MICROWAVE ANTENNAS
KS-15676 HORN-REFLECTOR AND WAVEGUIDE SYSTEM
ORIENTATION USING 21A COUPLER

CONTENTS PAGE

1. GENERAL

1.01 This section describes the orientation of the KS-15676 horn-reflector antenna using the 21A coupler shown in Fig. 1, or the F-56967 coupler, a preproduction version of the 21A coupler. The procedure adjusts the antenna position for maximum received signal and minimum level of higher-order modes. This procedure can be used to align new systems, and to more accurately align the antennas and adjust the cross-polarization discrimination of existing systems on an in-service basis.

> *Note:* Whenever an antenna is moved, or the circular waveguide is broken for any reason, the cross-polarization discrimination should be checked and readjusted, if necessary, at the conclusion of the operation.

1.02 When an incoming signal impinges on the KS-15676 antenna, most of its energy is coupled to the circular-waveguide run in the dominant mode, $TE^{\circ}_{1,1}$. This is the normal mode of transmission and the one to which the 1407A networks are designed to respond.

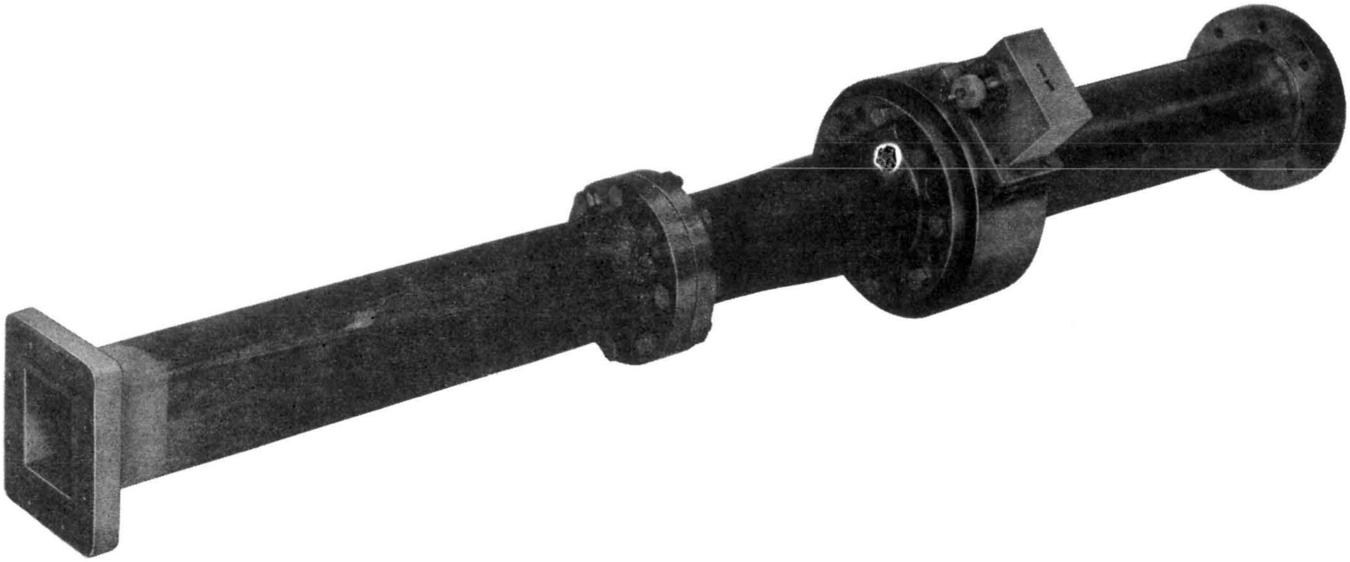

Fig. 1 — 21A Coupler

1.03 An improperly aimed antenna will cause unwanted higher-order modes, such as TM$^{\circ}_{0,1}$, to be generated in the throat of the feedhorn. The level of the TM$^{\circ}_{0,1}$ relative to the dominant mode is shown in Fig. 2 and depends on the amount of misaiming of the antenna in both azimuth and elevation. Each higher-order mode then travels down the waveguide. Most of it reflects off the 7A or 29B transducer, and returns to the flexible waveguide, where some of it may be reconverted to a downward-travelling TE$^{\circ}_{1,1}$ signal which adds amplitude and phase ripple to the normal received signal. Not all of the higher-order mode is reflected by the transducer; some of it is reconverted by the transducer to TE$^{\circ}_{1,1}$ to produce another interfering signal. The distortion caused by these phenomena depends on the height of the tower, the amount of higher-order mode present, and the amount of reconversion in the flexible waveguide and the transducer. More accurate antenna alignment reduces the higher-order modes present in the waveguide, thus reducing the distortion of the signal.

1.04 The radiation pattern of the transmitted TE$^{\circ}_{1,1}$ signal consists of one big lobe and several small side lobes. In contrast, the radiation patterns of most higher-order modes (of which TM$^{\circ}_{0,1}$ is one) have a null along the axis of the main lobe of the TE$^{\circ}_{1,1}$ mode. The radiation patterns of the TE$^{\circ}_{1,1}$ and TM$^{\circ}_{0,1}$ modes and the configuration of each of these modes in the circular waveguide are shown in Fig. 3. The antenna alignment procedure described in this section uses the null of the TM$^{\circ}_{0,1}$ pattern to accurately aim the antenna and uses the 21A coupler to detect the TM$^{\circ}_{0,1}$. Correct antenna orientation is indicated by minimum TM$^{\circ}_{0,1}$.

1.05 The following tools and apparatus are required at each repeater station:

QUANTITY	DESCRIPTION
1	21A Coupler (4194-MHz) or F-56967 Coupler (4140-MHz)
1	KS-20073 Telescope
1	J68340A, L3 or L4 Test Bay or J68345A, L1 or L2 Test Set (or equivalent microwave generator and monitoring equipment)
1	Polarad Model R or TR Microwave Receiver, with appropriate tuning unit to receive operating frequency of coupler (or equivalent receiver)

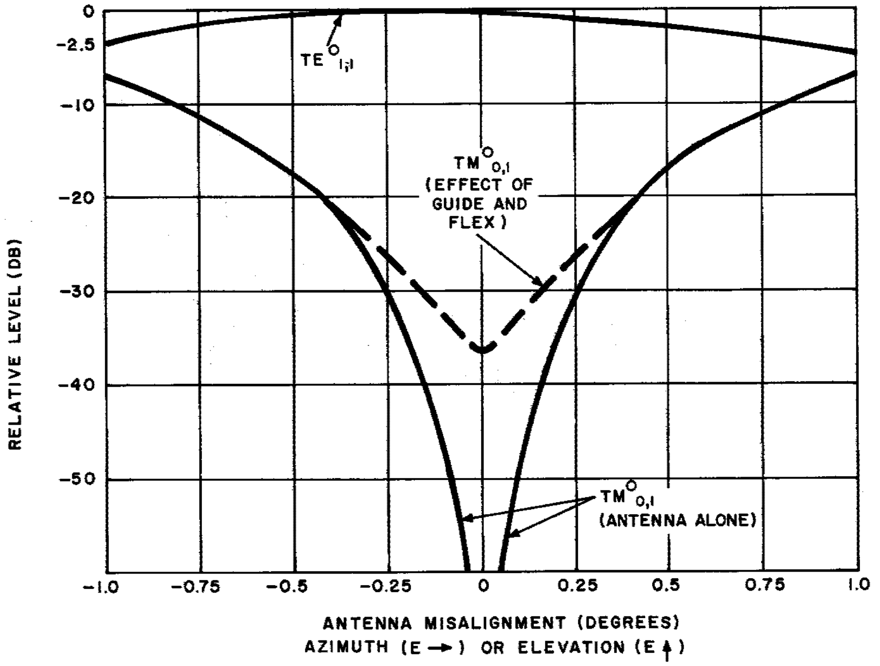

Fig. 2 — TM$^{\circ}_{0,1}$ and TE$^{\circ}_{1,1}$ Levels Versus Antenna Position

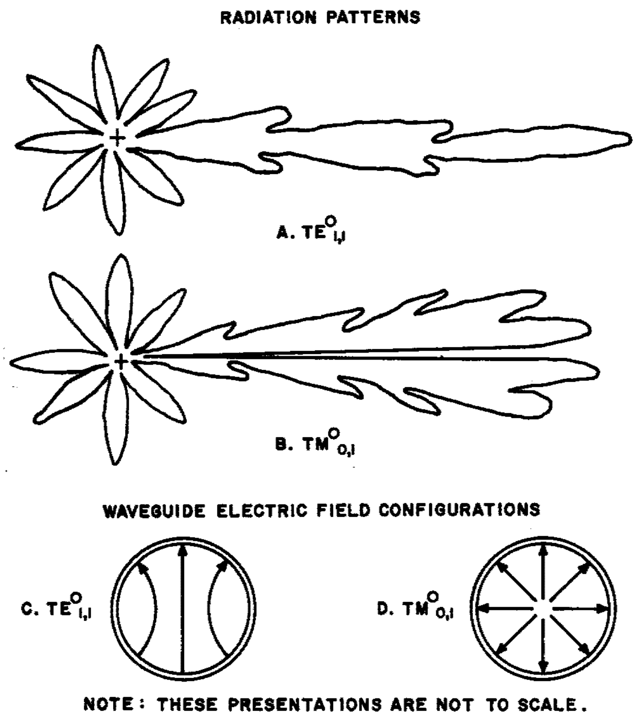

Fig. 3 — Radiation Patterns and Circular-Waveguide Field Configurations for $TE^{\circ}_{1,1}$ and $TM^{\circ}_{0,1}$ Modes

QUANTITY	DESCRIPTION
1*	Hewlett-Packard 493A or Alfred 562A Travelling-Wave Tube (TWT) Amplifier or equivalent (1-watt output at operating frequency of coupler)
1*	ED-64093- ( ), G1 Directional Coupler
1*	Microlab LA-60N Coaxial Low-Pass Filter
1	KS-15676, L13 Tilt-Adjusting Tool
1	KS-15676, L12 Azimuth-Adjusting Screw
1	P-38B664 Circular-Waveguide Wrench
2	1A Junctions (for use on working systems only) with two 500A terminations per 1A junction
2	WR229 Flexible Waveguide Sections (length in accordance with 2.06)
1	ED-50498-50 Search Tool
1	AT-8422 B Waveguide Stabilizer
1	AT-8421 B Network Jack
2	ED-63967-30, G4 Adapters
1	Adjustable Open-End Wrench with 3-inch capacity
2	Ratchet Wrenches with 3/8-inch square drive
1	1/2-Inch Socket with 3/8-inch square drive
1	7/16-Inch Socket with 3/8-inch square drive
1	3/8-Inch Socket with 3/8-inch square drive
1	5/16-Inch Socket with 3/8-inch square drive
1	1/4-Inch Socket with 3/8-inch square drive
1	1/2-Inch, 12-Point Box Wrench
1	7/16-Inch, 12-Point Box Wrench
20	Regular SF Hexagonal-Head 1/4-20 Bolts, 1-3/4 inches long for rectangular-waveguide flange
Misc	RF Patch Cords (RG-9B/U cable equipped with N-type connectors for interconnecting test equipment in the station)
3	24A Transducers
100 feet	1/2-Inch Heliax Low-Loss Coaxial Cable (Phelps-Dodge, Inc.), one 50-foot and two 25-foot lengths with female N-type connectors
2	Connectors, back-to-back, male N-type
Misc	Spare Circular- and Rectangular-Waveguide Gaskets
As reqd	Radiation Suits per Section 010-150-002
As reqd	Telephone communication systems between station-to-station radio bays and from station radio bays to antenna decks.

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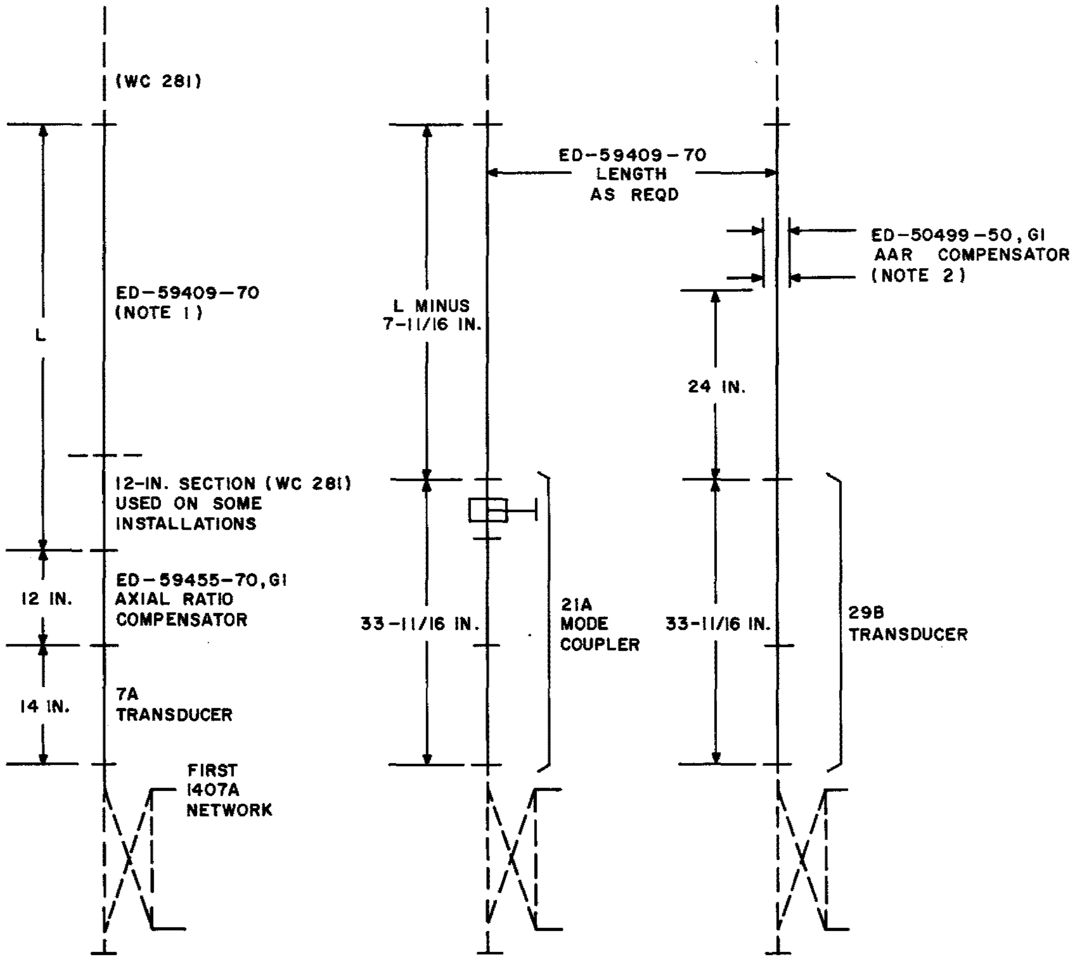
* Required to provide sufficient power output and monitoring when a J68345A test set is used.

Note: Provide flexibility in telephone connection to antenna decks for reuse at the base of the towers at the lower end of the circular-waveguide run.

Warning: To avoid injury caused by whipping cables, communication lines between the antenna decks and the radio bays should be run inside the tower structure.

If an existing route equipped with 7A transducers and ED-59455-90, G1 axial ratio compensators is to be realigned, the following is required:

QUANTITY	DESCRIPTION
1	ED-50499-50, G1 Axial Ratio Compensator (receiving end only)
1	AT-8390 Waveguide Alignment Wrench
	ED-59509-70 Rigid Circular Waveguide (length as required in accordance with Fig. 4)



A. 7A TRANSDUCER B. 21A COUPLER C. 29B TRANSDUCER

NOTES:

1. LENGTH OF FIRST SECTION OF WAVEGUIDE VARIES WITH TYPE OF TOWER AND PARTICULAR JOB INSTALLATION.
2. PROVIDE COMPENSATOR ON RECEIVING WAVEGUIDE RUNS ONLY.

Fig. 4 — Circular-Waveguide Modification — Simplified Diagram

2. WAVEGUIDE AND TEST SET TEST CONNECTIONS

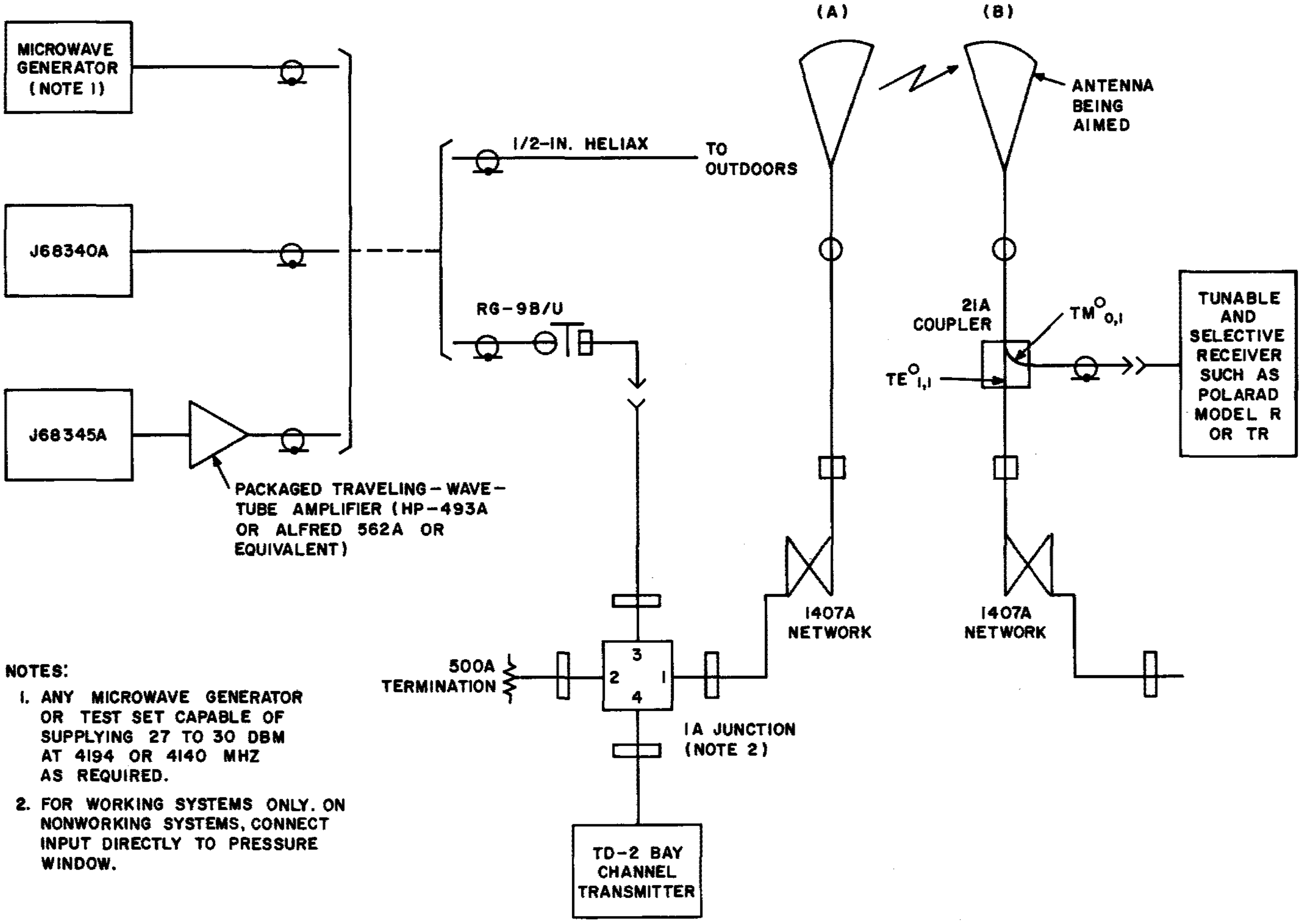
2.01 Fig. 5 is a simplified block diagram of the antenna systems, the test equipment, and their interconnections.

2.02 The detailed connections required in the 40A test bay and the 45A test set are shown in Fig. 6 and 15, respectively. The modifications required in the waveguide run of the antenna being aimed are shown in Fig. 4.

2.03 In this section, a working system is defined as one that is actually carrying service during the orientation procedure. In nonworking systems, the waveguide modifications (such as the installation of the 1A junction and the 21A coupler) are performed when the RF power is disconnected. To avoid disruption of service in working systems, the 1A junction and the 21A coupler must be installed on a hot-cut basis, as described in 2.05 and 2.06.

Caution: To avoid erroneous results, the antennas should not be oriented during periods of fading greater than 1 dB. Before proceeding with a hot cut, notify the responsible control office that a service hazard will exist during the time of installation and removal of the 1A junction and 21A coupler. Do not proceed until approval is obtained from the responsible control office.

Warning: RF energy radiated during hot cutting of a transmitter waveguide run may be hazardous to personnel. Installation personnel shall wear protective radiation suits (if required by Section 010-150-002) when installing the 1A junction or the 21A coupler, or when working with open transmitting waveguide sections.



NOTES:

1. ANY MICROWAVE GENERATOR OR TEST SET CAPABLE OF SUPPLYING 27 TO 30 DBM AT 4194 OR 4140 MHZ AS REQUIRED.
2. FOR WORKING SYSTEMS ONLY. ON NONWORKING SYSTEMS, CONNECT INPUT DIRECTLY TO PRESSURE WINDOW.

Fig. 5 — Block Diagram of Test Arrangement

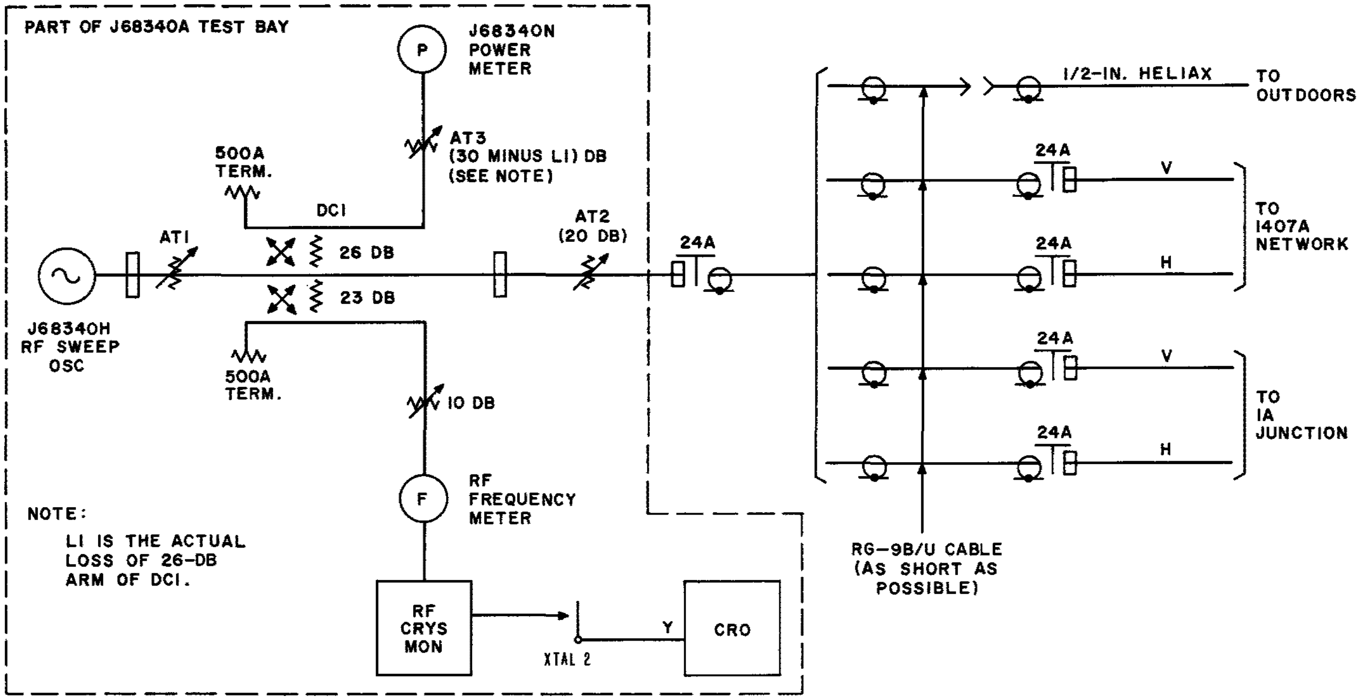


Fig. 6 — Test Connections Using J68340A Test Bay

Note: In these procedures, the antenna being aimed shall be designated the receiving antenna (B). The radiating antenna shall be designated the transmitting antenna (A). Since it is possible for both reception and transmission to be carried on by the same antenna at the same time, the term receiving or transmitting is used only to describe the function being performed by the antenna with respect to the test signal at the time of test.

2.04 Detailed procedures for tests are provided in Part 3. The hot-cutting procedures called for in Part 3 are provided in 2.05 and 2.06.

2.05 The procedure to be followed when hot cutting into the waveguide run is as follows.

Warning: Protective radiation suits shall be worn in accordance with Section 010-150-002.

(a) Install and secure the AT-8422 B waveguide stabilizer (Fig. 7) on the tower, just above the top flange to be opened; then position and tighten it to the waveguide so that the waveguide is immobilized.

(b) Install the AT-8421 B network jack (Fig. 8) on the tower so that the jack supports the bottom network.

Note: The jack shall be in the partially extended position.

(c) Remove all but two bolts from the top flange to be opened. Refer to Fig. 4.

(d) Remove all but two bolts from the bottom flange to be opened.

(e) Using a block and tackle, hoist the replacing section of waveguide into proximity with the section to be removed. Do not remove the line from the replacing section until the hot-cut procedure is completed.

Caution: Handle waveguide sections with extreme care so that they will not be dented. Dents may affect operation and the measurements made during tests.

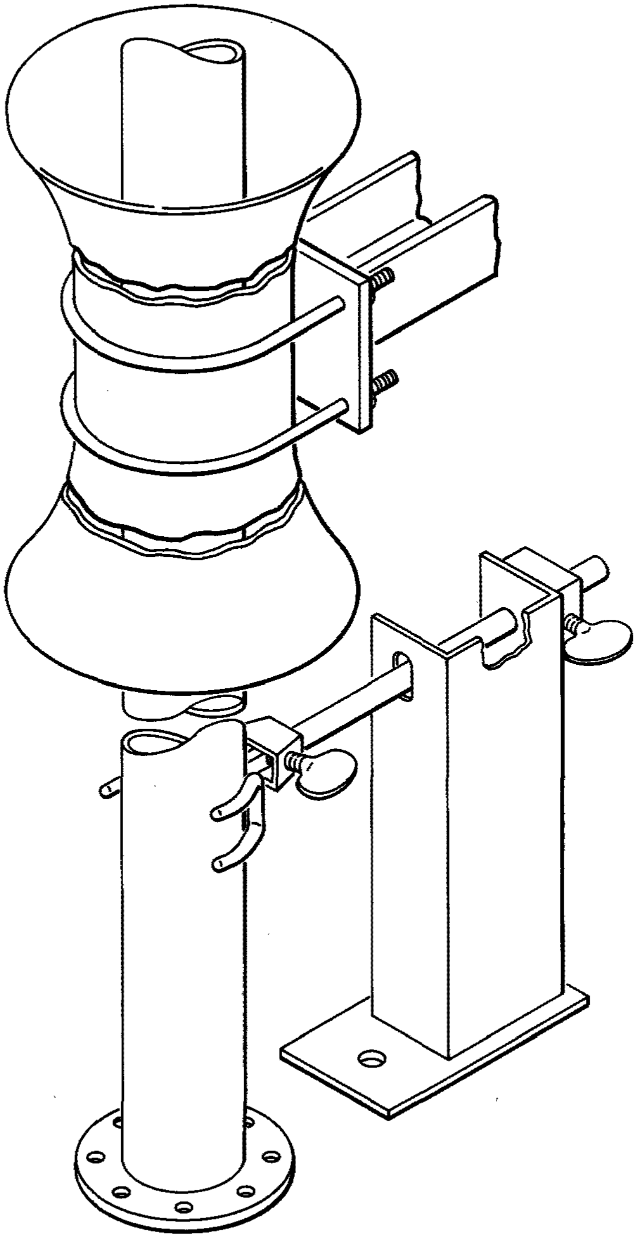


Fig. 7 — AT-8422 B Waveguide Stabilizer

(f) Position the replacing section next to the installed section so that the distance between the upper flanges equals that between the bottom flanges and both are as small as possible. Strap the sections together so that the equal separation of the flanges is maintained.

(g) Remove the nuts from the remaining bolts in the upper and lower flanges. Using the network jack, lower the networks approximately 1 inch.

(h) Remove the remaining bolts and displace the installed section with the section to be installed upon command of someone not handling the waveguide sections.

(i) Insert two bolts into each joint to prevent the loose piece from slipping. Using the network jack, raise the networks until the gap between the waveguide flanges is closed. Install and tighten all bolts to make the joint tight.

Note: Align all joints between WC281 waveguide sections with the AT-8390 B waveguide alignment wrench (see Fig. 9) when tightening the bolts.

(j) Remove the line from the installed section and tie it to the replaced section. Then carefully lower the replaced section to the ground.

2.06 The procedure to be followed when hot cutting a 1A junction to replace the flexible waveguide between the pressure window and the transmitter bay is as follows.

(a) Install flexible waveguide sections at arm 1 and arm 4 of the 1A junction to make up an assembly that will fit in place of the flexible waveguide normally connected between the pressure window and the radio bay.

Note: Arm 2 of the 1A junction is always terminated by a 500A termination; arm 3 is terminated by a 500A termination when the test signal source or receiver is not connected to the 1A junction.

(b) Strap the ends of the assembly to the ends of the flexible waveguide between the pressure window and the radio bay.

Warning: Personnel performing the hot cut must wear protective radiation suits if these are required by Section 010-150-002.

(c) Remove all screws that secure the flexible waveguide to the pressure window and the flange on the bay or rigid waveguide.

(d) Replace the flexible waveguide with the 1A junction and its connected flexible-waveguide sections upon command of someone not handling the equipment.

(e) Replace and tighten all screws.

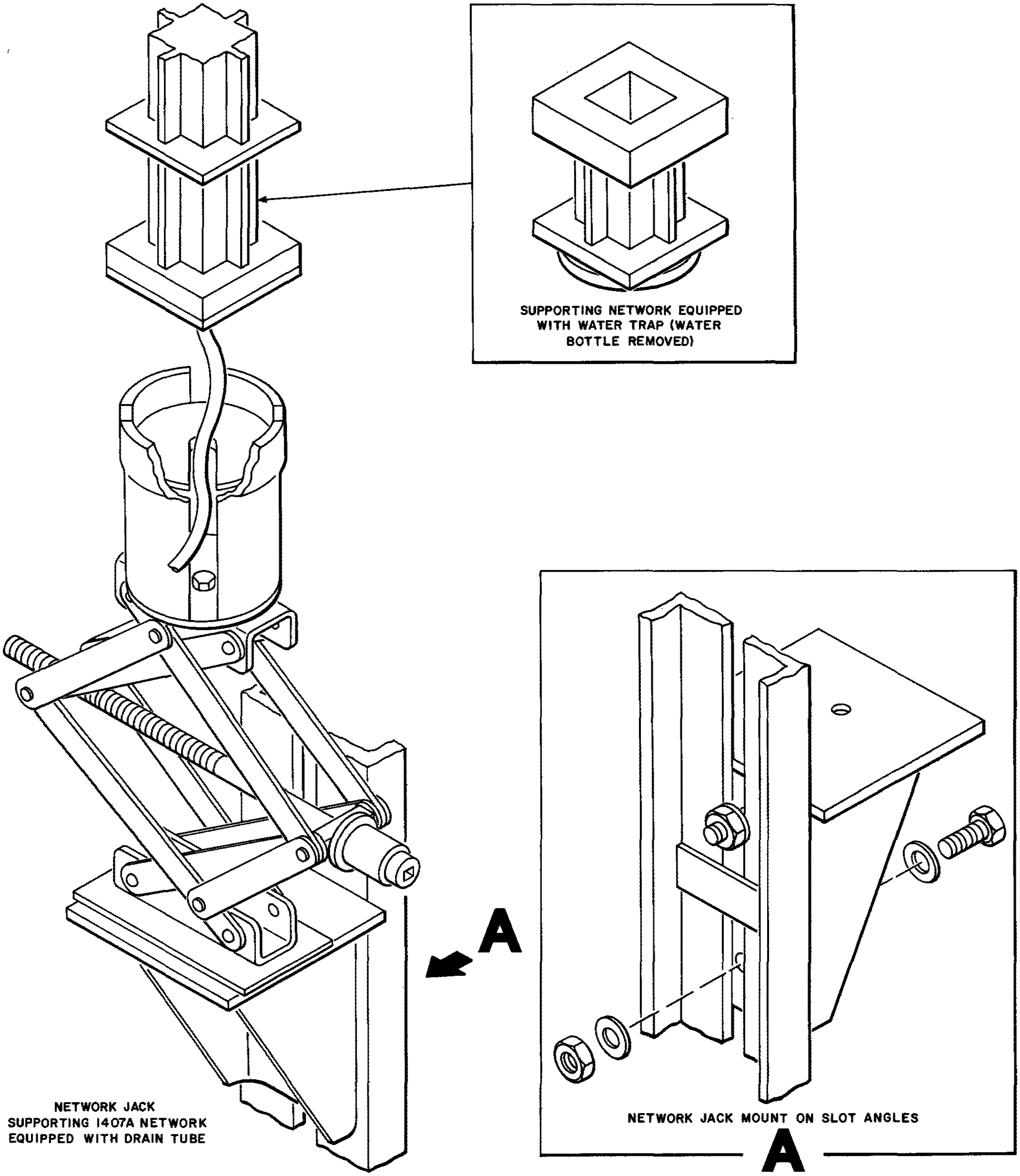


Fig. 8 — AT-8421 B Network Jack

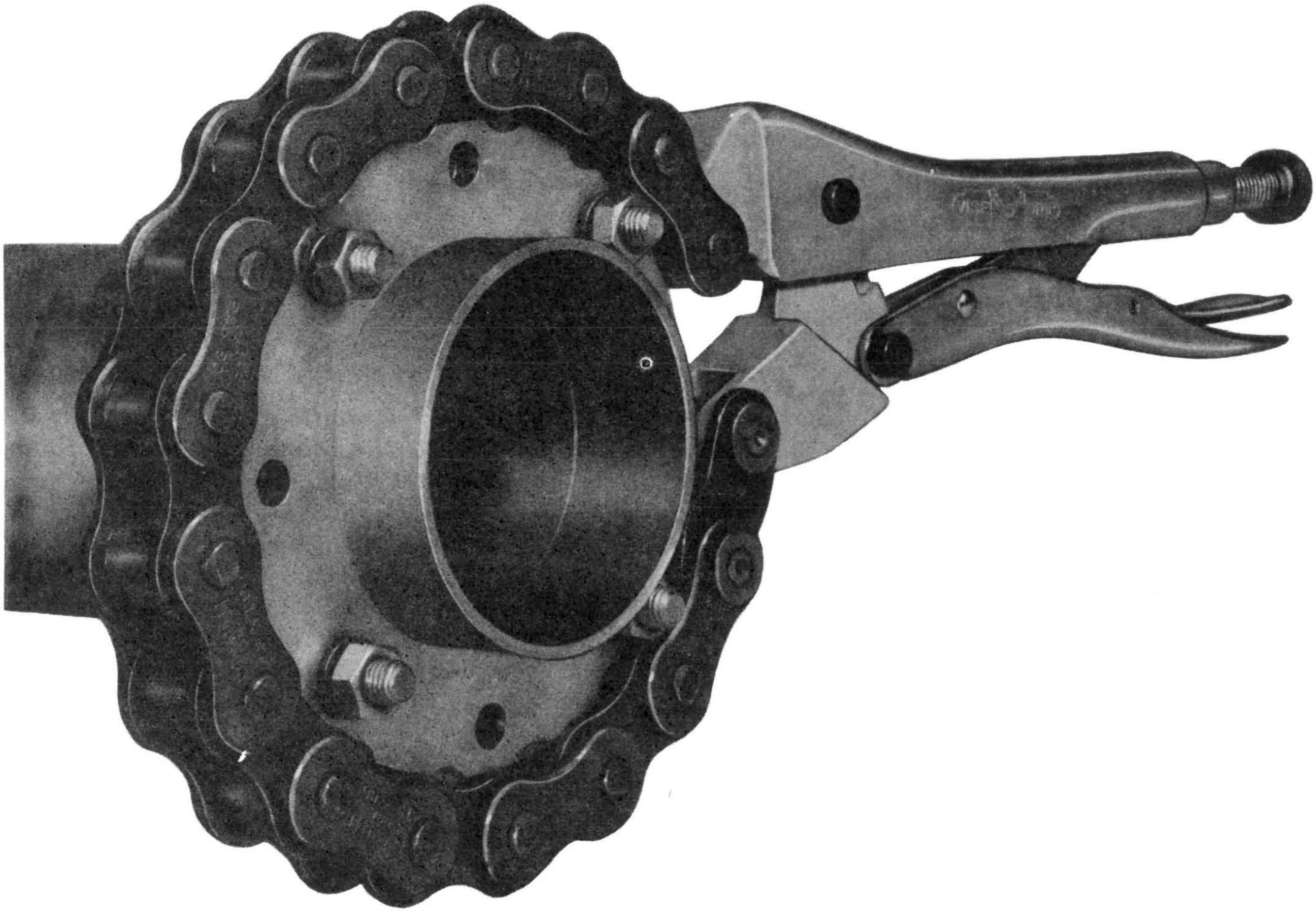


Fig. 9 — AT-8390 Waveguide Alignment Wrench

Transmitting Test Setup Using J68340A (40A) Test Bay

2.07 To provide the required test frequency and power output to the transmitting station antenna, proceed as follows.

(a) Make the test connections as shown in Fig. 6, but do not make any connections to the 24A transducer next to AT2.

(b) Set the attenuators on the test bay as follows:

AT1 — 7 dB

AT2 — 20 dB

AT3 — 30 dB minus the actual loss in the arm of DC 1.

(c) Set the frequency of the RF frequency meter for 4194 MHz (21A coupler) or 4140 MHz (F-56967 coupler).

(d) On the meter and control panel, set the MAIN POWER and RF SWEEPER switches to ON.

(e) On the RF sweep oscillator, set the SWEEP control to ON.

(f) Adjust the FREQUENCY knob until the pip is on the vertical center line of the oscilloscope, and note the magnitude of the dip.

(g) Set the SWEEP control to OFF.

(h) Adjust the CW FREQ screwdriver adjustment until the spot displayed on the oscilloscope is maximum in the negative direction.

Note: The magnitude of the dip shall be the same as that noted in (f).

(i) Make connection from AT2 to the 1A junction, Heliax cable, or 1407A network, as required, as shown in Fig. 6.

(j) Set attenuators as follows:

AT1— Reduce attenuation until power meter indicates 0 dBm, or until the attenuator is set to minimum.

AT2— 0 dBm.

(k) The 40A test bay now provides the required frequency to the antenna at a level of +30 dBm if the meter indication is 0 dBm, or at a level reduced from 30 dBm by the amount of the meter indication when other than 0 dBm is indicated.

Transmitting Test Setup Using J68345A (45A) Test Set

2.08 To provide the required test frequency and power output to the transmitting station antenna, proceed as follows.

> *Note:* In the following procedure, when two control designations are given [for example: LINE (POWER)] the first refers to the Hewlett-Packard 493A TWT amplifier and the second to the Alfred 562A TWT amplifier.

(a) Connect the test equipment in accordance with Fig. 15, and connect the 500A termination to the output of DC1.

(b) Set up the RF sweep oscillator for a single-frequency output of 4194 MHz (21A coupler) or 4140 MHz (F-56967 coupler) in accordance with Section 104-410-300.

(c) On the TWT amplifier, set the GAIN control to its maximum counterclockwise position. Set the LINE (POWER) switch to ON. After 3 minutes, the ON (HIGH VOLTAGE) lamp shall light.

(d) Adjust the GAIN control until the CATHODE CURRENT meter indicates RATED POWER (full scale).

(e) In the J68345D waveguide assembly, adjust AT1 until the meter on the RF sweep oscillator indicates 0 dBm.

> *Note:* The power output at DC1 is +30 dBm.

(f) If the Hewlett-Packard TWT amplifier is used, set the LINE switch to STANDBY. Disconnect the 500A termination; connect the output of DC1 to the 1A junction, Heliax cable, or 1407A network, as required; then set the LINE switch to ON.

> ***Caution: Operating the TWT into an open circuit may damage the TWT. Always set the LINE switch to STANDBY before removing the load from the TWT.***

> ***Warning: Radiation of 1 watt of RF power into the room may be hazardous to personnel.***

(g) If the Alfred TWT amplifier is used, remove the cable from the RF POWER INPUT jack. Disconnect the 500A termination; connect the output of DC1 to the 1A junction, Heliax cable, or 1407A network, as required; then reconnect the cable to the RF POWER INPUT jack.

> ***Warning: Radiation of 1 watt of RF energy into the room may be hazardous to personnel.***

> ***Caution 1. Driving the TWT while its output is disconnected may damage the TWT. Always disconnect the cable at the RF POWER INPUT jack before removing the load from the TWT.***

> ***Caution 2: Although the drive to the TWT can be removed by turning off the RF oscillator in the 45A test set, this is not recommended because the frequency of the oscillator momentarily sweeps across many megahertz when it is turned on or off. This frequency sweep can interfere with working channels.***

(h) After completing a procedure, if the TWT output is not required for a period of an hour or more, set the LINE (POWER) switch on the TWT to OFF.

> *Note:* The life of the TWT is limited as compared with other electron tubes. The TWT can be turned to OFF and later turned on without resetting the GAIN control.

3. NORMAL PROCEDURE FOR ALIGNING HORN-REFLECTOR ANTENNAS

3.01 Chart 1 contains the procedure for alignment of two KS-15676 horn-reflector antennas, one at each end of a radio hop, intended to work with each other.

3.02 This procedure is applicable to most radio hops. However, certain hops with short circular-waveguide runs require special treatment. Refer to Part 5 to determine if the hop in question requires special treatment. If special treatment is required, align the antennas in accordance with the applicable Chart in Part 5; if not, use the following procedure.

CHART 1

HORN-REFLECTOR ANTENNA ALIGNMENT PROCEDURE

STEP	PROCEDURE
	Note: Before proceeding, all joints between regular ED-59409 circular waveguide shall have been aligned with an AT-8390 alignment wrench.
	Caution: In working systems, do not cut in the 21A coupler or the 1A junction during periods of fading.
1	Install the 21A coupler in the waveguide of the antenna being aimed. If the system is a working one, use the procedure in 2.05. After installation, the coaxial arm shall be at an angle of 45 degrees ±5 degrees with respect to the side of the square flange.
	Note: In some cases, because of mechanical interferences, the center slip joint of the coupler may be loosened during installation,
	Warning: RF energy radiated during the hot cutting of a 21A coupler or 1A junction may be hazardous to personnel. Installation personnel shall wear protective radiation suits in accordance with Section 010-150-002 when installing the 21A coupler or the 1A junction.
2	If the station is part of a working system, install 1A junctions at the pressure windows of each station in accordance with the procedure in 2.06. Heed preceding ***Warning.***
3	Set up the 40A test bay or the 45A test set at the station supplying the radiated signal, in accordance with 2.07 or 2.08, respectively.
4	At the receiving end, use the 40A test bay or the 45A test set at an output level of approximately −35 dBm, connect the Polarad receiver to the test set, and calibrate the meter on the Polarad receiver.
5	Install the KS-20073 telescope securely on the antenna being aimed as shown in Fig. 10.
	Note: The antennas must be aimed within 1 degree of optimum before $TM^{\circ}_{0,1}$ aiming is performed. If the antenna to be aimed is part of a new system, proceed to Step 6 and aim the antenna for a maximum $TE^{\circ}_{1,1}$ signal. If an operating system is providing normal received signal levels, it may be assumed that the antenna is already aimed within 1 degree of its optimum position. For these antennas, proceed with Step 13.

Fig. 10 — KS-20073 Telescope Installed on Antenna

CHART 1 (Cont)	
STEP	**PROCEDURE**
6	Connect the Polarad receiver to the output of the horizontally polarized 1407A network at station B.
7	Radiate a horizontally polarized signal from antenna A. Loosen one flange of the circular flexible waveguide of antenna B so that it rotates freely, and adjust antenna B in azimuth while observing the signal strength on the Polarad receiver.
8	When the antenna is set in azimuth so that the received signal is maximum, repeat the procedure in Step 7 but adjust in elevation.
9	Tighten the loosened flange of the flexible waveguide.

CHART 1 (Cont)

STEP **PROCEDURE**

10 Repeat Steps 7 and 9, except loosen the flexible waveguide on the transmitting antenna, and move the antenna.

Note: Record the $TE^{\circ}_{1,1}$ signal level at the normally receiving antenna. Designate the power level as RL1.

11 Calculate the ***theoretical value*** of received signal power (designated P3) for the path being measured as follows. (Refer to the example of a calculation of P3.)

(a) From Table A, find what the received signal power for the frequency being used would be if there were no waveguide loss.

(b) From Table B, Column 2, find the attenuation per foot for the circular waveguide. Multiply by the total number of feet of circular waveguide for both transmitting and receiving antenna runs.

(c) From Table B, Column 3 or 4, find the attenuation per foot for the rectangular waveguide. Multiply by the total number of feet of rectangular waveguide for both transmitting and receiving runs.

(d) Figure the loss of the 1407A networks, which is approximately 0.4 dB for each network (0.8 dB per hop).

(e) Obtain the algebraic sum of Steps (a) through (d). This sum is the calculated received power (P3).

Example of a calculation of P3:

REFERENCE STEP	CONDITIONS		CALCULATION
(a)	Path length Test freq (chan 2)	26 mi 4194 MHz	−29.0 dBm, received signal
(b)	Circular waveguide: Transmitting Receiving Total	 269 ft 175 ft 444 ft	444 × 0.0036 = −1.6 dB
(c)	Rectangular waveguide: Transmitting Receiving Total	 54 ft 42 ft 96 ft	96 × 0.00805 = −0.8 dB
(d)	1407 Network loss (one at each end of hop)	0.4 dB each	−0.8 dB
(e)	Algebraic sum of calculations for Steps (a) through (d)		−32.2 dBm, calculated theoretical received power (P3)

CHART 1 (Cont)

STEP	PROCEDURE
11 (cont)	

TABLE A

NORMAL RECEIVED SIGNAL USING TWO KS-15676 ANTENNAS WITH +30 DBM TRANSMITTED POWER

ANTENNA SEPARATION (MILES)	RECEIVED SIGNAL (DBM)		ANTENNA SEPARATION (MILES)	RECEIVED SIGNAL (DBM)		ANTENNA SEPARATION (MILES)	RECEIVED SIGNAL (DBM)	
	4140 MHZ	4194 MHZ		4140 MHZ	4194 MHZ		4140 MHZ	4194 MHZ
7	−18.2	−17.7	20	−27.3	−26.8	42	−33.7	−33.2
8	−19.3	−18.8	21	−27.7	−27.2	44	−34.1	−33.6
9	−20.3	−19.8	22	−28.1	−27.6	46	−34.5	−34.0
10	−21.2	−20.7	23	−28.5	−28.0	48	−34.9	−34.4
11	−22.0	−21.5	24	−28.9	−28.4	50	−35.2	−34.7
12	−22.8	−22.3	26	−29.5	−29.0	52	−35.6	−35.1
13	−23.5	−23.0	28	−30.2	−29.7	54	−35.9	−35.4
14	−24.2	−23.7	30	−30.8	−30.3	56	−36.2	−35.7
15	−24.8	−24.3	32	−31.4	−30.9	58	−36.5	−36.0
16	−25.3	−24.8	34	−31.9	−31.4	60	−36.8	−36.3
17	−25.8	−25.3	36	−32.4	−31.9	62	−37.1	−36.6
18	−26.3	−25.8	38	−32.9	−32.4	64	−37.4	−36.9
19	−26.8	−26.3	40	−33.3	−32.8	66	−37.6	−37.1

Note 1: Received signal is calculated for transmitted power of +30 dBm. If transmitted power is less than +30 dBm, reduce received signal data requirements by the difference between +30 dBm and the actual radiated power.

Note 2: Data in chart neglects waveguide and filter losses.

TABLE B

WAVEGUIDE ATTENUATION

COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4
FREQUENCY (MHZ)	ATTENUATION OF 2.812 CIRCULAR WAVEGUIDE (DB PER FOOT)	ATTENUATION OF COPPER WR229 RECTANGULAR WAVEGUIDE (DB PER FOOT)	ATTENUATION OF BRASS WR229 RECTANGULAR WAVEGUIDE (DB PER FOOT)
4140	0.0037	0.00815	0.0114
4194	0.0036	0.00805	0.01125

CHART 1 (Cont)

STEP	PROCEDURE
12	Check the difference between the measured received signal power (RL1) recorded in Step 10 and the calculated theoretical received signal power (P3) obtained in Step 11. ***Requirement:*** P3 and RL1 shall not differ more than 3 dB.
13	Disconnect the Polarad receiver from the 1407A network.
14	Reconnect the Polarad receiver to the 21A coupler as shown in Fig. 5, and record the indication of the $\mathrm{TM}^{\circ}_{0,1}$ signal strength.
15	Align the telescope reticle on a distant stationary vertical target, such as the side of a house, at least 3000 feet away; then lock down the telescope mount. Record the telescope micrometer setting.
16	Using the azimuth micrometer adjustment on the telescope, displace the telescope 0.10 degree in either direction. Then adjust antenna until the target is brought back to its original position in the telescope. Record the $\mathrm{TM}^{\circ}_{0,1}$ signal strength. ***Note:*** If the antenna position now results in less $\mathrm{TM}^{\circ}_{0,1}$, repeat Step 15 in the same direction and move the antenna until the null is passed. If more $\mathrm{TM}^{\circ}_{0,1}$ results, move the antenna in the opposite direction until a null is found. Use smaller increments near the null to determine the precise position of the null.
17	Repeat Step 15 as often as required to plot a graph of the Polarad meter indication versus the antenna position. ***Requirement:*** A null that is greater than 30 dB down from the normal $\mathrm{TE}^{\circ}_{1,1}$ received signal shall appear as determined by the plot. If the null is less than 30 dB down, refer to corrective procedures in Part 4.
18	Set the antenna azimuth to the position of the azimuth null. Keeping the telescope sighted on the target, lock down the antenna in azimuth. The Polarad meter indication should be monitored to check that the antenna has not been moved while being locked down.
19	Align the telescope on a stationary horizontal target at least 3000 feet away and note the elevation setting of the antenna, as indicated by the elevation micrometer setting.
20	Locate the elevation null in a manner similar to Steps 16 and 17. ***Requirement:*** The null shall be more than 30 dB down from the normal $\mathrm{TE}^{\circ}_{1,1}$ received signal. If the null is less than 30 dB down, refer to Part 4 for corrective measures.
21	Align antenna A by radiating from antenna B and receiving at antenna A. Repeat Steps 1 through 20, but do not lock down antenna A in elevation if cross-polarization discrimination is to be adjusted immediately instead of later. ***Note:*** The equipment configuration shall be reversed at each station.

CHART 1 (Cont)

STEP	PROCEDURE
22	Remove the 21A coupler from the initial antenna B waveguide run in accordance with 2.05 and replace with the 29B transducer. ***Warning:* Protective radiation suits shall be worn in accordance with Section 010-150-002.** **Cross-Polarization Adjustment**
23	Misaim antenna A approximately 0.5 degree in an upward direction to provide a vertically polarized signal at antenna A.
24	Connect the transmitter to the horizontal 1407A network of antenna B, and connect the Polarad receiver to the 21A coupler in the antenna A waveguide run.
25	Loosen the circular joint of the transducer in the antenna B waveguide run, and, if necessary, loosen the square 1407A restrainer.
26	Rotate the 1407A networks in the antenna B waveguide run until the output at the 21A coupler of antenna A causes a minimum indication on the Polarad receiver at antenna A. Then tighten the restrainer and the circular flange of the transducer at antenna B.
27	Return antenna A to its original aimed position, using the telescope. Verify the null by using vertical polarization and the Polarad receiver connected to the 21A coupler. Making certain that the antenna does not shift, lock down antenna A in elevation.
28	Remove the 21A coupler from the antenna A waveguide run in accordance with the procedures in 2.05.
29	Transmit a horizontally polarized signal from antenna B, connect the Polarad receiver to the vertical 1407A network at antenna A, and adjust the 1407A networks until the meter on the Polarad receiver indicates a minimum.
30	Lock down the 1407A networks and the circular joint of the transducer on antenna A.
31	Install the ED-50498-50 search tool, shown in Fig. 11, on the first 4-foot long or longer section of the waveguide above the transducer on the normally receiving antenna. If no section is 4 feet long or longer, install the search tool on the transmitting antenna waveguide if sufficient length of waveguide is available there. If neither end has a 4-foot long or longer section, refer to Part 5.
32	Attach a scale around the circular-waveguide section close to the search tool, and position the scale so that the pointer on the search tool points to the markings on the tape. ***Note:*** The frequencies used in the following steps shall be selected in the upper, middle, and lower 100-MHz segments of the operating band (that is, 3700 to 3800, 3900 to 4000, and 4100 to 4200 MHz, respectively). The criterion for the selection of the actual frequency used within each segment is that the test frequency shall not interfere with channels carrying service. If a channel is in operation within a segment, it should be used.

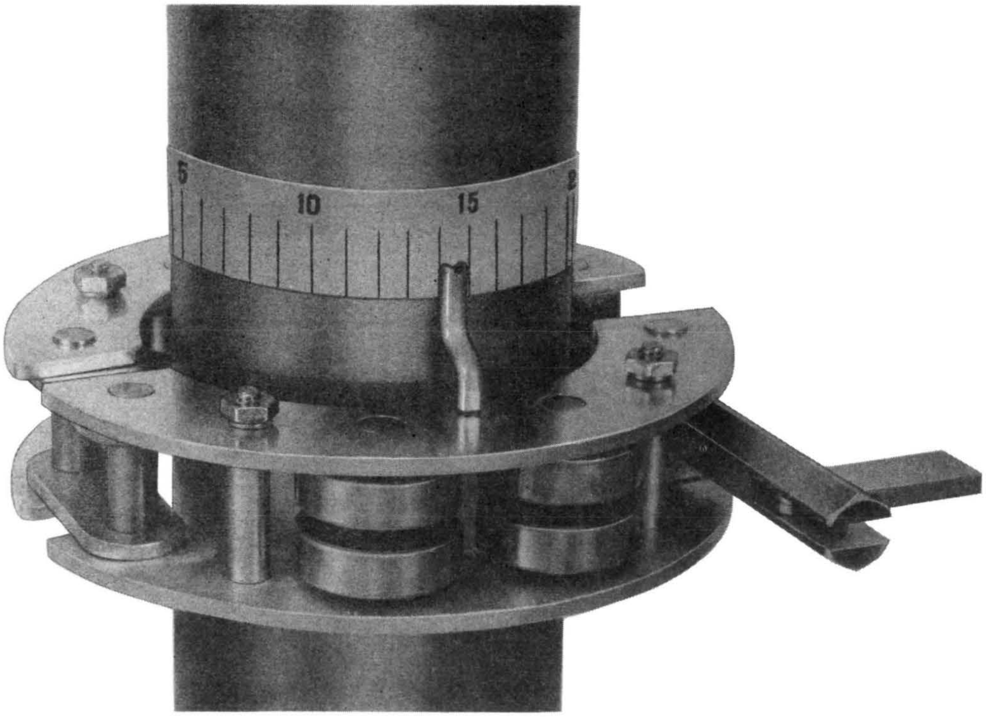


Fig. 11 — Search Tool

CHART 1 (Cont)

STEP	PROCEDURE
33	Transmit a single-frequency, horizontally polarized test signal from the normally transmitting station.
34	At the other station, connect the receiver to the horizontal 1A junction and tune the Polarad receiver to receive the test signal. Record the received level. ***Note:*** The 1A junctions are used in working systems only.
35	Switch the connections of the Polarad receiver to the vertical 1A junction.
36	Tighten the bolt on the search tool until it is finger tight; then tighten it approximately one additional turn.
37	Rotate the search tool and plot the signal indicated by the meter on the Polarad receiver with relation to the markings on the scale. ***Requirement:*** A 2-cycle sine-wave plot shall result for a 360-degree rotation of the search tool. (See Fig. 12.) If a normal presentation is not obtained no matter how loose the search tool, then the axial ratio compensator will not improve the cross-polarization discrimination at this polarization and frequency.

CHART 1 (Cont)

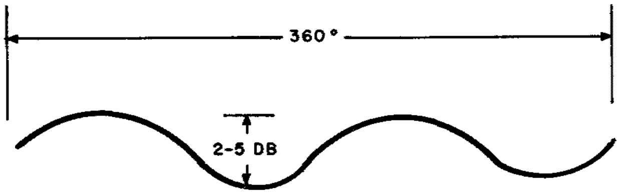
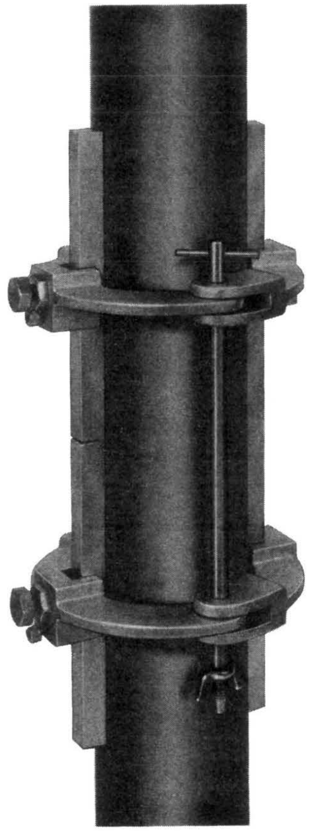
STEP	PROCEDURE
	 A. NORMAL  B. ABNORMAL (SEARCH TOOL SLIGHTLY TOO TIGHT)  C. ABNORMAL (SEARCH TOOL VERY TIGHT) **Fig. 12 — Plots of Cross-Polarization Versus Search Tool Position — Typical**
38	Transmit with vertical polarization and receive through the horizontal 1407A network. Repeat Step 37. ***Requirement:*** The two plots shall be in phase within 15 degrees of rotation of the search tool. If the plots are farther out of phase, one antenna (at least) is not correctly aimed in azimuth.
39	Remove the search tool and install the ED-50499, G1 axial ratio compensator (Fig. 13) on the waveguide section. Position the compensator so that the index faces the marking on the scale at which the search tool caused a minimum vertical-to-horizontal and horizontal-to-vertical signal.
40	Equally tightening both adjusting bolts on the axial ratio compensator, adjust for a minimum vertical-to-horizontal indication.

CHART 1 (Cont)

STEP	PROCEDURE
	 **Fig. 13 — Axial Ratio Compensator**
41	Measure the vertical-to-horizontal cross-polarization discrimination at three frequencies, one in each segment of the band. Then measure the horizontal-to-vertical cross-polarization discrimination at three frequencies. Using Table C as a guide, make and record the computations required. ***Note:*** When receiving a vertically polarized signal, measure the vertical signal output and record as (1); measure the horizontal signal output and record as (2). When receiving a horizontally polarized signal, measure the horizontal signal output and record as (1); measure the vertical signal output and record as (2). Subtract (2) from (1) to obtain the cross-polarization discrimination figure. ***Requirement:*** All cross-polarization discrimination figures shall be 30 dB or greater. If not, readjust the compensator until the requirement is met. ***Note:*** Readjusting the compensator may worsen a very good cross-polarization figure. This is acceptable, provided that the requirement is finally met at all six points.

<table>
<tr><th colspan="2">CHART 1 (Cont)</th></tr>
<tr><th>STEP</th><th>PROCEDURE</th></tr>
<tr><td>41
(cont)</td><td>
<table>
<tr><th colspan="8">TABLE C</th></tr>
<tr><th colspan="2" rowspan="3">RECEIVING FREQUENCY</th><th colspan="4">MEASURE (DB)</th><th>COMPUTE (DB)</th></tr>
<tr><th colspan="2">V OR H (1)</th><th colspan="2">V OR H (2)</th><th rowspan="2">CROSS-POLARIZATION DISCRIMINATION (1) — (2)</th></tr>
<tr><th>V</th><th>H</th><th>V</th><th>H</th></tr>
<tr><td rowspan="2">UPPER
(4100
to
4200)</td><td>V:———MHZ</td><td>√</td><td>—</td><td>—</td><td>√</td><td rowspan="2"></td></tr>
<tr><td>H:———MHZ</td><td>—</td><td>√</td><td>√</td><td>—</td></tr>
<tr><td rowspan="2">MIDDLE
(3900
to
4000)</td><td>V:———MHZ</td><td>√</td><td>—</td><td>—</td><td>√</td><td rowspan="2"></td></tr>
<tr><td>H:———MHZ</td><td>—</td><td>√</td><td>√</td><td>—</td></tr>
<tr><td rowspan="2">LOWER
(3700
to
3800)</td><td>V:———MHZ</td><td>√</td><td>—</td><td>—</td><td>√</td><td rowspan="2"></td></tr>
<tr><td>H:———MHZ</td><td>—</td><td>√</td><td>√</td><td>—</td></tr>
</table>

<i>Note:</i> V = vertical; H = horizontal.
</td></tr>
<tr><td>42</td><td>If the requirement in Step 41 still cannot be met, refer to Part 4 for possible troubles.</td></tr>
</table>

4. CORRECTIVE PROCEDURES FOR TROUBLE INDICATIONS

Filling in of $\mathrm{TM}^{\circ}_{0,1}$ Received Signal

4.01 If the $\mathrm{TM}^{\circ}_{0,1}$ null is less than 30 dB down from the $\mathrm{TE}^{\circ}_{1,1}$ signal level, either the flexible waveguide or a reflective path may be at fault.

Flexible Waveguide

4.02 Move the body of the circular flexible waveguide around and back and forth. If marked changes are noted, replace the flexible waveguide and repeat the aiming tests. If KS-15690 flexible waveguide is used, moving the position of its ends within the rotatable joints may affect the $\mathrm{TM}^{\circ}_{0,1}$ level. If so, adjust for minimum $\mathrm{TM}^{\circ}_{0,1}$ level.

Reflective Path

4.03 A reflection on the path results in two signals being received by the receiving antenna: one direct from the transmitting antenna and one from the direction of the reflecting surface. Typical reflecting surfaces are the earth, ponds, rooftops, etc., each of which will result in a signal arriving at an elevation angle different from that of the line-of-sight signal. With a vertically polarized transmitted signal, the main signal and the reflections will produce some $\mathrm{TM}^{\circ}_{0,1}$ in the receiving antenna. The strength of each $\mathrm{TM}^{\circ}_{0,1}$ component depends upon the strength of the received signal and the angle of arrival of each component with respect to the axis of the receiving antenna. If the antenna is aimed at the line-of-sight signal, the reflected signal will generate $\mathrm{TM}^{\circ}_{0,1}$. If the antenna is aimed at the reflection, the line-of-sight signal will produce $\mathrm{TM}^{\circ}_{o,1}$. If the antenna is aimed between the two, each produces $\mathrm{TM}^{\circ}_{o,1}$, and the 21A coupler will respond to the sum of the two components. In extreme cases no vertical null at all can be found; i.e., there is high $\mathrm{TM}^{\circ}_{o,1}$ level no matter where an antenna is aimed. With a horizontally polarized signal, on the other hand, the $\mathrm{TM}^{\circ}_{o,1}$ produced by each component depends upon the azimuth component of its angle of arrival with respect to the axis of the receiving antenna. All reflections from the typical reflecting surfaces noted above arrive at the same azimuth angle. Therefore, the $\mathrm{TM}^{\circ}_{o,1}$ produced by each will null out at the same antenna azimuth position, resulting in an azimuth null of normal depth. Thus, a reflection on the path may result in a shallow vertical null and a normal horizontal null. (In a small minority of cases, a reflection in the horizontal plane may be present, caused by the wall of a building or a canyon. This would tend to fill in a horizontal null and not affect a vertical null.)

4.04 The record of the path test, performed on the hop before the route was built, is a good source of information on the presence of reflections on the hop. Any reflection stronger than 20 dB down and more than 1/4 degree off the line-of-sight signal is suspect.

4.05 If the antenna in question is not carrying service, the presence of reflections can be verified as follows. Connect a 21A coupler at the base of the antenna and use connections shown in Fig. 14. Note that the circular waveguide is used as a transmission line down the tower. Connect the Polarad receiver to the vertical 1407A network. Orient the ED-59410-70, G1 transducer for maximum indication on the Polarad receiver. Then reaim the antenna for a null. If the null is 30 dB down or greater, the trouble is in the waveguide run. If the poor vertical null still persists, the path (or the antenna, in rare instances) is at fault.

$\mathrm{TE}^{\circ}_{1,1}$ Level Incorrect

4.06 If the measured $\mathrm{TE}^{\circ}_{1,1}$ is more than 3 dB down from the calculated value, one or more antennas may not be aimed on the main $\mathrm{TE}^{\circ}_{1,1}$ lobe. Reaim each antenna by scanning a wider sector. If the $\mathrm{TE}^{\circ}_{1,1}$ level does not increase to within 3 dB of the calculated value, the trouble is probably in the waveguide. Check for physical damage to the waveguide or flanges. Check for water in the waveguide run and air pressure alarms at the station. If the cause is not obvious, return-loss tests performed in accordance with Section 402-400-501 or 402-400-502 may locate a faulty waveguide section.

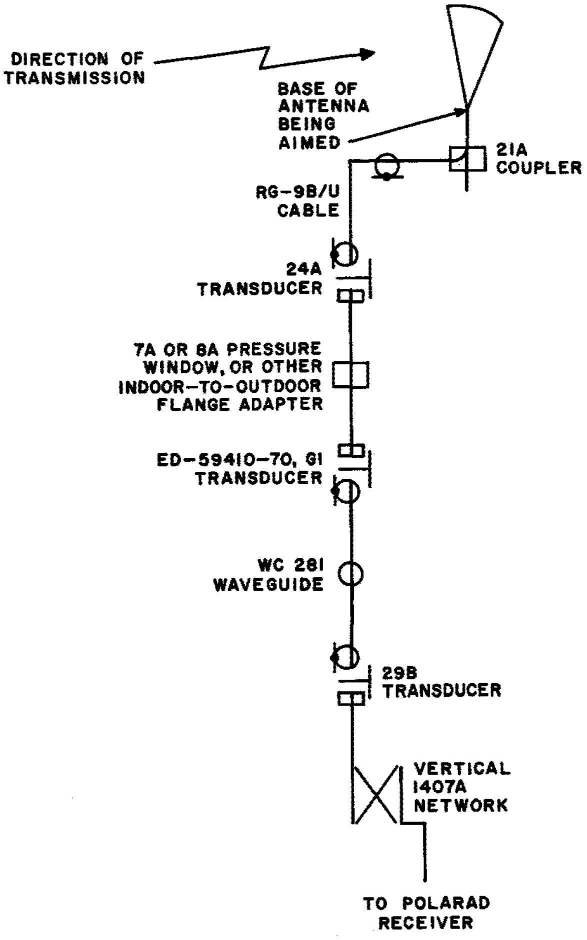


Fig. 14—Test Arrangement for Checking Path Loss (Nonworking Systems Only)

Insufficient Cross-Polarization Discrimination (XPD)

4.07 Cross-polarization discrimination is affected by literally everything that the signals encounter in their journey from the transmitting 1407A networks to the receiving networks. Some of the major causes of poor XPD are listed below, not necessarily in the order of importance.

(a) An antenna misaimed in azimuth will couple together vertically and horizontally polarized signals. If an axial ratio compensator (ARC) is applied to an antenna system to correct the vertical-to-horizontal coupling due to a misaimed antenna, the horizontal-to-vertical coupling will get worse, and vice versa; i.e., an ARC cannot compensate for the cross-polarization coupling due to a misaimed antenna. (This is the reason for the requirement in Step 38 of Chart 1.)

(b) Some pieces of circular flexible waveguide have a rather poor axial ratio; i.e., they are quite elliptical. The effect of the axial ratio of such a piece can be minimized by aligning it axially so that the axes of the ellipse coincide with those of the signal polarizations. This is accomplished in practice by rotating the flexible waveguide axially, with the flanges loose, for maximum XPD. The axial ratio of circular flexible waveguide can be sensitive to its configuration (i.e., bends) and the sensitivity varies from piece to piece. Out-of-limits XPD readings can often be improved markedly by moving the flexible waveguide slightly; if this occurs, the flexible waveguide should be replaced, because it cannot be expected to remain in the optimum configuration under the influence of the wind and the other environmental factors. The position of the end of the KS-15690 circular flexible waveguide within its flange clamp can also influence XPD.

(c) The alignment of the 1407A networks is very critical, and it is very difficult to maintain while locking the networks into position. Good XPD cannot be obtained unless the 1407A networks are properly aligned.

(d) Damage to waveguide and foreign matter in the waveguide can result in poor XPD. Return-loss tests per Section 402-400-501 or 402-400-502 may indicate such causes.

5. PROCEDURES FOR ALIGNING ANTENNA SYSTEMS HAVING SHORT CIRCULAR-WAVEGUIDE RUNS

5.01 ***Definition of a Short Waveguide Run:*** For the purposes of this part, a short waveguide run is one which satisfies any one or more of the following criteria.

(a) There is no waveguide section 4 feet long or longer on which to mount the adjustable axial ratio compensator (AARC).

(b) In order to remove the 21A coupler and install a 29B transducer, the joint at the hanger plate must be disturbed.

(c) If the antenna is carrying service, a joint including the flexible waveguide must be disturbed when installing the coupler. This represents a severe service hazard because the loose end of the flexible waveguide would be difficult to control.

Note: A long waveguide run is one which satisfies none of the above criteria.

5.02 Certain problems arise when the procedures of Part 3 are applied to short waveguide runs:

(a) There may not be sufficient space to insert the 21A coupler between the hanger plate and the top of the 1407A networks.

(b) Even where there is sufficient space to insert the 21A coupler, the flexible waveguide must be disturbed when removing the coupler, possibly invalidating any moding measurements made through the flexible waveguide.

(c) There is insufficient rigid waveguide on which to apply the ED-50499-50, G1 adjustable axial ratio compensator (AARC).

The procedures given in Charts 2 through 5 accomplish most of the objectives.

5.03 The cross-modulation distortion caused by higher-order moding is a function of the length of the circular waveguide. For a short waveguide run (as defined above), the waveguide length is short enough that the cross-modulation improvement to be gained is not worth the service hazards entailed in aiming the antenna with the $TM^{\circ}_{o,1}$ mode on a route carrying service. If the antenna is not carrying service, however, it should be aimed with $TM^{\circ}_{o,1}$ mode.

CHART 2

SHORT RUN FACING LONG RUN
OUT-OF-SERVICE

STEP	PROCEDURE
	Note: All joints between regular ED-59409-70 circular waveguide shall have been aligned with an AT-8390 waveguide alignment wrench.
1	Aim the antenna on the long run according to Chart 1, Steps 1 through 20.
2	Aim the antenna on the short run according to Chart 1, Steps 1 through 20, except do not install the 21A coupler until Step 14, at which time connect it directly to the base of the feedhorn (no circular flexible waveguide).
3	Remove the 21A coupler from the antenna of the short run and replace the circular flexible waveguide.
4	Adjust the XPD according to the procedure of Chart 1, Steps 23 through 42, calling the antenna on the long run antenna A and the antenna on the short run antenna B.

CHART 3

SHORT RUN FACING LONG RUN
IN-SERVICE

STEP	PROCEDURE
	Note: All joints between regular ED-59409-70 circular waveguide shall have been aligned with an AT-8390 waveguide alignment wrench.
1	Aim the antenna on the long run according to Chart 1, Steps 1 through 20.
2	Perform the procedure in Chart 1, Steps 23 to 38, calling the antenna on the long run antenna A, and the antenna on the short run antenna B.
3	If the two plots obtained are not in phase within 15 degrees of rotation of the search tool, move the antenna on the short run slightly in azimuth and repeat Chart 1, Steps 37 and 38.
4	If the plots obtained in Step 3 are closer together (more in phase) than those obtained in Step 2, keep moving the antenna in the same direction until the plots become in phase. If the plots obtained in Step 3 are farther apart (more out of phase) than those obtained in Step 2, move the antenna in the opposite direction until the plots become in phase. The antenna on the short run is now aimed adequately enough for the XPD to be adjusted.
5	Adjust the XPD in accordance with Chart 1, Steps 39 through 42.

CHART 4

SHORT RUN FACING SHORT RUN
OUT-OF-SERVICE

STEP	PROCEDURE
1	Aim the antennas according to Chart 1, Steps 1 through 27, except do not install 21A couplers until Step 14, at which time connect them directly to the base of the feedhorn (no circular flexible waveguide).
2	Remove the 21A couplers and reinstall the circular flexible waveguide.
3	Align the 1407A networks at station B vertically and horizontally, as judged by eye, and lock them down. Align the 1407A networks at station A per Chart 1, Steps 29 and 30.
4	If either end of the hop has sufficient waveguide for an axial ratio compensator, adjust the XPD per Chart 1, Steps 31 through 42. If not, proceed to Step 5.
5	Measure the resulting XPDs per Chart 1, Step 41. If the requirement is not met, refer to Part 4.
6	If the requirement of Step 41, Chart 1 is still not met, move one of the antennas slightly in azimuth and remeasure. Repeat until the XPD requirement is met, but do not move either antenna more than 0.5 degree off-axis.

CHART 5

SHORT RUN FACING SHORT RUN
IN-SERVICE

STEP	PROCEDURE
1	Install 1A junctions at the pressure windows of each station in accordance with the procedure in 2.06. ***Warning: RF energy radiated during the hot cutting of 1A junctions may be hazardous to personnel. Installation personnel shall wear protective radiation suits in accordance with Section 010-150-002 when installing 1A junctions.***
2	Attach the KS-20073 telescope to the transmitting antenna as shown in Fig. 10, adjusting its position so that the reticle of the telescope is aligned on a stationary target at least 3000 feet away and the micrometer adjustments of the telescope read 1.00 ±0.05 degree on their 0- to 2-degree scales. Note the initial azimuth and elevation settings.

CHART 5 (Cont)

STEP	PROCEDURE
3	Transmit a vertically polarized signal from the transmitting station. (The main lobe of a vertically polarized signal is sharper in azimuth than that of a horizontally polarized signal.) A vertically polarized channel may be used if available.
4	Connect the Polarad receiver to the 1A junction in the vertically polarized run at the receiving end of the hop. Tune the receiver to the test signal and note the signal level reading.
5	Unlock the transmitting antenna in azimuth and move to the left until the received signal level is 2 dB lower than that measured in Step 4. Center the telescope on the target and read the azimuth micrometer. Call this reading A_1.
6	Move the antenna to the right past the azimuth setting noted in Step 2 until the signal level drops back again to 2 dB lower than that measured in Step 4. Center the telescope on the target and read the azimuth micrometer. Call this reading A_2.
7	Set the azimuth micrometer to $A_o = 1/2\ (A_1 + A_2)$. Move the antenna until the target is centered in the telescope. Lock the antenna in azimuth.
8	Repeat Steps 5 through 7 with the receiving antenna.
9	Transmit a horizontally polarized signal from the transmitting station. (The main lobe of a horizontally polarized signal is sharper in elevation than that of a vertically polarized signal). A horizontally polarized channel may be used if available.
10	Connect the Polarad receiver to the 1A junction in the horizontally polarized run at the receiving end of the hop. Tune the receiver to the test signal and note the signal level reading.
11	Unlock the transmitting antenna in elevation and move it up until the received signal level is 2 dB lower than that measured in Step 10. Center the telescope on the target and read the elevation micrometer. Call this reading E_1.
12	Move the antenna down past the elevation setting noted in Step 2 until the signal level drops back again to 2 dB lower than that measured in Step 10. Center the telescope on the target and read the elevation micrometer. Call this reading E_2.
13	Set the elevation micrometer to $E_o = 1/2\ (E_1 + E_2)$. Move the antenna until the target is centered in the telescope. Lock the antenna in elevation.
14	Repeat Steps 11 through 13 with the receiving antenna.
15	Align the 1407A networks at the transmitting station vertically and horizontally, as judged by eye. Transmitting vertically and receiving horizontally, adjust the networks at the receiving station for minimum signal. Lock the networks in place.
16	If either end of the hop has sufficient waveguide for an axial ratio compensator, adjust the XPD per Chart 1, Steps 31 through 42. If not, proceed to Step 17.

CHART 5 (Cont)

STEP	PROCEDURE
17	Measure the resulting XPDs per Chart 1, Step 41. If the requirement is not met, refer to Part 4.
18	If the requirement of Step 41 still is not met, move one of the antennas slightly in azimuth and remeasure. Repeat until the XPD requirement is met, but do not move either antenna more than 0.5 degree off-axis.

6. INFORMATION TO BE RECORDED AND SAVED

6.01 The following form may be duplicated and used as a guide to provide a convenient method for recording the information to be saved.

ANTENNA ALIGNMENT DATA SHEET

Levels and Elevations

Initial azimuth $\text{TM}^{\circ}_{o,1}$ level* ——dBm
Initial elevation $\text{TM}^{\circ}_{o,1}$ level* ——dBm
Change in azimuth position* ——degrees
Change in elevation position* ——degrees
Final azimuth $\text{TM}^{\circ}_{o,1}$ level ——dBm
Final elevation $\text{TM}^{\circ}_{o,1}$ level ——dBm
Final $\text{TE}^{\circ}_{1,1}$ level measured ——dBm
$\text{TE}^{\circ}_{1,1}$ level calculated ——dBm

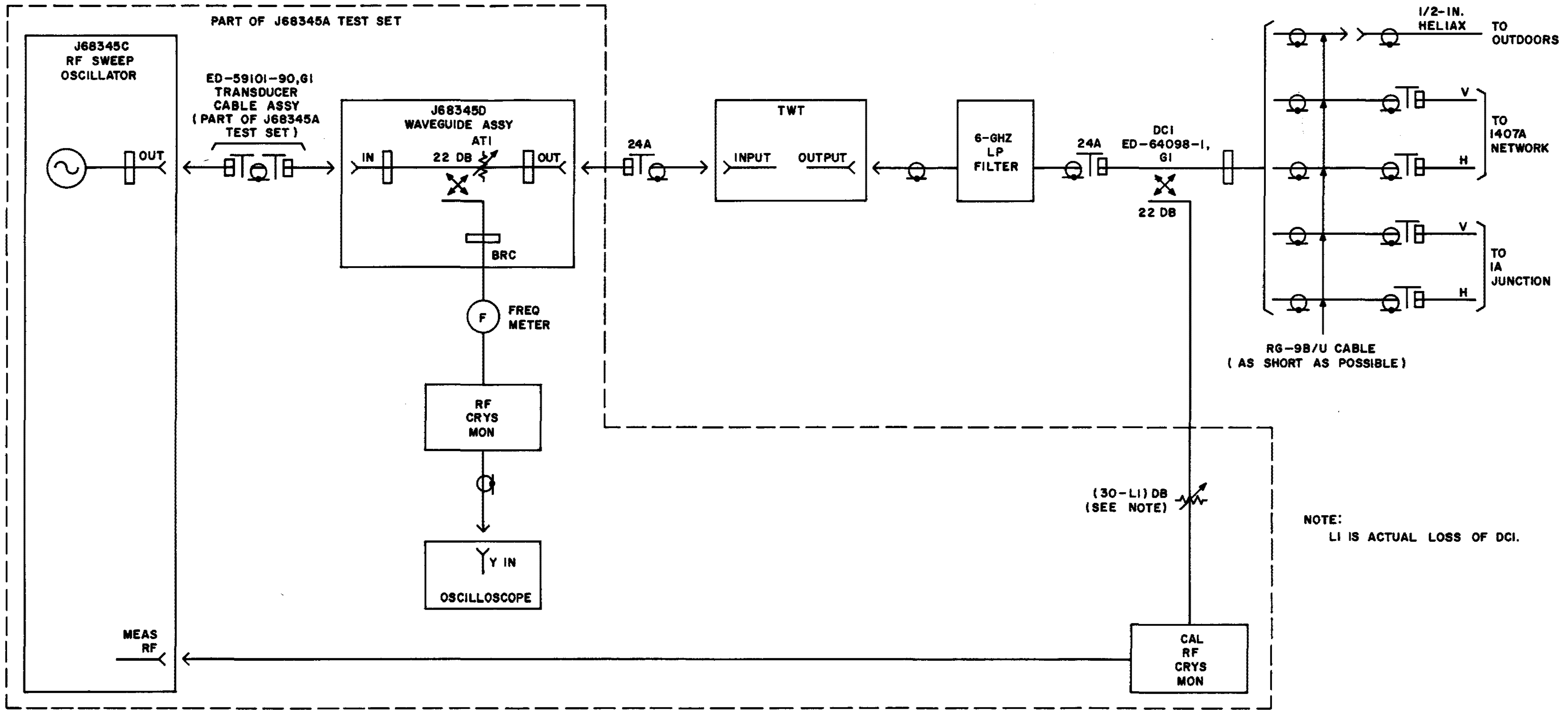
* Readjustment of working systems only.

Cross-Polarization Discrimination (XPD)

FREQUENCIES			XPD
Upper (4100 to 4200)	V → H	———MHz	————dB
	H → V	———MHz	————dB
Middle (3900 to 4000)	V → H	———MHz	————dB
	H → V	———MHz	————dB
Lower (3700 to 3800)	V → H	———MHz	————dB
	H → V	———MHz	————dB

Unusual Occurrences

Waveguide and Associated Equipment Changes



NOTE:
L1 IS ACTUAL LOSS OF DC1.

Fig. 15—Test Connections Using J68345A Test Set