10.7 ELECTROMAGNETIC COMPATIBILITY (EMC)

10.7.1 Circuit EMEC Classification

Circuit EMEC Classifications are as defined in Table 10.7.1-1. As a design goal, orbiter to payload wiring shall meet the requirements of Table 10.7.1-2 or utilize equivalent shielding.

10.7.2 Shuttle-Produced Interference Environment

10.7.2.1 Conducted Interference

(See Paragraph 7.3.7).

10.7.2.2 Radiated Interference

The Shuttle-produced radiated field environment shall be limited as specified in the following subparagraphs.

10.7.2.2.1 Magnetic Fields

10.7.2.2.1.1 Power Bus-Produced

The magnetic flux density (i.e. field intensity) values are reduced in accordance with the following equation for separation from the power busses in the Y-Z plane.

The formula for decibel reduction is $dB = 20 \log_{10} (57R^2)$; where R (meters) = radial separation in the Y-Z plane from the nearest port or starboard power bus as described by the following location coordinates.

For locations within 2.5 meters of the 576 or 1307 Xo locations, the value of R in the equation should be the separation from the Xo = 576 or Xo = 1307 locations in meters.

10.7.2.2.1.1.1 AC Magnetic Fields

The worst case value for AC magnetic fields is at locations near the Orbiter power buses at Yo=±79, Zo=349, Xo any value in the cargo bay. AC magnetic fields shall be limited to less than 140 dB above 1 picotesla (30 Hz to 2 kHz), falling 40 dB per decade to 50 kHz.

10.7.2.2.1.1.2 DC Magnetic Fields

The worst case value for DC magnetic fields is at locations near the Orbiter power buses at Yo=±79, Zo=349, Xo any value in the cargo bay. DC magnetic fields shall be less than 170 dB above 1 picotesla.

10.7.2.2.1.2 Lightning Produced

Lightning produced magnetic fields in the Payload Bay for vehicles in flight shall not exceed a peak level of 20 amperes/meter; for vehicles on the ground protected by facility or other structures the peak level shall not exceed 40 amperes/meter; and for vehicles on the ground not protected by facility or other structures the peak level shall not exceed 75 amperes/meter. The lightning produced magnetic fields in the Crew compartment for vehicles in flight shall not exceed a peak level of 3 amperes/meter; for vehicles on the ground protected by facility or other structures the peak level shall not exceed 5 amperes/meter; and for vehicles on the ground not protected by facility or other structures the peak level shall not exceed 10 amperes/meter. The rise to peak value is 2 microseconds and the fall to zero value is 100

microseconds. The payload shall be designed so that a failure due to a lightning strike shall not propogate to the Shuttle.

10.7.2.2.2 Electric Fields
Electric fields along the cargo bay center line under normal operating modes are defined in Figures 10.7.2.2.2-1 and 10.7.2.2.2-2 for unintentional emissions. These levels should be considered when evaluating the possibility of operating radio frequency receiving equipment or electric field sensing instruments in the cargo bay.

The values defined in Figure 10.7.2.2.2-3 are the maximum field intensities on the upper spherical wedges (+Xo, +Zo, +Yo) and (+Xo, +Zo, -Yo) of the payload bay envelope with the doors open.

Table 10.7.2.2.2-1 gives the frequency range and modulation type associated with the transmitter field strengths in Figure 10.7.2.2.2-3.

10.7.2.2.2.1 S-Band System
The worst case electric field intensities produced by Orbiter-installed S-Band transmitters are defined for the cargo bay and for the volume above the cargo bay/cabin.

10.7.2.2.2.1.1 Pre-Deployment/Non-Deployment
The S-Band electric field levels, in the payload bay envelope are defined by Figure 10.7.2.2.2-3.

10.7.2.2.2.1.2 Post-Deployment/Retrieval
The values defined in Figures 10.7.2.2.2.1.2-1, 10.7.2.2.2.1.2-2, 10.7.2.2.2.1.2-3 and 10.7.2.2.2.1.2-4 are the maximum field intensities that may impinge on payloads in the +Zo hemisphere above the Orbiter (antenna) during deployment and retrieval operations.

10.7.2.2.2.1.3 Extended Range Payload Communications Link (ERPCL) Produced Electric Field Intensities
Payloads manifested on flights where the ERPCL is installed may be exposed to electric field intensities in the +Zo hemisphere above the Orbiter during deployment and retrieval operations in addition to the field intensities listed in Paragraph 10.7.2.2.2.1.2. The maximum field intensities produced by the ERPCL that may impinge upon payloads are shown in Figure 10.7.2.2.2.1.3-1.

10.7.2.2.2.2 Ku-Band System
The Ku-Band electric field levels are defined in the following subparagraphs.

10.7.2.2.2.2.1 Pre-Deployment/Non-Deployment
The Ku-Band levels are greater along a line defined by the +Yo=90 and +Zo=444. Reduced levels can be expected in the -Y and lower Z areas of the cargo bay, however, the levels are payload geometry dependent and are defined by Figure 10.7.2.2.2-3.

10.7.2.2.2.2.2 Post Deployment/Retrieval
See Figure 10.7.2.2.2.2.2-1 for electrical field intensities when operating in the communications mode and Figure 10.7.2.2.2.2.2-2 when operating in the radar mode. When operating the Ku-Band system in the radar mode, the field may be attenuated in accordance with Paragraph 8.3.4.1.

For equipment that can be in the main beam of the Ku-Band Antenna, the field level can be approximated by:

$$E = \frac{2500}{R} \qquad (R = \text{METERS})$$

10.7.2.2.2.3 Electrostatic Discharges
The design of the cargo bay and cargo bay doors preclude any electrostatic discharges.

10.7.2.2.2.4 EVA Transmitter Characteristics
The maximum field intensities associated with the transmitters supporting an EVA crewman are 6.5 volts per meter at one meter from the TV antenna of the EMU and 3.8 volts per meter at one meter from the EMU EVA voice antenna. Transmitter characteristics associated with EVA activities are given in Table 10.7.2.2.2.4-1. Payloads shall be designed to meet these induced environments.

10.7.2.2.2.5 (Reserved)

10.7.2.3 OPTICAL/LASER RADIATION (INFRARED; OPTICAL; ULTRAVIOLET)

10.7.2.3.1 Shuttle Produced Optical/LASER Radiation
During Shuttle/Payload rendezvous and docked operations, the emitted shuttle optical radiations to be considered are: 1) The Trajectory Control Sensor (TCS) System, and 2) The Handheld - Lidar Ranging (HHL). The properties of the emissions from these two items are as follows:

Trajectory Control Sensor (TCS) System

Quantity		two
Range		CW 2 - 1500 meters (with retroreflector)
		Pulse 15 - 1500 meters (with retroreflector)
Location		Payload Bay
Pointing		+Zo
Control/Monitor		Aft Flight Deck
Scanning Angle		±25°
Scan Rate		X - ≤30 Hz
		Y - ≤1 Hz
Output Power:		
	CW	40 milliwatts peak at 850±10 nanometers at exit aperture
		20 milliwatts average at exit aperture
	Pulse	12 watts peak at 850±10 nanometers at exit aperture
		2.5 milliwatts average at exit aperture
Aperture		Max. Beam diameter - 16 millimeters (CW and Pulse) at exit aperture
Beam Divergence:		
	CW	Min. Beam divergence 0.1745 milliradians for half angle
	Pulse	Min. Beam divergence 1.9 milliradians for half angle
		Max. Beam width 23 milliradians for half angle (Pulse & CW)

Pulse Width	30 nanoseconds (Pulse)
Pulse Repetition Frequency	7 kilohertz (Pulse)
Wavelength - nm:	
CW	850±10
Pulse	850±10

Handheld Lidar (HHL) Equipment

Quantity	two
Range	≤12≥1500 ft (30% diffuse target) (3.7 - 457 meters) ≤12≥4500 ft (2.5 inch diameter retroreflector) (3.7 - 1372 meters)
Accuracy	±0.5 ft (0.15 meters)
Location	Aft Flight Deck
Pointing	any (by procedure)
Control/Monitor	Aft Flight Deck
Scanning Angle	N/A
Output Power:	
Average	32.3 microwatts at 775 nanometers
Peak	17.7 watts at 775 nanometers
Beam Divergence	1.7 milliradians (horizontal axis) 2.2 milliradians (vertical axis)
Aperture	Beam Diameter - 48 millimeters (horizontal), 32 millimeters (vertical) at exit aperture
Range Rate	0 - ≥10 ft/sec (0 - 3.05 meters/sec)
Accuracy	0.5 second average - 0.2 ft/sec at 1 Standard Deviation (S.D.) 1.0 second average - 0.1 ft/sec at 1 S.D. 2.0 second average - 0.05 ft/sec at 1 S.D. 5.0 second average - 0.02 ft/sec at 1 S.D. (0.6 - 0.006 meters/sec)
Pulse Repetition Frequency	150 Hz
Pulse Width	12 nanoseconds

10.7.2.3.2 Shuttle Equipments Sensitive to LASER Radiation

During Shuttle/payload rendezvous/dock missions, the only Orbiter equipment that is sensitive/susceptible to optical/Laser radiation are several cameras mounted in the payload bay, on the Remote Manipulator System (RMS) and the Star Trackers. These cameras are of three types, Silicon Charged-Coupled Device (CCD), Color Television Cameras (CCTV System) and the Silicon Intensified Target Vidicon with Monochrome Lens Array (SIT/MLA) used for viewing primarily during low light level conditions. The optical sensitivity and susceptibility of those items are listed in Table 10.7.2.3.2-1.

TABLE 10.7.1-1 CIRCUIT EMEC CLASSIFICATIONS

Freq. or Rise/Fall Time	Source Impedance (ohms)	Load Impedance (ohms)	Voltage or Sensitivity	Circuit Classification	Wire Type Reqd	Shield Grounding Reqmts
		100-600k	>100mv to ≤6v	ML	TWS	SPG**
	<100	0-200	>6v to ≤40v	HO	TW	None
		0-200	>40v	EO	TW	None
Analog, Alternating or Direct Current	≤2.5k	100-600k	≤100 mv	ML	TWS	SPG
		>600k			TWDS	SPG
		≥200	>100mv to ≤6v	ML	TWS	SPG
	<100	≥200	>6v to ≤40v	HO	TW	None
		≥200	>40v	EO	TW	None
≤50 KHz and Rise and Fall Time ≥10 Micro Seconds		≥10k	≤6v	ML	TWS	SPG
	<100	0-200	>6v to ≤40v	HO	TW	None
		0-200	>40v	EO	TW	None
	<2.5k	100-600k	≤100mv	ML	TWS	SPG
		>600k			TWDS	SPG
	≥200	>200	>100mv to ≤6v	ML	TWS	SPG**
		>200	>6v to ≤40v	HO	TW	None
		>200	>40v	EO	TW	None
>50 KHz and ≤1.024 MHz or Rise/ Fall Time ≤10 Micro Seconds	All	All	≤100mv	RF	TWDS*	MPG
		All	>100mv to ≤6v	RF	TWS*	MPG
		<1000	>6v	RF	TWS*	MPG
		≥1000			TWDS	MPG
>1.024 MHz	All	All	All	RF	COAX	MPG
TV Video				RF	TWS	MPG***

Symbols Used

KHz - Kilohertz	RF - Radio Frequency	< - less than	
MHz - Megahertz	TWS - Twisted Shielded	≤ - less than or equal to	
SPG - Single Point Ground	mv - Millivolts		
MPG - Multiple Point Ground	v - volts	> - greater than	
TW - Twisted	coax - coaxial	≥ - greater than or equal to	
TWDS - Twisted Double Shielded	k - Kilo		

* If the capacitance per foot is critical, controlled-impedance wiring, special shielded-twisted-pair cables (nominal 75 ohms), should be used.

** If circuit is balanced by transformer, differential or optical, the shield shall be multi-point grounded to structure.

*** Distance between shield grounds shall not exceed 18 meters.

TABLE 10.7.1-2 CARGO WIRE BUNDLE EDGE-TO-EDGE SEPARATION

Bundle	Routed Parallel To Bundle	Separation (in inches for parallel runs of D [feet])			
		1 > D	1 ≤ D < 3	3 ≤ D < 5	D ≥ 5
ML	H0	0	1.0	2.0	4.0
	E0	0	1.5	3.0	6.0
	RF	0	2.5	5.0	10.0
H0	E0	0	0.5	1.0	2.0
	RF	0	1.5	3.0	6.0
E0	RF	0	1.0	2.0	4.0

TABLE 10.7.2.2.2-1 ORBITER TRANSMITTER CHARACTERISTICS

TRANSMITTER	ANTENNA (1)	CARRIER FREQ(fc)	MODULATION
S-BAND FM	S-BAND HEMI	2250.0 MHz	FM
S-BAND PM (NETWORK TRANSPONDER)	S-BAND QUAD	2217.5 OR 2287.5 MHz	PSK, PM
PAYLOAD INTERROGATOR			
STDN (NASA) (2)	S-BAND PAYLOAD	2025.8334 TO 2117.9166 MHz	PM
DSN (NASA) (3)	S-BAND PAYLOAD	2110.2431 TO 2119.7924 MHz	PM
SGLS (DOD) (4)	S-BAND PAYLOAD	1763.721 TO 1839.795 MHz	PM
KU-BAND	KU-BAND		
	RETURN LINK	15.0034 GHz	QPSK, FM
	RADAR RANGING	13.883 GHz (5)	PULSED CARRIER PULSE RATES: 268, 3000, 7000 PPS PULSE WIDTH - 66.4 μs max. 122.0 ηs min.

NOTES:
1) Cargo bay radiation levels defined in Figure 10.7.2.2.2-3.
2) 801 Selectable channels over indicated frequency range. (See Appendix C)
3) 29 Selectable channels over indicated frequency range. (See Appendix C)
4) 20 Selectable channels over indicated frequency range. (See Appendix C)
5) Passive tracking uses frequency diversity technique employing center frequencies of 13.779, 13.831, 13.883, 13.935 and 13.987 GHz.

TABLE 10.7.2.2.2.4-1 EVA TRANSMITTER CHARACTERISTICS

TRANSMITTER	ANTENNA	CARRIER FREQ(fc)	MODULATION
EVA/ATC ATC AIR-TO-GROUND	UHF (10 WATTS)	259.7 MHz 296.8 MHz 243.0 MHz (GUARD BAND)	AM 90% VOICE
EVA (ORBITER-TO-EVA) DUPLEX	UHF (0.25 WATTS)	296.8 MHz NORMAL 259.7 MHz BACK-UP (SIMPLEX)	AM 90% VOICE
EVA (EVA-TO-ORBITER) EVA-1 A MODE B MODE EVA-2 A MODE B MODE SIMPLEX (BACKUP)	UHF (0.25 WATTS)	 259.7 MHz 279.0 MHz 279.0 MHz 259.7 MHZ 259.7 MHz	AM 90% VOICE PLUS BIOMED DATA ON 5.4 KHz SUBCARRIER NO BIOMED DATA

TABLE 10.7.2.3.2-1 Optical Sensitivity and Susceptibility of Cameras

	CCTV	SIT/MLA	ST
Location	Payload Bay#	Payload Bay#	Shuttle Orbiter Nose##
Field of View in degrees	11 - 17 (Variable)*	6.5 - 38 (Variable)*	10
Recieve Aperture in millimeters	100	80	33
Active Protection/Response Time	auto iris (3 sec)	auto iris (7 sec)	shutter (50 msecs)
Passive Protections	(0.85 mm) CM-500 filter	(2 mm) HA-11 filter	none
Damage Thresholds** in Joule/cm^2	unknown	16E-3	5E-9
Pointing	any (by procedure)	any (by procedure)	###

Legends:
* Horizontal Field of View (FOV); vertical FOV is 3/4 of horizontal FOV

** For point sources of 0.55 microns (micro meters) wavelength

# Xo=589.000, Yo=-71.500, Zo=446.0, for Camera A
Xo=1294.0, Yo=-87.000, Zo=446.0, for Camera B
Xo=1294.0, Yo=+87.500, Zo=446.0, for Camera C
Xo=589.000, Yo=+71.500, Zo=446.0, for Camera D
Xo=953.030, Yo=-70.760, Zo=462.36, for Elbow Camera in stowed position

Keel Camera Mounted Locations:

Xo=709.000, Yo=-4.000, Zo=Liner Level, for mount no: 1
Xo=902.000, Yo=-4.000, Zo=Liner level, for mount no: 2
Xo=1102.300, Yo=-4.000, Zo=Liner Level, for mount no: 3
Xo=1134.000, Yo=-4.000, Zo=Liner Level, for mount no: 4

Xo=423.6711, Yo=-54.4271, Zo=408.375, for Vertical Star Tracker
Xo=425.0043, Yo=-35.9998, Zo=418.0184, for Y-axis Star Tracker

Optical axis of the Vertical Star Tracker is inclined 3° in a plane rotated 41° from the +X axis toward the -Y axis. Optical axis of the Y Axis Star Tracker is in the X-Y plane and is rotated 10.567° away from the -Y axis toward the +X axis.

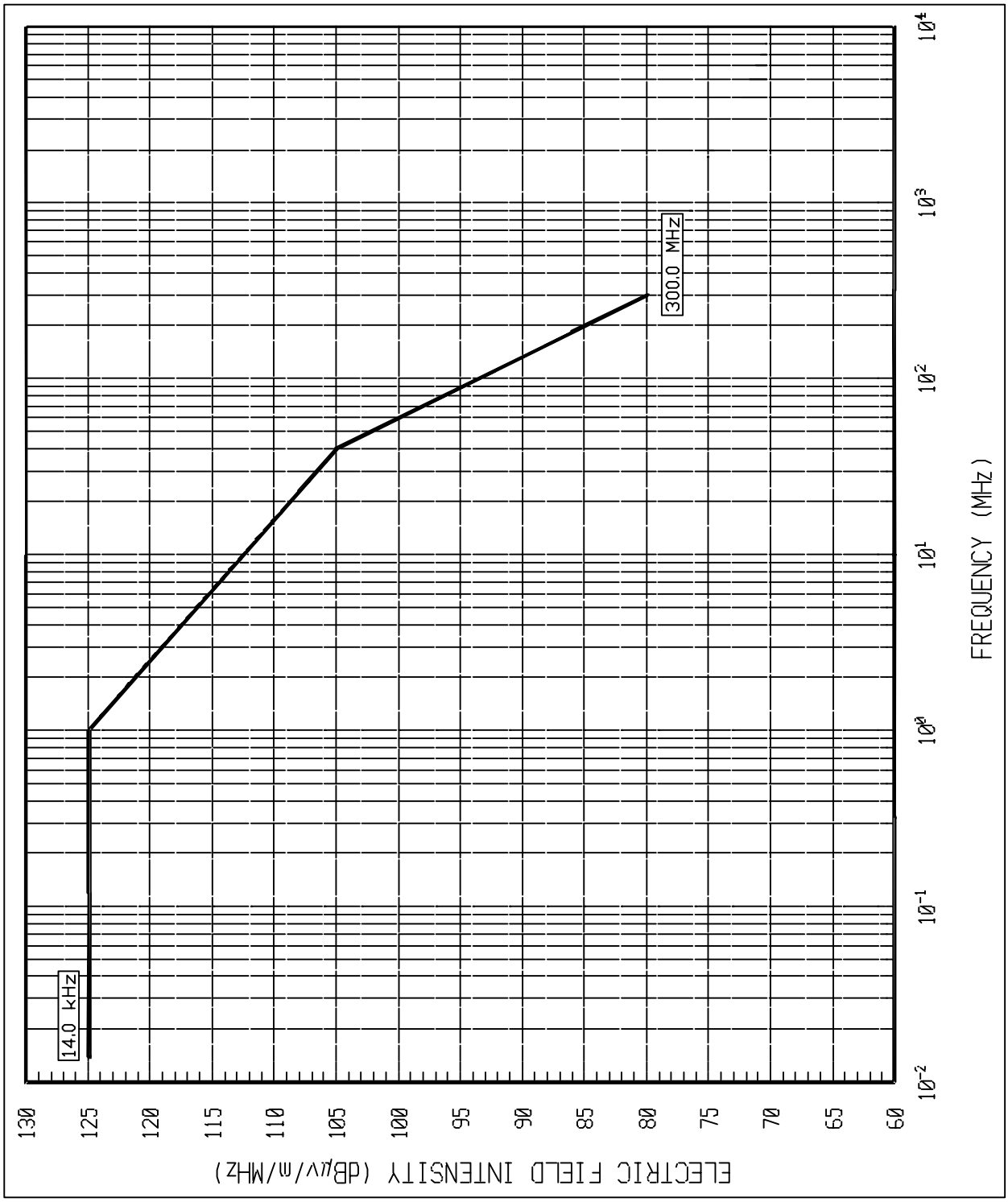

FIGURE 10.7.2.2.2-1 SHUTTLE-PRODUCED CARGO BAY RADIATED BROADBAND EMISSION LIMIT

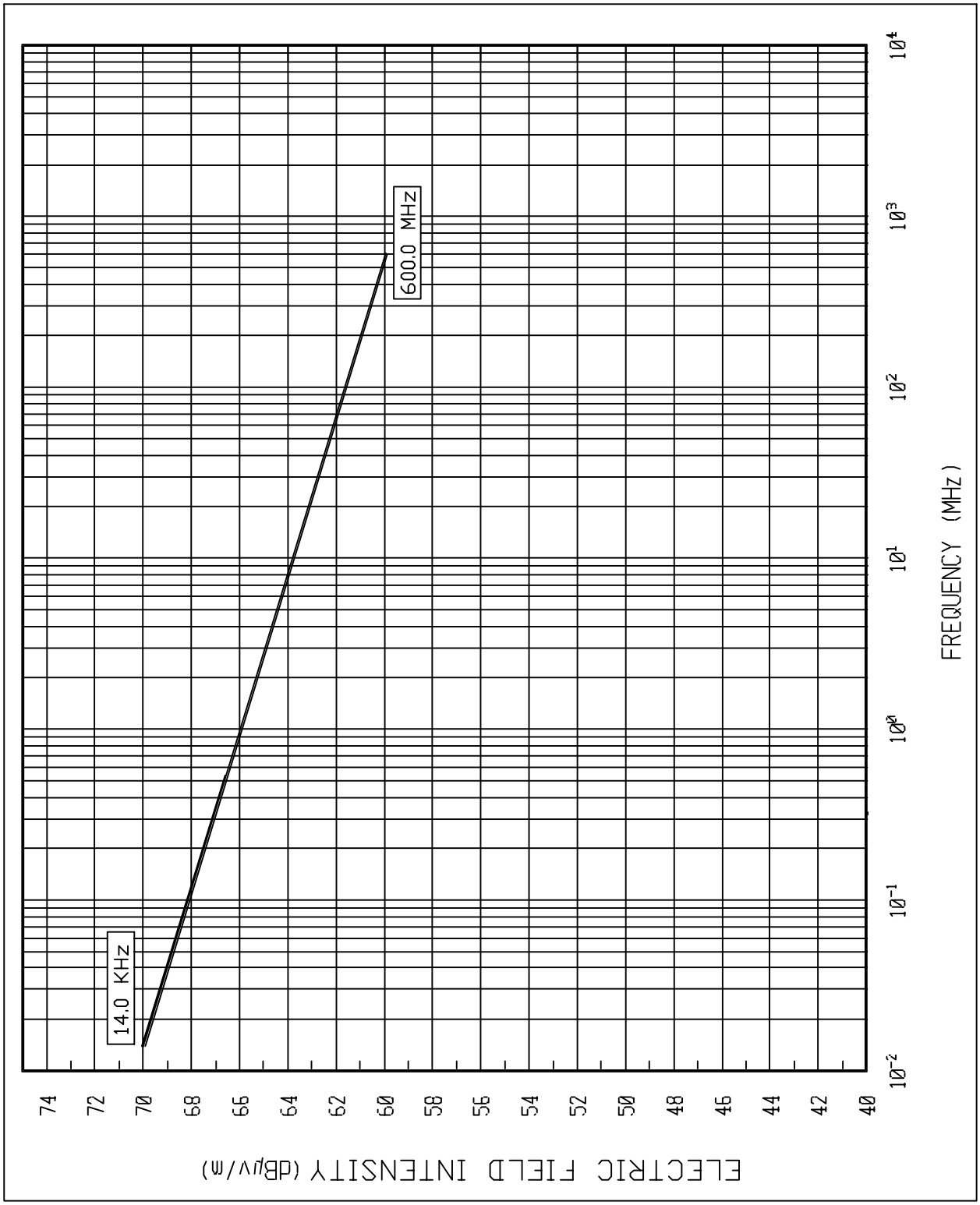

FIGURE 10.7.2.2.2-2 SHUTTLE-PRODUCED CARGO BAY RADIATED NARROWBAND EMISSION LIMIT

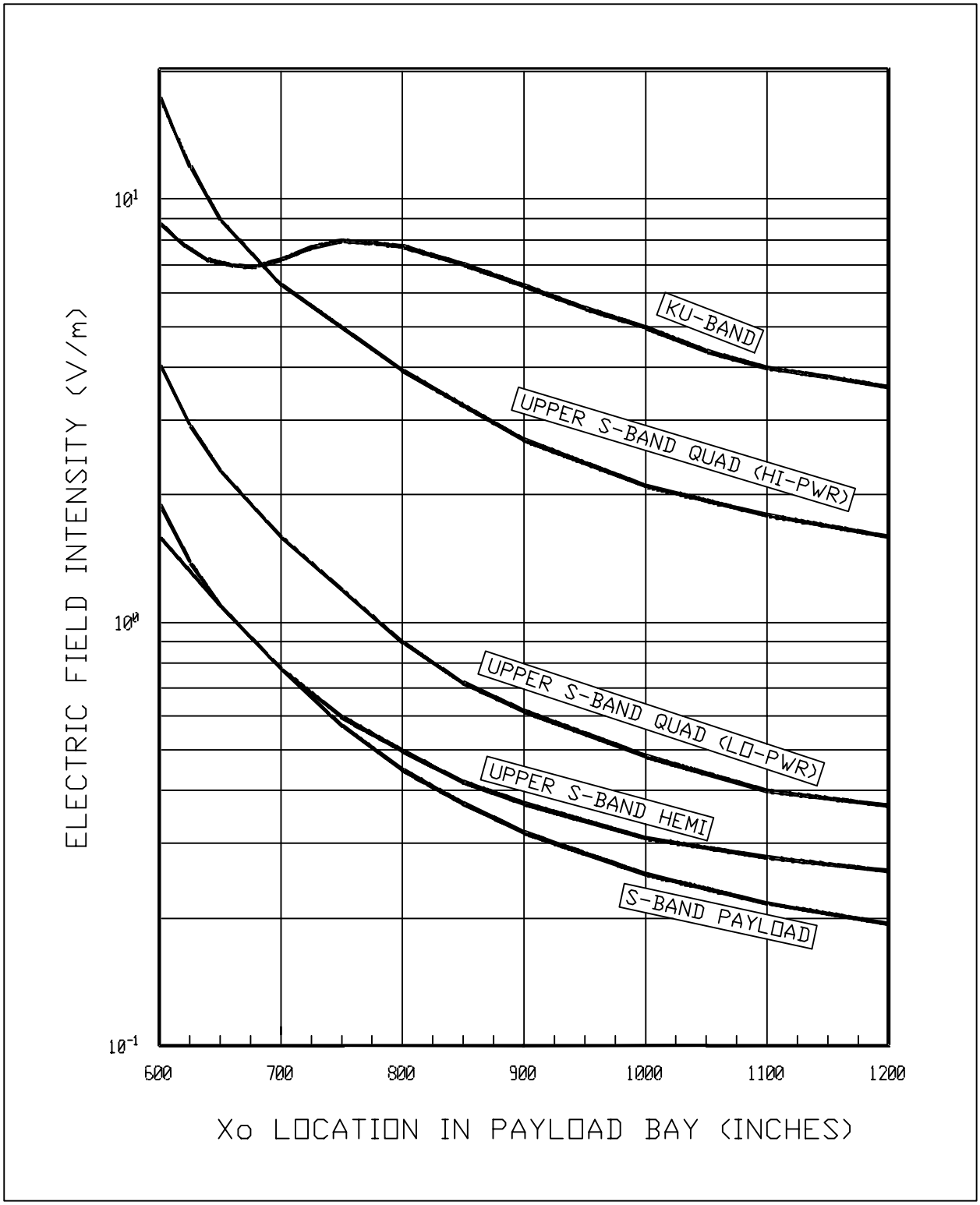

FIGURE 10.7.2.2.2-3 MAXIMUM ELECTRIC FIELD INTENSITIES ON PAYLOAD BAY ENVELOPE

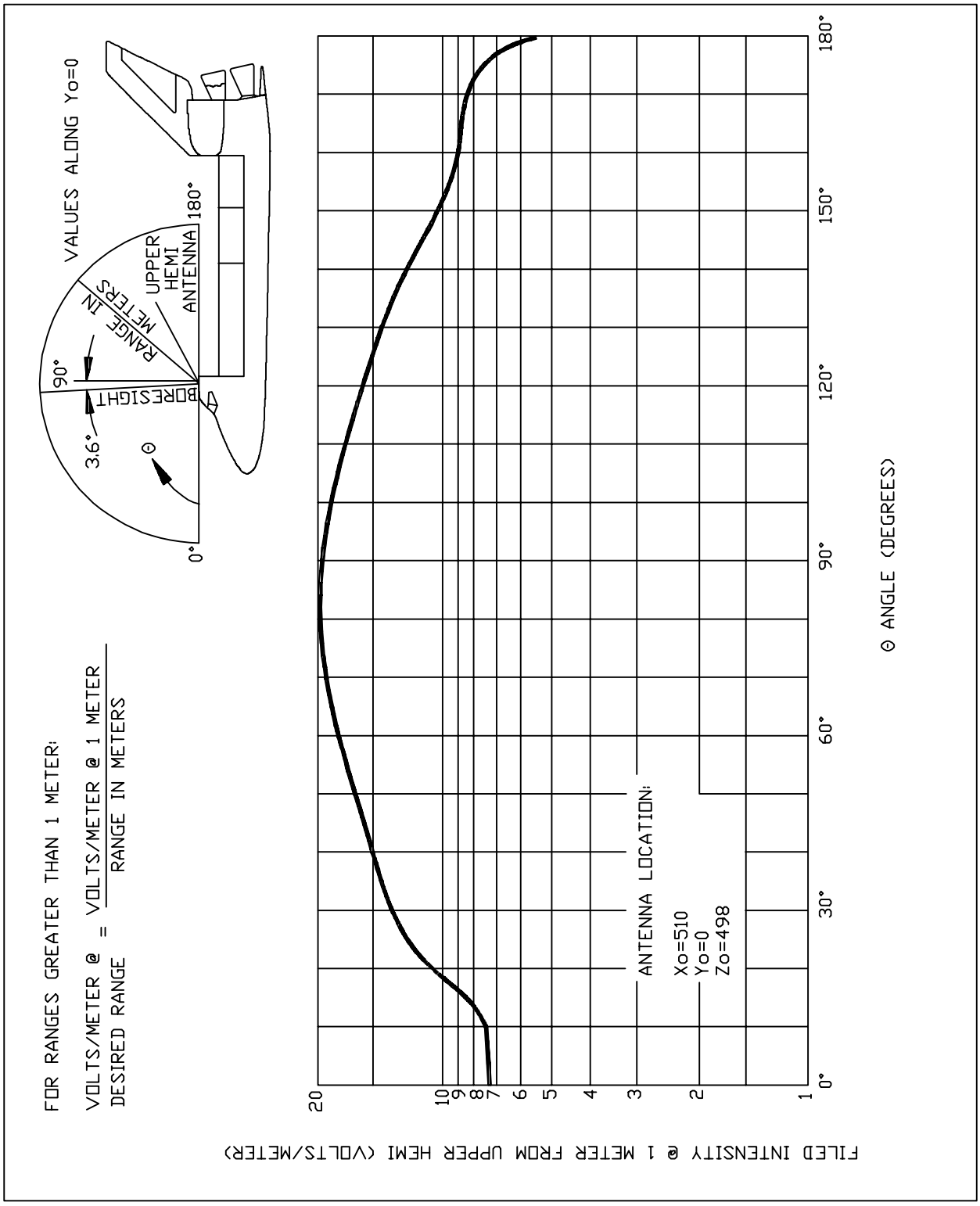

FIGURE 10.7.2.2.2.1.2-1 S-BAND FM TRANSMITTER (UPPER HEMI ANTENNA) MAXIMUM ELECTRIC FIELD INTENSITIES

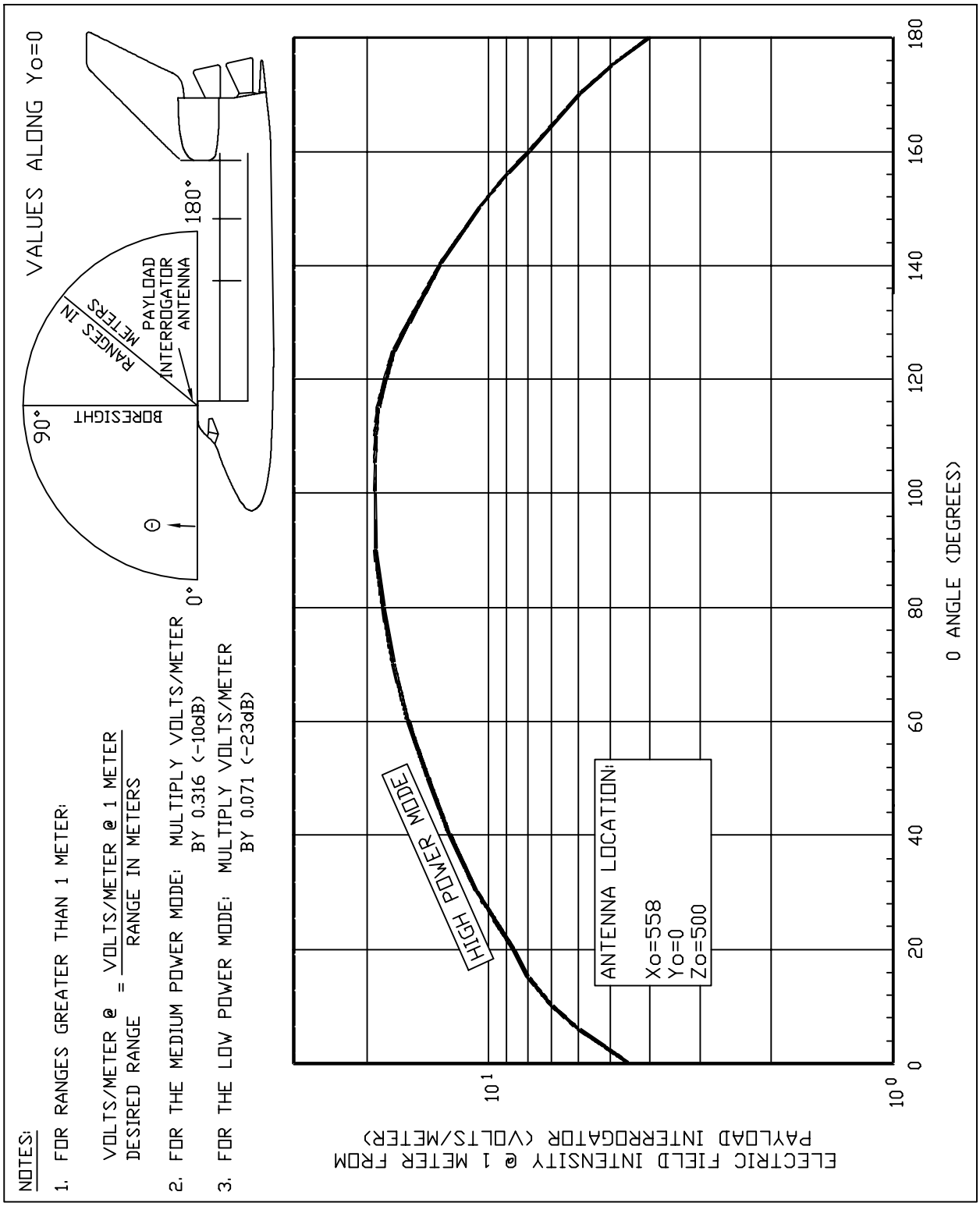

FIGURE 10.7.2.2.2.1.2-2 S-BAND (PAYLOAD INTERROGATOR) MAXIMUM ELECTRIC FIELD INTENSITIES

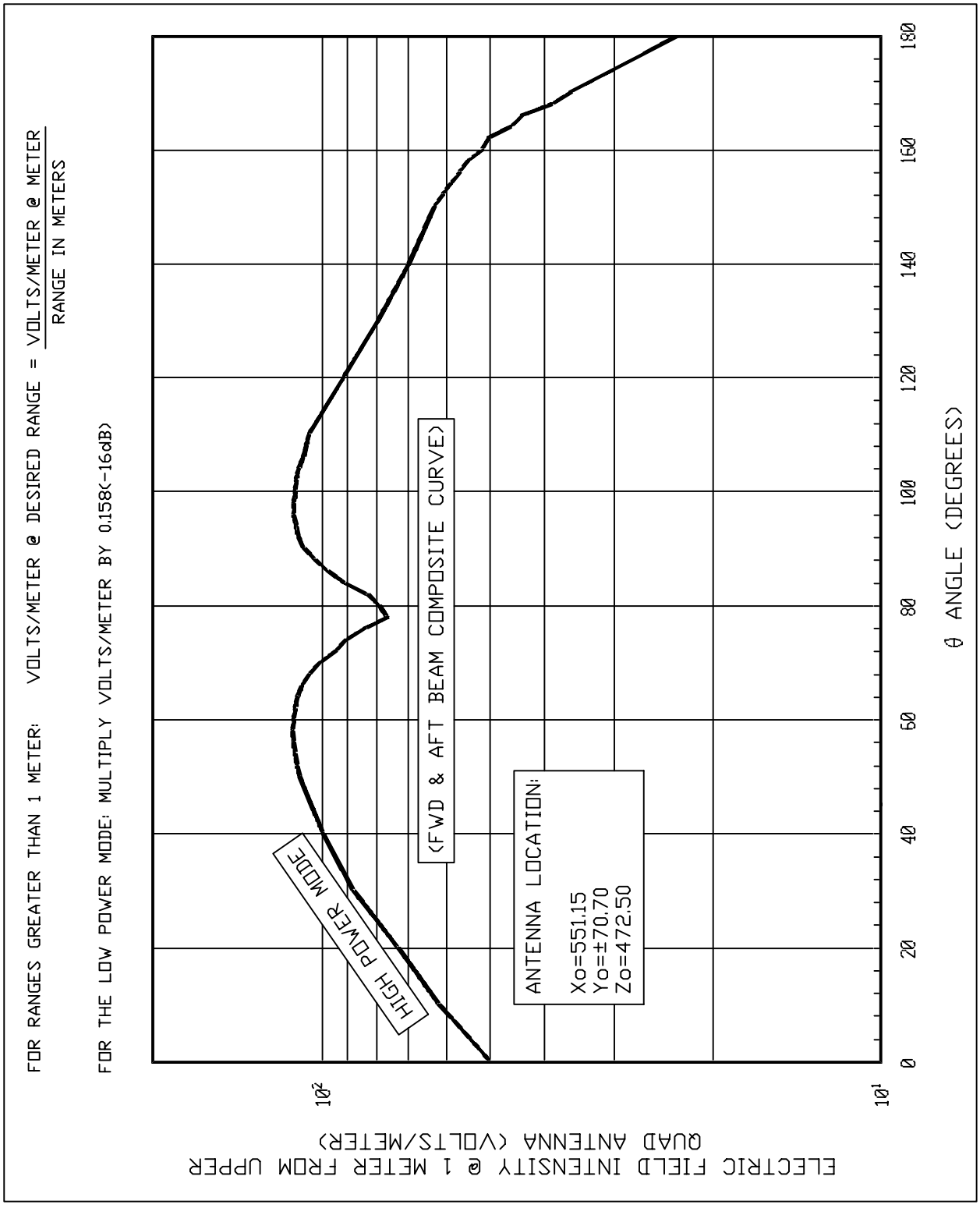

FIGURE 10.7.2.2.2.1.2-3 S-BAND NETWORK TRANSPONDER (UPPER QUAD ANTENNAS)
MAXIMUM ELECTRIC FIELD INTENSITIES

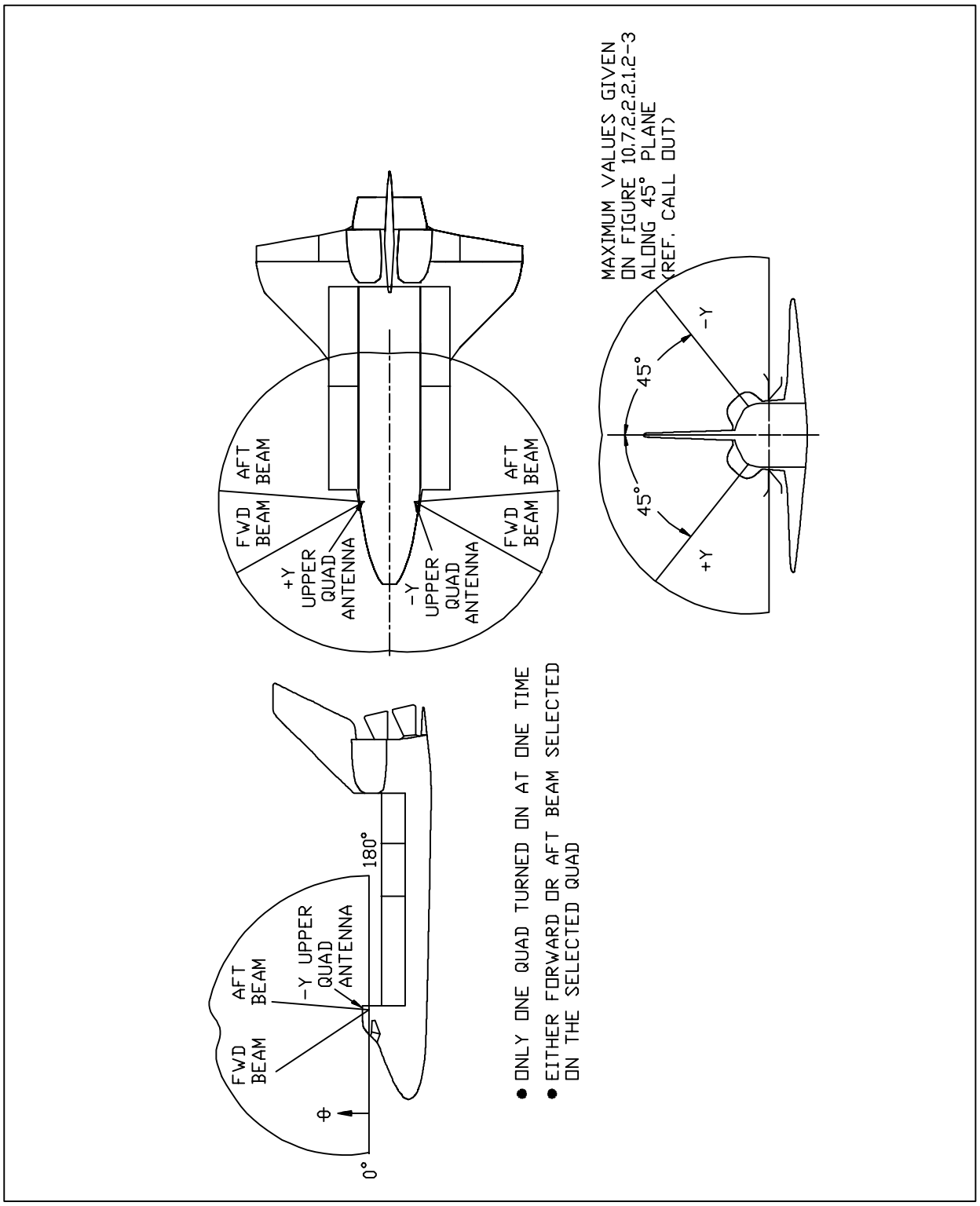

FIGURE 10.7.2.2.2.1.2-4 S-BAND NETWORK TRANSPONDER (UPPER QUAD ANTENNAS) BEAM CONFIGURATION

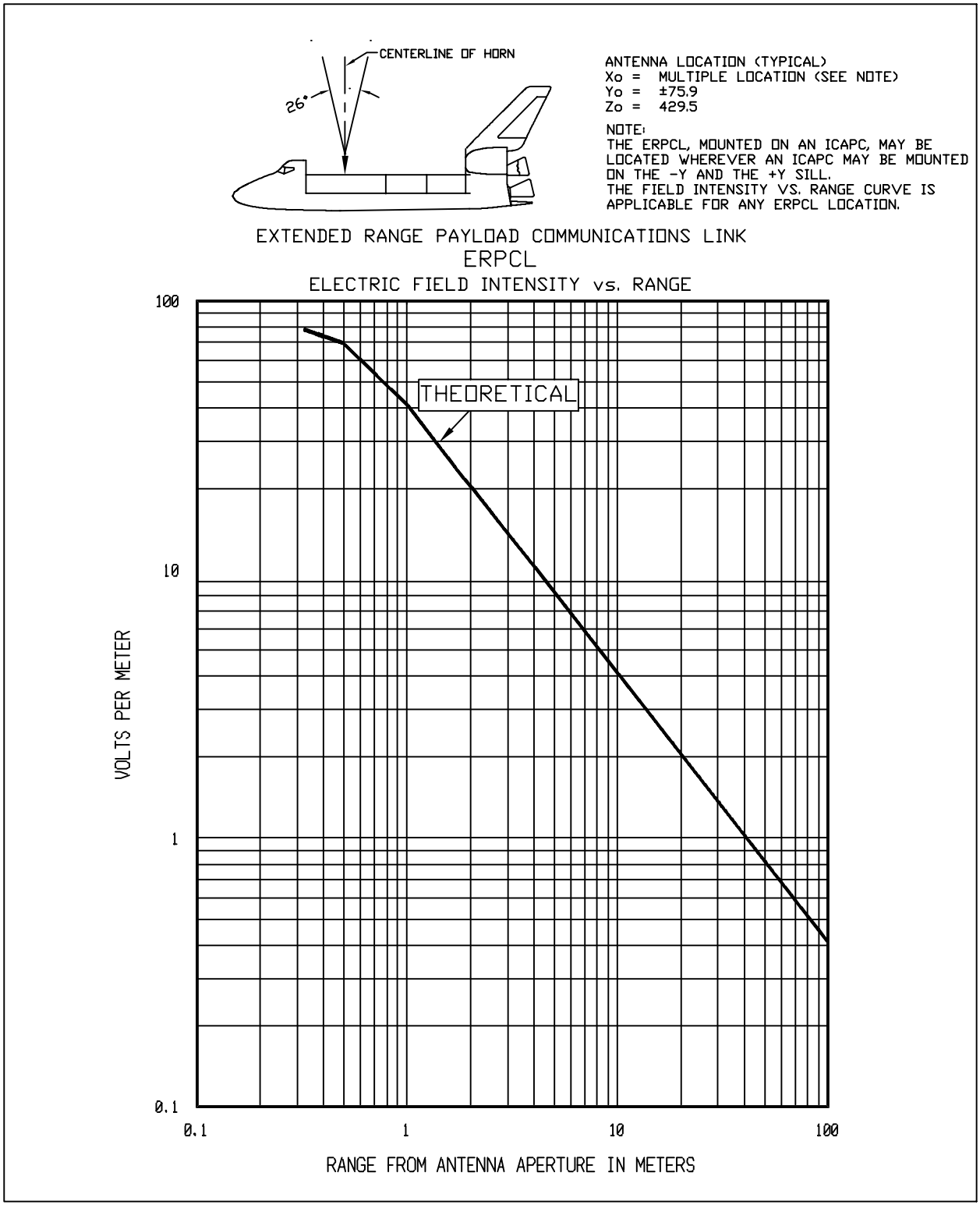

FIGURE 10.7.2.2.2.1.3-1 S-BAND EXTENDED RANGE PAYLOAD COMMUNICATIONS LINK (ERPCL) PRODUCED ELECTRIC FIELD INTENSITIES

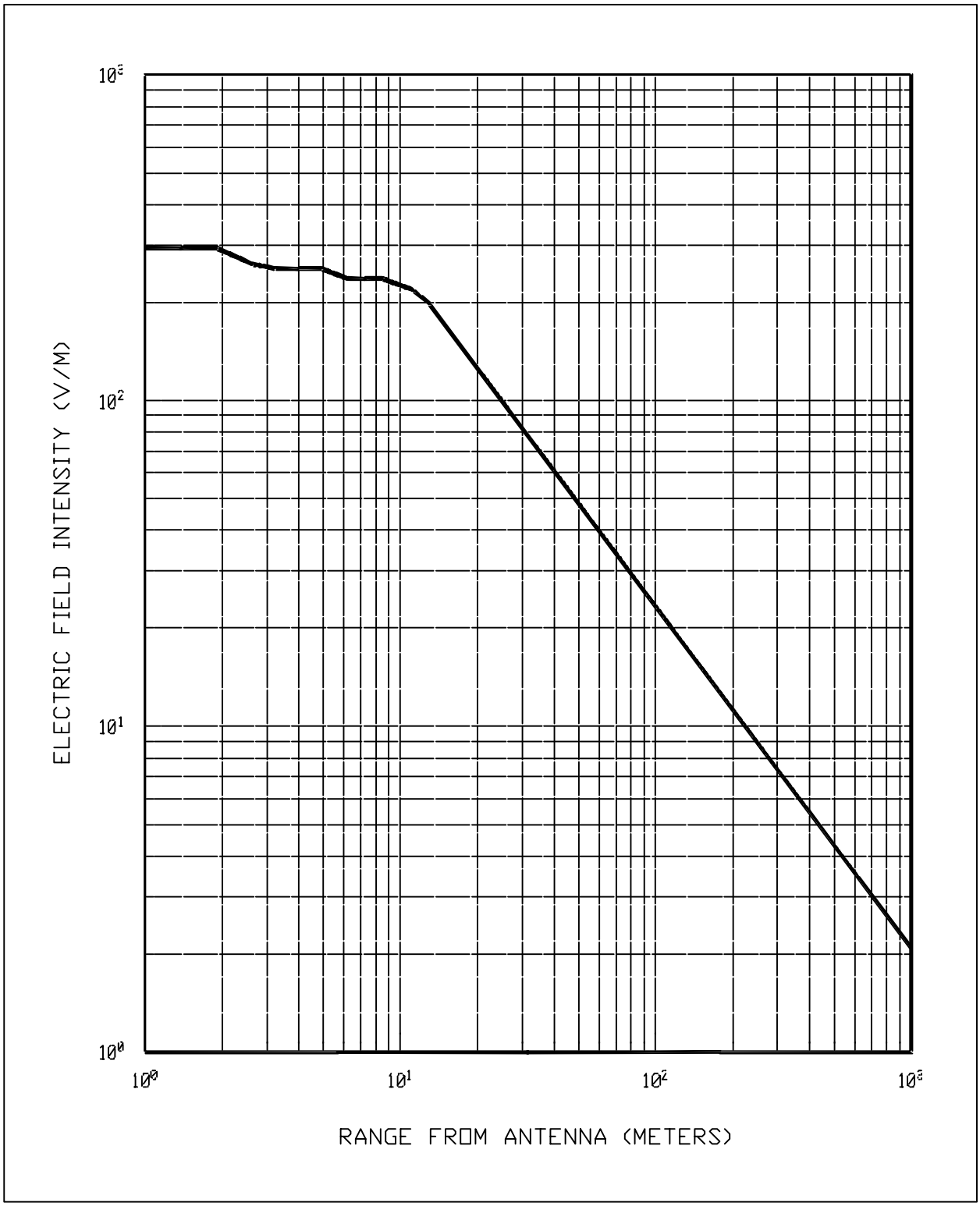

FIGURE 10.7.2.2.2.2.2-1 ORBITER KU-BAND SYSTEM: COMMUNICATION MODE ELECTRIC FIELD INTENSITY VS RANGE FROM ANTENNA

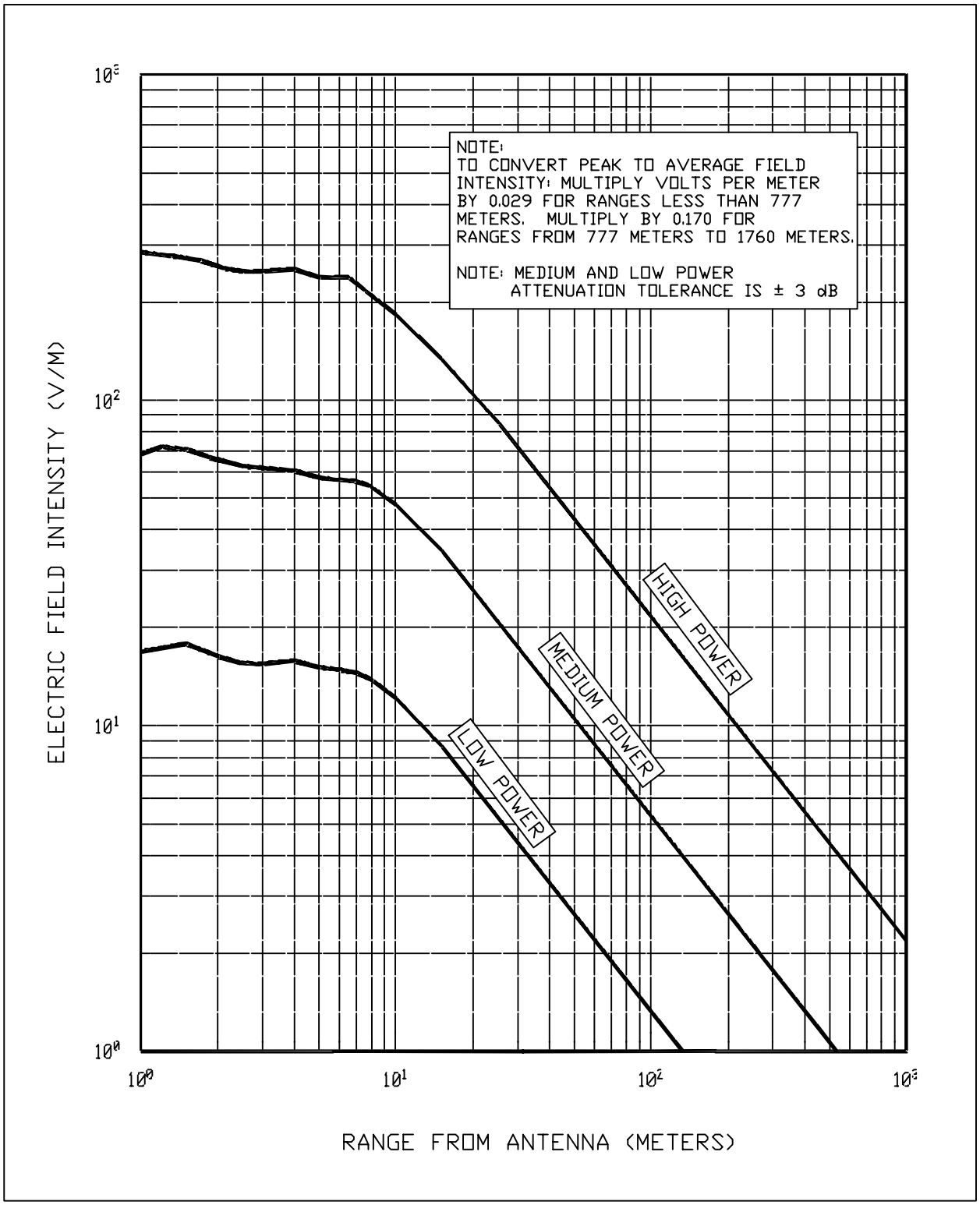

FIGURE 10.7.2.2.2.2.2-2 ORBITER KU-BAND SYSTEM: RADAR MODE PEAK ELECTRIC FIELD INTENSITY VS RANGE FROM ANTENNA

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