the medium speed clutch in the circuit at position eight of the hundreds stepping switch. The shafts are driven at medium speed while counting the last hundreds count and all tens counts. When all tens are counted, the tens stepper will have reached the finish position and the slow clutch is switched in by S308. Contacts of S301 switch the spectrum from hundreds to tens when the hundreds count has been completed. Wafer switch S306 controls the bias on the monitor hundreds and tens audio amplifiers and on the counter tube.

When the tens stepper reaches the finish position, the coils of motor relay K306 and finish relay K303 are energized through wafer switches S306 and S309. When energized, the motor relay places the tuning motor leads under control of the reverse relay and the C and F relay.

Power for operating the antenna relay K103 and T-R relay K102, which are mounted in the head unit, is controlled by the contacts on finish relay

K303. This feature prevents the transmitter dynamotor from being started until the master oscillator has been set on the desired operating frequency. Finish relay contacts also control the ready light circuit causing it to light when the equipment is ready for operation.

PART II

Equipment Evaluation

INTRODUCTION

Engineering evaluation of the AN/ARC-19 (XN-1) equipment has been conducted to determine its suitability for use in Naval Aircraft. Results are included in the following section for the items listed below:

Heat Exchanger
Weights
Receiver - sensitivity, AVC characteristics, selectivity, image and spurious responses, i-f rejection, regeneration, noise limiter operation, audio fidelity, audio distortion, a-f and r-f gain control characteristics, squelch operation and frequency stability,
Transmitter - carrier power output, modulation characteristics, fidelity, modulation distortion, tone modulation, frequency stability, sidetone, carrier shift, carrier noise level, and frequency modulation.
Microphone energizing current.
Input power requirements
Channel selection time
Transmit - receive interval
Channelization
Flight test

The specifications of Reference (o) and Reference (p) were used as guides in the evaluation of the equipment. Reference (o) is the specification which was originally intended to govern the operation of the production models of the AN/ARC-19 (XN-1) equipments. These were to be manufactured by Bendix Radio, Division of Bendix Aviation Corporation. The addendum, Reference (p) applies only to the engineering models of the subject equipment.

HEAT EXCHANGER TEMPERATURE TESTS

Tests were conducted to determine the operational characteristics of the heat exchanger in the equipment. Actual operation was simulated as nearly as possible in these tests. The transmitter and receiver were operated alternately, indicated by "transmitter on" and "transmitter off" respectively on the individual curve sheets. These tests were performed at room temperature $-50^{\circ}C$, and at $+50^{\circ}C$. Each run was continued until no further increase in temperature was noted from one cycle to the next. The temperature at several different points inside the equipment case were recorded by means of thermocouples and a pyrometer.

The equipment was operated at all times during the temperature measurements. The regular cycle was continued and temperatures recorded while the ambient temperature in the weather chamber was being changed. This procedure was followed to prevent the necessity of waiting a long period of time for the equipment to stabilize after the ambient temperature of the weather chamber had been changed.

Tests at Ambient Temperature of +30°C.

Figure 100 shows the heat exchanger temperatures during warm-up in a 30°C ambient with the equipment operating in the receive condition. The curves on this figure show the temperature of the air at the heat exchanger internal intake and the temperature of the air at the internal exhaust after the air had passed over the inside surfaces of the heat exchanger. The temperature of the air at the internal intake of the heat exchanger stabilized after 105 minutes at about 56°C. At the same point, the temperature of the air at the internal exhaust was 48°C. Comparison of these two curves shows that a reduction in temperature of 8°C was accomplished by the heat exchanger at this point. At any point on the time scale, the reduction in temperature of the air inside of the case afforded by the heat exchanger is indicated by the difference in these two curves at that point.

The two curves for the external surfaces of the heat exchanger show that the temperature of the external air passing through the external surfaces of the heat exchanger was increased by an amount proportional to the reduction in temperature of the air inside of the case.

Figure 101 shows the heat exchanger temperatures during warm-up, when the equipment was operated in a 30°C ambient temperature, on alternate transmit and receive cycles of 15 minutes each, as indicated in the figure. The curves in Figure 101 show that the stable temperature under these conditions was higher than when the equipment was operated on receive only. The temperature of the air inside the case at the heat exchanger intake was 63°C at the end of the 15-minute transmit interval after the stabilization period. The temperature of the air at the internal exhaust of the heat exchanger was 8.4°C lower than the temperature of the air at the intake.

The external blower is controlled by a snap-action thermostat which is located at the rear of the main deck. The blower motor is energized when the temperature of the air at the rear of the case reaches 40°C. Figure 102 shows the temperature of the air at the thermostat and the cavity temperature versus time. The cavity temperature curve in Figure 102 shows the temperature recorded with

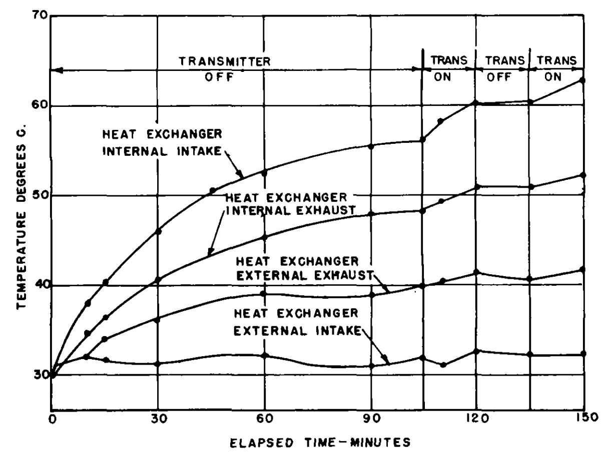


Figure 100.-Heat exchanger temperatures for AN/ARC-19 (XN-1) serial number 2, at room ambient conditions with primary supply 26.5 volts and transmitter cycled after stabilization.

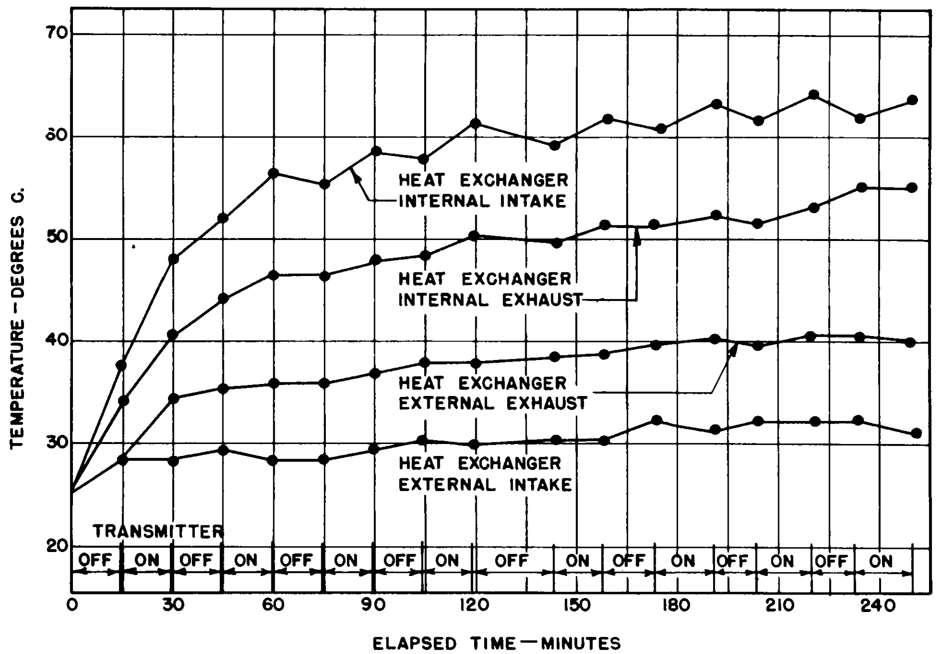


Figure 101.-Heat exchanger temperatures for AN/ARC-19 (XN-1), serial number 2, at room ambient conditions, with primary supply 26.5 volts.

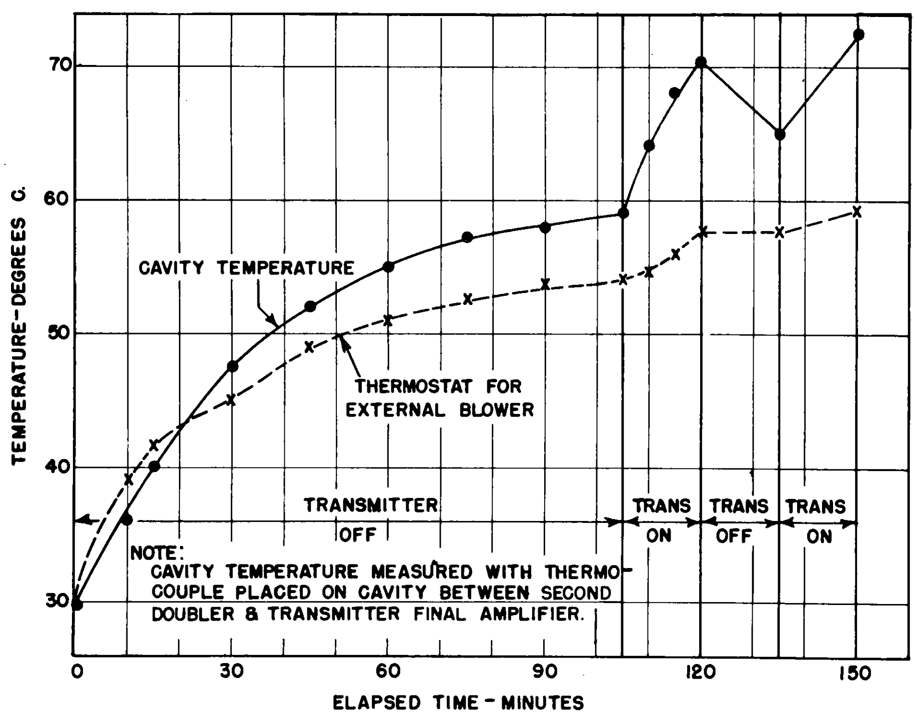


Figure 102.-Equipment warm-up of an AN/ARC-19 (XN-1), serial number 2, at room ambient conditions, with primary supply 26.5 volts and transmitter cycled after stabilization.

a thermocouple placed on the cavity between the final amplifier and the second doubler. The temperature at this point was the highest temperature recorded in the equipment when operated on transmit.

Figure 103 shows the cavity temperature and the temperature of the air at the thermostat during warm-up in a 30°C ambient when the equipment was operated on transmit and receive alternately for 15-minute periods. The maximum temperature of the cavity after stabilization was 76°C. At the time when the cavity temperature reached the maximum value, the temperature of the air at the thermostat was 60°C.

The temperatures of the dynamotor housings during warm-up in a 30°C ambient are shown in Figure 104. The maximum temperature of the receiver dynamotor when the equipment was operating on receive was 56°C. The transmitter dynamotor is not in operation when the equipment is operating on receive. The temperature of the transmitter dynamotor housing after stabilization was 50.5°C.

The temperature of the transmitter dynamotor, and the temperature of the receiver dynamotor when the equipment was operated on the 15 minute transmit and receive cycle, are shown in Figure 105. When the equipment was operated in this manner, the temperature of both dynamotors was increased over the

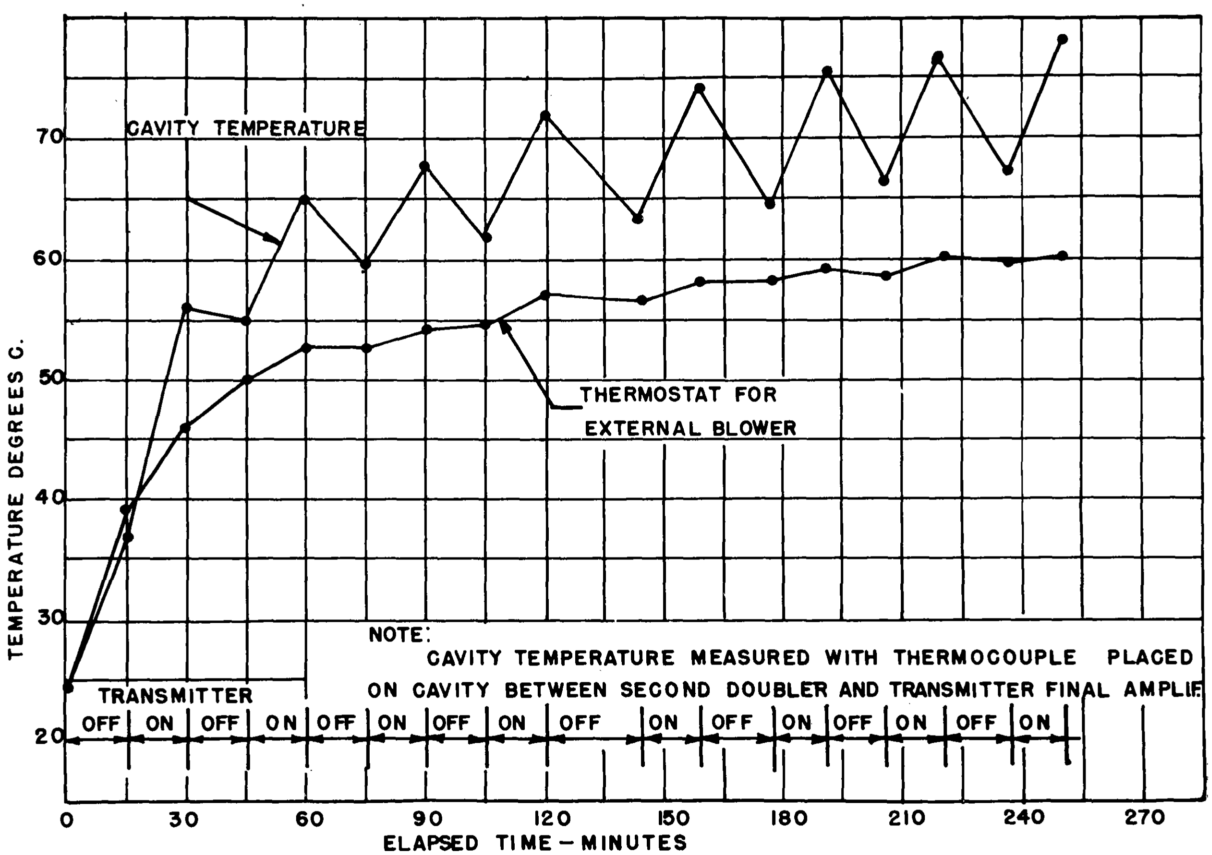


Figure 103.-Equipment Warm-up of AN/ARC-19 (XN-1), serial number 2, at Room Ambient Conditions with Primary Supply 26.5 volts

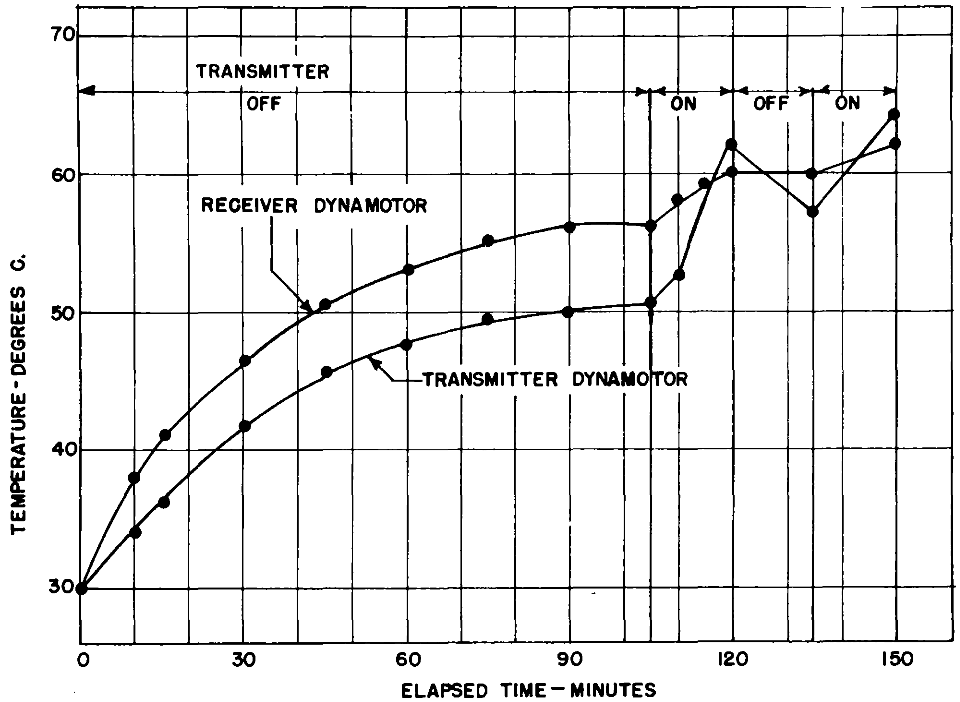


Figure 104.-Receiver and transmitter dynamotor temperatures of AN/ARC-19 (XN-1), serial number 2, at room ambient conditions, with primary supply 26.5 volts and transmitter cycled after stabilization.

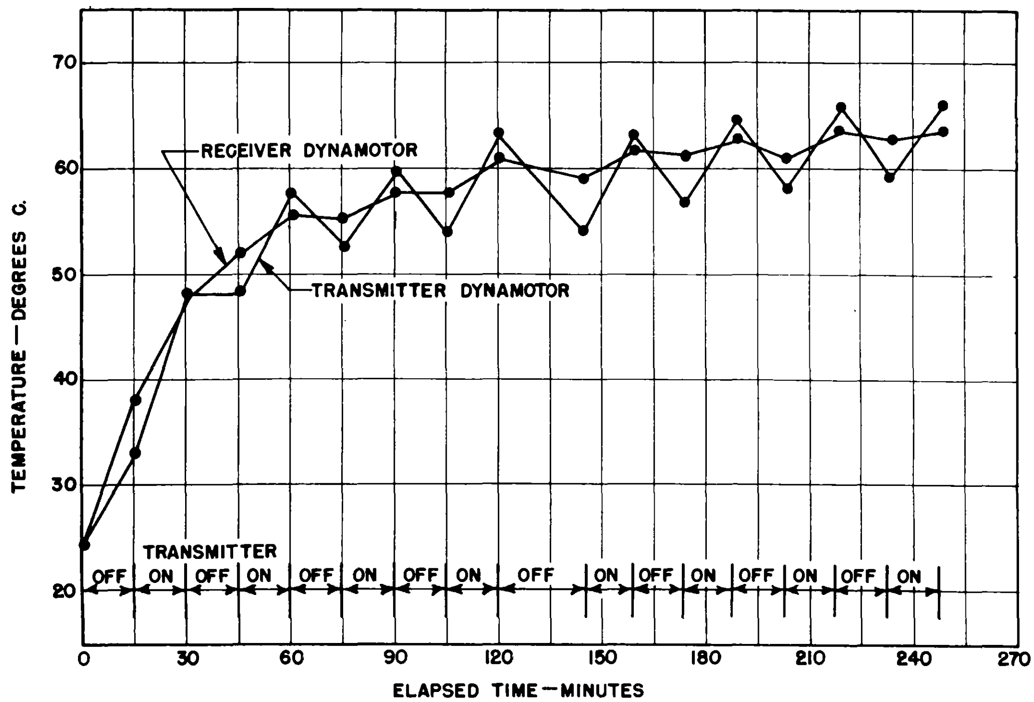


Figure 105.-Receiver and transmitter dynamotor temperatures of AN/ARC-19 (XN-1), serial number 2, at room ambient conditions with primary supply 26.5 volts.

temperature when operated on receive only. The maximum temperature of the transmitter dynamotor housing under this condition of operation was 66°C. The maximum temperature of the receiver dynamotor under the same condition of operation was 63°C.

Figures 106 and 107 show the temperatures of the outside surfaces of the crystal oven housings under both conditions of operation. When the equipment was operated on receive (Figure 106), the maximum temperature of the crystal oven cases was 52.5°C. The temperatures of the crystal oven cases when the equipment was operated on the 15-minute transmit-receive cycle is shown in Figure 107. The maximum temperature of the oven cases under this condition of operation in a 30°C ambient was 60°C for the small oven and 58.5°C for the large oven.

Tests at High Ambient Temperature

Figure 108 shows the heat exchanger temperature for operation of the equipment on the 15-minute transmit-receive cycle in an ambient temperature of 50°C. The equipment was put into operation at room temperature at the same time that the temperature of the weather chamber started to increase. The maximum temperature of the air inside of the case at the intake to the heat exchanger was 77°C. The temperature of the air inside of the case at the exhaust of the heat exchanger was 60°C. The reduction in temperature due to the heat exchanger was 17°C when operated under these conditions. The ambient temperature of the weather chamber is shown in this figure.

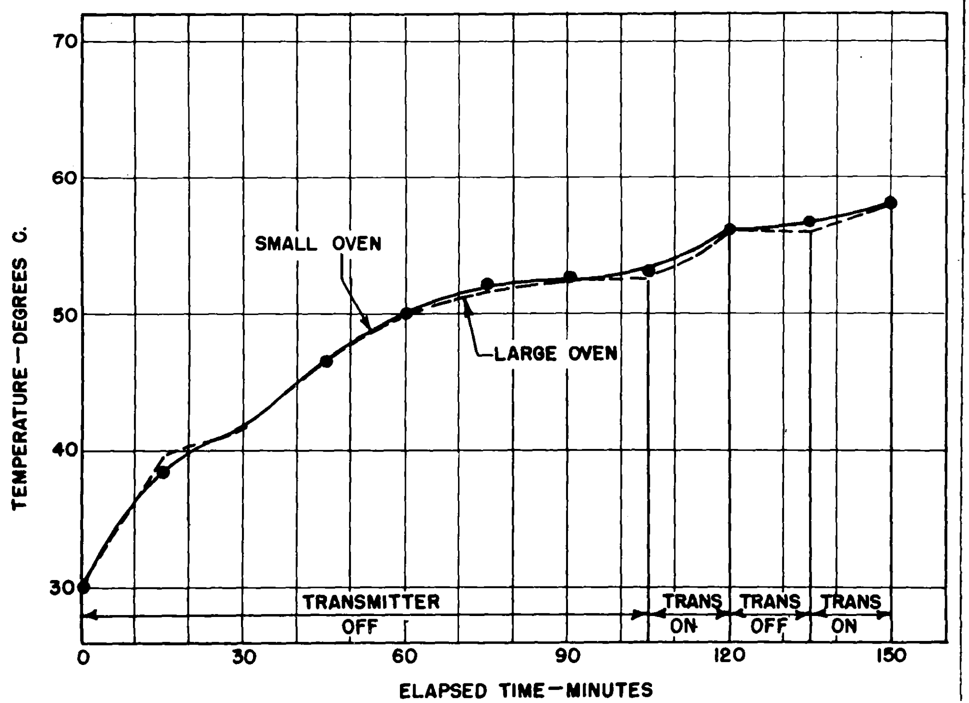


Figure 106.-Crystal oven case temperatures for AN/ARC-19 (XN-1), serial number 2, at room ambient conditions, with primary supply 26.5 volts and transmitter cycled after stabilization.

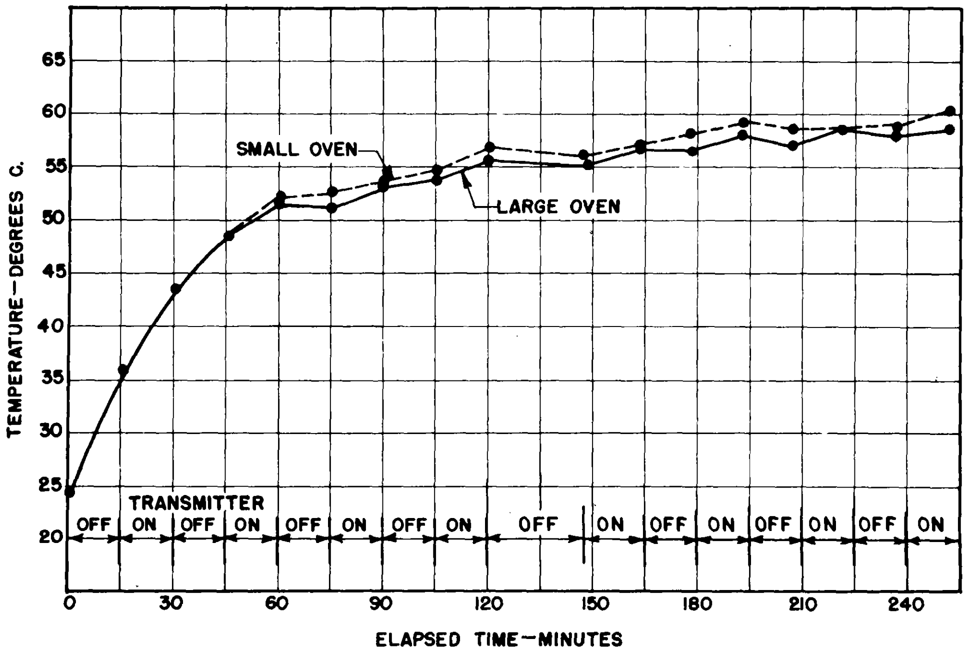


Figure 107.-Crystal oven case temperatures of AN-ARC-19 (XN-1), serial number 2, at room ambient conditions, with primary supply 26.5 volts.

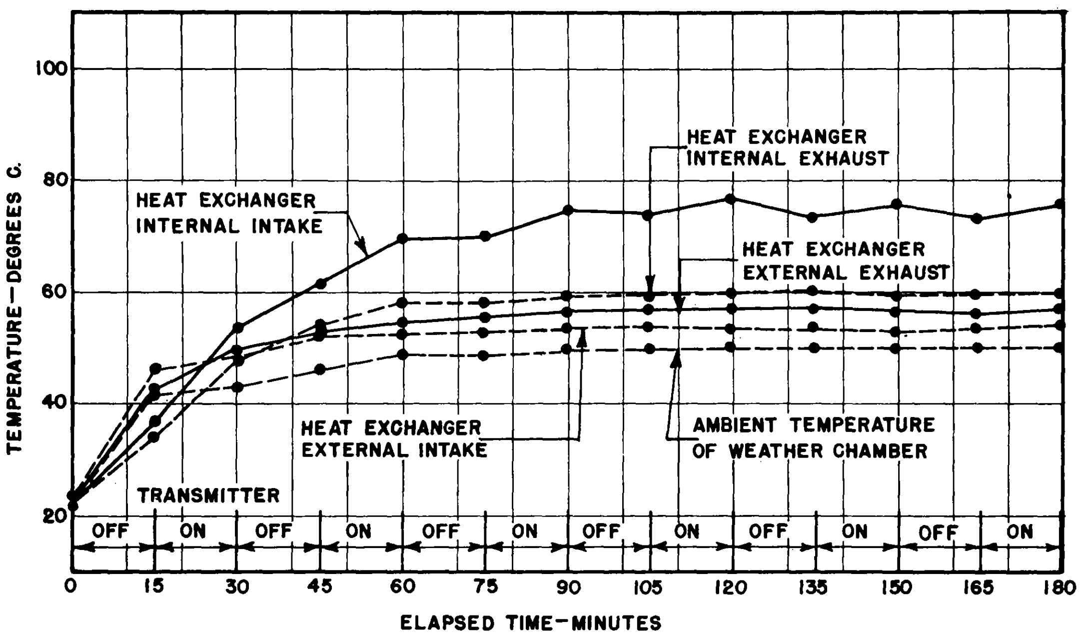


Figure 108.-Heat exchanger temperatures of AN/ARC-19 (XN-1), serial number 2, at high ambient temperature; primary supply 26.5 volts.

The temperature of the air inside the case at the thermostat when the equipment was operating in a 50°C ambient is shown in Figure 109. The maximum temperature at this point was 75°C. Figure 109 also shows the temperature of the first doubler tube. This temperature was measured on the plate of the 2C39 doubler tube. The maximum temperature of the plate of this tube was 80°C.

The temperatures of the modulation transformer case is shown in Figure 110. The highest temperature recorded for the modulation transformer case during this test was 71°C.

Figure 111 shows the temperatures of the dynamotor housing when the equipment was operated in a 50°C ambient. The maximum temperature of the receiver dynamotor housing was 80°C, recorded after 120 minutes of operation. The transmitter dynamotor housing reached a maximum temperature of 79°C.

The temperatures of the crystal oven cases when the equipment was operated in a 50°C ambient are shown in Figure 112. The temperature of the large crystal oven housing reached 91°C after two hours, as measured on the case of the crystal oven near the base. The temperature at this part of the oven housing was the highest temperature encountered. The maximum temperature of the small crystal oven housing was 76°C. The crystal oscillators were designed to operate with crystals maintained at a temperature not to exceed +75°C. Consequently, it was necessary to bring the large crystal oven temperature down below 75°C. This was done by placing a baffle

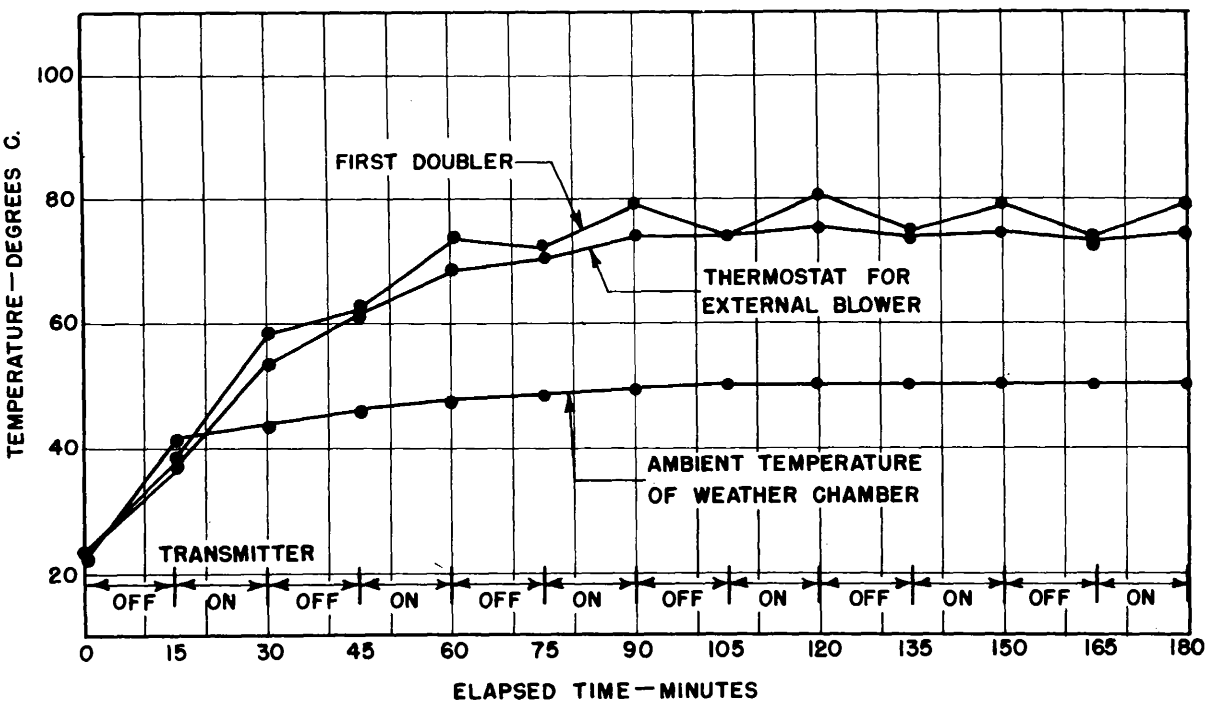


Figure 109.-Equipment Warm-up of AN/ARC-19 (XN-1), serial number 2, at High Ambient Temperature; Primary Supply 26.5 Volts.

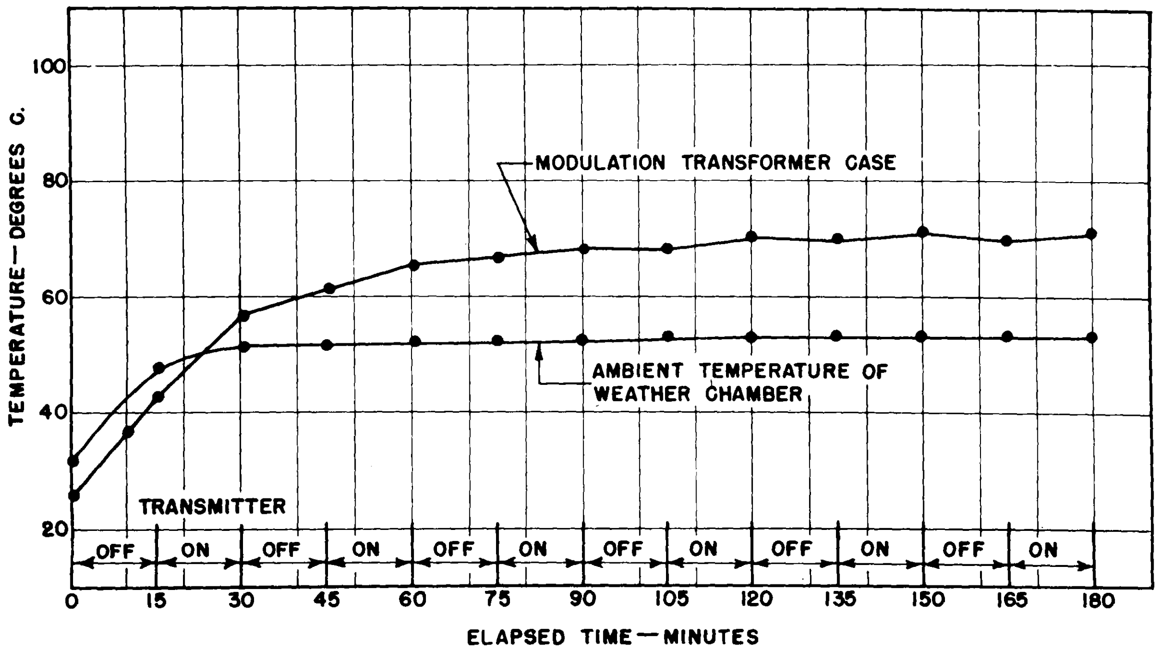


Figure 110.-Equipment Warm-up of AN/ARC-19 (XN-1), serial number 2 at High Ambient Temperature; Primary Supply 26.5 Volts

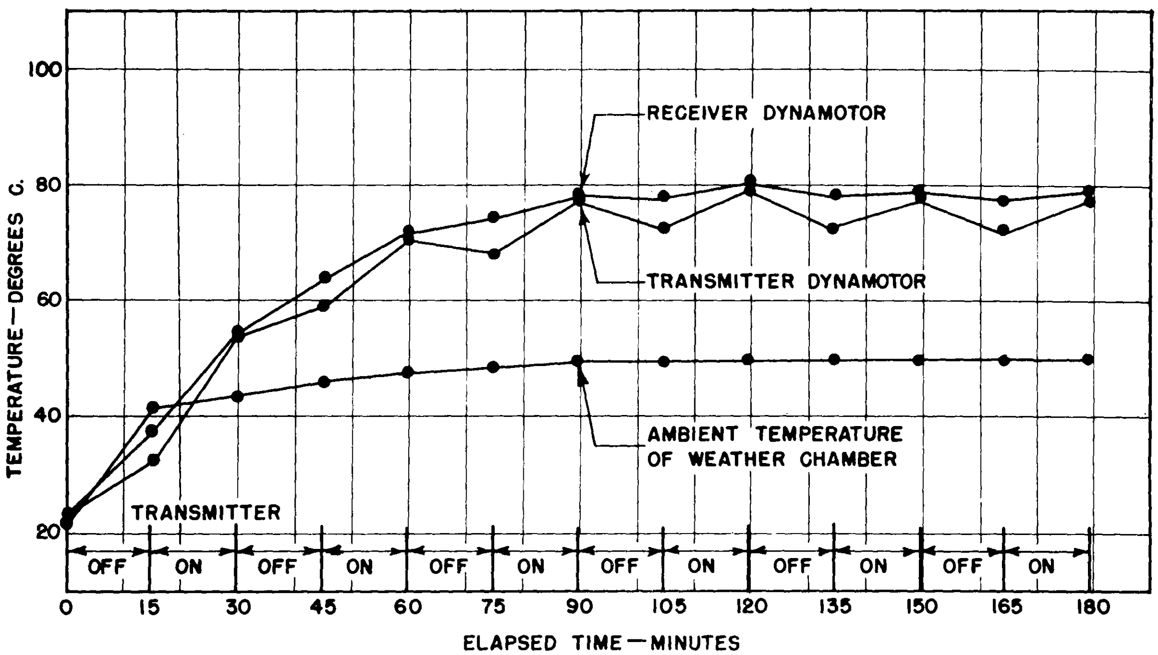


Figure 111.-Receiver and transmitter dynamotor temperatures of AN/ARC-19 (XN-1), serial number 2, at high ambient temperature, with primary supply 26.5 volts.

in the heat exchanger internal exhaust air stream which deflected a portion of this air around the large oven. Figure 108 shows that the heat exchanger internal exhaust air temperature never exceeds 60°C. The large oven is located only two inches from the outlet of the internal blower so that the baffle took the simple form of a curved piece of sheet metal mounted on the top of the filter choke on the i-f chassis.

Tests at Low Ambient Temperature

Figure 113 shows the temperatures of the heat exchanger intakes and exhausts when the equipment was operated in a -50°C ambient. The temperature of the air inside the case at the thermostat did not reach the 40°C temperature necessary to energize the external blower motor. The temperature of the air inside the case at the intake of the heat exchanger was +4°C and the temperature of the air at the exhaust of the heat exchanger was -8½°C.

The temperature of the cavity when the equipment was operated in an ambient of -50°C is shown in Figure 114. The stabilized temperature of the cavity under these conditions was +17°C.

The temperature of the first doubler tube is shown in Figure 114. The final temperature of the first doubler tube was +4°C. The temperature of the air inside the case at the thermostat is also shown as stabilizing to +3°C.

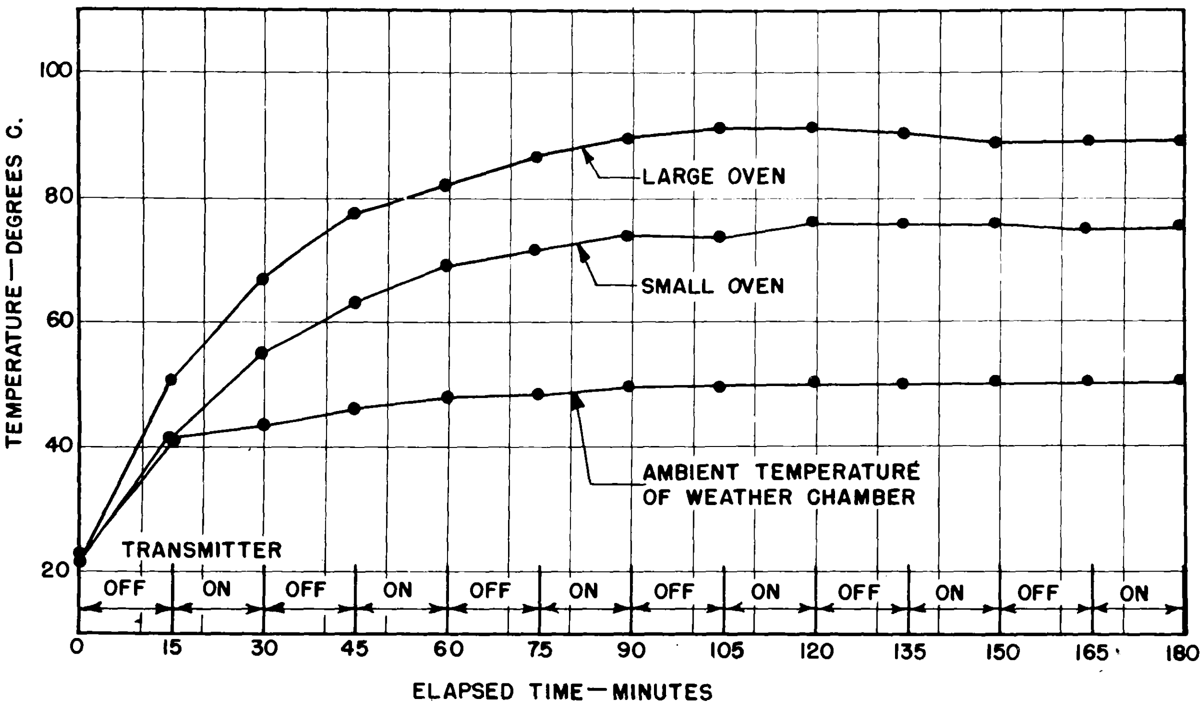


Figure 112.-Crystal oven case temperatures of AN/ARC-19 (XN-1), serial number 2, at high ambient temperature; primary supply is 26.5 volts.

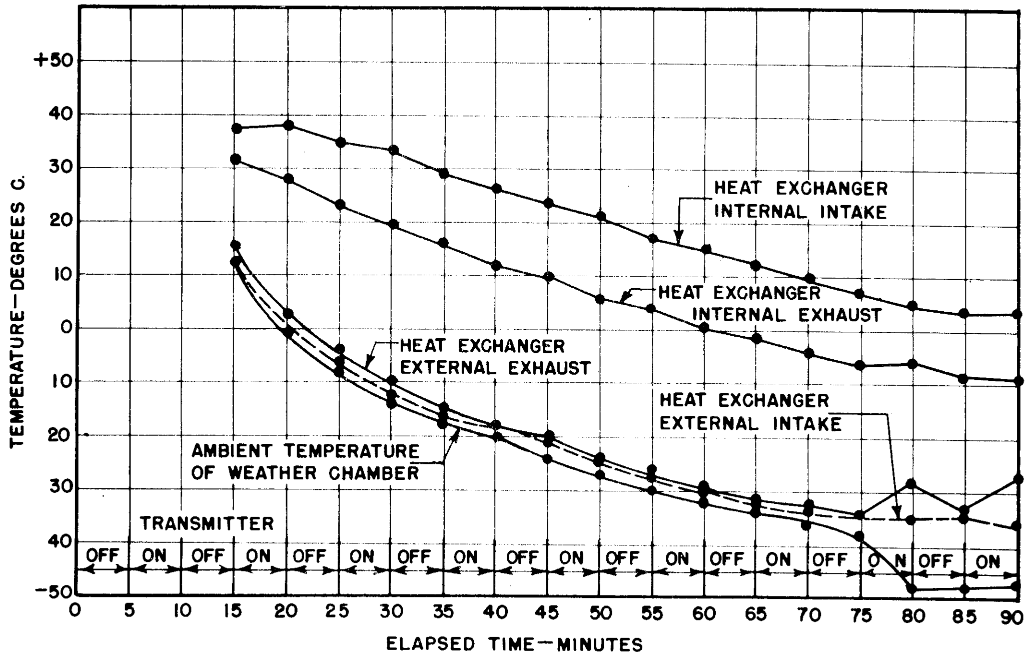


Figure 113.-Heat exchanger temperatures for AN/ARC-19 (XN-1), serial number 2, at low ambient temperature; primary supply is 26.5 volts.

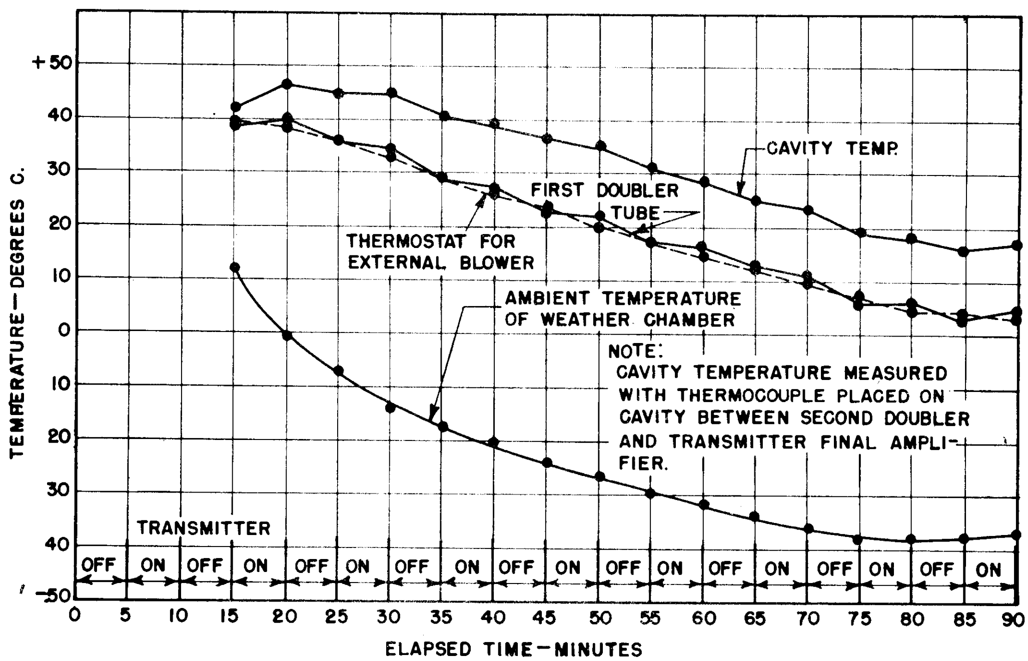


Figure 114.-Equipment warm-up of AN/ARC-19 (XN-1), serial number 2, at low ambient temperature. The primary supply is 26.5 volts.

Figure 115 shows the temperature of the receiver dynamotor housing when the equipment was operated in an ambient temperature of -50°C. The temperature of the receiver dynamotor stabilized at +11°C. The transmitter dynamotor temperature, also shown in Figure 115, stabilized at +4°C.

The stabilized temperature of the two crystal oven housings are only two degrees different (Figure 116); the large oven housing stabilized at +1°C and the oven housing stabilized at +3°C.

EQUIPMENT WEIGHTS

The weights of the total system and component parts are shown below:

Weights of
AN/ARC-19 (XN-1)

	Actual Weight (Pounds)	Specified Weight (Pounds)
Transmitter-Receiver (includes i-f and Monitor Units)	80.8	80.0
Mounting Rack	2.2	8.0
Control Box and Indicator	11.1	8.0
Mounting Plate (for Control Box)	0.3	0.3
Aneroid Control	0.375	1.0
Wiring Harness Consisting of:		
2 jack boxes		
1 junction box		
complete interconnecting cables and plugs*	6.0	
Antenna	2.55	
I-F Unit	8.6	
Monitor Unit	7.9	

* Power cable length-6 ft
Other cable lengths-4 ft each

RECEIVER PERFORMANCE

The receiver sensitivity was measured and the results are shown in Figures 117, 118, 119, and 120. A Ferris Model 48A signal generator was tuned to the receiver frequency and the signal strength was adjusted until a 4:1 signal-plus-noise to noise power ratio was obtained at the receiver output. All sensitivity measurements were conducted with the input signal 30 percent modulated at 1000 cps. Coupling from the signal generator to the receiver consisted of a five-foot length of 50-ohm coaxial cable fed directly from the "Hi" tap of the signal generator pad to the receiver antenna fitting. Since the audio noise level of

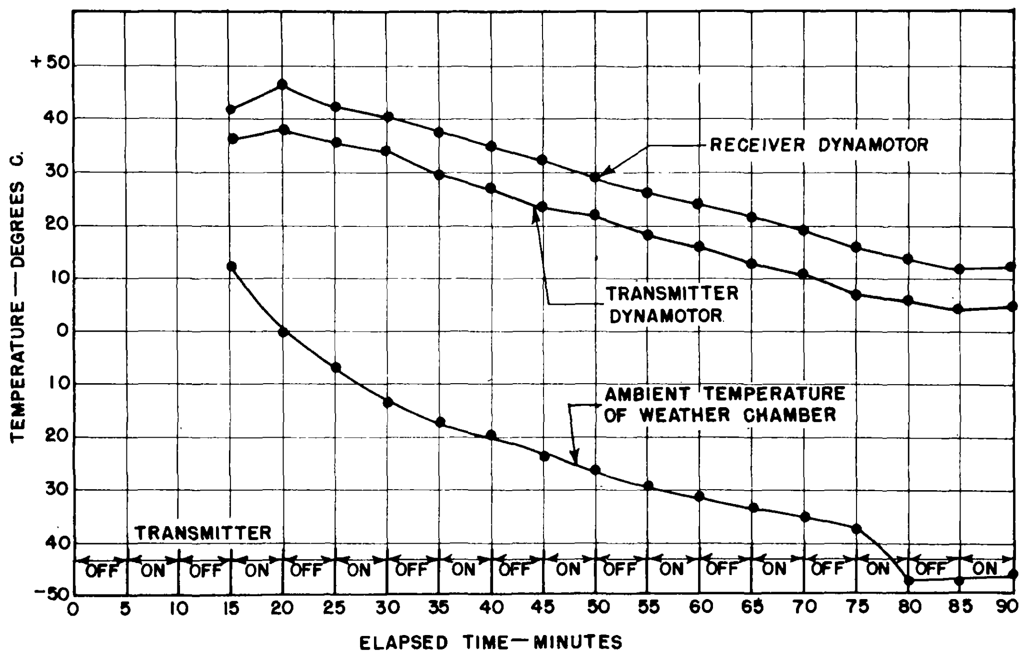


Figure 115.-Receiver and transmitter dynamotor temperatures of AN/ARC-19 (XN-1), serial number 2, at low ambient temperature; primary supply is 26.5 volts.

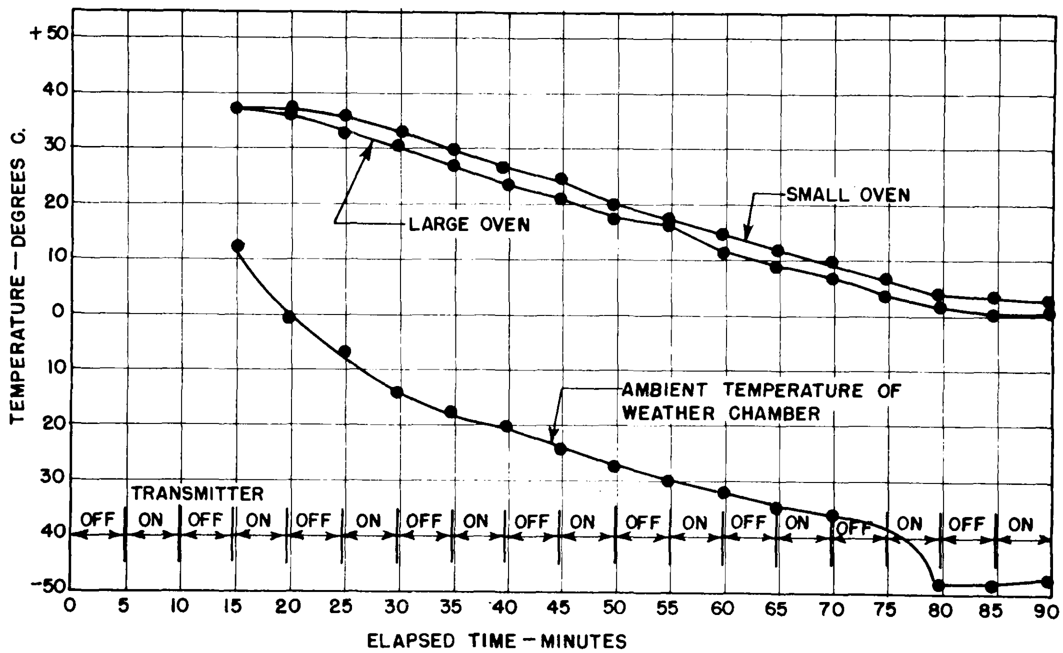


Figure 116.-Crystal oven case temperatures of AN/ARC-19 (XN-1), serial number 2, at low ambient temperature; primary supply is 26.5 volts.

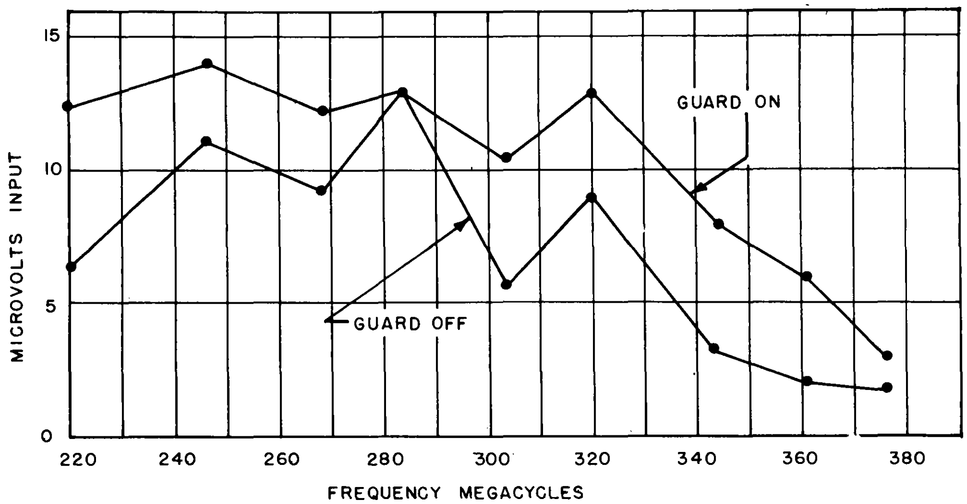


Figure 117.-Receiver main channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions, with primary supply 23.8 volts and squelch disabled.

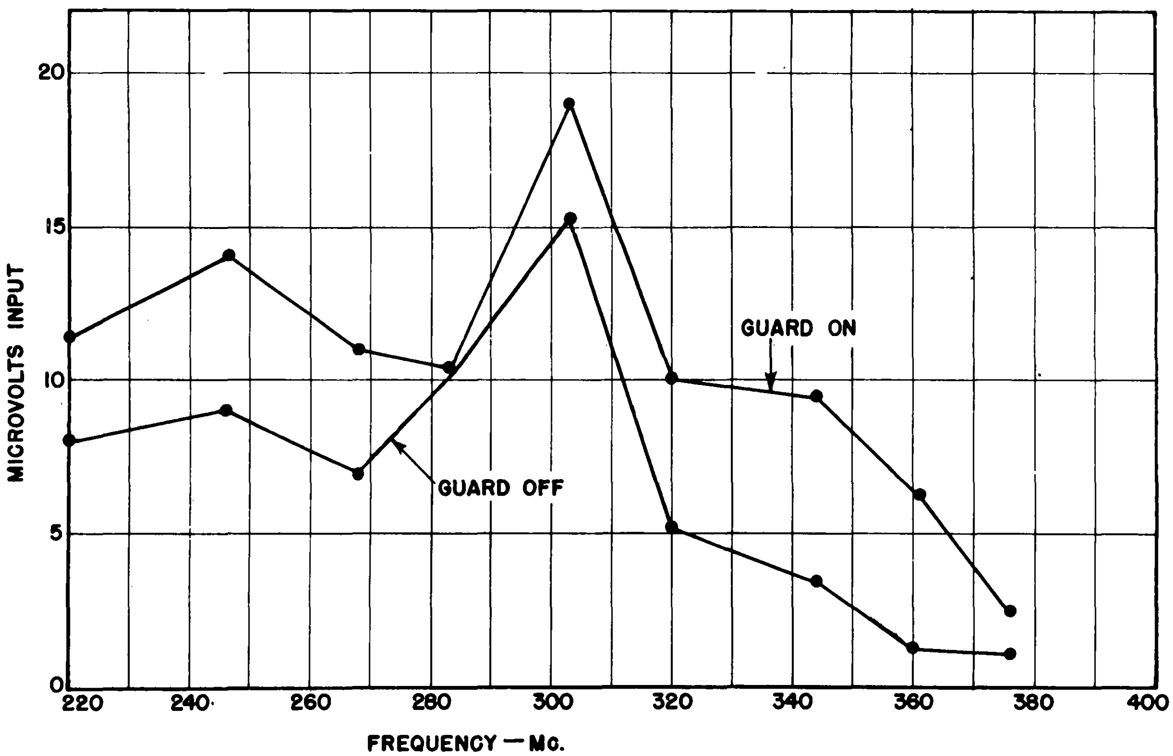


Figure 118.-Receiver main channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions with primary supply 26.5 volts and squelch disabled.

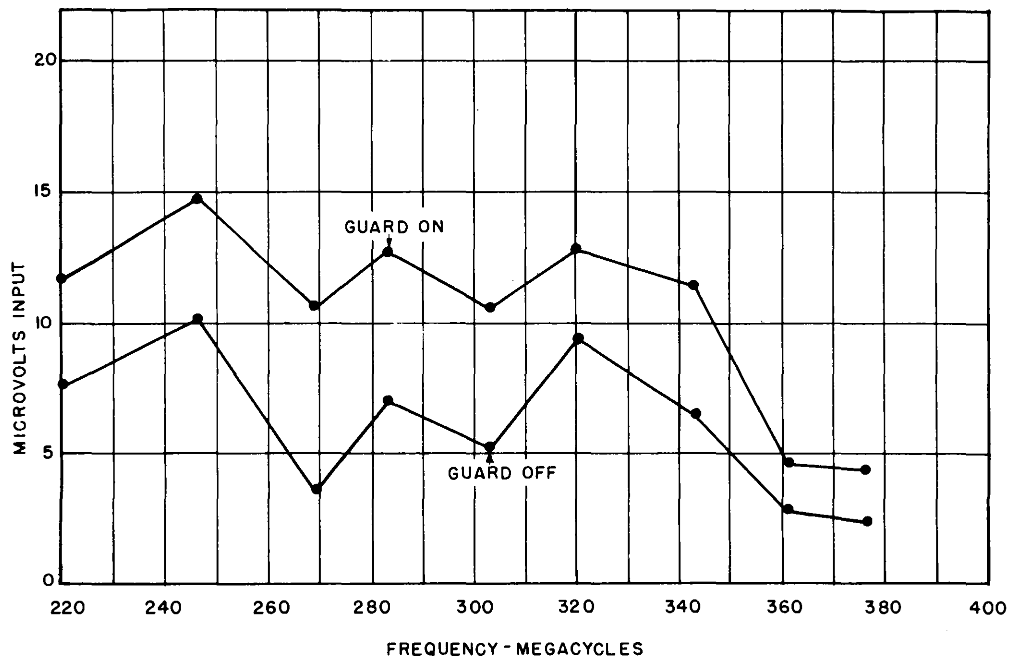


Figure 119.-Receiver main channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply 29.2 volts and squelch disabled.

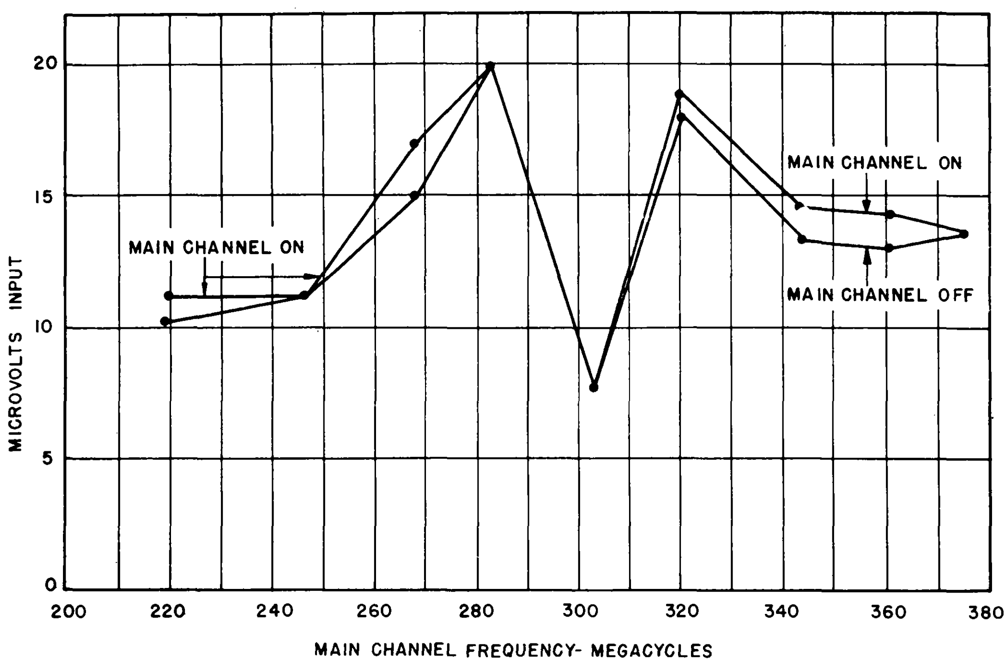


Figure 120.-Receiver guard channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply 26.5 volts and squelch disabled.

the receiver when operated in the "both" position was double that in the "main" position, main channel sensitivities were measured for each control box setting. Similarly, the guard channel sensitivities were measured for the "both" and "guard" selector switch positions of the control box. The increased noise level in the "both" position was due to the noise of the main channel mixer and the guard channel mixer being simultaneously fed into a common i-f amplifier. The noise level of the i-f was negligible compared with the noise level generated in the mixer circuits. The receiver main channel sensitivities at a standard primary supply voltage of 26.5 volts varied between the limits of 1.0 microvolt and 19.0 microvolts over the 220 to 376 Mc frequency range as shown in Figure 118. At each frequency the audio output was in excess of 100 milliwatts unless reduced to 100 milliwatts by the audio gain control. A change in primary supply voltage to 23.8 volts or 29.2 volts had no appreciable effect upon the sensitivities. Figures 117 and 119 show results of measurements at 23.8 volts and 29.2 volts, respectively. The slight discrepancies between the curves is due primarily to difficulty of tuning the signal generator and to variations of the room ambient noise level. It should be noted that the Ferris Model 48A signal generator is extremely difficult to tune properly to a receiver which has a narrow bandwidth such as the AN/ARC-19 (XN-1) receiver. The frequency stability and bandspread tuning of this generator are inadequate for precision measurements. As a result, the error in sensitivity measurements could be as great as 25 percent. The guard channel sensitivity was found to vary between 7.5 microvolts and 19.9 microvolts when the main channel receiver setting was varied within the limits of the frequency band (Figure 120).

Sensitivities were measured at the extremes of the specified temperature range for primary supply voltages of 23.8 volts and 26.5 volts. The results of the low temperature test, -50°C, are shown in Figure 121 and the results

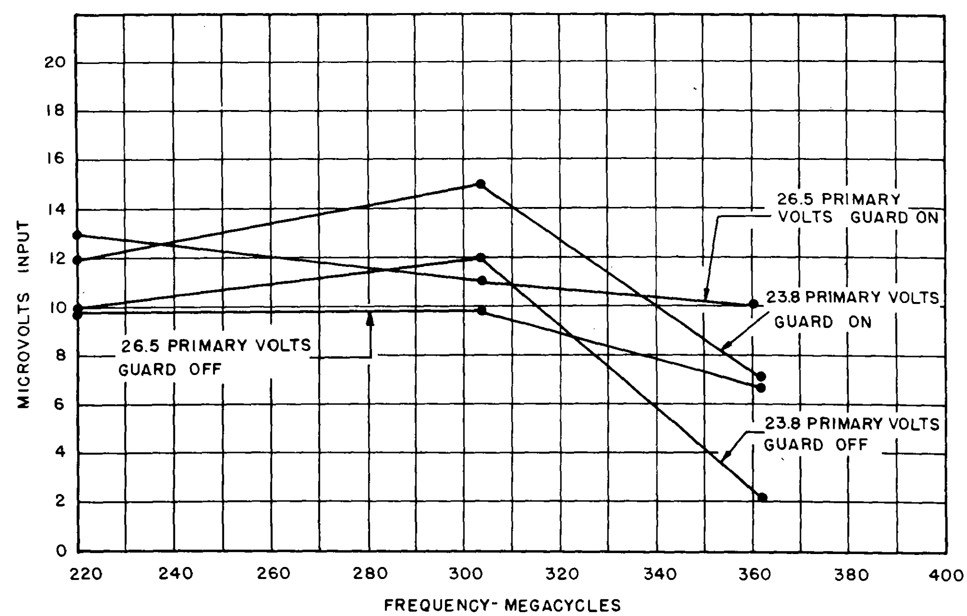


Figure 121.-Receiver main channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at -50°C ambient temperature, with squelch disabled.

of the high temperature test, +50°C, are shown on Figure 122. The conditions for optimum sensitivity occurred at +50°C where the sensitivities were best at the high frequency end of the band and were poorest at the low end. The sensitivity measurements during the temperature test indicated no sensitivity poorer than 16 microvolts.

Specifications of Reference (o) require the receiver AVC action to be such that a one-millivolt signal modulated 30 percent at 1000 cps will produce an audio output of 450 milliwatts to 600 milliwatts and that the output produced by a 40-microvolt signal and a 10-millivolt signal be less than two decibels below or above the output with a one-millivolt signal input. In addition, it is required that no blocking be produced by input signals up to two volts. Results of the AVC tests under Standard Conditions are shown in Figures 123 through 127. The receiver noise output power and AVC voltages are shown on the same figures. Figure 123 shows the characteristic of the receiver audio output versus the input signal at 220 Mc. In this case the output with a one-millivolt signal was 950 milliwatts. The output at 40 microvolts and 10 millivolts was minus 5.0 decibels and plus 0.2 decibels, respectively, from 950 milliwatts. The audio output level at the one-millivolt input can be reduced from 950 milliwatts to 500 milliwatts or below with the audio gain control to comply with the specifications, but the point at 40-microvolts input on the characteristic curve will remain three decibels below the specification requirements. Figures 124, 125, and 126 give the AVC data for a frequency of 303.8 Mc at 23.8, 26.5, and 29.2 primary supply voltages, respectively. The curves at 23.8 volts and 29.2 volts are entirely

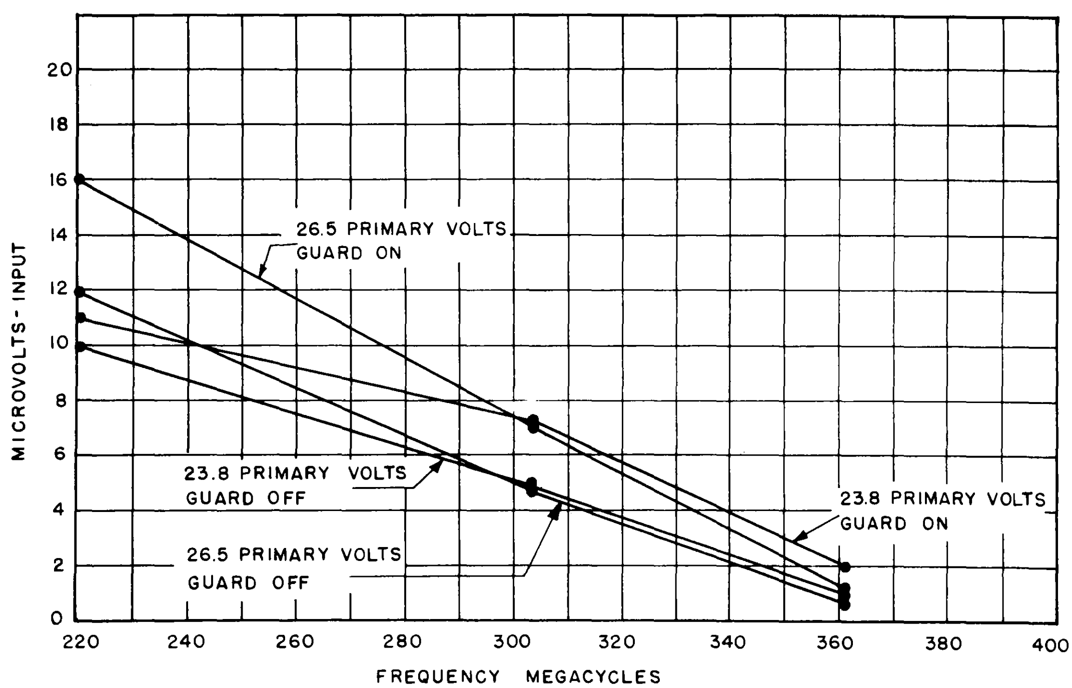


Figure 122.-Receiver main channel sensitivity of AN/ARC-19 (XN-1), serial number 4, at +50° ambient temperature with squelch disabled.

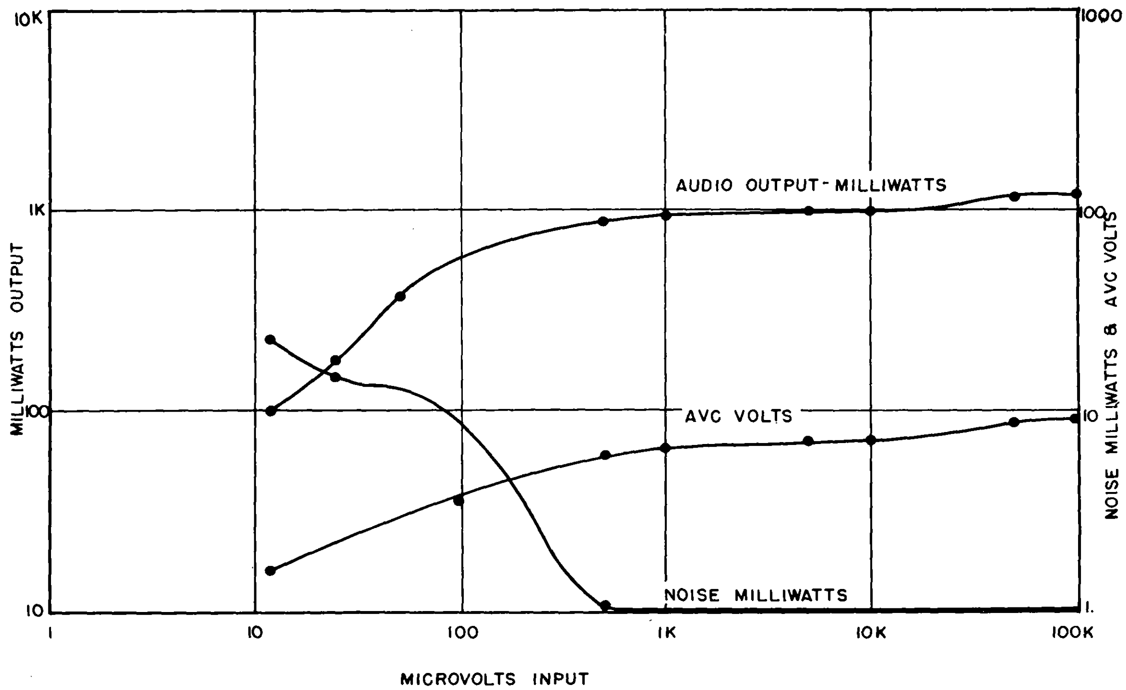


Figure 123.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Primary supply is 26.5 volts, frequency is 220 Mc and input is 30 percent modulated at 1,000 cps.

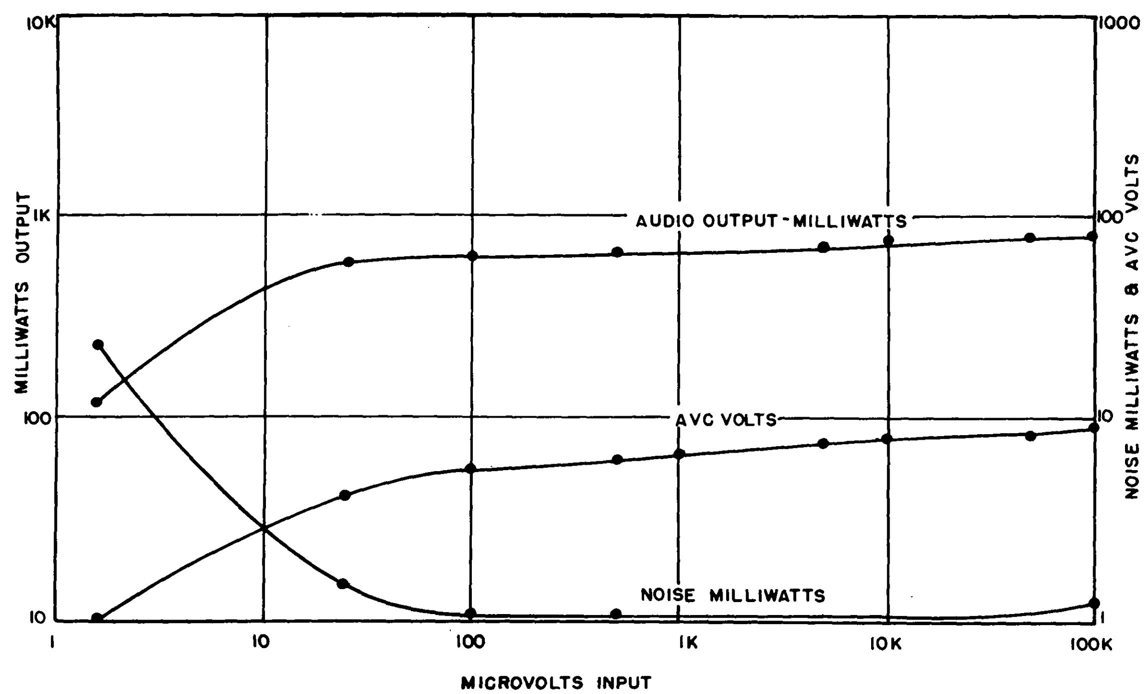


Figure 124.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Primary supply is 23.8 volts, frequency is 303.8 Mc and input is 30 percent modulated at 1,000 cps.

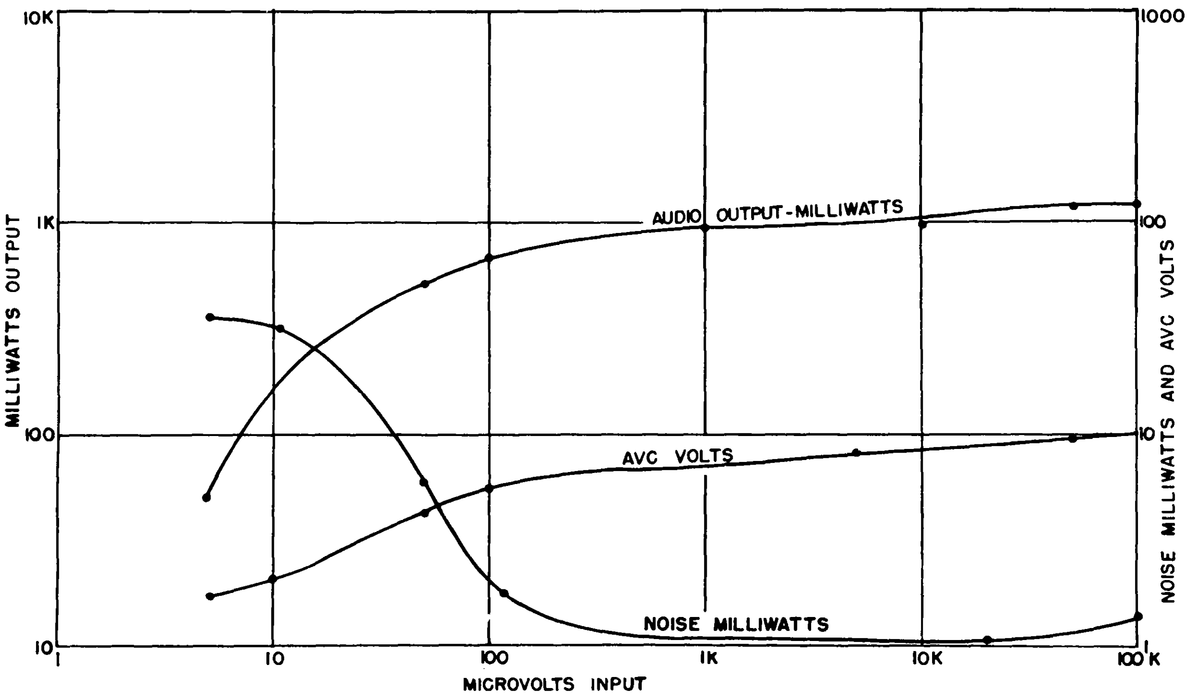


Figure 125.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Primary supply is 26.5 volts, frequency is 303.8 Mc, and input is modulated 30 percent at 1,000 cps.

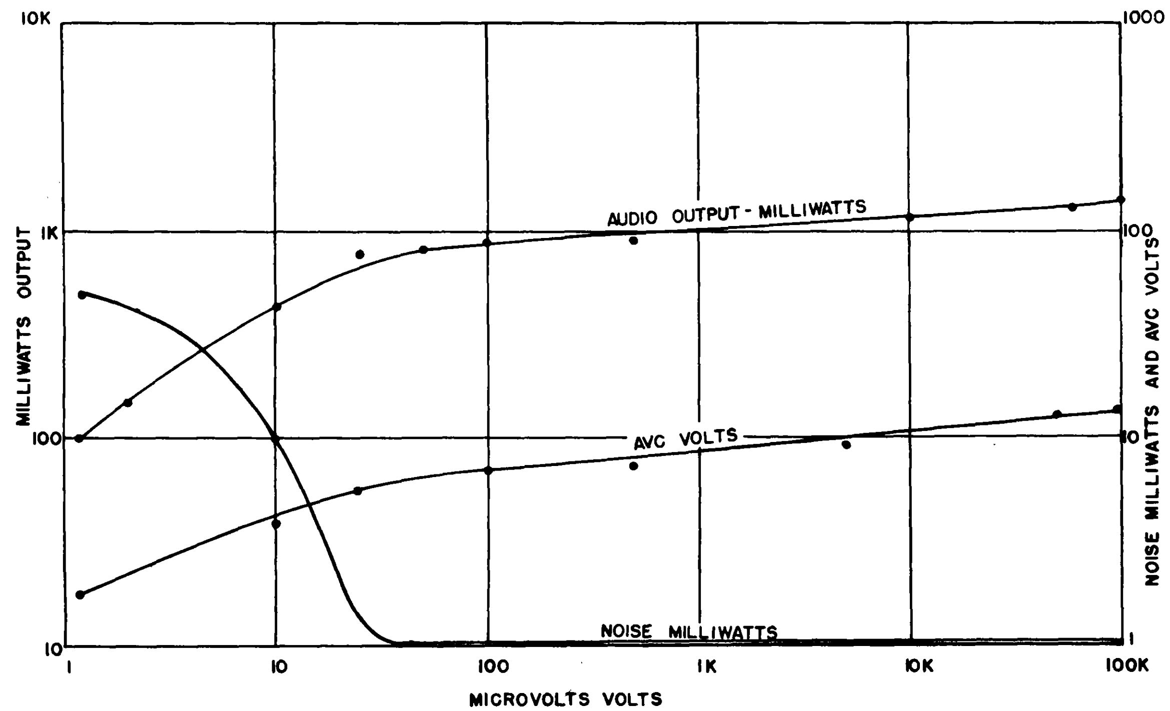


Figure 126.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Primary supply is 29.2 volts, frequency is 303.8 Mc, and input is 30 percent modulated at 1,000 cps.

within the specification limits while the curve for 26.5 volts deviates slightly from specification requirements at the 40-microvolt input level. There the output is down 3.2 decibels. Figure 127 is the AVC characteristic at 368.0 Mc and is within the specification requirements, while the guard channel AVC characteristic shown on Figure 128 is outside of the specified limits at the 40-microvolt input level where the output is down 3.4 decibels. The effect of the temperature test upon the receiver AVC characteristics is shown by the curves of Figures 129 and 130, the characteristic curves at a frequency of 361.4 Mc in an ambient temperature of -50°C and +50°C, respectively. The audio output leveled at approximately one watt during the test at -50°C while the output during the test at +50°C was approximately two watts. The audio output at +50°C was greater over the entire range of input signals than the audio output at -50°C. The AVC characteristic at +50°C is within specification limits, but the output for 40-microvolts input at a temperature of -50°C is 2.4 decibels below the output level for a one-millivolt signal.

The i-f selectivity was measured instead of the overall characteristic since no adequate test equipment was available for accurate overall selectivity measurements at these frequencies. However, the i-f selectivity may be considered to be identical to the overall selectivity due to the broadness of the r-f tuning circuits. Figure 131 shows the results of these measurements. The bandwidth was 60 kc at 6 decibels, 97 kc at 40 decibels, 110 kc at 60 decibels, and 126 kc at 80 decibels. This performance is in accordance with paragraph E-10d of Reference (o).

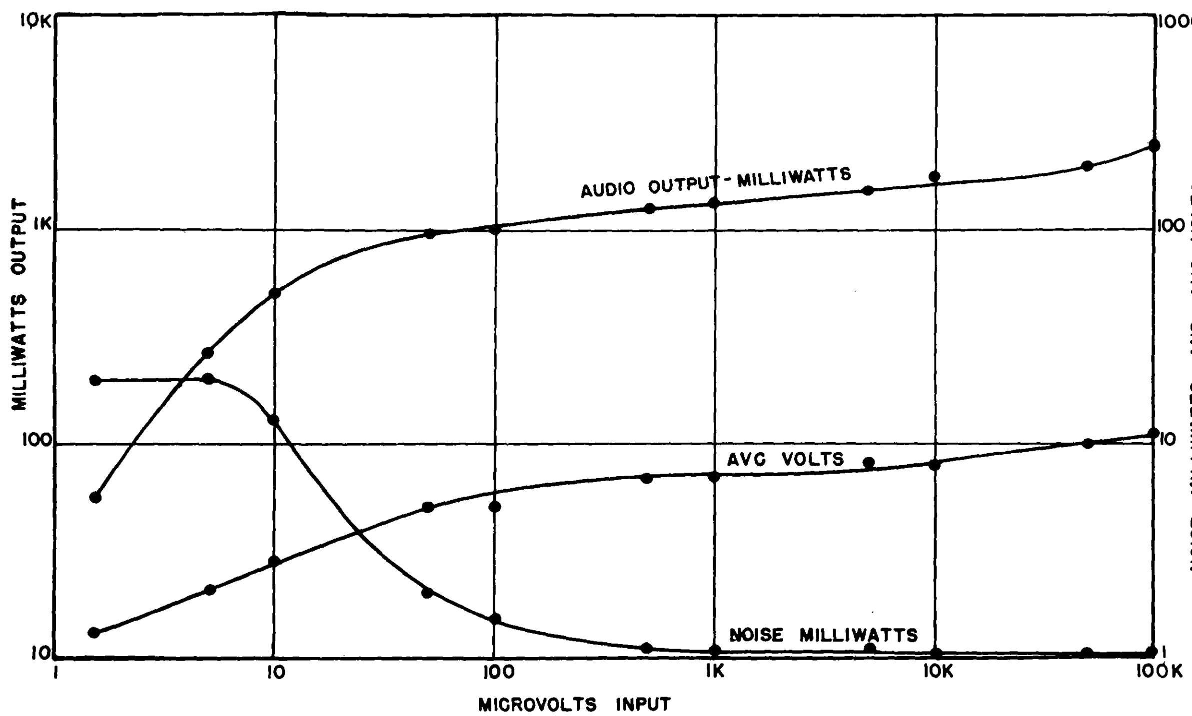


Figure 127.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Primary supply is 26.5 volts, frequency is 368.0 Mc, and input is 30 percent modulated at 1,000 cps.

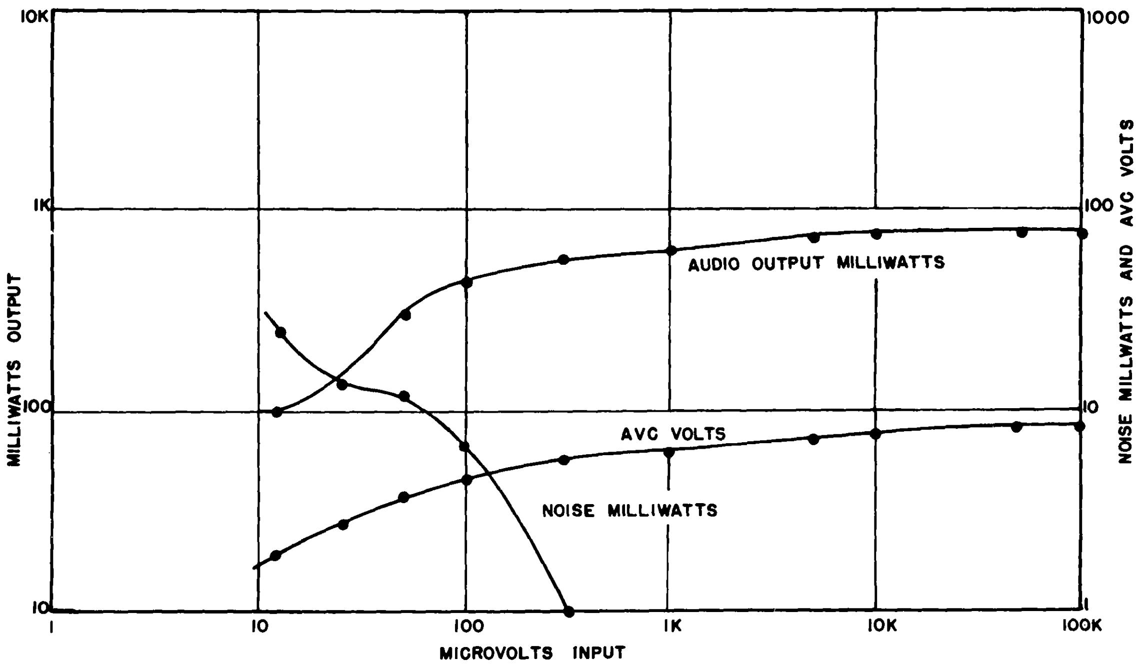


Figure 128.-Guard channel receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions with primary supply 26.5 volts. Frequency is 274.0 Mc; input is 30 percent modulated at 1,000 cps.

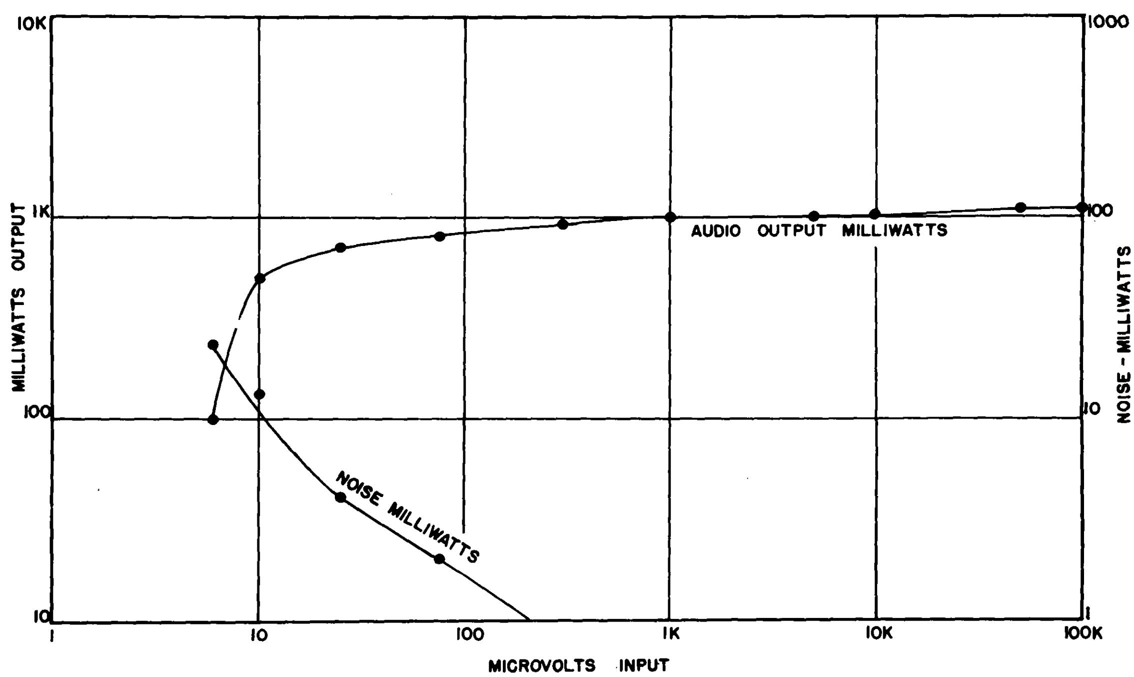


Figure 129.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at -50°C ambient temperature with primary supply 26.5 volts. Frequency is 361.4 Mc; input is 30 percent modulated at 1,000 cps.

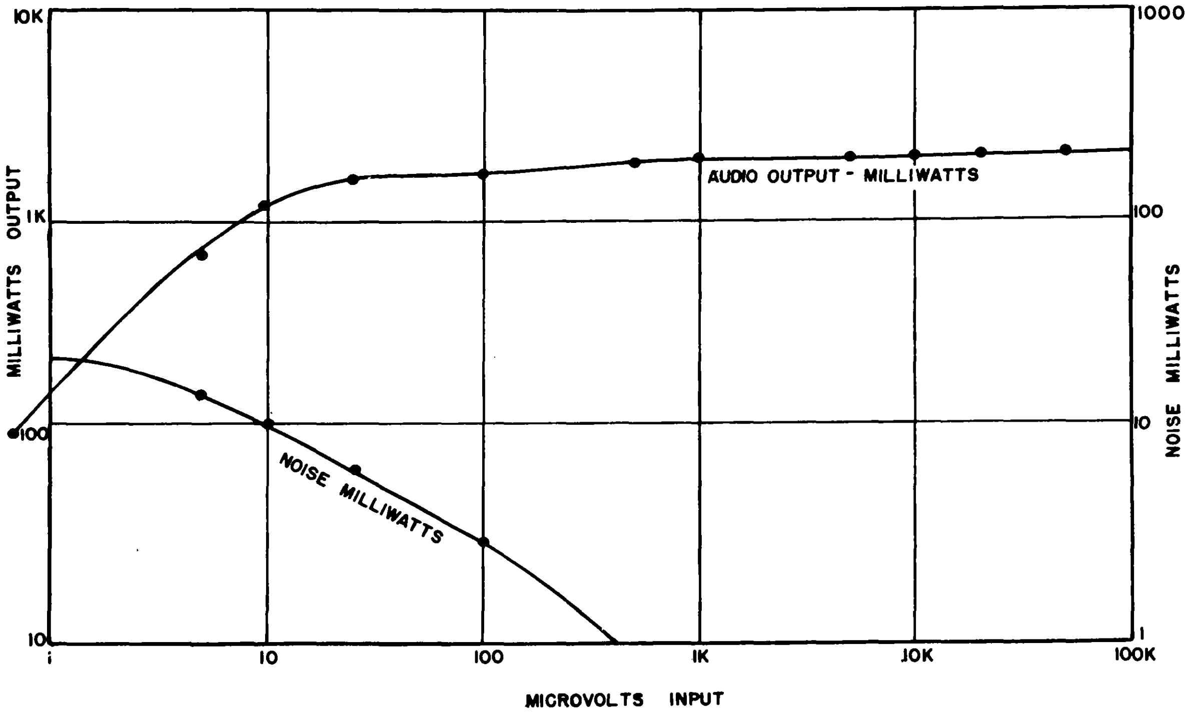


Figure 130.-Receiver AVC characteristics of AN/ARC-19 (XN-1), serial number 4, at +50°C ambient temperature. Primary supply is 26.5 volts, frequency is 361.4 Mc, and input is 30 percent modulated at 1,000 cps.

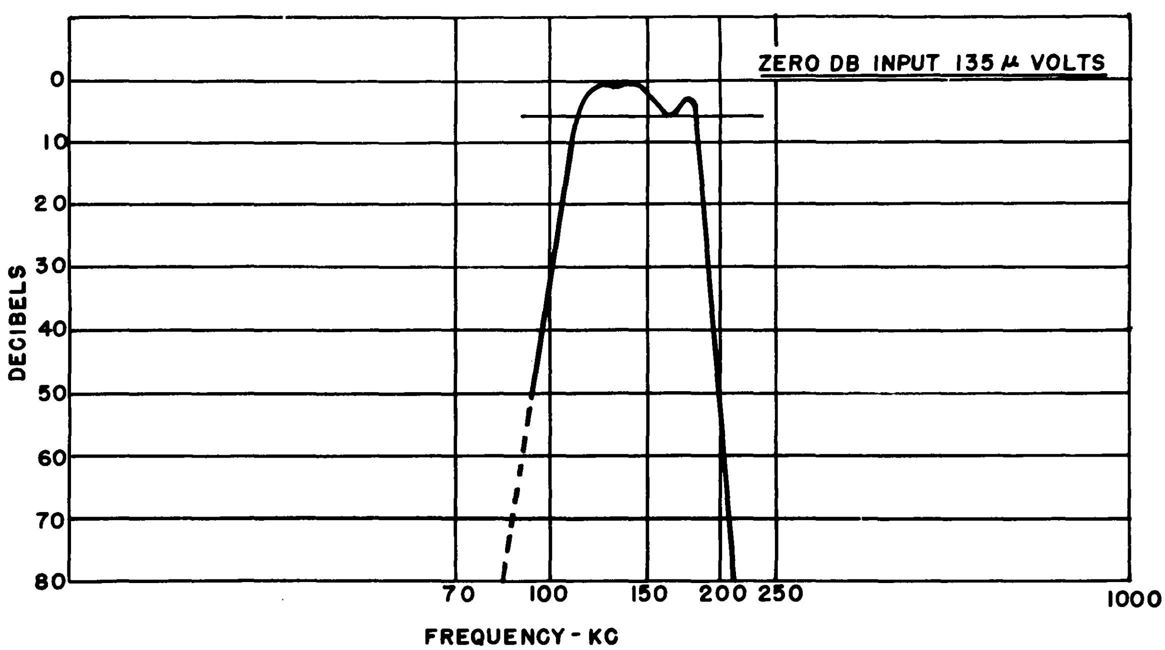


Figure 131.-I-F Selectivity of AN/ARC-19 (XN-1), Serial Number 4, at Room Ambient Conditions; Primary Supply 26.5 Volts.

The image and spurious responses have been measured and the results are shown in Figures 132 and 133. Figure 133 is an expanded scale graph of the same data that is shown in Figure 132, but Figure 133 was necessary to identify the responses which were present near the resonant frequency. In each section of both figures the receiver was first set on the desired channel frequency, then the frequency band of 200 to 500 Mc was investigated with a signal generator to determine the spurious responses. The operation principles of the subject equipment require the use of several crystal oscillators and a spectrum generator operating continuously. Consequently, many spurious responses are present. In most cases it has been possible to reduce the magnitude of the undesirable responses to a level which complies with the specifications, but some remained objectionable. Since the master oscillator operates at one-fourth of the conventional mixing frequency, harmonics of the master oscillator other than the fourth, are also present in the mixer tube. Hence the resulting spurious responses occur at multiples of the master oscillator frequency. Those existing within the 200 to 500 Mc band are shown in Figure 132. At frequencies below 310 Mc the magnitude of these responses is 60 decibels or more below the resonant response. Above 310 Mc the responses caused by the master oscillator harmonics were 40 decibels or more below that at the resonant frequency. A second cause of many spurious responses was the injection of the 100-kc spectrum from the monitor blocking oscillator through the 150-volt regulated supply to the receiver mixer stage. These are most clearly indicated by reference to Figure 133, where it may be seen that they are prevalent only near the resonant frequency. In general, these responses are 50 decibels or more below the resonant response. Other spurious responses were due to multiples of the guard channel crystal oscillator frequency and to the monitor comparison frequency (11 to 20 Mc) feeding into the receiver mixer stages, but the resulting responses were of lower magnitude and hence less objectionable than those previously described.

The AN/ARC-19 (XN-1) does not provide any image rejection, but the intermediate frequency was so selected that the image would fall between channels. However, the low frequency i-f causes the spurious responses to appear in pairs, 286 kc apart.

The arithmetic mean of the two frequencies (on either side of the nominal intermediate frequency) which are 40 decibels below resonance (98 kc and 192 kc) is 145 kc which is within 10 kc of 150 kc and complies with the requirements of paragraph E-10e of Reference (o).

The intermediate frequency rejection was found to be very good. No response was obtained for an input signal of 1.2 volts to the receiver at the intermediate frequency when the receiver was tuned to 220 Mc, 303.8 Mc, or 376 Mc. The i-f rejection is, therefore, better than 95 decibels.

An overall regeneration in the receiver occurred during the receiver measurements. Proper alignment of the frequency divider circuits eliminated the regeneration. The divider tuning is critical and great care must be exercised in aligning these circuits to insure proper receiver operation.

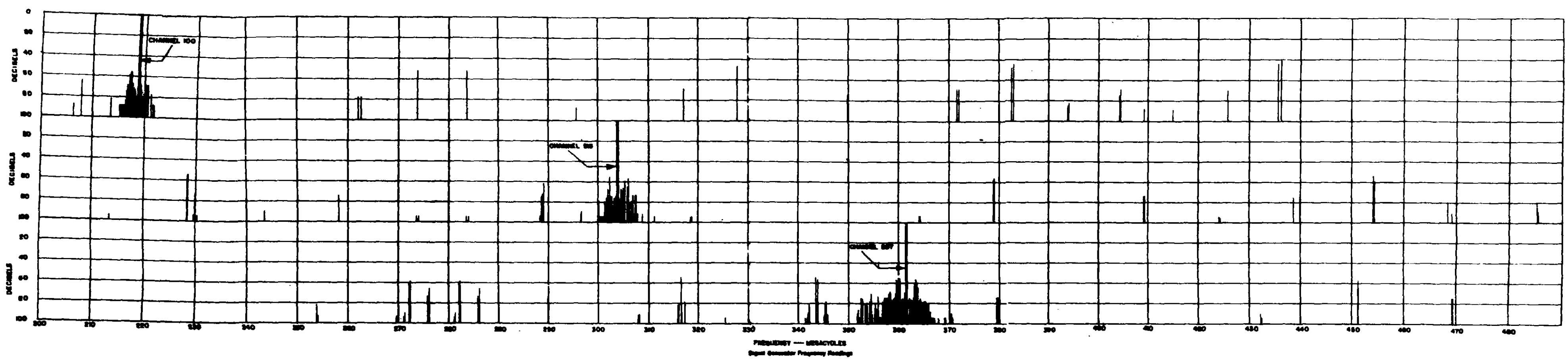


Figure 132.-Spurious Response Characteristics, at Standard Conditions, of AN/ARC-19 (XN-1), Serial Number 4, (given in Db below Resonant Response.)

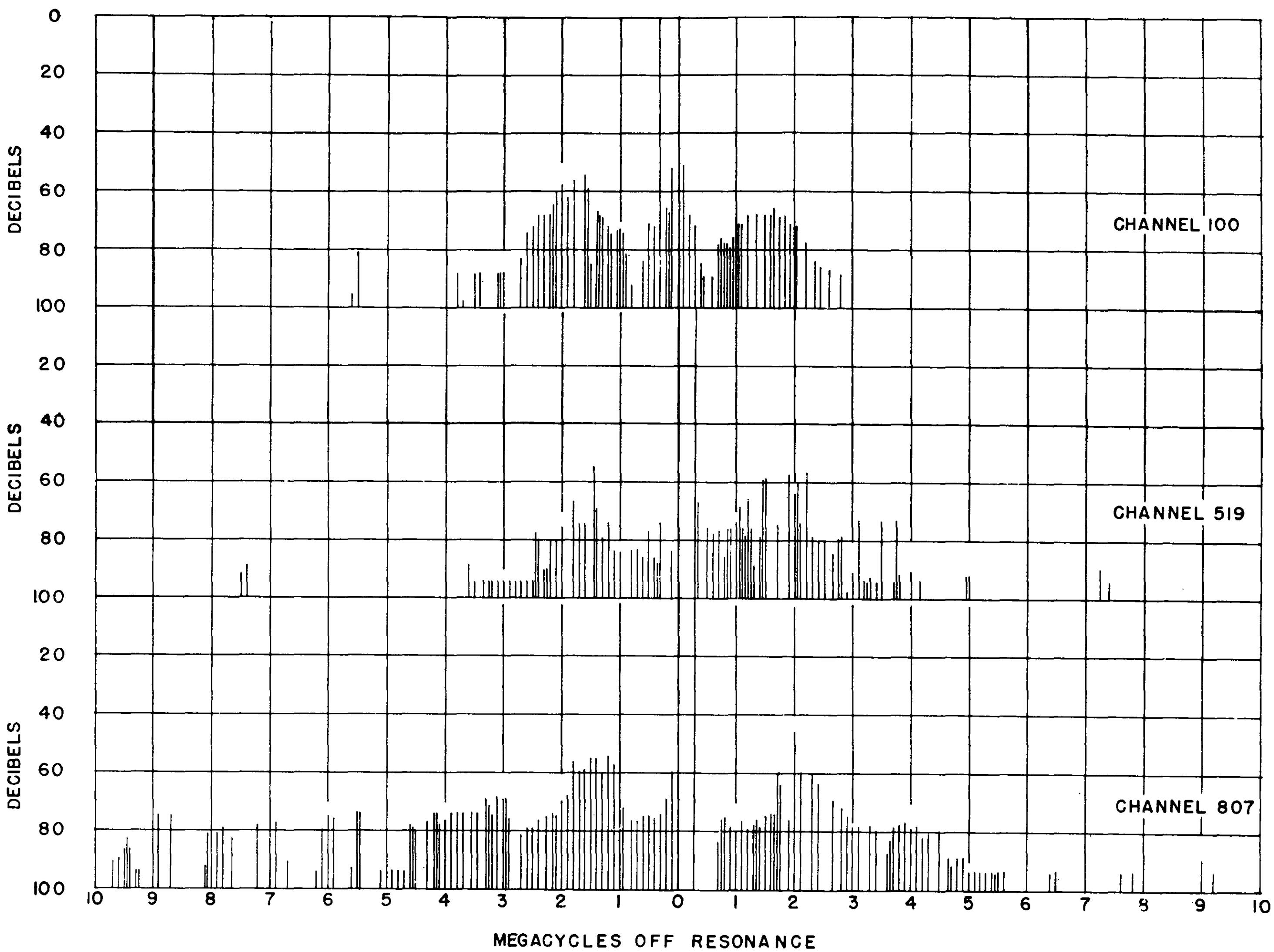


Figure 133.–Expanded Scale of Spurious Response Characteristics, at Standard Conditions, of AN/ARC-19 (XN-1), Serial Number 4, given in Db below Resonant Response

A test of the noise limiter operation was conducted in accordance with paragraph E-10h of Reference (o). A Ferris Model 48A signal generator and a Laboratory model duo-pulser noise generator were used in the manner described in the specification. However, no apparent change in input signal was necessary to produce the 100-milliwatt output with a six-decibel signal-plus-noise to noise ratio when the pulse generator was injecting noise signals in excess of one volt. Figures 134 and 135, show the operation of the noise limiter under conditions of noise output from a General Radio Company Strobotac Type 631B injected to the i-f input. A Dumont Type 224 oscilloscope was connected to the grid of the first audio amplifier following the noise limiter circuits. Figure 134 was photographed when the noise limiter was disabled, and Figure 135 was taken with the noise limiter operative. It may be seen that the noise limiter effectively reduced the noise pulse amplitude to the level of the modulation. A 140-kc signal modulated 30 percent by a 1000-cps sine wave was provided by a Ferris Model 16C signal generator simultaneously with the noise input at 500 cps. The width of the noise pulse was not measured.

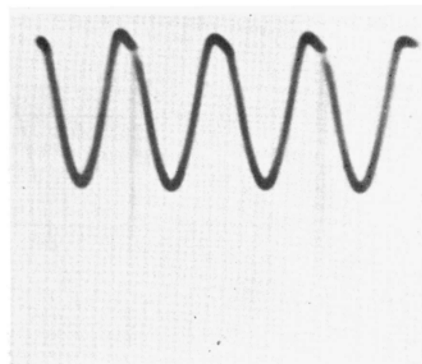


Figure 134.-Receiver audio signal, with noise injection, of AN/ARC-19 (XN-1), serial number 4, at standard conditions with limiter inoperative.

A receiver audio fidelity was measured for an audio frequency range of 60 to 10,000 cps (Figure 136). Maximum response occurred between 500 and 750 cps while the response at 1000 cps was down 0.5 decibel from the maximum level. The audio response at 300 cps was 1.7 decibels and at 4000 cps was 10.8 decibels below the 1000 cps response. Receiver audio distortion versus percent modulation is shown in Figure 137 for modulation frequencies of 400, 1000, and 5000 cps. The receiver noise limiter affected the audio distortion at high modulation levels. At a modulation frequency of 400 cps the audio distortion exceeded 15 percent for modulation levels above 62 percent. At higher audio frequencies the distortion was less than 15 percent for modulation levels up to 100 percent. Figure 138 indicates a slight change in percent distortion as a function of the primary supply voltage. The audio distortion was measured for input signals fed to the i-f input at 140 kc, and the results are shown in Figure 139. The limiting action of the AVC in the r-f stage is not realized since the signal injection is made to the i-f amplifier. Results comply with specifications.

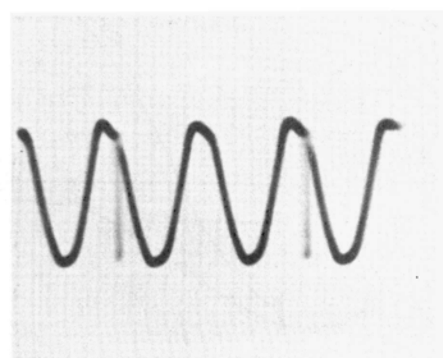


Figure 135.-Receiver audio signal, with noise injection, of AN/ARC-19 (XN-1), serial number 4, at standard conditions with limiter in operation.

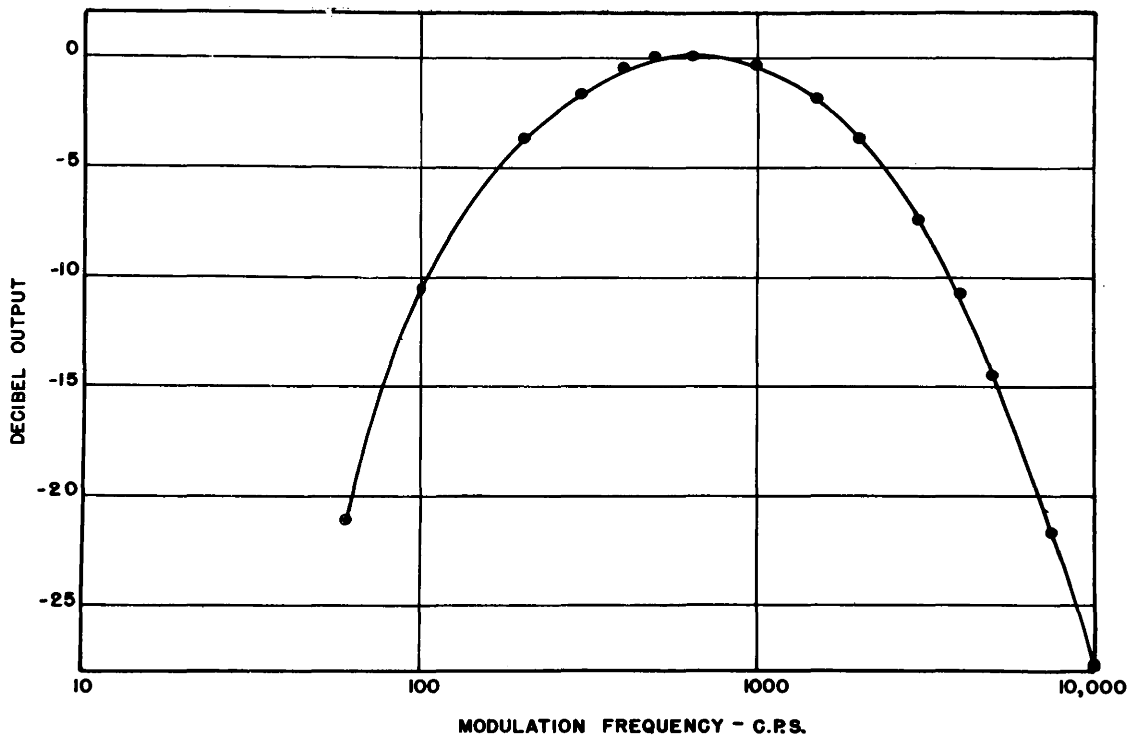


Figure 136.-Receiver audio fidelity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply 26.5 volts.

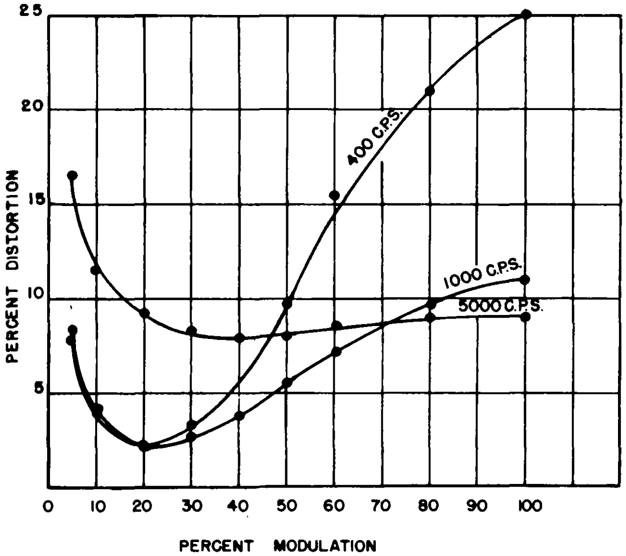


Figure 137.-Receiver audio distortion vs percent modulation for AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply 26.5 volts.

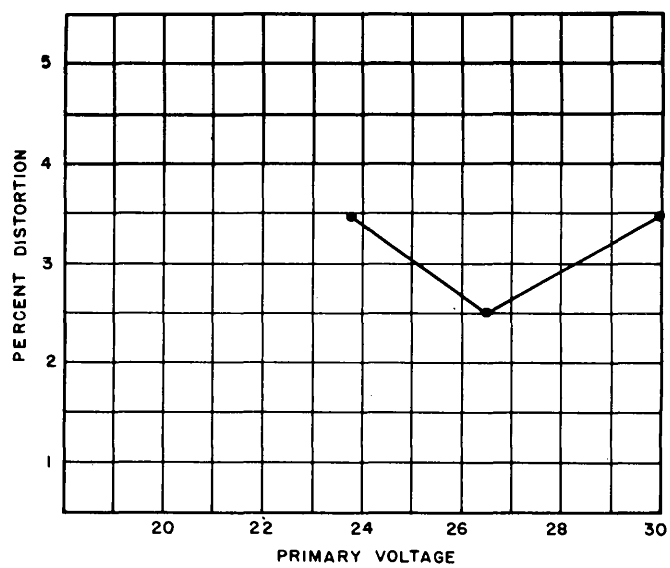


Figure 138.-Receiver audio distortion vs primary supply voltage for AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; input modulated 30 percent at 1,000 cps.

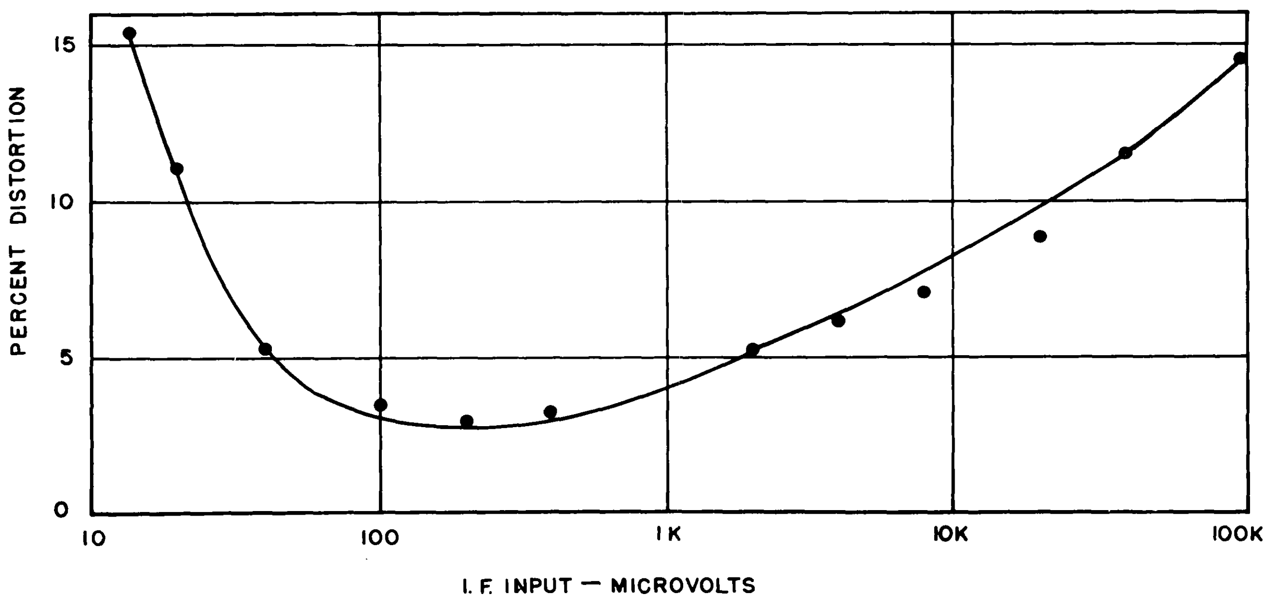


Figure 139.-Receiver audio distortion vs microvolts input to I. F. for AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply is 26.5 volts, and input frequency is 140 kc, 30 percent modulated at 1,000 cps.

The audio gain control characteristic curve and receiver reserve gain are shown in Figure 140. For this measurement a 2.5-microvolt input signal, 30 percent modulated with 1000 cps, was injected to the receiver input at a frequency of 268.4 Mc. The sensitivity control was set in the maximum position. At full audio gain the receiver audio output was 200 milliwatts with a 6-decibel signal-plus-noise to noise ratio. The audio output was then reduced by a decrease in the audio gain control setting. Approximately three-fourths of the maximum setting was required for 100 milliwatts output.

The optimum load resistance of the audio output circuit varied with modulation frequency. From Figure 141 it may be seen that the optimum resistive loads were 400, 900, and 2000 ohms for modulation frequencies of 400, 1000, and 3500 cps, respectively.

The r-f gain control characteristic is shown in Figure 142. It was possible through the use of the r-f gain control to decrease the sensitivity from 2.5 microvolts to 800 microvolts. Measurements were made at a frequency of 268.4 Mc.

A receiver squelch operation is shown in Figure 143 as a function of primary supply voltage. Operation of the noise silencer is accomplished

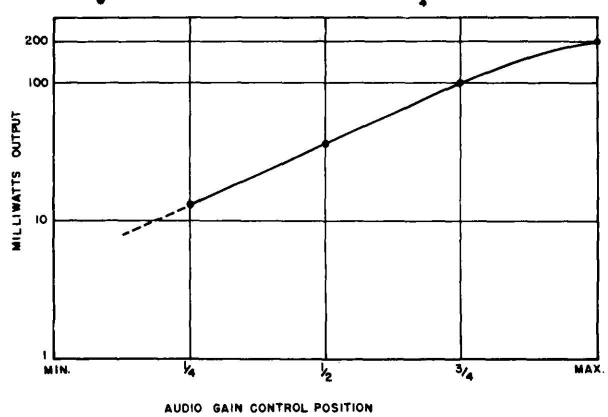


Figure 140.-Receiver reserve gain of AN/ARC-19 (XN-1), serial number 4; input 2.5 microvolts at 268.4 Mc, 30 percent modulated at 1,000 cps.

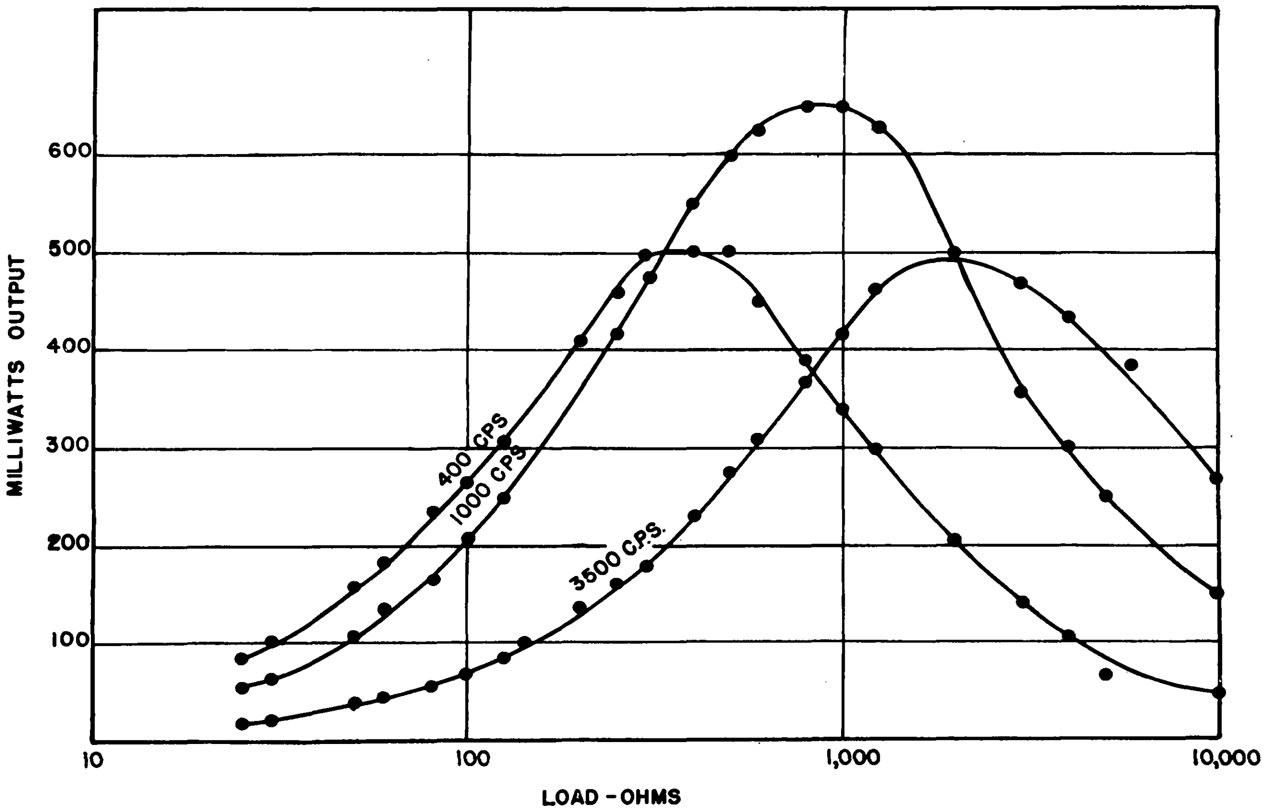


Figure 141.-Audio Output vs Load Resistance for AN/ARC-19 (XN-1), Serial Number 4; Input is 100 Microvolts at 303.8 Mc, 30 Percent Modulated at 1,000 cps.

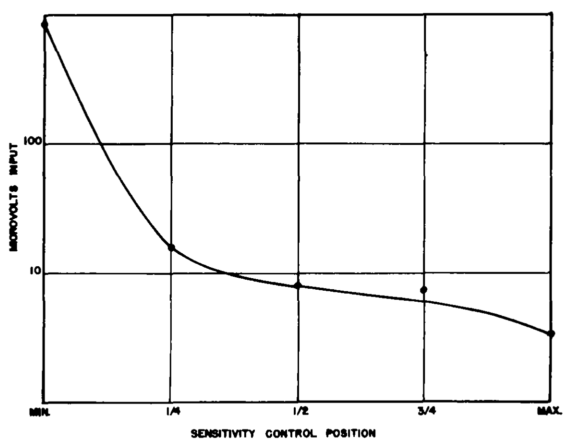


Figure 142.-Sensitivity control range of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions, with squelch disabled. Frequency is 268.4 Mc and the constant output is 200 Mw.

by a relay as previously described in this report. Its operation is positive, but not smooth, due to an abrupt change in audio output when the squelch relay is energized. However, operation of the squelch by a relay is considered to provide performance more desirable than the conventional squelch operation. A change in input of less than one decibel affected a change in output in from zero to a level in excess of 100 milliwatts. The signal input level (30 percent modulated) required to operate the squelch with the receiver operating at maximum sensitivity is shown in Figure 143. The microvolt level required for squelch operation may be increased above these values by the reduction of the r-f gain control.

TRANSMITTER PERFORMANCE

Transmitter carrier power output measurements were made using a 50-ohm load at the end of a five-foot, 50-ohm coaxial line. A matching section inserted in the coaxial line permitted maximum power to be obtained at the lamp load. A photocell was calibrated with a known d-c supply to convert light brilliance of the lamp load to r-f power output. Results of carrier power output measurements over the frequency band are plotted in Figure 144. Primary supply voltages of 23.8, 26.5, and 29.2 volts were used for the test. Specifications, Reference (p), require an output of 4.0 watts under Standard Conditions and 4.0 watts under Service Conditions. The actual carrier power output varied between 4.4 watts and 6.5 watts over the frequency range, and was between 5.5

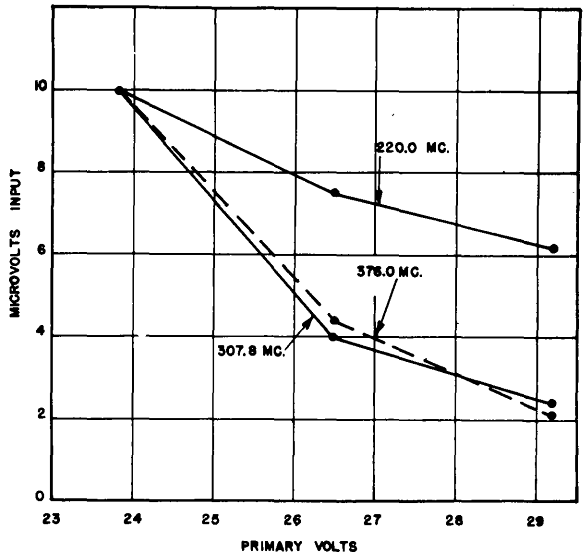


Figure 143.-Receiver squelch characteristics of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions. Coupling to the receiver input is made through five feet of 50-ohm coaxial cable.

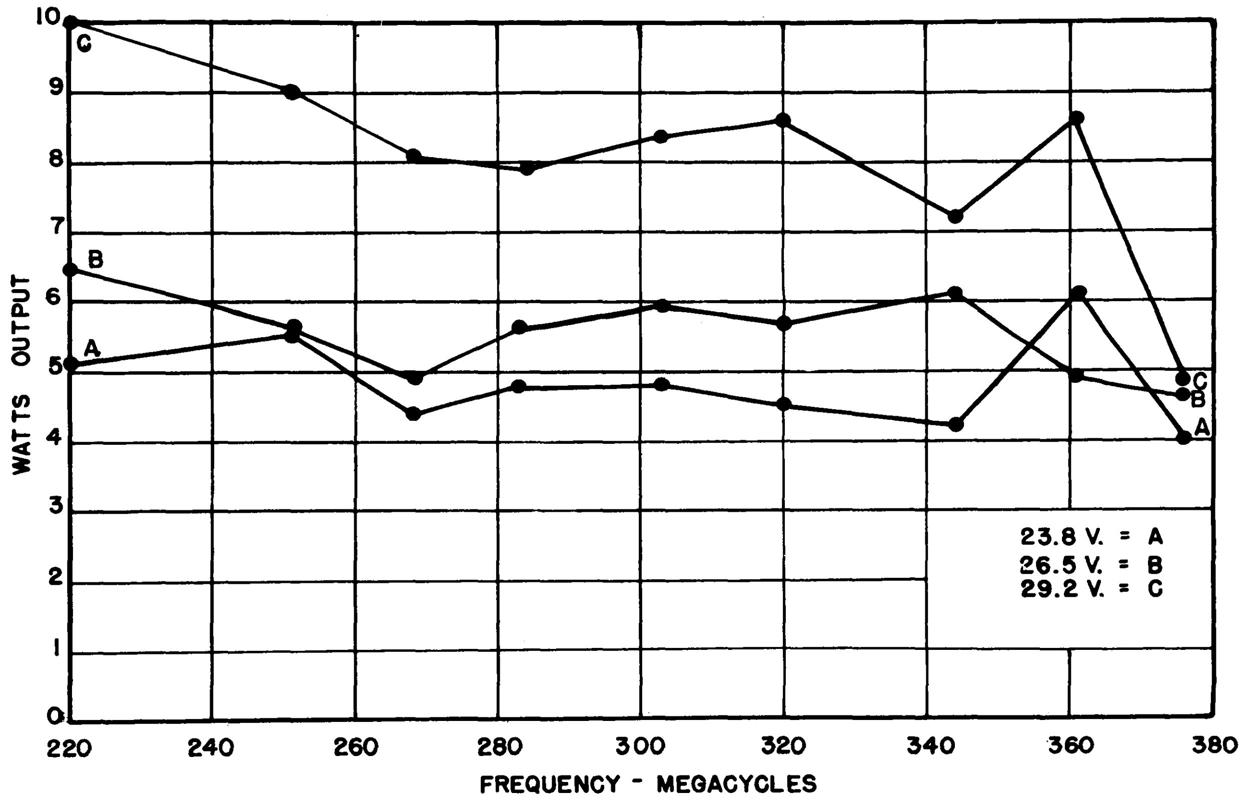


Figure 144.-Transmitter Power Output, at Room Ambient Conditions, of AN/ARC-19 (XN-1), Serial Number 4, with 50-ohm Resistive Load

watts and 6.0 watts over most of that frequency range. At a primary supply of 23.8 volts the carrier power was in excess of four watts, and at 29.2 volts was in excess of 4.9 watts for all frequencies. Reference to Figure 144 will show an apparent discrepancy in the data since the output at 361 Mc

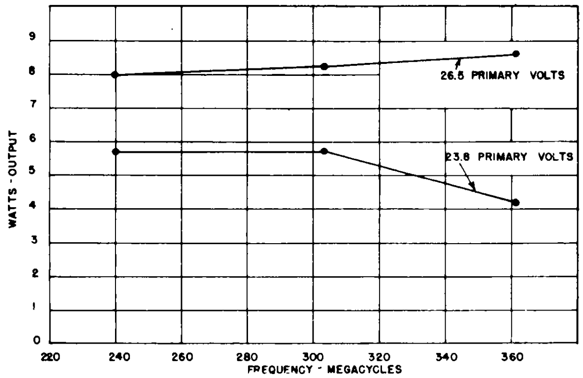


Figure 145.-Transmitter power output (at -50°C ambient temperature) of AN/ARC-19 (XN-1), serial number 4, with 50-ohm resistive load.

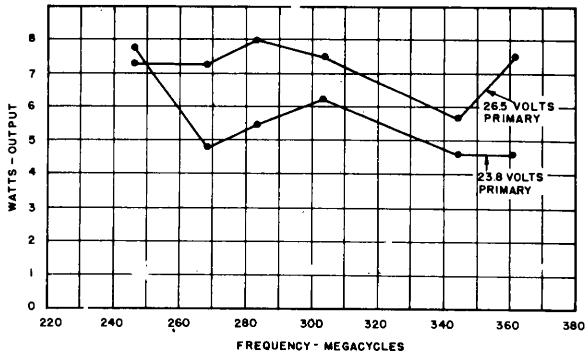


Figure 146.-Transmitter power output (at room ambient temperature) of AN/ARC-19 (XN-1), serial number 4, with 50-ohm resistive load.

was greater with a primary supply of 23.8 volts than for 26.5 volts. Such a condition can and does exist with this equipment. Since the oscillator first-doubler condenser gang and the second-doubler final-amplifier condenser gang are coupled to a common motor-drive system, any frequency correction accomplished by a change of the oscillator variable condenser also changes the tuning of the first doubler, second doubler, and final amplifier. If the drift characteristics of the oscillator circuit do not coincide with the drift of the three succeeding tuned circuits, frequency correction by the motor-drive system will detune the doubler and amplifier stages. However, assuming similar drift characteristics, the changes in transmitter power output will not be appreciable if the transmitter is exactly aligned and tracked so that the resonant peaks of the two doubler and one amplifier circuits always fall within the master oscillator mechanical slot width. This is true because the ± 40-kc swing of the master oscillator mechanical slot width will not appreciably detune the doubler and amplifier stages.

After the above test had been conducted at room ambient conditions, the transmitter, divider, and receiver circuits were realigned and the equipment was placed in the weather chamber. Following a two and one-half hour temperature stabilization time at an ambient temperature of -50°C, the equipment was turned on, and power output measurements were begun within five minutes after the equipment was made operative. The power output of the transmitter was within the minimum limit of the specifications throughout the frequency band. The lowest power output level was obtained on channel 807, (361.4 Mc), where the output was 4.2 watts with a primary supply of 23.8 volts. This is the lowest power output likely to be encountered under Service Conditions. Figure 145 shows the unmodulated carrier power output at other frequencies and at primary supply voltages of 23.8 volts and 26.5 volts for equipment operation in an ambient temperature of -50°C. Figures 146 and 147 show the data for the ambient temperature tests at room temperature and at +50°C, respectively. The room temperature data differs from the original room temperature power output measurements, Figure 144, due to the realignment of the transmitter before the latter tests. The minimum output at a primary supply of 23.8 volts was 4.6 watts at room temperature and 5.1 watts at 50°C.

The speech leveler circuit provided in the transmitter modulator permits attainment of high modulation levels with low microphone input voltages; yet, with greater increases in microphone voltage the modulation level remains relatively constant (Figure 148). The speech leveler circuit has been used in place of a clipper type modulator. The knees of the curves of Figure 148 are determined by the delay voltage applied to the speech leveler detector. Since the detector rectifies a small portion of the modulator a-f voltage to produce a negative bias and reduce the modulator gain, the delay voltage can be determined for only a single a-f level. The delay voltage can be determined to produce a given percent modulation at the knee of the curve for a single power output level. Any increase or decrease in carrier power output causes a decrease or increase, respectively, in the modulation percentage. It may be seen from Figure 148 that the knees of the curves occurred at a microphone input of approximately 0.75 volts, but the percent modulation at the leveling point varied between 52 percent and 68 percent. Further in-

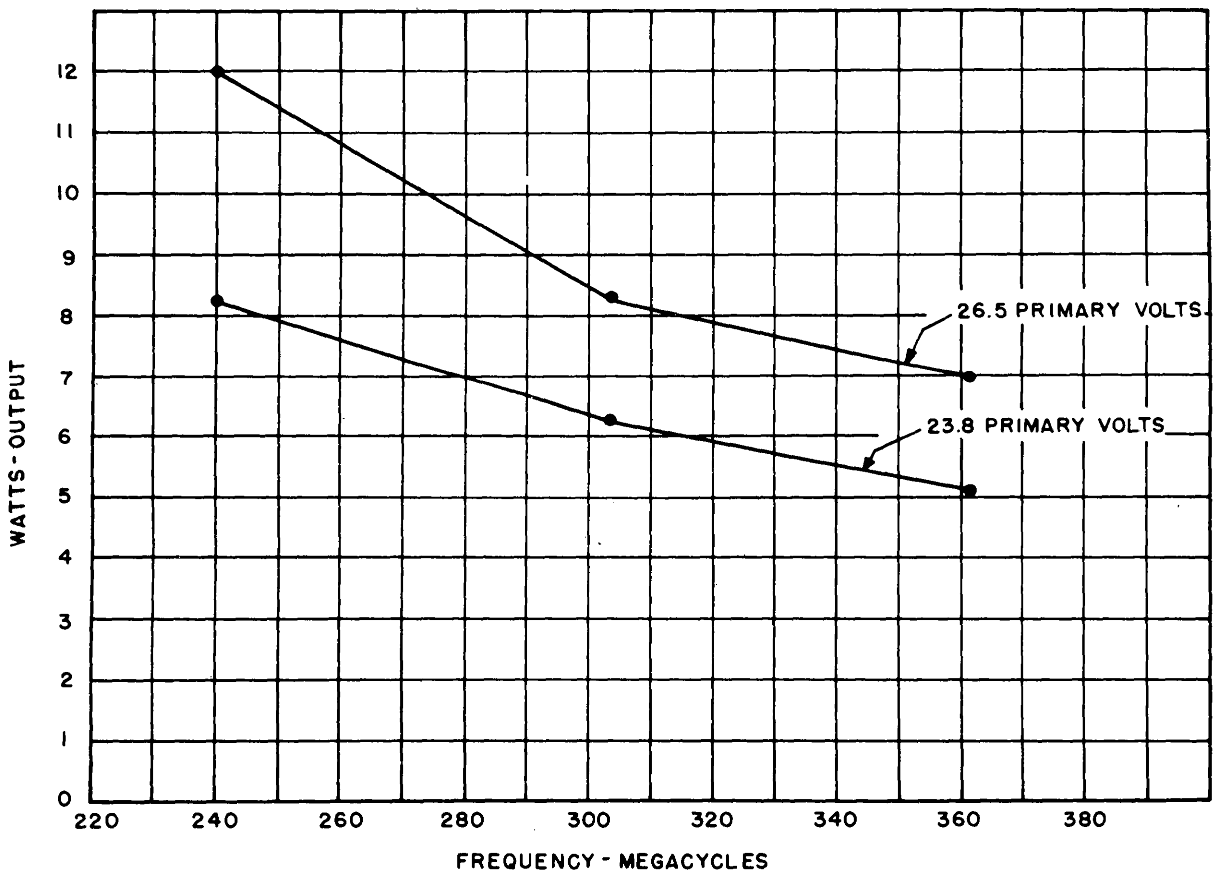


Figure 147.-Transmitter Power Output of AN/ARC-19 (XN-1), Serial Number 4, at +50°C Ambient Temperature with 50-ohm Resistive Load

crease of the microphone input to 7.8 volts increased the modulation level from 52 percent to 70 percent at 361.4 Mc and from 68 percent to 90 percent at 220 Mc.

The transmitter fidelity was satisfactory over the modulation frequency range of 300 cps to 3500 cps. The level at 300 cps was minus 0.5 decibels and at 3500 cps was minus 1.0 decibel from the response at 1000 cps. Specifications of Reference (o) permit a variation from the 1000-cps level of plus 1.4 decibels or minus 3.6 decibels. Figure 149 shows the fidelity characteristics at three r-f frequencies. Attenuation at frequencies below 300 cps is not as rapid as practicable without the use of iron core filters. The response at 50 cps is approximately four decibels below that at 1000 cps. The effect of tracking error is illustrated by the fidelity curve at 220 Mc. During measurements the master oscillator drifted enough for frequency correction to be made by the motor drive system, and caused a change in transmitter tuning. Since the transmitter carrier power output was changed, the microphone voltage input for a given percent modulation was also changed.

The total harmonic content of the modulation envelope was 7.5 percent at 30 percent modulation with 1000 cps, as shown in Figure 150. The distortion increased with an increase in percent modulation. Figure 151 shows transmitter distortion versus modulation frequency at a 30 percent modulation

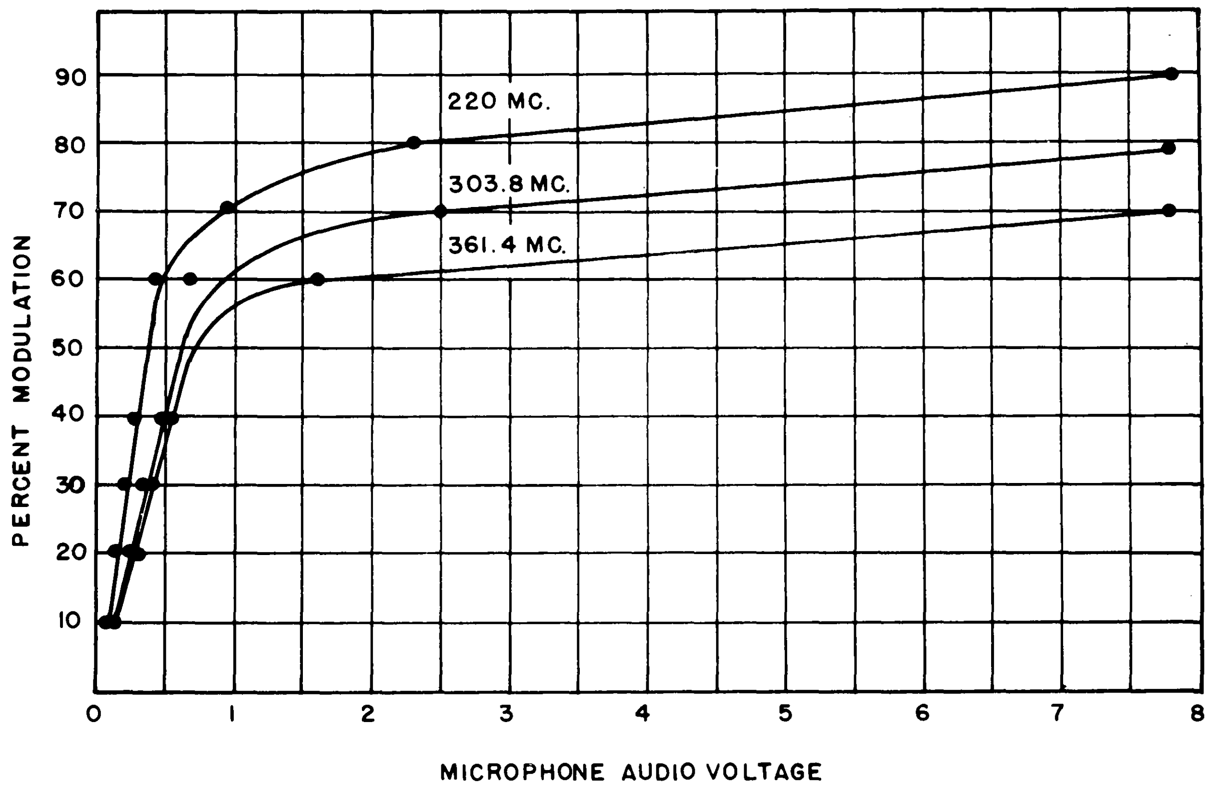
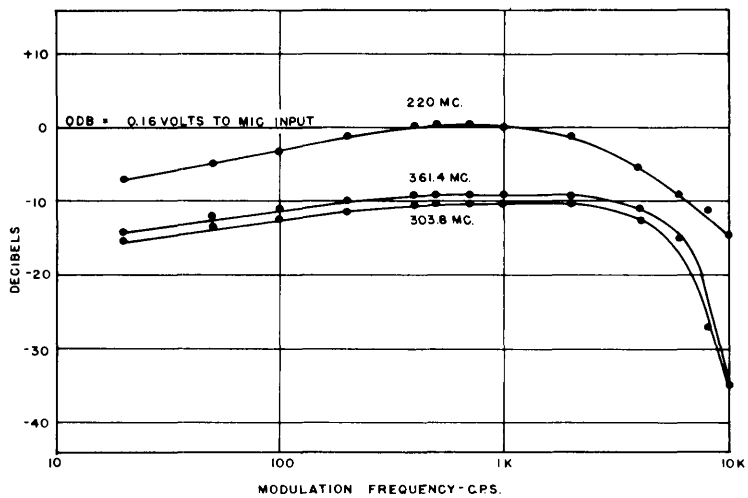


Figure 148.-Transmitter modulation characteristics, for voice operation, of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply is 26.5 volts.

Figure 149.-Transmitter fidelity of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions with 30 percent modulation; primary supply is 26.5 volts.



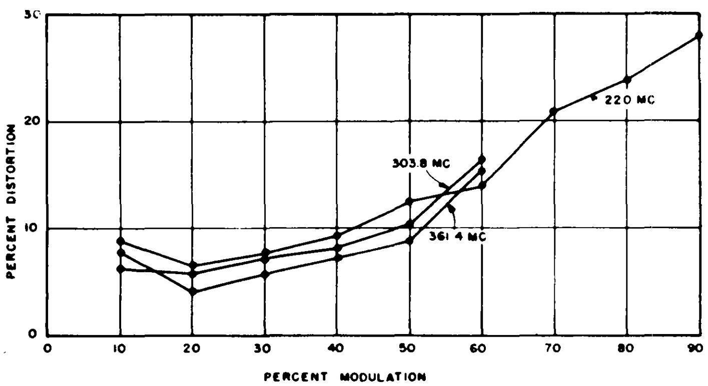
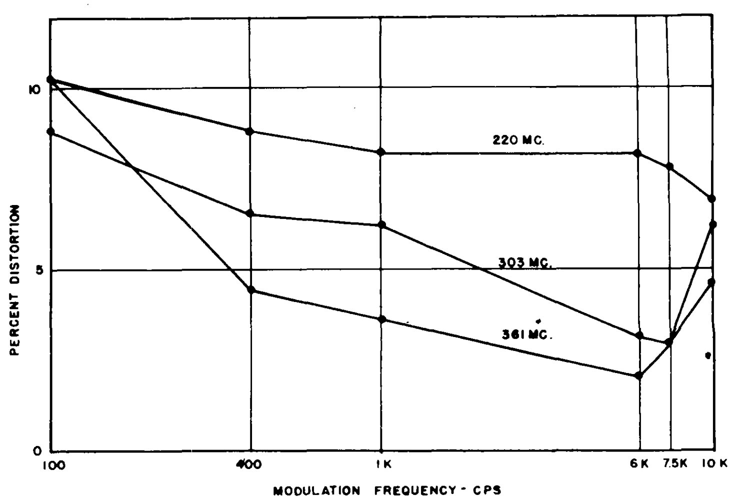


Figure 150.-Transmitter distortion vs percent modulation (for voice operation) of AN/ARC-19 (XN-1), serial number 4. Modulation frequency is 1,000 cps and primary supply is 26.5 volts.

Figure 151.-Transmitter distortion vs modulation frequency (for voice operation) of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions, and with 30 percent modulation. Primary supply is 26.5 volts.



level. At frequencies lower than 1000 cps the percent distortion increased slightly, but at higher audio frequencies the distortion decreased.

The microphone energizing current, measured with the dummy microphone connected and the equipment operated from a 26.5 volt d-c supply, was 50.0 milliamperes. This complies with the specifications.

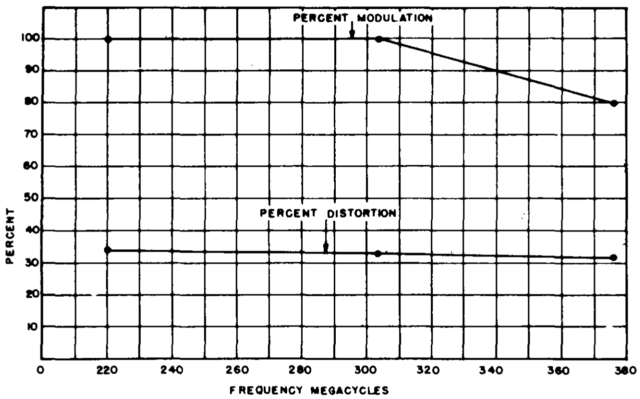


Figure 152.-Transmitter modulation characteristics and distortion with tone operation of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions; primary supply 26.5 volts.

The percent modulation of the r-f carrier during operation of the transmitter with tone modulation was 100 percent at 220 Mc and 303.8 Mc, but decreased to 80 percent at a carrier frequency of 376 Mc (Figure 152). Distortion measurements were made for these conditions of tone modulation and results are also shown in Figure 152. The percent distortion was as high as 34 percent, but it is believed that in normal operation of the transmitter this distortion would not impair the intelligence of the radio telegraphy when the transmitter is keyed. The frequency of the tone modulation was approximately 1000 cps. Paragraph E-101(5)b of Reference (o) permits the location of the modulation frequency to be between 800 and 1200 cps. Measurements were made by comparison with a Hewlett Packard Type 200C audio oscillator which was considered to be sufficiently accurate for this purpose.

The sidetone output during transmitter operation was unsatisfactory. A circuit change will be necessary to provide an adequate output level of the sidetone. No measurements were made of sidetone operation since a listening test showed no usable output.

The results of measurements of the transmitter carrier shift are shown in Figure 153 for a 1000-cps modulation frequency. Tests were conducted with a percent modulation meter designed and conducted at the Laboratory. The carrier level was measured with a meter which read average voltage. Both positive and negative peak modulation percentages were measured and were found to be approximately equal. The transmitter was modulated with 1000 cps at 30 percent or 60 percent and the carrier level noted. Modulation was then re-

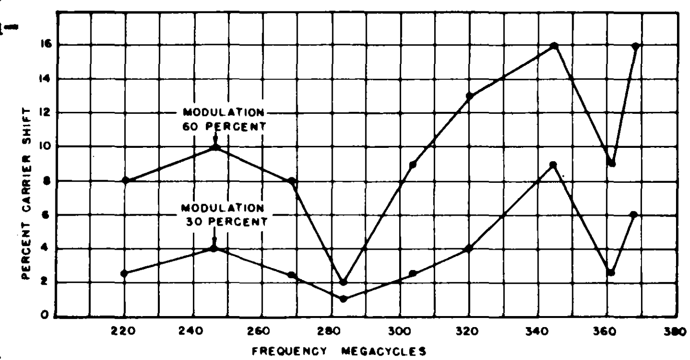


Figure 153.-Transmitter carrier shift of AN/ARC-19 (XN-1), serial number 4 at room ambient conditions. The modulation frequency is 1,000 cps and the primary supply in this case also is 26.5 volts.

moved and the increase in the carrier level was recorded as a percent of the orginal carrier level. Figure 153 shows that with 30 percent modulation the maximum carrier shift was nine percent at a carrier frequency of 344.6 Mc. With an orginal 60 percent modulated envelope at a carrier frequency of 344.6 Mc the amplitude increased 16 percent when the modulation was removed.

The transmitter carrier noise level under Standard Conditions was measured for carrier frequencies of 220 Mc, 303.8 Mc., and 376 Mc (Figure 154). A diode detector was used to obtain the noise signal from the unmodulated carrier and again from the same carrier when modulated 30 percent with 1000 cps. The voltage from the detector was amplified by a single audio amplifier stage and the output measured by a General Radio Type 583A power output meter. The noise level has been expressed in decibels for the ratio of output with 30 percent modulation to the output with no modulation. The ratio is least at the high end of the frequency band where, at 376 Mc, the ratio was 29.5 decibels.

Under Standard Conditions and with the emitted carrier amplitude modulated 80 percent at 1000 cps, the peak frequency deviation arising from frequency modulation of the master oscillator was 2.51 kc at a carrier frequency of 220 Mc. At all other carrier frequencies the peak frequency deviations were less than that above and are shown in Table 4.

INPUT POWER REQUIREMENTS

The input power requirements of the subject equipment are shown in Figure 155. The input current during warmup was lowest since plate voltage to the i-f amplifier is not applied until the monitor warm-up and cycling is complete. In addition, the external blower was not operating. After warm-up the monitor cycled and plate voltage was applied to the i-f amplifier at the completion of the cycle. When the internal temperature at the thermostat reached approximately 40°C, the thermostat operated and the external blower was started. The input current was then the normal receive current of the

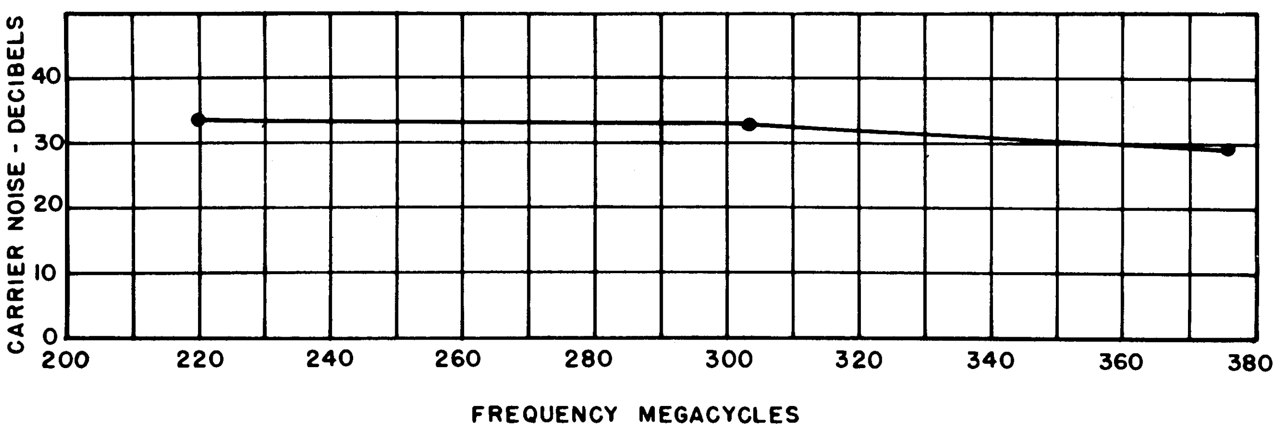


Figure 154.-Transmitter Noise Modulation of AN/ARC-19 (XN-1), Serial Number 4, at Room Ambient Conditions; Primary Supply 26.5 Volts.

TABLE IV Frequency Modulation
AN/ARC-19 (XN-1) Serial No. 4

Preset Position	Channel Number	Channel Frequency Mc	Amplitude Percent Modulation	F-M Peak Deviation kc
1	100	220.0	30	2.51
5	519	303.8	30	0.59
M	880	376.0	30	0.505
1	100	220.0	80	2.51
5	519	303.8	80	0.76
M	880	376.0	80	0.59

equipment as shown on a separate curve of Figure 155. The input current required during channel selection was measured during cycling when the tuning motor was driving at normal speed. It does not include motor starting current. The external blower was operating. When the push-to-talk microphone button was operated, and the selector switch was in the transmit tone position, the current drain of the transmitter stages caused the primary supply current to be increased to the values on the curve labeled transmitter current. Reference to Figure 155 shows that the current requirements at a primary supply of 26.5 volts are 13.8 amperes for receiving and 20.4 amperes for the transmitting condition.

CHANNEL SELECTION TIME

The elapsed time between the instant the channel selector switch is positioned to select a given channel, and the instant the equipment is in an operative condition on the selected channel, varies with the channel number selected and with the primary supply voltage as shown in Figure 156. The greatest time required for any channel change occurred when the equipment was stabilized on channel 875 and then recycled to the same channel. The time required for this change was 5.1 seconds with a 26.5-volt supply and 5.45 seconds with a 23.8-volt primary supply. The data for Figure 156 were recorded at room temperature, but a test at an ambient temperature of -50°C showed identical results.

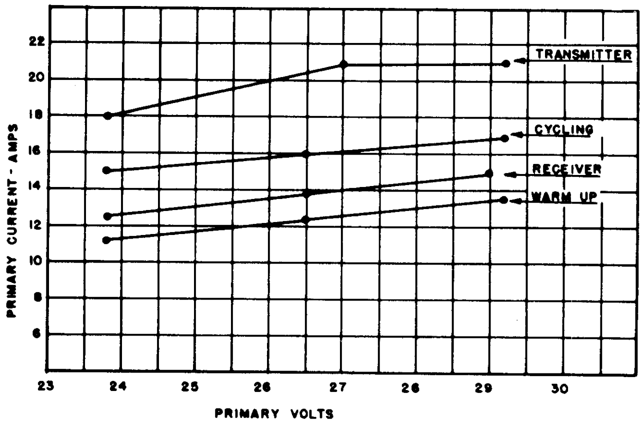


Figure 155.-Input power requirements of AN/ARC-19 (XN-1), serial number 4, at room ambient conditions.

The receiver i-f disable relay and squelch circuits operated satisfactorily to remove receiver audio output during channel selection. At the completion of the cycle the ready light was energized, and the channel indicator unit showed the selected channel number.

The receive-transmit time interval is very short, and accurate measurements were not made. However, the time was determined to be less than 500 milliseconds, the period required for the transmitter dynamotor to attain proper speed. The transmit-receive interval was much less since the change was dependent only upon relay operation.

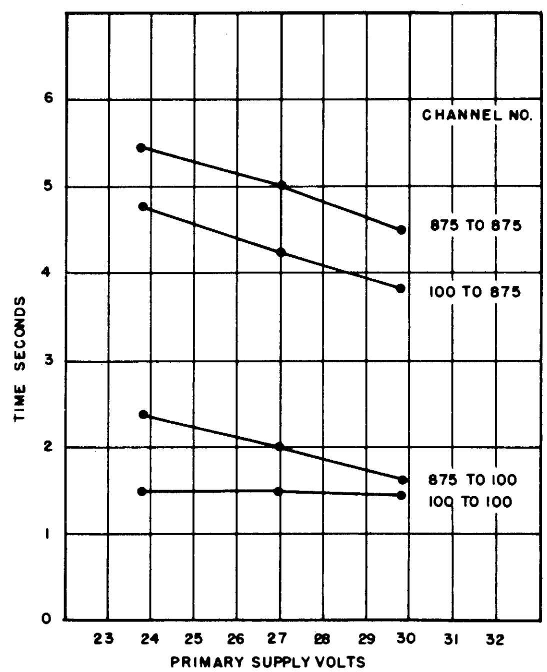


Figure 156.-Channel selection time of AN/ARC-19 (XN-1), serial number 3, at room ambient conditions.

FREQUENCY STABILITY

The distribution of error in frequency for 676 channel selections is shown in the following tabulation and in Figure 157. Of the 676 channel selections, 75 percent were within plus or minus 1.0 kc of the correct channel frequency, and none of the channels selected were off in frequency more than 3.84 kc. Only one channel showed an error of 3.84 kc and the remainder were within 3.0 kc of the correct channel frequency.

Distribution of error in frequency at room temperature for 676 channel selections of AN/ARC-19 (XN-1), serial number 3, with primary supply 26.5 volts:

Error (kc) From	Error (kc) To	Percent of Selections
More than -4.0		0.0
-4.0	-3.5	0.2
-3.5	-3.0	0.0
-3.0	-2.5	0.3
-2.5	-2.0	0.7
-2.0	-1.5	5.8
-1.5	-1.0	17.3
-1.0	-0.5	30.8
-0.5	0	23.8
0	0.5	14.9
0.5	1.0	5.5
1.0	1.5	0.7
More than 1.5		0.0

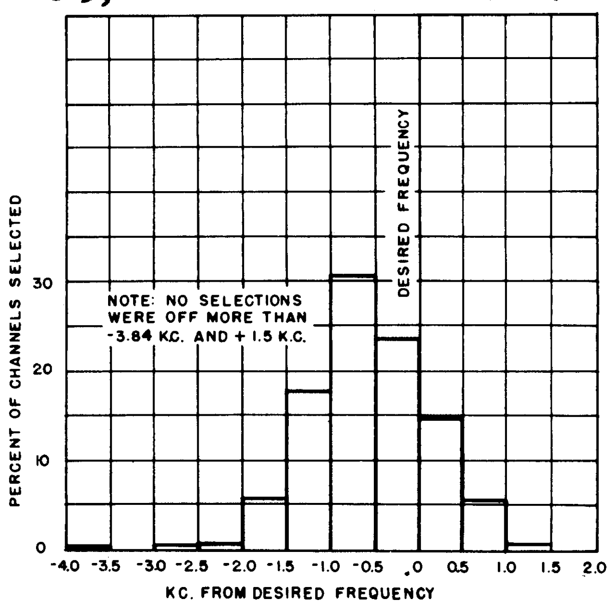


Figure 157.-Distribution of error in frequency for 676 channel selections of AN/ARC-19 (XN-1), serial number 3 at room ambient conditions; primary supply 26.5 volts.

Tests were conducted to determine the overall stability of the AN/ARC-19 (XN-1) at room temperature, at -50° C and at $+50^{\circ}$ C. These tests were conducted for both transmit and receive operation on eight discreet channels. The eight channels were selected in such a manner that all crystals and both polarities of the discriminator were included. The stability measurements were obtained by measuring the frequency of the r-f divider output. The error or drift in frequency thus obtained was multiplied by 20 to give the error at the output frequency. The frequency of the r-f divider output was measured with the frequency standard and frequency measuring setup described previously in this report. The accuracy of these frequency measurements is within 0.00001 percent.

Figure 158 shows the frequency stability for eight channels when the equipment is operated on transmit in room ambient conditions. The curves shown in the figure are labeled as to the number of the channel. These curves are plotted as actual frequency deviation from the allocated channel frequency against time. The maximum deviation from the allocated channel frequency for any of the eight channels is 4 kc at the output frequency. This deviation was recorded on only one channel and for all of the other channels the deviation was considerably less.

Figure 159 shows the frequency stability for eight channels when the equipment is operated on receive in room ambient conditions. The maximum frequency deviation of any of the eight channels under these conditions of operation is 2.8 kc. This deviation was recorded only on one of the eight channels and the maximum deviation for any of the other seven channels was less than 2 kc. The frequency deviation of channel number 500 in receive operation is less than 1 kc while, in transmit operation, this channel showed the maximum deviation of 4 kc. The accuracy for either receive or transmit condition is considerably better than the specifications for frequency stability demand.

Figure 160 shows the frequency stability during warm-up for an AN/ARC-19 (XN-1) equipment operating on transmit in room ambient conditions on channel number 100. This figure shows that the frequency of the equipment is well within the specified frequency limits after less than one minute warm-up. After this time, the maximum frequency deviation at the output frequency was 3.3 kc and after two and one-half minutes, the maximum frequency deviation was 2 kc at the output frequency.

The frequency stability of the AN/ARC-19 (XN-1) equipment in an ambient temperature of -50° C is shown in Figure 161 for three channels. The equipment was allowed to temperature stabilize for 2.5 hours at -50° C before applying power. The maximum frequency deviation recorded during this test was 3.1 kc. This deviation was recorded on channel number 210 with the equipment operating on receive.

Figure 162 shows the frequency stability when the equipment is operated in a $+50^{\circ}$ C ambient temperature. The equipment was allowed to temperature stabilize at $+50^{\circ}$ C for 1.5 hours before applying power. The maximum frequency deviation recorded during this test was 1.25 kc. This deviation was recorded on channel number 807 when the equipment was operated on transmit.

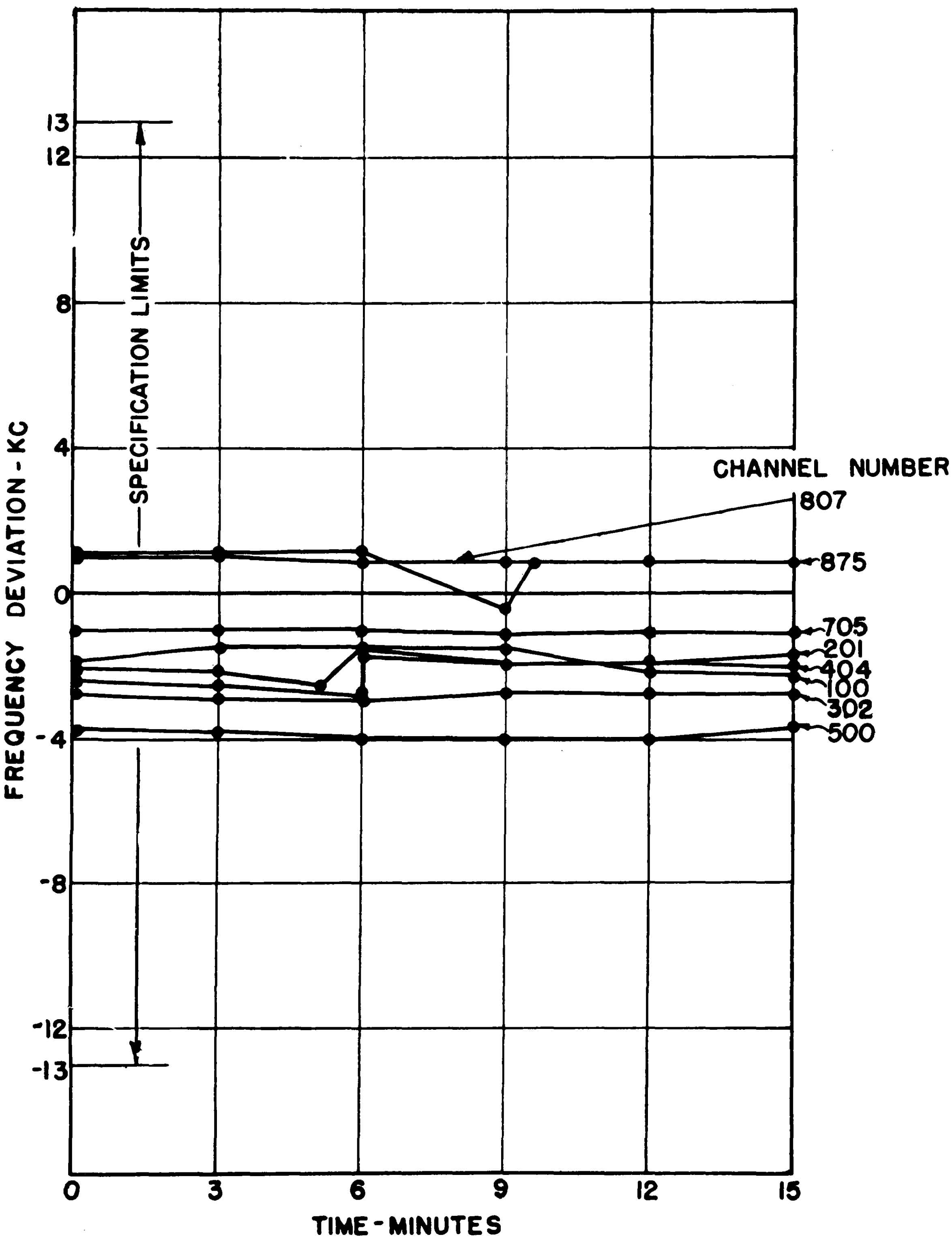


Figure 158.-Frequency stability of transmitter of AN/ARC-19 (XN-1), serial number 3, at room ambient conditions; primary supply 26.5 volts.

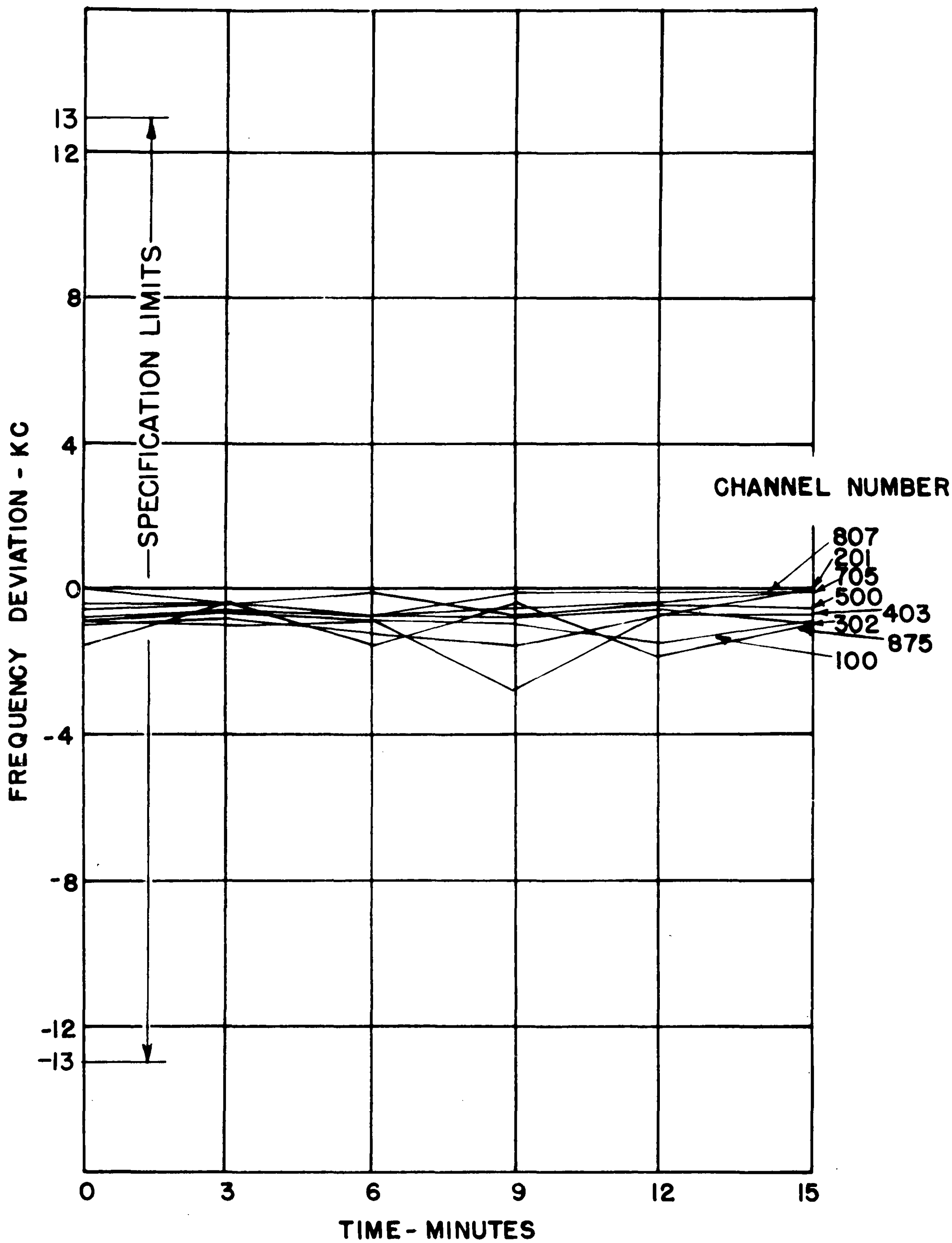


Figure 159.-Frequency stability (at room ambient conditions) of AN/ARC-19 (XN-1), serial number 3, in receive condition; primary supply 26.5 volts.

Figure 163 shows the channel frequency deviations when the AN/ARC-19 (XN-1) is operated in an ambient temperature of -50° C. These tests were spot checks of the frequency on channels not included in the other stability runs. These spot checks of channel frequency were made at supply voltages of 23.8 volts, 26.5, and 29.2 volts. When the supply voltage was reduced to 23.8 volts, the maximum deviation in frequency was 5.8 kc and was recorded on the lowest frequency channel when the equipment was operated on receive. The average deviation for all channels was greater when the supply voltage was decreased to 23.8 volts than for supply voltages of 26.5 volts and 29.2 volts. With a supply voltage of 26.5 volts, the maximum frequency deviation recorded was 4 kc on the lowest frequency channel when the equipment is operated on receive. The maximum frequency deviation when the equipment was operated with a supply voltage of 29.2 volts was 3.6 kc. The lowest frequency channel showed the greatest deviation.

Figure 164 shows spot checks of channel frequency deviations for the AN/ARC-19 (XN-1) when operated in an ambient temperature of +50° C with supply voltages of 23.8 volts, 26.5 volts, and 29.2 volts. The maximum frequency deviation recorded with a supply voltage of 23.8 volts was 1.4 kc, recorded on two channels. A frequency deviation of 1.5 kc was the maximum re-

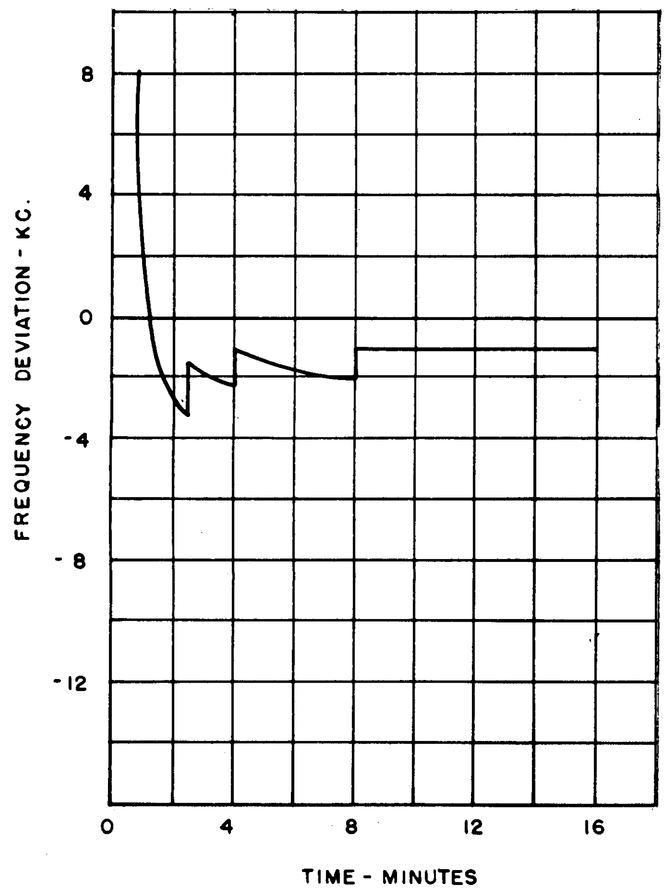


Figure 160.-Frequency stability during warm-up at room ambient conditions, of AN/ARC-19 (XN-1), serial number 3, in transmit condition, at channel 100; primary supply 26.5 volts.

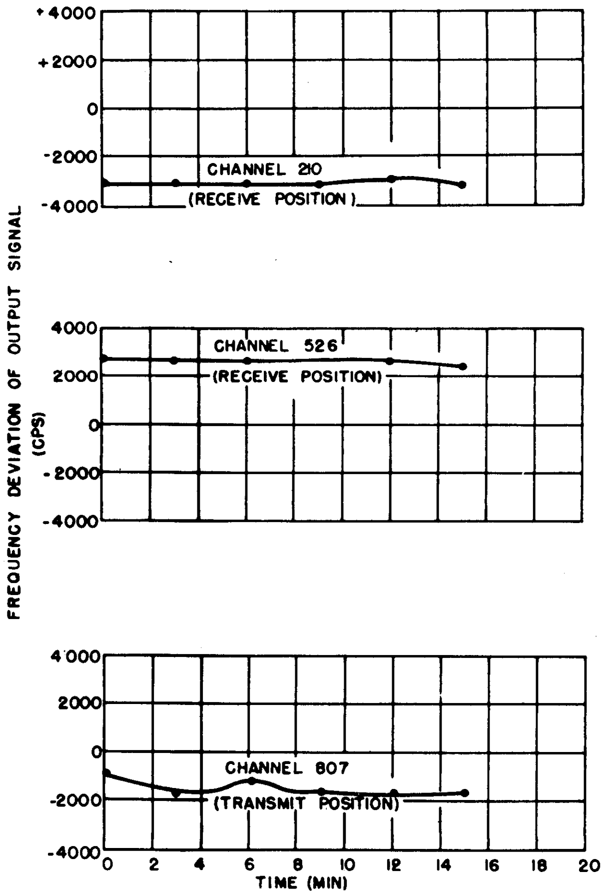


Figure 161.-Frequency stability of AN/ARC-19 (XN-1), serial number 3, at -50° C ambient temperature; primary supply is 26.5 volts.

corded with a supply voltage of 26.5 volts, and 1.3 kc was the maximum recorded with a supply of 29.2 volts.

The overall stability of the equipment is well within specifications for all Service Conditions.

The highest usable frequency of the transmitter and the receiver was 376 Mc, and the lowest frequency was 215 Mc. In order that the output frequency coverage be 225 to 400 Mc, it is desirable to provide an r-f tuning range of 215 to 400 Mc. The range below 225 Mc permits easy adjustment of the low frequency limit switch and provides a range below the first marker for monitor counting.

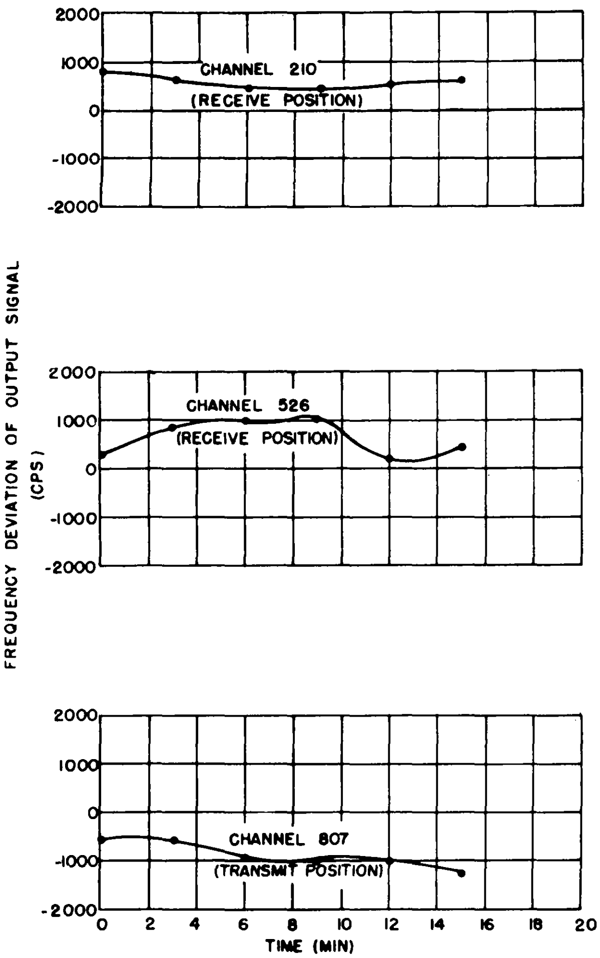


Figure 162.-Frequency stability at +50° C ambient temperature for AN/ARC-19 (XN-1), serial number 3; primary supply is 26.5 volts.

CHANNELIZATION

The accuracy of channel number selection (both indicated and actual equipment channel) was observed throughout the period of time that measurements were being made on the transmitter and receiver. These measurements were conducted for combinations of high, standard, and low temperatures and high, standard, and low voltages.

No channel selection failures were noted except when a stepper failed mechanically or the r-f divider was misaligned. The r-f divider, located between master oscillator and monitor, was found to require critical alignment before satisfactory channel selection was obtained. The stepper failures were due to broken armature return springs. This source of difficulty could be eliminated by improved spring manufacturing techniques. The steppers were found to operate normally at low temperatures if they were lubricated with a low temperature oil and properly adjusted for spring return tension.

The control box indicator unit was occasionally the cause of equipment non-functioning. This non-functioning took the form of complete channelization stoppage and was due to the numerous contact leaves and levers getting out of adjustment. A readjustment resulted in normal operation.

FLIGHT TEST

One complete unit of the AN/ARC-19 (XN-1) equipment was mounted in a Navy Type SNB-1 Aircraft BU. No. 39819. Components of the installation included:

- 1 transmitter-receiver unit
- 1 control box
- 1 vibration mount for transmitter-receiver unit
- 1 wiring harness consisting of cables, junction box and 2 jack boxes
- 1 Army type broad band stub antenna
- 2 Navy type HB-1A headsets
- 2 Navy type RS38A microphones

The board band antenna was mounted on the underside and in approximately the midsection of the fuselage. However, the antenna was not mounted for

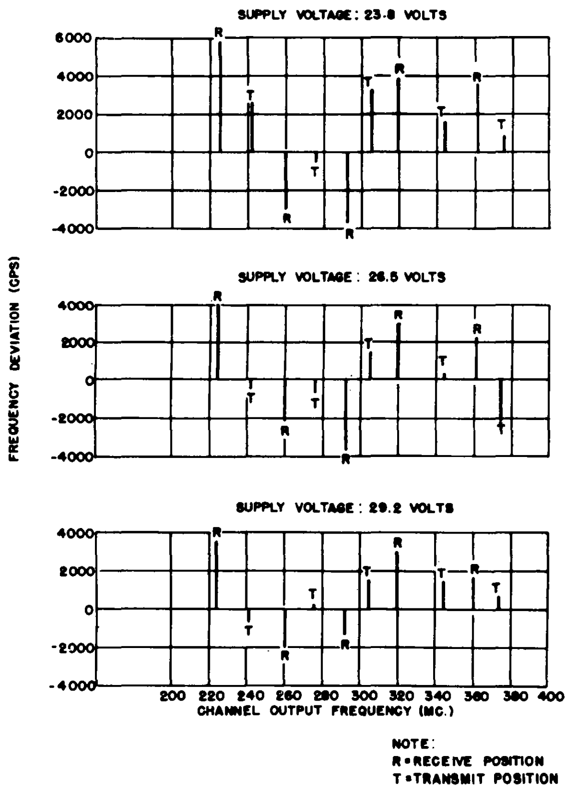


Figure 163.-Channel frequency deviations at -50° C ambient temperature for AN/ARC-19 (XN-1), serial number 3.

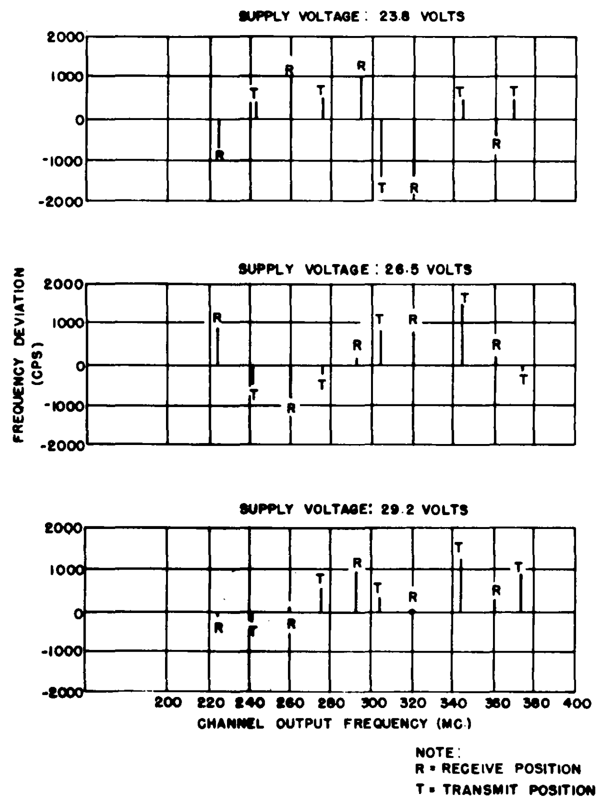


Figure 164.-Channel frequency deviations at 50° C ambient temperature for AN/ARC-19 (XN-1), serial number 3.

optimum performance. The mounting bracket at the base of the antenna extended approximately four inches beyond the ground plane because of mounting difficulties in the plane.

Another complete AN/ARC-19 (XN-1) equipment was installed as the ground station at the Laboratory. Again, the Army broad band antenna was used, and was mounted on a ground plane 36" x 36" which was elevated fifty feet above the actual ground level.

The flight was made from the Patuxent Naval Air Station. The airborne unit was flown at 10,000 feet on a course due south of the Laboratory. Listening tests were made by Laboratory personnel in the aircraft and at the Laboratory. The results of the flight tests showed that the maximum range for the above conditions was 97 miles for voice or tone operation. However, a null occurred at a distance of 70 miles from the Laboratory and the ground station temporarily lost contact with the airborne unit. The plane continued on its course and contact was again established at a distance of 75 miles. Two-way communication was maintained from this point to 97 miles which was the maximum range.

It was apparent during the flight test that vibration did not introduce any noticeable noise on the transmitted carrier or in the receiver audio output.

A number of channel selections were made without error with the equipment operating in the plane. Vibration did not effect channelization.

CONCLUSIONS

On the basis of tests conducted it is concluded that the AN/ARC-19 (XN-1) equipment possesses excellent frequency stability and provides ease of channel selection for 876 operating channels. However, several modifications must be made to make the equipment suitable for use in naval aircraft.

The equipment overall frequency stability is very good, and the greatest frequency deviation under any operating condition was measured to be 5.8 kc. This deviation occurred only once during the frequency measurements, and in all other cases it was less than 4.0 kc from the assigned channel frequency. Only a one minute warm-up time was necessary to bring the frequency within 4 kc of the assigned frequency. However, during some tests the equipment failed to select the proper channel. These failures were caused by the breakdown of the stepping motors. Hence, the use of the present type of stepping motors is considered to be undesirable.

The frequency divider circuits of the r-f assembly are extremely critical and difficult to track with the other variable-tuned r-f circuits. Since it is desirable to avoid all critical circuits, it is concluded that the use of this frequency divider is unsatisfactory.

The equipment frequently fails to select channels between channel number 600 and channel number 700. The failure to select these channels is due to the fact that the monitor i-f amplifier frequency lies between 11 and 20 Mc together with the fact that a higher monitor plate supply ripple existed in the equipment than during the bench tests. Refer to the discussions of the monitor development. It is desirable that the equipment reliably select channel numbers 600 through 700 as well as all channel numbers from 125 through 600 and from 700 through 999. Therefore, it is concluded that the equipment channel selection is unsatisfactory.

The transmitter sidetone output level was inadequate, and a redesign of the sidetone circuits will be required.

Since a low frequency i-f of 143.3 kc was used in the receiver, no image rejection could be realized in the r-f circuits and it was necessary to select the exact intermediate frequency which would cause the image response to fall between two operating channels. Though the image response is not objectionable when operating a communication system composed only of AN/ARC-19 (XN-1) equipments the image response will be objectionable when the AN/ARC-19 (XN-1) equipment is operated with less stable transmitters or with equipments with channel spacing of less than 200 kc.

Some of the receiver spurious responses below 310 Mc exceeded the maximum 60-decibel limitation of the specifications at frequencies near the receiver resonant frequency. Due to the low frequency i-f, all of these responses appeared in pairs separated by 286.6 kc. All of the spurious responses below a frequency of 310 Mc were greater than 50 decibels below the resonant response. Those above 310 Mc were 40 decibels or more below the resonant response and in accordance with the specifications.

The receiver audio fidelity is not in accordance with the specification requirements. It is considered that an improvement in the fidelity will improve the intelligibility of received signals.

The receiver AVC characteristic deviates slightly from the specification requirements, but the receiver operation is such that the AVC action would not be objectionable under actual flight conditions.

Although the receiver meets the 20-microvolt sensitivity requirement of the specifications, it would be desirable to improve the sensitivity. It is possible to accomplish this and to improve the AVC action by providing additional gain in the receiver r-f and mixer stages, where the gain in the present equipment is approximately two.

The addendum to the specifications, Reference (p), requires the frequency coverage of the equipment to be 225 to 390 Mc. However, during the evaluation measurements it was found that highest frequency of the transmitter and receiver tuning range was 376 Mc, or channel 880. The high frequency limitation is due only to a limited r-f tuning range, and could be corrected by a proper design of the r-f tuning elements. It is desirable to extend the frequency coverage of the r-f tuning components to provide a frequency range of 215 to 400 Mc.

Tests of the following items have been conducted, and the operation was found to be satisfactory.

Heat exchanger operation
Receiver sensitivity
I.F. selectivity
I.F. rejection
Receiver regeneration
Receiver noise limiter operation
Receiver audio frequency distortion
Receiver audio gain control range
Receiver sensitivity control range
Transmitter carrier power output
Transmitter modulation characteristic
Transmitter overall fidelity
Transmitter modulation distortion
Microphone d-c energizing current
Transmitter tone modulation characteristics
Transmitter carrier shift
Transmitter carrier noise level
Equipment input power requirements
Channel selection time
Transmitter frequency modulation
Receive-transmit time interval

Results of the flight tests showed the equipment capable of operating satisfactorily in a naval aircraft. The maximum range at an altitude of 10,000 feet was 97 miles, but a null occurred at 70 miles.

RECOMMENDATIONS

Since the AN/ARC-19 (XN-1) equipment possesses many desirable features, it is recommended that the following modifications be made to make it suitable for use in naval aircraft:

Eliminate stepping motors entirely or provide improved stepping motors which can withstand a life test similar to the performance necessary for operation in the subject equipment, thereby making channel selection more reliable and minimizing mechanical failure.

Replace the frequency divider circuits of the r-f assembly with a less critical circuit. It is possible to operate the master oscillator at a lower frequency range than the one presently used and follow the master oscillator with multiplier stages which are less critical than the frequency divider circuits.

Correct faulty equipment channel selection between channel number 600 and channel number 700 as suggested in the paragraphs under Description of Monitor Circuits, page 48.

Provide additional audio gain in the transmitter sidetone circuit.

Increase the receiver intermediate frequency to permit attenuation of the image response by the r-f tuning, thereby reducing both the image and other spurious responses.

Reduce the level of all spurious responses to at least 60 decibels below the resonant response for all frequencies below 310 Mc.

Improve the receiver fidelity to comply with the subject specifications.

Increase the receiver r-f gain to produce a sensitivity of five microvolts.

In the redesign of the r-f tuning components, extend the frequency coverage to provide a range of 215 to 400 Mc.

It is recommended that further flight tests be conducted to determine the extent of the null which was found to occur at 70 miles, and to make range measurements of other altitudes.

A proposal of a new system which offers a solution of the above deficiencies is presented in the following section of this report.

PART III

Proposed New System

INTRODUCTION

The present AN/ARC-19 (XN-1) equipment could be modified without major changes to comply with the specifications. However, there are a number of features in the present equipment which comply with specifications but are not in accordance with good engineering design and practice. The experience gained in the development and evaluation of the equipment provided information which showed that a complete redesign was more desirable than a modification of the present AN/ARC-19 (XN-1) equipment. The redesign permits the use of 3500 channels spaced 50 kc apart in the 225 to 400 Mc frequency band, and, in addition, eliminates many of the undesirable features in the present system.

A study of a number of multichannel crystal-saving circuits was made. It was concluded from this study that a modified "1407" principle, References (a, b, and c), was the most practical and would provide the desirable features listed below:

(1) A straightforward, relatively precise and simple tuning mechanism which operates from a single motor drive.

(2) A shaft to which the multiplier and amplifier stages of the transmitter and receiver r-f circuits may be coupled. This is true since the master oscillator is, at all times, disciplined by the monitor unit, and all transmitter and receiver r-f stages are ganged and tracked to the master oscillator.

(3) A frequency stability necessary for a channel spacing of 50 kc with a counting type of monitor simpler in design than that used in the present equipment.

(4) A minimum of quartz crystals. (Two would be used in the monitor and one in the guard channel receiver.)

The undesirable features of the present equipment which will be eliminated in the proposed design are :

(1) Lack of image rejection
(2) An r-f divider between the master oscillator and monitor.

(3) Complex control circuits requiring a relatively large number of stepping motors, relays, and wafer switches.
(4) Mechanical counters.

Although several other multichannel communication systems involving crystal-saving circuits appear simpler in form than the proposed block diagram, careful study will reveal that most of these systems rely on some critically adjusted circuit or complex mechanical arrangement for proper equipment operation. Some of these are: complex motor drives, critically tuned r-f stages, critically tuned frequency separators (balanced modulators), and continuously variable frequency dividers. Any one of these is likely to be a source of unreliable operation.

DESCRIPTION OF NEW SYSTEM

Block diagrams of the proposed new monitor and proposed new system are shown in Figure 165 and Figure 166, respectively.

Only two crystals are used in the monitor, one in the spectrum oscillator and one in the reference oscillator. The five crystals used in the reference oscillator in the present equipment have been reduced to one crystal in the new proposed monitor to save crystals and also to reduce the two counting speeds to one counting speed.

The use of only one counting speed greatly simplifies the monitor control circuits. Since only one counting speed is used, a spectrum harmonic marker must be placed at every channel, rather than at every "hundreds" channel and every "tens" channel. The counter, consequently, must register a count for every channel, or 3500 counts for a 50-kc channel spacing in the 225 to 400 Mc band. The counter is completely electronic in design, incorporating no relays. It is coupled directly to the essentially square wave output of the modified discriminator. The counting time is not limited by relays or steppers, therefore the counting can take place at a high rate of speed. Since the counting rate is high (for the reasons given previously) only a two-speed, motor-driven, gear reduction system is necessary, a high speed for counting and a slow speed for automatic frequency control. The counter is arranged so that it changes the gear reduction system from fast to slow speed at about the fifth from the last count in order that the master oscillator can be tuned into the proper channel frequency at slow speed. The use of only a single counting speed, only two condenser-shaft speeds, and an electronic counter has greatly simplified the monitor control circuits. In this design only two or three relays will be required in the control circuits. The three steppers and all of the wafer switches have been eliminated as well as a number of relays.

Since every channel is counted there is no need to switch the discriminator polarity. Likewise there is no need to switch the discriminator crossover frequency because local oscillator side-stepping circuits have been incorporated in the receiver, eliminating the necessity of shifting the master oscillator frequency for transmit-receive operation. Consequently, neither

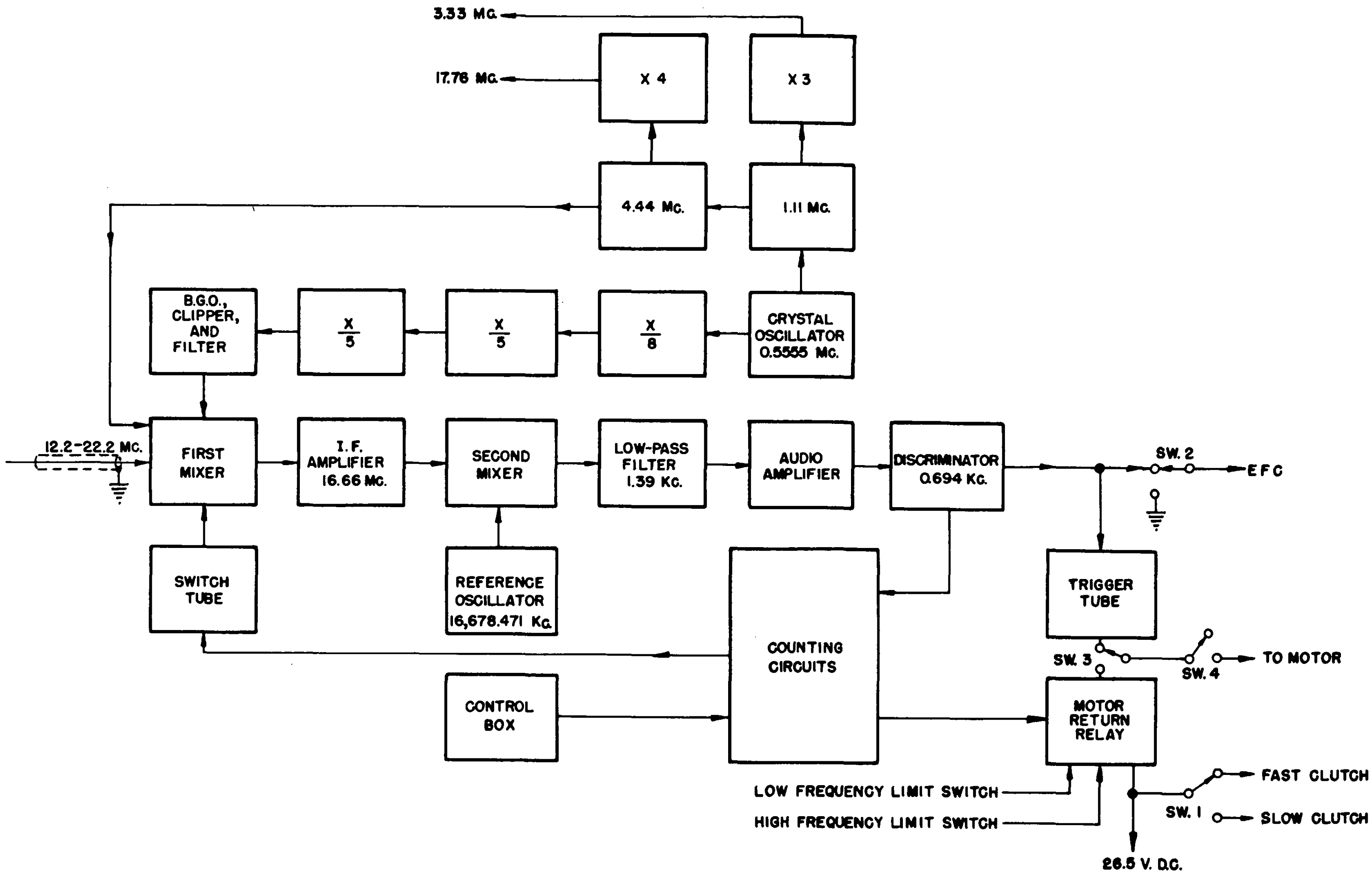


Figure 165.-Block Diagram of Proposed Monitor

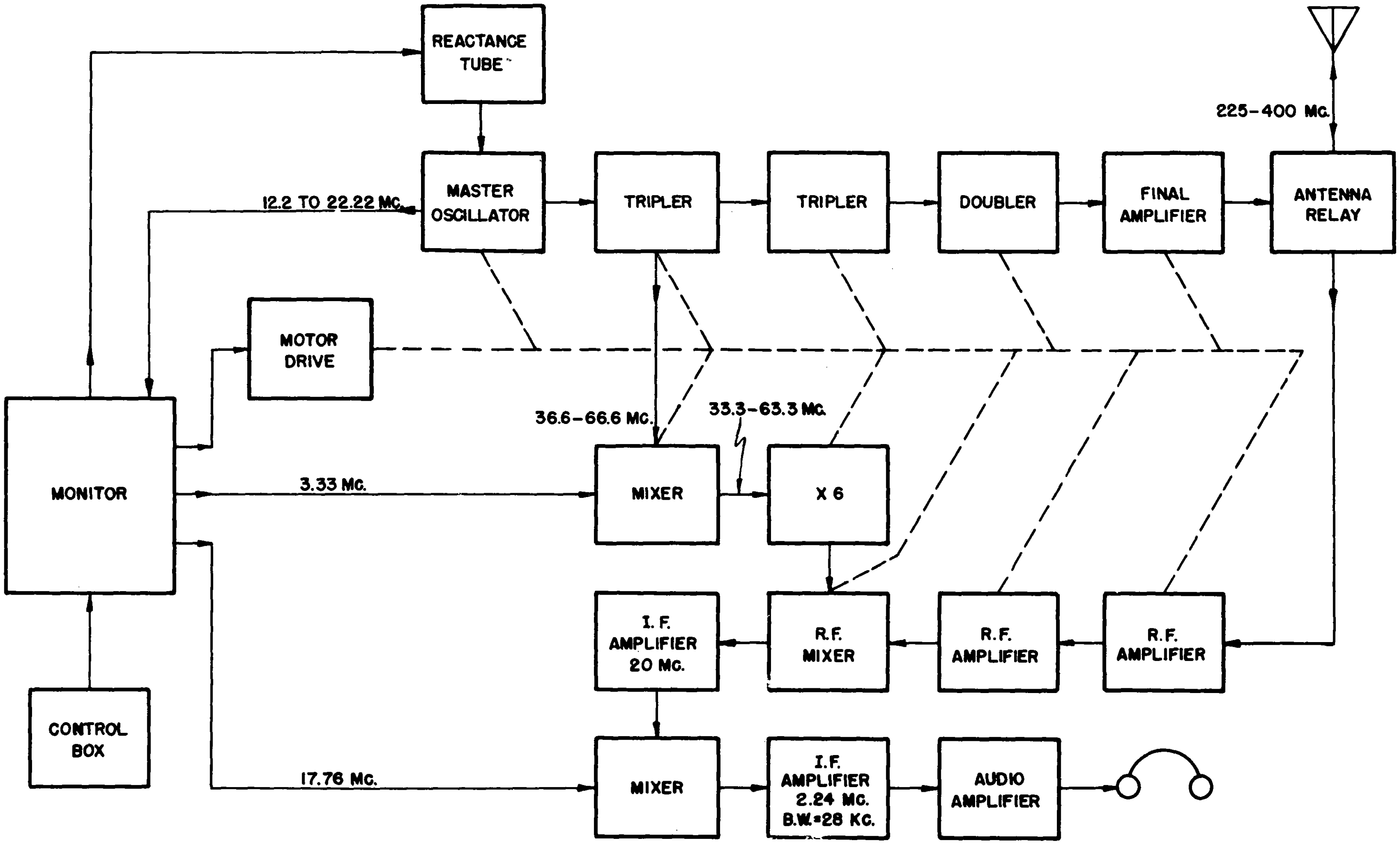


Figure 166.-Block Diagram of Proposed System

the discriminator polarity nor the discriminator crossover frequency is switched in the proposed new monitor. Evaluation of the AN/ARC-19 (XN-1) showed that its frequency stability anywhere within the band was better than ±5 kc under Service Conditions. This stability is adequate for a channel spacing of 50 kc. The proposed monitor should permit obtaining even better stabilities because the discriminator crossover frequency has been reduced from 25 to 0.694 kc and no switching is performed at the discriminator to change either its polarity or frequency. This switching was the cause of a portion of the ± 5-kc instability in the present equipment. This monitor will also be easier to align because of the fewer crystals and a single, very low, discriminator crossover frequency.

The monitor is designed to supply both the first and second local oscillator signals for the receiver, thus saving one or two crystals.

The counting circuits will consist of four decade counters in cascade. Such counters have been developed and demonstrated to be practicable and reliable. This counter will require a moderate number of components but will have the great advantage of providing a high speed and accurate count. The counter will count up to 4000 permitting all counting to be performed at one speed. This is another advantage because it simplifies the control circuits.

Figure 166 shows a block diagram of the complete new system. It is designed for a 50-kc channel spacing in the 225 to 400 Mc band. The receiver is a double superheterodyne receiver which will provide image signal attenuation of 80 decibels or more. The master oscillator operates at one-eighteenth the output frequency. The monitor is designed to use the master oscillator signal directly with no division in frequency.

During the development of the AN/ARC-19 (XN-1), an electronic-counting type of monitor was constructed to determine if it was practicable to perform the counting and switching functions of the three steppers with relays and an electronic counter. Figure 167 shows the schematic diagram of the electronic-counting type of monitor that was developed, and Figure 168 shows the system schematic diagram using this monitor, including a suitable control box.

It must be pointed out that the electronic-counting type of monitor that was developed had to perform all of the complex switching incorporated in the present equipment. The switching in the proposed new monitor is far less complex. Tubes V318 and V319 are used in the counting circuit. The counting impulses to the counter come from a set of contacts on the C and F relay in the trigger tube circuit. This monitor was tested and found to operate very satisfactorily. The monitor eliminated the use of steppers but a large number of relays were still used.

The control box for this system was simpler mechanically than the AN/ARC-19 (XN-1) control box in that it eliminated the stepping motor, several relays, and a number of switch contact leaves.

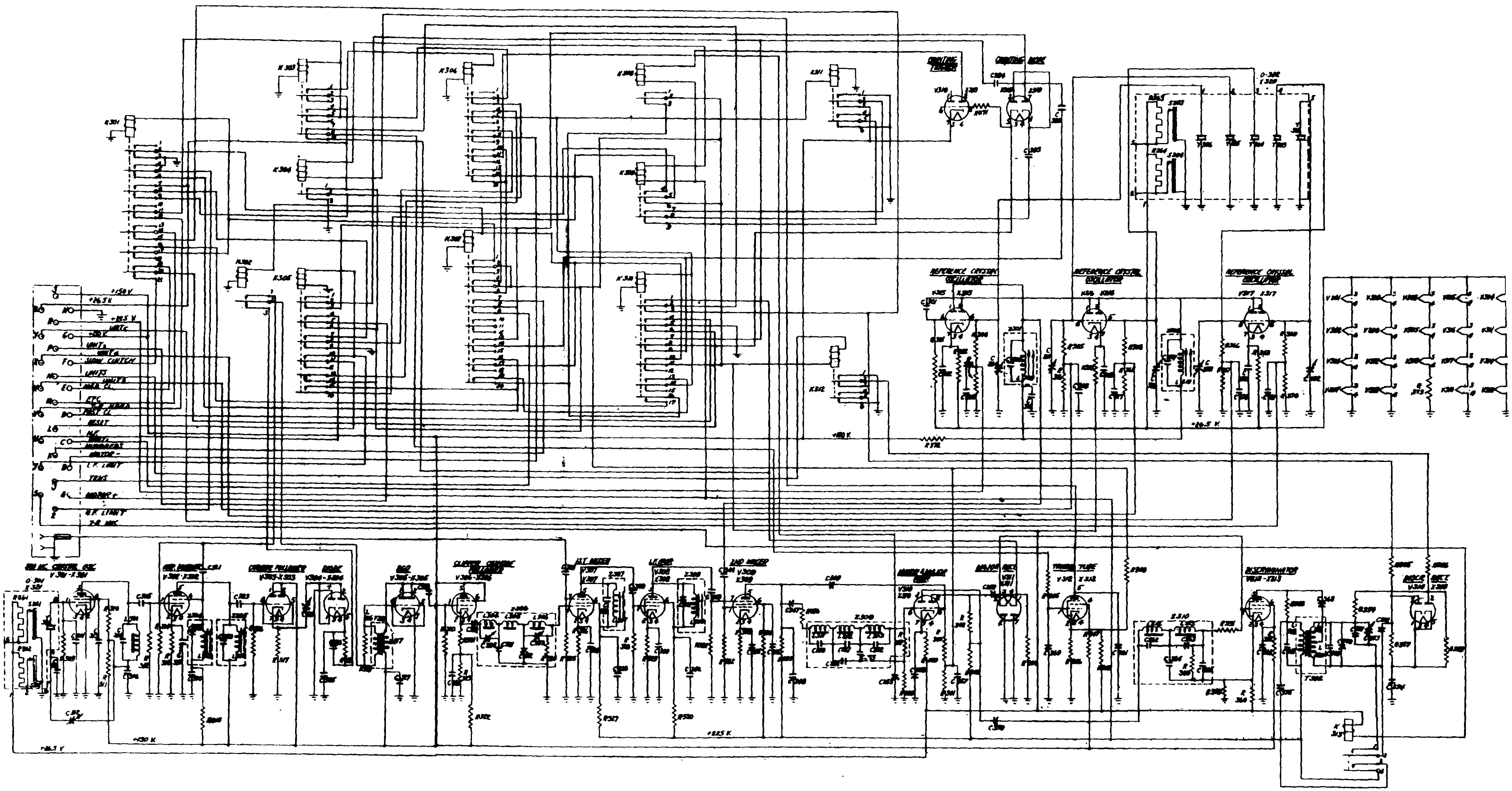


Figure 167.-Schematic Diagram of Electronic Counting Type Monitor

The result of the work on the electronic-counting type of monitor was so encouraging that the engineers responsible for the project were convinced that work on this type of monitor would be very worthwhile and should be carried to its logical conclusion.

The above proposal for a new system is a result of this conviction together with the evaluation of the AN/ARC-19 (XN-1).

The preceding paragraphs have outlined how the AN/ARC-19 (XN-1) can be redesigned to provide the Navy with a more suitable equipment and at the same time provide four times the number of channels.

REFERENCES

(a) Report of Research Laboratories of General Electric Company, Ltd. Serial No. 8368 FM of 21 January 1944.

(b) Report of Research Laboratories of General Electric Company, Ltd. Serial No. 8411 FM2 of 14 February 1944.

(c) Report of Research Laboratories of General Electric Company, Ltd. Serial No. 8431 FM2.

(d) VCNO conf. ltr. Op-20-Z/AEK(SC)S67-1, Serial 0546020 of 19 February 1944 to BuShips and BuAer.

(e) BuShips ltr. 913-925(S67) of 20 June 1944 to NRL.

(f) NRL ltr. C-F42-1/43 Serial 700-3631 of 26 June 1944 to BuShips.

(g) CNO ltr. Op-20-E/ls, Serial 0256520(SC), S67-1 of 27 June 1944 to BuShips.

(h) BuShips ltr. Serial 268(938) Serial 700-3794 of 5 July 1944 to NRL.

(i) NRL ltr. report C-F42-1/43 (317:JHD), Serial 310-679 of 13 July 1944 to BuAer.

(j) NRL ltr. report C-F42-1(317:KRS:JHD), (361) Serial 310-692 of 15 July 1944, Interim report on Problem No. S767R-C.

(k) BuShips ltr. Serial 1741(925B) of 5 August 1944 RSO 18854 to NRL.

(l) NRL conf. report C-F42-1/43(318:318:KRS), C-310-70/45(rab) on problem S767.1R-C of 21 April 1945 to BuShips.

(m) BuShips ltr. Serial 981(938) of 17 May 1945 to NRL.

(n) NRL ltr. C-F42-1/43(700) Serial C-700-2108/45 of 21 May 1945 to BuShips.

(o) BuShips Specifications CS-577 of 1 June 1946

(p) Enclosure (A) to NRL ltrs. F42-1/43(1445:CMR), 1400-430A/46(ebl; F42-1/43 (1445:CMR, 1400-429A/46(ebl).

PRNC-5304-4-13-48-100