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TECHNICAL MANUAL

CDAA ELECTRONIC MAINTENANCE
(AN/FRD-10)

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FOREWORD

This manual is intended to aid the working level technician involved with the electronic testing and maintenance of antenna elements and RF distribution equipment at AN/FRD-10 sites.

The term AN/FRD-10 is used throughout this manual as a simplification to refer to the following family of systems:

AN/FRD-10 (XN-2)
AN/FRD-10 (V)
AN/FRD-10A (V)

Information contained in this manual is primarily drawn from, and supersedes, three informal "hand-outs" prepared by the Naval Electronic Engineering Activity, Pacific (NEEACT PAC):

"Guidelines for a Multicoupler Testing and Phasing Program"
"Time Domain Reflectometer (TDR) Training"
"CDAA Electronic Maintenance (AN/FRD-10)"

In addition, information was obtained from Naval Electronic Systems Security Engineering Center (NAVELEXSECCEN) personnel and from Circularly Disposed Antenna Array (CDAA) survey reports compiled in the course of providing technical assistance to the AN/FRD-10 sites.

It is anticipated that occasional updates of this manual will be necessary as new equipment is fielded, new test equipment becomes available, and more knowledge is gained on AN/FRD-10 RF maintenance. Users are urged to provide comments, or useful information for inclusion in future revisions to:

Commanding Officer
Naval Electronic Systems Security Engineering Center
Attn: Code 310
3801 Nebraska Avenue, N.W.
Washington, DC 20393-5270

CHAPTER 1
INTRODUCTION

1.1 PURPOSE

Electronic maintenance of the Circularly Disposed Antenna Array (CDAA) involves inspecting and testing the electronic properties of the various components of the system to ensure peak operational performance. Due to the physical properties of a CDAA and the manner in which the antennas are used, an array can operate maintenance-free and appear normal until it has deteriorated to the point of being almost inoperative. Therefore, constant inspection and careful preventive maintenance are required to prevent system deterioration and costly repairs.

1.2 SCOPE

The comprehensive scope of this technical manual provides information to familiarize CDAA station personnel with the overall configuration of a CDAA system and to provide a basic understanding of its operation on both the component and system levels. More importantly, this manual explains the standard electronic tests required to properly evaluate the CDAA antennas, transmission lines, primary and distribution multicouplers, beamformers, goniometers, and Direction Finding (DF) operational systems. Each test description includes examples of and notes concerning typical test results, as well as problems to be aware of when performing these tests. This manual provides the following:

1. General overview of the station equipment and operation.
2. Basic principles of operation.
3. Time Domain Reflectometry (TDR) Test.
4. Smith Chart/VSWR Tests.
5. Antenna Amplitude and Phase Comparison Test.
6. Primary and Distribution Multicoupler Test.
7. Beamformer Test.
8. System Continuity Tests.
9. Description of Test Equipment.

1.3 GENERAL OVERVIEW OF STATION EQUIPMENT AND OPERATION

1.3.1 An aerial photograph of the Navy's AN/FRD-10 Circularly Disposed Antenna Array (CDAA) direction finding system, also known as a Wullenweber Antenna Array, is shown in Figure 1-1. Stations such as this are located throughout the world. The network they form is used to intercept and correlate information from a variety of signal sources.

1.3.2 The CDAA functions may be divided into two general categories: First, the array is used as a general purpose communications receiving antenna with the capability of selecting beams pointing in any direction. The second and most critical function of the CDAA is its direction finding capability. In this capacity, the CDAA and related RF circuitry make up a precision system in which maintenance is critical to its accuracy and operation.

1.3.3 When a wavefront from a signal source arrives at a CDAA site, it is received by the arrangement of antenna components shown in Figure 1-2. This arrangement consists of ground radials, low/high band ground bus, reflecting ground mat, low/high band reflection screens, low/high band antennas, and RG-85 A/U transmission lines. When a wavefront contacts the ground plane, as shown in Figure 1-3, a reflected wave is produced which has the effect of an "image" antenna below the ground plane; in addition, when a wavefront contacts a reflection screen, as shown in Figure 1-4, another reflected wave is produced behind the antenna elements. These reflected waves serve to increase the overall effectiveness of the antenna system.

1.3.4 A close-up of the physical components of a low band antenna is shown in Figure 1-5. The low band HF signal is picked up by the antenna mast and downwires, travels through the matching transformer, and through the transmission lines (RG-11, RG-85). A close-up of the physical components of a high band antenna is shown in Figu 1-6. The high band signal is picked up by the mast; travels through the tuning stub; into the feed point; down through the RG-11 cable, and into the RG-85 transmission line.

1.3.5 Once the low and high band signals reach the armored RG-85 A/U transmission lines, they travel underground to primary antenna multicouplers located inside the operations building, as shown in Figure 1-7. The signals then flow through the RF distribution system, as shown in Figure 1-8. Video information from the goniometers are channeled to receiver #1; while audio information from the beamformers are channeled to receivers #2 and #3.

1.3.6 An individual antenna element operates most efficiently at its resonant frequency. As received frequencies vary from the center frequency, efficiency falls off. To improve broadband performance, the antenna elements are designed with a low "Q" or efficiency factor. This enables the system to cover the 2 to 32 MHz high frequency spectrum using two types of antenna elements. Low band elements are designed to operate from 2 to 8 MHz while high band elements operate in the 8 to 32 MHz range.

1.4 BASIC PRINCIPLES OF OPERATION

1.4.1 Now we will briefly cover the concept and theory of direction finding. Referring to the left of Figure 1-9, we see a wavefront approaching a linear (a uniformly phase delayed) array of antennas. On the right of this figure, we see the resulting (linearly combined) beam pattern. This pattern shows two major lobes and thus indicates two possible directions from which the signal source might have originated. This ambivalence is eliminated by the use of reflection screens as shown in the left of Figure 1-10. The resulting beam pattern, shown on the right indicates the direction of the signal source.

1.4.2 In an actual CDAA, the antennas are positioned in a circle, and therefore unlike the linear case discussed above, the individual antenna wavefront signals cannot be combined (summed) until they are brought in phase (phase-matched). For audio information, this is done by beamformer circuitry which adds phase delays, as show Figure 1-11, to compensate for the inherent lag time between antenna signals that the circularly positioned antenna create. Similary, video information must also be phase-matched. This is accomplished by goniometer circuitry, as shown in Figure 1-12. These phase delays compensate for the lag time and produce a phase matched video signal at the combiner output. However, unlike the beamformer circuitry which is dedicated to a specific set of antenna signals, the goniometer circuitry rotates in a head that samples 120 degrees of antenna signals rotating through 360 degrees of azimuth.

1.4.3 The video information at the output of the goniometer is displayed on the Narrowband and Wideband Systems as shown in Figures 1-13 and 1-14. Two different display modes are shown: summing (Figure 1-13) and difference (Figure 1-14). Although they appear quite different, both displays indicate a signal source at zero degree azimuth. In the summing mode, the individual antenna signals on each half of the rotating goniometer head are added and, thus, yield a "lobe" in the azimuth direction of the signal source. However in the difference mode, the signals are subtracted and, thus yield a "null" in the azimuth direction of the signal source.

1.4.4 The overall phase and amplitude relationship of the signal flow through the CDAA system is shown in Figure 1-15. The wavefront contacts the CDAA and induces RF signals which are out of phase with respect to each antenna element. These signals remain out of phase as they enter and exit the primary multicouplers. The signals then enter the goniometers (for video information) and beamformers (for audio information). After passing through these units, the signals are phase-matched and combined to form coherent video and audio signals.

1.5 STANDARD ELECTRONIC TESTS

A description of the standard electronic tests can be found in the following chapters:

Chapter 2 – Time Domain Reflectometry (TDR) Test.
Chapter 3 – Smith Chart/VSWR Tests.
Chapter 4 – Antenna Amplitude and Phase Comparison Test.
Chapter 5 – Primary and Distribution Multicoupler Test.
Chapter 6 – Beamformer Test.
Chapter 7 – System Continuity Tests.

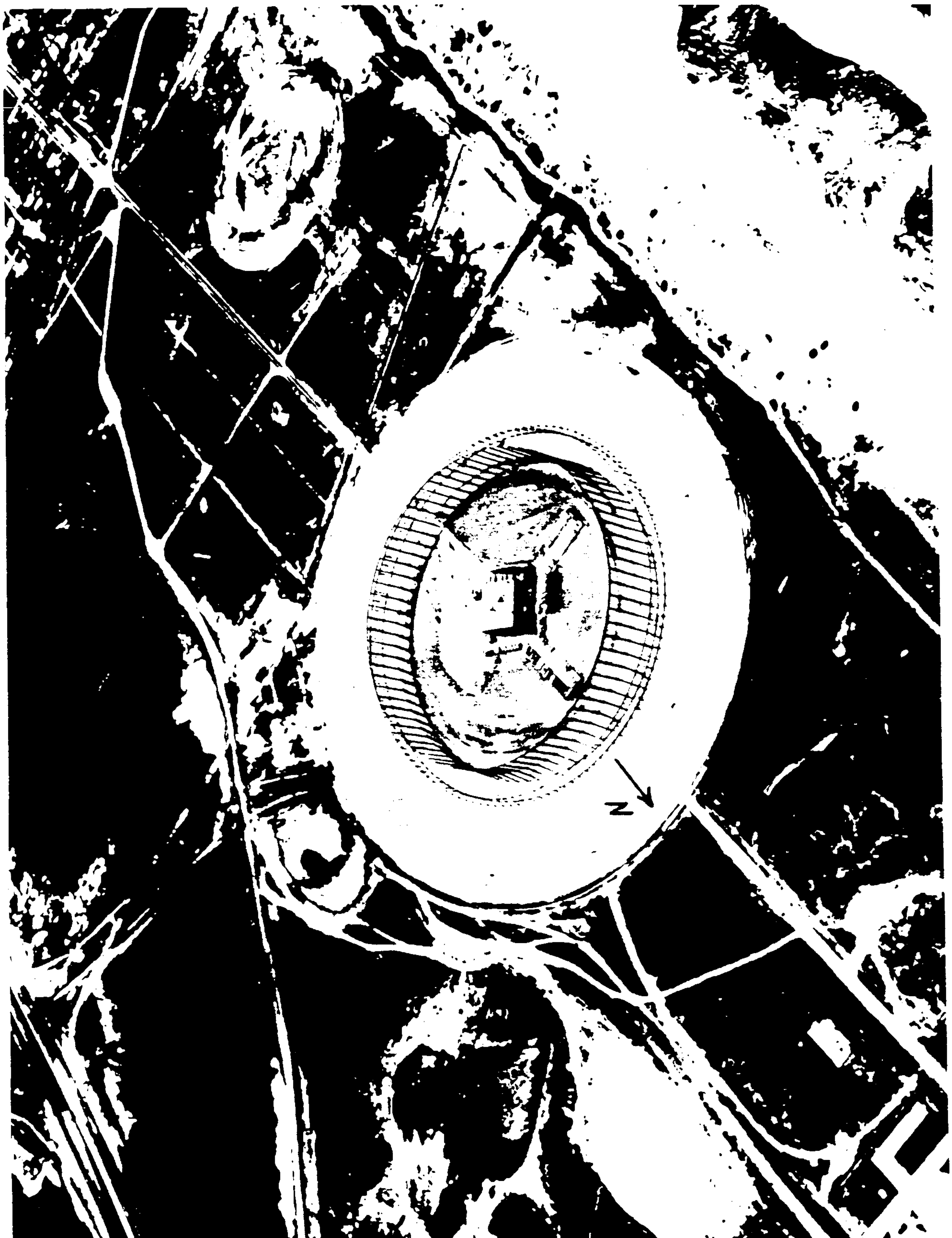


FIGURE 1-1. FRD-10 Circularly Disposed Antenna Array (Wullenweb r).

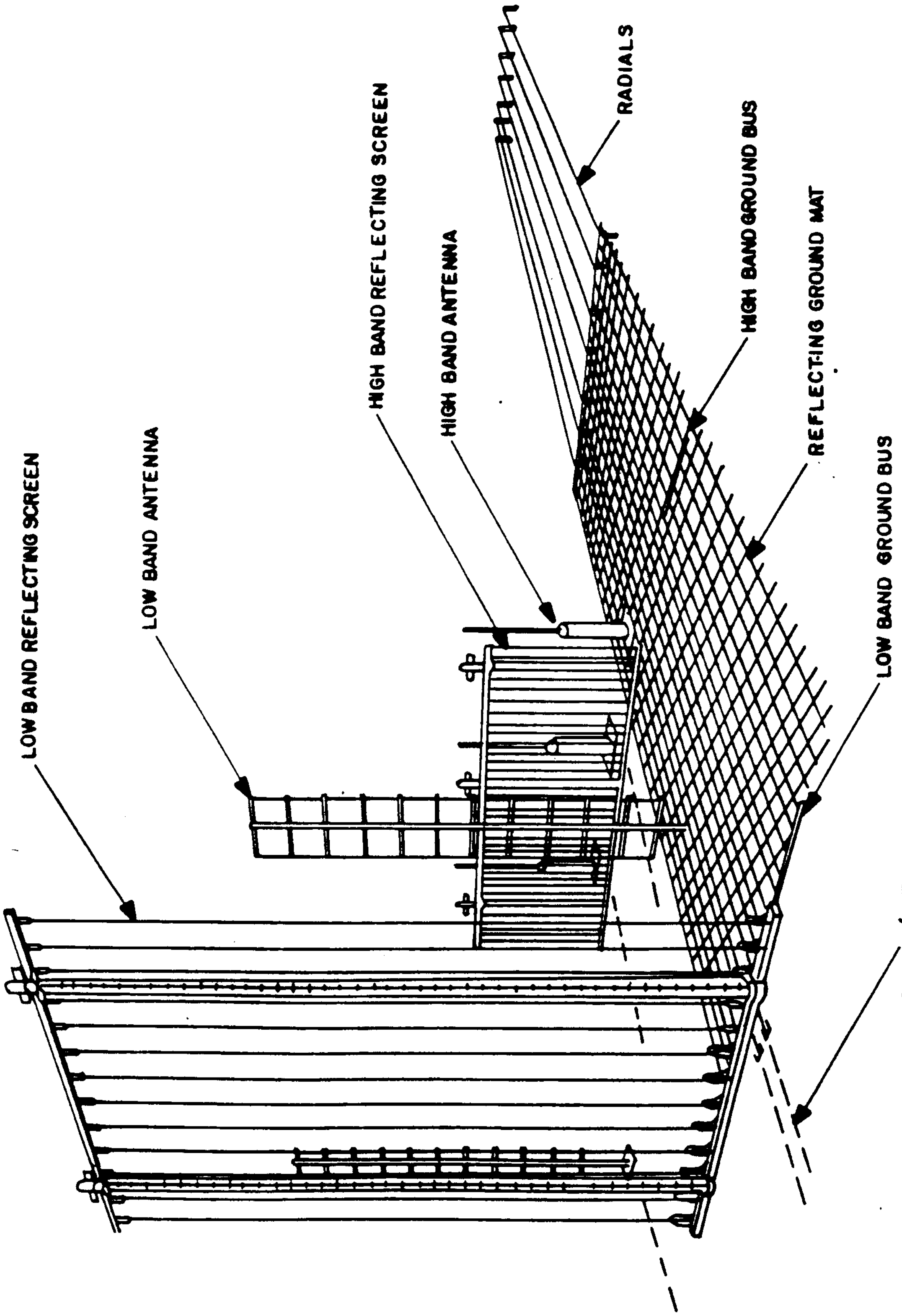


FIGURE 1-2. Major Compon of a Typical CDAA.

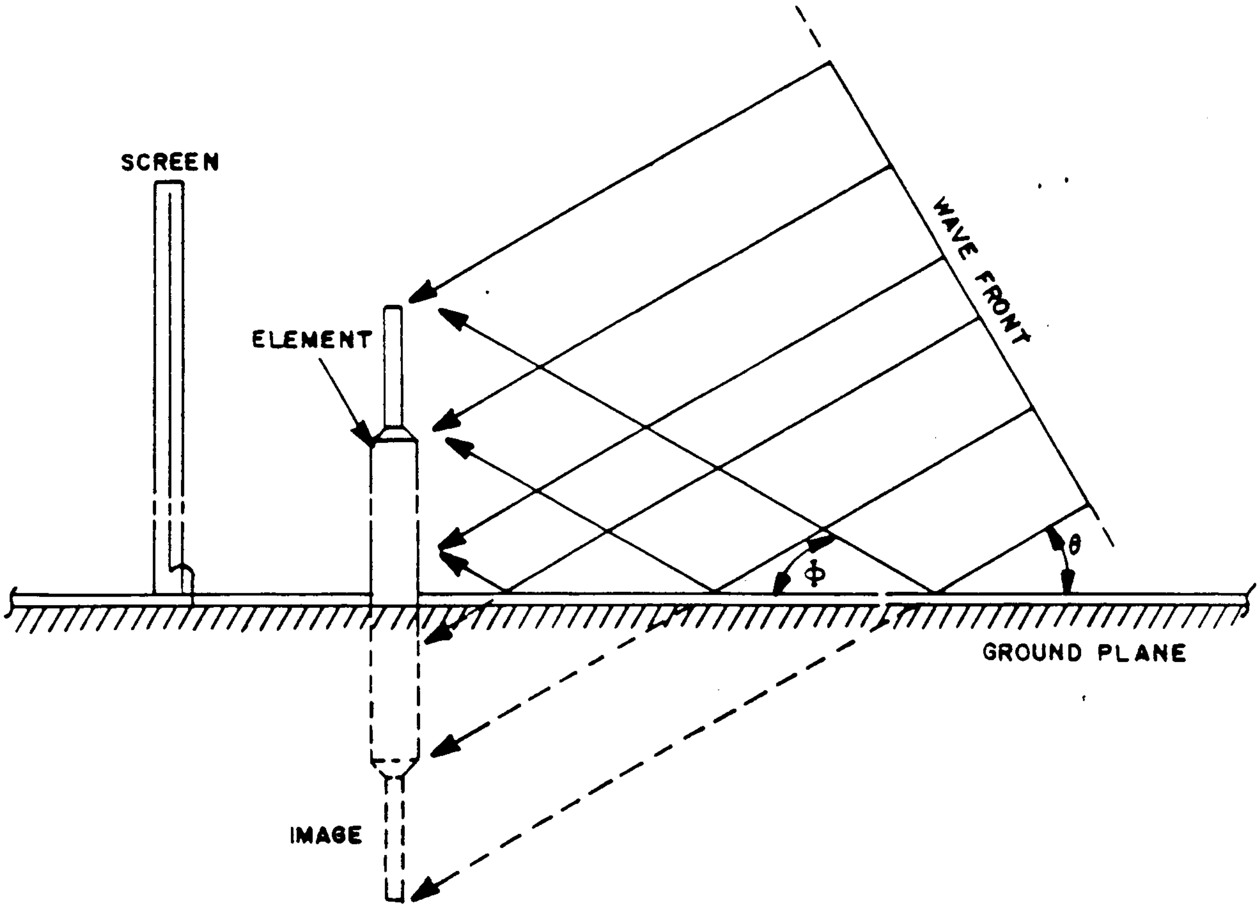


FIGURE 1-3. Principle of CDAA Reflecting Ground Plane.

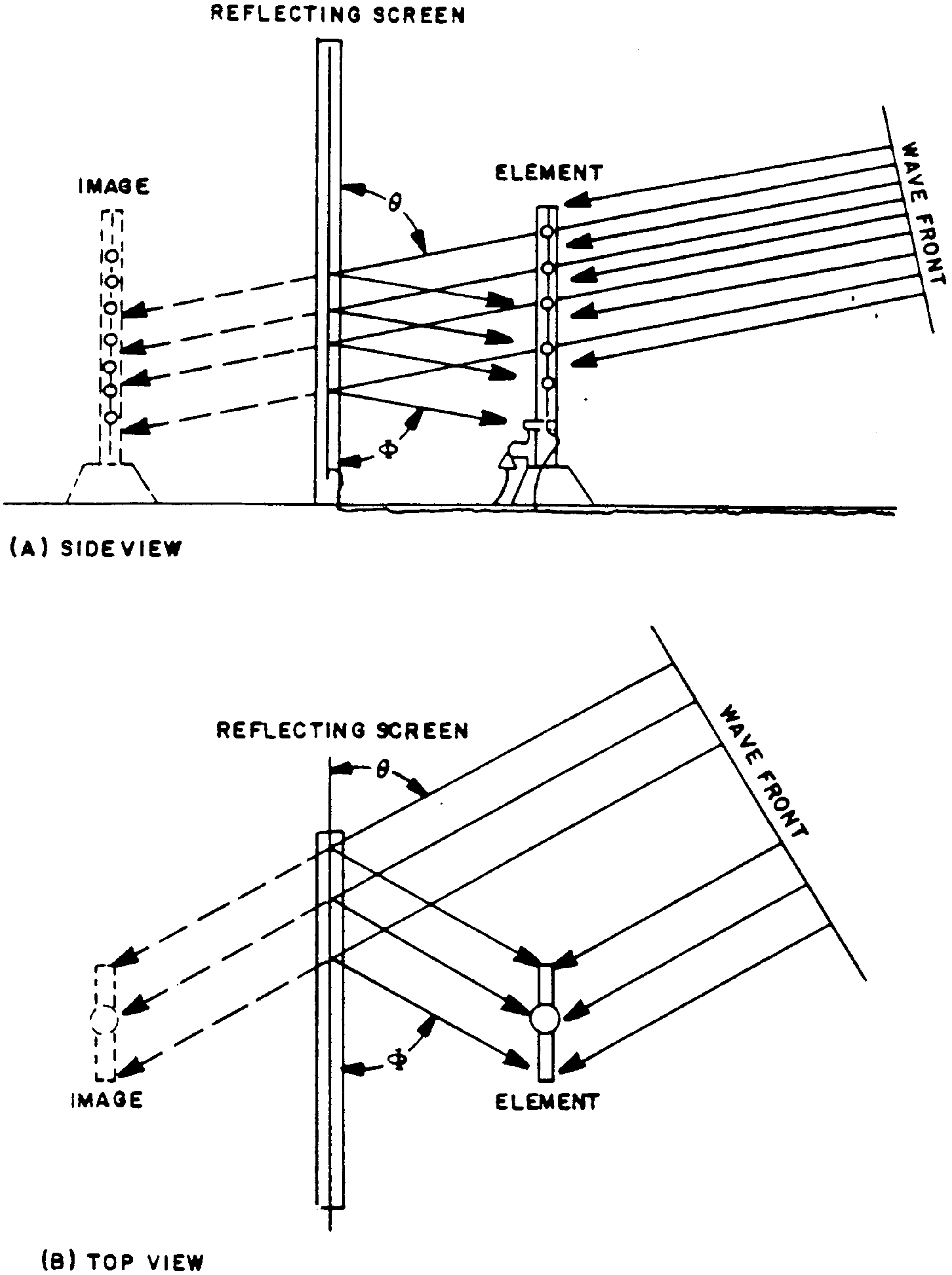


FIGURE 1-4. Principle of CDAA Reflecting Screen.

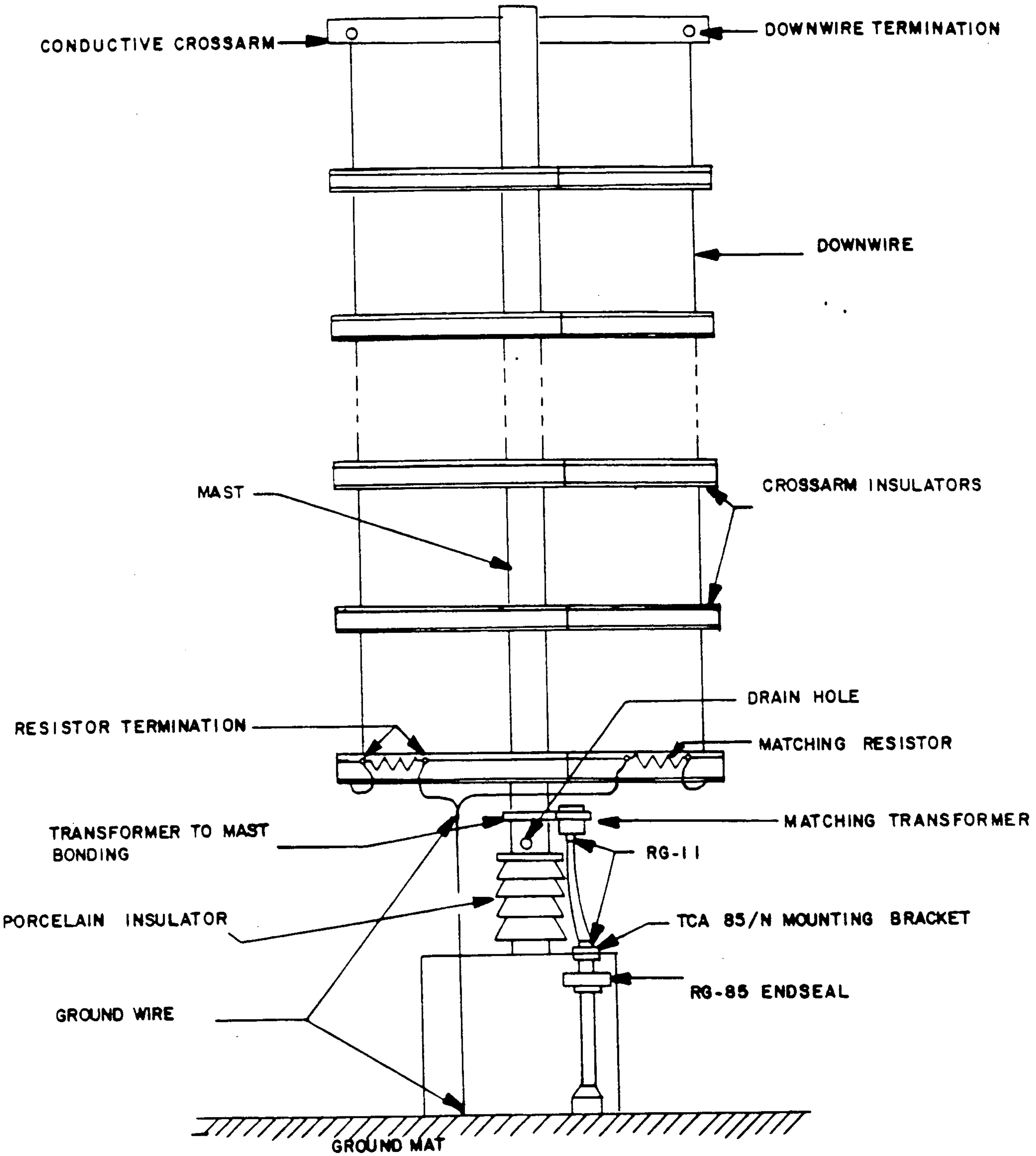


FIGURE 1-5. Components of a Low Band Antenna.

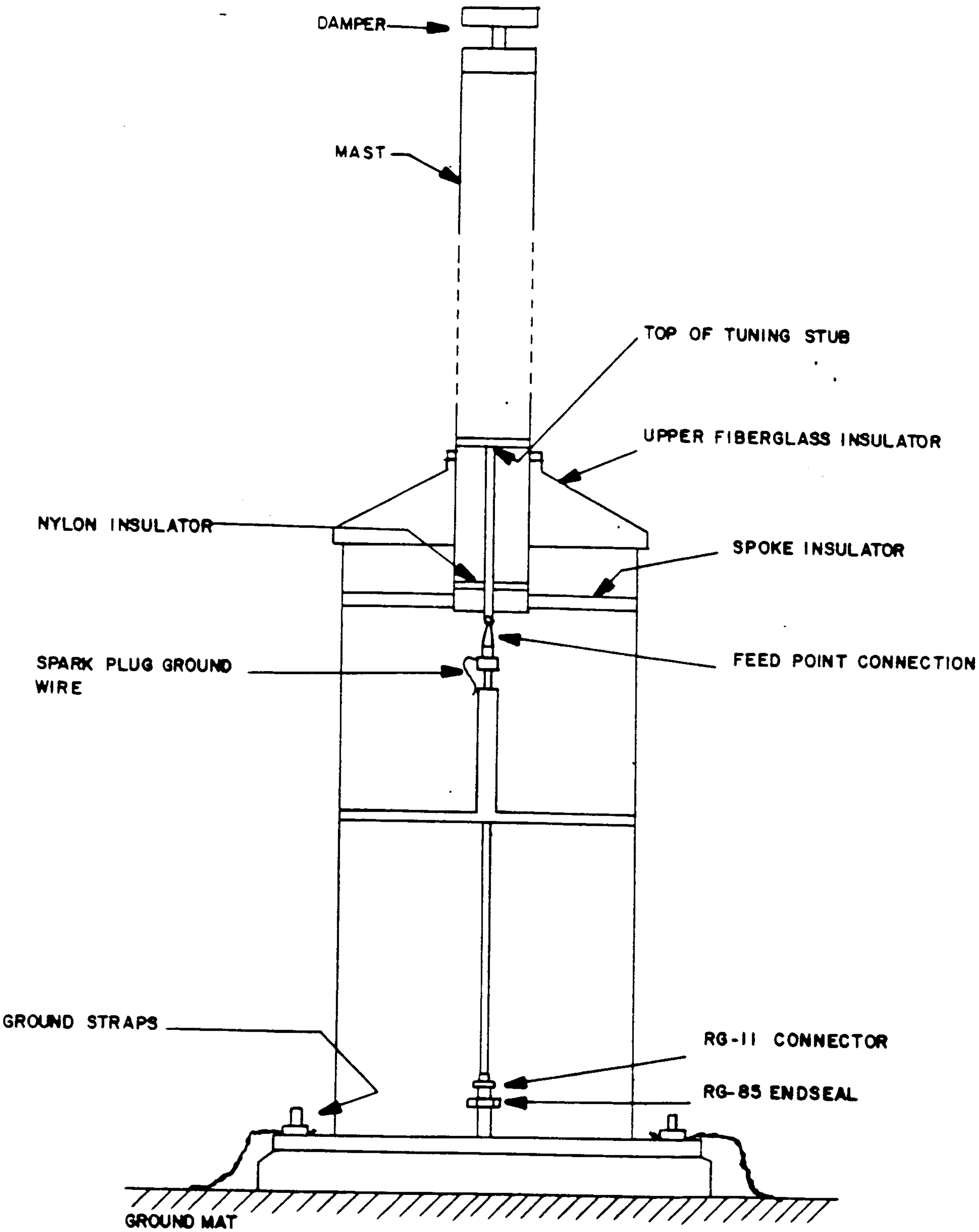


FIGURE 1-6. Components of a High Band Antenna.

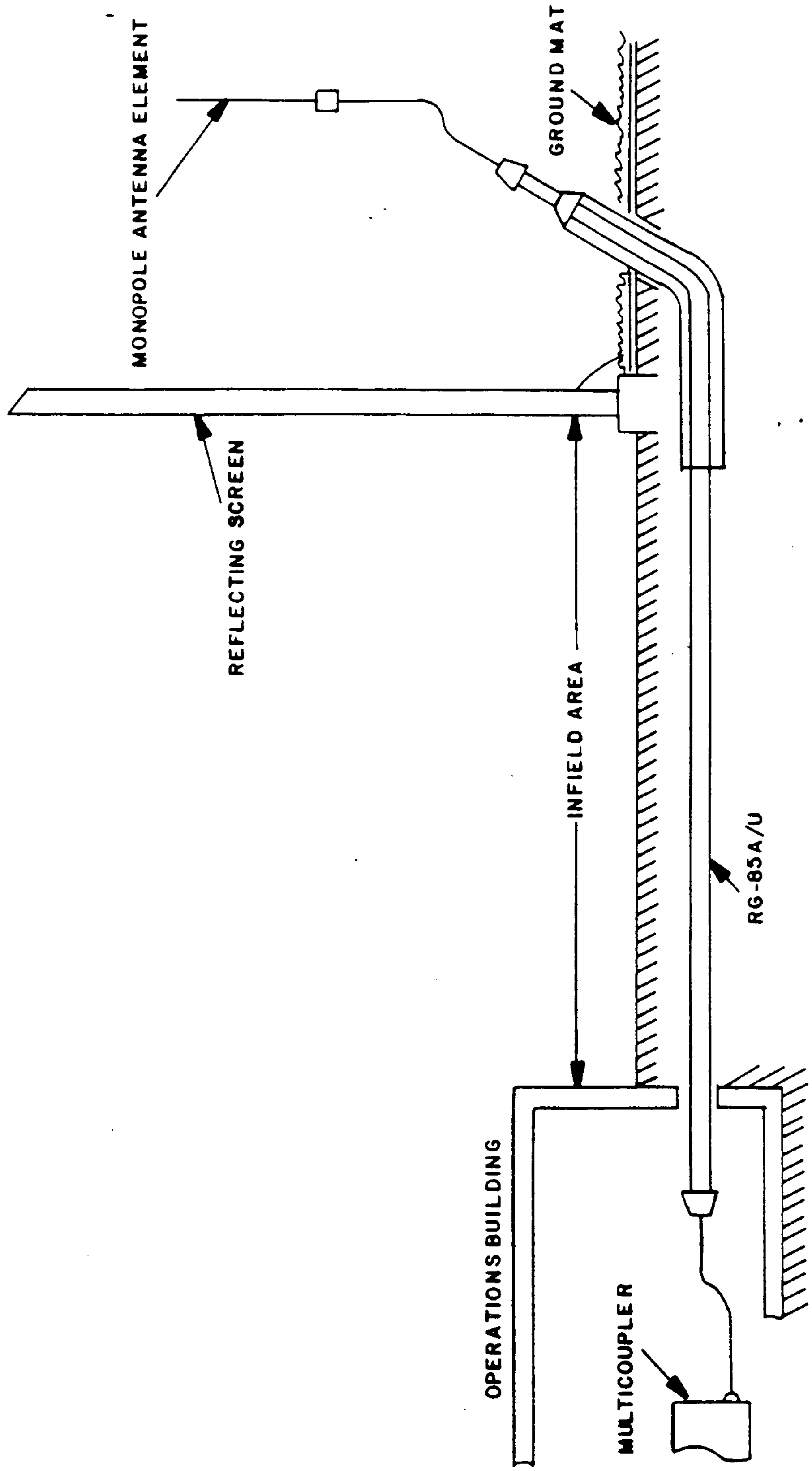


FIGURE 1-7. Typical Transmission Line Installation.

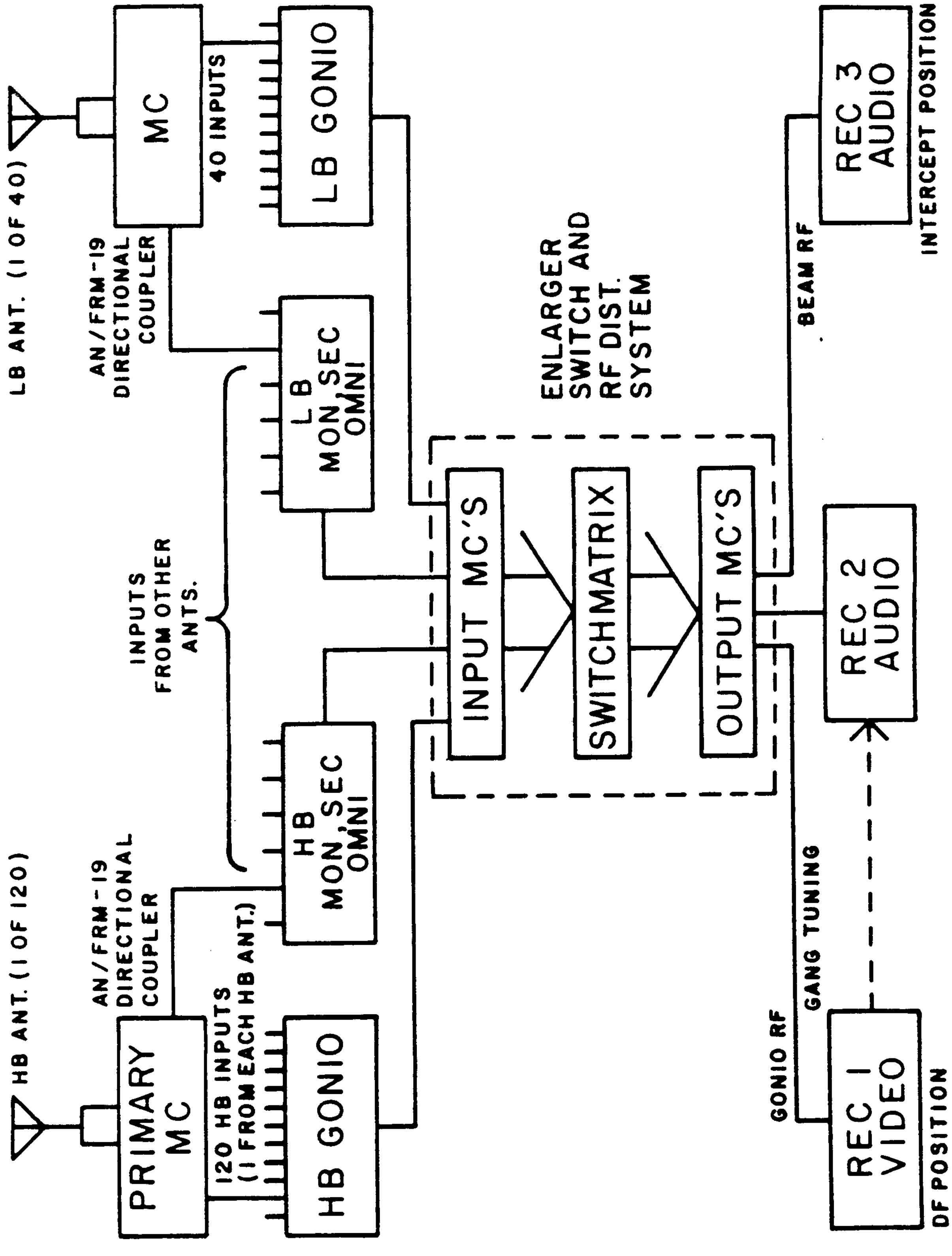


FIGURE 1-8. RF Signal Path of One Ar a Element to Various R ceivers.

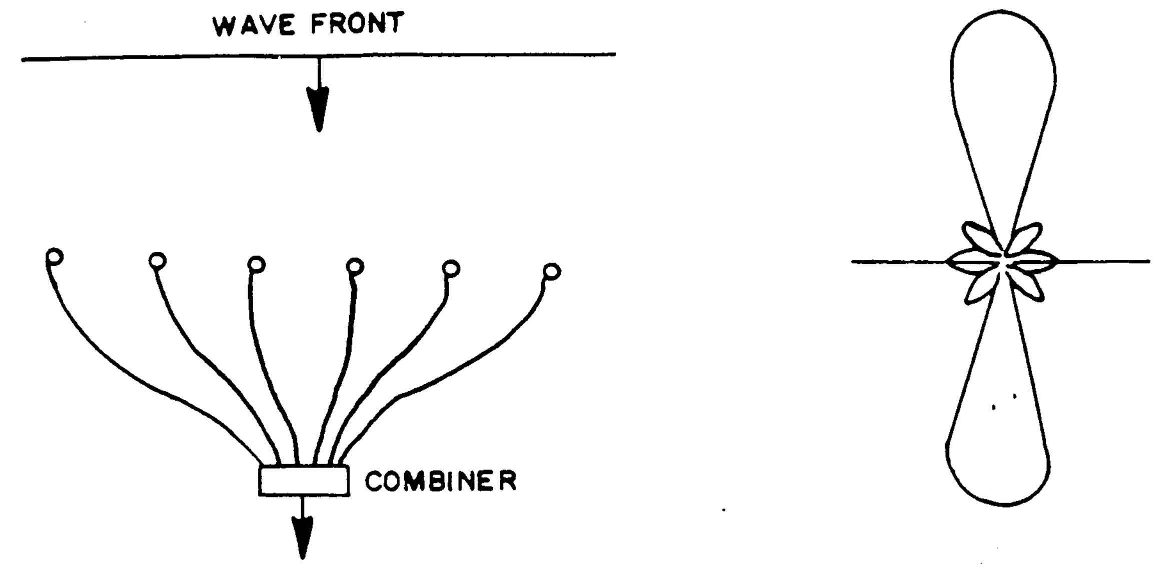


FIGURE 1-9. Linear Array and Characteristic Pattern.

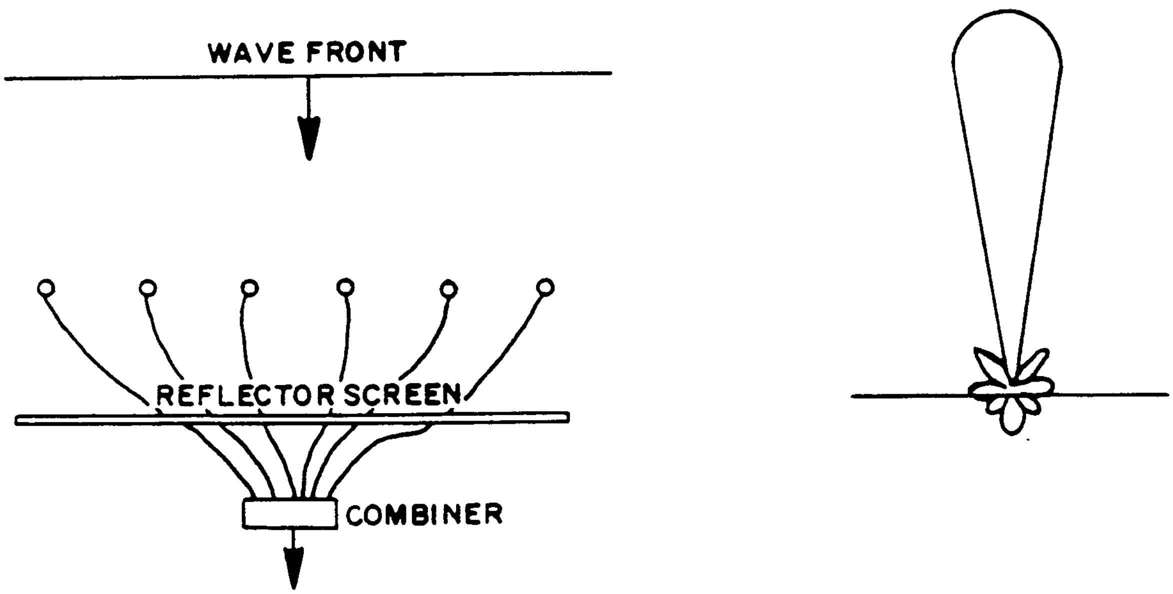


FIGURE 1-10. Linear Array with Reflector Screen and Characteristic Pattern.

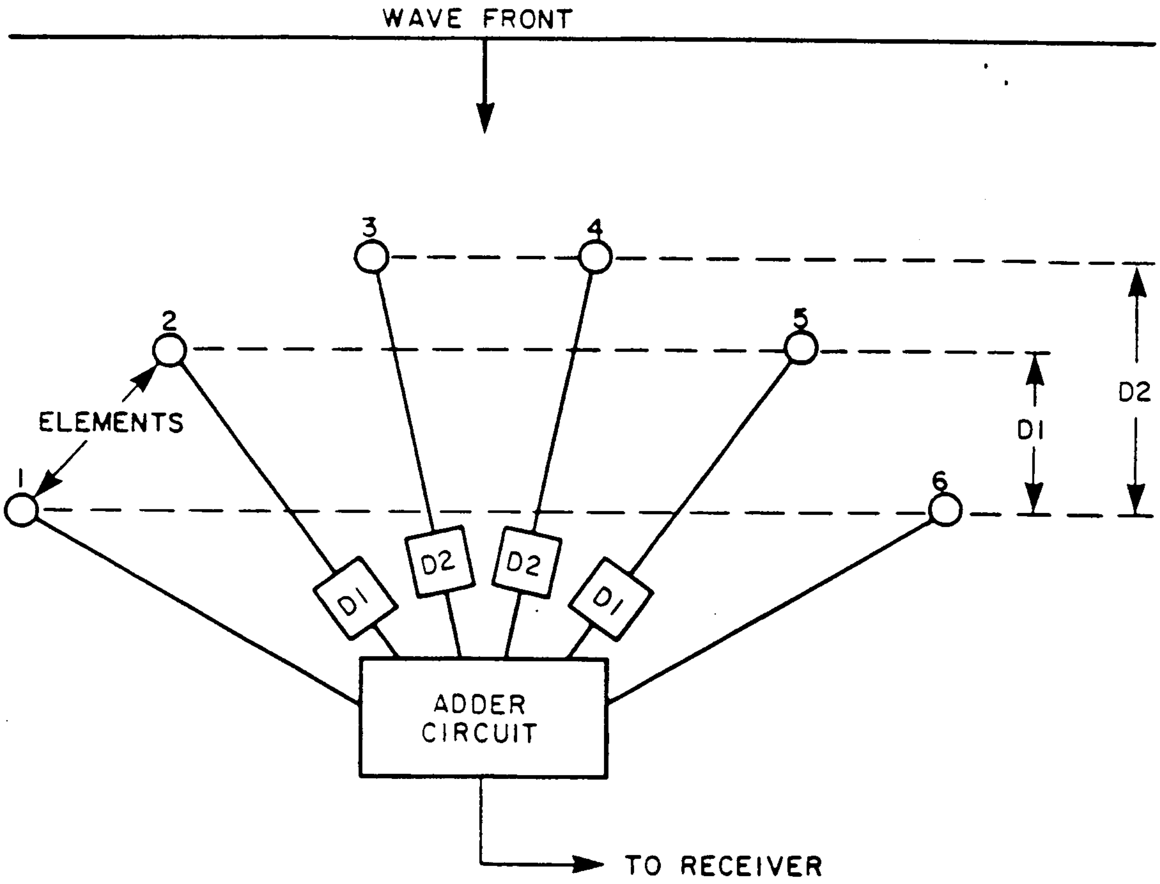


FIGURE 1-11. Fundamentals of the Beamforming Network.

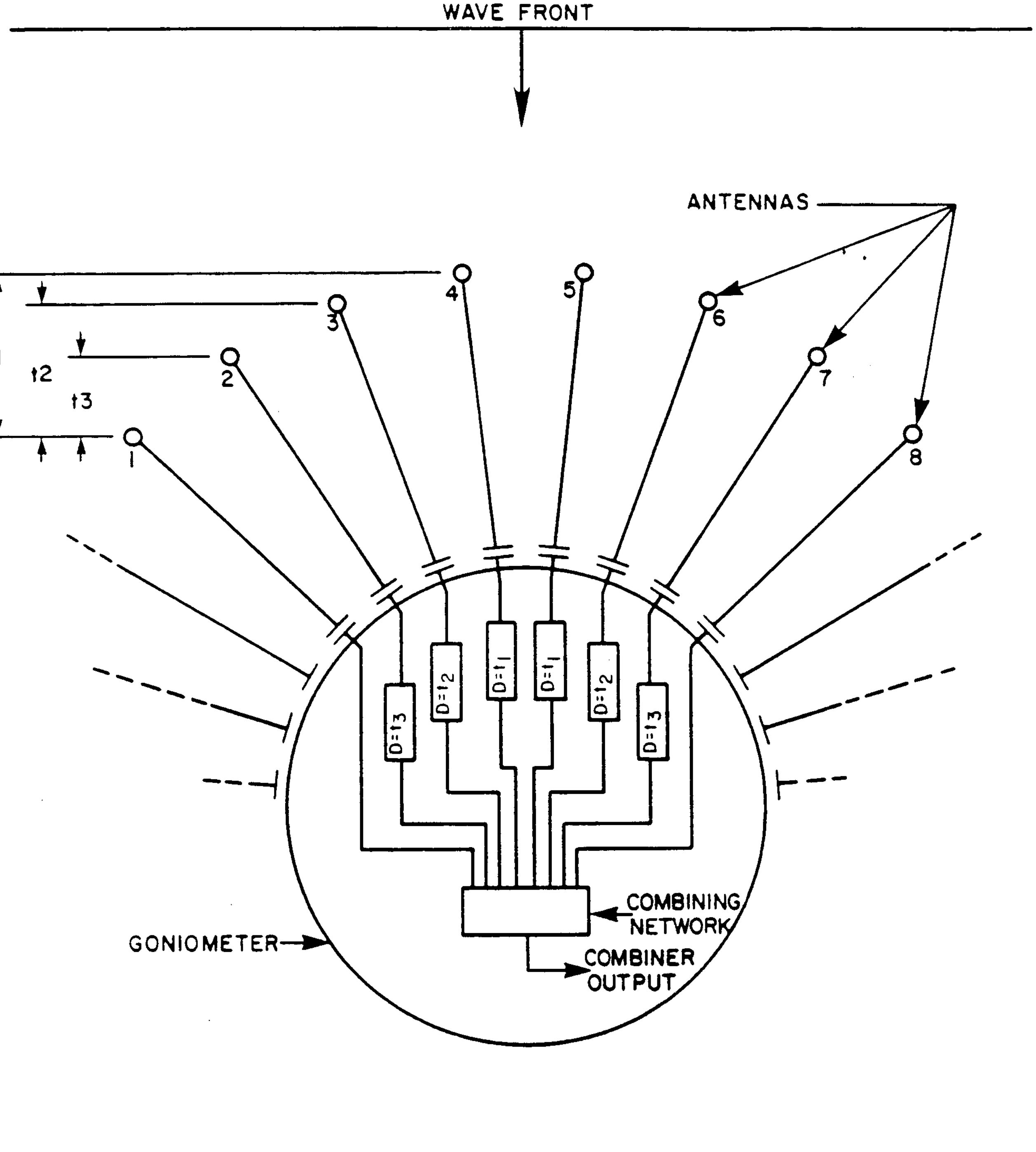


FIGURE 1-12. Fundamentals of the Goniometer.

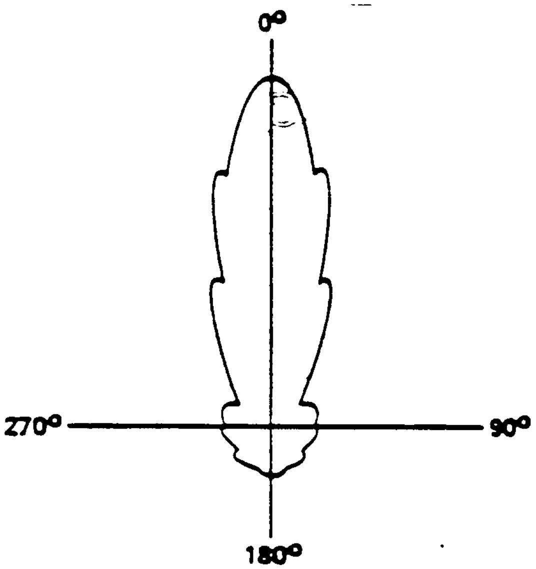


FIGURE 1-13. Sum Mode Output Pattern of a CDAA Goniometer.

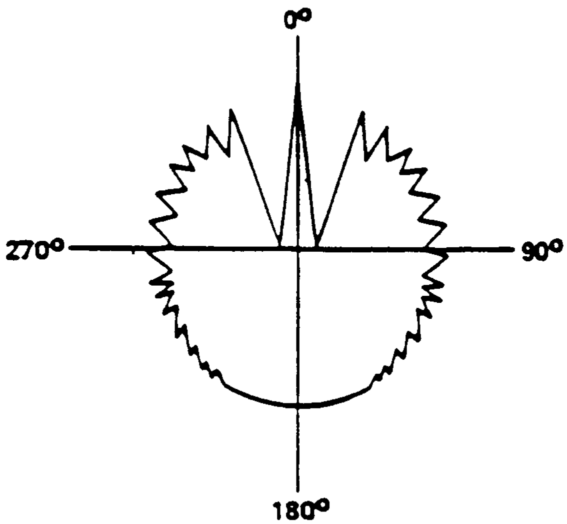


FIGURE 1-14. Diff rence Mode Output Pattern of CDAA Goniometer.

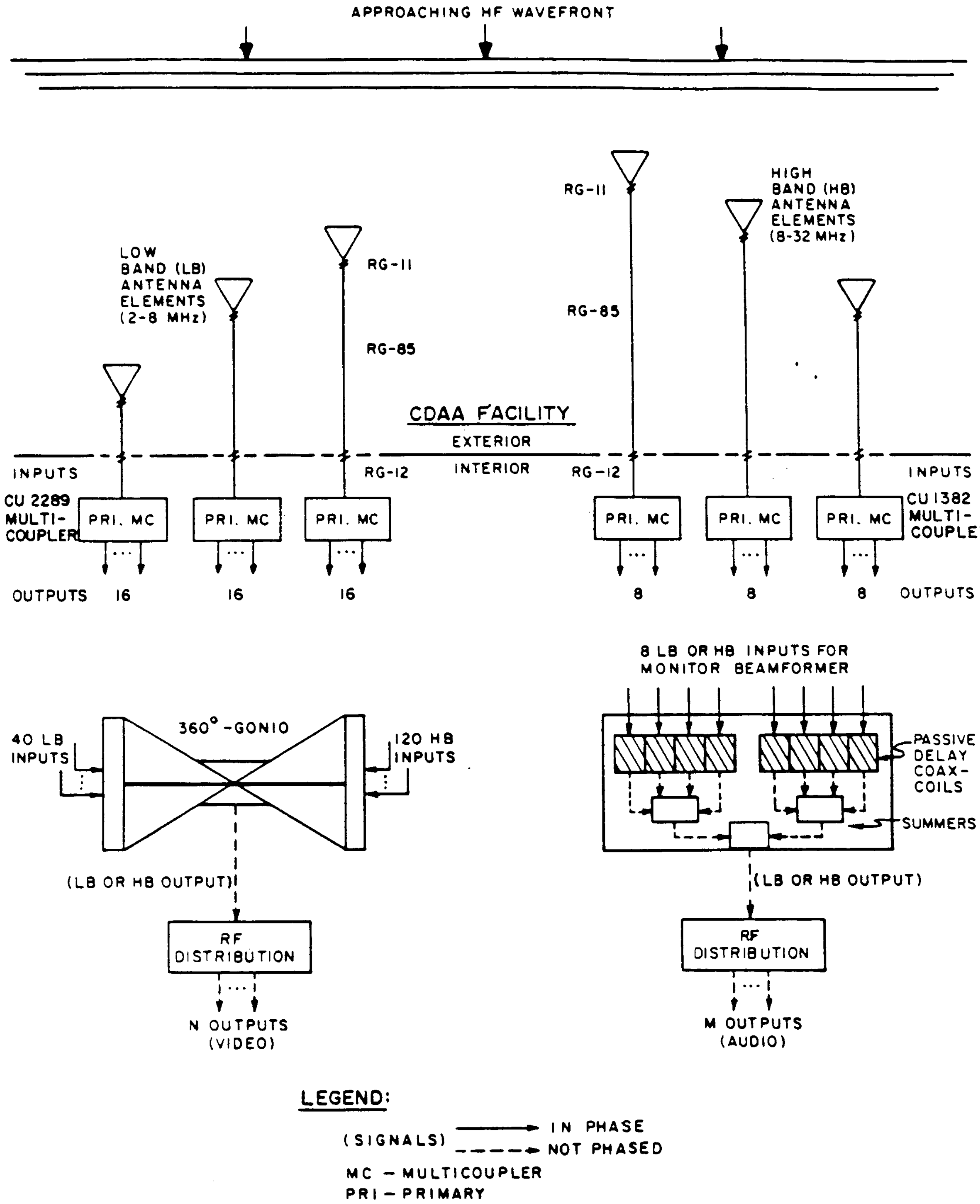


FIGURE 1-15. Fundamental Block Diagram of System Phase Relationships.

CHAPTER 2
TIME DOMAIN REFLECTOMETER

2.1 PURPOSE

The purposes of this chapter are to provide information on the operation of the Time Domain Reflectometer (TDR) and to document TDR "signatures" of typical antenna and transmission line problems to assist station forces (electronic maintenance technicians and antenna mechanics) in maintaining the AN/FRD-10 Circularly Disposed Antenna Array (CDAA).

2.2 INTRODUCTION

The TDR or "closed-loop radar" is used to locate impedance discontinuities in transmission lines and to characterize antennas. The TDR transmits a fast risetime pulse down the transmission line. Any deviation from the characteristic impedance of the transmission line results in a reflected pulse being propagated back to the TDR. By using high speed sampling of the reflected pulse, the TDR can locate impedance discontinuities and characterize the impedance as resistive, inductive, or capacitive. Due to its capability to characterize impedances, the TDR is an ideal tool to "fingerprint" antennas. Once a "fingerprint" or "signature" of a good antenna is obtained, "signatures" from all other similar antennas can be compared to it and the problem areas identified.

2.3 TDR FUNDAMENTALS

The magnitude and shape of the reflected pulse indicate the value and nature of the impedance, which can be resistive, inductive, or capacitive. In general, a resistive discontinuity having a value larger than the line impedance reflects a step of the same polarity as the incident step, and a step of the opposite polarity is reflected if the value is less than the line impedance. This is shown in Figure 2-1 for a positive incident step and typical loads. An inductive discontinuity reflects a voltage spike having the same polarity as the incident step, while a capacitive discontinuity reflects a voltage spike of the opposite polarity. Figure 2-2 shows the ideal versus actual displays for an inductive load. The actual display is not as sharp as the ideal due to the time response of the TDR. Therefore, using the TDR, the location, magnitude, and nature of the discontinuities in antenna and transmission line systems can be defined. Figure 2-3 shows a TDR connected in a typical test of an antenna and transmission line.

2.4 TEST EQUIPMENT

2.4.1 Hewlett-Packard 1415A Time Domain Reflectometer

2.4.1.1 Specifications. The Hewlett-Packard Model 1415A TDR can resolve discontinuities located as close as a centimeter or two apart, and as far away as 200 meters in polyethylene dielectric cable. With an available option, the detection of discontinuities can be extended to 1000 meters in polyethylene dielectric cable. Due to the fast risetime of the transmitted pulse, the HP Model 1415A TDR emits a broad band of frequencies ranging from DC to 2.3 GHz. Therefore all discontinuities, including small capacitive and inductive impedances, excited by this range of frequencies can be detected. This broad frequency spectrum may also interfere with very sensitive receivers by radiating from the antenna being tested to the adjacent antenna elements. However, any interference should be minimal since the amplitude of the transmitted pulse is only 0.25 volts. An important feature of the HP 1415A TDR is its tuneable interference filter which tunes out interference caused by strong on-the-air signals.

2.4.1.2 Preliminary. One low band antenna and one high band antenna, both in "good" condition as determined by visual inspection and TDR signatures, are chosen as references. The TDR signatures of these reference antennas are compared with the TDR signatures of the other antennas to determine the location and cause of any irregularities in the antennas and transmission lines.

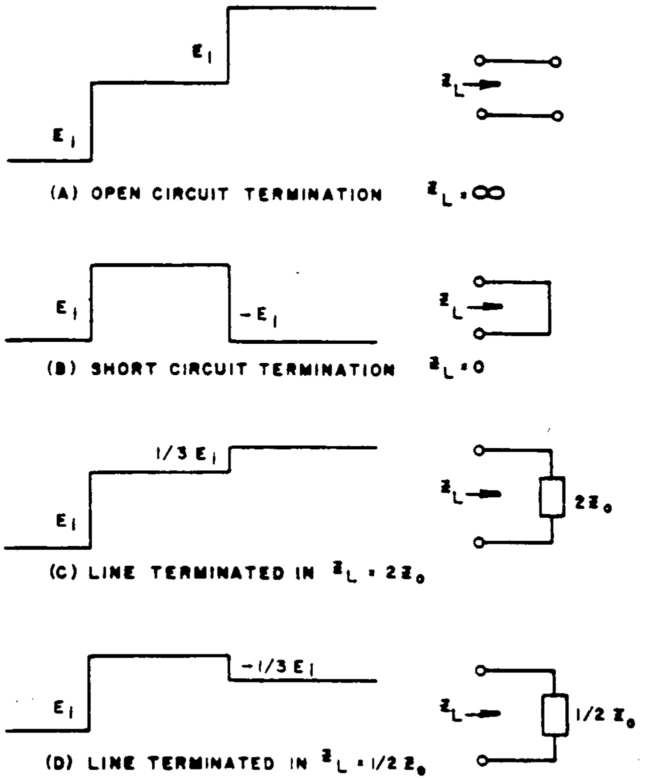


FIGURE 2-1. TDR Displays for Typical Loads.

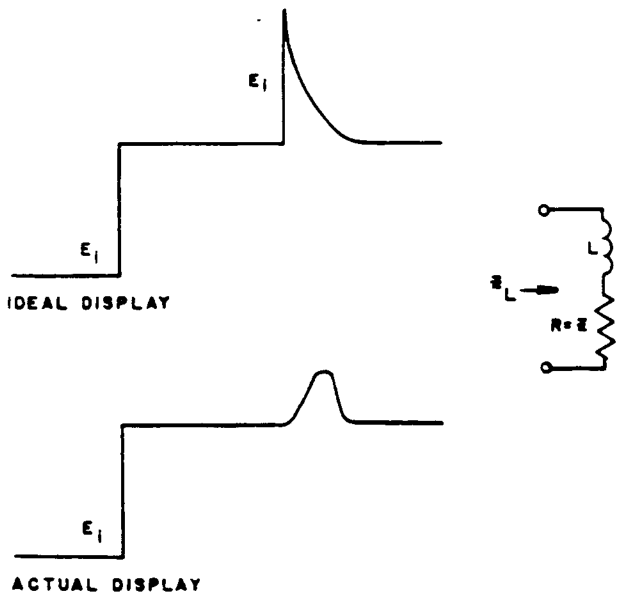


FIGURE 2-2. Ideal vs Actual Displays of R flecti n from a Small Inductor in Series with $R = Z_o$.

NOTE

For AN/FRD-10 low band antennas, the transformer series affect the TDR display. Therefore a reference will have to be chosen for each of the different series of transformers.

A description of the HP Model 1415A TDR front panel controls and connectors is provided in Table 2-1.

2.4.1.3 Calibration. The test equipment should be operating 15 minutes prior to performing the calibration procedures to provide adequate warm-up time. The following three procedures should be performed periodically, and whenever the HP Model 1415A TDR is operated in a different oscilloscope mainframe.

NOTE

Be sure the INTERFERENCE FILTER BW control is kept at the MAX position for each calibration procedure.

a. Perform the Initial Operation procedure given in Table 2-2.

b. Perform the Vertical Calibration procedure given in Table 2-3. Be sure STEP OUTPUT is connected to SIGNAL IN with two L-connectors.

c. Remove the two L-connectors between STEP OUTPUT and SIGNAL IN. Perform the Horizontal Calibration procedure given in Table 2-4, then replace the two L-connectors.

2.4.1.4 Test Procedure. Perform the test procedure described in Table 2-5. Table 2-6 gives typical settings for the front panel controls of the HP 140A Oscilloscope and HP Model 1415A TDR for testing AN/FRD-10 low and high band antenna systems.

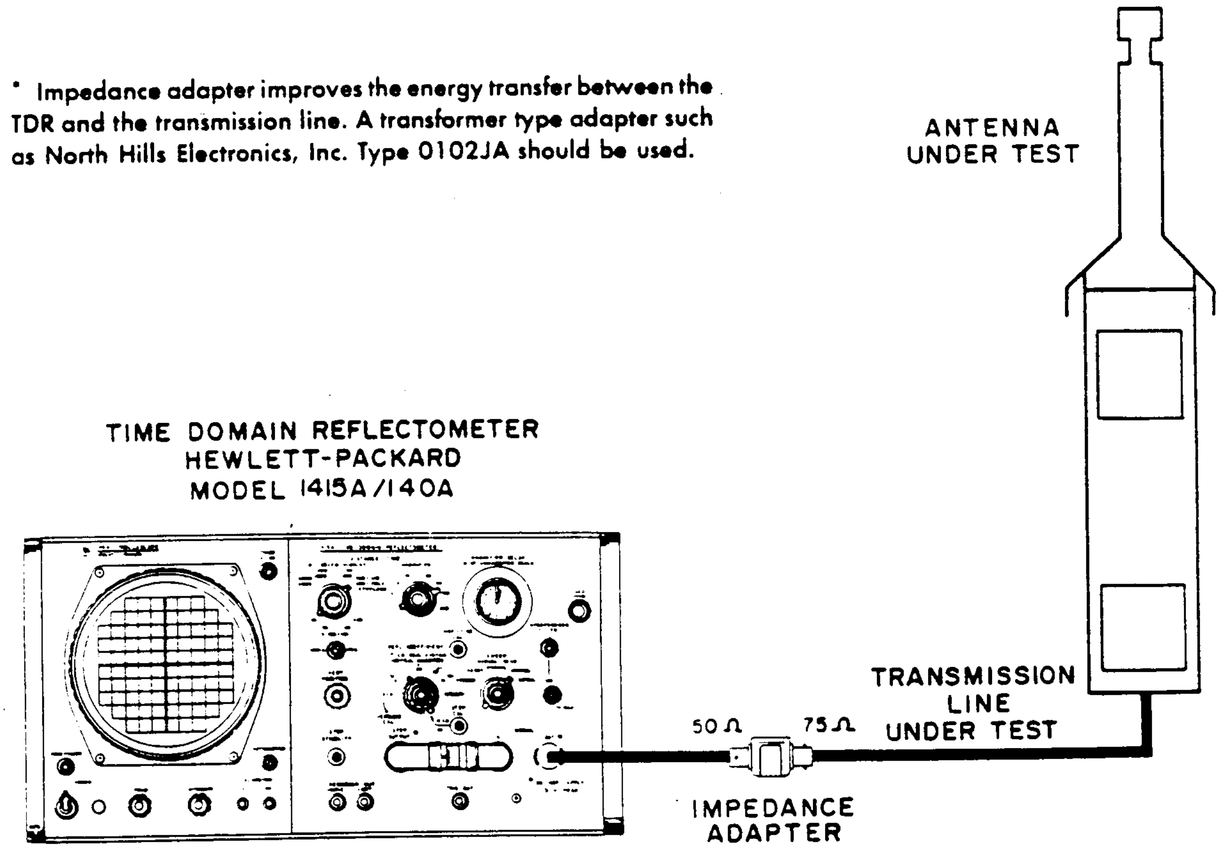
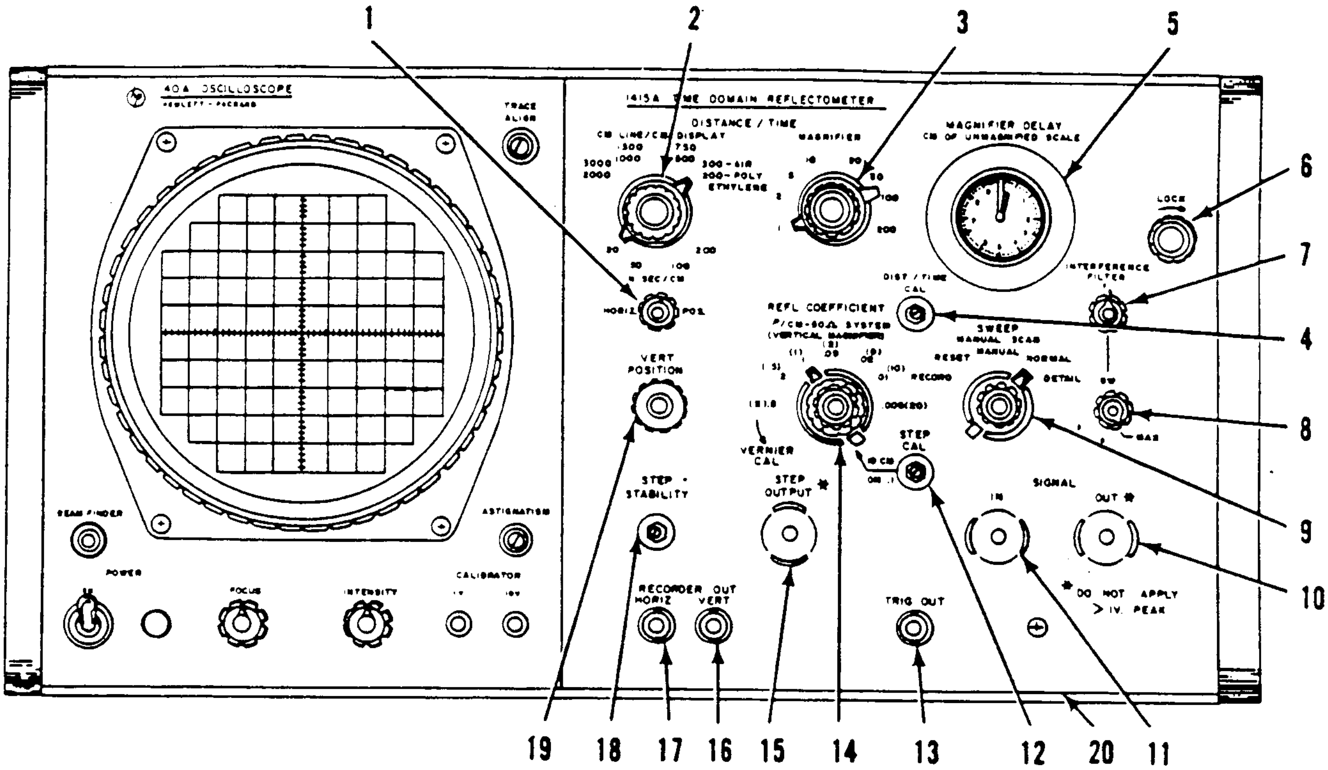


FIGURE 2-3. HP 1415A/140A Time Domain Reflectom ter, Test Diagram.

Table 2-1. HP 1415A TDR, Function of Controls and Connectors



1. HORIZ POS. Set the horizontal position of the display on the oscilloscope graticule. (Does not require frequent adjustment.)

2. DISTANCE/TIME CM LINE/CM DISPLAY. Adjust the basic time and distance scales. The four settings (five settings with available option) on this switch are calibrated both in nanoseconds per centimeter, and in centimeters of external transmission line per centimeter of display. Values are indicated for the two most common types of transmission lines, polyethylene dielectric (black numerals) and air dielectric (red numerals).

3. DISTANCE/TIME MAGNIFIER. Expands basic time and distance scales. The eight settings on this switch indicate horizontal display magnification from 1 to 200. These settings are used as division factors for DISTANCE in CM LINE/CM DISPLAY or for TIME in NSEC/CM. The display expands around the point selected by the MAGNIFIER DELAY (5) control, which is indicated by a brightened spot on the display.

4. DIST/TIME CAL. Sets distance/time scale (X-axis) calibration to compensate for slight differences in oscilloscope CRT deflection plate sensitivities.

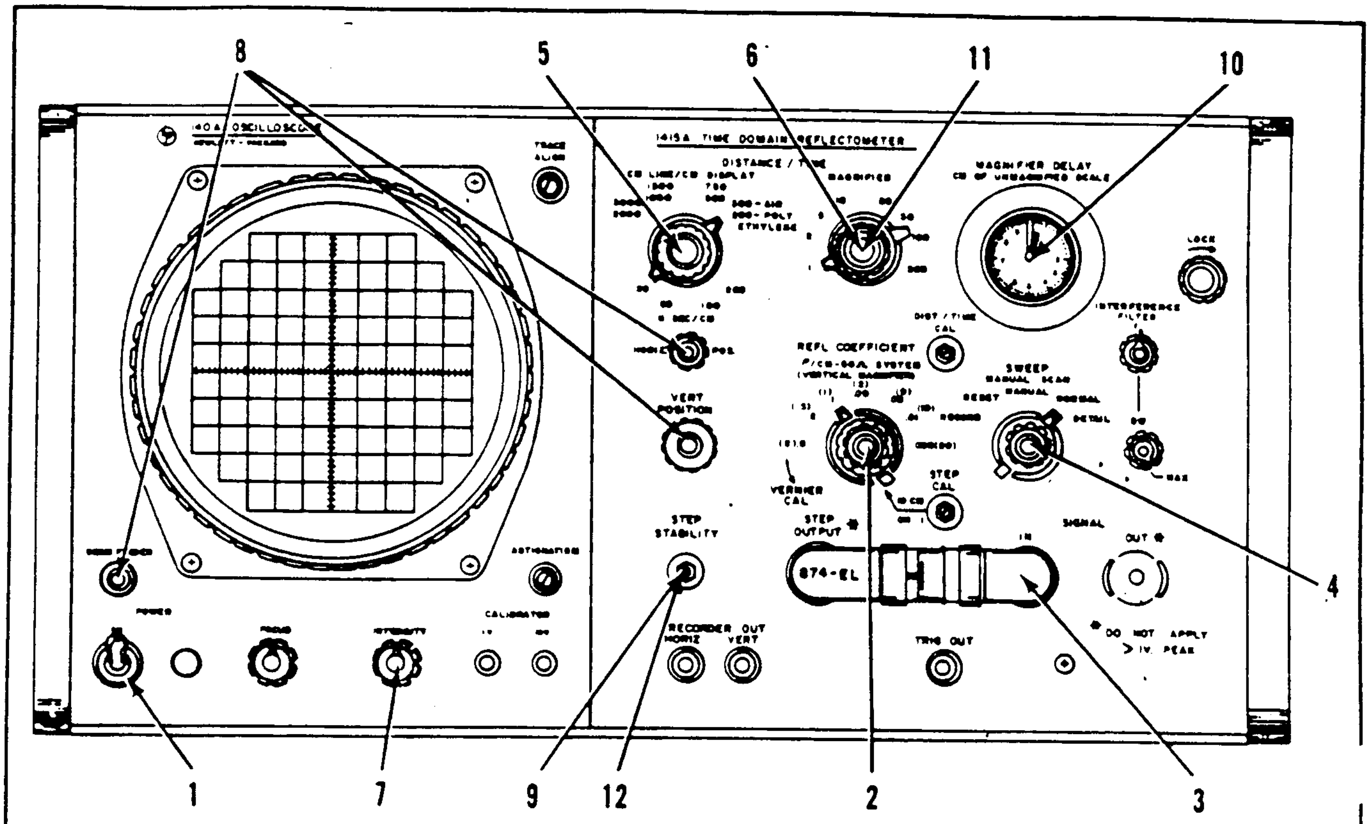
5. MAGNIFIER DELAY. Determines horizontal separation between any points on the display in centimeters. This 10-turn potentiometer is calibrated in tenths of millimeters from 0 to 10 centimeters, and uses a brightened dot on the display as an indicator; e.g., dot is midscreen with MAGNIFIER DELAY set at 5.00 centimeters. The reading on the control is used to calculate distance or time in conjunction with the basic DISTANCE/TIME CM LINE/CM DISPLAY (2) setting only, and is independent of the DISTANCE/TIME MAGNIFIER (3) setting.

6. LOCK. Rotate LOCK knob clockwise to mechanically secure Model 1415A in the oscilloscope mainframe.

Table 2-1. HP 1415A TDR, Function of Controls and Connectors – CONT.

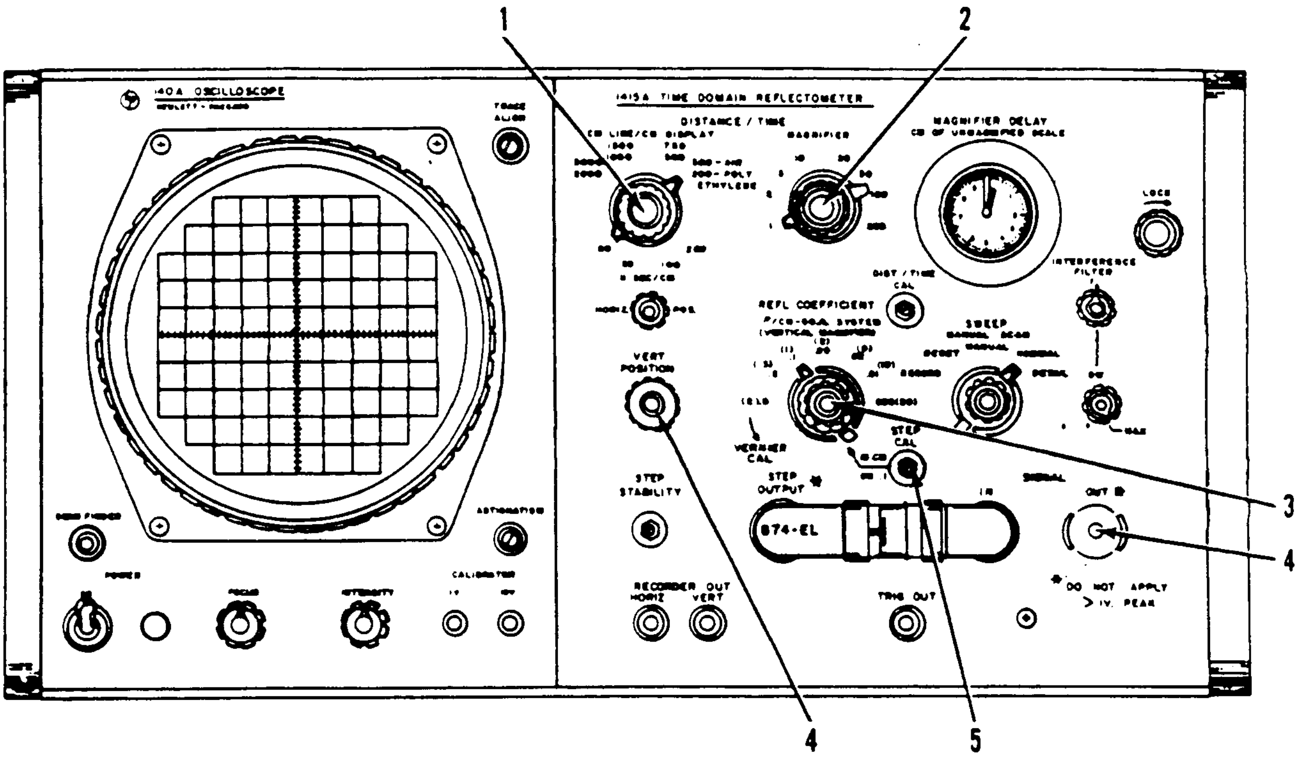
7. INTERFERENCE FILTER f_0. Eliminates narrowband RF interference.
8. INTERFERENCE FILTER BW. Used in conjunction with the f_0 control to reduce or eliminate broadband RF interference. This should be set at the MAX position at all times.
9. SWEEP. Horizontal scan mode of the instrument is selected by this five position switch as follows: RECORD position provides the signals to drive an external recorder through the RECORDER OUT (16 and 17) jacks; RESET position resets the recorder sweep to zero; MANUAL position sets up the MANUAL SCAN control for manual scanning of the input signal (also helpful for calibrating the external recorder); NORMAL position is used for normal scanning of the input signal (about 3000 samples per sweep, repetition rate of 50 Hz); and DETAIL position provides a higher sampling density for a more detailed sweep (about 30,000 samples per sweep, repetition rate of 5 Hz).
10. SIGNAL OUT. Provide connection for the external system in reflection measurements.
11. SIGNAL IN. Provides connection for the step input in reflection measurements.
12. STEP CAL. Calibrates vertical sensitivity (Y-axis) of the Model 1415A to compensate for slight differences in oscilloscope CRT deflection plate sensitivities.
13. TRIG OUT. Provides a delayed negative trigger output to trigger an external step generator such as the HP Model 215A Pulse Generator.
14. REFL COEFFICIENT (VERTICAL MAGNIFIER). Vertical scale of the instrument is determined by this control as follows: directly in reflection coefficient reading per centimeter; or (in parenthesis) in vertical magnification of 1. Calibration of the reflection assumes a 50 ohm external system. The VERNIER control provides variable adjustment between steps.
15. STEP OUTPUT. Supplies the negative step output (amplitude about 0.25 volts into a 50 ohm system). The display is normally inverted for negative-up presentation.
16. RECORDER OUT VERT. Supplies vertical deflection signal for an X-Y recorder. Output voltage is approximately 0 volts with the trace centered.
17. RECORDER OUT HORIZ. Supplies horizontal scan voltage for an X-Y recorder. Output is approximately +2.0 volts with beam at the left edge of the graticule, and +18 volts with beam at right edge of the graticule.
18. STEP STABILITY. Adjusts the stability of the output step pulses for minimum pulse jitter.
19. VERT POSITION. Adjusts the vertical position of the display on the oscilloscope screen.
20. NEG UP/POS UP. (Location on the inside bottom of Model 1415A.) Selects either negative-up or positive-up presentation of the display on the oscilloscope CRT screen. This switch is normally in the NEG UP position.
OPTIONS (for increase distance): There are two standard options available for the Model 1415A: Option 14 and H08-1415A. Option 14 provides an additional position for the DISTANCE/TIME switch. This added position is equal to 1000 ns/div expressed in time, or 10,000 CM LINE/CM DISPLAY (polyethylene) and 15,000 CM LINE/CM DISPLAY (air) expressed in distance.

Table 2-2. HP 1415A/140A TDR, Initial Operation



1. Turn instruments on. Warm-up at least 15 minutes before calibration.
2. Set REFL COEFFICIENT to 0.2 (.05).
3. Use two L-connectors to connect STEP OUTPUT to SIGNAL IN, as shown.
4. Set SWEEP to NORMAL.
5. Set DISTANCE/TIME to 20 NSEC/CM.
6. Set DISTANCE/TIME MAGNIFIER to 1.
7. Turn INTENSITY to a normal setting, about midrange, without blooming. Adjust FOCUS and ASTIGMATISM for sharpest display. If trace is not present, see steps 8 and 9.
8. Center trace on screen, using BEAM FINDER if necessary.
9. If step is unsuitable or not present, turn STEP STABILITY fully clockwise, then slowly counterclockwise, continuing just slightly past the point where a stable step locks in.
10. Adjust MAGNIFIER DELAY to position the dot on the step rise.
11. Set DISTANCE/TIME MAGNIFIER to 50. Re-trim MAGNIFIER DELAY if necessary to center step on the screen.
12. Trim STEP STABILITY for sharpest corner without losing stability of the trace. The trace should remain stable with MAGNIFIER at 200.

Table 2-3. HP 1415A TDR, Vertical Calibration



1. Set DISTANCE/TIME to 20 NSEC/CM.

2. Set DISTANCE/TIME MAGNIFIER to 1.

3. Set REFL COEFFICIENT to .1 (1), with VERNIER in CAL.

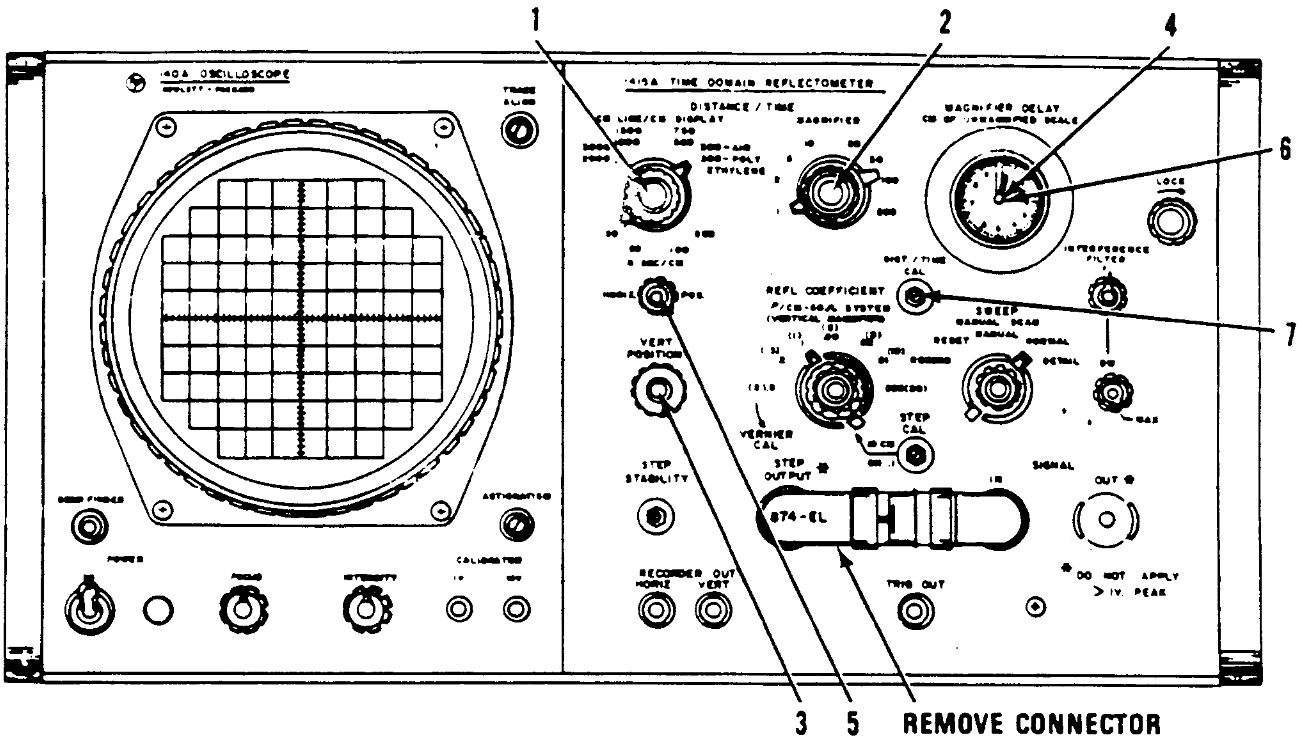
4. Position base line of display on bottom graticule line. Connect 50 ohm load, ±1%, to SIGNAL OUT.

NOTE

If the baseline shifts off the bottom graticule line when the 50 ohm load is connected, then adjust Step Zero Level R154 located inside the HP 1415A.

5. Adjust STEP CAL for a step amplitude of exactly 10 centimeters.

Table 2-4. HP 1415A TDR, Horizontal Calibration



1. Set DISTANCE/TIME to 20 NSEC/CM.
2. Set DISTANCE/TIME MAGNIFIER to 1.
3. Center display vertically.
4. Set MAGNIFIER DELAY to 0.00.
5. Adjust HORIZ POS to position the brightened dot exactly over the 0 cm (left edge) graticule line.
6. Turn MAGNIFIER DELAY clockwise to 10.00.
7. If the brightened dot is not exactly over the 10 cm (right edge) graticule line, adjust DIST/TIME CAL to position the dot half-way between its present position and the 10 cm graticule line.
8. Repeat steps 4 through 7 until MAGNIFIER DELAY reads 0.00 at the 0 cm graticule and 10.00 at the 10 cm graticule line.

Table 2-6. HP 140A Oscilloscop and HP 1415A TDR, C ntrol Settings for Testing AN/FRD-10 Antennas

CONTROL	SETTING
HP 140A Oscilloscope	
POWER	ON
FOCUS	Set for the sharpest display.
INTENSITY	Set for a bright display without blooming.
ASTIGMATISM	Set for the sharpest display.
TRACE ALIGN	Set to give a level display.
HP 1415A Time Domain Reflectometer	
STEP OUTPUT to SIGNAL IN	Use two L-connectors.
HORIZ POS	Set to center display horizontally.
VERT POS	Set to center display vertically.
*INTERFERENCE FILTER, f_0	Set for minimum interference.
INTERFERENCE FILTER, BW	MAX
CM LINE/CM DISPLAY	2000/3000
MAGNIFIER	5
REFL. COEFFICIENT	.1(1) OR .2(.5)
REFL. COEFFICIENT VERNIER	CAL
MAGNIFIER DELAY	Approximately 9.5 - 10.0 cm
*SWEEP MODE	NORMAL (usually) or DETAIL
DIST/TIME CAL	Do not touch – set in calibration.
STEP CAL	Do not touch – set in calibration.
**STEP STABILITY	Do not touch – set in calibration.

* If the display is distorted due to RF interference, adjust these controls for a sharp steady display.

** If the display is unstable or not present, adjust this control for the proper display.

2.4.2 Tektronix 1502 Time Domain Reflectometer

2.4.2.1 *Specifications.* The TEK 1502 TDR can resolve discontinuities located as close as 0.1 foot (2.5cm) apart, and as far away as 2000 feet (500 meters) in polyethylene dielectric cable. Due to the fast risetime of the transmitted pulse, the TEK 1502 TDR emits a broad band of frequencies ranging from DC to approximately 9 GHz. Therefore, all discontinuities, including small capacitive and inductive impedances, excited by this range of frequencies can be detected. This broad frequency spectrum may also interfere with very sensitive receivers. However, any interference should be minimal since the amplitude of the transmitted pulse is only 0.225 volts. The Tektronix 1502 TDR does not have a tuneable interference filter, therefore it may not work when plotting the signature of an antenna in a strong signal environment. Figure 2-4 shows the TEK 1502 TDR connected in a typical test of an antenna and a transmission line. A description of the TEK 1502 TDR front panel controls and connectors is provided in Table 2-7.

2.4.2.2 *Preliminary.* One low band antenna and one high band antenna, both in "good" condition as determined by visual inspection and TDR signatures, are chosen as references. The TDR signatures of these reference antennas are compared with the TDR signatures of the other antennas to determine the location and cause of any irregularities in the antennas and transmission lines.

NOTE

For AN/FRD-10 low band antennas, the transformer series affect the TDR display. Therefore a reference will have to be chosen for each of the different series of transformers.

2.4.2.3 *Calibration.* The test equipment should be operating 20 minutes prior to performing the operational checkout to provide adequate warm-up time. Then follow the operational checkout procedures in Table 2-8. This procedure should be performed periodically to ensure the proper operation of the TDR. The object of recording T

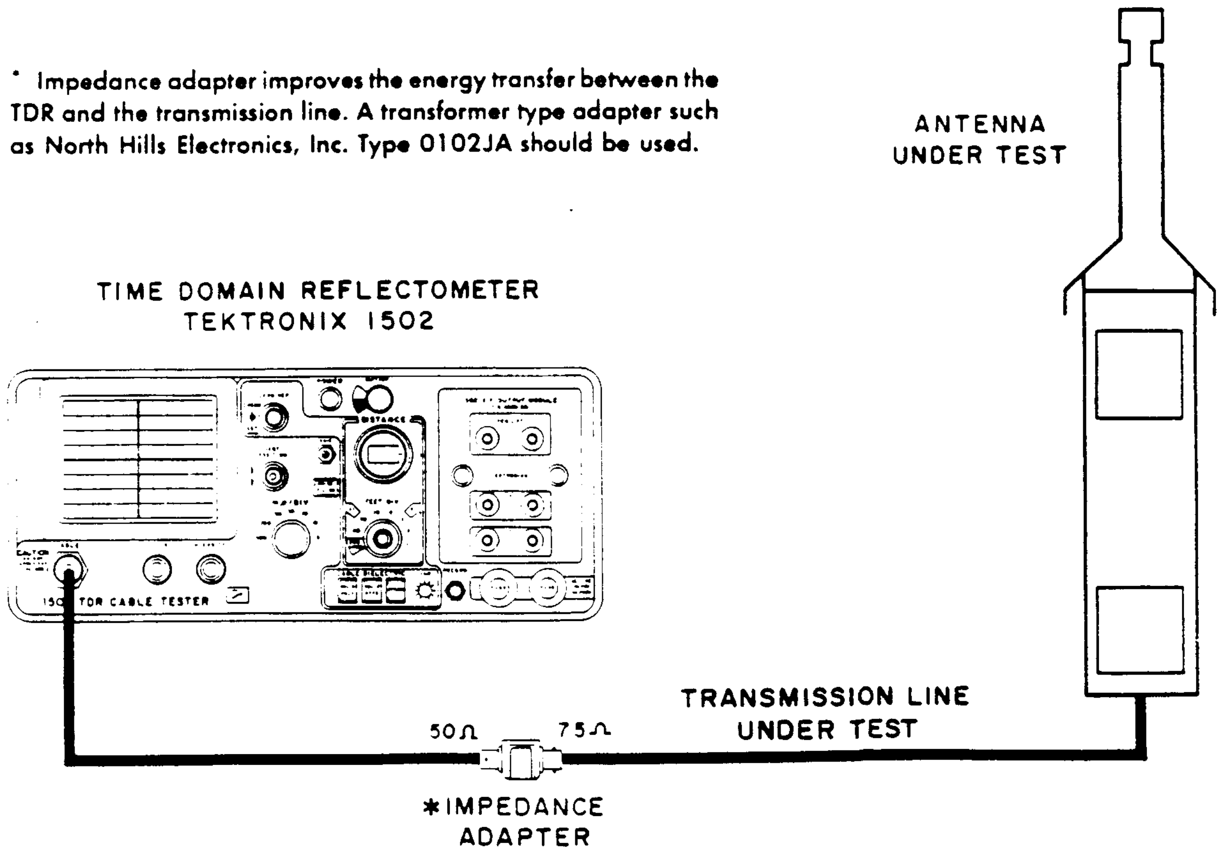


FIGURE 2-4. TEK 1502 Time Domain Reflectometer, Test Diagram.

signatures on an X-Y recorder is to allow better analysis of the resulting plot. By overlaying the test plot on the reference plot, and by holding the two plots up to the light, small variations in the test plot are easily seen. This procedure depends on the careful calibration of the TDR and the X-Y recorder. Usually, no attempt is made to calibrate the graph paper to the CRT grid. Only the zero and full scale on the paper is calibrated to correspond to zero and full scale respectively on the CRT.

2.4.2.4 Test Procedure. Table 2-9 describes the general procedure for locating a discontinuity in a cable. Table 2-10 gives typical TEK 1502 TDR front panel control settings for testing AN/FRD-10 low and high band antennas. In strong signal level environments, operation of the TEK 1502 TDR will be severely degraded. The Noise Filter on the TDR is not sufficient to reduce the RF interference, so that the display is broken up. This has been experienced at several AN/FRD-10 sites when testing the low band antennas. The only alternatives are to wait until the RF environment quiets down or to use an HP 1415A TDR.

2.4.3 Tektronix 1503 Time Domain Reflectometer. The TEK 1503 TDR was tested and found to be unsuitable for testing CDAA antennas. Interference to operational receivers throughout the HF spectrum was created due to the 5 to 10 volt test impulse. This impulse also has too narrow a bandwidth to be effective in antenna testing.

2.4.4 Biddle 430 Series Time Domain Reflectometers. The capabilities of the Biddle 430 series TDRs were reviewed and the only model that may be effective is the Model 431. However, the test impulse of 3 volts would cause too much interference throughout the HF spectrum.

2.5 ANALYSIS OF TEST RESULTS

2.5.1 AN/FRD-10 Circularly Disposed Antenna Array. The TDR signatures of the low band and high band antennas should be compared to the TDR signatures of the respective reference antenna to locate any impedance discontinuities. On the low band antennas, be sure to choose a reference antenna with the same series (100, 200, 500, etc.) transformer, since most series have different TDR presentations. After problem areas are detected, appropriate action should be taken to document the problems using forms provided and to correct the antenna/transmission line problem.

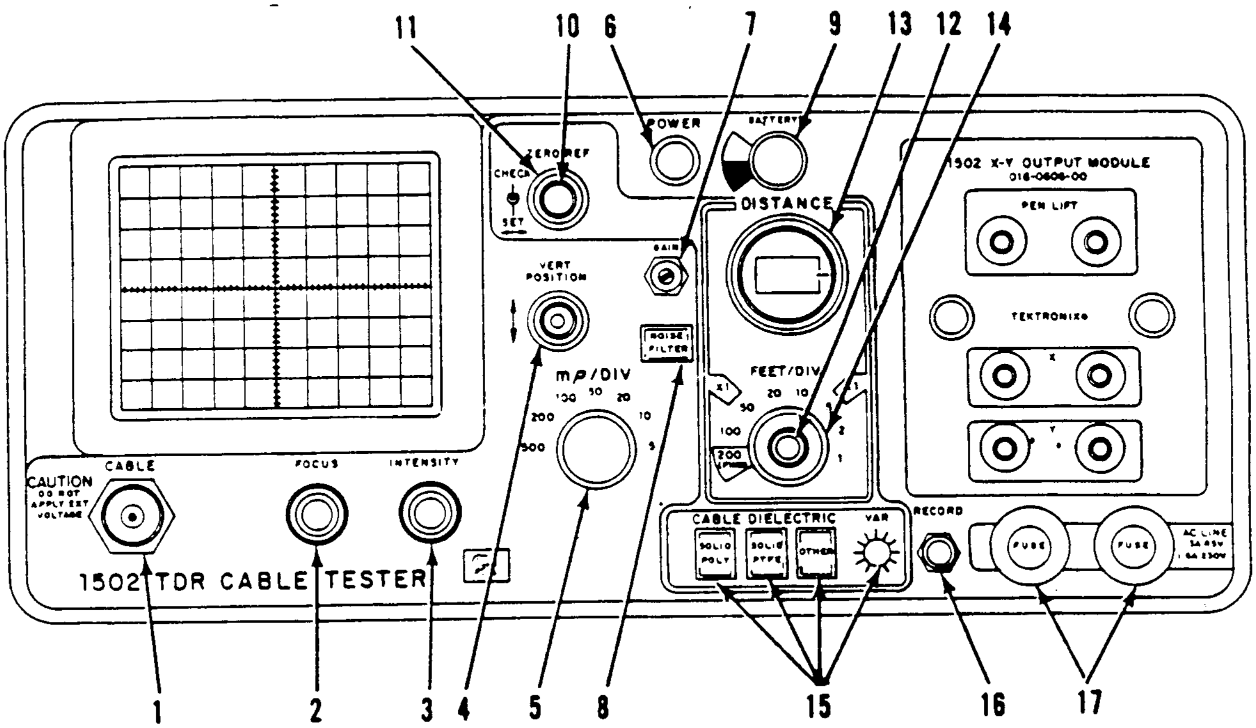
2.5.1.1 Low Band Antenna. A typical TDR response profile or signature for a low band antenna is given in Figure 2-5. Points "1" and "2" represent the characteristic impedances of the RG-85A/U and RG-11A/U cables, respectively; "3" represents the initial inductive response (upward spike) to the coupling transformer, while the inductive time delay or reactive spike is shown by the negative "kick" at point "4"; "5" indicates the point at which the mast begins to be seen. Point "6" represents the end of the downwires, and at point "7" the terminating resistors are encountered. At point "8" an inductive "kick" is shown just before dropping to ground. This inductive "kick" is not caused by wire-wound inductive resistors as originally believed, but is probably due to the inductance in the ground wires.

2.5.1.2 Typical reference TDR signatures for the different series of transformers are shown in Figure 2-6. TDR signatures of common low band antenna/transmission line problems are provided in Figures 2-7 to 2-21. A comparison of these signatures with the reference (dotted trace) will be useful in diagnosing a majority of the problems encountered. Figure 2-22 is a data sheet provided to document the condition of each low band antenna/transmission line. Without mounting the transformer on an antenna, low band transformer problems can be detected by using the test jig described in Paragraph 2.7.

2.5.1.3 High Band Antenna. A representative high band antenna TDR response profile or signature is shown in Figure 2-23. Point "1" represents the characteristic impedance of the RG-85A/U cable; "2" indicates the connection of the RG-85A/U cable to the RG-11A/U cable; "3" represents the spark plug connection; "4" indicates the ground wire of the spark plug; "5" is the top of the tuning stub; "6" indicates the bottom of the upper mast of the antenna; and "7" is the top of the antenna. The rest of the trace is due to reflections from the multiple discontinuities.

2.5.1.4 Typical reference TDR signature is shown in Figure 2-24. TDR signatures of common high band antenna/transmission line problems are provided in Figures 2-25 to 2-38. A comparison of these signatures with the reference (dotted trace) will be useful in diagnosing a majority of the problems encountered. Figure 2-39 is a data sheet provided to document the condition of each high band antenna/transmission line.

Table 2-7. TEK 1502 TDR, Function of Front Panel Controls

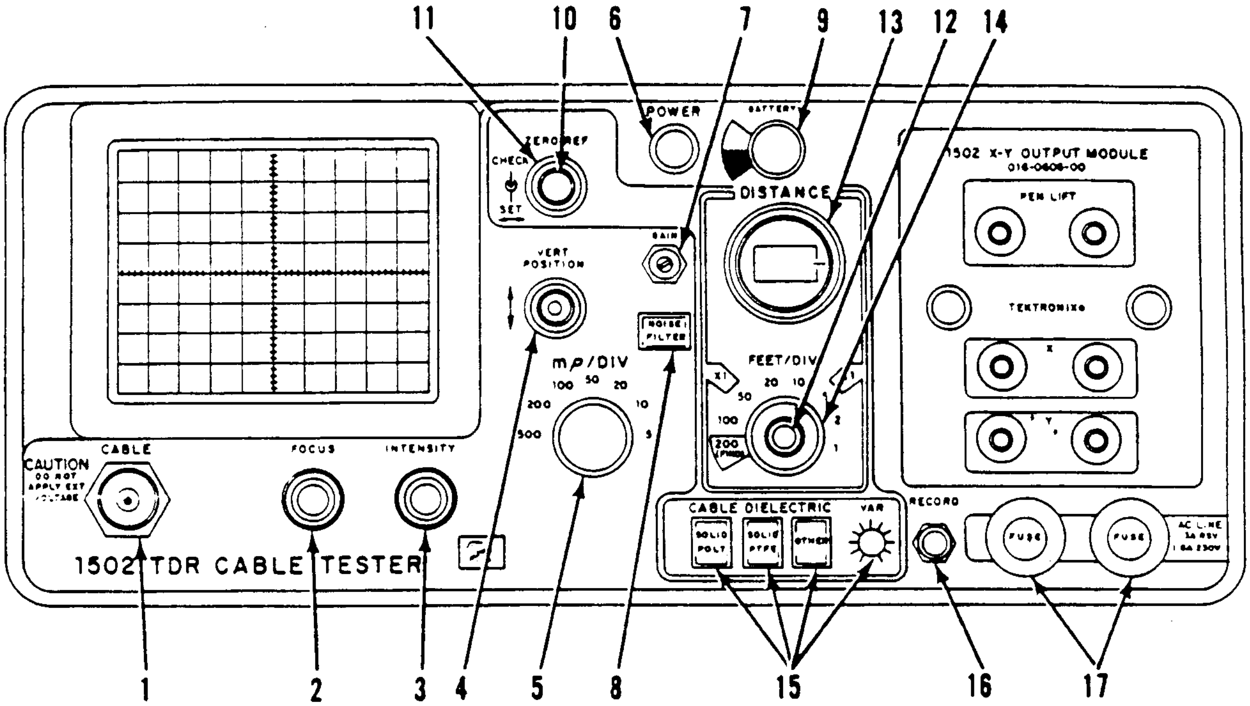


1. CABLE. BNC connector delivers 110 psec risetime pulse to the test cable and receives the reflected return pulse.
2. FOCUS. Adjust the focus of the CRT electron beam.
3. INTENSITY. Controls the brightness of the CRT display.
4. VERT POSITION. Vertical position controls of the CRT display. The outer control is a course adjustment and the inner control is a fine adjustment.
5. mρ/DIV. Selects the vertical deflection factor-5 mρ/div to 500 mρ/div (5-2-1 sequence).
6. POWER. Push-pull, off-on switch (pull for on). Does not affect the battery charging circuit.
7. GAIN. Screwdriver adjustments to set the gain of the vertical amplifier.
8. NOISE FILTER. Reduces displayed noise. Display rate is reduced by a factor of 10.
9. BATTERY. Meter to indicate the relative charge of the power pack.
10. ZERO REF CHECK. Momentary contact pushbutton. When pushed, check the horizontal location of the incident pulse on the CRT when the DISTANCE (13) dial is being used.
11. ZERO REF SET. Horizontal pulse position control for CRT display. Sets the incident pulse edge to the vertical reference line of the CRT when the DISTANCE (13) dial is at 000 or the ZERO REF CHECK button pushed.

Table 2-7. TEK 1502 TDR, Function of Front Panel Controls – CONT.

12. MULTIPLIER. Two-position switch (red control for X.1 or X1) multiplier. Affects both the DISTANCE (13) dial and the FEET/DIV (14) control.
13. DISTANCE. Indicates the distance from the TEK 1502 to the point on the cable where the display window begins. Two ranges: 100 feet at X.1 or 1000 feet at X1. Disabled when the FEET/DIV (14) is at 200 (FIND).
14. FEET/DIV. Selects the horizontal deflection factor: X1 = 1 - 200ft/div X.1 = 0.1 - 20ft/div
15. CABLE DIELECTRIC: SOLID POLY, SOLID PTFE, OTHER VAR. Three pushbuttons and screwdriver adjust. Selects the proper velocity of propagation. VAR from 0.55 to 1.0 when the OTHER pushbutton is pressed. Fully CW is for air dielectric. VAR control has reference marks every 30 degrees to indicate relative propagation constants.
16. RECORD. Two-position lever switch; pushed up and then released, it initiates X-Y recorder or a chart recorder.
17. AC LINE FUSES. Protection fuses for line power and battery charging circuits (0.5A fuses for 115 Vac; 0.3A fuses for 230 Vac).
PLUG-IN Controls and Connectors: 1. X-Y OUTPUT MODULE. The standard plug-in module for the TEK 1502. Used to drive an external X-Y Chart Recorder. X, Y, and PEN LIFT. Six front panel jacks used for driving an external X-Y recorder. X jacks are for horizontal drive. Y jacks are for vertical drive. PEN LIFT jacks are for pen control. 2. Y-T CHART RECORDER. An optional Tektronix Y-T chart recorder (Option 04) which replaces the X-Y OUTPUT MODULE.

Table 2-8. TEK 1502 TDR, Operational Checkout



1. Preset the front panel controls as follows:

CONTROLS	SETTING
FOCUS (2)	Midrange
INTENSITY (3)	Midrange
ZERO REF SET (11)	Fully CW
VERT POSITION (4)	Midrange
mρ/DIV (5)	500
DISTANCE	000
FEET/DIV (14)	1
X1 - X.1 (12)	X1
CABLE DIELECTRIC (15)	SOLID POLY

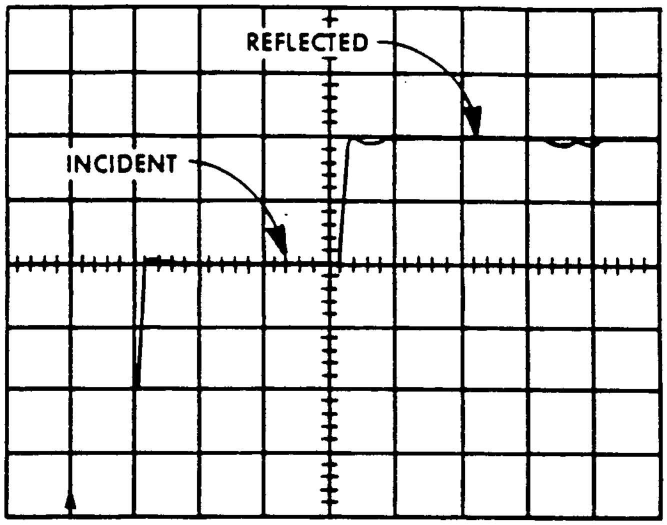
2. Adjust the INTENSITY (3) and FOCUS (2) controls for a clear, bright trace.

3. Adjust the VERT POSITION (4) control to set the trace two divisions below the horizontal centerline.

4. Attach a 3-foot solid polyethylene 50-ohm cable to the CABLE (1) connector.

5. Adjust the ZERO REF SET (11) and GAIN (7) controls to obtain the trace shown in the figure below. (If a length of cable other than 3 feet is used, then the reflected pulse will not appear 3 divisions to the right of the incident pulse. Instead, it will appear at a distance corresponding to the length of the cable.)

Table 2-8. TEK 1502 TDR, Operational Checkout – CONT.



NOTE

The incident pulse edge is the initial rise of the step pulse, and corresponds physically to the CABLE (1) connector on the TDR. The reflected pulse corresponds to the open end of the 50 ohm cable.

6. Set the DISTANCE (13) dial to 050 and check that the top of the step (open cable reflection) is displayed.

7. Press the ZERO REF CHECK (10) button and check that the incident pulse edge returns to the vertical reference line of the graticule. Reset the DISTANCE dial to 000.

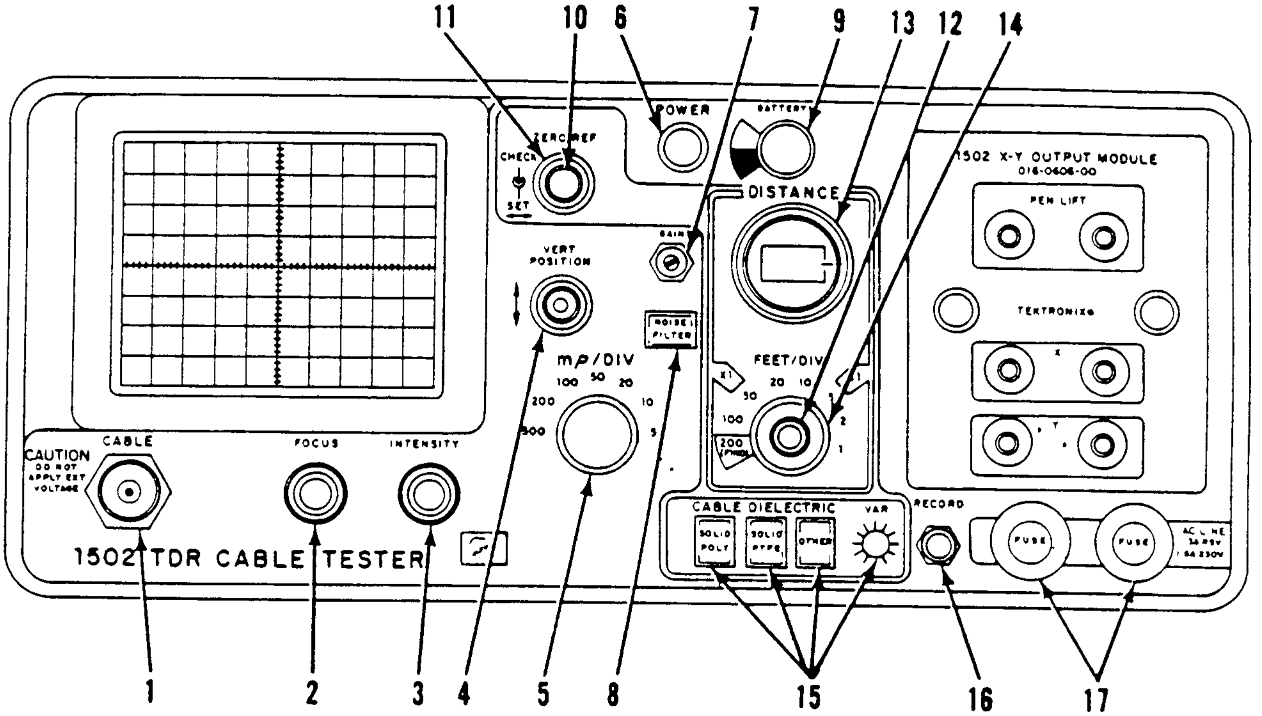
8. Change mρ/DIV (5) to 50 and adjust the POSITION (4) controls so the top of the incident pulse is on the horizontal centerline.

9. Press the NOISE FILTER (8) pushbutton and check for a reduction in the displayed noise as well as a reduction in the scan rate. Reset mρ/DIV (5) to 500, and release (by depressing a second time) the NOISE FILTER (8) button.

10. Lift up and hold the RECORD (16) switch. Check that a bright spot appears at the left edge of the CRT.

11. Release the RECORD (16) switch. The slow scan of the spot will trace the displayed waveform. When the scan is complete, the TEK 1502 will automatically return to its normal mode of scanning. For details on X-Y plotting procedures, refer to Paragraph 2.10.

Table 2-9. TEK 1502 TDR, Locating a Discontinuity in a Cable



1. To check cables using only the CRT display, the FEET/DIV (14) control and the MULTIPLIER (12) must be set so that the CRT display window is longer than the cable. For example, if the cable is 150 feet (46m) long, set the FEET/DIV (14) to 200 and the MULTIPLIER (12) at X.1.

NOTE

Use the X.1 MULTIPLIER (12) whenever possible to lessen the effects of jitter.

This setting of the FEET/DIV (14) control ensures that the reflected signal will appear in the display window. Be sure the DISTANCE (13) dial is set to 000. Count the number of graticule lines between the incident pulse rise and the reflected pulse rise on the CRT display, then multiply by the FEET/DIV (14) and MULTIPLIER (12) settings to obtain the length measurement.

NOTE

Always set the incident and reflected pulses to the 10% point of their amplitude, as shown below, for maximum accuracy.

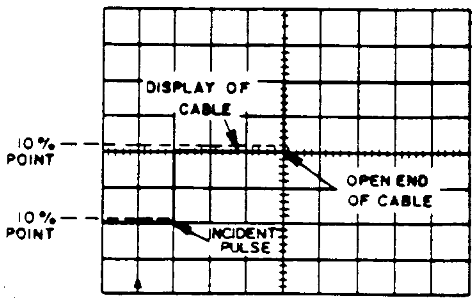
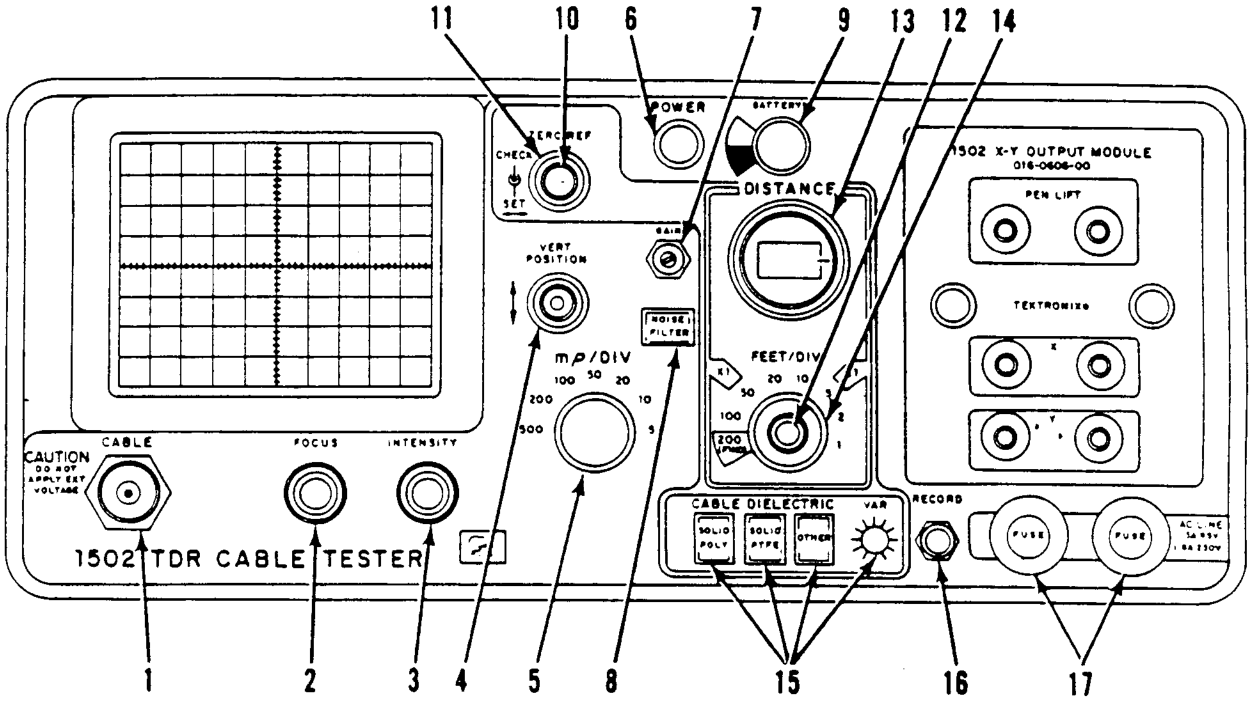


Table 2-9. TEK 1502 TDR, Locating a Discontinuity in a Cable – CONT.

2. The distance from the sampling bridge to the CABLE (1) connector should be taken into account when measuring cables less than 2 feet (60.96 cm) in length. Therefore, subtract 2.5 inches (6.35 cm) from your length measurement.
3. Cable lengths can be checked more accurately using the DISTANCE (13) dial in conjunction with the FEET/DIV (14) control. The DISTANCE (13) dial is used to find the discontinuity, while the FEET/DIV (14) control expands around the discontinuity. Be sure the DISTANCE (13) dial is set to 000. Push the ZERO REF CHECK (10) button and adjust the ZERO REF SET (11) control so that the incident pulse rise is set at the vertical reference graticule line marked with an arrow. Now turn the DISTANCE (13) dial clockwise until the reflected pulse is located on the same reference graticule line marked with an arrow. The reading on the DISTANCE (13) dial times the MULTIPLIER (12) gives the length from the CABLE (1) connector to the end of the cable (or to the discontinuity).
4. When checking cables longer than 1000 feet (304.8 meters), calibrate the incident pulse rise as in step 3 above. Then adjust the DISTANCE (13) dial until the reflected pulse reaches the right-hand edge of the graticule. Calculate the graticule display distance by multiplying the FEET/DIV (14) by the number of divisions across the graticule from the reference line. Add the graticule display distance to the DISTANCE (13) dial reading. Then multiply by the MULTIPLIER (12) setting for the total length of cable. **NOTE** In the 200 FEET/DIV setting, the DISTANCE (13) dial is inoperative. Therefore the total length of cable is calculated using the graticule display only, as explained in step 1.

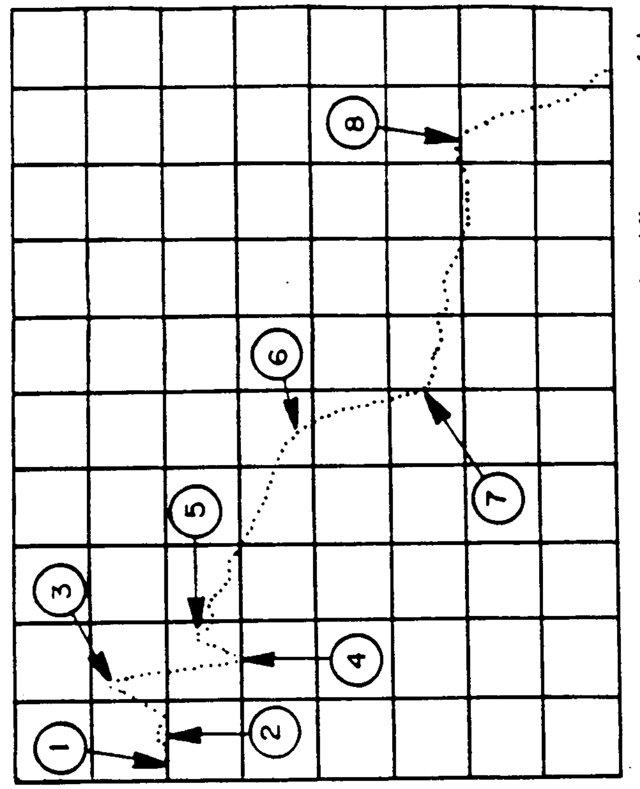
Table 2-10. TEK 1502 TDR, Typical Control Settings for Testing AN/FRD-10 Low and High Band Antennas



1. The following control settings are typical for testing AN/FRD-10 antennas.

CONTROL	SETTING
POWER (6)	ON
FOCUS (2)	Set for sharpest display image.
INTENSITY (3)	Set for bright display without blooming.
VERT POSITION (4)	Set to center display vertically.
CABLE DIELECTRIC (15)	Set to SOLID POLY.
GAIN (7)	Do not touch - set in calibration.
MULTIPLIER (12)	X1
DISTANCE (13)	For low band antennas: approx. 450 feet plus test cable length. For high band antennas: approx. 500 feet plus test cable length.
FEET/DIV (14)	For low band antennas: 20 For high band antennas: 10
mρ/DIV (5)	For low band antennas: 100 For high band antennas: 200
NOISE FILTER (8)	For low band antennas: On For high band antennas: On or Off

2. For the antenna/transmission line under test, disconnect the RG-12 transmission line from the directior coupler at the back of the primary multicoupler. Then connect the TDR to the RG-12 transmission line wit 75 ohm coaxial cable. Figure 2-4 illustrates the TEK 1502 TDR test setup.



Typical low band antenna TDR signature. The different areas of th antenna are pinpointed by the numbered arrows.

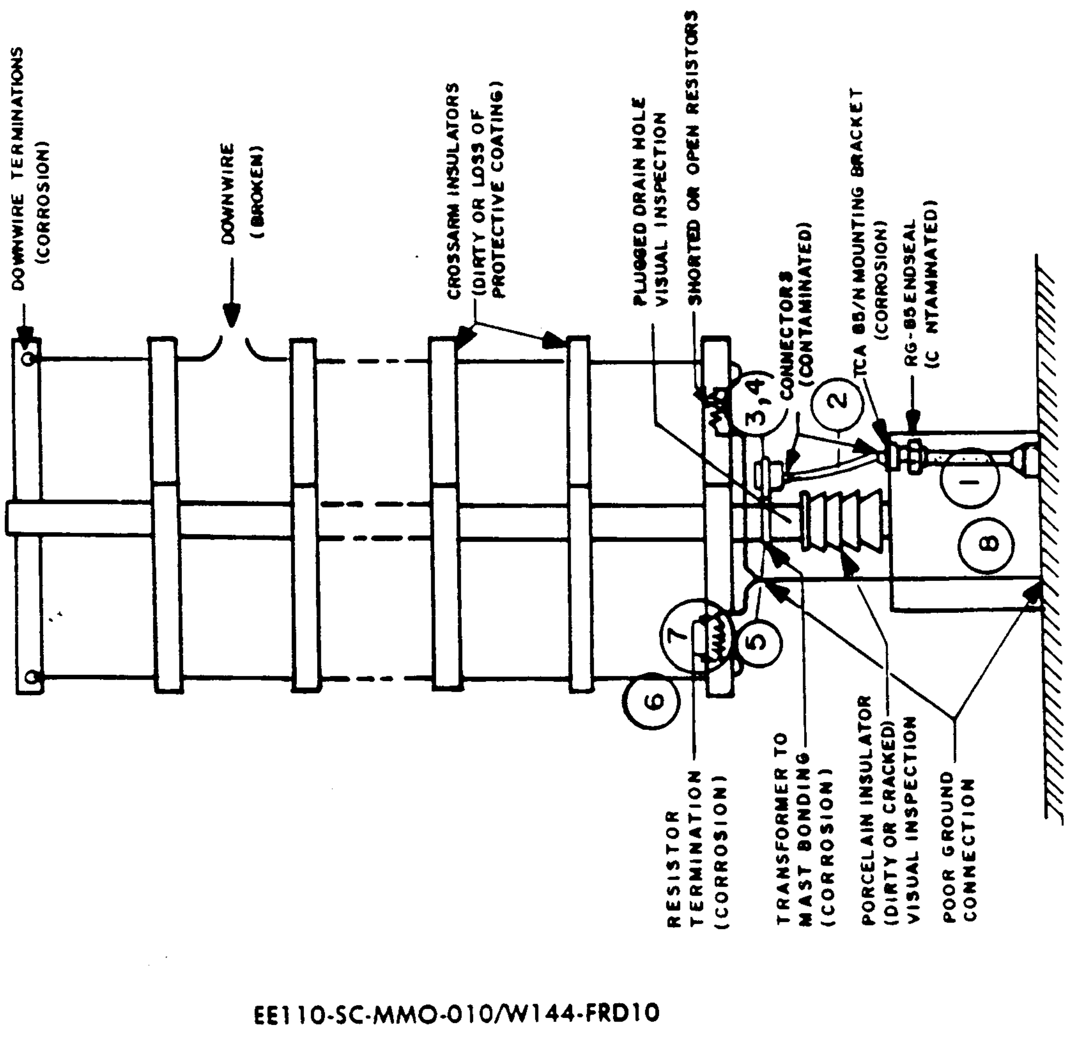


FIGURE 2-5. AN/FRD-10 Low Band Antenna, TDR Signature.

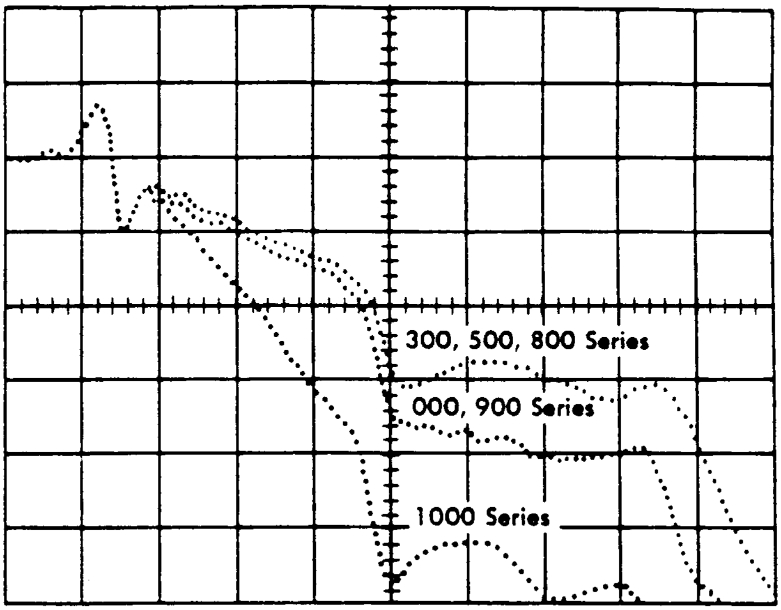


FIGURE 2-6. Low Band – Typical AN/FRD-10 low band antenna TDR signatures for the difference series of transformers.

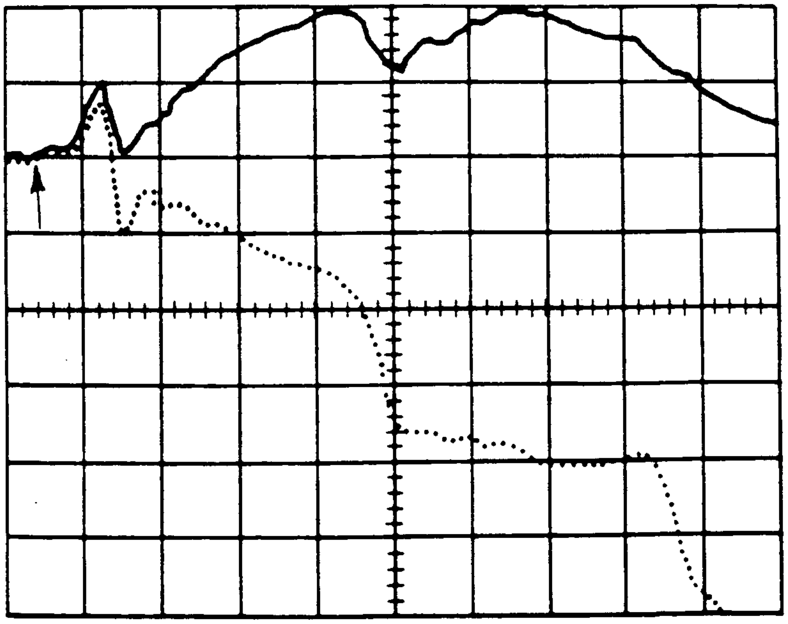


FIGURE 2-7. Low Band – This elevated display is due to a partial open circuit located between the RG-85 and RG-11 coaxial cables, as shown by the arrow. The problem can be attributed to either a corroded ground connection at the RG-85 endseal or corroded TCA 85/N bracket mounting screw.

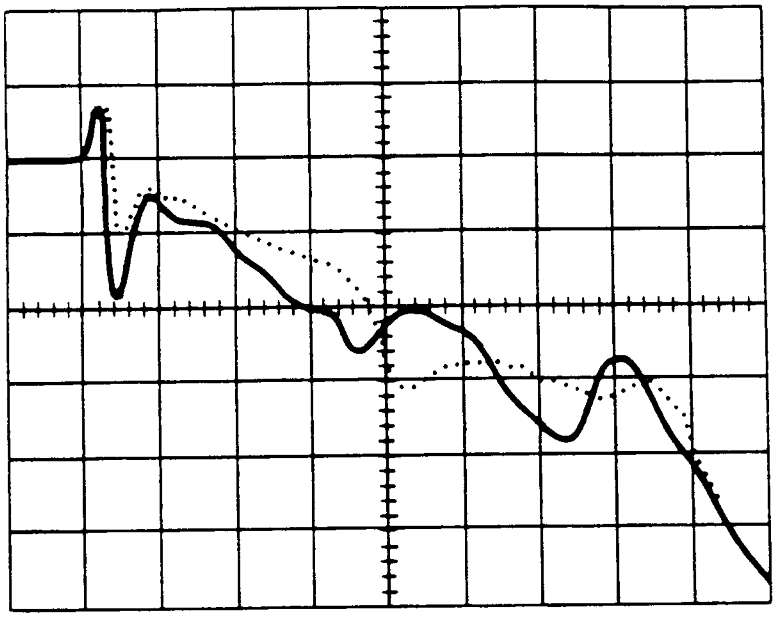


FIGURE 2-8. Low Band – The distorted TDR display is due to inductive 500 ohm terminating resistors.

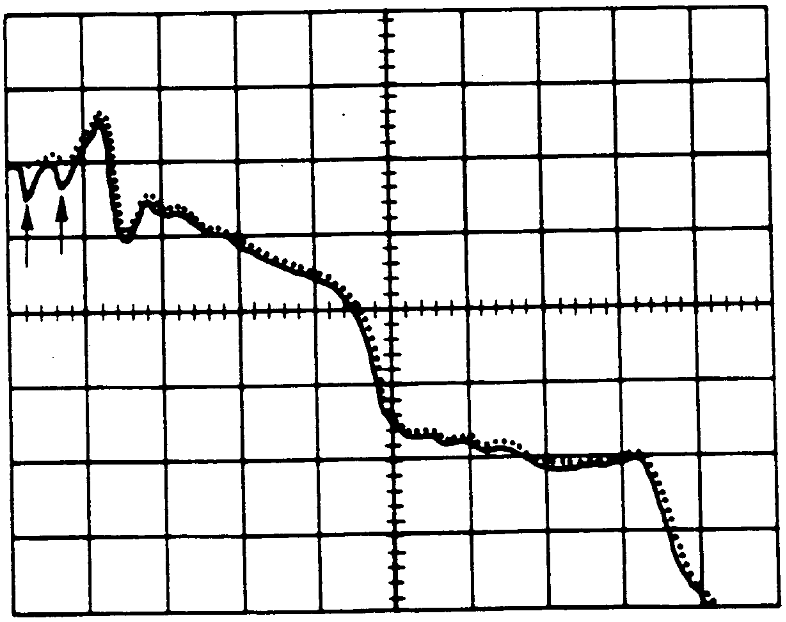


FIGURE 2-9. Low Band – Moisture in the RG-85 endseal and RG-11 A/U connectors causes partial shorts in the TDR signature (shown by the arrows).

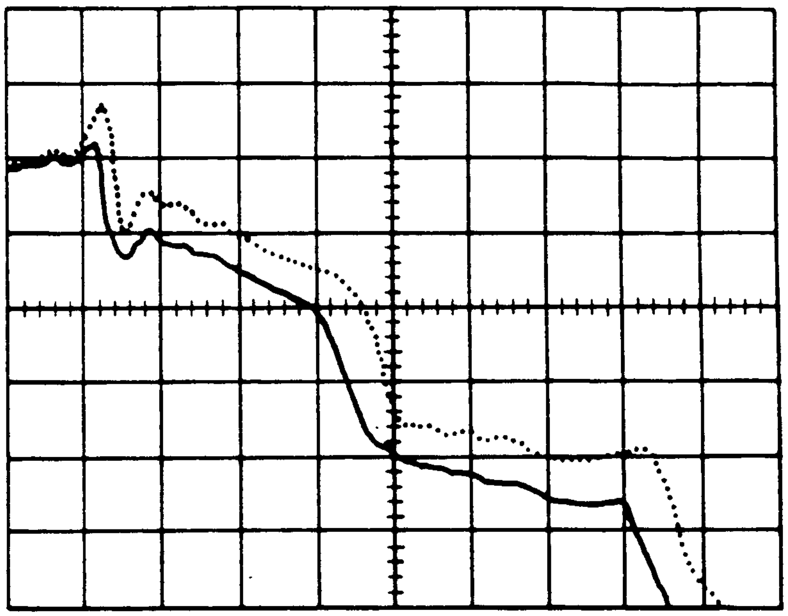


FIGURE 2-10. Low Band – A dirty transformer insulator causes a lower TDR display. The partial short between the transformer casing and RG-11 connector could be caused by a wet spider web or bee nest.

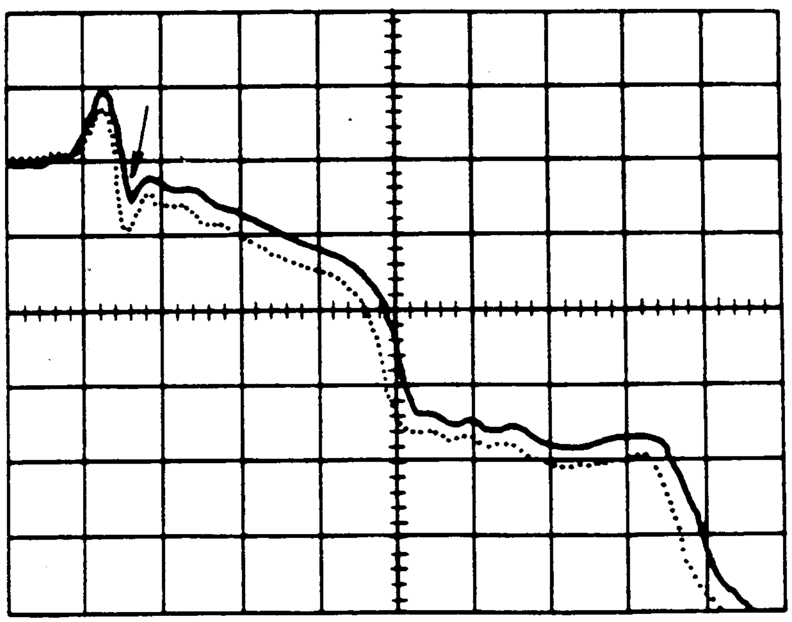


FIGURE 2-11. Low Band – A dirty bond between the transformer and mast caus s a higher TDR display and a smaller inductiv dip (as sh wn by the arrow).

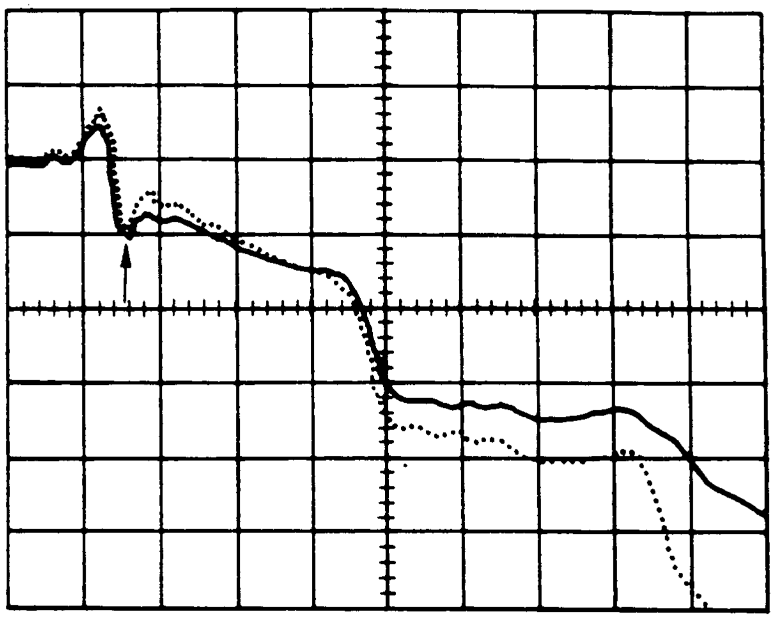


FIGURE 2-12. Low Band – A loose transformer bond to the mast caused this display. Note the similarity of the small dip and rise with those in figure 2-11.

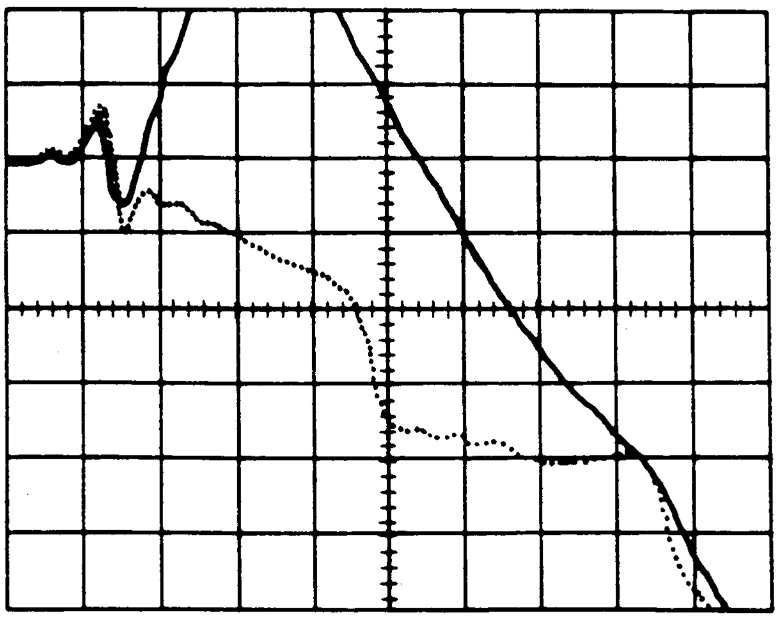


FIGURE 2-13. Low Band – This open circuit was caused by the transformer being disconnected from the mast. It demonstrates the importance of a good transformer bond.

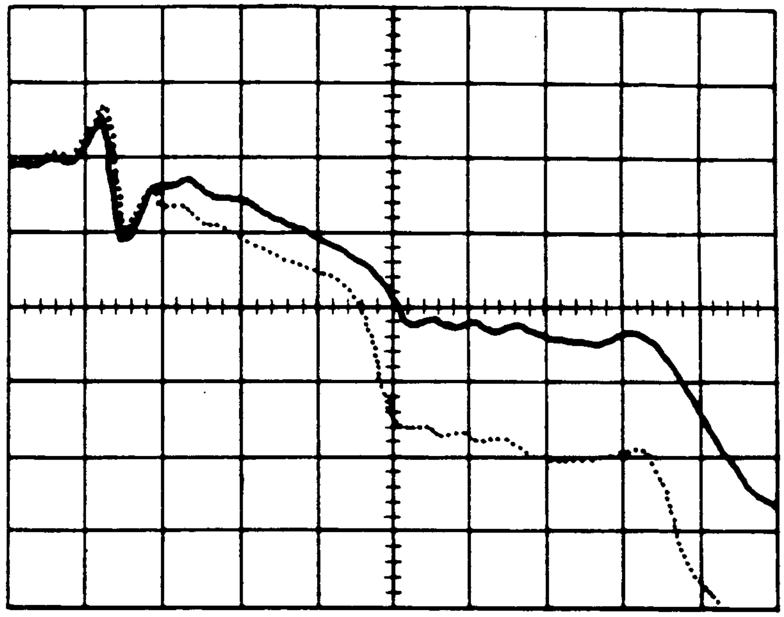


FIGURE 2-14. Low Band – The elevated display shown is caused by corroded downwire terminations or a broken downwire. The signature is identical to that for an open resistor as shown in Figure 2-19.

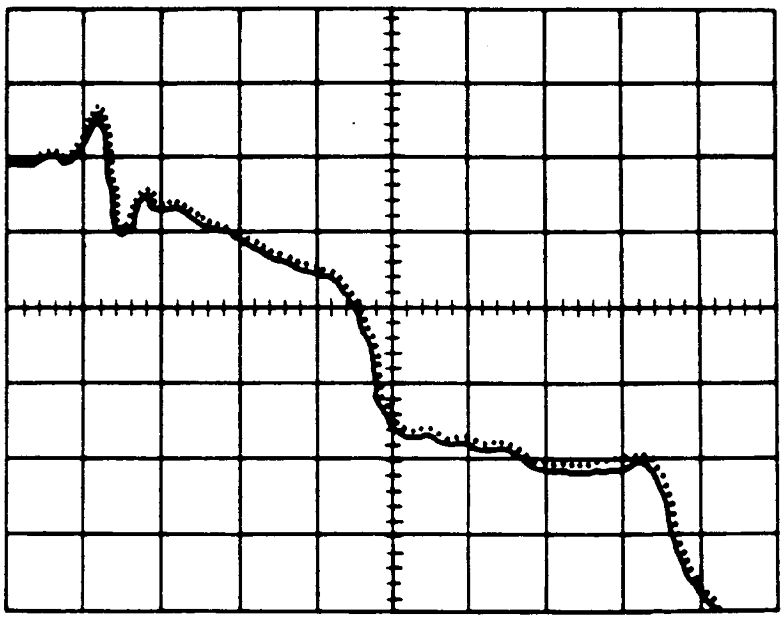


FIGURE 2-15. Low Band – The effect of downwires shorted together is not noticeabl from a typical TDR signature.

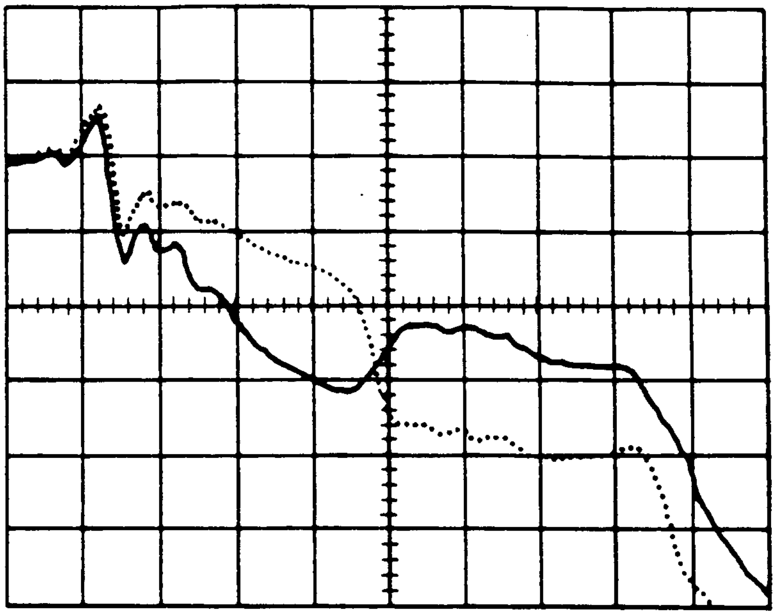


FIGURE 2-16. Low Band – This display shows the effect of downwires shorted to the mast at the lower crossarm due to moisture on the lower crossarms and the loss of protective coating on the arm's surface.

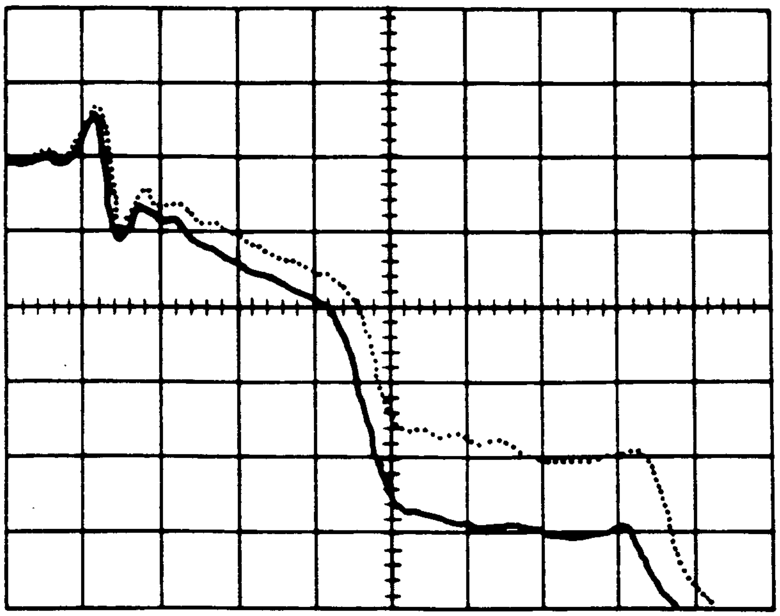


FIGURE 2-17. Low Band – The effect of one shorted terminating resistor is shown in this display.

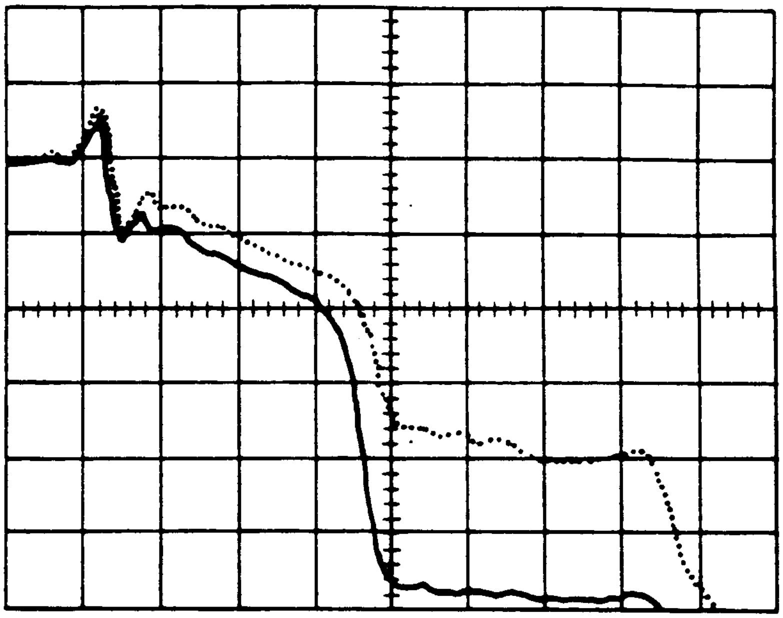


FIGURE 2-18. Low Band – Both terminating resistors are shorted in this display.

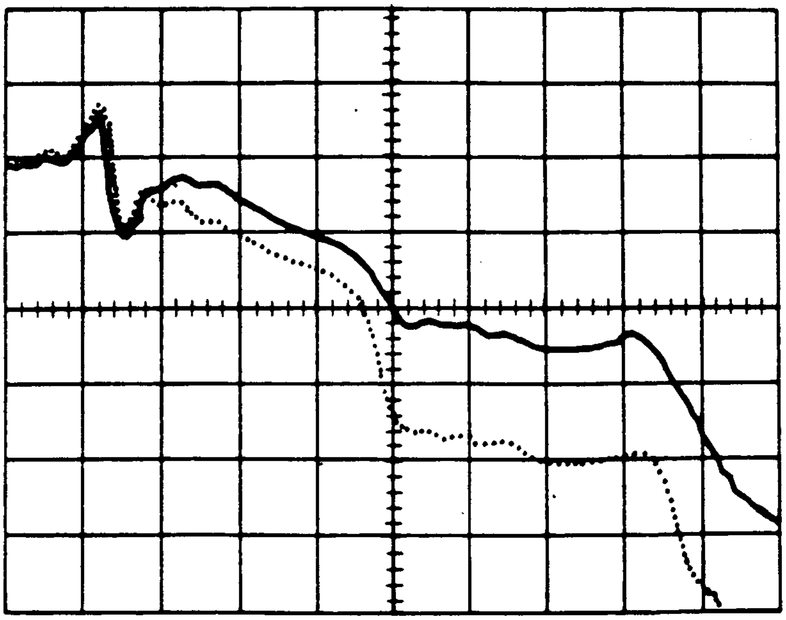


FIGURE 2-19. Low Band – The effect of an open terminating resistor is shown in this display. The TDR signature is similar to figure 2-14 caused by a broken downwire.

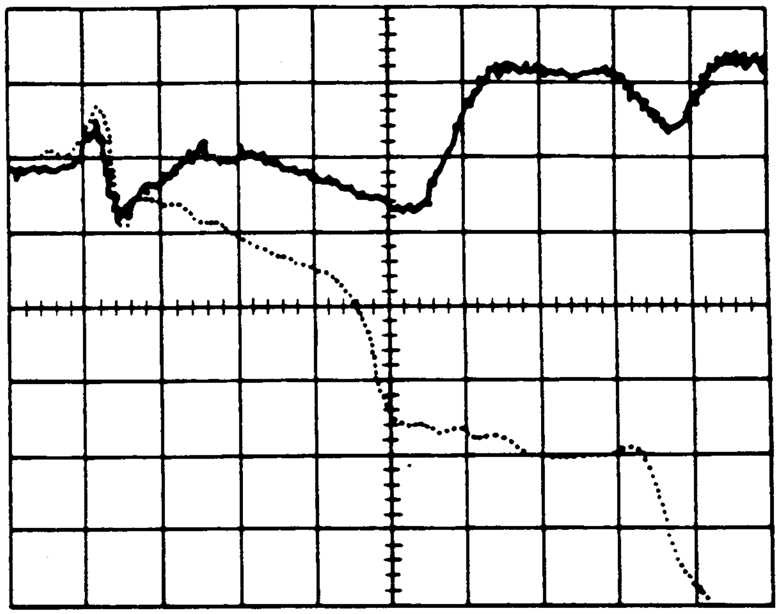


FIGURE 2-20. Low Band – Both terminating resistors are open in this display. Note the added RF noise in the display.

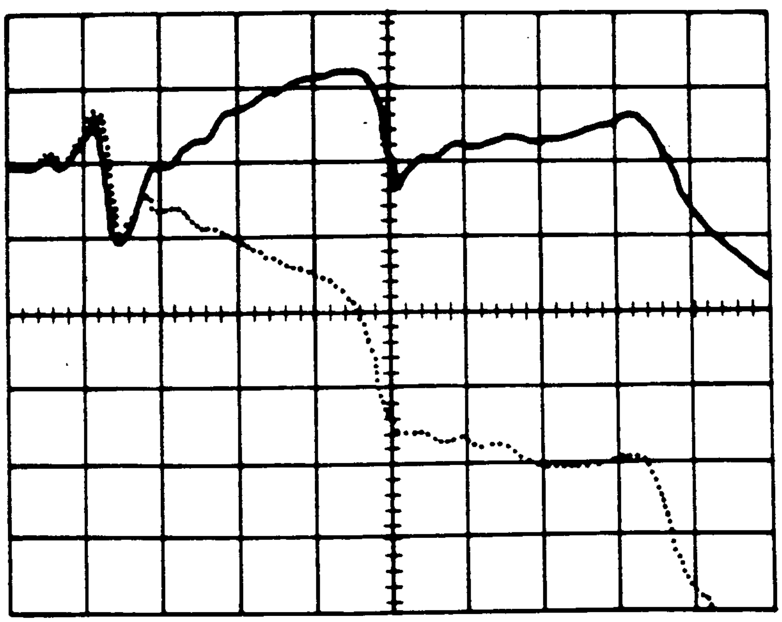


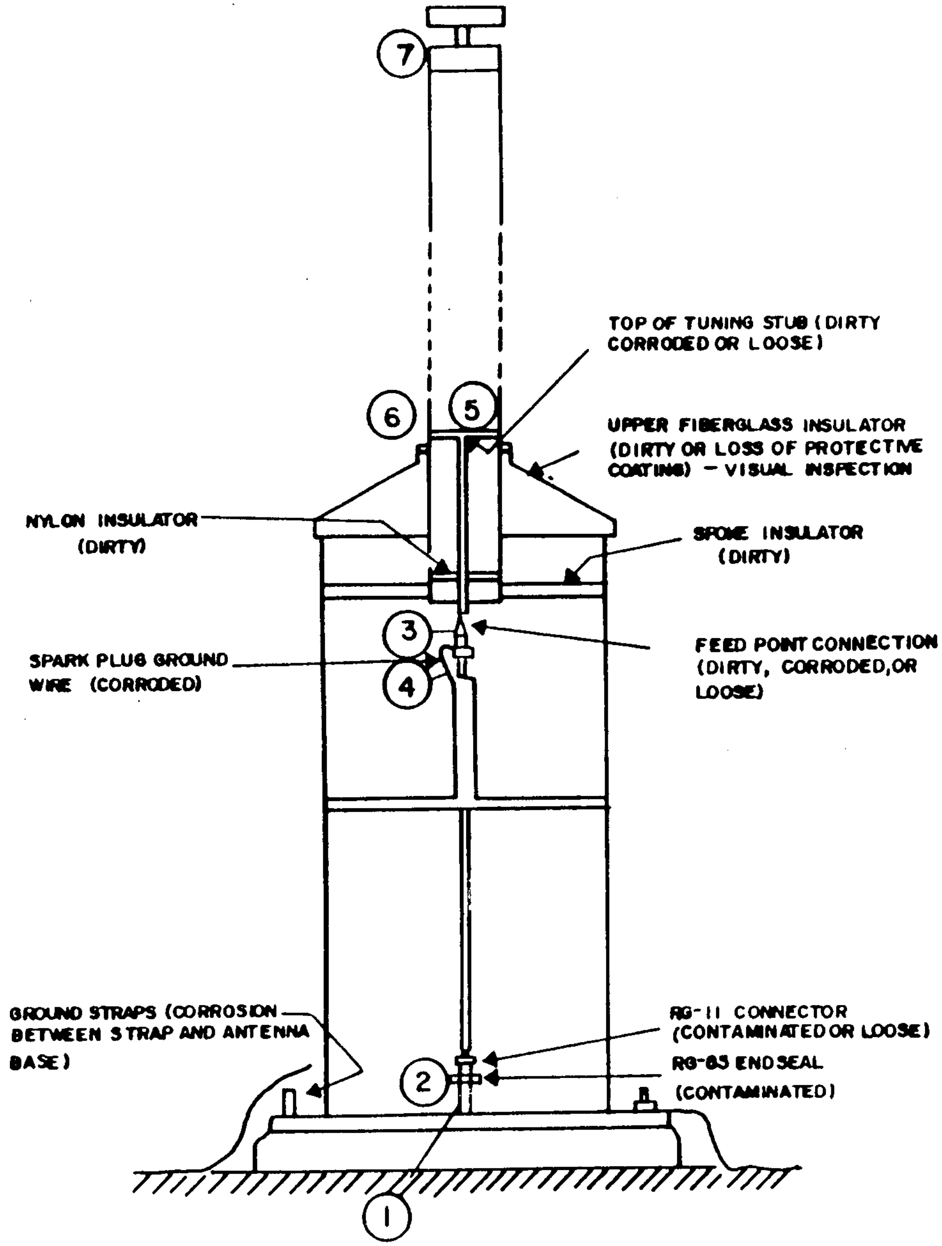
FIGURE 2-21. Low Band – The effect of a poor ground connection, as shown in this display, is similar to any other open circuit condition.

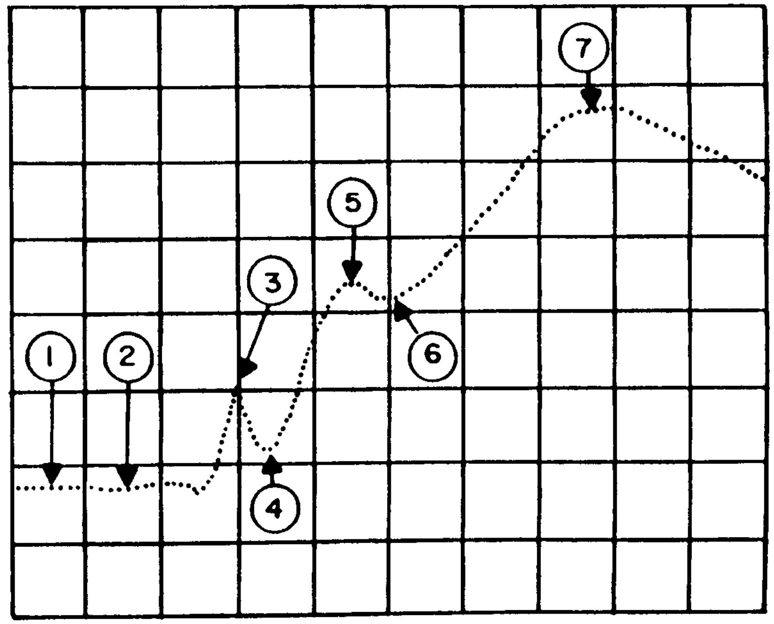
TDR Data Sheet – AN/FRD-10 Low Band Antennas

ANTENNA NUMBER	GOOD	PROBLEM AREA						
		RG-85	RG-11	TRANSFORMER	DOWNWIRE	RESISTOR	GROUND	OTHER

For additional copies, reproduce this form

FIGURE 2-22. TDR Data Sheet – AN/FRD-10 Low Band Antennas.





Typical high band antenna TDR signature. The different areas of th antennas are pinpointed by the numbered arrows.

FIGURE 2-23. *AN/FRD-10 High Band Antenna, TDR Signature.*

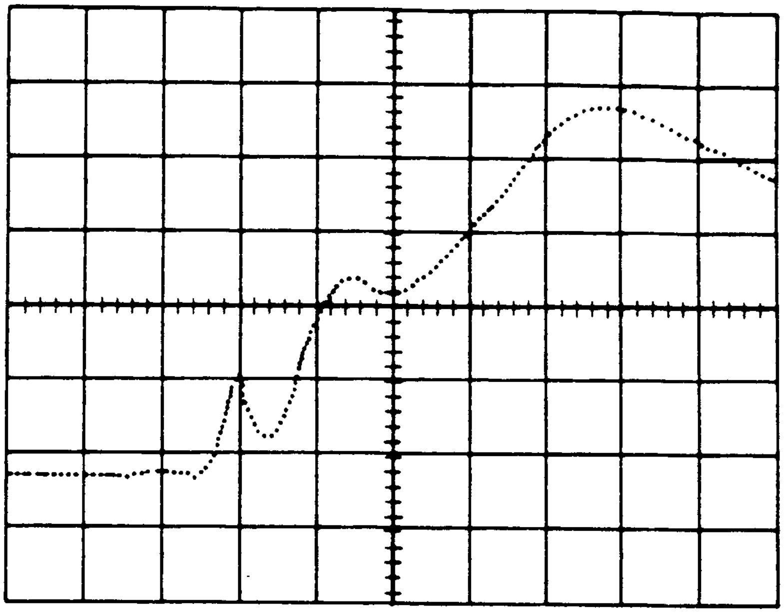


FIGURE 2-24. High Band – Typical AN/FRD-10 High Band Antenna TDR Signature.

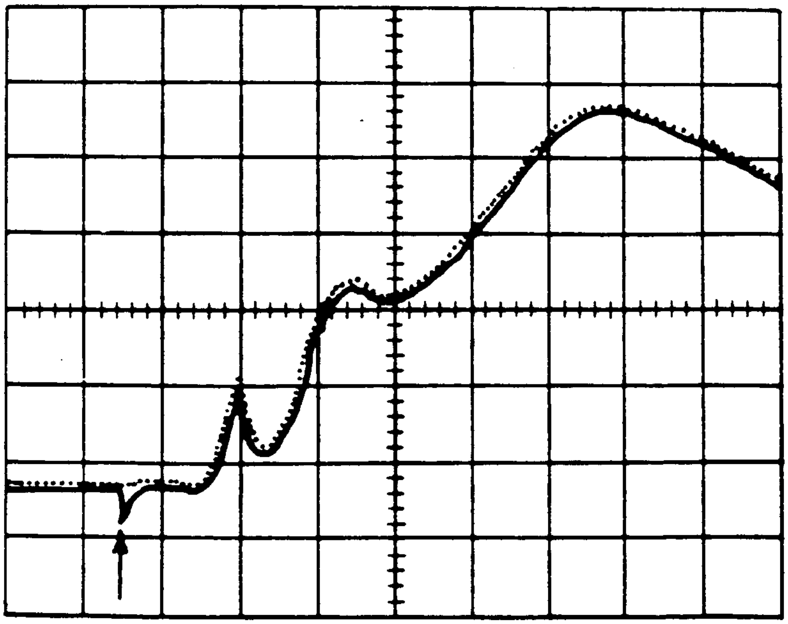


FIGURE 2-25. High Band – Moisture in the RG-85 endseal causes the partial short in the TDR signatur (shown by the arrow).

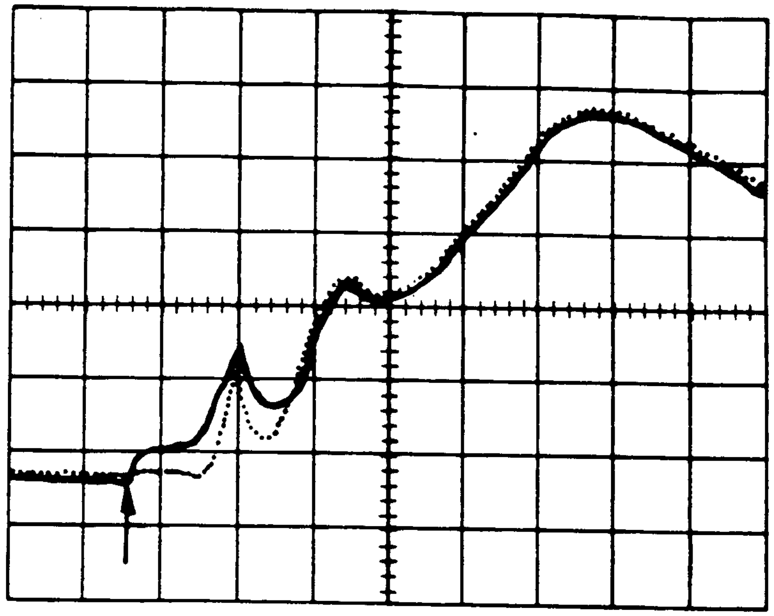


FIGURE 2-26. High Band – The increase in impedance in this figure is due to a corroded ground strap at the RG-85/RG-11 connection.

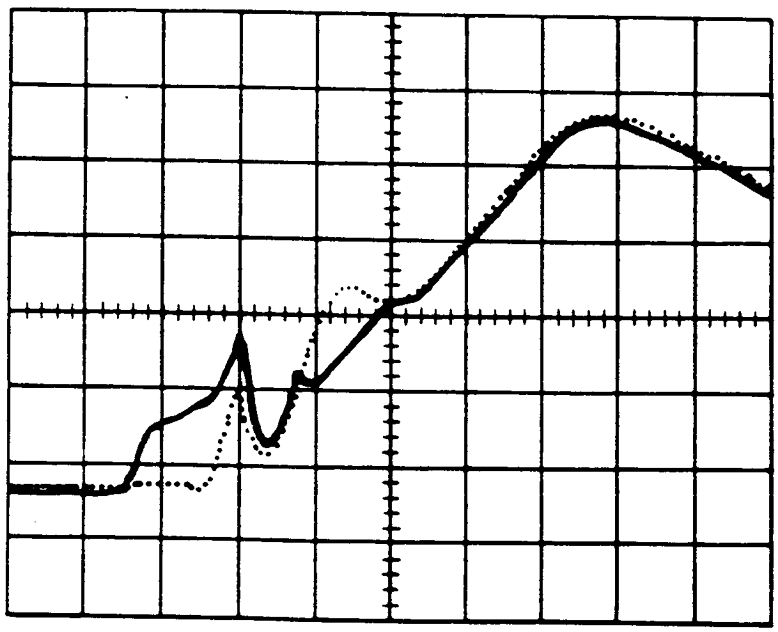


FIGURE 2-27. High Band – The effect of a loose "N" connector at the RG-85 endseal.

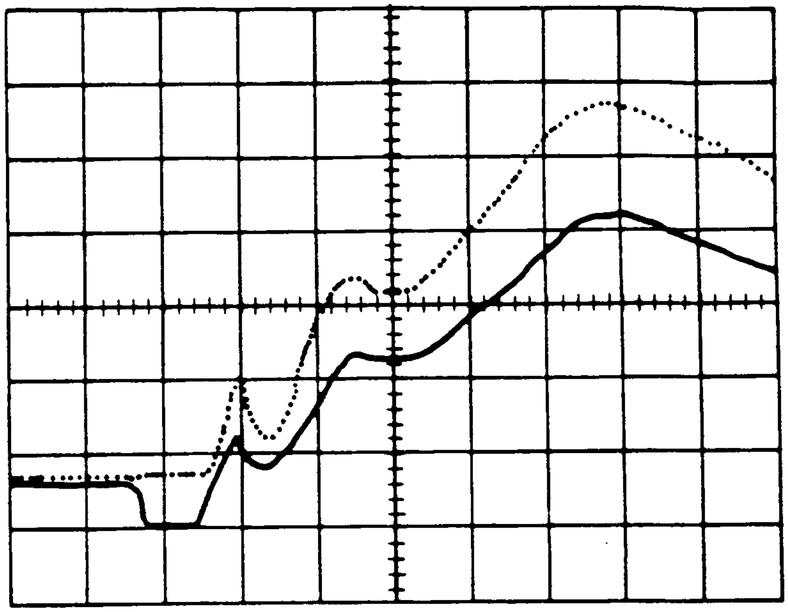


FIGURE 2-28. High Band – A partial short in this display was caused by water in the RG-85/RG-11 connector.

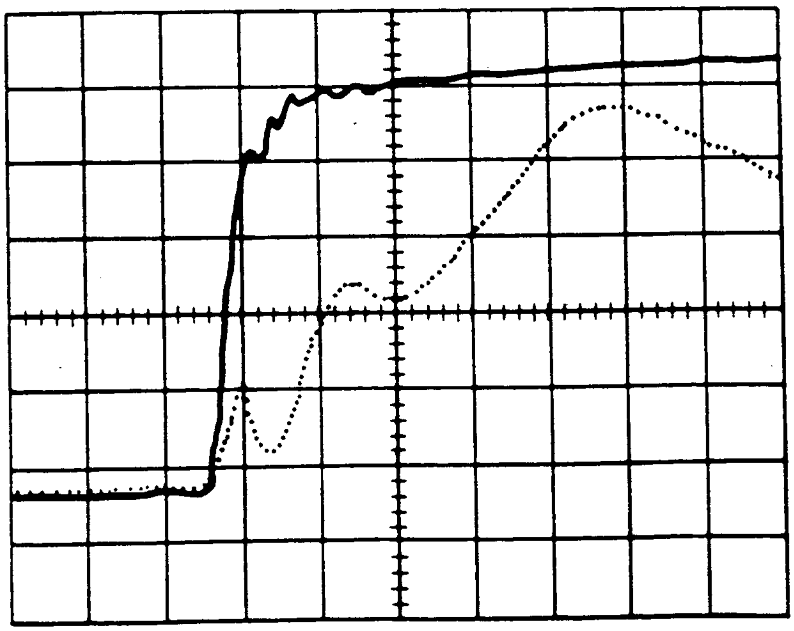


FIGURE 2-29. High Band – This display is caused by an open circuit in the RG-11 connector fitting at the spark plug end.

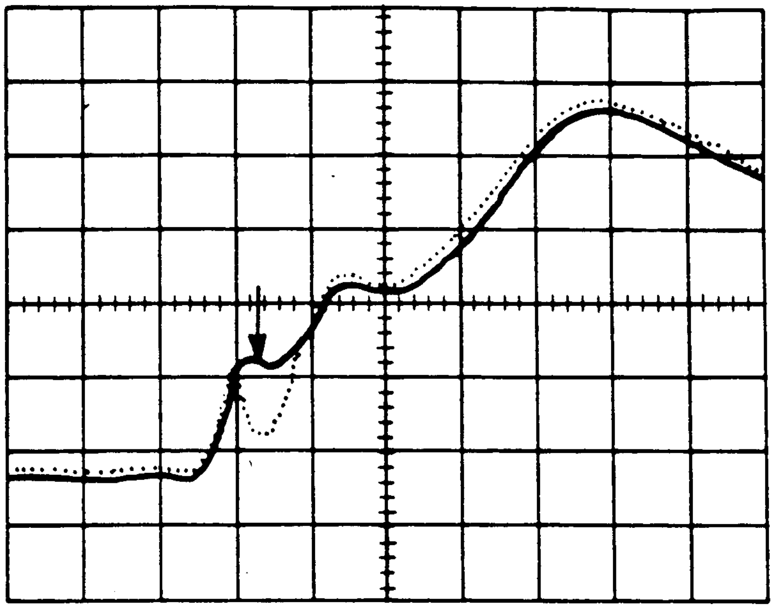


FIGURE 2-30. High Band – A poor spark plug ground causes a shallow dip as shown by the arrow.

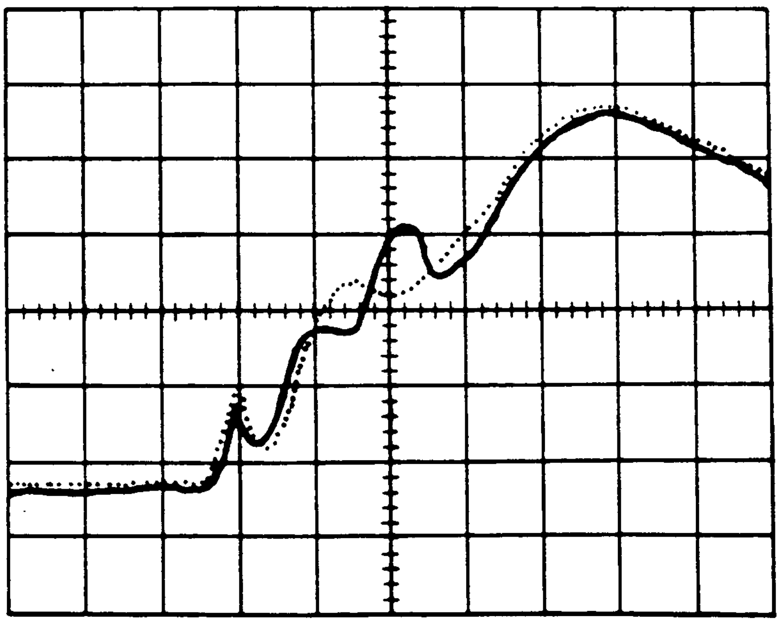


FIGURE 2-31. High Band – A spark plug ground wire that was too long caused this display.

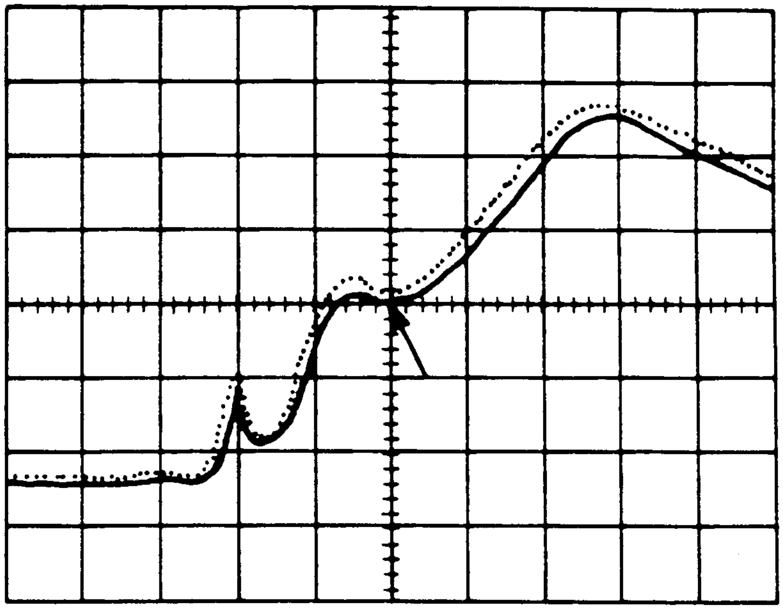


FIGURE 2-32. High Band – The effect of a dirty connection at the top of the tuning stub is shown in this figure.

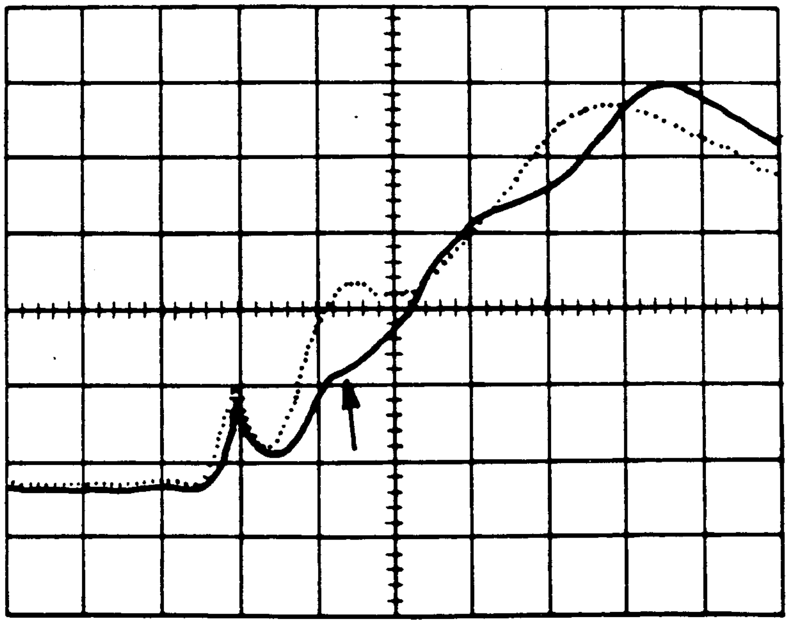


FIGURE 2-33. High Band – A severe tuning stub problem is shown by the almost complete absence of the second bump.

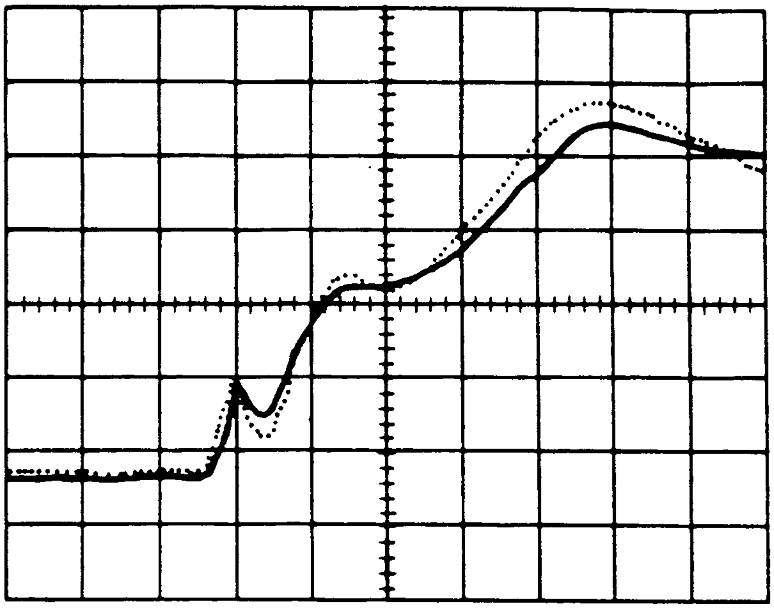


FIGURE 2-34. High Band – A loose set screw on the center conductor of the tuning stub caused this display.

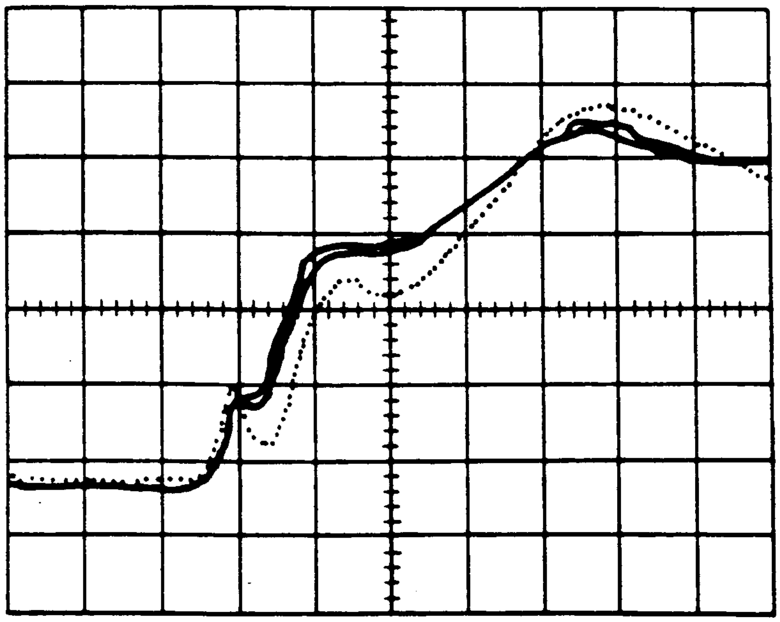


FIGURE 2-35. High Band – This varying (unstable) display was caused by a wet spider web shorting the upper mast to the lower sleeve.

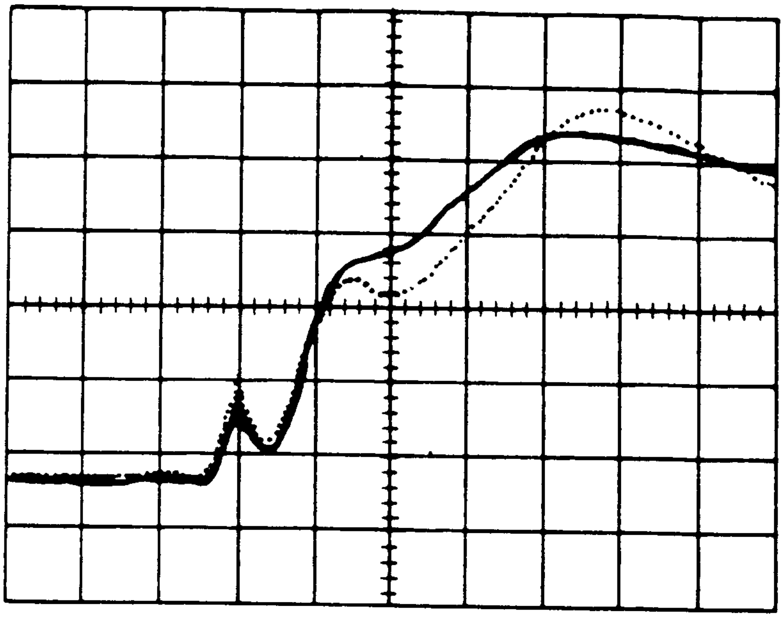


FIGURE 2-36. High Band – The effect of dirty spoke and nylon insulators is to eliminate the second dip.

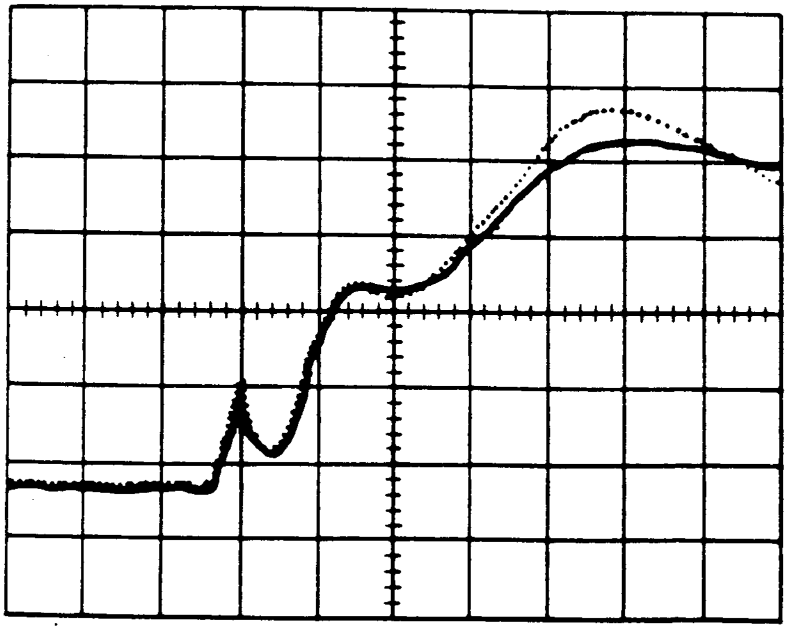


FIGURE 2-37. High Band – Corroded ground straps cause a flattening of the ringing at the top of the antenna.

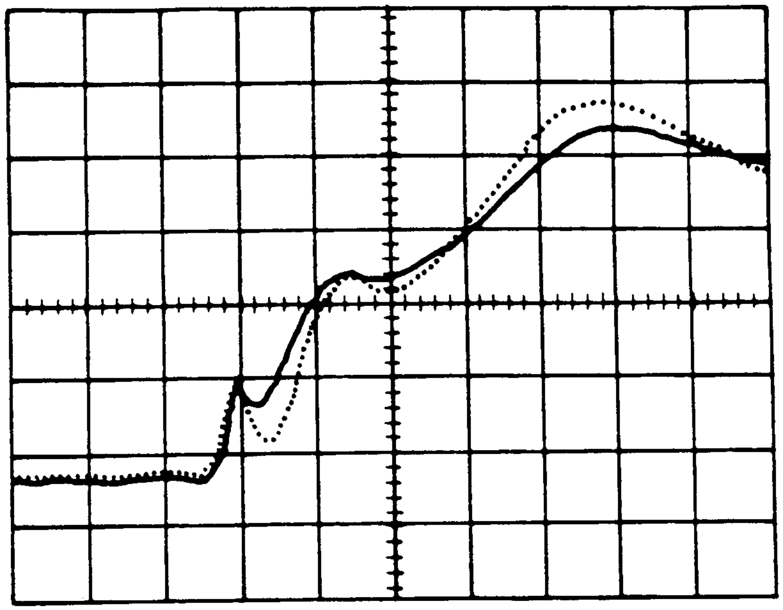


FIGURE 2-38. High Band – A moisture problem generally flattens out all peaks and dips in the TDR signature. After megging, the normal TDR display returns.

TDR Data Sheet – AN/FRD-10 High Band Antennas

ANTENNA NUMBER	GOOD	PROBLEM AREA							
		RG-85	RG-11	SPARK PLUG	FEEDPOINT	TUNING STUB	SPOKE & NYLON	GROUND STRAPS	OTHER

For additional copies, reproduce this form

FIGURE 2-39. TDR Data Sheet – AN/FRD-10 High Band Antennas.

2.6 PLOTTING OF TEST RESULTS

A procedure to plot the TDR signature on an HP 7000A X-Y Plotter is given beginning with Paragraph 2.10. A similar procedure would apply to other types of X-Y plotters. It is important to calibrate the X-Y plotter properly with the TDR so that all plots made at different times can be referenced to one another.

2.7 TTJ-1 LOW BAND TRANSFORMER TEST JIG (TDR AND AMPLITUDE/PHASE COMPARISON TEST)

2.7.1 Purpose. Previous electronic evaluations of various Circularly Disposed Antenna Array (CDAA) sites have shown that suspected problems with a transformer were often corrected by replacing it with a spare. However, the only way to test these bad transformers was to mount them on a known good low band antenna. Therefore a low band transformer test jig (TTJ-1) has been developed for bench testing the transformers before mounting them on the antennas. One test jig (TTJ-1) has been provided to each AN/FRD-10 site that has a direction finding mission. This test jig performs two basic tests:

1. Time Domain Reflectometer (TDR) Test of a low band transformer.
2. Amplitude/Phase Comparison Test of a low band transformer and a 45 inch cable.

The Time Domain Reflectometer (TDR) test of low band transformers is described in Paragraph 2.8. The Amplitude/Phase Comparison Test of a transformer and a 45 inch cable is described in Paragraph 2.9.

2.7.2 Background. The low band transformer test jig is designed to provide a simple method of testing the low band transformers before mounting on the antenna. The low band transformers rarely breakdown, however a quick and simple test can now be done by the station personnel or antenna mechanics. A description of the low band transformer test jig is provided in Table 2-11.

2.8 TIME DOMAIN REFLECTOMETER TEST OF A LOW BAND TRANSFORMER

2.8.1 Test Description. The low band transformer test jig is used to characterize individual transformers when isolated from the antenna. This is done by using the Time Domain Reflectometer. The TDR characterizes impedance, which makes it an ideal tool to "fingerprint" transformers. Transformer problems can be identified by comparing the "fingerprint" or signature of a reference (good) transformer with the signature of the transformer under test.

2.8.2 Test Setup. Figure 2-40 shows the test setup for TDR testing of low band transformers. In performing the hook-up for TDR testing, mount the transformer to the Plexiglas mount. Connect the TDR test cable to the TDR input on the transformer test jig. The toggle switch on the test jig must be in the TDR position.

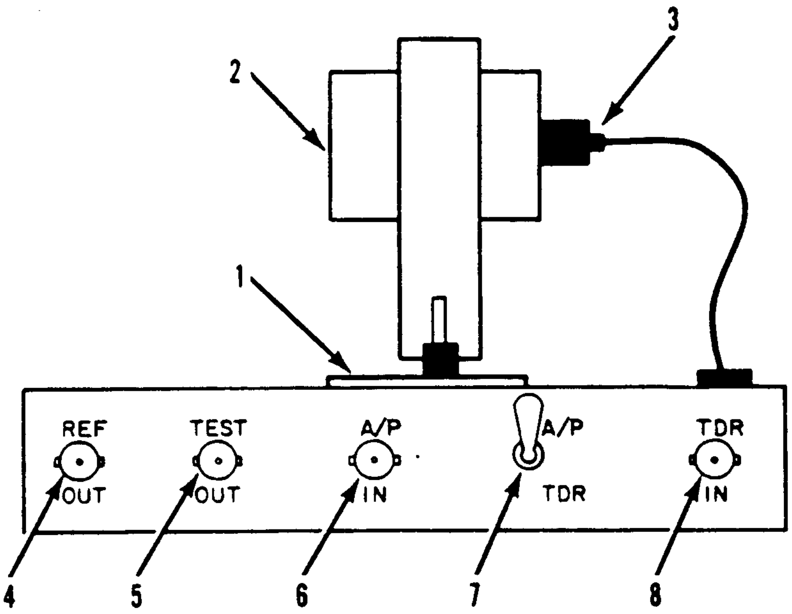
NOTE

> The preliminary calibration of HP 1415A or TEK 1502 TDRs for low band transformer testing is the same as the preliminary calibration of TDRs for AN/FRD-10 antenna testing.

Table 2-12 and Table 2-13 list the test procedure and control settings for the HP 1415A TDR, respectively. Table 2-14 lists the TEK 1502 TDR control settings for low band transformer testing.

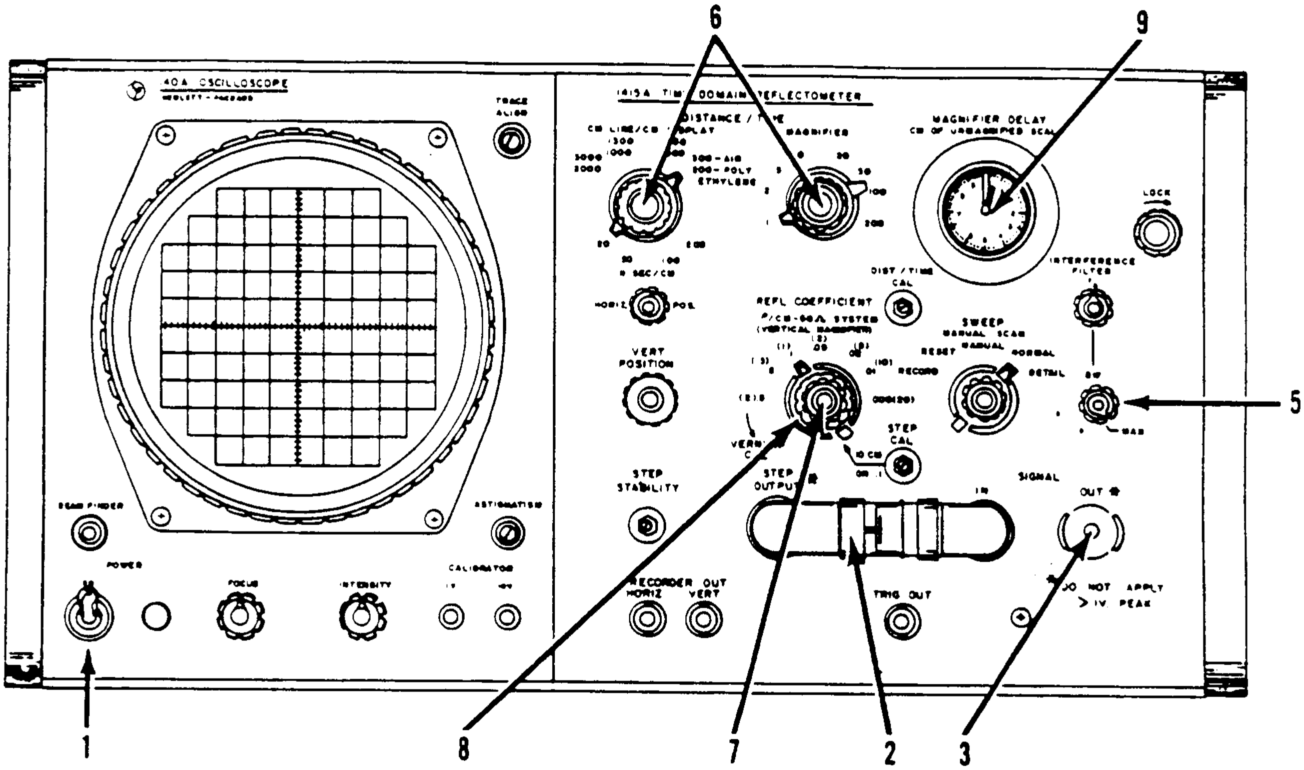
2.8.3 Test Results. The characteristic TDR signatures of good low band transformers are shown in Figures 2-41 and 2-42. Using the reference TDR signature of the same series as the test transformer, problems can then be detected. Figure 2-43 shows a bad TDR signature due to a short in the primary winding of the transformer. Figure 2-44 shows a bad TDR signature due to an open secondary winding. Figure 2-45 shows another bad TDR signature due to the transformer windings being reversed.

Table 2-11. Low Band Transformer Test Jig, Description



1. PLEXIGLAS TRANSFORMER MOUNT. The transformer mount will hold the transformer under test in place. The transformer mount may be adjusted to fit all transformer series.
2. LOW BAND TRANSFORMER. The low band transformer under test.
3. LOW BAND TRANSFORMER SOURCE INPUT. The N-type connector is the source input for the TDR Test and the Amplitude/Phase Comparison Test. This N-type connector is connected to the transformer under test.
4. REF OUT. Reference output for the Amplitude/Phase Comparison Test of the transformer and a 45 inch cable. This reference output will be connected to the reference channel of the network analyzer.
5. TEST OUT. Test output for the Amplitude/Phase Comparison Test of the transformer and a 45 inch cable. This test output will be connected to the test channel of the network analyzer.
6. A/P IN. This is the source input for the Amplitude/Phase Comparison Test of the transformer and a 45 inch cable.
7. A/P or TDR. This is a toggle switch that will set the test mode to either TDR Test or Amplitude/Phase Comparison Test of a transformer and a 45 inch cable. **NOTES** 1. The toggle switch must be set to the specified test being done. 2. For TDR test, the TEST OUT connector must be left open.
8. TDR IN. This is the TDR input for the TDR test of the low band transformer.

Table 2-12. HP 1415A TDR, Test Procedure



1. The test equipment should be operating 15 minutes prior to performing the test procedure to provide adequate warm-up time.

2. Connect STEP OUTPUT to SIGNAL IN with two L-connectors.

3. Connect the 50 ohm side of a 50-to-75 ohm impedance adapter to SIGNAL OUT.

4. In performing the hook-up for TDR testing, mount the transformer to the Plexiglas mount. Connect the TDR test cable (RG-307) to the TDR input on the transformer test jig. The toggle switch on the test jig must be in the TDR position. Connect the N-type connector to the low band transformer under test. Figure 2-40 shows the test setup for TDR testing of low band transformers.

NOTE

If the display is unsuitable or not present, adjust the TDR STEP STABILITY control for the proper display.

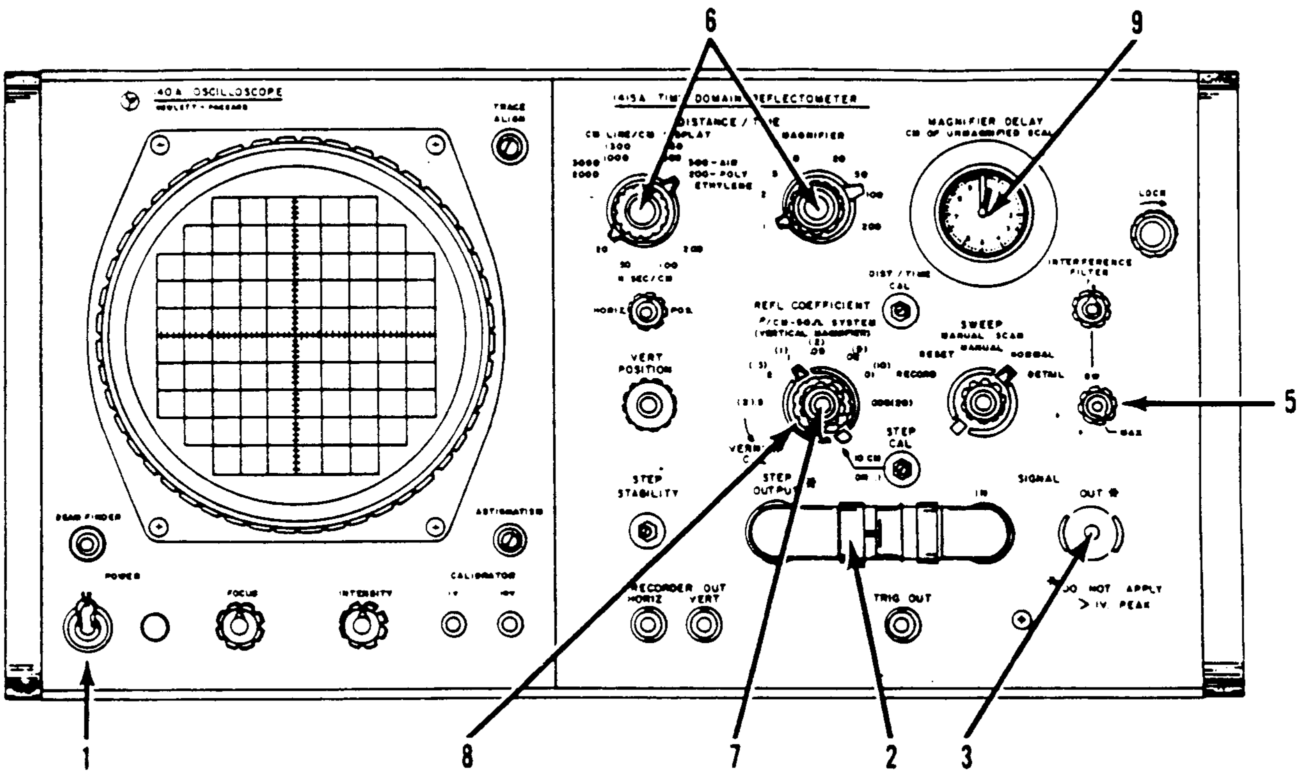
5. Set the INTERFERENCE FILTER BW control to MAX.

6. Set the DISTANCE/TIME to 750/500 CM LINE/CM DISPLAY and DISTANCE/TIME MAGNIFIER to 1. Set the SWEEP MODE to NORMAL.

7. Set REFL COEFFICIENT VERNIER to CAL.

8. Set REFL COEFFICIENT to .2(.5) for a full scale vertical display.

Table 2-12. HP 1415A TDR, Test Procedure



1. The test equipment should be operating 15 minutes prior to performing the test procedure to provide adequate warm-up time.

2. Connect STEP OUTPUT to SIGNAL IN with two L-connectors.

3. Connect the 50 ohm side of a 50-to-75 ohm impedance adapter to SIGNAL OUT.

4. In performing the hook-up for TDR testing, mount the transformer to the Plexiglas mount. Connect the TDR test cable (RG-307) to the TDR input on the transformer test jig. The toggle switch on the test jig must be in the TDR position. Connect the N-type connector to the low band transformer under test. Figure 2-40 shows the test setup for TDR testing of low band transformers.

NOTE

If the display is unsuitable or not present, adjust the TDR STEP STABILITY control for the proper display.

5. Set the INTERFERENCE FILTER BW control to MAX.

6. Set the DISTANCE/TIME to 750/500 CM LINE/CM DISPLAY and DISTANCE/TIME MAGNIFIER to 1. Set the SWEEP MODE to NORMAL.

7. Set REFL COEFFICIENT VERNIER to CAL.

8. Set REFL COEFFICIENT to .2(.5) for a full scale vertical display.

Table 2-12. HP 1415A TDR, Test Procedure – CONT.

9. Set MAGNIFIER DISPLAY to approximately 1.0 - 2.0 cm. The reflections from the low band transformer should be shown in the display. Otherwise adjust MAGNIFIER DELAY to display the entire range.

Compare the TDR signature with the reference to determine any impedance discontinuity. Use Figures 2-41 through 2-45 to help diagnose the problem areas.

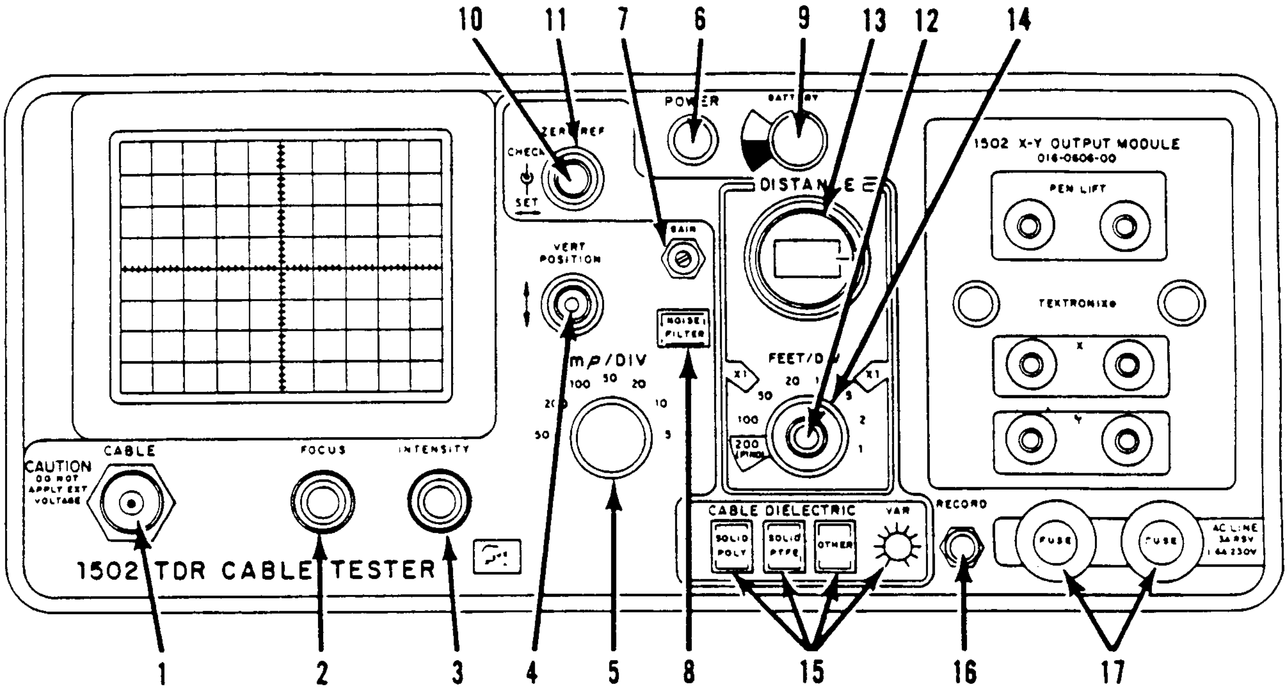
Table 2-13. HP 140A Oscilloscope and HP 1415A TDR, Control Settings for Testing AN/FRD-10 Transformers

CONTROL	SETTING
HP 140A Oscillscope	
POWER	ON
FOCUS	Set for the sharpest display.
INTENSITY	Set for a bright display without blooming.
ASTIGMATISM	Set for the sharpest display.
TRACE ALIGN	Set to give a level display.
HP 1415A Time Domain Reflectometer	
STEP OUTPUT to SIGNAL IN	Use two L-connectors.
HORIZ POS	Set to center display horizontally.
VERT POSITION	Set to center display vertically.
*INTERFERENCE FILTER, f_o	Set for minimum interference.
*INTERFERENCE FILTER, BW	MAX
CM LINE/CM DISPLAY	750/500
MAGNIFIER	1
REFL. COEFFICIENT	.2(.5)
REFL. COEFFICIENT VERNIER	CAL
MAGNIFIER DELAY	Approx. 1.0 - 2.0
*SWEEP MODE	NORMAL
DIST/TIME CAL	Do not touch – set in calibration.
STEP CAL	Do not touch – set in calibration.
**STEP STABILITY	Do not touch – set in calibration.

* If the display is distorted due to RF interference, adjust these controls for a sharp display.

** If the display is unstable or not present, adjust this control for the proper display.

Table 2-14. TEK 1502 TDR, Control Settings for Testing AN/FRD-10 Low Band Transformers



1. The following control settings are typical for testing AN/FRD-10 transformers.

CONTROL	SETTING
POWER (6)	ON
FOCUS (2)	Set for sharpest display image.
INTENSITY (3)	Set for bright display without blooming.
VERT POSITION (4)	Set to center display vertically.
CABLE DIELECTRIC (15)	Set to SOLID POLY.
GAIN (7)	Do not touch – set in calibration.
MULTIPLIER (12)	X1
DISTANCE (13)	000 for a 20 ft (RG-307) test cable.
FEET/DIV (14)	20
mρ/DIV (5)	200
NOISE FILTER (8)	ON or OFF

2. In performing the hook-up for TDR testing, mount the transformer to the Plexiglas mount. Connect the TDR test cable (RG-307) to the TDR input on the transformer test jig. The toggle switch on the test jig must be in the TDR position. Connect the N-type connector to the low band transformer under test. Figure 2-40 shows the test setup for TDR testing of low band transformers.

3. Compare the TDR signature with the reference to determine any impedance discontinuity. Use Figures 2-41 through 2-45 to help diagnose the problem areas.

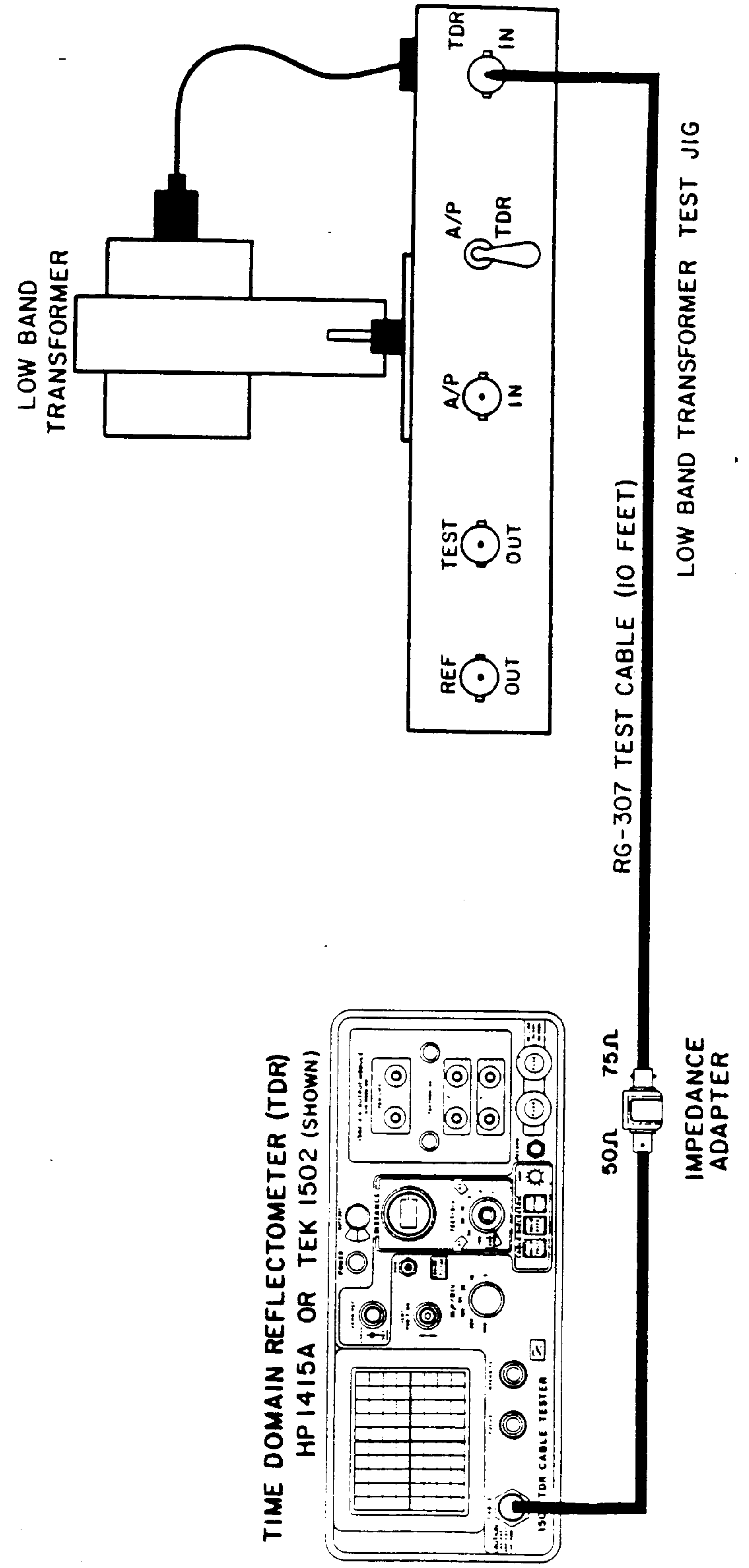
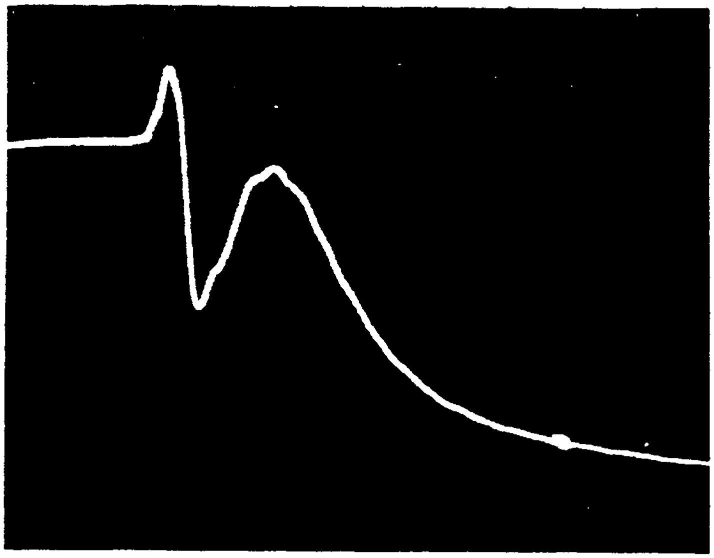
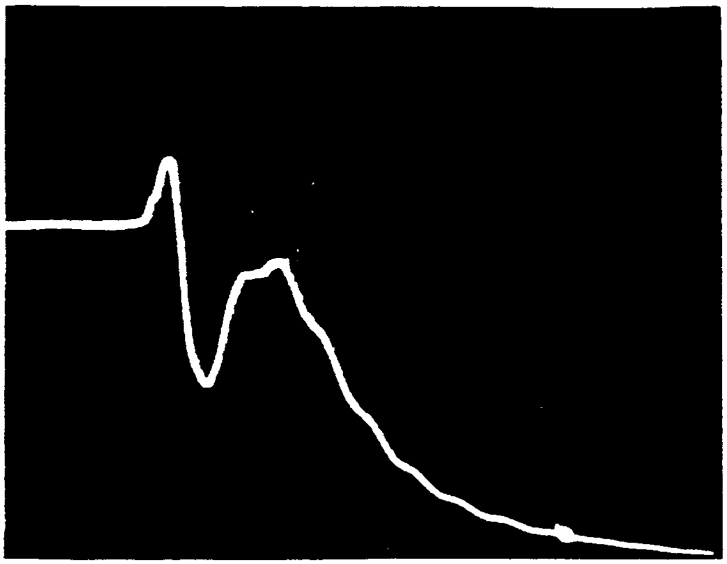


FIGURE 2-40. Low Band Transfc   Test Jig, TDR Test Setup.



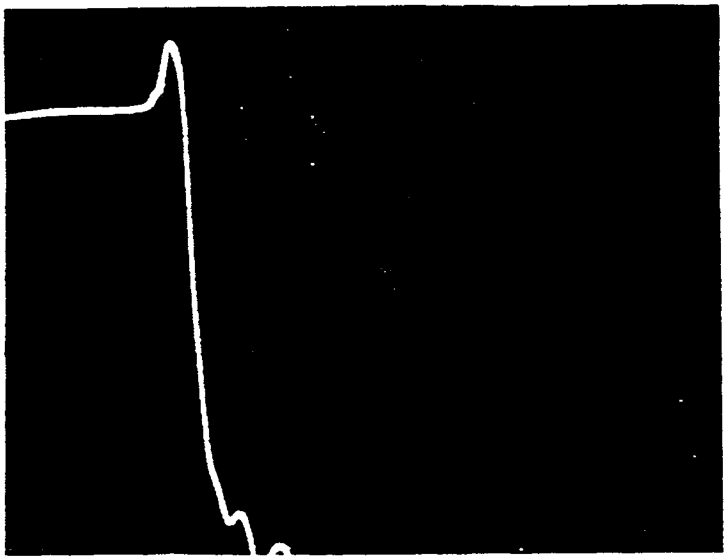
**TDR TEST
FOR
LOW BAND TRANSFORMER
SERIAL NO. 906**

FIGURE 2-41. Typical Low Band Transformer TDR Signature for a 900 Series Transformer.



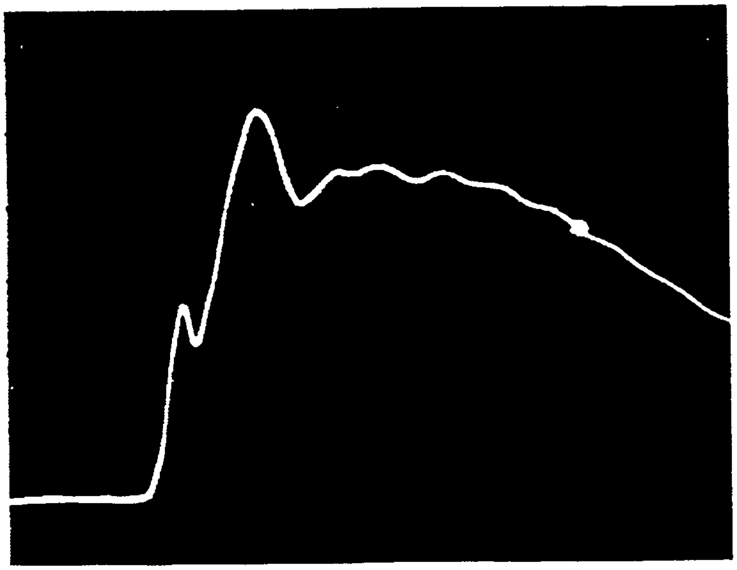
**TDR TEST
FOR
LOW BAND TRANSFORMER
SERIAL NO. 243**

FIGURE 2-42. Typical Low Band Transformer TDR Signature for a 200 Series Transformer.



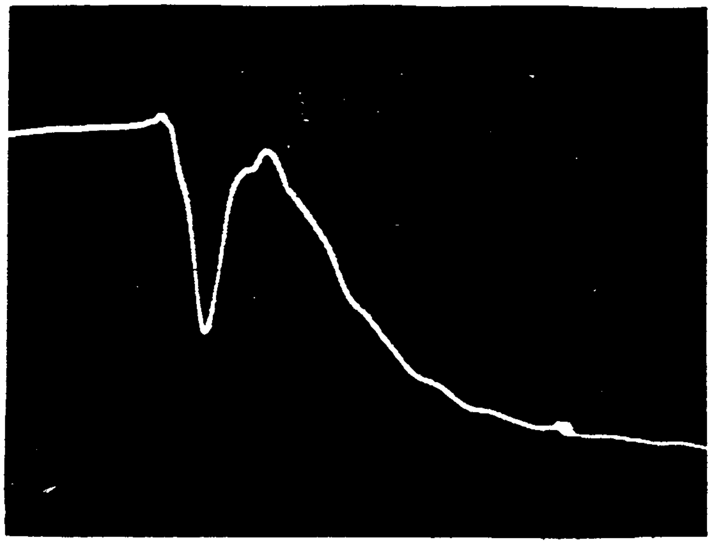
TDR TEST
FOR
LOW BAND TRANSFORMER
SERIAL NO. 889

FIGURE 2-43. Low Band Transformer TDR Signature with a Shorted Primary Winding.



TDR TEST
FOR
LOW BAND TRANSFORMER
SERIAL NO. 823

FIGURE 2-44. Low Band Transformer TDR Signature with an Open Secondary Winding.



TDR TEST
FOR
LOW BAND TRANSFORMER
SERIAL NO. 995

FIGURE 2-45. Bad Low Band Transformer TDR Signature Due to the Transformer Windings Being Reversed Resulting in a 180 Degree Phase Shift.

2.9 AMPLITUDE/PHASE COMPARISON TEST OF A LOW BAND TRANSFORMER AND A 45 INCH CABLE

2.9.1 Test Description

2.9.1.1 The amplitude and phase of incoming on-the-air signals are very critical for a CDAA direction finding system. The AN/FRD-10 CDAA low band transformers may produce amplitude and phase errors. Therefore, the Amplitude/Phase Comparison Test using the low band transformer test jig will provide a method of measuring the amplitude and phase of a low band transformer before mounting on the antenna.

2.9.1.2 The Amplitude/Phase Comparison Test uses a sweep oscillator to provide a test signal which is first divided and then injected into the low band transformer under test and the 45 inch cable as a reference. The amplitude and phase responses of the two received signals are then compared on the Network Analyzer. The tolerance for this test is: ±1.5 dB amplitude response and ±5.0 degrees phase tolerance.

2.9.2 Test Setup

2.9.2.1 HP 8407A/8412A Network Analyzer and HP 8601A Generator/Sweeper Test System.

1. Test Equipment
   a. Negative DC power supply
   b. Frequency counter
   c. Hewlett-Packard 11652A, Reflection/Transmission kit
   d. Two impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-12 MHz, such as North Hills Electronics 0102JA.
   e. One pair of phase-matched (electrically equal length) 75 ohm cables.
   f. Connectors, adapters, and 50 ohm cables as required.
2. Preliminary Instructions: Test equipment should be operating 15 minutes prior to performing calibration to provide adequate warm-up.

3. Test System Calibration

a. Connect equipment as shown in Table 2-16 for preliminary calibration, however replace the low band transformer test jig with the power splitter as shown in Figure 2-46. Connect impedance adapters directly to the HP 8407A to reduce unnecessary cabling.

b. Set controls as shown in Table 2-15.

c. To calibrate the phase of the network analyzer, set the mode switch to PHASE and adjust the PHASE VERNIER to position the trace on the center horizontal grid line of the display. If the response is not relatively flat, the positions of the impedance adapters can be switched to a combination that produces a flatter phase response. Note that cable "A" is phase-matched (electrically equal length) to cable "B".

d. To calibrate the amplitude of the network analyzer, set the mode switch to AMPL. If the amplitude display is not near the center horizontal grid line, adjust the DISPLAY REFERENCE switches until the amplitude display is approximately 0 dB. Turn DISPLAY REFERENCE CAL thumbwheels so that 0 dB appears. Then adjust the AMPL VERNIER to position the trace on the center horizontal grid line of the display.

e. To calibrate the HF frequency sweep range from 2 to 12 MHz, set the SWEEP MODE of the sweep generator to MANUAL. Turn the MANUAL knob fully counterclockwise. Then adjust the DC power supply until the frequency counter reads 2 MHz. Note that a small negative voltage (approximately −200 mV) is required to obtain a start frequency of 2 MHz. To obtain a stop frequency of 12 MHz, turn the MANUAL knob of the sweep generator fully clockwise. Adjust the FREQUENCY knob of the sweep generator until the frequency counter reads 12 MHz.

NOTE

Adjustments of HP 8412A HORIZ POSITION and HORIZ GAIN controls may be necessary to obtain a full scale trace of 2-12 MHz.

To verify the start frequency, turn the MANUAL knob fully counterclockwise and observe the frequency counter. If necessary, repeat step e. to obtain the desired frequency range.

f. Remove the power splitter and connect the cables to the transformer test jig as shown in Figure 2-47. Note that cable "A" and cable "B" should be connected to reference and test output of the transformer test jig, respectively.

g. Measure the relative amplitude and phase differences between the low band transformer under test and the 45 inch cable.

Table 2-15. HP 8407A/8412A Network Analyzer System, Control Settings

CONTROL	SETTING
HP 8407A/8412A Network Analyzer	
REF CHAN LEVEL ADJ	As required to stay in OPERATE range
DISPLAY REFERENCE	As required to obtain trace
HORIZ POSITION/HORIZ GAIN	As required to obtain calibrated 2-12 MHz across display (Refer to photos)
BW (kHz)	0.1
MODE	As required
AMPL. dB/div	1.0
PHASE deg/div	1.0 or 10.0
PHASE OFFSET	0
INTENSITY	As required
FOCUS	As required
HP 8601A Generator/Sweeper	
OUTPUT LEVEL	−20 dBm
SWEEP	VIDEO
FREQUENCY	As required to obtain 2-12 MHz across display
SWEEP MODE	FREE, FAST
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
DC Power Supply	
OUTPUT *	Approximately −200 mV for a 2 MHz start frequency. (Do not adjust to more than −500 mV and never apply a positive voltage to the EXT FM input on the HP 8601A.)
Frequency Counter	
INPUT	Scale for 2 to 12 MHz frequency range

* If a banana plug to BNC adapter is used on the power supply output, verify the DC continuity between the center pin of the BNC connector and the high (+) banana pin. (Some adapters contain a DC blocking capacitor. These adapters are usually blue.)

CAUTION

If a banana plug to BNC adapter is used on the power supply output, make certain the ground banana pin marked by the tab is connected to the positive (+) terminal of the power supply.

Table 2-16. HP 8407A/8412A Netw rk Analyzer System, Cable Connecti ns

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 8407A/8412A Network Analyzer			
VTO IN	Rear Panel	HP 8601A VTO OUT	RG-58/223
SWEEP IN		HP 8601A SWEEP OUT	RG-58/223
BLANKING		HP 8601A BLANKING OUT	RG-58/223
TEST CHANNEL	Front Panel	Test Jig, TEST OUT	RG-59/307*
REF CHANNEL		Test Jig, REF OUT	RG-59/307*
HP 8601A Generator/Sweeper			
RF OUT	Front Panel	Test Jig, A/P IN	RG-58/223
EXT FM		DC Power Supply	RG-58/223
AUX OUT		Frequency Counter, IN	RG-58/223
BLANKING OUT	Rear Panel	HP 8407A/8412A BLANKING IN	RG-58/223
SWEEP OUT		HP 8407A/8412A SWEEP IN	RG-58/223
VTO OUT		HP 8407A/8412A VTO IN	RG-58/223

* Cables must be amplitude and phase-matched. 50/75 ohm impedance adapters are required if there is an impedance difference between cables and test equipment.

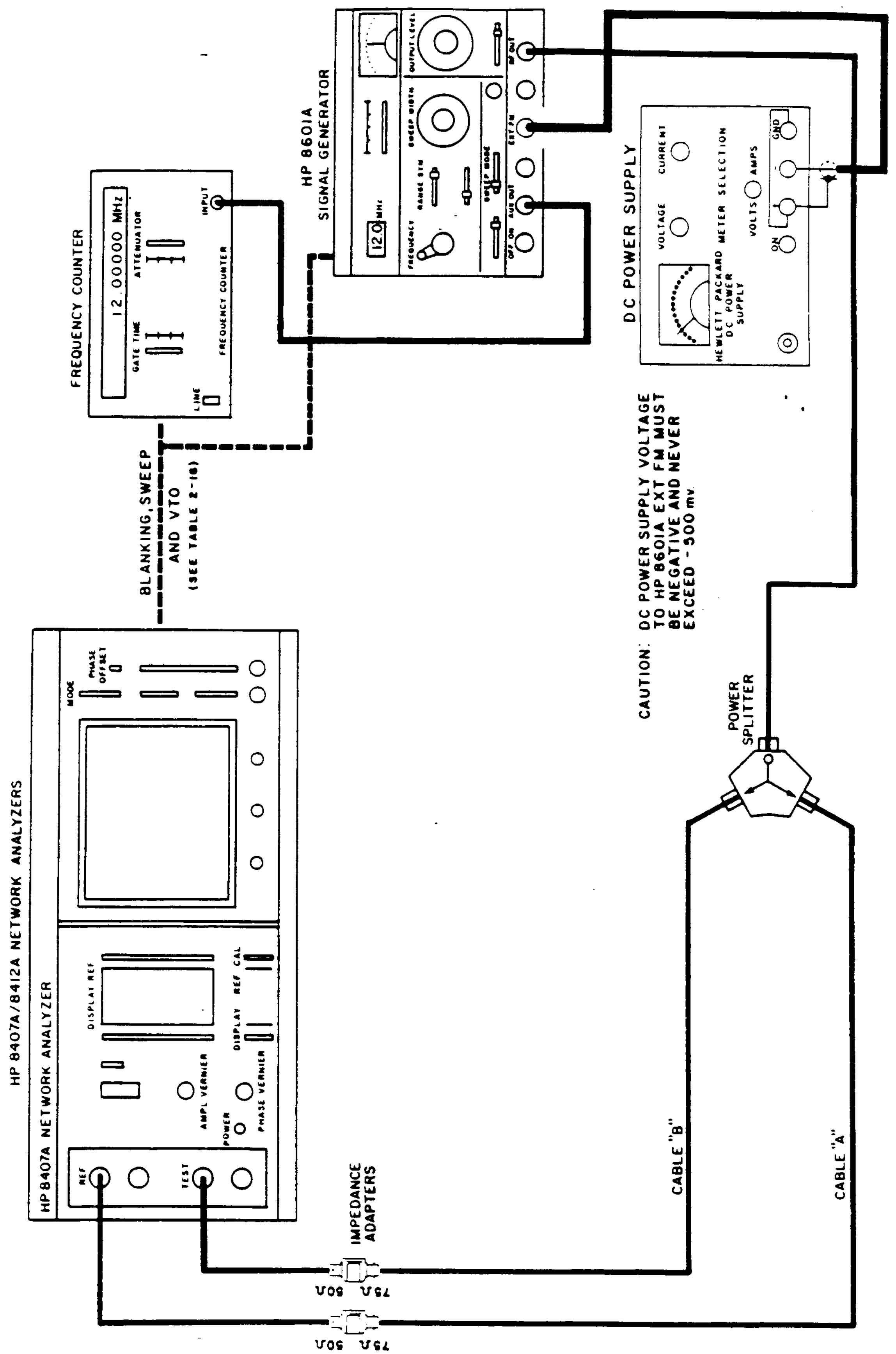


FIGURE 2-46. HP 8407A/8412A Network Analyzer Test System, Calibration Setup.

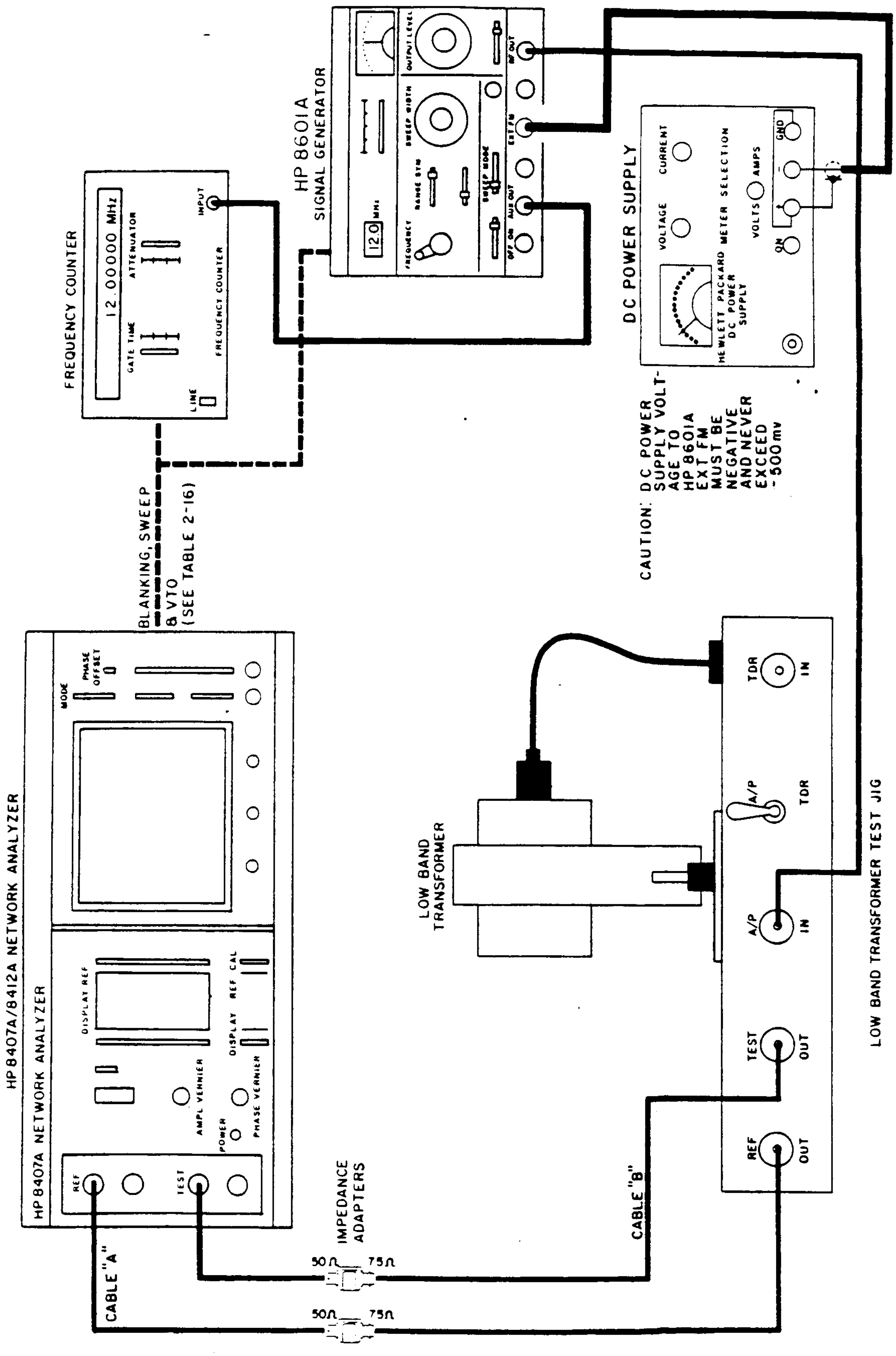


FIGURE 2-47. HP 8407A/8412A Network Analyzer System Low Band Transformer Test Setup.

2.9.2.2 *HP 3577A Network Analyzer Test System.*

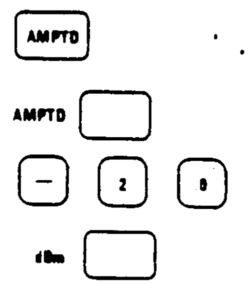
1. Test Equipment
   a. Hewlett-Packard 11652A, Reflection/Transmission kit
   b. Two impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-12 MHz, such as North Hills Electronics 0102JA.
   c. One pair of phase-matched (electrically equal length) 75 ohm cables. Note that the use of the normalization (NORMALIZE) function in the HP 3577A can eliminate the need for phase-matched cables.
   d. Connectors and adapters as required.
2. Preliminary Instructions: Test equipment should be operating 15 minutes prior to performing calibration to provide adequate warm-up.
3. Test System Calibration
   a. To set the HP 3577A output level to −20 dBm, press the following sequence of keys. Figure 2-48 shows the location of SOFTKEYS, DISPLAY FORMAT keys, and SOURCE keys.

(1) SOURCE selection key is used to display Amplitude menu.

(2) SOFTKEY used to change amplitude level.

(3) DATA ENTRY.

(4) SOFTKEY selection of units for the DATA ENTRY.



   b. To set the start and stop frequencies of the HP 3577A, press the following sequence of keys.

(1) SOURCE selection key to display frequency menu.

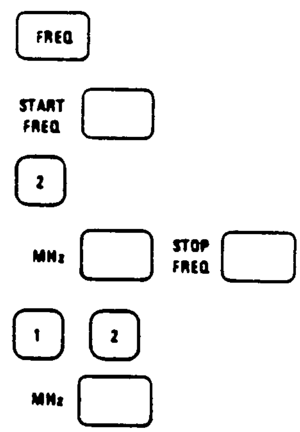
(2) SOFTKEY used to change the start frequency.

(3) DATA ENTRY.

(4) SOFTKEYS used to select units and stop frequency.

(5) DATA ENTRY.

(6) SOFTKEY to select units.



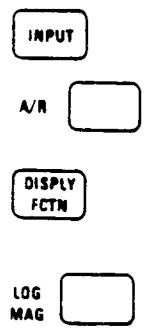
   c. Connect equipment shown in Figure 2-49 for the preliminary calibration of the Network Analyzer. Connect impedance adapters directly to the HP 3577A Network Analyzer to reduce unnecessary cabling.
   d. To set Trace 1 with amplitude mode calibration, press the following keys.

(1) DISPLAY FORMAT key to display input menu.

(2) SOFTKEY to select input.

(3) DISPLAY FORMAT key to display function menu.

(4) SOFTKEY used to select the Log Mag function of the active trace.



(5) DISPLAY FORMAT key to display scale menu.	SCALE
(6) SOFTKEY to change reference position.	REF POSN
(7) DATA ENTRY.	5 0
(8) SOFTKEYS to select units and change /div scale.	% /DIV
(9) DATA ENTRY.	1
(10) SOFTKEY to select units.	dB
(11) DISPLAY FORMAT key to display the Measurement Calibration menu.	MEASR CAL
(12) SOFTKEY to normalize measurement. This stores a trace in data register D1 and redefines the INPUT to be the old definition divided by the stored trace.	NORMLIZE

e. To set Trace 2 with phase mode calibration, press the following sequence of keys.

(1) DISPLAY FORMAT key is used to set trace 2 to be active and display function menu.	TRACE 2 DISPLY FCTN
(2) SOFTKEY to select phase function of active trace.	PHASE
(3) DISPLAY FORMAT key to display input menu.	INPUT
(4) SOFTKEY to select input.	A/R
(5) DISPLAY FORMAT key to display function menu.	SCALE
(6) SOFTKEY to change the reference position.	REF POSN
(7) DATA ENTRY.	5 0
(8) SOFTKEYS to select units and change /div scale.	% /DIV
(9) DATA ENTRY.	1
(10) SOFTKEY to select units.	deg
(11) DISPLAY FORMAT key to display the Measurement Calibration menu.	MEASR CAL
(12) SOFTKEY to normalize measurements. This stores a trace in data register D2 and redetermines the INPUT to be the old definition divided by the stored trace.	NORMLIZE

f. Remove the power splitter and connect cables to the transformer test jig as shown in Figure 2-50 and Table 2-17. Cable "A" and cable "B" should be on REF OUT and TEST OUT, respectively.

g. Trace 1 and Trace 2 will display the amplitude and phase measurements, respectively. To select the desired active trace, press the DISPLAY FORMAT keys Trace 1 or Trace 2. Meausre the relative amplitude and phase differences of the transformer under test.

2.9.3 Test Results

2.9.3.1 Typical low band transformer amplitude and phase responses are shown in Figures 2-51 and 2-52. Figure 2-53 shows bad amplitude and phase response due to a shorted primary winding. Figure 2-54 shows bad amplitude and phase responses due to an open secondary winding. Figure 2-55 shows another bad response due to a 180 degree phase response.

Table 2-17. HP 3577A Network Analyzer System, Cable Connections

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 3577A Network Analyzer			
OUTPUT	Front Panel	Test Jig, A/P IN	RG-58/223
INPUT R		Test Jig, REF OUT	RG-59/307*
INPUT A		Test Jig, TEST OUT	RG-59/307*
Low Band Transformer Test Jig			
A/P IN	Front Panel	Network Analyzer, OUTPUT	RG-58/223
REF OUT		Network Analyzer, INPUT R	RG-59/307*
TEST OUT		Network Analyzer, INPUT A	RG-59/307*
TRANSFORMER INPUT		Low Band Transformer Under Test	RG-59

* Cables may be amplitude and phase-matched. 50/75 ohm impedance adapters are required if there is an impedance difference between cables and test equipment.

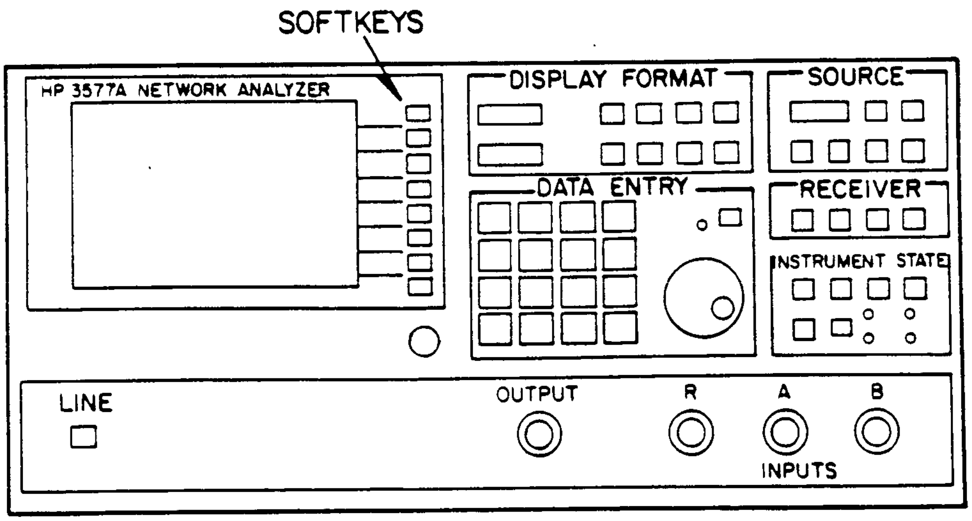


FIGURE 2-48. HP 3577A Netw rk Analyzer, Location of SOFTKEYS, DISPLAY FORMAT Keys, SOURCE Keys, and DATA ENTRY Keys.

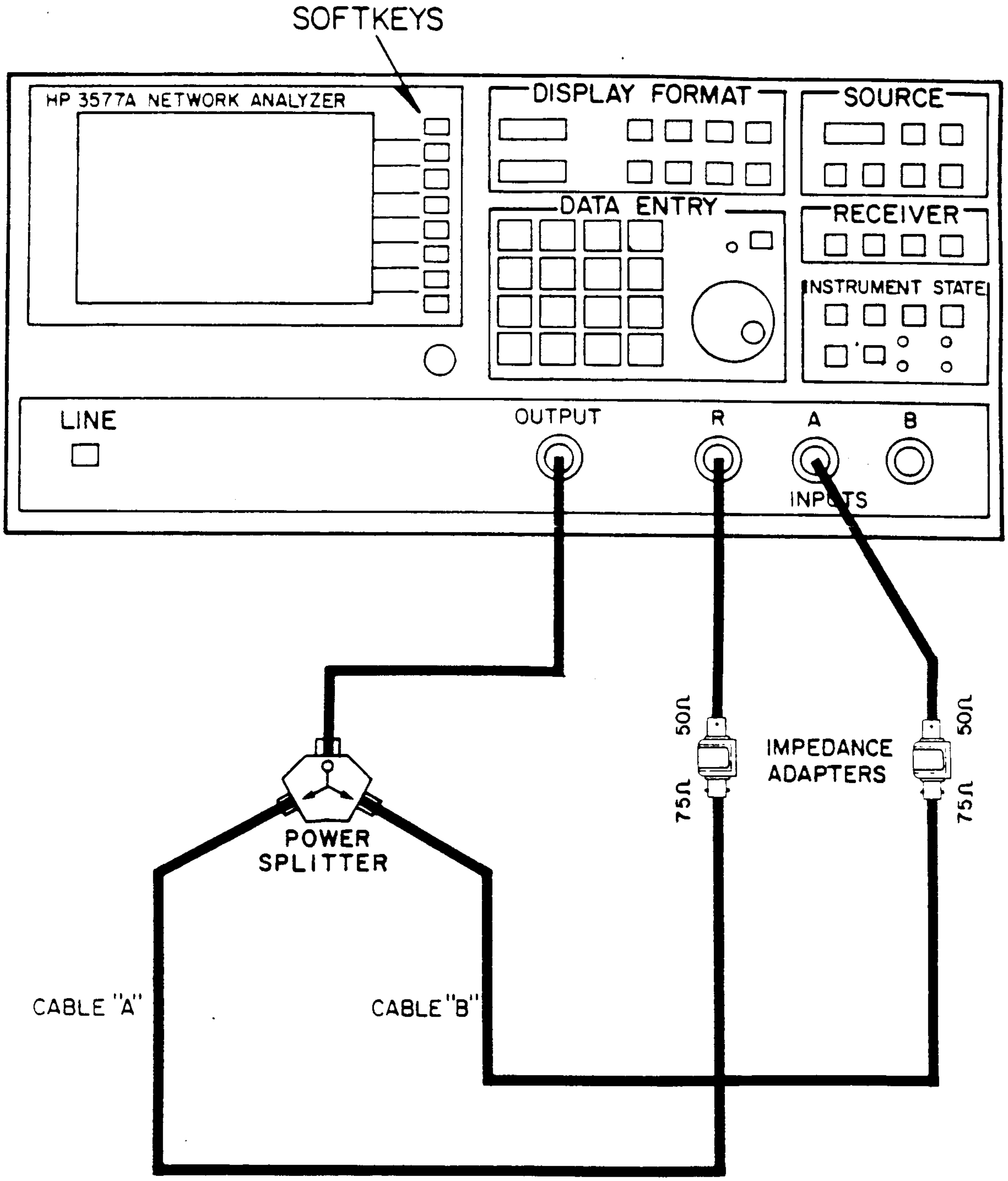


FIGURE 2-49. HP 3577A Network Analyzer Test System, Calibration Setup.

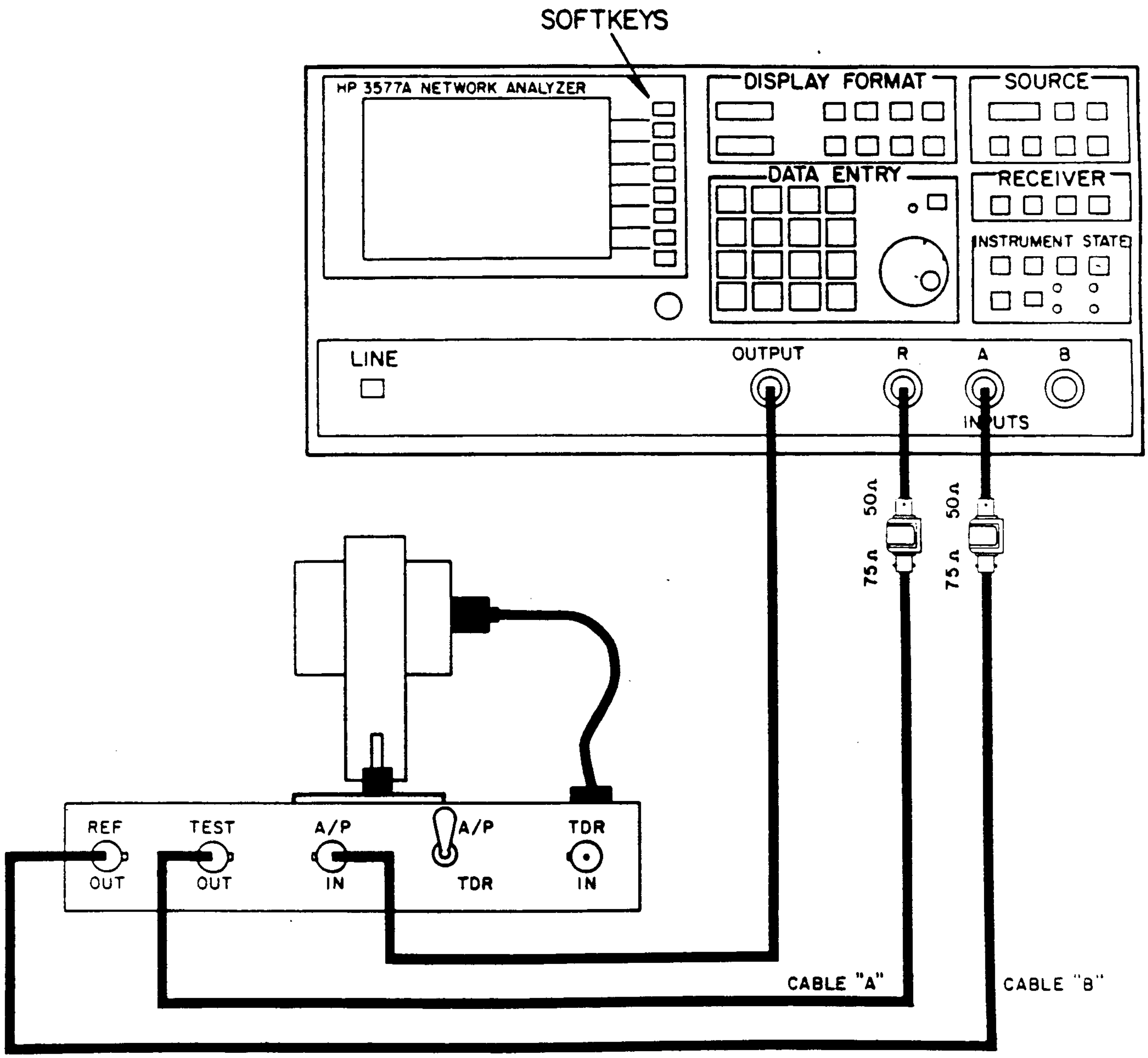
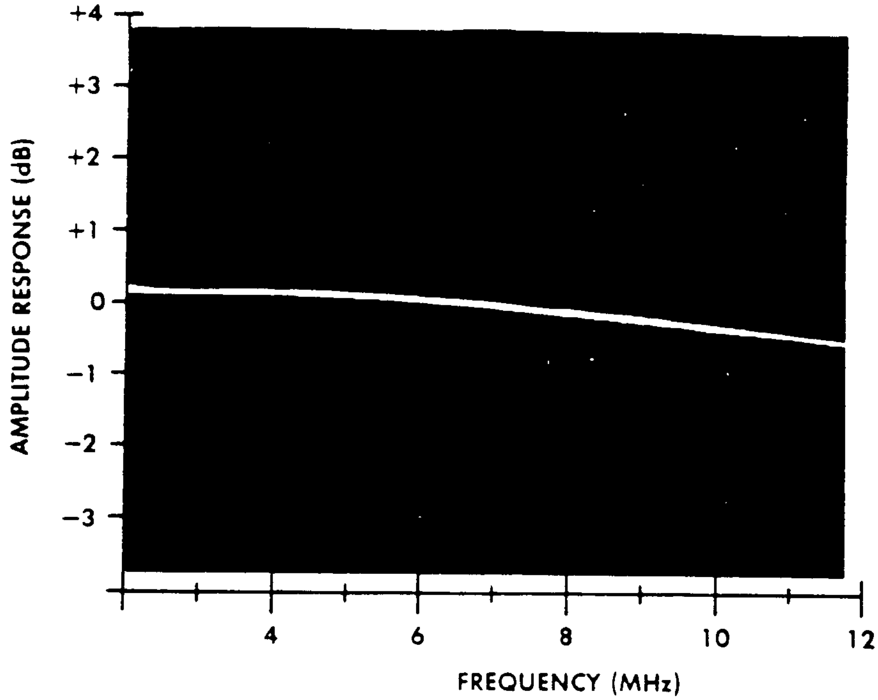


FIGURE 2-50. HP 3577A Network Analyzer System, Low Band Transformer Test Setup.

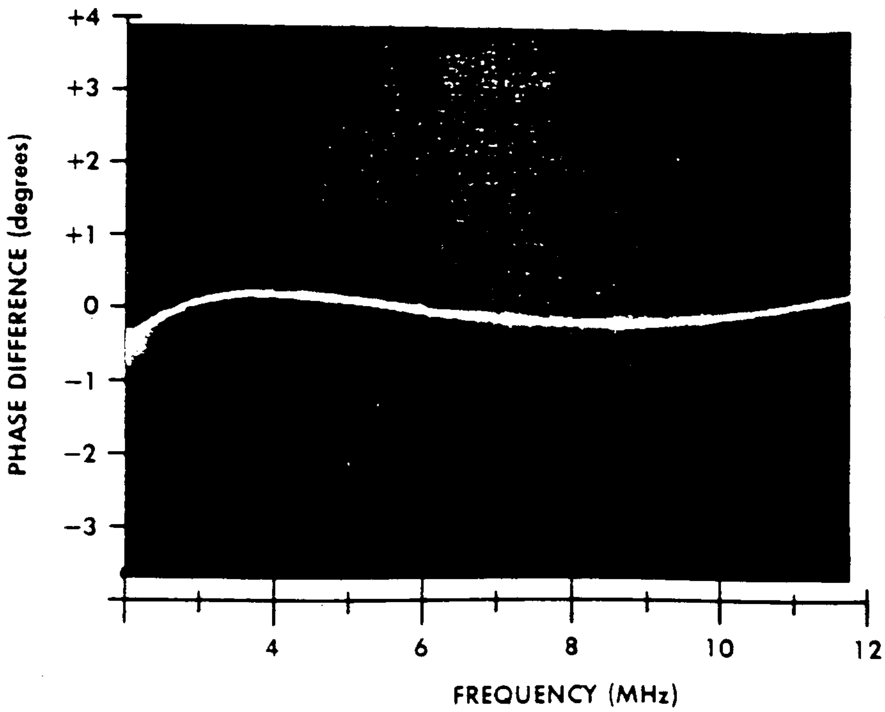


Typical amplitude response for low band transformer testing.

LOW BAND TRANSFORMER
AMPLITUDE AND PHASE
COMPARISON TEST

PHOTO: 1

TRANSFORMER: Serial No. 906



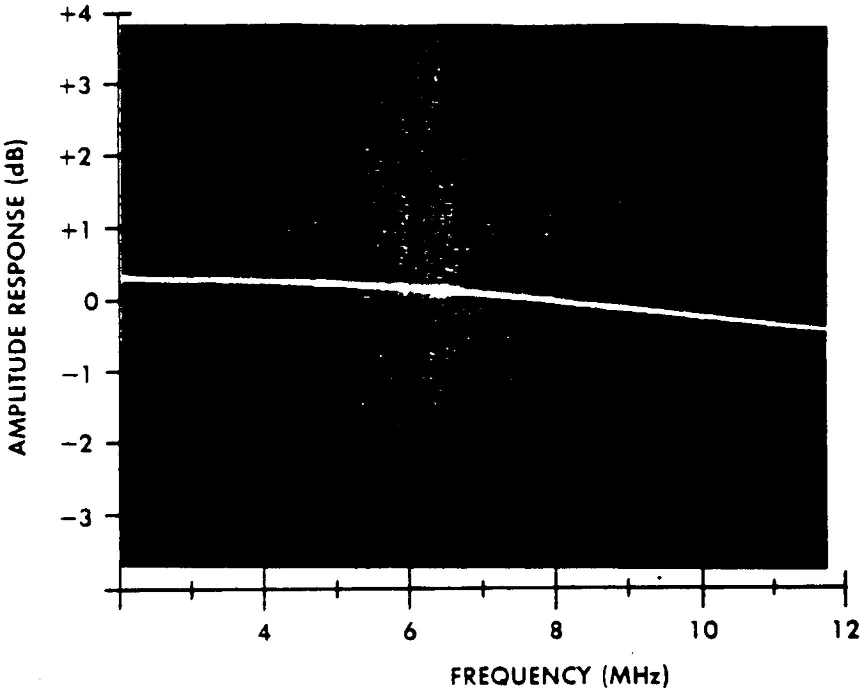
Typical phase response for low band transformer testing.

LOW BAND TRANSFORMER
AMPLITUDE AND PHASE
COMPARISON TEST

PHOTO: 2

TRANSFORMER: Serial No. 906

FIGURE 2-51. Typical Low Band Transf rmer Amplitude and Phas Response (S/N 906).

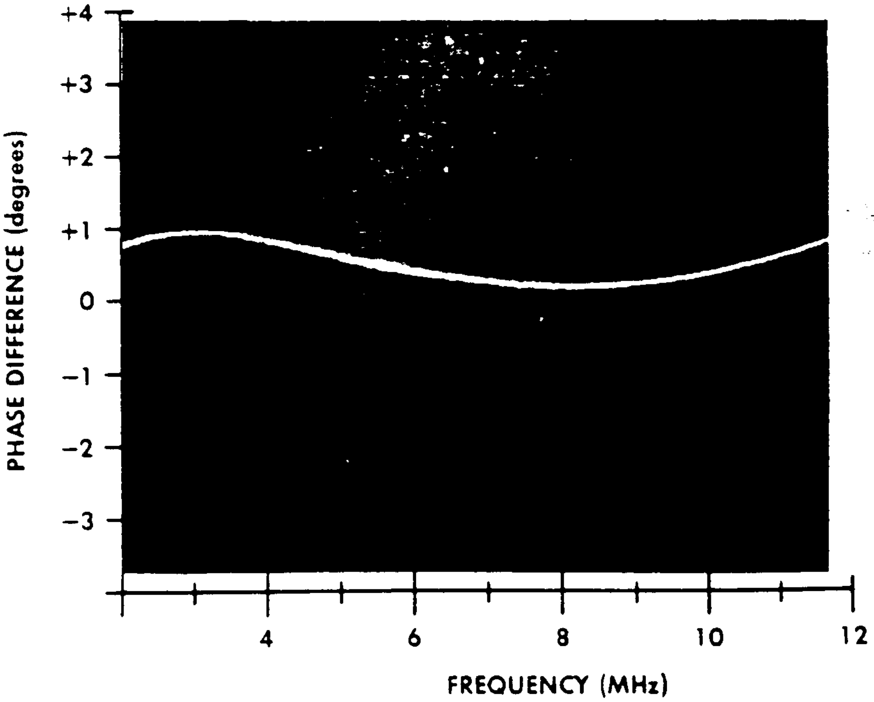


LOW BAND TRANSFORMER AMPLITUDE COMPARISON TEST

PHOTO: 1

TRANSFORMER: Serial No. 243

Typical amplitude response for low band transformer testing.



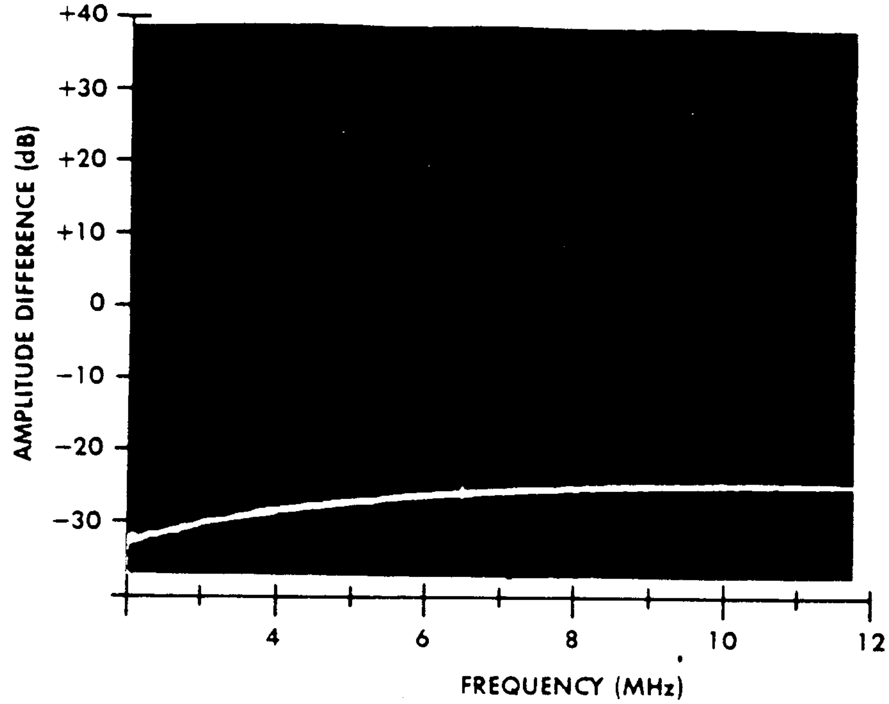
LOW BAND TRANSFORMER PHASE COMPARISON TEST

PHOTO: 2

TRANSFORMER: Serial No. 243

Typical phase response for low band transformer testing.

FIGURE 2-52. Typical Low Band Transformer Amplitude and Phase Respons (S/N 243).

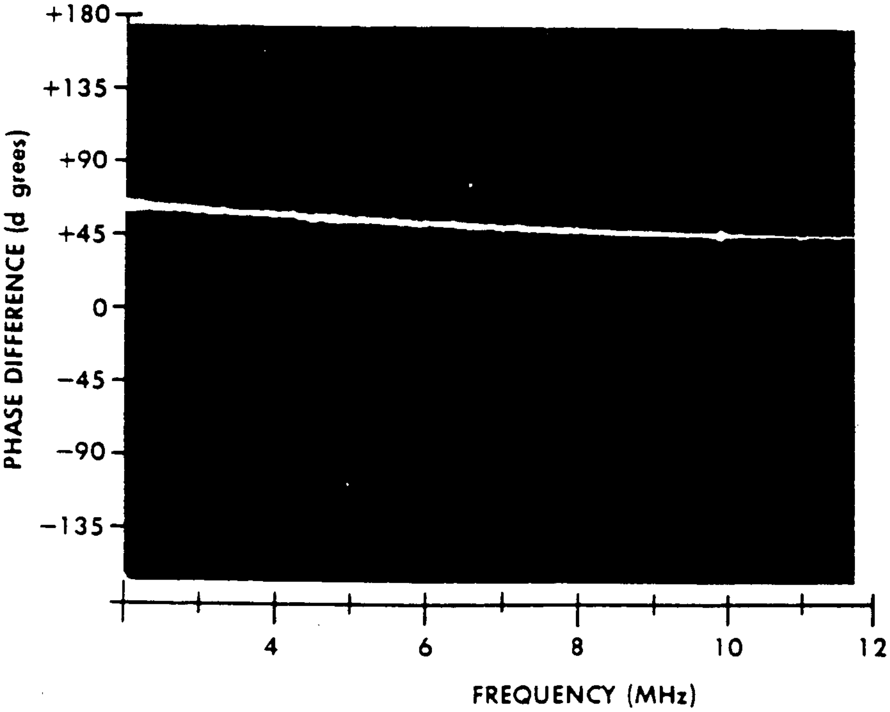


LOW BAND TRANSFORMER AMPLITUDE COMPARISON TEST

PHOTO: 1

TRANSFORMER: Serial N . 889

Bad amplitude response due to a shorted primary winding.



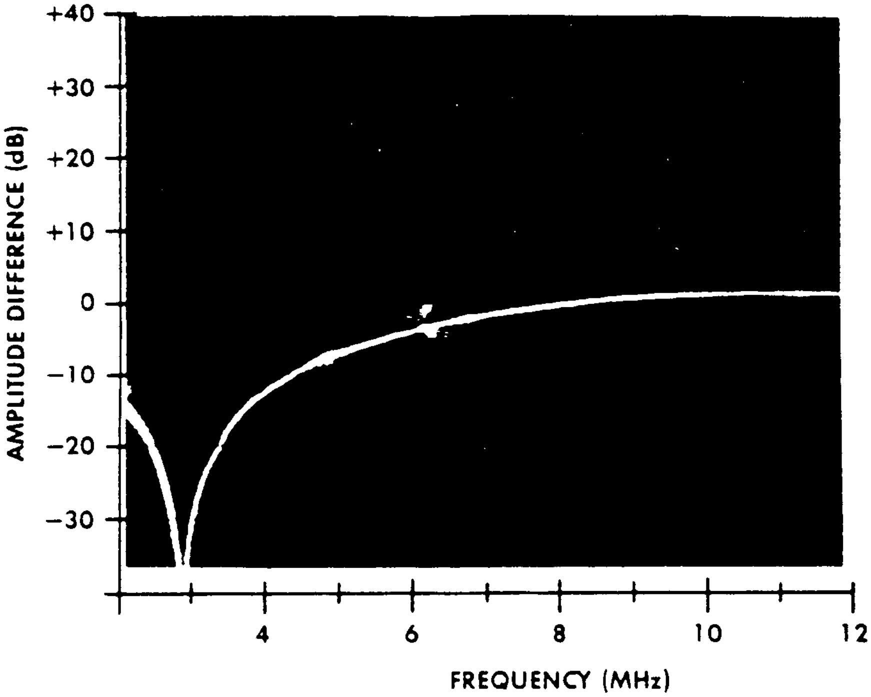
LOW BAND TRANSFORMER PHASE COMPARISON TEST

PHOTO: 2

TRANSFORMER: Serial No. 889

Bad phase response due to a shorted primary winding.

FIGURE 2-53. Bad Low Band Transf rmer Amplitude and Phase Response du to a Shorted Primary Winding.

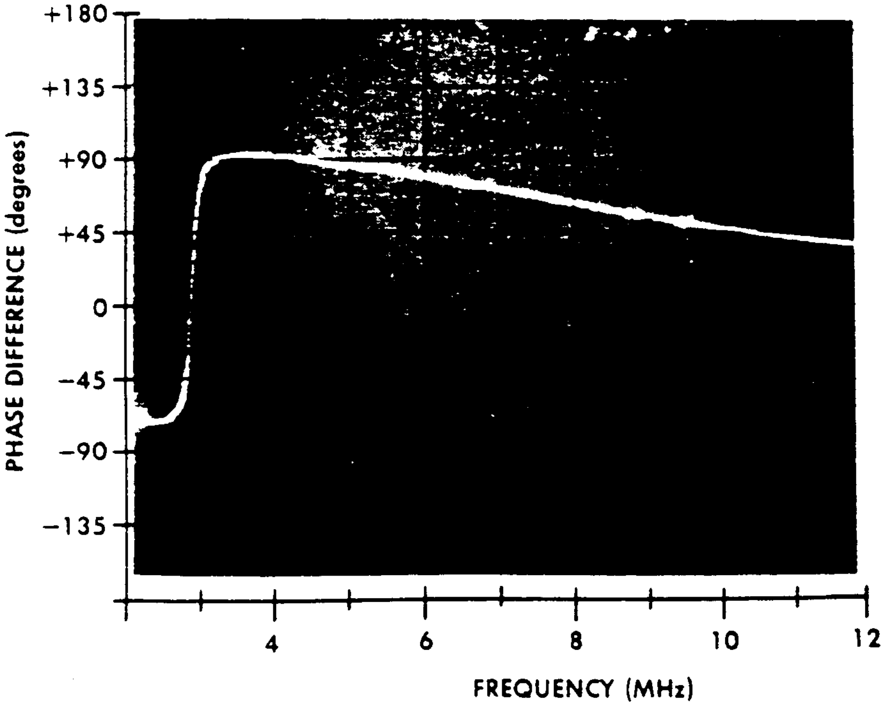


LOW BAND TRANSFORMER AMPLITUDE COMPARISON TEST

PHOTO: 1

TRANSFORMER: Serial No. 823

Bad amplitude response due to an open in the secondary winding.



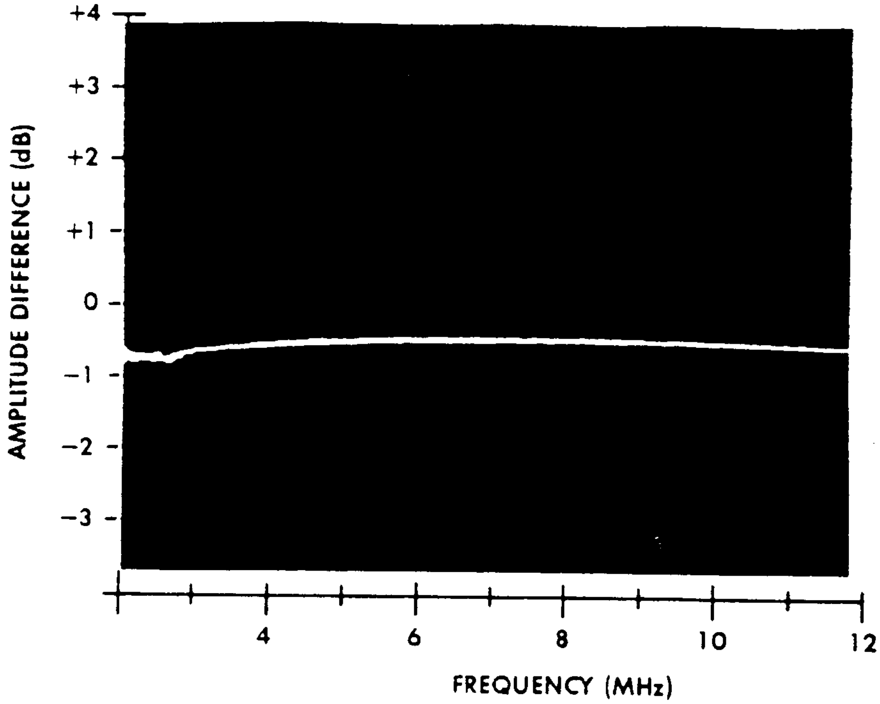
LOW BAND TRANSFORMER PHASE COMPARISON TEST

PHOTO: 2

TRANSFORMER: Serial No. 823

Bad phase response due to an open in the secondary winding.

FIGURE 2-54. Bad Low Band Transformer Amplitude and Phase Response due to an Open Secondary Winding.

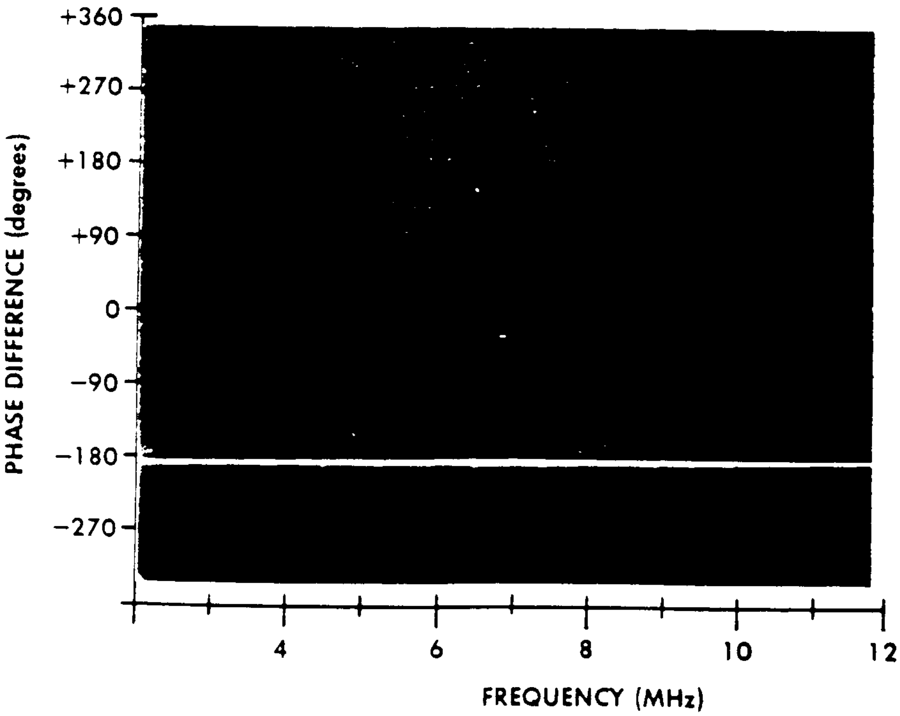


LOW BAND TRANSFORMER AMPLITUDE COMPARISON TEST

PHOTO: 1

TRANSFORMER: Serial No. 995

The amplitude response may look good, however the phase is out of tolerance.



LOW BAND TRANSFORMER PHASE COMPARISON TEST

PHOTO: 2

TRANSFORMER: Serial No. 995

Bad phase response due to the transformer windings being reversed.

FIGURE 2-55. Low Band Transformer Phase Respons du to Reversed Transform r Windings.

2.10 X-Y PLOTTING PROCEDURE

Using the HP 7000A or HP 7035B X-Y Recorder to record the TDR signatures allows for more accurate analysis of the plot. Tables 2-18 and 2-19 describe the front panel controls of the HP 7000A and HP 7035A, respectively. Table 2-19 is a sample plotting procedure using the HP 7000A Plotter with a TEK 1502 TDR.

2.11 CHART RECORDER CALIBRATION

The chart recorder should be adjusted so that the display on the face of the TDR CRT is accurately reproduced on the recorder's X-Y plot. In most cases, the grid on the chart recorder graph paper will not be the same as the grid on the face of the CRT. If the station has existing antenna reference TDR plots, check to see how they were set up and use the same procedure for repeatability. Usually, the graph paper grid is not used; instead, the chart recorder is adjusted so that zero on the CRT results in zero on the recorder chart and full scale on the CRT produces full scale on the recorder. Recorder calibration is performed independently for both the X-axis and Y-axis as follows:

1. Place the HP 1415A TDR SWEEP control in the MANUAL position.
2. Using the concentric MANUAL SCAN knob, position the CRT dot to the left until it is on the zero line.
3. On the chart recorder, adjust the X-axis ZERO control until the chart pen is over the X-axis zero line on the chart.
4. Using the concentric MANUAL SCAN knob again, position the CRT dot to the right until it is over the full scale line.
5. On the chart recorder, adjust the X-axis VERNIER control to set the chart pen over the right end (full scale) of the graph paper.

2.11.1 Observe that the zero and VERNIER controls interact with one another so it will be necessary to repeat steps 1 through 5. Sometimes it is faster to adjust the trace by "splitting-the-difference", e.g., when the CRT dot is repositioned back to zero, the chart pen will usually not return exactly to zero. Rather than adjusting the pen to zero, position the pen half way between its resting position and the zero position. Use the same split-the-difference technique for the full scale adjustment. In this manner, it will reduce the interaction between the zero and full scale adjustment and speed up the final calibration where zero on the CRT equates to zero on the chart and full scale on the CRT equals full scale on the chart recorder.

2.11.2 The same method should be used to calibrate the chart recorder Y-axis. Note that the VERTICAL POSITION control on the TDR is adjusted to move the CRT dot along the vertical (Y-axis) of the CRT screen. On the chart recorder, the Y ZERO and Y VERNIER controls are used to calibrate the chart pen to the TDR CRT in the Y-axis.

2.12 TEST SETUP FOR HP 7035B X-Y RECORDER

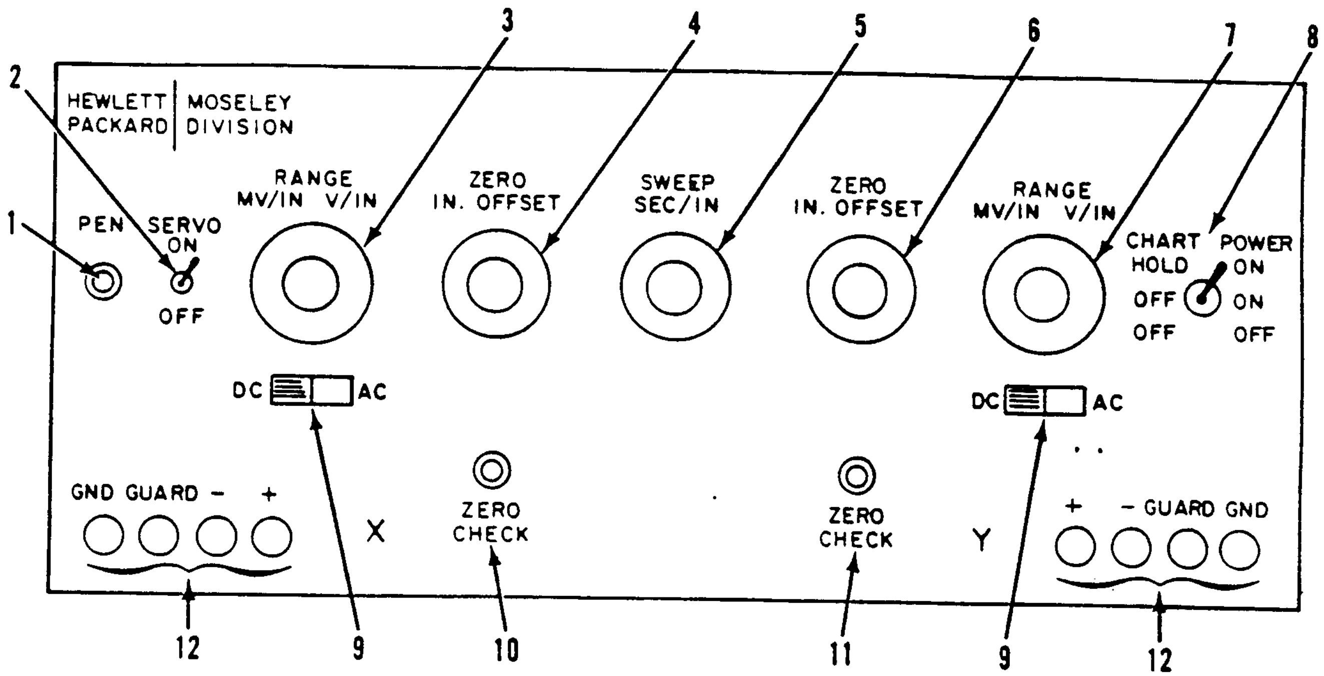
Connect the HP 1415A Time Domain Reflectometer to the HP 7035B X-Y Recorder as follows:

HP 1415A	HP 7035B
Horizontal Output	X-Input (See note)
Vertical Output	Y-Input (See note)

NOTE

Use a BNC to banana plug adapter (Smith Part No. 1686) to connect the TDR to the chart recorder input. Observe that the ground banana pin is identified by a marker tab on the body of the adapter. The ground pin should always be connected to the negative input on the chart recorder. Some banana-to-BNC adapters have an internal DC blocking capacitor between the coax center pin and the high (+) banana pin. This type of adapter is intended for audio or RF applications and will not work on the DC chart recorder input. Usually, these adapters with the internal capacitor are blue in color. If the chart recorder does not function properly, use an ohmmeter to verify DC continuity through the adapter.

Table 2-18. HP 7000A Recorder, Front Panel C ntrols



1. PEN. Push button to raise or lower pen.

2. SERVO. Switch on to activate plotter arm mechanism.

3. X RANGE. Controls the magnitude or limits of the plotter arm's horizontal response.

4. X ZERO. Controls the plotter arm's position along a horizontal axis.

5. SWEEP. Controls the speed at which the plotter arm moves across the chart.

6. Y ZERO. Controls the plotter arm's position along a vertical axis.

7. Y RANGE. Controls the magnitude or limits of the plotter arm's vertical response.

8. CHART/POWER. Switch to OFF/OFF position turns off entire plotter. Switched to OFF/ON position turns on plotter without activating the static hold for the chart. Switched to HOLD/ON position turns on plotter and static hold.

9. DC/AC. Selects range response to a DC or AC input signal.

10. X ZERO CHECK. Press to check horizontal position.

11. Y ZERO CHECK. Press to check vertical position.

12. X-Y INPUT JACKS.

Table 2-19. Plotting Procedures

NOTE

Since an exact plotting procedure would depend on the type of plotter and TDR that the user has available, only an example of how to make X-Y plots is given here. The following example is based on the HP Model 7000A X-Y plotter and TEK 1502 TDR.

1. Connect ground and negative terminals (12) together to eliminate possible noise problems.

2. Switch DC/AC selectors (9) to DC.

3. Switch SERVO (2) off.

4. Switch CHART/POWER control (8) to OFF/ON position.

5. Press PEN button (1) to raise pen off chart surface.

6. Position chart paper.

7. Switch CHART/POWER control (3) to HOLD/ON.

8. Connect X and Y output record cables from TEK 1502 to the corresponding INPUT JACKS (12) of the plotter.

CAUTION

Note the proper polarity orientation of the banana type connector which is used in the X and Y record output connection from the TDR. The word "GROUND" or "GND" should appear on one side of the banana plug. This side must be plugged into the ground plug of the X-Y plotter. Be aware that there are two type of banana connectors. Radio frequency banana plug connectors have a built-in coupling capacitor which does not pass the DC signal that the X-Y plotter receives from the TDR. These connectors are blue in color. The proper banana connectors are black in color and they do not have a coupling capacitor; therefore they will pass the necessary DC signals generated by the TDR which drives the X-Y plotter.

9. Set the plotter controls to the following settings:

CONTROLS	SETTINGS
X RANGE (3)	50 mV/in
X ZERO (4)	0 in offset
Y ZERO (6)	5 in offset
Y RANGE (7)	0.1 V/in

10. To calibrate the Y-axis for a full scale plot, disconnect cable from the TDR input. Switch SERVO (2) on.

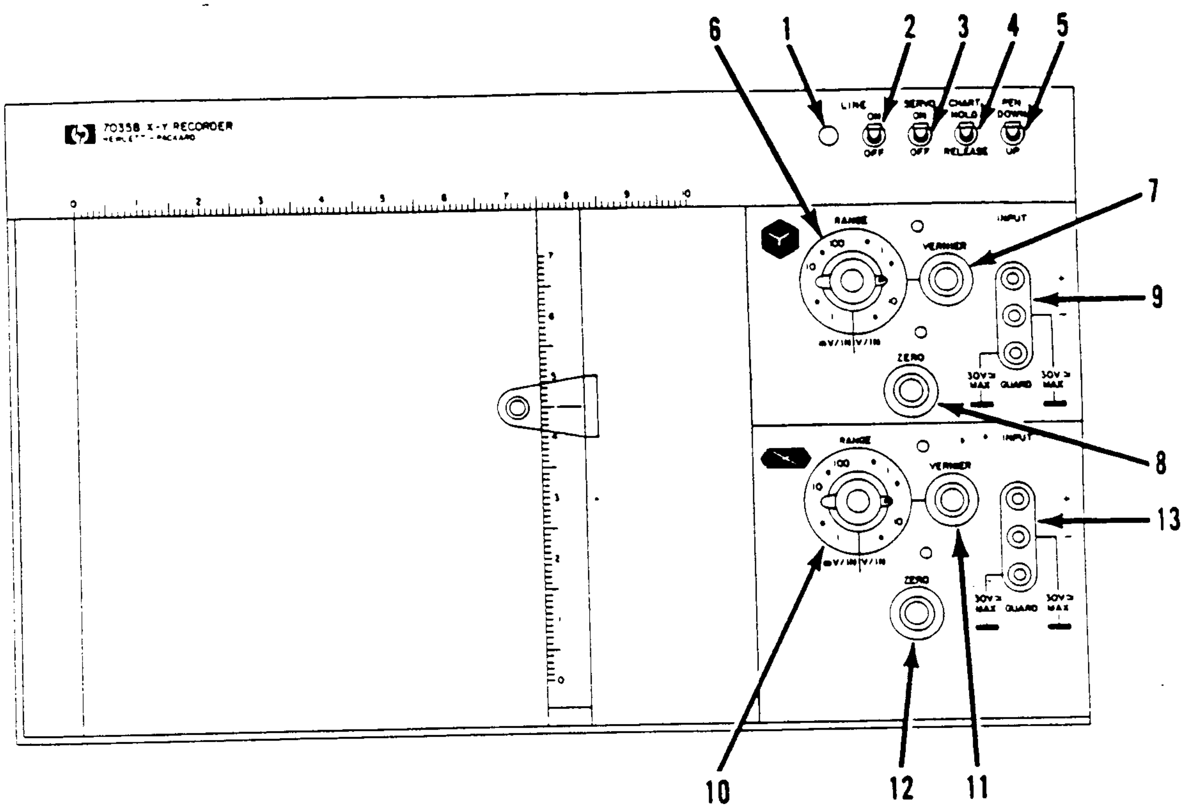
11. Push up and hold recorder switch on the TEK 1502. Adjust the position knob of the TDR to the middle graticule line.

12. Adjust the Y-ZERO variable knob to position the pen on the center graticule line.

Table 2-19. Plotting Procedures – CONT.

13. Adjust the position knob of the TDR to the bottom graticule line. Adjust the Y-RANGE variable knob to position the pen on the bottom graticule line of the graph paper.
14. Switch SERVO (2) off. Release record switch.
15. To calibrate the X-axis for a full scale plot, switch SERVO (2) on. Push up and hold recorder switch on the TEK 1502.
16. Adjust the X-ZERO variable knob to position the pen to the left most graticule line on the graph paper.
17. Release record switch and observe the trace on the TDR display. When the trace reaches the right most graticule line, turn the SERVO switch off. If the pen position did not reach the right edge of graph paper, turn the X-RANGE variable knob slightly clockwise. If pen position went passed the graph paper, turn the X-RANGE variable slightly counterclockwise. This procedure may take several fine adjustments to achieve the proper positioning.
18. Push up and hold the record switch. Turn SERVO (2) switch on. Repeat step 17 until the plotter display matches the TDR display.
19. The plotter is now calibrated for a full scale plot. Connect test cable to the TDR input. Push up and hold TEK 1502 recorder switch. Press PEN button (1) to lower pen to chart surface. Release TEK 1502 recorder switch to commence plotting. As the pen nears the end of the plot, it might be necessary to press the PEN button (1) to raise the pen off the chart. This will ensure that the pen does not write off the chart's margin or leave an ink trace across the chart when the plotter arm resets at the end of the plot.

Table 2-20. HP 7035B Recorder, Front Panel Controls



1. Indicator Lamp. When illuminated, power is available to recorder circuits.

2. LINE Switch. ON – All circuits are energized except Servo system; OFF – All power to recorder is off.

3. SERVO Switch. ON – Servo system is energized; OFF – Servo system is deenergized (standby).

4. CHART Switch. HOLD – Activates chart paper holddown; RELEASE – Releases chart paper.

5. PEN Switch. DOWN – Pen is on paper for tracing; UP – Pen is raised off paper for no tracing.

NOTE

Pen may be controlled automatically by external equipment, using connector on back of recorder.

6. RANGE Selector. Select five calibrated or five uncalibrated range positions for Y-axis.

7. VERNIER Control. Adjust sensitivity on uncalibrated RANGE positions for Y-axis.

8. ZERO Control. Multi-turn control to adjust position of pen for Y-axis.

9. INPUT Terminals. To two terminals for polarized Y-axis signal input. Bottom terminal for guard input (removeable shorting strap between negative and guard inputs).

Table 2-20. HP 7035B Recorder, Front Panel Controls – CONT.

10. RANGE Selector. Selects five calibrated or five uncalibrated range positions for X-axis.
11. VERNIER CONTROL. Adjusts sensitivity on uncalibrated RANGE position for X-axis.
12. ZERO Control. Multi-turn control to adjust position of pen for X-axis.
13. INPUT Terminals. Top two terminals for polarized X-axis signal input. Bottom terminal for guard input (removeable shorting strap between negative and guard input) **NOTE** X- and Y-axis inputs may be inputted by connectors on rear of recorder.

CHAPTER 3
SMITH CHART/VSWR TESTS

3.1 INTRODUCTION

Antenna characteristics, such as impedance, are a function of frequency. The Smith chart test utilizes the HP 8414A Polar Display to measure antenna impedances over the nominal test frequencies of 2 to 12 MHz for low band and 8 to 32 MHz for high band. The HP 8414A is a plug-in display that is used in place of the HP 8412A Phase/Magnitude Display. Not all CDAA sites have the HP 8414A, however the HP 8412A may be used to measure the VSWR of the antenna element. The HP 3577A has greater capability and can also be used for the Smith chart/VSWR tests. Because of the additional features contained in the HP 3577A, the separate frequency counter, signal generator (HP 8601A), DC power supply and phase-matched cables can be eliminated. The Smith chart plot of the antenna allows rapid reading of the resistive and reactive components of the impedance, and also the power transfer efficiency or VSWR of the antenna element.

3.2 SMITH CHART GRAPHICAL ANALYSIS

A full detailed Smith chart is shown in Figure 3-1. At first glance, the Smith chart appears to be a formidable array of circles and curved lines and quite confusing. However, the following discussion (Paragraph 3.2.1) will take the chart apart and functionally describe its parts to provide a comprehensive understanding of its purpose. A step-by-step description on how to use the chart is given in Paragraph 3.2.2. In order to accommodate those who desire a more fundamental understanding of the Smith chart, a rigorous but brief explanation of its development is provided for background information in Paragraph 3.3 followed by a more simplified interpretation in Paragraph 3.4.

3.2.1 Understanding the Smith Chart. The Smith chart shown in Figure 3-1 is a circular graphic display that contains various circular scales. The horizontal line through the center of the circle, marked RESISTANCE COMPONENT is the only straight line on the chart. This line is also referred to as the Real Axis. Centered on the Real Axis are Constant Resistance Circles each of which is tangent to the rim of the circle at the infinite resistance point as shown in Figure 3-2. All points along each Constant Resistance Circle have the same resistive value as the point where it crosses the Real Axis. All resistance components from zero to infinity can be plotted.

3.2.1.1 Superimposed over the Constant Resistance Circles are segments of circles tangent to the straight line Real Axis at the infinite resistance point with the circles centered off the edge of the chart as illustrated in Figure 3-3. These circles are Constant Reactance Circles. The outer rim of the chart is called the Reactance Axis and is scaled as relative reactance. Points along each Constant Reactance Circle segment have the same relative value as the point where it intersects the Reactance Axis on the rim of the chart. All points above the Real Axis contain an INDUCTIVE REACTANCE COMPONENT and all points below the Real Axis contain a CAPACITIVE REACTANCE COMPONENT. Since the scales go from zero to infinity, complex impedances can be plotted.

3.2.1.2 Peripheral scales around the outside circumference of the chart (Refer to Figure 3-1) relate to quantities which change with position along a transmission line. The two outer scales are calibrated in terms of wavelength along the transmission line. The scale in the clockwise direction is WAVELENGTH TOWARD GENERATOR and the scale in the counter-clockwise direction is WAVELENGTH TOWARD LOAD. The circumference of the chart represents one-half wavelength. The two inner scales represent ANGLE OF REFLECTION COEFFICIENT in degrees and ANGLE OF TRANSMISSION COEFFICIENT in degrees.

3.2.1.3 Several relevant parameters related to the magnitude of reflections from the load are plotted as RADIALLY SCALED PARAMETERS and are scaled under the circular Smith chart. These parameters are:

1. Attenuation in 1 db steps
2. Reflection loss in db
3. VSWR in db
4. Coefficient of reflection
5. VSWR.

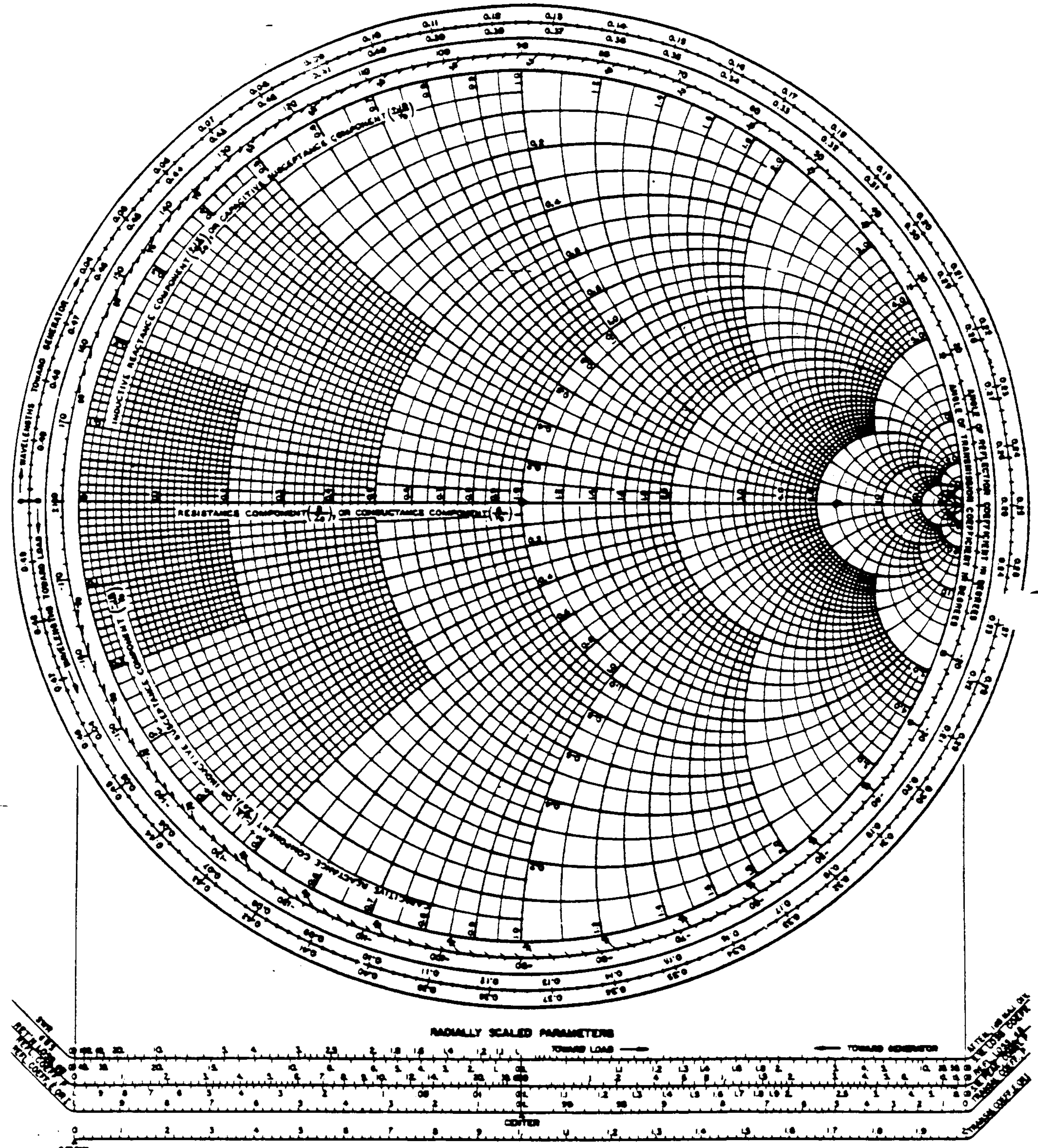


FIGURE 3-1. Smith Chart.

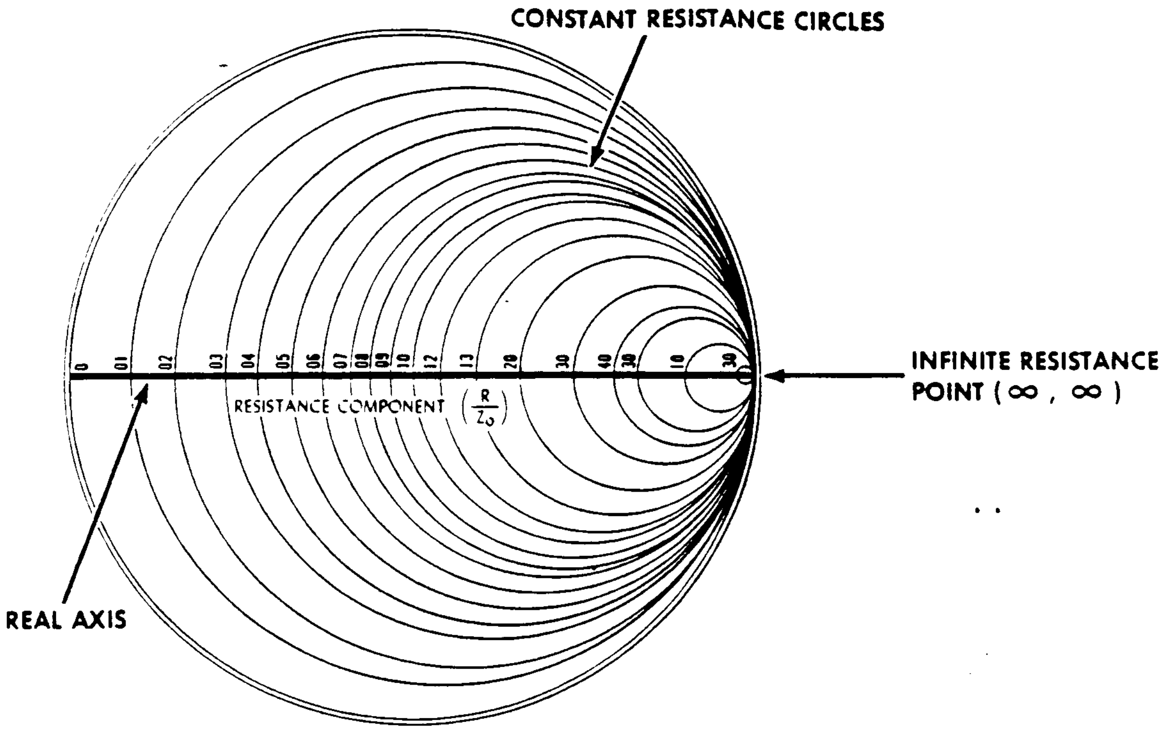


FIGURE 3-2. Smith Chart Resistance Scales.

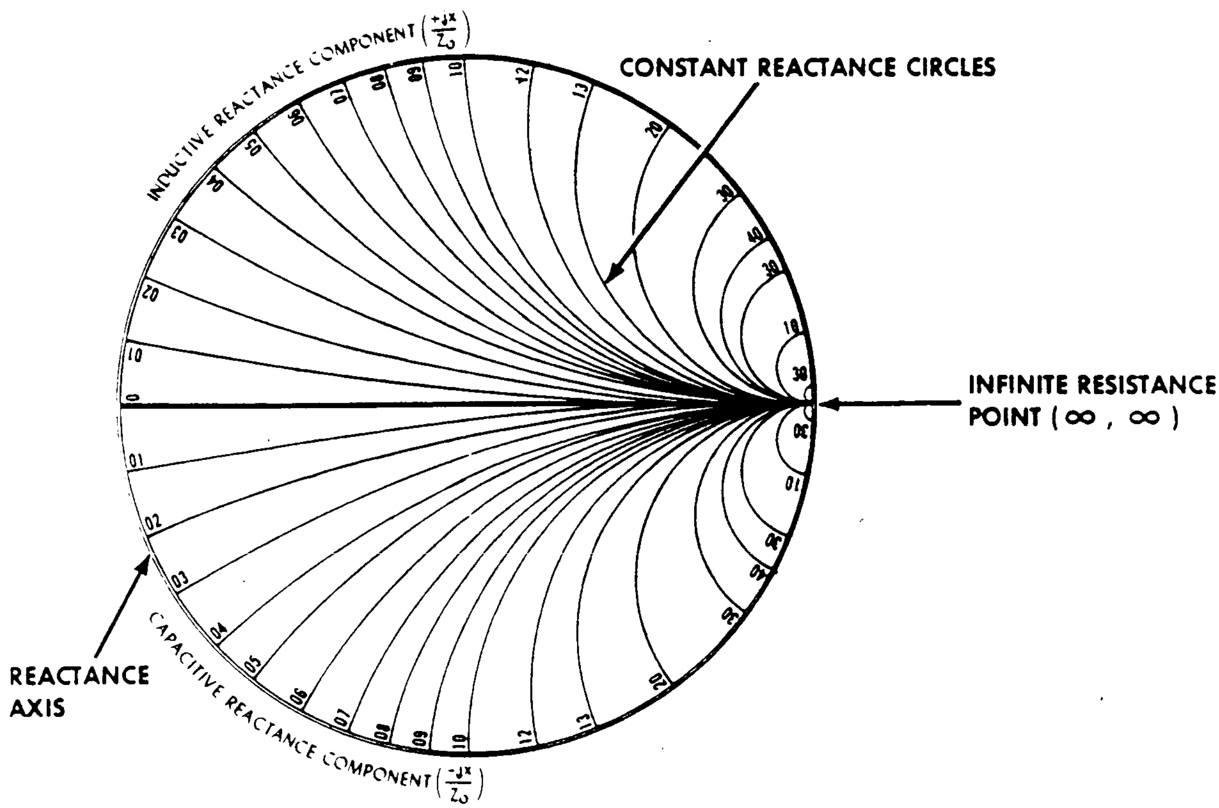


FIGURE 3-3. Smith Chart Reactance Scal s.

3.2.2 Using the Smith Chart. When plotting impedances on the Smith chart, normalized values must be u. Normalized impedance is the actual impedance divided by the characteristic impedance of the transmission line. Normalization is required to make the Smith chart applicable to all possible values of characteristic impedances of transmission lines.

Examples: For a 50 ohm coaxial cable, the normalized value is 50/50 or 1

An impedance of 150 ohms would have a normalized value of 150/50 = 3.0 ohms

Similarly, z = 0.7 ohms (lower case z being a normalized value) corresponds to a value 0.7 x 50 = 35 ohms

As stated, any complex impedance can be plotted on the chart.

Example: Assume the load on a 50 ohm coaxial cable (transmission line) is 42.5 − j31.5 ohms. When normalized the value equals 0.85 −j0.63 ohms.

First, using Figure 3-4, note 0.85 on the real axis and locate the corresponding Constant Resistance Circle. Next, find 0.63 on the periphery of the lower half of the chart since the quantity (−j) indicates a capacitive reaction component. Note the Constant Reactance Circle representing −j0.63. The point where the Constant Resistance Circle intersects the Constant Reactance Circle represents the complex impedance 0.85 − j0.63.

3.2.2.1 Draw a radial line from the center (1.0) of the chart through the impedance point to the outer rim. Using this point 1.0 on the Real Axis as the center, draw a circle that passes through the impedance point 0.85 −j0.63. This circle is called the Constant Gamma Circle and its radius is equal to the Coefficient of Reflection. Observe that the Constant Gamma Circle intersects the Real Axis at two points. To the right, the point of intersection represents the stan-- wave ratio (SWR) and in this example equals 2.0. This means that the voltage measured at this point along transmission line would be maximum. The second intersection to the left of center, one-quarter wavelength away, is the minimum voltage point and is equal to the reciprocal of the SWR.

3.2.2.2 The points where the radial line intersects the ANGLE OF COEFFICIENT scale (peripheral) represents the phase angle in degrees of the coefficient of reflection. This is the angle by which the reflective wave leads or lags the incident (outgoing) wave. It should be noted that when the reflected and incident waves add in phase (maximum voltage), the impedance is resistive and greater than the characteristic impedance of the transmission line and the phase angle of the coefficient of reflection is zero. Also observe that moving in a clockwise direction (toward the generator) the reflective voltage lags the incident voltage and the phase angle is negative for the first quarter wavelength and the impedance of the reactive component is negative or capacitive. The reflective and incident waves at the quarter wavelength (90°) point are out of phase with the phase angle of coefficient of reflection at 180 degrees. Moving further in the clockwise direction the voltages are more in phase and between one-quarter and one-half wavelength from the voltage maximum the reactive component is inductive. The reflective wave leads the incident wave and the reflective coefficient has a positive angle.

3.3 FUNDAMENTAL DEVELOPMENT OF THE SMITH CHART

Figure 3-5 shows a mathematically involved version of a Smith chart. In this figure, the chart is represented by the unit circle described by the $\bar{\Gamma}$ (Reflection Coefficient) Plane where

$$\bar{\Gamma} = \Gamma r + j\Gamma i = (\Gamma r, \Gamma i) = |\bar{\Gamma}| \exp(j\phi) = \Gamma < \phi \quad [1].$$

The normalized impedance (z) is defined by and related to the Γ plane by the following equation:

$$\bar{Z} = r + jx = (r, x) = \bar{Z}_l/\bar{Z}_o = (1 + \bar{\Gamma})/(1 - \bar{\Gamma}) \quad [2]$$

where r is the resistance component of impedance; j is the unit imaginary number (square-root of −1); x is the reactive component; $\bar{Z}_l$ is the load impedance, and $\bar{Z}_o$ is the characteristic impedance.

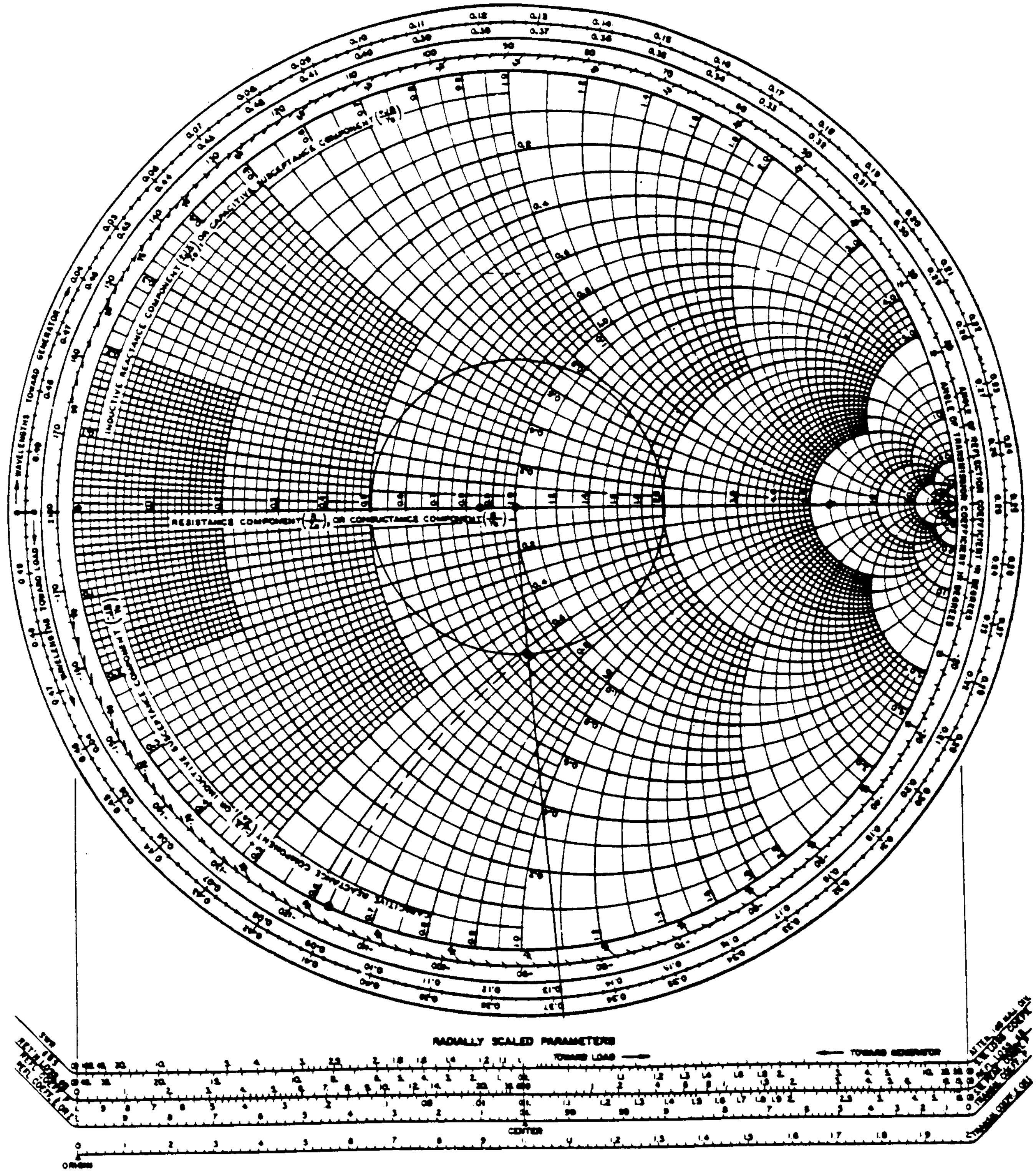


FIGURE 3-4. Plotting a Complex Impedance on th Smith Chart.

3.3.1 The circles of constant r and x, shown on the Smith charts of Figures 3-5 and 3-6, were derived from equatio [2] by solving for, and equating, real and imaginary components. The derivation is not done here, but the resultant equalities are:

$$\left(\Gamma r - \frac{r}{1+r}\right)^2 + \Gamma i^2 = \left(\frac{1}{1+r}\right)^2 \qquad [3]$$

$$\left(\Gamma r - 1\right)^2 + \left(\Gamma i - \frac{1}{x}\right)^2 = \left(\frac{1}{x}\right)^2 \qquad [4]$$

By recognizing the "form" of equations [3] and [4], note the squared terms, we see that they describe a family of circles in the $\bar{\Gamma}$ plane, where each circle is associated with a specific (constant) value of r of x. For illustrative purposes, circles were drawn for r = (0, 0.5, 1, 2) and x = (0, 0.5, 1, 2), as shown in Figure 3-5.

3.3.2 The Smith chart also contains other information such as the angle of the reflection coefficient (ϕ), which indicates the phase of $\bar{\Gamma}$, i.e., $\bar{\Gamma} = \Gamma < \phi$. The angle of reflection coefficient is related to $\bar{\Gamma}$ and $\bar{z}$ by the following equation:

$$\phi = \left[-jLn\left(\frac{\bar{\Gamma}}{|\bar{\Gamma}|}\right)\right] = \left[-jLn\left\{\frac{(\bar{z}-1)}{(\bar{z}+1)\ |\bar{\Gamma}|}\right\}\right] \qquad [5]$$

The outermost scales of a Smith chart indicate the distance, in terms of wavelengths, that the normalized impedance (z) is from either the generator or load. Thus a change in cable length translates into a rotation of the display pattern. The antenna power transfer efficiency or VSWR, denoted by (s), can be determined for any $\bar{\Gamma}o$, as shown in Figure 3-5. The VSWR of $\bar{\Gamma}o$ is found by rotating $\bar{\Gamma}o$ to the $\Gamma r >1$ half-axis. The 'tip' of $\bar{\Gamma}$ as read on the $\bar{\Gamma}r >1$ half-axis gives the value of s_O, which is the VSWR of $\bar{\Gamma}o$.

NOTE

Refering to Figure 3-5, notice that the normalized impedance of $\bar{\Gamma}o$ is $z_O = (r_O, x_O) = (1, 2)$.

3.4 SIMPLIFIED INTERPRETATION OF THE SMITH CHART

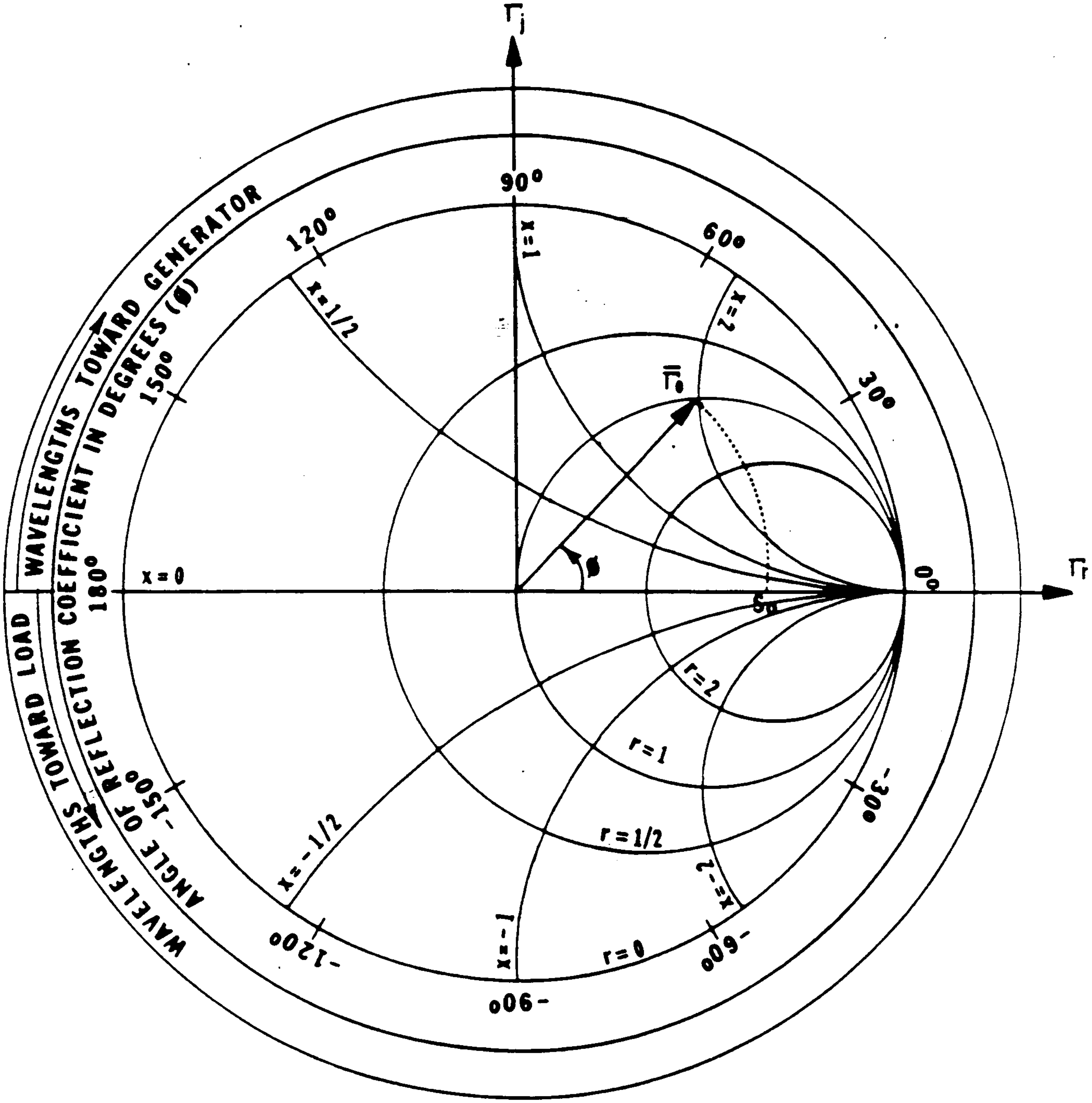
A simplified interpretation of the Smith chart is illustrated in Figure 3-6. In this case, the Smith chart is interpreted in general terms of families of constant r and x circles which comprise the normalized impedance z(f) = z = r + jx = (r, x) (The Γ plane is ignored). Basic circuit analysis dictates that when x is negative (lower half-plane), the reactance is capacitive; if x is positive (upper half-plane), the reactance is inductive; and if x =0, then there are no reactive components and z is a pure resistance (if r ≠ 0).

3.4.1 In this interpretation any impedance $\bar{z}_O = (r_O, x_O)$ at a frequency f_O located in the upper half-plane has an inductive component denoted by $\bar{z}_O = (r_O, +x_O)$; while any impedance located in the lower half-plane has a capacitive component denoted by $\bar{z}_O = (r_O, -x_O)$. Any point located on the horizontal axis is purely resistive and has no reactance, with the exception of point C, which has an infinite resistance and reactance. Thus by using this simplified interpretation coupled with a basic understanding of what the angle of reflection coefficient (ϕ) represents, and how VSWR(s) is determined (as explained in paragraph 3.3.2), one can quickly perform an approximate analysis of a Smith chart display.

3.4.2 For the seriously interested reader, a rudimentary proof of the infinite impedance $\bar{z}_C$ = (infinity, infinity), at point C can be performed by applying either equations [3] or [4] under the conditions r = infinity and x = infinity; which when applied to equation [3] yields: $\bar{\Gamma} = \Gamma r - j\Gamma i = (\Gamma r, \Gamma i) = 1 + j0 = (1,0)$ = Point C on the $\bar{\Gamma}$ plane. (Refer to Figure 3-5).

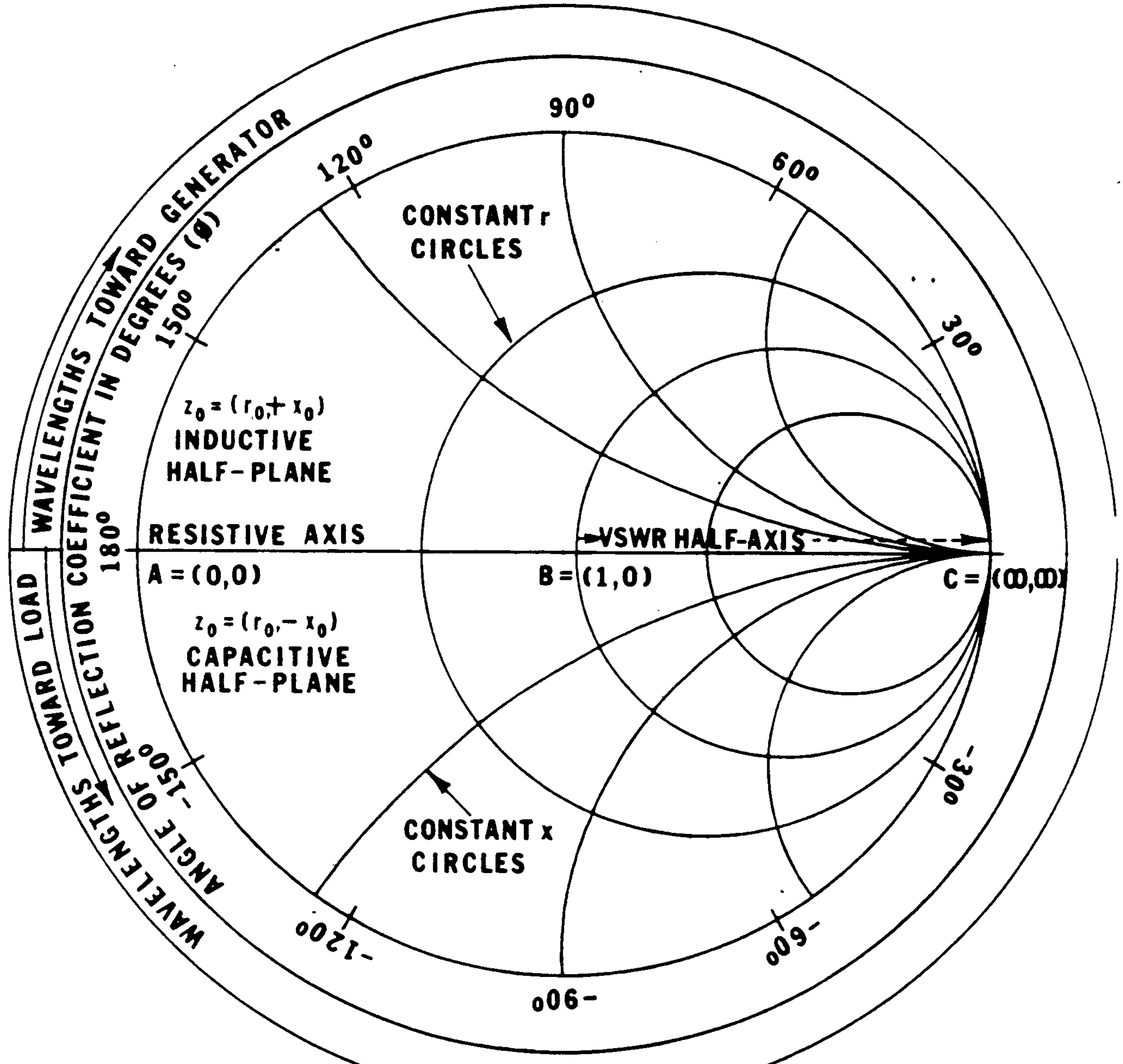
3.5 TEST DESCRIPTION

Problems which cannot be easily detected using the TDR test, such as non-uniform grounding or cable lengt produce noticeable changes in the Smith chart display. Two Smith chart tests using different network analyzers. HP 8407A/8414A and HP 3577A, are described herein.



$$\bar{\Gamma} = \Gamma_r + j\,\Gamma_i = |\Gamma| \exp(j\phi) = \Gamma \angle \phi$$

FIGURE 3-5. Smith Chart in Terms of the $\bar{\Gamma}$ Plan .



$z = r + jx = (r, x)$

FIGURE 3-6. Smith Chart in Terms of th Gen ral $\bar{Z}$ Plane.

3.5.1 The Smith chart test setup using HP 8407A/8414A is shown in Figure 3-7. The output of the sweep oscillator is split into two equal amplitude and phase-coherent or phase-matched signals: reference and test signal. The lower test signal passes through the directional coupler to the antenna under test. Normally, the antenna causes a reflection of the signal which then returns back through the transmission line into the directional coupler and out through the reflected port. The reflected signal then goes into the test channel of the network analyzer. On the other hand, the reference signal travels through several transmission lines and impedance adapters before entering the reference channel of the network analyzer. This is done to add phase delays to the reference signal equal to the phase delays that the test signal accumulates through the test system. The network analyzer then measures the amplitude and phase differences between the reflected test signal and the reference signal. The test equipment control settings for HP 8407A/8414A system are given in Table 3-1 and cable connections are summarized in Table 3-2.

3.5.2 The Smith chart test setup using the HP 3577A is shown in Figure 3-8. The output of the HP 3577A Network Analyzer is split into two signals: reference and test. The test signal passes through the "source" then "load" ports of the directional bridge, travels to the antenna under test, is reflected by the antenna, returns back through the "load" port, and out through the "reflected" port. The reflected signal then goes into the test channel of the HP 3577A Network Analyzer. The reference signal travels through one short cable. By use of the normalizing feature of the HP 3577A the reference cable is made equal to the test cable (phase-matched) inside the HP 3577A and all measurements are made with this in memory. The network analyzer then measures the amplitude and phase differences between the reflected test signal and the reference signal. By use of the normalizing feature on the new HP 3577A Network Analyzer, long phase-matched cables are eliminated. For control settings and cable connections for the HP 3577A refer to Tables 3-3 and 3-4, respectively.

3.5.3 Test Setups/Calibration. Again refer to Figure 3-7 or Figure 3-8 showing the external connections for the Smith chart test setups and calibration.

3.5.3.1 HP 8407A/8414A Network Analyzer Setup/Calibration. For HP 8407A/8414A setup, the 160′ cable run between two antennas is connected to the RG-85 cable adapters on adjacent antenna elements to form the reference path. The operator in the goniometer room makes the necessary reference and test path connections for the Smith chart test unit at the back of the respective multicouplers via the RG-12 transmission lines leading to the test and reference antenna elements. The calibration procedure requires for one person in the antenna field to terminate the end of the RG-11 cable on the test antenna with a perfectly matched load (75 ohms, typically), a short, and an open. At the same time, a Smith chart test unit operator in the goniometer room adjusts his equipment by calibrating the polar display's center using the CENTERING button and dial controls. Also cable lengths are checked to meet the following conditions:

CONDITIONS
(For both HP 8407A/HP 8414A and HP 3577A Systems)

Termination Used on Test Antenna	Polar Display Calibration Point (Points A, B, C; refer to Figure 3-6)
Short Circuit	A: z = (0, 0)
Perfectly Matched Load (75 ohm)	B: z = (1, 0)
Open Circuit	C: z= (infinity, infinity)

In order to meet these conditions (especially the calibration points), the operator in the goniometer room will need to change either the length of the test or reference channel, by using coaxial cable extensions of various lengths on either channel, so as to match their lengths and thereby reduce the "sweep area" or "play" of the CRT cursor. Ideally, the sweep area of the cursor should approach zero as the difference between test and reference channel lengths approaches zero. However in practice, the best that can be achieved is to match the channel lengths so as to obtain a small circular sweep of about a quarter-inch in diameter and centered about the various calibration points for a given termination installed on the test antenna.

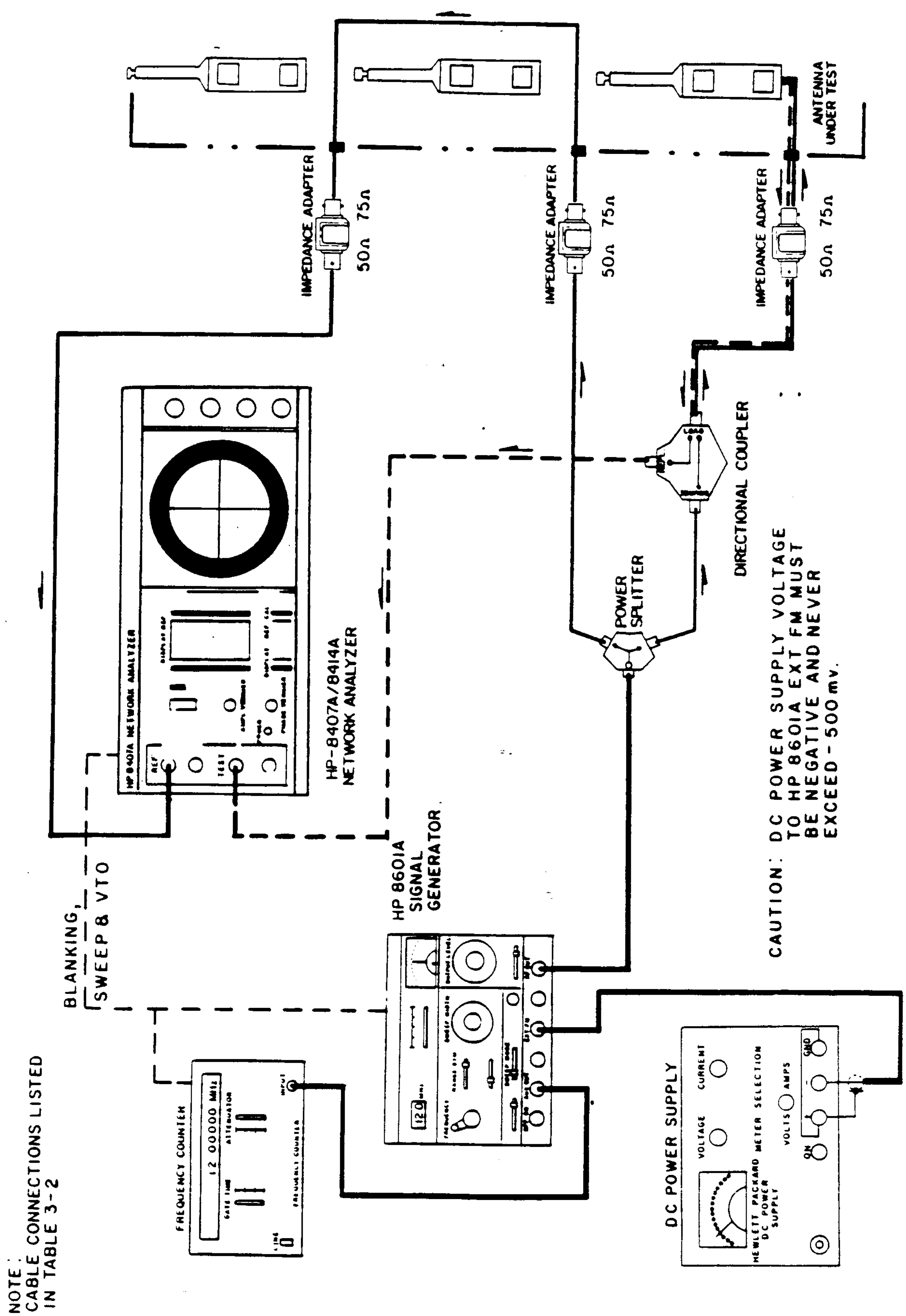


FIGURE 3-7. Simplified Driving Point In ance (Smith Chart), Test Diagram.

Table 3-1. HP 8407A/8414A Network Analyzer System, C ntrol Settings

CONTROLS	SETTING
HP 8407A/8414A Network Analyzer	
REF CHAN LEVEL ADJ	As required to stay in "OPERATE" range
DISPLAY REFERENCE	As required to obtain trace
VERTICAL POSITION	As required to center trace vertically with 75 ohm termination
HORIZONTAL POSITION	As required to center trace horizontally with 75 ohm termination
INTENSITY	As required
FOCUS	As required
HP 8601A Generator/Sweeper	
OUTPUT LEVEL	−30 dBm
SWEEP	VIDEO
FREQUENCY	As required to obtain 2-12 MHz (low band) and 8-30 MHz (high band) across display
SWEEP MODE	FREE, MANUAL
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
DC Power Supply	
OUTPUT *	Approximately −200 mV for a 2 MHz start frequency. (Do not adjust to more than −500 mV and never apply a positive voltage to the EXT FM input on the HP 8601A.)
Frequency Counter	
INPUT	Scale for 2 to 30 MHz frequency range

* If a banana plug to BNC adapter is used on the power supply output, verify the DC continuity between the center pin of the BNC connector and the high (+) banana pin. (Some adapters contain a DC blocking capacitor. These adapters are usually blue.)

CAUTION

If a banana plug to BNC adapter is used on the power supply output, make certain the ground banana pin marked by the tab is connected to the positive (+) terminal of the power supply.

Table 3-2. HP 8407A/8414A Network Analyzer System, Cable Connections

FUNCTION	CONNECTED TO	CABLE TYPE
HP 8407A/8414A Network Analyzer		
VTO IN	HP 8601A VTO OUT	RG-58/223
SWEEP IN	HP 8601A SWEEP OUT	RG-58/223
BLANKING	HP 8601A BLANKING OUT	RG-58/223
TEST CHANNEL	DIRECT. COUPLER (REFL.)	RG-59/307**
REF CHANNEL	Reference Antenna Transmission Line	RG-59/307*
HP 8601A Generator/Sweeper		
RF OUT	Power Splitter IN	RG-58/223
EXT FM	DC power supply	RG-58/223
AUX OUT	Frequency Counter in	RG-58/223
BLANKING OUT	HP 8407A/8414A BLANKING IN	RG-58/223
SWEEP OUT	HP 8407A/8414A SWEEP IN	RG-58/223
VTO OUT	HP 8407A/8414A VTO IN	RG-58/223
Power Splitter		
INPUT	HP 8601A RF OUT	RG-58/223
OUT	Directional coupler (Source)	RG-59/307**
OUT	Reference Antenna Transmission Line	RG-59/307*
DC Power Supply		
OUTPUT	HP 8601A EXT FM **CAUTION** 1. Only negative voltage should be applied to HP 8601A. 2. Voltage should not exceed −500 mV.	RG-58/223
Frequency Counter		
INPUT	HP 8601A AUX OUT	RG-58/223
Directional Coupler		
SOURCE	Power Splitter OUT	RG-58/223**
REFL	HP 8407A TEST CHAN.	RG-59/307**
LOAD	Antenna Under test	RG-59/307**

** Cables should be approximately one-half the length of * cables so that the incident and reflected signal is electrically equal to the reference signal.

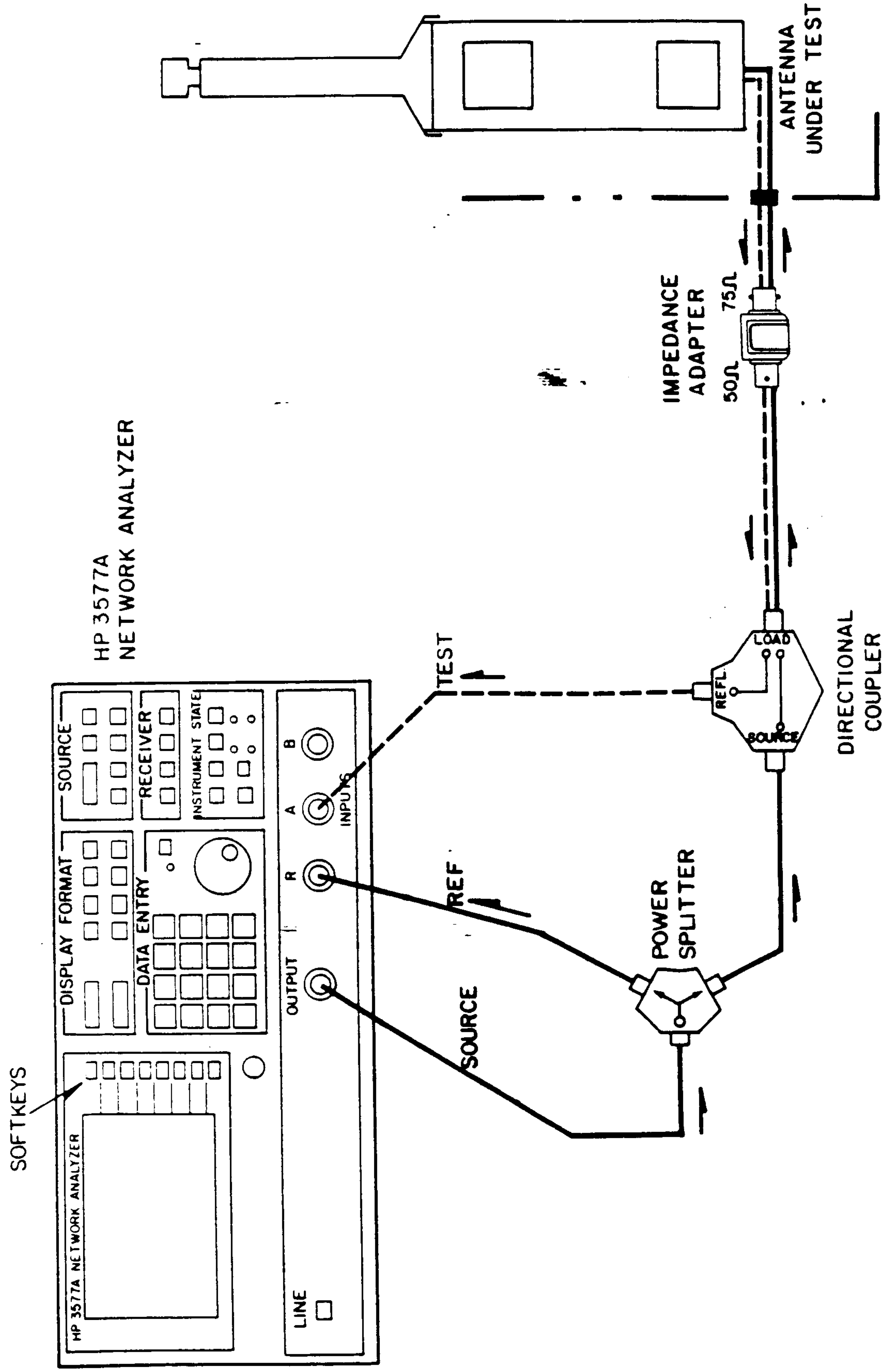


FIGURE 3-8. Simplifi d Driving Point Impedance (Smith Chart), Test Diagram.

Table 3-3. HP 3577A Network Analyzer System, Control Settings

HARDKEY	SOFTKEY	VALUE
a. INPUT	A/R	—
b. DISPLAY FCTN	POLAR	—
c. SCALE	FULL SCALE SMITH CHART ON	1.000 units
d. AMPTD	−10 dBm	—
e. SWEEP MODE	CONT	
f. FREQ	START FREQ	2 MHz (low band) 8 MHz (high band)
	STOP FREQ	12 MHz (low band) 32 MHz (high band)
h. TRIG MODE	FREE RUN	

Table 3-4. HP 3577A Network Analyzer System, Cable Connections

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 3577A Network Analyzer			
OUTPUT	Front Panel	POWER SPLITTER INPUT	RG-58/223
INPUT R		POWER SPLITTER OUT	RG-58/223
INPUT A		DIRECTIONAL COUPLER, REFL	RG-58/223
Power Splitter			
INPUT		HP 3577A OUTPUT	RG-58/223
OUT		HP 3577A INPUT R	RG-58/223
OUT		DIRECTIONAL COUPLER, SOURCE	RG-58/223
Directional Coupler			
SOURCE		POWER SPLITTER OUT	RG-58/223
REFL		HP 3577A INPUT A	RG-58/223
LOAD		ANTENNA UNDER TEST	

Note: Cables need not be amplitude or phase-matched since the normalization capability of the instrument will compensate for signal path differences.

3.5.3.2 HP 3577A Network Analyzer Setup/Calibration. For HP 3577A setup, calibration is also required. This is carried out by one person in the antenna field used to terminate the end of the RG-11 cable on the test antenna with a perfectly matched load (75-ohms), a short, and an open. At the same time, the operator in the goniometer room only needs to work with the panel keys on the HP 3577A. Because of the internal normalization capabilities of the HP 3577A, no change in cable length is needed (as is necessary using the HP 8407A/8414A test setup). The calibration procedure for the HP 3577A test system is given in paragraph 3.5.3.3.

3.5.3.3 HP 3577A Network Analyzer Calibration Procedure. The following step-by-step procedure using the HP 3577A Network Analyzer is a basic method for measuring antenna impedance characteristics as a function of frequency. The only information needed to know for this procedure is a very basic knowledge of the HP 3577A Network Analyzer.

1. Set up equipment, as shown in Figure 3-8, using a known good antenna (this antenna can be found by use of the TDR test).
2. Turn on power to network anlayzer. Wait about fifteen minutes to warm up equipment.
3. Configure the HP 3577A Network Analyzer as shown in Table 3-3.
4. Press DISPLAY FORMAT hard key "MEASR CAL".
5. Have someone go out to the chosen antenna with headsets/walkie talkie to allow communications between persons at network anlayzer and antenna.
6. Using the communication system, instruct the person out in the field to remove the RG-11 cable from the RG-11/RG-85 adaptor which is inside of high band antennas or on the low band antennas.
7. Press softkey "ONE PORT FULL CAL" on network analyzer.
8. Press softkey "CONTINUE CAL".
9. Instruct the person to install the short at end of RG-85 when the network analyzer screen shows "INSTALL SHORT".
10. Press softkey "CONTINUE CAL".
11. Instruct the person at antenna to install Perfectly Matched Load (75 ohm) when screen shows "INSTALL REF LOAD".
12. Press softkey "CONTINUE CAL".
13. At this point, calibration should be complete; a check of the calibration will confirm this. Refer to Figure 3-6 and Conditions chart for the designation and location of the calibration points corresponding to a particular termination of the test antenna.
    a. When cable is an open circuit, the Smith chart should show a point at infinity (Calibration Point C) since an open circuit has infinite resistance.
    b. A short would register a point at zero (Calibration Point A) since a short circuit has no impedance.
    c. The Perfectly Matched Load (75 ohm) should register a theoretical point at 1 (Calibration Point B) since the antenna is a 75 ohm system. However, in practice, the actual point may be on either side of 1, according to the accuracy of the 75 ohm resistor.
14. Reconnect antenna.
15. Press INSTRUMENT STATE hardkey "SAVE" on network analyzer to store Calibration Data in HP 3577A for remainder of test.

NOTE

If recalibration is needed, return to step 3 and repeat the procedure. This must be done, since during the calibration process the input on the network analyzer changes from A/R to a user defined function. If this is not changed back to A/R, the CALIBRATION WILL NOT OPERATE PROPERLY.

3.5.4 Test Results

3.5.4.1 The normal low band antenna element Smith charts for the different series of transformers are shown in Figures 3-9 and 3-10. The dark trace is the typical Smith chart display for a low band antenna with a 300, 500, or 800 series transformer. Also observe that the Smith chart displays for the different transformer series are very similar.

Therefore, the electrical characteristics of the antenna, such as VSWR, are not drastically changed by having diffe. series of transformers.

3.5.4.2 Figure 3-11 illustrates a Smith chart display distorted by having inductive terminating resistors on the low band antenna.

3.5.4.3 The reference Smith chart display for the high band antennas is shown in Photo B7 of Figure 3-12. Problems with the spark plug and tuning stub of the antenna caused the distorted displays in Photos B8 through B10 of Figures 3-12 and 3-13.

3.6 VSWR TESTING: GENERAL

If the HP 8414A Polar Display is not available to perform Smith chart tests, then the HP 8412A Phase/Magnitude Display may be used to measure the VSWR of the antenna element. VSWR is the ratio of the transmission loss in an unmatched system to the transmission loss in the same system when matched. VSWR can also be interpreted as $s = V_{max}/V_{min}$ of a standing wave caused by a reflection of the transmitted signal. Thus, a VSWR of 1 is better than VSWR of 2 because less power is lost or reflected). The VSWR test concept is similar to the Smith chart test, except that the reference and test signals do not have to be in phase. The HP 3577A system can also be used for the VSWR test.

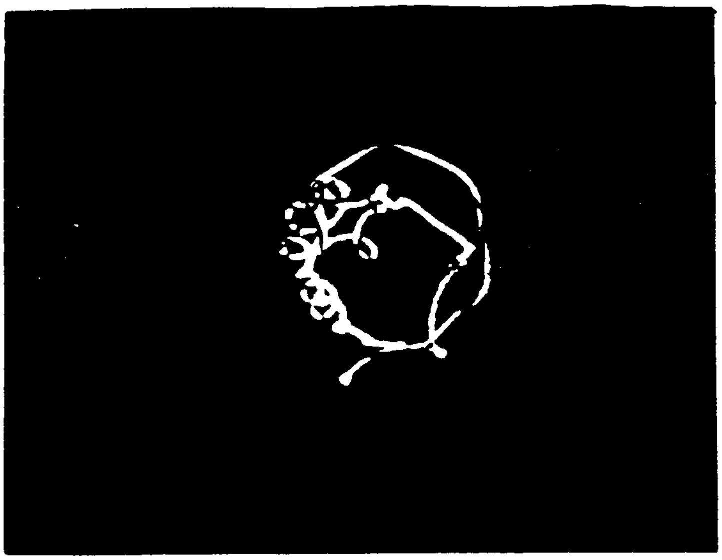
3.6.1 Test Setup. In the simplified VSWR test setup for HP 8407A/8412A system, shown in Figure 3-14, the antenna element under test is connected to the test cable at the back of the multicoupler associated with that element.

NOTE

Disconnect the RG-12 from its directional coupler and connect the RG-12 to the test cable with a BNC-to-N adapter.

The other end of the test cable is connected to the LOAD PORT of the direction coupler, while the REFLECTED PORT is connected to the test channel of the Network Analyzer. Observe that the reference signal for the network analyzer is connected directly to the power splitter without going through the antenna transmission lines, since phase is not critical for this test. For the HP 3577A system, the test setup is identical to the Smith chart test. This is shown in Figure 3-8.

3.6.2 Test Results. The reference low and high band antenna element VSWR plots are shown in Figure 3-15. A comparison of the Smith chart display, VSWR plot, and TDR signatures for three antennas are shown in Figures 3-16 through 3-18. In each case, the Smith chart display and VSWR plot both indicated discrepancies in the antennas. However, the TDR display was only able to diagnose one problem clearly. This demonstrates the importance of the Smith chart or VSWR test in detecting problems which the TDR is not able to diagnose.



ANTENNA SMITH CHART

PHOTO: B1

STATION: NSGA

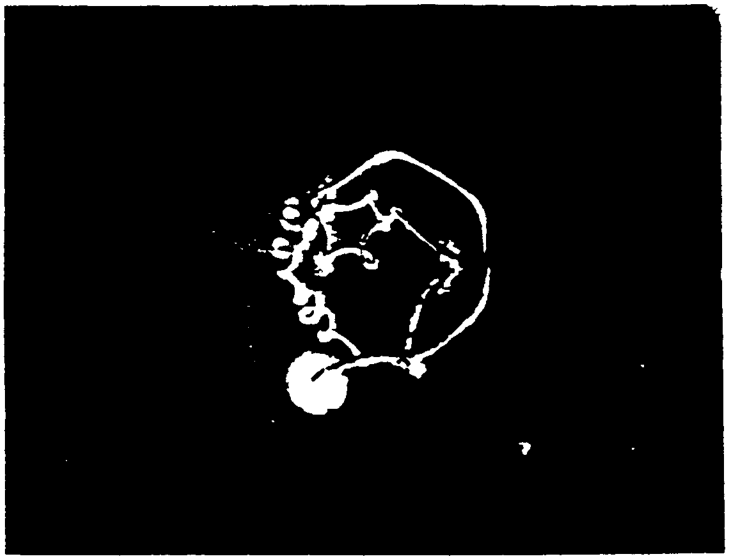
LOCATION: Edzell, Scotland

DATE: 16 Sep 1981

ANTENNA: LB 28 (2-12 MHz)

TRANSFORMER: Serial No. 79

Reference Smith chart display for low band antennas with transformer serials numbers less than 100. (The dark trace is the display for 300/500/800 series transformers.)



ANTENNA SMITH CHART

PHOTO: B2

STATION: NSGA

LOCATION: Edzell, Sc tland

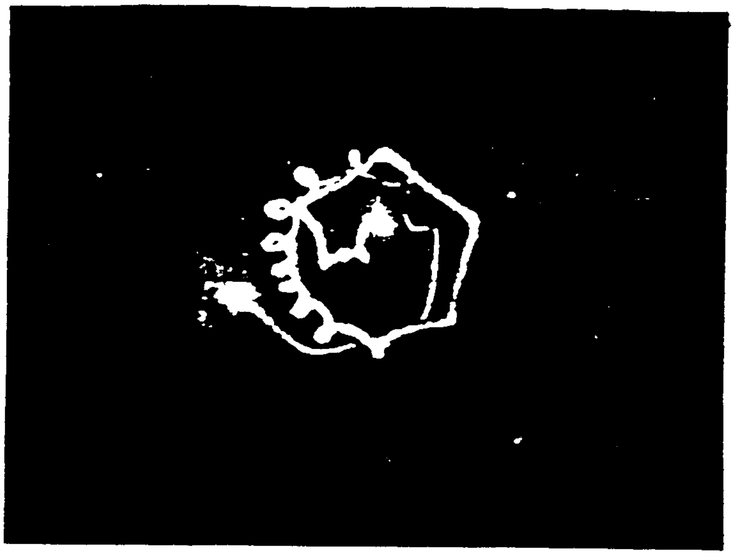
DATE: 16 Sep 1981

ANTENNA: LB 9 (2-12 MHz)

TRANSFORMER: Serial No. 539

Reference Smith chart display for low band antennas with 300, 500, and 800 series transformers.

FIGURE 3-9. Reference Smith Chart Displays for Low Band Antennas with Under 100 and 300/500/800 Series Transformers.



ANTENNA SMITH CHART

PHOTO: B3

STATION: NSGA

LOCATION: Sabana S ca, PR

DATE: 8 Apr 1981

ANTENNA: LB 34 (2-12 MHz)

TRANSFORMER: Serial No. 917

Reference Smith chart display for low band antennas with 900 series transformers. (The dark trace is the display for 300/500/800 series transformers.)

ANTENNA SMITH CHART

PHOTO: B4

STATION: NSGA

LOCATION: Sabana Seca, PR

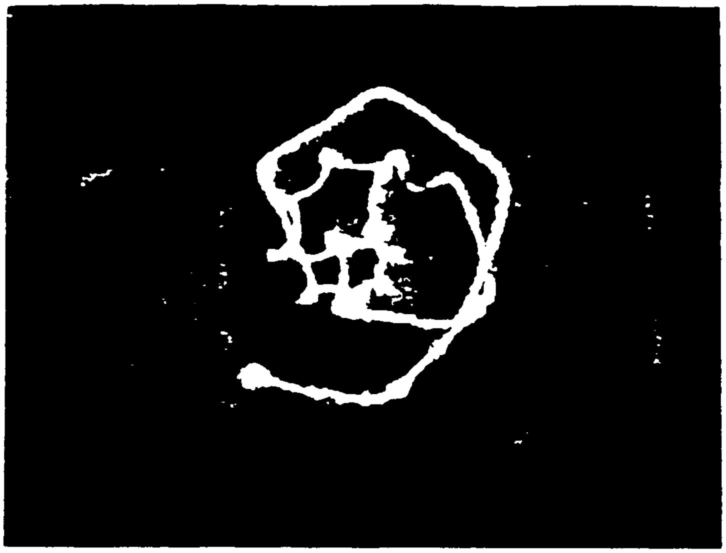
DATE: 8 Apr 1981

ANTENNA: LB 37 (2-12 MHz)

TRANSFORMER: Serial N . 1044

Reference Smith chart display for low band antennas with transformers greater than 1000 series. (The dark trace is the display for 300/500/800 series transformers.)

FIGURE 3-10. Reference Smith Chart Displays for Low Band Antennas with 900 and 1000 Series Transformers.



ANTENNA SMITH CHART

PHOTO: B5

STATION: NSGA

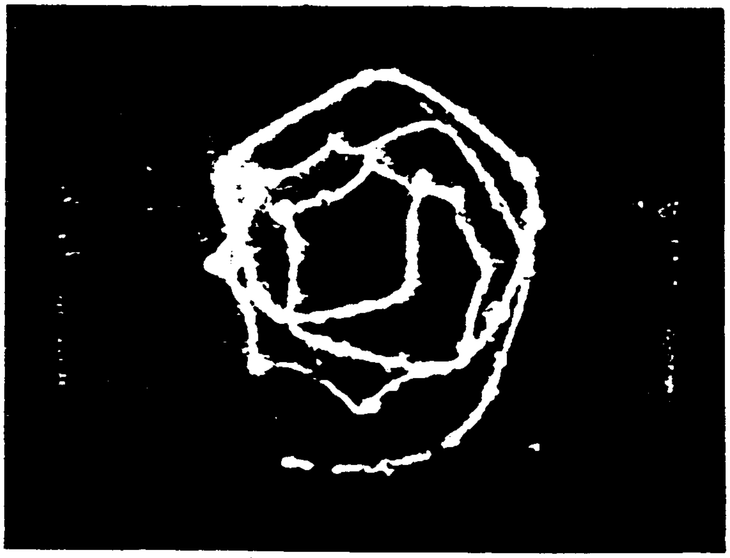
LOCATION: Sabana Seca, PR

DATE: 8 Apr 1981

ANTENNA: LB 7 (2-12 MHz)

TRANSFORMER: Serial No. 1030

This distorted Smith chart display is due to one inductive 500-ohm terminating resistor.



ANTENNA SMITH CHART

PHOTO: B6

STATION: NSGA

LOCATION: Sabana Seca, PR

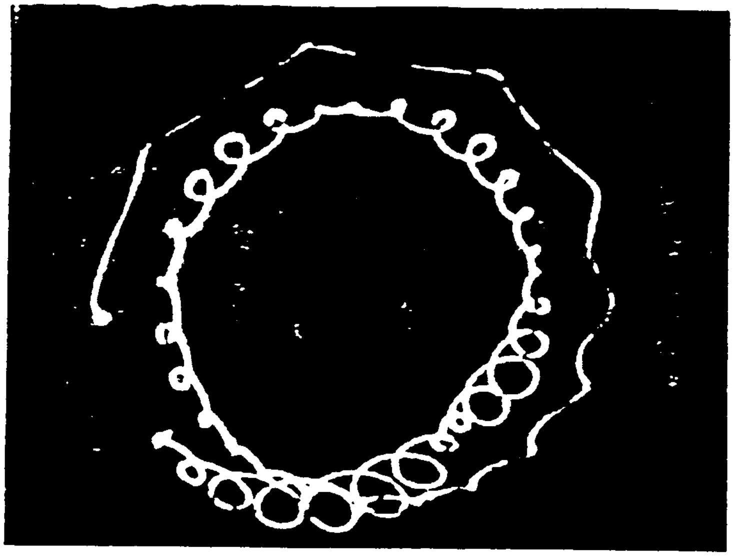
DATE: 8 Apr 1981

ANTENNA: LB 16 (2-12 MHz)

TRANSFORMER: Serial No. 1314

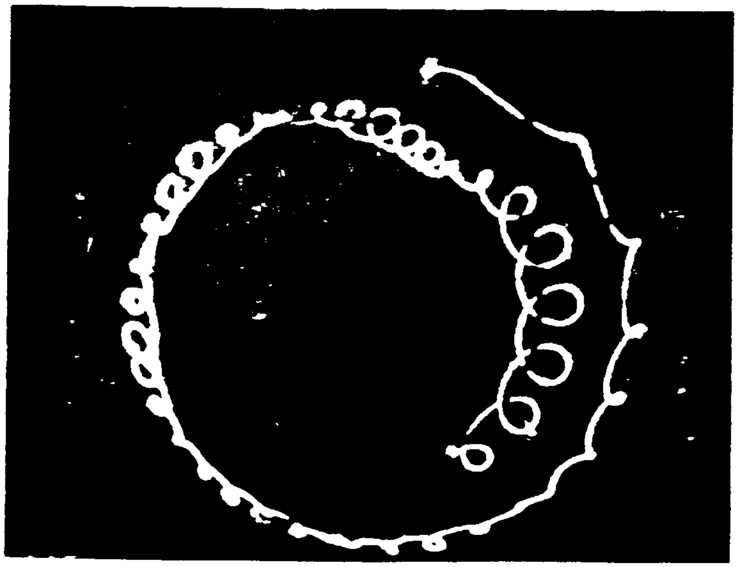
With two inductive 500-ohm terminating resistors, this display is distorted even further.

FIGURE 3-11. Effect of Having Inductiv Terminating Resistors.



ANTENNA SMITH CHART
PHOTO: B7
STATION: NSGA
LOCATION: Sabana Seca, PR
DATE: 8 Apr 1981
ANTENNA: HB 65 (8-32 MHz)

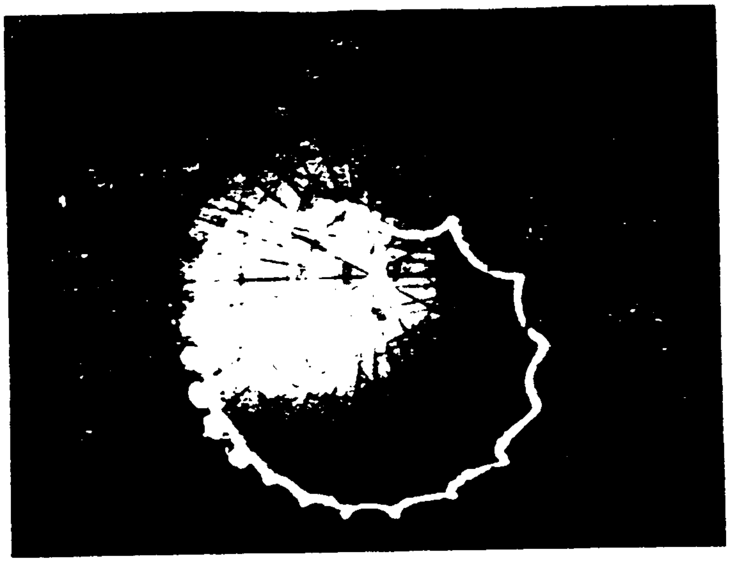
Reference Smith chart display for high band antennas.



ANTENNA SMITH CHART
PHOTO: B8
STATION: NSGA
LOCATION: Sabana Seca, PR
DATE: 8 Apr 1981
ANTENNA: HB 62 (8-32 MHz)

A spark plug problem caused this distorted display. (The dark trace is the reference Smith chart display.)

FIGURE 3-12. Reference High Band Antenna Smith Chart Displays and the Effect of a Spark Plug Problem.



ANTENNA SMITH CHART

PHOTO: B9

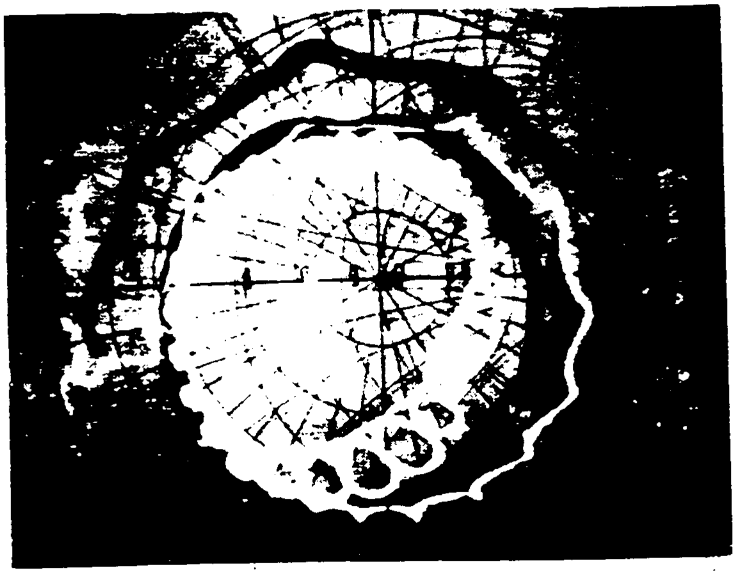
STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 8 Apr 1981

ANTENNA: HB 95 (8-32 MHz)

This distorted Smith chart display is due to a tuning stub problem.



ANTENNA SMITH CHART

PHOTO: B10

STATION: NSGA

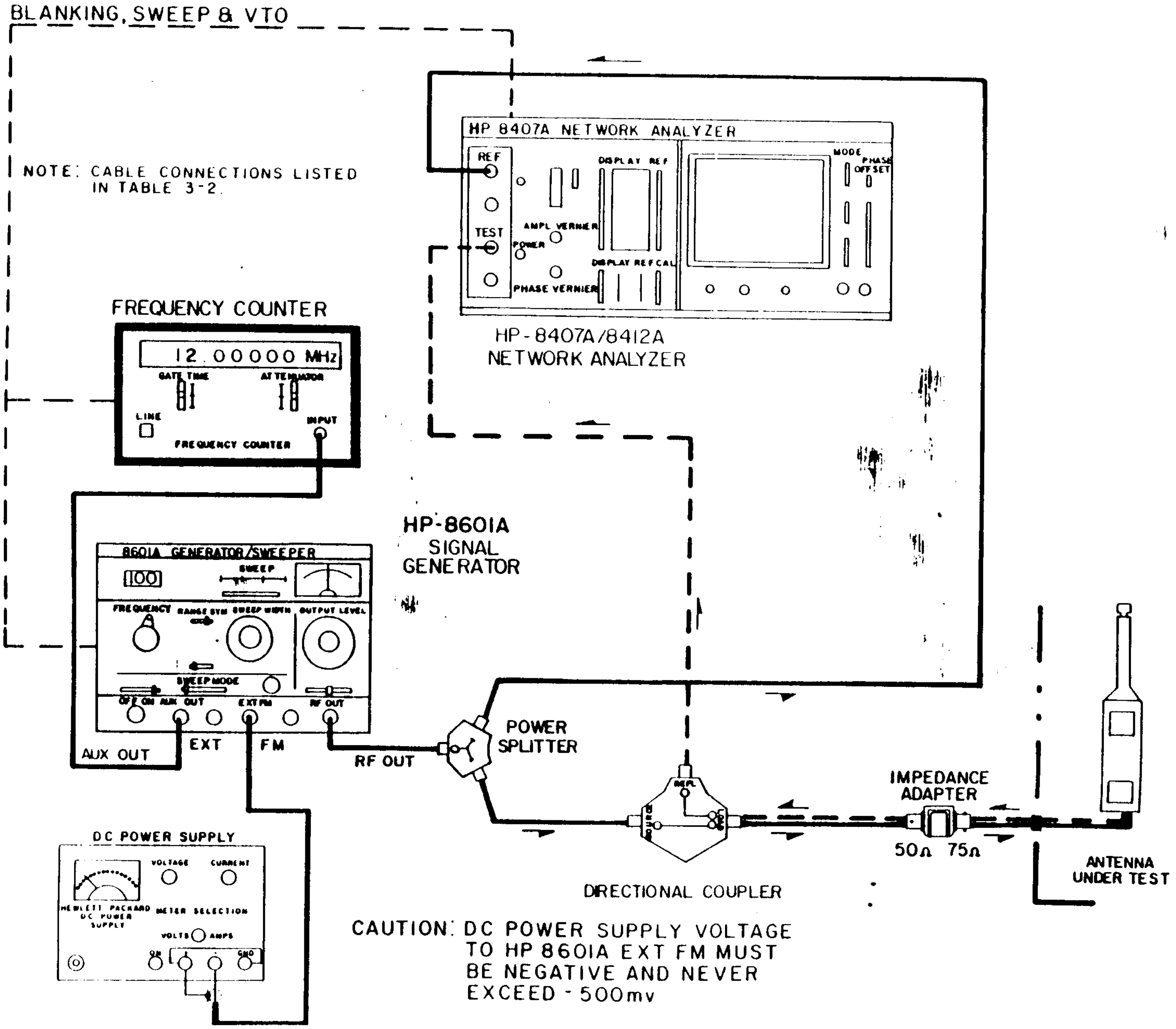
LOCATION: Sabana Seca, PR

DATE: 8 Apr 1981

ANTENNA: HB 90 (8-32 MHz)

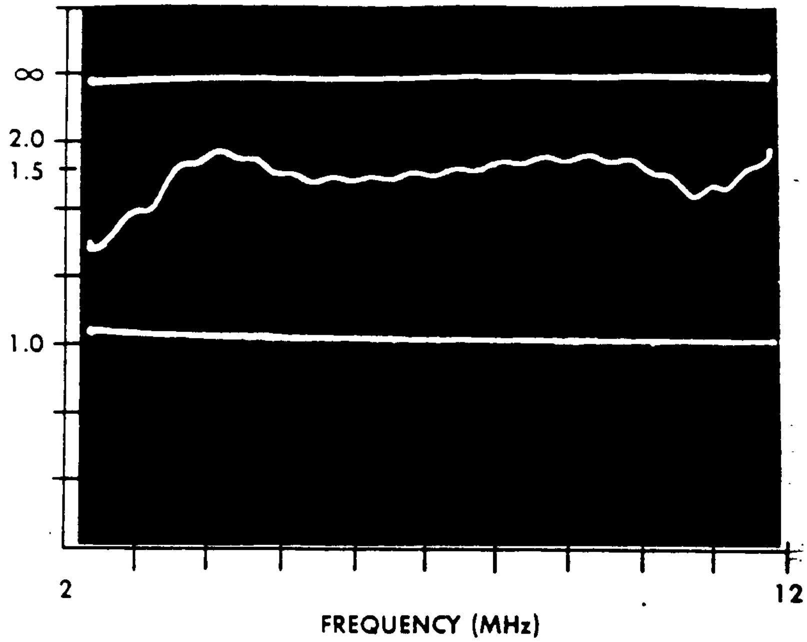
A problem at the top of the tuning stub caused this display.

FIGURE 3-13. Effect of Tuning Stub Problems.



CAUTION: DC POWER SUPPLY VOLTAGE TO HP 8601A EXT FM MUST BE NEGATIVE AND NEVER EXCEED - 500mv

FIGURE 3-14. Simplified 'R Test Diagram.



VSWR TEST

PHOTO: B11

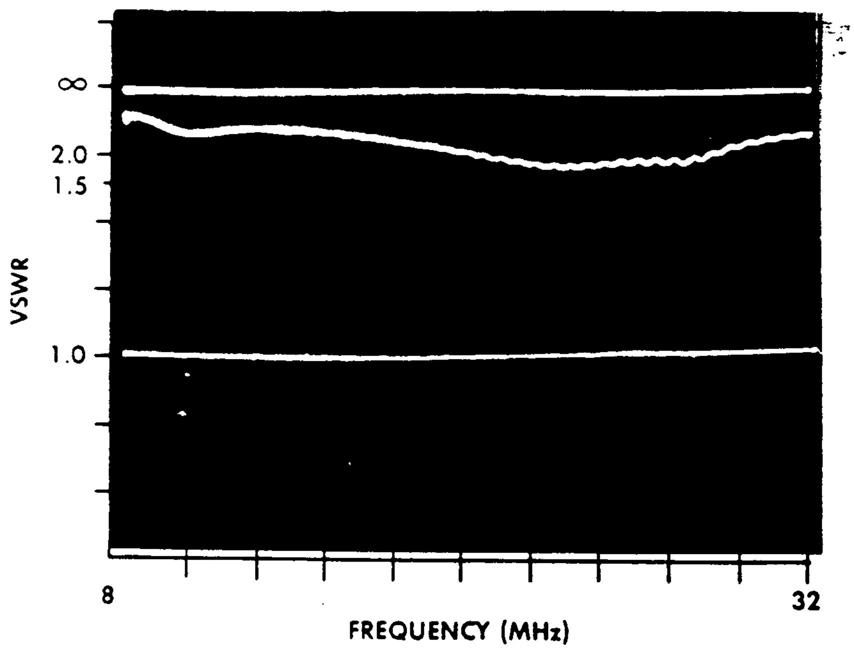
STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 9 Apr 1981

ANTENNA: LB 39 (2-12 MHz)

Reference low band antenna VSWR plot.



VSWR TEST

PHOTO: B12

STATION: NSGA

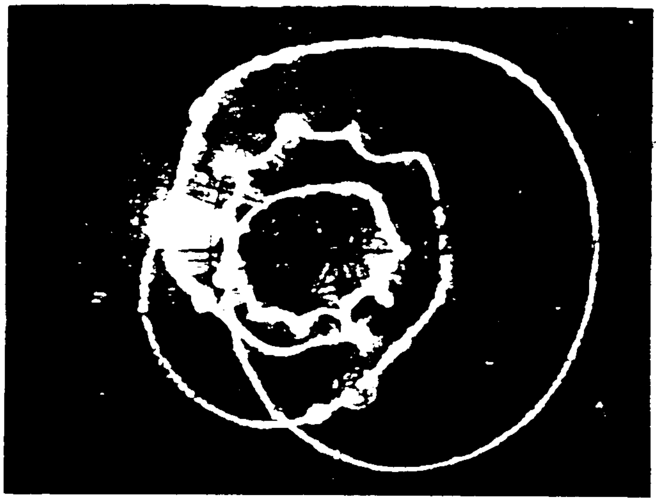
LOCATION: Sabana Seca, PR

DATE: 9 Apr 1981

ANTENNA: HB 91 (8-32 MHz)

Reference high band antenna VSWR plot.

FIGURE 3-15. Reference Low and High Band Antenna Element VSWR Plots.



SMITH CHART

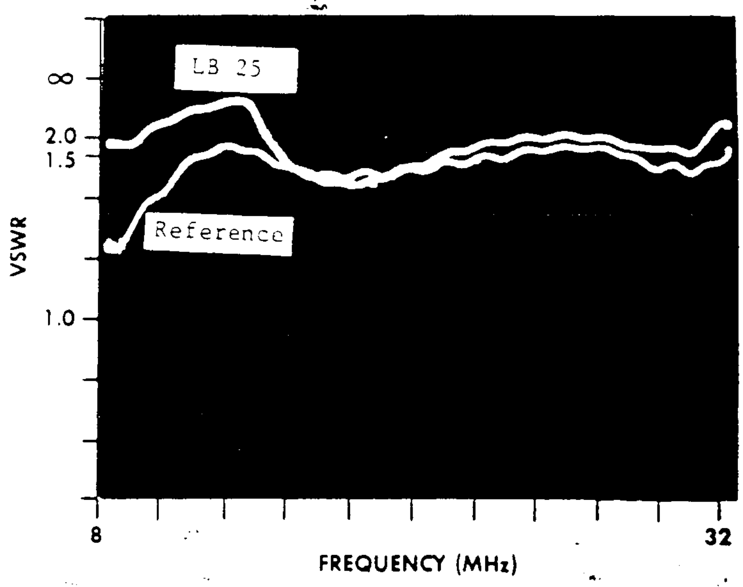
PHOTO: B13

STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 8 Apr 1981

ANTENNA: LB 25 (2-12 MHz)



VSWR TEST

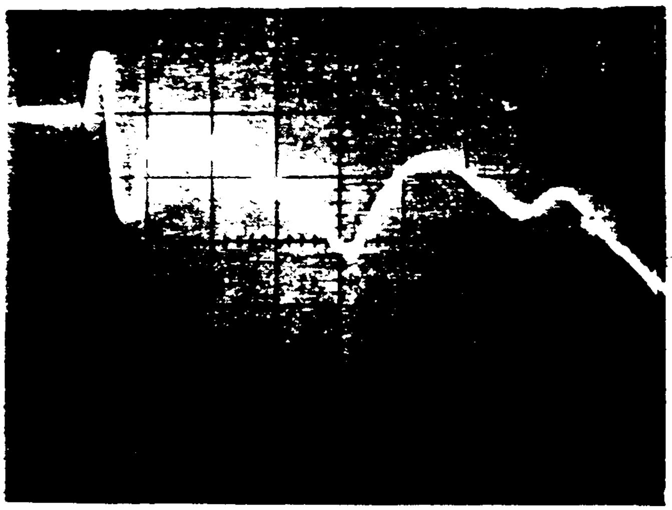
PHOTO: B14

STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 9 Apr 1981

ANTENNA: LB 25 (2-12 MHz)



TDR SIGNATURE

PHOTO: B15

STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 3 Apr 1981

ANTENNA: LB 25

FIGURE 3-16. Smith Chart Display, VSWR Plot, and TDR Signature all Indicate a Problem with Low Band Antenna 25.

CHAPTER 4
ANTENNA AMPLITUDE AND PHASE COMPARISON TEST

4.1 TEST DESCRIPTION

The first two antenna element tests, TDR and Smith chart/VSWR, require the manual comparison of individual results with a reference presentation to evaluate array uniformity. However, the swept frequency amplitude and phase comparison test uses the HP 8407A or HP 3577A Network Analyzer, which automatically measures the differences between antenna responses in real time.

4.1.1 As shown in the test diagram of Figure 4-1, the test signal from the sweep oscillator is sent out the transmission line to an antenna. The transmitted test signal is received on the two adjacent antennas and returns back through the transmission lines to the network analyzer. The network analyzer then measures and displays the amplitude and phase differences between the antenna responses as a function of frequency.

4.2 TEST SETUP

The connection points between the test system and an antenna element are at the RG-12 antenna cables at the back of the multicoupler bay cabinets. To hook up a test cable to an antenna element, disconnect the RG-12 from its directional coupler. Then attach a test cable with appropriate adapters to the RG-12. Table 4-1 and Table 4-2 show the control settings and cable connections for the test setup in Figure 4-1.

NOTE

Note that this test can be performed more quickly using the AN/FRM-19 switching heads as shown in Figure 4-2. However, this setup would include other elements (directional couplers, multicouplers, and AN/FRM-19) in the test results. The test signal is also severely attenuated by the loss in the directional couplers and AN/FRM-19 therefore on-the-air signals interfere with the test results. In addition, less stringent phase criteria are necessary due to the phase specifications of these elements. Therefore, it is highly recommended that they be excluded by performing the test as shown in Figure 4-1, and manually switch the test leads at the back of the primary multicouplers.

4.3 TEST RESULTS

4.3.1 The typical low band antenna phase comparison display within ±5.0 degrees is shown in Photo C1 of Figure 4-3. The phase anomaly at 6.5 MHz is due to the physical distance between the antennas and screen, and is characteristic of all CDAAs.The spacing between the antenna elements and the reflector screen varies from site to site, consequently the frequency at which the anomaly occurs may vary at some sites. Photos C2 to C4 show non-uniform phase comparisons between antenna elements due to a transformer problem, a shorted resistor, and a bad transmission line connector.

4.3.2 The typical high band antenna phase comparison display is shown in Photo C5 of Figure 4-5. Phase anomalies at 9 MHz and 27 MHz are normally present due to the physical distance between the antennas and screen. Photos C6 to C8 show large phase errors due to an unterminated screen wire, poor spark plug ground connection, and an open connection. Figure 4-7 shows the effect that large metal objects located close to the array have on the antenna phase response.

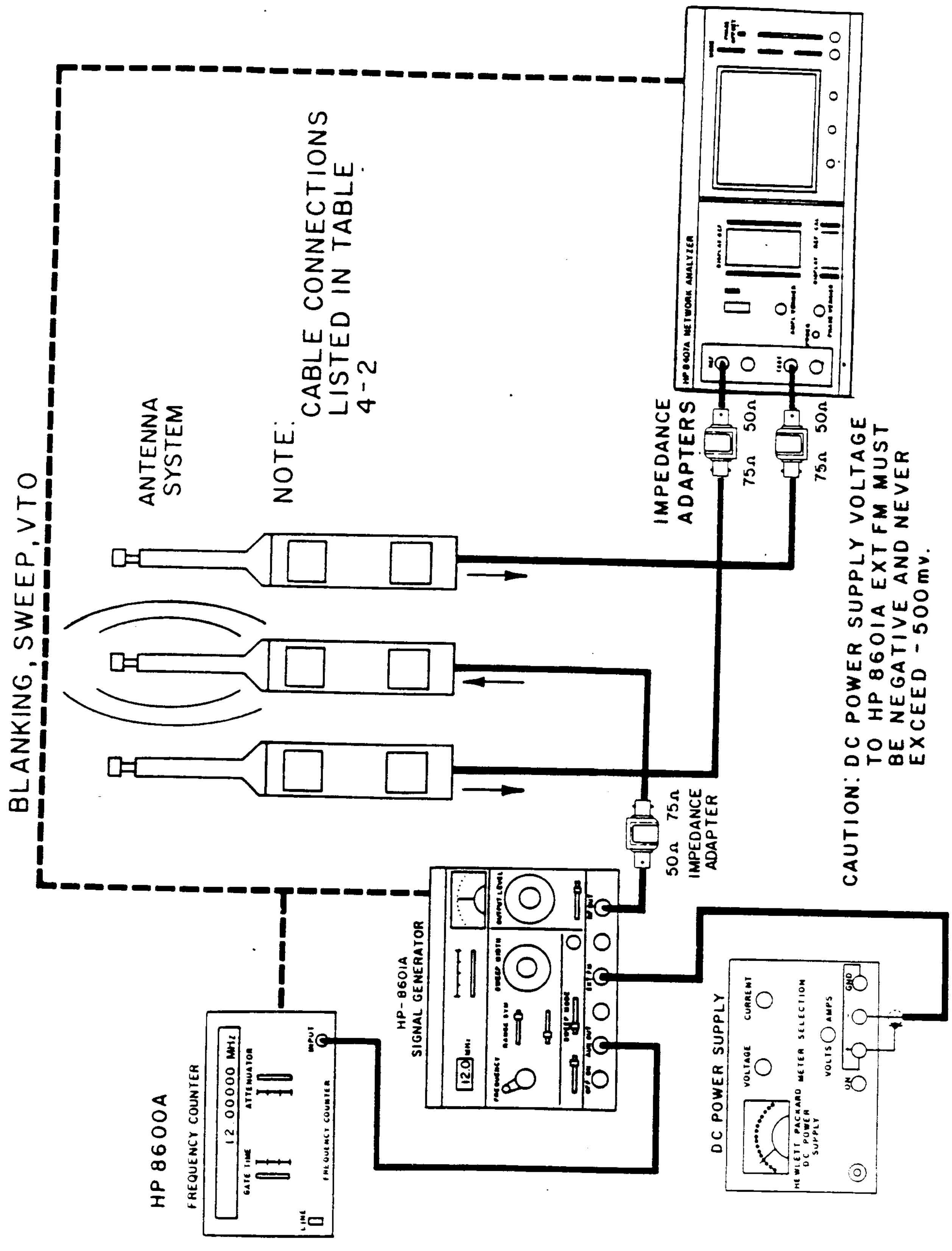


FIGURE 4-1. Simplified Phase/Amp) Comparison, Test Diagram.

Table 4-1. HP 8407A/8412A Netw rk Analyzer System, Control Settings

CONTROL	SETTING
HP 8407A/8412A Network Analyzer	
REF CHAN LEVEL ADJ	As required to stay in "OPERATE" range
DISPLAY REFERENCE	As required to obtain trace
HORIZ POSITION/HORIZ GAIN	As required to obtain calibrated 2-12 MHz (low band) and 8-30 MHz (high band)
BW (kHz)	0.1
MODE	As required
AMPL. dB/div	1.0
PHASE deg/div	10.0
PHASE OFFSET	0
INTENSITY	As required
FOCUS	As required
HP 8601A Generator/Sweeper	
OUTPUT LEVEL	−30 dBm
SWEEP	VIDEO
FREQUENCY	As required to obtain 2-12 MHz (low band) and 8-30 MHz (high band) display
SWEEP MODE	FREE, MANUAL
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
DC Power Supply	
OUTPUT *	Approximately −200 mV for a 2 MHz start frequency. (Do not adjust to more than −500 mV and never apply a positive voltage to the EXT FM input on the HP 8601A.)
Frequency Counter	
INPUT	Scale for 2 to 30 MHz frequency range

* If a banana plug to BNC adapter is used on the power supply output, verify the DC continuity between the center pin of the BNC connector and the high (+) banana pin. (Some adapters contain a DC blocking capacitor. These adapters are usually blue.)

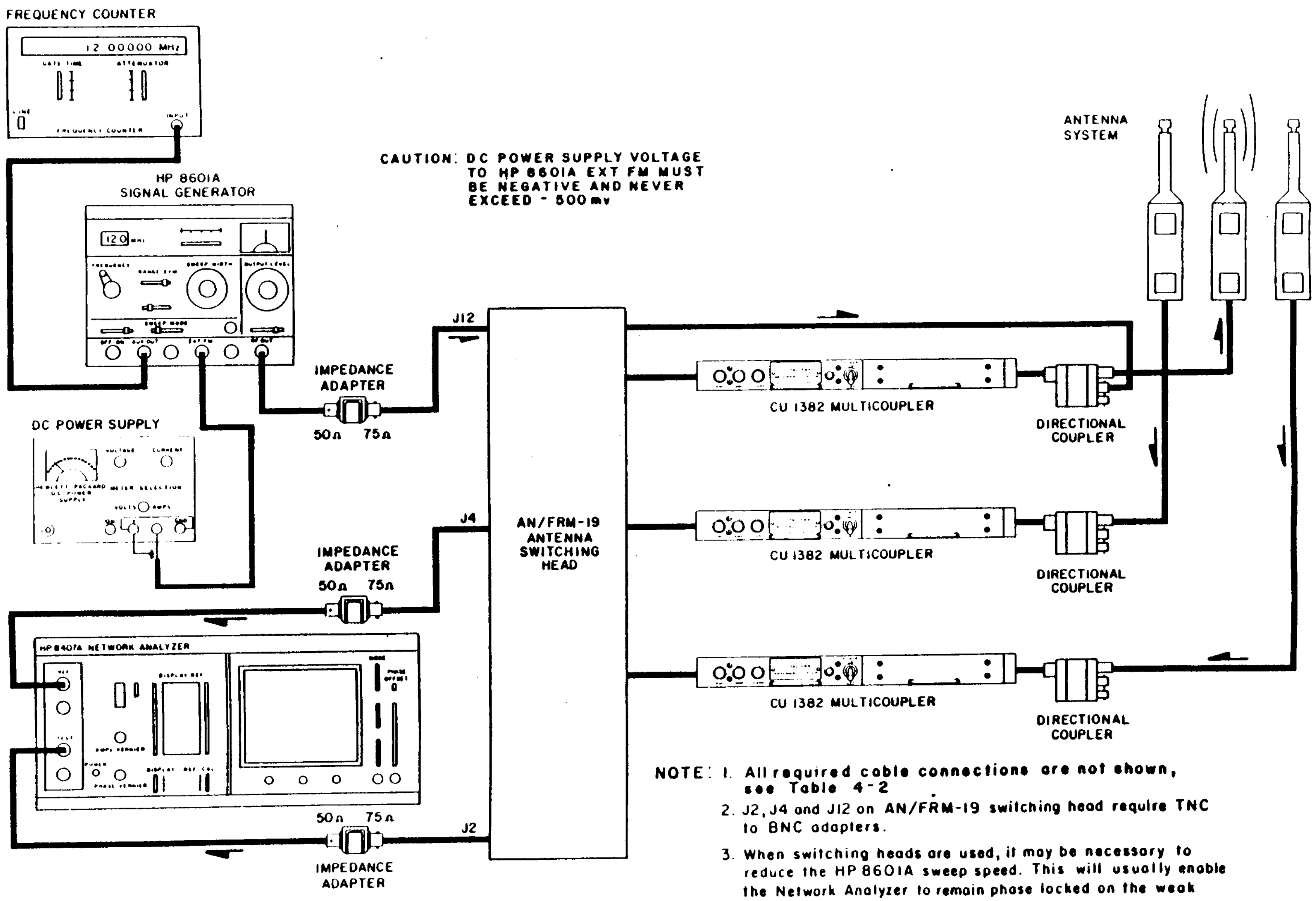
CAUTION

If a banana plug to BNC adapter is used on the power supply output, make certain the ground banana pin marked by the tab is connected to the positive (+) terminal of the power supply.

Table 4-2. HP 8407A/8412A Netw rk Analyzer System, Cable Connections

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 8407A/8412A Network Analyzer			
VTO IN	Rear Panel	HP 8601A VTO OUT	RG-58/223
SWEEP IN		HP 8601A SWEEP OUT	RG-58/223
BLANKING		HP 8601A BLANKING OUT	RG-58/223
TEST CHANNEL	Front Panel	TEST ANTENNA	RG-59/307*
REF CHANNEL		REFERENCE ANTENNA	RG-59/307*
HP 8601A Generator/Sweeper			
RF OUT	Front Panel	ANTENNA UNDER TEST	RG-59/307
EXT FM		DC POWER SUPPLY	RG-58/223
AUX OUT		FREQUENCY COUNTER IN	RG-58/223
BLANKING OUT	Rear Panel	HP 8407A/8412A BLANKING IN	RG-58/223
SWEEP OUT		HP 8407A/8412A SWEEP IN	RG-58/223
VTO OUT		HP 8407A/8412A VTO IN	RG-58/223
DC Power Supply			
OUTPUT	Front (Use banana to BNC adapter)	HP 8601A EXT FM (Use negative voltage only. Do not exceed −500 mV.)	RG-58/223
Frequency Counter			
INPUT		HP 8601A AUX OUT	RG-58/223

* Cables should be amplitude and phase matched. 50/75 ohm impedance adapters are required if there is an impedance difference between cables and test equipment.

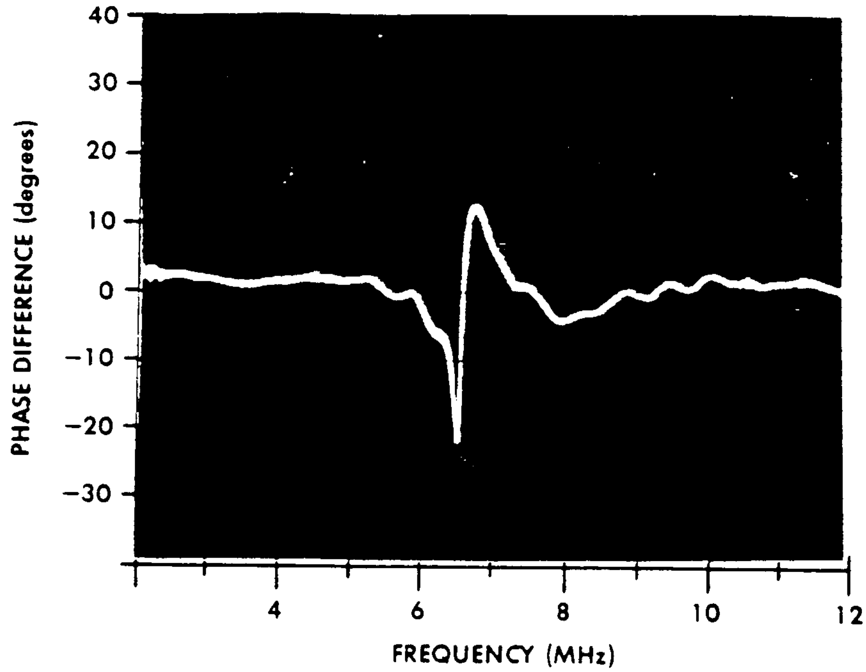


NOTE: 1. All required cable connections are not shown, see Table 4-2

2. J2, J4 and J12 on AN/FRM-19 switching head require TNC to BNC adapters.

3. When switching heads are used, it may be necessary to reduce the HP 8601A sweep speed. This will usually enable the Network Analyzer to remain phase locked on the weak test signal.

FIGURE 4-2. Simplifi d Antenna/Transmission Line/Multicoupler Phase Comparison, Test Diagram.



ANTENNA PHASE COMPARISON

PHOTO: C1

STATION: NSGA

LOCATION: Galeta Island, PM

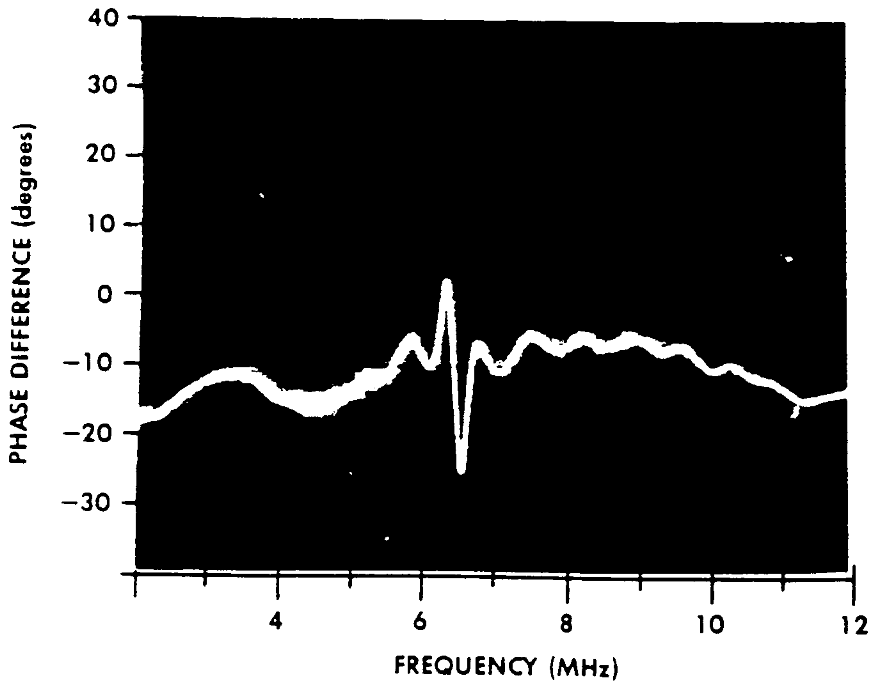
DATE: 15 Jan 1982

REFERENCE: LB 18

TEST: LB 20

XMIT: LB 19

Typical low band antenna phase comparison display.



ANTENNA PHASE COMPARISON

PHOTO: C2

STATION: NSGA

LOCATION: Galeta Island, PM

DATE: 15 Jan 1982

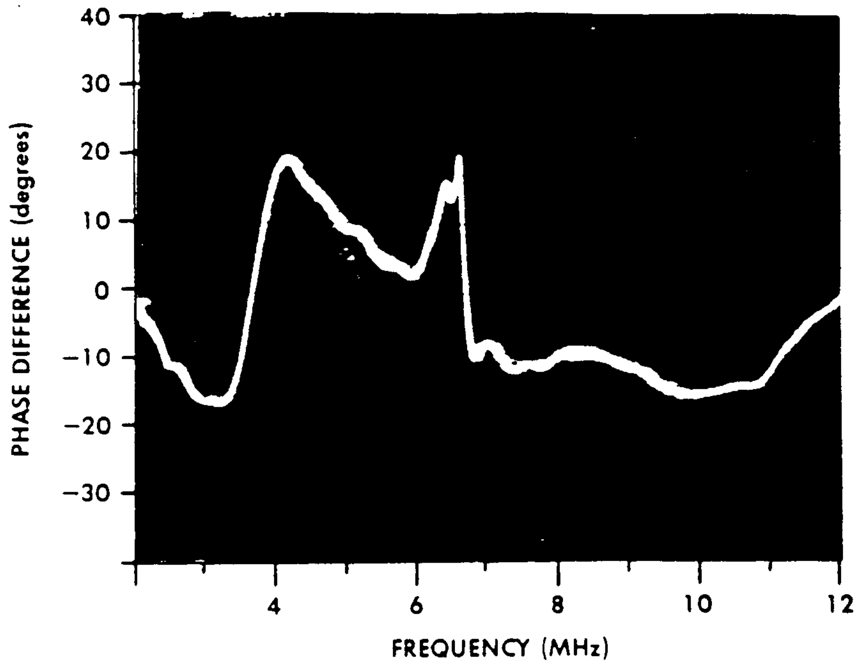
REFERENCE: LB 23

TEST: LB 25

XMIT: LB 24

A problem with the transformer on LB 23 caused this large phase error.

FIGURE 4-3. Low Band Antenna Phase Comparison Display.



ANTENNA PHASE COMPARISON

PHOTO: C3

STATION: NSGA

LOCATION: Galeta Island, PM

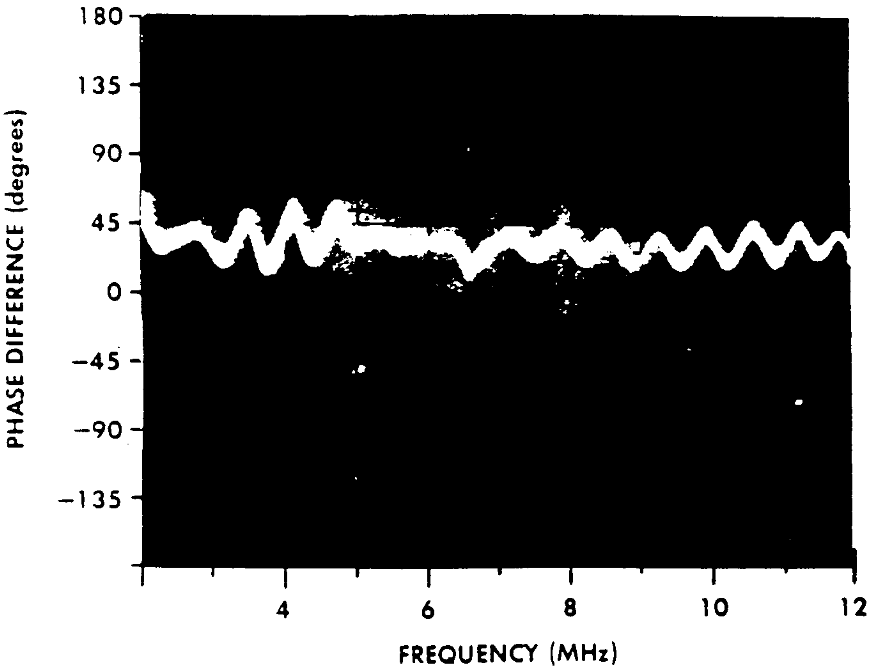
DATE: 15 Jan 1982

REFERENCE: LB 37

TEST: LB 39

XMIT: LB 38

A shorted resistor on LB 39 caused this phase display.



ANTENNA PHASE COMPARISON

PHOTO: C4

STATION: NSGA

LOCATION: Galeta Island, PM

DATE: 15 Jan 1982

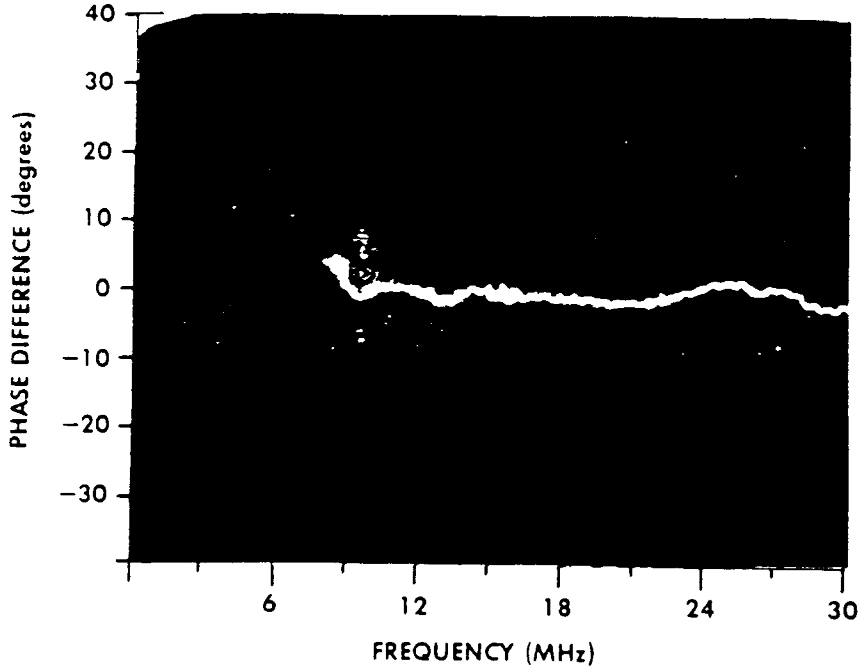
REFERENCE: LB 33

TEST: LB 35

XMIT: LB 34

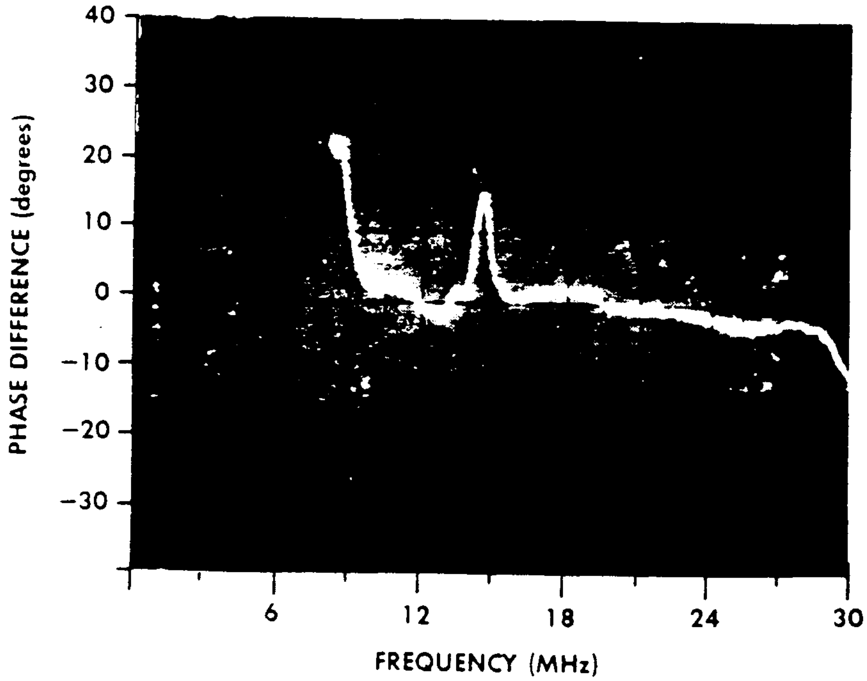
A bad transmission line connector on LB 35 caused this large phase error.

FIGURE 4-4. Non-Uniform Display Due to a Shorted Resistor and a Bad Connector.



ANTENNA PHASE COMPARISON
PHOTO: C5
STATION: NSGA
LOCATION: Galeta Island, PM
DATE: 15 Jan 1982
REFERENCE: HB 59
TEST: HB 30
XMIT: HB 29

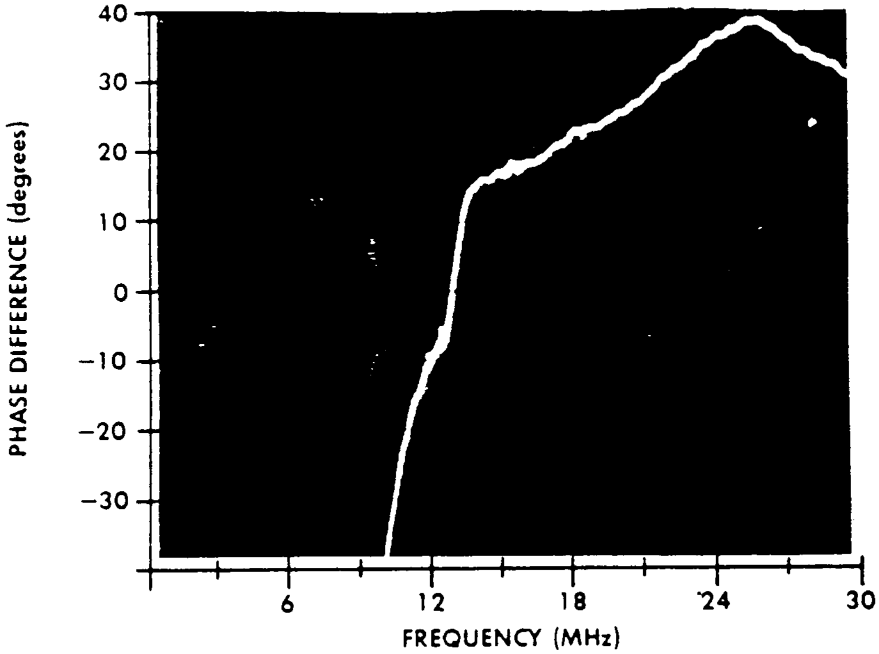
Typical high band antenna phase comparison display.



ANTENNA PHASE COMPARISON
PHOTO: C6
STATION: NSGA
LOCATION: Galeta Island, PM
DATE: 15 Jan 1982
REFERENCE: HB 59
TEST: HB 61
XMIT: HB 60

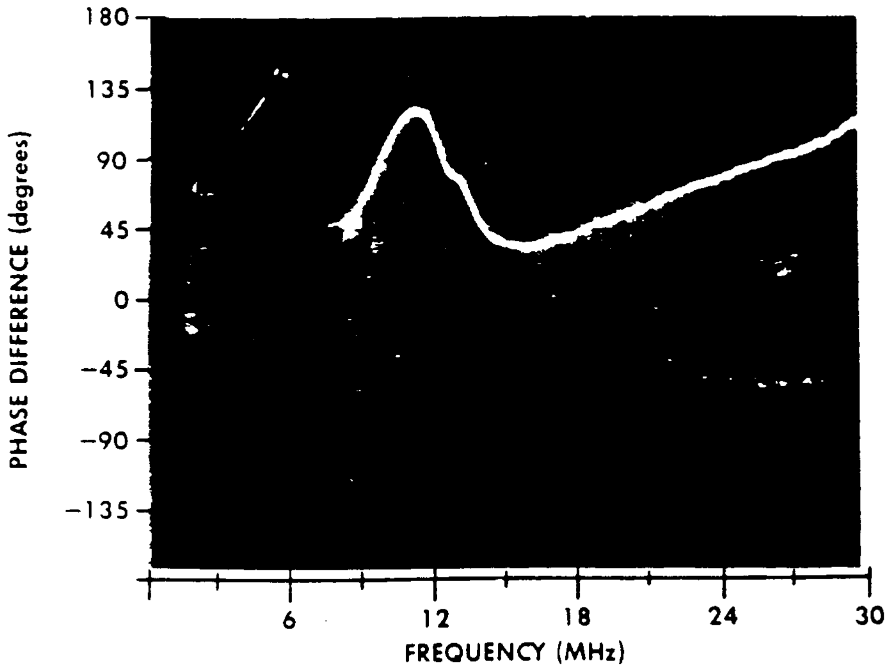
The sharp phase spike at 15 MHz is due to a screen wire not terminated to the ground bus bar.

FIGURE 4-5. High Band Antenna Phase Comparis n Display.



ANTENNA PHASE COMPARISON
PHOTO: C7
STATION: NSGA
LOCATION: Galeta Island, PM
DATE: 15 Jan 1982
REFERENCE: HB 30
TEST: HB 32
XMIT: HB 31

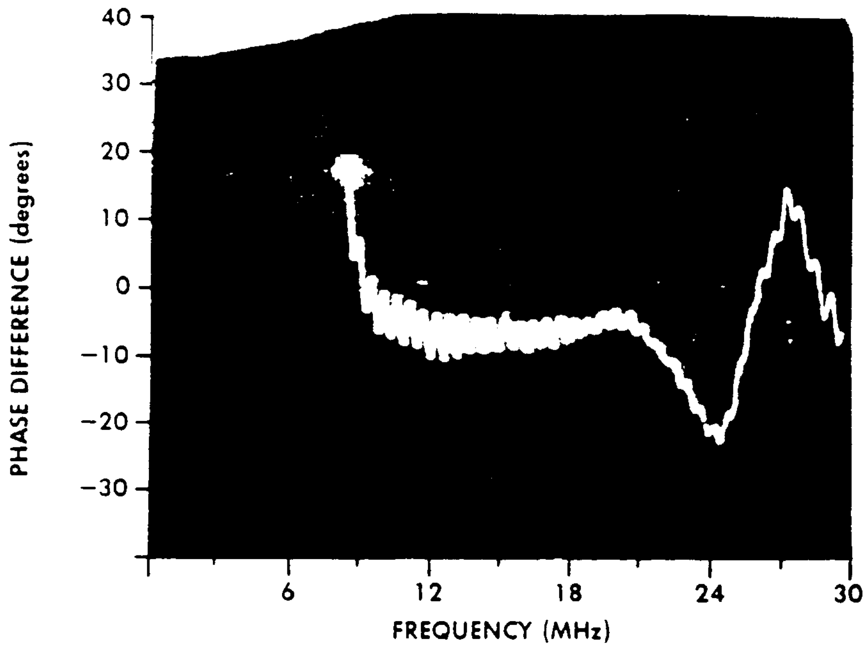
The effect of a poor spark plug ground connection on HB 32 is shown in this display.



ANTENNA PHASE COMPARISON
PHOTO: C8
STATION: NSGA
LOCATION: Galeta Island, PM
DATE: 15 Jan 1982
REFERENCE: HB 43
TEST: HB 45
XMIT: HB 44

An open connection on HB 45 caused this large phase error.

FIGURE 4-6. Large Phase Errors on High Band Antenna Due to Poor Spark Plug Connecti n and Open Connector.



ANTENNA PHASE COMPARISON

PHOTO: C9

STATION: NSGA

LOCATION: Sabana Seca, PR

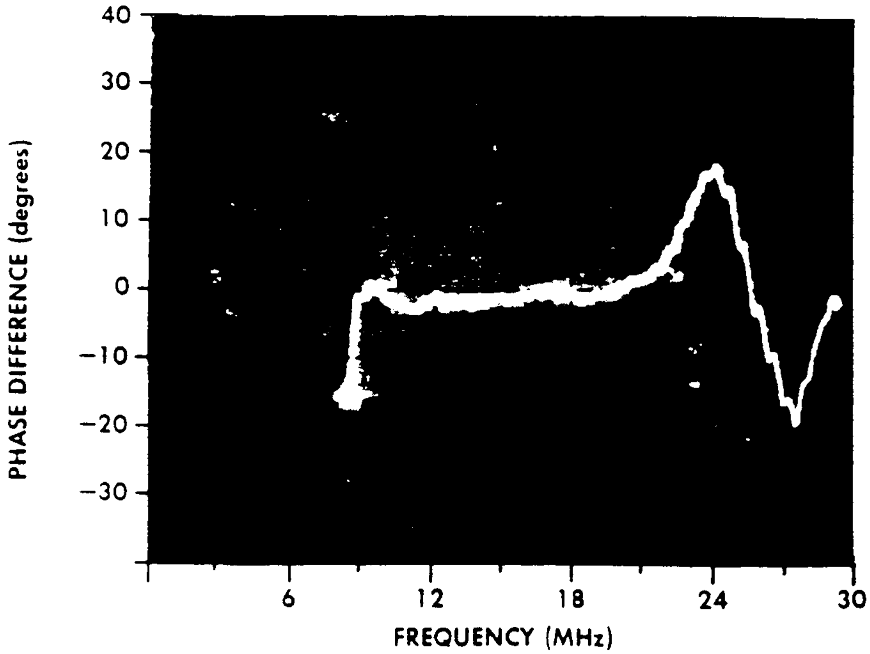
DATE: 2 Apr 1981

REFERENCE: HB 8

TEST: HB 11

XMIT: HB 10

Large phase errors between 21 and 30 MHz due to metal preformed grips located between HB 9 and HB 10.



ANTENNA PHASE COMPARISON

PHOTO: C10

STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 2 Apr 1981

REFERENCE: HB 9

TEST: HB 11

XMIT: HB 10

The large phase errors are inverted from the previous photo since the transmission path is now from HB 10 to HB 9.

FIGURE 4-7. The Effect of Metal Preformed Grips Caused This Phase Error Display on High Band Antenna.

CHAPTER 5
PRIMARY AND DISTRIBUTION MULTICOUPLER TEST

5.1 PURPOSE

This chapter provides information, instruction, and assistance on the alignment of various antenna multicouplers used in AN/FRD-10 Circularly Disposed Antenna Array (CDAA) systems. This chapter includes:

1. Standardized test setups using different types of test equipment.
2. Phase adjustment procedures for different types of multicouplers that provide accurate phase alignment.
3. Procedure to select a station reference multicoupler.

5.2 DESCRIPTION

There are many similar paths through which RF signals enter a CDAA system. A typical path consists of an antenna element, a transmission line, a multicoupler, and various beamformers. To assure DF accuracy and receiving performance, it is essential that the RF paths be as nearly identical as possible. Multicouplers, which are the only active devices in these paths are prone to drift and change with age, consequently these devices require regular attention to maintain proper operation.

As part of the Circularly Disposed Antenna Array (CDAA) Test and Development Program, the Naval Electronics Engineering Activity, Pacific (NEEACTPAC) has developed testing and alignment procedures using state-of-the-art swept frequency and Continuous Wave (CW) techniques to assist CDAA sites in the development of their own multicoupler testing and phase alignment programs. The testing and phase alignment program should be performed in accordance with established Preventive Maintenance Schedules.

5.2.1 **Amplitude Uniformity.** Signals passing through each multicoupler must receive the same gain (amplification). There are no adjustments for gain. It is determined by design factors, however it is important to check the amplitude of test signals passing through the multicouplers to verify that the device is functioning properly.

5.2.2 **Phase Uniformity and Alignment.** These tests are performed to assure that signals pass through each multicoupler with the same speed. Figure 5-1 shows 7.2° phase shift that will result if a 10 MHz signal passes through a multicoupler .002 μsec faster than the reference multicoupler. The speed with which signals pass through the multicoupler is determined by the capacitance and inductance that are adjustable and must be aligned to establish the desired phase uniformity.

5.2.3 The importance of proper multicoupler maintenance and phasing cannot be over-emphasized. Experimental tests have shown that phase errors in the antennas, transmission lines, or multicouplers can seriously degrade the direction finding accuracy of the CDAA system. Therefore, it is the intent of this chapter to assist CDAA sites in the development or upgrading of their own viable multicoupler testing and phasing program to insure optimum system performance.

5.2.4 Multicoupler testing and phasing procedures described in this chapter utilize the general test configuration shown in Figure 5-2. A swept-frequency HF signal (2-32 MHz) or CW test signal is distributed to two multicouplers by a power splitter and phase-matched or phased-normalized cables. The multicoupler outputs are then connected to phase/amplitude measurement test equipment through these cables. The test equipment measures the relative phase and amplitude differences between the test and reference multicouplers.

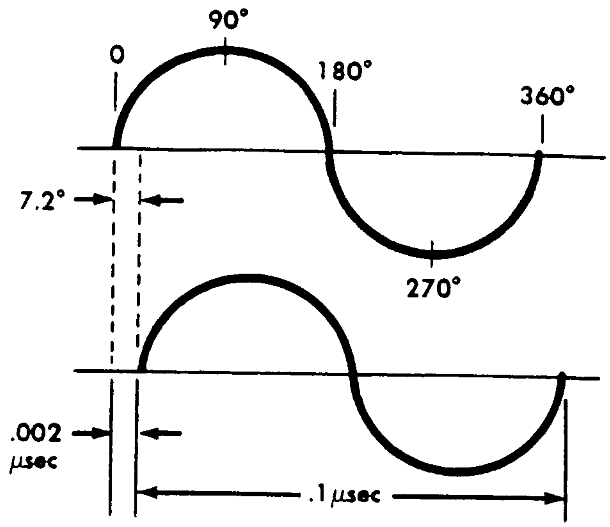


FIGURE 5-1. 7.2° Phase Shift.

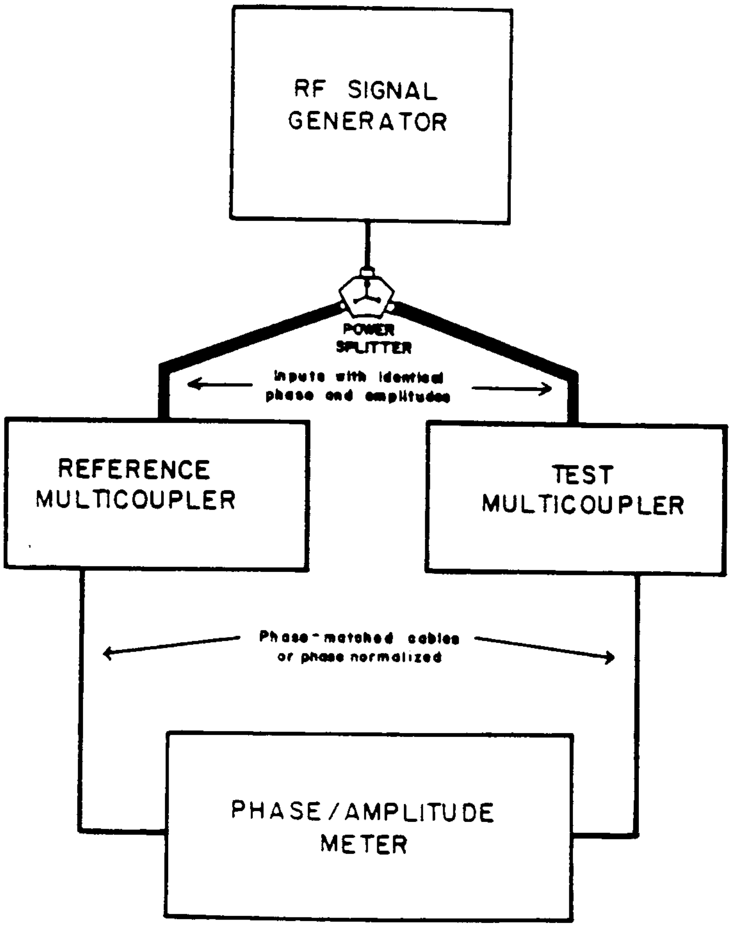


FIGURE 5-2. General Test Block Diagram.

5.3 TEST SETUP

Test equipment setups are described in the following paragraphs:

Paragraph 5.5 – HP 8407A/8412A Network Analyzer System
Paragraph 5.6 – HP 8405A Vector Voltmeter
Paragraph 5.7 – HP 3577A Network Analyzer

Paragraphs 5.5 and 5.8 use swept-frequency techniques while paragraph 5.6 uses CW test procedures.

5.4 PHASE ALIGNMENT PROCEDURES

The multicoupler phase alignment procedures are described in the following paragraphs:

Paragraph 5.8 – CU-1382G/FRR and CU-1382H/FRR Multicouplers
Paragraph 5.9 – CU-2289/FRR Multicoupler

5.4.1 **Selection of a Station Reference Multicoupler.** Paragraph 5.10 describes one method of selecting a station reference multicoupler. This method samples 25 multicouplers and identifies the multicoupler whose phase response is closest to the median value of the 25 multicouplers. This procedure will minimize the number of multicouplers that are out of tolerance and require adjustment.

5.5 HP 8407A/8412A NETWORK ANALYZER AND HP 8601A GENERATOR/SWEEPER TEST SYSTEM

5.5.1 **Test Equipment.** The following test equipment is required to perform this test procedure:

1. HP 8407A/8412A Network Analyzer
2. HP 8601A Generator/Sweeper
3. Negative DC Power Supply (HP 6200 Series or equivalent)
4. Frequency Counter (HP 5381 or equivalent)
5. HP 11652A Reflection/Transmission Kit
6. Four impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-32 MHz, such as North Hills Electronics 0102JA (optional)
7. Two pairs of phase-matched (electrically equal length) 75 ohm cables
8. Two UG-914/U female-to-female BNC adapters
9. Connectors, adapters, and 50 ohm cables as required

5.5.2 **Preliminary Procedure.** Test equipment should be operating 15 minutes prior to performing calibration to provide adequate warm-up time. Additionally, refer to Paragraphs 5.8 and 5.9 for the specific warm-up times of the multicouplers under test.

5.5.3 **Test System Calibration.** Perform the following steps:

1. Connect equipment as shown in Figure 5-3 and Table 5-1, but replace the multicoupler with identical barrel connectors (UG-914/U).

CAUTION

Do not apply a positive DC voltage, or a negative DC voltage exceeding 500 mV, to the "EXT FM" input on the HP 8601A, as this will damage the instrument.

2. Set controls as shown in Table 5-2.

5.3 TEST SETUP

Test equipment setups are described in the following paragraphs:

Paragraph 5.5 – HP 8407A/8412A Network Analyzer System
Paragraph 5.6 – HP 8405A Vector Voltmeter
Paragraph 5.7 – HP 3577A Network Analyzer

Paragraphs 5.5 and 5.8 use swept-frequency techniques while paragraph 5.6 uses CW test procedures.

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5.5 HP 8407A/8412A NETWORK ANALYZER AND HP 8601A GENERATOR/SWEEPER TEST SYSTEM

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3. Negative DC Power Supply (HP 6200 Series or equivalent)
4. Frequency Counter (HP 5381 or equivalent)
5. HP 11652A Reflection/Transmission Kit
6. Four impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-32 MHz, such as North Hills Electronics 0102JA (optional)
7. Two pairs of phase-matched (electrically equal length) 75 ohm cables
8. Two UG-914/U female-to-female BNC adapters
9. Connectors, adapters, and 50 ohm cables as required

5.5.2 **Preliminary Procedure.** Test equipment should be operating 15 minutes prior to performing calibration to provide adequate warm-up time. Additionally, refer to Paragraphs 5.8 and 5.9 for the specific warm-up times of the multicouplers under test.

5.5.3 **Test System Calibration.** Perform the following steps:

1. Connect equipment as shown in Figure 5-3 and Table 5-1, but replace the multicoupler with identical barrel connectors (UG-914/U).

CAUTION

Do not apply a positive DC voltage, or a negative DC voltage exceeding 500 mV, to the "EXT FM" input on the HP 8601A, as this will damage the instrument.

2. Set controls as shown in Table 5-2.

Table 5-1. HP 8407A/8412A, B Network Analyzer System, Cabl Connections

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 8407A/8412A Network Analyzer			
VTO IN	Rear Panel	HP 8601A VTO OUT	RG-58/223
SWEEP IN		HP 8601A SWEEP OUT	RG-58/223
BLANKING		HP 8601A BLANKING OUT	RG-58/223
TEST CHANNEL	Front Panel	TEST M/C OUT (J3)	RG-58/223*
REF CHANNEL		REFERENCE M/C OUT (J3)	RG-58/223*
HP 8601A Generator/Sweeper			
RF OUT	Front Panel	POWER SPLITTER IN	RG-58/223
EXT FM		DC POWER SUPPLY	RG-58/223
AUX OUT		FREQUENCY COUNTER IN	RG-58/223
BLANKING OUT	Rear Panel	† HP 8407A/8412A BLANKING IN	RG-58/223
SWEEP OUT		HP 8407A/8412A SWEEP IN	RG-58/223
VTO OUT		HP 8407A/8412A VTO IN	RG-58/223
Power Splitter			
INPUT		HP 8601A RF OUT	RG-58/223
OUT		REFERENCE M/C IN	RG-58/223*
OUT		TEST M/C IN	RG-58/223*

* Cables must be amplitude and phase-matched. 50/75 ohm impedance adapters are required if there is an impedance difference between the test equipment and the equipment under test.

† HP 8412B does not have a "BLANKING IN" jack so this connection may be omitted.

Table 5-2. HP 8407A/8412A Network Analyzer System, Control Settings

CONTROL	SETTING
HP 8407A/8412A Network Analyzer	
REF CHAN LEVEL ADJ	As needed to stay in "OPERATE" range
DISPLAY REFERENCE	As needed to obtain trace
HORIZ POSITION/HORIZ GAIN	As needed to obtain calibrated 2-32 MHz across display (refer to photos)
BW(kHz)	0.1
MODE	As needed
AMPL. dB/div	1.0
PHASE deg/div	1.0
PHASE OFFSET	0
INTENSITY	As needed
FOCUS	As needed
HP 8601A Generator/Sweeper	
OUTPUT LEVEL	−30 dBm
SWEEP	VIDEO
FREQUENCY	As needed to obtain 2-32 MHz across display
SWEEP MODE	FREE, FAST
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
DC Power Supply	
OUTPUT *	Approximately −200 mV for a 2 MHz start frequency. (Do not adjust to more than −500 mV and never apply a positive voltage to the EXT FM input on the HP 8601A.)
Frequency Counter	
INPUT	Scale for 2 to 32 MHz frequency range

* If a banana plug to BNC adapter is used on the power supply output, verify the DC continuity between the center pin of the BNC connector and the high (+) banana pin. (Some adapters contain a DC blocking capacitor. These adapters are usually blue.)

CAUTION

If a banana plug to BNC adapter is used on the power supply output, make certain the ground banana pin marked by the tab is connected to the positive (+) terminal of the power supply.

3. To calibrate the phase of the network analyzer, set the mode switch to PHASE and adjust the PHASE VERNIER to position the trace on the center horizontal grid line of the display. If the response is not relatively flat, the positions of the impedance adapters can be switched to a combination that produces a flatter phase response. Observe that cable "A" is phase-matched (electrically equal length) to cable "B" and cable "C" is phase-matched to cable "D".

4. To calibrate the amplitude of the network analyzer, set the mode switch to AMPL and adjust the AMPL VERNIER to position the trace on the center horizontal grid line of the display.

NOTE

Since the primary multicouplers have 2 to 32 MHz band pass filters and the HP 8601A signal generator sweeps from 1 to 32 MHz, the network analyzer will not have a reference signal between 1.0 and 2.0 MHz. Depending on the sweep speed, the network analyzer's phase lock loop will not respond quickly enough to display the actual value near 2 MHz. Therefore a negative voltage is applied to offset the start frequency of the signal generator to 2 MHz instead of 1 MHz. This will result in having a constant reference signal, therefore being able to measure the phase and amplitude near 2 MHz.

5. Calibrate the HF frequency sweep range from 2 to 32 MHz as follows:

a. Set the SWEEP MODE of the sweep generator to MANUAL.
b. Turn the MANUAL knob fully counterclockwise.
c. Adjust the DC power supply until the frequency counter reads 2 MHz (approximately −200 mV).
d. Turn the MANUAL knob of the sweep generator fully clockwise.
e. Adjust the FREQUENCY knob of the sweep generator until the frequency counter reads 32 MHz.

NOTE

Adjustments of HP 8412A Horizontal position and Horizontal gain may be necessary to obtain a full scale trace of 2-32 MHz.

f. To verify the start frequency, turn the MANUAL knob fully counterclockwise and observe the frequency counter.

g. If necessary, repeat this procedure (step 5) as required to obtain the desired frequency range.

6. Remove the barrel connectors and connect the cables to the multicouplers as shown in Figure 5-3. Observe that cable "A" and cable "B" are connected to output J3 of the reference and test multicouplers, respectively.

7. Measure the relative amplitude and phase differences between the multicouplers. Refer to the appropriate multicoupler paragraph for detailed alignment procedures if the results are not within specifications.

5.6 HP 8405A VECTOR VOLTMETER TEST SYSTEM

The HP 8405A Vector Voltmeter was specified for aligning multicoupler phase twenty years ago before network analyzers were widely available. This instrument measures CW signals only and is not recommended for aligning multicouplers. Most CDAA sites still have HP 8405A's and this instrument can be used in place of a network analyzer in an emergency. For this reason, information on the HP 8405A is included.

5.6.1 Test Equipment.

The following test equipment is required to perform this test procedure:

1. HP 8405A Vector Voltmeter (with isolators)
2. HP 8601A or AN/URM-25 (or equivalent) Signal Generator
3. "T" connector, such as HP 11529A Power Splitter
4. Two impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-32 MHz, such as North Hills Electronics 0102JA

5. Two pairs of phase-matched (electrically equal length) 75 ohm cables
6. Two 75 ohm terminations
7. 50 ohm cables and connectors as required
8. Two "T" connectors

5.6.2 Preliminary Procedure. Test equipment should be operating 45 minutes prior to performing calibration to provide adequate warm-up time. Additionally, refer to Paragraphs 5.8 and 5.9 for the specific warm-up times of the multicouplers under test.

5.6.3 Test System Calibration. Perform the following steps:

1. Connect equipment as shown in Figure 5-4 and Table 5-3, but replace both multicouplers with identical barrel connectors.

NOTE

The tee connectors and 75 ohm terminations are needed to load the multicoupler outputs because the Vector Voltmeter has high impedance inputs.

NOTE

Connect impedance adapters directly to the power splitter to minimize cabling.

2. Adjust the signal generator for a −30 dBm CW output at the first test frequency.
3. Tune the vector voltmeter FREQ RANGE-MHz control to the appropriate frequency range.

NOTE

The APC UNLOCKED light should be off.

4. Set the vector voltmeter AMPLITUDE CHANNEL SELECTOR to "A" and adjust the AMPLITUDE RANGE control for an on-scale reading. Record the channel "A" amplitude in dB.
5. Set the vector voltmeter AMPLITUDE CHANNEL SELECTOR to "B" and record the reading.

NOTE

The channel "A" and "B" amplitudes should be equal ±0.5 dB.

6. Set the vector voltmeter PHASE OFFSET control to zero.
7. Set the PHASE RANGE control to ±6.0 degrees.
8. Adjust the phase zero vernier (inner PHASE RANGE, red knob) to zero the phase meter.

5.6.3.1 Reference Multicoupler Absolute Amplitude and Phase Measurements.

1. Calibrate the vector voltmeter test set-up at one of the test frequencies (2.5, 4, 6, 8, 12, 14, 18, 21, 24, 26, 28 and 30 MHz).
2. Replace the channel "B" barrel connector, used for calibration, with the station's reference multicoupler.
3. Measure and record the amplitude and phase shift of the standard.

NOTE

It may be necessary to adjust the vector voltmeter PHASE OFFSET controls to obtain an on-scale phase reading.

4. Repeat steps 1, 2, and 3 for each test frequency.

5.6.3.2 Relative Amplitude and Phase Measurements.

1. Calibrate the vector voltmeter test setup.
2. Insert the station reference and test multicouplers as shown in Figure 5-4.
3. Measure and record the phase and amplitude differences between the test and reference multicouplers.
4. If necessary, refer to the appropriate multicoupler paragraph for alignment procedures. Record the final phase and amplitude measurements.

NOTE

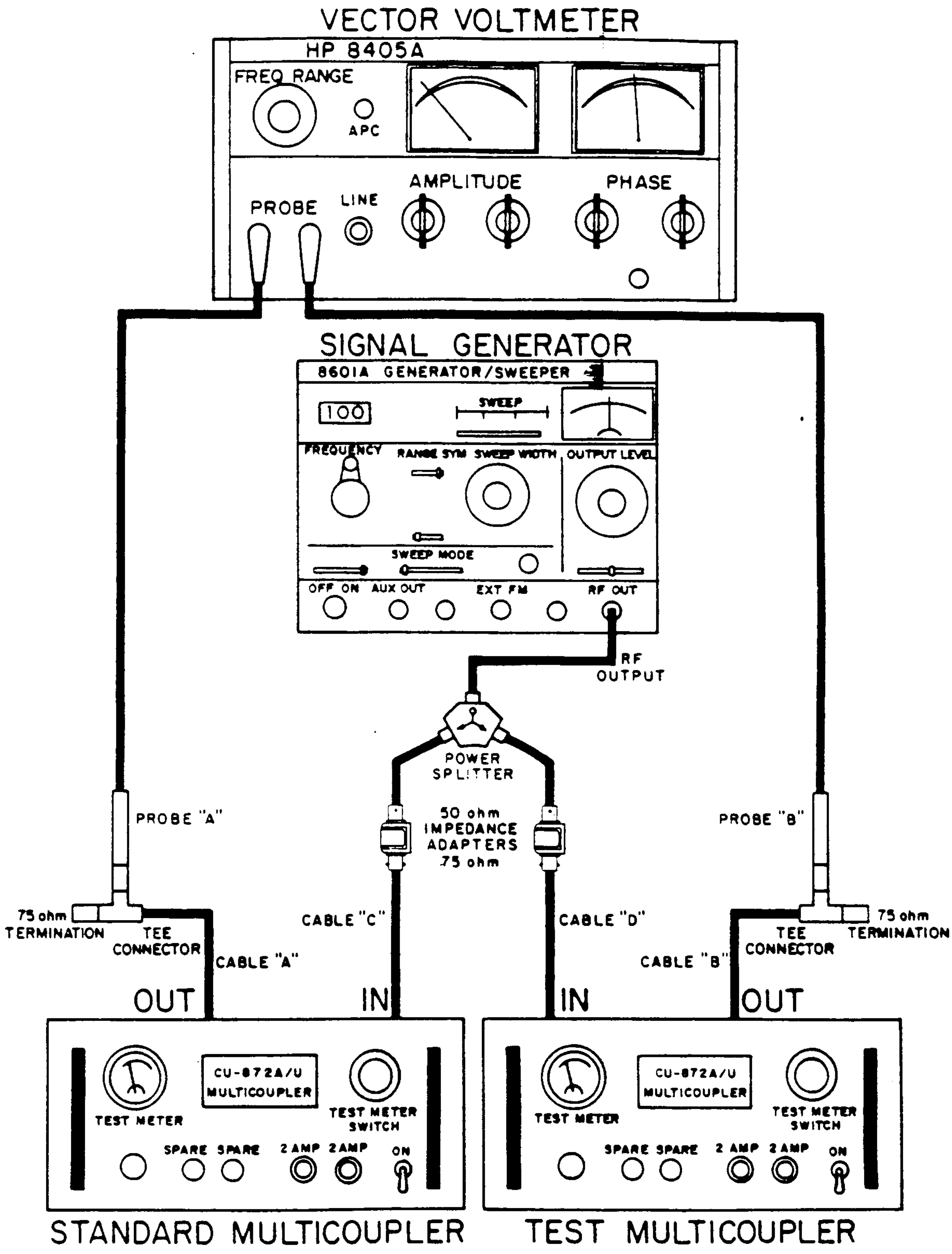
In general, any multicoupler adjustment will affect both the amplitude and the phase at all frequencies. The primary drawback to the vector voltmeter CW phase and amplitude adjustment procedures is that all frequencies must be rechecked after each adjustment.

5. Repeat the above calibration and measurement procedures for each test frequency (2.5, 4, 6, 8, 12, 14, 18, 21, 24, 26, 28 and 30 MHz).

Table 5-3. HP 8405A Vector Voltmeter System, Cable Connections

FUNCTION	CONNECTED TO	CABLE TYPE
HP 8405A Vector Voltmeter		
PROBE "A"	TEE CONNECTOR (REFERENCE)	(PROBE)
PROBE "B"	TEE CONNECTOR (TEST)	(PROBE)
HP 606A/B Generator/Sweeper		
RF OUT	POWER SPLITTER IN	RG-58/223
Reference Multicoupler		
OUTPUT (J3)	75 ohm TEE CONNECTOR (REF)	RG-59/307*
INPUT	POWER SPLITTER OUTPUT	RG-59/307*
Test Multicoupler		
OUTPUT (J3)	75 ohm TEE CONNECTOR	RG-59/307*
INPUT	POWER SPLITTER OUTPUT	RG-59/307*

* Cables must be amplitude and phase-matched. 50/75 ohm impedance adapters are required if there is an impedance difference between cables and test equipment.



NOTE: TERMINATE ALL UNUSED CONNECTORS ON MULTICOUPLER DURING TEST.

FIGURE 5-4. HP 8405A Multicoupler Phase/Amplitude Comparison, Test Diagram. (Shown connected to the now bsolete CU-872A/U multicoupler)

5.7 HP 3577A NETWORK ANALYZER SYSTEM

The HP 3577A represents a new generation of network analyzers and replaces the HP 8407A series which is no longer available from Hewlett-Packard.

5.7.1 Test Equipment. The following test equipment is required to perform this test procedure:

1. HP 3577A Network Analyzer
2. HP 11652A Reflection/Transmission Kit
3. Four impedance adapters, 50 to 75 ohm, with a flat phase and amplitude response across 2-32 MHz, such as North Hills Electronics 0102JA (optional)
4. Two pairs of 50 ohm cables
5. Connectors and adapters as required

5.7.2 Preliminary Procedure. Test equipment should be operating 15 minutes prior to performing calibration to provide adequate warm-up time. Additionally, refer to Paragraphs 5.8 and 5.9 for the specific warm-up times of the various multicouplers.

5.7.3 Test System Calibration. Perform the following steps:

1. To set the HP 3577A output level to −30 dBm, press the following sequence of keys. Figure 5-5 shows the location of SOFTKEYS, DISPLAY FORMAT keys, and SOURCE keys.

a. SOURCE selection key is used to display amplitude menu.	[AMPTD]
b. SOFTKEY used to change amplitude level.	AMPTD [ ]
c. DATA ENTRY.	[−] [3] [0]
d. SOFTKEY selection of units for the DATA ENTRY.	dBm [ ]

2. To set the HP 3577A start and stop frequencies, press the following sequence of keys.

a. SOURCE selection key to display frequency menu.	[FREQ]
b. SOFTKEY used to change the start frequency.	START FREQ [ ]
c. DATA ENTRY.	[2]
d. SOFTKEYS used to select units and stop frequency.	MHz [ ] STOP FREQ [ ]
e. DATA ENTRY.	[3] [2]
f. SOFTKEY to select units.	MHz [ ]

3. Connect equipment shown in Figure 5-6 and Table 5-4 but replace the multicouplers with identical barrel connectors.
4. To calibrate Trace 1 for amplitude mode, press the following keys.

a. DISPLAY FORMAT key to display input menu.	[INPUT]

b. SOFTKEY to select inputs.

c. DISPLAY FORMAT key to display function menu.

d. SOFTKEY used to select the Log Mag function of the active trace.

e. DISPLAY FORMAT key to display scale menu.

f. SOFTKEY to change reference position.

g. DATA ENTRY.

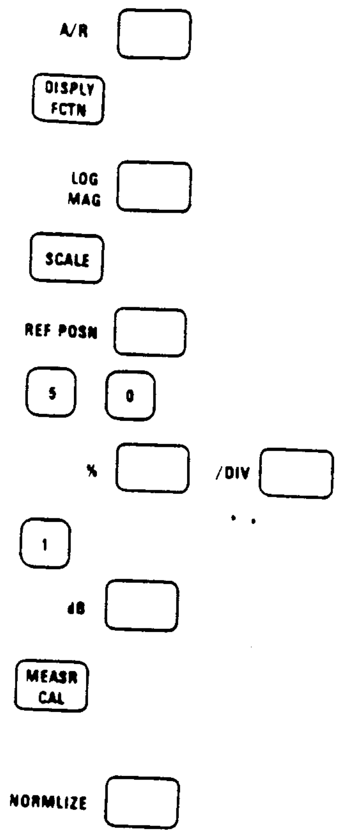
h. SOFTKEYS to select units and change /div scale.

i. DATA ENTRY.

j. SOFTKEY to select units.

k. DISPLAY FORMAT key to display the Measurement Calibration menu.

l. SOFTKEY to normalize measurement. This stores a trace in data register D1 and redefines the INPUT to be the old definition divided by the stored trace.



5. To set Trace 2 with phase mode calibration, press the following sequence of keys.

a. DISPLAY FORMAT keys are used to set trace 2 to be active and display function menu.

b. SOFTKEY to select phase function of active trace.

c. DISPLAY FORMAT key to display input menu.

d. SOFTKEY to select inputs.

e. DISPLAY FORMAT key to display scale menu.

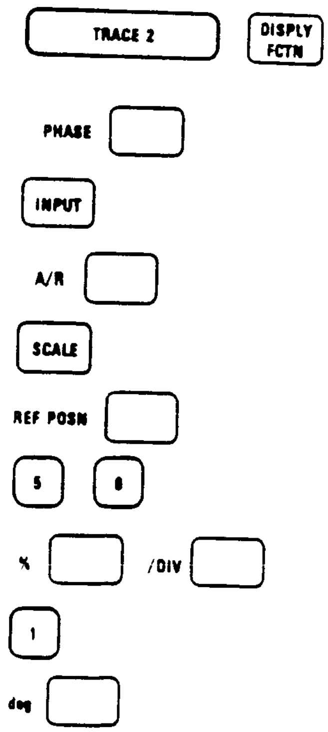
f. SOFTKEY to change the reference position.

g. DATA ENTRY.

h. SOFTKEYS to select units and change /div scale.

i. DATA ENTRY.

j. SOFTKEY to select units.



k. DISPLAY FORMAT key to display the Measurement Calibration menu. — MEASR CAL

l. SOFTKEY to normalize measurements. This stores a trace in data register D2 and redefines the INPUT to be the old definition divided by the stored trace. — NORMLIZE

6. Remove barrel connectors and connect the cables to the multicouplers as shown in Figure 5-6. Cable "A" and cable "B" of reference and test multicouplers, respectively, should be on output J3 when testing.

7. Trace 1 and Trace 2 will display the amplitude and phase measurements, respectively. To select the desired active trace, press the DISPLAY FORMAT keys Trace 1 or Trace 2. Measure the relative amplitude and phase differences between multicouplers. Refer to the appropriate multicoupler chapter for detailed alignment procedures if the results are not within specifications.

NOTE

The marker knob will give specific values of amplitude and phase given a specific frequency.

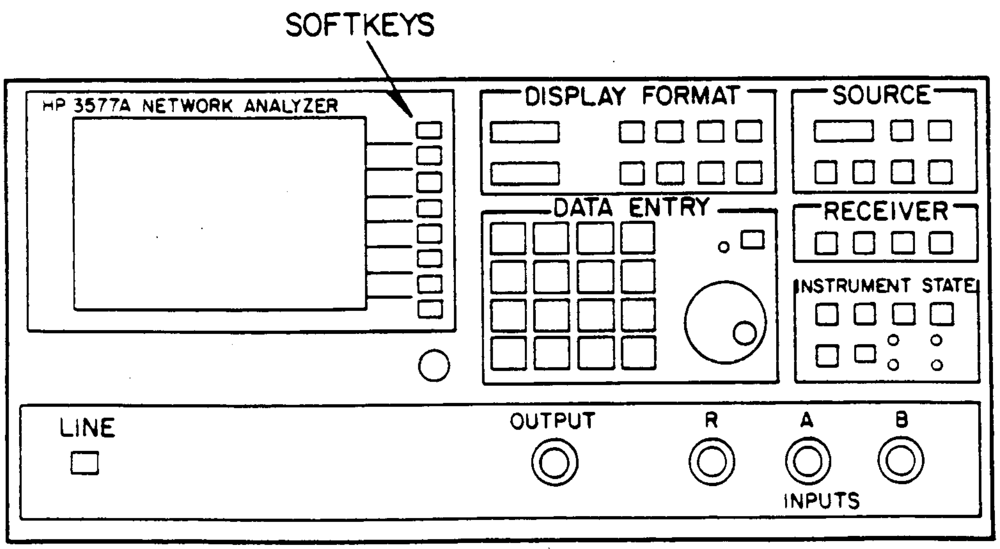
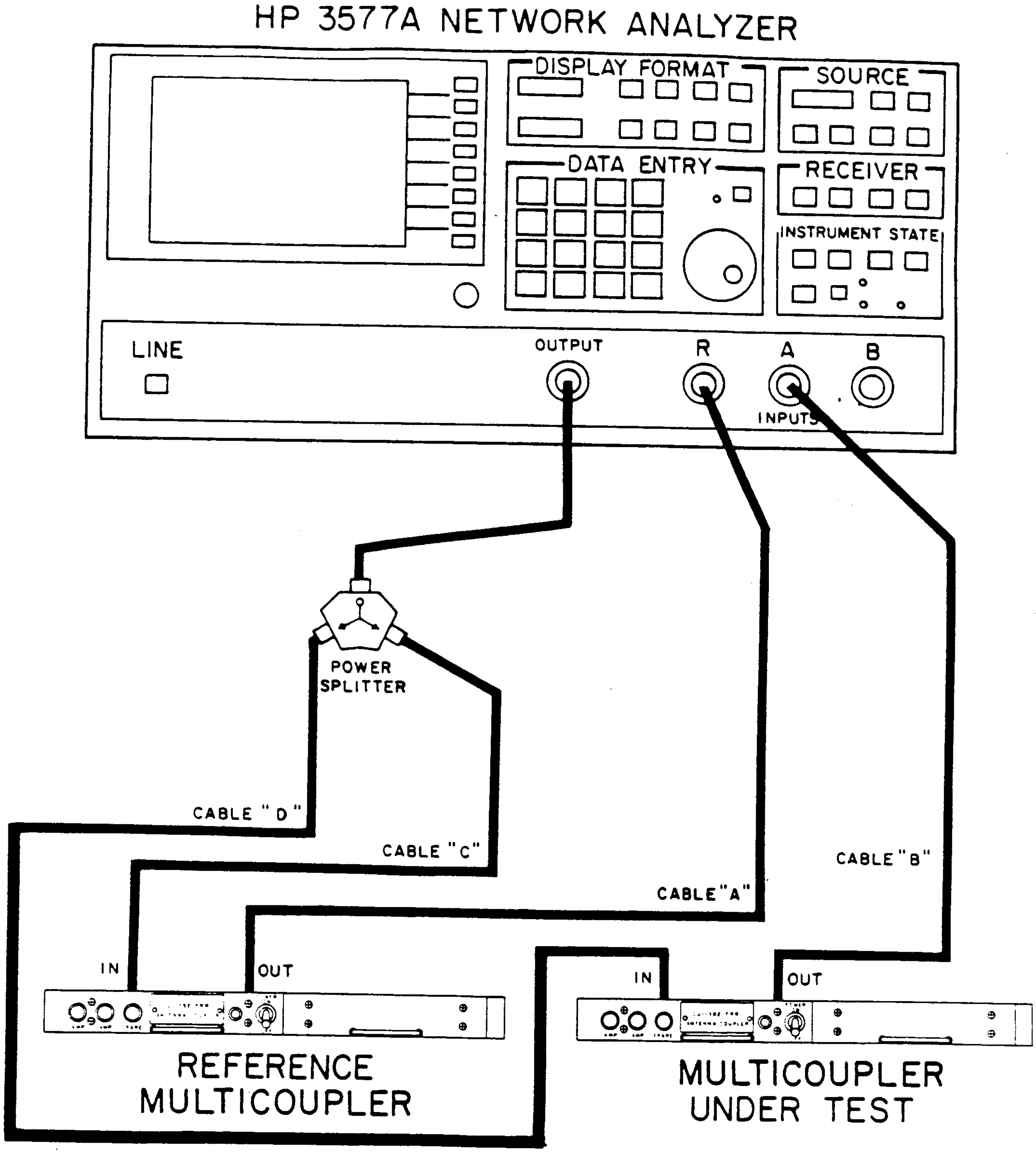


FIGURE 5-5. HP 3577A Network Analyzer, Locati n f SOFTKEYS, DISPLAY FORMAT Keys, SOURCE Keys, and DATA ENTRY Keys.



NOTE: TERMINATE ALL UNUSED CONNECTORS ON MULTICOUPLER DURING TEST.

FIGURE 5-6. HP 3577A Network Analyzer System, Multicoupler Phase/Amplitude Comparison Test Diagram.

Table 5-4. HP 3577A Network Analyzer System, Cable Connecti ns

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 3577A Network Analyzer			
OUTPUT	Front Panel	POWER SPLITTER IN	RG-58/223
INPUT R		REFERENCE M/C OUT (J3)	RG-58/223
INPUT A		TEST M/C OUT (J3)	RG-58/223
Power Splitter			
INPUT		HP 3577A OUT	RG-58/223
OUT		REFERENCE M/C IN	RG-58/223
OUT		TEST M/C IN	RG-58/223
Reference Multicoupler			
INPUT (J9)	Rear Panel	POWER SPLITTER OUT	RG-58/223
OUTPUT (J3)		HP 3577A INPUT R	RG-58/223
Test Multicoupler			
INPUT (J9)	Rear Panel	POWER SPLITTER OUT	RG-58/223
OUTPUT (J3)		HP 3577A INPUT A	RG-58/223

NOTE: Cables need not be amplitude or phase-matched since the normalization capability of the instrument will compensate for signal path differences.

5.8 CU-1382G/FRR AND CU-1382H/FRR MULTICOUPLERS ALIGNMENT PROCEDURES

CU-1382/FRR 8-output multicoupler is very similar to the 16-output CU-2289/FRR multicoupler. They have similar circuitry and therefore the phase/amplitude and isolation alignment procedures will be similar for both types of multicouplers. The major difference is the presence of additional circuitry in the 16-output CU-2289/FRR as shown in Figure 5-7. The 1:2 power divider, at the output of the bandpass filter, splits the filtered RF input into two signals to drive two 1:8 divider circuits. Figure 5-8 shows the top view of the coupler.

5.8.1 Test Procedure.

5.8.1.1 Output-to-Output Isolation Adjustment. This test consists of the following steps: (The CU-1382G/FRR and CU-1382H/FRR type multicouplers have 50 ohm input/output impedance.)

1. Turn on the CU-1382/FRR multicoupler. The unit should have a warm-up period of one hour prior to alignment to provide adequate warm-up time.
2. Remove top cover from test equipment (refer to Figure 5-9). Do not remove the cover from the reference multicoupler.

NOTE

On CU-2289 multicouplers and later Model CU-1382 multicouplers, holes are provided in the output transistor heat sink to gain access to adjustments C17, C19, C21 and C23 which are located under the heat sink. On early Model CU-2289 and CU-1382 multicouplers, it may be necessary to remove the heat sink to adjust these capacitors. If this is done, it is essential to use a small muffin fan blowing directly on the transistors to prevent heat damage while the heat sink is removed. As an alternative to the fan, remove the heat sink and drill access holes in it. An easy way to do this is to temporarily remove a heat sink from a CU-2289 multicoupler and use it as a drill template.

3. Calibrate test system using the following procedure:
   a. Set up the test equipment as shown in Figure 5-10, but replace multicoupler with a barrel connector.
   b. Set controls as shown in Table 5-2, but set display REFERENCE to 0.
   c. Set the mode switch to AMPL and adjust the AMPL VERNIER to position the trace on the center horizontal grid line of the display. Figure 5-11 is an example of an Output-to-Output Isolation calibration display.

NOTE

Since the primary multicouplers have 2 to 32 MHz band pass filters and the HP 8601A signal generator sweeps from 1 to 32 MHz, the network analyzer will not have a reference signal between 1.0 and 2.0 MHz. Depending on the sweep speed, the network analyzer's phase lock loop will not respond quickly enough to display the actual value near 2 MHz. Therefore a negative voltage is applied to offset the start frequency of the signal generator to 2 MHz instead of 1 MHz. This will result in having a constant reference signal, therefore being able to measure the phase and amplitude near 2 MHz.

   d. Calibrate the HF frequency sweep range from 2 to 32 MHz as follows:
      (1) Set the SWEEP MODE of the sweep generator to MANUAL.
      (2) Turn the MANUAL knob fully counterclockwise.
      (3) Adjust the DC power supply until the frequency counter reads 2 MHz (approximately −200 mV).
      (4) Turn the MANUAL knob of the sweep generator fully clockwise to obtain a stop frequency of 32 MHz.
      (5) Adjust the FREQUENCY knob of the sweep generator until the frequency counter reads 32 MHz.

NOTE

Adjustments of HP 8412A Horizontal position and Horizontal gain may be necessary to obtain a full scale trace of 2-32 MHz.

      (6) To verify the start frequency, turn the MANUAL knob fully counterclockwise and observe the frequency counter.
      (7) If necessary, repeat this procedure (step d.) as required to obtain the desired frequency range.
   e. Set display REFERENCE to −40 dB. Test system calibration now complete.
   f. Remove barrel connector and connect cables to multicoupler as shown in Figure 5-10.

4. The outputs are tested as pairs (1 and 2, 3 and 4, 5 and 6, 7 and 8). If the network analyzer indicates an isolation less than 40 dB, adjust the capacitor associated with the output connectors (Table 5-6). Figure 5-12 is an example of Output-to-Output Isolation which is less than 40 dB.

5. If the isolation is still less than 40 dB, adjust the inductor (Figure 5-9) associated with the output connectors (Table 5-6), by spreading or squeezing the turns of the inductor until the isolation is greater than 40 dB

6. When the isolation is greater than 40 dB, reconnect cables "A" and "B" to the output connectors of next sequential test as shown in Table 5-6. Perform steps 4 and 5. When all of the tests for an individual an... coupler have each produced greater than 40 dB isolation, this procedure is complete. Figure 5-13 is an example of the desired Output-to-Output Isolation which is greater than 40 dB.

5.8.1.2 Phase and Amplitude Alignment.

NOTE

Output-to-Output Isolation Adjustment must be accomplished before performing this alignment procedure.

The CU-1382G/FRR and CU-1382H/FRR multicouplers have 50 ohm input/output impedances. See the test setups in Figures 5-3 and 5-6. The following steps will be performed:

Steps 1 and 2. These are identical to steps listed in Paragraph 5.8.1.1.

3. Use −10 dBm RF output.

4. Connect cable "B" to output 1 of the test multicoupler. Adjust capacitor C39 (refer to Figure 5-9) for minimum phase difference within ±2.0 degrees across 2-32 MHz (see Figure 5-15). Amplitude difference should not exceed ±0.5 dB.

5. Connect cable "B" to outputs 2 through 8 while adjusting the corresponding individual capacitors listed in Table 5-7. The minimum phase difference should be within ±2.0 degrees across a frequency range of 2-32 MHz. The amplitude difference should not exceed ±0.5 dB.

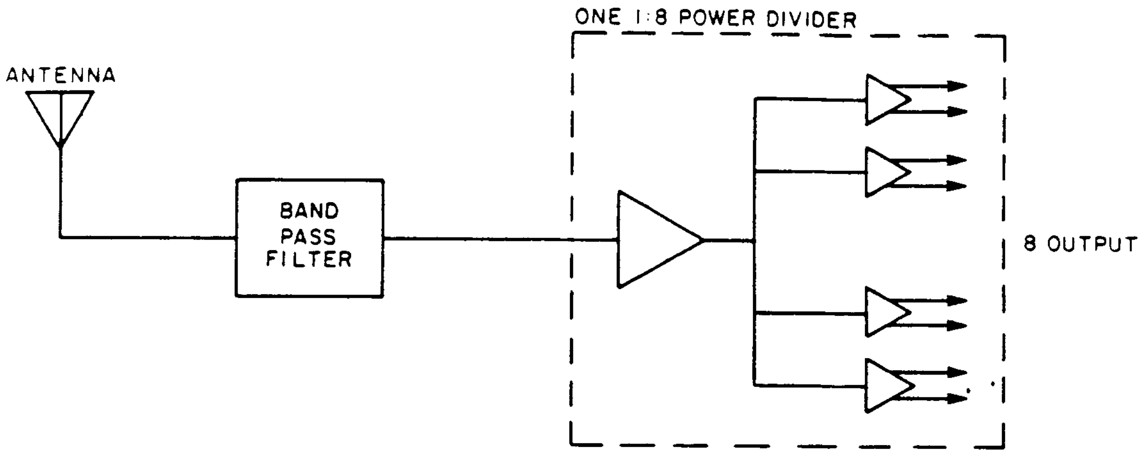
NOTE

If the required phase tracking cannot be achieved by tuning these capacitors, it may be necessary to adjust the windings on toroid inductors L8 in the bandpass filter (see Figure 5-14). On some production runs, these windings were closely spaced in four quadrants. Determine which type of spacing is used in the station's reference multicoupler and position the L8 windings in the unit under test so that it is similar to L8 in the reference multicoupler. Make small adjustment in the L8 windings to optimize the phase tracking.

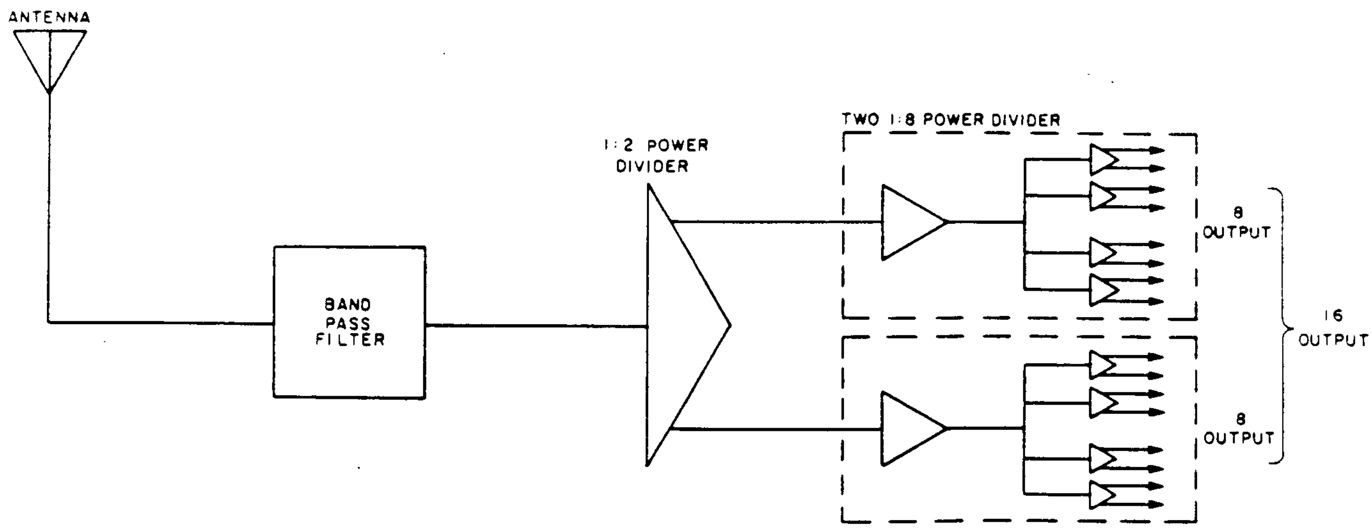
To adjust these toroids, manually break the glue holding the wire and reposition turns so they are evenly spaced around the core. To affect low frequency phase response, adjust the windings on inductor L8. High frequency phase response may be corrected by adjusting the windings on inductor L2. If adjusting of these capacitors and inductor remain ineffective in acquiring satisfactory phase/amplitude alignment, then the capacitor and inductors mentioned in Paragraph 5.8.1.1 should also be adjusted.

6. It may be necessary to apply additional heat conducting dielectric grease (silicone compound) to the heat sink on the top of the divider assembly. Replace top cover to insure good thermal conduction from the dust cover.

5.8.1.3 Alignment Problems. Severe amplitude and phase tracking problems for CU-1382G multicouplers are shown in Figures 5-16 and 5-17. Spikes in the amplitude and phase responses shown in Figure 5-16 are due to an oscillating transistor which required replacement. The phase problem shown in Photo D4 of Figure 5-17 were corrected by adjusting fixed inductors L8 and L2 for the low and high frequency responses, respectively, on the RF Filter board.

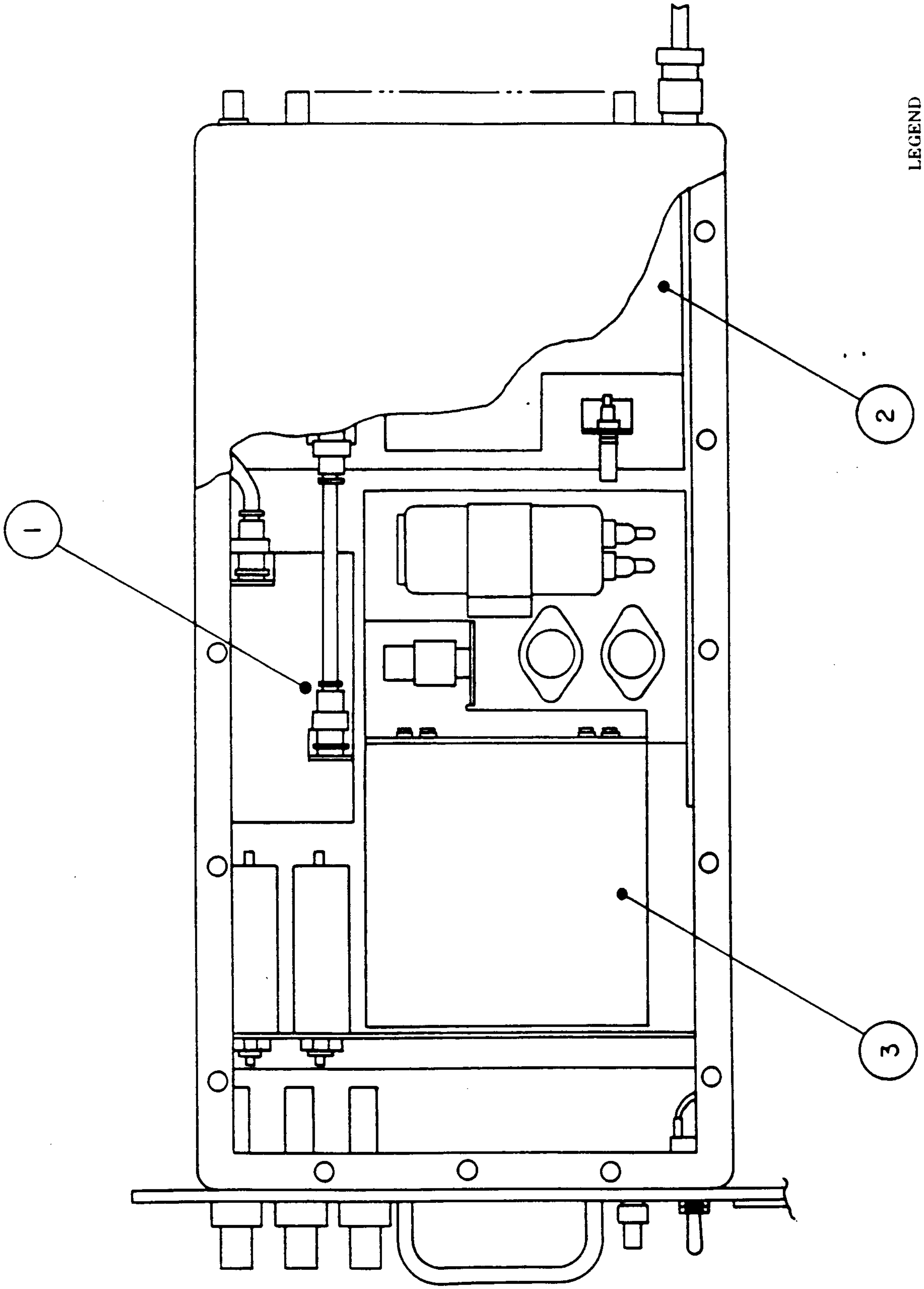


a) CU-1382/FRR



b) CU-2289/FRR

FIGURE 5-7. CU-1382/FRR and CU-2289/FRR, Block Diagram Depicting Their Differences.



LEGEND
1 RF FILTER, 1A1
2 1:8 DIVIDER, 1A2
3 POWER SUPPLY, 1A3

FIGURE 5-8. CU-1382G/FRR Antenna Mulicoupler, Top View Showing Location of Assemblies.

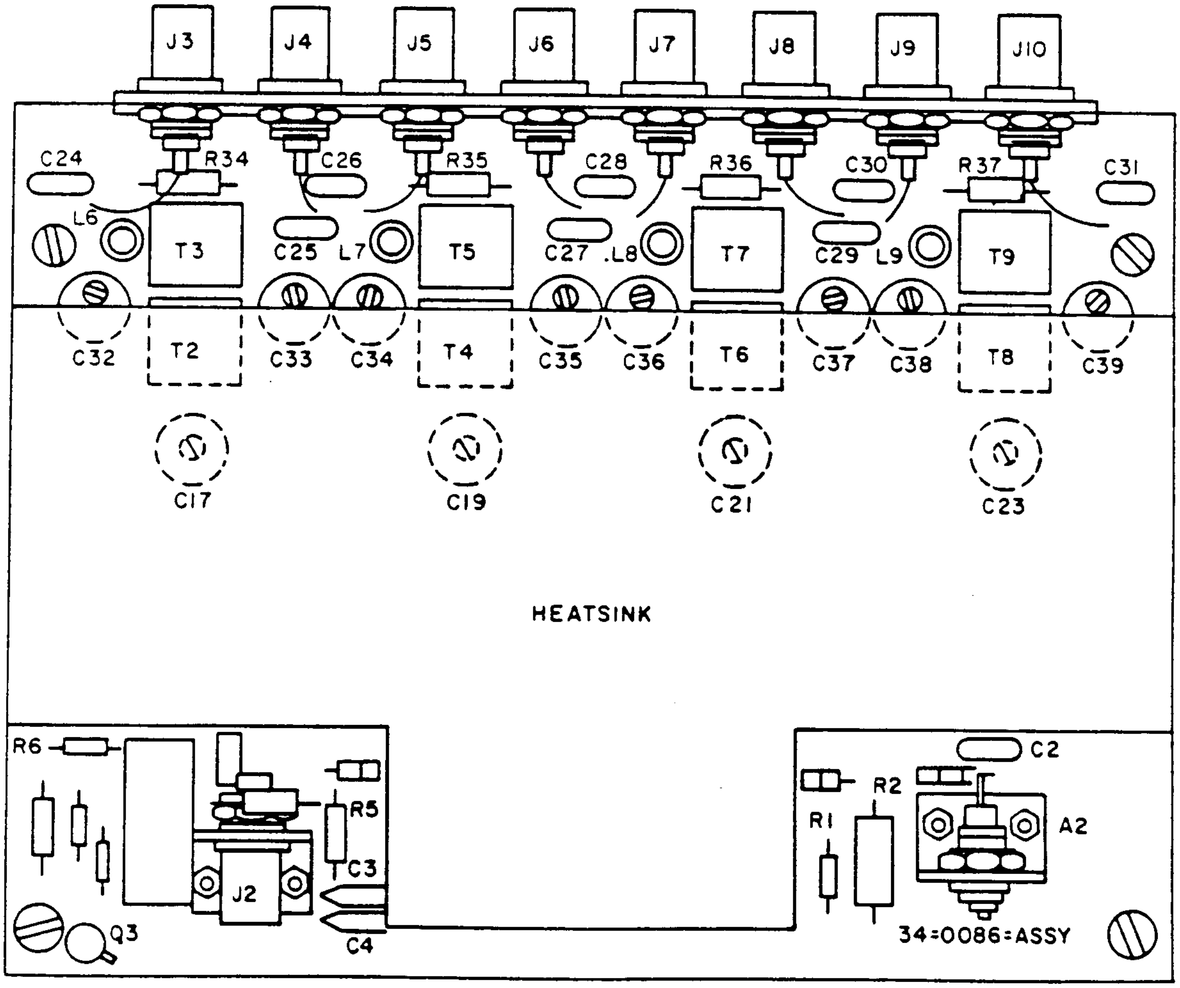


FIGURE 5-9. Divider Assembly 1A2, Location of Adjustments.

NOTE: 1. Terminate all unused connectors during test.

2. Isolation tests must be performed on output pairs 1 and 2, 3 and 4, 5 and 6, 7 and 8.

3. Cable connections listed in Table 5-2

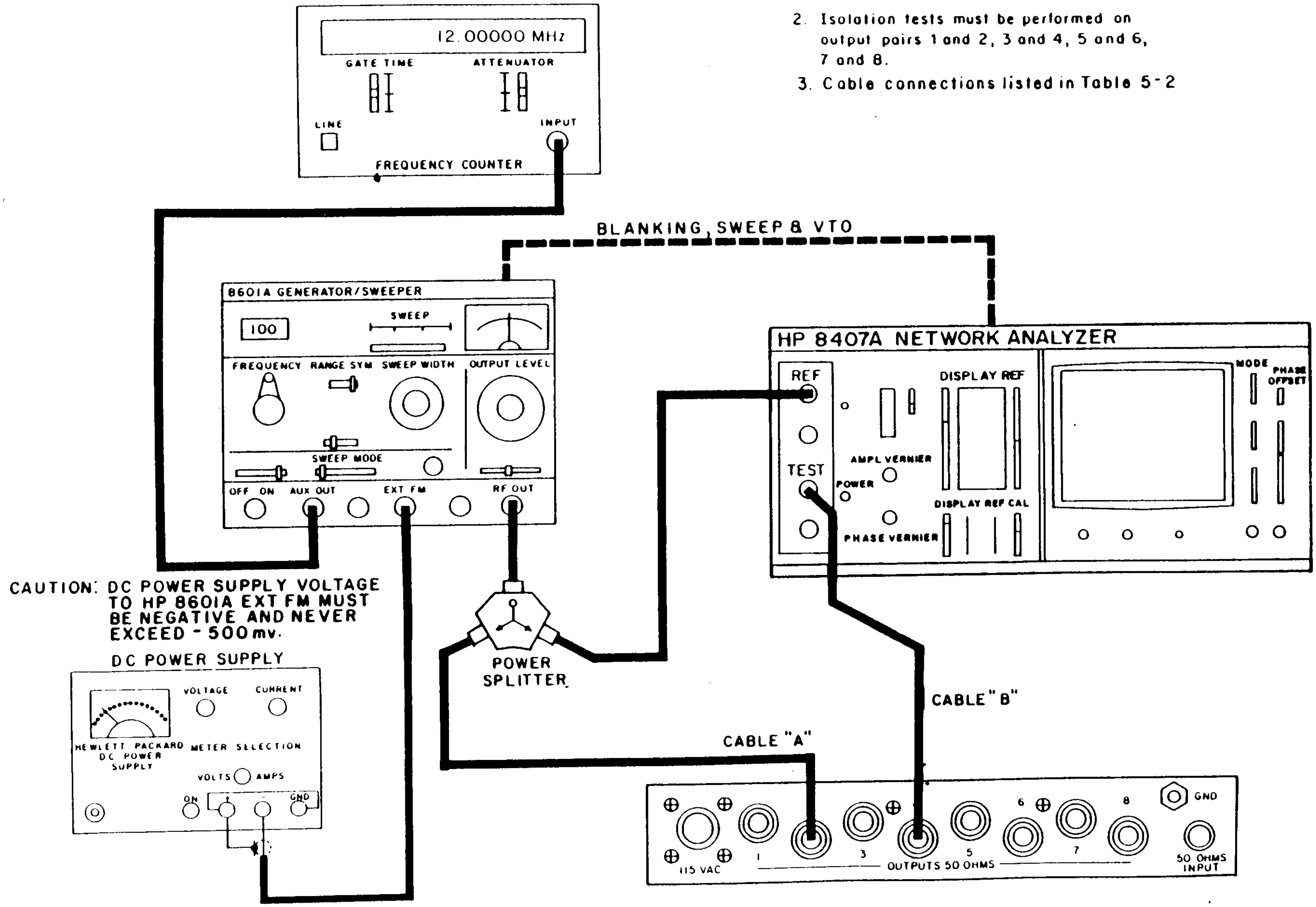


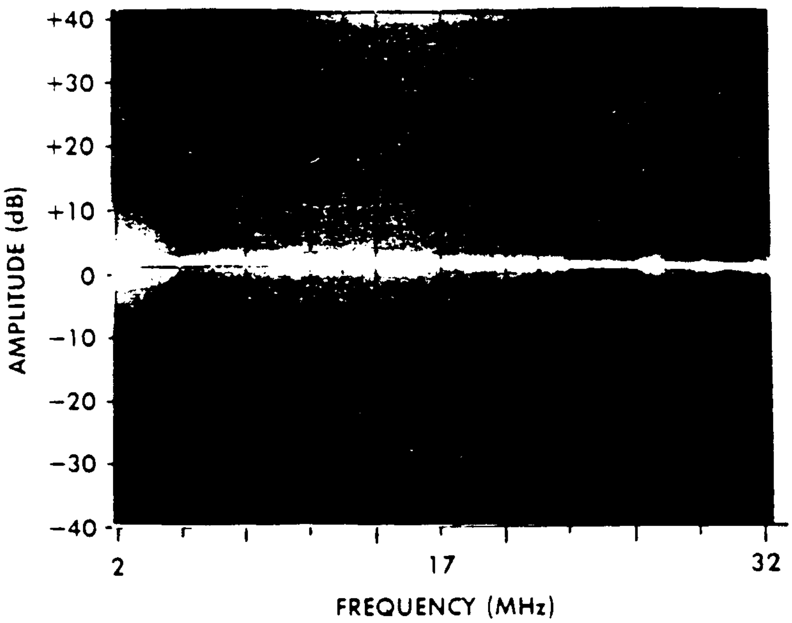
FIGURE 5-10. *CU-1382/FRR Multicoupler Output-to-Output Isolation Test, Block Diagram.*

Table 5-5. CU-1382/FRR Isolation Test Equipment Settings

SWEEPER SETTINGS (HP 8601A)	
OUTPUT LEVEL	−10 dB
SWEEP	VIDEO
FREQUENCY	As needed to obtain 2-32 MHz across display
SWEEP MODE	Free, manual
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
SIGNAL PROCESSOR SETTINGS (HP 8407A/8412A)	
REF CHAN LEVEL ADJ	As needed to stay in "OPERATE' range
DISPLAY REFERENCE	−40 dB
HORIZ POSITION/HORIZ GAIN	As needed to obtain calibrated 2-32 MHz across display
BW (kHz)	0.1
MODE	AMPL
AMPL dB/div	10

Table 5-6. Output-to-Output Isolation Adjustment Components

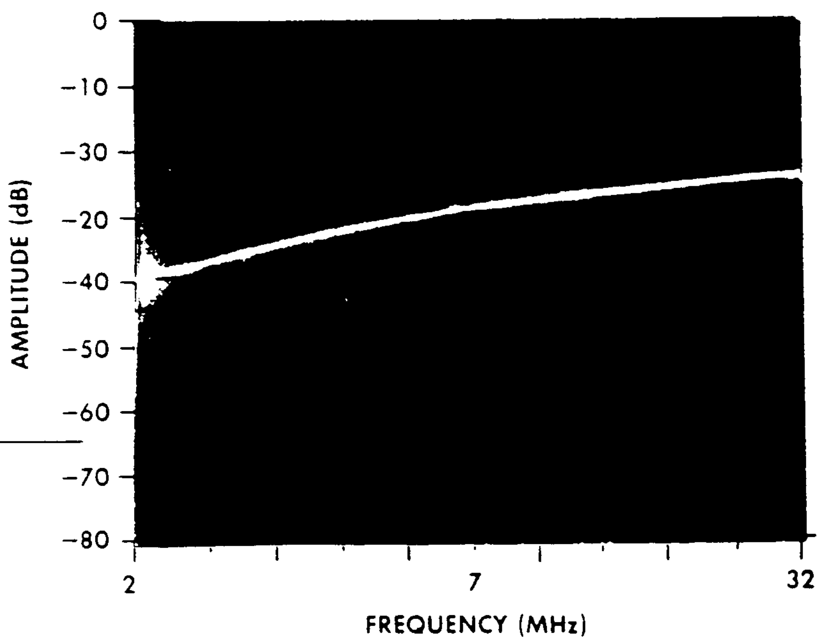
OUTPUT	CAPACITOR ADJUSTMENT	INDUCTOR ADJUSTMENT
1, 2	C23	L9
3, 4	C21	L8
5, 6	C19	L7
7, 8	C17	L6



OUTPUT-TO-OUTPUT
ISOLATION

CALIBRATION PROCEDURE

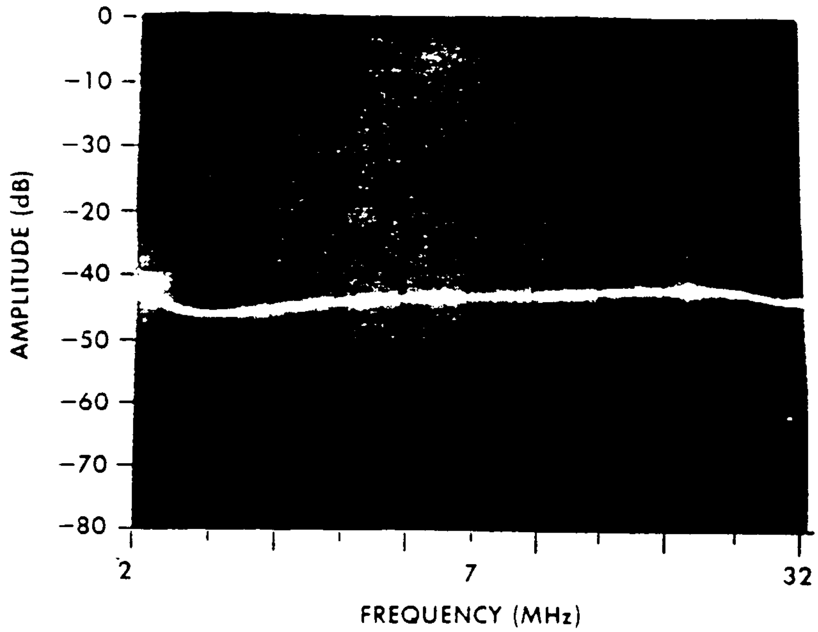
FIGURE 5-11. Example of Output-to-Output Isolation Calibration Display.



MULTICOUPLERS
CU-1382G/FRR
&
CU-1382H/FRR

OUTPUT-TO-OUTPUT
ISOLATION TEST

FIGURE 5-12. Example of Output-to-Output Isolati n Which is Less Than 40 dB.



MULTICOUPLERS
CU-1382G/FRR
&
CU-1382H/FRR

OUTPUT-TO-OUTPUT
ISOLATION TEST

FIGURE 5-13. Example of Output-to-Output Isolation Which is Greater Than 40 dB.

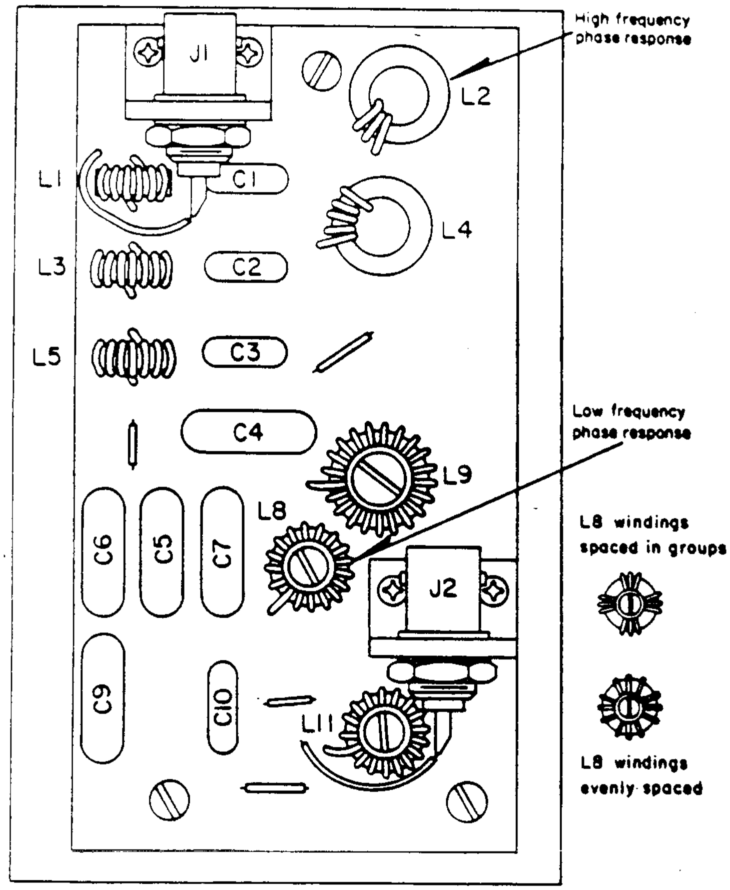


FIGURE 5-14. Location of Inductors L2 and L8 for High and Low Frequency Response.

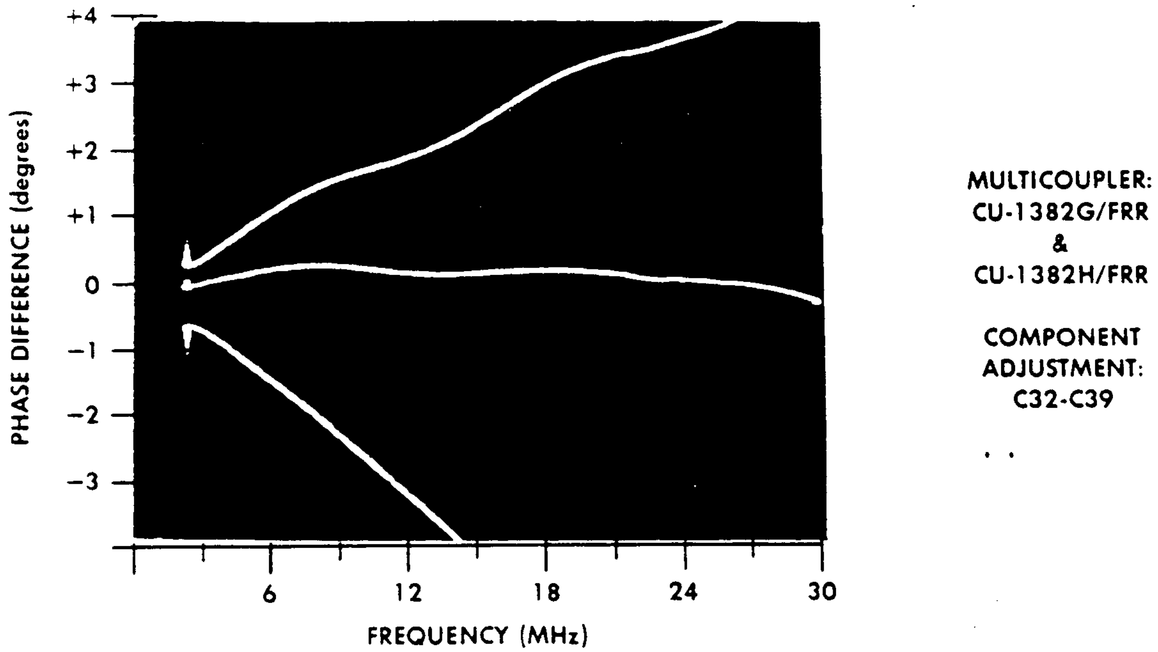
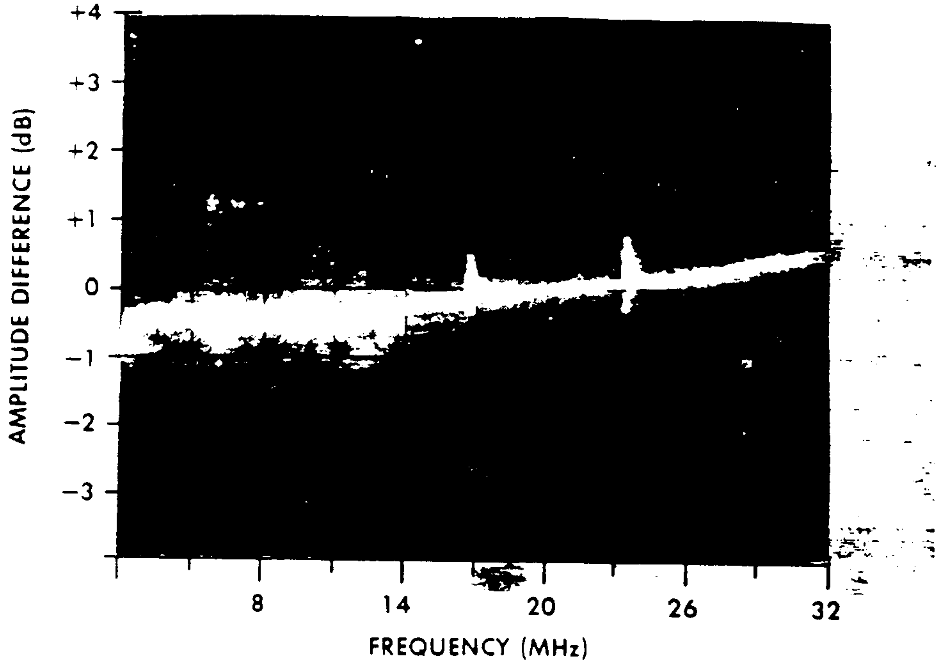


FIGURE 5-15. Example of the Adjustment Range of Capacitors C32–C39 of the CU-1382G/FRR and CU-1382H/FRR Multicouplers.

Table 5-7. CU-1382G/FRR and CU-1382H/FRR Multicouplers, Capacitor Adjustments

OUTPUT	CAPACITOR ADJUSTMENT
1 (J10)	C39
2 (J9)	C38
3 (J8)	C37
4 (J7)	C36
5 (J6)	C35
6 (J5)	C34
7 (J4)	C33
8 (J3)	C32



MULTICOUPLER
AMPLITUDE COMPARISON

PHOTO: D1

STATION: NSGA

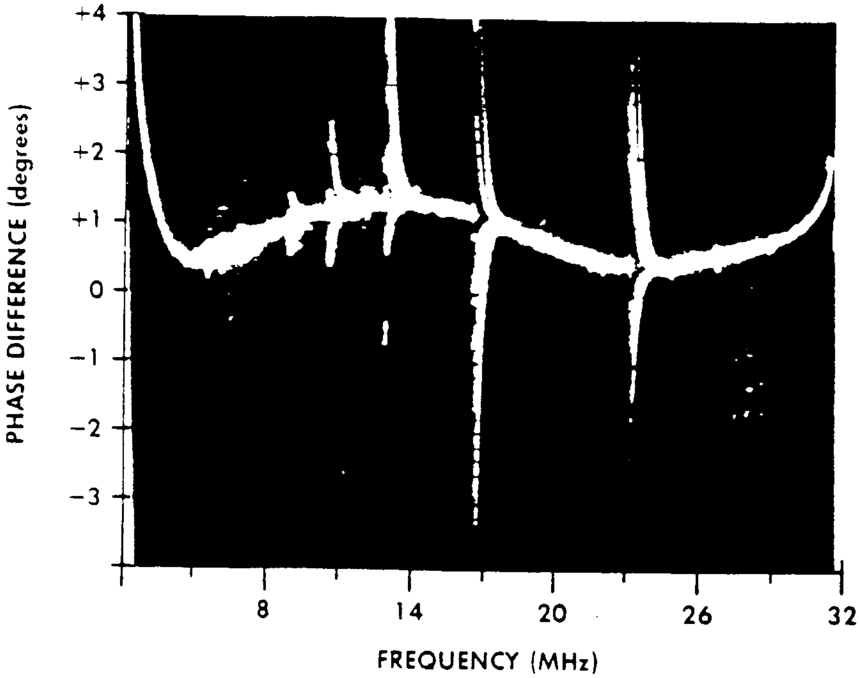
LOCATION: Edzell, Scotland

DATE: 12 Sep 1981

REFERENCE: Std

TEST: LB 16 cas.

Spikes in the amplitude response due to an oscillating transistor.



MULTICOUPLER
PHASE COMPARISON

PHOTO: D2

STATION: NSGA

LOCATION: Edzell, Scotland

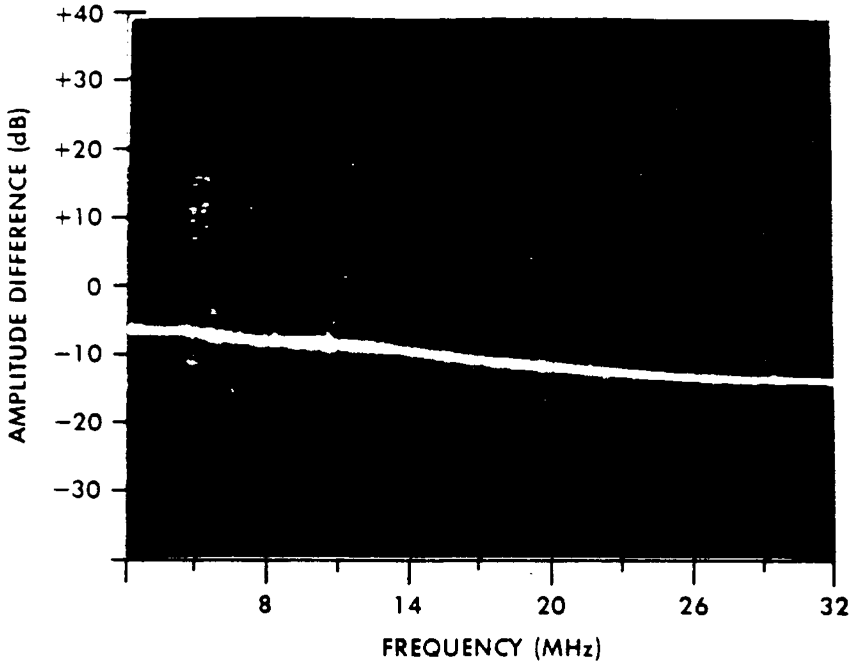
DATE: 12 Sep 1981

REFERENCE: Std

TEST: LB 16 cas.

Spikes in the phase response due to an oscillating transistor.

FIGURE 5-16. Spikes in the Amplitude and Phase Response Due to a Bad Transistor.



MULTICOUPLER
AMPLITUDE COMPARISON

PHOTO: D3

STATION: NSGA

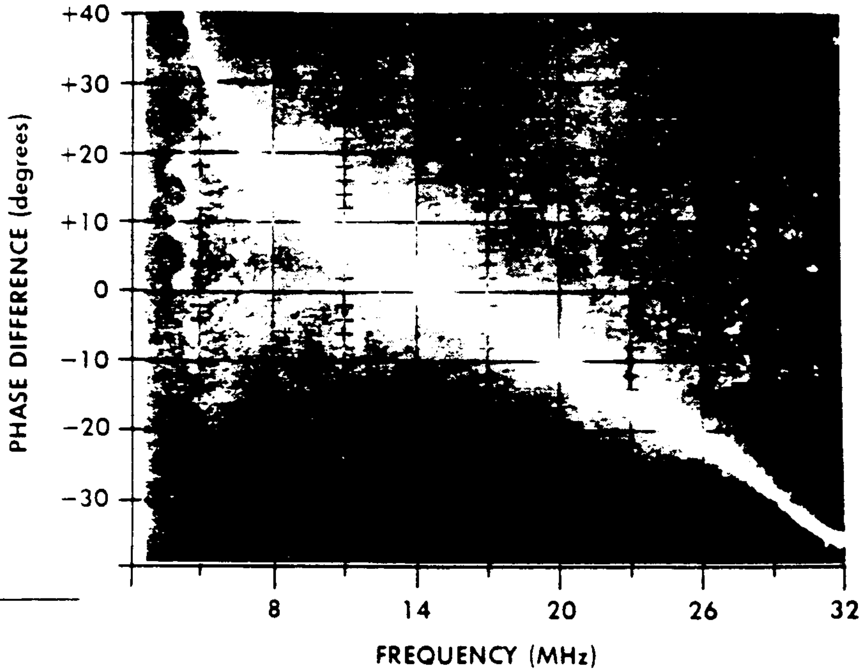
LOCATION: Edzell, Scotland

DATE: 11 Sep 1981

REFERENCE: Std

TEST: HB 104

A bad output transistor on the Divider Assembly board caused this low amplitude response.



MULTICOUPLER
PHASE COMPARISON

PHOTO: D4

STATION: NSGA

LOCATION: Edzell, Scotland

DATE: 12 Sep 1981

REFERENCE: Std

TEST: HB 72

A bad RF Filter board caused this severe phase problem.

FIGURE 5-17. Severe Amplitude and Phase Tracking Problems f r a CU-1382/FRR Multicoupler.

5.9 CU-2289/FRR MULTICOUPLER ALIGNMENT PROCEDURES

CU-2289/FRR 16-output multicoupler is very similar to the 8-output CU-1382/FRR multicoupler. They have similar circuitry and therefore the phase/amplitude and isolation alignment procedures will be similar for both types of multicouplers. An overall view of the multicoupler with dust cover removed is shown in Figure 5-19. The detail block diagram is shown in Figure 5-18.

5.9.1 Test Procedure.

5.9.1.1 Output-to-Output Isolation Adjustment. This test consists of the following steps:

1. Turn on the CU-2289/FRR multicoupler. The unit should have a warm-up period of one hour prior to alignment to provide adequate warm-up time.
2. Remove top cover from test multicoupler (refer to Figure 5-20). Do not remove the cover from the reference multicoupler.

NOTE

On CU-2289 multicouplers and later Model CU-1382 multicouplers, holes are provided in the output transistor heat sink to gain access to adjustments C17, C19, C21 and C23 which are located under the heat sink. On early Model CU-2289 and CU-1382 multicouplers, it may be necessary to remove the heat sink to adjust these capacitors. If this is done, it is essential to use a small muffin fan blowing directly on the transistors to prevent heat damage while the heat sink is removed. As an alternative to the fan, remove the heat sink and drill access holes in it. An easy way to do this is to temporarily remove a heat sink from a CU-2289 multicoupler and use it as a drill template.

3. Calibrate test system using the following procedure:
   a. Set up the test equipment as shown in Figure 5-21, but replace multicoupler with a barrel connector.
   b. Set controls as shown in Table 5-8, but set display REFERENCE to 0.
   c. Set the mode switch to AMPL and adjust the AMPL VERNIER to position the trace on the center horizontal grid line of the display. Figure 5-11 is an example of an Output-to-Output Isolation calibration display.

NOTE

Since the primary multicouplers have 2 to 32 MHz band pass filters and the HP 8601A signal generator sweeps from 1 to 32 MHz, the network analyzer will not have a reference signal between 1.0 and 2.0 MHz. Depending on the sweep speed, the network analyzer's phase lock loop will not respond quickly enough to display the actual value near 2 MHz. Therefore a negative voltage is applied to offset the start frequency of the signal generator to 2 MHz instead 1 MHz. This will result in having a constant reference signal, therefore being able to measure the phase and amplitude near 2 MHz.

   d. Calibrate the HF frequency sweep range from 2 to 32 MHz as follows:
      (1) Set the SWEEP MODE of the sweep generator to MANUAL.
      (2) Turn the MANUAL knob fully counterclockwise.
      (3) Adjust the DC power supply until the frequency counter reads 2 MHz (approximately −200 mV).
      (4) Turn the MANUAL knob of the sweep generator fully clockwise to obtain a stop frequency of 32 MHz.
      (5) Adjust the FREQUENCY knob of the sweep generator until the frequency counter reads 32 MHz.

NOTE

Adjustments of HP 8412A Horizontal position and Horizontal gain may be necessary to obtain a full scale trace of 2-32 MHz.

(6) To verify the start frequency, turn the MANUAL knob fully counterclockwise and observe the frequency counter.

(7) If necessary, repeat this procedure (step d.) as required to obtain the desired frequency range.

e. Set display REFERENCE to −40dB. Test system calibration now complete.

f. Remove barrel connector and connect cables to multicoupler as shown in Figure 5-21.

4. The outputs are tested as pairs (1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12, 13 and 14, 15 and 16). If the network analyzer indicates an isolation less than 40 dB, adjust the capacitor associated with the output connectors (Table 5-9).

5. If the isolation is still less than 40 dB, adjust the inductor (Figure 5-20) associated with the output connectors (Table 5-9), by spreading or squeezing the turns of the inductor until the isolation is greater than 40 dB.

6. When the isolation is greater than 40 dB, reconnect cables "A" and "B" to the output connectors of the next sequential test as shown in Table 5-9. Perform steps 4 and 5. When all of the tests for an individual antenna coupler have each produced greater than 40 dB isolation, this procedure is complete.

5.9.1.2 Phase and Amplitude Alignment.

NOTE

Output-to-Output Isolation Adjustment must be accomplished before performing this alignment procedure.

The CU-2289/FRR and CU-1382H/FRR multicouplers have 50 ohm input/output impedances. See the test setups in Figures 5-3 and 5-6. The following steps will be performed:

Steps 1 and 2. These are identical to those listed in Paragraph 5.9.1.1.

3. Use −10 dBm RF output.

4. Connect cable "B" to output 1 of the test multicoupler. Adjust capacitor 1A3, C39 (refer to Figure 5-20) for minimum phase difference within ±2.0 degrees across 2-32 MHz (see Figure 5-23). Amplitude difference should not exceed ±0.5 dB.

5. Connect cable "B" to outputs 2 through 16 while adjusting the corresponding individual capacitors listed in Table 5-10. The minimum phase difference should be within ±2.0 degrees across a frequency range of 2-32 MHz. The amplitude difference should not exceed ±0.5 dB.

NOTE

Phase tracking is not always possible by adjusting these capacitors. The problem can be caused by the fixed toroid inductors L8 or L2. Turns of the toroid should be uniformally distributed on the toroidal core (see Figure 5-22). If not, these inductors should be repaired or replaced.

To adjust these toroids, carefully break the glue holding the wire and reposition turns so they are evenly spaced around the core. To affect low frequency phase response, adjust the windings on inductor L8. High frequency phase response may be corrected by adjusting the windings on inductor L2 (refer to Figure 5-22). If adjustment of these capacitors and inductors fails to give good phase/amplitude alignment, the capacitor and inductors mentioned in Paragraph 5.8.1.1 should also be adjusted.

6. It may be necessary to apply additional heat conducting, dielectric grease (silicone compound) to the heat sink on the top of the divider assembly and replace top cover to insure good thermal conduction from the dust cover.

5.10 THE SELECTION OF A STATION REFERENCE MULTICOUPLER

5.10.1 Purpose. The station reference multicoupler represents the average response of station multicouplers in good condition. Its phase and amplitude response are used as references to which other multicouplers are adjusted (for a minimum of phase and amplitude differences).

The selection is made from a sampling of station multicouplers in good condition. The multicoupler with the median response of this group is selected and used as the station standard.

5.10.2 **Procedure.** Perform the following steps:

1. Select 26 multicouplers in good condition.
2. Select one multicoupler as a temporary reference.
3. Using the appropriate multicoupler test procedure, compare the 25 remaining multicouplers (labeled alphabetically for identification to the temporary reference). Record the phase differences at 2.5, 4, 6, 8, 12, 14, 18, 21, 24, 26, 28, and 30 MHz.
4. List the multicouplers according to the magnitude of their phase differences (ranked 1 through 25). Make a one-column list for each frequency as shown in Figure 5-24.
5. Find the multicoupler that falls closest to the middle of the list (i.e., ranking 13) for *all* frequencies and designate it the station reference. The following example illustrates this procedure:

EXAMPLE:

(1) Rank the multicouplers as shown in Figure 5-24 and list all the multicouplers on a tally sheet (refer to Figure 5-22). The tally sheet shown in Figure 5-25 lists the multicouplers and the number of times each was ranked 11th, 12th, 13th, 14th, 15th, etc.

(2) Make a slash mark to tally each time the multicoupler phase difference was ranked 13th.

(3) Repeat step (2) above for rankings 12 and 14 (if necessary 11 and 15, followed by 10 and 16, 9 and 17, 8 and 18, etc.). Take a sub-total after each pair of positions (if necessary summing each successive sub-total across a row). The first multicoupler reaching a sub-total greater than or equal to 12 (slashes) is the station's reference multicoupler. In this example, Figure 5-25 shows that "M" is the selected reference.

NOTE

If there were another multicoupler with a greater sub-total value, it would supersede.

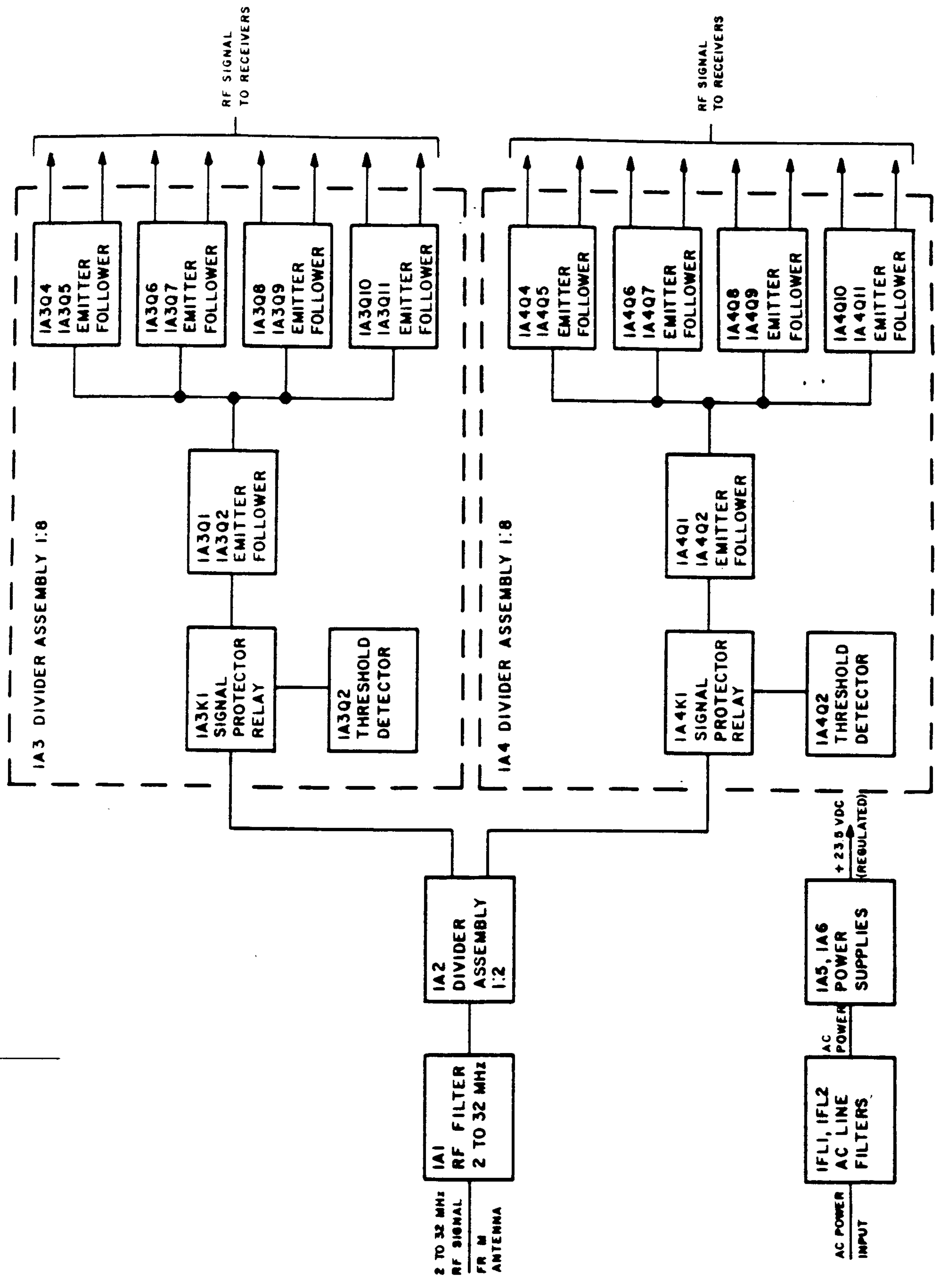
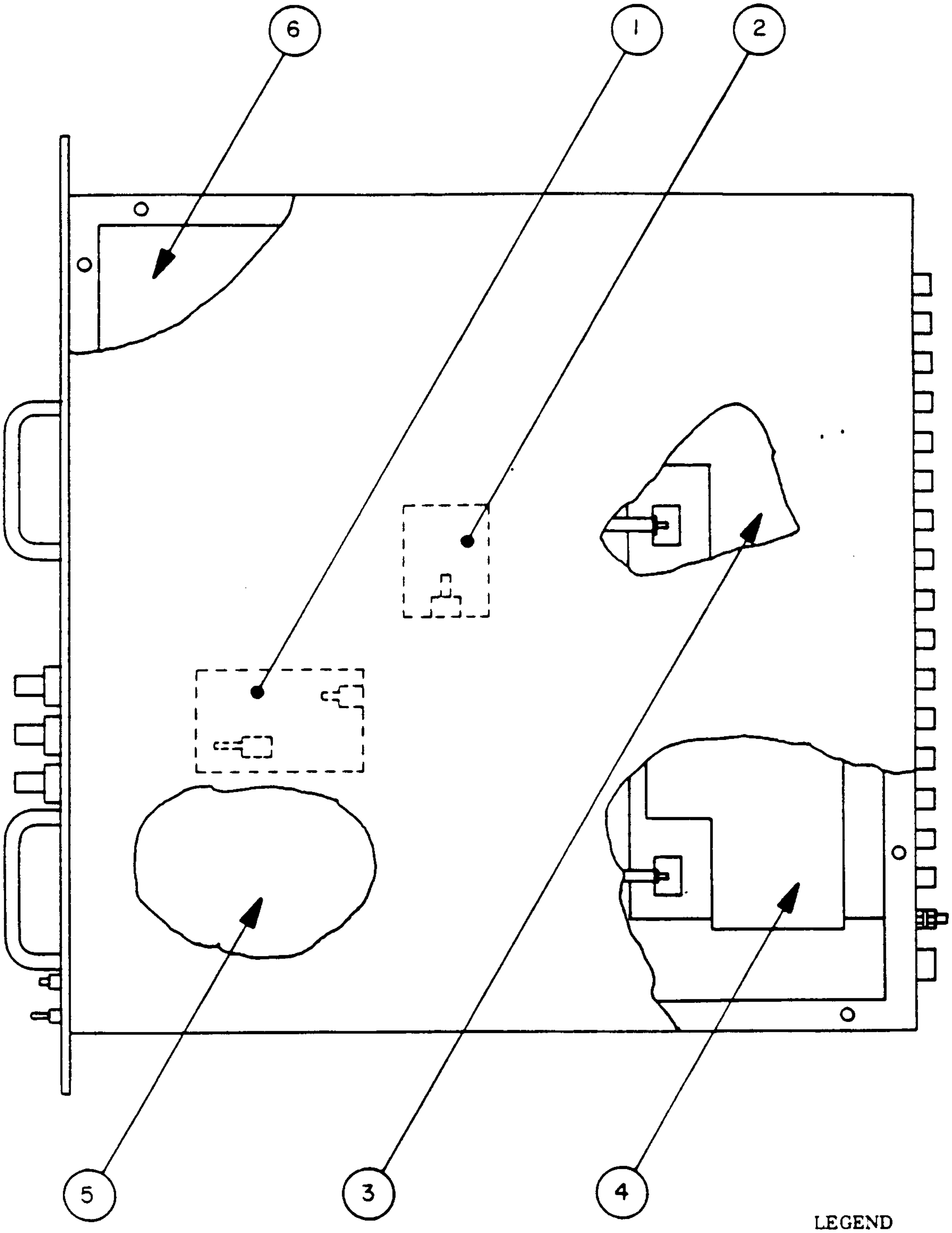


FIGURE 5-18. CU-2289/FRR Multicoupler, Block Diagram.



LEGEND
1 RF FILTER, 1A1
2 1:2 DIVIDER, 1A2
3 1:8 DIVIDER, 1A3
4 1:8 DIVIDER, 1A4
5 POWER SUPPLY, 1A5
6 POWER SUPPLY, 1

FIGURE 5-19. CU-2289/FRR Multicoupler, Location of Assemblies.

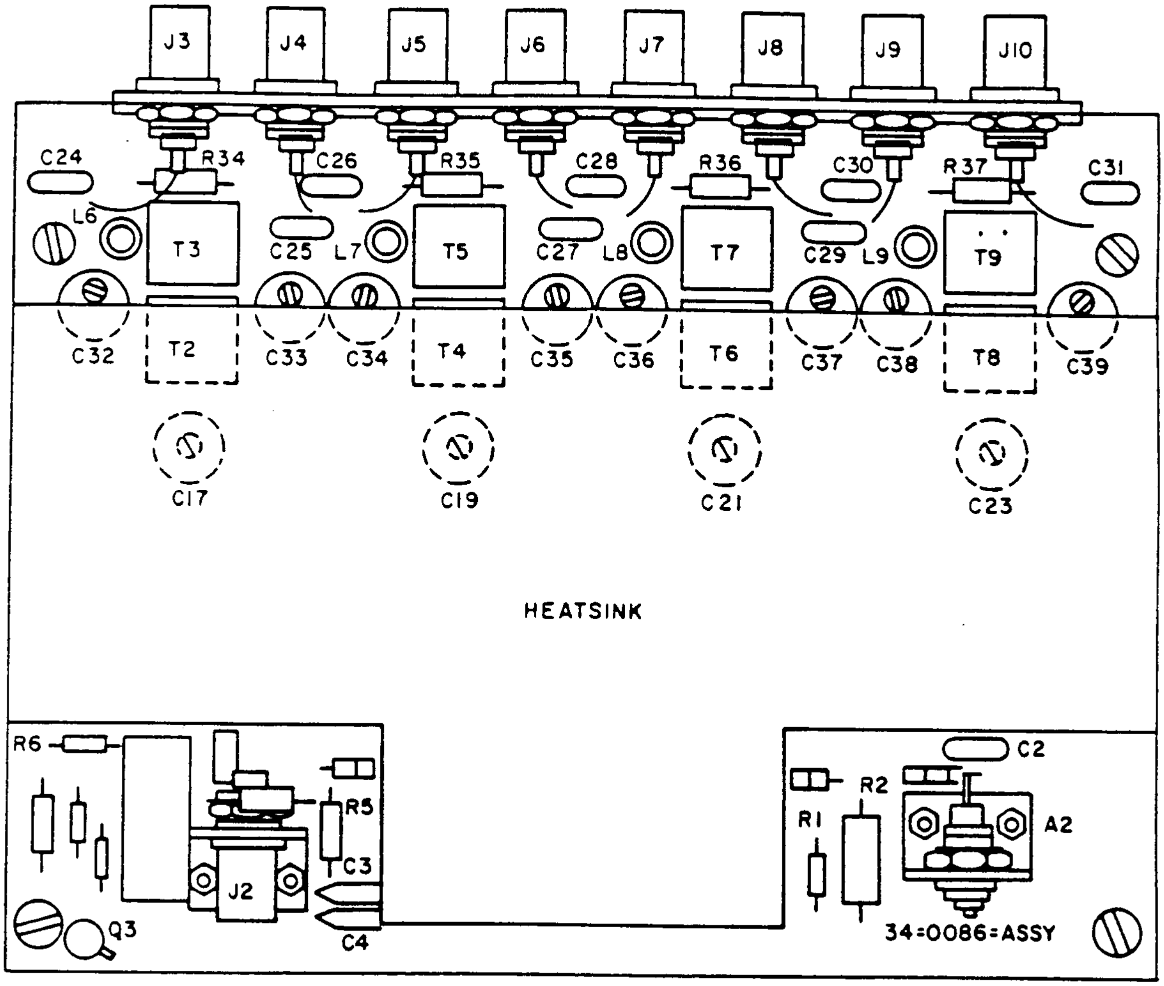
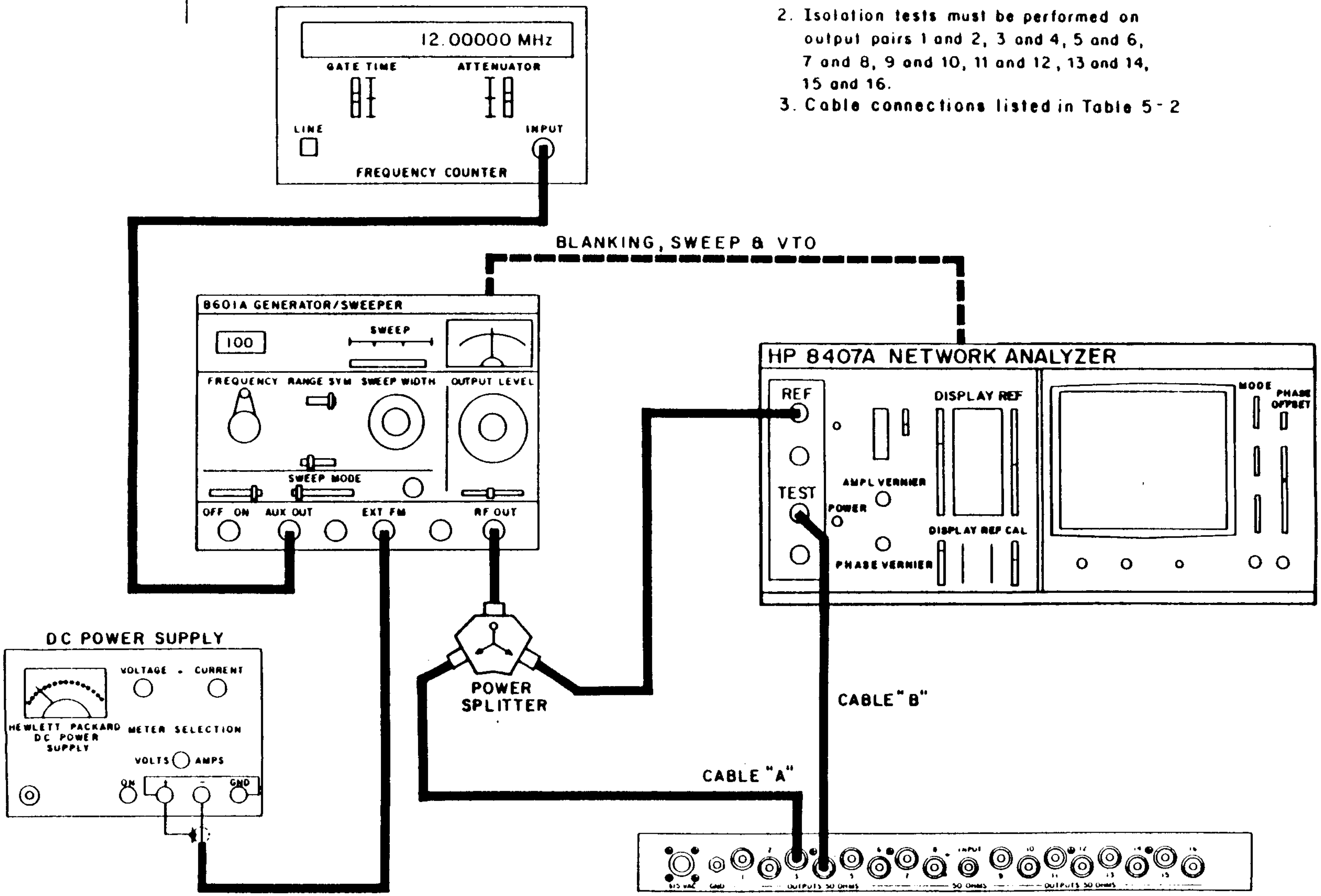


FIGURE 5-20. *Capacitor Assembly for CU-2289/FRR Multicoupler (Divid r Assemblies 1A3 and 1A4).*

NOTE: 1. Terminate all unused connectors during test.

2. Isolation tests must be performed on output pairs 1 and 2, 3 and 4, 5 and 6, 7 and 8, 9 and 10, 11 and 12, 13 and 14, 15 and 16.

3. Cable connections listed in Table 5-2



CAUTION: DC POWER SUPPLY VOLTAGE TO HP 8601A EXT FM MUST BE NEGATIVE AND NEVER EXCEED -500mv.

FIGURE 5-21. CU-2289/FRR Multicoupler Ou[illegible]o-Output Isolation Test, Block Diagram.

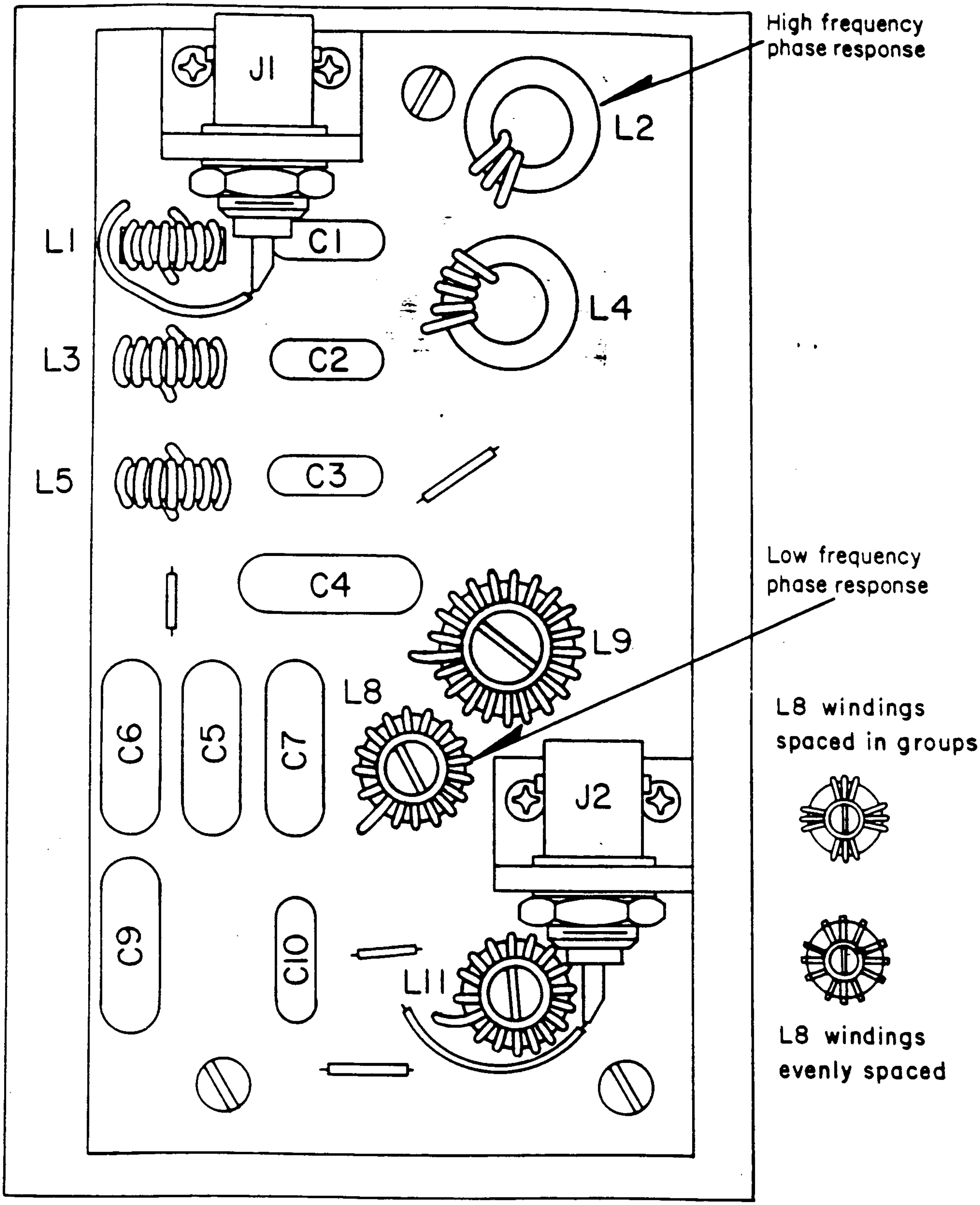
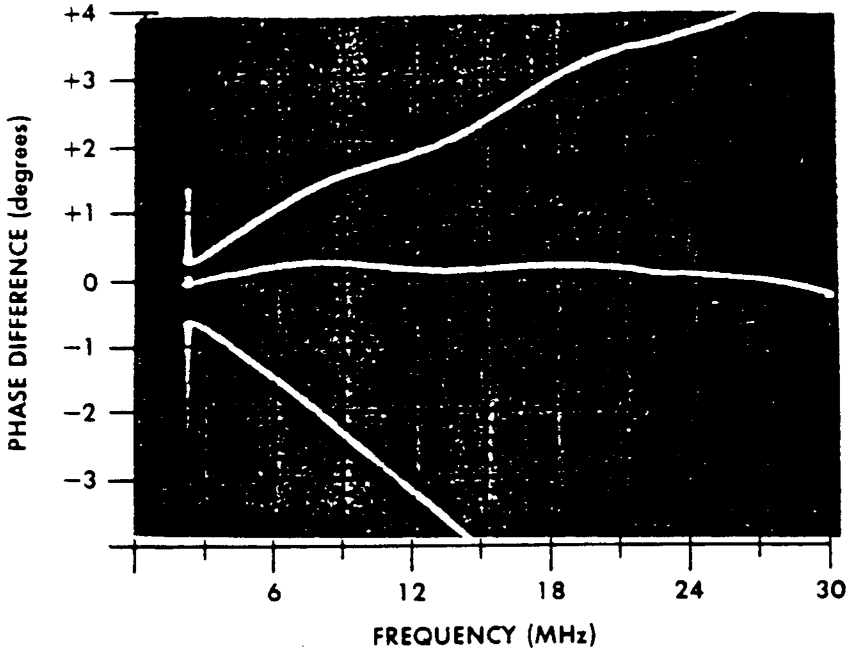


FIGURE 5-22. Location of Inductors L2 and L8 for High and Low Frequ ncy Respons .



MULTICOUPLER:
CU-2289/FRR

COMPONENT
ADJUSTMENT:
C32-C39

FIGURE 5-23. Example of the Adjustment Range of Capacitors C32–C39 of the CU-2289/FRR Multicoupler (Divider Assemblies 1A3 and 1A4).

Table 5-8. CU-2289/FRR Isolation Test Equipment Settings

SWEEPER SETTINGS (HP 8601A)	
OUTPUT LEVEL	−10 dB
SWEEP	VIDEO
FREQUENCY	As needed to obtain 2-32 MHz across display
SWEEP MODE	Free, manual
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
SIGNAL PROCESSOR SETTINGS (HP 8407A/8412A)	
REF CHAN LEVEL ADJ	As needed to stay in "OPERATE' range
DISPLAY REFERENCE	−40 dB
HORIZ POSITION/HORIZ GAIN	As needed to obtain calibrated 2-32 MHz across display
BW (kHz)	0.1
MODE	AMPL
AMPL dB/div	10

Table 5-9. Output-to-Output Isolation Adjustment Components

OUTPUT	CAPACITOR ADJUSTMENT	INDUCTOR ADJUSTMENT
1, 2	1A4, C23	1A4, L9
3, 4	C21	L8
5, 6	C19	L7
7, 8	C17	L6
9, 10	1A3, C23	1A3, L9
11, 12	C21	L8
13, 14	C19	L7
15, 16	C17	L6

Table 5-10. CU-2289/FRR Multicoupler, Capacitor Adjustments

OUTPUT	CAPACITOR ADJUSTMENT
1	1A3, C39
2	1A3, C38
3	1A3, C37
4	1A3, C36
5	1A3, C35
6	1A3, C34
7	1A3, C33
8	1A3, C32
9	1A4, C39
10	1A4, C38
11	1A4, C37
12	1A4, C36
13	1A4, C35
14	1A4, C34
15	1A4, C33
16	1A4, C32

FREQUENCY	2.5 MHz		4 MHz			30 MHz	
RANKING POSITION	MC.	PHASE DIFF.	MC.	PHASE DIFF.		MC.	PHASE DIFF.
1	A	+5.1	E	+4.0		F	+11.0
2	B	+3.6	W	+3.5		H	+ 9.5
3	C	+2.0	V	+3.3		R	+ 8.0
4	D	+1.9	R	+3.1		W	+ 2.0
5	E	+1.7	Y	+2.1		A	+ 1.8
6	F	+1.5	L	+0.5		I	+ 1.6
7	G	+1.4	A	+0.2		O	+ 1.0
8	H	+1.0	X	+0.1		X	+ 0.6
9	I	+1.0	O	−0.1		P	+ 0.6
10	J	+0.7	P	−0.2		E	+ 0.6
11	K	+0.6	D	−0.2		V	+ 0.4
12	L	+0.5	K	−0.2		M	+ 0.3
13	M	+0.3	Q	−0.2		T	0.0
14	N	+0.1	F	−0.2		C	− 0.1
15	O	0.0	C	−0.3		Y	− 0.1
16	P	0.0	M	−0.4		U	− 0.2
17	Q	−0.3	J	−0.4		J	− 0.8
18	R	−0.8	I	−0.9		Q	− 0.8
19	S	−1.1	G	−0.9		B	− 1.8
20	T	−1.1	S	−1.4		N	− 1.9
21	U	−1.1	B	−2.1		G	− 2.9
22	V	−1.1	U	−2.7		L	− 5.9
23	W	−1.2	T	−3.0		K	− 6.0
24	X	−1.4	H	−4.1		D	− 6.1
25	Y	−2.3	N	−4.5		S	− 6.3

FIGURE 5-24. Example of a List of Phase Differences Used to Selected a Station Reference Multicoupler (MC).

MC. NO.	OCCURRENCES AT 13TH	OCCURRENCES AT 12TH, 14TH	SUBTOTAL 12TH – 14TH	OCCURRENCES AT 11TH, 15TH	SUBTOTAL 11TH – 15TH
A				/	1
B		/	1		1
C	//	////	6	////	10
D					
E	/	/	2	/	3
F		/	1	/	2
G	/	/	2	//	4
H				/	1
I	/		1		1
J		//	2	//	4
K		/	1		1
L		/	1		1
M	////	////	8	////	12
N		/	1		1
O				/	1
P		/	1	//	3
Q	//		2	/	3
R		/	1		1
S		/	1	/	2
T	/		1	//	3
U		/	1		1
V					
W		//	2	/	3
X					
Y		/	1		1

Station Standard Multicoupler "M"

FIGURE 5-25. Example of a Tally Sheet Used to Select a Station Reference Multicoupler.

CHAPTER 6
BEAMFORMER TEST

6.1 TEST DESCRIPTION

The beamformer test quickly verifies that each input is contributing to the beamformer output. The beamformer test system (Figure 6-1) utilizes the AN/FRM-19 to inject the test signal into the desired input element. The test signal enters the system via the J1 input on the back of the AN/FRM-19; travels through the switching heads, and then to the input directional coupler on the selected multicoupler. The corresponding multicoupler output then feeds the beamformer under test. The output of the beamformer is then routed to the specified distribution multicoupler. The output of the distribution multicoupler is available at the patch panel. From the patch panel, the output is connected to the test channel of the network analyzer.

NOTE

The sweep oscillator output is split to provide the network analyzer with a reference signal. To reduce the difference between the test signal and the reference signal, additional attenuation is added to the reference signal path.

6.1.1 By indexing the AN/FRM-19 switching head, the test signal is connected from one beamformer input to the next. The corresponding swept frequency beamformer amplitude response is then displayed on the network analyzer. By analyzing the display for each corresponding beam input, it can be determined if the input element is missing (e.g. disconnected), attenuated, or has a frequency selective attenuation problem, anywhere in the operating frequency range.

6.2 TEST SETUP

Figure 6-1 illustrates beamformer test setup while Tables 6-1 and 6-2 show the control settings and cable connections for this test. Once a problem is detected, the test signal is then traced back from the beamformer patch panel; to the distribution multicoupler; through the beamformer; and to the primary multicoupler until the problem is found. Any malfunctioning equipment will have a good test response at its input, but a bad response at its output.

6.3 TEST RESULTS

Typical low and high band beamformer amplitude responses are shown in Figure 6-2. Figures 6-3 through 6-5 show degraded amplitude responses due to:

Photo E3 – a bad primary multicoupler,
Photo E4 – a bad connector on the cable from the primary multicoupler to the beamformer,
Photo E5 – a bad connector in the beamformer,
Photo E6 – a dirty connector on the cable from the distribution multicoupler to the manual patch panel,
Photo E7 – an oscillating primary multicoupler, and
Photo E8 – a CU-1280/FRD-10A(V) distribution multicoupler with low gain.

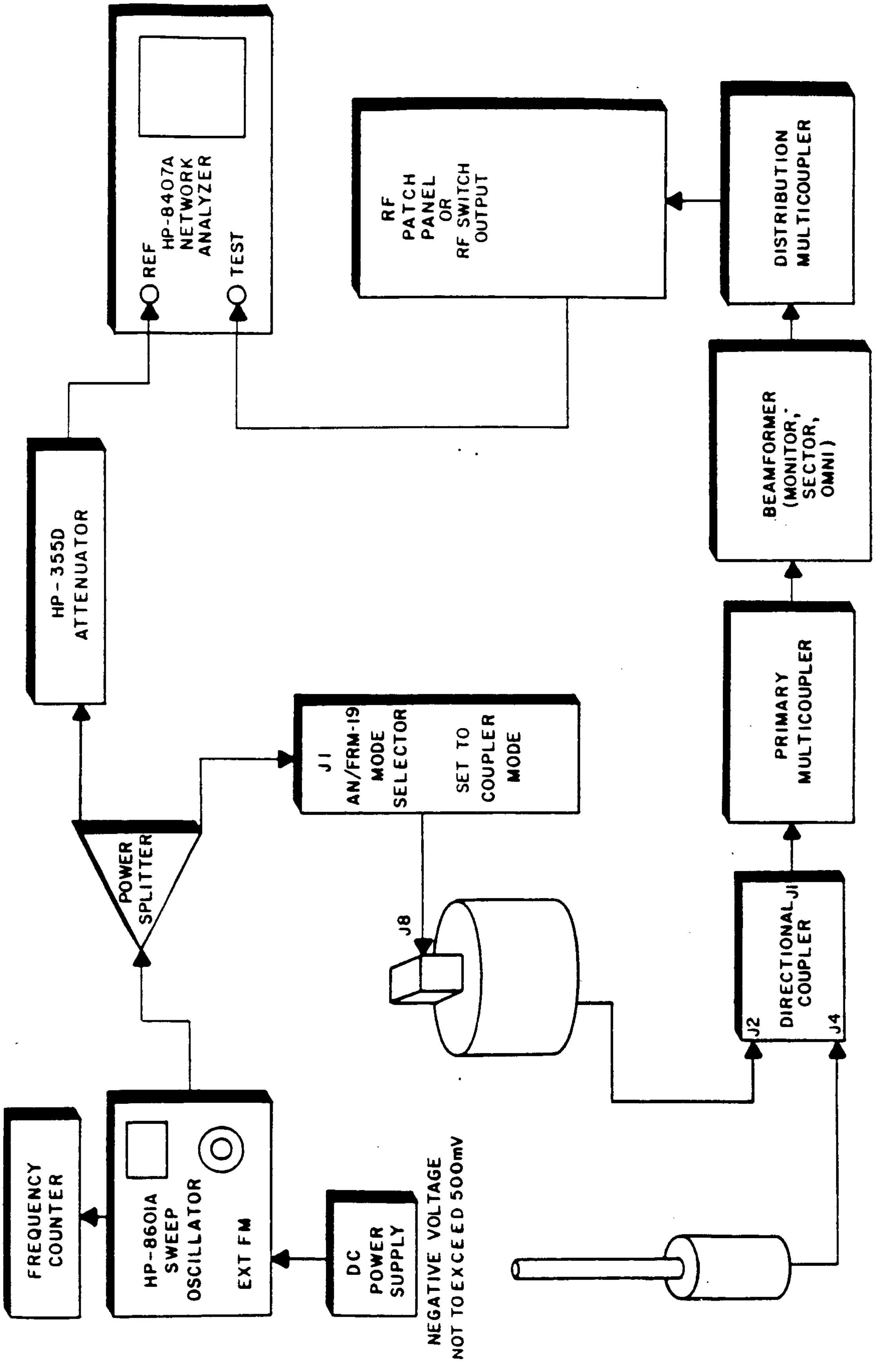


FIGURE 6-1. Beamformer Tes[illegible]ial, Flow and T st Setup.

Table 6-1. HP 8407A/8412A Network Analyzer System, Contr l Settings

CONTROLS	SETTING
HP 8407A/8412A Network Analyzer	
REF CHAN LEVEL ADJ	As required to stay in "OPERATE" range
DISPLAY REFERENCE	As required to obtain trace
HORIZ POSITION/HORIZ GAIN	As required to obtain calibrated 2-32 MHz across display (refer to photos)
BW (kHz)	0.1
MODE	Amplitude
AMPL. dB/div	10.0
PHASE OFFSET	0
INTENSITY	As required
FOCUS	As required
HP 8601A Generator/Sweeper	
OUTPUT LEVEL	0 dBm
SWEEP	VIDEO
FREQUENCY	As required to obtain 2-32 MHz across display
SWEEP MODE	FREE, FAST
1 kHz MOD	OFF
CRYSTAL CAL	OFF
RANGE	110
FRM-19 Mode Selector	
MODE SELECTOR	Coupler mode
ATTENUATION	0 dB
INDEX	Desired low/high band element
DC Power Supply	
OUTPUT *	Approximately −200 mV for a 2 MHz start frequency. (Do not adjust to more than −500 mV and never apply a positive voltage to the EXT FM input on the HP 8601A.)
Frequency Counter	
INPUT	Scale for 2 to 32 MHz frequency range

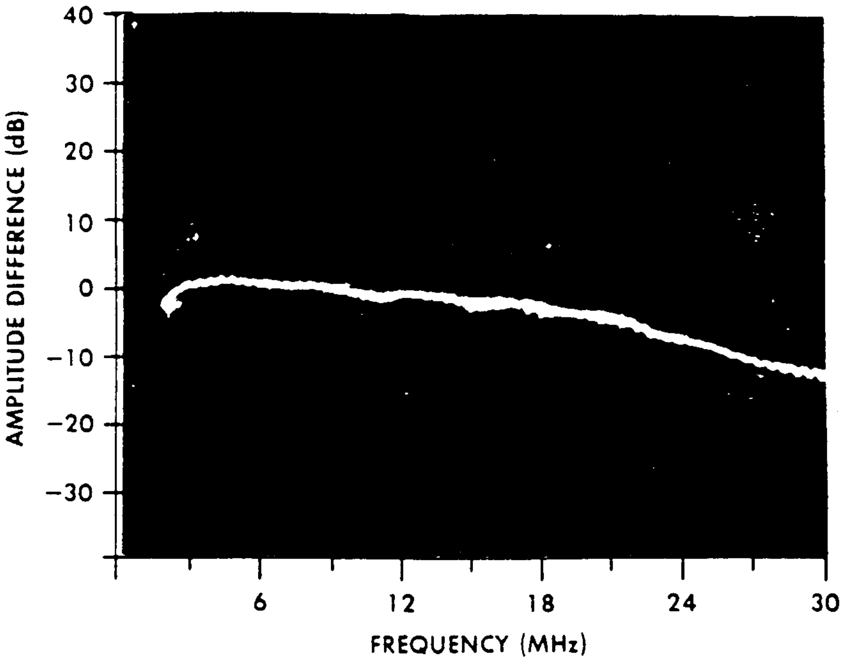
* If a banana plug to BNC adapter is used on the power supply output, verify the DC continuity between the center pin of the BNC connector and the high (+) banana pin. (Some adapters contain a DC blocking capacitor. These adapters are usually blue.)

CAUTION

If a banana plug to BNC adapter is used on the power supply output, make certain the ground banana pin marked by the tab is connected to the positive (+) terminal of the power supply.

Table 6-2. HP 8407A/8412A Network Analyzer System, Cable C nnecti ns

FUNCTION	LOCATION	CONNECTED TO	CABLE TYPE
HP 8407A/8412A Network Analyzer			
VTO IN	Rear Panel	HP 8601A VTO OUT	RG-58/223
SWEEP IN		HP 8601A SWEEP OUT	RG-58/223
BLANKING		HP 8601A BLANKING OUT	RG-58/223
TEST CHANNEL	Front Panel	RF PATCH PANEL	RG-59/307
REF CHANNEL		HP 355D ATTENUATOR	RG-59/307
HP 8601A Generator/Sweeper			
RF OUT	Front Panel	POWER SPLITTER	RG-59/307
EXT FM		DC POWER SUPPLY	RG-58/223
AUX OUT		FREQUENCY COUNTER IN	RG-58/223
BLANKING OUT	Rear Panel	HP 8407A/8412A BLANKING IN	RG-58/223
SWEEP OUT		HP 8407A/8412A SWEEP IN	RG-58/223
VTO OUT		HP 8407A/8412A VTO IN	RG-58/223
Power Splitter			
INPUT		HP 8601A RF OUT	RG-59/307
OUTPUT		MODE SELECTOR A7J1	RG-59/307
OUTPUT		HP 355D ATTENUATOR	RG-59/307



BEAMFORMER RESPONSE TEST

PHOTO: E1

STATION: NSGA

LOCATION: Edzell, Scotland

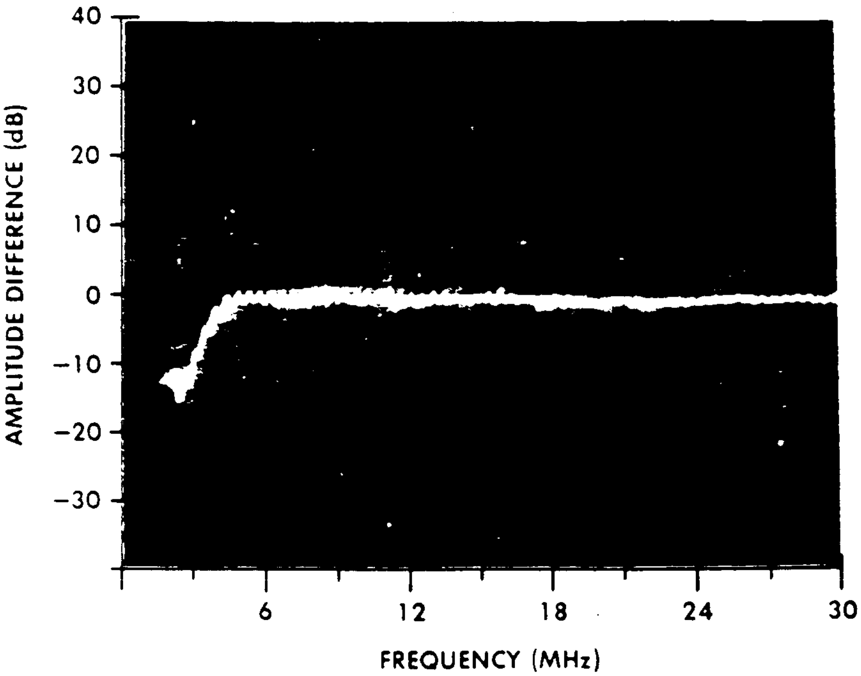
DATE: 18 Sep 1981

BEAM: Monitor 1

BAND: Low

ELEMENT: LB 1

Typical low band beamformer amplitude response.



BEAMFORMER RESPONSE TEST

PHOTO: E2

STATION: NSGA

LOCATION: Edzell, Scotland

DATE: 18 Sep 1981

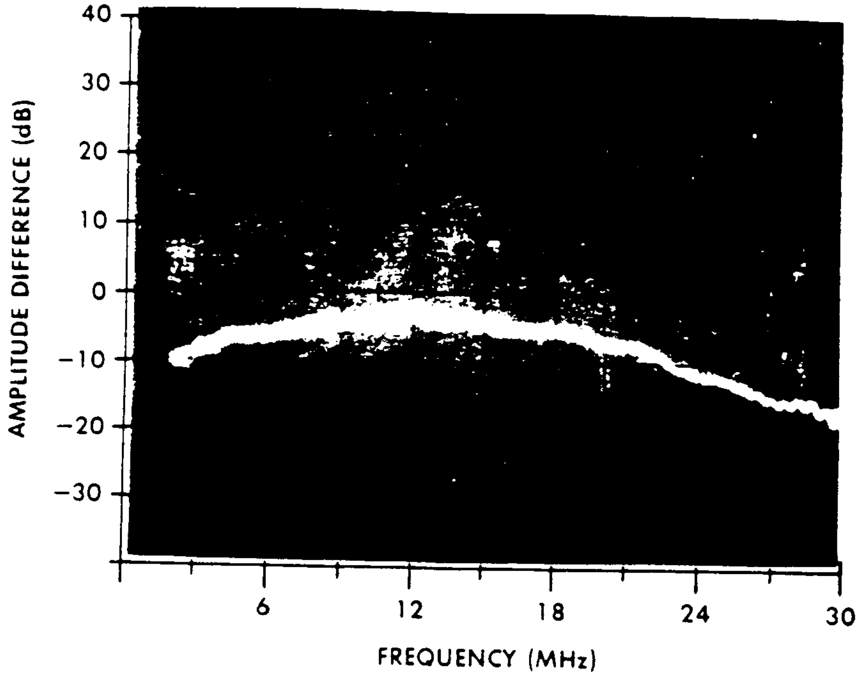
BEAM: Monitor 1

BAND: High

ELEMENT: HB 1

Typical high band beamformer amplitude response.

FIGURE 6-2. Typical Low and High Band Beamformer Amplitude Response.



Effect of a bad primary multicoupler output (J3).

BEAMFORMER RESPONSE TEST

PHOTO: E3

STATION: NSGA

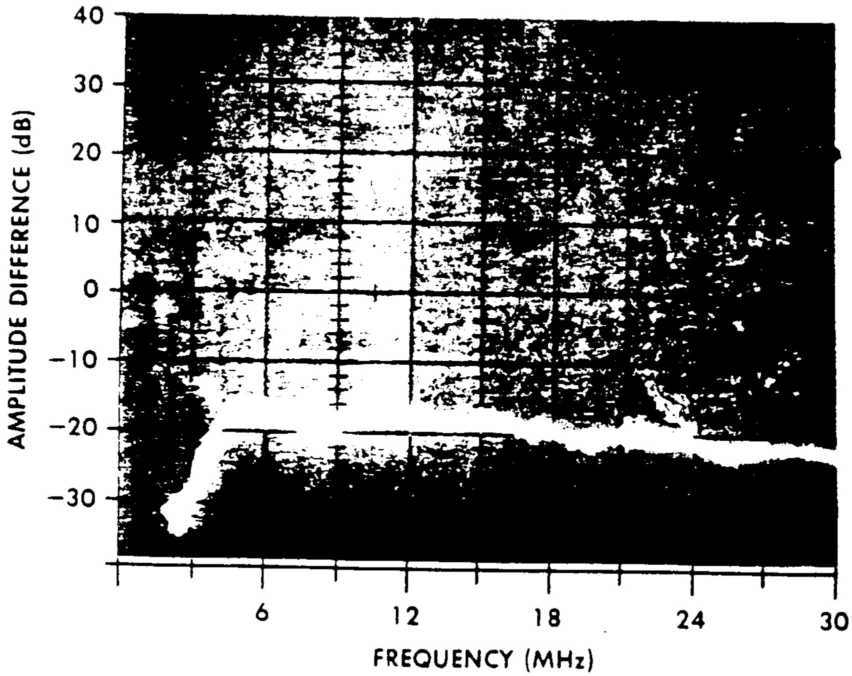
LOCATION: Galeta Island, PM

DATE: 19 Jan 1982

BEAM: Monitor 2

BAND: Low

ELEMENT: LB 2



Effect of a bad connector on the cable from the primary multicoupler to the beamformer.

BEAMFORMER RESPONSE TEST

PHOTO: E4

STATION: NSGA

LOCATION: Galeta Island, PM

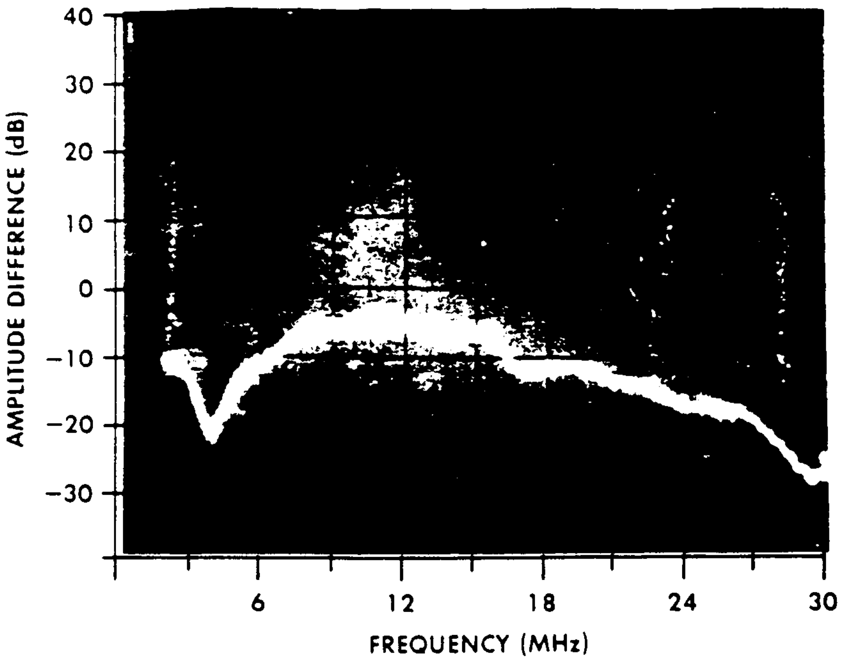
DATE: 19 Jan 1982

BEAM: Monitor 4

BAND: High

ELEMENT: HB 9

FIGURE 6-3. *Degraded Beamformer Amplitude Response Due to a Bad Primary Multicoupler and Cable Connector.*



BEAMFORMER RESPONSE TEST

PHOTO: E5

STATION: NSGA

LOCATION: Galeta Island, PM

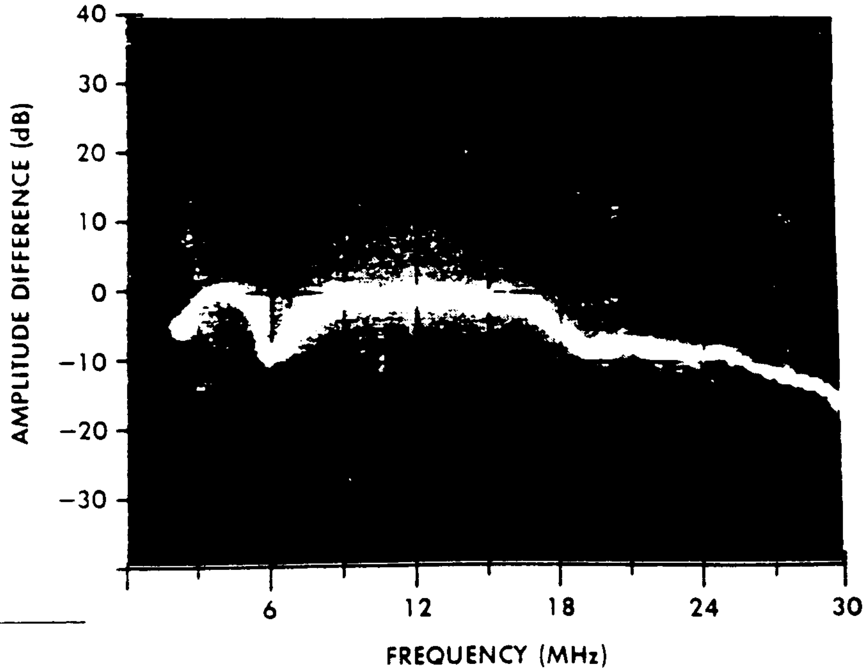
DATE: 19 Jan 1982

BEAM: Monitor 8

BAND: Low

ELEMENT: LB 12

Effect of a bad connector in the beamformer.



BEAMFORMER RESPONSE TEST

PHOTO: E6

STATION: NSGA

LOCATION: Galeta Island, PM

DATE: 19 Jan 1982

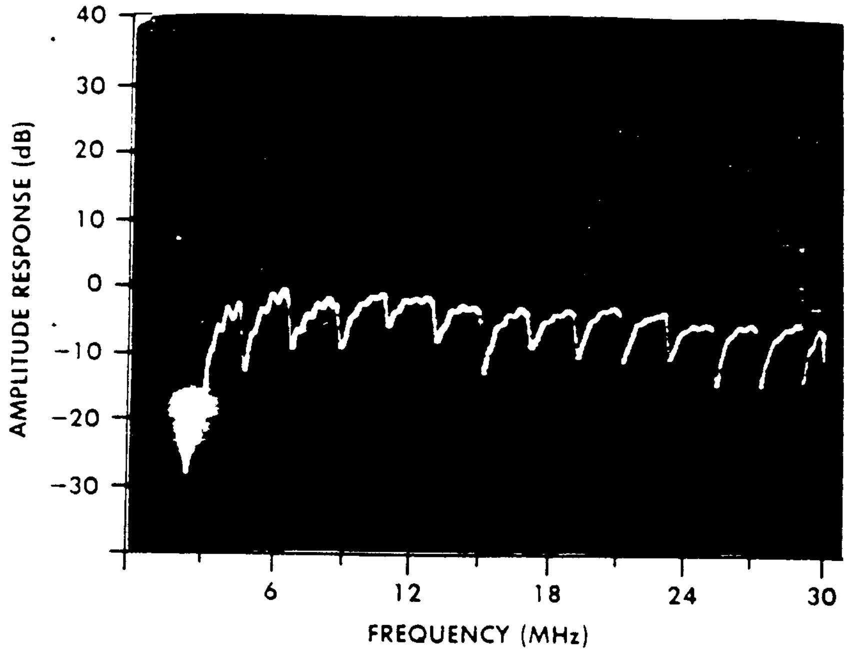
BEAM: Monitor 26

BAND: Low

ELEMENT: LB 30

Effect of a dirty connector on the cable from the distribution multicoupler to the manual patch panel.

FIGURE 6-4. Degraded Beamformer Amplitude Response Due to Bad Cable Connectors.



BEAMFORMER RESPONSE TEST

PHOTO: E7

STATION: NSGA

LOCATION: Sabana Seca, PR

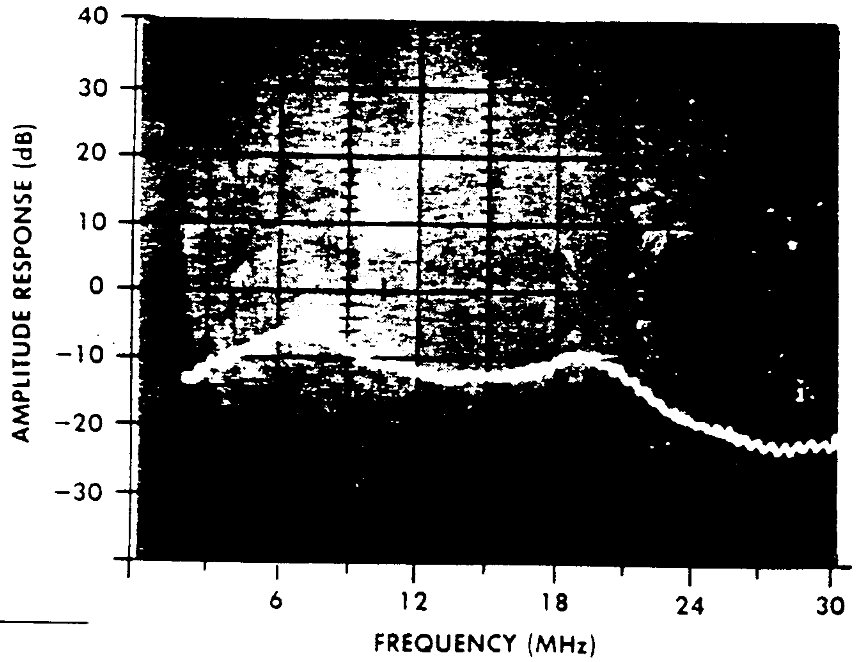
DATE: 9 Apr 1981

BEAM: Monitor 1

BAND: High

ELEMENT: HB 117

Effect of an oscillating primary multicoupler. (See the multicoupler phase and amplitude responses in Figure D4, Chapter 4.)



BEAMFORMER RESPONSE TEST

PHOTO: E8

STATION: NSGA

LOCATION: Sabana Seca, PR

DATE: 9 Apr 1981

BEAM: Monitor 16

BAND: Low

ELEMENT: LB 20

Effect of a CU-1280/FRR-10A(V) distribution multicoupler with low gain.

FIGURE 6-5. Bad Amplitude Response Due to an Oscillating Primary Multicoupler and a CU-1280 Distribution Multicoupler with Low Gain.

CHAPTER 7
SYSTEM CONTINUITY TESTS

7.1 TEST DESCRIPTION

The system continuity test provides a means of quickly checking the signal paths from each antenna element through the RF distribution system to the receiving equipment. Furthermore, the procedure provides a quick check of the operational status of the equipment in both low and high band systems. The following six functions are tested:

1. Narrowband (NB) and wideband (WB) bearing accuracy, display presentation, and operation.
2. Video signal path uniformity for individual inputs of the 360-degree goniometer.
3. System sensitivity (minimum detectable signal).
4. Audio signal path uniformity for individual inputs of monitor and omni beamformers.
5. RF switching network operation.
6. Antenna continuity.

7.1.1 All of the above functions can be checked in less than one hour by injecting a Continuous Wave (CW) signal into the front end of the system while observing the results on a receiver at the output of the system. Since there is only one RF path from the front end to the receiver, most problems that might degrade this path are readily apparent. This test should be performed during the weekly downtime so that there is no interference with DF operations. Furthermore, being a CW test, the injected test signal is not likely to interfere with signals of interest for other systems.

7.1.2 Some problems such as cold solder joints are frequency sensitive; they occur at some frequencies but not at other frequencies. These problems are unusual and are best found with the swept frequency testing techniques detailed in the previous chapters.

7.2 TEST SETUP

A frequency stable signal generator such as an HP 8640A is needed for these tests.

NOTE

HP 606A contained in the AN/FRM-19 does not provide the needed frequency accuracy or stability.

The output signal from the generator is applied to J1 on the back of the AN/FRM-19 Mode Selector chassis. By using the TEST FUNCTION switch on the front panel of this unit, signals may be injected via the AN/FRM-19 switching heads and the directional couplers at the input to the multicouplers. When this switch is placed in the COUPLER position, test signals are applied through the directional coupler to the input of the multicoupler selected by the switching head. The selected multicoupler is identified by the digital display on the front panel of the Mode Selector. Test functions 1 through 5 listed in paragraph 7.1 use the AN/FRM-19 Mode Selector TEST FUNCTION switch in COUPLER mode. The test diagram is shown in Figure 7-1. For function 6, the antenna continuity check, the TEST FUNCTION switch is placed in the ANTENNA position. This routes the test signal via the switching head and the directional coupler to the selected antenna, as shown in Figure 7-2. The signal radiates to adjacent antennas where they enter the system. Note that for all testing, the CALIBRATE LEVEL attenuator on the Mode Selector front panel must be in the zero attenuation position.

7.2.1 Since this test procedure involves injecting a test signal through the AN/FRM-19 while the effects are observed on a DF receiving system, it is essential that voice communications exist between these equipments. Sound powered phones work well for this. Another scheme that works well is to use conventional telephone handsets. Connect the microphone element in series with the earphone on each handset, then connect the handsets in series with a 9 volt battery or a small DC power supply. Any type of coaxial cable should be installed between the AN/FRM-19 equipment rack and the narrowband console for this communications. As a temporary measure, it may be possible to use the antenna input cable to the SSS watch receiver normally located near narrowband. This cable usually terminates on the RF patch panel near the AN/FRM-19 (see Figure 7-3).

7.3 TEST PROCEDURES

NOTE

> AC power to the AN/FRM-19 Error Comparator must be on since this unit supplies 15 DC volts to the Mode Selector. The position of the various front panel controls on the Error Comparator are not important.

7.3.1 **Testing.** Low band testing is performed at a nominal 4 MHz; high band testing uses a nominal 14 MHz. Prior to testing, tune a receiver connected to an omni antenna input to find quiet frequencies near 4 and 14 MHz. These will be the test frequencies to which the signal generator will be set. Place the BAND SELECTOR switch on the Mode Selector front panel to the band (low/high) being tested. This will route the test signal to the appropriate switching head. Use the INDEX DRIVE switch (Mode Selector) to select the desired multicoupler or antenna into which the test signal will be injected.

7.3.1.1 With the signal generator set for the CW test frequency and at a level of −30 dBm, the resulting narrowband display should have the following characteristics for both high angle and low angle reception.

1. Narrowband beam null should be sharp and narrow.
2. Narrowband beam display should be symmetrical about the beam null.
3. Bearing accuracy should be within the required system specification.

7.3.2 **Bearing Accuracy.** To test for bearing accuracy, perform the weekly DF accuracy test as outlined in the Preventive Maintenance Cards. Another comparable method would be to place the TEST FUNCTION switch in the COUPLER position and check the station specifications to determine the azimuth of the antenna that normally feeds this multicoupler (for example, high band antenna element No. 1 is located at an azimuth of 1.5 degrees). Table 7-1 lists the azimuths of each antenna element for a typical AN/FRD-10 site. Observe that the test signal is present on the DF scope and carefully align the cursor on this signal. Verify that the display reads 1.5 degrees azimuth to within the required accuracy. If an error is found, repeat this test using another DF console. Errors in goniometer alignment or multicoupler cable patching will show up at both NB positions (SSS and SDF). Errors caused by a problem in the NB position will not be present when another position is tested. To check the ADF for bearing accuracy, run the "@CAL" program.

NOTE

> To test for ABI bearing accuracy, the AN/FRM-19 TEST FUNCTION switch must be switched from COUPLER to SIMULATOR mode. This will shift the bearing 180 degrees so that the correct reading should be 181.5 degrees for high band element No. 1.

7.3.2.1 After the single element bearing accuracy and display presentation are verified, use the AN/FRM-19 INDEX DRIVE switch to step the signal around the array. As the signal is stepped from one multicoupler input to the adjacent multicoupler, no large changes in signal strength (deflection) should be observed on the DF scope. Also verify that the test signal steps in equal 9-degree shifts for low band antennas and 3-degree shifts for high band antennas. This test will check for video signal path uniformity for individual inputs of the 360-degree goniometer.

7.3.3 **System Sensitivity.** To test for system sensitivity, tune the signal generator to the desired test frequency and set the output power level to −30 dBm. This relatively strong signal is necessary to overcome path losses in the goniometer heads and in the directional couplers at the input to the multicouplers. Tune the receiver to the same frequency and verify that the video signal is present on the DF scope. The technician at the NB position should use the phone communications to direct the technician at the AN/FRM-19 to reduce the level of the signal generator. This signal level should be reduced, while increasing the NB video gain to maximum, until it is seen as weak but clearly visible on the DF scope. Typical output level should be in the −45 dBm range. Then reset the signal generator to −30 dBm. Both NB positions (SSS and SDF) should now be tested for proper operation of the Low/High Angle and Sum/Difference modes.

7.3.4 Audio Signal Paths and RF Switching Networks. To test the audio signal paths and RF switching networks at the SSS and SDF consoles, tune the NB receiver to the test signal using the CW mode. As the DF cursor is rotated through 360 degrees, the test signal should be heard at only those azimuths corresponding to the coverage of the beamformers being fed by that one multicoupler. Table 7-2 gives the azimuth coverages for each multicoupler for a typical AN/FRD-10 site. For example, if low band element No. 1 is being fed the test signal, then the signal should be heard as an audible tone from 330 degrees through 42 degrees azimuth. If the audio signal can not be heard continuously over this range, then a check of the NB and distribution RF switches is required. The test signal should then be switched to the next multicoupler using the AN/FRM-19 INDEX DRIVE switch to check all audio signal paths.

7.3.5 Wideband System's DF Accuracy. The wideband system's DF accuracy and sensitivity can be verified by:

1. manually alarming WARS tuned to the test frequency in the MANUAL MODE and saving the signal at the TIP panel, and
2. manually exercising the WBCS (DF) system using simulated OP flashes, to perform a manual dub of the low band and high band test signals at −30 dBm.

After the data is processed, the beam display and bearing on the DFDU should be identical to the results on the NB displays. This test is performed only once for low band and high band.

7.3.6 Antenna Continuity. Antenna continuity can be checked by setting the AN/FRM-19 TEST FUNCTION switch to the ANTENNA position. The gain at the NB receiver or the output of the signal generator will have to be reduced for this test since there is less path loss. After verifying the proper DF display, the test signal is stepped using the AN/FRM-19 INDEX DRIVE to check the condition of each antenna. Verify that the test signal steps in equal 9-degree shifts for low band antennas and 3-degree shifts for high band antennas. Problems in antennas will show up as distortions in the null or one of the sidelobes. This test will only need to be performed at either the SSS or SDF position.

7.4 TEST RESULTS

Typical NB/WB displays and problem displays for the COUPLER mode check are shown in Figures 7-4 and 7-5, respectively. Typical NB/WB displays for the ANTENNA mode check are shown in Figure 7-6.

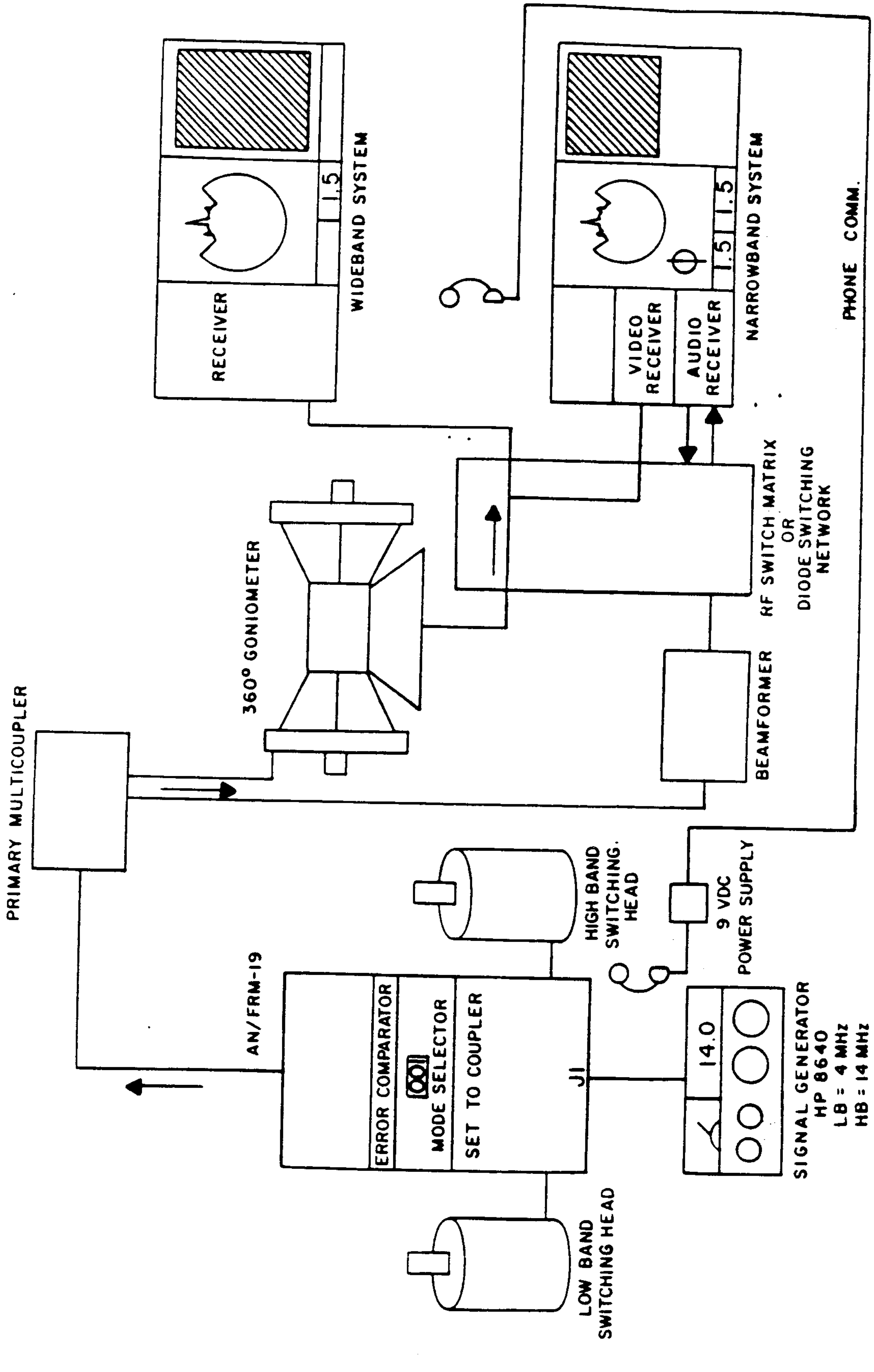


FIGURE 7-1. CDAA System Cont(Test, COUPLER Mode Check.

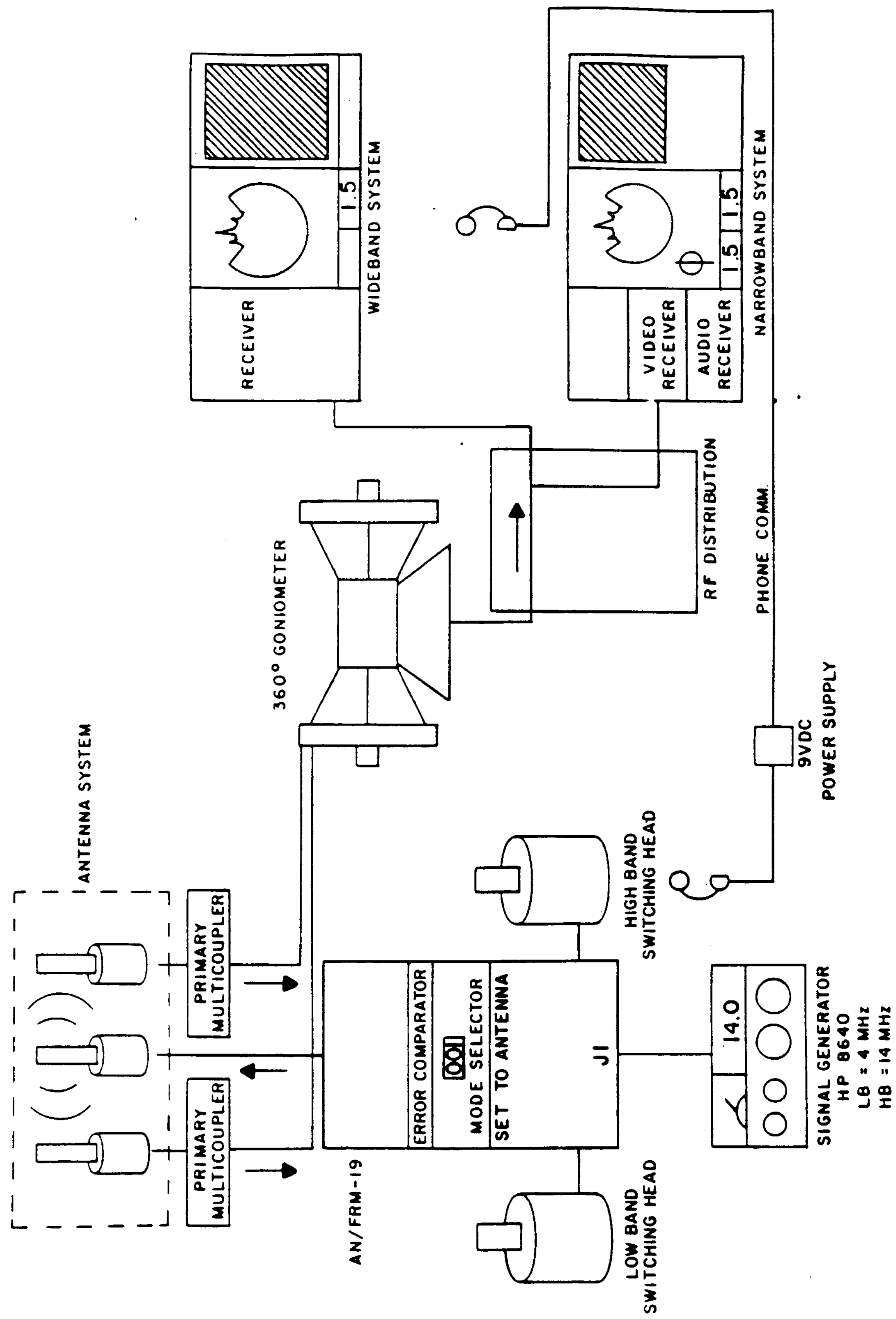
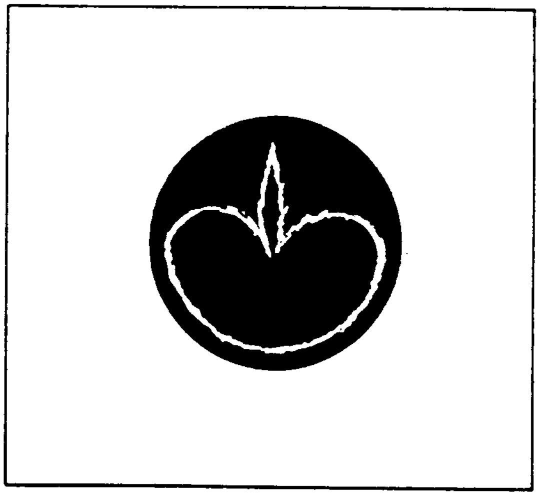


FIGURE 7-2. CDAA System Continuity Test, ANTENNA Mode Check.

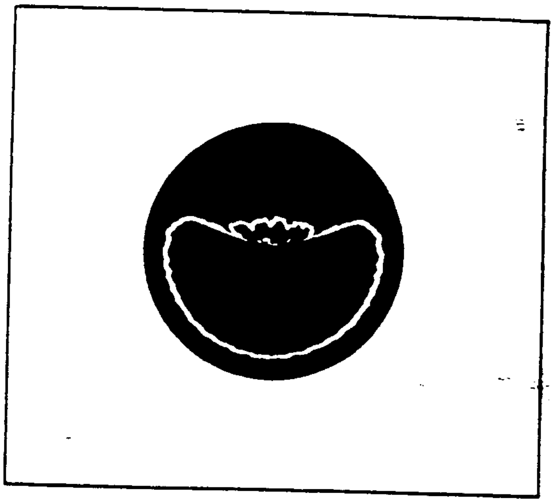
Table 7-1. Video Bearings

ELEMENT NO.	AZIMUTH LB	AZIMUTH HB	ELEMENT NO.	AZIMUTH HB	ELEMENT NO.	AZIMUTH HB
1	4.5	1.5	41	121.5	81	241.5
2	13.5	4.5	42	124.5	82	244.5
3	22.5	7.5	43	127.5	83	247.5
4	31.5	10.5	44	130.5	84	250.5
5	40.5	13.5	45	133.5	85	253.5
6	49.5	16.5	46	136.5	86	256.5
7	58.5	19.5	47	139.5	87	259.5
8	67.5	22.5	48	142.5	88	262.5
9	76.5	25.5	49	145.5	89	265.5
10	85.5	28.5	50	148.5	90	268.5
11	94.5	31.5	51	151.5	91	271.5
12	103.5	34.5	52	154.5	92	274.5
13	112.5	37.5	53	157.5	93	277.5
14	121.5	40.5	54	160.5	94	280.5
15	130.5	43.5	55	163.5	95	283.5
16	139.5	46.5	56	166.5	96	286.5
17	148.5	49.5	57	169.5	97	289.5
18	157.5	52.5	58	172.5	98	292.5
19	166.5	55.5	59	175.5	99	295.5
20	175.5	58.5	60	178.5	100	298.5
21	184.5	61.5	61	181.5	101	301.5
22	193.5	64.5	62	184.5	102	304.5
23	202.5	67.5	63	187.5	103	307.5
24	211.5	70.5	64	190.5	104	310.5
25	220.5	73.5	65	193.5	105	313.5
26	229.5	76.5	66	196.5	106	316.5
27	238.5	79.5	67	199.5	107	319.5
28	247.5	82.5	68	202.5	108	322.5
29	256.5	85.5	69	205.5	109	325.5
30	265.5	88.5	70	208.5	110	328.5
31	274.5	91.5	71	211.5	111	331.5
32	283.5	94.5	72	214.5	112	334.5
33	292.5	97.5	73	217.5	113	337.5
34	301.5	100.5	74	220.5	114	340.5
35	310.5	103.5	75	223.5	115	343.5
36	319.5	106.5	76	226.5	116	346.5
37	328.5	109.5	77	229.5	117	349.5
38	337.5	112.5	78	232.5	118	352.5
39	346.5	115.5	79	235.5	119	355.5
40	355.5	118.5	80	238.5	120	358.5

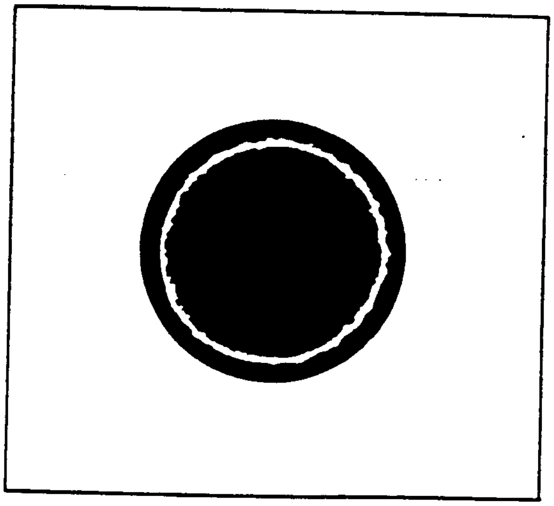


Normal beam is sharp and symmetrical. DF bearing corresponds to the signal input azimuth.

FIGURE 7-4. Low Band NB/WB Displays for COUPLER Mode Check of CDAA System Continuity Test.



Weak signal path to goniometer.



Missing signal path to goniometer.

FIGURE 7-5. Low Band and High Band NB/WB Displays f r COUPLER Mode Check of CDAA System Continuity Test.

Table 7-2. Audio Coverage

ELEMENT NO.	AZIMUTH COVERAGE	ELEMENT NO.	AZIMUTH COVERAGE
Low Band Monitor Beamformers:			
1	330- 42	21	150-222
2	342- 54	22	162-234
3	342- 54	23	162-234
4	254- 66	24	174-246
5	6- 78	25	186-258
6	18- 90	26	198-270
7	18- 90	27	198-270
8	30-102	28	210-282
9	42-114	29	222-294
10	54-126	30	234-306
11	54-126	31	234-306
12	66-138	32	246-318
13	78-150	33	258-330
14	90-162	34	270-342
15	90-162	35	270-342
16	102-174	36	282-354
17	114-186	37	294- 6
18	126-198	38	306- 18
19	126-198	39	306- 18
20	138-210	40	318- 30
High Band Monitor Beamformers:			
1- 4	354- 18	61- 64	174-198
5- 8	6- 30	65- 68	186-210
9-12	18- 42	69- 72	198-222
13-16	30- 54	73- 76	210-234
17-20	42- 66	77- 80	222-246
21-24	54-78	81- 84	234-258
25-28	66- 90	85- 88	246-270
29-32	78-102	89- 92	258-282
33-36	90-114	93- 96	270-294
37-40	102-126	97-100	282-306
41-44	114-138	101-104	294-218
45-48	126-150	105-108	306-330
49-52	138-162	109-112	318-342
53-56	150-174	113-116	330-354
57-60	162-186	117-120	342- 6

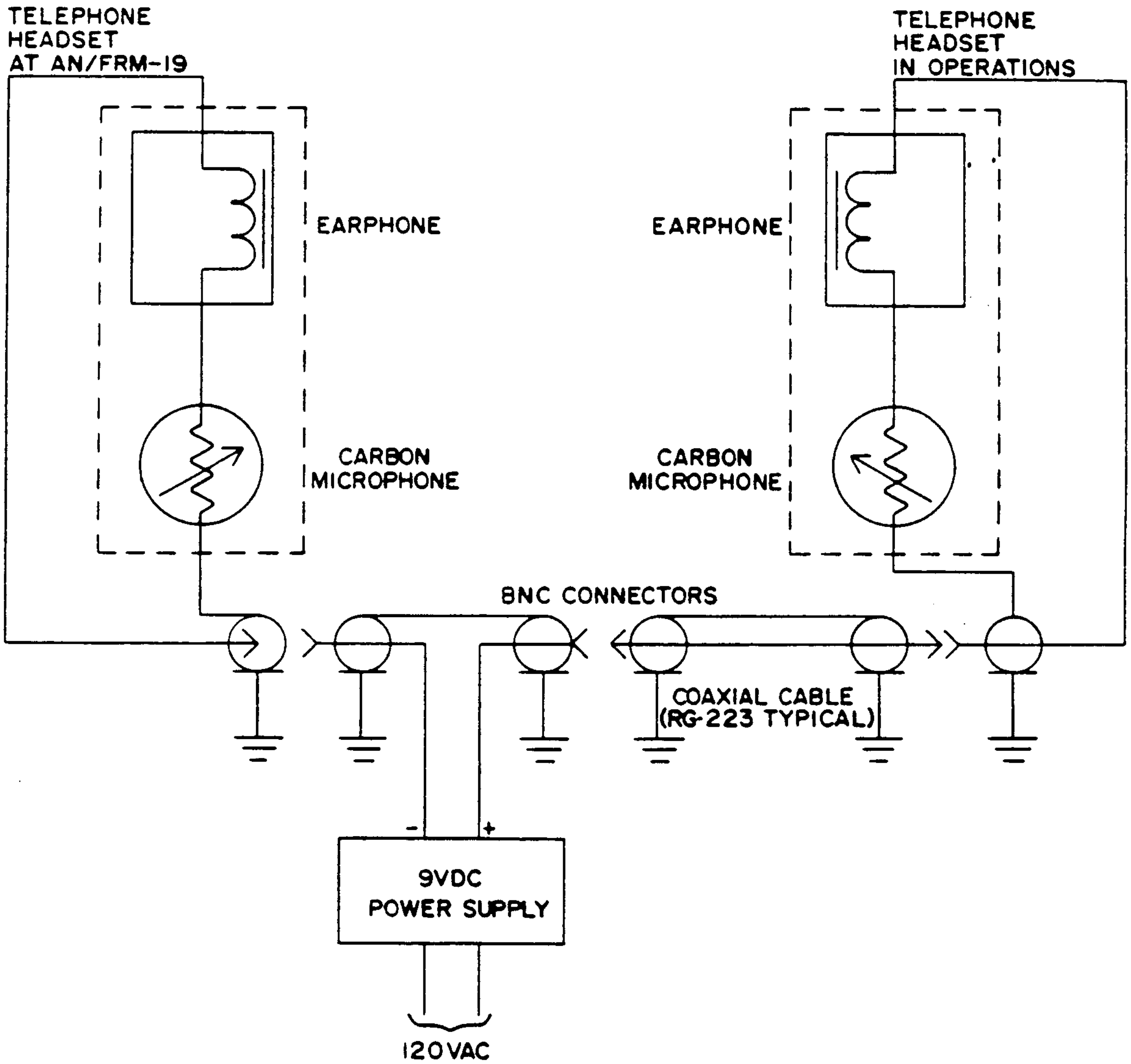
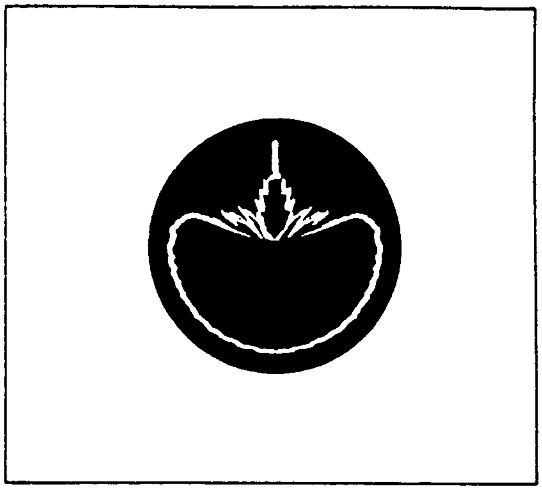
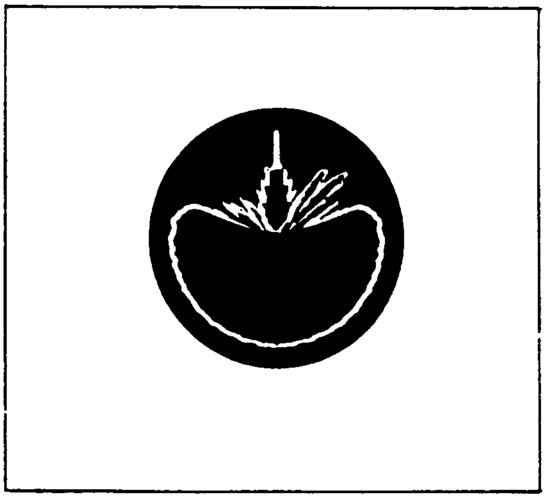


FIGURE 7-3. AN/FRM-19 to DF Receiver Phon Communications System (Used between test personnel).



Normal beam is sharp and symmetrical. DF bearing corresponds to the signal input azimuth.



Bad symmetry caused by a problem in the rotor beamformer.

FIGURE 7-6. Low Band NB/WB Displays for ANTENNA Mode Check of CDAA System Continuity Test.

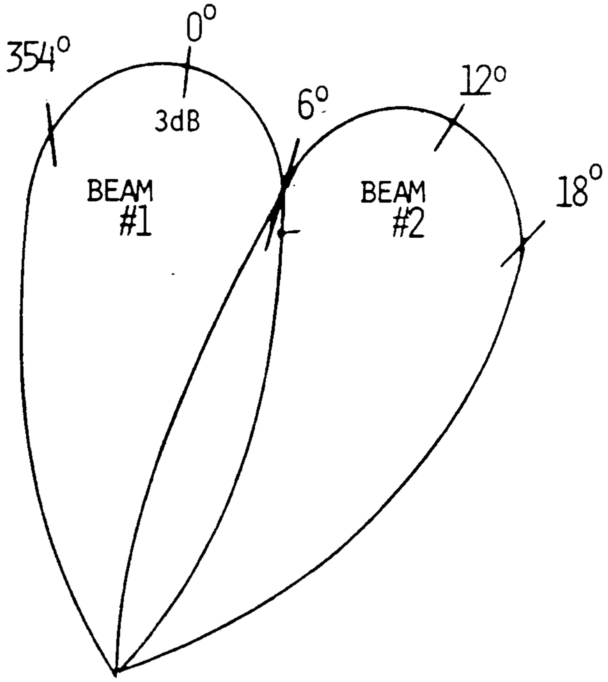
LOW BAND MONITOR BEAMFORMER TABLE

Antenna No.	Azimuth	Contributes RF To Monitor Beams					
1	4.5	29	30	1	2	3	4
2	13.5	1	2	3	4	5	30
3	22.5	1	2	3	4	5	30
4	31.5	1	2	3	4	5	6
5	40.5	2	3	4	5	6	7
6	49.5	3	4	5	6	7	8
7	58.5	3	4	5	6	7	8
8	67.5	4	5	6	7	8	9
9	76.5	5	6	7	8	9	10
10	85.5	6	7	8	9	10	11
11	94.5	6	7	8	9	10	11
12	103.5	7	8	9	10	11	12
13	112.5	8	9	10	11	12	13
14	121.5	9	10	11	12	13	14
15	130.5	9	10	11	12	13	14
16	139.5	10	11	12	13	14	15
17	148.5	11	12	13	14	15	16
18	157.5	12	13	14	15	16	17
19	166.5	12	13	14	15	16	17
20	175.5	13	14	15	16	17	18
21	184.5	14	15	16	17	18	19
22	193.5	15	16	17	18	19	20
23	202.5	15	16	17	18	19	20
24	211.5	16	17	18	19	20	21
25	220.5	17	18	19	20	21	22
26	229.5	18	19	20	21	22	23
27	238.5	18	19	20	21	22	23
28	247.5	19	20	21	22	23	24
29	256.5	20	21	22	23	24	25
30	265.5	21	22	23	24	25	26
31	274.5	21	22	23	24	25	26
32	283.5	22	23	24	25	26	27
33	292.5	23	24	25	26	27	28
34	301.5	24	25	26	27	28	29
35	310.5	24	25	26	27	28	29
36	319.5	25	26	27	28	29	30
37	328.5	26	27	28	29	30	1
38	337.5	27	28	29	30	1	2
39	346.5	27	28	29	30	1	2
40	355.5	28	29	30	1	2	3

NOTE: Three types of beamformers are used:
(1) Skewed left.
(2) Center.
(3) Skewed right.

APPENDIX A

DESCRIPTION OF TEST EQUIPMENT



12° WIDE

TYPICAL BEAM PATTERNS

SECTOR BEAMS

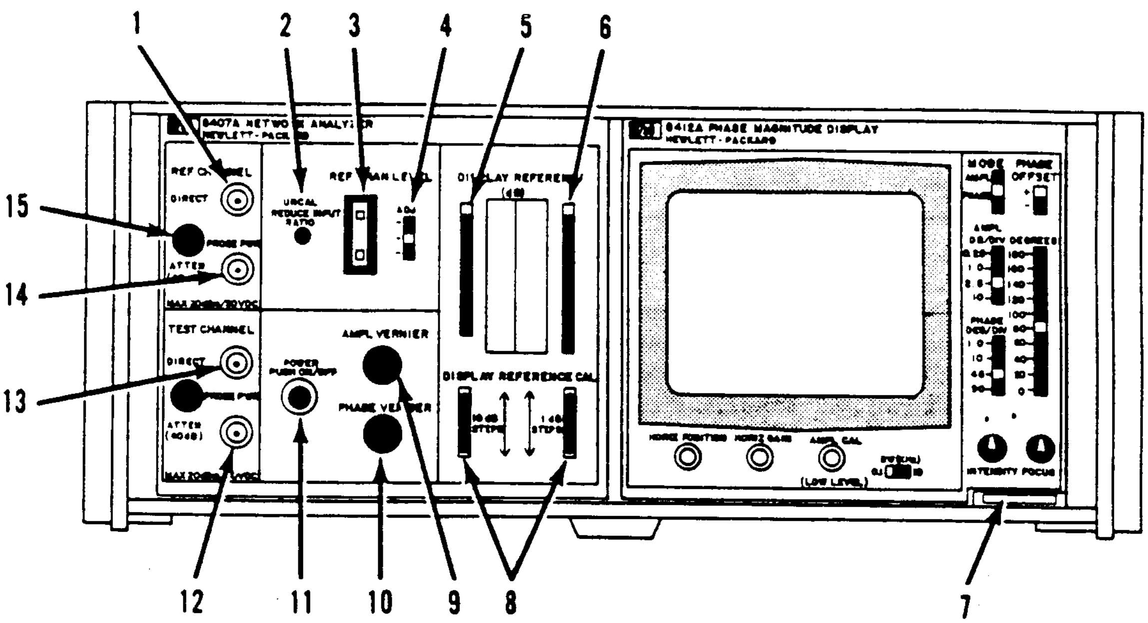
BEAM NO.	BORESITE AZIMUTH (degrees)
1	0
2	60
3	120
4	180
5	240
6	300

60° WIDE

HIGH BAND MONITOR BEAMFORMER TABLE

Monitor Beam No.	Boresite Azimuth	-3dB Points	Antenna Elements							
1	0	354, 6	117	118	119	120	1	2	3	4
2	12	6, 18	1	2	3	4	5	6	7	8
3	24	18, 30	5	6	7	8	9	10	11	12
4	36	30, 42	9	10	11	12	13	14	15	16
5	48	42, 54	13	14	15	16	17	18	19	20
6	60	54, 66	17	18	19	20	21	22	23	24
7	72	66, 78	21	22	23	24	25	26	27	28
8	84	78, 90	25	26	27	28	29	30	31	32
9	96	90, 102	29	30	31	32	33	34	35	36
10	108	102, 114	33	34	35	36	37	38	39	40
11	120	114, 126	37	38	39	40	41	42	43	44
12	132	126, 138	41	42	43	44	45	46	47	48
13	144	138, 150	45	46	47	48	49	50	51	52
14	156	150, 162	49	50	51	52	53	54	55	56
15	168	162, 174	53	54	55	56	57	58	59	60
16	180	174, 186	57	58	59	60	61	62	63	64
17	192	186, 198	61	62	63	64	65	66	67	68
18	204	198, 210	65	66	67	68	69	70	71	72
19	216	210, 222	69	70	71	72	73	74	75	76
20	228	222, 234	73	74	75	76	77	78	79	80
21	240	234, 246	77	78	79	80	81	82	83	84
22	252	246, 258	81	82	83	84	85	86	87	88
23	264	258, 270	85	86	87	88	89	90	91	92
24	276	270, 282	89	90	91	92	93	94	95	96
25	288	282, 294	93	94	95	96	97	98	99	100
26	300	294, 306	97	98	99	100	101	102	103	104
27	312	306, 318	101	102	103	104	105	106	107	108
28	324	318, 330	105	106	107	108	109	110	111	112
29	336	330, 342	109	110	111	112	113	114	115	116
30	348	342, 354	113	114	115	116	117	118	119	120

Table A1-1. HP 8407A Network Analyzer, Controls, Indicators and Connectors



FRONT PANEL

1. REF CHANNEL DIRECT Input Connector. Reference channel RF input for signal inputs in the range of −10 to −90 dBm. If the input RF signal is greater than −10 dBm, the ATTEN input should be used. In this case a 50 ohm termination must be connected to DIRECT input.

2. UNCAL REDUCE INPUT RATIO Light. This is an overload indicator that monitors signal levels of the test channel within the instrument. When an overload occurs, either the reference channel signal must be increased, or the test channel signal must be decreased. The reference channel signal may be increased by either adjusting the REF CHANNEL LEVEL ADJ attenuator switch or by changing the RF input cable from ATTEN to DIRECT input. The test channel signal may be decreased by changing the RF input cable from DIRECT to ATTEN input, or by reducing the RF signal level from the sweep oscillator.

3. REF CHAN LEVEL Meter. An indication in the OPERATE range of the meter shows that the reference channel input signal level is in the correct range to make signal measurements.

4. REF CHAN LEVEL ADJ. The switch is a three position attenuator in the reference channel. Each step is 20 dB. The switch allows the reference channel signal to be adjusted to produce a REF CHAN LEVEL meter indication in the OPERATE range.

5. DISPLAY REFERENCE (dB) 10 dB/Step. This switch offsets the amplitude trace on the HP 8412A Phase-Magnitude Display by adding or reducing gain of the test channel in 10 dB steps.

6. DISPLAY REFERENCE (dB) 1 dB/Step. This switch offsets the amplitude trace on the HP 8412A Phase-Magnitude Display by adding or reducing gain of the test channel in 1 dB steps.

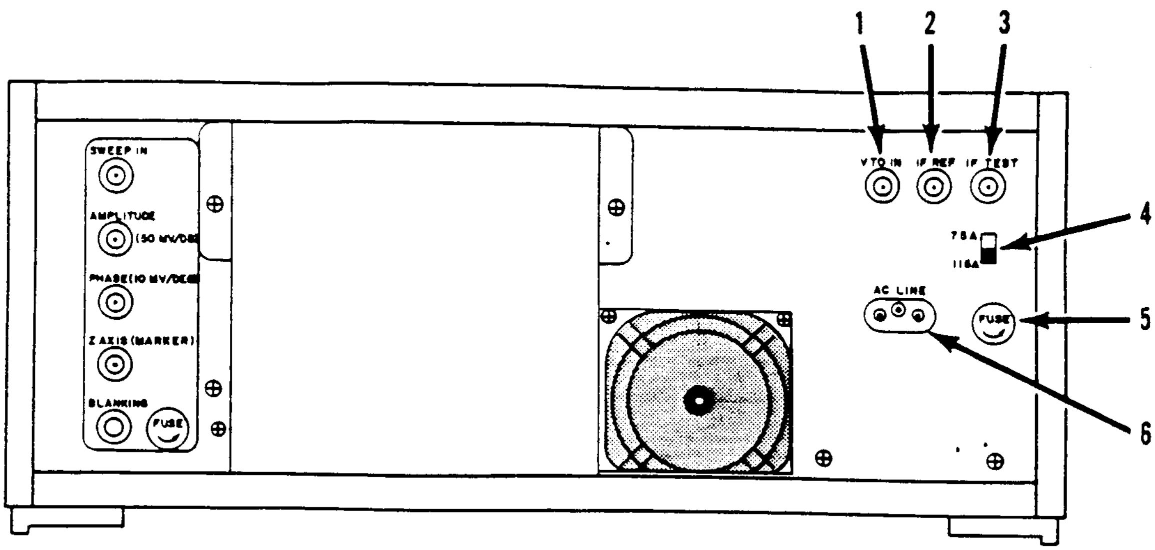
7. Pivoting level installs, retains, and extracts the plug-in display units.

8. DISPLAY REFERENCE CAL Thumbwheels. These thumbwheels set the scales for the DISPLAY REFERENCE 10 dB/Step and 1 dB/Step switches. This allows the scales to be set at zero dB for the calibration position of the switches. When measuring gain or attenuation, the displayed magnitude trace may be

Table A1-1. HP 8407A Network Analyzer, Controls, Indicators and Connect rs – CONT.

returned to the calibration point on the graticule with the DISPLAY REFERENCE switches. This allows the total gain or attenuation of the unit under test to be read directly from the DISPLAY REFERENCE scales.
9. AMPL VERNIER. Uncalibrated test channel gain vernier with at least 2 dB of continuous range. Gain increases with clockwise rotation.
10. PHASE VERNIER. Uncalibrated vernier adjustments of the phase between reference and test channel signals. Range is at least 50 degrees.
11. POWER ON/OFF. Combination line power switch and power indicator. Switch illuminates when instrument is on.
12. TEST CHANNEL ATTEN (40 dB) Input Connector. Test channel RF input that attenuates the RF input signal by 40 dB greater than the TEST CHANNEL DIRECT input. Signal input range for the ATTEN input is between +20 and −50 dBm. If the input RF signal is less than −50 dBm, the DIRECT input should be used. Damage level is above +26 dBm and 50 Vdc.
13. TEST CHANNEL DIRECT Input Connector. Test channel RF input that is used for signal inputs in the range of −10 to −90 dBm. If the input RF signal is greater than −10 dBm, the ATTEN input should be used. In this case, a 50 ohm termination must be connected to DIRECT input. Damage level is above +26 dBm and 50 Vdc.
14. REF CHANNEL ATTEN (40 dB) Input Connector. Reference channel RF input that attenuates the RF input signal by 40 dB greater than the REF CHANNEL DIRECT input. Signal input range for the ATTEN input is between +20 and −50 dBm. Damage level is above +20 dBm and 50 Vdc.
15. REF CHANNEL PROBE POWER Connector. Provides power for active reference channel accessory probe.

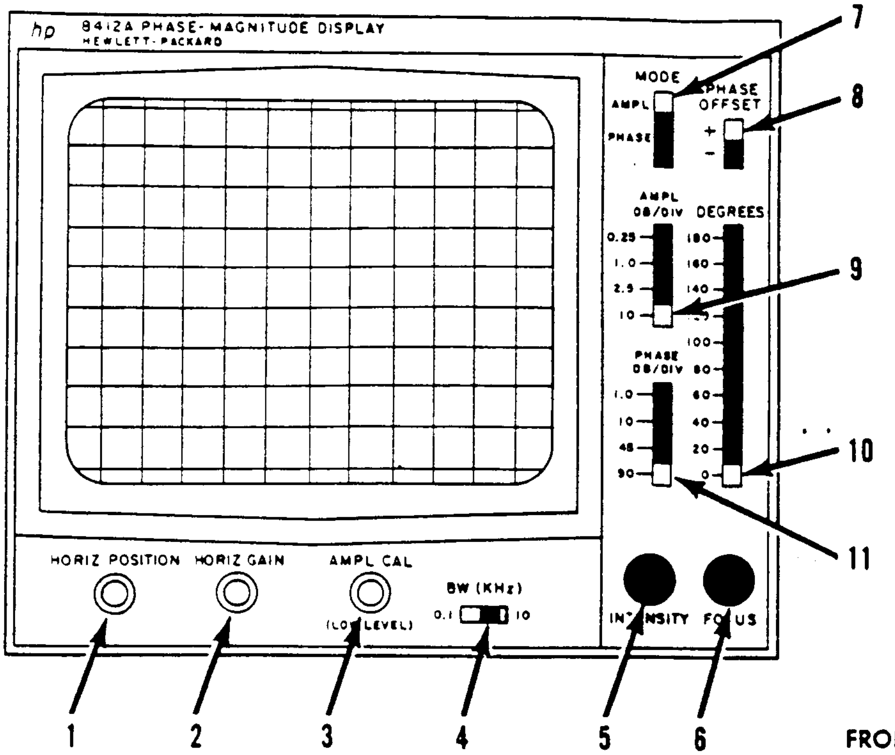
Table A1-2. HP 8407A Network Analyzer, C ntrols and Connectors



REAR PANEL

1. VTO IN Connector. Input for voltage tuned oscillator (VTO) signal from sweeper. VTO signal frequency should be in the range of 200.1 to 310 MHz and power level should be between −5 and −15 dBm nominal. The VTO signal is frequency locked to the sweeper RF output signal. The HP 8601A or 8690B/8698B Sweep Oscillator VTO output provides the proper signal.
2. IF REF Connector. IF reference channel signal output. This signal is a 278 kHz sine wave with fixed amplitude at about 1 volt p-p.
3. IF TEST Connector. IF test channel signal output. This is a 278 kHz sine wave containing all the amplitude and phase information present on the RF input signal. Amplitude range is 0 to about 1 volt p-p.
4. Line Voltage Selector. Permits operation from 115 to 230 Vac. Number showing on the slider is the selected operating voltage. Adjacent number on the panel in the correct line fuse rating.
5. Power Line Fuseholder. Fuse should have rating shown adjacent to the number on line voltage selector.
6. AC LINE Power Cable Connector. NEMA type with offset pin connected to HP 8407A Network Analyzer cabinet. Power requirements: 115 or 230 Vac ±10%, 50 to 60 Hz, approximately 85 watts.

Table A1-3. HP 8412A Phase-Magnitude Display, Controls



FRONT PANEL

1. HORIZ POSITION. Sets the horizontal position of the display. (Does not require frequent adjustment.)

2. HORIZ GAIN. Adjusts gain of horizontal amplifier to change length of displayed trace. (Does not require frequent adjustment.)

3. AMPL CAL (LOW LEVEL). Adjusts calibration of amplitude amplifier for signals displayed on lower half of CRT screen. (Does not require frequent adjustment.)

4. BW (kHz). Selects bandwidth passed by the reference and test channels. This allows decreasing bandwidth when necessary to filter noise from the display.

5. INTENSITY. Controls the brightness of the trace.

6. FOCUS. Controls the sharpness of the trace.

7. MODE. Selects AMPL (amplitude), PHASE, or both amplitude and phase (DUAL) to display on the screen. When both amplitude and phase are displayed, the amplitude trace is brighter than the phase trace for easy identification.

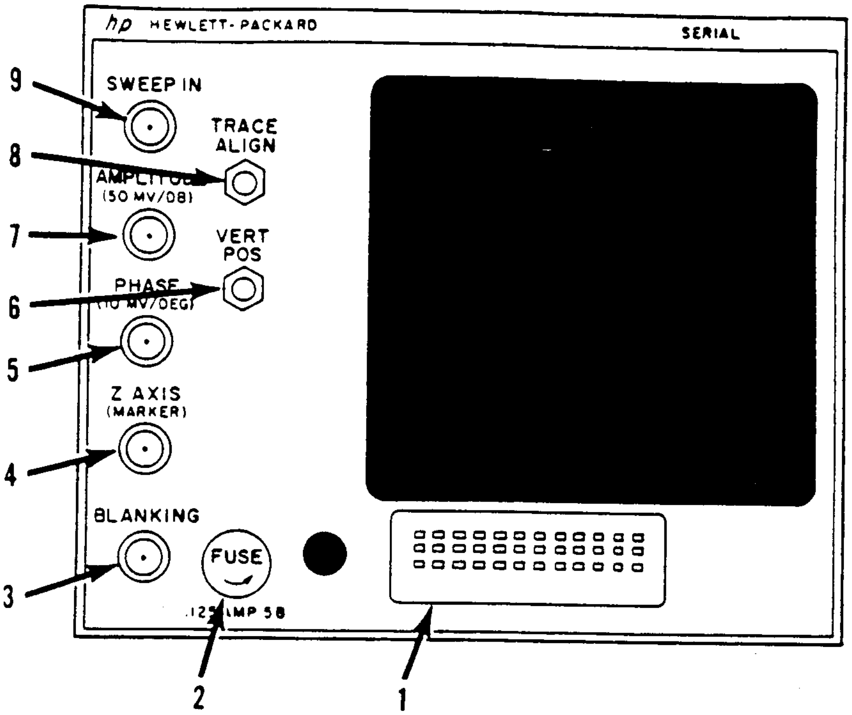
8. PHASE OFFSET Polarity Switch. From zero degrees, offset is selected either in the negative or positive direction up to 180 degrees. The polarity switch selects the direction from zero and works in connection with the DEGREES switch to select offset.

9. AMPL dB/DIV. Selects the calibrated resolution of the test channel amplitude display.

Table A1-3. HP 8412A Phase-Magnitude Display, Controls – CONT.

10. PHASE OFFSET DEGREES. Selects offset in 20 degrees steps. The switch works in conjunction with the PHASE OFFSET polarity switch to select up to 180 degrees in either the positive or negative direction from zero degrees. The phase offset plus the display reading gives the measured phase reading.
11. PHASE DEG/DIV. Selects the calibrated resolution of phase display.

Table A1-4. HP 8412A Phase-Magnitude Display, C ntrols and Connectors



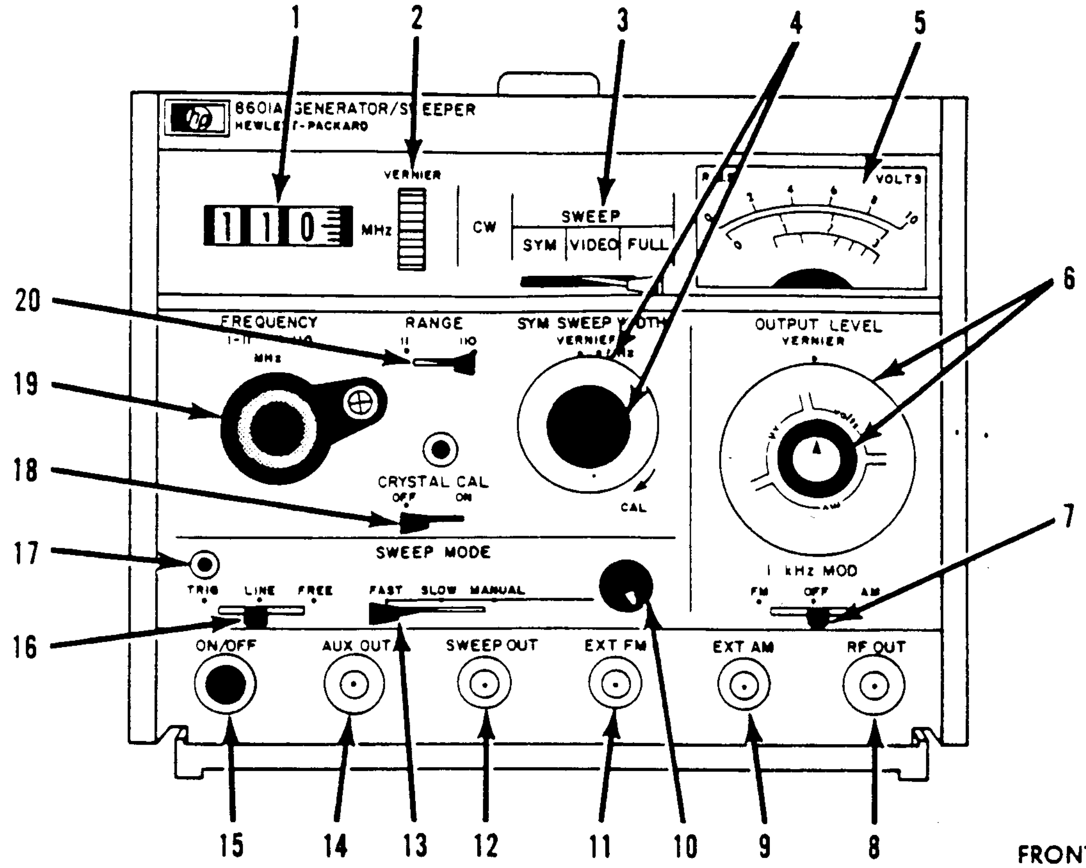
REAR PANEL

1.	Mainframe Interface Connector J1. Makes all necessary connections with HP 8407A or HP 8410A mainframe.
2.	Fuseholder. Fuse protection in 175 Vac line from mainframe. Fuse is ⅛ ampere slow blow.
3.	BLANKING Connector J6. Input for blanking signal from sweeper. The signal blanks the trace during sweeper retrace (−4V blanks, 0V unblanked). [This input has been eliminated on HP 8412B.]
4.	Z-axis Connector J5. Marker input to Z-axis that intensity modulates the trace, placing a bright dot on the trace at the selected marker frequency with HP Model 8690A/B. The input can both mark and blank (−5V intensifies, +5V blanks).
5.	PHASE (10 MV/DEG) Connector J4. Voltage output is proportional to the phase angle of the test signal compared to the reference signal. Output is 10mV/degree positive voltage for phase angles of 0 to +180 degrees and negative voltage for angles of 0 to −180 degrees.
6.	VERT POS. Zeroes phase and amplitude traces vertically.
7.	AMPLITUDE (50 MV/DB) Connector J3. Depending on the transducer used of the unit under test, The voltage output is proportional to the amplitude ratio of (1) $[20\log_{10}(V_{TEST}/V_{REF})]$, (2) $[20\log_{10}(I_{TEST}/I_{REF})]$, or (3) $[20\log_{10}(V_{RETURN}/V_{INCIDENT})]$.

Table A1-4. HP 8412A Phase-Magnitude Display, Controls and Connectors – CONT.

8. TRACE ALIGN. Used to align CRT trace to the horizontal graticule. Adjustment should be performed with sweep oscillator set for minimum sweep width.
9. SWEEP IN Connector J2. Input for sweeper signal that goes to horizontal (x-axis) amplifier.

Table A1-5. HP 8601A Generat r/Sweeper, Controls, Indicators and Connectors

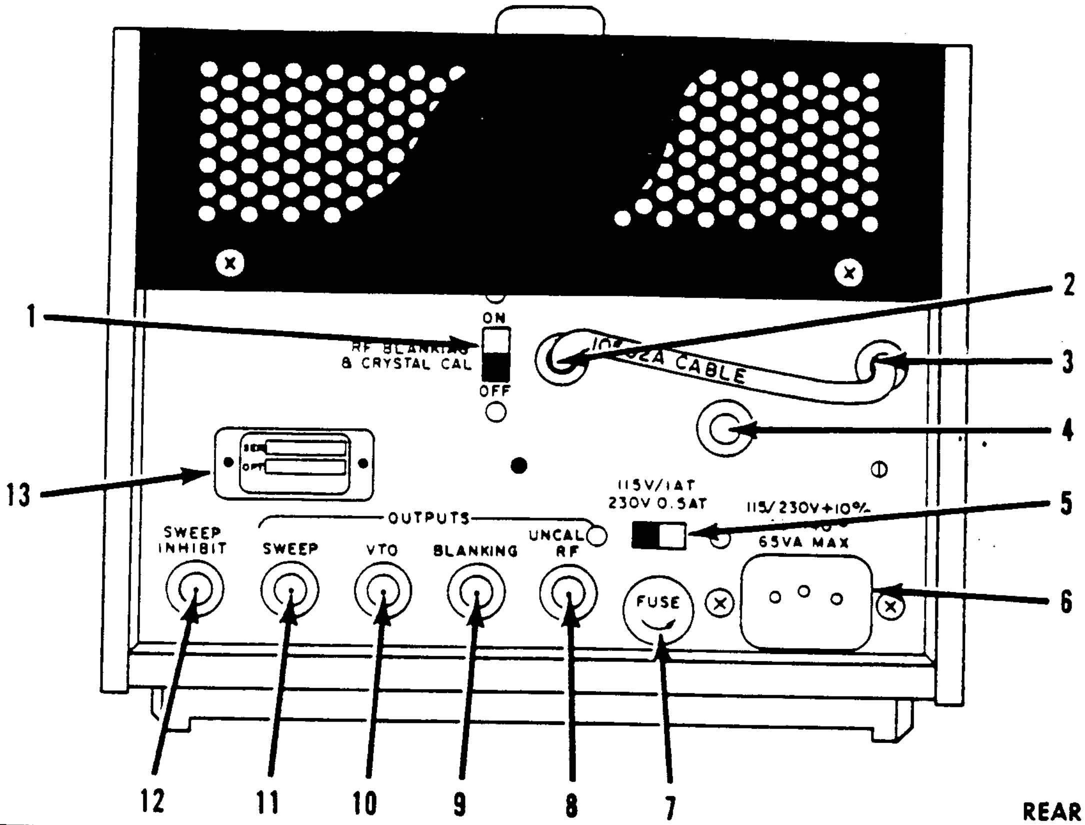


1. Digital Frequency Readout. Indicates CW frequency, SYM sweep center frequency, or VIDEO sweep upper frequency limit, depending on position of CW/SWEEP switch. Numerals to left side of decimal point light indicate frequency. Upward rotation increases frequency.
2. FREQUENCY VERNIER. Fine tunes RF output frequency. Adjustment range is approximately ±0.1% of frequency. Upward rotation increases frequency.
3. CW/SWEEP. Selects FULL, VIDEO, SYMMETRICAL sweeps or CW operation. FULL sweeps full range; 0.1 to 11 MHz (range 11). 1.0 to 110 MHz (range 110). VIDEO sweeps from bottom of the band to frequency indicated on digital frequency readout. SYM sweeps symmetrically about the center frequency indicated on the digital frequency readout. CW generates a fixed frequency that is selected by the digital frequency readout.
4. SYM SWEEP WIDTH/VERNIER. Selects sweep width about center frequency. Blue numbers correspond to range 11; black numbers correspond to 110. The SWEEP WIDTH VERNIER adjusts the sweep width from the calibrated position to zero width.
5. Meter. Indicates RF output level in dBm or volts rms into 50 ohms.
6. OUTPUT LEVEL/VERNIER. Adjusts RF output level. Output is calibrated when OUTPUT LEVEL VERNIER is adjusted for 0 dBm meter reading. Blue numbers correspond to black meter scale (volts rms). Clockwise rotation increases output level.

Table A1-5. HP 8601A Gen rator/Sweeper, Controls, Indicators and Connectors – CONT.

7. 1 kHz MOD. Turns on either internal frequency or amplitude modulated at 30%, 1 kHz rate. In FM position output is frequency modulated at 7.5 kHz deviation, 1 kHz rate (75 kHz peak deviation on high range).
8. RF OUT. Calibrated RF output (into 50 ohms).
9. EXT AM. Input for external amplitude modulating signals.
10. Manual/Sweep Speed Control. Manual sweep control in MANUAL mode; sweep speed vernier in FAST and SLOW modes. Clockwise rotation sweeps upward across band (in MANUAL) or increases sweep speed (in SLOW and FAST).
11. EXT FM. Input for modulation signals at rates up to 10 kHz. Modulation (deviation) sensitivity is 5 MHz/volt in range 110; 0.5 MHz/volt in range 11.
12. SWEEP OUT. Output ramp voltage concurrent with RF sweep. Output is approximately 0 to +7 volts in all sweep modes.
13. FAST/SLOW/MANUAL. Selects sweep speed or manual operation.
14. AUX OUT. Auxiliary output used for frequency monitoring. Output level is approximately 0.5V p-p into 200 ohms. Output frequency is 0.1 to 11 MHz on both ranges. (Range 110 output is divided by ten.) Provides about a −5 volt DC level for decimal point movement when using HP 8600A Digital Marker for frequency measurement.
15. ON/OFF. Depressing turns instrument on or off; lamp illuminates when instrument is on.
16. TRIG/LINE/FREE. Selects sweep trigger. In TRIG position, sweep is started by depressing trigger button. Retrace occurs automatically, or sweep can be terminated manually by depressing trigger button a second time. In LINE position, sweep repetition rate is synchronized with line frequency. In FREE position, sweep is derived from internal sweep generator and system is free running.
17. TRIGGER Pushbutton. Initiates single sweep each time it is pressed momentarily when TRIG/LINE/FREE switch is in TRIG position (SYM, VIDEO, or FULL SWEEP modes).
18. CRYSTAL CAL. Activates 5 MHz calibrator circuit. Output beat-signals at 5 MHz intervals are used to calibrate single or very slow swept frequency readout.
19. FREQUENCY. Selects CW frequency, SYMMETRICAL sweep center frequency, or VIDEO sweep upper frequency limit, depending on position of CW/SWEEP switch. Clockwise rotation increases frequency.
20. RANGE. Selects desired frequency range. Decimal point indicator light is automatically placed for correct frequency readout (MHz).

Table A1-6. HP 8601A Generator/Sweeper, C ntrols and Connectors



REAR PANEL

1. RF BLANKING/CRYSTAL CAL. Enables and disables RF blanking and crystal calibrator circuit.

2. VTO Output (Option 007 only). 200.1 to 211 MHz in Range 11, 201 to 310 MHz in Range 110. Minimum amplitude is −15 dBm. For normal operating modes connect this VTO output to the LO INPUT. When using 8601A as a tracking generator leave VTO output unconnected.

3. LO INPUT (Option 007 only). For normal operating modes, connect VTO output to LO INPUT. When using 8601A as a tracking generator connect output of external oscillator to LO INPUT.

4. AUX OUT (Option 004 only). Auxiliary output used for frequency monitoring. Output level is approximately 0.5 Vp-p into 200 ohms. Output frequency is 0.1 to 11 MHz on both ranges. (Range 110 output is divided by ten.)

5. Line Voltage Switch. Slide switch selects proper primary circuit for 115 or 230 Vac operation. Exposed number indicates primary voltage to be used.

CAUTION

Before plugging in power cable, check that line voltage switch is set for correct AC line voltage.

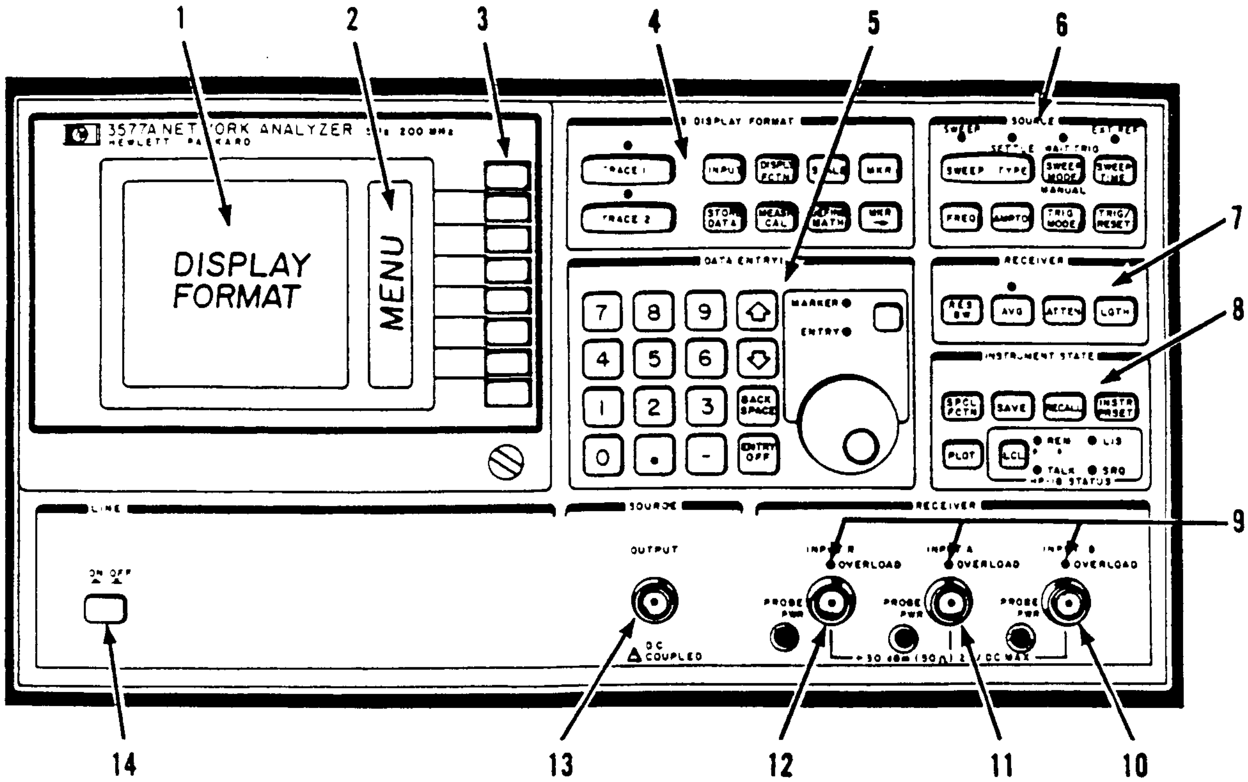
6. Power Cable Connector.

7. LINE FUSE. Primary circuit overcurrent protection. For 115 Vac operation, use 1 amp, slow-blow fuse. For 230 Vac operation, use 0.5 amp, slow-blow fuse.

Table A1-6. HP 8601A Generator/Swe per, Controls and Connectors – CONT.

8. UNCAL RF. RF output concurrent with front panel RF OUT but is not calibrated or blanked during sweep retrace.
9. BLANKING. Output is a rectangular pulse of approximately −4V that occurs during retrace portion of sweep.
10. VTO OUTPUT. 200.1 to 211 MHz in Range 11; 201 to 310 MHz in Range 110. Minimum amplitude is −15 dBm.
11. SWEEP. Sweep voltage output concurrent with RF sweep. Output is approximately 0 to +7 volts in all sweep modes.
12. SWEEP INHIBIT. A sweep inhibit pulse (momentary ground), adjustable for any frequency point across the swept range, is applied to momentarily stop the 8601A sweep. This pause enables the HP 8600A Digital Marker to measure the frequency at the particular point in the sweep.
13. Identification Plate. Serial number that identifies individual instrument. First three or four digits identify the serial prefix. If instrument includes a standard modification (called an Option) then the option number is given on the identification plate just below the serial number.

Table A1-7. ***HP 3577A Network Analyzer, Controls Indicators, and Connectors***



FRONT PANEL

1. CRT (cathode ray tube) display. Trace information, digitally stored as complex data (real and imaginary), is automatically formated for viewing and displayed on the CRT screen. Any of seven different display formats may be derived from the same trace data and appropriate scale changes made without repeating a measurement. Four graticules – rectangular (dual trace) LINEAR or LOG, POLAR, and SMITH chart – are electronically generated, eliminating need for screen overlays. Marker information and sweep parameters are displayed above and below the CRT graticule.

2. MENU display area of the CRT. A MENU is a list of softkey labels that automatically appears on the CRT screen next to the column of softkeys. MENUs are displayed whenever a hardkey is pressed or (if MENU is more than one level deep) when certain softkeys are pressed for requesting particular parameters to be modified or measurement to be made. This permits control of many features with a minimum number of front panel keys by redefining the softkeys with each new MENU.

3. SOFTKEY. This column of eight keys with no stenciling are called SOFTKEYS. The function of each key is defined (or redefined) by the designated softkey label of each MENU. These keys control/initiate the menu-driven operation of the analyzer.

NOTE

The lettered keys are referred as HARDKEYS. The only function of most of the hardkeys is to display a menu of softkey labels. Exceptions are the keys in the DATA ENTRY section and INSTR PRESET, LCL, and TRIG/RESET hardkeys in the INSTRUMENT STATE section.

4. DISPLAY FORMAT is one of five front panel sections. The ten hardkeys in this section are used to select the active trace on the CRT and to display menus of softkeys used to:

Table A1-7. HP 3577A Network Analyzer, Controls, Indicators, and Connectors – CONT.

INPUT	define screen trace in terms of receiver inputs, stored data, user defined constants, and user defined functions
DISPLAY FCTN	define screen trace in terms of how the complex data is intrepreted (LOG MAG, PHASE, GROUP DELAY, etc.)
SCALE	define graticule scale (REF LEVEL, /DIV, etc.)
MKR	(marker) read data from the displayed trace
MKR →	(marker goes into) enter data using the position of the marker
STORE DATA	store complex data as defined under the INPUT hardkey
MEASR CAL	normalize or do partial (two term) or full (three term) error correction of one-port measurements
DEFINE MATH	define three constants and five functions
TRACE 1 TRACE 2	are used to select the active trace. The active trace is indicated by the illuminated LED over either the TRACE 1 or TRACE 2 key and by a bright trace and marker information block on the CRT screen. Other hardkeys in the DISPLAY FORMAT section are used for data entry or mode selection for one of the two traces.

5. DATA ENTRY section is used for entering or modifying data. The ten digit keypad is used to supply numeric values for a chosen parameter, while the appropriate units (Hertz, dBm, etc.) are supplied via softkeys. In addition, the rotary knob can be used for continuous adjustments, while the increment/decrement (arrow) keys allow values to be changed in steps. The BACKSPACE hardkey is used to correct data entries or trace arithmetic equations. The ENTRY OFF key is used to keep the knob from changing an ENTRY value or to clear the CRT screen of menus and messages. The knob can be used in one of two modes: to move the MARKER or for (continuous) ENTRY (i.e., data modification). It toggles between these two modes when the key above the knob is pressed. The two LEDs, marked MARKER and ENTRY, show which mode the knob is in.

NOTE

It is good operating practice to keep the knob in the MARKER mode so that accidental rotation of knob does not change whatever entry currently appears in the MENU.

6. SOURCE section keys allow the user to define an appropriate input signal for the device under test or test measurement being conducted. The seven hardkeys when pressed display menus of softkeys which control the parameters of the source; while the four LEDs provide status indications of the source during both setup and use. The LED marked EXT REF will be illuminated whenever an external frequency reference source is connected to the rear panel input and remains within prescribed/preset accuracy; otherwise, the analyzer switches to its own internal reference causing the EXT REF LED to extinguish and the audible beep alarm to sound. The parameters controlled by the hardkeys include: SWEEP TYPE (linear, alternate, log, amplitude, or CW), SWEEP MODE (continuous, single or manual), SWEEP TIME, FREQuency, AMPliTuDe, TRIGger MODE (free run, line, and external), and TRIGger/RESET.

Table A1-7. HP 3577A Netw rk Analyzer, Controls, Indicators, and Connectors – CONT.

7. RECEIVER section allows the user to control and configure the analyzer's RECEIVER inputs, A, B, and R. The four hardkeys RES BW, AVG, ATTEN, and LENGTH, when pressed, are used to display the softkey menus provided to control resolution bandwidth, vector-averaging, attenuation, impedance, and electrical length compensation for each of the the three inputs. When averaging is on, the LED above the AVG hardkey is illuminated.
8. INSTRUMENT STATE section implements several useful utility functions. The six hardkeys in this section may be used to SAVE and RECALL instrument state, PRESET the HP 3577A, PLOT what appears on the CRT screen using an external plotter, monitor the HP-IB STATUS of the analyzer, or use the special functions (SPCL FCTN) built into the HP 3577A. Special functions include changing the HP-IB address, conducting confidence testing, turning the beeper alarm on and off, performing service diagnostic tests, and INPUT S-parameter control.   **NOTE**   INSTRUMENT STATE is also a term that refers to the state or values of all parameters. This state or condition may be SAVEd and later RECALLed using the appropriate hardkey within this section.
9. OVERLOAD indicators associated with each of the three RECEIVER inputs, A, B, and R. OVERLOAD occurs when a signal level greater than 0.0 dBm (with ATTEN = 20 dB) or −20 dBm (with ATTEN = 0 dB) is applied to a RECEIVER input. When an input is overloaded the measurement accuracy is degraded and action should be taken to reduce the input signal level. When the overload occurs, the analyzer sounds an audible alarm (if the beeper is ON), illuminates the red LED marked OVERLOAD above the input being overloaded, and displays a warning message on the CRT screen. The red alarm LED is a real-time indication of an overload condition while the CRT screen message remains until the beginning of a new sweep.
10. RECEIVER INPUT B Connector. This 50-ohm, Type N, female coaxial connector provides signal input to one of three identical measurement channels (in this case, B) within the analyzer's RECEIVER section. Use of the specific input, A, B, or R is defined and controlled by the preprogrammed test menu selected by pressing the appropriate hardkeys (and sometimes softkeys) as indicated by test set-up and CRT screen messages.
11. RECEIVER INPUT A Connector. This 50-ohm, Type N, female connector provides access to measurement channel, A, and its use is also menu-driven and controlled.
12. RECEIVER INPUT R Connector. This 50-ohm, Type N, female connector provides access to measurement channel, R, and its use is also menu-driven and controlled.
13. SOURCE OUTPUT Connector. This 50-ohm, Type N, female coaxial connector provides the signal source for all test measurements made with the HP 3577A. The OUTPUT signal is controlled by the keys in the SOURCE section. Characters across the bottom of the CRT screen display show the status of the frequency and amplitude of the source. For LOG and ALTERNATE SWEEP TYPEs the amplitude data does not appear on the CRT screen.   The OUTPUT protection circuit will open the output path if a signal level greater than 4 volts appears on the connector. This open condition is called TRIPPED and a screen message "SOURCE TRIPPED, clear trip on AMPTD menu" will direct user to the AMPTD menu where the CLEAR TRIP softkey may be found, then used to clear open condition.

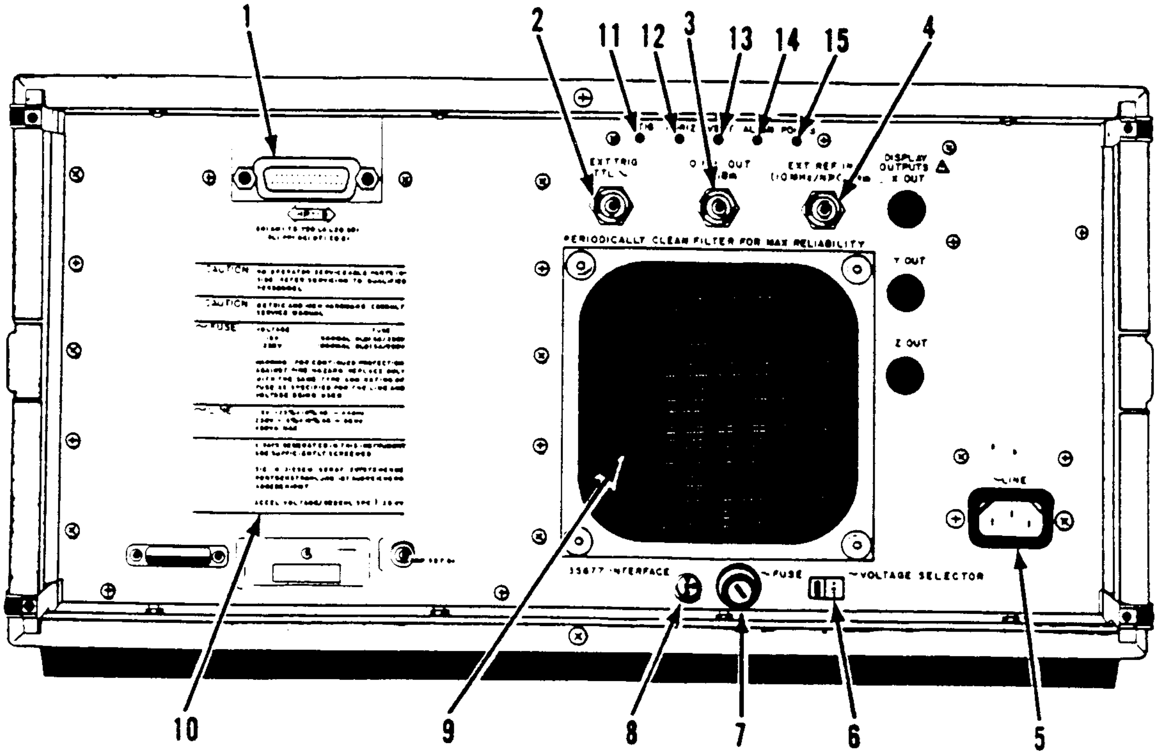
Table A1-7 HP 3577A Network Analyz r, Controls, Indicators, and Connect rs – CONT.

14. LINE ON/OFF. This two-position, maintained action, pushbutton LINE power switch controls the application of electrical power to the instrument. Turn on power by pressing this LINE switch to the ON position as indicated by the marking above the switch.

NOTE

Each time the HP 3577A is powered ON a self-test of ROM and RAM is run and the results (pass/fail) are displayed on the screen. (Normally the CRT will not show these results because it hasn't warmed up). The beeper will sound and all front panel LED's should illuminate when the instrument is first turned on. The operator should visually verify that all LED's illuminate. Also, the cooling fan on the rear panel should operate and the SWEEP LED should start flashing about once per second.

Table A1-8. HP 3577A Network Analyzer, Controls, Indicators, and Connectors



REAR PANEL

1. HP-IB Connector. The HP 3577A is designed for use with the Hewlett-Packard Interface Bus (HP-IB), HP's implementation of IEEE Standard 448-1978, "Standard Digital Interface for Programmable Instruction." The analyzer is connected to the HP-IB by connecting an HP-IB interface cable to this connector.

2. EXT TRIG Connector. This 50-ohm BNC female connector provides means to apply an EXTernal TRIGger to the instrument. Trigger signal should be a negative TTL transistion or contact closure to ground, with a minimum pulse width of (typically) 1-microsecond.

3. 10 MHz 0 dBm Connector. This 50-ohm BNC female connector provides means of supplying Reference Frequency Output of 10 MHz at a 0 dBm (typically) level for use by external devices.

4. EXT REF IN Connector. This 50-ohm BNC female connector is for providing an EXTernal REFerence frequency INput to the analyzer. A frequency of 10 MHz/N (where N is an integer from 1 to 100) at a level of 0 dBm ±10 dB nominal may be used.

5. AC LINE Power Cable Connector. This is a NEMA type with offset center grounding pin. Power requirements: 115 Vac +10%, −25% (47 Hz to 440 Hz); or 230 V +10%, −15% (47 Hz to 66 Hz); 450 VA maximum.

6. AC Line VOLTAGE SELECTOR Switch. This switch permits operations from either a 115 or 230 volt AC LINE power source. Number showing on slider is the operating voltage. Fuse rating corresponding to selected voltage is found in the CAUTION, FUSE, LINE information block area stenciled on the left side of rear panel below HP-IB connector.

7. Power Line Fuseholder. Fuse should have rating corresponding to the AC line VOLTAGE SELECTOR setting. See rear panel information block.

Table A1-8 HP 3577A Network Analyzer, Controls, Indicators, and Connect rs – CONT.

8. 35677 INTERFACE Connector. This connector is used only with the HP 35677A/B S-Parameter Test Set and is used with a special interface cable to interconnect the rear panels of both instruments.
9. Fan and Filter Assembly. Cooling fan should operate whenever analyzer is turned ON. Filter should be kept clean.
10. Information Block. This stenciled area contains CAUTIONS, FUSE, and LINE information pertaining to safe operation of the instrument.
11. ASTIG Control. CRT Display astigmatism adjustment control. Used in conjunction with FOCUS control to obtain sharp and clear display.
12. HORIZ Control. CRT Display X-axis position adjustment control. Used to center pattern on face of CRT screen.
13. VERT Control. CRT Display Y-axis position adjustment control. Used to center pattern on face of CRT screen.
14. ALIGN Control. CRT Display alignment adjustment control. Used to rotate display until it is parallel with the bottom of the CRT Display screen bezel.
15. FOCUS Control. CRT Display focus adjustment control. Used in conjunction with ASTIG control to obtain a sharp and clear display.

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