AD-A063 811 ARMY COMMUNICATIONS-ELECTRONICS ENGINEERING INSTALLAT--ETC F/G 17/2
ELECTROMAGNETIC COMPATIBILITY STUDY OF A PROPOSED NATO SATELLIT--ETC(U)
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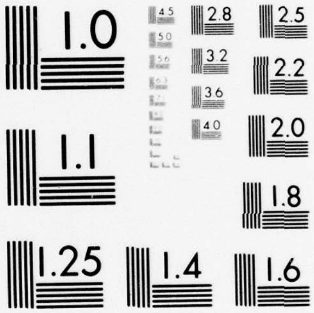

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ELECTROMAGNETIC COMPATIBILITY STUDY OF A PROPOSED NATO SATELLITE EARTH TERMINAL AT THE US NAVAL STATION, KEFLAVIK, ICELAND

BY

⑩ JOHN L. WORD

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Electromagnetic Engineering Office
Electromagnetic Compatibility Engineering Division

⑪ January 1979 ⑫ 52p.

⑨ Field measurement rept. 31 Aug-14 Oct 78

HEADQUARTERS
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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER
CCC-EMEO-ECD-79-MR-48

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (*and Subtitle*)
Electromagnetic Compatibility Study of a Proposed NATO Satellite Earth Terminal at the US Naval Station, Keflavik, Iceland

5. TYPE OF REPORT & PERIOD COVERED
Field Measurement Report
31 Aug - 14 Oct 78

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(*s*)
John L. Word

8. CONTRACT OR GRANT NUMBER(*s*)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
HQ, USACEEIA
ATTN: CCC-EMEO-ECD
Fort Huachuca, AZ 85613

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
HQ, USACEEIA
ATTN: CCC-EMEO-ECD
Fort Huachuca, AZ 85613

12. REPORT DATE
January 1979

13. NUMBER OF PAGES
Forty Eight (48)

14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)

15. SECURITY CLASS. (*of this report*)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)
Distriubtion unlimited. ~~Field Measurements and evaluation.~~ Effective Jan 1979

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)
Electromagnetic Compatibility (EMC)
Satellite Earth Terminal
NATO
Keflavik, Iceland
SATCOM III

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)
The results of on-site measurements and analysis are provided which evaluate the electromagnetic compatibility of a proposed NATO Satellite Earth Terminal with the environment at the US Naval Station, Keflavik, Iceland. It is concluded that all five candidate locations are satisfactory provided that downlink (receive) frequencies are selected in accordance with the guidance provided herein. A list of proposed downlink frequencies, provided by the NATO Integrated Communications System Management Agency, has been evaluated and is acceptable.

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SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

ACKNOWLEDGEMENT

Acknowledgement is given to Commander Dick Heine, US Naval Station, and Mr. George Stroebel, US Naval Communication Station, for the excellent support of the EMC measurement team during their stay at the US Naval Station, Keflavik, Iceland.

Acknowledgement is also given to the measurement team for their contribution in accomplishing this effort. The Team Chief, Eduardo F. Bracamonte, and the Technicians, Steve A. Hussey, Richard E. Crossland, and Mauricio F. Chavez performed their part of the mission under arduous weather conditions.

ABSTRACT

The results of measurements and analysis are provided which evaluate the Electromagnetic Compatibility (EMC) of the proposed NATO satellite earth terminal with the environment at the US Naval Station, Keflavik, Iceland. The on-site measurements were conducted at five candidate locations by the Electromagnetics Engineering Office of the US Army Communications-Electronics Engineering Installation Agency.

It is concluded that, from an EMC viewpoint, all five candidate sites are satisfactory for the location of the proposed earth terminal provided that the downlink (receive) frequencies are selected in accordance with the guidance contained herein. A list of proposed downlink frequencies, provided by the NATO Integrated Communications System Management Agency (NICSMA), has been evaluated and is acceptable.

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1.0 INTRODUCTION

1.1 ASSIGNMENT OF THE TASK. In August 1978, this Agency was requested by the Atlantic Division Naval Facilities Engineering Command (LANTNAVFACENGCOM) in Norfolk, Virginia, to perform an Electromagnetic Compatibility (EMC) survey for a proposed NATO satellite earth terminal at the US Naval Station, Keflavik, Iceland (reference 1). In fulfillment of this request, this Agency performed on-site EMC field measurements at five candidate locations.

1.2 BACKGROUND. Currently, an interim AN/MSC-46 satellite earth terminal exists at Keflavik. Plans are being made for a new permanent earth terminal in accordance with the NATO, Phase III program. The NATO Satellite Communication Phase III (SATCOM III) Ground Terminal System, described in reference 5, will handle digital traffic in the Time Division Multiplex/Quadraphase Shift Keyed/Frequency Division Multiple Access (TDM/QPSK/FDMA) mode with Spread Spectrum Multiple Access (SSMA) links added as required.

The five candidate sites surveyed have been designated as Site 3A, 3B, 3C, 3D, and 3E. Table 1 shows the approximate coordinates and description of each site. Figure 1 is a site layout diagram of the US Naval Station, Keflavik, Iceland and shows the five sites.

Table 2 shows the principal characteristics of the proposed SATCOM III earth terminal. Measurements and analyses were made to accommodate accessing either the NATO IIIA or the Defense Satellite Communication System (DSCS) Atlantic satellite. Table 3 shows the look angles (azimuth and elevation angle) from the five sites to the satellites.

There are six downlinks proposed. The proposed data rates and operating frequencies, as provided by the NATO Integrated Communications System Management Agency (NICSMA) in reference 3, are shown in Table 4.

1.3 APPROACH TO THE TASK.

1.3.1 General Objective. The general objective of the EMC study was to conduct on-site measurements and perform analyses which identify potential electromagnetic interference (EMI) to the proposed satellite earth terminal.

1.3.2 General Requirements.

1.3.2.1 Personnel. A five man EMC measurement team from the Electromagnetics Engineering Office (EMEO), of this Agency, was required to conduct the field measurements, analyze the data and prepare the technical report.

1.3.2.2 Equipment. Receivers, amplifiers, antennas and ancillary equipment were required to cover the frequency range of interest (See Appendix A for a detailed equipment list). A 45 foot tower was provided by the US Naval Communication Station at Keflavik.

1.3.2.3 External Support. The US Naval Communication Station and US Naval Station, Keflavik, Iceland, provided a portable power generator, a tower, a tower erection team and on-site support.

1.3.3 Schedule. On-site measurements were conducted from 31 August thru 14 October 1978 as follows:

SITE	TIME PERIOD OF MEASUREMENTS
3C	31 Aug - 7 Sep 78
3E	8 Sep - 17 Sep 78
3A	18 Sep - 27 Sep 78
3D	28 Sep - 4 Oct 78
3B	5 Oct - 14 Oct 78

2.0 SUMMARY OF RESULTS

2.1 GENERAL. The results of the field measurements are summarized in this section. The details of the measurement procedure, measurement equipment, data reduction and analysis techniques are provided in Appendix A.

2.2 SIGNALS OBSERVED. The measurement system recorded all incoming signals in the frequency range of 5810 - 7750 MHz which covers the downlink (receive) frequency range (7250 - 7750 MHz) and the image bands of the proposed earth terminal. In general, the same signals were received at each site but differed primarily in signal strength and angle of arrival. Site 3D received a few less signals, and weaker signal strengths, because it was lower in elevation than the other sites and received some screening from the terrain.

A total of 12 signals at Site 3A, 11 signals at Site 3B, 10 signals at Site 3C, 6 signals at Site 3D and 11 signals at Site 3E were observed in the frequency range of 7250 - 7750 MHz. No significant image band signals were detected. All of the signals appeared to be terrestrial in origin. Tables 5 thru 9 show the signals observed at Site 3A, 3B, 3C, 3D and 3E, respectively. Tables 5 thru 9 show the documented frequency, arrival azimuth, elevation angle, polarity, bandwidth, power density and whether or not the signal is strong enough to be a potential interferer to the proposed earth terminal.

2.3 DYE-5 TROPO MEASUREMENTS. Also included in the study was a measurement of the DYE-5 Tropo signals at each of the five sites. The DYE-5 Tropo Site, shown on Figure 1, consists of four 120 foot parabolic billboard antennas and operates at frequencies of 906, 918, 930 and 942 MHz with up to 50 kilowatts of power into each antenna. Two of the antennas point in a westward direction, and two of the antennas point in an eastward direction toward the five candidate satellite earth terminal sites.

The DYE-5 Tropo Site was of interest to the EMC project engineer for two reasons:

a. Fundamental power densities, if strong enough, could cause case penetration problems to the proposed earth terminal.

b. Eighth order harmonics of the tropo transmitters would lie in the normal operating frequency range of the proposed earth terminal and could, if strong enough, cause interference.

Table 10 shows the measured power densities of the fundamental frequencies of the DYE-5 transmitters at each site. Case penetration is normally assumed to occur at power densities of +20 dBm/m^2 or greater. As Table 10 shows, none of the signals are strong enough to cause case penetration.

Eighth order harmonics of the DYE-5 transmitters would show in Tables 5 thru 9 as frequencies of 7248, 7344, 7440 and 7536 MHz at azimuths of approximately 255 to 275 degrees. Only one possible eighth order harmonic was received at Site 3D and its signal strength (power density) was too weak to interfere with the proposed earth terminal.

It is therefore concluded that the DYE-5 Tropo transmitters will have no significant impact on the proposed NATO satellite earth terminal.

2.4 POTENTIAL EMI TO THE PROPOSED NATO SATELLITE EARTH TERMINAL. Some of the signals received were strong enough to be above the on-tuned interference threshold of the proposed NATO satellite earth terminal and are considered to be possible interferers. Table 11 shows a list of these frequencies and the regions of possible interference (recommended frequency separation).These regions of possible interference should be avoided in selecting downlink (receive) frequencies. If the earth terminal were to operate in the regions defined in Table 11, then it would be highly probable that interference to the earth terminal receivers, caused by terrestrial transmitters, would occur.

In comparing the proposed downlink frequencies in Table 4 with the regions of possible interference in Table 11, it can be seen that all of the proposed frequencies are acceptable.

Although Table 11 shows that some sites are better than others, it is concluded that all five candidate locations are suitable, from an EMC viewpoint, for the NATO earth terminal if the proposed frequencies of Table 4 are utilized. Other downlink frequencies can be selected, if desired, by merely avoiding the regions of possible interference defined in Table 11. The information contained in Table 11 is also shown in a graphical form in Appendix B.

3.0 EFFECTS OF AIRCRAFT

3.1 GENERAL. This Agency has been asked on several occasions whether aircraft flying in or near the main beam of a microwave antenna or a satellite earth terminal will have an impact on system performance. References 2, 3, 4 and 6 express a concern as to the effects of low flying aircraft on the performance of the proposed NATO earth terminal receiver as well as the effects of the earth terminal transmitter on the aircraft communications and possible hazards to the aircraft.

As Figure 1 shows, all of the candidate earth terminal locations are near the Keflavik Airport. In an attempt to determine the frequency of occurrence of aircraft in or near the main beam at the five candidate earth terminal sites, the EMC measurement team made visual observations which are shown in Table 12. However, Table 12 cannot be considered as very accurate since the observations were highly subjective and were made over a very limited time period.

Very little research has been conducted on the effects of aircraft and therefore this Agency considers it to be beyond the state-of-the-art to give an authoritative answer to all the questions asked. However, the following paragraphs provide what information is known and what steps this Agency is taking to solve these questions in the future.

3.2 EFFECTS OF AIRCRAFT ON SATELLITE EARTH TERMINAL RECEIVER PERFORMANCE. Some tests have been performed to determine the effects of aircraft on microwave links, however this Agency knows of no tests made with respect to earth terminal systems.

3.2.1 Recent Tests Conducted. This Agency has recently funded the US Department of Commerce, National Telecommunications and Information Administration (NTIA), Institute for Telecommunication Sciences (ITS), Boulder, Colorado 80303, to conduct tests over existing 8 GHz microwave links which cross runways at the international airports at Atlanta, Georgia and Chicago, Illinois. Their report (reference 7) will be published soon, however their preliminary findings are:

a. Aircraft in motion during take-off, taxi or landing, can cause signal fades of up to 20 dB.

b. The effects of reflections or multipath do not appear to be significant.

c. Since microwave links usually employ diversity and fade margins of 30 to 40 dB, system performance should not be significantly affected by aircraft.

The application of NTIA/ITS's results to a satellite earth terminal is of questionable validity. A 20 dB signal fade would be detrimental to an earth terminal which does not employ diversity and typically has a fade margin of 5 to 10 dB. However, the 20 dB fades observed by NTIA/ITS were caused by large, relatively slow moving (taxi, take-off, landing) aircraft intersecting a microwave beam over very short microwave links. It seems doubtful to this author that large aircraft would fly close enough(and slow enough)to an earth terminal beam to cause such a large fade. However, until such time as earth terminal tests are conducted, this area remains unknown.

3.2.2 Further Studies Planned. This Agency hopes to further the study of the effects of aircraft by:

a. Funding the University of Houston to conduct a laboratory experiment entitled "Simulation Study on Aircraft Blockage Effects on Microwave Links Traversing Runways and Taxiways". Ultrasonic waves and aircraft models will be used to perform the simulation.

b. Flying aircraft through existing digital microwave links in the Fort Huachuca, Arizona area as part of the ongoing digital transmission tests.

3.3 EFFECTS OF SATELLITE EARTH TERMINAL TRANSMITTERS ON AIRCRAFT COMMUNICATION SYSTEMS. Air Traffic Control (ATC) communication systems operate in the VHF-FM (25 - 70 MHz), VHF (100 - 155 MHz) and UHF (200 - 285 MHz) frequency bands. Since the satellite earth terminal transmits in the frequency range of 7900 - 8400 MHz, there should be no interference to the aircraft communication systems.

3.4 HAZARDS TO THE AIRCRAFT. There are two types of hazards to be considered as an aircraft flies through the beam of a high power transmitter: (1) hazards to electroexplosive devices (EEDs) being transported, and (2) hazards to on board personnel. EEDs are explosive devices, such as cartridges, squibs, blasting caps, igniters and primers, which can be accidentally fired if exposed to high amounts of electromagnetic energy. There is a time factor involved with exposure of personnel to high radiation levels, but the firing of EEDs would be nearly instantaneous. The greater hazard would probably be to EEDs being transported, however if an authoritative answer on personnel hazards is desired it should be obtained from:

Commander
US Army Environmental Hygiene Agency
ATTN: HFE-RL-M
Aberdeen Proving Ground, MD 21010

Reference 8 states that a maximum allowable power density of 100 watts per square meter is considered safe for EEDs transported in metallic containers or for externally loaded weapons on an aircraft in flight. Up to 26.5 watts per square meter is considered safe for taxing aircraft with externally loaded weapons or for EEDs transported in non-metallic containers. Using the more stringent requirement of 26.5 watts per square meter, Table 13 shows the predicted "hazard distances" for the proposed NATO earth terminal for various transmitter power levels using the analytical techniques of references 8 and 9. "Hazard distance" is that distance from the earth terminal antenna, along the bore sight axis, which is considered hazardous to EEDs.

The normal operating transmitter power of the proposed earth terminal was not provided to this Agency, however other earth terminals of this type rarely ever exceed 250 watts during normal operation. As Table 13 shows, there is no predicted potential hazard for transmitter power levels of up to 1000 watts. The maximum output power of the proposed earth terminal is 5000 watts (see Table 2) which should only be considered for use in an anti-jamming situation during wartime conditions. At the full 5000 watts of transmitter power, a potential hazard is predicted to exist to aircraft carrying EEDs if they fly through the 0.2 degree beamwidth and are within 11,738 feet of the earth terminal.

If the potential hazard to aircraft, which is only predicted to exist at excessive earth terminal transmitter power levels, is a major concern, then two possible solutions are: (1) restrict flight patterns and (2) limit the earth terminal output power to a maximum of 1000 watts at the antenna feed.

4.0 CONCLUSIONS. The following conclusions are provided:

a. All five candidate sites are suitable, from an EMC viewpoint, for the proposed NATO satellite earth terminal if the downlink (receive) frequencies are carefully selected.

b. The proposed downlink frequencies, provided by NICSMA and shown in Table 4, have been evaluated and are acceptable. Other downlink frequencies may be selected, if desired, by following the guidance contained in this report.

c. The existing high power DYE-5 Tropo transmitters should have no effect on the proposed earth terminal.

d. The effect of low flying aircraft on the performance of the earth terminal receivers is largely unknown. Any adverse effects would probably be the same for each site.

e. The earth terminal transmitters should have no effect on aircraft communications or instrumentation.

f. No hazard to the aircraft as it passes through the earth terminal beam is predicted for normal operating transmitter power levels. At the full maximum 5000 watts of transmitter power, used only during anti-jamming wartime conditions, a potential hazard is predicted.

FIGURE 1

SITE LAYOUT DIAGRAM OF THE US NAVAL STATION, KEFLAVIK, ICELAND

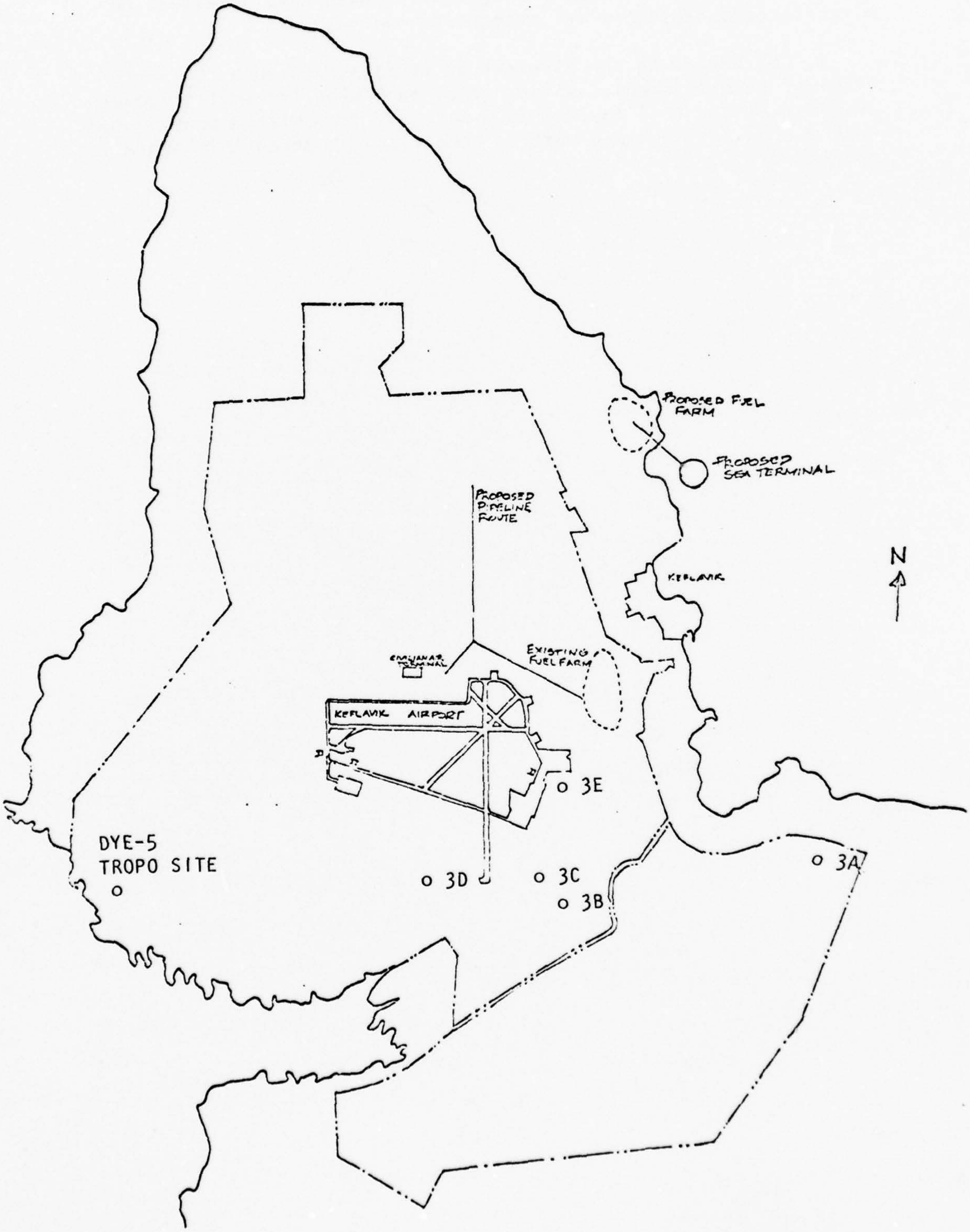


TABLE 1

APPROXIMATE SITE COORDINATES AND DESCRIPTION

SITE	LATITUDE	LONGITUDE	DESCRIPTION
3A	63° 57' 58" N	22° 30' 0" W	Original NATO site outside of fenced area but within the agreed area.
3B	63° 57' 30" N	22° 34' 03" W	Area South of contractor camp.
3C	63° 57' 51" N	22° 35' 30" W	Area in vicinity of Commander Iceland Defense Forces (COMICEDEFOR) and Proposed Hardened Command Post.
3D	63° 57' 52" N	22° 37' 50" W	Just North of the road to NAVFAC/DYE-5 but approximately one mile West of the South end of runway 03.
3E	63° 58' 38" N	22° 34' 58" W	Area in vicinity of Interim AN/MSC-46 Satellite Earth Terminal.

TABLE 2

NATO SATCOM III EARTH TERMINAL CHARACTERISTICS

ANTENNA SIZE	46 FOOT PARABOLIC ANTENNA WITH CASSEGRAIN FEED
Transmit Frequency Range	7.9 - 8.4 GHz
Transmit Antenna Gain	59 dBi minimum
Transmit Power (at feed)	1 watt to 5 kW
Receive Frequency Range	7.25 - 7.75 GHz
Receive Antenna Gain	58 dBi minimum
Receive Antenna 3 dB Beamwidth	0.2 Degrees
Antenna First Side Lobe	±0.28 degrees from center bore 15 dB below main beam
Receive System Noise Temperature	220° K, including radome
Intermediate Frequencies:	
700 MHz bandwidth (1 dB)	120 MHz minimum
70 MHz bandwidth (1 dB)	40 MHz for SSMA links 10 MHz for QPSK links
Communications Modems	QPSK
Data Rates: without FEC	100 kb/s to 10 Mb/s
with FEC	100 kb/s to 2 Mb/s
Demodulator Filter	
3 dB Bandwidth	0.9 Hertz/bit per second
No. of poles	5 pole Butterworth

This table is based upon references 2, 3, 4 and 5.

TABLE 3

LOOK ANGLES

	PRIMARY SATELLITE NATO IIIA at 18° W, 0° N		BACKUP SATELLITE DSCS ATLANTIC at 12° W, 0° N	
SITE	True North Azimuth	Elevation Angle	True North Azimuth	Elevation Angle
3A	175.0	+17.7	168.3	+17.3
3B	174.9	+17.7	168.3	+17.3
3C	174.9	+17.7	168.2	+17.3
3D	174.9	+17.7	168.2	+17.3
3E	174.9	+17.7	168.3	+17.3

TABLE 4

PROPOSED DOWNLINK (RECEIVE) CHARACTERISTICS OF THE NATO EARTH TERMINAL

	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6
Frequency (MHz)	7325.543	7313.320	7326.000	7314.884	7317.950	7321.505
Data Rate (kb/s) (without FEC)	139	980	173	450	760	139
Modulation	QPSK	QPSK	QPSK	QPSK	QPSK	QPSK

1. Half rate and three quarter rate forward error correction (FEC) coding will be used on selected links.

2. This table is based upon reference 3.

TABLE 5

SIGNALS RECEIVED AT SITE 3A

NO.	FREQUENCY MHz	TRUE NORTH AZIMUTH DEGREES	ELEVATION ANGLE DEGREES	POLARITY	APPARENT BANDWIDTH MHz	POWER DENSITY dBm/m^2	POTENTIAL INTERFERER
1	7745.1	8	-1	H	2.2	-85.2	No
		56	0	H	2.0	-89.1	No
		292	0	45	2.0	-89.3	No
		323	0	45	3.0	-73.3	Yes
2	7638.2	29	-1	H	3.0	-79.5	Yes
		56	-1	H	0.5	-97.4	No
3	7588.9	31	-1	H	4.1	-77.6	Yes
4	7550.0	57	0	45	0.7	-86.0	No
		311	-1	45	1.6	-70.4	Yes
5	7477.3	30	-1	H	2.3	-84.6	No
6	7445.6	20	-1	45	2.0	-91.2	No
7	7439.3	61	0	H	0.3	-96.5	No
8	7428.2	30	0	45	2.1	-79.5	Yes
		58	0	45	1.0	-94.8	No
9	7390.7	56	+1	H	1.2	-87.6	No
		325	0	H	2.2	-72.0	Yes
10	7345.0	59	0	V	2.5	-87.2	No
11	7298.3	60	+1	V	0.3	-93.0	No
12	7298.0	68	+1	H	1.2	-94.8	No

NOTE: 1. Multiple entries of the same frequency, received from different directions, indicate the presence of ground reflections or multipath conditions.

2. The "apparent bandwidth" corresponds to the bandwidth of the received signal at the peak noise level of the measurement equipment.

TABLE 6

SIGNALS RECEIVED AT SITE 3B

NO.	FREQUENCY MHz	TRUE NORTH AZIMUTH DEGREES	ELEVATION ANGLE DEGREES	POLARITY	APPARENT BANDWIDTH MHz	POWER DENSITY dBm/m^2	POTENTIAL INTERFERER
1	7747.4	8	0	V	2.9	-88.3	No
		57	0	H	2.9	-77.3	Yes
2	7638.2	30	0	H	4.0	-86.0	No
		55	0	H	3.9	-80.6	Yes
3	7588.8	31	0	45	0.8	-95.1	No
		55	0	H	1.9	-86.4	No
4	7550.1	55	0	H	3.0	-64.1	Yes
5	7477.3	30	0	H	1.0	-95.0	No
		56	0	H	1.9	-88.8	No
6	7438.5	59	0	45	2.0	-91.2	No
7	7428.2	30	0	H	3.0	-84.4	No
		56	0	H	3.0	-88.0	No
8	7390.8	55	0	H	1.9	-73.9	Yes
		343	+1	H	1.1	-89.9	No
9	7345.0	57	0	H	0.9	-96.8	No
10	7298.3	58	0	V	0.8	-94.3	No
11	7297.9	67	0	H	0.9	-95.5	No

NOTE: 1. Multiple entries of the same frequency, received from different directions, indicate the presence of ground reflections or multipath conditions.

2. The "apparent bandwidth" corresponds to the bandwidth of the received signal at the peak noise level of the measurement equipment.

TABLE 7

SIGNALS RECEIVED AT SITE 3C

NO.	FREQUENCY MHz	TRUE NORTH AZIMUTH DEGREES	ELEVATION ANGLE DEGREES	POLARITY	APPARENT BANDWIDTH MHz	POWER DENSITY dBm/m^2	POTENTIAL INTERFERER
1	7745.2	6	+1	H	2.6	-87.3	No
		22	+1	H	2.6	-86.8	No
		56	+1	H	2.7	-77.5	Yes
2	7638.2	56	+1	H	2.9	-82.2	Yes
3	7588.8	32	0	H	3.0	-88.2	No
		58	0	H	3.0	-83.5	No
4	7550.0	32	0	H	4.6	-78.0	Yes
		58	-1	H	4.6	-58.9	Yes
		308	0	H	4.6	-74.0	Yes
		324	0	H	4.6	-70.4	Yes
		350	0	H	4.6	-71.7	Yes
5	7477.3	32	0	H	1.8	-90.3	No
		58	-1	H	1.8	-84.0	No
6	7446.4	22	0	V	3.0	-89.1	No
7	7428.1	32	0	45	1.0	-95.4	No
		56	0	45	1.0	-93.2	No
8	7390.7	20	0	H	2.0	-83.6	Yes
		56	0	H	2.0	-78.3	Yes
		340	0	H	2.0	-89.1	No
9	7345.1	59	+1	45	0.3	-96.9	No
10	7298.0	68	+1	H	1.0	-96.6	No

NOTE: 1. Multiple entries of the same frequency, received from different directions, indicate the presence of ground reflections or multipath conditions.

2. The "apparent bandwidth" corresponds to the bandwidth of the received signal at the peak noise level of the measurement equipment.

TABLE 8

SIGNALS RECEIVED AT SITE 3D

NO.	FREQUENCY MHz	TRUE NORTH AZIMUTH DEGREES	ELEVATION ANGLE DEGREES	POLARITY	APPARENT BANDWIDTH MHz	POWER DENSITY dBm/m^2	POTENTIAL INTERFERER
1	7747.4	61	+1	H	0.6	-97.9	No
		76	0	H	0.5	-98.2	No
2	7550.0	25	0	H	2.0	-86.1	No
		56	0	H	1.6	-86.7	No
		73	0	H	1.0	-93.0	No
		356	0	H	2.0	-90.6	No
3	7439.4	276	+1	V	5.4	-86.5	No
4	7390.8	55	+2	V	0.4	-95.6	No
		72	+1	H	0.4	-93.7	No
5	7345.0	73	0	45	0.5	-92.5	No
6	7298.3	74	0	H	0.2	-99.0	No

NOTE: 1. Multiple entries of the same frequency, received from different directions, indicate the presence of ground reflections or multipath conditions.

2. The "apparent bandwidth" corresponds to the bandwidth of the received signal at the peak noise level of the measurement equipment.

TABLE 9

SIGNALS RECEIVED AT SITE 3E

NO.	FREQUENCY MHz	TRUE NORTH AZIMUTH DEGREES	ELEVATION ANGLE DEGREES	POLARITY	APPARENT BANDWIDTH MHz	POWER DENSITY dBm/m^2	POTENTIAL INTERFERER
1	7745.2	30	+1	45	7.9	-57.0	Yes
		62	+1	H	3.9	-79.4	Yes
2	7638.2	36	+1	H	1.1	-95.2	No
		62	+1	H	1.1	-91.5	No
3	7588.8	34	+1	H	2.9	-81.8	No
		60	0	H	1.1	-91.8	No
4	7550.0	60	+1	H	3.9	-58.6	Yes
		314	+1	H	2.9	-76.8	Yes
		356	+1	H	1.9	-70.2	Yes
5	7477.3	34	+1	H	2.9	-81.9	Yes
		58	+1	H	1.1	-90.6	No
6	7439.2	63	+1	H	11.8	-74.8	No
7	7428.2	34	+1	H	2.9	-84.1	No
8	7390.7	27	0	45	2.0	-61.1	Yes
		58	0	H	1.9	-81.0	Yes
9	7345.0	61	-1	H	2.9	-90.3	No
10	7298.3	61	0	45	0.2	-93.5	No
11	7298.0	70	0	H	1.9	-93.1	No

NOTE: 1. Multiple entries of the same frequency, received from different directions, indicate the presence of ground reflections or multipath conditions.

2. The "apparent bandwidth" corresponds to the bandwidth of the received signal at the peak noise level of the measurement equipment.

TABLE 10

FUNDAMENTAL DYE-5 TROPO SIGNALS MEASURED

SITE	Measured Power Densities in dBm/m^2			
	906 MHz	918 MHz	930 MHz	942 MHz
3A	(1)	(1)	(2)	-38.1
3B	(1)	(1)	-46.3	-45.4
3C	(1)	(1)	-36.5	-31.7
3D	-48.3	(1)	-14.8	-10.2
3E	(1)	(1)	-37.2	-34.9

NOTE: (1) The signals were below the threshold of the measurement equipment and therefore too weak to measure.

(2) The transmitter was not operating during the measurement period.

TABLE 11

REGIONS OF POSSIBLE INTERFERENCE TO THE PROPOSED EARTH TERMINAL WHEN ORIENTED AT EITHER THE NATO IIIA OR THE DSCS ATLANTIC SATELLITE

SITE	POTENTIAL INTERFERING FREQUENCY MHz	RECOMMENDED SEPARATION MHz	REGION OF POSSIBLE INTERFERENCE IN MHz	
			FROM	TO
3A	7745.1	±1.9	7743.2	7747.0
	7638.2	±1.7	7636.5	7639.9
	7588.9	±2.3	7586.6	7591.2
	7550.0	±1.2	7548.8	7551.2
	7428.2	±1.2	7427.0	7429.4
	7390.7	±1.3	7389.4	7392.0
3B	7747.4	±1.6	7745.8	7749.0
	7638.2	±2.1	7636.1	7640.3
	7550.1	±1.7	7548.4	7551.8
	7390.8	±1.1	7389.7	7391.9
3C	7745.2	±1.5	7743.7	7746.7
	7638.2	±1.6	7636.6	7639.8
	7550.0	±2.5	7547.5	7552.5
	7390.7	±1.1	7389.6	7391.8
3D	None	None	None	None
3E	7745.2	±4.2	7741.0	7749.4
	7550.0	±2.1	7547.9	7552.1
	7477.3	±1.6	7475.7	7478.9
	7390.7	±1.6	7389.1	7392.3

TABLE 12

NUMBER OF AIRCRAFT OBSERVED TO BE FLYING IN OR NEAR THE MAIN BEAM OF THE PROPOSED EARTH TERMINAL WHEN ORIENTED TOWARD THE NATO IIIA OR THE DSCS ATLANTIC SATELLITE

SITE	NO. OF AIRCRAFT	TIME PERIOD*
3A	1	18 Sep - 27 Sep 78
3B	1	5 Oct - 14 Oct 78
3C	0	31 Aug - 7 Sep 78
3D	10	28 Sep - 4 Oct 78
3E	0	8 Sep - 17 Sep 78

*Daylight hours only when the EMC team was taking on-site measurements.

TABLE 13

PREDICTED EED HAZARD DISTANCES FOR THE PROPOSED NATO SATELLITE EARTH TERMINAL AT 8400 MHz

TRANSMITTER POWER WATTS	HAZARD DISTANCE (1)	
	METERS	FEET
Up to 1000	(2)	(2)
1100	1101	3612
2000	2004	6573
3000	2642	8668
4000	3170	10402
5000	3578	11738

(1) Hazard distance is defined as the distance from the transmit antenna, along the bore sight axis, at which the radiated power density is predicted to be 26.5 w/m^2. The hazard criterion of 26.5 w/m^2 is based upon reference 8 and the prediction techniques are based upon references 8 and 9.

(2) For transmitter powers of up to 1000 watts, the predicted power density never reaches 26.5 w/m^2 at any distance. Therefore, no hazard exists.

APPENDIX A. EMC FIELD MEASUREMENT AND ANALYSIS

A.1 INTRODUCTION

A.1.1 Measurement Objective. The measurement objective was to detect and identify any potential source of EMI to the proposed earth terminal receivers (six downlinks as per Table 4). The measurement system recorded all incoming signals in the frequency range of 5810 - 7750 MHz which covers the downlink (receive) frequency range (7250 - 7750 MHz) and the image bands of the proposed earth terminal.

A.1.2 Analysis Objective. The analysis objective was to identify any interference problems based on measured data and to provide guidelines for selecting frequencies for the proposed earth terminal.

A.2 EMC MEASUREMENTS

A.2.1 Measurement System.

a. See Table 14 for major items of equipment and their characteristics, and Figure 2 for a diagram of the measurement system configuration.

b. In addition, ancillary equipment such as antenna tripod with pan and tilt head, rf connectors, adapters, cables, rotary waveguide joint, scope camera and X-Y recorder were used to complete the measurement system.

c. All instrumentation requiring calibration was certified at the "A" level by the Standards and Calibration Laboratory, US Army Electronic Proving Ground, Fort Huachuca, AZ, prior to the survey.

A.2.2 Measurement Procedures.

a. Antenna Height. At each candidate site, the measurement system antenna (4 foot parabolic dish) was mounted on a 45 foot tower. The resulting height above ground for the center of the four foot dish was 50 feet.

b. Satellite Survey Measurement Routine. The measurement routine was divided into five phases. The first three phases covered the downlink frequency band using a four foot dish and the last two phases covered the image frequencies. In the first phase, a 5° bracket around the look angles to each satellite was covered at 2° increments to detect any signals in this area. In the second phase, a 360° scan of the horizon was made, again at 2° increments, to detect any signals from terrestrial sources. The third phase consisted of documenting the signals detected in the previous two phases in terms of actual arrival azimuth, elevation angle, polarization, amplitude, and frequency. The fourth phase involved monitoring the look angles to each satellite in the image bands with the conical log spiral antenna. In the last phase, the image signals detected in the prior phase were docuemented using the four foot dish.

c. All signals were recorded on X-Y plots. However, final documentation was made on CRT photographs for the purpose of obtaining power spectral densities and total power flux densities. Precision frequency determination was made by signal substitution, using the sweep oscillator and frequency counter shown in Figure 2.

d. Equipment Checks. The measurement system net gain and sensitivity were determined daily. The sensitivity was normally -120 dBm for a 100 kHz spectrum analyzer bandwidth.

A.3 ANALYSIS

A.3.1 Data Reduction Procedure.

a. Spectral characterization of each signal consisted of the center frequency, power spectral density and power flux density. The power flux density was obtained by approximating:

$$P = 10 \log \int_{f_1}^{f_2} p(f)df - G_m - A_m \qquad \text{Equation 1}$$

where:

P = power flux density (dBm/m^2) of a signal

$p(f)$ = power spectral density (mW/Hz)

G_m = measurement system net gain (dB)

A_m = measurement antenna effective area (dBm^2)

by $$P = 10 \log \sum_{i=1}^{n} (10^{P_i/10}) - G_m - A_m \qquad \text{Equation 2}$$

where:

P_i = amplitude (dBm/BW$_m$) of the received signal at frequency f_i

BW_m = bandwidth of the measurement receiver

b. Each signal was also identified by the following:

(1) Polarization of maximum amplitude

(2) Arrival azimuth of maximum amplitude

(3) Arrival elevation of maximum amplitude

The documented signals and power flux densities are provided in Tables 5 thru 9 of this report. A sample X-Y plot and CRT photograph of a signal is provided in Appendix C.

A.3.2 Filter Characteristics and Interference Criterion. The interference criterion used in this EMC study was an interference-to-noise ratio of -10 dB for the satellite receivers. Table 15 shows the interference thresholds and significant filter characteristics used in the EMC study for the six proposed downlinks shown in Table 4. Since reference 3 and Table 4 indicate that some of the downlinks will use forward error correction (FEC) coding, all six downlinks were analyzed for half rate, three quarter rate, and no FEC to cover all possible cases.

A.3.3 Interference Analysis

a. Potential interference was determined from the following:

$$I = 10 \log \sum_{i=1}^{n} [(10^{P_i/10})/OTR_i] - G_m - A_m + A_t \qquad \text{Equation 3}$$

where:

I = predicted effective signal power (dBm) of a detected signal at the proposed earth terminal receiver.

P_i, G_m, and A_m were previously defined.

OTR_i = rejection due to bandwidth mismatch.

$$OTR_i = [1+(2|f_0-f_i|/BW_1)^{2N_1}] \times [1+(2|f_0-f_i|/BW_2)^{2N_2}] \qquad \text{Equation 4}$$

f_0 = RF frequency corresponding to the center of the modem or IF band pass = center of received signal.

f_i = RF frequency of P_i.

BW_1 = 3 dB bandwidth of the first Butterworth filter.

N_1 = Number of poles of the first Butterworth filter.

BW_2 = 3 dB bandwidth of the second Butterworth filter.

N_2 = Number of poles of the second Butterworth filter.

A_t = effective area of the earth terminal antenna in the direction of the detected signal (dBm^2).

$= G(\Theta, f) + 10 \log (\lambda^2/4\pi)$

where:

λ = wavelength in meters.

$G(\Theta,f)$ = *antenna gain* (dBi) which is a function of off-axis angle, Θ, and frequency f. Antenna gain is based upon reference 10.

b. Whenever I exceeds IT, a possible interference condition exists and frequency separations required to avoid possible interference were determined by the following method:

$$IT \geqslant 10 \log \sum_{i=1}^{n} [(10^{P_i/10})/OFR_i] - G_m - A_m + A_t \qquad \text{Equation 5}$$

where:

IT = interference threshold (defined in Table 15) in dBm.

OFR_i is defined as in Equation 4, except that f_0 is varied so that the inequality of Equation 5 becomes satisfied. All other parameters are as previously defined.

The results of the interference analysis are provided in Table 11 and Appendix B.

FIGURE 2

EMC MEASUREMENT SYSTEM CONFIGURATION

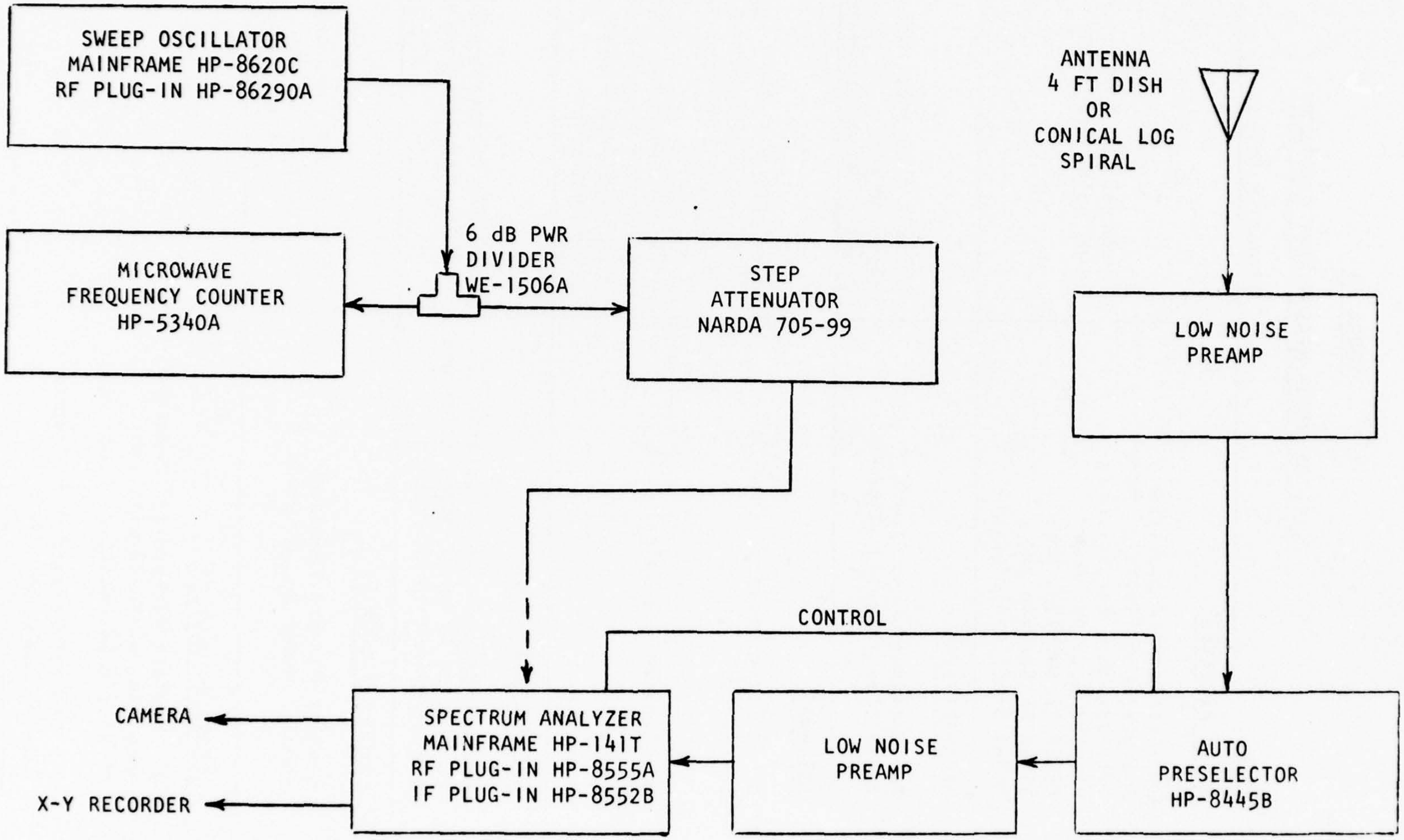


TABLE 14

LIST OF MAJOR MEASUREMENT EQUIPMENT

ITEM	CHARACTERISTICS
BASIC RECEIVER	
Hewlett-Packard Spectrum Analyzer consisting of Model 141T Variable Persistence Display Section, Model 8552B IF Section, Model 8555A RF Section and Model 8445B Preselector	10 MHz-40 GHz frequency range 30 dB noise figure
PREAMPLIFIERS	
Two Watkins-Johnson Solid State Amplifiers, Model WJ-5300-89	4-8 GHz frequency range 44-48 dB gain 2.5-3.2 dB noise figure
ANTENNAS	
a. 4 Ft Parabolic Dish with Horn Feed	5.8-8 GHz frequency range 34 dB gain,2.9° beamwidth from 5.8-6.4 GHz 36 dB gain,2.3° beamwidth from 7.25-7.75 GHz
b. Conical Log Spiral	1-10 GHz frequency range 4.5 dB gain from 5.8-6.4 GHz 3 dB gain from 7.25-7.75 GHz $\simeq$ 90° beamwidth
SWEEP OSCILLATOR	
Hewlett-Packard Sweep Oscillator consisting of an HP-8620C mainframe and an HP-86290A RF Plug-in	2-18 GHz frequency range ±20 MHz frequency accuracy
FREQUENCY COUNTER	
Hewlett-Packard Frequency Counter Model No. HP-5340A	10 Hz-18 GHz frequency range Accuracy: ± 1 count ± time base error
RECORDING DEVICES	
a. Hewlett-Packard X-Y recorder, Model No. HP-7034A with two HP-17171A DC Amplifier Plug-ins	
b. Hewlett-Packard Oscilloscope Camera, Model No. HP-197A	

TABLE 15

INTERFERENCE THRESHOLDS (IT) AND SIGNIFICANT FILTER CHARACTERISTICS FOR THE PROPOSED DOWNLINK EARTH TERMINAL

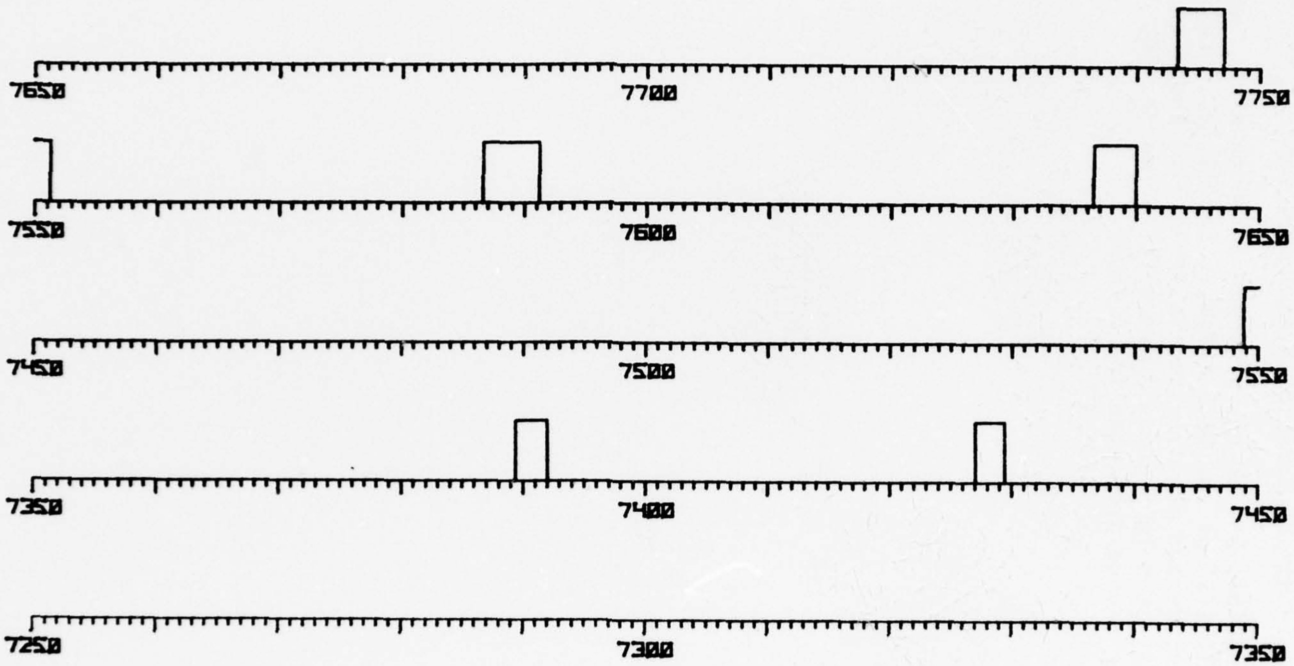
				70 MHz IF FILTER			DEMODULATOR FILTER				
LINK NO.	DATA RATE kb/s	FEC	SYMBOL RATE kb/s	3 dB BW MHz	NO. OF POLES	MAX. REJ. dB	3 dB BW MHz	NO. OF POLES	MAX. REJ. dB	IMAGE BAND REJ. dB	INTERFERENCE THRESHOLD IT in dB
1	139	No FEC	139	12	10	60	0.125	5	>35	>40	-134.2
		3/4 Rate	185	12	10	60	0.167	5	>35	>40	-132.9
		1/2 Rate	278	12	10	60	0.250	5	>35	>40	-131.2
2	980	No FEC	980	12	10	60	0.882	5	>35	>40	-125.7
		3/4 Rate	1307	12	10	60	1.176	5	>35	>40	-124.5
		1/2 Rate	1960	12	10	60	1.764	5	>35	>40	-122.7
3	173	No FEC	173	12	10	60	0.156	5	>35	>40	-133.2
		3/4 Rate	231	12	10	60	0.208	5	>35	>40	-132.0
		1/2 Rate	346	12	10	60	0.311	5	>35	>40	-130.2
4	450	No FEC	450	12	10	60	0.405	5	>35	>40	-129.1
		3/4 Rate	600	12	10	60	0.540	5	>35	>40	-127.9
		1/2 Rate	900	12	10	60	0.810	5	>35	>40	-126.1
5	760	No FEC	760	12	10	60	0.684	5	>35	>40	-126.8
		3/4 Rate	1013	12	10	60	0.912	5	>35	>40	-125.6
		1/2 Rate	1520	12	10	60	1.368	5	>35	>40	-123.8
6	139	No FEC	139	12	10	60	0.125	5	>35	>40	-134.2
		3/4 Rate	185	12	10	60	0.167	5	>35	>40	-132.9
		1/2 Rate	278	12	10	60	0.250	5	>35	>40	-131.2

NOTE: 1. All filters are assumed to be Butterworth.

2. IT = Interference threshold at the output of the receiving antenna
= 10 log (KT_sB) -10 in dBw
= 10 log (KT_sB) +20 in dBm
where K = Boltzman's constant = 1.38×10^{-23} Joules/°K
T_s = System noise temperature = 220°K
B = net 3 dB bandwidth in Hertz

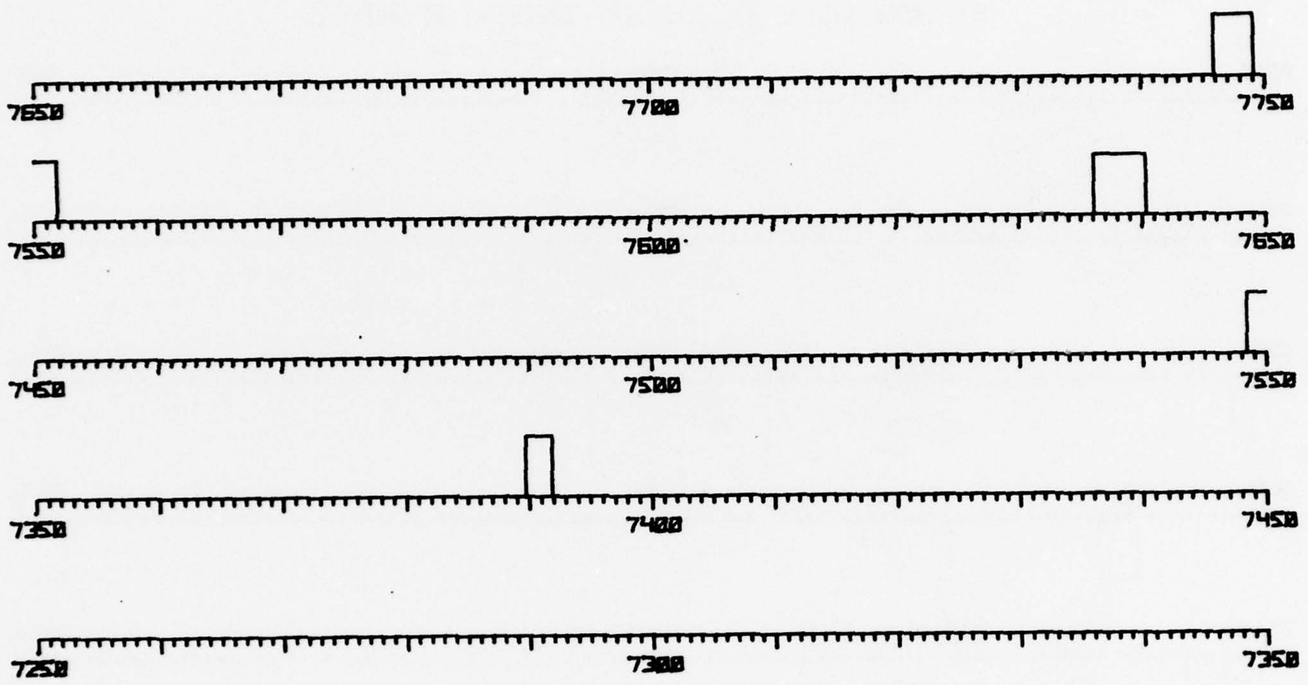
APPENDIX B. REGIONS OF POSSIBLE EMI TO THE PROPOSED EARTH TERMINAL

The regions of possible EMI to the proposed earth terminal, when oriented at either the NATO IIIA or the DSCS Atlantic Satellite, were identified by the theoretical study and are provided in Table 11. These regions are graphically illustrated in Figures 3 thru 6 for Sites 3A, 3B, 3C, and 3E. There is no interference predicted for Site 3D.



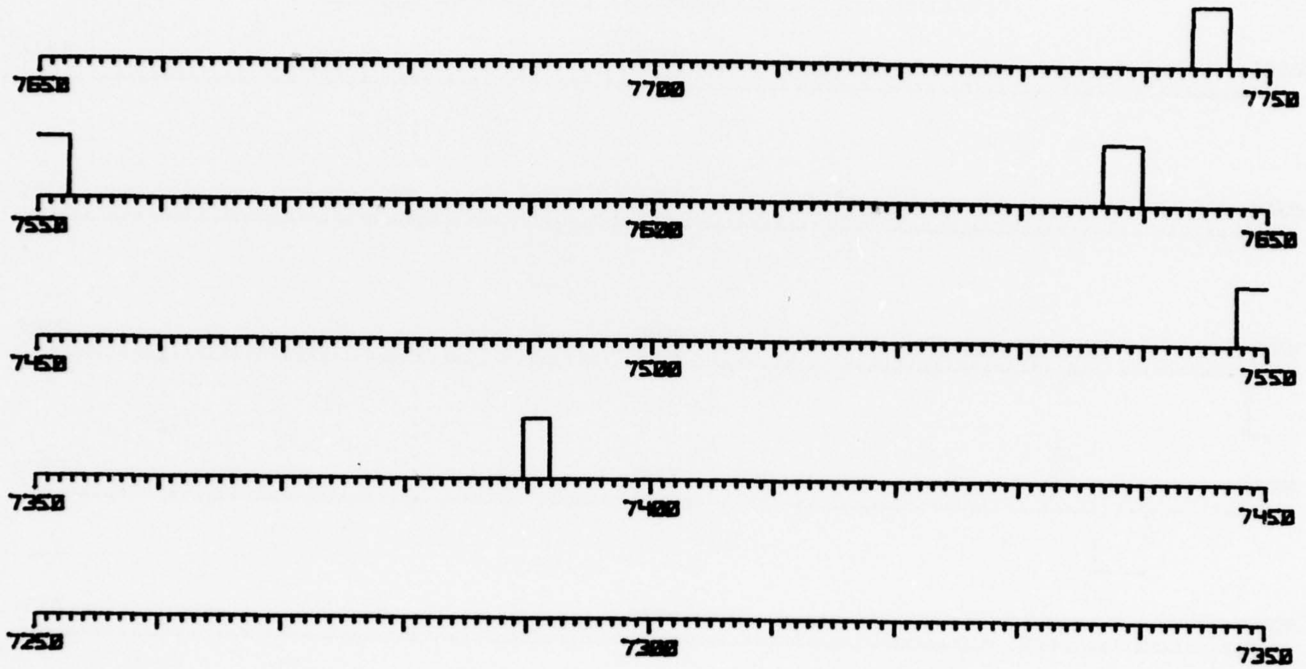
REGIONS OF POSSIBLE INTERFERENCE TO THE PROPOSED
NATO EARTH TERMINAL AT SITE 3A

FIGURE 3



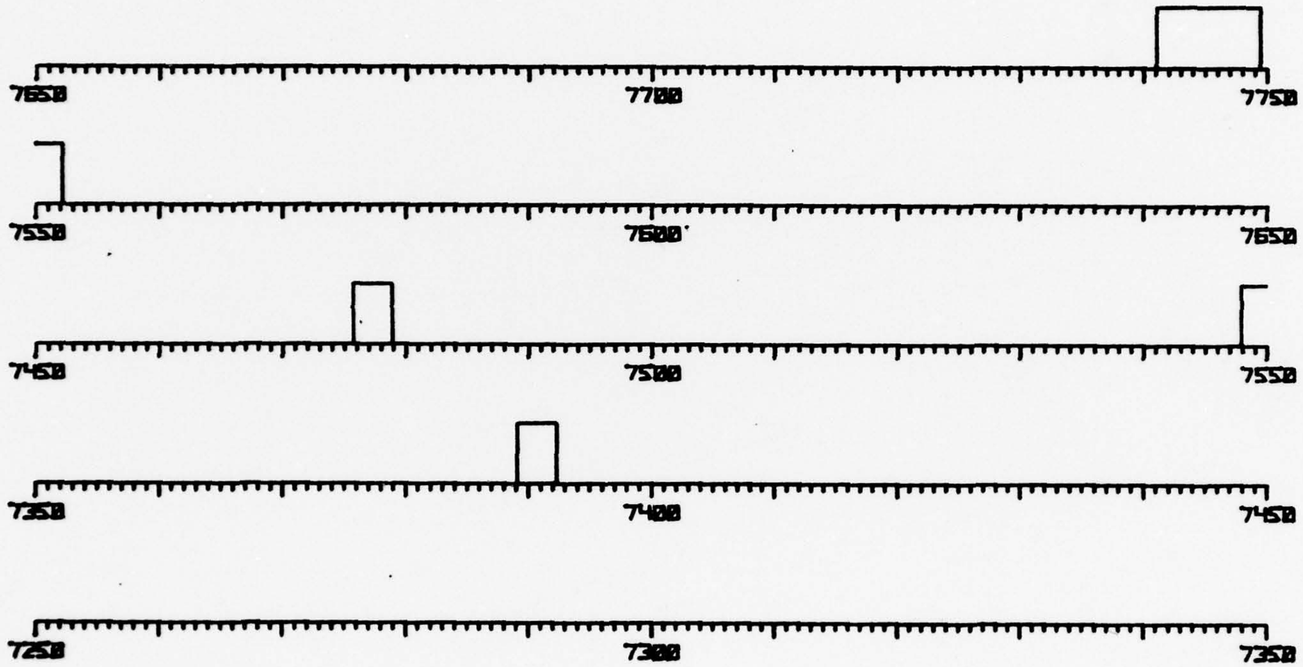
REGIONS OF POSSIBLE INTERFERENCE TO THE PROPOSED
NATO EARTH TERMINAL AT SITE 3B

FIGURE 4



REGIONS OF POSSIBLE INTERFERENCE TO THE PROPOSED
NATO EARTH TERMINAL AT SITE 3C

FIGURE 5



REGIONS OF POSSIBLE INTERFERENCE TO THE PROPOSED
NATO EARTH TERMINAL AT SITE 3E

FIGURE 6

APPENDIX C. SAMPLE PHOTOGRAPHS AND X-Y PLOTS

Figure 7 shows sample photographs of two signals documented at Site 3C. Figure 8 shows a sample X-Y plot of signals received at Site 3A at five different azimuths.

FIGURE 7

SPECTRUM ANALYZER
EMC PHOTO DATA SHEET

SITE 3C

DATE 5 SEP 78

Time 1500
Bandwidth 100 kHz
Input Attenuator 10 dB
Scantime 20 M Sec/div
Mode [✓ 10] 2 L
Center Frequency 7477.3 MHz
Azimuth 58°
Elevation -1°
Polarity [✓ H] V 45
n/a

Instrumentation
Scanwidth 0.2M Hz/div
Video Filter [✓ 0] 10k 100 10
Log Ref -10 dBm V/div

CABLES
A
B
C
D
E

External Attenuator 0 dB

Remarks

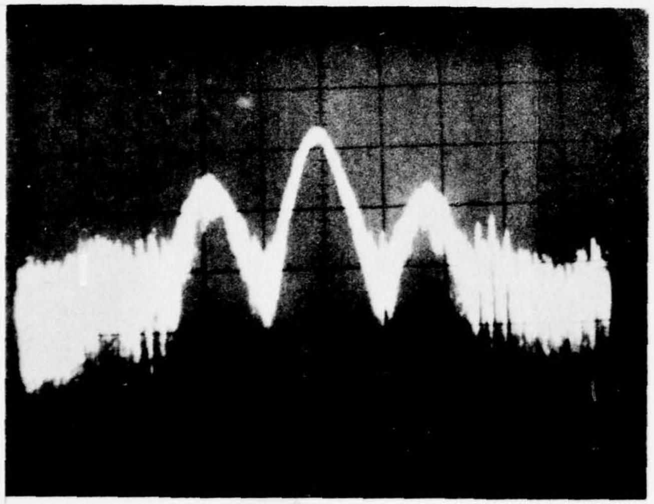
Time 1505
Bandwidth 100 kHz
Input Attenuator 10 dB
Scantime 20 M Sec/div
Mode [✓ 10] 2 L
Center Frequency 7588.8 M Hz
Azimuth 58°
Elevation 0°
Polarity [✓ H] V 45
n/a

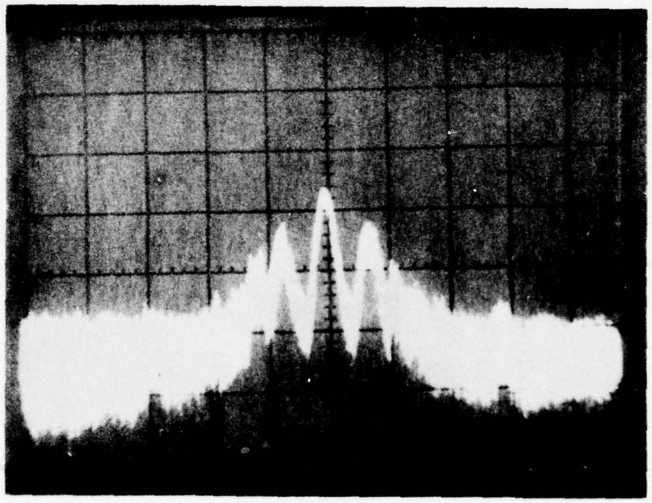
Instrumentation
Scanwidth 0.5M Hz/div
Video Filter [✓ 0] 10k 100 10
Log Ref 0 dBm V/div

CABLES
A
B
C
D
E

External Attenuator 0 dB

Remarks





SPECTRUM ANALYZER X-Y PLOT SHEET

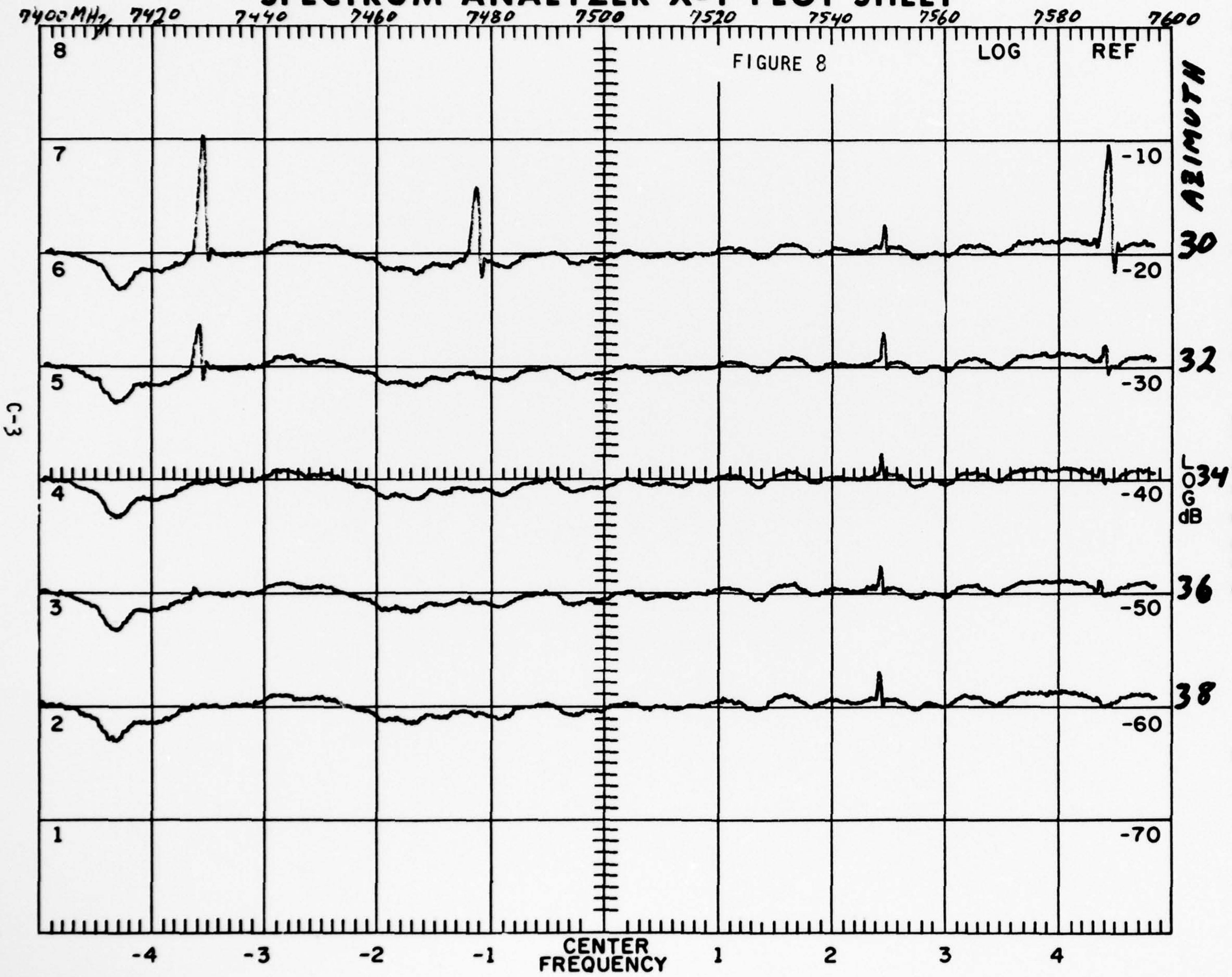


FIGURE 8

Site 3A

Date 25 SEP 78

Time 1400

Instrumentation ___ ___ ___

Bandwidth 100 kHz

Scanwidth 20 MHz/div

Input Attenuator 10 dB

Video Filter ☒ ☐ 10k ☐ 100 ☐ 10

Scantime 2 Sec/div

Log Ref -40.0 dBm V/div

Mode [✓ 10] ☐ 2 ☐ L

Center Frequency 7500 MHz

Azimuth ___ ___ ° ☐ n/a

Elevation 0 °

Polarity ☐ H ☐ V [✓ 45]

External Attenuator ___ ___ dB

Cables

A ___ ___

B ___ ___

C ___ ___

D ___ ___

E ___ ___

Remarks

APPENDIX D. REFERENCES

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