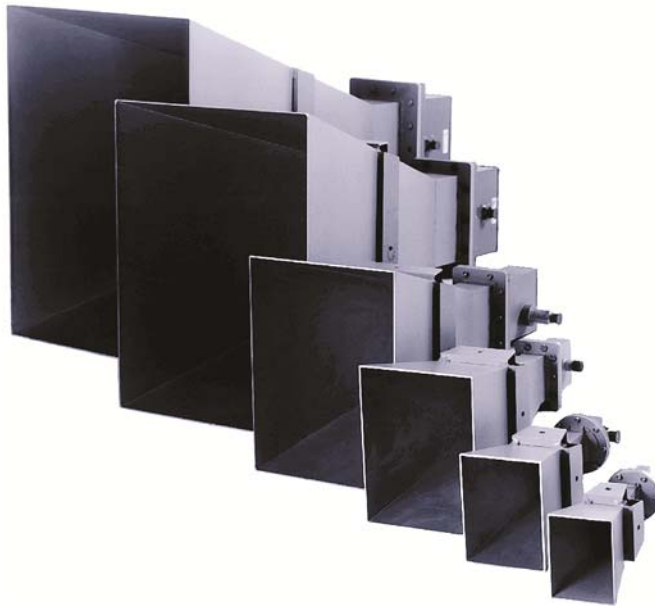


Model 3160 Series

Pyramidal Horn Antenna

User Manual



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An ESCO Technologies Company

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Table of Contents


Notes, Cautions, and Warnings	vii
1.0 Introduction	9
ETS-Lindgren Product Information Bulletin	10
2.0 Maintenance	11
Annual Calibration	11
Service Procedures	12
3.0 Specifications	13
Electrical Specifications	13
Physical Specifications	14
4.0 Mounting Instructions	15
3160-09 and 3160-10 Only	16
3160-09.....	16
3160-10.....	16
Mount to 4-TR.....	17
Mount to 7-TR and Mast.....	17
Mount to 2x2 Boom.....	18
5.0 Typical Data	19
Typical VSWR (3160-06).....	19
Typical Gain and Antenna Factor (3160-06).....	20
Typical Half-Power Beamwidth (3160-06)	21
6.0 Radiated Emissions Measurements	23
Measure Ambient Field Strength Values	23
Conversion Formulas.....	24
Equation 1.....	24
Equation 2.....	25
Equation 3.....	25
Equation 4.....	25
Equation 5.....	25
Equation 6.....	26
Equation 7.....	26
Equation 8.....	26

Equation 9.....	26
Appendix A: Warranty	27
Appendix B: Power Requirements.....	29
3160-01.....	30
Table 1: Model 3160-01 Power Requirements at 1 Meter.....	30
Table 2: Model 3160-01 Power Requirements at 3 and 10 Meters	30
3160-02.....	31
Table 3: Model 3160-02 Power Requirements at 1 Meter.....	31
Table 4: Model 3160-02 Power Requirements at 3 and 10 Meters	31
3160-03.....	32
Table 5: Model 3160-03 Power Requirements at 1 Meter.....	32
Table 6: Model 3160-03 Power Requirements at 3 and 10 Meters	32
3160-04.....	33
Table 7: Model 3160-04 Power Requirements at 1 Meter.....	33
Table 8: Model 3160-04 Power Requirements at 3 and 10 Meters	33
3160-05.....	34
Table 9: Model 3160-05 Power Requirements at 1 Meter.....	34
Table 10: Model 3160-05 Power Requirements at 3 and 10 Meters	34
3160-06.....	35
Table 11: Model 3160-06 Power Requirements at 1 Meter.....	35
Table 12: Model 3160-06 Power Requirements at 3 and 10 Meters	35
3160-07.....	36
Table 13: Model 3160-07 Power Requirements at 1 Meter.....	36
Table 14: Model 3160-07 Power Requirements at 3 and 10 Meters	36
3160-08.....	37
Table 15: Model 3160-08 Power Requirements at 1 Meter.....	37
Table 16: Model 3160-08 Power Requirements at 3 and 10 Meters	37
3160-09.....	38
Table 17: Model 3160-09 Power Requirements at 1 Meter.....	38
Table 18: Model 3160-09 Power Requirements at 3 and 10 Meters	38
3160-10.....	39
Table 19: Model 3160-10 Power Requirements at 1 Meter.....	39
Table 20: Model 3160-10 Power Requirements at 3 and 10 Meters	39
Appendix C: Model 3160 Series Data.....	41
3160-01.....	41
VSWR: 3160-01.....	41

Gain / Antenna Factor: 3160-01	41
Half-Power Beamwidth: 3160-01	42
Antenna Pattern: 3160-01 at 1.2 GHz	43
3160-02.....	44
VSWR: 3160-02.....	44
Gain / Antenna Factor: 3160-02	44
Half-Power Beamwidth: 3160-02.....	45
Antenna Pattern: 3160-02 at 1.41 GHz	46
3160-03.....	47
VSWR: 3160-03.....	47
Gain / Antenna Factor: 3160-03	47
Half-Power Beamwidth: 3160-03	48
Antenna Pattern: 3160-03 at 2.15 GHz	49
3160-04.....	50
VSWR: 3160-04.....	50
Gain / Antenna Factor: 3160-04	50
Half-Power Beamwidth: 3160-04	51
Antenna Pattern: 3160-04 at 3.3 GHz	52
3160-05.....	53
VSWR: 3160-05.....	53
Gain / Antenna Factor: 3160-05	53
Half-Power Beamwidth: 3160-05	54
Antenna Pattern: 3160-05 at 4.9 GHz	55
3160-06.....	56
VSWR: 3160-06.....	56
Gain / Antenna Factor: 3160-06	56
Half-Power Beamwidth: 3160-06.....	57
Antenna Pattern: 3160-06 at 7.0 GHz	58
3160-07.....	59
VSWR: 3160-07.....	59
Gain / Antenna Factor: 3160-07	59
Half-Power Beamwidth: 3160-07	60
Antenna Pattern: 3160-07 at 10.3 GHz	61
3160-08.....	62
VSWR: 3160-08.....	62
Gain / Antenna Factor: 3160-08	62

Half-Power Beamwidth: 3160-08	63
Antenna Pattern: 3160-08 at 15.2 GHz	64
3160-09	65
VSWR: 3160-09	65
Gain / Antenna Factor: 3160-09	65
Half-Power Beamwidth: 3160-09	66
Antenna Pattern: 3160-09 at 22.0 GHz	67
3160-10	68
VSWR: 3160-10	68
Gain / Antenna Factor: 3160-10	68
Half-Power Beamwidth: 3160-10	69
Antenna Pattern: 3160-10 at 33.0 GHz	70

Notes, Cautions, and Warnings

	<p>Note: Denotes helpful information intended to provide tips for better use of the product.</p>
<p>CAUTION</p>	<p>Caution: Denotes a hazard. Failure to follow instructions could result in minor personal injury and/or property damage. Included text gives proper procedures.</p>
<p>WARNING</p>	<p>Warning: Denotes a hazard. Failure to follow instructions could result in SEVERE personal injury and/or property damage. Included text gives proper procedures.</p>



See the ETS-Lindgren *Product Information Bulletin* for safety, regulatory, and other product marking information.

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1.0 Introduction

The **ETS-Lindgren Model 3160 Series Pyramidal Horn Antenna** is a series of pyramidal standard gain horn antennas designed specifically for utilization in emissions and immunity testing over the frequency range of 1 GHz to 40 GHz. The Model 3160 Series includes models 3160-01 through 3160-10.

Each Model 3160 Series antenna is linearly polarized and has medium gain, wide half-power beamwidth (HPBW) in both the horizontal and vertical planes, low VSWR over the recommended operating frequency range, and constant antenna factors so that the antennas can be used without looking up tables or charts.

The performance of the Model 3160 Series is precise and predictable through design parameters. Both input and output are well matched to 50 Ω and 377 Ω respectively. Comparisons of measured versus computed gain and antenna factors have been found to be within ± 0.5 dB. The Model 3160 Series antennas are considered to be the standard reference of measurements above 1 GHz, as is the resonant dipole for measurements below 1 GHz.

Each Model 3160 Series antenna is ruggedly constructed for good electromagnetic performance.

- Models 3160-01 through 3160-06 are welded using precise toolings and aluminum sheet metal.
- Models 3160-07 and 3160-08 are investment casted using an aluminum compound.
- Models 3160-09 and 3160-10 are electroformed using deposition of copper at a rate of 0.001 inch/hour for the highest precision available.
- Models 3160-01 through 3160-08 are conversion coated and painted for protection against corrosion and changes in the weather.

Each Model 3160 Series antenna comes completely assembled with a high performance, low VSWR, coax-to-waveguide adapter. Below 18 GHz, the transition from coax to waveguide is made using a female Precision N connector. Above 18 GHz, the transition uses female K connectors. The coax-to-waveguide adapters are the only power-limiting component, and can be removed if high fields are desired. For this purpose, the RF generator must be equipped with waveguide ports. In such a configuration, fields in excess of 10,000 V/m at 10 meters can be obtained.

Each Model 3160 Series antenna comes with a standard 1/4–20 mount. Horizontal and vertical polarizations are obtained by rotating the antennas from one position on the mount to the other. The mounts have been placed so as not to interfere with incoming electromagnetic energy. For the variety of mounting options available for the Model 3160 Series, see *Mounting Instructions* on page 15.

The Model 3160 Series may be used for either transmission or reception. The 50 ohm input impedance is well-matched for generating high electric fields with little power reflected back to the amplifier, reducing the chance of saturation. As a receiver, the antennas are matched to free space (377 ohms). Typical performance data is provided beginning on page 19. Methods for radiated emissions measurement are described on page 23.

For TEMPEST applications, all Model 3160 Series antennas, especially models 3160-03 and up, can be mounted on standard 12-, 18-, or 24-inch reflector dishes. The resulting antenna factor is usually about 20 dB lower than that of the antennas by themselves. However, the HPBW drops to less than 50 and the far field distance increases drastically making near field performance less predictable.

ETS-Lindgren Product Information Bulletin

See the ETS-Lindgren *Product Information Bulletin* included with your shipment for the following:

- Warranty information
- Safety, regulatory, and other product marking information
- Steps to receive your shipment
- Steps to return a component for service
- ETS-Lindgren calibration service
- ETS-Lindgren contact information

2.0 Maintenance

CAUTION

Before performing any maintenance, follow the safety information in the ETS-Lindgren *Product Information Bulletin* included with your shipment.



Maintenance of the Model 3160 Series is limited to external components such as cables or connectors.

If you have any questions concerning maintenance, contact ETS-Lindgren Customer Service.

- When not in use, the Model 3160 Series Pyramidal Horn Antenna should be stored on a shelf face down to keep dust out of the feed areas.
- If the Model 3160 Series is used outdoors, the antennas should be checked for water accumulations. Water has a high dielectric constant and can alter performance.
- If an antenna is dropped, the feed/horn joint should be checked for misalignment.

Annual Calibration

The electromagnetic performance of the Model 3160 Series is almost exclusively dependent on the physical dimensions of the horns. Comparisons with computed gain and antenna factor result in differences within 1 dB. Therefore, it is not necessary to calibrate Model 3160 Series antennas; only a mechanical check is required to guarantee performance. However, if calibration is required, see the *Product Information Bulletin* included with your shipment for information on ETS-Lindgren calibration services.

Service Procedures

For the steps to return a system or system component to ETS-Lindgren for service, see the *Product Information Bulletin* included with your shipment.

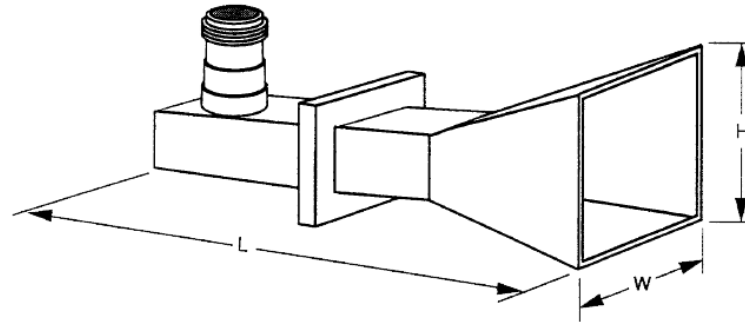
3.0 Specifications

Electrical Specifications

- The VSWR indicated in the following table is that of the pyramidal horn antenna and coax-to-waveguide adapter. The VSWR of the antenna by itself is of the order of 1.1:1.
- The maximum continuous power indicated in the following table is mainly limited by the coax-to-waveguide adapter. The antenna itself is capable of handling continuous power on the order of 10^4 Watts to 10^7 Watts.

Model	Frequency GHz	AF dB(1/m)	VSWR w/ feed	Max. Cont. Power, W	Connector Type
3160-01	0.96 1.40	15.40	1.6	550	Prec. N
3160-02	1.12 1.70	16.85	1.5	500	Prec. N
3160-03	1.70 2.60	20.60	1.5	250	Prec. N
3160-04	2.60 3.95	23.80	1.5	200	Prec. N
3160-05	3.95 5.85	27.30	1.5	200	Prec. N
3160-06	5.85 8.20	29.90	1.5	200	Prec. N
3160-07	8.20 12.40	33.50	1.5	200	Prec. N
3160-08	12.40 18.00	37.15	1.5	200	Prec. N
3160-09	18.00 26.50	40.30	1.5	50	K
3160-10	26.50 40.00	43.55	1.5	10	K

Physical Specifications



Model	Height H, cm	Width W, cm	Length L, cm	Weight kg	Construction
3160-01	62.6	46.9	103.2	25.000	Welded
3160-02	52.8	39.6	88.3	10.000	Welded
3160-03	34.0	26.0	62.2	4.545	Welded
3160-04	23.5	17.5	53.3	2.273	Welded
3160-05	15.7	11.6	36.2	1.620	Welded
3160-06	11.6	8.6	30.5	0.795	Welded
3160-07	7.6	5.8	22.9	0.426	Invest. Cast
3160-08	5.1	3.8	15.9	0.284	Invest. Cast
3160-09	3.5	2.7	10.5	0.114	Electro-formed
3160-10	2.5	1.8	9.5	0.057	Electro-formed

4.0 Mounting Instructions

CAUTION

Before connecting any components, follow the safety information in the ETS-Lindgren Product Information Bulletin included with your shipment.

CAUTION

The Model 3160 Series antennas are precision measurement devices. Handle your antenna with care.



Horizontal and vertical polarizations can be achieved by rotating the antenna from one mount to the other.

The Model 3160 Series Pyramidal Horn Antenna is equipped with a standard 1/4–20 mount. The mount is placed so as not to interfere with incoming electromagnetic energy.

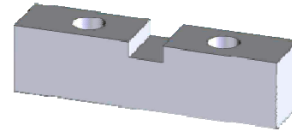
Once mounted, remove the red cover from the Type N connector and attach a cable between the antenna and a transmitting/receiving RF device. Rotate the antenna for horizontal and vertical polarizations as needed.

3160-09 and 3160-10 Only

The 3160-09 and 3160-10 antennas ship with a supplemental mount that may be used with the 4-TR Tripod, 7-TR Tripod, mast, and 2x2 boom.

3160-09

- 103255 Clamping Block

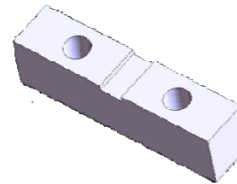


- 103256 Mounting Bracket

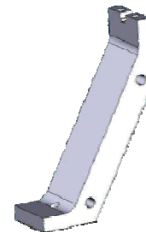


3160-10

- 103253 Clamping Block



- 103254 Mounting Bracket



Mount to 4-TR

Model 3160 Series antennas mount directly to an ETS-Lindgren 4-TR Tripod; no additional hardware is required. Secure the mount onto the 4-TR by tightening the 1/4–20 UNC mount knob.

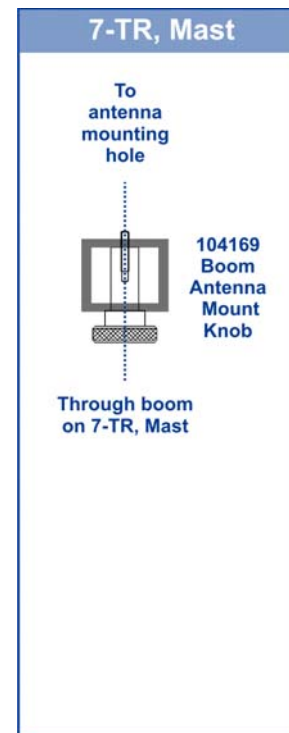
Mount to 7-TR and Mast

Following is an option for mounting the Model 3160 Series onto an ETS-Lindgren 7-TR Tripod or mast. Contact the ETS-Lindgren Sales Department for information on ordering optional mounting hardware.



Mast refers to 2070 Series, 2075, and 2175 Antenna Towers.
7-TR refers to 109042, 106328, and 108197 booms:

- *109042 boom*—Straight boom; for general antenna mounting on a 7-TR
- *106328 boom*—Offset boom; for general antenna mounting on a 7-TR with pneumatic or manual polarization
- *108197 boom*—Center rotate boom; for rear-mount stinger-type antennas only

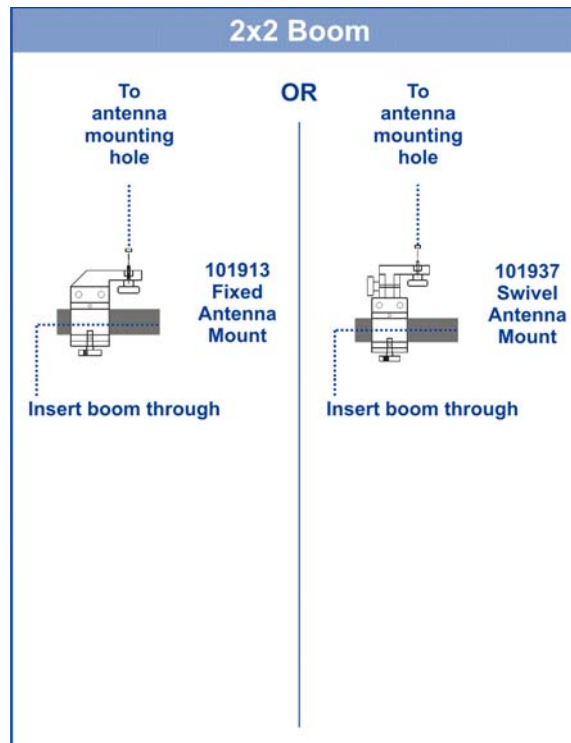


Mount to 2x2 Boom

Following are options for mounting the Model 3160 Series onto a 2x2 boom. Contact the ETS-Lindgren Sales Department for information on ordering optional mounting hardware.



2x2 boom refers to a typical 2-inch by 2-inch boom.

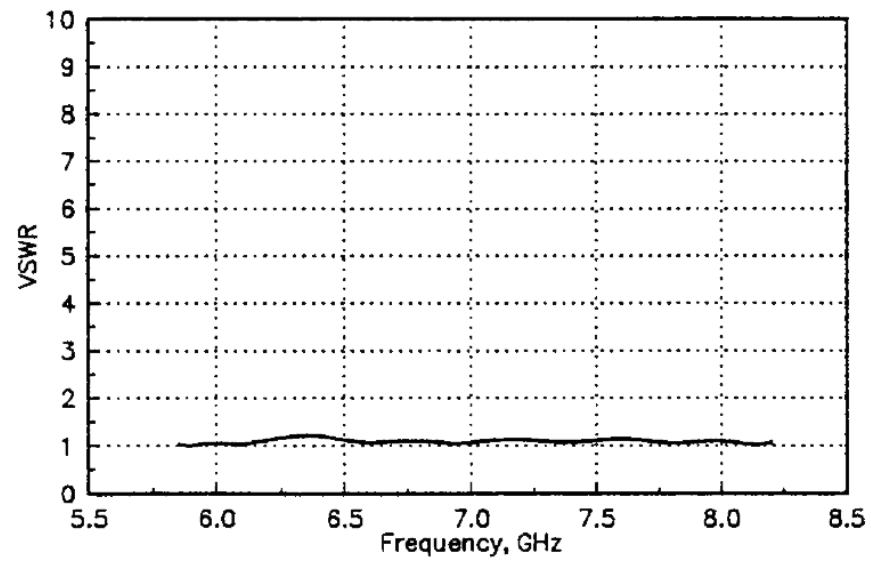


5.0 Typical Data

Following is typical electromagnetic performance data for the Model 3160 Series Pyramidal Horn Antenna, using Model 3160-06 data as representative of the series. See *Model 3160 Series Data* on page 41 for data for all Model 3160 Series antennas.

Typical VSWR (3160-06)

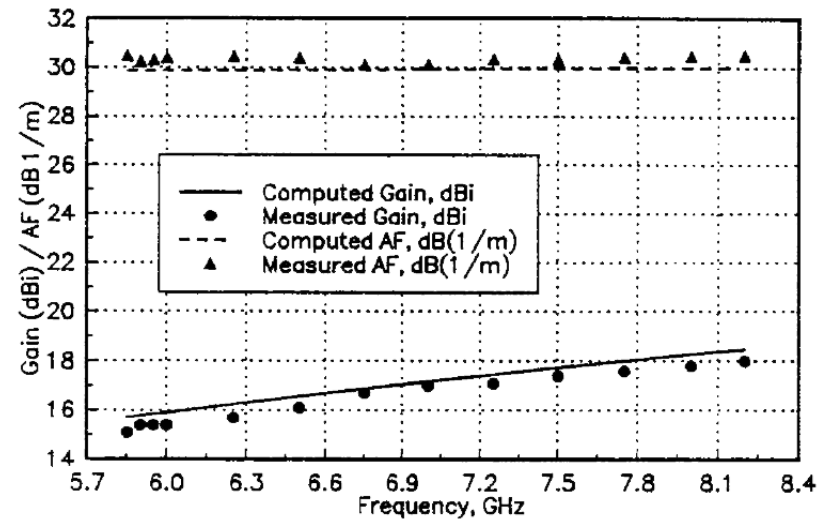
The following shows the antenna/coax-to-waveguide adapter assembly.



Typical Gain and Antenna Factor (3160-06)

Following is a plot of computed and measured gain and antenna factor versus frequency. The measured and computed results are within 3 dB, which is typical of pyramidal horns. Differences are attributed to imperfections in the measurements setup. The left vertical scale is for the gain measured in dBi, and the right vertical scale is for the antenna factor in $\text{dB}(\text{m}^{-1})$. The antenna factor spans only 0.6 dB from minimum to maximum; therefore, it may be considered constant over the entire frequency band without loss of accuracy. The gain is computed from the antenna factor using:

$$G(\text{dB}) = 20 \log (f_{\text{GHz}}) - AF_{\text{dB}(\text{m}^{-1})} + 30.22$$

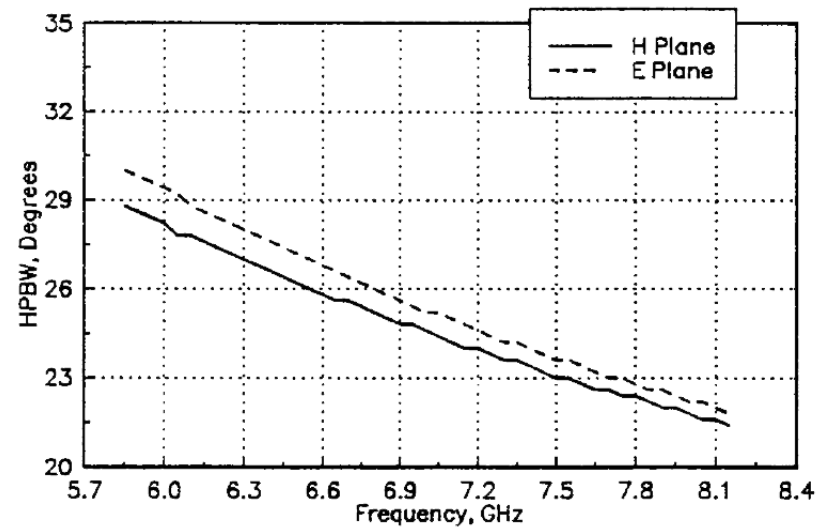


Typical Half-Power Beamwidth (3160-06)

Following is a plot of the half-power beamwidth (HPBW) versus frequency. The information provides the size of the Equipment Under Test (EUT) that can be illuminated without scanning. The size of the EUT can be obtained as:

$$\text{EUT} = 2 \left[\text{Distance} \cdot \tan \left(\frac{\text{HPBW}}{2} \right) \right]$$

Distance is the distance between the EUT and the aperture of the antenna



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6.0 Radiated Emissions Measurements

Measure Ambient Field Strength Values

1. Install the antenna where measured field strength values are desired.
2. Adjust the desired orientation of the antenna for both bore site direction and polarization.
3. Connect the output connector of the antenna to the input of the receiving system using a low VSWR, low loss coaxial cable. The Model 3160 Series Pyramidal Horn Antennas are designed for receiving systems having 50 Ω input impedance. Other values of receiving system input impedance will require correction for the difference in impedance mismatch.
4. Set desired measurement frequency on the receiving system. Make sure that the selected frequency is one that can be used with the antenna that is connected to the system.
5. Measure the RF voltage, V_a , referenced to the input port of the receiving system. The units of the measurement should be in decibels referenced to 1 microvolt, dB(μ V). If the units of measurements are millivolts, they should be converted to dB(μ V) by:

$$V_a = 20 \log_{10} (\text{RF voltage in microvolts})$$

$$V_a = 20 \log_{10} V_d$$

6. Determine the field strength at the frequency of observation by adding the voltage reading on the receiving system in dB(μ V) to the antenna factor in dB(m^{-1}):

$$\text{RF Voltage, dB}(\mu\text{V}) + \text{Antenna Factor, dB}(m^{-1}) = \\ \text{Field Strength, dB}(\mu\text{V}/m)$$

$$E_a = V_a + AF$$

The losses of the coaxial cable, A_c , should be included in the computations. In this case, the previous equation becomes:

$$\text{RF Voltage, dB}(\mu\text{V}) + \text{Cable Loss, dB} + \\ \text{Antenna Factor, DB}(\text{m}^{-1}) = \text{Field Strength, dB}(\mu\text{V}/\text{m})$$

$$E_a = V_a + A_c + AF$$

Conversion Formulas

Following are some useful conversion formulas, including how the constants are obtained:

EQUATION 1

$$\text{dBm} = \text{dB}(\mu\text{V}) - 107$$

The power is related to the voltage and the system impedance as:

$$P = \frac{V^2}{R}$$

In a 50 Ω system, the previous equation becomes:

$$10 \log_{10} P = 20 \log_{10} V - 10 \log_{10} (50)$$

Converting from dB to dBm for power and from dB(V) to dB(μ V) for voltage, the overall constant becomes:

$$30 - 120 - 10 \log_{10} (50) = -107$$

EQUATION 2

$$\text{dB}(\text{mW}/\text{m}^2) = \text{dB}(\mu\text{V}/\text{m}) - 115.8$$

The constant in this equation is obtained by considering the Poynting vector which relates the power density in (W/m^2) to the electric field strength in (V/m) by:

$$P = \frac{|E|^2}{\eta}$$

Where η is the free space characteristic impedance equal to $120\pi \Omega$. Transforming the previous questions to decibels and using the appropriate conversion factors to convert $\text{dB}(\text{W}/\text{m}^2)$ to $\text{dB}(\text{mW}/\text{m}^2)$ for power density and $\text{dB}(\text{V}/\text{m})$ to $\text{dB}(\mu\text{V}/\text{m})$ for the electric field, the constant becomes:

$$30 - 120 - 10 \log_{10}(120\pi) = -115.8$$

EQUATION 3

$$\text{dB}(\mu\text{V}/\text{m}) = \text{dB}(\mu\text{V}) + \text{AF}$$

EQUATION 4

$$\text{V}/\text{m} = 10^{\frac{\text{dB}(\mu\text{V}/\text{m}) - 120}{20}}$$

EQUATION 5

$$\text{dB}(\mu\text{A}/\text{m}) = \text{dB}(\mu\text{V}/\text{m}) - 51.5$$

The magnetic field strength is related to the electric field strength via the characteristic impedance of free space. When the transformation is made to decibels, the constant becomes:

$$20 \log_{10}(120\pi) = 51.5$$

EQUATION 6

$$A/m = 10^{\frac{dB(\mu A/m) - 120}{20}}$$

EQUATION 7

$$dB(W/m^2) = 10 \log (V/m \cdot A/m)$$

EQUATION 8

$$dB(mW/m^2) = dB(W/m^2) + 30.0$$

EQUATION 9

$$dB(pT) = dB(\mu A/m) + 2.0$$

The magnetic flux density **B** in (T) is related to the magnetic field strength **H** in (A/m) by the permeability of the medium in (H/m). For free space, the permeability is $\mu_0 = 4\pi \cdot 10^{-7}$ H/m. Converting from (T) to (pT) and from (A/m) to ($\mu A/m$) and taking the log, the constant becomes:

$$240 - 120 + 20 \log_{10} (4\pi \times 10^{-7}) = 2.0$$

Appendix A: Warranty



See the *Product Information Bulletin* included with your shipment for the complete ETS-Lindgren warranty for your Model 3160 Series.

DURATION OF WARRANTIES FOR MODEL 3160 SERIES

All product warranties, except the warranty of title, and all remedies for warranty failures are limited to two years.

Product Warranted	Duration of Warranty Period
Model 3160 Series Pyramidal Horn Antenna	2 Years

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Appendix B: Power Requirements

The Model 3160 Series Pyramidal Horn Antenna is an efficient transmitting antenna, capable of generating high electric field strengths using little power. For a given electric field strength, the required power can be computed using the transmission equation:

$$\text{Power Transmitted} = \frac{(\text{Field Strength})^2 (\text{Distance in meters})^2}{(30 \times \text{Numeric Gain})}$$

$$P_t = \frac{|E|^2 R^2}{30 g}$$

The typical power requirements in Watts for the 3161-06 are shown in Table 11 Table 12 on page 35. Distance is measured from the aperture of the antenna.

The maximum continuous power that can be applied is 250 W, and the maximum peak power is 8 kW. For example, to generate an electric field equal to 100 V/m at a distance of 3 meters at a frequency of 6.25 GHz, the calibration antenna factor read from Table 1 is 29.9 dB(m⁻¹). The gain in dB is computed using:

$$G(\text{dB}) = 20 \log(F_{\text{GHz}}) - \text{AF} + 30.22$$

$$G(\text{dB}) = 20 \log(6.25) - 29.9 + 30.22 = 16.2$$

The numeric gain is obtained as:

$$g = 10^{1.62} = 42.1$$

Applying this equation, we obtain:

$$P_t = \frac{|E|^2 R^2}{30 g} = \frac{(100)^2 (3)^2}{30 (42.2)} = 71.1 \text{ W}$$

3160-01

TABLE 1: MODEL 3160-01 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
0.96	14.6	28.8	15.3	11.58	46.31	289.41
1.00	14.9	31.1	15.3	10.72	42.90	268.10
1.05	15.3	34.0	15.3	9.79	39.17	244.81
1.10	15.7	37.1	15.3	8.99	35.94	224.64
1.15	16.0	40.2	15.4	8.28	33.13	207.06
1.20	16.4	43.5	15.4	7.67	30.66	191.64
1.25	16.7	46.8	15.4	7.12	28.49	178.04
1.30	17.0	50.2	15.5	6.64	26.56	165.99
1.35	17.3	53.7	15.5	6.21	24.84	155.27
1.40	17.6	57.2	15.5	5.83	23.31	145.68
1.45	17.8	60.8	15.6	5.48	21.93	137.09

TABLE 2: MODEL 3160-01 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	200 V/m	10 V/m	20 V/m	50 V/m
0.96	26.05	104.19	416.75	11.58	46.31	289.41
1.00	24.13	96.51	386.06	10.72	42.90	268.10
1.05	22.03	88.13	352.53	9.79	39.17	244.81
1.10	20.22	80.87	323.49	8.99	35.94	224.64
1.15	18.64	74.54	298.17	8.28	33.13	207.06
1.20	17.25	68.99	275.96	7.67	30.66	191.64
1.25	16.02	64.09	256.38	7.12	28.49	178.04
1.30	14.94	59.76	239.03	6.64	26.56	165.99
1.35	13.97	55.90	223.58	6.21	24.84	155.27
1.40	13.11	52.45	209.78	5.83	23.31	145.68
1.45	12.34	49.35	197.40	5.48	21.93	137.09

3160-02

TABLE 3: MODEL 3160-02 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
1.12	14.5	28.0	16.7	11.91	47.62	297.63
1.15	14.7	29.4	16.7	11.33	45.31	283.18
1.20	15.0	31.9	16.7	10.46	41.84	261.48
1.25	15.4	34.4	16.8	9.69	38.77	242.34
1.30	15.7	37.0	16.8	9.01	36.06	225.37
1.35	16.0	39.6	16.8	8.41	33.64	210.26
1.40	16.3	42.4	16.9	7.87	31.48	196.74
1.45	16.5	45.1	16.9	7.38	29.54	184.61
1.50	16.8	48.0	16.9	6.95	27.79	173.68
1.55	17.1	50.9	16.9	6.55	26.21	163.79
1.60	17.3	53.8	17.0	6.19	24.77	154.83
1.65	17.5	56.8	17.0	5.87	23.47	146.67
1.70	17.8	59.9	17.0	5.57	22.28	139.23

TABLE 4: MODEL 3160-02 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	200 V/m	10 V/m	20 V/m	50 V/m
1.12	26.79	107.15	428.58	11.91	47.62	297.63
1.15	25.49	101.95	407.78	11.33	45.31	283.18
1.20	23.53	94.13	376.53	10.46	41.84	261.48
1.25	21.81	87.24	348.97	9.69	38.77	242.34
1.30	20.28	81.13	324.53	9.01	36.06	225.37
1.35	18.92	75.69	302.77	8.41	33.64	210.26
1.40	17.71	70.83	283.31	7.87	31.48	196.74
1.45	16.61	66.46	265.84	7.38	29.54	184.61
1.50	15.63	62.52	250.09	6.95	27.79	173.68
1.55	14.74	58.96	235.86	6.55	26.21	163.79
1.60	13.93	55.74	222.95	6.19	24.77	154.83
1.65	13.20	52.80	211.21	5.87	23.47	146.67
1.70	12.53	50.12	200.50	5.57	22.28	139.23

TABLE 5: MODEL 3160-03 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
1.70	14.4	27.4	20.4	12.17	48.69	304.31
1.75	14.6	28.9	20.4	11.52	46.10	288.10
1.80	14.8	30.5	20.5	10.93	43.72	273.23
1.85	15.1	32.1	20.5	10.38	41.53	259.54
1.90	15.3	33.7	20.5	9.88	39.51	246.93
1.95	15.5	35.4	20.5	9.41	37.64	235.28
2.00	15.7	37.1	20.5	8.98	35.92	224.50
2.05	15.9	38.9	20.5	8.58	34.32	214.49
2.10	16.1	40.6	20.6	8.21	32.83	205.20
2.15	16.3	42.4	20.6	7.86	31.45	196.55
2.20	16.5	44.2	20.6	7.54	30.16	188.48
2.25	16.6	46.1	20.6	7.24	28.95	180.96
2.30	16.8	47.9	20.6	6.96	27.83	173.91
2.35	17.0	49.8	20.6	6.69	26.77	167.32
2.40	17.1	51.7	20.7	6.45	25.78	161.14
2.45	17.3	53.6	20.7	6.21	24.85	155.34
2.50	17.5	55.6	20.7	6.00	23.98	149.88
2.55	17.6	57.6	20.7	5.79	23.16	144.74
2.60	17.7	59.6	20.7	5.60	22.38	139.90

TABLE 6: MODEL 3160-03 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	200 V/m	10 V/m	20 V/m	50 V/m
1.70	27.39	109.55	438.20	12.17	48.69	304.31
1.80	24.59	98.36	393.44	10.93	43.72	273.23
1.90	22.22	88.90	355.58	9.88	39.51	246.93
2.00	20.20	80.82	323.27	8.98	35.92	224.50
2.10	18.47	73.87	295.49	8.21	32.83	205.20
2.20	16.96	67.85	271.42	7.54	30.16	188.48
2.30	15.65	62.61	250.44	6.96	27.83	173.91
2.40	14.50	58.01	232.04	6.45	25.78	161.14
2.50	13.49	53.96	215.83	6.00	23.98	149.88
2.60	12.59	50.37	201.46	5.60	22.38	139.90

3160-04

TABLE 7: MODEL 3160-04 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
2.60	14.8	30.5	23.7	10.95	43.78	273.64
2.70	15.2	32.8	23.7	10.18	40.70	254.39
2.80	15.5	35.1	23.7	9.49	37.95	237.18
2.90	15.8	37.6	23.7	8.87	35.47	221.71
3.00	16.0	40.1	23.7	8.31	33.24	207.77
3.10	16.3	42.7	23.7	7.81	31.22	195.15
3.20	16.6	45.4	23.7	7.35	29.39	183.70
3.30	16.8	48.1	23.7	6.93	27.72	173.28
3.40	17.1	50.9	23.8	6.55	26.20	163.77
3.50	17.3	53.7	23.8	6.20	24.81	155.06
3.60	17.5	56.7	23.8	5.88	23.53	147.06
3.70	17.8	59.6	23.8	5.59	22.35	139.71
3.80	18.0	62.7	23.8	5.32	21.27	132.94
3.90	18.2	65.8	23.8	5.07	20.27	126.68
3.95	18.3	67.4	23.8	4.95	19.80	123.72
3.80	18.0	62.7	23.8	5.32	21.27	132.94
3.90	18.2	65.8	23.8	5.07	20.27	126.68
3.95	18.3	67.4	23.8	4.95	19.80	123.72

TABLE 8: MODEL 3160-04 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	200 V/m	10 V/m	20 V/m	50 V/m
2.60	24.63	98.51	394.04	10.95	43.78	273.64
2.70	22.90	91.58	366.33	10.18	40.70	254.39
2.80	21.35	85.38	341.53	9.49	37.95	237.18
2.90	19.95	79.82	319.26	8.87	35.47	221.71
3.00	18.70	74.80	299.18	8.31	33.24	207.77
3.10	17.56	70.25	281.02	7.81	31.22	195.15
3.20	16.53	66.13	264.53	7.35	29.39	183.70
3.30	15.60	62.38	249.52	6.93	27.72	173.28
3.40	14.74	58.96	235.82	6.55	26.20	163.77
3.50	13.96	55.82	223.28	6.20	24.81	155.06
3.60	13.24	52.94	211.77	5.88	23.53	147.06
3.70	12.57	50.30	201.19	5.59	22.35	139.71
3.80	11.96	47.86	191.43	5.32	21.27	132.94
3.90	11.40	45.60	182.41	5.07	20.27	126.68
3.95	11.14	44.54	178.16	4.95	19.80	123.72

TABLE 9: MODEL 3160-05 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
3.95	14.92	31.08	27.21	10.73	42.91	268.16
4.00	15.03	31.84	27.21	10.47	41.88	261.72
4.10	15.24	33.39	27.22	9.98	39.93	249.56
4.20	15.44	34.98	27.23	9.53	38.12	238.25
4.30	15.63	36.59	27.24	9.11	36.44	227.72
4.40	15.83	38.24	27.24	8.72	34.86	217.90
4.50	16.01	39.92	27.25	8.35	33.40	208.73
4.60	16.19	41.63	27.26	8.01	32.02	200.15
4.70	16.37	43.38	27.27	7.68	30.74	192.12
4.80	16.55	45.15	27.28	7.38	29.53	184.58
4.90	16.72	46.95	27.29	7.10	28.40	177.50
5.00	16.88	48.78	27.30	6.83	27.34	170.84
5.10	17.04	50.64	27.31	6.58	26.33	164.57
5.20	17.20	52.52	27.32	6.35	25.39	158.66
5.30	17.36	54.44	27.33	6.12	24.49	153.08
5.40	17.51	56.38	27.34	5.91	23.65	147.81
5.50	17.66	58.34	27.35	5.71	22.85	142.83
5.60	17.81	60.34	27.36	5.52	22.10	138.11
5.70	17.95	62.36	27.37	5.35	21.38	133.64
5.80	18.09	64.40	27.38	5.18	20.70	129.39
5.85	18.16	65.43	27.39	5.09	20.38	127.35

TABLE 10: MODEL 3160-05 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	150 V/m	10 V/m	20 V/m	50 V/m
3.95	24.13	96.54	217.21	10.73	42.91	268.16
4.00	23.56	94.22	212.00	10.47	41.88	261.72
4.50	18.79	75.14	169.07	8.35	33.40	208.73
5.00	15.38	61.50	138.38	6.83	27.34	170.84
5.50	12.85	51.42	115.69	5.71	22.85	142.83
5.85	11.46	45.85	103.16	5.09	20.38	127.35

3160-06

TABLE 11: MODEL 3160-06 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
5.85	15.7	37.1	29.8	8.98	35.91	224.43
5.90	15.8	37.7	29.8	8.83	35.33	220.79
5.95	15.8	38.4	29.9	8.69	34.76	217.24
6.00	15.9	39.0	29.9	8.55	34.21	213.79
6.25	16.2	42.1	29.9	7.91	31.64	197.73
6.50	16.6	45.4	29.9	7.34	29.36	183.49
6.75	16.9	48.8	29.9	6.83	27.33	170.81
7.00	17.2	52.3	29.9	6.38	25.51	159.46
7.25	17.5	55.8	29.9	5.97	23.88	149.27
7.50	17.7	59.5	30.0	5.60	22.41	140.08
7.75	18.0	63.2	30.0	5.27	21.08	131.77
8.00	18.3	67.1	30.0	4.97	19.88	124.23
8.20	18.5	70.2	30.0	4.75	18.99	118.69

TABLE 12: MODEL 3160-06 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	150 V/m	10 V/m	20 V/m	50 V/m
5.85	20.20	80.79	181.79	8.98	35.91	224.43
5.90	19.87	79.48	178.84	8.83	35.33	220.79
5.95	19.55	78.21	175.97	8.69	34.76	217.24
6.00	19.24	76.96	173.17	8.55	34.21	213.79
6.25	17.80	71.18	160.16	7.91	31.64	197.73
6.50	16.51	66.06	148.63	7.34	29.36	183.49
6.75	15.37	61.49	138.35	6.83	27.33	170.81
7.00	14.35	57.41	129.16	6.38	25.51	159.46
7.25	13.43	53.74	120.91	5.97	23.88	149.27
7.50	12.61	50.43	113.47	5.60	22.41	140.08
7.75	11.86	47.44	106.73	5.27	21.08	131.77
8.00	11.18	44.72	100.63	4.97	19.88	124.23
8.20	10.68	42.73	96.14	4.75	18.99	118.69

TABLE 13: MODEL 3160-07 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	500 V/m
8.20	15.1	32.3	33.4	10.33	41.31	258.20
8.25	15.1	32.7	33.4	10.21	40.83	255.20
8.50	15.4	34.6	33.4	9.64	38.56	240.98
8.75	15.6	36.6	33.4	9.12	36.48	227.97
9.00	15.9	38.6	33.4	8.64	34.57	216.03
9.25	16.1	40.6	33.4	8.20	32.81	205.05
9.50	16.3	42.8	33.4	7.80	31.19	194.92
9.75	16.5	44.9	33.5	7.42	29.69	185.57
10.00	16.7	47.1	33.5	7.08	28.30	176.90
10.25	16.9	49.3	33.5	6.75	27.02	168.87
10.50	17.1	51.6	33.5	6.46	25.82	161.40
10.75	17.3	54.0	33.5	6.18	24.71	154.45
11.00	17.5	56.3	33.5	5.92	23.68	147.97
11.25	17.7	58.7	33.5	5.68	22.71	141.92
11.50	17.9	61.2	33.5	5.45	21.80	136.26
11.75	18.0	63.6	33.6	5.24	20.95	130.96
12.00	18.2	66.1	33.6	5.04	20.16	125.99
12.40	18.5	70.2	33.6	4.75	18.98	118.65

TABLE 14: MODEL 3160-07 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	150 V/m	10 V/m	20 V/m	50 V/m
8.20	23.24	92.95	209.14	10.33	41.31	258.20
8.50	21.69	86.75	195.20	9.64	38.56	240.98
9.00	19.44	77.77	174.99	8.64	34.57	216.03
9.50	17.54	70.17	157.89	7.80	31.19	194.92
10.00	15.92	63.69	143.29	7.08	28.30	176.90
10.50	14.53	58.11	130.74	6.46	25.82	161.40
11.00	13.32	53.27	119.86	5.92	23.68	147.97
11.50	12.26	49.05	110.37	5.45	21.80	136.26
12.00	11.34	45.36	102.05	5.04	20.16	125.99
12.40	10.68	42.72	96.11	4.75	18.98	118.65

TABLE 15: MODEL 3160-08 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				100 V/m	200 V/m	400 V/m
12.4	15.0	31.9	37.0	10.44	41.78	167.12
12.5	15.1	32.4	37.0	10.29	41.15	164.59
13.0	15.4	34.9	37.1	9.55	38.21	152.82
13.5	15.7	37.5	37.1	8.90	35.58	142.34
14.0	16.0	40.1	37.1	8.31	33.24	132.96
14.5	16.3	42.8	37.1	7.78	31.14	124.54
15.0	16.6	45.6	37.1	7.31	29.24	116.95
15.5	16.9	48.4	37.2	6.88	27.52	110.08
16.0	17.1	51.4	37.2	6.49	25.96	103.85
16.5	17.3	54.3	37.2	6.14	24.55	98.19
17.0	17.6	57.3	37.2	5.81	23.25	93.01
17.5	17.8	60.4	37.2	5.52	22.07	88.28
18.0	18.0	63.5	37.3	5.25	20.98	83.94

TABLE 16: MODEL 3160-08 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	50 V/m	100 V/m	150 V/m	10 V/m	20 V/m	40 V/m
12.4	23.50	94.00	211.51	10.44	41.78	167.12
12.5	23.15	92.58	208.31	10.29	41.15	164.59
13.0	21.49	85.96	193.42	9.55	38.21	152.82
13.5	20.02	80.07	180.15	8.90	35.58	142.34
14.0	18.70	74.79	168.28	8.31	33.24	132.96
14.5	17.51	70.05	157.62	7.78	31.14	124.54
15.0	16.45	65.78	148.01	7.31	29.24	116.95
15.5	15.48	61.92	139.33	6.88	27.52	110.08
16.0	14.60	58.42	131.44	6.49	25.96	103.85
16.5	13.81	55.23	124.27	6.14	24.55	98.19
17.0	13.08	52.32	117.72	5.81	23.25	93.01
17.5	12.41	49.66	111.73	5.52	22.07	88.28
18.0	11.80	47.21	106.23	5.25	20.98	83.94

TABLE 17: MODEL 3160-09 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				10 V/m	100 V/m	200 V/m
18.0	15.1	32.4	40.2	0.10	10.30	41.19
18.5	15.3	34.1	40.2	0.10	9.78	39.13
19.0	15.5	35.8	40.2	0.09	9.31	37.23
19.5	15.8	37.6	40.3	0.09	8.87	35.47
20.0	16.0	39.4	40.3	0.08	8.46	33.85
20.5	16.2	41.2	40.3	0.08	8.08	32.34
21.0	16.3	43.1	40.3	0.08	7.73	30.94
21.5	16.5	45.0	40.3	0.07	7.41	29.63
22.0	16.7	46.9	40.3	0.07	7.10	28.42
22.5	16.9	48.9	40.4	0.07	6.82	27.28
23.0	17.1	50.9	40.4	0.07	6.56	26.22
23.5	17.2	52.9	40.4	0.06	6.31	25.23
24.0	17.4	54.9	40.4	0.06	6.07	24.29
24.5	17.6	56.9	40.4	0.06	5.85	23.42
25.0	17.7	59.0	40.4	0.06	5.65	22.60
25.5	17.9	61.1	40.5	0.05	5.46	21.82
26.0	18.0	63.2	40.5	0.05	5.27	21.09
26.5	18.2	65.3	40.5	0.05	5.10	20.40

TABLE 18: MODEL 3160-09 POWER REQUIREMENTS AT 3 AND 10 METERS

Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	1 V/m	10 V/m	75 V/m	1 V/m	10 V/m	20 V/m
18.0	0.01	0.93	52.14	0.10	10.30	41.19
19.0	0.01	0.84	47.12	0.09	9.31	37.23
20.0	0.01	0.76	42.84	0.08	8.46	33.85
21.0	0.01	0.70	39.16	0.08	7.73	30.94
22.0	0.01	0.64	35.97	0.07	7.10	28.42
23.0	0.01	0.59	33.19	0.07	6.56	26.22
24.0	0.01	0.55	30.75	0.06	6.07	24.29
25.0	0.01	0.51	28.60	0.06	5.65	22.60
26.0	0.00	0.47	26.70	0.05	5.27	21.09
26.5	0.00	0.46	25.82	0.05	5.10	20.40

3160-10

TABLE 19: MODEL 3160-10 POWER REQUIREMENTS AT 1 METER

Frequency GHz	Gain dB	Gain Num.	AF dB(1/m)	Field Strength @ 1 m		
				10 V/m	50 V/m	100 V/m
26.50	15.28	33.70	43.39	0.10	2.47	9.89
27.00	15.43	34.89	43.40	0.10	2.39	9.55
28.00	15.72	37.32	43.42	0.09	2.23	8.93
29.00	16.00	39.82	43.45	0.08	2.09	8.37
30.00	16.27	42.37	43.47	0.08	1.97	7.87
31.00	16.53	44.97	43.50	0.07	1.85	7.41
32.00	16.78	47.63	43.52	0.07	1.75	7.00
33.00	17.02	50.34	43.55	0.07	1.66	6.62
34.00	17.25	53.09	43.58	0.06	1.57	6.28
35.00	17.47	55.88	43.61	0.06	1.49	5.97
36.00	17.69	58.72	43.64	0.06	1.42	5.68
37.00	17.89	61.59	43.67	0.05	1.35	5.41
38.00	18.09	64.49	43.70	0.05	1.29	5.17
39.00	18.29	67.43	43.73	0.05	1.24	4.94
40.00	18.47	70.39	43.77	0.05	1.18	4.74

TABLE 20: MODEL 3160-10 POWER REQUIREMENTS AT 3 AND 10 METERS

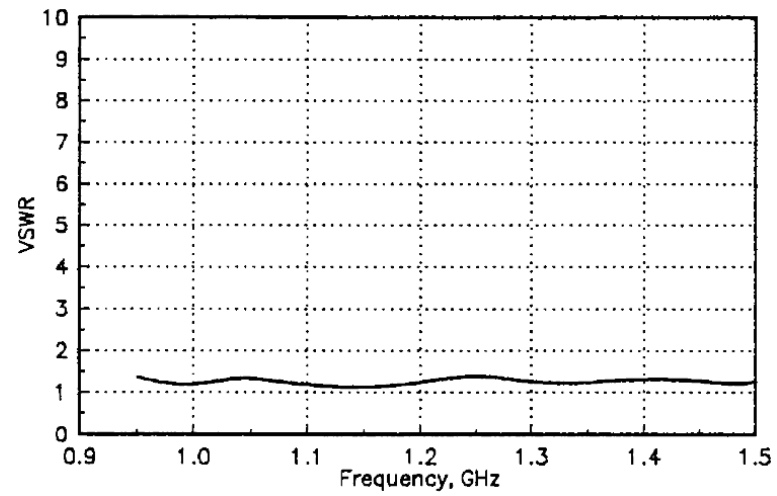
Frequency GHz	Field Strength @ 3 meters			Field Strength @ 10 meters		
	1 V/m	10 V/m	30 V/m	1 V/m	5 V/m	10 V/m
26.50	0.01	0.89	8.01	0.10	2.47	9.89
27.00	0.01	0.86	7.74	0.10	2.39	9.55
28.00	0.01	0.80	7.23	0.09	2.23	8.93
29.00	0.01	0.75	6.78	0.08	2.09	8.37
30.00	0.01	0.71	6.37	0.08	1.97	7.87
31.00	0.01	0.67	6.00	0.07	1.85	7.41
32.00	0.01	0.63	5.67	0.07	1.75	7.00
33.00	0.01	0.60	5.36	0.07	1.66	6.62
34.00	0.01	0.57	5.09	0.06	1.57	6.28
35.00	0.01	0.54	4.83	0.06	1.49	5.97
36.00	0.01	0.51	4.60	0.06	1.42	5.68
37.00	0.00	0.49	4.38	0.05	1.35	5.41
38.00	0.00	0.47	4.19	0.05	1.29	5.17
39.00	0.00	0.44	4.00	0.05	1.24	4.94
40.00	0.00	0.43	3.84	0.05	1.18	4.74

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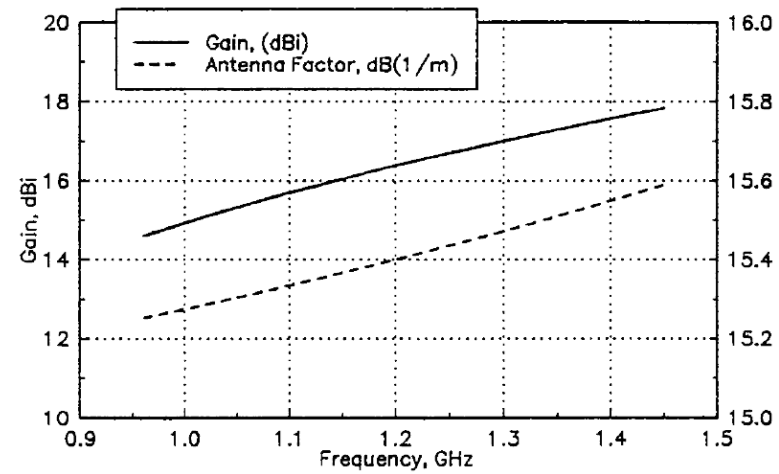
Appendix C: Model 3160 Series Data

3160-01

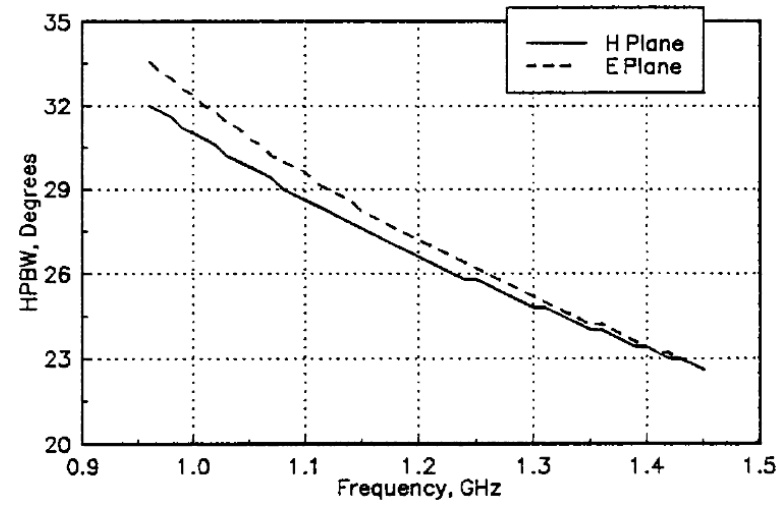
VSWR: 3160-01



GAIN / ANTENNA FACTOR: 3160-01

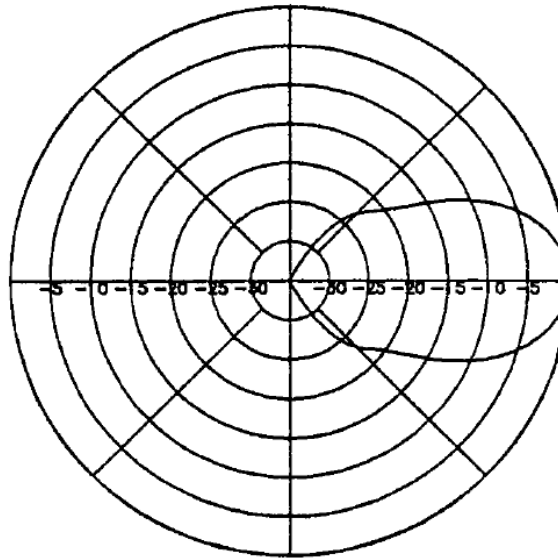


HALF-POWER BEAMWIDTH: 3160-01

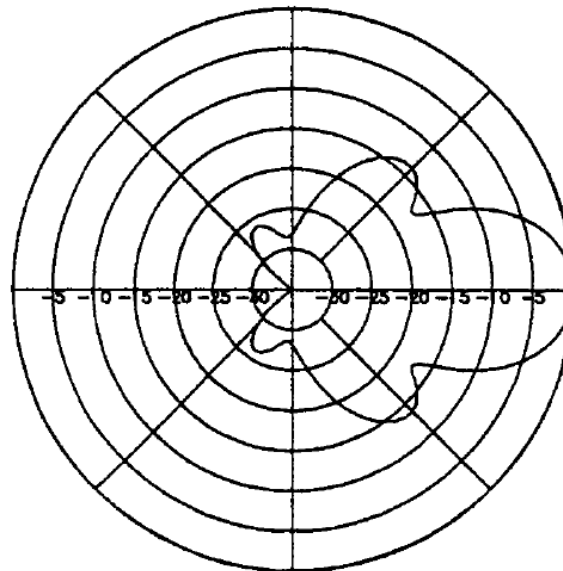


ANTENNA PATTERN: 3160-01 AT 1.2 GHZ

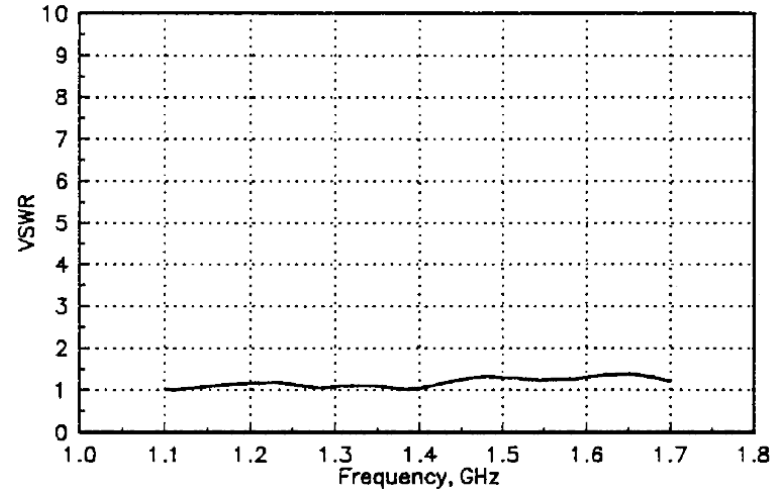
H-PLANE: 3160-01



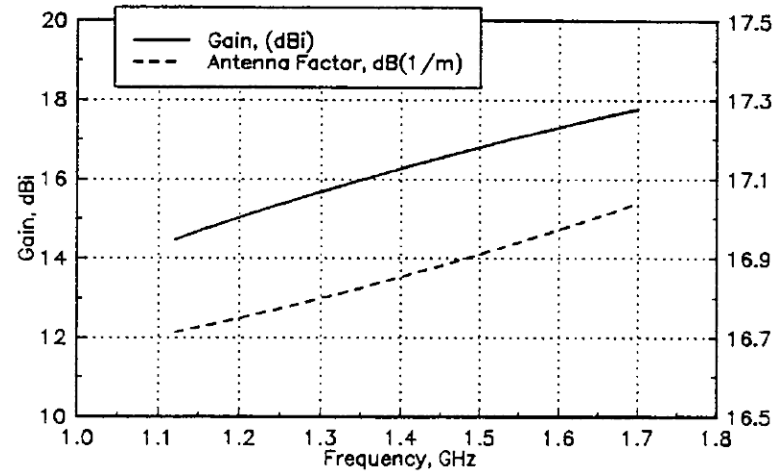
E-PLANE: 3160-01



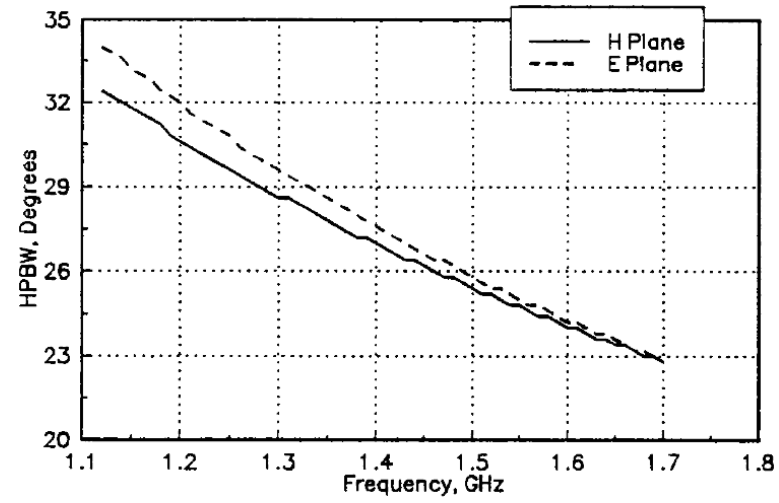
VSWR: 3160-02



GAIN / ANTENNA FACTOR: 3160-02

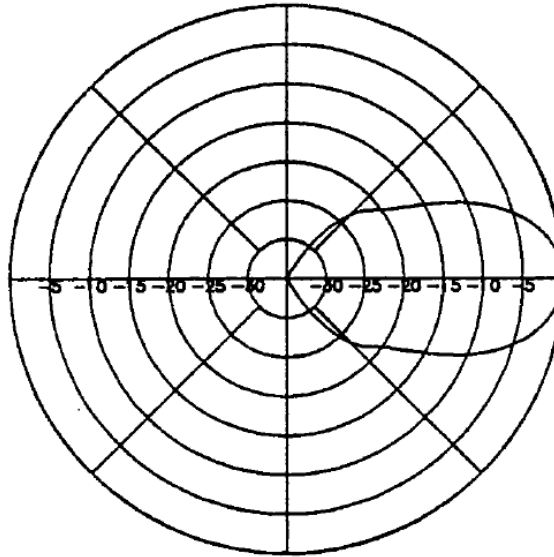


HALF-POWER BEAMWIDTH: 3160-02

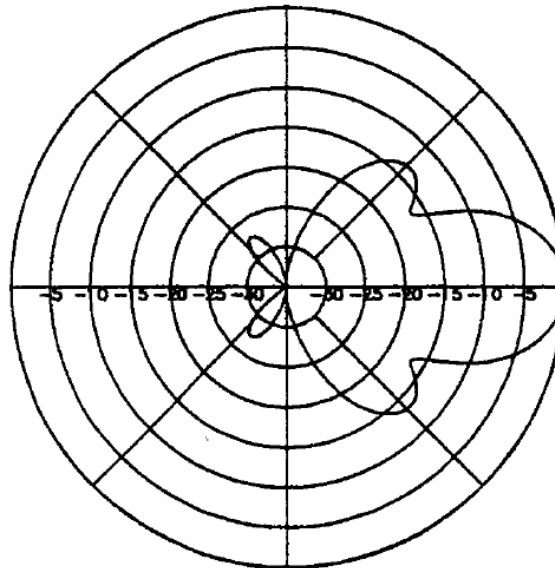


ANTENNA PATTERN: 3160-02 AT 1.41 GHZ

H-PLANE: 3160-02

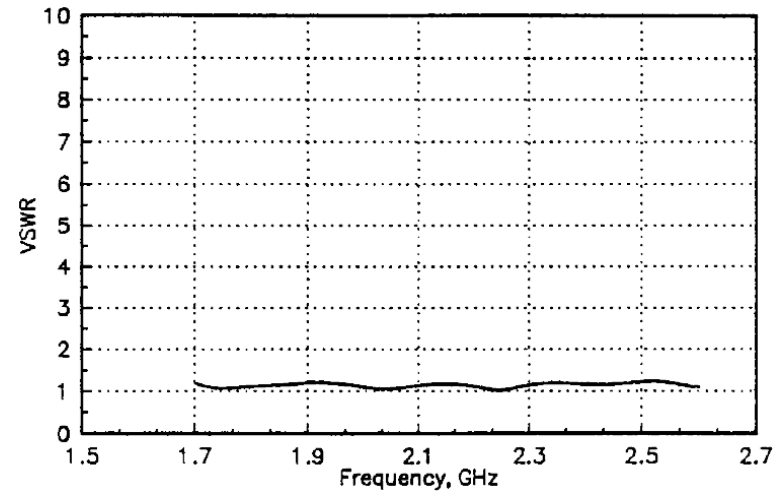


E-PLANE: 3160-02

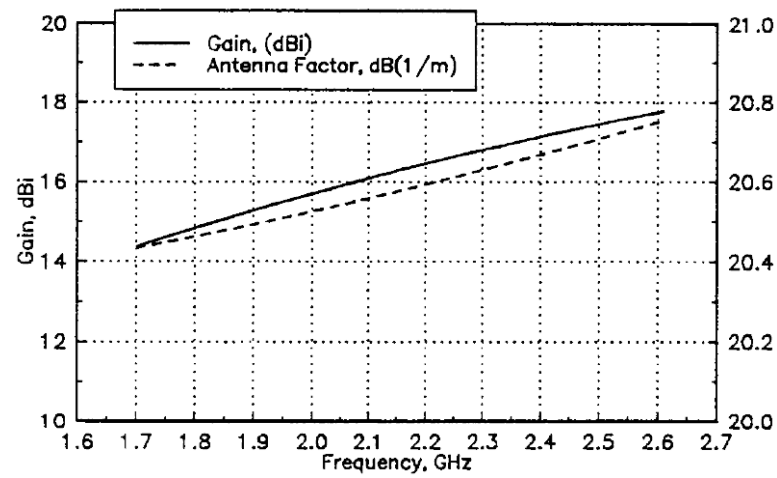


3160-03

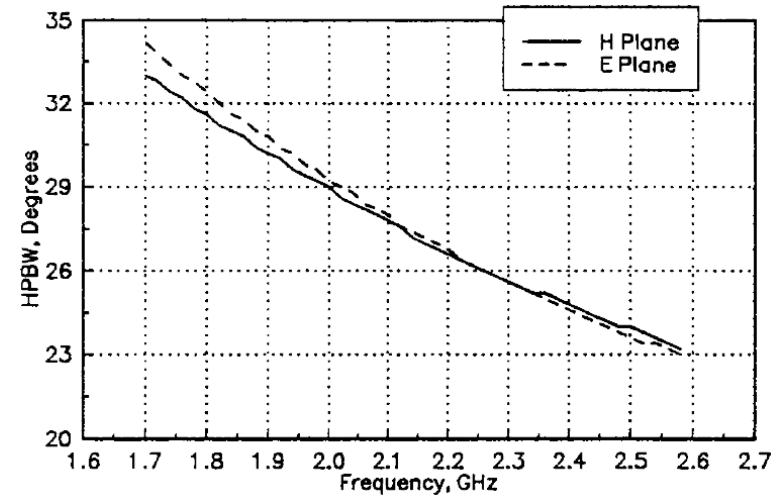
VSWR: 3160-03



GAIN / ANTENNA FACTOR: 3160-03

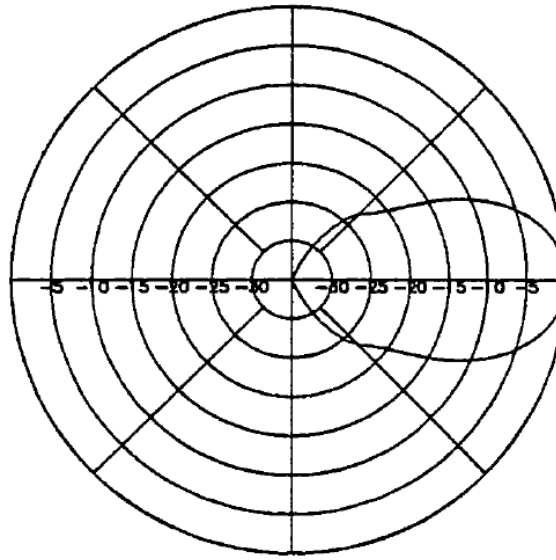


HALF-POWER BEAMWIDTH: 3160-03

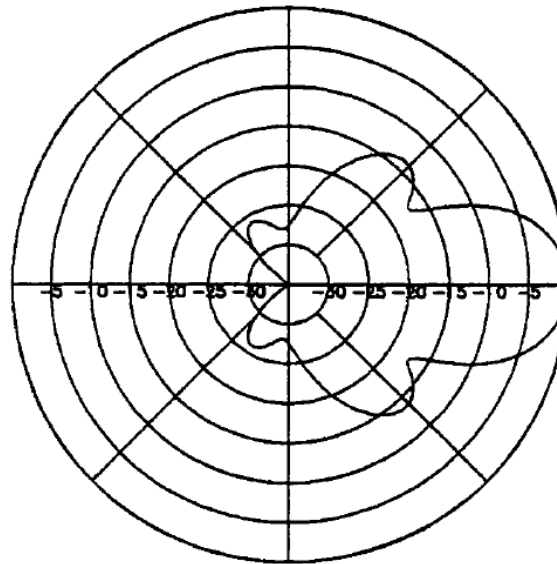


ANTENNA PATTERN: 3160-03 AT 2.15 GHZ

H-PLANE: 3160-03

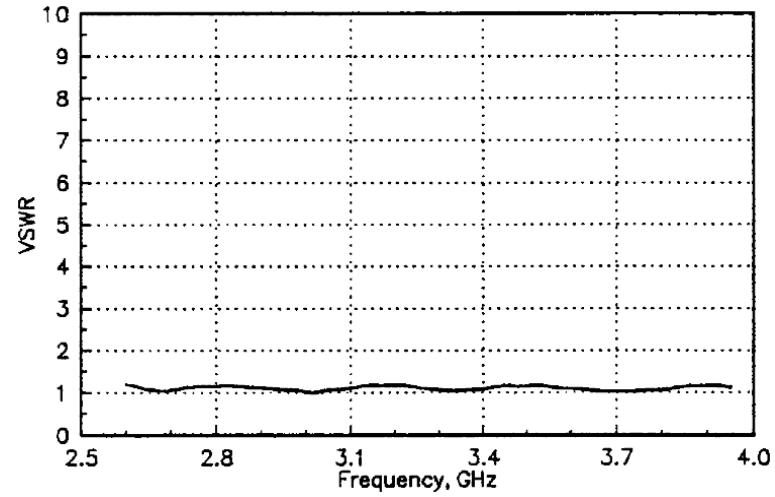


E-PLANE: 3160-03

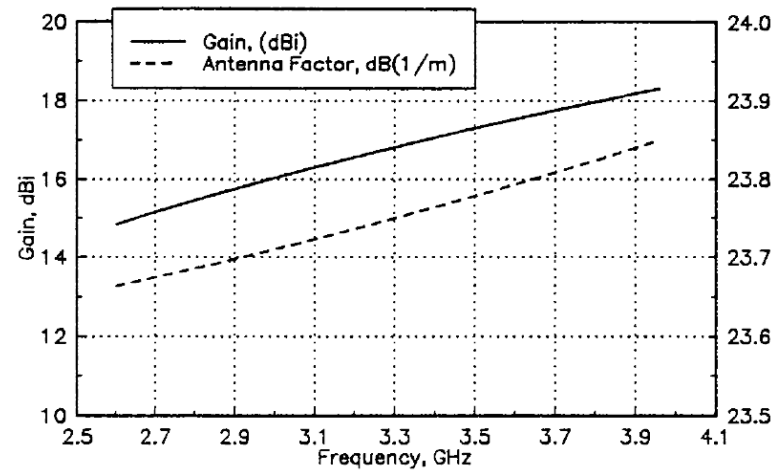


3160-04

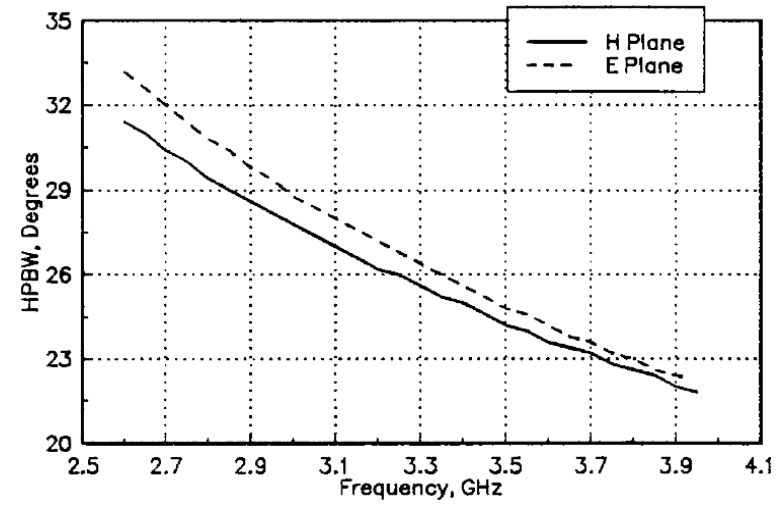
VSWR: 3160-04



GAIN / ANTENNA FACTOR: 3160-04

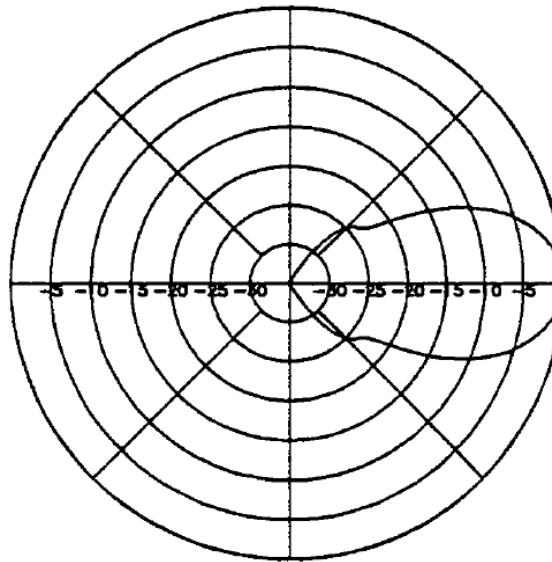


HALF-POWER BEAMWIDTH: 3160-04

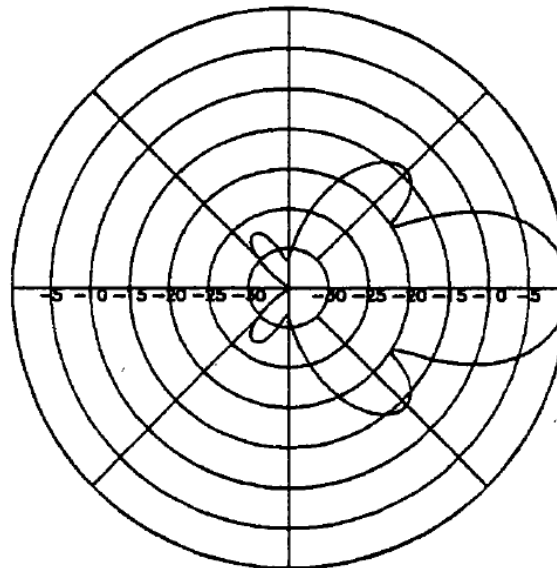


ANTENNA PATTERN: 3160-04 AT 3.3 GHZ

H-PLANE: 3160-04

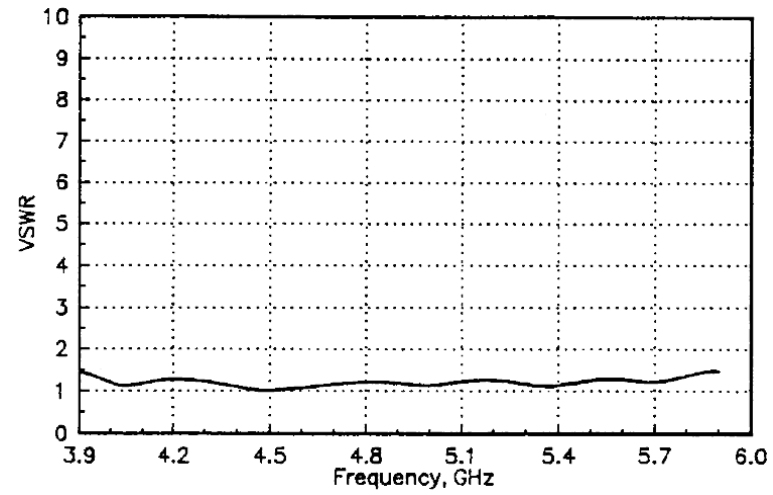


E-PLANE: 3160-04

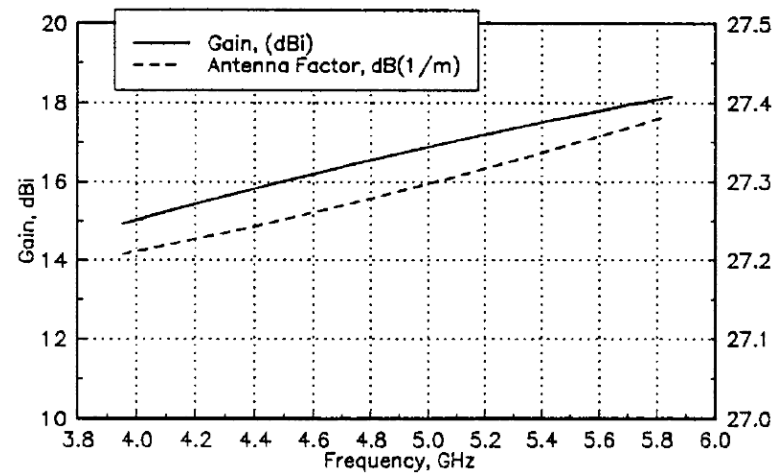


3160-05

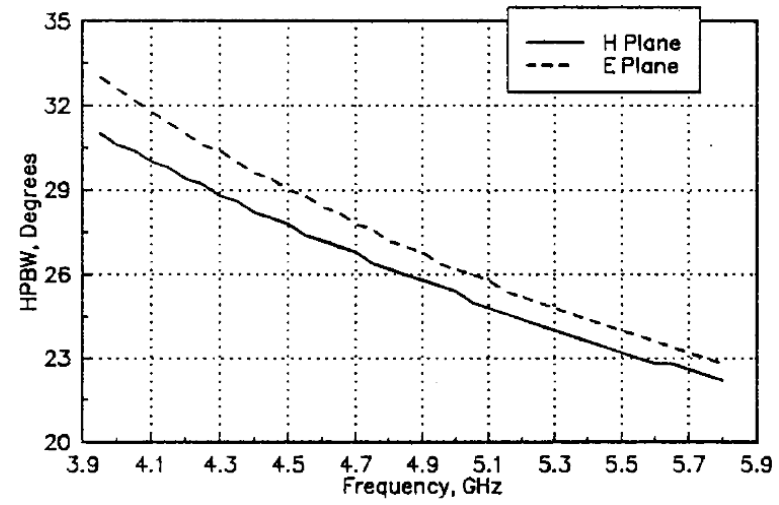
VSWR: 3160-05



GAIN / ANTENNA FACTOR: 3160-05

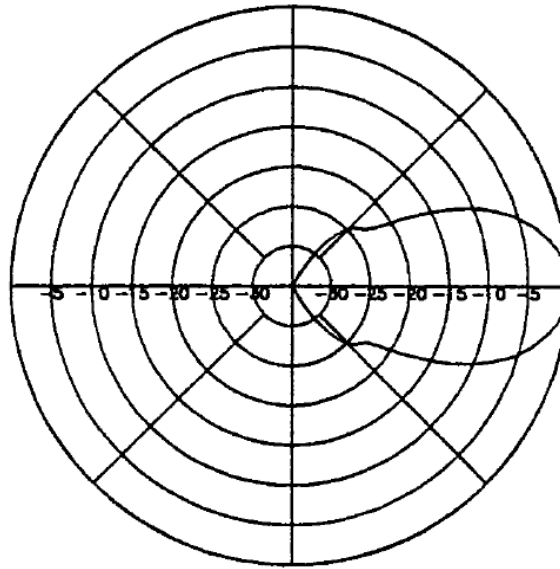


HALF-POWER BEAMWIDTH: 3160-05

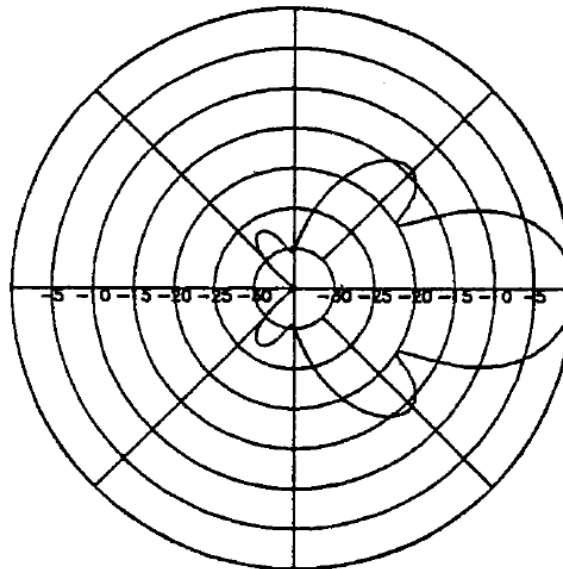


ANTENNA PATTERN: 3160-05 AT 4.9 GHZ

H-PLANE: 3160-05

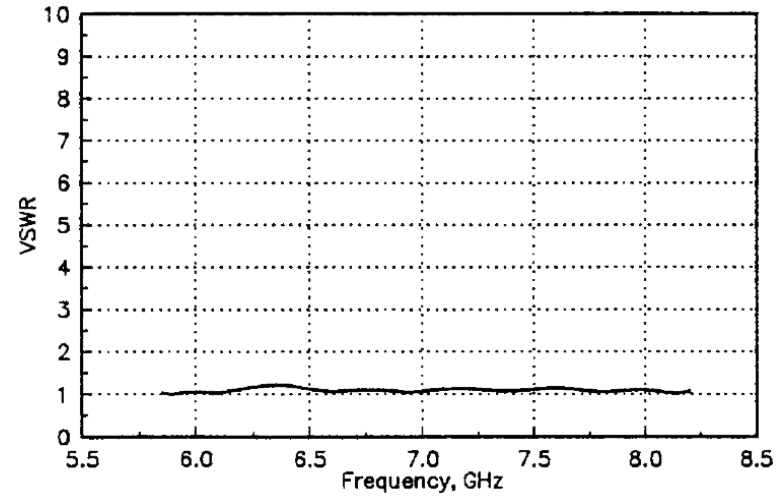


E-PLANE: 3160-05

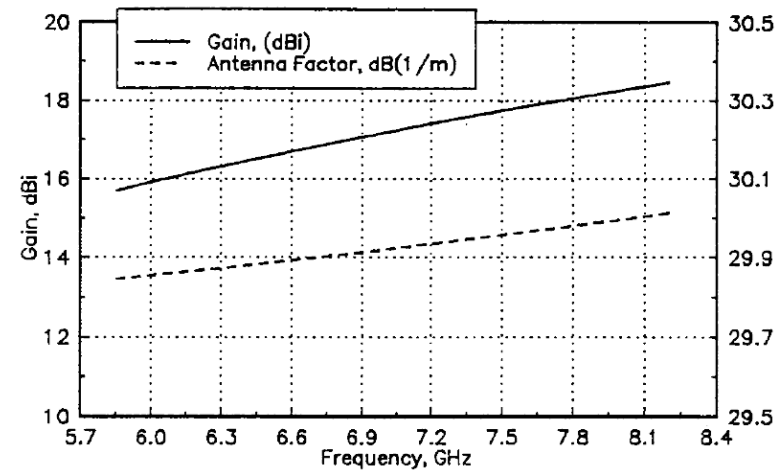


3160-06

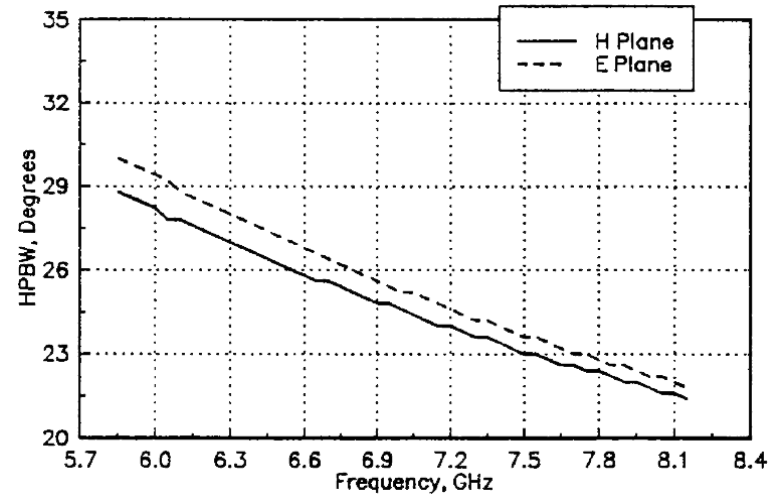
VSWR: 3160-06



GAIN / ANTENNA FACTOR: 3160-06

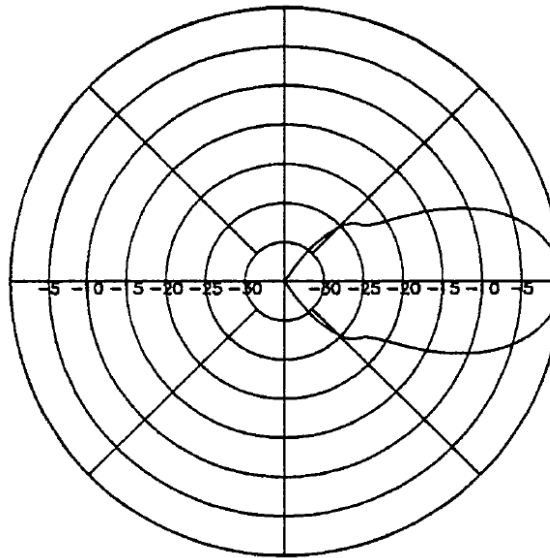


HALF-POWER BEAMWIDTH: 3160-06

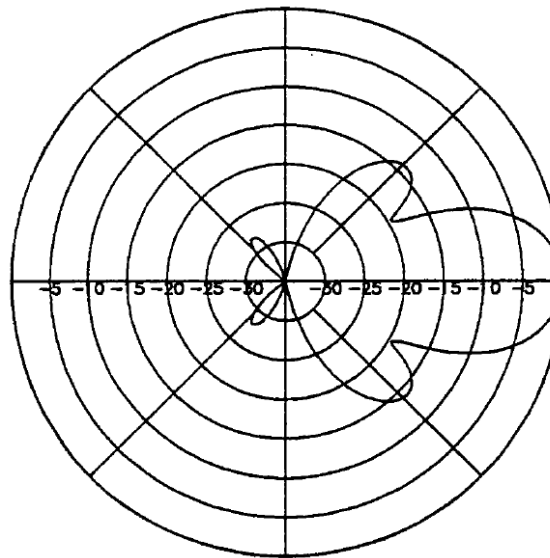


ANTENNA PATTERN: 3160-06 AT 7.0 GHZ

H-PLANE: 3160-06

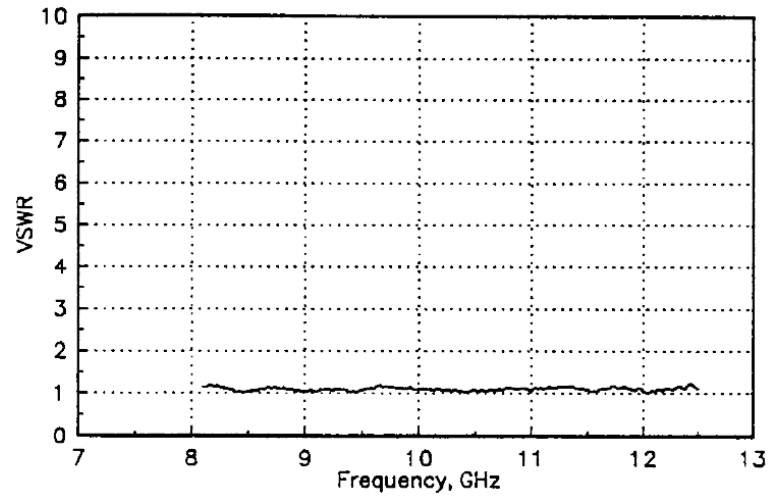


E-PLANE: 3160-06

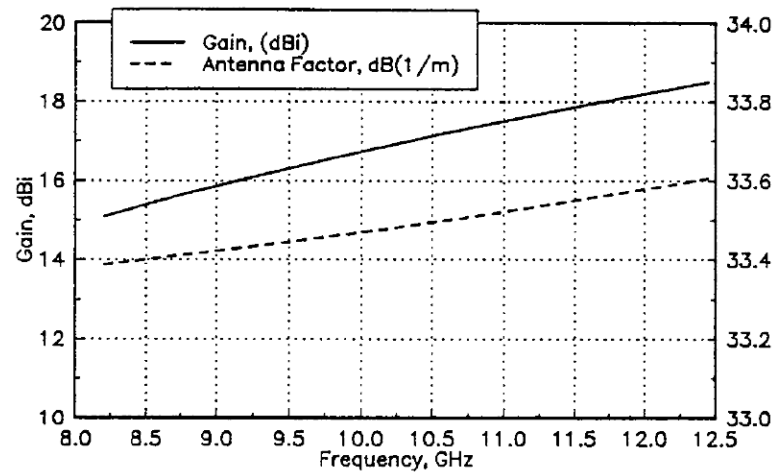


3160-07

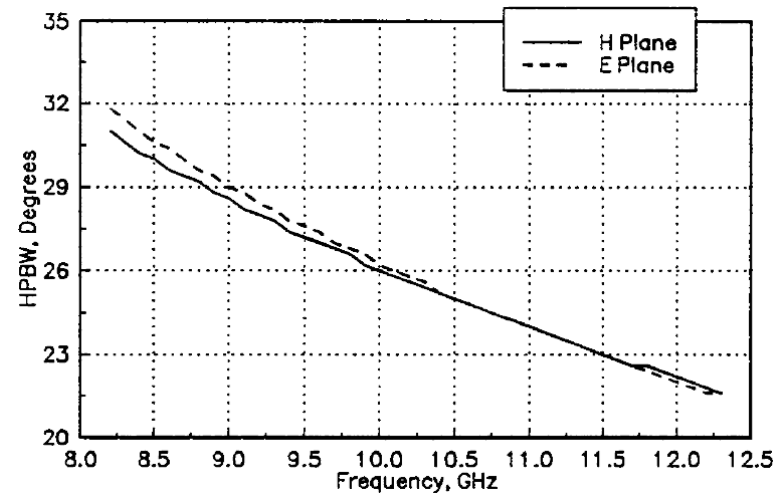
VSWR: 3160-07



GAIN / ANTENNA FACTOR: 3160-07

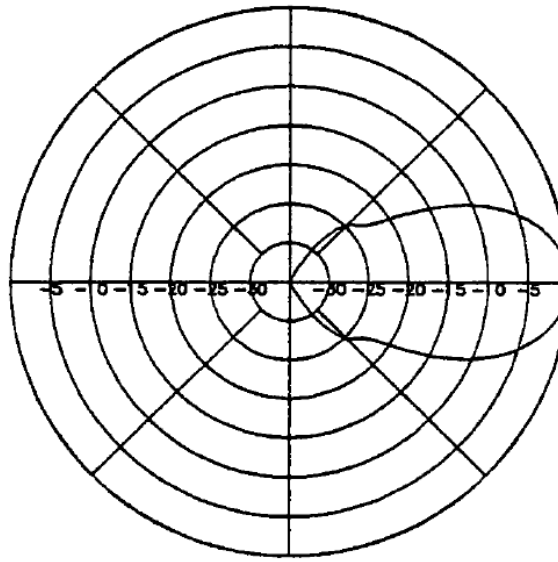


HALF-POWER BEAMWIDTH: 3160-07

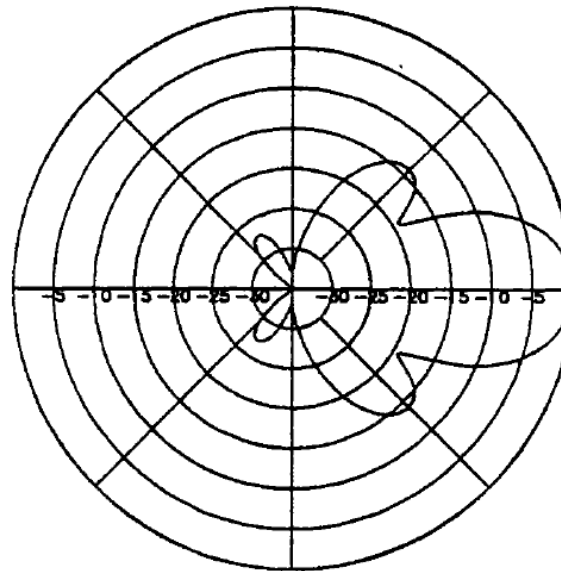


ANTENNA PATTERN: 3160-07 AT 10.3 GHZ

H-PLANE: 3160-07

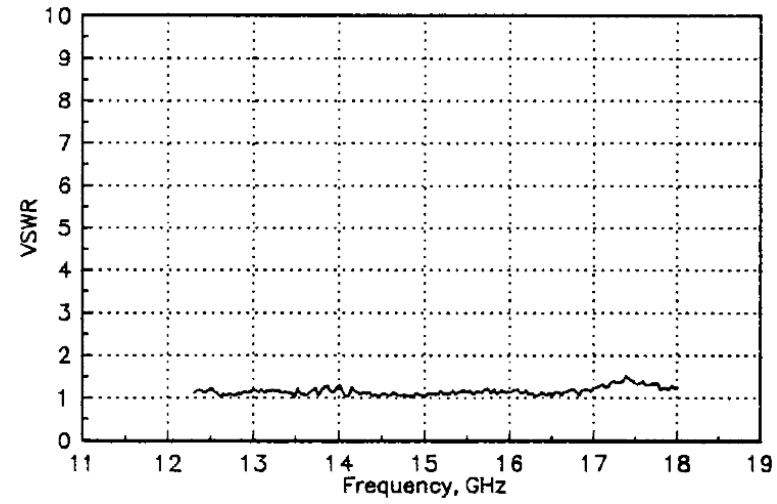


E-PLANE: 3160-07

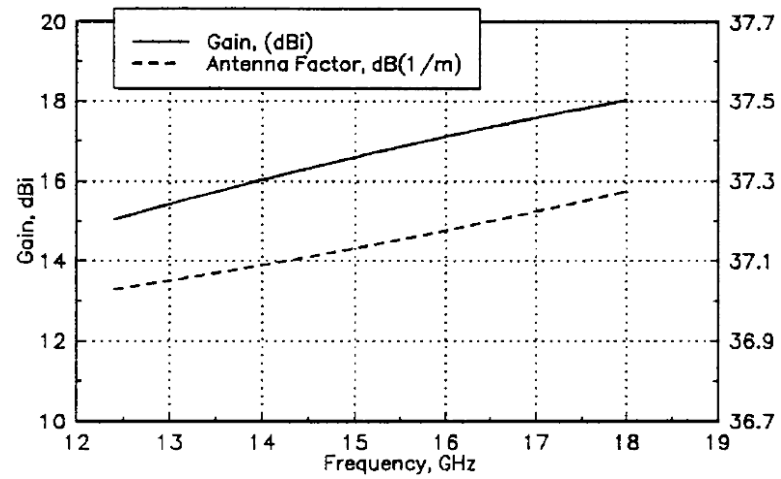


3160-08

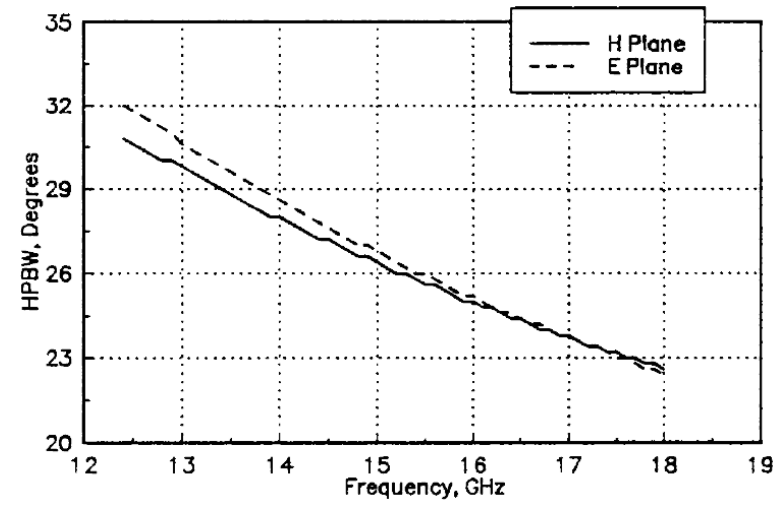
VSWR: 3160-08



GAIN / ANTENNA FACTOR: 3160-08

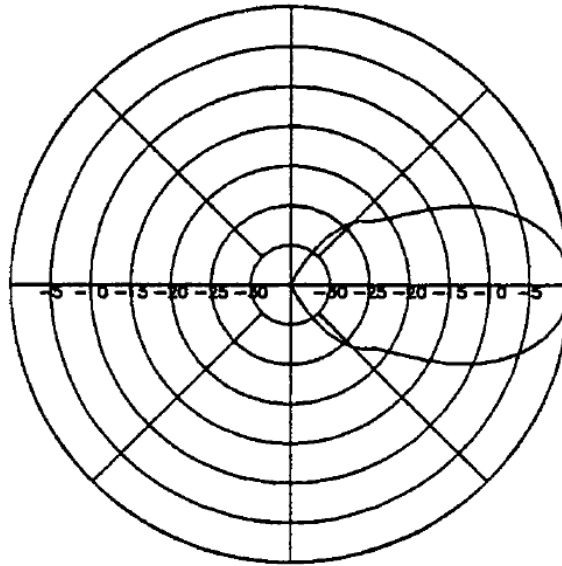


HALF-POWER BEAMWIDTH: 3160-08

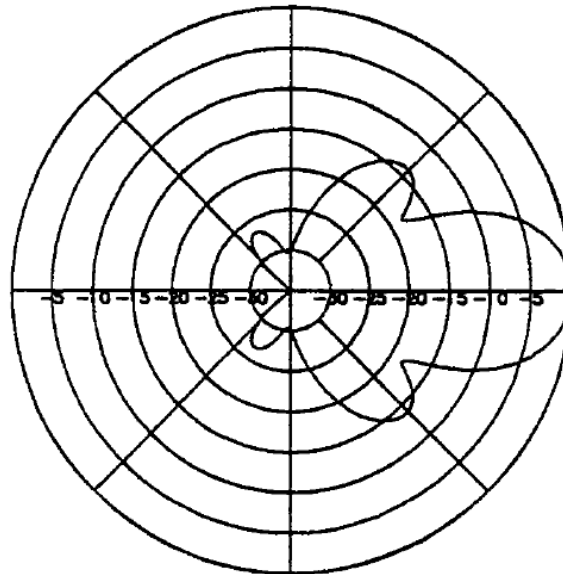


ANTENNA PATTERN: 3160-08 AT 15.2 GHZ

H-PLANE: 3160-08

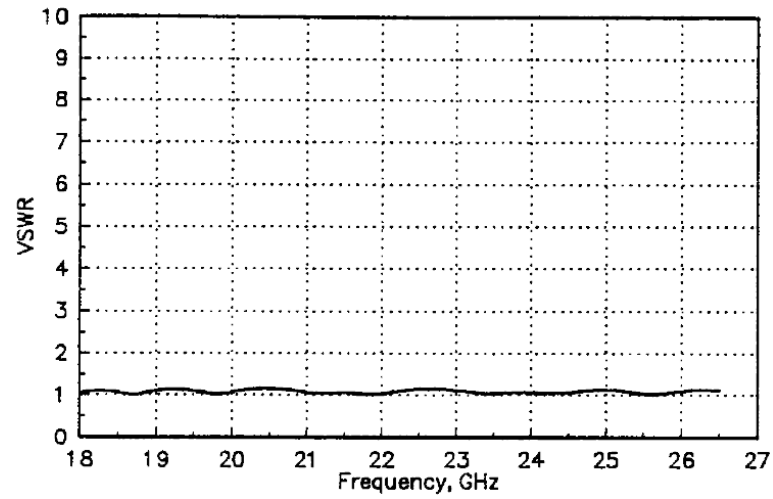


E-PLANE: 3160-08

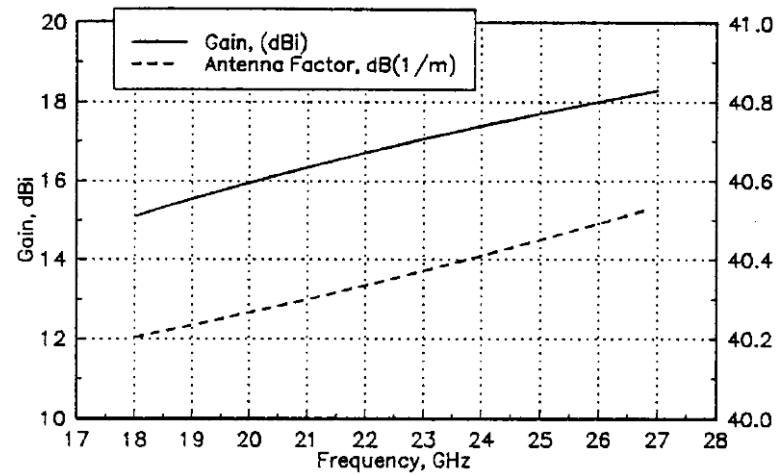


3160-09

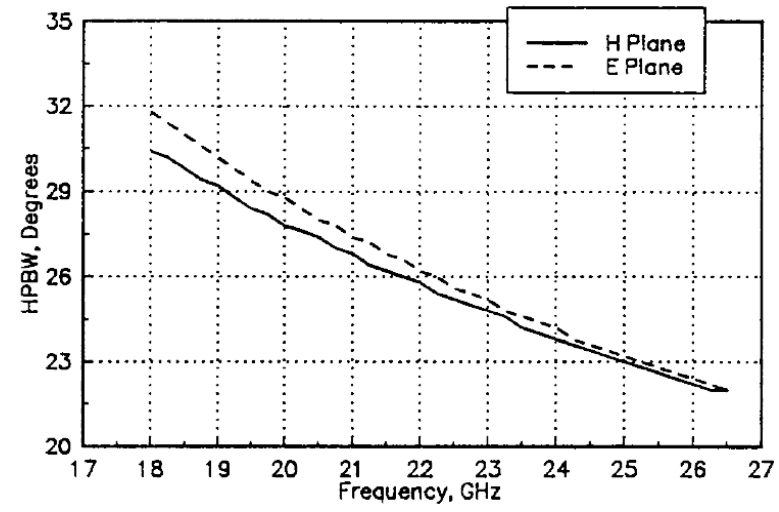
VSWR: 3160-09



GAIN / ANTENNA FACTOR: 3160-09

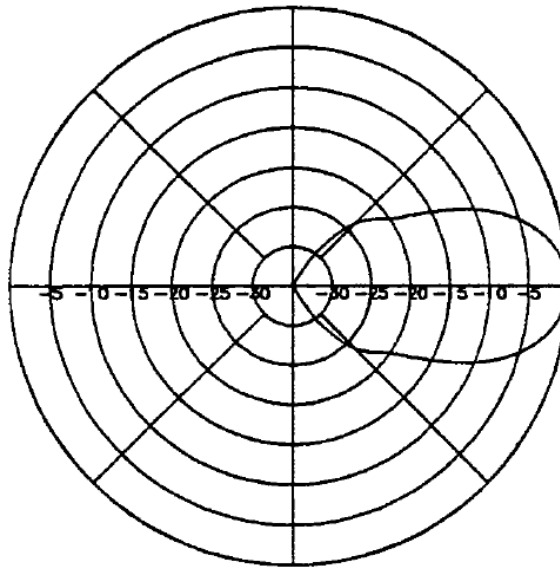


HALF-POWER BEAMWIDTH: 3160-09

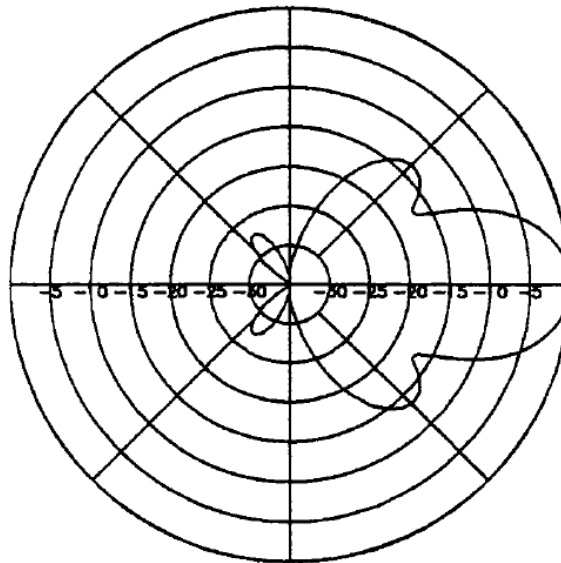


ANTENNA PATTERN: 3160-09 AT 22.0 GHZ

H-PLANE: 3160-09

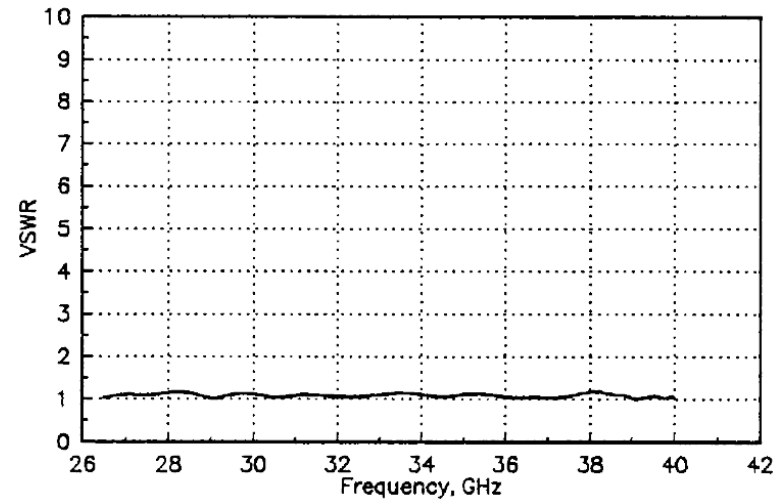


E-PLANE: 3160-09

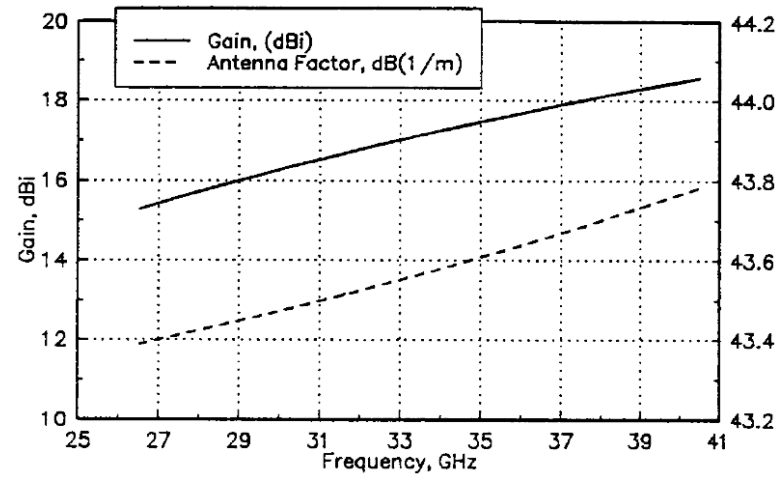


3160-10

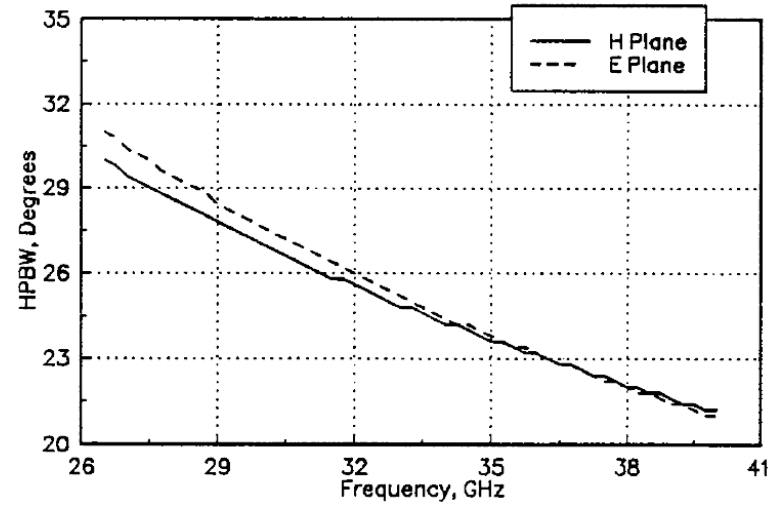
VSWR: 3160-10



GAIN / ANTENNA FACTOR: 3160-10

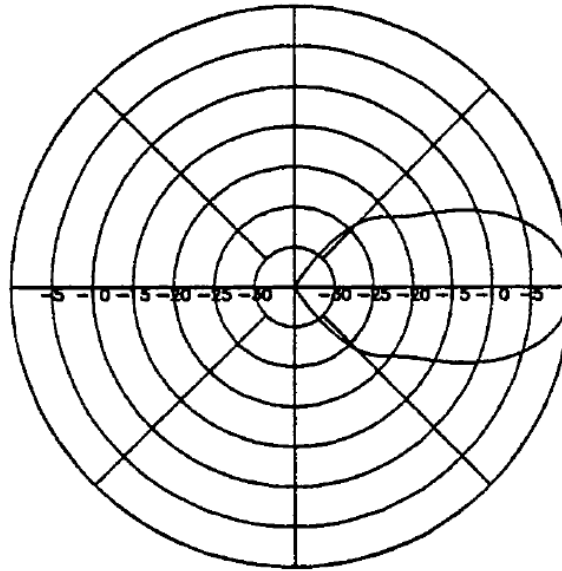


HALF-POWER BEAMWIDTH: 3160-10



ANTENNA PATTERN: 3160-10 AT 33.0 GHZ

H-PLANE: 3160-10



E-PLANE: 3160-10

