NASA SP-5080

TECHNOLOGY UTILIZATION

WEATHER SATELLITE PICTURE RECEIVING STATIONS

INEXPENSIVE CONSTRUCTION OF AUTOMATIC PICTURE TRANSMISSION GROUND EQUIPMENT

A REPORT

By Charles H. Vermillion

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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Technology Utilization Division
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Foreword

Weather satellites, together with communications satellites, are among the products of space research of most practical benefit to mankind. The capability of satellites to observe conditions in the earth's atmosphere rapidly and comprehensively was recognized early as a tool that would aid in global weather forecasting.

To obtain global weather data quickly at a central point for study, designers adopted data-storage readout procedures for the early weather satellites. Later, with the addition to some satellites of the continuous broadcasting feature of the Automatic Picture Transmission (APT) System, information could be transmitted immediately directly to local weather stations. APT enables remote sites to receive instant weather information both day and night.

When it was designed in 1960, APT used state-of-the-art components to meet its requirements. Some parts were expensive. The recent advent of less expensive, high-quality electronic components, together with the use of advanced electronic design experience, has made possible equipment which can easily be built in most parts of the world. This report is a guide to the construction of an economical, useful APT and DRIR weather instrument for the direct reception of daytime and nighttime cloudcover pictures from satellites.

Rudolph A. Stampfl
Deputy Assistant Director
for Advanced Projects,
Technology Directorate,
Goddard Space Flight Center.

Contents

Summary

This report describes how one can procure or build the antenna, FM receivers, and other components for the automatic picture transmission (APT) ground station. A facsimile video enhancement device is also described, along with the direct readout infrared (DRIR) adapter unit which can convert the APT system to receive nighttime as well as daytime cloudcover data. The DRIR system takes advantage of the NIMBUS III high resolution infrared radiometer (HRIR) which transmits pictures over the same frequencies used by the APT system in the daytime. Detailed drawings and parts lists are included for each system. Installation, alignment, and operation of the complete APT ground station are also described.

APT ground stations are inexpensive and reliable. They can be built from surplus parts for under $500 or procured for as low as $5000. With them, scientists, local weather stations, amateurs, and others can receive satellite-taken photographs of the earth as APT-equipped satellites pass overhead.

It is currently planned that APT systems compatible with the ground station will be flown on Nimbus and ESSA satellites at least until 1972. It is probable that similar or advanced APT systems will be available after 1972, although these programs are still in a tentative planning stage.

C. Vermillion
NASA/GSFC
Systems Division

CHAPTER 1

Introduction To The APT System

The automatic picture-transmission (APT) system developed by the U. S. National Aeronautics and Space Administration (NASA) is a unique television system enabling a weather satellite to take cloudcover pictures over wide areas and transmit them to simple and inexpensive ground stations anywhere on earth.

The first APT-equipped satellite was TIROS VIII, an experimental version, launched December 21, 1963. Two APT-equipped experimental Nimbus satellites, launched August 28, 1964 and May 15, 1966, successfully demonstrated the APT system by transmitting thousands of APT pictures directly to receiving stations all over the world. The later TIROS operational satellites, named ESSA* when they achieve orbit, will provide continuous APT coverage on a regular operational basis. These satellites are built and launched under the technical direction of the NASA Goddard Space Flight Center and are operated by the U. S. Environmental Science Services Administration (ESSA).

By using APT equipment, a ground station can receive photographs and other pictorial information transmitted by APT-equipped satellites passing overhead taking photographs and infrared pictures of the clouds and terrain in the vicinity of the ground station. In addition, there is an experimental program for the relay of pictorial information to APT ground stations through an ATS satellite as shown in fig. 1. This experiment may lead to additional uses for the APT ground stations in the future (Ref. 1).

APT ground station equipment is inexpensive and reliable. It can be built using surplus equipment for a few hundred dollars or purchased ready-made for around $5000. Simplicity, direct reception and "instant" pictures make the APT system particularly useful to meteorologists, weather services, commercial organizations, government agencies, and educational institutions. For instance meteorologists at weather offices and TV stations can receive daily pictorial displays of the local cloudcover in less time than it would take to dial a telephone and get a complete weather forecast. A weather picture from a typical APT-equipped satellite is complete within about 200 seconds. Pictures of cloud patterns signifying weather conditions are thus immediately observable. Utility companies can keep an eye on weather changes affecting power and water consumption. Individual

*ESSA = Environmental Survey Satellite.

INEXPENSIVE APT GROUND STATIONS

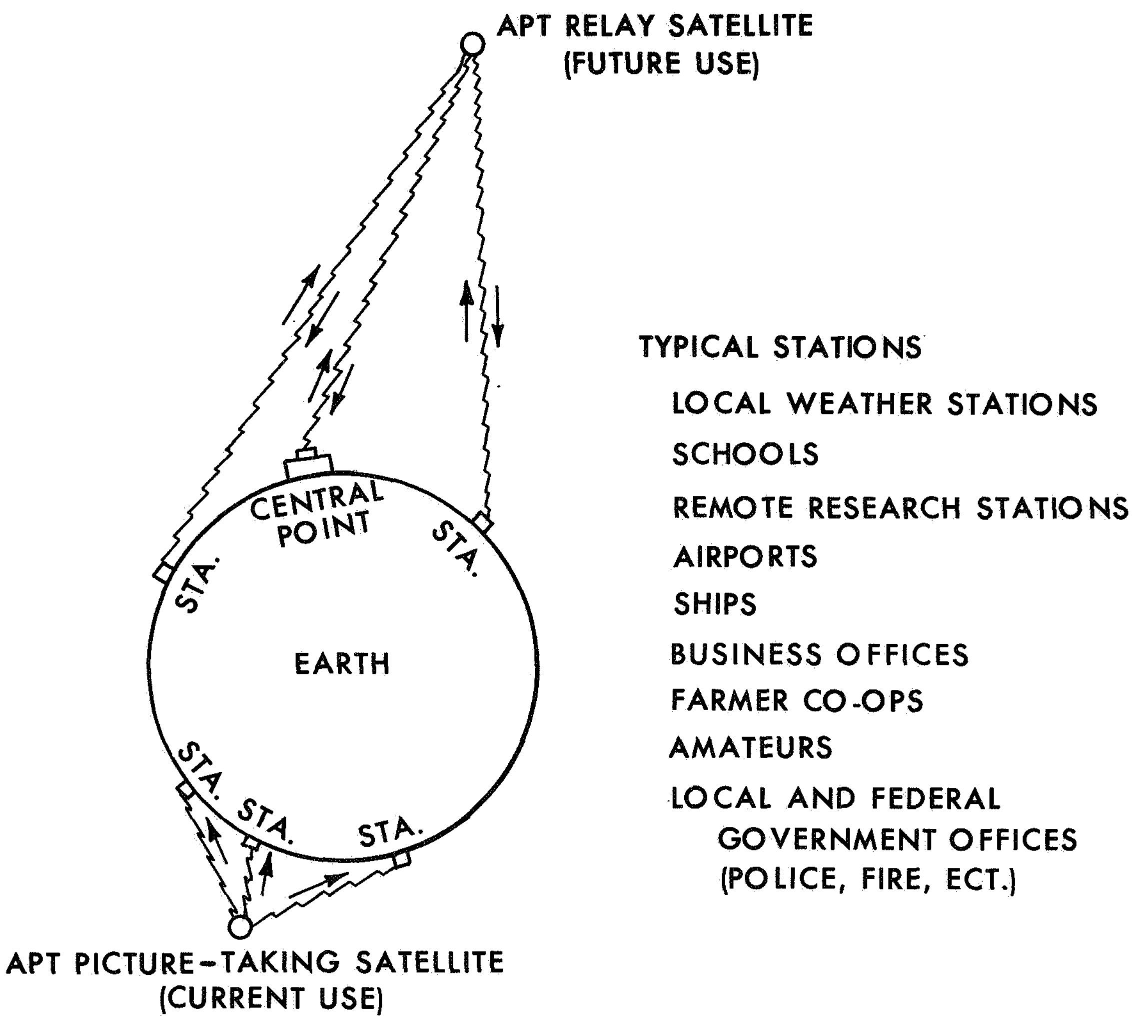

Figure 1.—APT ground equipment used with picture-taking satellites and picture-relay satellites.

weather services can provide detailed data on conditions hundreds of miles around their station. The universally available cloudcover pictures can also provide weather data to improve meteorological interpretation in localities not normally served by weather bureaus. At present, weather satellites in the Nimbus and ESSA series include APT equipment in their payloads. APT ground stations have already sprung up all over the world, and thousands of cloudcover pictures are recorded every week.

CHAPTER 2

How The APT System Works

THE APT-EQUIPPED SATELLITE

The operation of the APT system, now carried by ESSA and Nimbus satellites, can be compared to regular television operation. When these weather satellites cross the day portion of the globe in their near-polar orbits, their special television cameras (vidicons) are pointed at the Earth below. The system is completely automatic and requires no ground commands for operation. In the daylight portion of the revolution, an internal sequence timer exposes the vidicon and begins the read-out process a few seconds later. This process is accomplished by scanning the stored picture from the face of the vidicon. This picture is scanned 800 times, resulting in 800 lines of picture information (ref. 2). The density of electrons stored on the face of the picture, which correspond to the shades of grey in the picture, is detected by the electron beam in the vidicon. The resulting current beam is used to amplitude-modulate a 2400-Hz subcarrier, which is sent to the APT transmitter for relay to waiting ground stations (fig. 2).

An APT satellite will pass within range of any ground station two or three times during daytime. A receiving station can receive weather pictures taken over regions up to 2000 miles distant. For example, the station in Greenbelt, Maryland, can receive pictures taken from Central America to Greenland. Local weather pictures are of primary interest, however, and these can be obtained from ESSA and Nimbus satellites, which pass almost directly overhead once daily. Each picture covers an area measuring approximately 1200 miles (1920 km) square (Nimbus) or 1700 miles (2730 km) square (ESSA); a pair of successive pictures will overlap about 30 percent on the ESSA satellite and 50 percent on Nimbus III (figs. 3 and 4).

The satellite radiates approximately 5 watts of power. The power received on the ground within the area of reception (fig. 4) is sufficient for clear pictures if the station has the proper receiving equipment. (See figs. 5 and 6 for an idea of the distance useful pictures may be transmitted.) The area of reception increases proportionately with increasing altitude of the satellite (e.g., 1400 km for the ESSA series and 1200 km for Nimbus III. Each station should be able to acquire a satellite at about 5 degrees in elevation, which represents an approximate line-of-sight distance of 3500 miles.

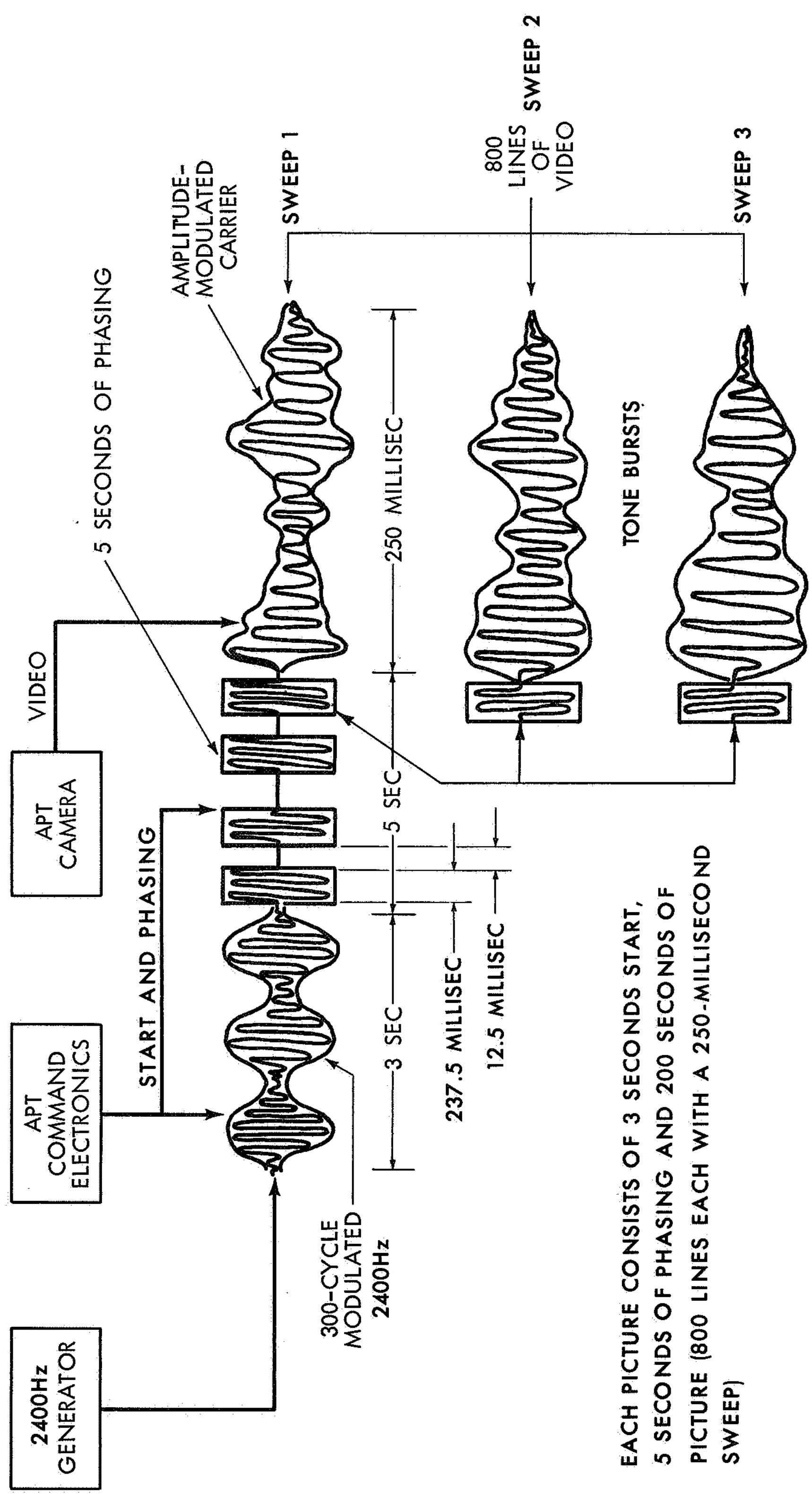

Figure 2. —Signal structure from an APT-equipped satellite.

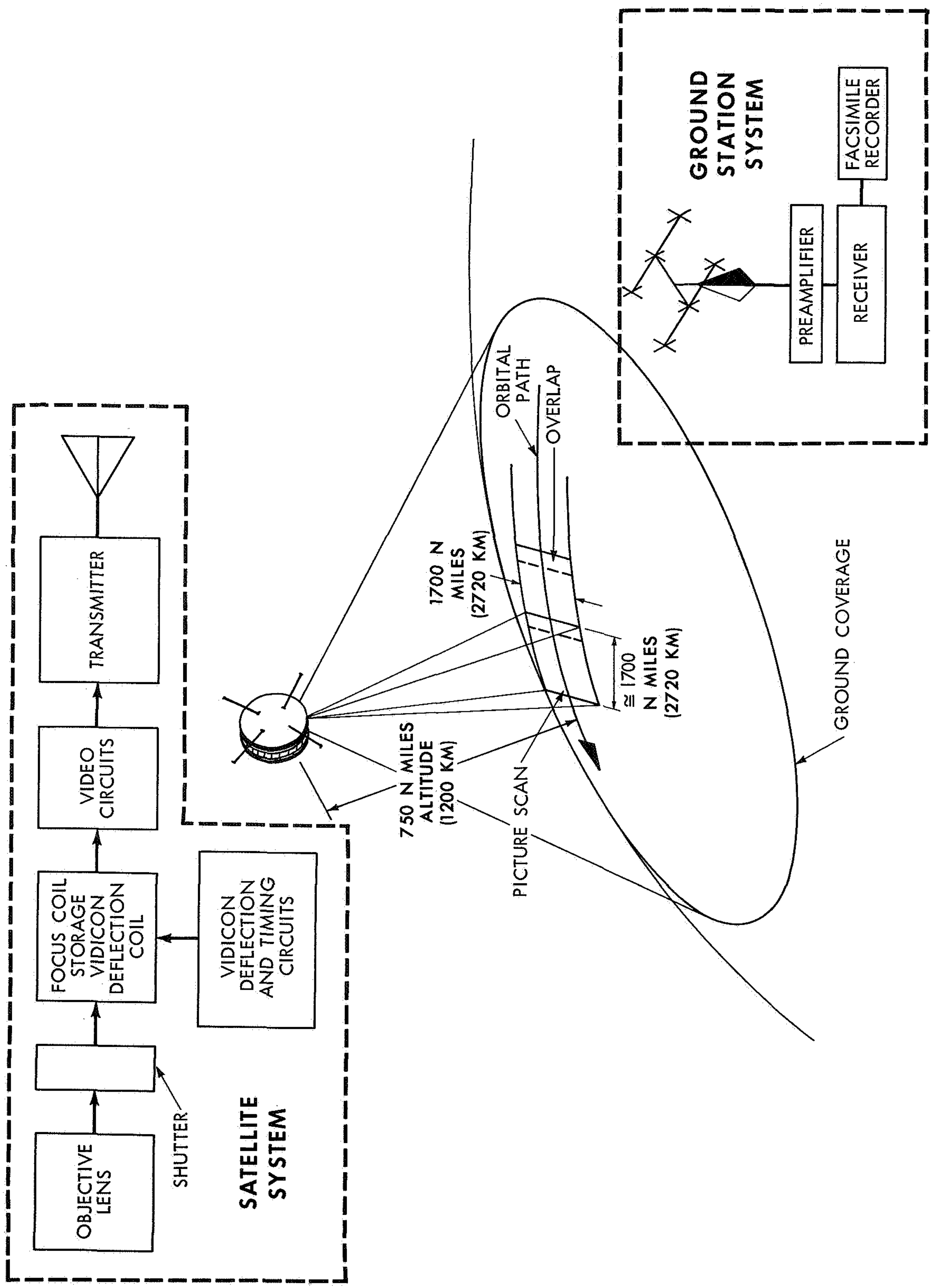

Figure 3.—Automatic Picture Transmission (APT) system.

Figure 4.—Area of reception for the GSFC station.

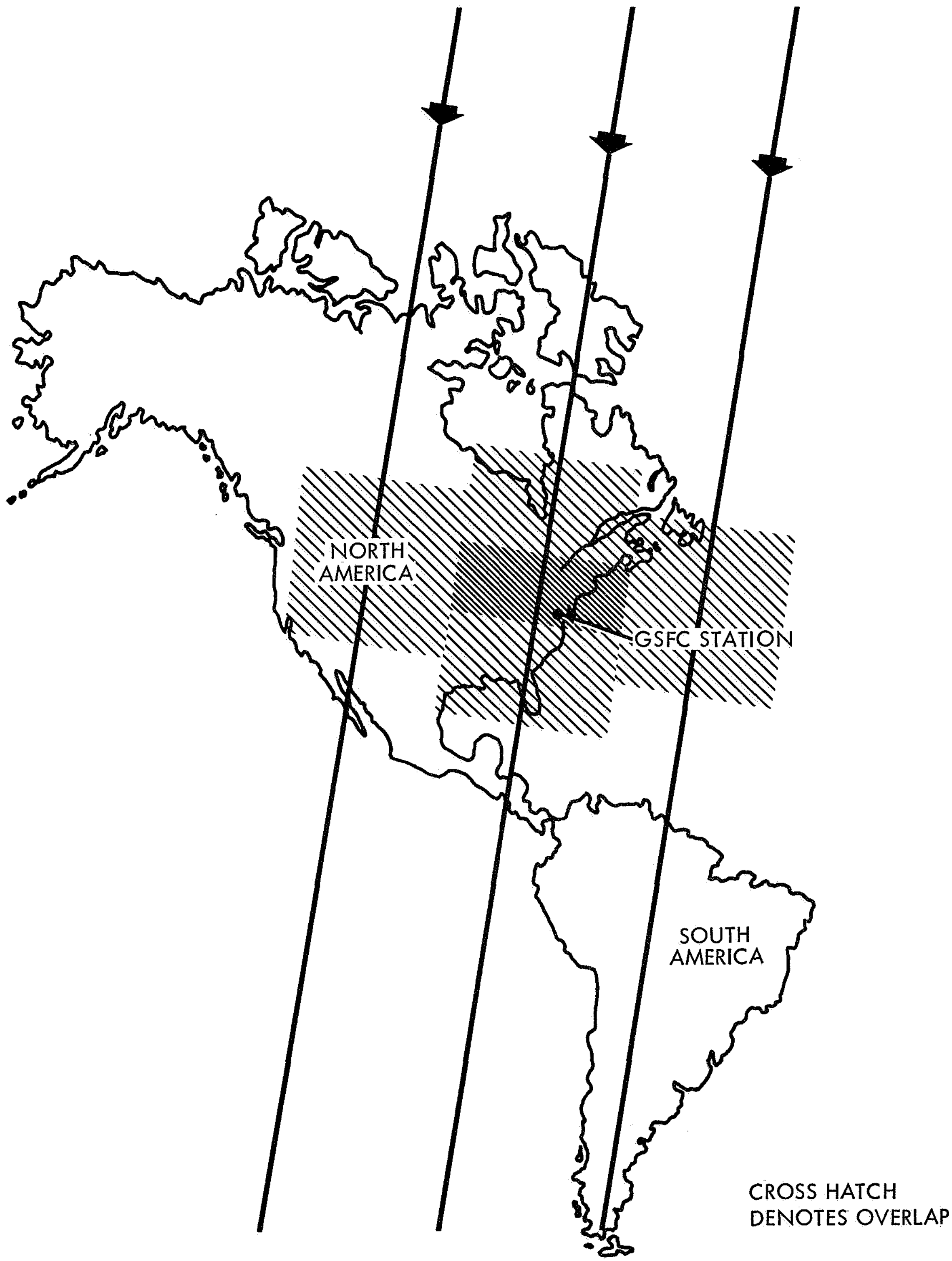

Figure 5.—Area of local reception.

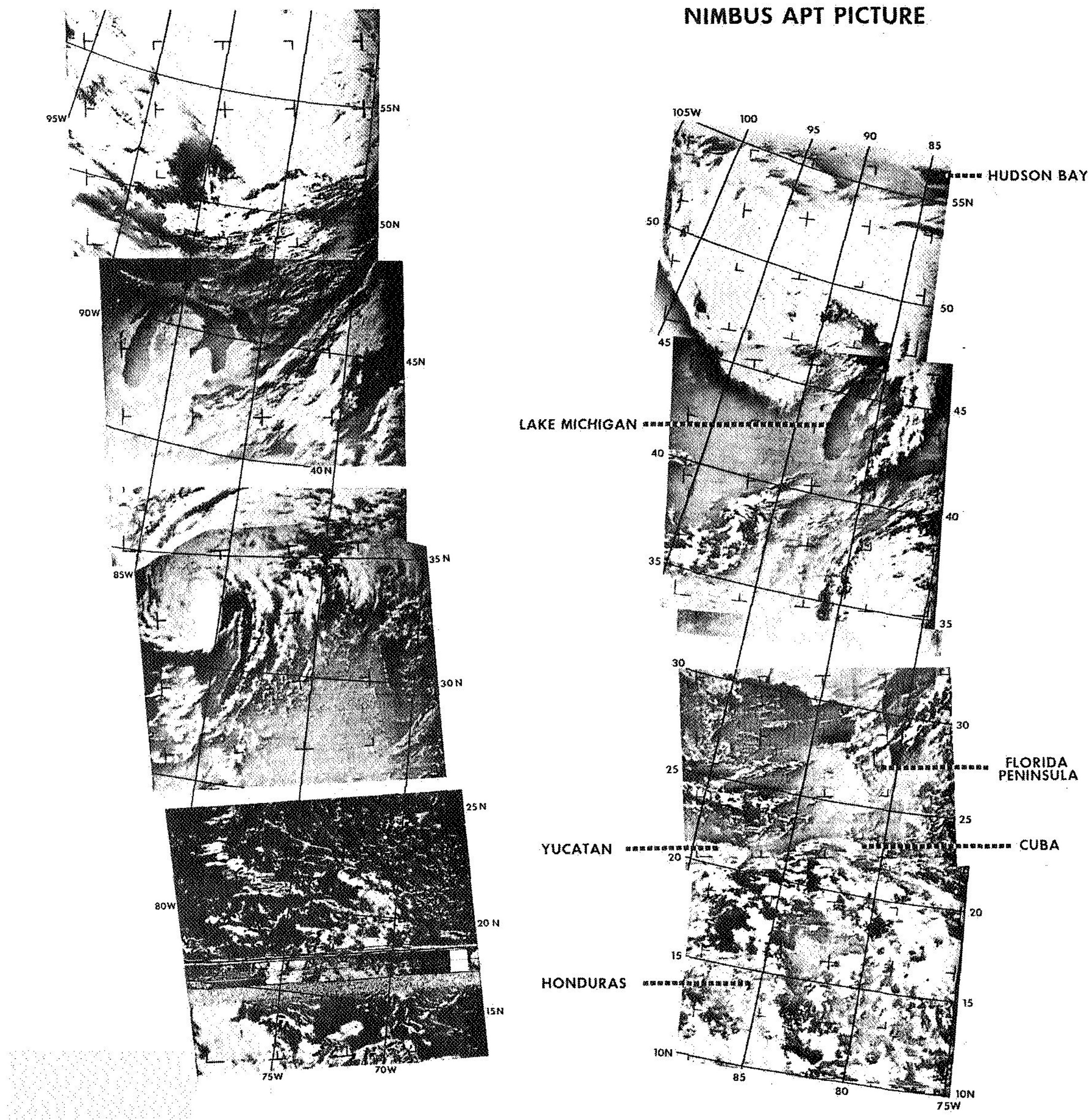

Figure 6.—Nimbus APT pictures received at Goddard Space Flight Center.

THE APT GROUND STATION

Once the satellite is in range, the video signal can be heard in the receiver output. The first picture transmitted is of little value because:

- It is usually "noisy."
- It is not of the local area.
- The station did not receive the start and phase portion of the transmission.

This is a good time to tune the receiver and make a last-minute check of the station to verify its readiness to receive pictures. The antenna operator tracks the satellite with the orbital prediction data he has calculated using the information he has received from the National Environmental Satellite Center by mail or teletype.* (The APT User's Guide, ref. 3, is a requirement for all APT stations and explains satellite tracking in detail.) By the time the first local picture is transmitted, the station will receive a good clear signal, indicated by a "buzzing" sound that interrupts the normal "beep" tone. This is the 300-cycle start, followed by the phasing signal (refer to fig. 2). Together these take 8 seconds. The 800 lines of picture information that immediately follow take 200 seconds to be transmitted and received. ESSA spacecraft, with their rolling-wheel method of stabilization, revolve at 10 rpm and will not take another picture until they are again in proper position. This takes about 140 seconds, during which time the spacecraft transmits no picture information, only a steady 2400-Hz tone. After the satellite senses that it is in position, another picture is taken and transmitted.

The Nimbus spacecraft is different from the ESSA spacecraft because it is an Earth-oriented satellite always pointing toward the Earth; there is no time lapse between the end of one picture and the start of another.

About twenty minutes are required to track an overhead pass from horizon to horizon. Each satellite will yield up to five good pictures per pass.

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*For all material and prediction data needed to calculate orbital information, write to: APT Coordinator, United States Department of Commerce, Environmental Science Services Administration, National Environmental Satellite Center, Washington, D. C. 20233. USA.

CHAPTER 3

Building The APT Ground Station

Figure 7 is a simplified block diagram of the APT ground station described in this report. During construction, every precaution should be taken to prevent errors in wiring. Each component should be checked before it is used. Care in the early stages of construction can save much time and money later.

The component and circuit descriptions which follow assume only that the builder has a good background in electronics and adequate test equipment.

THE ANTENNA

DESCRIPTION

The antenna, apart from its pedestal, is a critical component of the system. It can easily be built to the following specifications or purchased from $25.00 to $250.00 (at U. S. prices).

The antennas are pictured in figs. 8 and 9.* Whether purchased or handmade, the antenna must have the following characteristics:

- Desirable antenna gain: at least 11 db for elevations from 5 to 90 to 5 degrees
- Acceptable antenna gain: at least 9 db for elevations from 15 to 90 to 15 degrees. Nine db will insure local coverage
- Beamwidth: 45 ± 5 degrees. This is wide enough to provide easy tracking, yet narrow enough to yield sufficient gain
- Frequency: 130 to 140 MHz
- Polarization: right-hand circular

---

*The antennas pictured are made by TACO, although Scientific Atlanta, Hi Gain Cushcraft, Textran, and other antenna manufactures build equally satisfactory equipment. For general construction techniques, see: Radio Amateurs Handbook. American Radio Relay League, 225 Main St., Newington, Connecticut, 06111. Latest edition: $4.00; and VHF Handbook. Radio Publications, Danbury Road, Wilton, Connecticut, 06897, latest edition: $2.95.

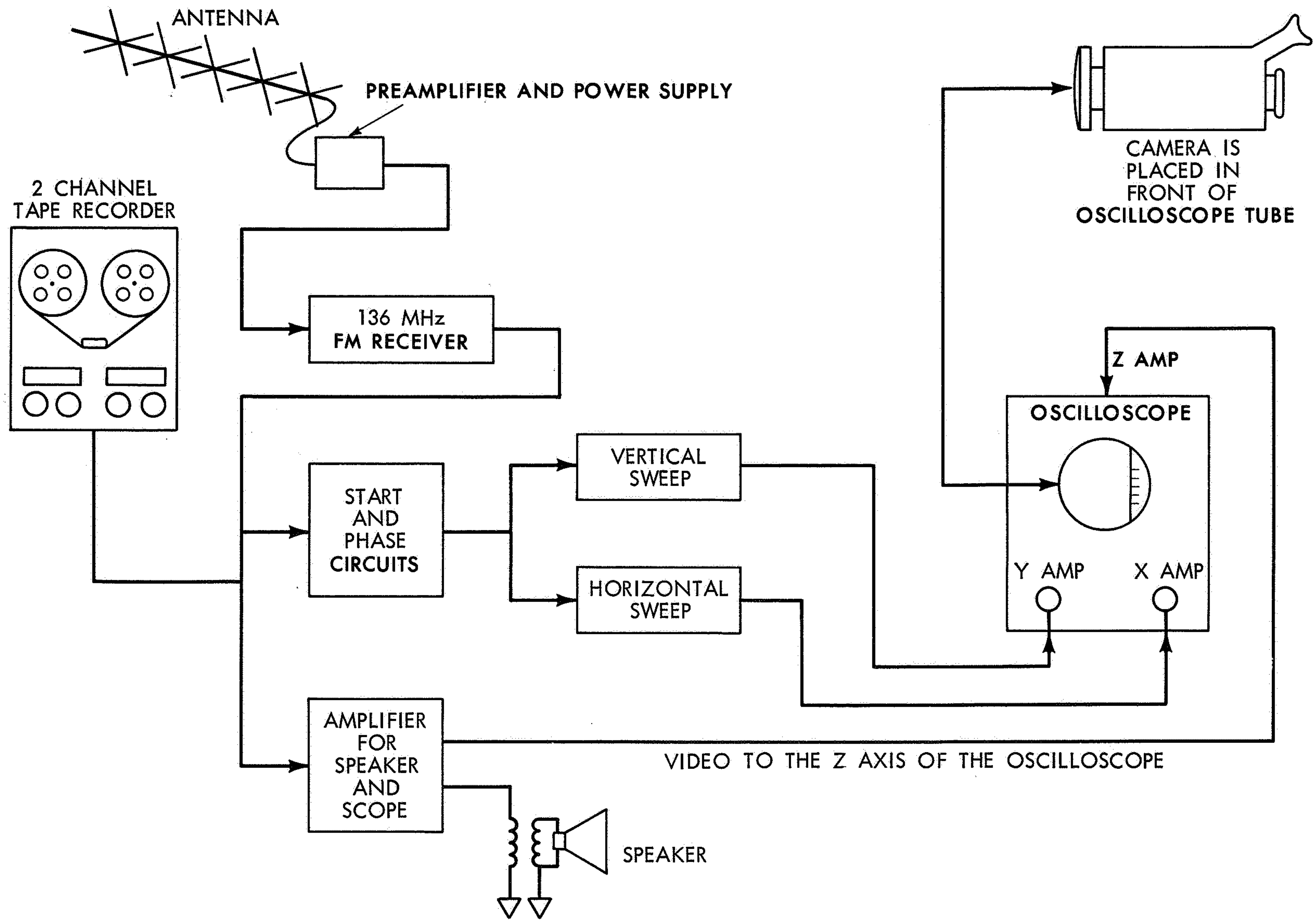


Figure 7.—Simplified block diagram of the low-cost APT station.

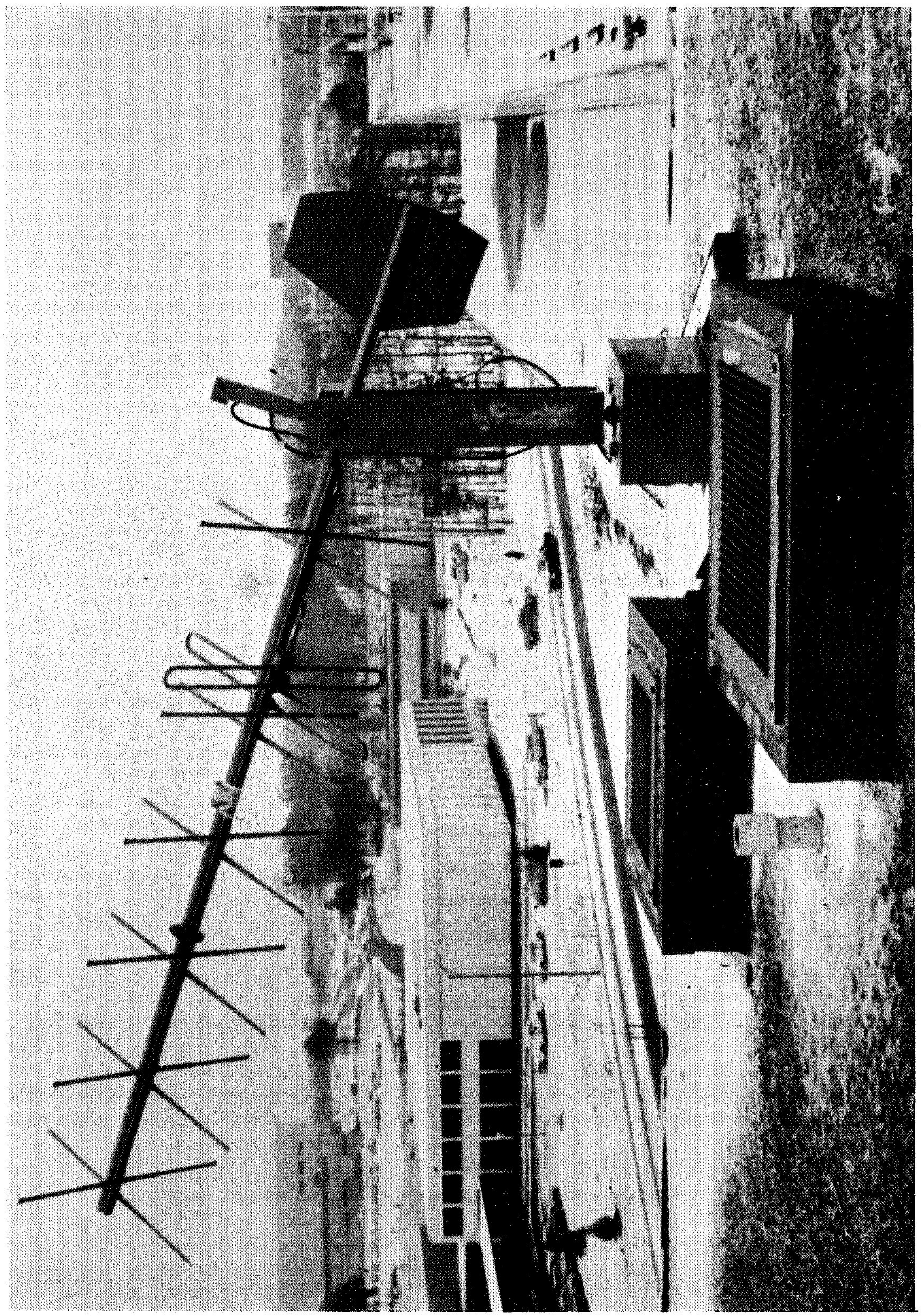


Figure 8.—Dual-axis, single-boom crossed Yagi array.

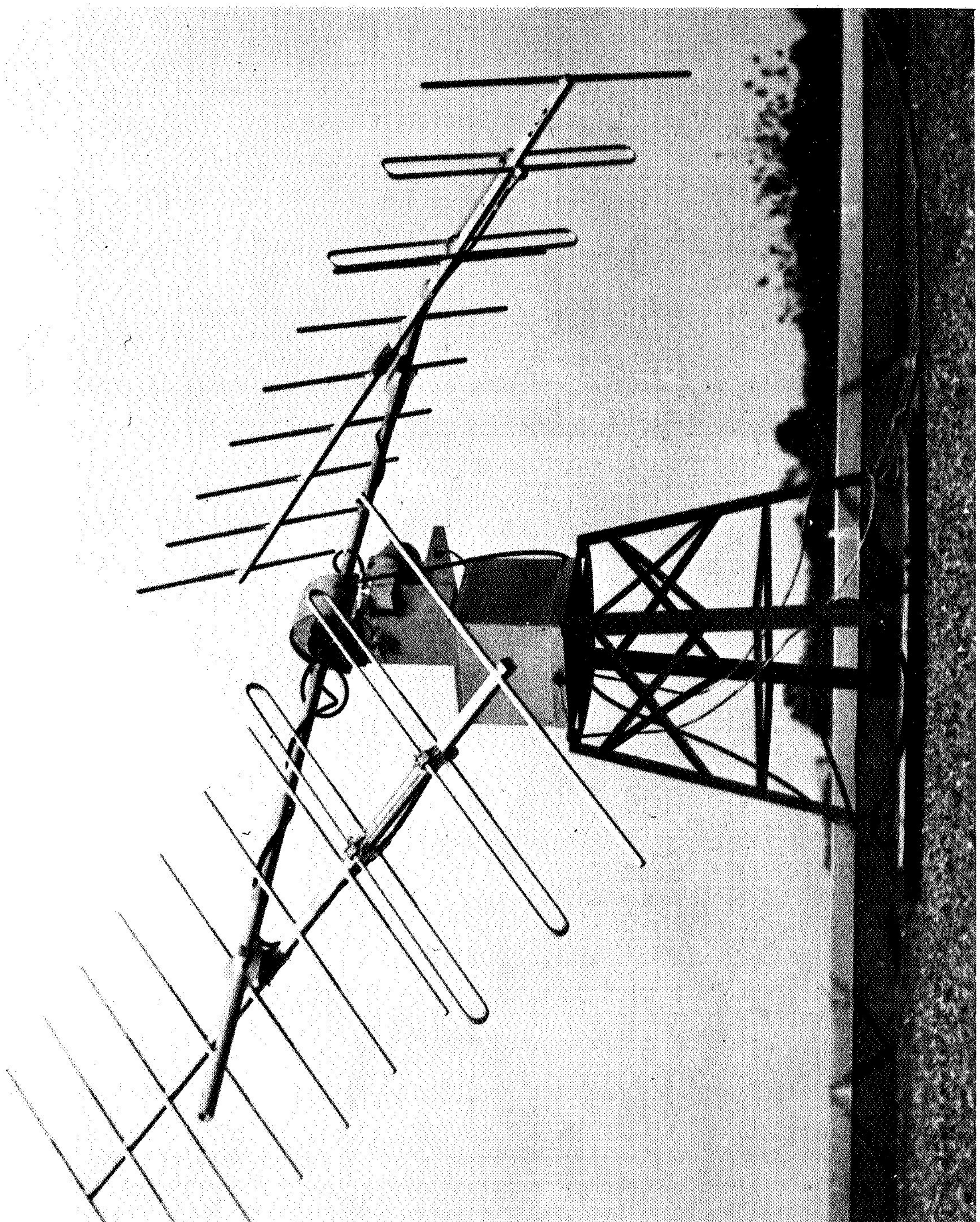


Figure 9.—Dual-axis, double-boom crossed Yagi array.

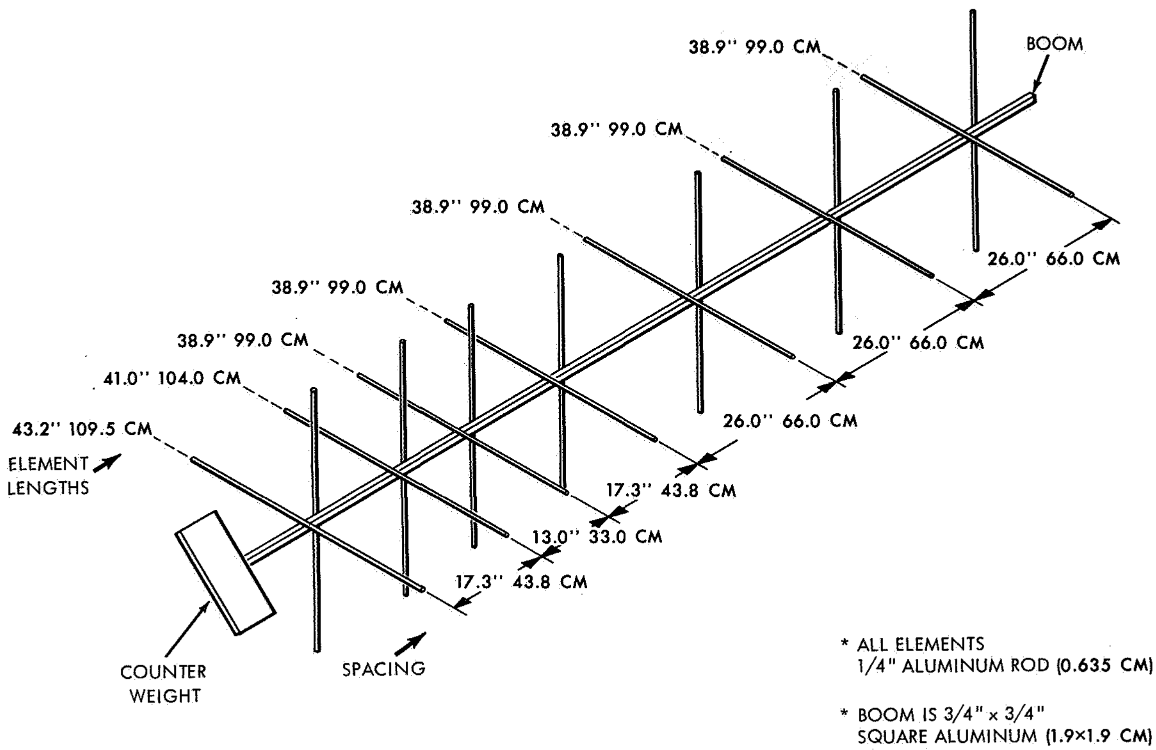


Figure 10. —Antenna element-spacing diagram.

Figure 10 gives element lengths and spacings for a single-boom, crossed-Yagi array. A matching device is required to match the impedance of the array to that of the coaxial transmission line. A gamma match is suggested.

In fig. 11 the connections of the arrays, phasing lines, coaxial switches, and the transmission line are shown. The lengths of cable are joined with coaxial TEE fittings. Switches permit selection of various antenna polarizations to improve the signal.

An overall view of the antenna array is shown in fig. 12. A rectangular boom is preferable to a round one because it is easier to mount the elements on it. Rectangular tubing, however, is more expensive and harder to obtain. If the boom is heavy enough, strengthening guy wires will not be needed. Guy wires, if used, should be nonmetallic and provided with a means for keeping them taut.

ANTENNA POSITIONING DEVICE

The antenna must be mounted so that it can be positioned in azimuth and elevation. Motors for this purpose can be purchased from any of several manufacturers.* The motors should be procured with a control box which can be used in controlling them from the stations.

*A suitable type is the Cornell-Dubilier Electronics, Type HAM-M rotator, which sells for $130.00.

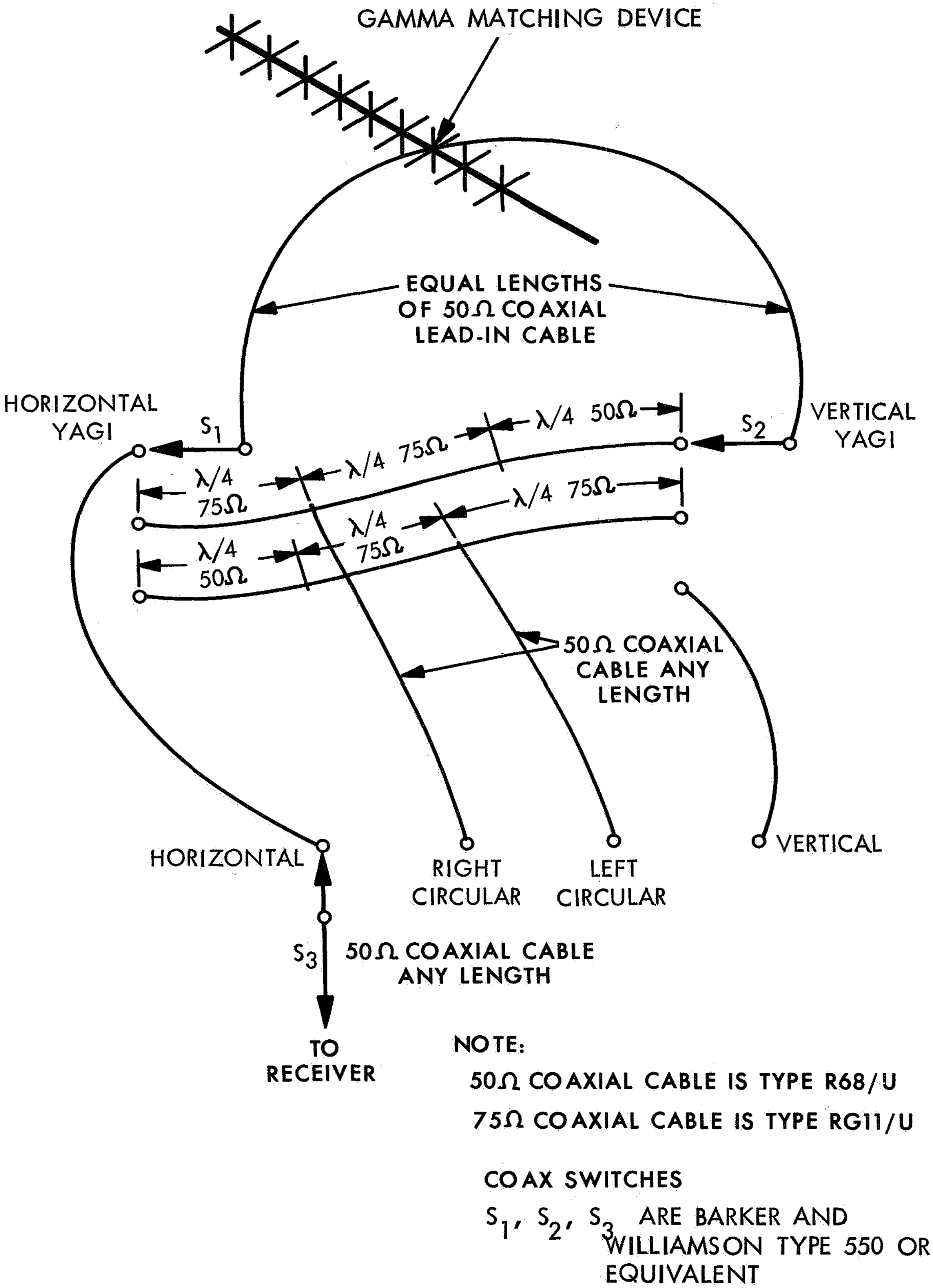


Figure 11.—Antenna-phasing diagram.

The motor shafts must be drilled and pinned with the gears. Select large "cast" gears for strength.* They must be at least 1-inch thick and of sufficient radius to give a 2-to-1 speed reduction. This will yield the proper speed and torque needed to move an antenna of the size mentioned. Refer to figs. 13 and 14 for a mechanical guide for the pedestal and motor mounting.

After the antenna is assembled and working properly, it must be oriented. Since the satellites are not in true polar orbits, the pedestal must be positioned so that it does not hit the azimuth stops during tracking (fig. 15). Set the antenna so that it will rotate from 350 degrees to 170 degrees with 0 degrees at TRUE NORTH (fig. 16). To rotate the antenna from 170 degrees through 350 degrees, the elevation rotator must be run all the way to the other side, with the antenna placed in the western sector. The antenna will track the satellite from horizon to horizon even when the satellite pass is at maximum elevation angle.

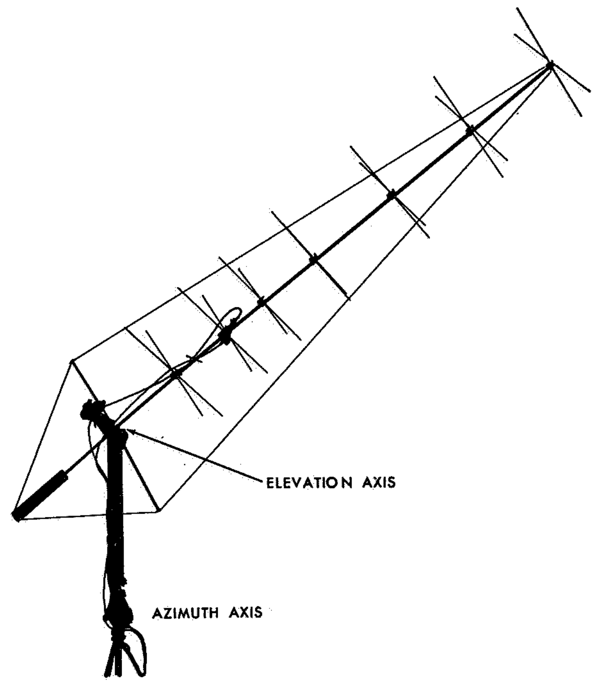


Figure 12.—Assembled Yagi boom support.

Bolt the antenna pedestal to a solid, level surface. This will help damp any oscillation and prevent the pedestal from blowing over in a storm. To bolt the base, pour a solid concrete foundation anchoring large bolts in the concrete before it has hardened. Fasten the antenna base to these bolts after the concrete dries. The antenna may be placed on a roof or tower, if the structure can support the weight (typical weight: 500 pounds).

The position control boxes are usually packed with the motors. Refer to the manufacturer's manual to calibrate the antenna position so that it reads the same as the meter indication. The scales must be removed and scribed, as shown in fig. 17. This may require the services of a draftsman, since these scales are an important part of the console.

ANTENNA PREAMPLIFIERS

The antenna's direct signal is too weak for reception. This condition becomes more severe as the distance is increased between the antenna and the receiver. The signal level must be boosted by a preamplifier located on the antenna pedestal. Of

*Those made by Boston, American Gear, or equivalent manufacturers will be satisfactory.

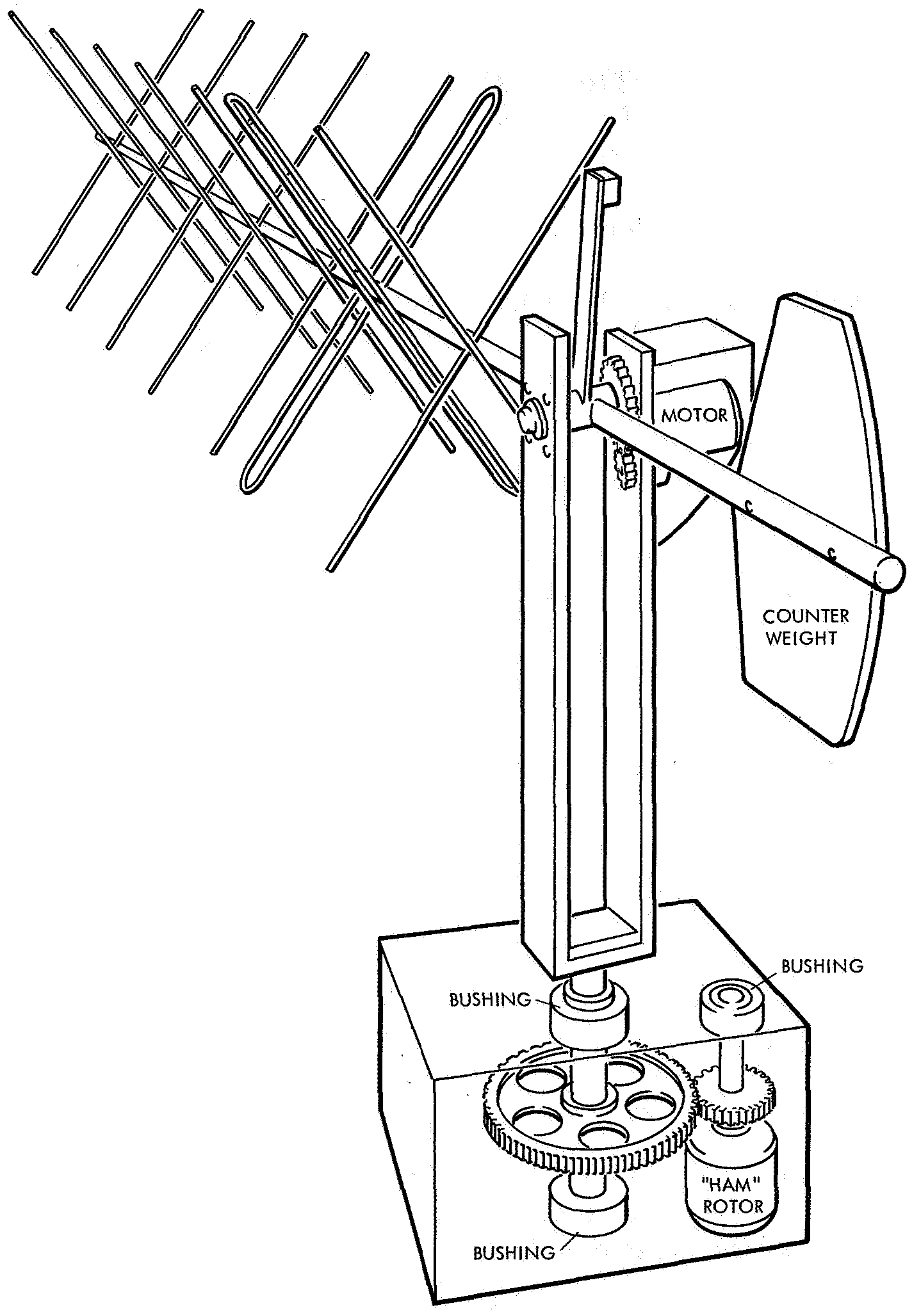


Figure 13.—Mechanical assembly of antenna pedestal.

the two versions of the preamplifier discussed here, version 1 is the easiest to build and can be used with any type of receiver, but it is expensive. Version 2 can only be used with the receiver described in this document because it receives power from that receiver. Version 2 is recommended.

Figure 18 shows the schematic and coil construction data for preamplifier version 1. When this design is used, it is recommended that two preamplifiers be fabricated and placed in series to improve the signal level. The two units may be

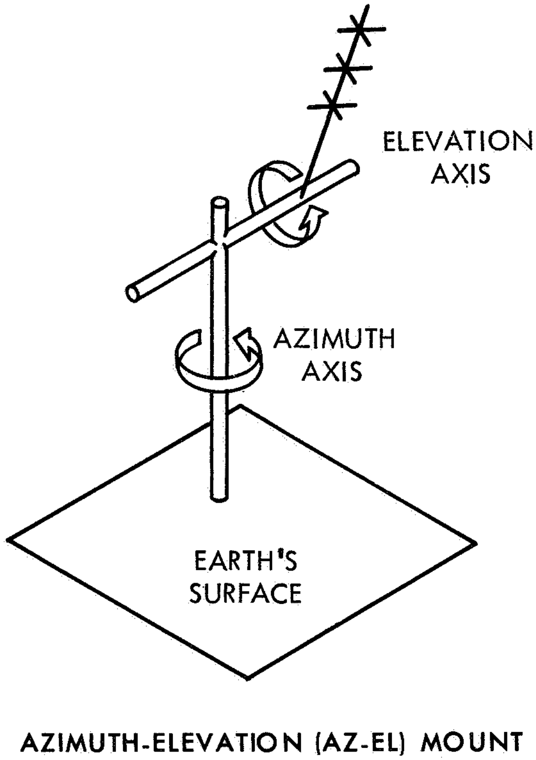


Figure 14.—Simplified antenna positioning.

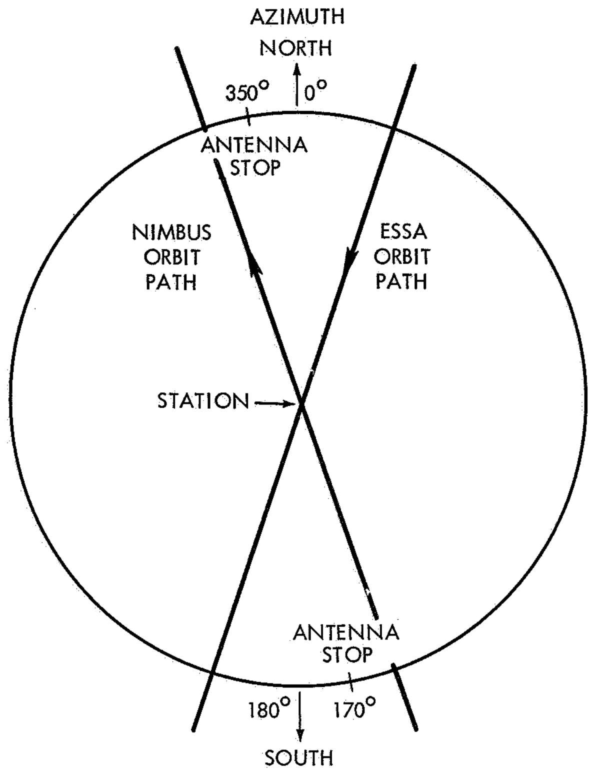


Figure 15.—Antenna orientation.

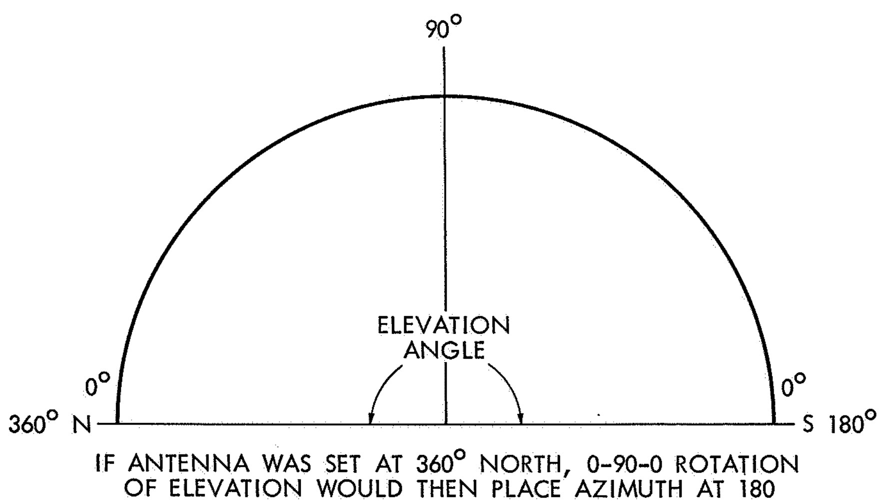


Figure 16.—Limits of antenna orientation.

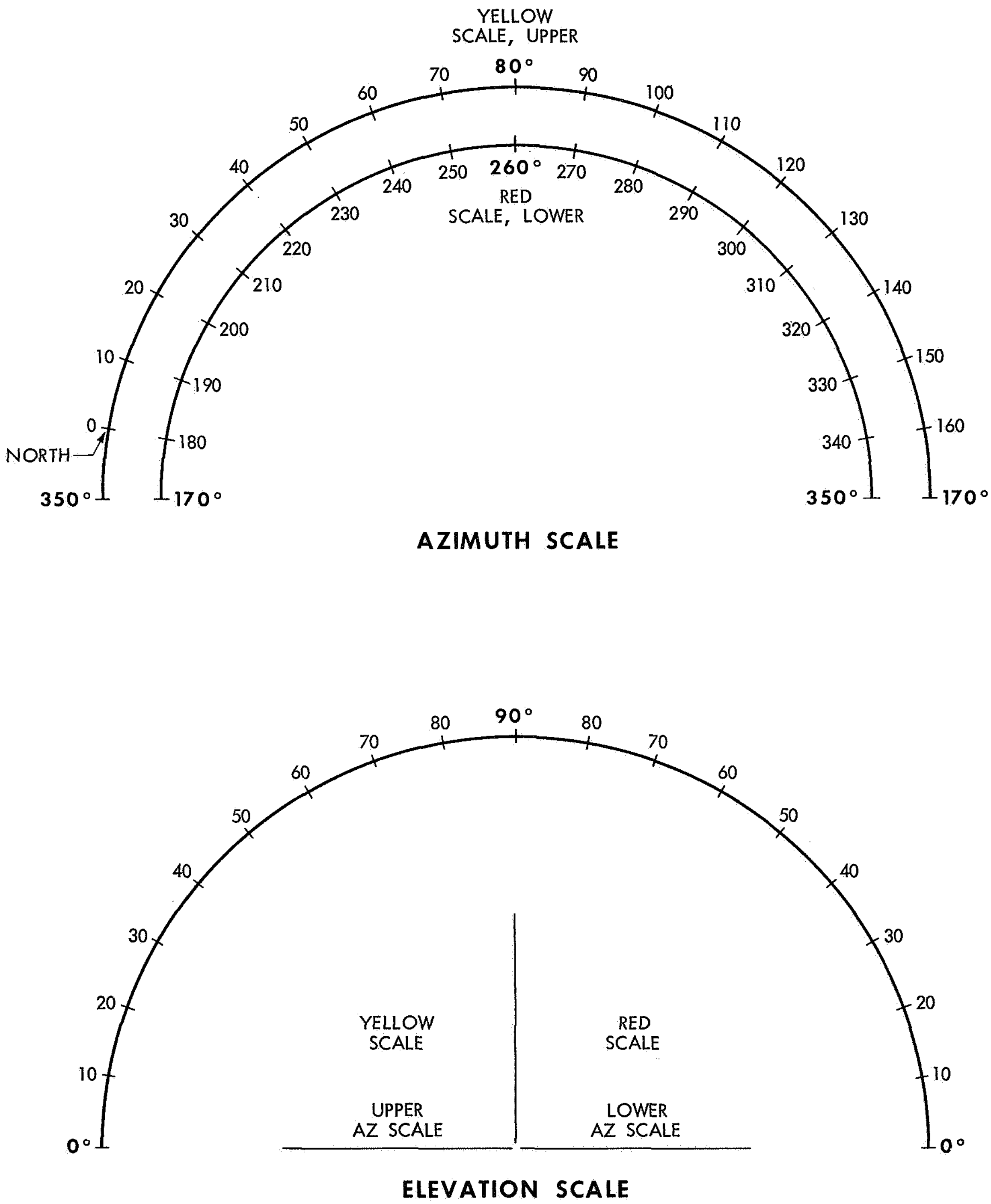
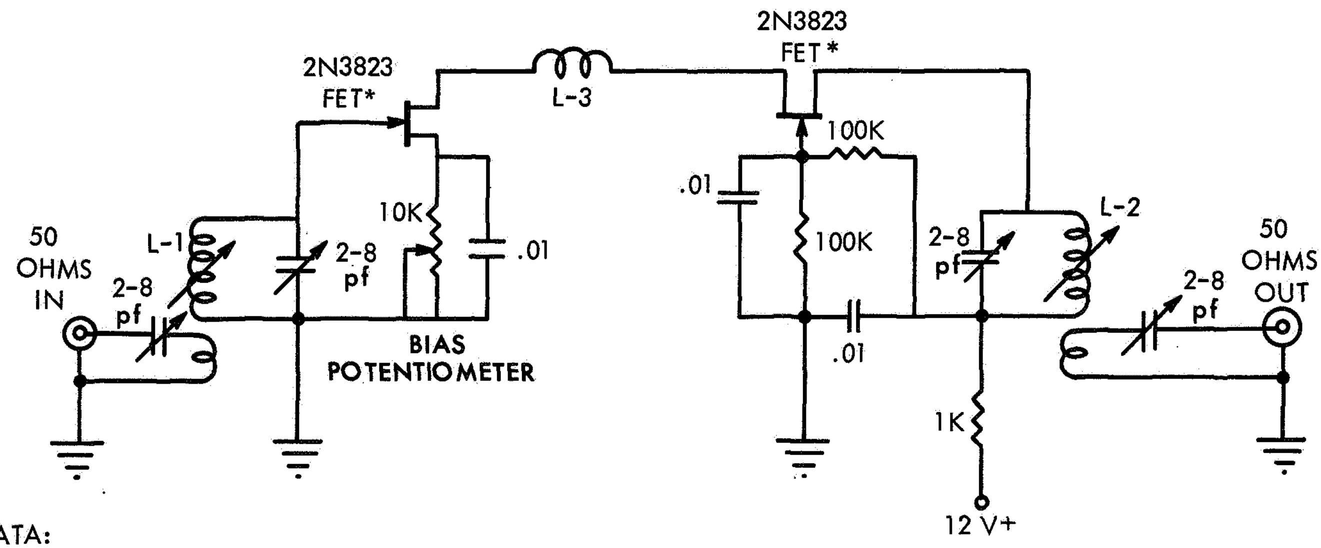


Figure 17.—Scales for recalibration of antenna-control boxes.



COIL DATA:
L-1; PRIMARY, TWO TURNS #22 PLASTIC INSULATED WIRE, CLOSE WOUND OVER THE COLD END OF THE SECONDARY.
SECONDARY, SIX TURNS #22 WIRE SPACED TO FILL FORM.

L-2; PRIMARY, SIX TURNS #22 WIRE SPACED TO FILL FORM.
SECONDARY, ONE TURN #22 PLASTIC INSULATED WIRE, CLOSE WOUND OVER THE COLD END OF THE SECONDARY.

USE CAMBION COIL FORM, PART #1536-4-2.

L-3; THIRTEEN TURNS #26 ENAMEL COATED WIRE, CLOSE WOUND ON 100K OHM 1/2W. RESISTOR AS CORE.

*FIELD - EFFECT TRANSISTOR (TEXAS INSTRUMENTS).

CAPACITOR VALUES IN MICROFARADS UNLESS OTHERWISE SPECIFIED.

Figure 18.—Antenna preamplifier, version 1, schematic.

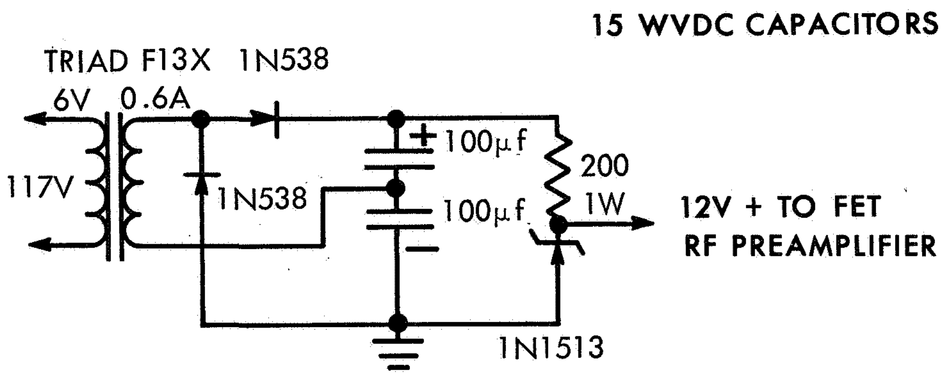


Figure 19.—Antenna preamplifier, version 1, power supply schematic.

placed in a single box of rigid aluminum construction that is completely weatherproof. Power can be fed in through an epoxy-sealed hole. Type-N coaxial connectors are used for input and output.

The number of turns in coil L3 does not appear to be critical. It can be adjusted at 136 MHz for the best noise figure. In order to keep distributed capacity to a minimum, the transistors were wired into the circuit and soldered directly to the leads. Leads should be as short as possible. All sensitive components must be protected from heat by placing a metal clamp between the soldering connection and the component body while heat is applied.

Tuning is not critical. A 136-MHz weak signal should be induced in the receiving antenna during all tuning adjustments. The bandwidth will be several MHz wide. Tuning can be accomplished with a noise generator.* If transmission line lengths are changed, amplifier circuits will probably need retuning.

The 2.8-pf capacitors used are the miniature type, about 3/8 inch (0.95 cm) in diameter. These capacitors should be soldered directly to the coil lugs. The adjustable capacitors across the input and output tank circuits are best set to near-resonance with the coil slug at its mid position. Fine tuning can be done from the top of the chassis.

Proper setting of the bias potentiometer is important because it affects both noise figure and gain. At zero bias, the circuit gain is at maximum and the amplifier is noisy. As the bias is increased, the noise output decreases exponentially. The bias control is properly set when both the gain and the noise decrease slowly. An exact value of bias cannot be given, because it varies with transistor characteristics.

Figure 19 shows a suitable power supply for preamplifier version 1.

Figures 20, 21, 22, 23, and 24 show the schematic and construction details for preamplifier version 2. This preamplifier receives its dc operating voltage

*If this equipment is not available, refer to: Radio Amateur's Handbook, ibid, or the VHF Handbook, ibid.

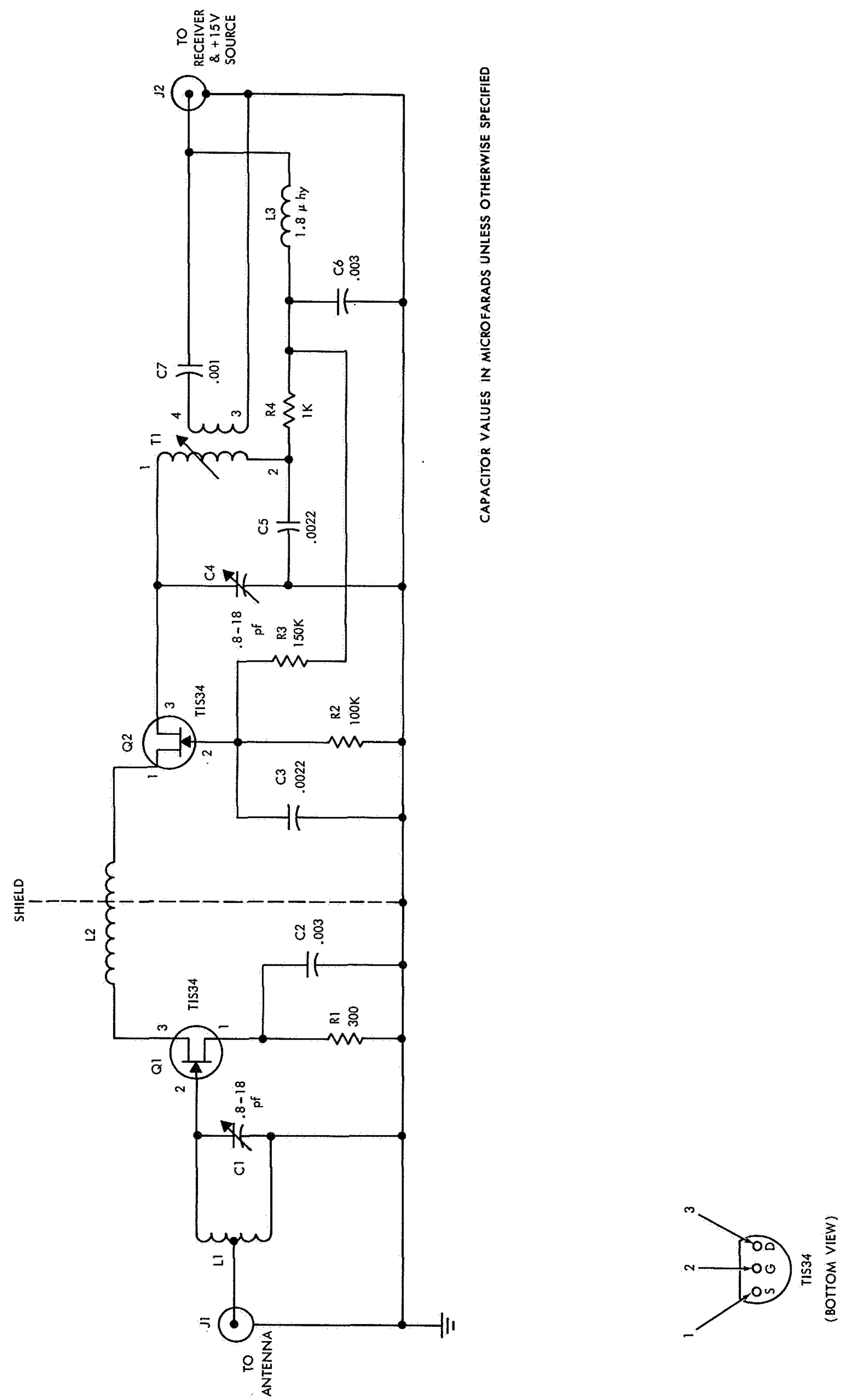
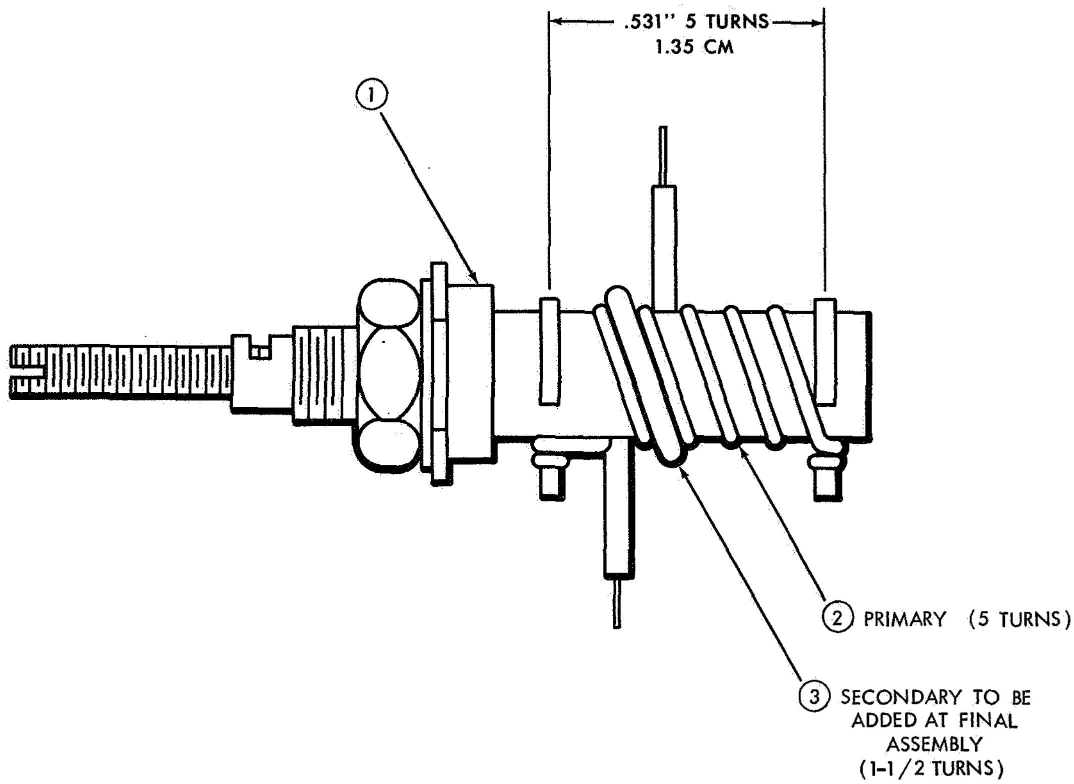
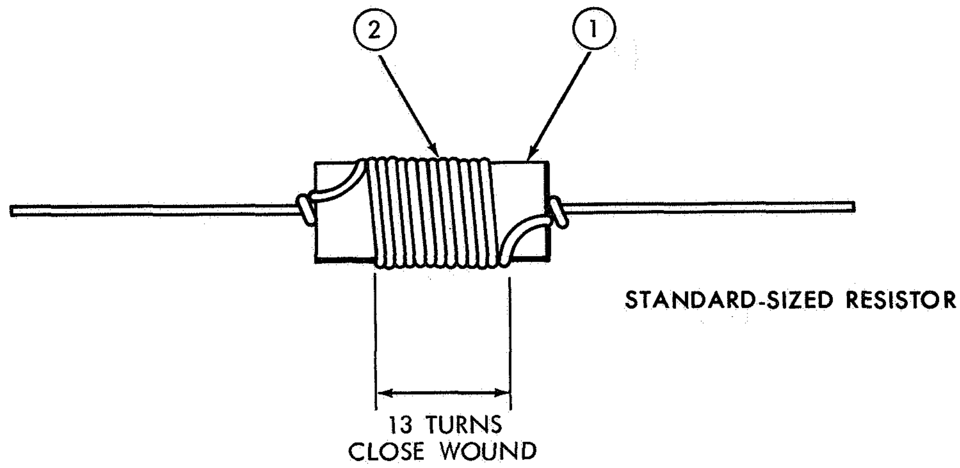


Figure 20.—Antenna preamplifier, version 2, schematic.



PART NO.	ITEM	DESCRIPTION
	4	SOLDER, SN60/SN63
8530	3	WIRE, SOLID, BELDEN #22, THERMOPLASTIC INSULATION
8020	2	BUS WIRE, BELDEN #20, TINNED COPPER
4500-2	1	COIL FORM, J.W. MILLER

Figure 21.—Output transformer T1 for antenna preamplifier, version 2.



	3	SOLDER, SN60/SN63
8065	2	WIRE, SOLID, BELDEN #26 HNC NYCLAD
RN20	1	RESISTOR, FIXED COMPOSITION , 100K, 1/2 WATT
PART NO.	ITEM	DESCRIPTION

Figure 22.—Neutralizing inductor L2 for antenna preamplifier, version 2.

from the receiver through the same coaxial cable that carries the amplified signal. The mounting details and alignment data given for preamplifier version 1 apply to this version also.

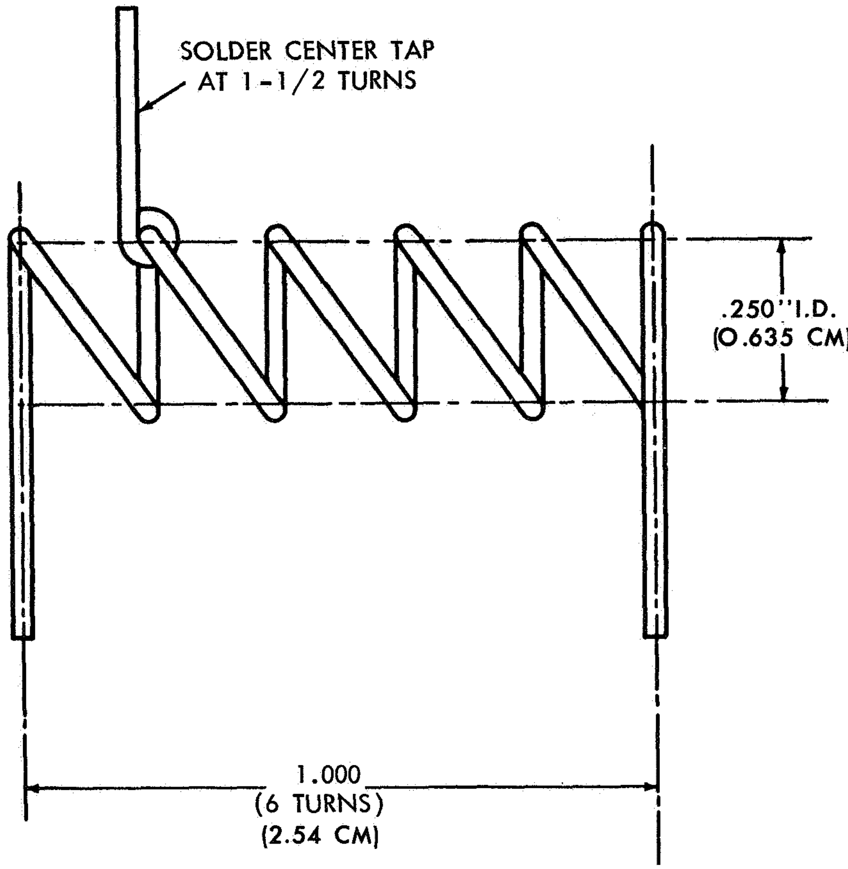
THE FM RECEIVER

PROCUREMENT OR CONSTRUCTION?

The FM receiver is the most critical part of the APT station. It must be relatively noise-free and equipped with automatic frequency control (AFC), automatic gain control (AGC), and a meter to indicate signal strength for tracking purposes.

Whether the receiver is designed for telemetry or is a communication receiver/converter combination, it should:

- Have a 1-microvolt input for 27 db of quieting.
- Have a 50-kHz bandwidth minimum, 80-kHz maximum.
- Be crystal-controlled if possible.



PART NO.	ITEM	DESCRIPTION
	2	SOLDER, SN60/SN63
8019	1	BUS WIRES, BELDEN #18 TINNED COPPER

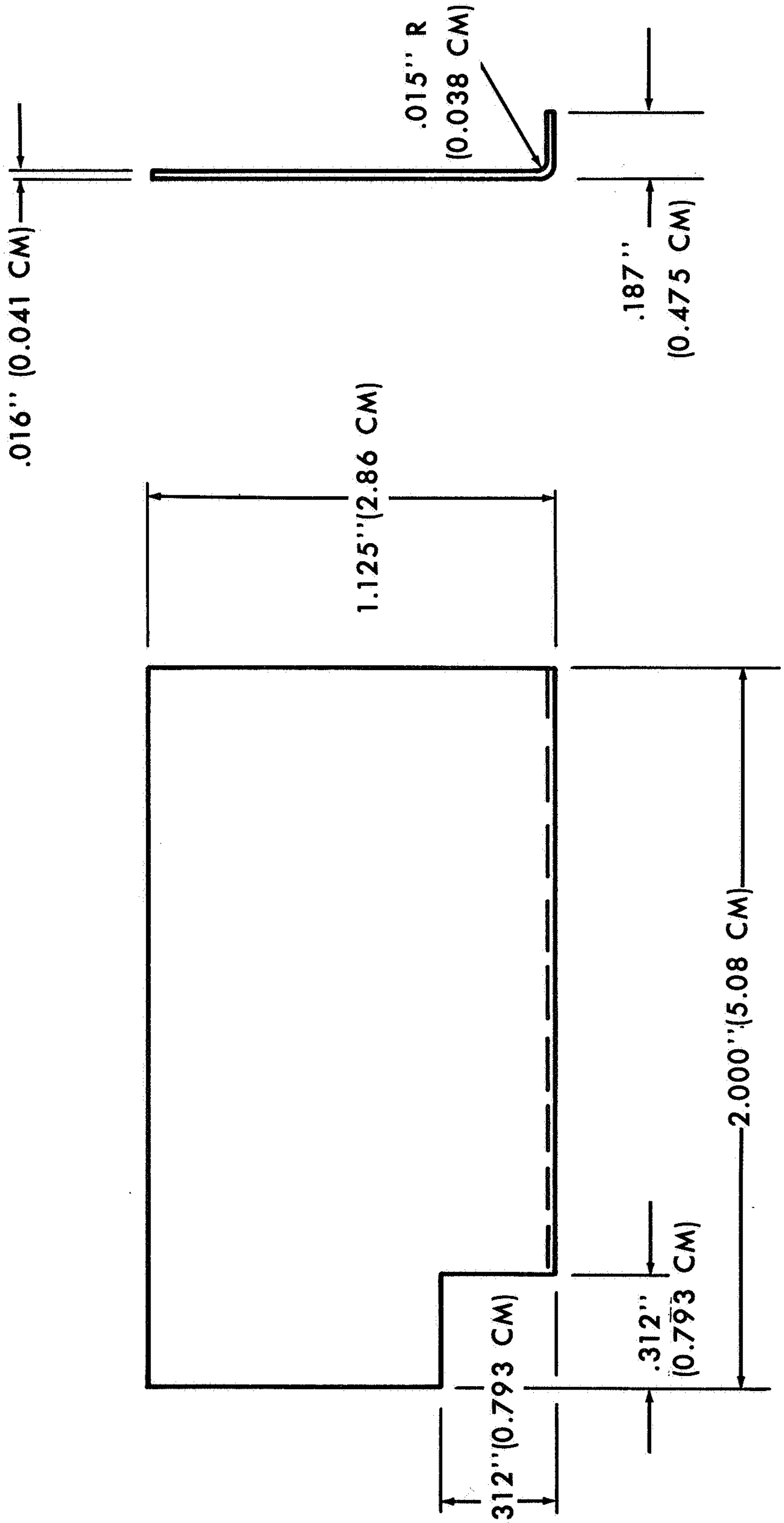
Figure 23.—Input inductor L1 for antenna preamplifier, version 2.

- Be capable of receiving the following frequencies: 135.6 MHz Weather Facsimile (WEFAX); 136.95 MHz (Nimbus); 137.5 MHz and 137.62 MHz (ESSA).*

The builder may procure his receiver in any of the following ways:

- Most suitable is the use of a standard telemetry receiver—readily available from most surplus equipment dealers. Some receivers may have to be converted to accommodate the necessary frequencies.

*ESSA has proposed that every other APT-equipped satellite use 137.62 MHz to avoid a conflict between two ESSA satellites in operation at the same time.



NOTE: BREAK SHARP EDGES AND REMOVE ALL BURRS.

Figure 24. —Shield for antenna preamplifier, version 2.

- Combine a good quality "ham" communications receiver, such as the BC603, and a commercially available frequency converter.* The BC603 is a military designation for an AM-FM receiver; the range of 21 to 25 MHz is satisfactory and is available in this receiver.
- Be sure to specify the four input frequencies mentioned above when ordering the converter and crystals. The frequencies can be converted from the 136-MHz range down to the receiver range. Choose a frequency within the range of the receiver for the converter output. Hardwire the converter output directly to the receiver input. Disconnect the receiver antenna if it is connected and match the impedances to the tracking antenna if they are unmatched. The receiver output must be one volt peak-to-peak for normal operation with the video electronics described under the Facsimile Unit.
- Build the receiver yourself. This is advantageous because you can integrate it into the oscilloscope housing along with the video electronics. Figures 25, 26, 27, 28, and 29 show the schematic and other details needed to build the receiver. The required parts are listed in Appendix A. The crystal specification given by fig. 26 should be used when purchasing the receiver's crystal. The receiver components should be mounted on fiber printed circuit boards, with appropriate holes drilled beneath tuning slugs that have bottom adjustments.

If the receiver is built into the oscilloscope plug-in unit, a plug-in extender must be made. The only mechanical detail of this extender necessary to the functioning of the receiver is that the extender match the oscilloscope's internal connector. The extender permits access to the internal circuits of the receiver. After the receiver is finished, the following alignment procedure should be observed:

FM RECEIVER ALIGNMENT

To align the FM receiver:

(1) Set the frequency of an FM-signal generator to 10.7 MHz to align the IF. Check the frequency with a counter if one is available. If not, refer to suggested procedures in the ARRL or VHF Handbook.

(2) Place the plug-in on the extender and apply power with the POWER ON switch.

(3) Turn the AFC switch to OFF. Connect the output of the FM-signal generator to pin 7 of tube V4.

(4) Connect the oscilloscope to pin 2 of tube V8.

(5) Increase the FM-signal generator output level until a signal is observed on the oscilloscope.

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*A suitable converter can be obtained from Ameco Equipment Corporation, Tapetone, and other manufacturers for about $48.00, including the power supply. (Specify input and output frequencies when ordering.)

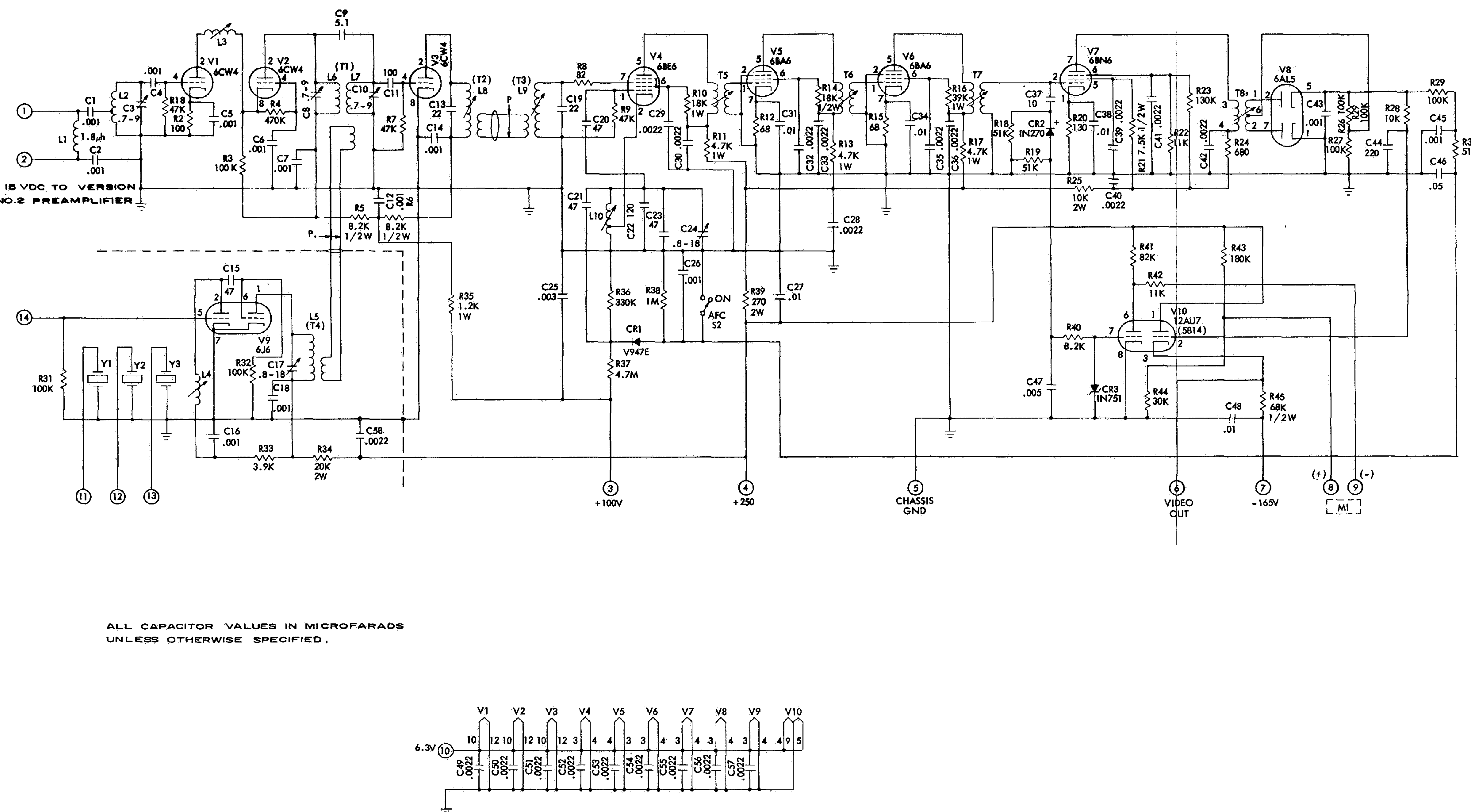


Figure 25. —VHF receiver schematic.

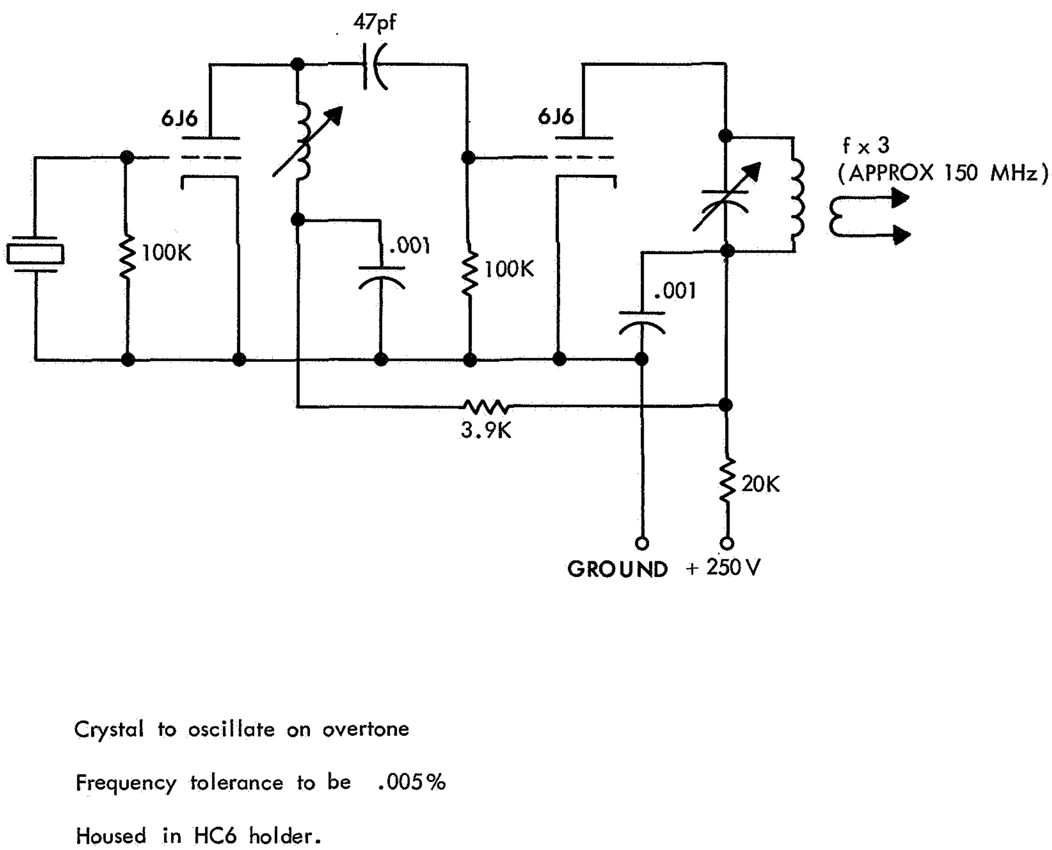


Figure 26. —Receiver-crystal circuit schematic.

(6) Using a fiberglass tuning tool, adjust the bottom tuning slug of transformer T8 (reached from the bottom of the plug-in through a hole in the PC board) for maximum amplitude as observed on the oscilloscope. Do not adjust the top tuning slug of T8.

(7) Adjust IF transformer T7 for maximum output amplitude as observed on the oscilloscope. The bottom tuning slug (reached from the bottom side of the plug-in through a hole in the PC board) should be adjusted first, followed by the adjustment of the top tuning slug (through the hole at the top of the IF can).

(8) Repeat step 7 for IF transformer T6.

(9) Repeat step 7 for IF transformer T5.

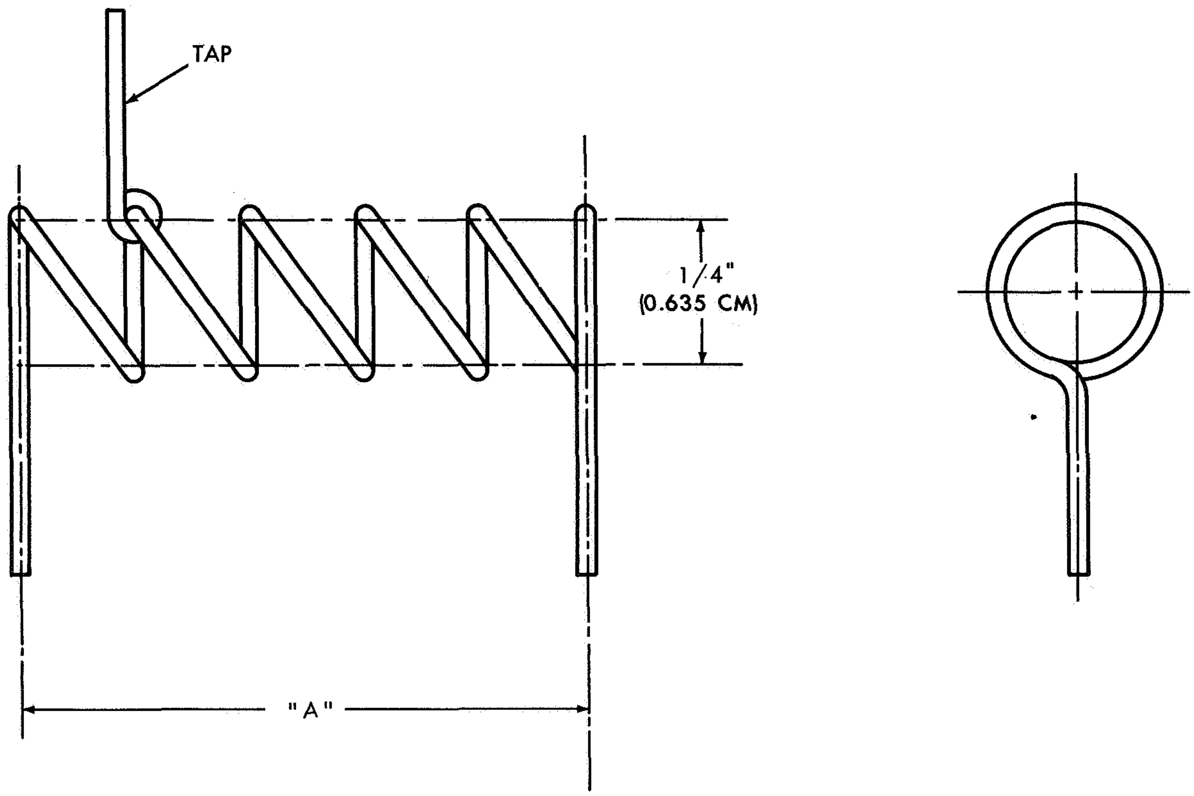
(10) Because of some interaction between stages, repeat steps 6 through 9 if a large adjustment was required for any stage.

(11) Connect the oscilloscope to pin 5 of tube V8.

(12) Adjust the top tuning slug of discriminator transformer T8 to zero-volt level at pin 5 of tube V8.

(13) Connect the FM-signal generator to pin 2 of tube V3.

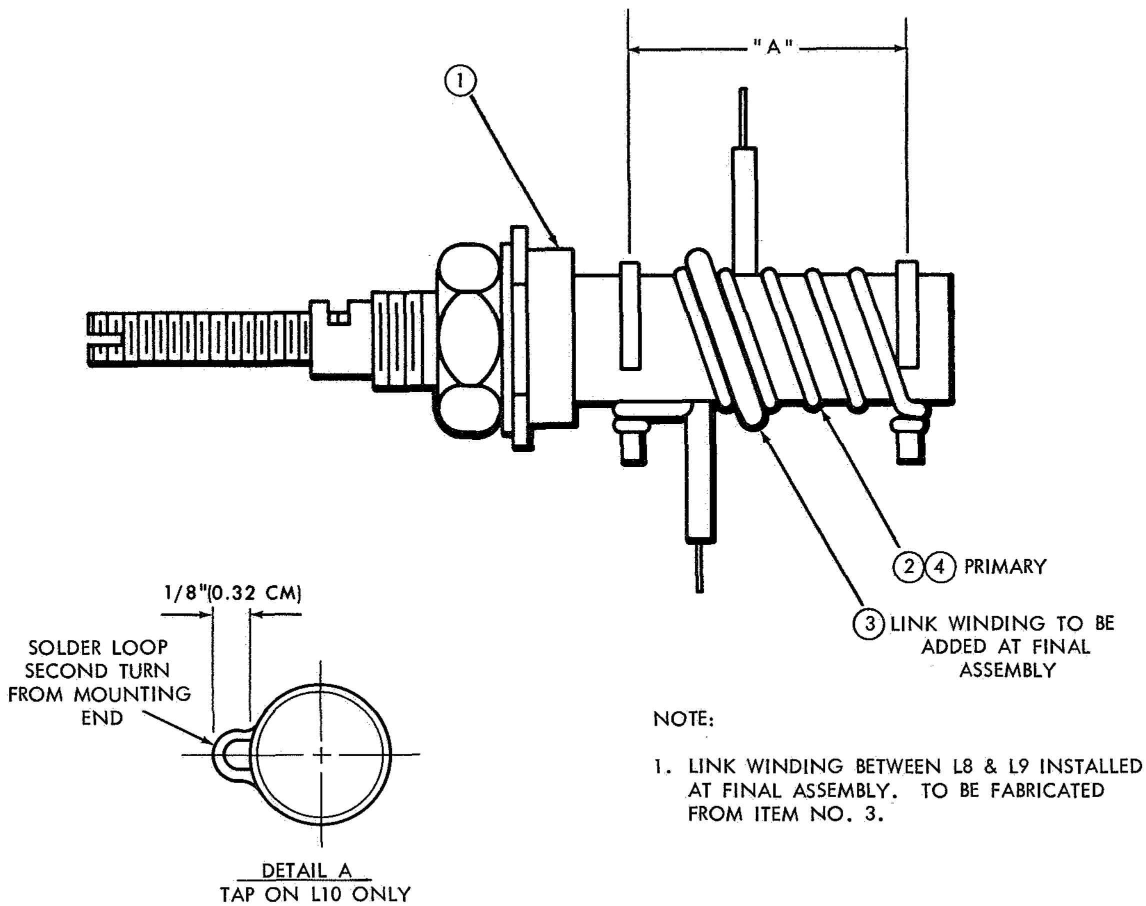
(14) Adjust the FM-signal generator frequency to 17.55 MHz. Check the frequency with a counter.



SYMBOL	DIMENSION "A"	NO. OF TURNS	WIRE SIZE	TAP
L2	5/8" (1.59 CM)	4	#18	1 TURN
L5	3/4" (1.90 CM)	6	#18	NONE
L6	3/4" (1.90 CM)	6	#18	NONE
L7	3/4" (1.90 CM)	5	#18	NONE
L1	3/4" (1.90 CM)	6	#18	1 3/4 TURN

	2	SOLDER, SN60/SN63
8019	1	BUS WIRE, BELDEN #18 TINNED COPPER
PART NO.	ITEM	DESCRIPTION

Figure 27.—Inductors L1, L2, L5, L6, and L7 for VHF receiver.



NOTE:

1. LINK WINDING BETWEEN L8 & L9 INSTALLED AT FINAL ASSEMBLY. TO BE FABRICATED FROM ITEM NO. 3.

SYMBOL	DIMENSION "A"	NO. OF TURNS	WIRE SIZE	TAP	LINK WINDING
L4	CLOSE WOUND	9	#26	NONE	NONE
L8	CLOSE WOUND	25	#26	NONE	2 TURNS
L9	CLOSE WOUND	25	#26	NONE	2 TURNS
L10	1/2" (1.27 CM)	6	#18	2 TURNS	NONE

REQD	PART NO.	ITEM	DESCRIPTION	SYM
AR		5	SOLDER, SN60/SN63	
AR	8065	4	WIRE, SOLID, BELDEN #26, HNC NYLCLAD	
AR	8035	3	WIRE, SOLID, BELDEN #22, THERMOPLASTIC INSULATION	
AR	8019	2	BUS WIRE, BELDEN #18, TINNED COPPER	
1	4500-2	1	COIL FORM, J. W. MILLER	

Figure 28.—Inductors L4, L8, L9, and L10 for VHF receiver.

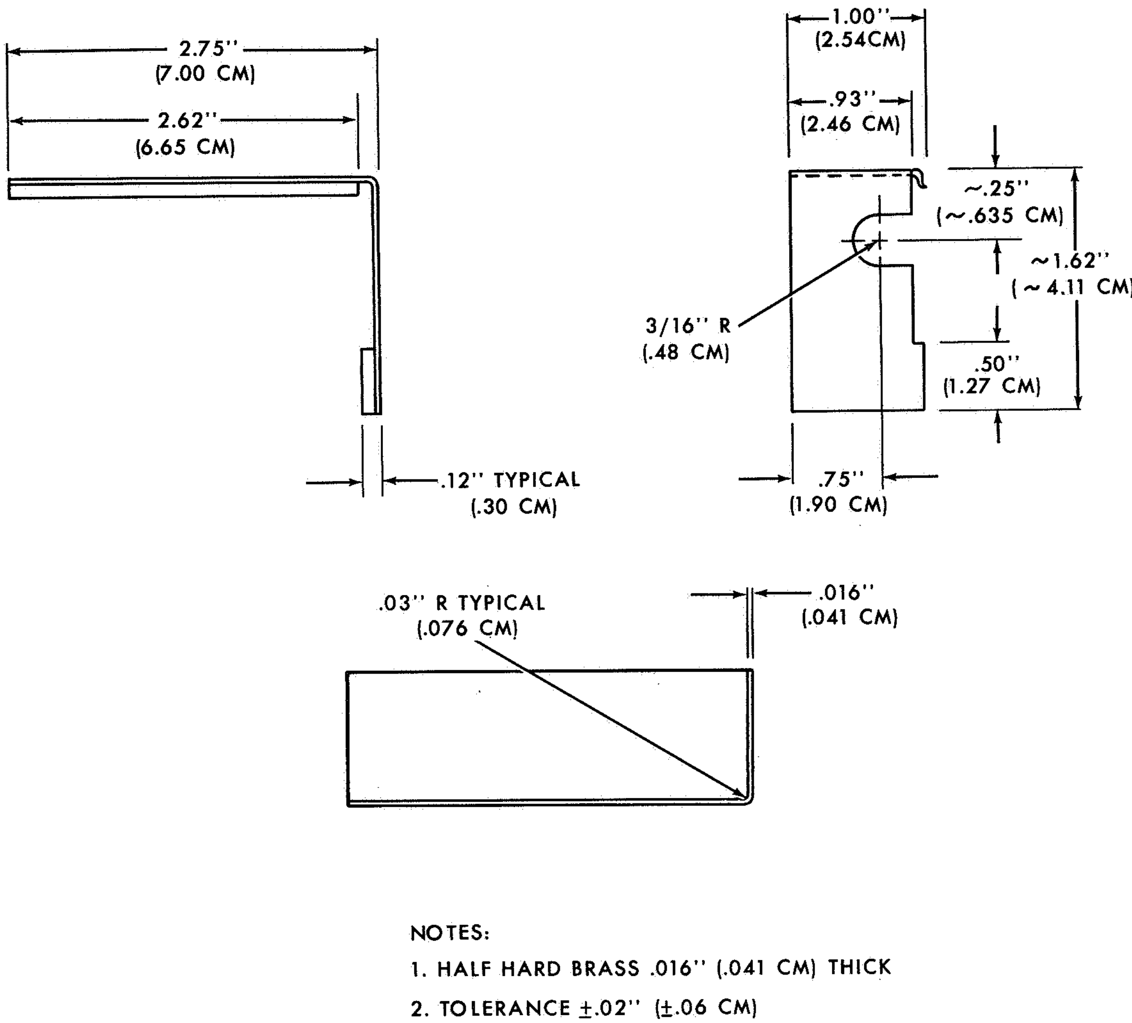


Figure 29.—Shield for VHF receiver.

(15) Observe the signal at pin 7 of tube V8.
(16) Adjust inductor L10 for maximum output. Frequency across L10 should be 28.25 MHz.
(17) Set the CHANNEL switch to B.
(18) Adjust inductor L4 for maximum dc level at the junction of resistors R33 and R37. The level should be from 120 to 160 volts dc. Frequency across L4, which can be checked with a grid-dip meter, should be 51.5 MHz.
(19) Using a grid-dip meter, adjust capacitor C17 for maximum output at 154.5 MHz.
(20) Set the FM-signal generator to 136.95 MHz and 10 kHz deviation. Check the frequency with a frequency counter.
(21) Connect the output of the signal generator to the RF input at the front panel. NOTE: 15 volts dc is supplied through the RF cable to the

antenna preamplifiers; therefore, use capacitor coupling between the signal generator and the RF input.

(22) Connect the oscilloscope to pin 3 of tube V10.

(23) Tune capacitor C10 for maximum output.

(24) Tune capacitor C8 for maximum output.

(25) Tune inductor L3 for maximum output.

(26) Tune capacitor C3 for maximum output.

(27) Set the FM-signal generator to 137.5 MHz and set the CHANNEL selector switch to C. Adjust inductor L9 for maximum output.

(28) Set the FM-signal generator to 135.6 MHz and set the CHANNEL selector switch to A. Adjust inductor L8 for maximum output.

(29) Because of some interaction between stages, steps 21 through 28 should be repeated if a large adjustment was required for any stage.

(30) If the SIGNAL strength meter does not read zero with no signal input, adjustment in voltage divider R43, R44 may be required.

(31) Turn the AFC switch to ON.

(32) Set the FM-signal generator to 136.95 MHz and set the CHANNEL selector switch to B. Observe peak-to-peak amplitude on the CRT when the W. F.-PIC switch is in the W. F. mode. With 10-kHz input deviation applied to the receiver, the signal should be ±0.3 centimeter peak-to-peak in amplitude. Adjustment can be made by changing resistor R95, which is located on the receiver board.

THE FACSIMILE UNIT

The electrical portion of the facsimile unit consists of the video electronics and an oscilloscope display device. The video electronics may be built as a separate unit. If this is done, almost any model oscilloscope may be used. Both the video electronics and the receiver may be built into the same housing as the oscilloscope if an Analab Model M1100 or its equivalent is obtained. This model should be obtained without the plug-in unit and panel markings. Figure 30 shows the finished station when all the electronics are incorporated into the Analab oscilloscope. The oscilloscope must have the following features:

- Flat-face, low-persistency cathode-ray tube (CRT) (such as P11 phosphor), 5 inches (approx. 12 cm) in diameter, with less than 0.005 inch (0.012 cm) spot size for 800-line resolution. (Increased spot size creates slight degradation.)
- X and Y (horizontal and vertical) amplifiers.
- Z-axis input.
- A mounting ring (bezel) to connect "scope" camera.

Figure 31 shows the location of all the controls on the plug-in. The front panel should be made of heavy gauge aluminum for rigidity. Measure the internal space for the plug-in so that the connector already in the oscilloscope may be used.

The last steps are: (1) wiring the video electronics, (2) properly connecting this unit to the oscilloscope, and (3) mounting a scope camera on the CRT. (The

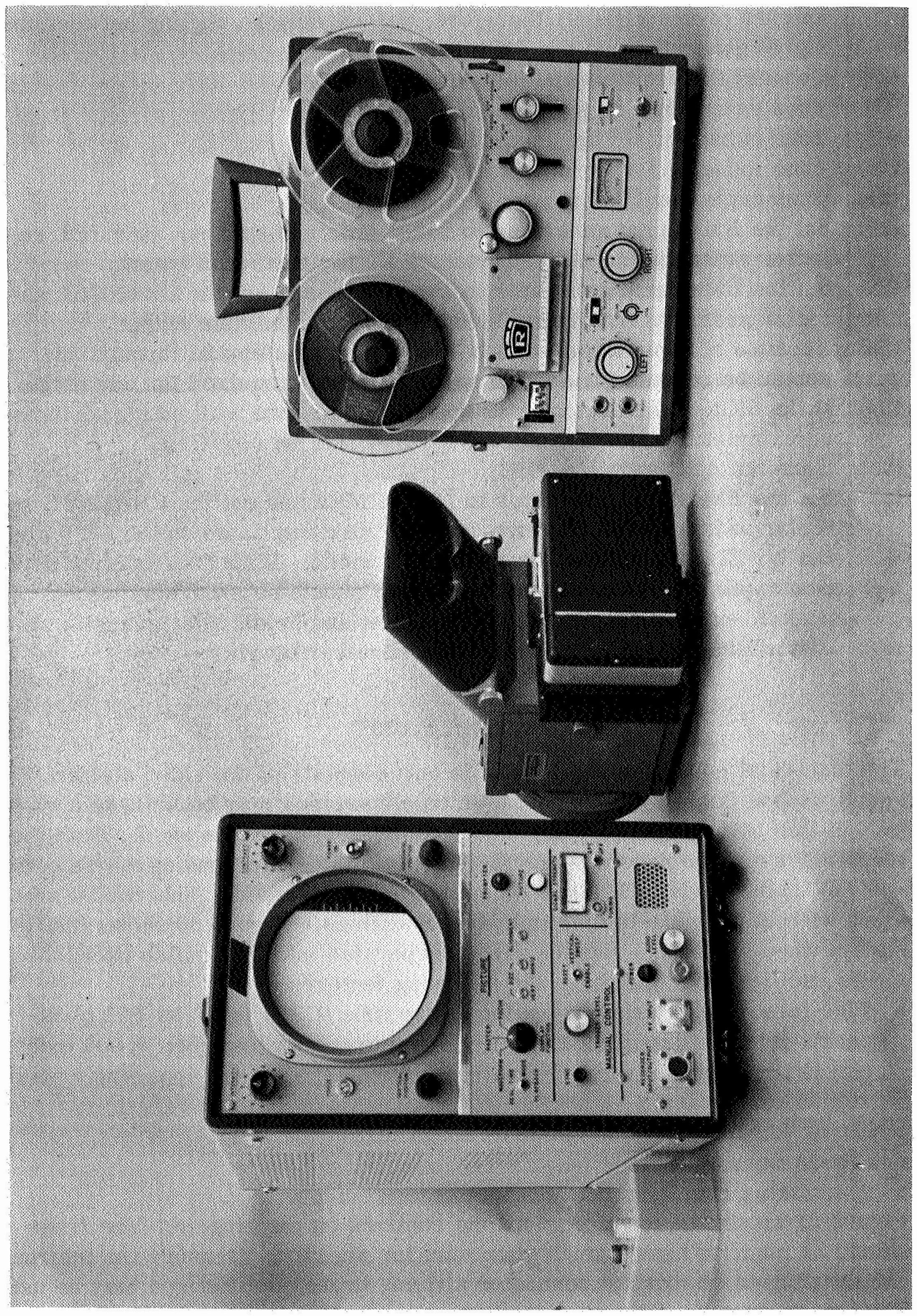


Figure 30.—Assembled APT station.

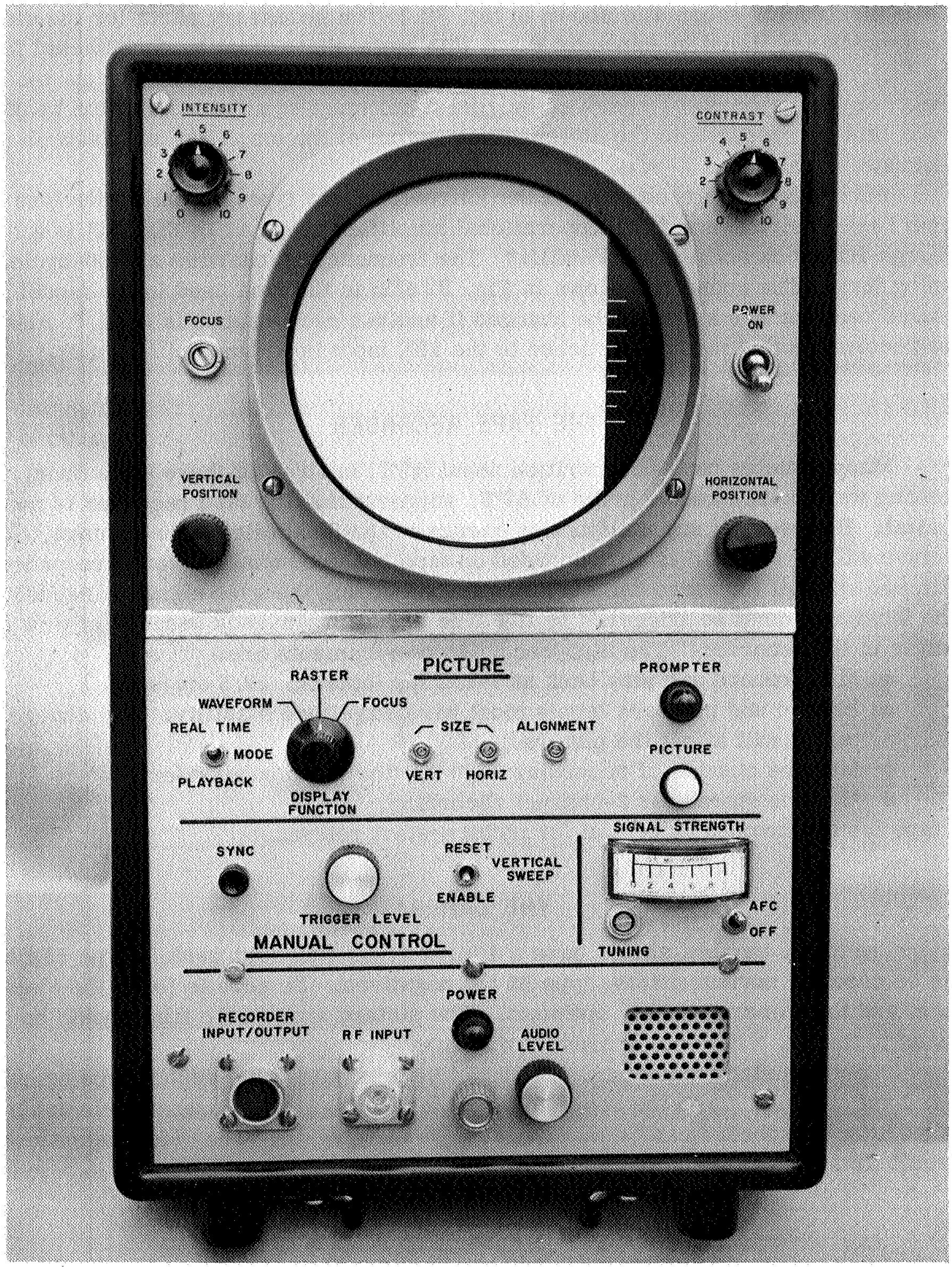


Figure 31.—APT station controls.

video electronics schematic shown in fig. 32.) The necessary parts for the video electronics are listed in Appendix B. A thin metal plate must be constructed for the face of the CRT, and calibrated in centimeters. The video output from the tape recorder (in playback) or receiver (in real time) must be adjusted to 2 cm peak-to-peak; this corresponds to the 800-millivolt output of the amplifier and assures an adequate signal to the Z-axis.

All integrated circuits are of the Fairchild epoxy type.* Semiconductors are from Texas Instruments.* The operational amplifier used (A1 in Fig. 32) is a George Philbrick solid-state P65AU.* The frequency standard is a 2400-cycle tuning fork. The connector shown in Fig. 32 (J2) is the type used in the model 1100 Analab oscilloscope and must be changed if another oscilloscope is used.* Also, the receiver output must be matched to the 10K input impedance of this unit.

THE TAPE RECORDER

Many articles have been written about APT; in some of these the author, seeking ways to reduce the price of APT, suggests that the tape recorder is not essential. However, if any malfunction occurs in the facsimile or the camera, the picture will be lost if it is not recorded on tape. A good quality stereo recorder with one channel for video and the other for recording the sync signal is needed. The facsimile must be triggered by the sync signal in playback because of wow and flutter in the recorder. The tape-recorder requirements are:

- Must record and play back at 7-1/2 ips (approx. 19.5 cm/sec).
- Record and playback levels must have amplitude stability. Any change in output will affect the picture.
- Must be capable of recording 2400 Hz (the video subcarrier).
- Must be stereo for 2-channel recording.

A tape footage counter is helpful for picture-start reference.

THE CAMERA

The scope camera should have a 4 in. × 5 in. Polaroid back. Type 52 film can be used for normal prints, type 55 for negatives. Be sure to focus the electron beam and the camera to their optimum. The picture size on the film should be adjusted to 3.5 in. × 3.5 in. (approx. 9 × 9 cm).

The video electronics (fig. 32) should be fabricated on a vector-type breadboard and "rigged" up to the scope for troubleshooting. Once operation is established, the breadboard can be incorporated on the plug-in. The video-detecting circuit (fig. 33) can be built into the oscilloscope mainframe.

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*Other equivalent brands can be used.

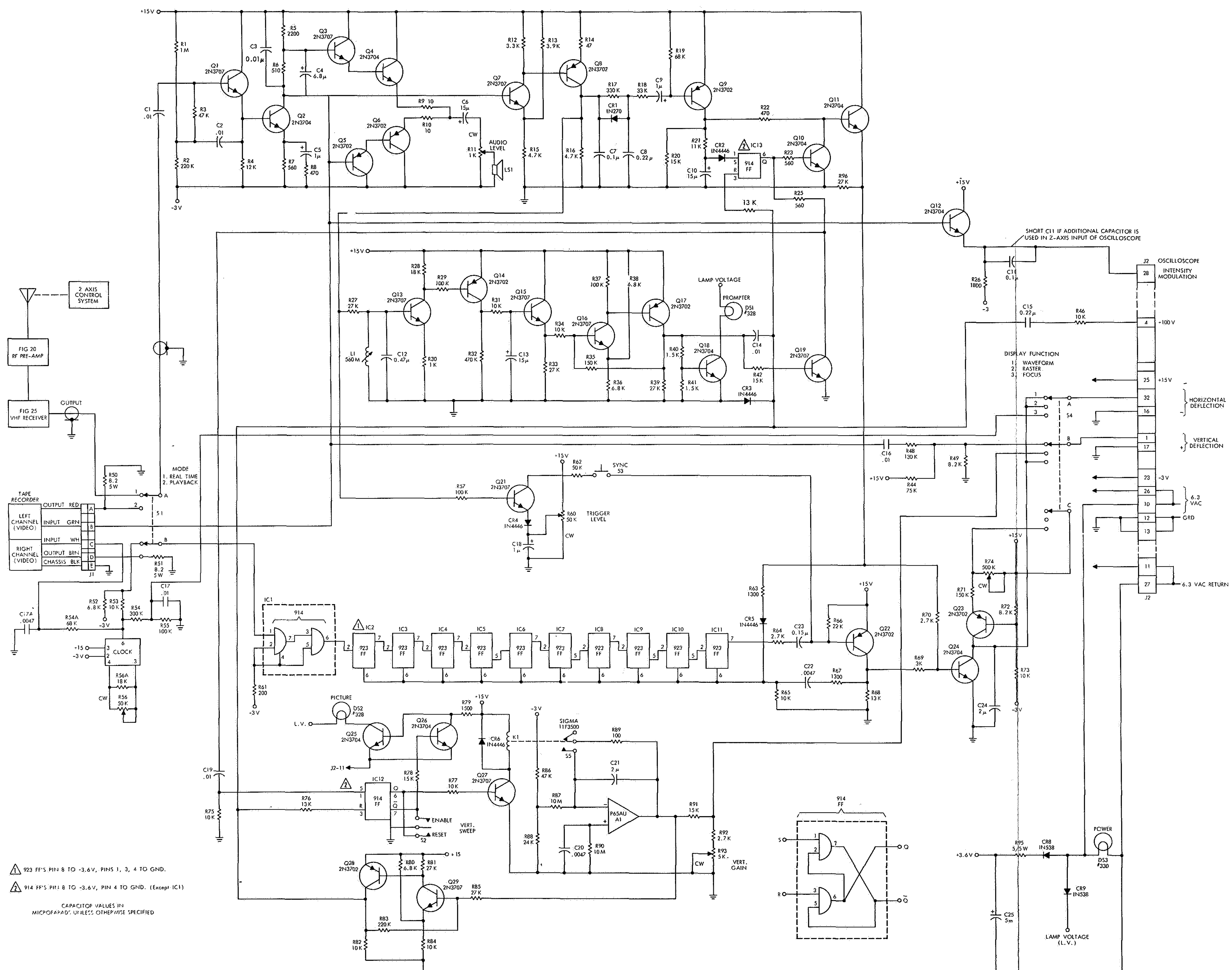

Figure 32. —Video electronics schematic.

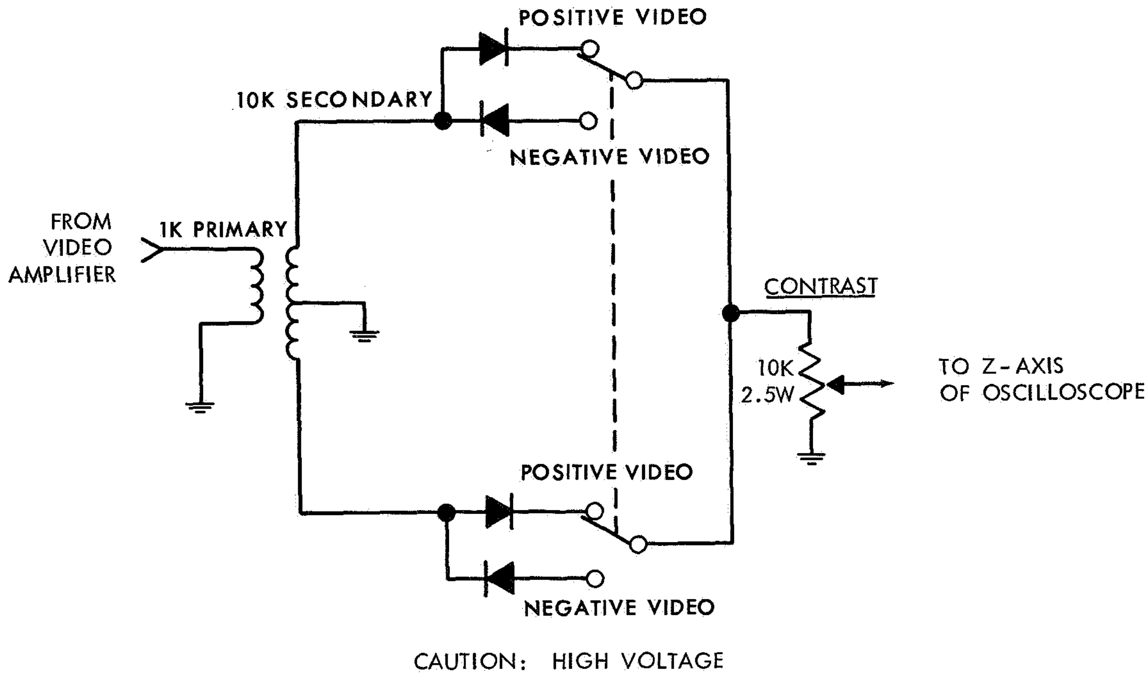

Figure 33.—Video detecting and matching circuit schematic.

CHAPTER 4

Operation Of The Overall System

SYSTEM OPERATION

Figure 34 is a block diagram of the APT station. All system-level discussion is relative to this diagram.

The picture is created a line at a time on the cathode-ray tube (similar to conventional television but at the sweep rates in the satellite camera). The resulting raster is photographed on Polaroid film, which provides a processed photograph about 15 seconds after the end of each picture transmission or about 3.5 minutes after actual exposure by the satellite camera.

Vertical and horizontal sweep generators create the raster, the vertical generator providing a 200-second sweep and the horizontal generator providing a repetitive 250-millisecond sweep. The internal clock and binary dividers control the rate of the horizontal sweep. After the automatic circuitry performs initial synchronization, the horizontal sweep is controlled by the clock (either the actual frequency standard during real-time operation, or the recorded frequency standard signal during playback).

Vertical sweep, produced by an operational integrator containing an operational amplifier, is initiated by the combined control of the 300-Hz detector and the automatic synchronization circuit.

Automatic synchronization occurs during the 5-second period of the video signal just before picture transmission. The synchronization pulse generator is enabled by the 300-Hz detector, then self-disabled after synchronization pulse generation to prevent disruption of the synchronization timing during picture transmission.

The receiver-display unit is capable of either real-time or playback modes of operation. In the unit, the modulated raster is presented for picture photography, the video waveform is presented for calibration and observation, and a focusing waveform may be displayed to facilitate optimum line focusing.

During real-time and playback operation, the adjustment of the output level of the tape recorder or receiver to calibrate the amplitude of the video signal is made by observing the video waveform on the WAVEFORM display function.

The tape-recorder used in this system is a good quality, home-type stereo recorder. One channel contains the video signal and the other contains the clock

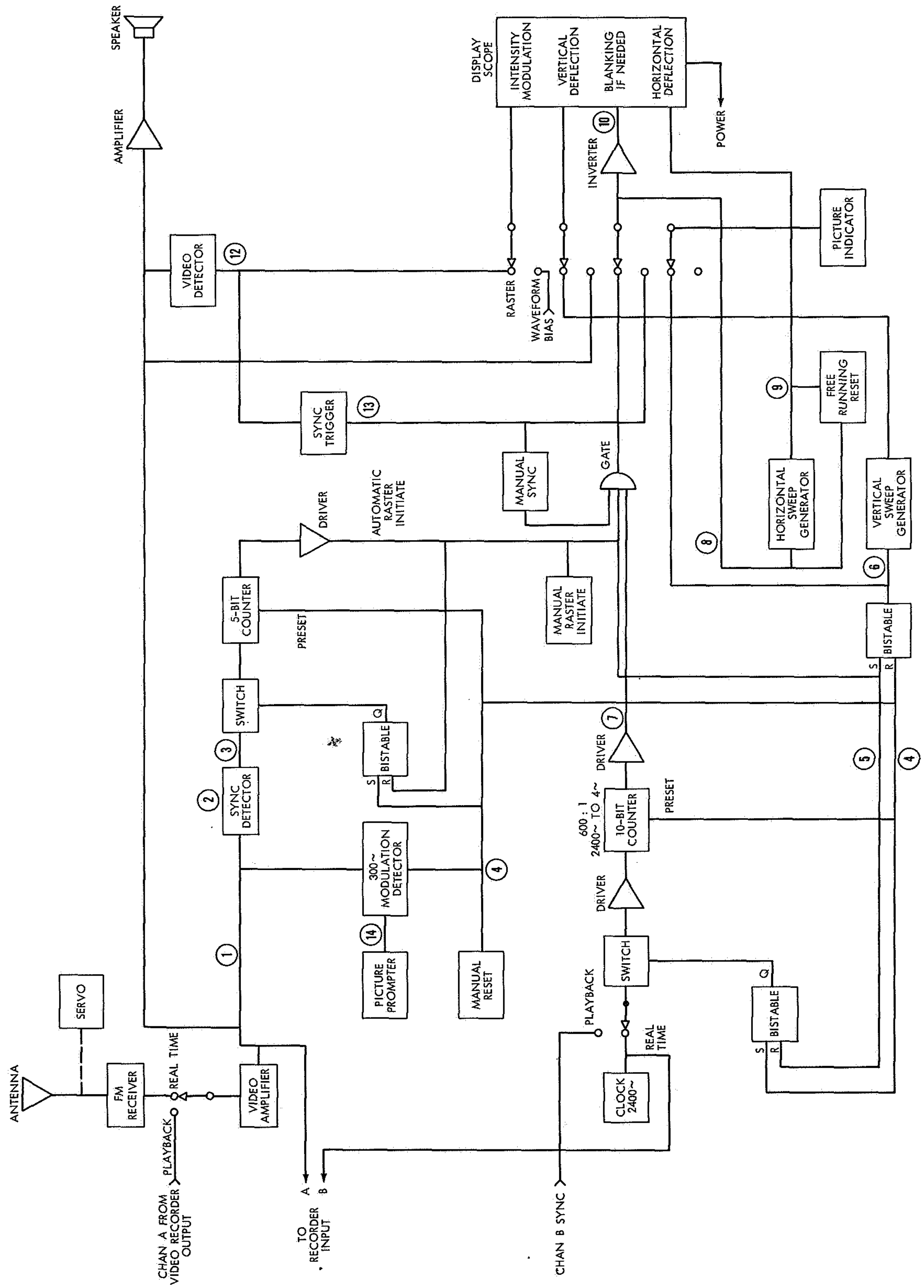

Figure 34.—APT station electronics, block diagram.

signal for accurate picture synchronization. The unit includes a digital display to facilitate location of individual picture information. Operation is simple, as described in the recorder manual. The unit interconnects with the receiver/display unit by the tape-recorder interconnect cable.

The oscilloscope camera shown in fig. 30 is a Fairchild Model 453-A-2.* It rapidly converts from 3.25- by 4.25-inch pack-back to 4- by 5-inch single-sheet operation. The unit's swing-away mount allows easy access to the CRT face and calibration plate. The binocular viewing port permits observation of the CRT display, even during film exposure.

Accessories for the system include photographic film, magnetic tape, and signal and control cables.

CONTROL PANEL FEATURES

- Control Unit (Plug-in).
- MODE switch: selects the video and synchronization signal sources. In the real-time mode, the video signal is received from the FM receiver during actual satellite transmission and synchronization is maintained by the internal frequency standard. In the playback mode, the video signal is received from the tape-recorder video channel, and synchronization is maintained by the recorded clock signal.
- DISPLAY FUNCTION switch: selects the display presented on the CRT phosphor as follows:

    WAVEFORM: displays the video waveform of successive picture lines, enabling observation of the video signal and amplitude calibration during playback operation.

    RASTER: displays the modulated raster for picture photography.

    FOCUS: displays the 2400-Hz clock signal swept vertically at four expanded sweeps per second to enable optimum focusing.
- SIZE CONTROLS

    VERT: provides adjustment of vertical raster size.

    HORIZ: provides adjustment of horizontal raster size.
- ALIGNMENT CONTROL: permits adjustment of the frequency of the internal frequency standard, thus controlling any skewing of the picture during scan.
- TRIGGER LEVEL control: sets the level at which the manual synchronization circuit triggers from the video waveform.
- SYNC pushbutton: enables the manual sync trigger circuit.
- VERTICAL SWEEP switch: provides manual reset or initiation of the vertical sweep (automatic during normal operation).
- Tuning control: if the internal receiver was built, this provides optimum tuning of the FM receiver to the satellite RF-transmission frequency.

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*Other equivalent brands can be used.

- AFC Switch: provides enabling or defeat of the automatic frequency control, greatly reducing the effects of internal-receiver local-oscillator drift.
- AUDIO LEVEL control: permits adjustment of the video signal level of audio readout.
- PROMPTER indicator: lights upon the receipt of 300-Hz modulation of the video carrier, indicating the end of the previous picture and prompting the operator for the subsequent picture.
- PICTURE indicator: lights about one second before commencement of picture information, indicating the time for the camera shutter to be opened.
- SIGNAL STRENGTH meter: indicates the relative level of the RF signal received by the antenna (internal receiver).
- POWER light: lights when the power switch is ON and power is applied to the receiver/display unit.
- RECORDER INPUT/OUTPUT connector: provides input and output video and clock signals to and from the tape recorder.
- RF INPUT connector: accepts the RF signal from the RF interconnect cable attached to the RF preamplifier (internal receiver).

Some display unit features are:

- INTENSITY control: permits adjustment of the picture-intensity level.
- CONTRAST control: permits adjustment of the picture contrast.
- FOCUS control: permits adjustment of the focus of the CRT electron beam.
- POWER switch: applies the input power to the unit.
- VERTICAL POSITION control: permits adjustment of the vertical position of the CRT spot.
- HORIZONTAL POSITION control: permits adjustment of the horizontal position of the CRT spot.

The black calibration plate provides amplitude increments for calibration in the "playback" mode.

THE VHF RECEIVER

The operation of the VHF receiver is described stage-by-stage in relation to the receiver schematic, fig. 26. The received RF signal is amplified by a cascade amplifier, V1 and V2, tuned to the 135.6- to 137.5-MHz bandwidth. The amplified RF signal is mixed in transformer T1 with a signal from the first oscillator to produce a 17.55-MHz signal.

The frequency of the first oscillator V9 is determined by one of three crystals selected from the front panel. The choice of crystal depends upon the frequency of the incoming signal, which in turn is dependent on the satellite. The output tank circuit is tuned to the third harmonic of the crystal. This third harmonic is mixed with the incoming RF signal in T1.

The 17.55-MHz signal from T1 is amplified by V3. The amplified signal is then mixed in amplifier V4 with a 28.25-MHz signal from the second oscillator to produce a 10.7-MHz second-IF frequency.

The second oscillator consists of a tuned network whose frequency is determined primarily by a voltage-variable capacitor, CR1. The 10.7-MHz signal is kept frequency-stabilized by feedback from the discriminator output. This automatic frequency control (AFC) action thus keeps the second-IF frequency at the center of the discriminator's bandwidth.

The second-IF signal is amplified by V5, V6, and V7 to produce a 10.7-MHz signal sufficient to drive discriminator V8. The discriminator produces a video output which is applied to cathode follower V10. The video signal both drives the signal level meter and the video electronics.

VIDEO ELECTRONICS

The video electronics consists of the video amplifier, synchronization circuits, a clock, and vertical and horizontal sweep generators. These circuits are shown schematically on fig. 32 and are described in relation to that figure.

The video amplifier, consisting of Q1, Q2, Q3, Q4, Q5, and Q6, receives the video signal from the receiver during real-time mode and from the tape recorder during playback mode. The video signal is voltage-amplified by Q1 and Q2. The resulting signal then drives the speaker through Q3, Q4, Q5, and Q6 and drives the intensity-modulation transformer located in the main frame (fig. 32) through emitter-follower Q12.

The synchronization circuits produce horizontal and vertical reset pulses that precisely align the picture scanned on the cathode-ray tube with the picture transmitted by the spacecraft. The alignment is accomplished during the eight-second inter-picture phasing interval. Vertical sync is achieved during an initial three seconds of 300-Hz modulation of the carrier; horizontal sync is achieved during the following five-second transmission of phasing pulses.

The 300-Hz modulation envelope is detected by a tuned circuit, L1 and C12, resonated at 300 Hz. The detected 300-Hz signal is amplified by Q13 and rectified by Q14. The rectified signal charges C13 positively. Eventually, the positive charge on C13 reaches the threshold voltage of a Schmidt trigger, Q16 and Q17. (Q15 is an emitter - following isolating C13 from the input impedance of Q16.) When the threshold voltage is reached, Q15 produces a transition to +15 volts. This transition causes the following functions to occur:

(1) Turn-on of the PROMPTER lamp through Q18 to alert the operator that the inter-picture phasing period has begun.
(2) Resetting of the horizontal sweep, phasing lockout flip-flop, IC13, through C14.
(3) Turn-off of the PICTURE light by turning off Q25.
(4) Resetting of the vertical sweep generator by resetting flip-flop IC12. (This reset returns the sweep on the cathode-ray tube to the top of the picture.)

Conditions 1, 3, and 4 above are held throughout the five-second phasing-pulse period to the beginning of the next picture. It is during this phasing-pulse period that the horizontal sweep is synchronized.

During the five-second phasing pulse interval, the 250-millisecond blanks are in phase with the 12.5-millisecond tone burst (which begins each horizontal sweep line transmitted during the 200-second picture interval). A reset pulse is developed from each 12.5-millisecond blank. This aligns the tone burst at the left edge of the sweep.

Transistor Q8 amplifies and half-wave rectifies the video signal received from the video amplifier. Capacitor C9 filters the 2400-Hz AM carrier from the video. The network consisting of R19, R20, R21, C10, and CR2 has a characteristic fast pulse-rise time and slow pulse-fall time. Therefore, to turn Q9 on quickly, the 2400-Hz signal rapidly charges C10.

Capacitor C10 remains charged during the first 237.5-millisecond pulse interval. The 12.5-millisecond blank period that follows allows C10 to discharge to the point where Q9 is turned off.

Since the network's rise time response is fast, the negative-going edge of the pulse at the collector of Q9 occurs simultaneously with the beginning of the next 237.5-millisecond pulse. This negative edge is differentiated and applied to Q11 to produce a 7-millisecond reset pulse. This reset pulse performs the following functions:

- Applies a pulse through CR5 to the reset input of the clock countdown flip-flops.
- Sets the IC13 horizontal-sweep phasing-lockout flip-flop. The horizontal-sweep phasing-lockout flip-flop IC13 prevents pulses that would be produced by this horizontal synchronization circuit during the picture interval from resetting the clock countdown flip-flops. This is done by holding the collector of Q9 low with Q11. Q11 is held on with the high-Q output of flip-flop IC13. Another clock countdown reset pulse can occur only after the 300-Hz interpicture interval is received and detected, causing flip-flop IC13 to be reset again.

The clock generates the four-pulse-per-second reset pulses used by the horizontal sweep generator. The frequency source of the clock is a 2400-Hz tuning fork. An internal alignment potentiometer permits adjusting the frequency precisely to 2400 Hz. The tuning-fork output is squared by passing the signal through two gates (IC1). The ten-stage binary counter then divides the 2400-Hz gate output by 600 to obtain the required four pulses per second.

The four pps square wave drives a one-shot circuit to produce a 2-millisecond reset pulse on each negative transition of the binary countdown output square wave.

The pulses produced by the divided clock are coincident with the front edge of the tone burst beginning on each horizontal sweep line. Coincidence is thus created by the countdown reset pulse of the synchronization circuit. This pulse is approximately 7 milliseconds long and occurs at the end of the 12.5-millisecond blank which, when using the 250-millisecond horizontal time reference, is in phase with the tone burst. In order that the tone burst begin at the left edge of the cathode ray tube trace, the binary countdown must be preset by 20 counts (approximately 20 milliseconds).

Amplifier A1 produces a 200-second sawtooth waveform, which is applied to the vertical sweep amplifier. When the 300-Hz interpicture tone is detected by the synchronization circuits, Q27 turns on to close relay K1. Relay K1 discharges the voltage across C21 to zero, driving the output of the operational amplifier to zero. When the phasing interval is completed, K1 opens and the operational amplifier is again permitted to integrate.

A constant current source, a capacitor, and a parallel switch are used to generate the 250-millisecond horizontal sawtooth sweep. The constant current source charges capacitor C24 at a constant rate, producing a linear voltage ramp. The charging current is controlled by the voltage at the base of Q22 and by the value of the emitter-to-collector resistance. The four-pulse-per-second waveform, generated by the clock, is applied to electronic switch Q24, which is placed parallel to C24. Therefore, four times per second the output of C24 is discharged to ground through switch Q24. The 250-millisecond sawtooth waveform is applied to the horizontal-deflection amplifier located within the oscilloscope main frame.

CHAPTER 5

Preparations For Picture Taking

CABLE CONNECTIONS

Before operation, electrical power must be applied to the receiver/display unit, each antenna-positioning control box, and the tape recorder. Interconnecting cables are required as follows:

- Stacking harness from the antenna to the preamplifier input.
- RF cable from the preamplifier output to the receiver/display unit.
- Interconnect cable between the receiver/display unit and the tape recorder.
- Control cables from the antenna positioning system to the control units.

The antenna and antenna-positioning system can be operated by moving the lever switches of the units which control the azimuth and elevation of the antenna. Read the meter scales carefully for proper indication. These units supply power to the drive motors and brake solenoids of the antenna-positioning system.

RECEIVER DISPLAY UNIT PREPARATION

To prepare the receiver display unit for picture taking:

(1) Apply power to the unit with the POWER switch on the display unit front panel. The POWER light should go on. Allow about 15 minutes for warmup.

(2) Set INTENSITY and CONTRAST to 0.

(3) Set the MODE switch to REAL TIME.

(4) Set the DISPLAY FUNCTION switch to RASTER.

(5) Reset the vertical sweep.

(6) Increase the INTENSITY until the horizontal scan line is visible.

(7) Adjust the horizontal and vertical positioning controls so that the line intersects the top corner formed by the circular phosphor edge and the left edge of the calibration graticule (fig. 35).

(8) Now adjust the HORIZONTAL POSITION control counterclockwise until the left end of the scan line touches the edge of the phosphor on the left side.

(9) Next adjust the HORIZONTAL SIZE control so that the right end of the scan line is positioned in the upper corner where the phosphor edge

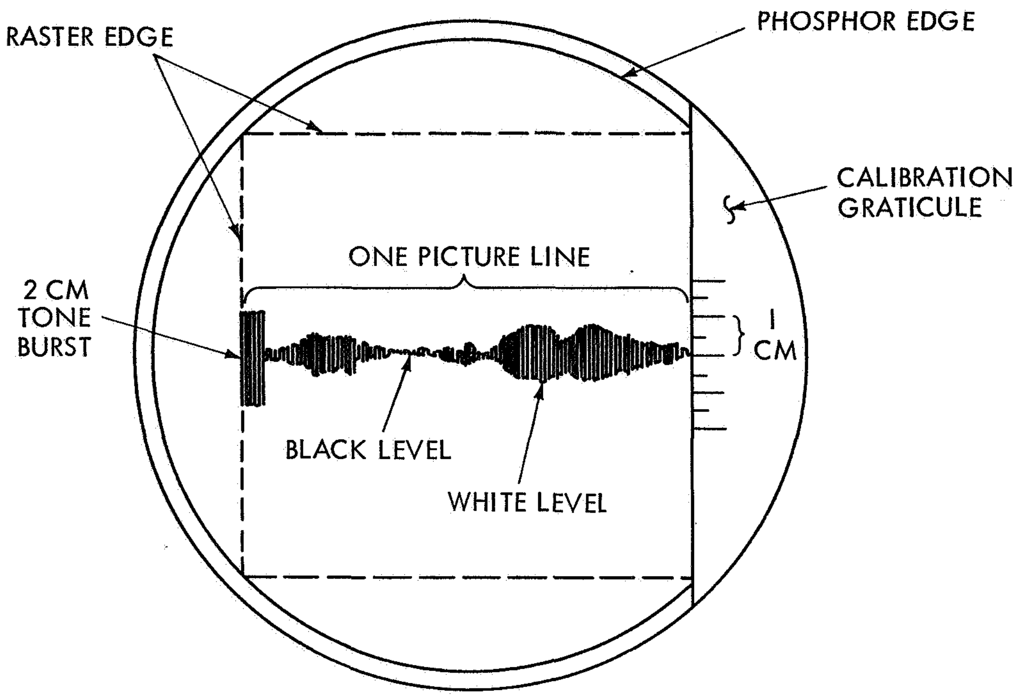


Figure 35.—Oscilloscope showing waveform mode.

meets the calibration graticule. Adjustment of raster size and horizontal size are now complete.

(10) Enable the vertical sweep, and note the time.

(11) After an elapsed time of 200 seconds from the enabling of vertical sweep, adjust the VERTICAL SIZE control so that the right end of the scan line is positioned at the bottom corner formed by the phosphor edge, and at the left edge of the calibration graticule.

(12) Set the DISPLAY FUNCTION switch to FOCUS.

(13) Adjust the intensity for optimum display of the focus signal.

(14) Adjust FOCUS and astigmatism (inside) controls for maximum resolution of the focus signal.

Preliminary picture adjustments are now complete. The position of the scan line, as initially set, should be checked before each period of operation. Focus and vertical raster size can be checked weekly, or less frequently if no adjustment appears necessary.

CAMERA PREPARATION

The camera clamp-ring must be attached to the display unit bezel according to instructions in the camera instruction manual. Next, affix the camera body to the clamp-ring swingaway mount but do not lock it in place.

Two adjustments must now be performed: setting the image size and focusing the image. The display unit scan line may be used to set the image size.

(1) Set the MODE switch to REAL TIME.
(2) Set the DISPLAY FUNCTION switch to RASTER.
(3) Set INTENSITY at 10 and CONTRAST at 0.
(4) Set the VERTICAL SWEEP to RESET. The scan line should be visible at the top of the normal raster area; reposition it if necessary.
(5) Lock the camera into position against the clamp ring.
(6) Set the aperture at f:2.8 and open the shutter.
(7) Open the rear of the Polaroid pack-back, if used, and remove any film pack. Install the focusing adapter.
(8) Referring to the camera manual for the method of adjustment, set up the image size by observing the scan-line image on the focusing plate. Adjust the camera adjustments so that the scan line is placed about 1/8 inch above the bottom edge of the focusing plate.
(9) Open the left-side access door on the camera and, while observing the actual scan line, adjust the vertical position of the scan line, positioning it at the bottom of the normal raster area.
(10) Close the access door and observe the image of the scan line on the focusing plate. It should be visible at the top of the plate. If it is not, adjust the camera-lens position to place the image of the scan line about 1/8 inch down from the top of the focusing plate.
(11) Adjust the vertical position to put the scan line at the top of the normal raster area.
(12) Now switch the DISPLAY FUNCTION switch to FOCUS. Observe the focus waveform on the focusing plate. This may require a magnifying glass and darkened room.
(13) Adjust the position of the camera back to obtain the best focus. The adjustment of the lens position or the camera back may necessitate a readjustment of both to remove observable interaction.
(14) Upon optimum adjustment, lock the camera adjustments. Close the aperture to f:4 and close the shutter. Remove the focusing adapter, install the film pack, and close the camera back.

If a 4 in. × 5 in. back is used as the camera back, preliminary adjustments are similar to those made using the 3.25 in. × 4.25 in. pack-back. Focusing and image size adjustment are accomplished when the 4 in. × 5 in. back is installed and the 4 in. × 5 in. Polaroid adapter has not been installed. After adjustments are complete, the Polaroid adapter may be installed.

TAPE RECORDER PREPARATION

The tape recorder may be used according to its instruction manual, except for the following items:

(1) Attach the interconnect cable according to wiring notations on the "Video Electronics" schematic found in this report.
(2) Approximate normal AUDIO LEVEL and tone settings should be marked on the control panel for both recording and playback.

(3) Good quality magnetic tape (instrumentation grade) should be used for this unit. Lower grade tapes will allow "dropouts" in which several cycles of clock signal may be lost, causing a horizontal shift in the picture.

(4) The tape recorder should be modified so that each channel operates on half a track. The tape may be played in only one direction.

(5) To achieve the disabling of the recorder speaker and to achieve low noise, use the external speaker jacks instead of the preamplifier output in playback. The video electronics is wired for low impedance at the recorder input.

CHAPTER 6

Procedures During Picture Taking

REAL-TIME OPERATION

Before satellite acquisition:

(1) Complete all preliminary operations.
(2) Position the antenna toward ascent "look angle" (Refer to APT User's Guide (ref. 3) for orbital information).
(3) Set the MODE switch to REAL TIME.
(4) Set the AUDIO LEVEL control high enough to pick up receiver noise.
(5) Upon receipt of the satellite signal, adjust TUNING for maximum signal.
(6) Enable the tape recorder in the record mode.

For manual synchronization which is necessary only if the initial picture is required:

(1) Set the DISPLAY FUNCTION switch to WAVEFORM.
(2) Set CONTRAST to 0.
(3) Set INTENSITY to 10.
(4) Observe the video waveform on the CRT phosphor, either by viewing it through the binocular-viewing port or by swinging the camera housing aside. Observe, in the waveform, the full carrier tone bursts. (See fig. 34.)
(5) Adjust the manual sync TRIGGER LEVEL fully CCW.
(6) Depress the SYNC pushbutton and slowly adjust the TRIGGER LEVEL control clockwise until the horizontal sweep is reset by the pulses of the tone bursts. Release the SYNC pushbutton. The tone bursts should now appear at the far left of the sweep opposite the calibration plate. Correct sync is obtained only when manual sync occurs on a full-width tone burst; sync on a half burst may shift one-half of the data code stripe to the opposite side of the picture. This will be corrected upon receipt of picture-sync information at the beginning of the next picture.
(7) Close the binocular viewing port or close and lock the camera housing.
(8) Set the INTENSITY and CONTRAST controls to the desired levels. These levels, which vary with the type of film used, should have been determined through prior use.

(9) Set the DISPLAY FUNCTION switch to RASTER.
(10) Reset and enable the vertical sweep.
(11) Open the camera shutter. The picture is now being photographed.

For automatic synchronization, upon completing the transmission of the first picture:

(1) Set the DISPLAY FUNCTION switch to RASTER.
(2) Set INTENSITY AND CONTRAST as desired. The first complete picture will be indicated by the presence of sync information (a 3-second period of 300-Hz modulation and a 5-second period of partly blanked video carrier). The PROMPTER indicator will light for about 7 seconds and go off, and the PICTURE indicator will then light. Raster scanning should have begun.
(3) When the PICTURE indicator lights, open the camera shutter to expose the film. During reception, it is occasionally necessary to reposition the antenna in order to track the satellite and receive adequate signal level. The antenna position should be updated about every minute, using Nimbus and ESSA look-angle data for the reception locality.
(4) Close the shutter at the end of picture transmission (200 seconds), indicated audibly by the 300-Hz modulation, or visually by the PICTURE light going out.
(5) Remove the exposed film.
(6) When the PICTURE indicator relights, open the shutter to photograph the next picture.
(7) After the recommended development time, separate the Polaroid print from the negative. Immediately coat the print with the print coater supplied with the film.
(8) As the satellite begins to approach the horizon, the signal strength will diminish to a level below the limiting level of the receiver and noise will become audible. The signal-to-noise ratio and the picture quality diminish proportionately. At this point, the satellite pass may be considered complete.
(9) Close the camera shutter, if it is open, and process the picture.
(10) Stop the tape recorder.

If the satellite transmission has been recorded, the picture may be rephotographed by playing back the recording for possible improvement of picture quality by variation of intensity and contrast. Copies may also be produced in this manner.

PLAYBACK OPERATION

(1) Complete all preliminary operations.
(2) Set the MODE switch to PLAYBACK.
(3) Set the DISPLAY FUNCTION switch to WAVEFORM.
(4) Set CONTRAST to 0.
(5) Set INTENSITY to 10.
(6) Install tape to correct the location of recorded data.

(7) Adjust the channel VOLUME AUDIO LEVEL control to provide a 2/cm peak-to-peak signal amplitude for full video carrier which occurs during ESSA tone bursts, Nimbus data code stripe, 300-Hz modulation, or sync waveform. You can adjust the amplitude by comparing it with the calibration plate on which the major divisions are 1-cm increments.

Operation from this point is identical with real-time operation, except for antenna positioning and RF receiver adjustments.

ALTERNATE FACSIMILE UNIT

It may be possible to buy from a surplus outlet a standard facsimile unit such as those used in news agencies or police bureaus. The standard facsimile unit is a mechanical device using gears and clutches in place of electronic sweep cathode-ray tubes.

The video waveform is a standard facsimile format, described earlier, and is adaptable to any 240-rpm mechanical recorder. The described antenna-receiver combination will provide the necessary video signal to operate a 240-rpm recorder without modification. Some facsimilies, however, use a 120-rpm drum speed and will require modification before being used.

Generally, in the following standard facsimile recorders the start and phase procedure is similar but the method of display varies.

- Electrolytic paper: The video is converted from an analog voltage into a "marking current" and applied from a metal bar through the moving paper to a rotating drum. The chemical content of the paper allows a current flow proportional to the incoming video.
  The action of current passing from the metal bar through the paper causes the depositing of iron ions (many: black; a few: white) on the paper, thus reproducing the picture as seen by the spacecraft.
- Photosensitive paper: The video is used to vary a light source, which is usually a gas-filled tube energized to some ionizing potential. The video varies the ionizing potential, causing a proportional change in the intensity of the light tube. The light is optically focused on the photosensitive paper and traverses in a lateral direction to form the 200-second vertical sweep. The paper, in this instance, is formed on a rotating drum which revolves at a 240-rpm rate or four revolutions per second. This constitutes the horizontal frequency of four pulses per second.
  After exposure, the paper is removed from the drum and subjected to a two-chemical developing process. Final prints are available within seconds.
- Negative film: As in the photosensitive paper facsimile, the video, once detected, is applied to a light source. The resultant light beam is focused through a minute aperture and focused once more on an oscillating mirror. The mirror oscillates at four sweeps per second (240 rpm). The image from the mirror is once again focused on a high quality, 70 millimeter, fine grain film. The film slowly traverses in front of the

scanning. A video light beam forms the vertical sweep while an oscillating mirror forms the horizontal sweep.

The preceding types of facsimile recorders are all suited for APT. They may be purchased from a price range of $4,000 to $35,000. Included in the cost of a second-hand unit should be the price of making it operational.

CHAPTER 7

The Facsimile Video Enhancement Device

INTRODUCTION

This chapter contains information on the installation, operation, and maintenance of the facsimile video enhancement device (also known as the video remodulation unit). The purpose of the device is to restore and improve facsimile video that has been degraded in passage from satellite to earth because of transmission conditions or a system fault. The facsimile receiving station will have difficulty in presenting a picture suitable for meteorological evaluation if conditions are poor or the equipment is faulty. The video remodulation unit provides a means to overcome the difficulty. No maintenance of the unit is required, and installation requires no special conditions. Figure 36 is a block diagram of the video remodulation unit.

PHYSICAL DESCRIPTION

A 5 × 10 × 3-inch metal box houses the video remodulation unit components which are mounted on a printed-circuit board. Input and output connectors are BNC types. The unit weighs 3. 5 pounds. It operates over the temperature range of 15°to 40°C. ; it can withstand temperatures ranging from -20°to +60°C.

INSTALLATION

No special installation information is required for this unit because it is series-connected and can be mounted wherever convenient.

OPERATION

The video remodulation unit corrects for the black shift observed on the modulated waveform received from many weather satellites. A provision for selecting a nonlinear transfer function enables the user to enhance the white or black areas. A four-position switch located on the front panel selects one of four modes of operation: The first switch position bypasses the internal circuitry and connects the input signal directly to the output connector. The second position provides a linear operating mode; in this position, the unit demodulates the input amplitude-modulated video waveform and resets the black level of the envelope waveform. The resultant waveform is amplified and

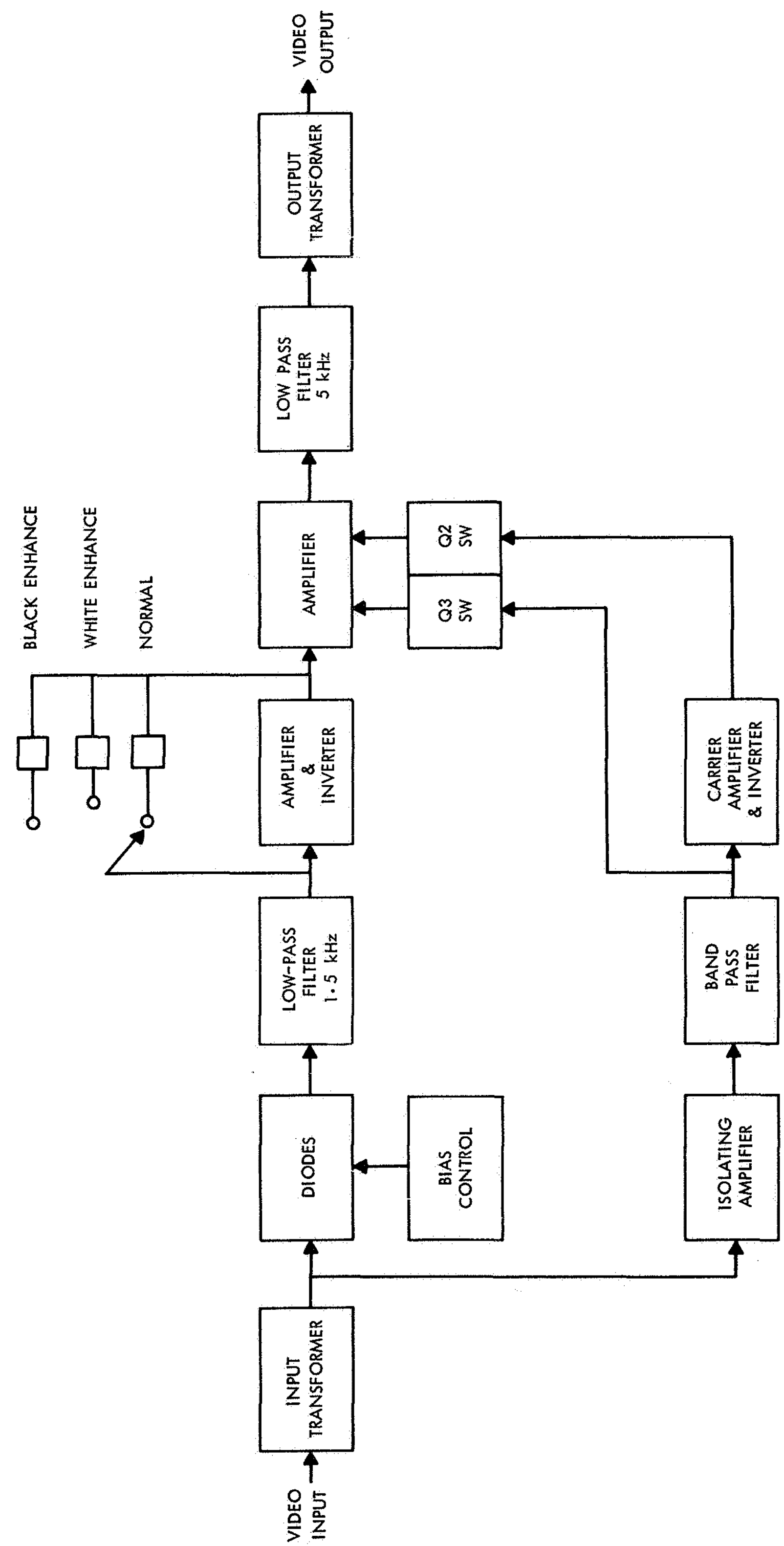


Figure 36. — Video remodulation unit block diagram.

applied to a modulation circuit. The modulation circuit remodulates the waveform with the original 2400-Hz subcarrier frequency detected from the input waveform. The third and fourth positions operate essentially the same as the second mode, with the exception of the nonlinear networks. These are switched into the feedback of the operational amplifier, which then amplifies the rebiased envelope waveform. The third position enhances the black area of the picture, and the fourth position enhances the white area. Enhancing the black area reduces contrast in the white area. Conversely, enhancing the white area reduces contrast in the black area.

OPERATING CONTROLS AND INDICATORS

The controls and indicators for the facsimile video enhancement device are:

- ON/OFF switch— Applies power to the APT remodulation unit
- POWER light— Comes on when power is applied to the unit
- Mode-select switch— Selects the mode of operation:

  Position 1— Applies input signal directly to output connector, bypassing unit

  Position 2— Corrects for black shift in the received video waveform, if necessary— the dynamic input-to-output (I/O) transfer characteristic is linear

  Position 3— Corrects for black shift— increases black-area contrast, if necessary

  Position 4— Corrects for black shift; provides the capability of enhancing the white picture areas
- BLACK SET control— Operates in mode positions 2, 3, and 4 and selects the input-modulation level between 0 and +1.0v that is to be the black zero-modulation level at the output (Figures 37 and 38 show where the values of 0 and 10 indicate potentiometer direction.)
- CONTRAST control— Sets the contrast of the output waveform when the mode select switch is in position 2 (fig. 39)— (This contrast has a range of 0- to 12-db input-to-output gain.)
- BLACK ENHANCEMENT— Selects transfer character in mode position 3, increases the contrast in the black areas, and compresses the contrast in the white areas.

  GAIN 1— Selects initial gain characteristics of I/O transfer characteristics (fig. 40).

  BREAK— Selects break point between GAIN 1 positions and GAIN 2 positions (fig. 41).

  GAIN 2— Selects gain of the break point (fig. 42).
- WHITE ENHANCEMENT— Selects the transfer characteristic in mode switch position 4, increases the contrast in the white areas, and compresses the contrast in the black areas.

  GAIN 1— Selects initial gain characteristics of I/O transfer characteristics (fig. 43).

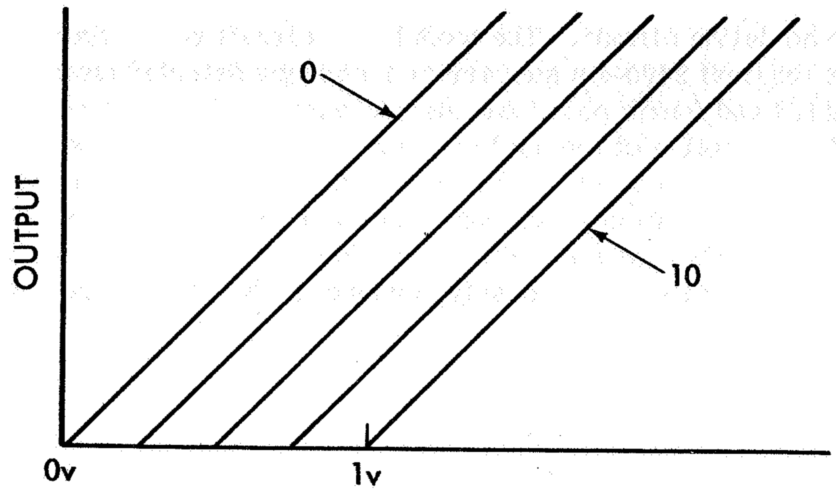


Figure 37. — Black set curves.

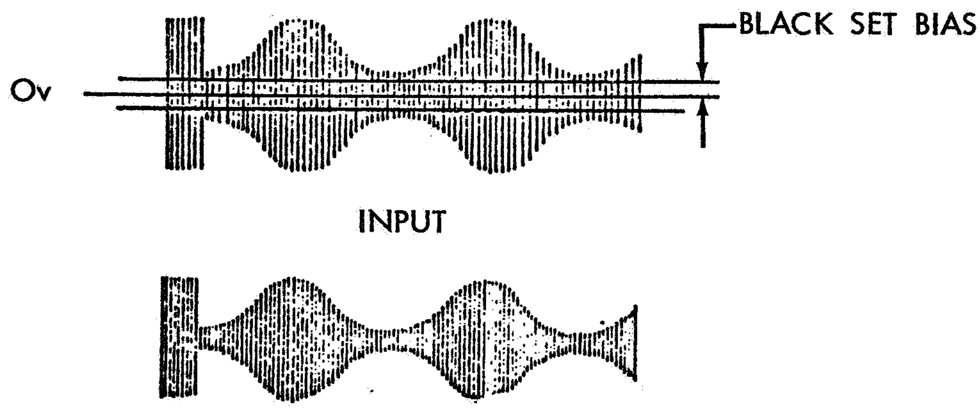


Figure 38. — Rebias effect.

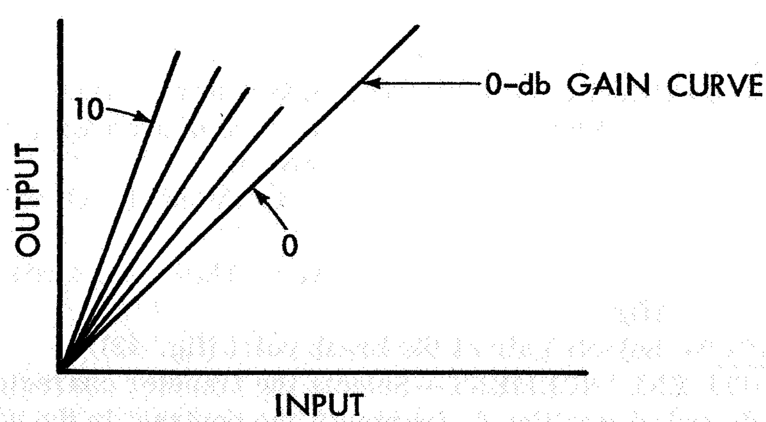


Figure 39. — Contrast curves.

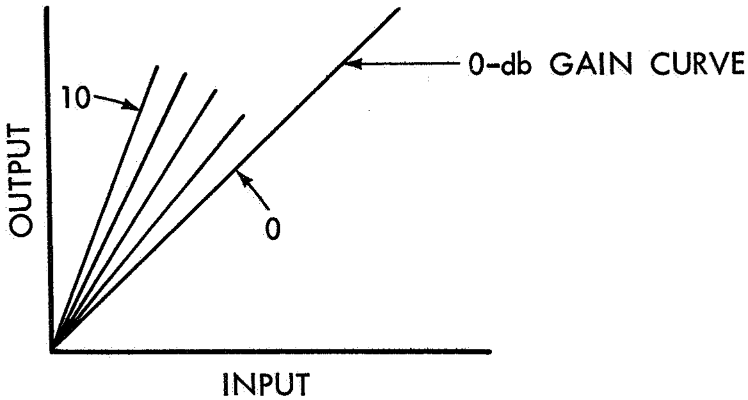


Figure 40. — Initial gain curves.

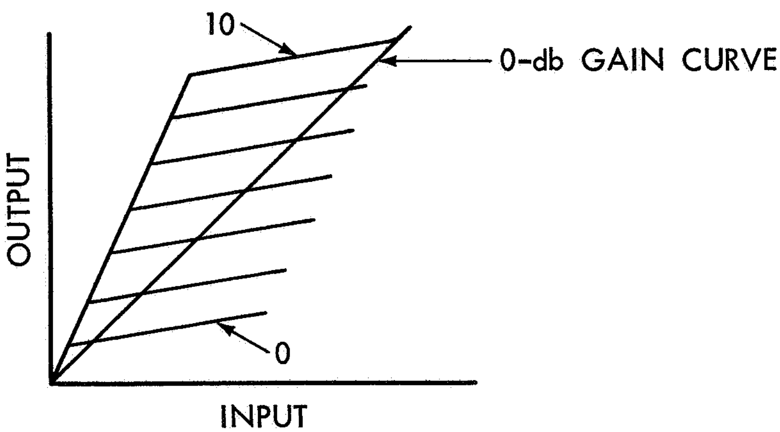


Figure 41. — Gain curves.

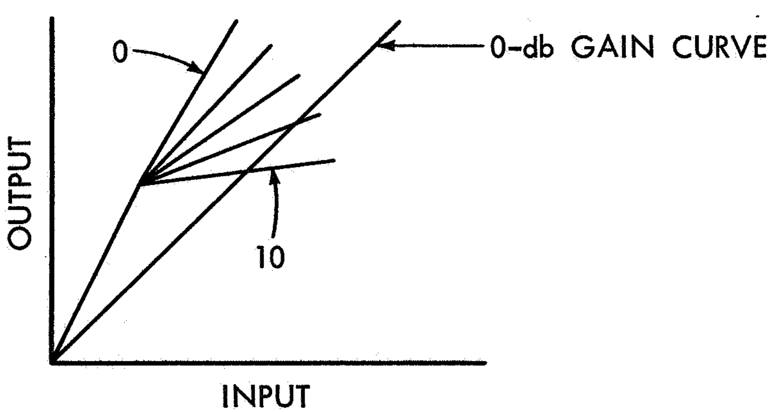


Figure 42. — Post-break-point gain curves.

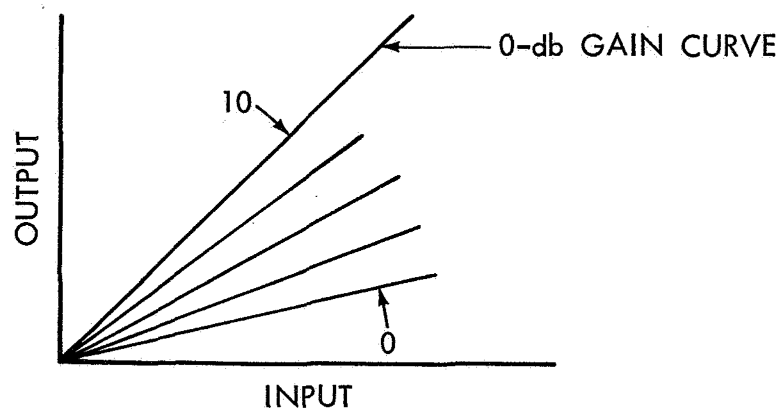


Figure 43.—Initial gain curves.

BREAK—Selects break point between GAIN 1 positions and GAIN 2 positions (fig. 44).

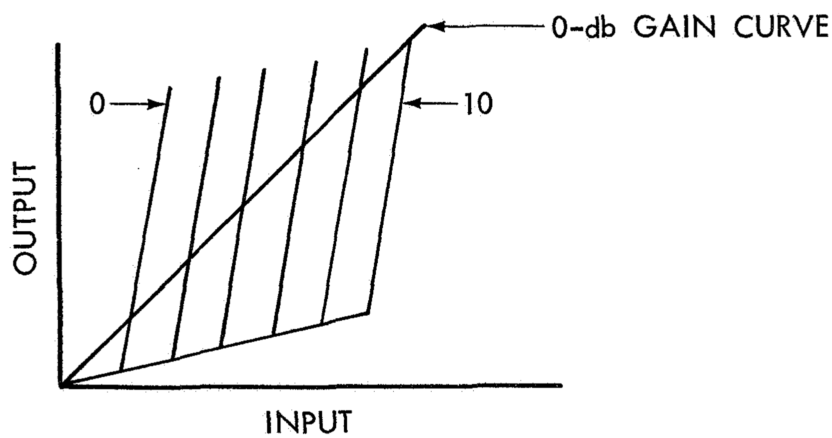


Figure 44.—Break-point curves.

GAIN 2—Selects gain after break point (fig. 45).

OPERATING PROCEDURES

The unit operates in four steps:

1. Set input level from receiver or tape recorder to approximately 0 dbm.
2. Select mode of operation—If picture is to be displayed as received, place mode selector switch in BYPASS position.
3. Use switch position 2 to set the black level to zero-output modulation. Observe the output signal with an oscilloscope and adjust the BLACK SET control to a point where the minimum output black-level modulation is zero. Adjust the output level to approximately 2v peak to peak with the CONTRAST control.

GAIN 2—Selects gain after break point (Figure 10)

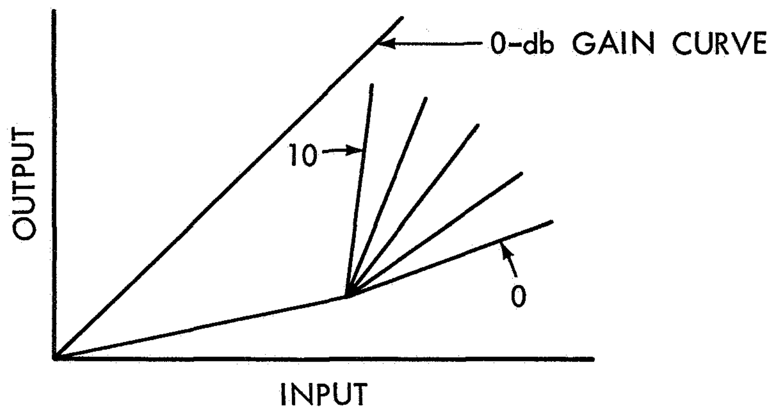


Figure 45. — Gain after break-point curves.

4. In the WHITE ENHANCEMENT or BLACK ENHANCEMENT modes, adjust the BLACK SET control as previously described. Adjust the GAIN 1, BREAK, and GAIN 2 controls while observing the picture for desired characteristics. The transfer curve can be checked by running an I/O response check with a sine-wave oscillator and rms meter. Adjust the sine-wave generator to 2.4 kHz and plot the input-versus-output curve in 0.1v-output-voltage increments. The curve should intersect the unity gain curve near 0 dbm. To approximate the control settings for a desired transfer function, refer to fig. 46 ((a) through (f)) and use the information from (a) through (f) to plot the approximate transfer function. Draw a line from the origin with the desired initial gain slope. Determine GAIN 1 setting from fig. 46(a) or (b); select the desired curve break point. Determine BREAK setting from fig. 46(b) or (e) and draw a line from the break point to the 0-dbm point on a unity gain curve. (The slope of this line will give the gain required after the break point.) Determine GAIN 2 control setting by following the GAIN 1 setting curve on fig. 46(c) or (f) until it intersects with the required gain determined from the plot in fig. 47.

PRINCIPLES OF OPERATION

The information relating to the control functions and their effects constitutes operational principles but, this section is primarily on the electrical circuitry. (The video remodulation unit parts list is Appendix C.)

Figure 48 is a schematic of the video remodulation unit. The signal applied to the BNC input connectors is connected directly to the output when the mode select switch is in the BYPASS position. When the mode switch is in position 2, 3, or 4, the signal is applied to a 600-ohm/10-kilohm impedance-matching transformer. The transformer output is rectified by a full-wave rectifier.

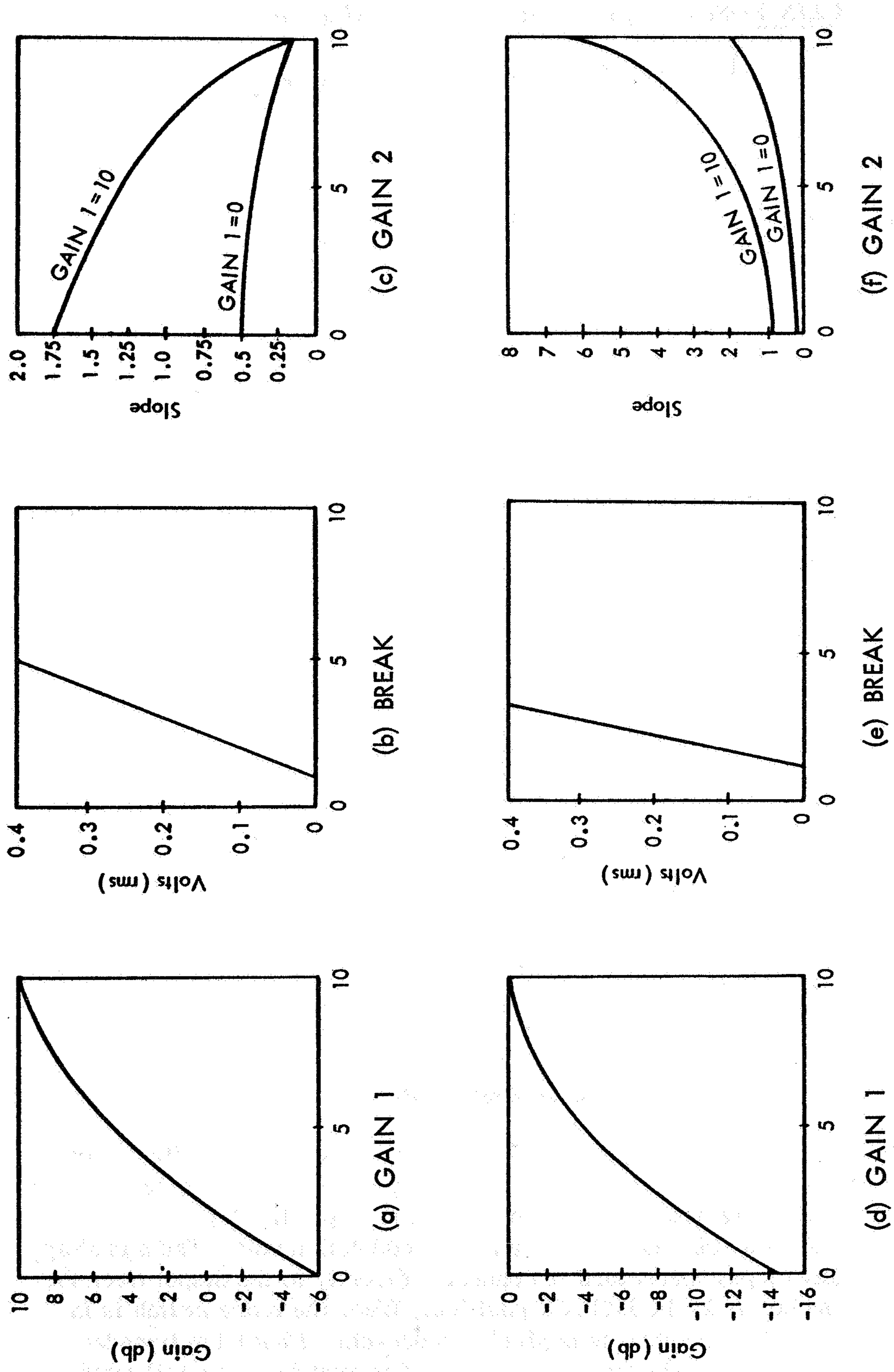


Figure 46. — Black ((a) - (c)) and white ((d) - (f)) accentuation curves.

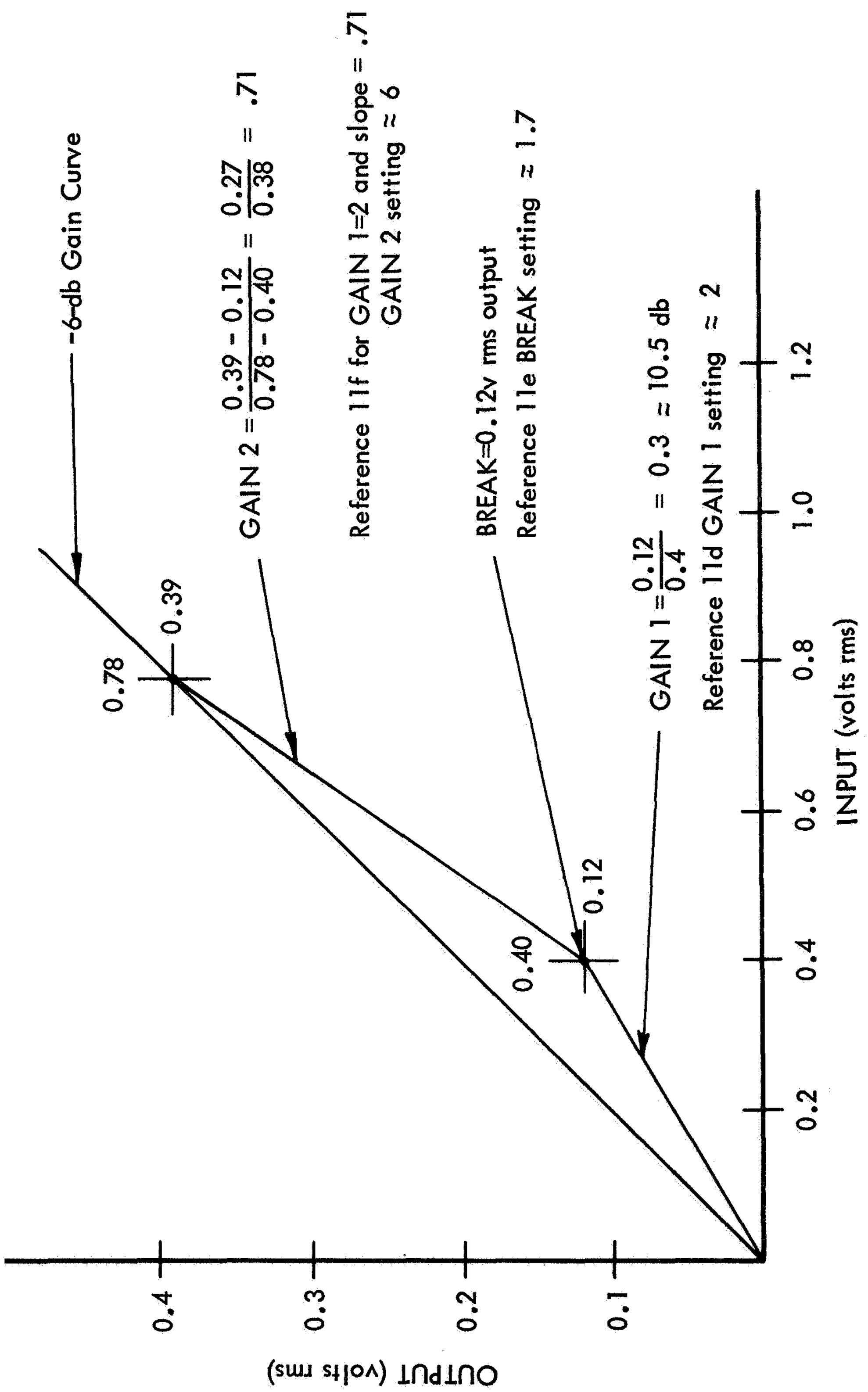


Figure 47. — GAIN-control-setting determination.

A circuit connected to one side of the transformer detects the carrier frequency. This signal is applied to an emitter-follower circuit that prevents imbalance of the transformer output. The emitter-follower output passes through a 2400-Hz bandpass filter with a bandwidth of approximately ±7 percent. Operational amplifier IC3, operating near its open-loop gain, amplifies the 2400-Hz filter output. The output-modulation circuit uses the 2400-Hz frequency.

A full-wave rectifier circuit containing CR1 and CR2 rectifies the impedance-matching transformer output. Passing the rectified signal through a 1500-Hz low-pass filter provides the modulation envelope which eliminates the rectified carrier frequency. Operational amplifier IC1 amplifies this waveform envelope.

In the linear mode, switch position 2, feedback resistor value R2 essentially determines the gain. In the BLACK ENHANCEMENT mode, the value of R20 determines GAIN 1. When the output of the operational amplifier is sufficiently negative to forward-bias the base-emitter junction of transistor Q4, resistors R4 and R10 become inserted into the feedback loop, reducing the gain of amplifier IC1. Q4 base potentiometer R31 sets the break point; after the break point, R4 sets the gain.

In the WHITE ENHANCEMENT mode, switch position 4, potentiometer R20 sets GAIN 1. When the output of operational amplifier IC3 becomes sufficiently negative to forward-bias the base-emitter junction of transistor Q5, resistor R5 acts as a shunt-impedance divider to ground, reducing the feedback voltage. Therefore, when the output of the operational amplifier exceeds the break voltage set by Q5 and base divider R5, the gain of the operational amplifier will increase, resulting in greater white contrast. The 2400-Hz carrier frequency detected from the incoming video signal remodulates the conditioned waveform envelope, then amplifies the waveform envelope. Passing the envelope through two voltage dividers (R15, R17, R16, and R18) provides modulation. At a 2400-Hz rate, connections are made alternately through transistors Q1 and Q2 from the divider point to ground.

The voltage dividers terminate at the positive and negative inputs of operational amplifier IC2, which develops the symmetrical remodulated waveform. The square-wave output of IC2 passes through a 5000-Hz bandpass filter which, by removing the upper harmonics, produces the 2400-Hz amplitude-modulated sine-wave output. This signal is applied to T2, a 600-ohm impedance transformer.

The white and black accentuation curves shown in figs. 49 and 50, respectively, illustrate the effects of gain variations. These curves compared with those in fig. 46 show the versatility of the remodulation unit.

MAINTENANCE

No maintenance is required. The unit is constructed for high reliability and does not require the usual maintenance procedures.

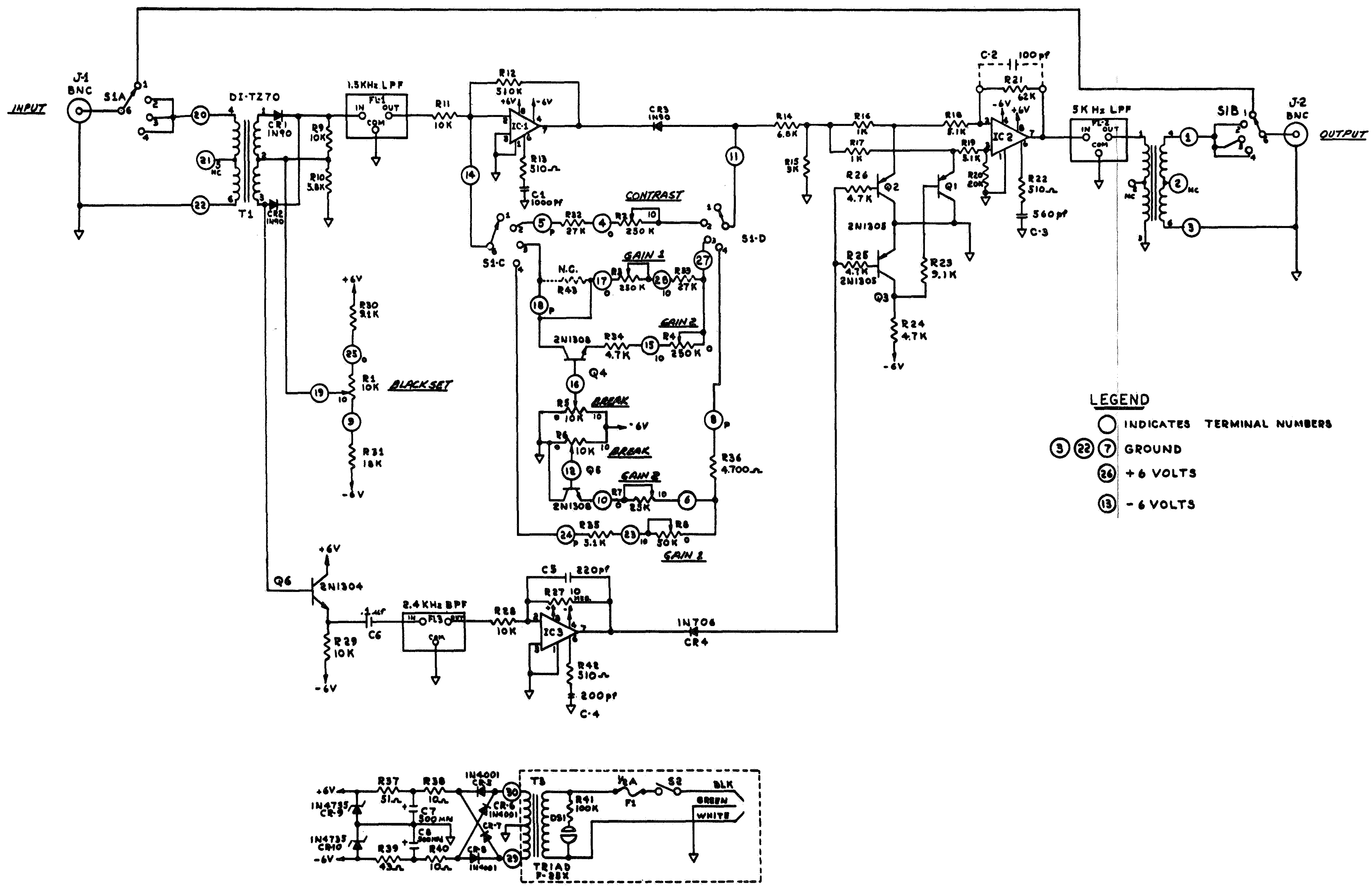


Figure 48. —Video remodulation unit schematic diagram.

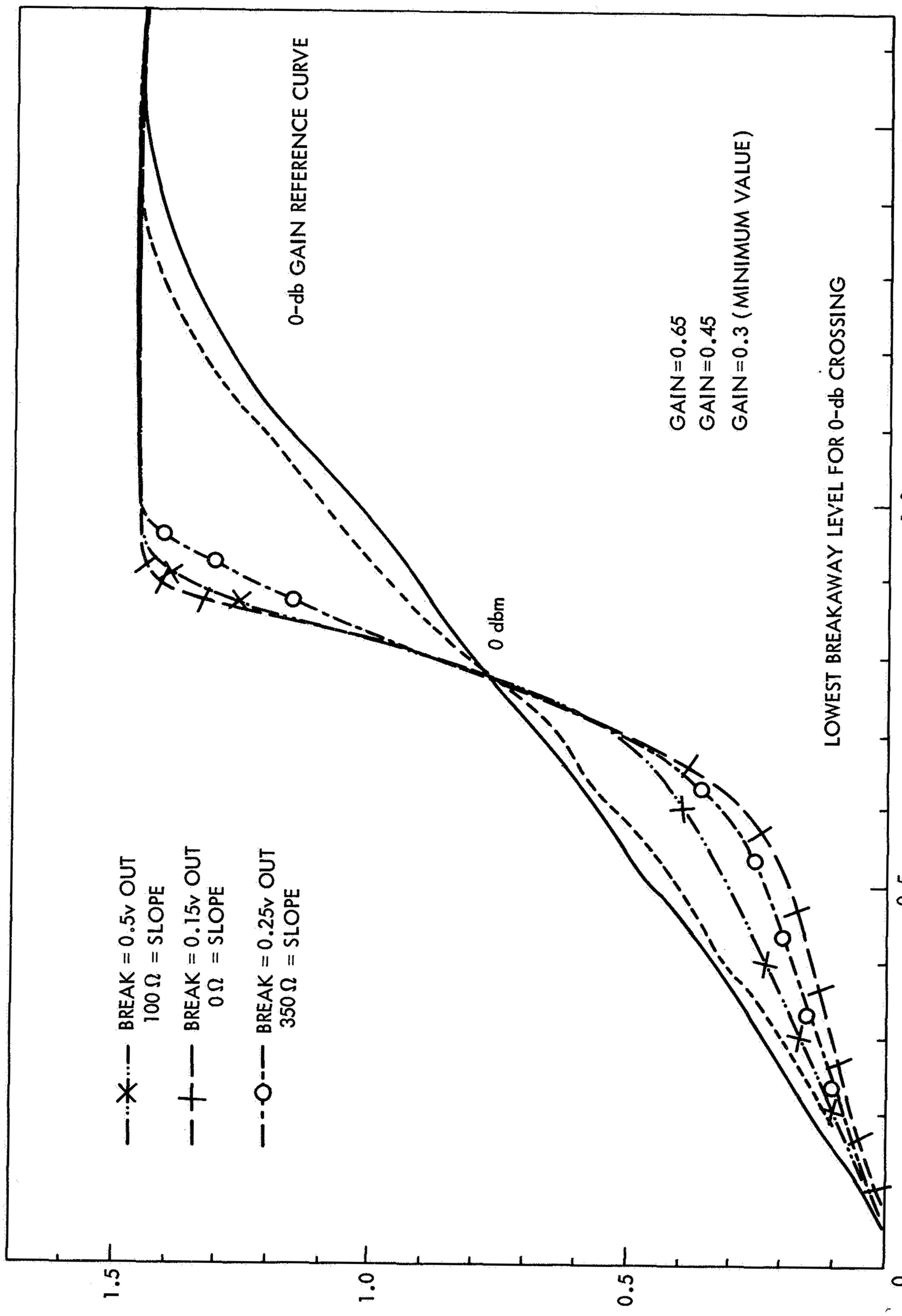


Figure 49. — White accentuation curve.

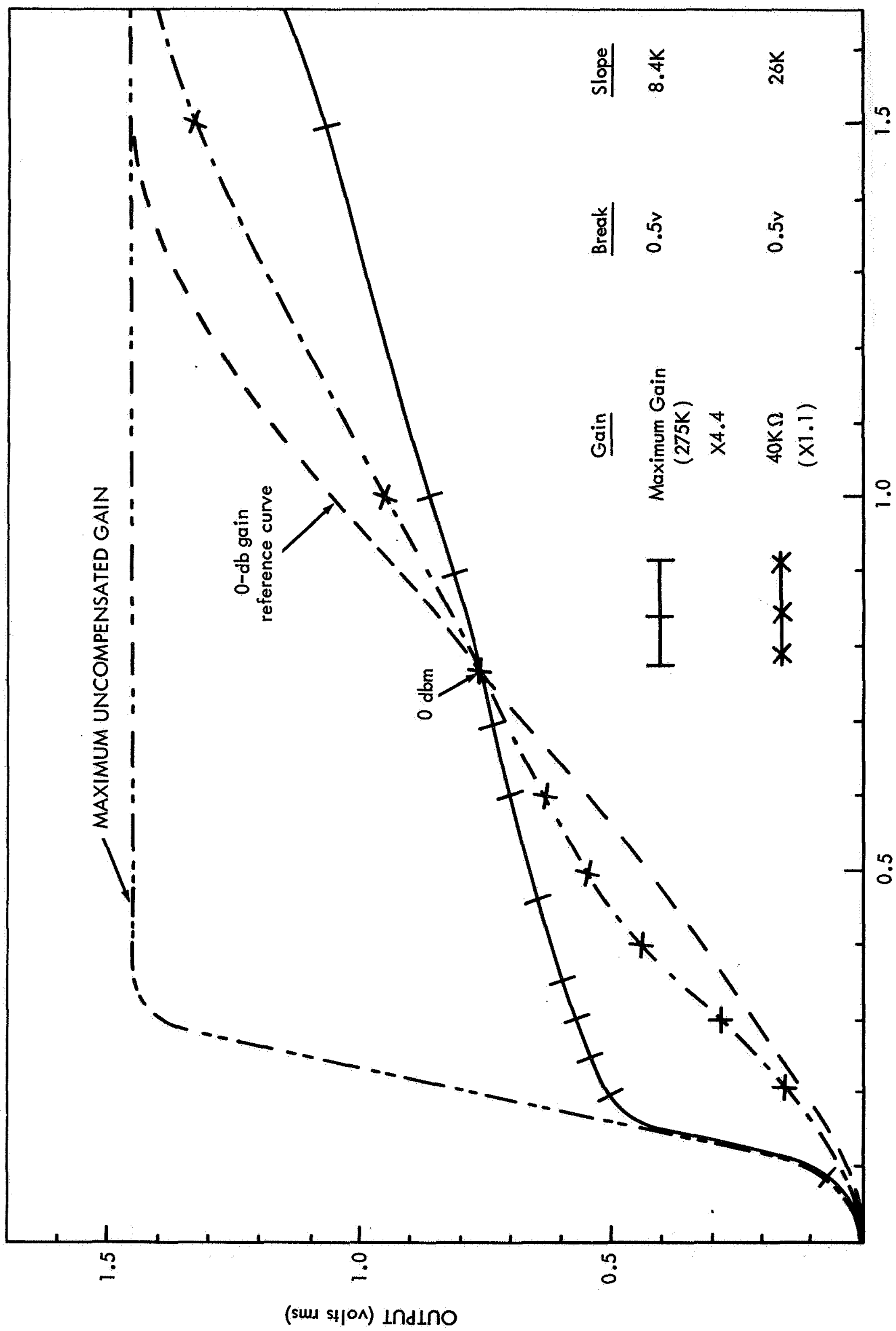


Figure 50. — Black accentuation curve.

CHAPTER 8

Direct Readout Infrared Satellite System

FOREWORD

As successful as the daylight cloudcover photography has been, it still represents only a part of the useful coverage. Cloudcover photography of the nighttime portion of the earth is equally important and design techniques for obtaining this information have been actively pursued. Nimbus I and II have successfully demonstrated that infrared sensors, such as the high resolution infrared radiometer (HRIR), are capable of providing measurements of cloud-top heights in addition to nighttime cloudcover imaging.

This chapter describes the construction and operation of the direct readout infrared radiometer (DRIR) system and the method for converting APT ground stations for receiving both daytime and nighttime cloudcover data. Nighttime cloudcover data can now be received from Nimbus III which carries the DRIR system.

Detailed drawings and parts list are included. Installation, alignment, and operation of the DRIR unit are also described.

The DRIR unit is inexpensive and is simple to install. With it, scientists, local weather stations, amateurs, and others can receive infrared pictures of the nighttime portion of the earth as satellites equipped with scanning radiometer (SR) systems pass overhead.

It is planned that SR systems compatible with APT ground stations equipped with DRIR units will be flown on Nimbus and ESSA satellites until 1971. It is probable that similar SR systems will be available after 1971.

Herbert I. Butler
Chief, Operational Satellites Office
NASA/GSFC

INTRODUCTION

The DRIR system developed by the U.S. National Aeronautics and Space Administration is a simply-constructed adapter unit which may be used to convert APT stations for the reception and processing of infrared nighttime cloudcover picture data in addition to the daytime cloudcover data transmitted by various meteorological satellites. The infrared data are received directly from the satellites during nighttime passes and are transmitted on the same frequency band used to transmit APT pictures during daylight hours. The DRIR adapter is required to display the DRIR pictures since their picture format differs from the APT format to accommodate the 48-rpm infrared radiometer scan rate. Specific details presented in this report pertain to the video electronics schematic (fig. 32).

At present, the only DRIR equipped satellite is Nimbus III, an experimental version launched April 14, 1969. Nimbus I and II, equipped with individual APT and high resolution infrared radiometer (HRIR) subsystems and launched August 28, 1964, and May 15, 1966, successfully demonstrated full daytime and nighttime picture coverage capability (figs. 51 and 52). The TIROS M and improved TIROS operational satellites (ITOS), named ESSA (Environmental Survey Satellite) when they achieve orbit, will provide continuous DRIR coverage on a regular operational basis. These satellites are built and launched under the technical direction of the NASA Goddard Space Flight Center (GSFC) and are operated by the U.S. Environmental Science Services Administration (ESSA).

The DRIR adapter utilizes transistors and integrated circuits to achieve the maximum in solid state reliability, maintainability, and circuit simplicity. Internal modifications required to convert the video electronics to dual daylight—DRIR operation is minimal and only requires installation of a rear-chassis connector, a relay, and some extra wiring.

Figures 54 and 57 reveal that the NASA unit was fabricated on printed circuit boards. The normal user does not have access to printed circuit manufacturing facilities; therefore the author has not included the printed circuit layout. It is recommended that the builder use breadboard materials to build the DRIR adapter unit.

By using the DRIR adapter, a ground station receiving data transmitted by APT/DRIR equipped satellites will double its pictorial coverage of the clouds and terrain in the vicinity of the ground station. Simplicity, continuous coverage, direct reception, and "instant" pictures make the DRIR equipped APT ground stations particularly useful to meteorologists, weather services, commercial organizations, government agencies, and educational institutions requiring more complete and accurate meteorological information.

HOW THE APT/DRIR SYSTEM WORKS

The APT system (satellite and ground station) transmits slow scan television pictures of cloudcover and terrain below the satellite in realtime to APT

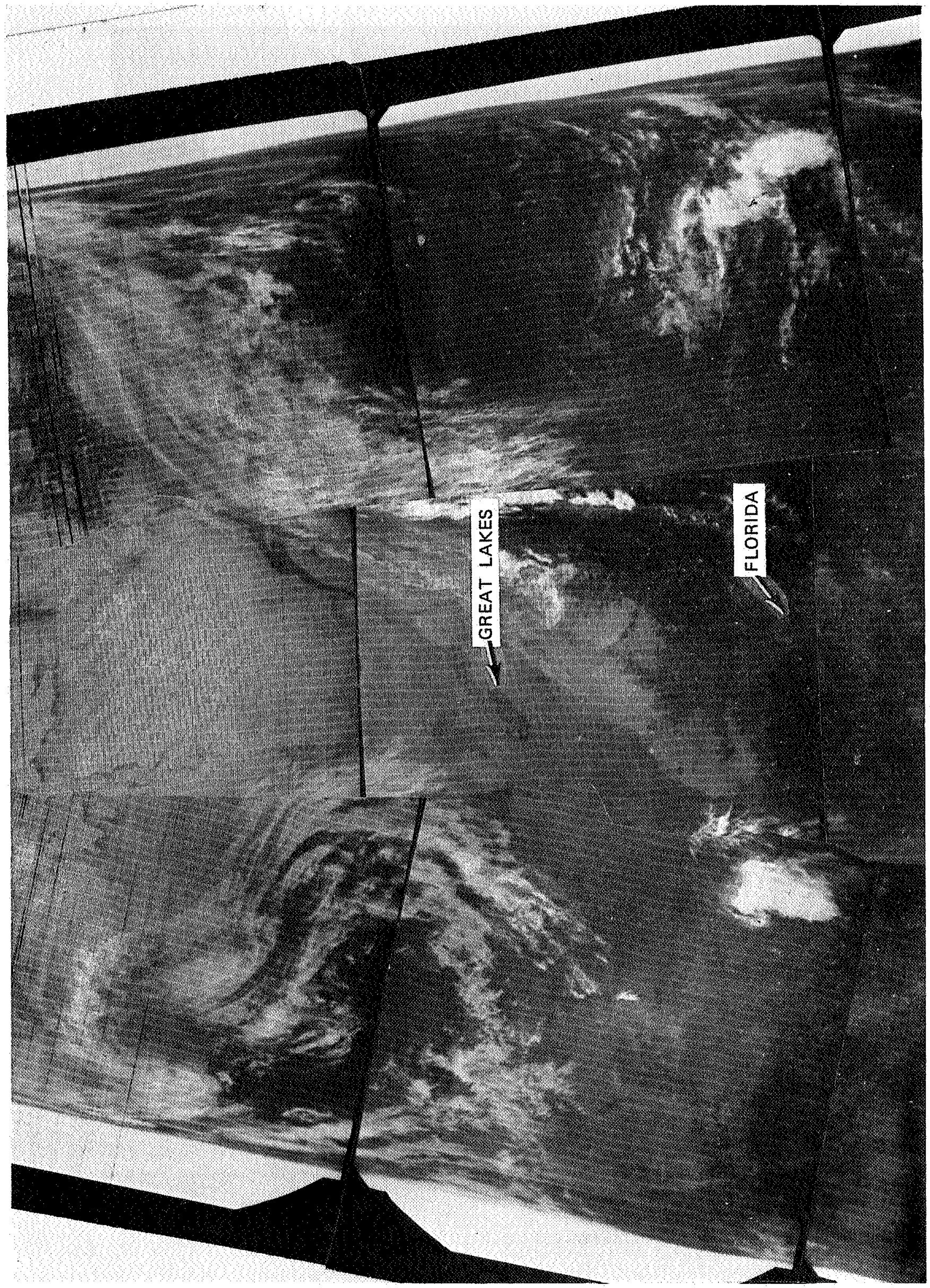


Figure 51. — Nimbus III DRIR, three successive passes showing entire continental United States, taken April 19-20, 1969.

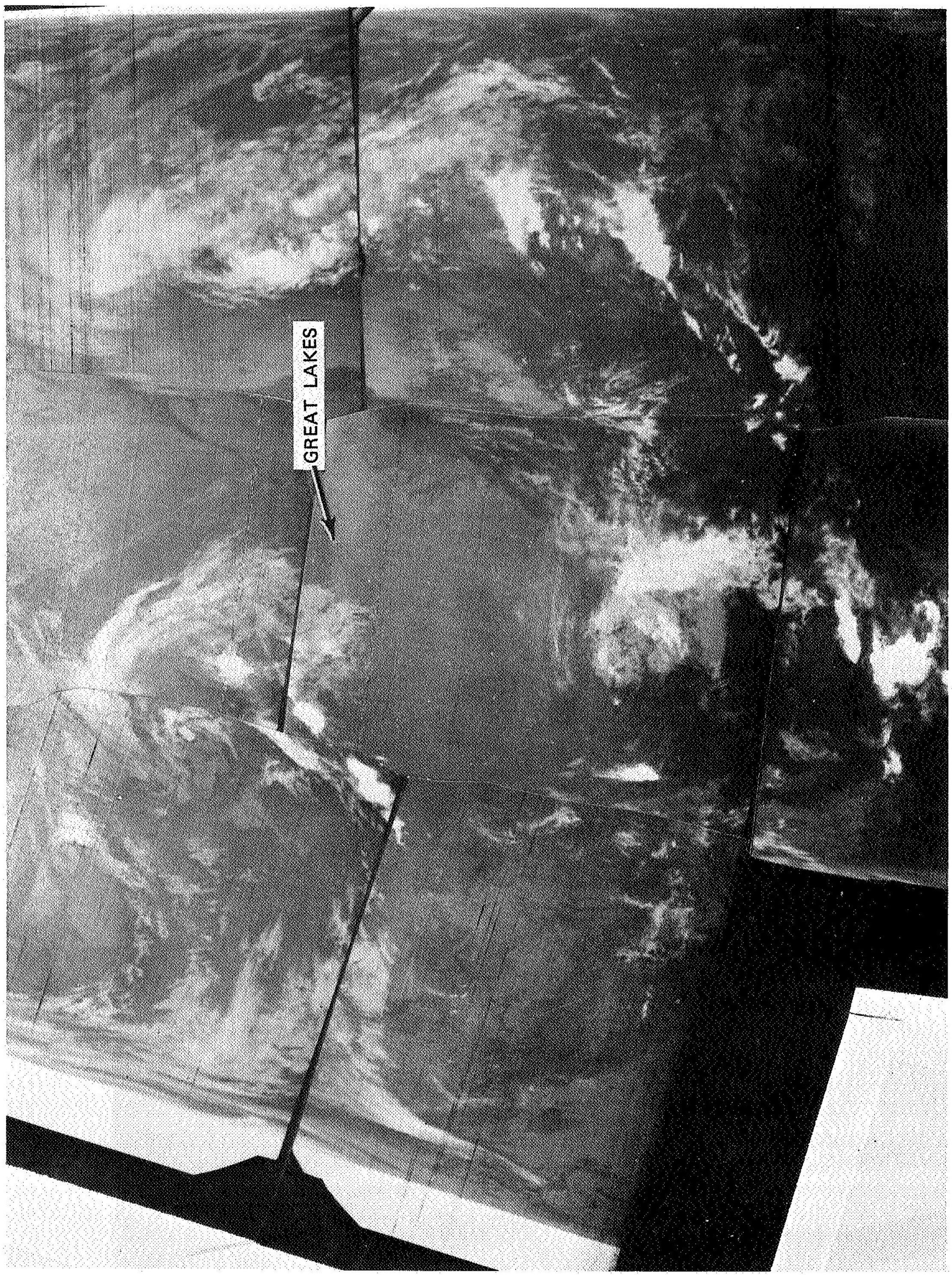


Figure 52. — Nimbus III DRIR, three successive passes showing entire continental United States, May 1–2, 1969

stations throughout the world for reproduction on facsimile equipment. Usefulness of the APT system can be increased by modifications designed to permit the reception and processing of infrared data during the nighttime portion of each orbit. Modifications of the infrared radiometer and APT subsystems on the Nimbus III, TIROS M, and ITOS spacecraft consist of making the radiometer output compatible with the APT transmitter and switching the APT or radiometer subcarrier to the transmitter at the proper time. Switching is controlled by ground-initiated commands that are transmitted to the satellites from command and data acquisition (CDA) stations located at Fairbanks, Alaska, and Wallops Island, Virginia.

CHARACTERISTICS OF THE DRIR ADAPTER

The DRIR adapter unit permits the APT station to display the DRIR pictures transmitted by DRIR equipped meteorological satellites. The infrared picture information is transmitted during nighttime passes on the same radio-frequency band used to transmit APT pictures during daylight hours. The spacecraft's DRIR system mechanically scans the earth's surface perpendicular to the spacecraft's orbit path at a 48 rpm rate. As the spacecraft moves in its orbital path, the line by line scan produces a continuous picture. The spacecraft radiometer scans a full 360 degrees; therefore, only approximately 33 percent of the total scan period represents the earth's surface. For ground station synchronization, a series of seven marker pulses are transmitted which identify the beginning of each scan line. The scanned optical information is passed through a 3.4 to 4.2 (Nimbus) and 10 to 12.5 (Tiros) micron infrared bandpass filter and is detected by a lead-selenide infrared detector. The system has a dynamic range of 190°K to 340°K. The seven marker pulses and infrared detector output amplitude modulate a 2400-Hz subcarrier frequency. In turn, this modulated subcarrier frequency is applied to the spacecraft's FM transmitter. Because of the difference in the APT and DRIR format and scan rates, a DRIR adapter unit is required to receive and display this nighttime picture information. The adapter unit provides synchronization and generates the horizontal and vertical sweep waveforms required by the APT station.

SPECIFICATIONS

Power Input:	115v, 50 to 60 Hz
Sweep Time:	Adjustable by ten-turn pot to accommodate present spacecraft scan rates.
Picture Synchronization:	Sweep phasing is accomplished automatically.

OPERATING INSTRUCTIONS

GENERAL

When receiving DRIR pictures, the operation is slightly modified from the operation of the photo receiver alone. When the DRIR adapter unit is plugged into the photo receiver, all front panel controls on the photo receiver are still valid with the exception of the following:

a. WAVEFORM-PICTURE Switch— has no effect.
b. SYNC Switch— has no effect.

OPERATING CONTROLS AND INDICATORS

POWER ON Switch— applies 115v, 60-Hz power from the photo receiver to the adapter unit. The switch places the photo receiver in the DRIR Receiving Mode.

POWER Light— indicates presence of 115v power.

WAVEFORM-PICTURE Switch— selects the display that is presented on the cathode ray tube. In the WAVEFORM position, the video waveform, which modulates the intensity of the cathode ray tube beam, can be observed. In the PICTURE position mode, the cathode ray tube beam, which is intensity modulated, scans the raster picture on the face of the tube.

VERTICAL RESET Push Button— resets the scanning trace to the top of the cathode ray tube.

END OF PICTURE Light— indicates that the vertical sweep of the CRT has reached the bottom of the screen. A new film should be inserted into the camera and the vertical sweep should be reset with the VERTICAL RESET button.

Vertical End of Picture Tone— produces an audible signal simultaneously with the END OF PICTURE light.

VERTICAL SWEEP TIME Ten-Turn Potentiometer— controls the vertical sweep time. The required pot setting (V) for a desired time (T_V) is given by $V = 1000/(0.963T_V - 23.2)$. The required settings for the following sweep times are given for convenience.

T_V (sec)	128	200	370	400	500	Infinity
V (units)	10.00	5.90	3.00	2.76	2.18	0

HORIZONTAL SWEEP TIME Ten-Turn Potentiometer— controls the horizontal sweep time. The required pot setting (H) for any desired sweep time (T_h) is given by $H = 12\ T_h - 4$. The required settings for the following horizontal sweep times are listed for convenience.

T_h(sec)	0.333	0.500	0.750	1.000	1.16 sec
H (units)	0	2.00	5.00	8.00	10.00

OPERATING PROCEDURE, REAL-TIME

The procedure listed below should be followed when receiving real-time satellite transmission of DRIR pictures.

a. Connect cable between the photo receiver and the adapter unit and turn the power switches ON for both units. Note indication of red pilot lamp on the adapter unit. The power should be applied to the photo receiver 15 minutes before a satellite pass.
b. On the photo receiver:
   (1) Set the TAPE/RCVR switch to the RCVR position.
   (2) Set the CHANNEL selector to the satellite frequency to be received.
   (3) Set the AUDIO LEVEL control to a point sufficient to hear receiver noise.
c. On the DRIR adapter unit, set the VERTICAL SWEEP TIME and HORIZONTAL SWEEP TIME. Approximate potentiometer settings are 3.00 for the VERTICAL SWEEP TIME potentiometer and 2.00 for the HORIZONTAL SWEEP TIME potentiometer.
d. Position the antenna elevation/azimuth to the point where the satellite will come over the horizon.
e. When the satellite signal is received, the video signal can be recognized by either its characteristic sound or waveform displayed on the cathode ray tube's face. When the satellite is first detected, the tape recorder should be placed in the record mode.
f. Set the WAVEFORM/PICTURE switch to the PICTURE position. This begins the picture raster.
g. Transmission of DRIR pictures is continuous. Therefore, a picture can be started when the signal is first received. Reset the scan line on the CRT to the top of the screen by pushing the VERTICAL RESET button.
h. Set the INTENSITY and CONTRAST controls to the optimum display level by viewing the trace through the camera binocular viewing port. Recording the signal on tape permits the operator to optimize these settings during playback.
i. Close the binocular viewing port and open the camera shutter to record the picture on Polaroid film.
j. When the tone and End of Picture light indicate completion of the picture, close the shutter, insert a new film, push the VERTICAL RESET button, and open the shutter to receive the next picture.

k. A picture takes approximately 370 seconds to receive. During this period, however, the antenna must stay pointed at the satellite as it moves across the sky. The azimuth and elevation versus time location may be previously calculated from orbital data (See APT Users Guide) or it may be tracked by keeping the antenna pointed in the direction of maximum signal strength as indicated by the signal strength meter located on the photo receiver.

OPERATING PROCEDURE – PLAYBACK

If the satellite transmission was recorded on tape, the pictures may be photographed by playing back the tape record. Possible improvement in picture quality may be achieved by variation of the intensity and contrast controls located on the photo receiver.

a. Rewind tape to the position of the desired picture and turn on recorder.
b. Place the TAPE/RCVR switch on the photo receiver in the TAPE position.
c. Place the WAVEFORM/PICTURE switch, located on the adapter unit, in the WAVEFORM position and increase the left channel recorder playback level until the data tone burst is two centimeters peak-to-peak as indicated by major division lines on the calibration plate on the right edge of the cathode ray tube.
d. Place the WAVEFORM/PICTURE switch on the adapter unit in the PICTURE position.
e. Check the setting of intensity and contrast controls.
f. Reset the VERTICAL SWEEP and open the camera shutter.

THEORY OF OPERATIONS

INTRODUCTION

The DRIR adapter unit generates the horizontal and vertical sweep signals required for the reception of infrared pictures from the Nimbus and TIROS M satellites. These sweep signals are applied to the deflection amplifiers that drive the CRT deflection plates in the photo receiver. A detailed operation of each circuit follows. The block diagram (fig. 53) and electrical schematic (fig. 54) are included for reference.

HORIZONTAL SYNC DETECTOR

Most of the electronics in the DRIR adapter are devoted to the reliable detection of the horizontal sync signal which precedes every horizontal line of picture information. This signal is processed as illustrated in fig. 55. The

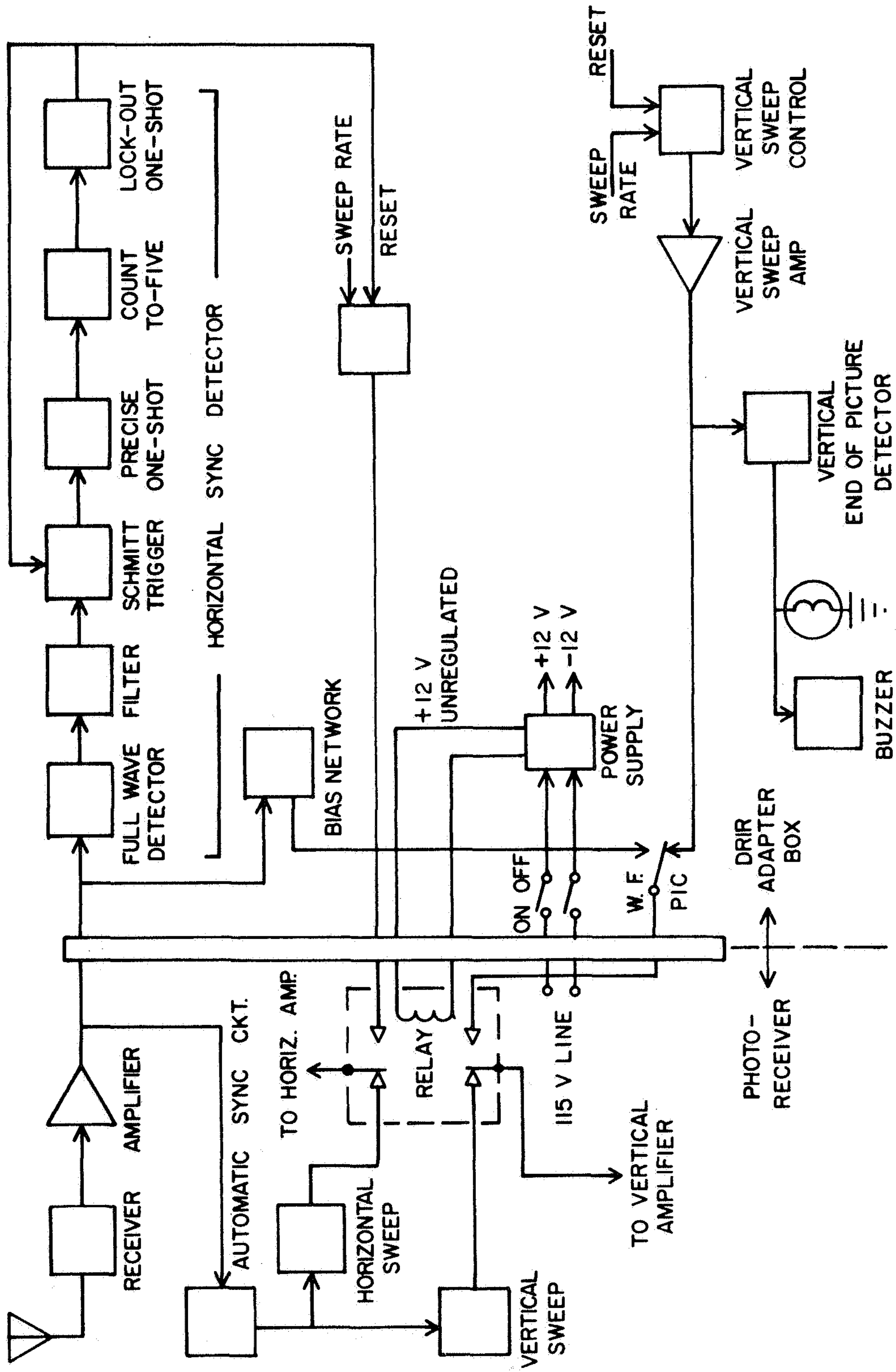


Figure 53. — Block diagram, DRIR adapter box for photo receiver.

video signal passes through (a) a unity-gain, full-wave detector, (b) a filter which removes the carrier and all higher frequencies, (c) a Schmitt trigger which shapes the waveform, (d) a precise-charge, one-shot multivibrator which deposits a charge on capacitor C8 each time the Schmitt trigger turns on, (3) a count-to-five circuit which triggers after the Schmitt trigger has turned on five (5) times within sixty (60) milliseconds, and (f) a lock-out, one-shot multivibrator which initiates the horizontal sweep and inhibits the receipt of any further signals for one second after a sync signal is received. The lock-out one-shot multivibrator assures that the picture information of about 0.5 second duration cannot inadvertantly trigger the count-to-five circuit and initiate an unwanted horizontal sweep.

HORIZONTAL SWEEP

A constant current source, capacitor, and parallel switch is used to generate the horizontal sawtooth sweep waveform. The constant current source charges capacitor C13 at a constant rate producing a linear ramp. The charging current is controlled by the fixed voltage at the base of Q11 and the value of the emitter resistors R48 and R50. Resistor R50 is the HORIZONTAL SWEEP TIME control which permits adjustment of the horizontal sweep time. The pulse produced by the synchronization circuitry is applied to Schmitt trigger circuit Q10 and Q11. Adjustment of R49 moves the picture produced on the CRT to the left.

VERTICAL SWEEP

The sawtooth waveform which is applied to the vertical sweep amplifier of the photo receiver is produced by operational amplifier A1. The slope of the positive going output waveform is dependent upon the values of C14, R54, and the voltage at the junction of R55 and R53. The horizontal sweep time is controlled by ten-turn potentiometer R55.

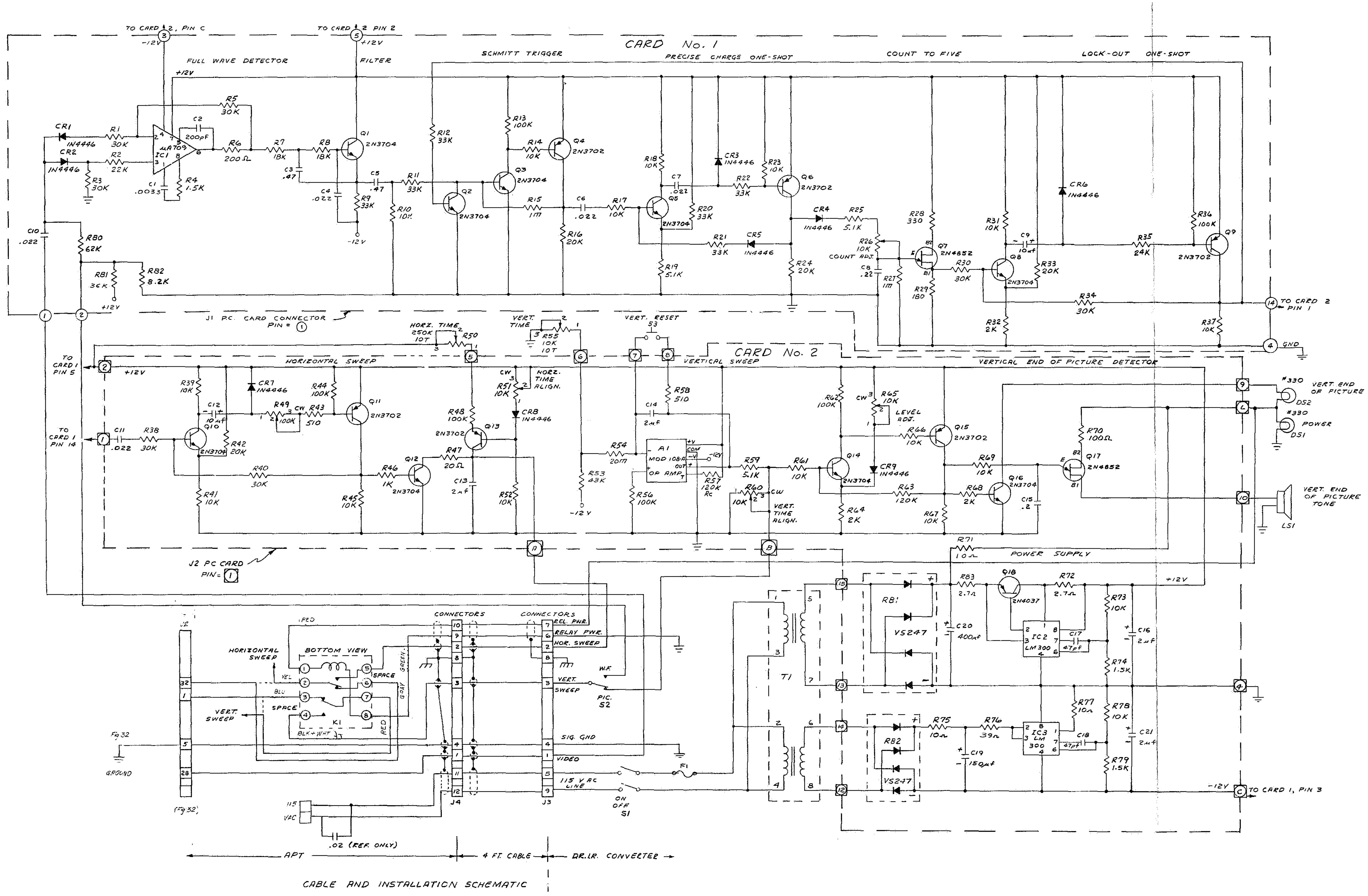
The vertical sweep waveform is reset to zero (trace to top of CRT) with the VERTICAL RESET button.

VERTICAL END OF PICTURE DETECTOR

The vertical sweep signal is monitored by the Vertical End of Picture detector. When the vertical sweep is complete (4.00 volts) the Schmitt trigger, comprised of Q14 and Q15, switches on. Q16 drives the light, and the unijunction transistor oscillator Q17 drives the speaker to announce the completion of the picture.

POWER SUPPLY

The power supply contains two integrated circuit regulators. The +12 volt output voltage is determined by the voltage divider R73 and R74, and current limiting is established by R72. Power transistor Q18 controlled by



NOTE: ALL POINTS LABELED ⏚ ARE CONNECTED TO SIGNAL GROUND TIE POINT.

Figure 54. — DRIR system schematic.

The carrier frequency is 2400 Hz.

The 7 marker pulses are each 6 msec. duration, and the interval between sync pulses is 6 msec.

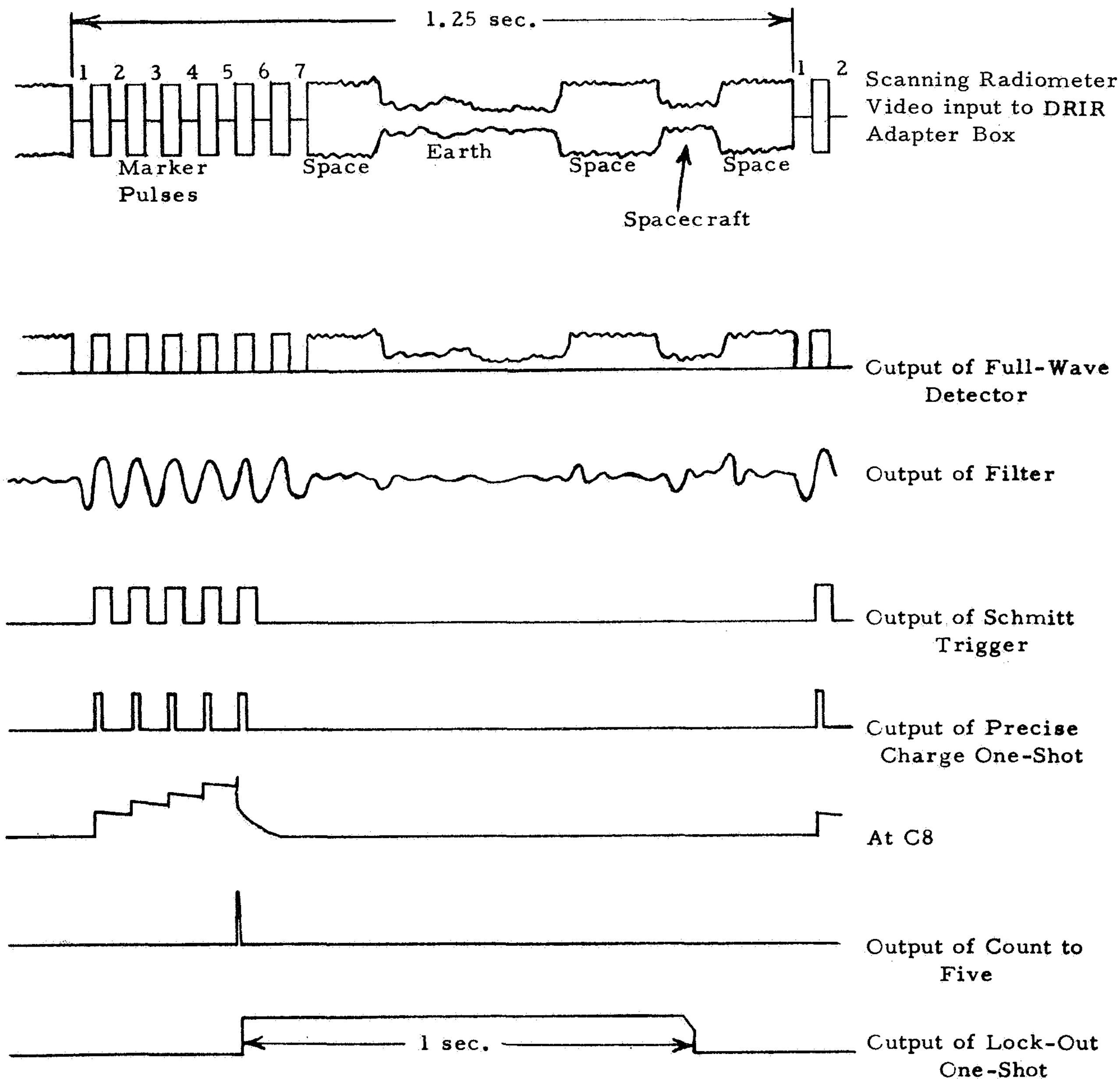


Figure 55.—Waveforms of horizontal sync detector.

the +12 volt regulator supplies approximately 70 ma at 12 volts. The negative supply is similar, but supplies 20 ma and does not require a power transistor. Batteries may be substituted providing they have the current capability.

INSTALLATION INTO PHOTO RECEIVER

INSTALLATION

The following modifications to the video electronics (fig. 32) make it compatible with the DRIR adapter box. The appropriate cable and installation schematic is included with the electrical schematic. The cable contains six shielded pairs with an overall insulator of plastic tubing.

a. Mount the rear connector and relay as illustrated in fig. 56.
b. Disconnect wire on J2, pin 1, and splice to new wire running to relay pin 7. Disconnect wire on J2, pin 32, and splice to new wire running to relay pin 2.
c. Run cable from the following pins on the connector as shown in the electrical schematic.

Connector Pin	Cable Type	To
1	Shielded Wire	J2 pin 28
2	Shielded Wire	Relay pin 5
3	Shielded Wire	Relay pin 4
4	Shielded Wire	J2 pin 5 and ground
8	AWG 22 Gauge Wire	Chassis ground (See fig. 56)
9 & 10	Twisted pair or shielded pair	Relay pins 8 and 1
11	Twisted pair or shielded pair	115 VAC

d. Run wires from relay pins 3 and 6 to J2, pins 1 and 32, respectively.
e. Connect all shields electrically to connector pin 8, taking care not to short other pins. The shields at the other end of the wires are not terminated electrically.
f. Run wire from J2, pin 5, to fig. 32 ground.
g. Check continuity of all wires for agreement with cable and installation schematic.

Figures 57 and 58 show the assembled DRIR adapter unit.

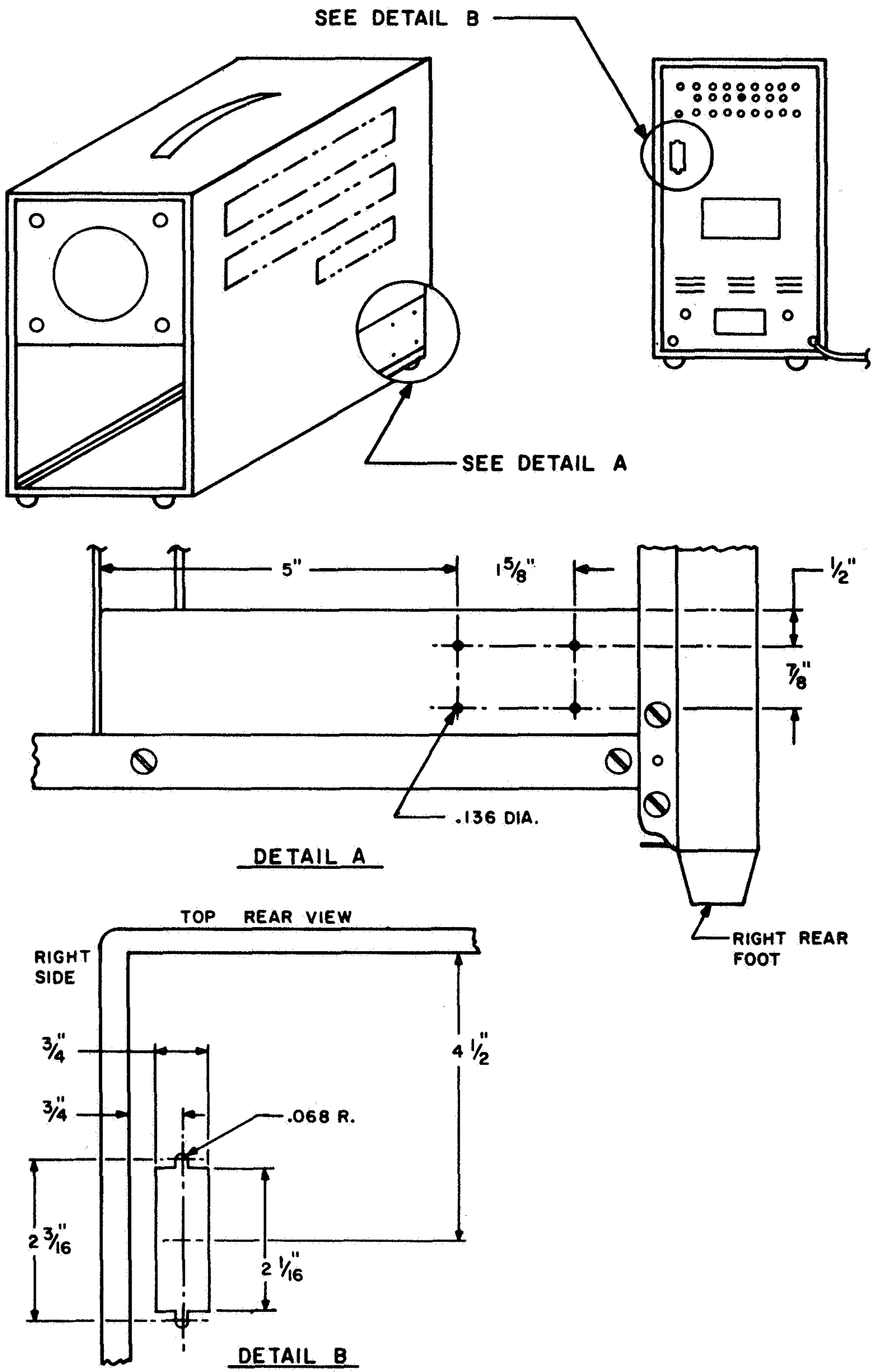


Figure 56. — Suggested location for DRIR connection into APT station.

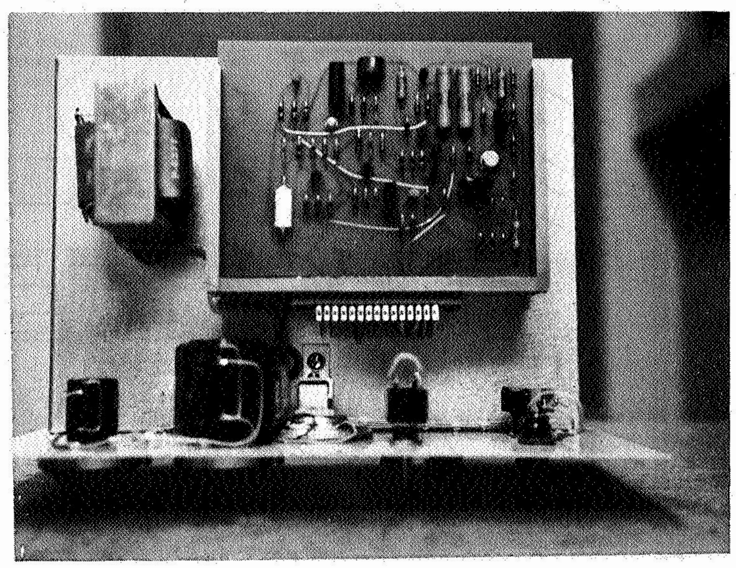


Figure 57. — Top of DRIR electronics.

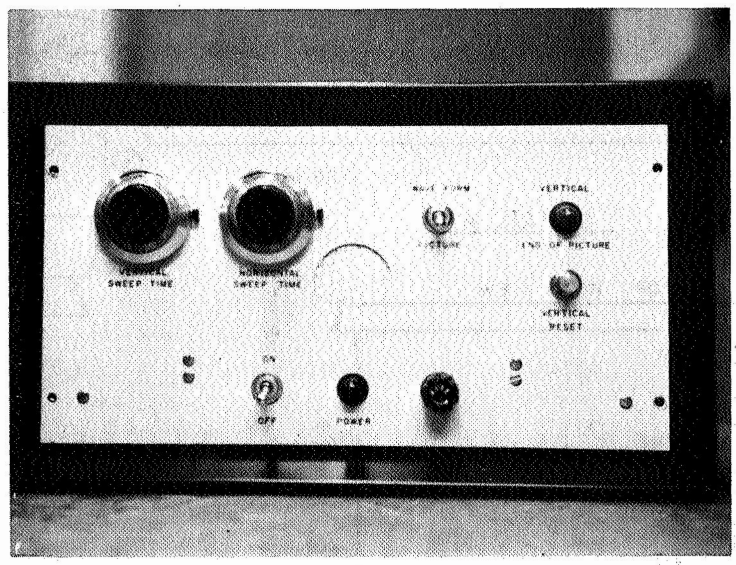


Figure 58. — Front view, DRIR adapter.

ALIGNMENT PROCEDURES

EQUIPMENT REQUIRED

a. Tape recorder and DRIR tape.
b. Oscilloscope
c. Digital voltmeter (3 digits)

INITIAL SET-UP

a. Connect the tape recorder with a recorded DRIR tape to the recorder input connector of the photo receiver.
b. Set the TAPE/RCVR switch on the photo receiver to the TAPE position.
c. Place the WAVEFORM/PICTURE switch located on the DRIR adapter unit to the WAVEFORM position.
d. Adjust the left channel recorder playback level until the amplitude of the waveform displayed on the CRT is approximately two centimeters peak-to-peak.

COUNT-TO-FIVE CIRCUIT ALIGNMENT

a. Plug tape recorder into photo receiver.
b. Connect the oscilloscope to C8 - R26 junction.
c. Adjust R26 so that Q7 triggers on the fifth pulse as pictured in fig. 55.

HORIZONTAL SWEEP CIRCUIT ALIGNMENT

a. Apply input signal to photo receiver from DRIR tape.
b. Connect oscilloscope to C13 - R47 junction using 10M-ohm probe.
c. Set front panel HORIZONTAL SWEEP TIME adjustments to 2.00.
d. Adjust R51 to a position where the ramp waveform reaches 4 volts in exactly 0.500 seconds.

VERTICAL SWEEP CIRCUIT ALIGNMENT

a. Apply input signal to photo receiver from DRIR tape.
b. Set front panel VERTICAL SWEEP TIME adjustments to 3.00.
c. Connect a digital voltmeter to pin B of the DRIR adapter unit.
d. Reset vertical sweep (digital voltmeter will read zero) and time exactly 370 seconds from the release of the

vertical reset button. Record the voltage displayed by the DVM at 370 seconds. If the voltage reading is not 4.00 volts, adjust R60 and repeat above procedure. Clockwise rotation of R60 will increase amplitude.

VERTICAL END OF PICTURE DETECTOR ALIGNMENT

a. Apply signal to photo receiver from DRIR tape.
b. Note voltage at pin B at the time the Vertical End of Picture light and the tone come on. This voltage must be observed before the end of picture indication occurs since there is a jump in voltage at this point.
c. Adjust R65 so that the end of picture indication occurs when the vertical sweep reaches 4.00 volts.

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2. Stampfl, R. A. and Stroud, W. G.: The Automatic Picture-Transmission (APT) TV Camera System for Meteorological Satellites, NASA TN D-1915, 1963.
3. National Weather Satellite Center, Environmental Science Services Administration: The APT User's Guide, Washington, 1965. (Available from the Superintendent of Documents, Government Printing Office, Washington, D.C., 20402, as Document C52-8, $1.00).
4. Nimbus III Real Time Transmission Systems, Nimbus Project NASA/GSFC, Greenbelt, Maryland, 20771.

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Appendix A

VHF Receiver Parts List

Quantity	Part Number	Description	Symbol
		Solder, SN60/SN63	
	8022	Bus wire, #22 tinned copper, Belden*	
35	2010-B	Terminal, Useco*	
4	4500-2	Coil form, ceramic, 1/4" (.635 cm) diameter, J. W. Miller*	L4, L8
		Coil form, ceramic, 1/4" diameter, J. W. Miller*	L9, L10
1	9S2	Shield, tube, 9-pin min., 1-15/16" (4.92 cm) high, Cinch*	
1	7S4	Shield, tube, 7-pin min., 2-1/4" (5.72 cm) high, Cinch*	
4	7S3	Shield, tube, 7-pin min., 1-3/4" (4.45 cm) high, Cinch*	
1	7S2	Shield, tube, 7-pin min., 1-3/8" (3.49 cm) high, Cinch*	
3	04-210-04	Socket, crystal, HC-6 holder, Elco*	
1	9PC-M2	Socket, tube, 9-pin min., P.C., Cinch*	
6	7PC-M2	Socket, tube, 7-pin min., P.C., Cinch*	
3	5NS-2	Socket, tube, Nuvistor, P.C., Cinch*	
3		Crystal units, quartz, as follows:	
		Frequency to be determined by carrier	
		$f(crystal) = \frac{f(carrier) + 17.55}{3}$	
		Channel A = 51.05 MHz (135.6)	
		Channel B = 51.50 MHz (136.95)	
		Channel C = 51.683 MHz (137.50)	
		Channel D = 51.720 MHz (137.62)	
1		Resistor, fixed comp., 270 ohm, 2w 5%	R39
1		Resistor, fixed comp., 20K, 2w 5%	R34
1		Resistor, fixed comp., 10K, 2w 5%	R25
1		Resistor, fixed comp., 1.2K, 1w 5%	R35
1		Resistor, fixed comp., 39K, 1w 5%	R16
3		Resistor, fixed comp., 4.7K, 1w 5%	R11, R3
		Resistor, fixed comp., 4.7K, 1w 5%	R17
2		Resistor, fixed comp., 18K, 1w 5%	R10, R14
1		Resistor, fixed comp., 68K, 1/2w 5%	R45
2		Resistor, fixed comp., 8.2K, 1/2w 5%	R5, R6
1		Resistor, fixed comp., 30K, 1/4w 5%	R44
1		Resistor, fixed comp., 180K, 1/4w 5%	R43
1		Resistor, fixed comp., 82K, 1/4w 5%	R41
1		Resistor, fixed comp., 8.2K, 1/4w 5%	R40
1		Resistor, fixed comp., 1 M., 1/4w 5%	R38
1		Resistor, fixed comp., 4.7 M., 1/4w 5%	R37
1		Resistor, fixed comp., 330K, 1/4w 5%	R36
1		Resistor, fixed comp., 3.9K, 1/4w 5%	R33
1		Resistor, fixed comp., 10K, 1/4w 5%	R28
1		Resistor, fixed comp., 680 ohm, 1/4w 5%	R24
1		Resistor, fixed comp., 130K, 1/4w 5%	R23
2		Resistor, fixed comp., 11K, 1/4w 5%	R22, R42
1		Resistor, fixed comp., 7.5K, 1/4w 5%	R21
1		Resistor, fixed comp., 130 ohm, 1/4w 5%	R20

*Other equivalent brands can be used.

VHF Receiver Parts List — (Continued)

Quantity	Part Number	Description	Symbol
3		Resistor, fixed comp., 51K, 1/4w 5%	R18, R19
		Resistor, fixed comp., 51K, 1/4w 5%	R30
2		Resistor, fixed comp., 68 ohm, 1/4w 5%	R12, R15
1		Resistor, fixed comp., 150 ohm, 1/4w 5%	R8
1		Resistor, fixed comp., 470K, 1/4w 5%	R4
6		Resistor, fixed comp., 100K, 1/4w 5%	R3, R26
		Resistor, fixed comp., 100K, 1/4w 5%	R27, R29
		Resistor, fixed comp., 100K, 1/4w 5%	R31, R32
1		Resistor, fixed comp., 100 ohm, 1/4w 5%	R2
3		Resistor, fixed comp., 47K, 1/4w 5%	R1, R7
		Resistor, fixed comp., 47K, 1/4w 5%	R9
1	12AU7	Tube, electron, RCA*	V10
1	6J6	Tube, electron, RCA*	V9
1	6AL5	Tube, electron, RCA*	V8
1	6BN6	Tube, electron, RCA*	V7
2	6BA6	Tube, electron, RCA*	V5, V6
3	6CW4	Tube, electron, RCA*	V1, V2
		Tube, electron, RCA*	V3
1	1464-PC	Transformer, disctr, 10.7 MHz, J.W. Miller*	T8
3	1463-PC	Transformer, I.F., 10.7 MHz, J.W. Miller*	T5, T6
		Transformer, I.F., 10.7 MHz, J.W. Miller*	T7
1	MST-115D	Switch, miniature toggle, SPDT, Alco*	S2
1		Inductor, per Figure 27	L10
1		Inductor, per Figure 27	L9
1		Inductor, per Figure 27	L8
1		Inductor, per Figure 27	L4
1		Inductor, per Figure 25	L7
1		Inductor, per Figure 25	L6
1		Inductor, per Figure 25	L5
1		Inductor, per Figure 25	L2
1		Inductor, per Figure 25	L1
1	20A337RB1	Inductor, J.W. Miller*	L3
1	IN751	Diode, zener, 5. 1v Motorola*	CR3
1	IN270	Diode, germanium, Sylvania*	CR2
1	V47E/947	Diode, volt. var. cap., 4-7pf/14V, TRW*	CR1
21	DD-222	Capacitor, 0.0022μf/1000v (GMV), Centralab*	C28, C29
		Capacitor, 0.0022μf/1000v (GMV), Centralab*	C30, C32
		Capacitor, 0.0022μf/1000v (GMV), Centralab*	C33, C35
		Capacitor, 0.0022μf/1000v (GMV), Centralab*	C36
		Capacitor, 0.0022μf/1000v (GMV), Centralab*	C39, C42
		Capacitor, 0.0022μf/1000v (GMV), Centralab*	C49-C58
1	DD-502	Capacitor, 0.005μf/1000v (GMV), Centralab*	C47
1	DA-503	Capacitor, 0.05 μf/30v 100-20%, Centralab*	C46
1	DM-221	Capacitor, 220 pf/1000v 10%, Centralab*	C44
1	DM-10-100J	Capacitor, 10 pf 500v 5%, Elemenco*	C37
5	DD-6-103	Capacitor, 0.01μf/600v (GMV), Centralab*	C27
		Capacitor, 0.01μf/600v (GMV), Centralab*	C31
		Capacitor, 0.01μf/600v (GMV), Centralab*	C34
		Capacitor, 0.01μf/600v (GMV), Centralab*	C38
		Capacitor, 0.01μf/600v (GMV), Centralab*	C48
1	DD-302	Capacitor, 0.003μf/1000v (GMV), Centralab*	C25
1	DM-10-121G	Capacitor, 120 pf/500v 2%, Elemenco*	C22
1	VC-4-G	Capacitor, Variable, .8-18.0 pf, J.F.D.*	C24

*Other equivalent brands can be used.

APPENDIX A

VHF Receiver Parts List — (Concluded)

Quantity	Part Number	Description	Symbol
3	DM-10-470J	Capacitor, 47 pf/500v 5%, Elemenco*	C15, C20
		Capacitor, 47 pf/500v 5%, Elemenco*	C21
2	DC-220K	Capacitor, 22 pf/200v 10%, Nytronics*	C13, C19
1	DM-10-101J	Capacitor, 100 pf/500v 5%, Elemenco*	C11
1	DM-10-050K	Capacitor, 5 pf/500v 5%, Elemenco*	C9
4	VC-1-G	Capacitor, Variable, 0.7-9.0 pf, J.F.D.*	C3, C8
		Capacitor, Variable, 0.7-9.0 pf, J.F.D.*	C10, C17
11	DD-102	Capacitor, 0.001μf/1000v 10%, Centralab*	C2, C5
		Capacitor, 0.001μf/1000v 10%, Centralab*	C6, C7
		Capacitor, 0.001μf/1000v 10%, Centralab*	C12, C14
		Capacitor, 0.001μf/1000v 10%, Centralab*	C16, C18
		Capacitor, 0.001μf/1000v 10%, Centralab*	C26, C43
		Capacitor, 0.001μf/1000v 10%, Nytronics*	C45
2		Capacitor, 0.001μf/100v 10%, Nytronics*	C1, C4
1	DM10---	Capacitor-valve, "TBD," Elemenco*	C23

*Other equivalent brands can be used.

Appendix B

Video Electronics Parts List

Note: This list is subject to revision and should be used only as a guide.

Quantity	Part Number	Description
1	WMF1D22	Capacitor, mylar, 0.0022μf/100V 10%, Cornell-Dubilier*
3	WMF1D47	Capacitor, mylar, 0.0047μf/100V 10%, Cornell-Dubilier*
6	WMF151	Capacitor, mylar, 0.01μf/100V 10%, Cornell-Dubilier*
1	WMF1S47	Capacitor, mylar, 0.047μf/100V 10%, Cornell-Dubilier*
4	MFP1P1	Capacitor, mylar, 0.1μf/100V 10% Cornell-Dubilier*
1	MFP1P22	Capacitor, mylar, 0.22μf/100V 10%, Cornell-Dubilier*
2	MFP2P47	Capacitor, mylar, 0.47μf/100V 10%
3	150D105X0035A2	Capacitor, solid tantalum, 1μf/50V 20%, Sprague*
2	Y146XR-15	Capacitor, solid tantalum, 2μf/50V 20%, Aerovox*
1	150D685X0035B2	Capacitor, solid tantalum, 6.8μf/50V 20%, Sprague*
1	150D156X0020B2	Capacitor, solid tantalum, 15μf/50V 20%, Sprague*
2	MTP226MO15P1A	Capacitor, wet tantalum, 22μf/15V 20%, Mallory*
1	MTP157M020P1C	Capacitor, wet tantalum, 150μf/20V 20%, Mallory*
1	39D508G010HP4	Capacitor, al. electrolytic, 5000μf/10V 20%, Sprague*
1		Resistor, carbon comp., 8.2 ohm, 1/4w 5%
2		Resistor, carbon comp., 10 ohm, 1/4w 5%
1		Resistor, carbon comp., 15 ohm, 1/4w 5%
1		Resistor, carbon comp., 220 ohm, 1/4w 5%
2		Resistor, carbon comp., 560 ohm, 1/4w 5%
3		Resistor, carbon comp., 1K, 1/4w 5%
2		Resistor, carbon comp., 1.2K, 1/4w 5%
2		Resistor, carbon comp., 1.3K, 1/4w 5%
4		Resistor, carbon comp., 1.5K, 1/4w 5%
1		Resistor, carbon comp., 2.2K, 1/4w 5%
1		Resistor, carbon comp., 3K, 1/4w 5%
1		Resistor, carbon comp., 4.7K, 1/4w 5%
3		Resistor, carbon comp., 6.8K, 1/4w 5%
1		Resistor, carbon comp., 7.5K, 1/4w 5%
2		Resistor, carbon comp., 8.2K, 1/4w 5%
1		Resistor, carbon comp., 9.1K, 1/4w 5%
8		Resistor, carbon comp., 10K, 1/4w 5%
1		Resistor, carbon comp., 12K, 1/4w 5%
2		Resistor, carbon comp., 13K, 1/4w 5%
3		Resistor, carbon comp., 15K, 1/4w 5%
3		Resistor, carbon comp., 16K, 1/4w 5%
1		Resistor, carbon comp., 18K, 1/4w 5%
1		Resistor, carbon comp., 20K, 1/4w 5%
1		Resistor, carbon comp., 22K, 1/4w 5%
7		Resistor, carbon comp., 27K, 1/4w 5%
2		Resistor, carbon comp., 47K, 1/4w 5%
1		Resistor, carbon comp., 51K, 1/4w 5%
2		Resistor, carbon comp., 56K, 1/4w 5%
1		Resistor, carbon comp., 62K, 1/4w 5%
1		Resistor, carbon comp., 68K, 1/4w 5%
2		Resistor, carbon comp., 82K, 1/4w 5%
4		Resistor, carbon comp., 100K, 1/4w 5%
1		Resistor, carbon comp., 150K, 1/4w 5%

*Other equivalent brands can be used.

Video Electronics Parts List — (Concluded)

Quantity	Part Number	Description
2		Resistor, carbon comp., 180K, 1/4w 5%
2		Resistor, carbon comp., 220K, 1/4w 5%
1		Resistor, carbon comp., 330K, 1/4w 5%
1		Resistor, carbon comp., 470K, 1/4w 5%
1		Resistor, carbon comp., 1.5 M, 1/4w 5%
2		Resistor, carbon comp., 10 M, 1/4w 5%
1		Resistor, carbon comp., 4.7 ohm, 1w 5%
1		Resistor, carbon comp., 110 ohm, 2w 5%
1	V-4	Potentiometer, 1 turn, 1K, 1w 20%, Mallory*
2	273-1-502M	Potentiometer, 25 turn, 5K, 1/4w 10%, Bourn*
1	273-1-103M	Potentiometer, 25 turn, 10K, 1/4w 10%, Bourn*
1	U-35	Potentiometer, 50K, 1w 20%, Mallory*
1	F1-100K-R1-100K	Potentiometer, 1 turn-dual, 100K, 1/2w 20%, Centralab*
10	2N3702	Transistor, Texas Instrument*
8	2N3704	Transistor, Texas Instrument*
8	2N3707	Transistor, Texas Instrument*
5	IN4446	Diode, General Electric*
2	IN538	Diode, Texas Instrument or General Electric*
1	IN270	Diode, Sylvania*
3	mL91428	Integrated ckt, dual gate, Fairchild*
10	mL92328	Integrated ckt, J-K flip-flop, Fairchild*
1	VIC-10	Inductor, variable, 0.54H
1	FS-32 (Special)	Frequency standard, 2400 Hz, American Time Products*
1	PG65AU	Amplifier, operational, Philbrick*
2	#328	Lamp, mid. flanged T-1-3/4, General Electric*
1	#330	Lamp, mid. flanged T-1-3/4, General Electric*
1	162-843-933-502	Lamp holder, yellow, Dialco*
1	162-843-975-502	Lamp holder, white, Dialco*
1	162-843-931-502	Lamp holder, red, Dialco*
1	Model 13.0-1 Ma.	Meter, Emico*
1	MFG. Type 250	Phone plug, black, Switchcraft*
2	3502	Phone plug, Switchcraft*
1	26-159-32	Connector, Amphenol*
3	50-6007-3314	Connector, insert polarization, Elco*
1	22A062100	Speaker, 2-1/2" (5 cm), 100 ohm, Quam*
8	K-700G	Knob, aluminum instrument knobs
1	K-500G	Knob, aluminum instrument knobs
1	50-2-1G	Knob, Raytheon*
2	115-253	Flexible shaft, E.F. Johnson*
1	Allied 47D4096	Bearing, H.H. Smith
5 ft	8445	Tape recorder cable, Belden*

*Other equivalent brands can be used.

APPENDIX C

Video Remodulation Unit Parts List

Symbol	Description	Part No.	Vendor*
R1	Potentiometer, 10 kΩ, ±10%, 1/2 w	65	IRC-CTS
R2	Potentiometer, 250 kΩ, ±10%, 1/2 w	65	IRC-CTS
R3	Potentiometer, 250 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R4	Potentiometer, 250 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R5	Potentiometer, 10 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R6	Potentiometer, 10 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R7	Potentiometer, 25 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R8	Potentiometer, 50 kΩ, ±10%, 1/2 w	65LT	IRC-CTS
R9	Resistor, 10 kΩ, ± 5%, 1/4 w	RC07GF103J	Ohmite
R10	Resistor, 5.8 kΩ, ± 5%, 1/4 w	RC07GF582J	Ohmite
R11	Resistor, 11 kΩ, ± 5%, 1/4 w	RC07GF113J	Ohmite
R12	Resistor, 510 kΩ, ± 5%, 1/4 w	RC07GF514J	Ohmite
R13	Resistor, 510 kΩ, ± 5%, 1/4 w	RC07GF511J	Ohmite
R14	Resistor, 6.8 kΩ, ± 5%, 1/4 w	RC07GF682J	Ohmite
R15	Resistor, 3 kΩ, ± 5%, 1/4 w	RC07GF302J	Ohmite
R16	Resistor, 1 kΩ, ± 5%, 1/4 w	RC07GF102J	Ohmite
R17	Resistor, 1 kΩ, ± 5%, 1/4 w	RC07GF102J	Ohmite
R18	Resistor, 5.1 kΩ, ± 5%, 1/4 w	RC07GF512J	Ohmite
R19	Resistor, 5.1 kΩ, ± 5%, 1/4 w	RC07GF512J	Ohmite
R20	Resistor, 20 kΩ, ± 5%, 1/4 w	RC07GF203J	Ohmite
R21	Resistor, 62 kΩ, ± 5%, 1/4 w	RC07GF623J	Ohmite
R22	Resistor, 510 kΩ, ± 5%, 1/4 w	RC07GF511J	Ohmite
R23	Resistor, 9.1 kΩ, ± 5%, 1/4 w	RC07GF912J	Ohmite
R24	Resistor, 4.7 kΩ, ± 5%, 1/4 w	RC07GF472J	Ohmite
R25	Resistor, 4.7 kΩ, ± 5%, 1/4 w	RC07GF472J	Ohmite
R26	Resistor, 4.7 kΩ, ± 5%, 1/4 w	RC07GF472J	Ohmite
R27	Resistor, 10 MΩ, ± 5%, 1/4 w	RC07GF106J	Ohmite
R28	Resistor, 10 kΩ, ± 5%, 1/4 w	RC07GF103J	Ohmite
R29	Resistor, 10 kΩ, ± 5%, 1/4 w	RC07GF103J	Ohmite
R30	Resistor, 9.1 kΩ, ± 5%, 1/4 w	RC07GF912J	Ohmite
R31	Resistor, 18 kΩ, ± 5%, 1/4 w	RC07GF183J	Ohmite
R32	Resistor, 27 kΩ, ± 5%, 1/4 w	RC07GF273J	Ohmite
R33	Resistor, 27 kΩ, ± 5%, 1/4 w	RC07GF273J	Ohmite
R34	Resistor, 4.7 kΩ, ± 5%, 1/4 w	RC07GF472J	Ohmite
R35	Resistor, 5.1 kΩ, ± 5%, 1/4 w	RC07GF512J	Ohmite
R36	Resistor, 4.7 kΩ, ± 5%, 1/4 w	RC07GF472J	Ohmite
R37	Resistor, 51 kΩ, ± 5%, 1/4 w	RC07GF510J	Ohmite
R38	Resistor, 10 kΩ, ± 5%, 1/4 w	RC07GF100J	Ohmite
R39	Resistor, 43 kΩ, ± 5%, 1/4 w	RC07GF430J	Ohmite
R40	Resistor, 10 kΩ, ± 5%, 1/4 w	RC07GF100J	Ohmite

*Equivalent components are acceptable.

Video Remodulation Unit Parts List—(Continued)

Symbol	Description	Part No.	Vendor*
R41	Resistor, 100 kΩ, ± 5%, 1/4 w	RC07GF104J	Ohmite
R42	Resistor, 510 kΩ, ± 5%, 1/4 w	RC07GF511 J	Ohmite
C1	Capacitor, 1000pf, ± 5%, 500 v	CD19F102J	Cornell-Dubilier
C2	Capacitor, To Be Determined		
C3	Capacitor, 560pf, ± 5%, 500 v	CD19F561J	Cornell-Dubilier
C4	Capacitor, 220pf, ± 5%, 500 v	CD15F221J	Cornell-Dubilier
C5	Capacitor, 200pf, ± 5%, 500 v	CD15F201J	Cornell-Dubilier
C6	Capacitor, .1μf, -20% +80%50 v	CK-104	Centralab
C7	Capacitor, 500μf,-10% +75%10 v	39D507G010EJ4	Sprague
C8	Capacitor, 500μf,-10% +75%10 v	39D507G010EJ4	Sprague
CR1	Diode, IN90	IN90	Sylvania
CR2	Diode, IN90	IN90	Sylvania
CR3	Diode IN90	IN90	Sylvania
CR4	Diode, IN706	IN706	Dickson
CR5	Rectifier, IN4001	IN4001	Tex. Instr.
CR6	Rectifier, IN4001	IN4001	Tex. Instr.
CR7	Rectifier, IN4001	IN4001	Tex. Instr.
CR8	Rectifier, IN4001	IN4001	Tex. Instr.
CR9	Diode, Zener IN4735 (Case 59)	IN4735	Motorola
CR10	Diode, Zener IN4735 (Case 59)	IN4735	Motorola
Q1	Transistor, 2N1305	2N1305	Tex. Instr.
Q2	Transistor, 2N1305	2N1305	Tex. Instr.
Q3	Transistor, 2N1305	2N1305	Tex. Instr.
Q4	Transistor, 2N1308	2N1308	Tex. Instr.
Q5	Transistor, 2N1308	2N1308	Tex. Instr.
Q6	Transistor, 2N1306	2N1306	Tex. Instr.
IC1	Integrated Circuit, Linear, Differential	MA702C	Fairchild
IC2	Integrated Circuit, Linear, Differential	MA702C	Fairchild
IC3	Integrated Circuit, Linear, Differential	MA702C	Fairchild
T1	Transformer, 10KCT, 600ΩCT	DI-T270	UTC
T2	Transformer, 10KCT, 600ΩCT	DI-T270	UTC
T3	Transformer, 12.6VCT, 1.5 amps	F-25X	Triad
S1	Switch, 4 pole, 5 throw	PA-1013	Centralab
S2	Switch, SPST, Miniature	83050	AH&H
DS1	Pilot Light Assembly, Neon Lamp	249-7840-1433 or 0933)-504	Dialco
F1	Fuse, 1/2 amp, 3 AG, Slo-Blo	3131500	Littlefuse
	Fuseholder, Miniature	342004A	Littlefuse
FL1	Filter, 1.5 kHz, Low Pass	701A121001	EMR
FL2	Filter, 5kHz, Low Pass	701A122001	EMR
FL3	Filter, 2.4kHz, Band Pass	700A181001	EMR
J1	Connector, BNC, Bulkhead Mount	UG-1094/U	Amphenol

*Equivalent components are acceptable.

APPENDIX C

Video Remodulation Unit Parts List—(Concluded)

Symbol	Description	Part No.	Vendor*
J2	Connector, BNC, Bulkhead Mount	UG-1094/U	Amphenol
P1	Plug, Polarized AC, w/6' cord	172365V	Belden
	PC Board, EMR 01-11-101		

*Equivalent components are acceptable.

APPENDIX D

DRIR Parts List

Symbol	Description	Part No.	Vendor*
R1	Resistor, 30kΩ ± 5%, 1/4 W	RC07GF303J	Ohmite
R2	Resistor, 22kΩ ± 5%, 1/4 W	RC07GF223J	Ohmite
R3	Resistor, 30kΩ ± 5%, 1/4 W	RC07GF303J	Ohmite
R4	Resistor, 1.5kΩ ± 5%, 1/4 W	RC07GF152J	Ohmite
R5	Resistor, 30kΩ ± 5%, 1/4 W	RC07GF303J	Ohmite
R6	Resistor, 200Ω ±5%, 1/4 W	RC07GF204J	Ohmite
R7	Resistor, 18kΩ ± 5%, 1/4 W	RC07GF183J	Ohmite
R8	Resistor, 18kΩ ± 5%, 1/4 W	RC07GF183J	Ohmite
R9	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R10	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R11	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R12	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R13	Resistor, 100kΩ ± 5%, 1/4 W	RC07GF104J	Ohmite
R14	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R15	Resistor, 1MΩ ±5%, 1/4 W	RC07GF105J	Ohmite
R16	Resistor, 20kΩ ± 5%, 1/4 W	RC07GF203J	Ohmite
R17	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R18	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R19	Resistor, 5.1kΩ ± 5%, 1/4 W	RC07GF512J	Ohmite
R20	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R21	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R22	Resistor, 33kΩ ± 5%, 1/4 W	RC07GF333J	Ohmite
R23	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R24	Resistor, 20kΩ ± 5%, 1/4 W	RC07GF203J	Ohmite
R25	Resistor, 5.1kΩ ± 5%, 1/4 W	RC07GF512J	Ohmite
R26	Potentiometer, 10k	Type 156-2	IRC
R27	Resistor, 1MΩ ±5%, 1/4 W	RC07GF105J	Ohmite
R28	Resistor, 330Ω ± 5%, 1/4 W	RC07GF331J	Ohmite
R29	Resistor, 180Ω ± 5%, 1/4 W	RC07GF181J	Ohmite
R30	Resistor, 30kΩ ± 5%, 1/4 W	RC07GF303J	Ohmite
R31	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R32	Resistor, 2kΩ ± 5%, 1/4 W	RC07GF202J	Ohmite
R33	Resistor, 20kΩ ±5%, 1/4 W	RC07GF203J	Ohmite
R34	Resistor, 30kΩ ±5%, 1/4 W	RC07GF303J	Ohmite
R35	Resistor, 24kΩ ±5%, 1/4 W	RC07GF243J	Ohmite
R36	Resistor, 100kΩ ±5%, 1/4 W	RC07GF104J	Ohmite
R37	Resistor, 10kΩ ±5%, 1/4 W	RC07GF103J	Ohmite
R38	Resistor, 30kΩ ±5%, 1/4 W	RC07GF303J	Ohmite
R39	Resistor, 10kΩ ±5%, 1/4 W	RC07GF103J	Ohmite
R40	Resistor, 30kΩ ±5%, 1/4 W	RC07GF303J	Ohmite
R41	Resistor, 10kΩ ±5%, 1/4 W	RC07GF103J	Ohmite

*Equivalent components are acceptable.

DRIR Instruction Manual—(Continued)

Symbol	Description	Part No.	Vendor*
R42	Resistor, 20kΩ ± 5%, 1/4 W	RC07GF203J	Ohmite
R43	Resistor, 510Ω ± 5%, 1/4 W	RC07GF511J	Ohmite
R44	Resistor, 100kΩ ± 5%, 1/4 W	RC07GF104J	Ohmite
R45	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R46	Resistor, 1kΩ ± 5%, 1/4 W	RC07GF102J	Ohmite
R47	Resistor, 20Ω ± 5%, 1/4 W	RC07GF200J	Ohmite
R48	Resistor, 100kΩ ± 5%, 1/4 W	RC07GF104J	Ohmite
R49	Potentiometer, 100kΩ	Type 156-2	IRC
R50	Potentiometer, 250kΩ 10 Turn	Type 3400	IRC
R51	Potentiometer, 10KΩ	Type 156-2	IRC
R52	Resistor, 10kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R53	Resistor, 43kΩ	RC07GF433J	Ohmite
R54	Resistor, 20 MΩ	RC07GF106J	Ohmite
R55	Potentiometer, 10kΩ 10 Turn	Type 7300	IRC
R56	Resistor, 100 kΩ ± 5%, 1/4 W	RC07GF104J	Ohmite
R57	Resistor, 120 kΩ ± 5%, 1/4 W	RC07GF124J	Ohmite
R58	Resistor, 510Ω ± 5%, 1/4 W	RC07GF511J	Ohmite
R59	Resistor, 5.1 kΩ ± 5%, 1/4 W	RC07GF512J	Ohmite
R60	Potentiometer, 10 kΩ	Type 156-2	IRC
R61	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R62	Resistor, 100 kΩ ± 5%, 1/4 W	RC07GF104J	Ohmite
R63	Resistor, 120 kΩ ± 5%, 1/4 W	RC07GF124J	Ohmite
R64	Resistor, 2 kΩ ± 5%, 1/4 W	RC07GF202J	Ohmite
R65	Potentiometer, 10 kΩ	Type 156-2	IRC
R66	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R67	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R68	Resistor, 2 kΩ ± 5%, 1/4 W	RC07GF202J	Ohmite
R69	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R70	Resistor, 100Ω ± 5%, 1/4 W	RC07GF104J	Ohmite
R71	Resistor, 10Ω ± 5%, 1/4 W	RC07GF100J	Ohmite
R72	Resistor, 2.7Ω ± 5%, 1/4 W	RC07GF2R7J	Ohmite
R73	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R74	Resistor, 1.5 kΩ ± 5%, 1/4 W	RC07GF152J	Ohmite
R75	Resistor, 10Ω ± 5%, 1/4 W	RC07GF100J	Ohmite
R76	Resistor, 39Ω ± 5%, 1/4 W	RC07GF390J	Ohmite
R77	Resistor, 10Ω ± 5%, 1/4 W	RC07GF100J	Ohmite
R78	Resistor, 10 kΩ ± 5%, 1/4 W	RC07GF103J	Ohmite
R79	Resistor, 1.5 kΩ ± 5%, 1/4 W	RC07GF152J	Ohmite
R80	Resistor, 62 kΩ ± 5%, 1/4 W	RC07GF623J	Ohmite
R81	Resistor, 36 kΩ ± 5%, 1/4 W	RC07GF363J	Ohmite
R82	Resistor, 8.2 kΩ ± 5%, 1/4 W	RC07GF822	Ohmite
R83	Resistor, 2.7Ω ± 5%, 1/4 W	RC07GF2R7J	Ohmite

*Equivalent components are acceptable.

DRIR Instruction Manual—(Continued)

Symbol	Description	Part No.	Vendor*
Q1	Transistor, 2N3704		Texas Instr.
Q2	Transistor, 2N3704		Texas Instr.
Q3	Transistor, 2N3704		Texas Instr.
Q4	Transistor, 2N3702		Texas Instr.
Q5	Transistor, 2N3704		Texas Instr.
Q6	Transistor, 2N3702		Texas Instr.
Q7	Transistor, 2N4852		Motorola
Q8	Transistor, 2N3704		Texas Instr.
Q9	Transistor, 2N3702		Texas Instr.
Q10	Transistor, 2N3704		Texas Instr.
Q11	Transistor, 2N3702		Texas Instr.
Q12	Transistor, 2N3704		Texas Instr.
Q13	Transistor, 2N3702		Texas Instr.
Q14	Transistor, 2N3704		Texas Instr.
Q15	Transistor, 2N3702		Texas Instr.
Q16	Transistor, 2N3704		Texas Instr.
Q17	Transistor, 2N4852		Motorola
Q18	Transistor, 2N4037		RCA
A1	Operational Amplifier	Mod. 108A	Analogue Devices
IC1	Integrated Circuit, Linear	MA 709-C	Fairchild
IC2	Integrated Circuit, Linear	LM-300	NSI
IC3	Integrated Circuit, Linear	LM-300	NSI
RB1	Rectifier Bridge	VS 247	Varo
T1	Transformer	P-6377	Thic-Stan
LS1	Speaker	22AD62100	Quam
F1	Fuse, 1/2 amp., 3AG, Slo-Blo	3131500	Littlefuse
	Fuseholder, Miniature	342004A	Littlefuse
J3	Connector, Plug	57-30140	Amphenol
	Connector, Socket	57-40140	Amphenol
J4	Connector, Plug	57-30140	Amphenol
	Connector, Socket	57-40140	Amphenol
DS1	Lamp Assembly	101-3830-0971-201	Dialco
	Bulb	#330	G. E.
DS2	Lamp Assembly	101-3830-0972-201	Dialco
	Bulb	#330	G. E.

*Equivalent components are acceptable.

DRIR Instruction Manual—(Concluded)

Symbol	Description	Part No.	Vendor*
S1	Switch, DPST	81024GB	Arrow-Hart
S2	Switch, SPDT	81021AV	Arrow-Hart
S3	Switch	3391-GL	Arrow-Hart
K1	Relay	103MPCX31	Magnecraft
	Cable	8768	Belden
	Turns Counting Dial	RB-Duodial	Beckman Ins.
CR1	Diode, 1N4446		G. E.
CR2	Diode, 1N4446		G. E.
CR3	Diode, 1N4446		G. E.
CR4	Diode, 1N4446		G. E.
CR5	Diode, 1N4446		G. E.
CR6	Diode, 1N4446		G. E.
CR7	Diode, 1N4446		G. E.
CR8	Diode, 1N4446		G. E.
CR9	Diode, 1N4446		G. E.
C1	Capacitor, .0033 μf	DM-19-332J	Arco
C2	Capacitor, 200 pf	DM-19-201J	Arco
C3	Capacitor, .47 μf	192P4749R8	Sprague
C4	Capacitor, .022 μf	192P2239R8	Sprague
C5	Capacitor, .47 μf	192P4749R8	Sprague
C6	Capacitor, .022 μf	192P2239R8	Sprague
C7	Capacitor, .022 μf	75F1R5A223	G. E.
C8	Capacitor, .22 μf	75F3R5A224	G. E.
C9	Capacitor, 10 μf	MTA-10D35	Mallory
C10	Capacitor, .022 μf	192P2239R8	Sprague
C11	Capacitor, .022 μf	192P2239R8	Sprague
C12	Capacitor, 10 μf	MTA-10D35	Mallory
C13	Capacitor, 2 μf	Mi2 DE1-205	Marshall
C14	Capacitor, 2 μf	Mi2 DE1-205	Marshall
C15	Capacitor, .22 μf	192P2249R8	Sprague
C16	Capacitor, 2 μf	MTA-2D50	Mallory
C17	Capacitor, 47 pf	DM-15-470J	Arco
C18	Capacitor, 47 pf	DM-15-470J	Arco
C19	Capacitor, 150 μf	MTA-150F35	Mallory
C20	Capacitor, 400 μf	TL-1216	Sprague
C21	Capacitor, 2 μf	MTA-2D50	Mallory

*Equivalent components are acceptable.

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