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TEST AND EVALUATION OF THE AIR TRAFFIC CONTROL RADAR BEACON SYSTEM ELECTRONIC SCAN ANTENNA (SPECIFICATION TESTS)

Anthony D. Bradley

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INTERIM REPORT

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16. Abstract

The air traffic control radar beacon system (ATCRBS) electronic scan antenna (ESA) consists of 56 array modules placed on a platform (ring) constructed around the top of an airport surveillance radar tower. A shelter beneath the tower provides an enclosure for the control and radiofrequency (RF) distribution system of the ESA.

This interim report covers the specification tests to determine compliance with portions of the engineering requirement applicable to field testing.

It was concluded that the ESA performed the basic functions of beam stepping, agile beam repositioning, beam hopover and the generation of side-lobe suppression (SLS), improved SLS (ISLS), sum channel, and difference channel antenna beam pattern characteristics. The data obtained during the effort met the specification requirements, taking into account field environmental effects.

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INTRODUCTION

GENERAL.

The air traffic control radar beacon system (ATCRBS) electronic scan antenna (ESA) can be considered: (1) a replacement for the existing 28-foot linear-array beacon antenna; (2) a flexible, agile beam antenna providing optimum capability when integrated with an Automated Radar Terminal System (ARTS); or (3) a data link, phased-array antenna for use with the discrete address beacon system (DABS). The results of the technical test program will be applicable, in part, to all three areas, but they are primarily intended to satisfy the requirements of the ATCRBS improvement program while providing base data for future testing.

This interim report covers the specification tests performed in accordance with the National Aviation Facilities Experimental Center (NAFEC) product plan prepared under Agreement No. 03-152, ATCRBS Transmitter Site Improvements Program.

TEST PROGRAM OBJECTIVES. The objectives of the ATCRBS ESA technical test program are to:

1. Demonstrate and determine compliance with portions of the ESA engineering requirement (FAA-ER-240-013a) applicable to field testing and acceptance from the contractor (specification tests).

2. Measure and evaluate the ability of the ESA to overcome siting problems in a representative field environment as compared to the existing ATCRBS configuration (field environment tests).

3. Recommend ESA specification changes which clarify and/or improve antenna characteristics. Verification of the improvements may require modification to the antenna and further testing.

TEST PROGRAM PROCEDURES. The requirements to accept the antenna from the contractor at NAFEC and to fulfill the objectives of the ATCRBS improvement program will be met through this test program. The test program was scheduled, with the exception of the preparatory tests, to start after completion of the installation and checkout procedures of the contractor.

The testing has been divided into four categories; they are: (1) preparatory tests, (2) specification tests, (3) field environment tests, and (4) system tests.

SPECIFICATION TEST OBJECTIVES.

The objective of the specification tests is to determine compliance of the ESA with portions of the engineering requirement applicable to field testing.

BACKGROUND.

The FY-72 Federal Aviation Administration (FAA)/Systems Research and Development Service (SRDS), Research and Technical Resume titled, "ATCRBS Transmitter Site Equipment," contained an SRDS development project 033-241-01C titled, "Development of ATCRBS Electronic Beam Antenna." This project, under the cognizance of ARD-240 provided for the development and evaluation of a mechanically independent ESA. The antenna is electronically interfaced with the primary radar antenna and performs the function of an ATCRBS interrogating antenna including side lobe suppression (SLS) and improved side lobe suppression (ISLS).

A specification for the antenna (FAA-ER-240-013a, "ATCRBS Electronic Scan Antenna") was prepared and a contract (DOT-FA72WA-2704) issued on September 10, 1971, for its development and installation at NAFEC.

Prior to installation at NAFEC the ESA was tested by the contractor at an antenna range to determine compliance with portions of the specification (reference 2). Those specification areas which were suitable for testing in the field were identified and included in the test and evaluation effort at NAFEC. A site test plan, contract item 7B (reference 3), was prepared by the contractor concerning these specific areas and data sheets prepared for the field acceptance. The installation of the ESA at NAFEC was completed in January 1974.

DISCUSSION

DESCRIPTION OF EQUIPMENT.

ELECTRONIC SCAN ANTENNA DESCRIPTION. The ESA, as designed and built, consists of 56 array modules placed on a platform (ring) constructed around the top of an airport surveillance radar (ASR) tower (figure 1). A shelter beneath the tower provides an enclosure for the control and radiofrequency (RF) distribution systems of the ESA.

The ATCRBS ESA provides a fan beam at any one of 2,048 azimuth beam positions. Directional and omni patterns are provided as well as a difference-receiving pattern. Proper combinations of the directional and omni pattern for both the normal SLS and the ISLS interrogations can be formed by the ESA. The directional pattern can be lifted over nearby buildings to reduce reflections. Performance monitoring is provided to indicate operational status, and a built-in test function is provided to isolate faults to replaceable modules. A more detailed description of the ATCRBS ESA is contained in reference 1.

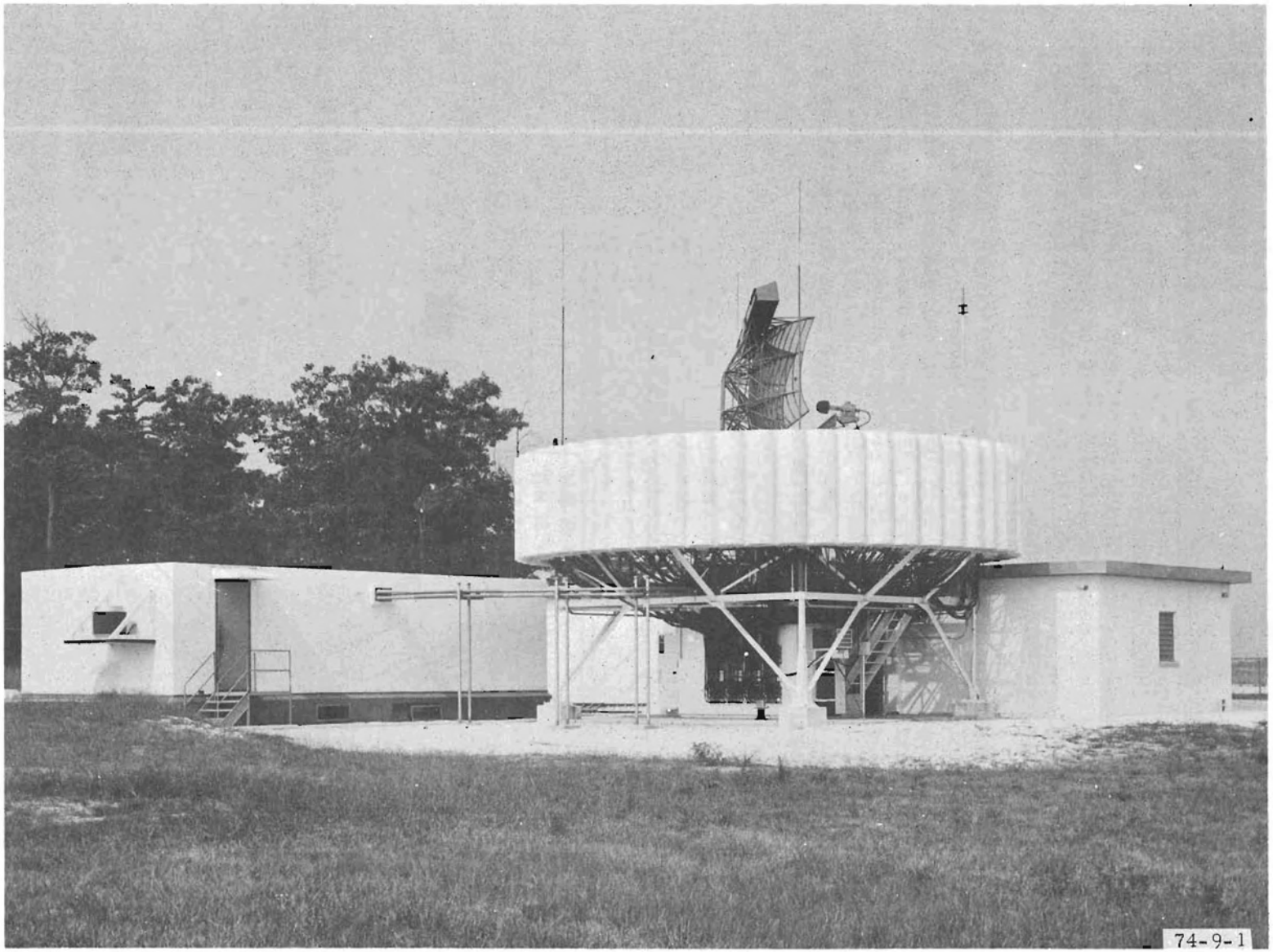


FIGURE 1. THE ATCRBS ELECTRONIC SCAN ANTENNA

TERMINAL RADAR/BEACON TEST FACILITY CONFIGURATION. The siting of the ESA in the test program was critical to evaluate system performance. Certain requirements, such as testing of the beam "hopover" feature, made it necessary to choose a site which violated correct siting practices. In fact, the site selected presented undesirable terrain and obstacles to the ESA characteristic of some in-service sites, but within the limits for which the antenna was designed to produce improved performance.

The site selected at NAFEC is adjacent to the aircraft hangar (Bldg 301) and the Atlantic City Municipal Terminal Building, as shown in figure 2. The site configuration, shown in figure 3, includes critical placement of the ASR-5-type equipment building, the 17-foot ASR antenna tower, and the ASR-7 radar fiberglas buildings (vans). The site provides a clear view of the airfield (for vertical lobing measurements) and the aircraft hangar obstruction, which is approximately 12.5° wide and 3.1° high from the center of the ESA (for beam hopover and reflection experiments).

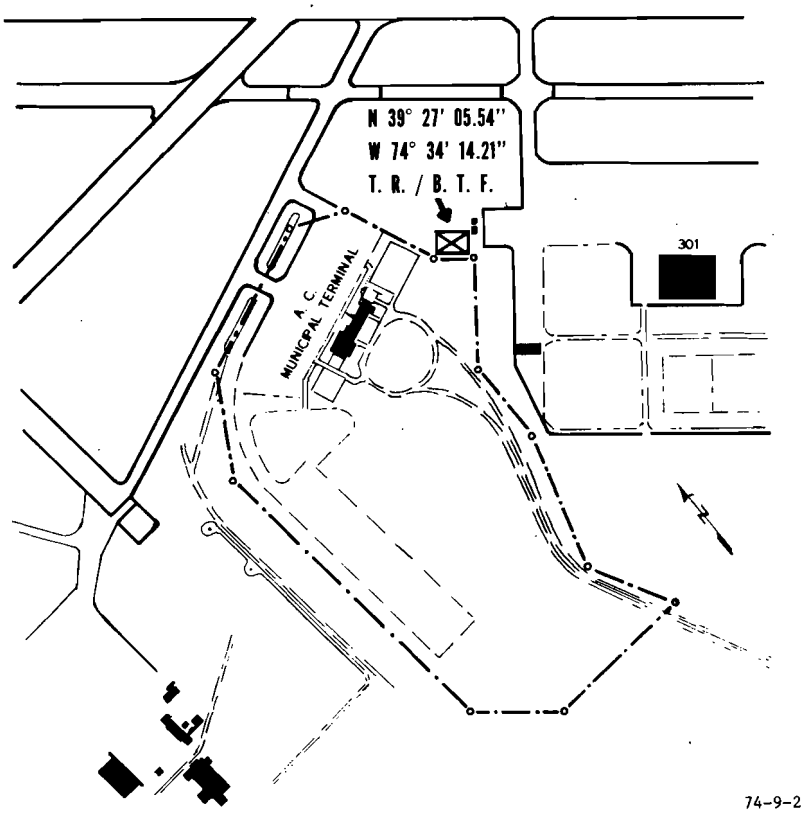


FIGURE 2. TERMINAL RADAR/BEACON TEST FACILITY SITE AT NAFEC

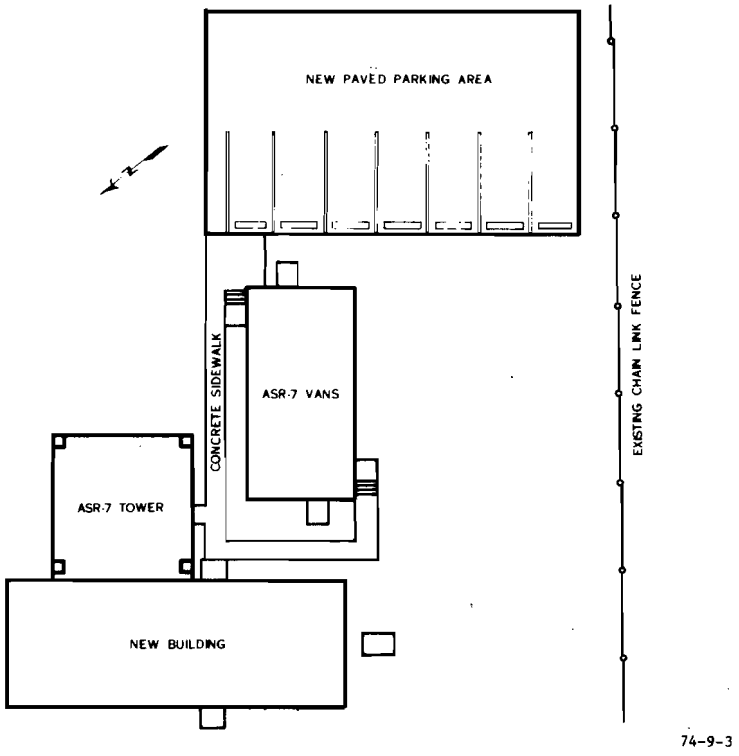


FIGURE 3. TERMINAL RADAR/BEACON TEST FACILITY CONFIGURATION

The equipment building is located adjacent to, and partially under the ESA. The site provides coverage (minus obstructions) to the approach to runways 13-31 and 4-22. Figure 4 shows the terminal equipment.

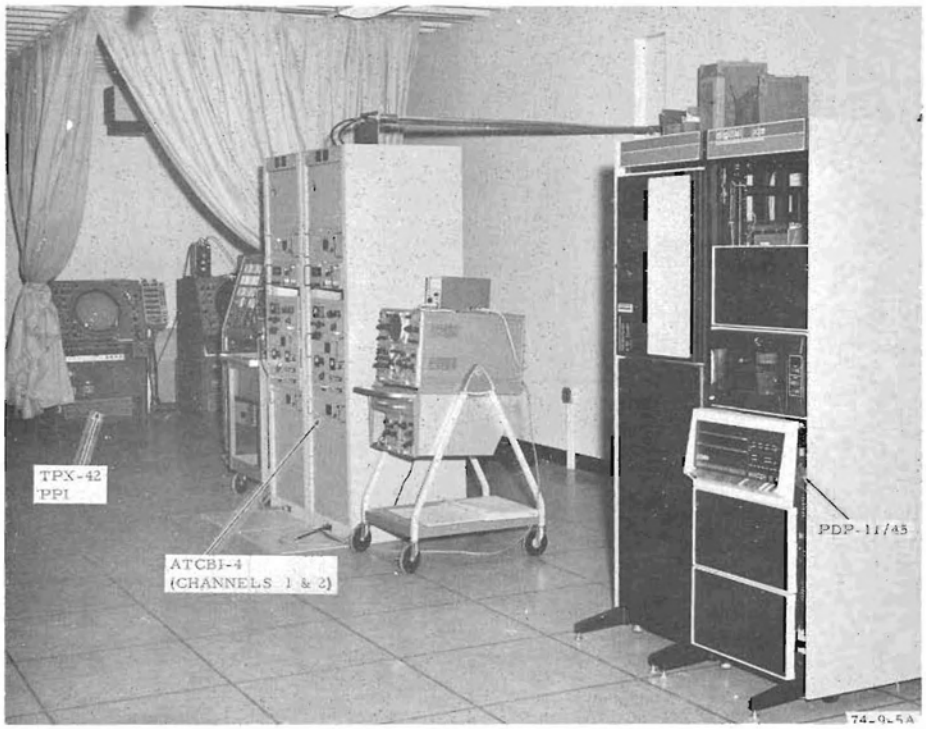


FIGURE 4. TERMINAL RADAR/BEACON TEST FACILITY EQUIPMENT

SPECIFICATION ITEMS.

The specification items to be tested at NAFEC were grouped under six sections.

1. Mechanical inspection

   (a) Installation requirements

2. Adjustment optimization

   (a) North alignment
   (b) ISLS P_1 pattern optimization

3. Operational control capabilities

   (a) ACP input
   (b) Antenna beam switching
   (c) Agile beam capability
   (d) Beam hopover

4. Operational performance

   (a) VSWR's (Voltage Standing Wave Ratios)
   (b) Electromagnetic radiation environment
   (c) Built-in test features
   (d) Casualty mode

5. System operation

   (a) Maintainability
   (b) Availability
   (c) Ease of maintenance

6. Antenna pattern tests

   (a) 1030-MHz and 1090-MHz horizontal pattern tests
   (b) 1030-MHz and 1090-MHz vertical pattern tests
   (c) Transmitted pulse characteristics
   (d) Pointing accuracy

Data collection techniques (test procedures) for the test and evaluation of the ESA are comprised of various methods developed over the past few years to satisfy requirements to investigate the performance of the ATCRBS and to demonstrate the improvements made in the system through development efforts. Some of the techniques are self-explanatory, such as recording equipment parameters, but other techniques require further explanation. Data collection methods employed during the specification tests which require detail description are included in appendix A.

TEST PROCEDURES AND RESULTS

MECHANICAL INSPECTION. A mechanical inspection was performed at the completion of the installation. The items pertaining to the structural aspects and construction of the ESA at NAFEC were examined during this effort. Most of the items were described in the installation report prepared by the contractor and included in the first interim report concerning the preparatory testing of the ESA (reference 4). Minor mechanical exceptions were noted and corrected later in the test program.

ADJUSTMENT OPTIMIZATION.

Two items were included under adjustment optimization, i.e., the alignment of the ESA with Magnetic North and the proper phasing of the directional and omni transmission paths to control the crossover points of the ISLS P_1 pattern. Both of the items are described in the installation report prepared by the contractor and included in the first interim report concerning the preparatory testing of the ESA (reference 4). The results of the alignment of the ESA were reflected in the antenna pattern measurements performed during the specification tests.

OPERATIONAL CONTROL CAPABILITY.

The operation control capabilities of the ESA were listed as azimuth scan rate, azimuth change pulse (ACP) input, antenna beam switching, agile beam capability, and beam hopover.

ACP INPUT. The azimuth scan rate of the ESA was tested by observing the antenna control unit (ACU) azimuth indicator shown in figure 5 to determine that the azimuth scan rate could be synchronized with the rotation of the ASR-7 radar. In addition, the internal rotation control of the ESA was observed by varying the revolution per minute (r/min) control of the ACU and measuring the spacing of the internal azimuth change pulse (ACP) generator and the azimuth indicator. A variable rotation rate between 5 and 20 r/min was recorded during the test.

In addition the ESA was driven by external ACP's over the range of 5 to 20 r/min.

The ACP waveform generated by the TR/BTF was measured on an oscilloscope. The interface to the ESA had to be changed since the characteristics of the ACP were specified for the ASR-7 azimuth pulse generator (APG) located on the rotary joint of the radar antenna. This signal was processed at the TR/BTF before distribution to various equipments, including the ESA at the facility.

ANTENNA BEAM SWITCHING. The 2,048 beam positions of the ESA were confirmed during this test by observing the switching of both the phase shifters and the quadrant switches shown in figure 6. A selected portion of the rotation was slowed to permit the status of the switching diodes to be examined between the ACP count.

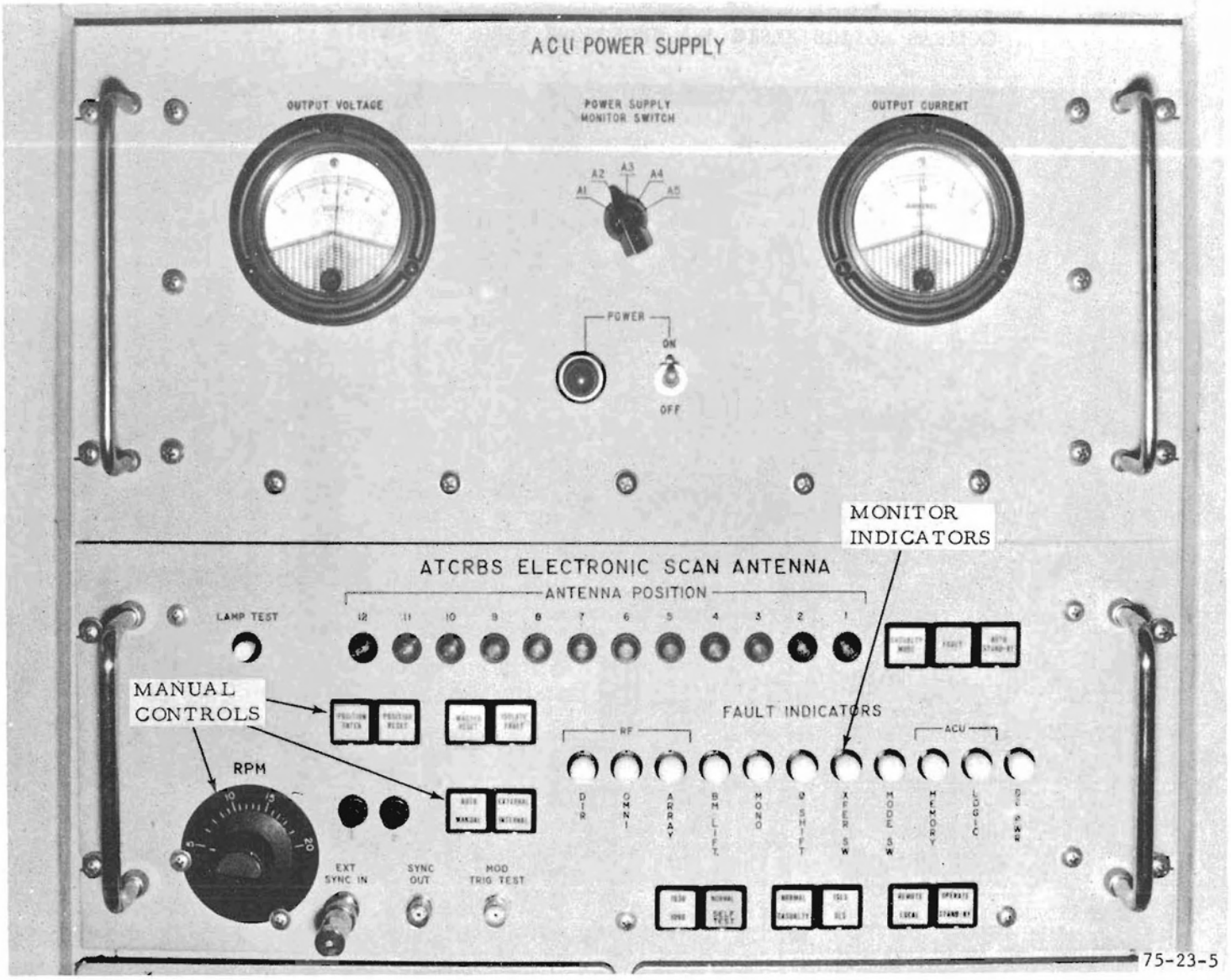


FIGURE 5. ESA ENCLOSURE (ANTENNA CONTROL UNIT)

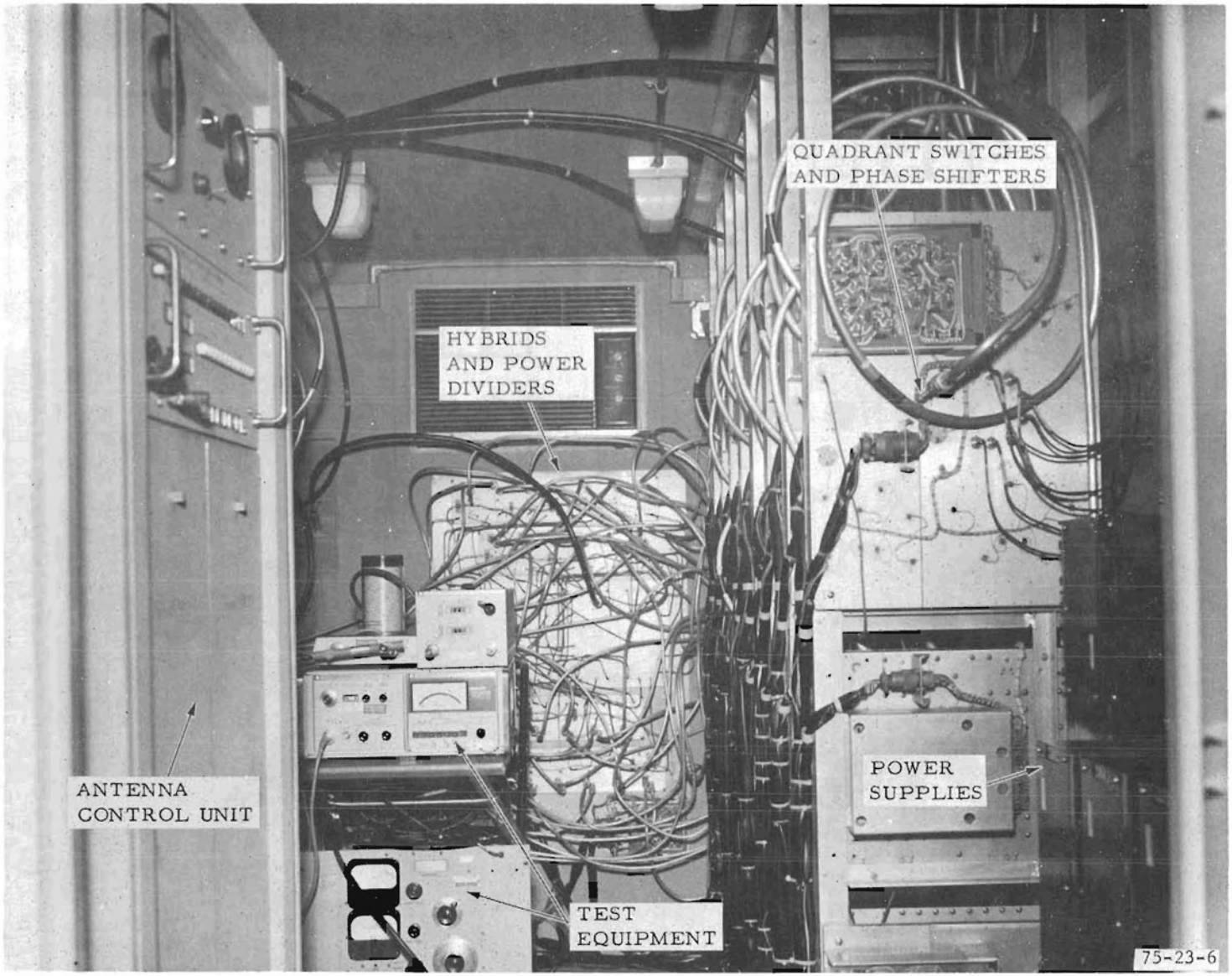


FIGURE 6. ESA ENCLOSURE (RF DISTRIBUTION SYSTEM)

The timing of the antenna beam switching was observed on an oscilloscope synchronized with the noninterlaced mode 3/A interrogation from the ATCBI-4. It was noted that the ESA entered a receive mode after the receipt of the mode 3/A interrogation and that switching to "transmit" mode occurred after the receipt of the beacon sync-trigger (BST).

AGILE BEAM CAPABILITY. The ESA agile beam capability to accept a 12-bit azimuth command was demonstrated by repositioning the pointing of the antenna within 5 microseconds (μs) of an agile beam command. The time required was divided between the agile command to the activation of the diode drivers and the switching of the diodes (1.4 μs and 1.1 μs, respectively). An agile beam enable gate was provided 200 μs before the agile beam command.

In addition, the ESA could be manually positioned to a preset antenna pointing position for test purposes using a 12-bit azimuth word inserted on the indicator panel of the ACU.

BEAM HOPOVER. The beam hopover function was checked for both sector and point selectability of either 0°, 2°, or 4° beam hopover. There were 224 selections available, giving a resolution of 1.6° for the beam hopover feature. The 0°, 2°, or 4° function could be exercised by rotation of a coded switch in the ACU for each of the 224 positions. In addition, a beam hopover inhibit circuit was provided which could override the 2° and 4° beam hopover function. Confirmation that the beam hopover function took place was accomplished during pattern measurements (ATCRBS 1030-megahertz (MHz) and 1090-MHz vertical patterns).

OPERATIONAL PERFORMANCE.

The operational performance dealt with VSWR, the electromagnetic radiation environment, built-in test features, and the casualty mode of the ESA.

VSWR. The voltage standing wave ratio measurements performed during the specification test are listed in table 1. The measurements were performed using a network analyzer and placing the mode switch in preset steady state conditions representing the SLS or ISLS P_1, P_2, and P_3 transmission times and the sum and difference channel receiver modes.

TABLE 1. VOLTAGE STANDING WAVE RATIO MEASUREMENTS

Operation Time	VSWR Measurements SLS (1030 MHz)	ISLS (1030 MHz)
P_1	1.35	1.20
P_2	1.50	1.50
P_3	1.35	1.22
	(1090 MHz)	(1090 MHz)
Receive	1.50	1.13

ELECTROMAGNETIC RADIATION ENVIRONMENT. The electromagnetic radiation environment presented to the ESA by the ASR-7 radar did not affect the operation of the antenna. The normal power output of the ASR-7 during the specification test was about 0.5 megawatts (MW). The radiation from the ASR-7 radar was checked during the preparatory tests (reference 4) to confirm that no personnel hazard existed in working areas.

BUILT-IN TEST FEATURES. The built-in test features of the ESA were tested during the effort for both fault monitoring and fault isolation. Various faults were selected and simulated during the test, including diode, driver board, and array faults. A particular element was selected and shorted or removed causing a fault to register on the ACU indicator panel. The procedure for fault isolation as described in the instruction manual was exercised and the fault isolated to the correct module. This procedure was continually exercised during the test and evaluation to isolate and correct true faults.

Several faults were selected during the testing to determine if they increased the VSWR readings. The ones selected included a transfer switch, a beam lift diode fault, loss of transmission path to one vertical array and a monopulse diode switch fault. The highest VSWR reading recorded for each condition noted was 1.33 (transfer switch fault). It was noted that the casualty mode required further definition (not restricted to VSWR) for the operation of the ESA.

SYSTEM OPERATION.

The electronic scan antenna was maintained by contract personnel during the period of the specification tests. The ease of maintenance of the ESA was investigated by keeping daily logs on maintenance actions and evaluating the availability of corrective maintenance aids (built-in test functions, test points, etc.), component accessibility, and restoration of the equipment to effective operation after a shutdown.

The consideration of maintenance data pertaining to the availablity of the ESA began after the completion of the 48-hour test (48 consecutive hours of operation without failure) on June 27, 1974. Prior to this test, the ESA was in a shakedown condition during which time various faults were isolated and corrected by contract personnel. In addition, the testing of the ESA and its utilization was not continuous since the TR/BTF was made available for other activities and generally restricted RF operation (ATCBI-4 interrogating) to normal working hours.

MAINTAINABILITY. A summary of the maintenance logs for the period of July 1 to December 10, 1974, is given in table 2. The maintenance activity includes the location and type of faults, the corrective maintenance performed on the equipment, the repair time, and a classification of either fatal fault or casualty mode based on whether or not the ESA could be operated in a reduced performance state with the fault.

TABLE 2. ESA MAINTENANCE ACTIVITIES

Date of Occurrence	Fault Location	Type Fault	Fault Classification	Corrective Active	Repair Time Hrs	Repair Time Min
7-8-74	Phase Shifter Assembly 38	Repeating True Fault (RF)	Casualty	Assembly Replacement With Spare	0	45
7-9-74	ACU (RF)	Intermittent Self-Test Fault	Casualty	Self-Test Circuits Reset	0	02
7-11-74 7-12-74	Mode Switch; ACU	Intermittent External Interupts	Fatal	Self-Test Circuits Reset	0	10
7-17-74	RF Array	Intermittent True Fault	Casualty	Self-Test Circuits Reset	0	05
7-18-74	RF Array (IA2)	Repeating True Fault (RF)	Casualty	Repaired Cabling Connector	0	30
7-19-74	ACU (Self-Test)	Repeating External Interupt	Fatal	Corrected Ext. Equip. Fault	0	30
7-25-74	ACU (Input Triggers)	Repeating External Interupt	Fatal	Corrected Ext. Equip. Fault	0	15
7-26-74	ACU (Input Triggers)	Repeating External Interupt	Fatal	Corrected Ext Equip. Fault	0	15
7-30-74	Phase Shifter Assembly No. 31	Intermittent True Fault (CR)	Casualty	Self-Test Circuits Reset	0	05
7-31-74	ACU (?)	Intermittent External Interrupt	Casualty	Self-Test Circuits Reset	0	05
7-31-74	RF Array (IA 39)	Intermittent True Fault (RF)	Casualty	Self-Test Circuits Reset	0	05
8-01-74 8-02-74 8-05-74	ACU (RF) (Self-Test)	Intermittent Self-Test Fault	Casualty	Self-Test Circuits Reset Self-Test Circuits Self-Test Circuit Adjust	0 0 0	02 02 30
8-01-74 8-05-74 8-12-74	ACU (Input Triggers)	Intermittent External Interrupt	Fatal	Self-Test Circuits Reset Self-Test Circuits Ext. Equip. Repair	0 0 4	05 05 00
8-09-74	RF Array (IA5)	Intermittent True Fault (BL)	Casualty	Self-Test Circuits Reset	0	05
8-12-74	RF Array (IA24)	Repeating True Fault (B1)	Casualty	Assembly Solder Joint Repair	1	00
8-14-74	RF Array (LA39)	Intermittent True Fault (RF)	Casualty	Self-Test Circuits Reset	0	05
8-15-74	RF Array (IA38)	Intermittent True Fault (B1)	Casualty	Self-Test Circuits Reset	0	05
8-15-74 to 8-22-74	ACU (Input Triggers)	Repeating External Interrupt	Fatal	Switched to Alternate Trigger Source (B1-4 No. 2)	0	30
8-19-74	Primary Power	Long-Term External Interrupt	Fatal	ESA PWR Recycle/Reset (Pri. Pwr Repairs)	0 2	10 00
8-26-74	RF Array (IA5)	Intermittent True Fault (B1)	Casualty	Self-Test Circuits Reset	0	05
8-28-74	RF Array (IA39)	Repeating True Fault (RF)	Casualty	Wiring to Self-Test Test Circuits Repaired (BD Corrector)	0	15
8-28-74	RF Array (IA41)	Repeating True Fault	Casualty	Repaired Short In Self-Test Wiring	0	30
8-29-74	ACU (Trigger Inputs)	Intermittent External Interrupt	Fatal	Self-Test Circuits Reset	0	05
9-03-74	D.C. Power Supplies	Intermittent (Pri) Ext. Interrupt (Pwr)	Fatal	Recycled Primary Power Input	0	10
9-03-74	ACU (Control) (Logic)	Repeating True Fault (Lightning Strike)	Fatal	Replaced Circuit Board Assembly (IE17) Pwr Transient Damage	2	00
9-03-74 9-09-74	ACU (RF Control Logic)	Repeating True Fault (Lightning Strike)	Fatal	Repair to Damaged Circuit Board Components (IE32)	6	00
9-03-74 9-10-74 to 9-20-74	ACU (Trigger Inputs)	Intermittent External Interrupts (Lightning Strike)	Fatal	Self-Test Circuits Reset Repairs to (B1-4) External Equip.	0 Each Occurrence (45	05 00)

TABLE 2. ESA MAINTENANCE ACTIVITIES (continued)

Date of Occurrence	Fault Location	Type Fault	Fault Classification	Corrective Active	Repair Time Hrs	Repair Time Min
9-03-74 9-11-74 to 10-4-74	ACU (Trigger Outputs)	Repeating True Fault (Lightning Strike)	Fatal Ext. Equip. Only	Repair to Damaged Circuit Board Components (1E15,1E16,1E18) (28IC's)	60	00
9-06-74	D.C. Power Supplies	Intermittent Ext. Interrupt (Pri. Pwr)	Fatal	ESA Pwr Recycle Reset Reset	0	10
9-11-74	RF Array (1A14)	Repeating True Fault (B1)	Casualty	RF Assembly Solder Joint Repair: Component Repair	1	30
9-12-74	RF Array (IA56)	Intermittent True Fault (RF)	Casualty	Repaired short In Self-Test Wiring	0	30
9-16-74 to 10-04-74	ACU (RF Self-Test)	Intermittent Self-Test Fault	Casualty	ACU Circuit Modified After Determination of Cause	0	02 Each Occurrence 2 to 3 Times/ Day
9-18-74	ACU (Trigger Inputs)	Repeated True Fault	Fatal	Self-Test Circuits Reset	0	05
9-19-74				(Ext. Equip. Repair Dist. Amp'l's)	6	00
9-23-74 to 9-26-74	ACU (Trigger Inputs)	Intermittent External Interrupt (Lightning Strike)	Fatal	Self-Test Circuits Resets (Mod 5 1/U Repairs)	0	02 Each Occurrence
9-30-74	RF Array (IA5)	Repeating True Fault (B1)	Casualty	RF Assembly Solder Joint Repaired	1	00
10-1-74	RF Array (IA14)	Intermittent True Fault (RF)	Casualty	Self-Test Circuits Reset	0	05
10-7-74 to 10-23-74	ACU (Remote Override)	Intermittent External Interrupts	Fatal	External Equip. Recycled	0	05 Each Occurrence
10-9-74	RF Array (IA35)	Repeating True Fault (RF)	Casualty	(Mod 5 1/0 Modification) Repaired Short In Self-Test Wiring RF Assembly Solder	0	15
10-23-74	RF Array (IA43)	Repeating True Fault (B1)	Casualty	Joint Repaired	0	30
10-24-74 to 11-20-74	ACU (B1 Self-Test)	Intermittent External Interrupt When Remote Beam Lift Sectoring Control Enabled	Casualty	Self-Test Circuits Reset (ACU Circuit Modification Required To Correct)	0	02 Each Occurrence
11-04-74	RF Array (IA5)	Repeating True Fault (RF)	Casualty	RF Assembly Replaced With Spare	0	45
11-05-74	RF Array (IA4)	Repeating True Fault (RF)	Casualty	RF Assembly Replaced With Spare	0	45
11-13-74 to 11-15-74	ACU (Self-Test)	Intermittent External Interrupts	Fatal	Self-Test Circuits Reset (Mod 5 Interrupts When Using Other PDP Programs)	0	02
11-14-74	Phase Shifter Assembly No. 16	Repeating True Fault (CR)	Casualty	Assembly Replaced With Spare	0	30
11-15-74	RF Array (IA14)	Intermittent True Fault	Casualty	Self-Test Circuit Reset	0	05
11-18-74	RF Array (IA14)	Intermittent True Fault	Casualty	Self-Test Circuit Reset	0	05
11-19-74	External (Input Triggers)	Repeating External Interrupts	Fatal	Input Triggers Switched To Alternate Source (Other B1-4)	0	30
11-20-74	External (Input Triggers)	Repeating External Interrupts	Fatal	Input Triggers Switched To Alternate Source (Other B1-4)	0	30
11-21-74	External (Input Triggers)	Repeating External Interrupts	Fatal	Input Triggers Switched To Alternate Source (Other B1-4	0	30
11-25-74 to Present	ACU (Remote Self-Test)	Intermittent External Interrupt	Fatal	Self-Test Circuits Reset (Fault Whenever B1-4 Switched)	0	02 Each Occurrence

TABLE 2. ESA MAINTENANCE ACTIVITIES (continued)

Date of Occurrence	Fault Location	Type Fault	Fault Classification	Corrective Active	Repair Time Hrs	Repair Time Min
11-27-74	Phase Shifter Assembly No. 27	Intermittent Fault (CR)	Casualty	Self-Test Circuits Reset	0	05
12-2-74	ACU (Self-Test)	Intermittent (Primary Power Transients-High Winds)	Casualty	Self-Test Circuits Reset	0	05
12-3-74	Phase Shifter Assembly No. 43	Repeating True Fault (RF)	Casualty	Assembly Replaced With With Spare	0	30
12-3-74	RF Array (IA14)	Intermittent True Fault (RF)	Casualty	Self-Test Circuits Reset	0	05
12-10-74	RF Array (IA14)	Repeating True Fault (RF)	Casualty	Cable Connector Replaced	2	00
12-11-74	ACU (Memory Self-Test) (Input Triggers)	Repeating External Interrupt	Fatal	Input Triggers Switched To Alternate Source (B1-4 No. 2 P.C. BD Programs)	0	30
12-12-74		Repeating External Interrupt	Fatal	Input Triggers Switched To Alternate Source (B1-4 No. 2 P.C. BD Programs)	0	30
12-13-74	ACU Memory Self-Test) (Input Triggers)	Repeating External Interrupt	Fatal	Input Triggers Switched To Alternate Source (B1-4 No. 2 P.C. BD Programs)	0	30
12-16-74	RF Array (IA3)	Repeating True Fault (BL) (Rain Leakage Into Array)	Casualty	A5 Circuit Board Replaced With Spare After Array Dried Out	1	30
1-2-75	RF Array (IA17)	Repeating True Fault (BL)	Casualty	RF Assembly Solder Joint Repaired	0	45
1-6-75	RF Array (IA35)	Repeating True Fault (RF)	Casualty	Self-Test Wiring Short Repaired	0	15

ESA AVAILABILITY CALCULATION

Total Uptime (Normal Operation) = 1,648 hours

Casualty Fault Downtime = 16.95 hours

Inoperative Downtime = 9.10 hours

$$\text{Casualty Time} = \text{Casualty Downtime} - \left(\text{Self-Test Readout and Reset}\right) = 16.95 - 0.60 = 16.35 \text{ hours}$$

(30 Faults X 0.02 hours = 0.60 hours)

$$\text{Inoperative Time} = \text{INOP} + \text{Casualty Self-Test Readout} = 9.10 + 0.60 = 9.70 \text{ hours}$$

$$\text{Percent Availability} = \frac{1648 + 16.35}{1648 + 16.35 + 9.70} = \frac{1664.35}{1674.05} = 99.42 \text{ Percent}$$

$$\text{Percent Normal Operation} = \frac{1648}{1674.05} = 98.44 \text{ Percent}$$

The types of faults were catagorized as true faults (repeating intermittent), external interrupt faults, and ghost faults due to random noise transients in the self-test circuitry. Normal maintenance activities are not listed since they could be scheduled to permit continuous service from the ESA under field conditions. Normal maintenance activities averaged 15.0 hours per week based on actual hands-on equipment tests (including bench repairs of removed units).

AVAILABILITY. The maintenance of the ESA during the period after 48-hour test was routine, with the exception of the period after the TR/BTF was struck by lighting on September 3, 1974. Damage was extensive to the TR/BTF distribution system and other equipments (including ESA). An estimate of the availability of ESA calculated with this data was 99.4 percent (table 2). The calculation included the periods of times (with no fault operation) when application of RF energy was removed after normal working hours (standby condition) and the system returned to operation (ATCBI-4 interrogating) the next work day. The availability of the ESA with normal operation (no casualty-mode operating time included in calculation) was 98.4 percent.

EASE OF MAINTENANCE. Corrective maintenance aids, in particular the built-in test functions, were very useful during the test and evaluation. The combination of the self-test functions and a dedicated maintenance effort led to the correction of connector problems encountered early in the test program.

The equipment was accessible for test and corrective maintenance. One area posed a problem for maintenance personnel. When either drawer of ACU was extended, the door to the enclosure had to be opened and work performed from outside of the shelter. It was suggested that the enclosure be extended to provide some weather protection for maintenance personnel.

ANTENNA PATTERN TESTS.

Antenna pattern measurements included in the ESA field specification tests involved the ATCRBS 1030-MHz and 1090-MHz horizontal and vertical pattern tests, transmitted pulse measurements, and pointing accuracy. Test data were collected at ground-based test sites and airborne flight tests.

The ground-based test sites used during field specification tests were located at the phototheodolite P-13, airport surface detection equipment (ASDE-2) building 228, field test site (~060° radial) and the aircraft hangar, building 301 (figure 7). In addition, some ground-based vertical pattern measurements were made in the immediate vicinity of the ESA (approximately 125 feet from the antenna on both the 060° and 295° radials).

The airborne flight tests involved an instrumented and/or transponder-equipped aircraft which followed prescribed flight profiles within the range of coverage of the ESA. Independent aircraft position information (range, azimuth, altitude, and elevation angle) was provided by the Extended Area Instrumentation Radar (EAIR) facility. The airborne flights included both radial and tangential flightpaths to the TR/BTF.

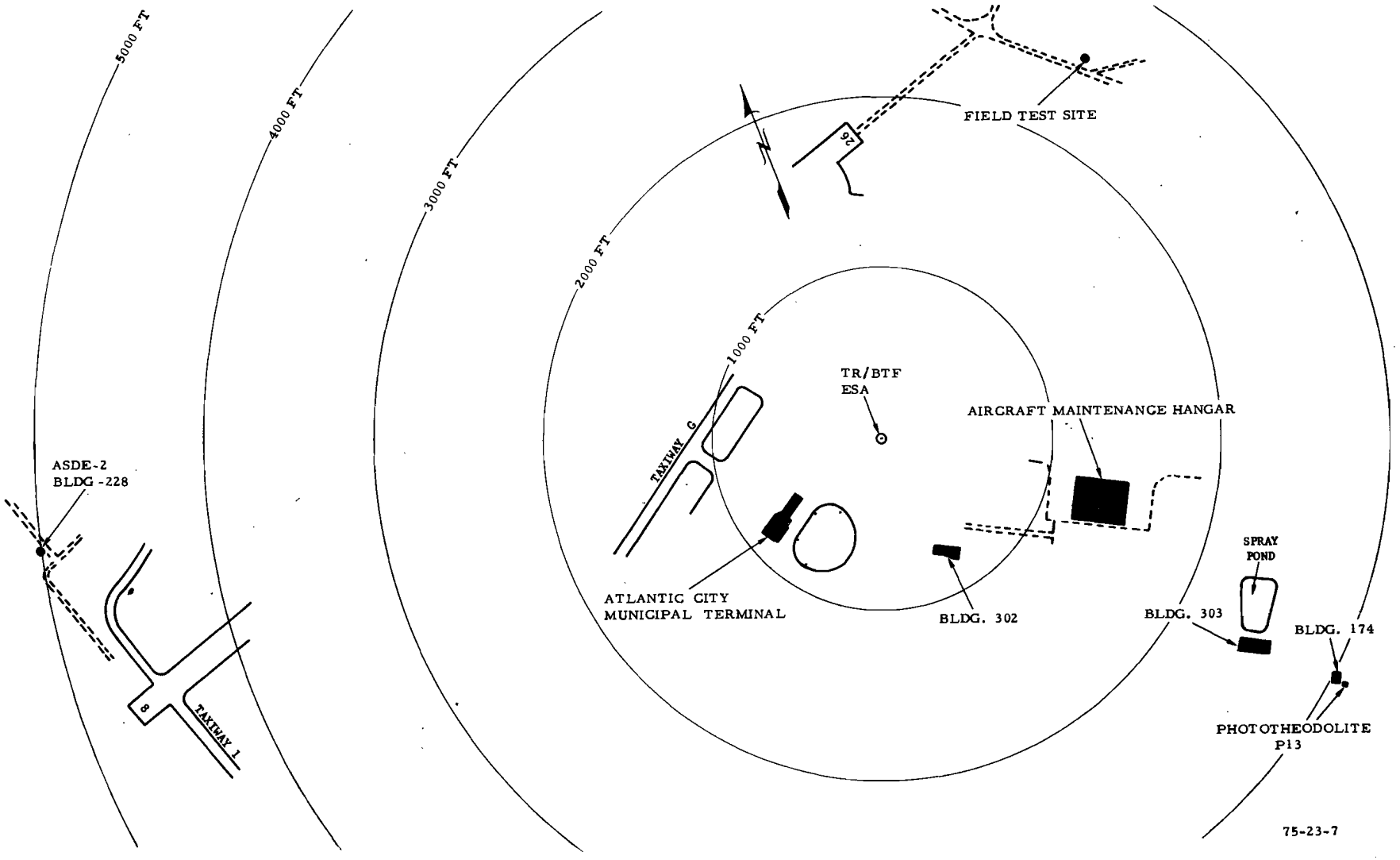


FIGURE 7. GROUND-BASED TEST SITE LOCATIONS

1030-MHz AND 1090-Mhz HORIZONTAL PATTERN TESTS. Horizontal pattern measurements (1030 MHz) began on March 4, 1974, at the phototheodolite P-13 site by photographing the transmitted pulse (P_1 and P_2) amplitude as described in section 1 of appendix A. It was noted that the P_2 omni pattern was fluctuating as the ESA directional beam rotated through the azimuth of the P-13 site. An investigation of the problem by the contractor led to the implementation on April 2, 1974, of an antenna modification which separated the junction of the omnidirectional RF path from the directional RF path at the quadrant switch during the transmission of the P_2 pulse. This modification had a side effect of prohibiting the lifting of the omnidirectional (P_2) pattern during the execution of the beam hopover function. A set of antenna patterns for SLS and ISLS operation, recorded at P-13 before and after the field change, is shown in appendix B, figures B-1 and B-2. The stability of the P_2 pulse after the modification is noted on both the SLS and ISLS antenna patterns in figure B-2.

The antenna pattern recording instrumentation was moved to the ASDE-2 platform site. Figure B-3 is a sample of the 1030-MHz horizonal antenna pattern for SLS operation, zero-degree beam hopover taken at the ASA E-2 platform (0.9° elevation angle). Two areas of concern were observed on the antenna pattern. One involved the changing amplitude of the omnidirectional (P_2) signal level, and the other involved a pronounced side lobe on the directional (P_1) pattern. In addition, a reflection of the directional P_1 pulse from the aircraft hangar building arrived at the ASDE-2 site approximately 2.5 μs after P_1. This reflected P_1 pulse fell on the trailing portion of the direct P_2 pulse and varied in signal level as the ESA rotated through the azimuth of the hangar building.

The pronounced side lobe effect on the P_1 pattern and changing amplitude of the omnidirectional pulse (P_2) were isolated to signal interference from low elevation angles (below the direct signal path). A metal screen (20 feet X 50 feet) was placed in front of the ESA to block RF transmission at these angles, and both conditions were eliminated from the pattern observed at the ASDE-2 platform. The results at the ASDE-2 site indicated that field environmental conditions (ground multipath) significately influenced both the directional (P_1) and omnidirectional (P_2) antenna patterns. A detailed description and analysis of the results obtained at the ASDE-2 site will be included in the test and evaluation report concerning the field environment tests of ESA.

Horizontal antenna patterns (1030 MHz) were recorded at the field test site (060° radial) for SLS and ISLS operation. The patterns, shown in figures B-4 through B-9, include the 0°, 2°, and 4° beam hopover function with the tower raised to 40 feet (0.5° elevation angle from ESA) and 75 feet (1.3° elevation angle from ESA), respectively.

Horizontal antenna patterns (1090 MHz) were recorded at the field test site for the sum channel for 0°, 2°, and 4° beam hopover with the tower raised to 75 feet (1.3° elevation angle from ESA). The patterns are shown in figures B-10 through B-12. Figure B-13 illustrates the effect of a 4° beam hopover condition on the received signal from the field test site (75-foot

tower) at the ESA sum and difference output. An examination of the data obtained from the field-test site confirmed that the beam hopover feature (2° and 4°) provided a decrease in signal strength at low elevation angles for both the transmit (1030 MHz) and receive (1090 MHz) modes of ESA operation.

During airborne radial and partial orbital flights, the transmitted 1030-MHz horizontal patterns were recorded by using the high-speed film technique (section 4 of appendix A). The Extended Area Instrumentation Radar (EAIR) facility tracked the aircraft during the test and provided a computer-derived table of the aircraft position relative to the center of the ASR-7 (TR/BTF) radar. A sample of the EAIR tabulated data is shown in table A-1 in appendix A. The airborne data was time-correlated with the EAIR facility time, permitting the signal level to be plotted against the elevation angle or azimuth of the aircraft from the TR/BTF (altitude was held constant during the flights).

Flights were conducted on 6/14/74, 7/16/74, and 7/18/74. The data extracted from the high-speed film includes the signal level of the directional beam and the highest side lobe and the omnidirectional signal level. The reduced data is shown in figures 8 through 14. The data recorded on 6/14/74 was obtained before introducing a 3 -dB change in the P_2 output signal level relative to P_3. (This modification is discussed under transmitted pulse measurements.)

In addition, the received 1090-MHz horizontal antenna pattern was recorded during flight tests using the transponder performance analyzer (TPA) system (section 5 of appendix A). The results of the flight test are shown in figures B-14 through B-17. The calculated elevation angle of each directional beam pattern is noted on the figure along with other test conditions.

The results of the 1030-MHz (transmit) and 1090-MHz (receive) horizontal pattern tests (airborne and ground-based) produced side lobe and back lobe levels of $\leq$-21 dB and an omnidirectional (P_2) level of -17 dB with reference to the peak of the main directional beam. The directional (P_1) antenna beam (1030 MHz) exercised during ISLS operation was within +2.5 dB to -4.0 dB of the omnidirectional beam (P_2) outside the main directional interrogating beam.

A shoulder was noted on the 1090-MHz receive pattern at the field test site (figure 10b) was analyzed by the contractor employing data recorded during the antenna range tests (reference 5). The study isolated the shoulder effect to the defocusing of the antenna beam at low elevation angles.

<u>1030-MHz AND 1090-MHz VERTICAL PATTERN TESTS</u>. Vertical antenna patterns were measured using the data collection method described in section 2 of appendix A. A CW RF signal was transmitted through a horn antenna positioned on a portable tower (maximum height of 50 feet) at 1-foot increments above ground level and located approximately 125 feet from the ESA on both the 060° and 295° radial. The ESA was held in a fixed azimuth position along the radial. The 1030-MHz and 1090-MHz signal level was recorded at the sum output of the ESA for the 0°, 2°, and 4° beam hopover function. A standard gain horn was used to obtain

DATE: 6/14/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF 0.9° TO 10.0°
TEST CONDITIONS:
MODE 3/A INTERROGATION, ISLS-ON, TRANSMITTED PEAK POWER = 350 W, 060° RADIAL AT 5,000 FT ALTITUDE

DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL - 10.0 dB PER MAJOR DIVISION
HORIZONTAL - 1.0° PER MAJOR DIVISION

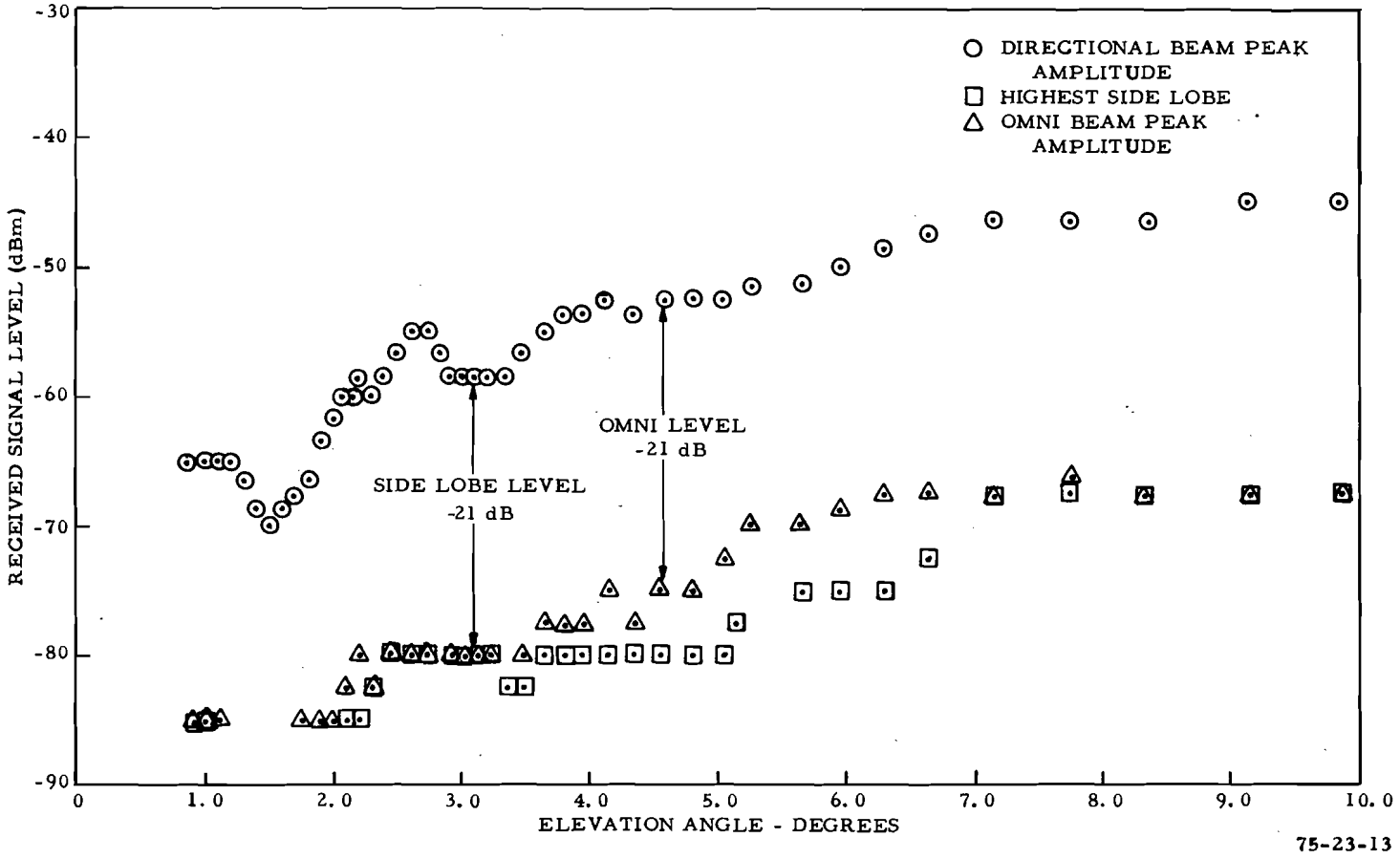


FIGURE 8. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR SLS FROM 0° TO 10° ELEVATION ANGLES (6/14/74)

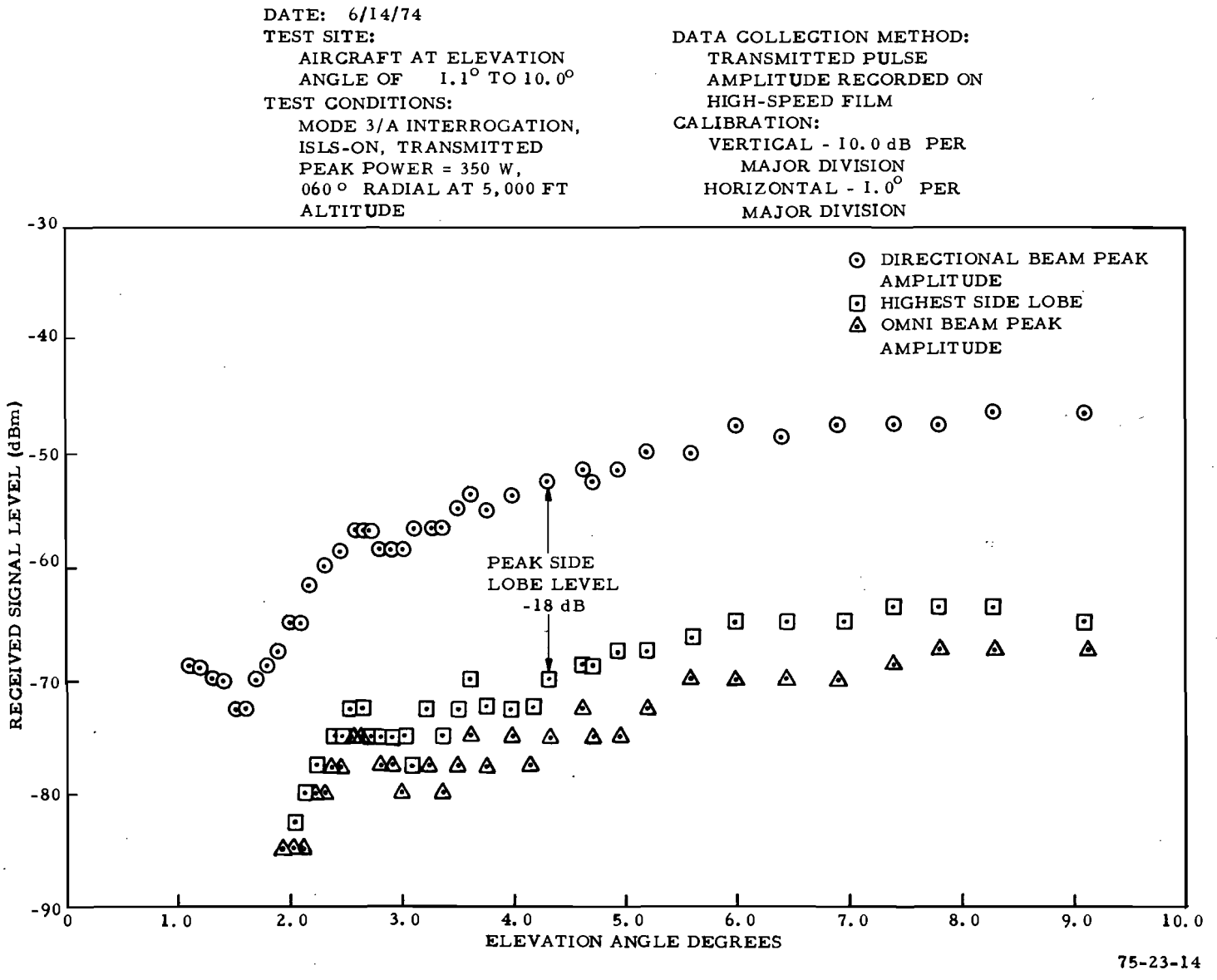


FIGURE 9. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR ISLS FROM 0° TO 10° ELEVATION ANGLES (6/14/74)

DATE: 7/16/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF~3°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-ON, TRANSMITTED PEAK POWER = 400 W, PARTIAL ORBIT AT 15 NMI AND 5,000 FT ALTITUDE
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL- 10.0 dB PER MAJOR DIVISION
HORIZONTAL- 4° PER MAJOR DIVISION

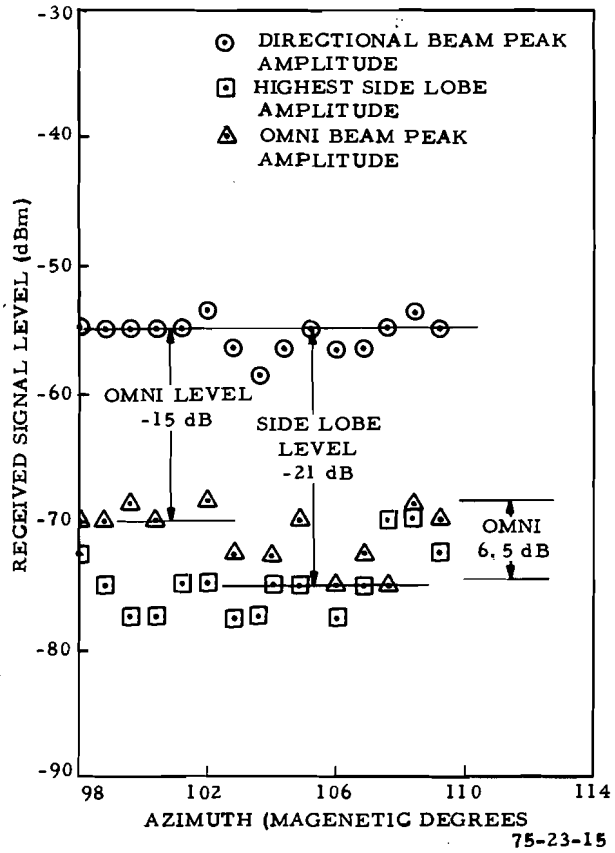


FIGURE 10. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR SLS AT A 3° ELEVATION ANGLE (7/16/74)

DATE: 7/16/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF~9°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-ON, TRANSMITTED PEAK POWER = 400 W, PARTIAL ORBIT AT 10 NMI AND 8,000 FT ALTITUDE
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL- 10.0 dB PER MAJOR DIVISION
HORIZONTAL- 10° PER MAJOR DIVISION

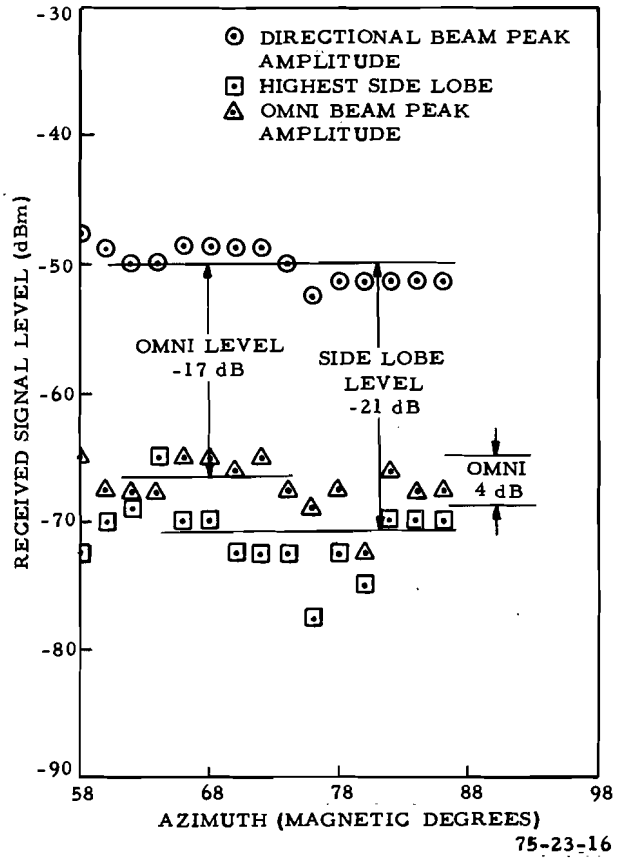
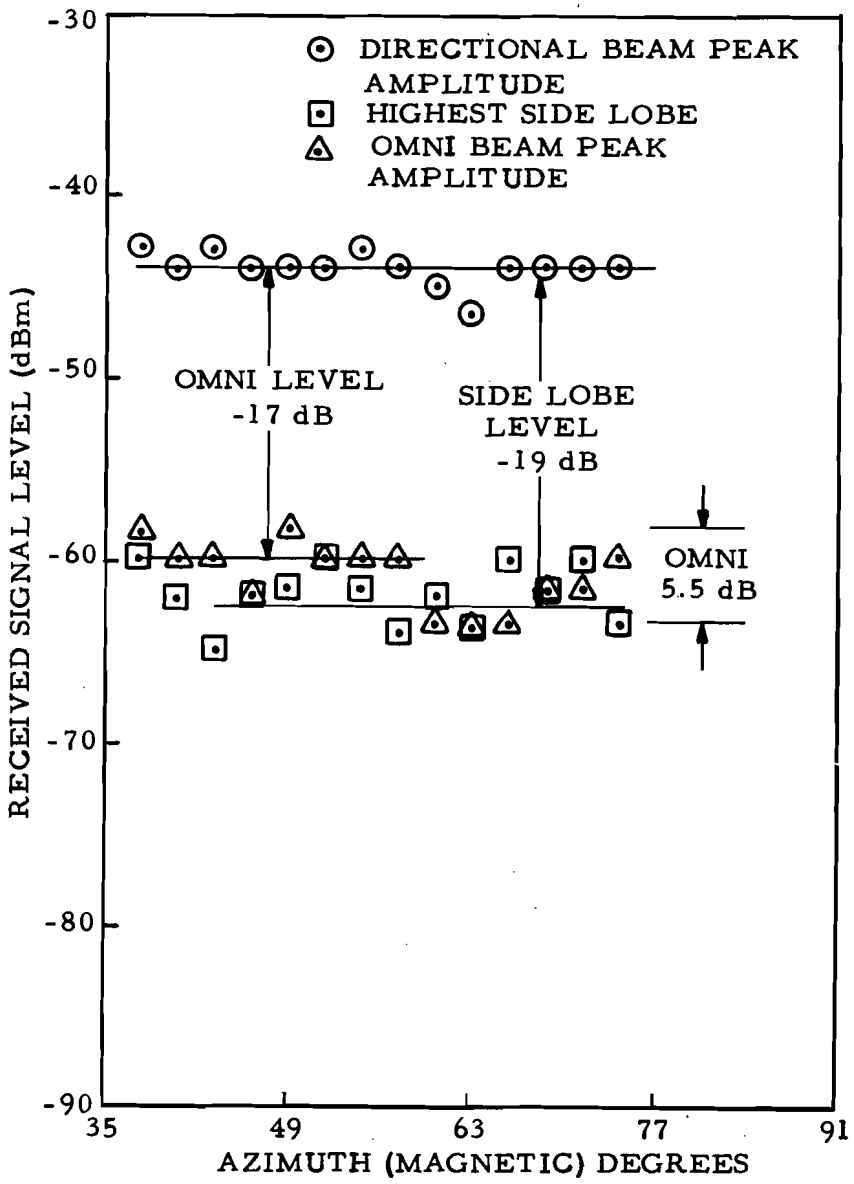


FIGURE 11. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR SLS AT A 9° ELEVATION ANGLE (7/16/74)

DATE: 7/16/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF ~17°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-ON, TRANSMITTED PEAK POWER = 400 W, PARTIAL ORBIT AT 5 NMI AND 10,000 FT ALTITUDE
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL - 10.0 dB PER MAJOR DIVISION
HORIZONTAL - 14° PER MAJOR DIVISION



75-23-E-17

FIGURE 12. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR SLS AT A 17° ELEVATION ANGLE (7/16/74)

DATE: 7/18/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF ~ 3°
TEST CONDITIONS:
MODE 3/A INTERROGATION, ISLS - ON, TRANSMITTED PEAK POWER = 400 W, PARTIAL ORBIT AT 15 NMI AND 5,000 FT ALTITUDE
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL - 10 dB PER MAJOR DIVISION
HORIZONTAL - 4° PER MAJOR DIVISION

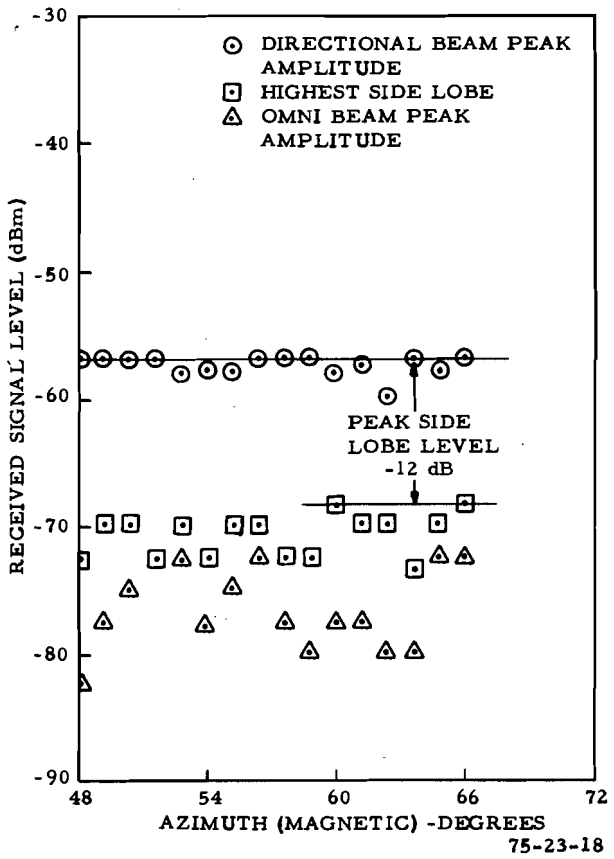


FIGURE 13. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR ISLS AT A 3° ELEVATION ANGEL (7/18/74)

DATE: 7/18/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE~9°
TEST CONDITIONS:
MODE 3/A INTERROGATION, ISLS-ON, TRANSMITTED PEAK POWER = 400 W, PARTIAL ORBIT AT 10 NMI AND 8,000 FT ALTITUDE
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE RECORDED ON HIGH-SPEED FILM
CALIBRATION:
VERTICAL- 10 dB PER MAJOR DIVISION
HORIZONTAL - 10° PER MAJOR DIVISION

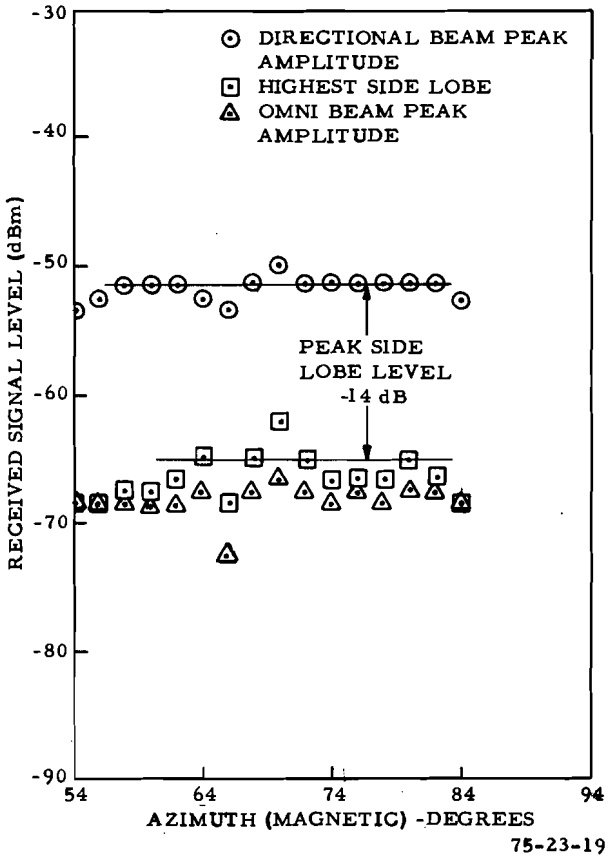


FIGURE 14. MAIN BEAM, SIDE LOBE, AND OMNI SIGNAL LEVEL FOR ISLS AT A 9° ELEVATION ANGLE (7/18/74)

a reference signal from the CW source. The recorded patterns are plotted in figures 15 and 16 for 1030 MHz and 1090 MHz 0°, 2°, and 4° beam hopover on the 060° and 295° radial, respectively. The measurements approximate the vertical pattern of the antenna since the 125 feet radial distance places the source in the far field of the ESA 8-foot vertical aperature (without receiving excessive indirect signals from the ground terrain).

The results demonstrated the sharp cutoff of the vertical beam pattern at the zero-degree point on the ESQ. Appropriate reductions in signal strength were realized for the 2° and 4° beam hopover feature on both transmit (1030 MHz) and receive (1090 MHz) modes of operation. The differences in the patterns recorded on the two radials are attributed to the presence of the roof of the equipment building on the 295° radial compared to a lower ground plane (unobstructed) on the 60° radial.

TRANSMITTED PULSE CHARACTERISTICS. During the specification tests, three significant field changes were made to the SLS/ISLS mode switch to improve the performance of the ESA. The first involved the modification of the mode switch driver assembly to provide faster RF PIN diode switching, correcting RF pulse width and rise time distortion of P_2 in SLS operation. The next change involved the mode switch diode control gates for SLS operation, permitting a relative 3-dB increase in P_2 omni pulse amplitude relative to the P_3 pulse. A third field change replaced the PIN diodes originally used in the mode switch, type UM 7010 to type UM 6207, to provide faster RF pulse switching for SLS operation. Figures 17, 18, and 19 show the improvement in the P_2 pulse shape and amplitude as a result of the modifications to the mode switch. A photo of P_2 (figure 17) was taken at the P-13 site for SLS and ISLS operation (P_1 amplitude is changing due to antenna rotation). Another set (figure 18) taken at the field test site (060° radial) shows the improvement in the shape of P_2 and a 3-dB difference in amplitude during SLS and ISLS operation. Figure 19 shows the equalization of the signal level of P_2 for SLS and ISLS operation (taken at the field test site).

During the flight tests, the amplitude of the transmitted P_1, P_2, and P_3 pulses were measured along the radial of the ESA with the antenna fixed in the 100° azimuth position. The flightpath was tracked by the EAIR and controlled to within 2.0° of the 100° radial. The transmitted pulse amplitude printout instrumentation (section 3 of appendix A) permitted the comparison of the P_1, P_2, and P_3 signal levels.

The results are shown in figure 20, with the elevation angle from the ESA obtained from the EAIR aircraft position information. A ± 2.5-dB variation over the 5° to 35° elevation angles was noted in the level of the P_2 omnidirectional signal measured from the peak of the P_1 directional signal. The omnidirectional (P_2) level was 17 dB below the peak directional (P_1) signal.

POINTING ACCURACY. Two aspects of the pointing accuracy of the ESA were examined during the field specification tests. The position of the center of the transmitted directional pattern and the null of the different pattern were measured at 1030 MHz using the CW RF amplitude measurement technique described in section 2 of appendix A. (The CW source, set to 1090 MHz, interfered with local ATCRBS operation and was not employed during this test).

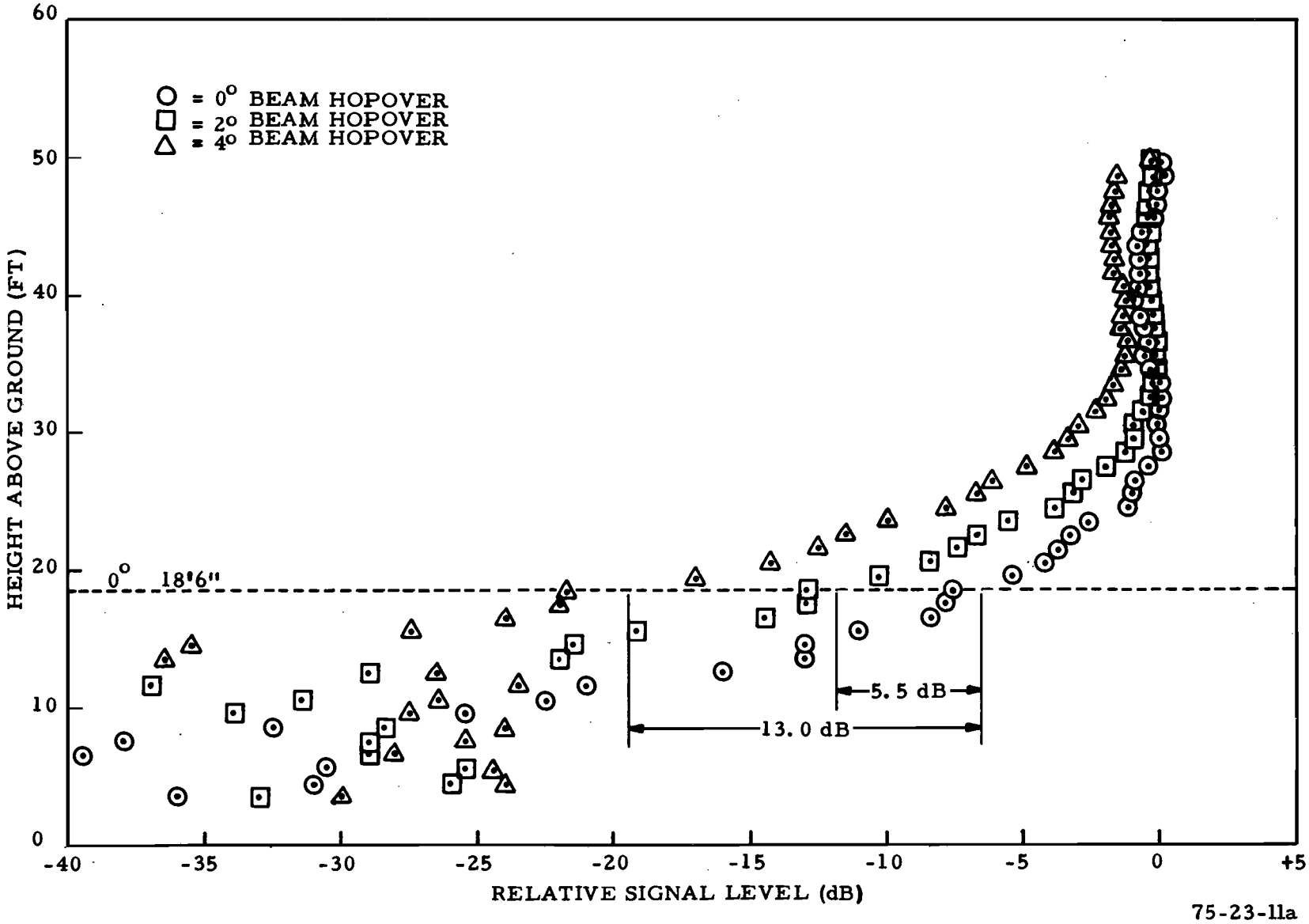


FIGURE 15a. 1030-MHz VERTICAL ANTENNA PATTERN OF 060° RADIAL FOR 0°, 2°, AND 4° BEAM HOPOVER (Sheet 1 of 2)

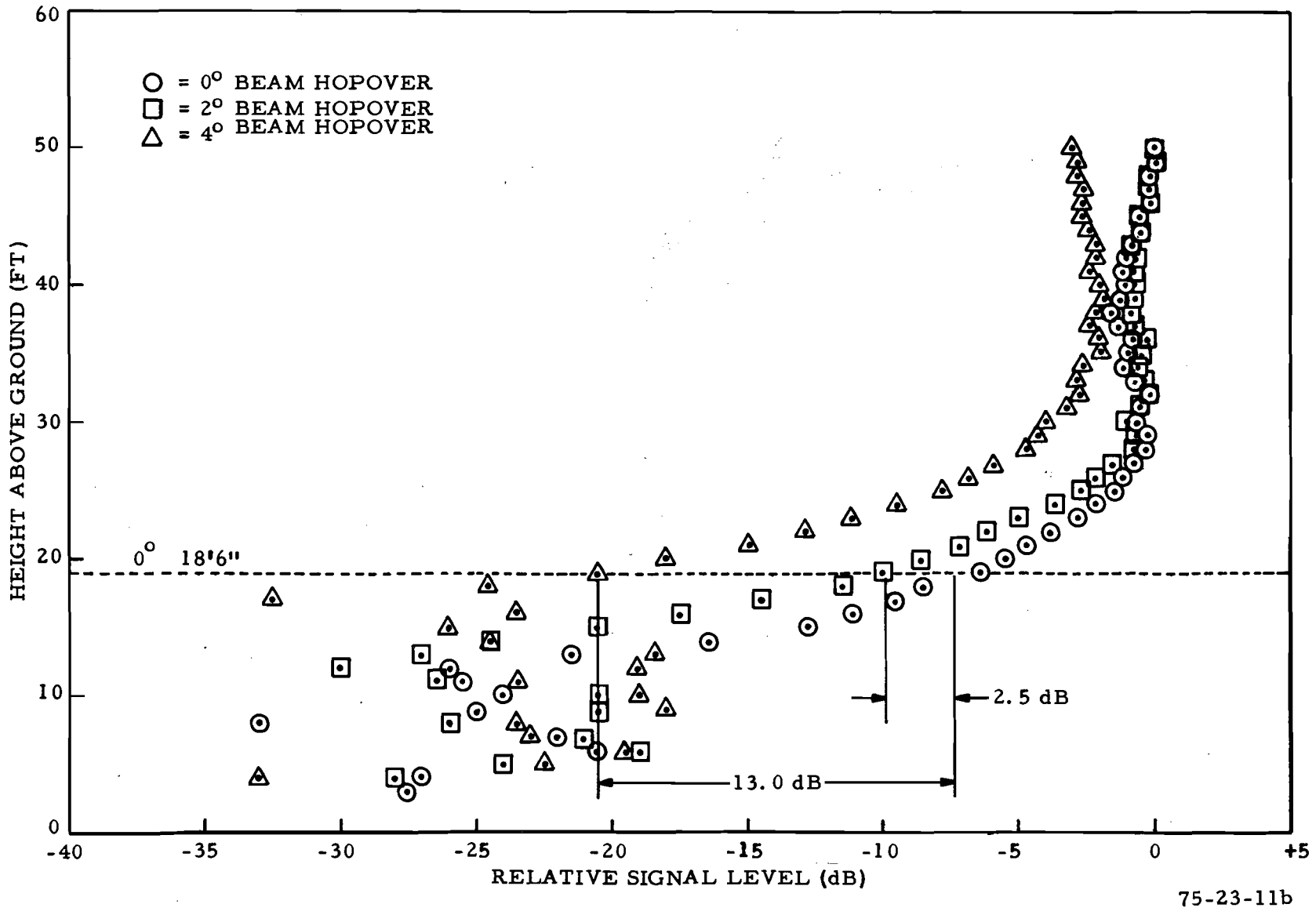


FIGURE 15b. 1090-MHz VERTICAL ANTENNA PATTERN OF 060° RADIAL FOR 0°, 2°, and 4° BEAM HOPOVER (Sheet 2 of 2)

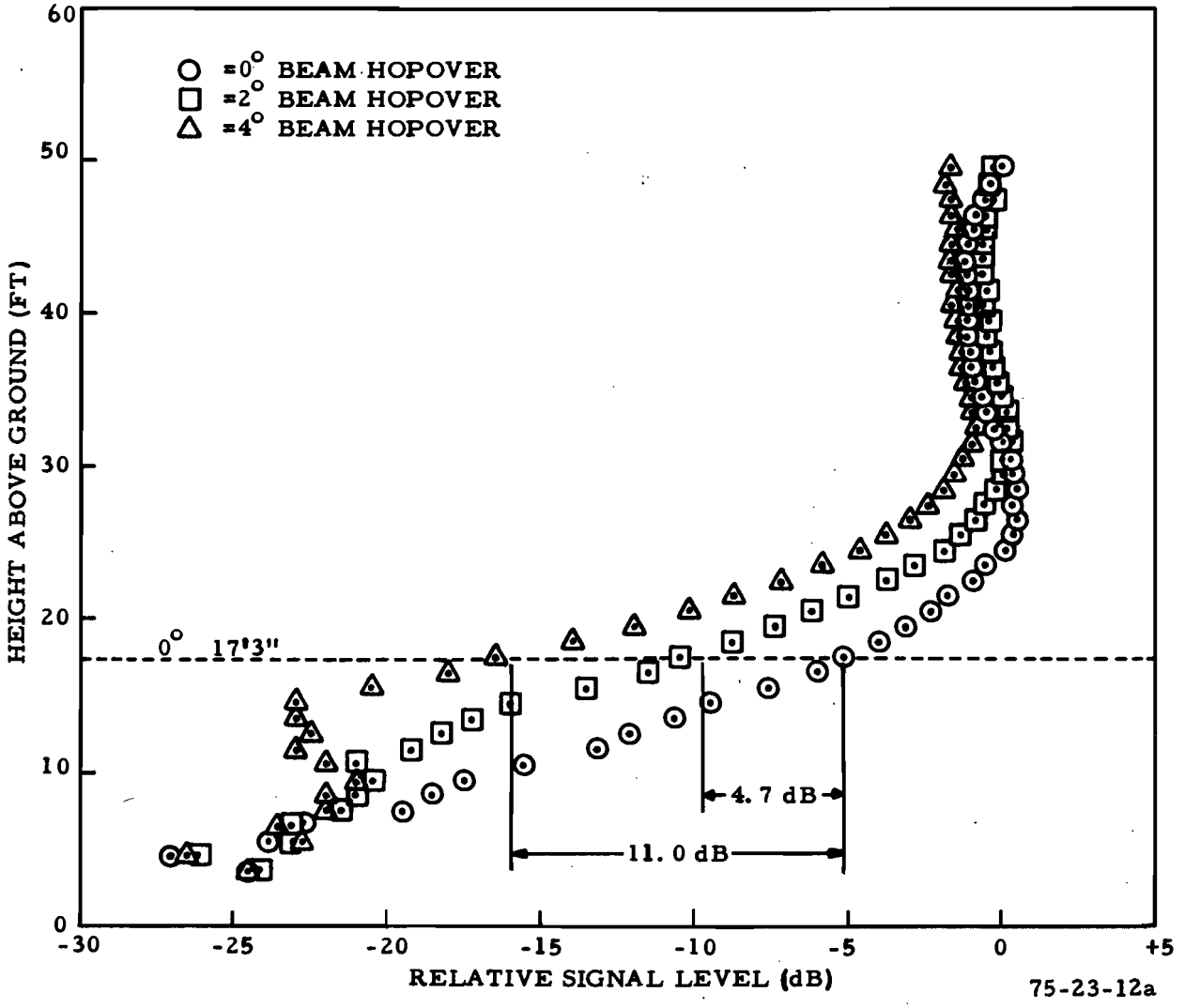


FIGURE 16a. 1030-MHz VERTICAL ANTENNA PATTERN ON 295° RADIAL FOR 0°, 2° AND 4° BEAM HOPOVER (Sheet 1 of 2)

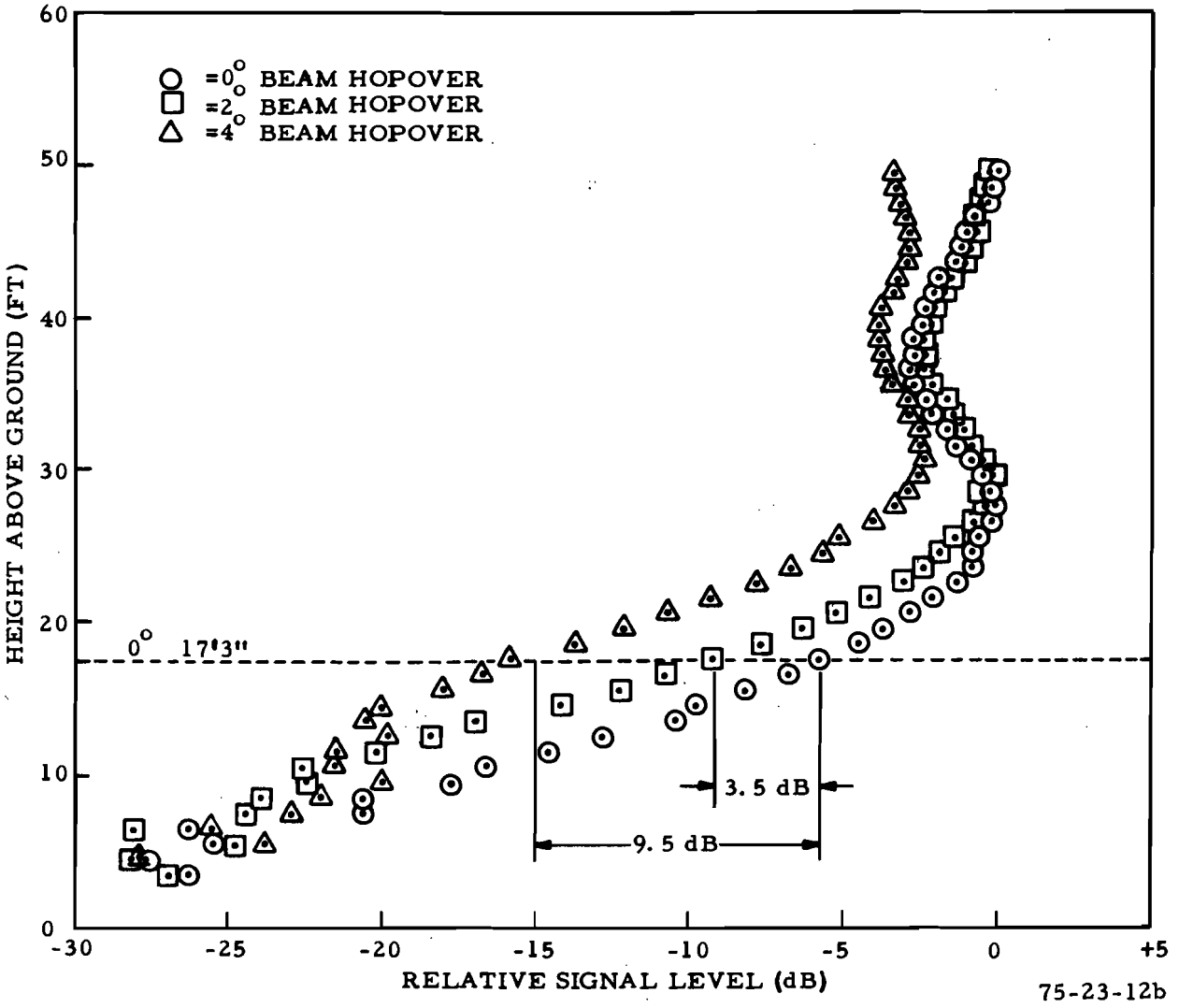
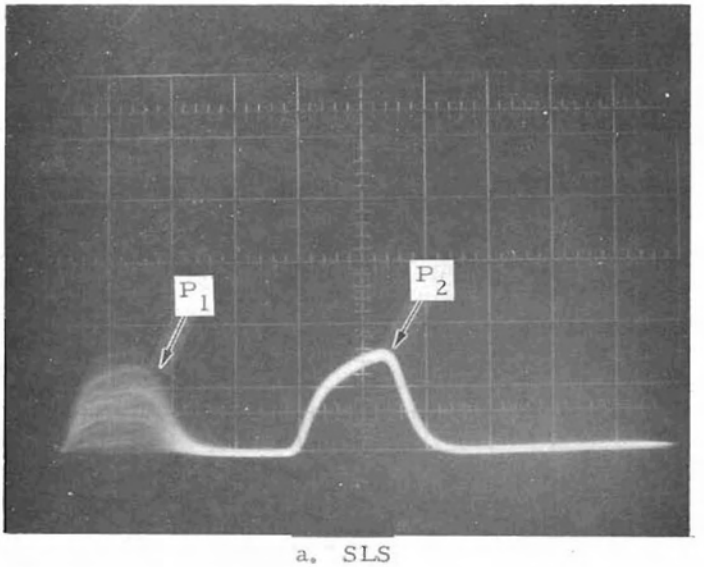
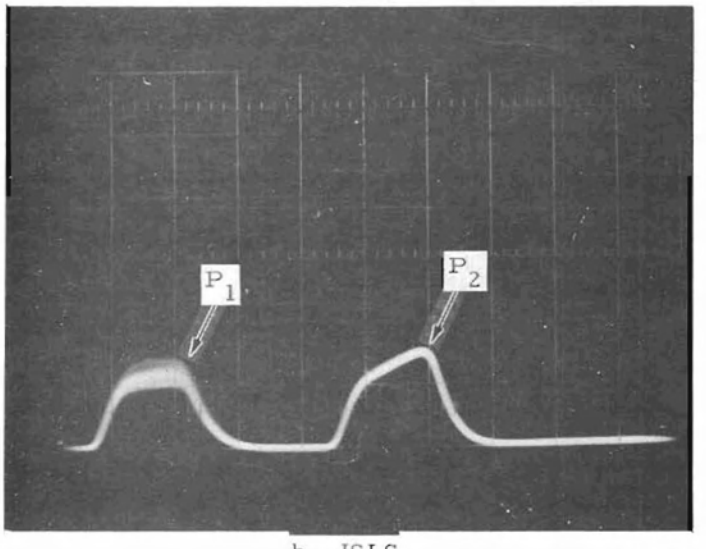


FIGURE 16b. 1090-MHz VERTICAL ANTENNA PATTERN ON 295° RADIAL FOR 0°, 2°, AND 4° BEAM HOPOVER (Sheet 2 of 2)

DATE: 4/22/74
TEST SITE:
PHOTOTHEODOLITE P-13
TEST CONDITIONS:
MODE 3/A INTERROGATION, P_1 AND P_2
TRANSMITTED PEAK POWER = 300 WATTS
DATA COLLECTION METHOD:
TRANSMITTED PULSE WAVEFORM MEASUREMENTS
CALIBRATION:
VERTICAL - 7.5 dB PER MAJOR DIVISION
HORIZONTAL - 0.5 μs PER MAJOR DIVISION



a. SLS

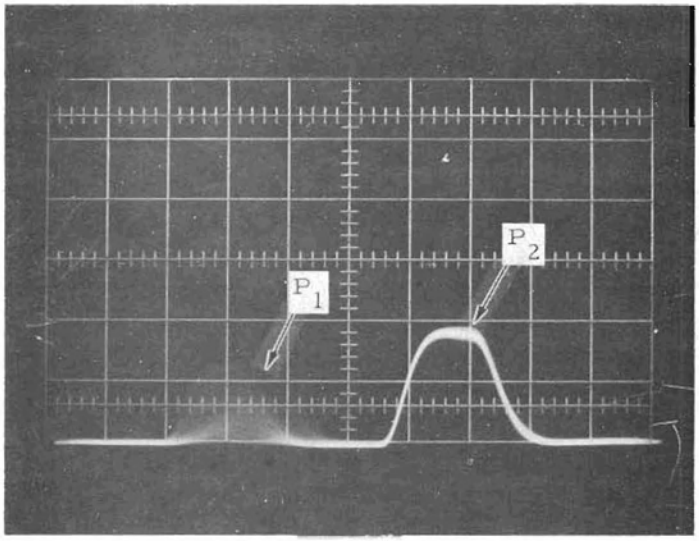


b. ISLS

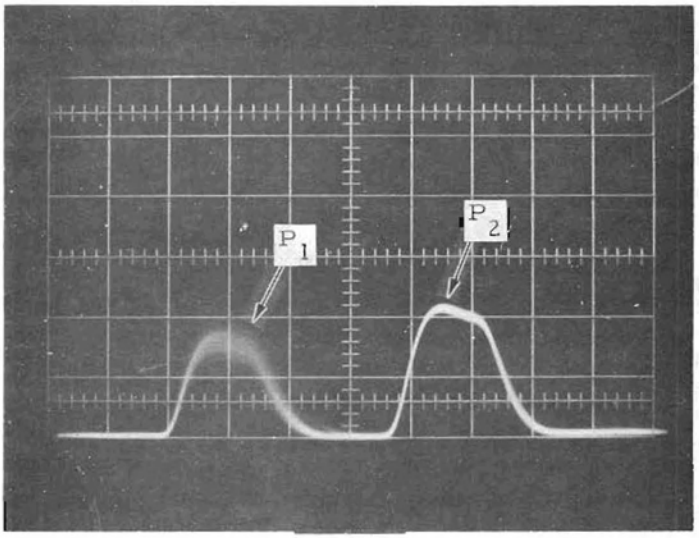
75-23-8

FIGURE 17. ORIGINAL P_2 PULSE CHARACTERISTICS FOR SLS AND ISLS OPERATION

DATE: 6/21/74
TEST SITE:
FIELD TEST SITE
TEST CONDITIONS:
MODE 3/A INTERROGATION, P_1 AND P_2
TRANSMITTED PEAK POWER = 350 WATTS
TOWER HEIGHT = 75 FT
DATA COLLECTION METHOD:
TRANSMITTED PULSE WAVEFORM MEASUREMENTS
CALIBRATION:
VERTICAL - 8.5 dB PER MAJOR DIVISION
HORIZONTAL - 0.5 μs PER MAJOR DIVISION



a. SLS

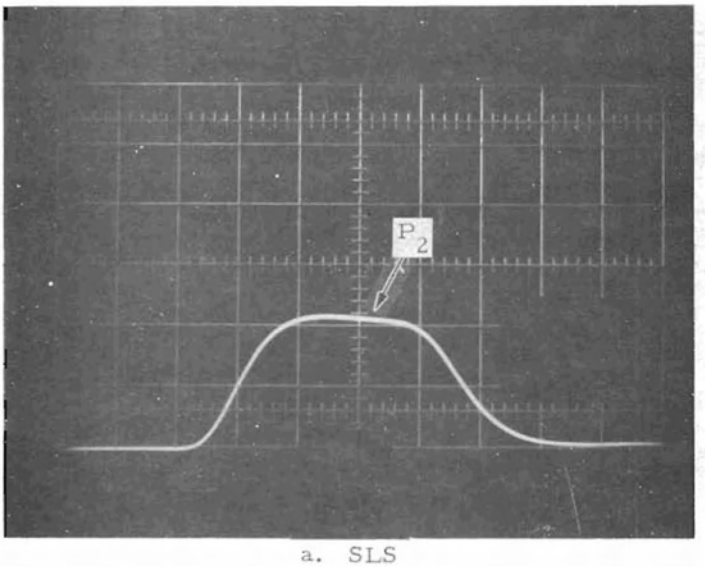


b. ISLS

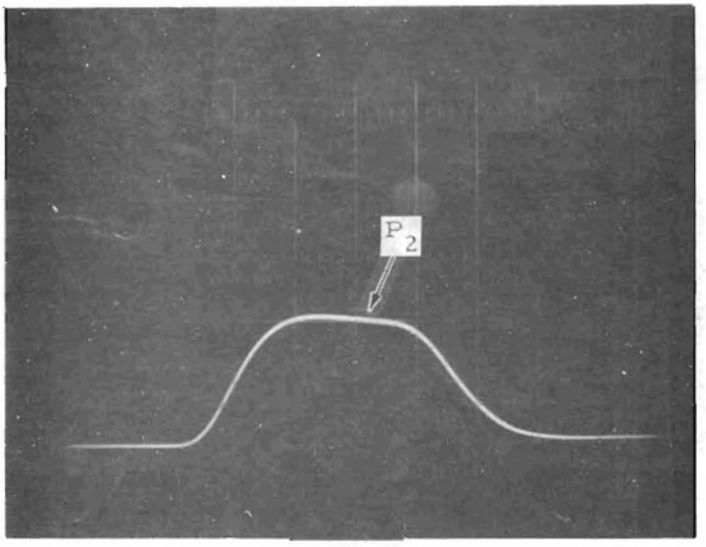
75-23-9

FIGURE 18. IMPROVED P_2 PULSE CHARACTERISTIC FOR SLS AND ILS OPERATION

DATE: 7/29/74
TEST SITE:
FIELD TEST SITE
TEST CONDITIONS:
MODE 3/A INTERROGATION, P_2
TRANSMITTED PEAK POWER =600 W
TOWER HEIGHT =75 FT
DATA COLLECTION METHOD:
TRANSMITTED PULSE WAVEFORM MEASUREMENTS
CALIBRATION:
VERTICAL - 7.7 dB PER MAJOR DIVISION
HORIZONTAL - 0.2 μs PER MAJOR DIVISION



a. SLS



b. ISLS

75-23-10

FIGURE 19. EQUALIZED P_2 PULSE AMPLITUDE FOR SLS AND ISLS OPERATION

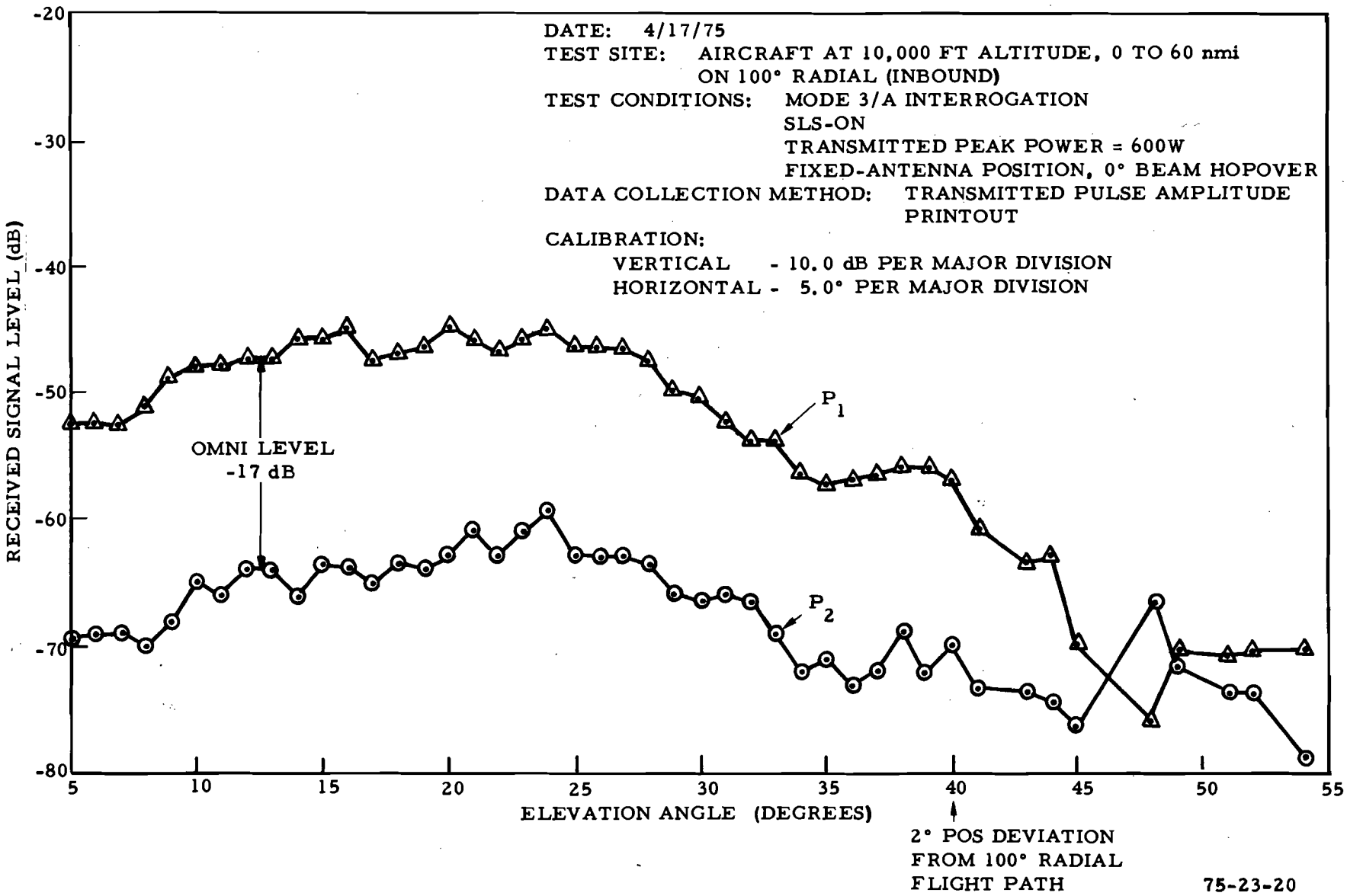


FIGURE 20. P_1 AND P_2 AMPLITUDE COMPARISON FOR FIXED-RADIAL FLIGHT (ZERO DEGREE BEAM HOPOVER)

The ESA directional beam was held in a fixed position over the aircraft hangar, building 301. The CW source was connected to an antenna on the building which was positioned to locate equal amplitude on either side of the (SLS) directional antenna pattern. The measurements were made using the HP8413A network analyzer gain indicator at the TR/BTF and positioning directions given to the crew on the aircraft hangar, building 301. The two positions (10-dB points on the directional beam) were marked on the aircraft hangar, building 301. The center of the beam was surveyed, and the azimuth from the TR/BTF calculated using the NAFEC grid coordinate system. Several different beam positions were checked during the test. The position of the null of the difference pattern was measured using the same test configuration, by substituting the difference channel on the ESA in place of the directional (sum channel). The null of the difference pattern was noted at the ESA as the antenna on the hangar was positioned for a minimum received signal level. Several beam positions were tested and surveyed using the NAFEC grid coordinate system.

A total of eleven different azimuth positions (0.703° steps) were examined over the aircraft hangar, building 301. The depth of the null compared to the peak of the sum channel ranged between 18.5 dB and 46.5 dB and was dependent upon local structures which interfered with the signal between the sites. The results of the pointing accuracy tests indicate an offset of approximately 0.6°, due to a combination of alignment procedures and the shifting of the magnetic declination from 10° 22" to 10° 30" from the time of installation (1973) to the date of the test (April 28, 1975). The difference in pointing direction of the ESA and the resulting beam position was within 0.1°, considering the offset of 0.6°.

SUMMARY OF RESULTS

The results obtained during the specification tests of the ATCRBS electronic scan antenna at NAFEC are summarized as follows:

1. The ESA demonstrated its ability (per specification requirement) to step through 2,048 beam positions in scan (free run, or slaved to the ASR-7 antenna rotation) and agile mode. Agile beam repositioning required 2.5 μs for a change in azimuth pointing direction.

2. The 0°, 2°, and 4° beam hopover function (for the directional beam) could be selected for 224 independent positions. The beam hopover function (2° and 4°) provided a reduction in signal strength for the lower elevation angles from the ESA for both transmit and receive modes of operation.

3. The VSWR measurement for SLS, ISLS, and receive modes (sum and difference channels) fell within the specified ratio of 1.5:1 (maximum limit).

4. Maintenance data accumulated after the completion of the 48-hour test on June 27, 1974, was used to calculate the availability of the ESA. A figure of 99.4-percent availability was calculated for the antenna operating in standby, normal, and casualty modes.

5. The built-in test functions of the ESA isolated faults to particular modules. (The antenna self-testing features were employed throughout the test and evaluation effort.)

6. A modification was made to the antenna control unit to isolate the omni signal path through the quadrant switches from the directional path during transmission of the P_2 (omni) pulse. The modification resulted in an improvement of the omnidirectional (P_2) pattern characteristics.

7. The 1030-MHz and 1090-MHz horizontal antenna pattern measurements produced side lobe and back lobe levels of $\leq$-21 dB and an omnidirectional (P_2) level of -17 dB with reference to the peak of the main directional beam. A shoulder noted on the 1090-MHz receive pattern was attributed to inherent defocusing of the antenna beam at low elevation angles.

8. Modifications were made to the SLS and ISLS mode switch to improve the transmitted pulse characteristics. The amplitude level of the P_2 pulse was raised 3 dB with respect to the P_1 and P_3 transmitted pulse amplitude to improve SLS system performance.

9. The pointing accuracy tests indicated an offset on the ESA of 0.6° for the 1030-MHz directional sum and difference pattern. The accuracy (considering the offset) was within 0.1°. The depth of the notch in the difference pattern ranged between 18.5 dB and 46.5 dB below the amplitude of the sum channel of the ESA.

CONCLUSIONS

Based on the results obtained during the NAFEC specification tests of the ESA, it is concluded that:

1. The ESA performed the basic functions of beam stepping (free run, or slaved to the ASR-7 antenna rotation), agile beam repositioning, beam hopover, and the generation of SLS, ISLS, sum channel, and difference channel antenna-beam pattern characteristics (horizontal and vertical) for 1030 MHz and 1090 MHz.

2. The availability of the ESA for testing was high (99.4 percent). Built-in test functions demonstrated the ability to isolate faults to particular modules.

3. The data obtained during the field specification tests meet the specification requirements, taking into account field environment effects on the antenna pattern characteristics.

REFERENCES

1. ATCRBS Transmitter Site Improvements Program, Product Plan, Agreement No. 03-152, Activity No. 033-241-010, Testing Electronic Scan Antenna, NAFEC, Atlantic City, New Jersey, July 1973.

2. ATCRBS Electronic Beam Antenna, DOT/FAA Specification, Engineering Requirement No. FAA-ER-240-013a dated 15 June, 1971, Amendment 1 dated 30 Oct. 1970, Amendment 2, dated 11 January 1971.

3. ATCRBS Electronic Scan Antenna Site Test Plan, Contract Item 7B, Contract DOT-FA72WA-2704, dated 11 June 1973.

4. Bradley, A.D., Test and Evaluation of ATCRBS Electronic Scan Antenna Preparatory Test, System Research and Development Service, Washington, D.C., Interm Report No. FAA-RD-74-176, November 1974.

5. Quarter Section Antenna Pattern Test Procedure for ATCRBS Electronic Scan Antenna, Test Procedure ATC-380-TPI, Control No. DOT FAT2WA-2704 Issue B, 12/14/72.

APPENDIX A

DATA COLLECTION METHODS

Several data collection techniques were employed to determine ESA performance regarding antenna patterns during both ground-based tests and airborne flight tests. These techniques involved:

1. Transmitted pulse amplitude and waveform measurements (photographs);
2. Continuous wave (CW) radiofrequency (RF) source amplitude measurements;
3. Transmitted pulse amplitude printout;
4. Transmitted pulse amplitude recording on high-speed film; and
5. Transponder performance analyzer (TPA) system.

The method of calibration for each data collection technique followed essentially the same procedures. The vertical deflection or signal level readings were calibrated in relative power levels using a reference RF signal source. The RF signal source produced a desired signal pulse characteristic or CW reference level. The signal was attenuated in fixed increments (1-dB or 10-dB steps) of output power while the resulting waveform or reading was recorded on film, marked on a recorder chart, or tabulated by hand, depending upon the data collection technique. The procedure was repeated as often as necessary to insure that the instrumentation was calibrated for the existing test conditions.

The horizontal deflection time base of the oscilloscope or XY plotter was used to correlate the data recorded with the antenna rotation or angular position of the ESA. In addition, a record of the real time (established by NAFEC Range Control) was used to correlate the test data with the position of the aircraft relative to the ESA using the tracking data from the Extended Area Instrumentation Radar (EAIR) Facility. A sample of the EAIR data translated to the coordinates of the TR/BTF (ESA) position is shown in table A-1.

TRANSMITTED PULSE AMPLITUDE AND WAVEFORM MEASUREMENTS (PHOTOGRAPHS).

An instrumentation package was assembled to record antenna patterns and characteristics of the transmitted pulse waveforms by photographing an oscilloscope CRT which provided an instant record of the displayed image. A block diagram of the instrumentation package is shown in figure A-1.

The technique involved the synchronization of the horizontal sweep of the oscilloscope with the timing of either the transmitted pulses or the rotation of the ESA; i.e., with beacon sync trigger or the north pulse (ARP) originating at the TR/BTF.

The antenna pattern was obtained by intensifying only the peak amplitude of the detected radiofrequency pulses (P_1 and P_2) on the vertical deflection of the oscilloscope. Complete 360° antenna patterns were recorded by taking a series of photograph employing a delayed sweep preset to fixed intervals after the arrival of the north marker from the TR/BTF. The vertical deflection was

TABLE A-1. SAMPLE OF EAIR RADAR TRACKING DATA

EAIR PROGRAM (OCT. 1973) E SCAN 033-241-00C
RUN NO. 2 OF R1332 TASK 3 DATE 7/18/74

EAIR DATA ROTATED -1C. DEG. -0. MIN. -0. SEC.
EAIR DATA TRANSLATED X= 8148.808 FT. Y= 71.232 FT. Z= -13.75C FT.
EAIR DATA REFERENCED LAT 39. DEG. 27. MIN. 5.540CC SEC. LCN 74. DEG. 34. MIN. 14.21CCC SEC. 91.500 FT. ALT.

	TIME	AZIMUTH	ELEVATICN	RANGE	- X -	- Y -	- Z -	HEIGHT
6C149.C	16/42/29.0	59.322	5.299	17.9C9	93185.837	55282.C10	10048.5C0	1C421.750
6C15C.C	16/42/3C.0	59.321	5.277	17.982	93568.717	55511.C74	10049.5C0	1C424.5CC
6C151.C	16/42/31.0	59.329	5.265	18.C56	93963.48C	55728.C46	10C66.750	1C443.750
6C152.C	16/42/32.0	59.319	5.249	18.130	94342.972	55974.C75	10077.5C0	1C457.250
6C153.C	16/42/33.0	59.318	5.227	18.2C5	94736.178	562C9.354	10077.5CC	1C459.50C
6C154.C	16/42/34.0	59.317	5.212	18.278	95117.864	56438.531	10088.0C0	1C472.500
6C155.C	16/42/35.0	59.325	5.193	18.351	955C7.977	56653.C89	10092.5C0	1C479.250
6C156.C	16/42/36.0	59.315	5.169	18.425	95883.C61	56858.228	10C85.CCC	1C474.250
6C157.C	16/42/37.0	59.3C1	5.159	18.496	96242.596	57141.797	10105.0CC	1C496.25C
6C158.C	16/42/38.0	59.288	5.123	18.566	966CC.448	57385.37C	10072.750	1C466.75C
6C159.C	16/42/39.0	59.297	5.093	18.636	96979.C77	57587.937	10052.0C0	1C448.000
6C16C.C	16/42/4C.0	59.307	5.077	18.7C3	97339.527	5778C.772	10C57.75C	1C455.75C
6C161.C	16/42/41.0	59.316	5.062	18.772	9771C.795	57979.735	10063.5C0	1C464.25C
6C162.C	16/42/42.0	59.325	5.046	18.841	98081.551	58178.594	10070.0C0	1C472.750
6C163.C	16/42/43.0	59.312	5.028	18.915	98452.2C1	58429.221	10072.5C0	1C478.00C
6C164.C	16/42/44.0	59.31C	5.012	18.988	98833.339	58659.964	10079.750	1C487.75C
6C165.C	16/42/45.0	59.319	4.982	19.C61	99227.649	58871.625	10058.250	1C468.5C0
6C166.C	16/42/46.0	59.326	4.955	19.136	99629.127	59C93.588	10043.0C0	1C455.750
6C167.C	16/42/47.0	59.336	4.937	19.211	100032.287	593C9.373	10045.750	1C461.0CC
6C168.C	16/42/48.0	59.346	4.921	19.285	1CC429.674	59522.746	10052.250	1C470.250
6C169.C	16/42/49.0	59.346	4.903	19.359	1C0818.957	59751.563	10053.750	1C474.C00
6C17C.C	16/42/5C.0	59.353	4.891	19.431	1012C2.527	59964.C40	10065.250	1C488.250
6C171.C	16/42/51.0	59.361	4.867	19.501	1C15EC.168	6C166.879	10052.5C0	1C477.250
6C172.C	16/42/52.0	59.362	4.851	19.573	101958.534	6C39C.466	10057.25C	1C485.0CC
6C173.0	16/42/53.0	59.359	4.827	19.643	1C2324.781	6C613.642	10043.5C0	1C473.750
6C174.C	16/42/54.0	59.367	4.812	19.710	102685.C52	6C8C7.489	10046.0C0	1C478.500
6C175.C	16/42/55.0	59.376	4.788	19.781	1C3C67.818	61C13.344	10032.0CC	1C466.500
6C176.C	16/42/56.0	59.384	4.775	19.852	1C3448.947	61217.627	10042.0C0	10479.5CC
6C177.C	16/42/57.0	59.393	4.754	19.925	1C3841.889	61428.648	10034.0C0	1C474.00C
6C178.C	16/42/58.0	59.402	4.745	19.999	104238.44C	61641.580	10051.750	1C494.500
6C179.C	16/42/59.0	59.422	4.726	2C.C73	1C4647.698	61833.943	10049.75C	1C495.000
6C18C.C	16/43/ C.	59.440	4.714	2C.148	1C5C58.745	62C33.539	10061.750	1C509.25C
6C181.C	16/43/ 1.0	59.452	4.690	20.223	1C5465.474	62244.186	10047.5C0	1C498.000
6C182.C	16/43/ 2.0	59.460	4.655	2C.296	105860.680	62456.67C	10C07.25C	1C460.250
6C183.C	16/43/ 3.0	59.469	4.642	2C.371	1C6263.250	62672.362	10018.0CC	1C474.00C
6C184.C	16/43/ 4.0	59.477	4.627	2C.443	1C6649.932	62879.684	10020.25C	1C478.750
6C185.0	16/43/ 5.0	59.485	4.597	20.513	107028.557	63C83.624	9990.250	1C451.000
6C186.C	16/43/ 6.0	59.490	4.588	2C.584	1C74C6.428	63293.382	10004.5CC	1C467.750
6C187.C	16/43/ 7.0	59.497	4.582	2C.653	107776.465	63491.582	10023.75C	1C489.750
6C188.C	16/43/ 8.0	59.497	4.566	20.723	1C8143.602	6371C.289	10024.250	1C492.75C
6C189.C	16/43/ 9.0	59.504	4.557	2C.793	108519.264	63911.616	10038.0C0	1C509.000
6C19C.C	16/43/1C.0	59.512	4.539	2C.865	1C89C6.663	64119.3CC	10032.5CC	1C5C6.750
6C191.C	16/43/11.0	59.520	4.515	2C.937	1C9295.157	64328.C66	10014.5C0	1C491.00C
6C192.C	16/43/12.0	59.516	4.497	21.C12	1C9666.C95	64567.667	10C1C.250	1C489.25C
6C193.C	16/43/13.0	59.522	4.473	21.C85	110076.408	64784.247	9992.0C0	1C474.000
6C194.C	16/43/14.0	59.521	4.472	21.162	11C478.4C3	65C21.897	10027.0C0	10512.00C
6C195.0	16/43/15.0	59.529	4.454	21.236	110876.007	65235.232	10021.250	10509.0CC
6C196.C	16/43/16.0	59.537	4.425	21.311	111281.116	65453.221	9990.250	1C480.750
6C197.C	16/43/17.0	59.545	4.415	21.385	111677.762	65666.234	10003.25C	1C496.500
6C198.C	16/43/18.0	59.552	4.406	21.456	112C58.274	6587C.626	10016.25C	1C512.00C
6C199.C	16/43/19.0	59.559	4.391	21.527	11244C.33C	66C75.922	10014.5C0	1C513.C00
6C2CC.C	16/43/2C.0	59.572	4.385	21.598	112826.647	66268.606	10033.250	1C534.500

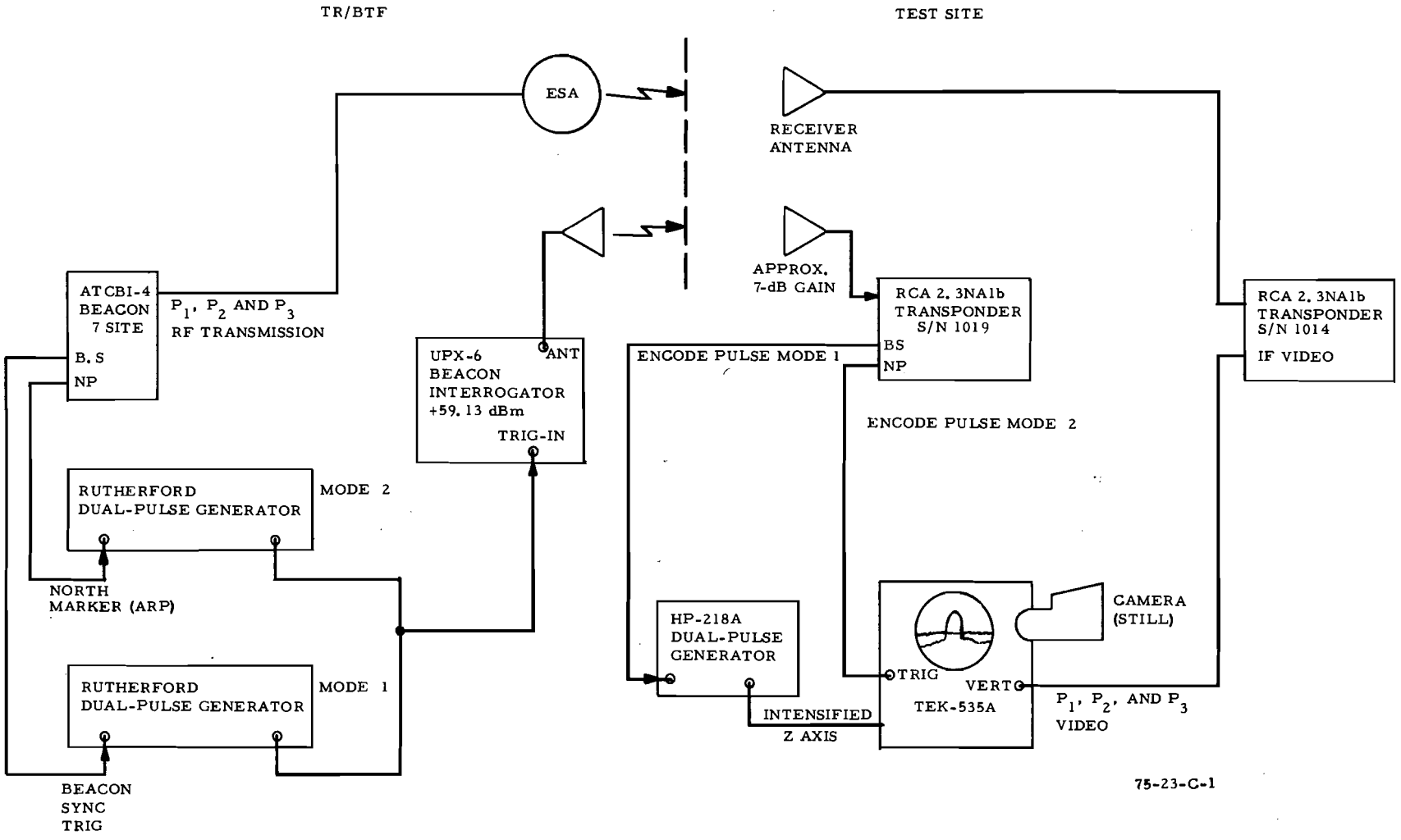


FIGURE A-1. TRANSMITTED PULSE AMPLITUDE AND WAVEFORM MEASUREMENTS (PHOTOGRAPHS)

calibrated during each test in 1-dB steps over the dynamic range of the log receiver using an RF pulse generator at the test site. This photographic technique was limited during the testing to ground-based data collection applications.

CONTINUOUS WAVE RADIOFREQUENCY SOURCE AMPLITUDE MEASUREMENTS.

Two (RF) amplitude measurement techniques were employed during the evaluation. The first CW measurement instrumentation is shown in figure A-2. The network analyser (model HP 8410A) provided a calibrated output of both phase and amplitude of the received energy compared to a reference signal input obtained through another fixed antenna.

The CW RF source was positioned at a point in space from which an antenna pattern was to be examined and recorded either by direct amplitude reading or on an XY plotter. The two types of recordings permitted both vertical and horizontal antenna patterns to be measured during the evaluation.

The vertical patterns were recorded by adjusting the height of the CW source in fixed steps (1-foot increments) and recording the amplitude of the received energy on the HP 8413A amplitude/phase meter. The ESA directional beam was held stationary (pointing in the direction of the RF source) and the frequency manually set for 1030 MHz or 1090 MHz.

The horizontal patterns were recorded by rotating the ESA at a slow scan rate and recording the amplitude (Y axis) of the received energy on an XY plotter as the recorder's pen moved at a slow rate along the X axis. For example, the 0°, 45°, 90°, etc., beam positions were marked on the recording paper as the antenna passed the respective angular position. The result was an image of the horizontal antenna pattern calibrated in both amplitude (Y) and antenna angular pointing position.

The CW RF was adjusted to 10 MHz off the frequency of the ESA which was controlled at the ACU during the recording of data (1030 MHz or 1090 MHz). This deviation from the operating frequency did not significantly degrade the represented performance of the ESA.

The off-frequency signal was required since on-frequency transmissions interfered with other ATCRBS systems at NAFEC.

The second CW measurement instrumentation is shown in figure A-3. The dual-channel test tracking receiver (Hazeltine Model 2309) provided a detected RF signal over a 60-dB dynamic range for both the sum and difference channels of the ESA. As the antenna beam rotated, the antenna pattern was obtained by photographing the detected signal (video) displayed on a calibrated oscilloscope. Complete 360° patterns were recorded by taking a series of photographs employing a delayed sweep preset to fixed intervals after the arrival of the north

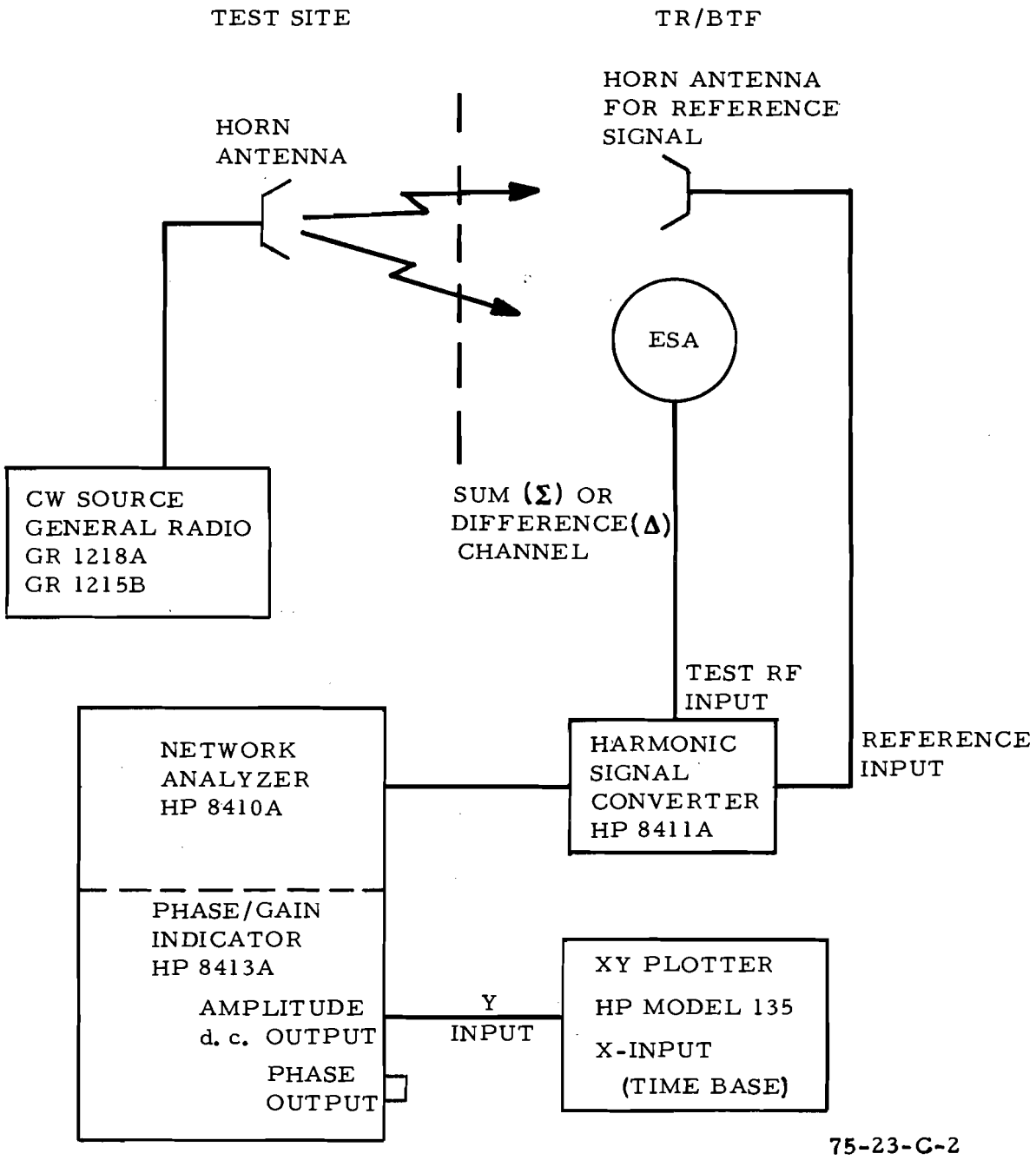


FIGURE A-2. CONTINUOUS-WAVE (CW) RADIOFREQUENCY SOURCE AMPLITUDE MEASUREMENT (NETWORK ANALYZER TECHNIQUE)

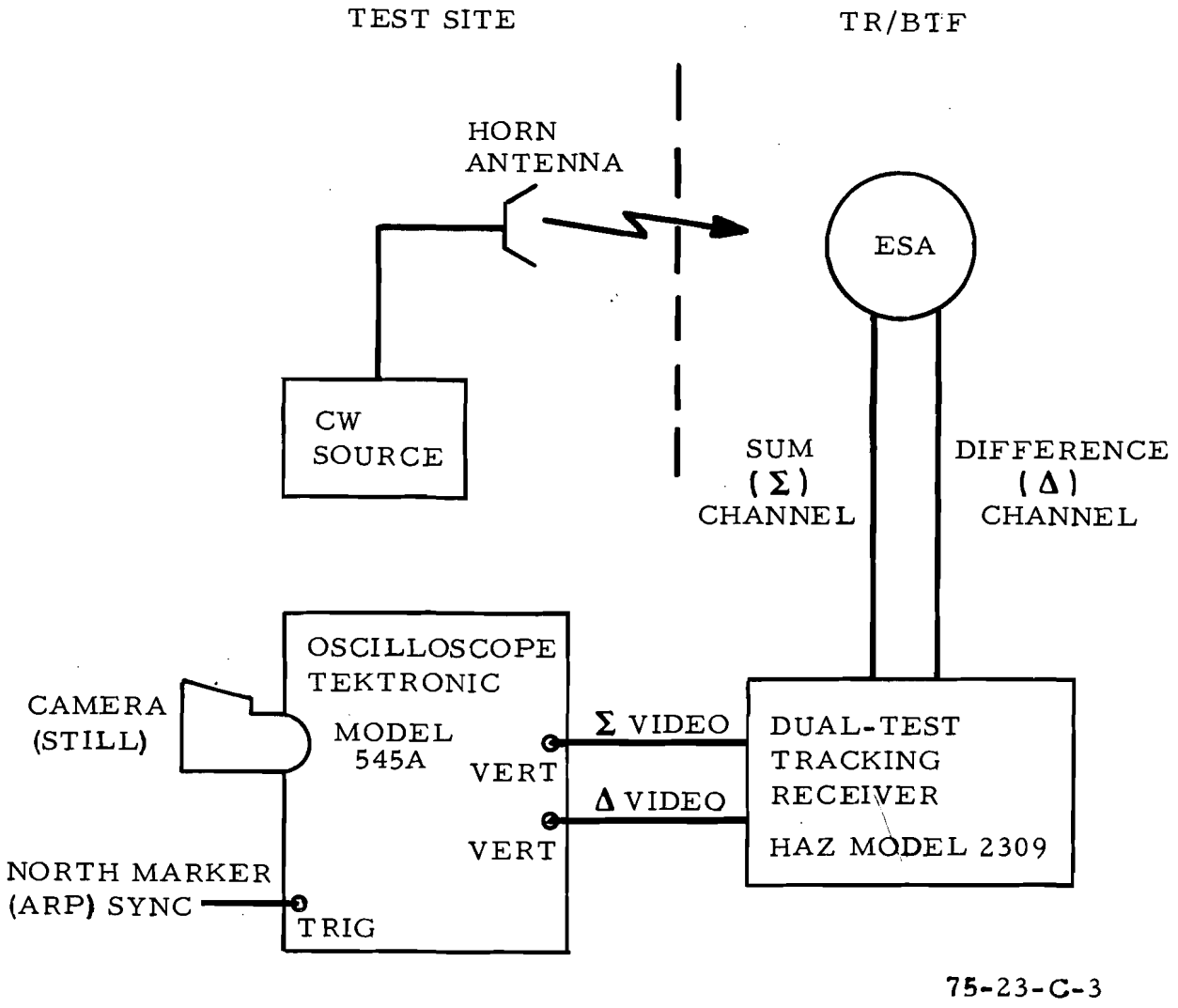


FIGURE A-3. CONTINUOUS-WAVE (CW) RADIOFREQUENCY SOURCE AMPLITUDE MEASUREMENTS (DUAL-TEST TRACKING RECEIVER TECHNIQUE)

marker from the distribution system of the TR/BTF. The CW source was adjusted to 1090 MHz during the testing until it was noted that some interference was being experienced by other ATCRBS systems at NAFEC. The CW techniques were limited during the testing to ground-based data collection applications.

TRANSMITTED PULSE AMPLITUDE PRINTOUT.

An ILC/DDC model VADC-B was interfaced with the log receiver and a line printer to digitally record the peak amplitude of the detected mode 3/A interrogation pulses (P_1, P_2, and P_3). The device was employed during airborne measurements taken for a fixed antenna position along a selected radial from the TR/BTF.

The technique, shown in figure A-4, was limited in data rate to the speed of the printer which was between two and three lines per second. In addition, time was recorded on the line with each reading. Synchronization of the system was obtained from the TR/BTF by independently encoding and transmitting the beacon sync trigger. The sample gate (30 ns) was positioned on the peak of each transmitted pulse within $\pm$ 100 ns.

TRANSMITTED PULSE AMPLITUDE RECORDING ON HIGH-SPEED FILM.

The dynamic antenna pattern of the ESA was recorded in real time using a procedure involving high-speed film (75 feet per minute) instrumented in an aircraft. A block diagram of the application of the high-speed film is shown in figure A-5.

The procedure involved synchronizing an oscilloscope horizontal trace with the TR/BTF beacon sync trigger and displaying the detected P_1 and P_2 transmitted pulses vertically on the CRT screen. Only a small portion (vertical slit) of the screen was exposed as a high-speed film passed in front of the display. The ESA was placed in a scan mode, at the normal radar antenna rotation rate, permitting the film to continuously record a 360° antenna pattern with the amplitude of the received signal calibrated in decibels through the dynamic range of the log receiver. In addition, reflected signals from nearby buildings (for example, aircraft hangar building 301) could be recorded by adjusting the size of the exposed portion of the CRT to permit the time-delayed reflection-path signals to be filmed during the process. A sample of the high-speed film taken for SLS and ISLS operation on an inbound radial flight (060° radial) at 10,000 feet altitude is shown in figure A-6.

TRANSPONDER PERFORMANCE ANALYZER SYSTEM.

Another technique used during the testing of the ESA involved the adaptation of the transponder performance analyzer (TPA) to record the received (1090 MHz) transponder reply amplitude to obtain an antenna pattern during airborne flight tests.

The system was adapted during the flight tests to record the amplitude of the aircraft's transponder reply using a calibrated receiver. The side-lobe suppression (SLS) was eliminated and the target permitted to "ring around" as the antenna rotated at 15 r/min. The transponder replies were received throughout the rotation of the antenna both in the directional main beam and the side lobes.

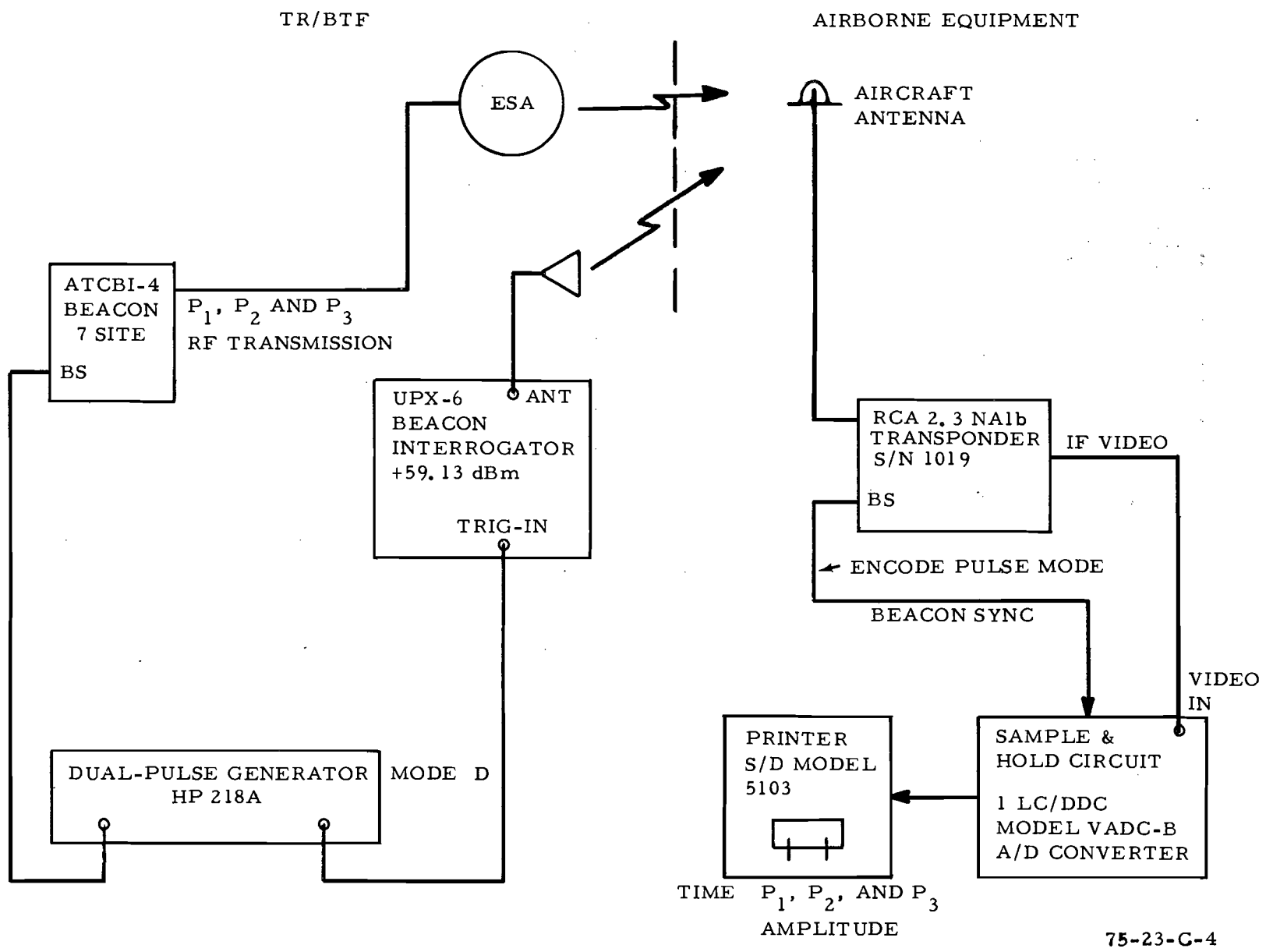


FIGURE A-4. TRANSMITTED PULSE AMPLITUDE PRINT OUT

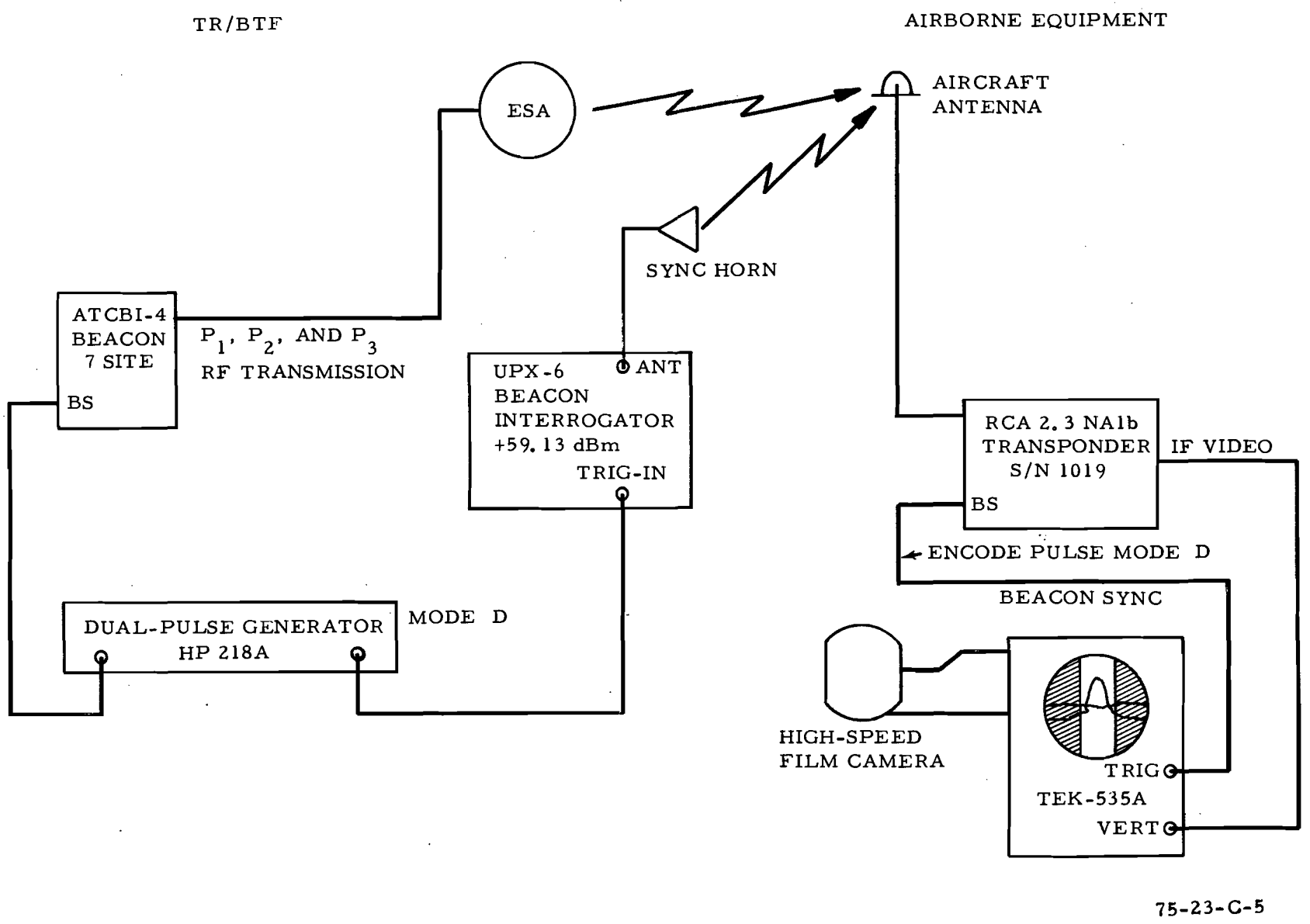
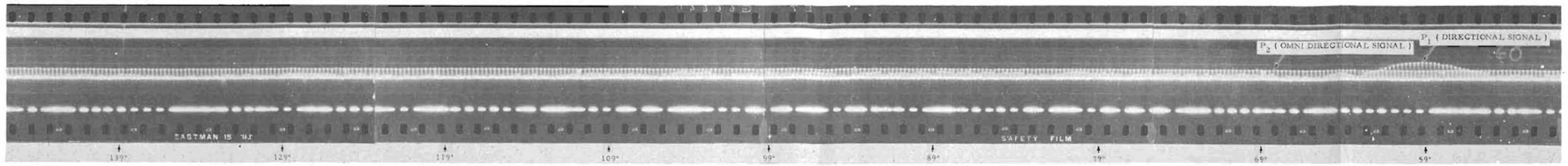
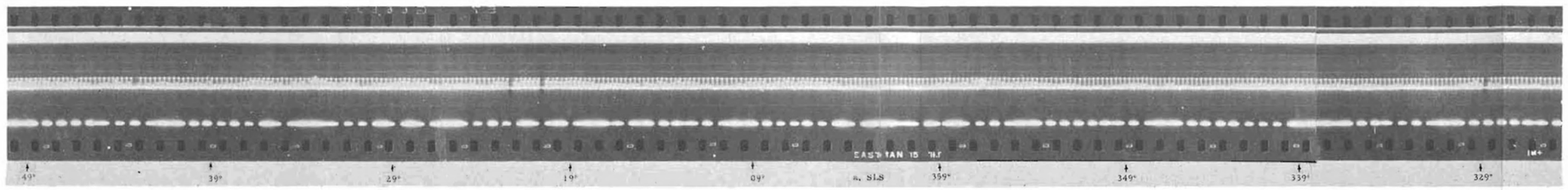
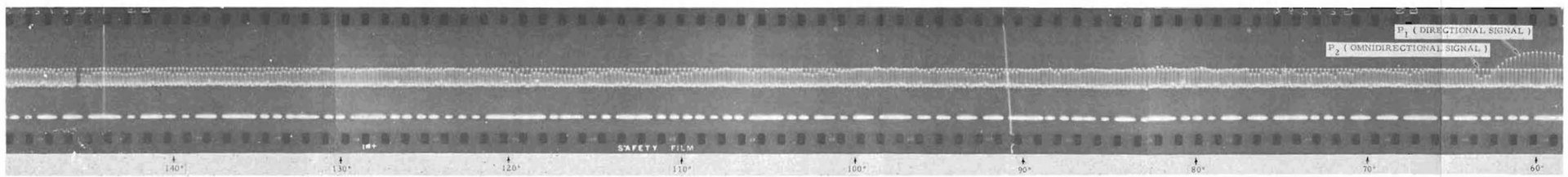


FIGURE A-5. TRANSMITTED PULSE AMPLITUDE RECORDING ON HIGH-SPEED FILM





DATE: 7/16/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF ~8°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-ON, BEAM HOPOVER
TRANSMITTED PEAK POWER = 600 W, 059° AZIMUTH AT 8,000 FT. ALTITUDE, RANGE ~10 nmi
DATA COLLECTION METHOD:
TRANSMITTED PULSE AMPLITUDE
RECORDED ON HIGH SPEED FILM
CALIBRATION:
VERTICAL - 12.5 dB PER MAJOR DIVISION
HORIZONTAL - 10.0° PER MAJOR DIVISION



DATE : 7/18/74
TEST SITE :
AIRCRAFT AT ELEVATION ANGLE OF ~8°
TEST CONDITIONS :
MODE 3/A INTERROGATION ISLS-ON BEAM HOPOVER
TRANSMITTED PEAK POWER = 600 W, 060° AZIMUTH AT 8,000 FT. ALTITUDE, RANGE ~10 nmi
DATA COLLECTION METHOD :
TRANSMITTED PULSE AMPLITUDE
RECORDED ON HIGH SPEED FILM
CALIBRATION :
VERTICAL - 6.25 dB PER MAJOR DIVISION
HORIZONTAL - 10.0° PER MAJOR DIVISION

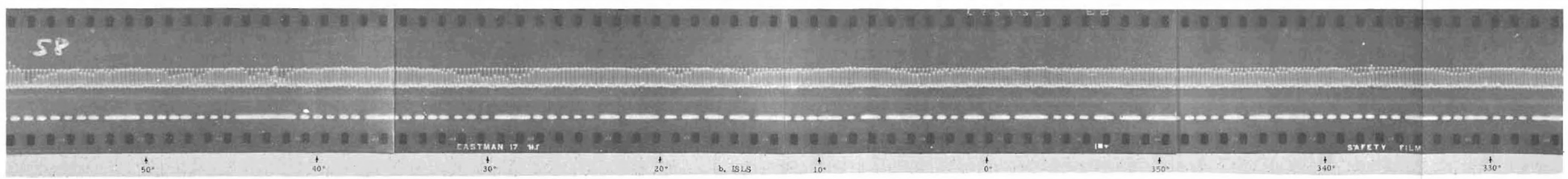


FIGURE A-6. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS (SAMPLE) FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER

APPENDIX B

ATCRBS ESA FIELD SPECIFICATION MEASUREMENTS

The ESA field specification patterns include both the ground-based and airborne flight test data measured during the test and evaluation effort. ATCRBS 1030-MHz and 1090-MHz horizontal patterns were recorded using various data collection techniques described in appendix A. The patterns in this appendix are a sample of those which were taken during the evaluation. They represent the patterns which either apply to the specification test or demonstrate a particular aspect of antenna operation.

The ESA field specification antenna patterns are shown in figures B-1 to B-17.

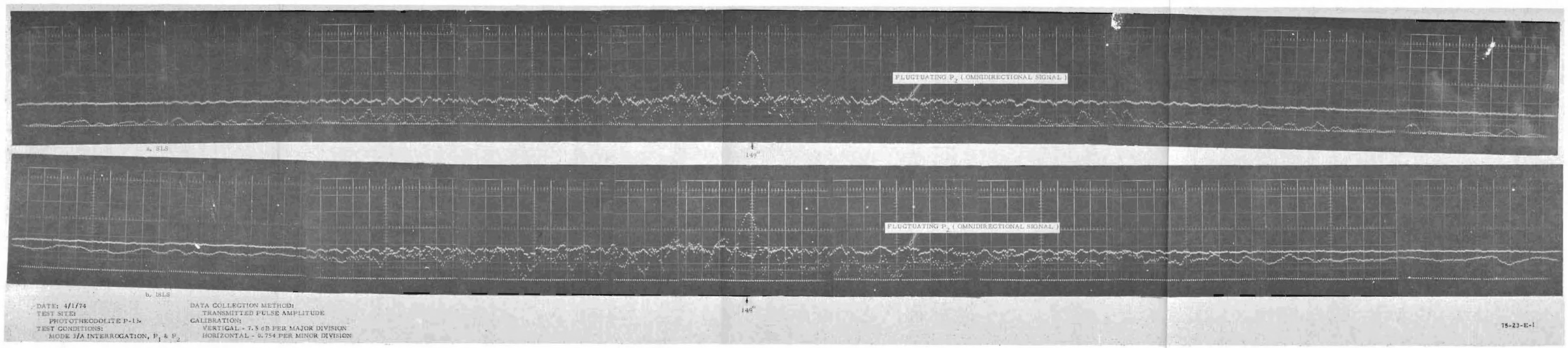


FIGURE B-1. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER AT P-13 (4/1/74)

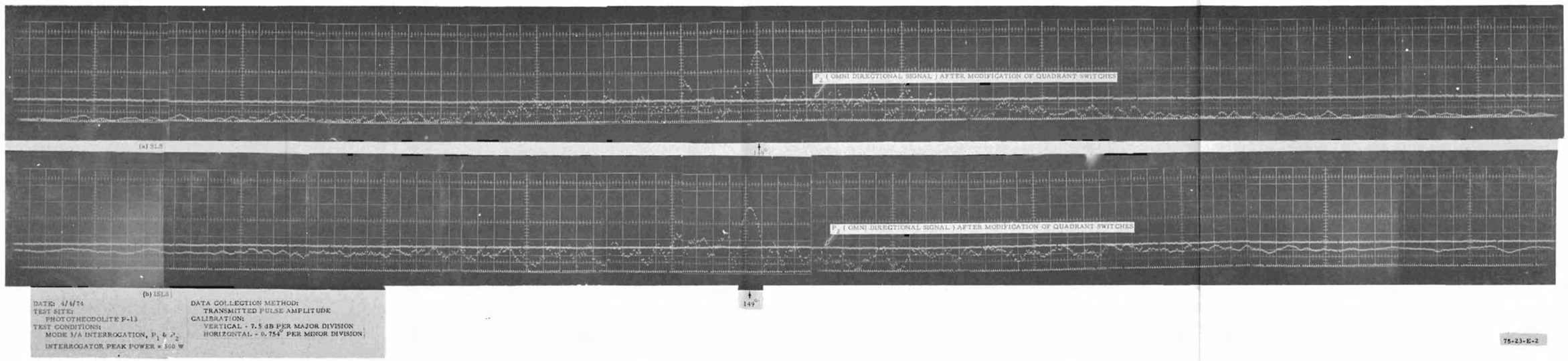


FIGURE B-2. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER AT P-13 (4/4/74)

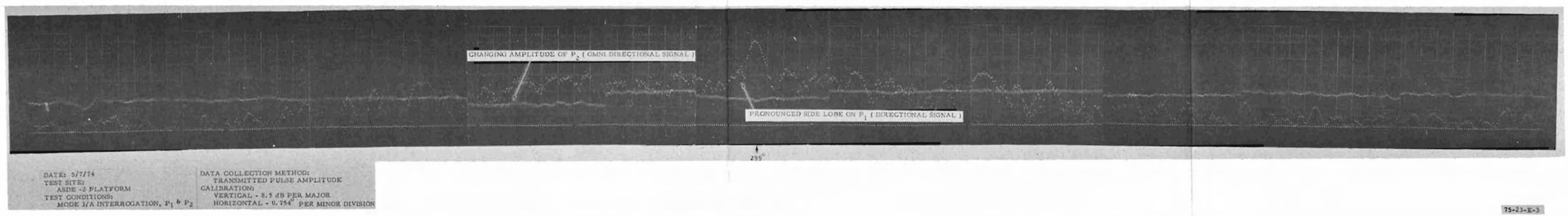


FIGURE B-3. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER AT ASDE-2 PLATFORM (5/7/74)

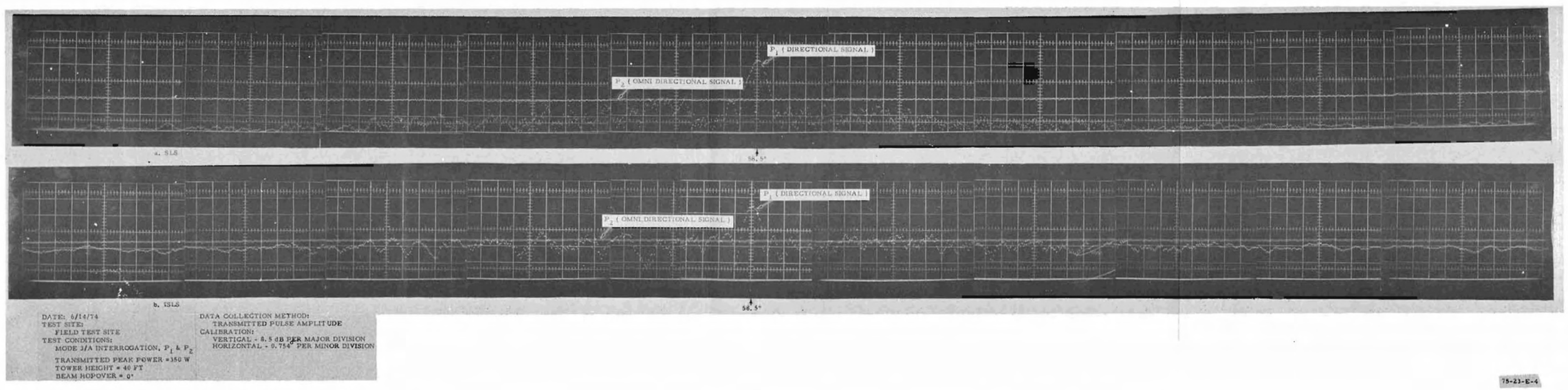


FIGURE B-4. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER, 40-FOOT TOWER AT FIELD TEST SITE (6/14/74)

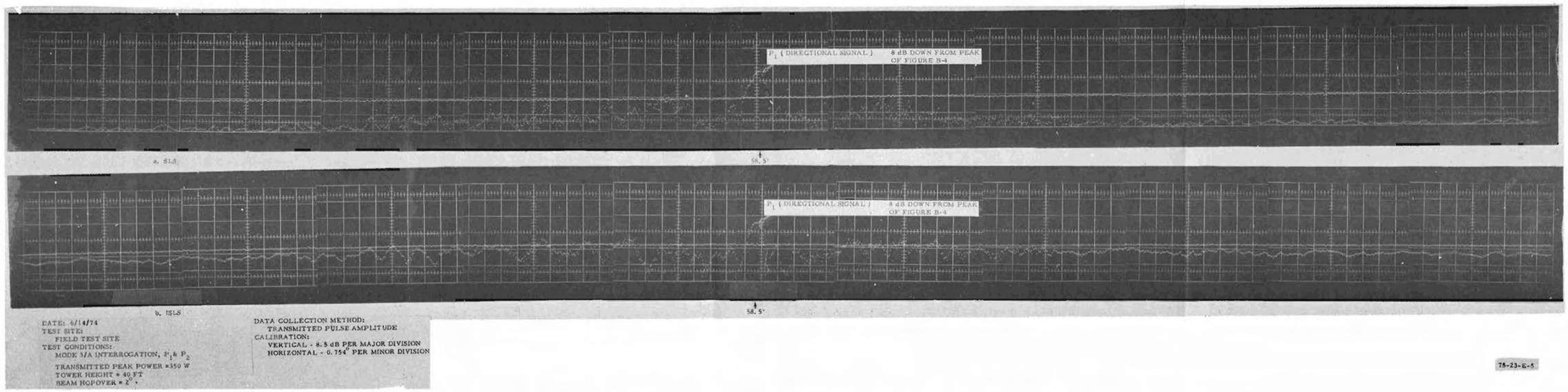


FIGURE B-5. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, 2° BEAM HOPOVER, 40-FOOT TOWER AT FIELD TEST SITE (6/14/74)

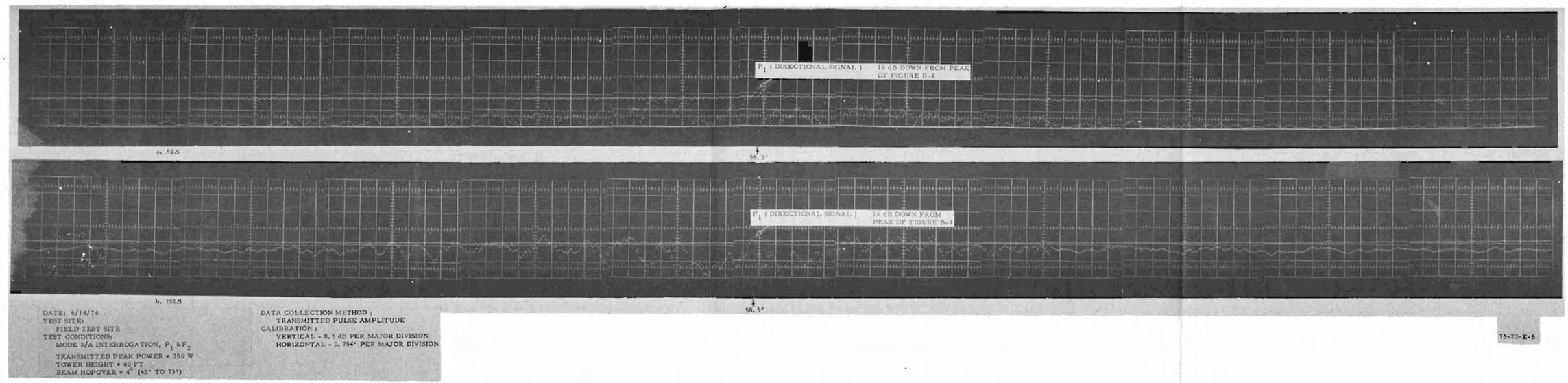


FIGURE B-6. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, 4° BEAM HOPOVER, 40-FOOT TOWER AT FIELD TEST SITE (6/14/74)

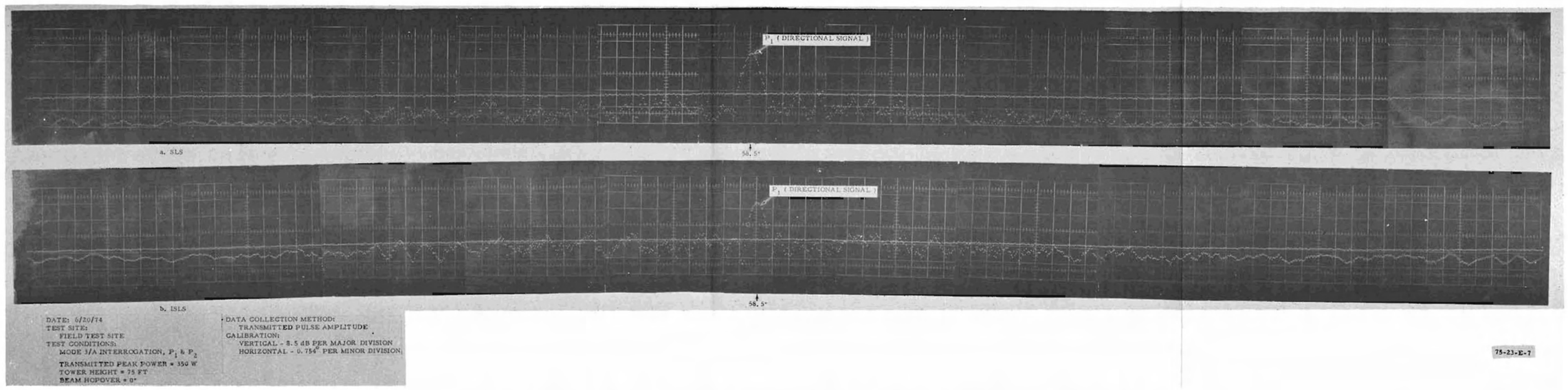


FIGURE B-7. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, ZERO-DEGREE BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (6/20/74)

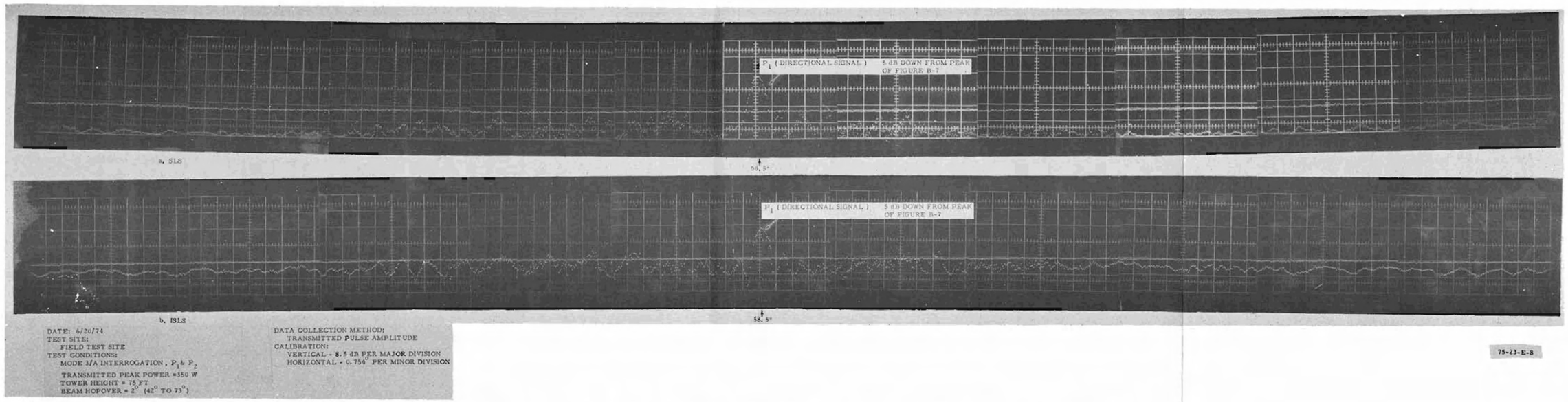


FIGURE B-8. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, 2° BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (6/20/74)

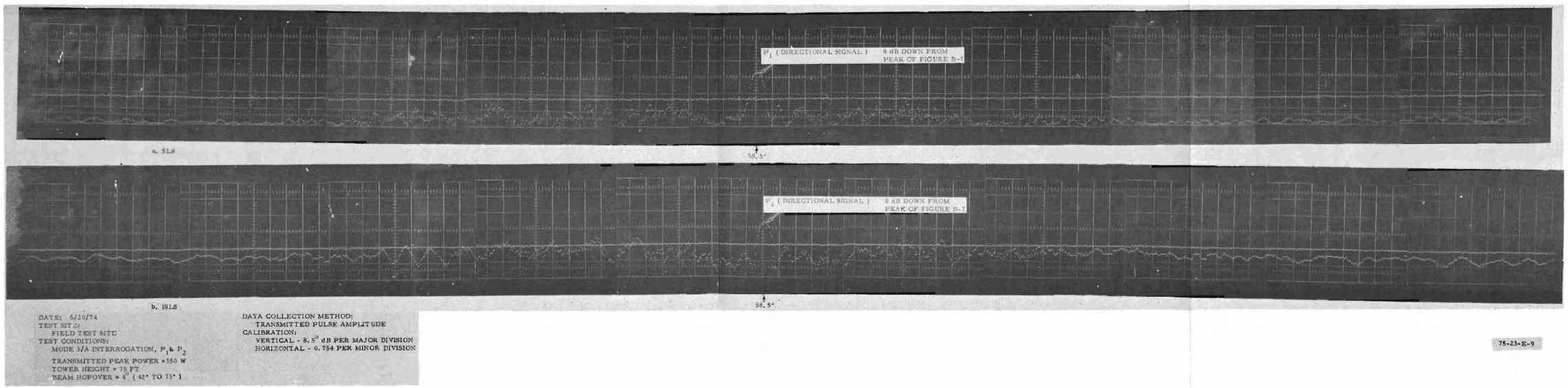


FIGURE B-9. ATCRBS ESA 1030-MHz HORIZONTAL ANTENNA PATTERNS FOR SLS AND ISLS, 4° BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (6/20/74)

DATE: 7/5/74
TEST SITE:
FIELD TEST SITE
TEST CONDITIONS:
ESA RECEIVES MODE SELECTED (1090MHz)
NETWORK ANALYZER TEST SET-UP
TOWER HEIGHT = 75 FT
BEAM HOPOVER (NONE)
DATA COLLECTION METHOD:
CONTINUOUS-WAVE RF AMPLITUDE
CALIBRATION:
VERTICAL-10 dB PER MAJOR DIVISION
HORIZONTAL - 45° PER MAJOR DIVISION

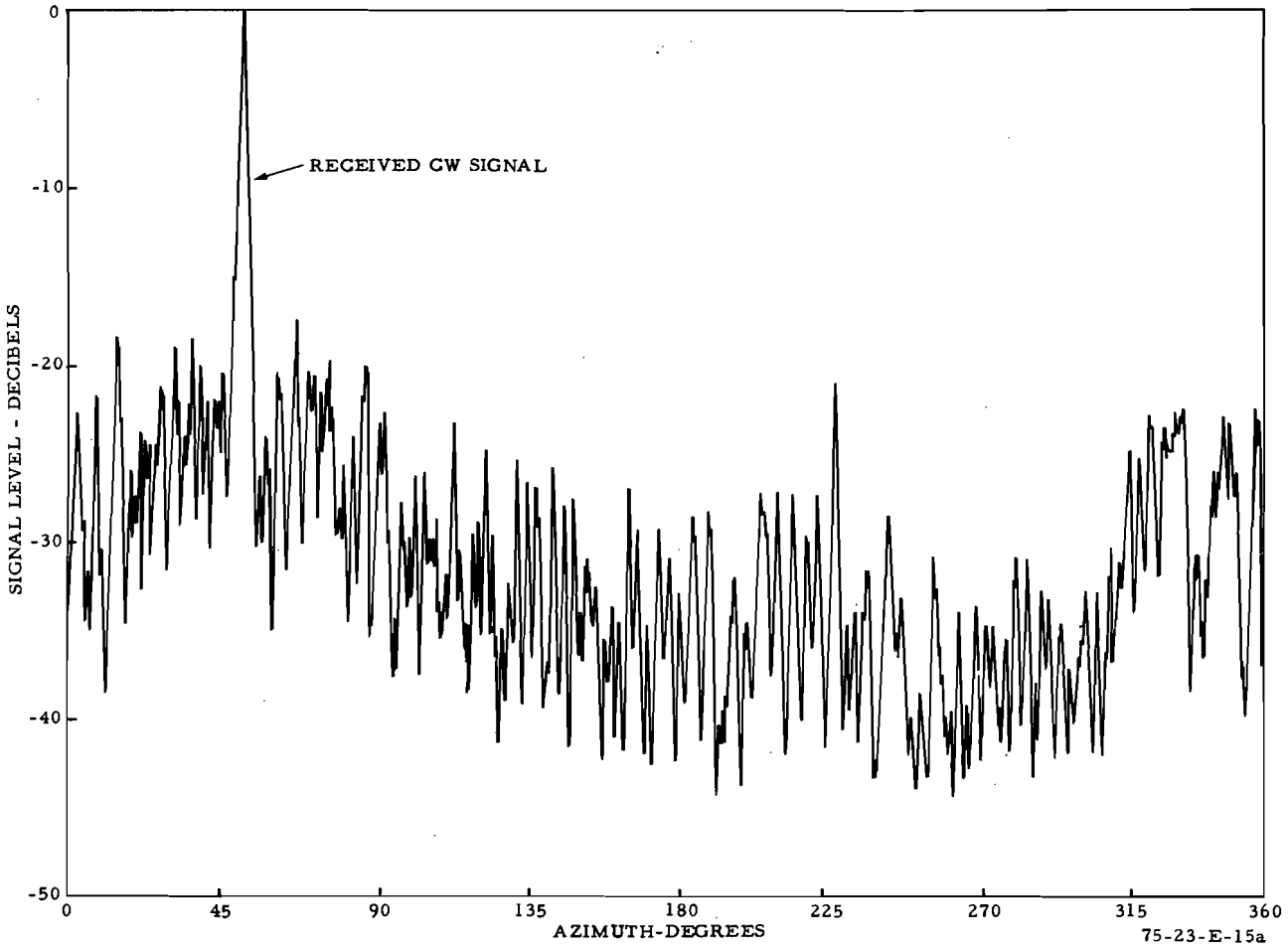


FIGURE B-10a. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS (COMPLETE AND EXPANDED) FOR SUM (Σ) CHANNEL ZERO-DEGREE BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (7/5/74) (COMPLETE)

DATE: 7/5/74
TEST SITE:
FIELD TEST SITE
TEST CONDITIONS:
ESA RECEIVES MODE SELECTED (1090MHz)
NETWORK ANALYZER TEST SET-UP
TOWER HEIGHT =75 FT
BEAM HOPOVER (NONE)
DATA COLLECTION METHOD:
CONTINUOUS-WAVE RF AMPLITUDE
CALIBRATION:
VERTICAL- 10 dB PER MAJOR DIVISION
HORIZONTAL - 11° PER MAJOR DIVISION

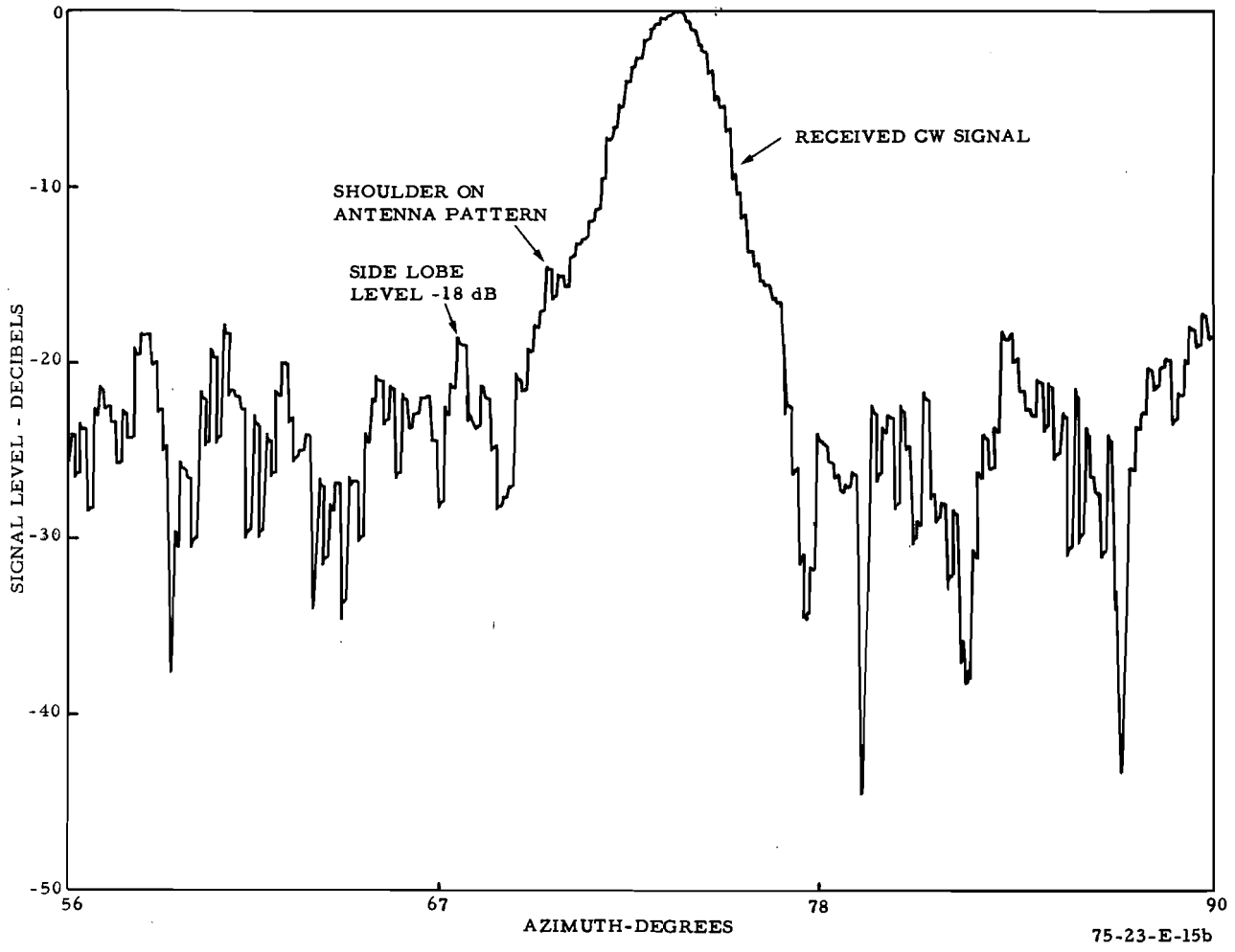


FIGURE B-10b. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS (COMPLETE AND EXPANDED) FOR SUM (Σ) CHANNEL ZERO-DEGREE BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (7/5/74) (EXPANDED)

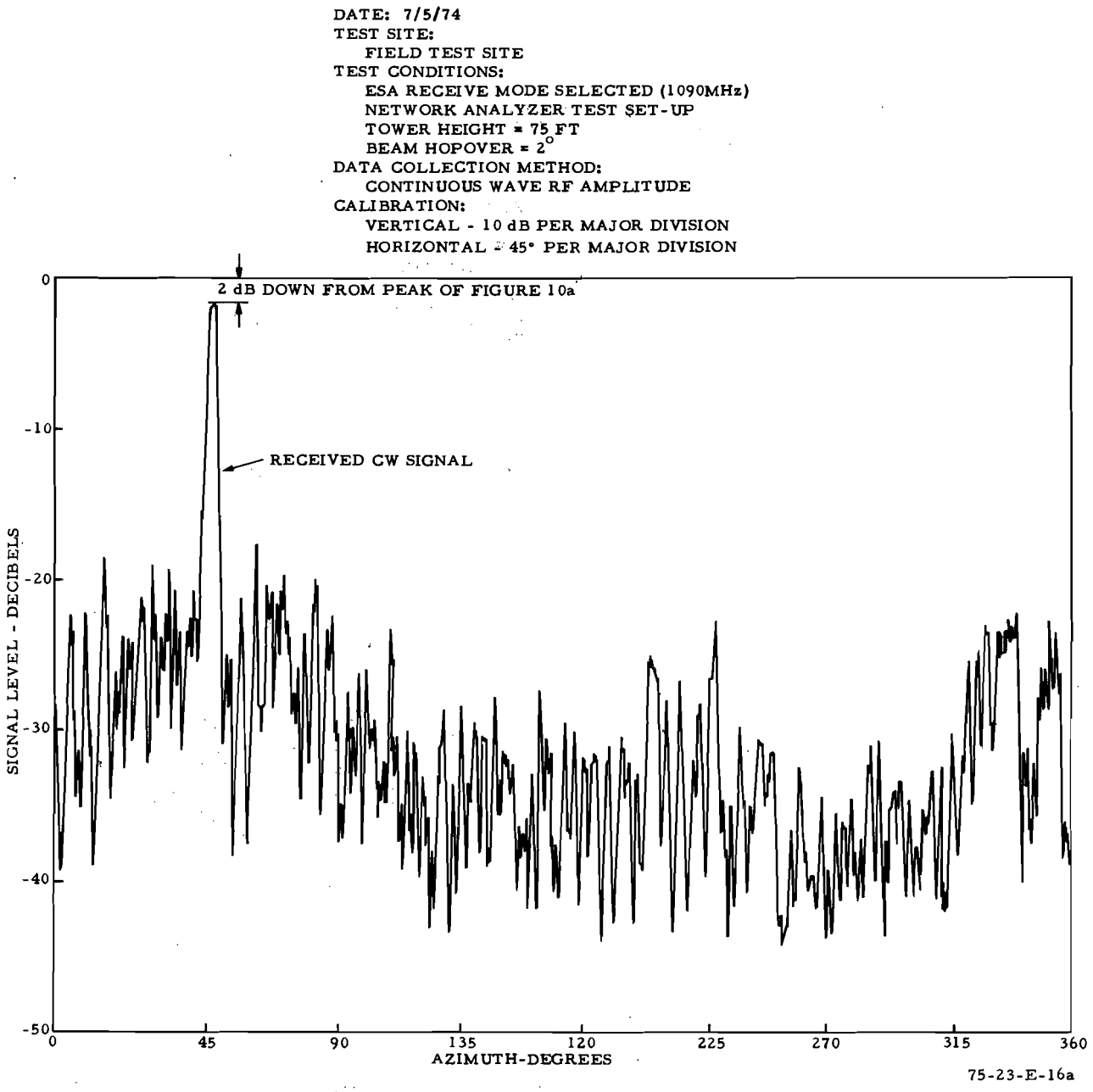


FIGURE B-11a. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS (COMPLETE AND EXPANDED) FOR SUM (Σ) CHANNEL 2° BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (7/5/74) (COMPLETE)

DATE: 7/5/74
TEST SITE:
FIELD TEST SITE
TEST CONDITIONS:
ESA RECEIVE MODE SELECTED (1090 MHz)
NETWORK ANALYZER TEST SET_UP
TOWER HEIGHT = 75 FT
BEAM HOPOVER = 4°
DATA COLLECTION METHOD:
CONTINUOUS-WAVE RF AMPLITUDE
CALIBRATION:
VERTICAL - 10 dB PER MAJOR DIVISION
HORIZONTAL - 11° PER MAJOR DIVISION

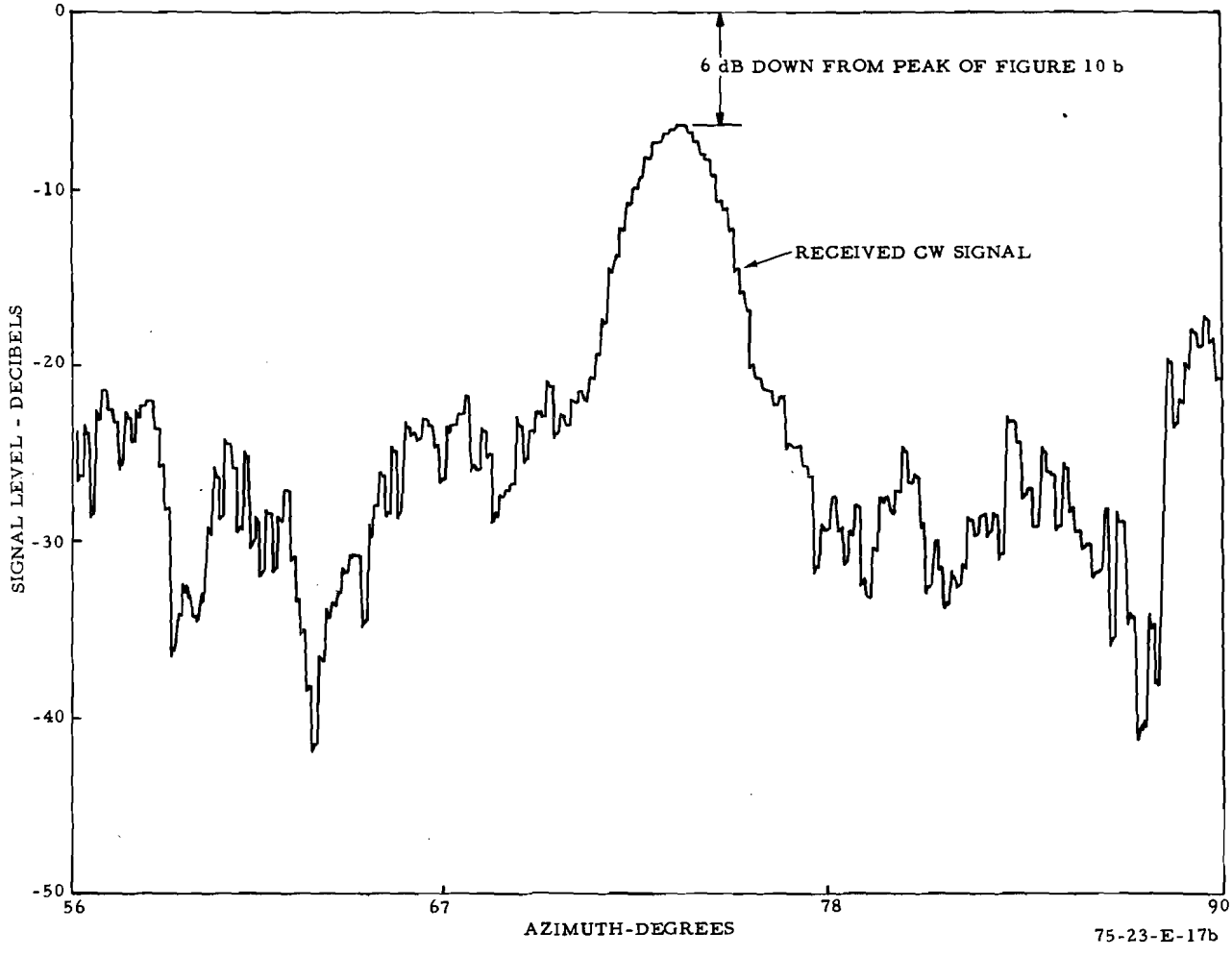
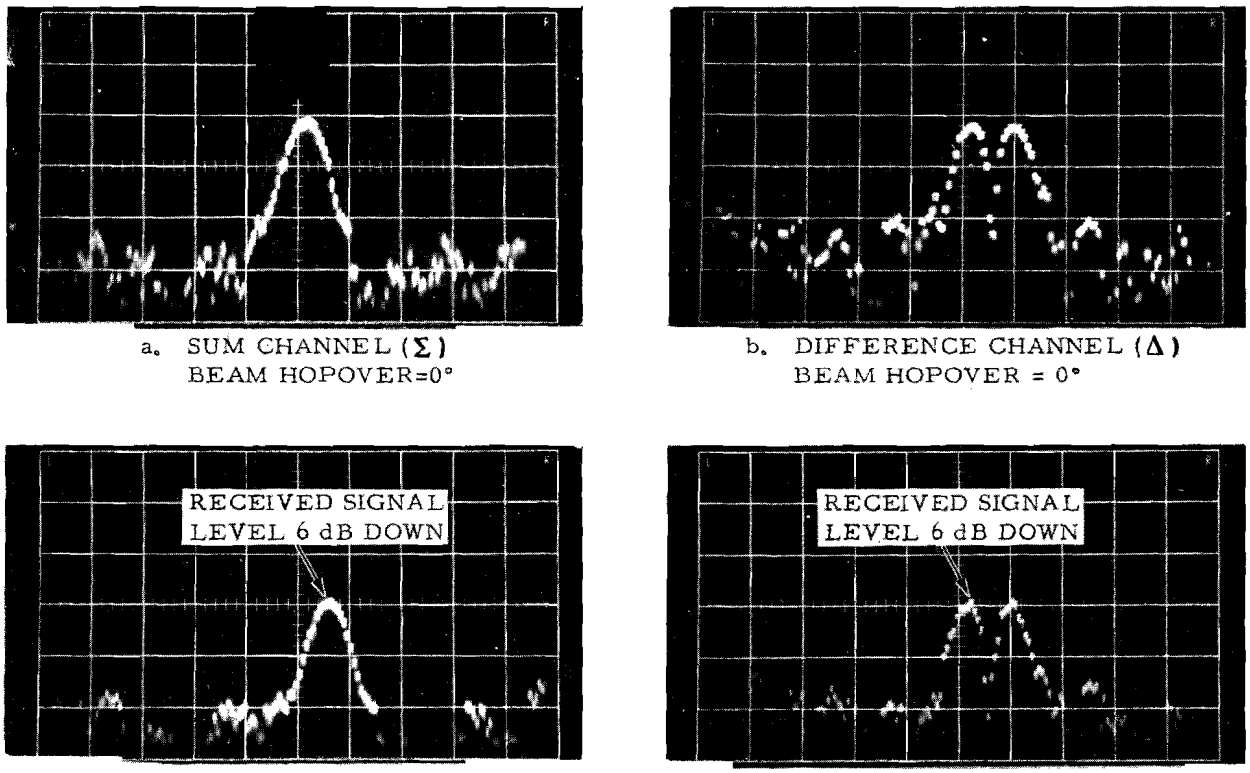


FIGURE B-12b. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS (COMPLETE AND EXPANDED) FOR SUM (Σ) CHANNEL, 4° BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (7/5/74) (EXPANDED)

DATE : 7/5/74
TEST SITE : FIELD TEST SITE
TEST CONDITIONS :
ESA RECEIVED MODE SELECTED (1090 MHZ)
DUAL-CHANNEL RECEIVER SUM AND
DIFFERENCE CHANNEL
BEAM HOPOVER = 0° AND 4°
DATA COLLECTION METHOD :
CONTINUOUS WAVE - RF AMPLITUDE
CALIBRATION :
VERTICAL - 8.3 dB PER MAJOR DIVISION
HORIZONTAL - 3.77° PER MAJOR DIVISION



a. SUM CHANNEL (Σ)
BEAM HOPOVER=0°

b. DIFFERENCE CHANNEL (Δ)
BEAM HOPOVER = 0°

c. SUM CHANNEL (Σ)
BEAM HOPOVER=4°

d. DIFFERENCE CHANNEL (Δ)
BEAM HOPOVER=4°

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FIGURE B-13. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS (PARTIAL) FOR SUM (Σ) AND DIFFERENCE (Δ) CHANNEL 0° AND 4° BEAM HOPOVER, 75-FOOT TOWER AT FIELD TEST SITE (7/5/74)

DATE: 6/5/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF 3.9°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-OFF, TRANSMITTED PEAK POWER = 1,000 W, RECEIVED REPLY SIGNAL LEVEL RECORDED
DATA COLLECTION METHOD:
TRANSPONDER PERFORMANCE ANALYZER
CALIBRATION:
VERTICAL - 12 dB PER MAJOR DIVISION
HORIZONTAL - 4.5° PER MAJOR DIVISION

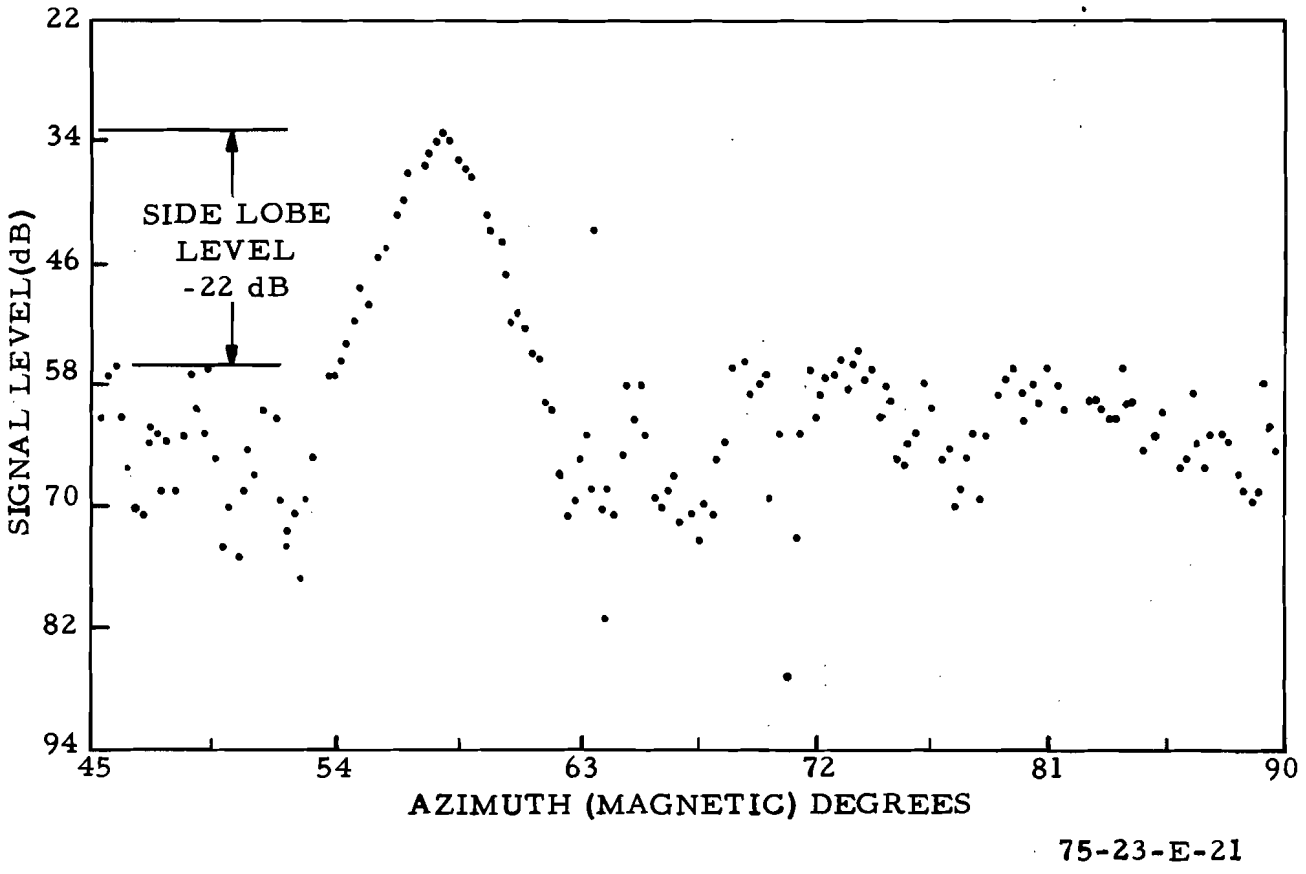

FIGURE B-14. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS FOR SUM (Σ) CHANNEL, ZERO-DEGREE BEAM LIFT, INBOUND RADIAL FLIGHT ON 060° AT 500-FEET ALTITUDE (6/5/74)

DATE: 6/5/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF 5.9°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-OFF, TRANSMITTED PEAK POWER = 1,000 W, RECEIVED REPLY SIGNAL LEVEL RECORDED
DATA COLLECTION METHOD:
TRANSPONDER PERFORMANCE ANALYZER
CALIBRATION:
VERTICAL - 12 dB PER MAJOR DIVISION
HORIZONTAL - 4.5° PER MAJOR DIVISION

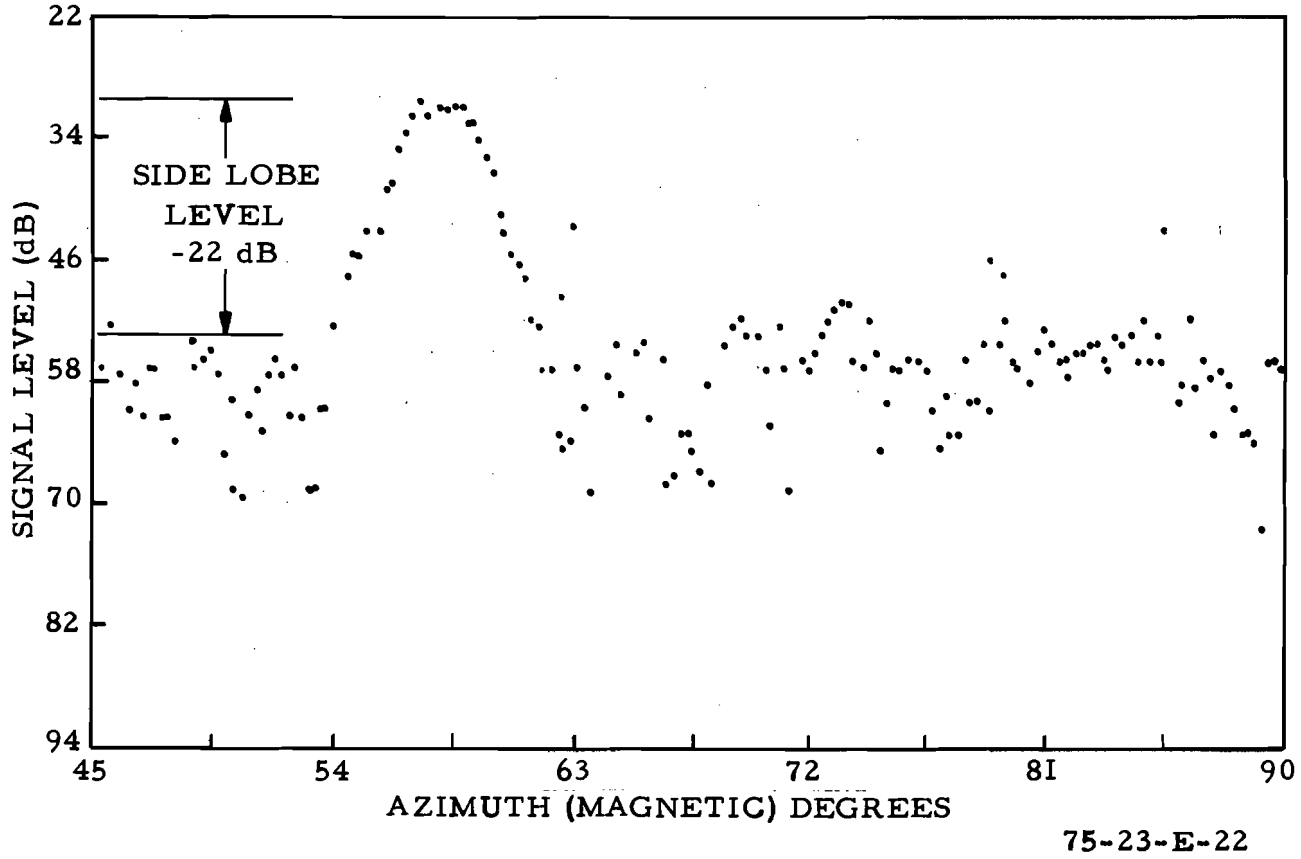

FIGURE B-15. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS FOR SUM (Σ) CHANNEL ZERO-DEGREE BEAM LIFT, INBOUND RADIAL FLIGHT ON 060° AT 500-FOOT ALTITUDE (6/5/74)

DATE: 6/5/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF 7.9°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-OFF TRANSMITTED PEAK POWER = 1,000 W, RECEIVED REPLY SIGNAL LEVEL RECORDED
DATA COLLECTION METHOD:
TRANSPONDER PERFORMANCE ANALYZER
CALIBRATION:
VERTICAL - 12 dB PER MAJOR DIVISION
HORIZONTAL - 4.5° PER MAJOR DIVISION

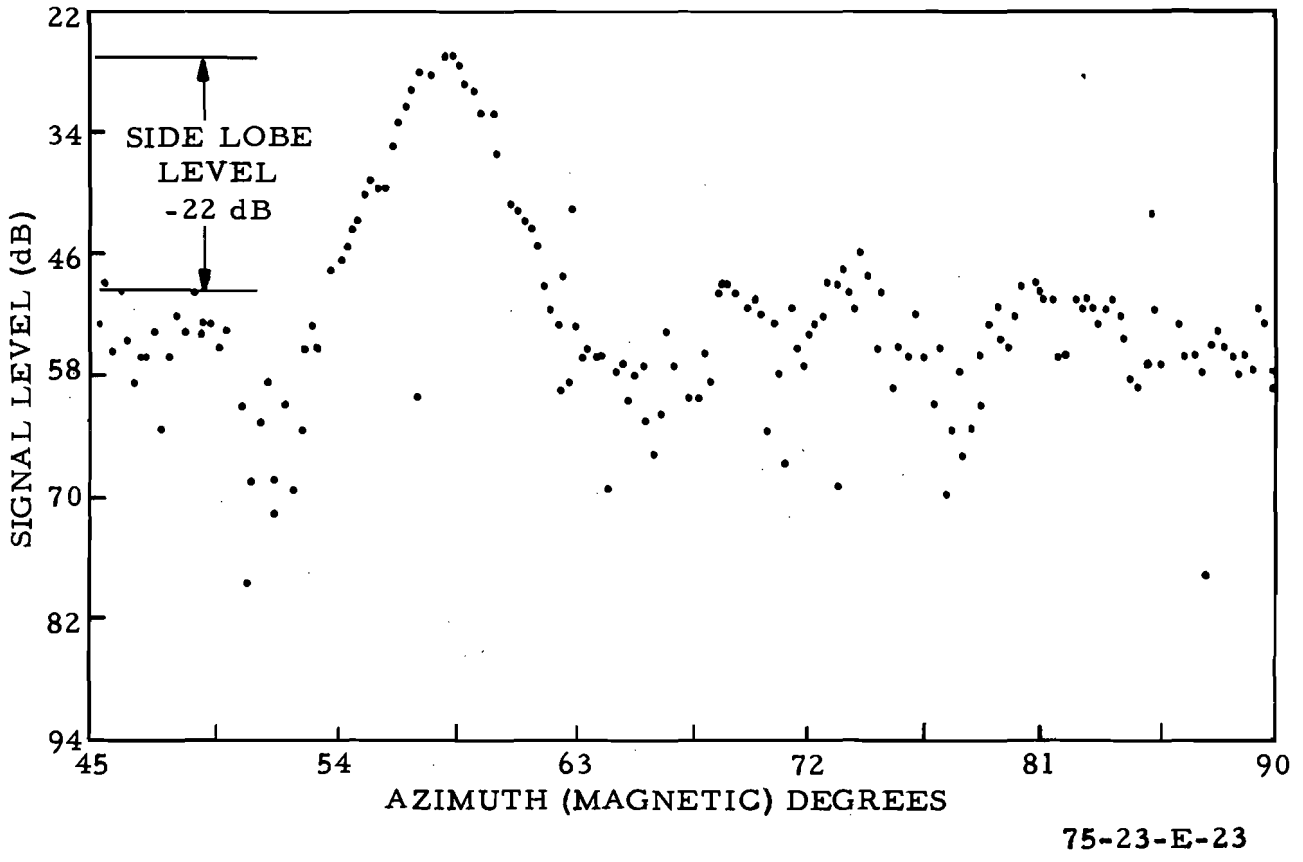

FIGURE B-16. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS FOR SUM (Σ) CHANNEL ZERO-DEGREE BEAM LIFT, INBOUND RADIAL FLIGHT ON 060° AT 500-FEET ALTITUDE (6/5/74)

DATE: 6/5/74
TEST SITE:
AIRCRAFT AT ELEVATION ANGLE OF 10.6°
TEST CONDITIONS:
MODE 3/A INTERROGATION, SLS-OFF, TRANSMITTED PEAK POWER = 1,000 W, RECEIVED REPLY SIGNAL LEVEL RECORDED
DATA COLLECTION METHOD:
TRANSPONDER PERFORMANCE ANALYZER
CALIBRATION:
VERTICAL - 12 dB PER MAJOR DIVISION
HORIZONTAL - 4.5° PER MAJOR DIVISION

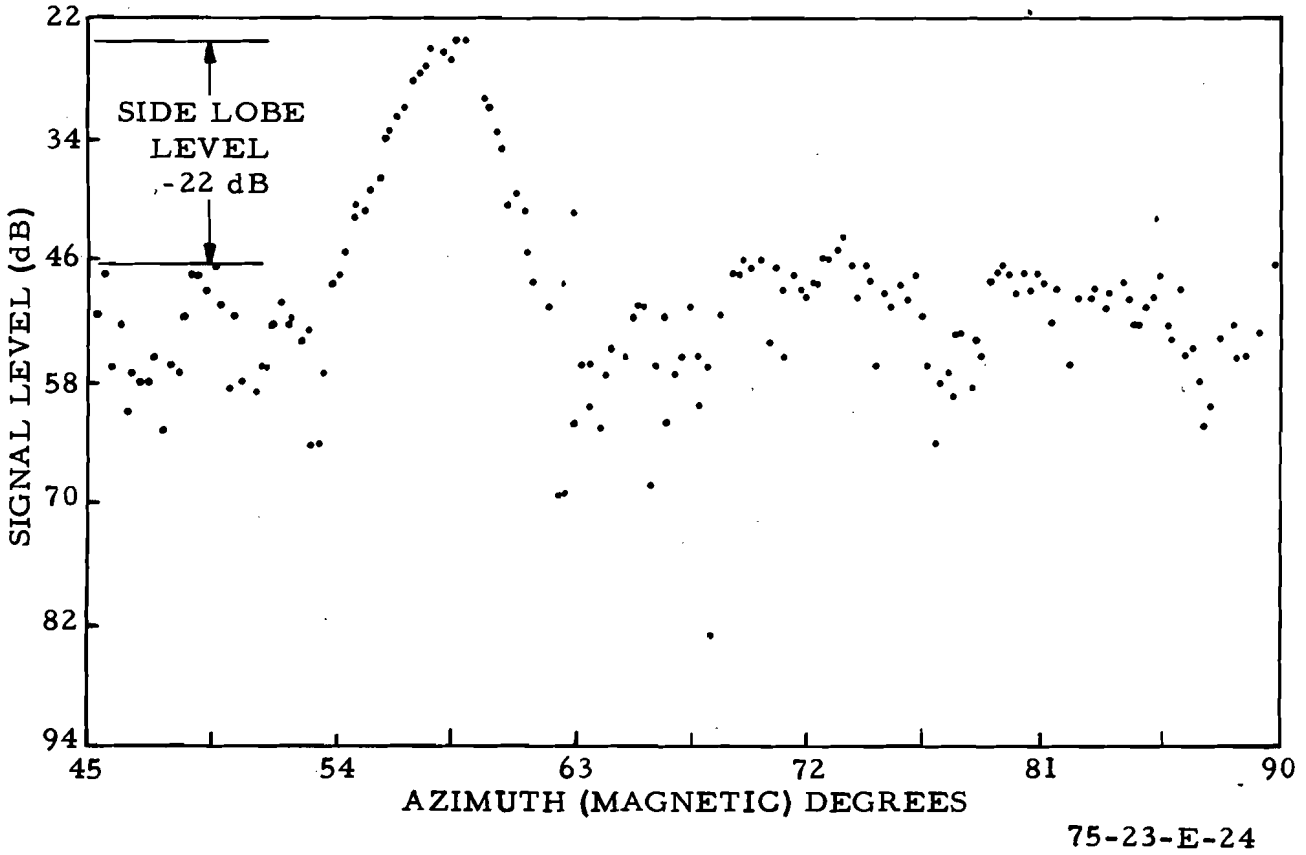

FIGURE B-17. ATCRBS ESA 1090-MHz HORIZONTAL ANTENNA PATTERNS FOR SUM (Σ) CHANNEL ZERO-DEGREE BEAM LIFT, INBOUND RADIAL FLIGHT ON 060° AT 500-FOOT ALTITUDE (6/5/75)