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DESIGN AND EVALUATION OF PORTABLE ANTENNAS FOR LOCATION OF SOURCES OF RADIO NOISE EMANATING FROM POWER-LINE HARDWARE

by

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The purpose of this study is the design, construction, analysis and measurement of three customized Log-Periodic Dipole Arrays (LPDA) for use in locating PLN sources. Modifications to standard LPDA designs include a feeder boom with convenient construction features with emphasis on a compact, lightweight, portable structure. The Numerical Electromagnetics

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Design and Evaluation of Portable Antennas for Location of Sources of Radio Noise Emanating from Power-Line Hardware

by

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Power-line noise (PLN) is a major contribution to factors which cause the loss of signals at naval receiving sites. Navy Signal-to-Noise Enhancement Program (SNEP) teams have developed portable instrumentation for the location of RF noise-producing power-line hardware. An important component of this instrumentation is a lightweight antenna with modest directivity and wide bandwidth (60-800 MHz).

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I. INTRODUCTION

Noise from sources on, or associated with, power lines is often the primary factor degrading the performance of receiving sites. While most sites have modest amounts of power-line noise, its level at some sites is so severe that all Signals of Interest (SOI) are below the level of power-line noise. Such sites are ineffective and corrective actions must be taken to detect and eliminate the sources of the noise.

Signal-to-Noise Enhancement Program (SNEP) teams have developed procedures and specialized instrumentation that is specifically designed to obtain the information needed for the identification, measurement, and mitigation of all factors that adversely affect the performance of a receiving site [Ref. 1]. This instrumentation contains several mobile and portable equipment configurations for the detection of RF noise emanating from power-line hardware.

The portable instrumentation requires broadband (60-800 MHz) compact, light weight directional antennas, for locating power-line hardware noise sources. The choice of Log-Periodic Dipole Arrays (LPDA) evolved from various attempts to use less capable sensors. The LPDA has identical performance and electrical characteristics over a band of frequencies, rather than a distinct frequency, and therefore is characterized as a "frequency independent" antenna.

The purpose of this thesis is the design, construction, and evaluation of the performance of LPDAs to support the power-line noise location system. These antennas must cover frequency bandwidths of 60-150 MHz, 100-800 MHz, and 200-800 MHz, respectively. The basic design features of small size, light weight and portability, are all factors that constrain the antenna gain and the choice of construction materials.

Chapter II describes the causes of, the mitigation of, and the methods of locating power-line noise. It also analytically describes the design procedure for the LPDA.

Chapter III contains a description of the geometry and electrical performance of the LPDAs and a detailed description of their construction.

Chapter IV describes LPDA modelling using the Numerical Electromagnetics Code (NEC). Included are calculated electrical performance, measurements and field trails performed to evaluate the LPDAs, and the comparison of the data obtained from the two different approaches.

Finally, in Chapter V, the results of the evaluation and recommendations regarding the design of the LPDAs are summarized.

II. BACKGROUND

A. POWER-LINE INTERFERENCE

Electronic noise pollution can originate from sources or high voltage transmission lines, from distribution-line hardware, and sometimes from industrial and other users of electric power. Radio Frequency Interference (RFI) from power lines is principally caused either by small spark or corona (electrostatic) discharge. The RFI sound in a radio receiver is an undulating, frying, buzzing, or scratching noise. Power line RFI can be traced to several sources:

- Interference attributed to the components of a transmission or a distribution system.
- Interference attributed to "consumer" equipment connected to distribution power lines.
- Interference remotely generated and coupled into the line by normal electromagnetic propagation.

The operation of most sources of power-line noise is highly dependent on weather, wind, and the physical condition of power-line hardware. The variable and erratic operation of most sources of power-line noise makes it very difficult to accomplish effective mitigation actions without the proper instrumentation and measurement procedures.

B. THE MITIGATION OF POWER-LINE NOISE

A multiple step procedure for the mitigation of power-line noise has evolved from several years of work at naval receiving sites by SNEP teams. This technical approach can be summarized in the following basic steps [Ref. 1]:

- Identify and locate on a map all power lines that are within line-of-sight of the uppermost part of the receiving antenna, regardless of distance from the antenna.

- Measure the temporal and spectral properties of all forms of noise at the output ports of the RF distribution system of a receiver site. Sort the various types of noise into categories. Identify the output ports containing power-line noise and determine the direction to each source. Repeat this procedure several times each day and for several days of the week.

- Simultaneously, with the previous step, conduct an external noise survey along power lines that are within azimuth sectors, shown by internal measurements to contain active sources. Locate poles or support towers that contain active sources of noise.

- Identify the specific hardware components containing power-line noise sources and develop a mitigation program to eliminate the sources.

C. LOCATION OF POWER-LINE NOISE SOURCES

SNEP teams have developed specialized instrumentation in order to obtain the information needed for the identification and measurement of the factors that affect the performance of a receiving site.

There are two methods which have proven successful for locating sources of power-line noise. Figure 1 describes an instrumentation configuration installed in a noise-quiet vehicle and used in the "moving-vehicle location technique", while Figure 2 illustrates instrumentation used where roadways are not available for vehicle travel, or when only portable instrumentation is available.

The moving-vehicle location technique involves driving along sections of a power line suspected of containing sources of noise, and watching a three-axis spectrum analyzer display for sudden increases in the frequency of observed noise. If a source is active, power-line noise will appear on the low-frequency end of the display. As a source is approached the maximum frequency of the noise will increase. This process must be repeated until a sharp peak in maximum frequency is shown on the display. Whenever a sharp peak occurs the vehicle will be passing a pole or some other component of a power line containing a source. Figure 3 illustrates the frequency increment produced by the instrumentation. Figure 4 shows the location of two gap noise sources. In both figures the ambient signals from television, FM broadcast, and land mobile radio services can be observed.

The second location technique uses simpler equipment. While not as effective nor as fast as the first technique, most sources can be located with the simple equipment shown in Figure 2. In practice, the receiver is tuned to a frequency of 60-80 MHz; a rod antenna is used and the receiver is moved along a power line until noise is detected. The receiver can be hand carried along a power line, or it can be carried by a

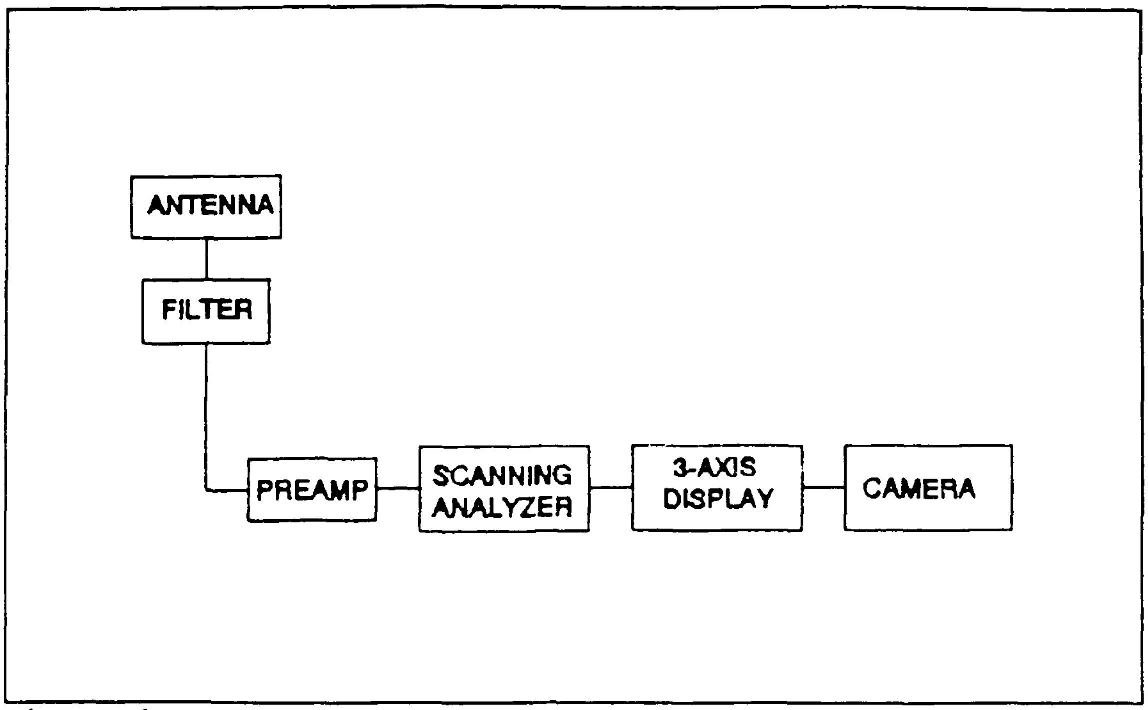

Figure 1. Mobile Instrumentation (From Ref.1).

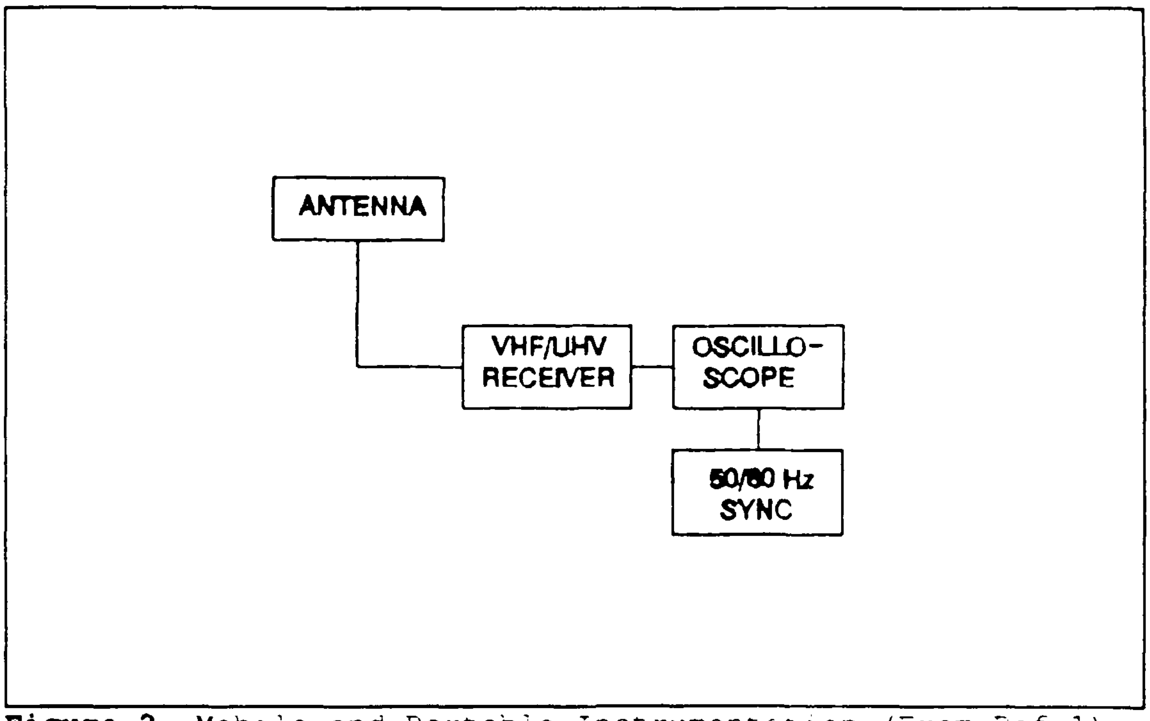

Figure 2. Mobile and Portable Instrumentation (From Ref.1).

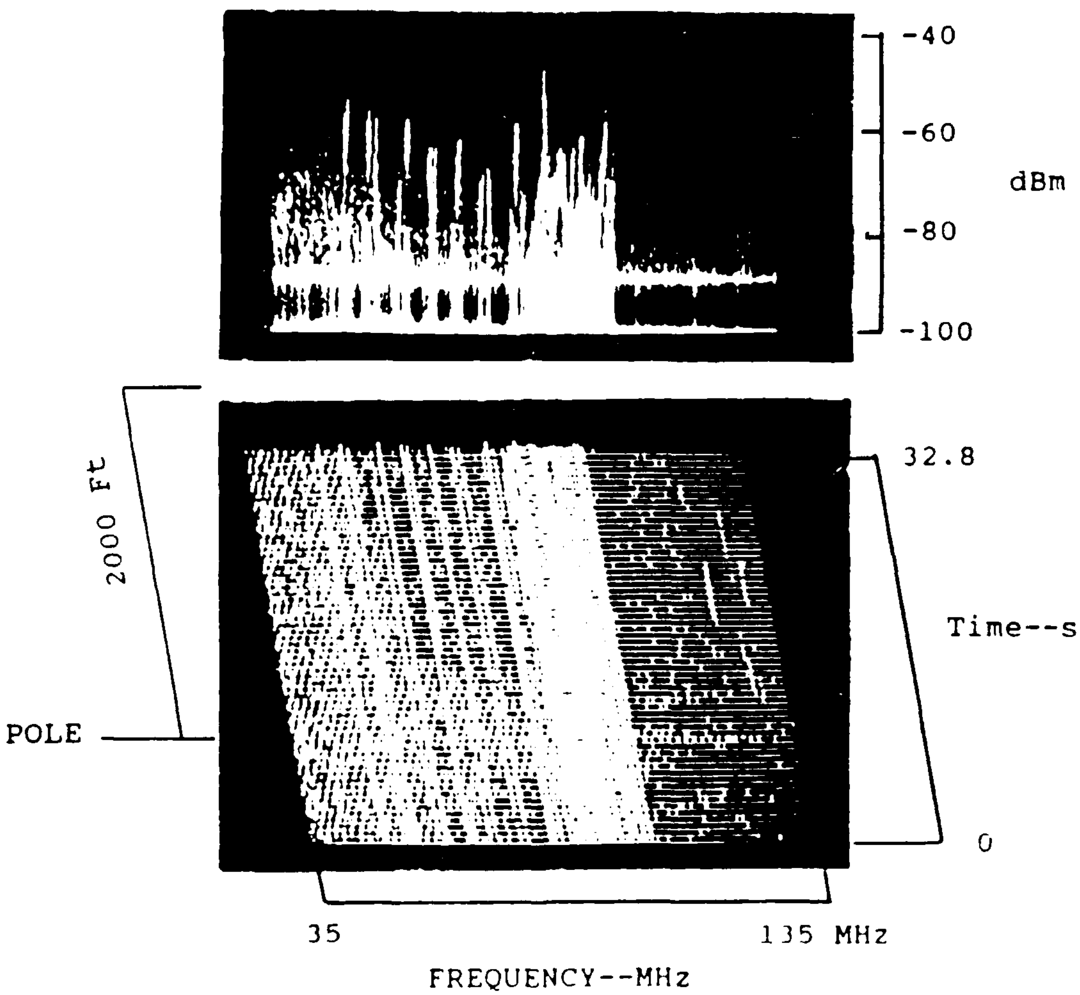

Figure 3. Frequency Spectrum Used for Location of a Noise Source (From Ref.1).

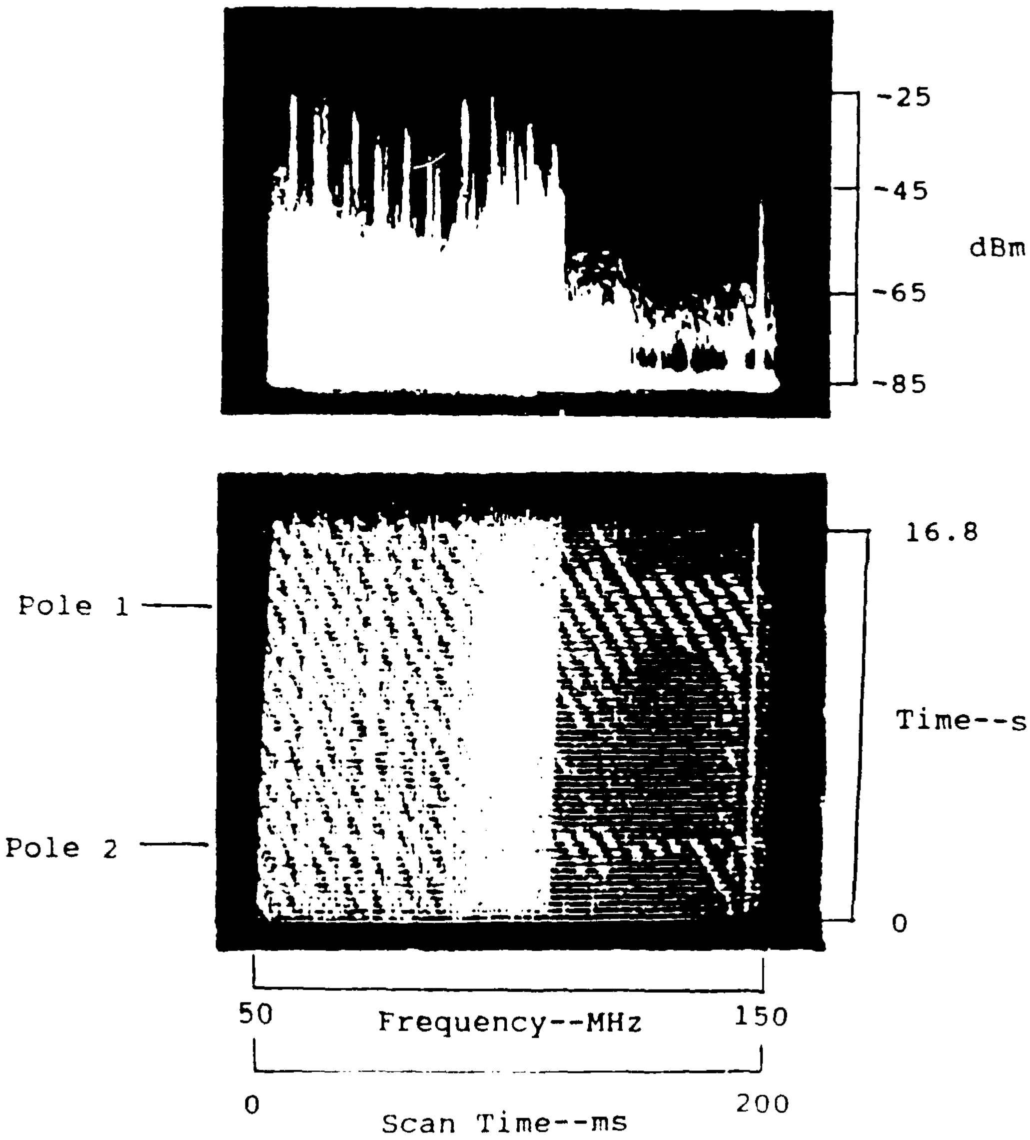

Figure 4. Frequency Spectrum Showing the Locations of Two Noise Sources (From Ref.1).

noise-quiet vehicle. A roof-mounted rod antenna has been found to be effective in locating the general vicinity of a source. The frequency of the receiver is then increased in about 30 MHz increments and moved along the power line until the source of the noise is localized to a single pole. The oscilloscope can be used to observe the temporal structure of the noise to aid in determining the type of the source.

Sometimes it is impossible to tell if a noise source is located on a single pole or another nearby power pole with the simple instrumentation. In such cases, a broad-band directional antenna is required to locate the source. It is used to replace the rod antenna for directional measurements in the immediate vicinity of the source. By pointing the antenna at each pole and measuring the amplitude of the noise, it is possible to identify which pole contains a source. This approach is required whenever a source is located among complex power-line hardware configurations.

D. LPDA DESIGN PROCEDURE

A log-periodic dipole array antenna is a "frequency independent" antenna which performs almost identically over a band of frequencies. The basic concept for wide-band performance is the absence of characteristic lengths in the antenna structure; that is if the structure repeats itself by a particular dimensional scaling ratio τ it will have the same properties at frequency f as at frequency $\tau \cdot f$.

The result of this scaling is that the geometry of log-periodic antenna structures is chosen so that the electrical properties repeat periodically, with a period of the logarithm of the frequency.

R.L.Carrel, of the University of Illinois, conducted an extensive analysis of the LPDA in his doctoral dissertation. He developed a computer code to compute impedances, radiation patterns, and voltage and current distributions on more than 100 different LPDAs. He then compared the calculations with corresponding experimental models with excellent agreement. [Ref. 2]

There are two basic parameters in the design of an LPDA: the scale factor τ, and the angle formed between the center line and the tips of the dipoles α. An alternate parameter σ is an "aspect ratio" for each cell consisting of a single dipole and the transmission line between that dipole and the next adjacent dipole.

Figure 5 illustrates the geometry , connection method, feeding method, and the basic parameters of an LPDA. Examination of the geometry discloses that the scale factor, the apex angle and the aspect ratio are related by the equation:

$$\sigma = 0.25 \cdot (1-\tau) \cdot \cot\alpha \;. \qquad \textbf{(1)}$$

The method of feeding provides a built-in broadband balun and in addition introduces a 180° phase shift between adjacent

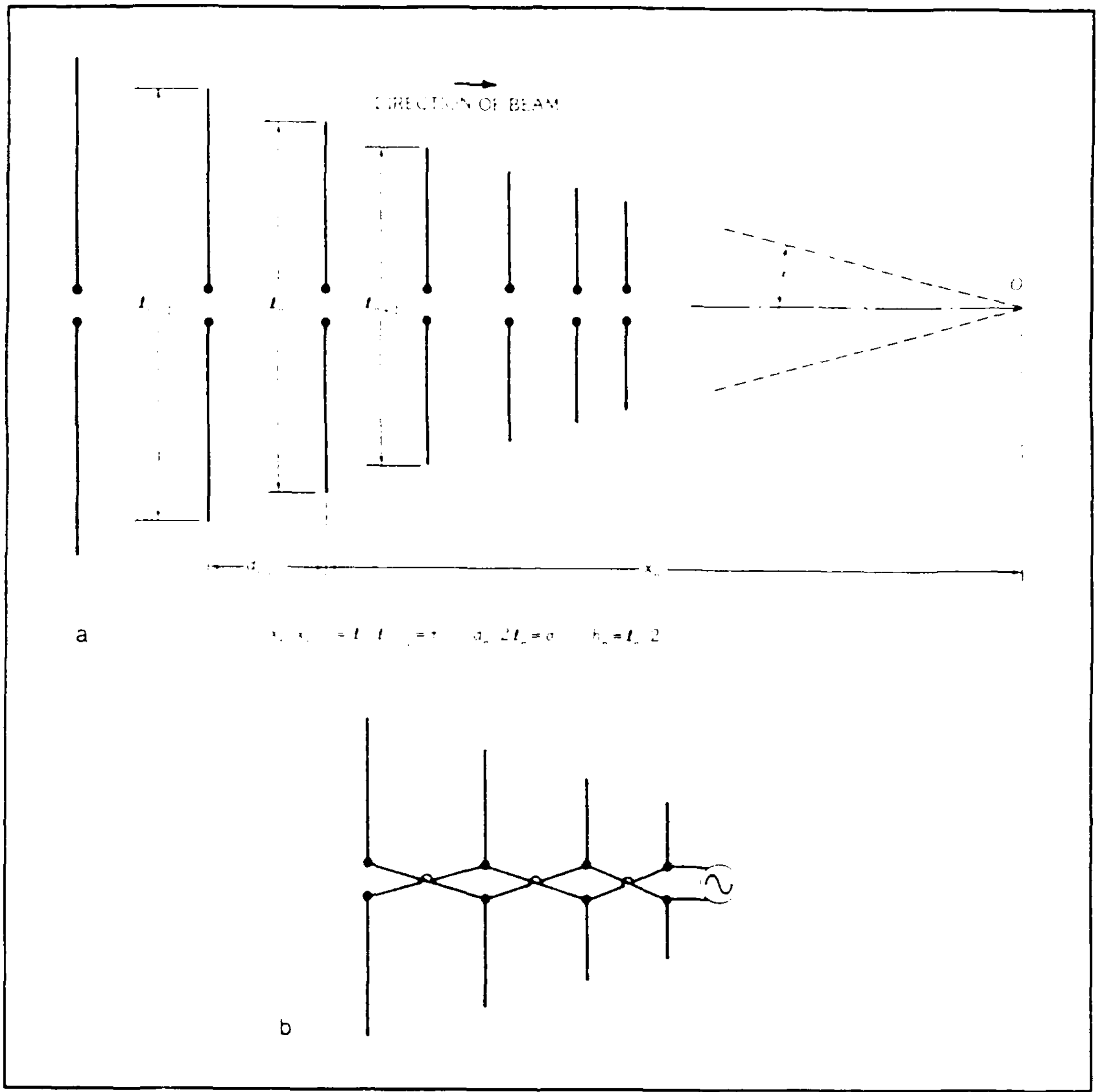

Figure 5. (a) Geometry of the LPDA, (b) Feed and Connection Method.

elements. By using a twin-boom feeder and the connection method shown, the input current of a few dipoles will be significantly larger than any of the others. These dipoles are called the active region of the LPDA and they produce most of the radiated fields.

As the frequency changes, the active region will move along the axis of the LPDA in a manner such that the dimensions of the active region, in wavelengths, remain almost constant. For this reason the radiation pattern is insensitive to frequency changes. The band of frequency-independent patterns is somewhat less than the ratio of the longest to the shortest dipole lengths. This ratio, called the structure bandwidth B_s, is given by:

$$B_s=\frac{L_1}{L_N}=\tau^{1-N} , \tag{2}$$

where L_1 and L_N represent the length of the first (longest) and last (shortest) dipoles of the LPDA respectively.

The operating bandwidth B and the structure bandwidth B_s are related by:

$$B_s=B\cdot B_{ar} , \tag{3}$$

where B_{ar} is the bandwidth of the active region, and depends on the parameters of the LPDA. An empirical formula exists for the calculation of B_{ar}:

$$B_{ar}=1.1+7.7\cdot(1-\tau)^2\cdot\cot\alpha . \tag{4}$$

Once the dipole base currents have been determined, the far-fields can be calculated and from them the directivity. These data can be represented as plots of constant directivity contours, on τ and σ axes, as represented in Figure 6.

The boom length L of the LPDA depends on the design specifications. It can be computed as :

$$\frac{L}{\lambda_{max}} = \frac{1}{4} \cdot \left(1 - \frac{1}{B_s}\right) \cdot \cot\alpha \ , \qquad (5)$$

where λ_{max}, corresponds to the lowest frequency of the design.

The number of elements N of the LPDA is:

$$N = 1 + \frac{\log B_s}{\log\left(\frac{1}{\tau}\right)} \ . \qquad (6)$$

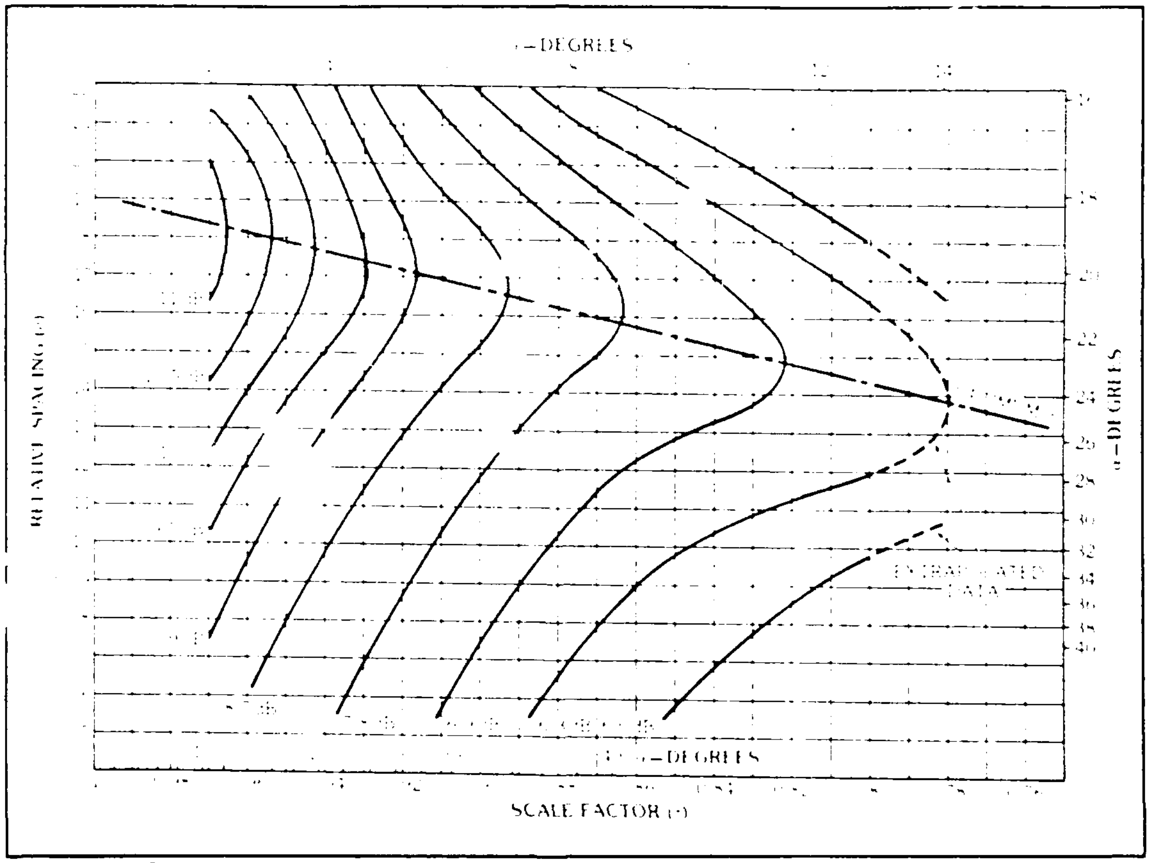

Figure 6. Computed Contours of Constant Directivity for Z_0=100Ω and L/D=177 (From Ref.2).

To compute the length of each element L_n, the first element of the LPDA is set equal to a half wavelength at the lowest usable frequency. Then the length of all successive elements is computed as:

$$L_{n+1}=\tau \cdot L_n \ . \tag{7}$$

The relative spacing d_n between successive elements of the LPDA is given by:

$$d_n=2 \cdot \sigma \cdot L_n \ . \tag{8}$$

The next step in the design is setting the input impedance of the feeder R_0 to the desired value. As an intermediate step, the length-to-diameter ratio L/D for the elements is selected. Using Figure 7, the average characteristic impedance of the dipole Z_a is computed.

A mid-step of the design of the feeder input impedance is the computation of the relative aspect ratio σ', which is given from the equation:

$$\sigma' = \frac{\sigma}{\sqrt{\tau}} \ . \tag{9}$$

Using the relative aspect ratio σ' and Figure 8, the feeder characteristic impedance is computed.

This particular design of the LPDAs deviates from Carrel's original design. Instead of round tubes, two U-shaped aluminum channels are used as feed lines for the antenna. This choice was made because the aluminum channels provide light structure

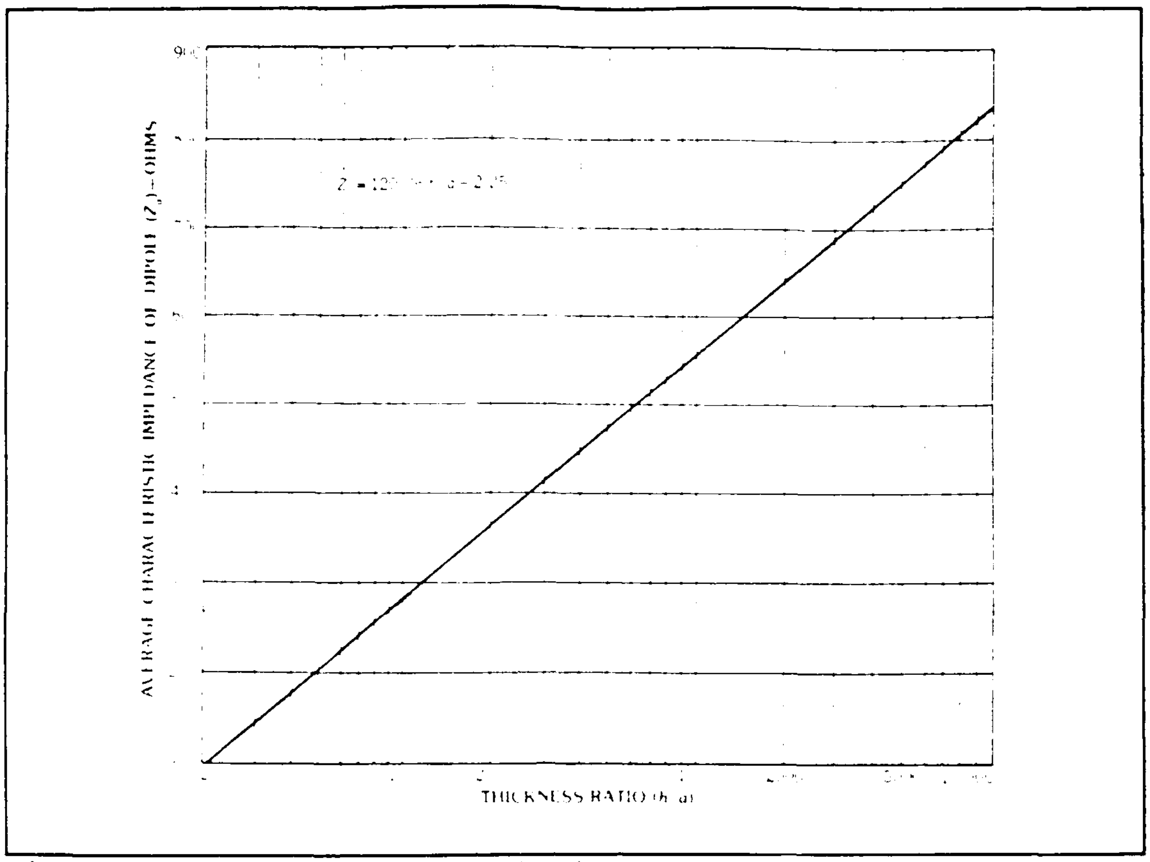

Figure 7. Average Characteristic Impedance of a Dipole versus Thickness Ratio (From Ref.2).

weight, easy scaling during the construction, and convenience in assembling/disassembling the antennas.

To obtain the desired feeder input impedance, the characteristic impedance must be selected. For U-channel booms this is done by fixing the separation distance between the two channels of the feeder as shown in Figure 9.

Since an equation for the calculation of the separation distance *s* does not exist, an approximate formula is used. From transmission line theory, the characteristic impedance of a parallel-plate waveguide is given by:

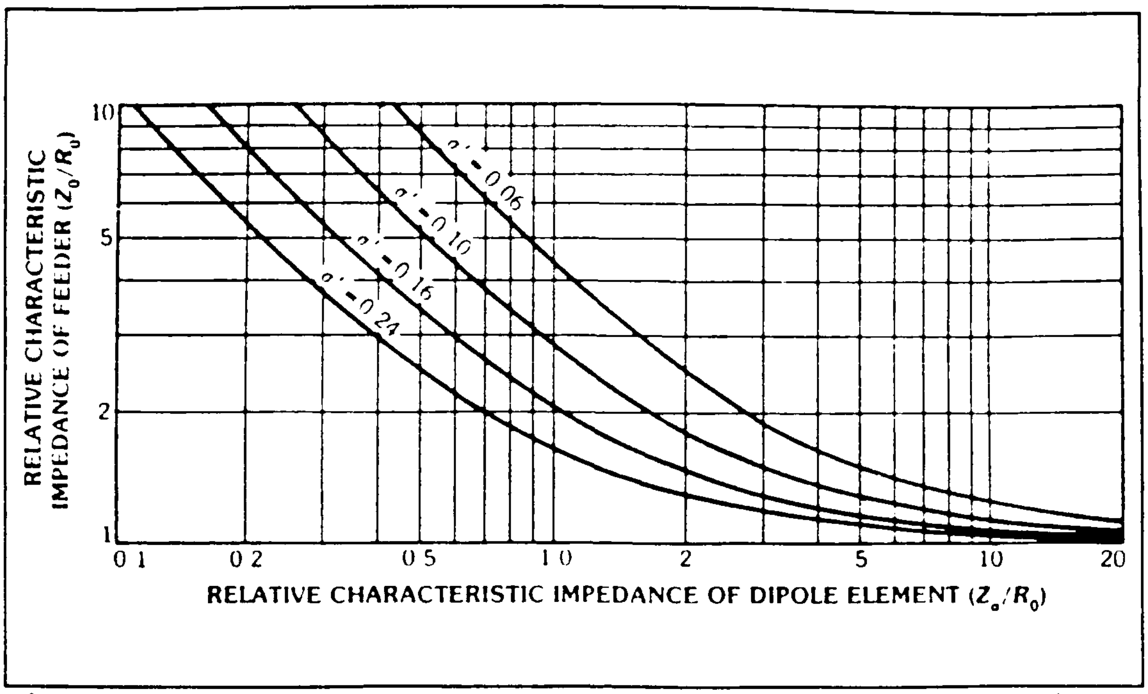

Figure 8. Relative Feeder Impedance versus Relative Dipole Impedance (From Ref.2).

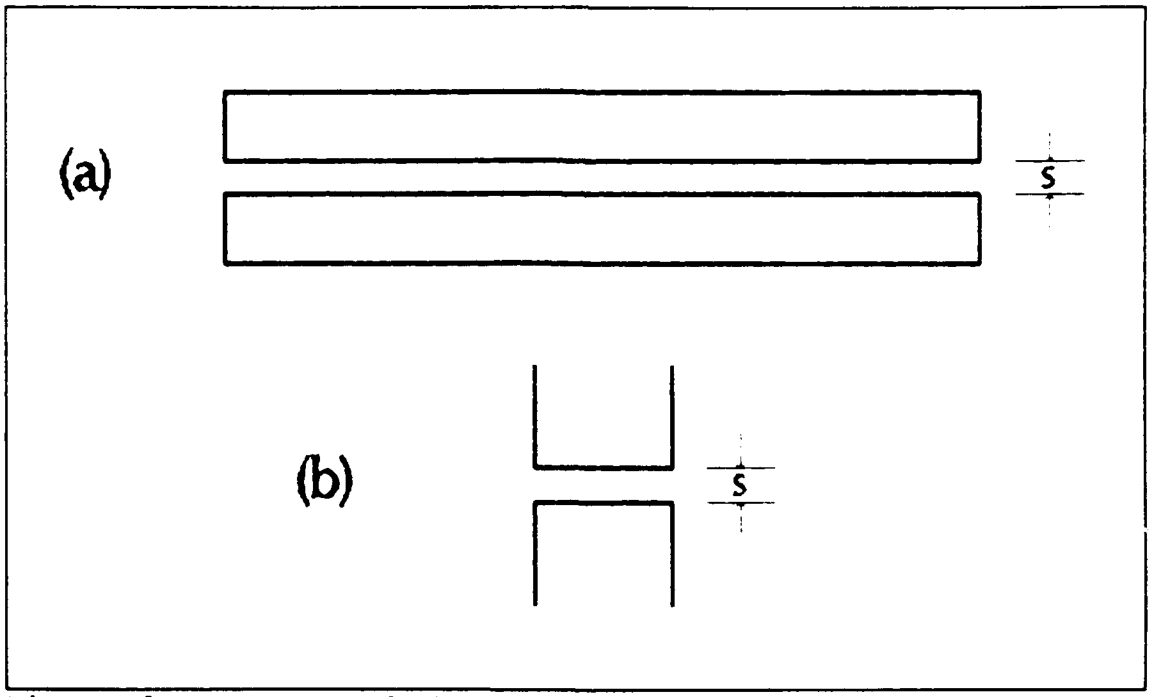

Figure 9. Geometry of the Feeder: (a) Side View, (b) End View.

$$Z_0 = \frac{\eta_0 \cdot s}{w} \ , \tag{10}$$

where s is the distance between the plates, w is the width of the plates, and η_0 is the intrinsic impedance of free space.

The equation used in the design is based on Equation (10), but modified to allow for 10% losses due to the fringing effect of the sides of the channels. The final formula is:

$$Z_0 = \frac{\eta_0 \cdot s}{1.1 \cdot w} \ . \tag{11}$$

There is a graphical solution for Equations (1) through (6) using a series of nomographs, but it is less accurate.

III. LPDA DESIGN AND CONSTRUCTION

To support the instrumentation described in Chapter II, three LPDAs covering 200-800 MHz, 100-600 MHz, and 60-150 MHz were designed and constructed. The portability of the antennas limits their size, resulting in low gain. Aluminum was chosen for the construction material to meet requirements of strength and low weight. Elements were fabricated from 2011 aluminum solid rods.

A. 200-800 MHz LPDA

1. Design

A moderate antenna gain of 6.9 dBd was considered to be acceptable in view of the size and weight limitations of this design. By using Figure 6, a scaling factor of $\tau=0.89$ was chosen, resulting in a short boom length with a corresponding aspect ratio of $\sigma=0.09$.

Following the design procedure of Chapter II, the LPDA characteristics are:

- Apex Angle $\alpha=17$
- Active Region Bandwidth $B_{ar}=1.4$
- Structure Bandwidth $B_s=5.62$
- Boom Length $L=1.006$ m
- Number of Elements $N=16$.

Using Equations (7) and (8), the length L_n and the relative spacing d_n of the elements were computed. The results are summarized in Table 1. After selecting a thickness ratio L/D=87 and a feeder input impedance R_0=50Ω, Figures 7 and 8, and Equations (9) through (11) were used to compute the following characteristics of the antenna:

- Dipole Average Characteristic Impedance Z_a=260 Ω
- Relative Aspect Ratic σ′=0.095
- Feeder Characteristic Impedance Z_0=65 Ω
- Distance between Boom Channels s=2.5 mm .

Finally, the diameter of each element was calculated to satisfy the selected thickness ratio. The results are shown in Table 1.

2. Construction

The feeder consists of two identical 6063 aluminum U-shaped channels, 0.5"×0.5"×0.093" (width-height-thickness). Because the calculated element diameters do not correspond to readily available aluminum rod sizes, all elements were divided into three groups, each group having a diameter equal to that of standard rod stock. These groups are:

- Elements 1 through 5: D=3/16"
- Elements 6 through 10: D=5/32"
- Elements 11 through 16: D=1/8" .

TABLE 1

COMPUTED ELEMENT LENGTHS, DIAMETERS, AND RELATIVE SPACING

200-800 MHz LPDA

ELEMENT #	LENGTH [m]	DIAMETER [m]	SPACING [m]
1	0.750	0.0086	0.135
2	0.668	0.0077	0.120
3	0.594	0.0068	0.107
4	0.529	0.0061	0.095
5	0.471	0.0054	0.085
6	0.419	0.0048	0.075
7	0.373	0.0043	0.067
8	0.332	0.0038	0.060
9	0.295	0.0034	0.053
10	0.263	0.0030	0.047
11	0.234	0.0027	0.042
12	0.208	0.0024	0.037
13	0.185	0.0021	0.033
14	0.165	0.0019	0.030
15	0.147	0.0017	0.026
16	0.131	0.0015	-----

The above group divisions were chosen to hold antenna dimensions as close to the theoretical design as possible.

To excite both channels of the feeder boom, an electrical connection (short circuit) was made at the end of the antenna at distance δ=0.1 m from the first element. The LPDA as constructed is shown in Figure 10.

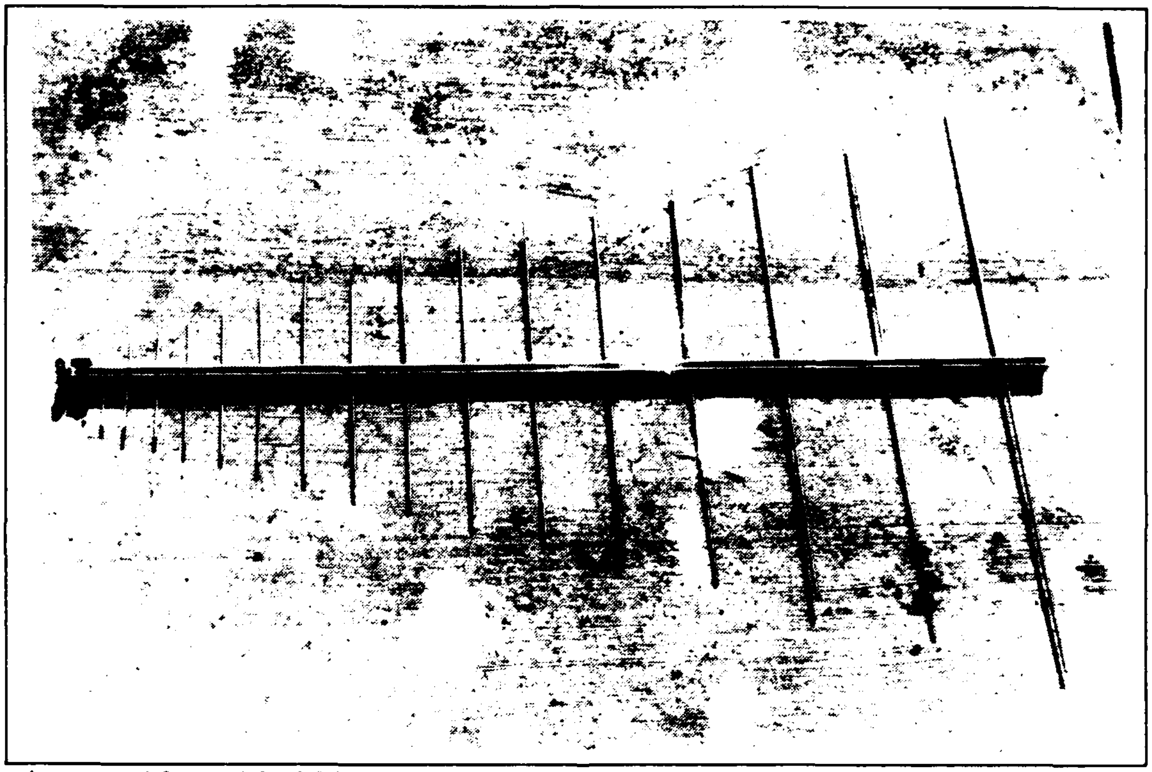

Figure 10. 200-800 MHz Log-Periodic Antenna.

B. 100-800 MHz LPDA

1. Design

An antenna gain of 6.3 dBd was selected for this design. A scaling factor of τ=0.884 was chosen, resulting in an aspect ratio of σ=0.06.

The antenna parameters are:

- Apex Angle α=25.8°
- Active Region Bandwidth B_{ar}=1.31
- Structure Bandwidth B_s=10.52
- Boom Length L=1.405 m
- Number of Elements N=20 .

For a thickness ratio L/D=100 and feeder input impedance of R_0=50Ω, the characteristics of the LPDA are:

- Dipole Average Characteristic Impedance Z_a=283 Ω
- Relative Aspect Ratio σ'=0.064
- Feeder Characteristic Impedance Z_0=81 Ω
- Distance between Boom Channels s=6 mm .

Calculated element length, diameter, and relative spacing are shown in Table 2.

2. Construction

The feeder 6063 aluminum U-shaped channels are 1.0"×1.0"×0.125" (width-height-thickness). Element group sizes are:

- Elements 1 through 5: D=9/32"
- Elements 6 through 10: D=1/4"
- Elements 11 through 16: D=5/32"
- Elements 16 through 20: D=3/32" .

The feeder boom electrical connection was placed at distance δ=0.1 m from the first element. The LPDA is shown in Figure 11.

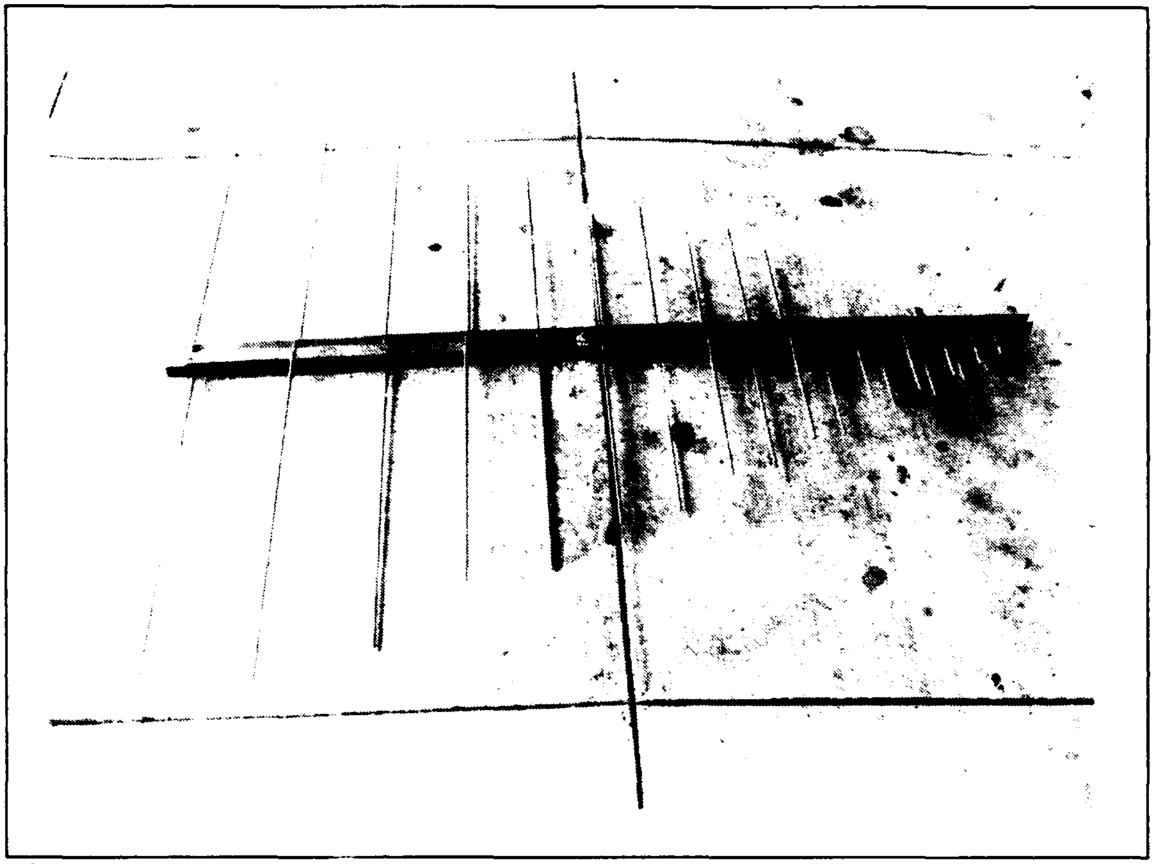

Figure 11. 100-800 MHz Log-Periodic Antenna.

C. 60-150 MHz LPDA

1. Design

An antenna gain of 6.0 dBd was chosen. The scaling factor τ=0.87 was selected and the corresponding aspect ratio σ=0.08 was determined. The results are:

- Apex Angle $\alpha=22.1°$
- Active Region Bandwidth B_{ar}=1.42
- Structure Bandwidth B_s=3.55
- Boom Length L=1.21 m
- Number of Elements N=10 .

TABLE 2

COMPUTED ELEMENT LENGTHS, DIAMETERS, AND RELATIVE SPACING

100-800 MHz LPDA

ELEMENT #	LENGTH {m}	DIAMETER {m}	SPACING {m}
1	1.500	0.0091	0.180
2	1.326	0.0080	0.159
3	1.172	0.0071	0.141
4	1.036	0.0063	0.124
5	0.916	0.0055	0.110
6	0.810	0.0081	0.097
7	0.716	0.0071	0.086
8	0.633	0.0063	0.076
9	0.559	0.0055	0.067
10	0.495	0.0049	0.059
11	0.437	0.0062	0.052
12	0.386	0.0055	0.046
13	0.342	0.0049	0.041
14	0.302	0.0043	0.036
15	0.267	0.0038	0.032
16	0.236	0.0033	0.028
17	0.209	0.0030	0.025
18	0.184	0.0026	0.022
19	0.163	0.0023	0.019
20	0.144	0.0020	-----

A thickness ratio of L/D=150 and a feeder input impedance of R_0=50Ω, resulted in LPDA characteristics of:

- Dipole Average Characteristic Impedance Z_a=325 Ω
- Relative Aspect Ratio σ'=0.086
- Feeder Characteristic Impedance Z_0=70 Ω
- Distance between Boom Channels s=5.2 mm .

Computed element lengths, diameters, and relative spacing are in Table 3.

TABLE 3

COMPUTED ELEMENT LENGTHS, DIAMETERS, AND RELATIVE SPACING

60-150 MHz LPDA

ELEMENT #	LENGTH [m]	DIAMETER [m]	SPACING [m]
1	2.500	0.0167	0.400
2	2.175	0.0145	0.348
3	1.892	0.0126	0.303
4	1.646	0.0110	0.263
5	1.432	0.0095	0.230
6	1.246	0.0083	0.200
7	1.084	0.0072	0.173
8	0.943	0.0063	0.152
9	0.821	0.0055	0.132
10	0.714	0.0047	-----

2. Construction

The feeder U-channels are 1.0"×1.0"×0.125" (width-height-thickness). Element group sizes are:

- Elements 1 through 3: D=5/8"
- Elements 4 through 6: D=3/8"
- Elements 7 through 10: D=1/4" .

The feeder boom electrical connection is at a distance of δ=0.15 m from the first element. The LPDA is shown in Figure 12.

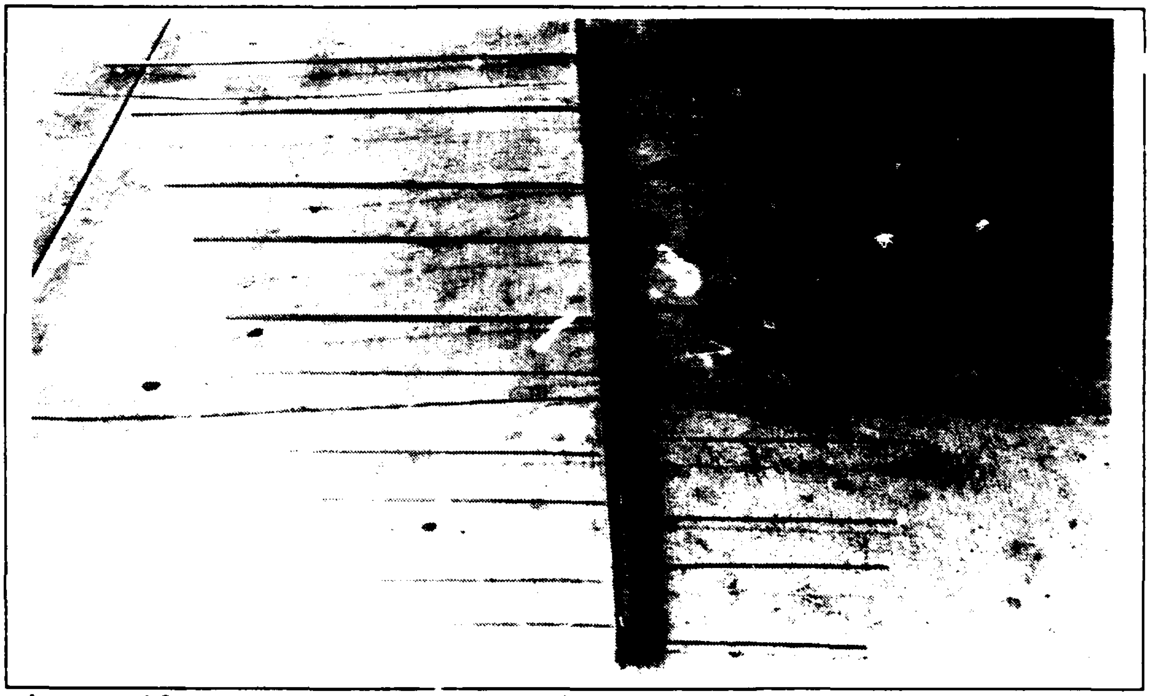

Figure 12. 60-150 MHz Log-Periodic Antenna.

D. CONSTRUCTION DETAILS

The feed point, electrical connection, and element attachment method are identical in all three designs. They are presented in a series of photographs, shown in Figures 13-17.

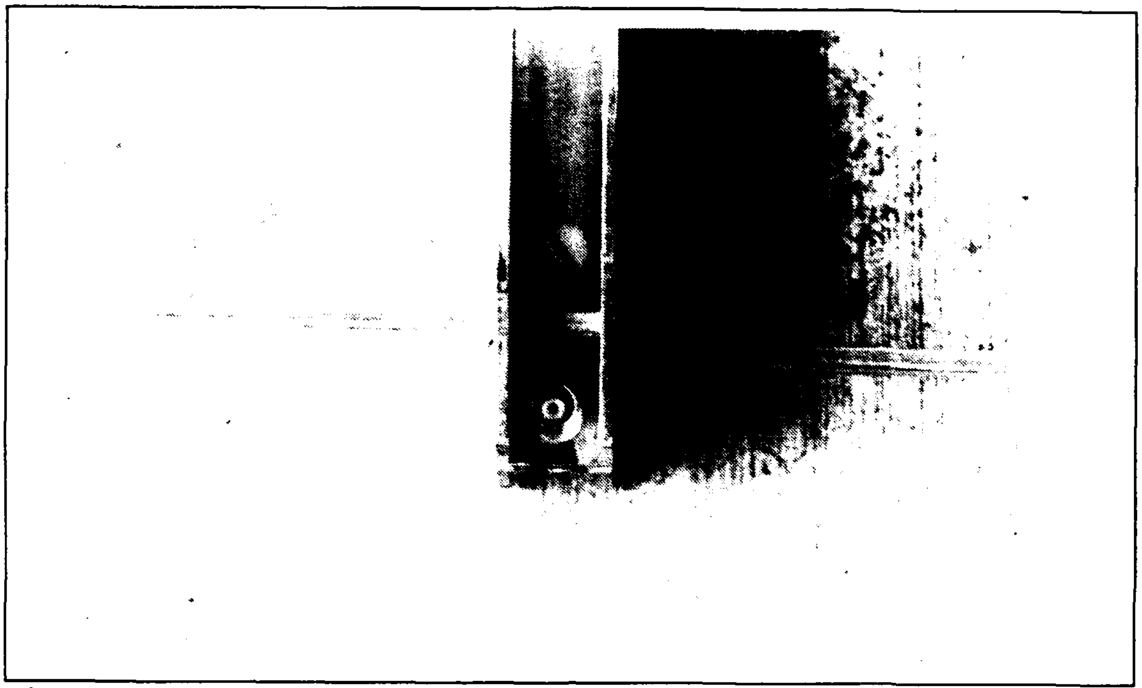

Figure 13. Upper Boom Channel Feed Point Connection.

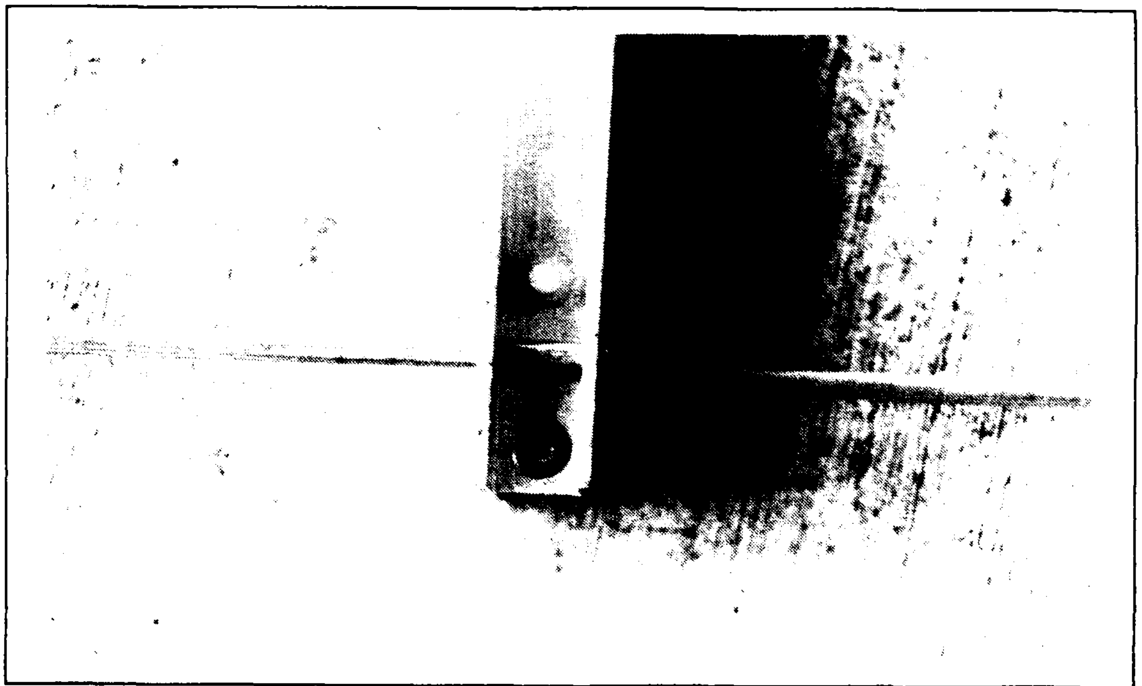

Figure 14. Lower Boom Channel Feed Point Connection.

Figure 15. Electrical Connection at the End of the Feeder.

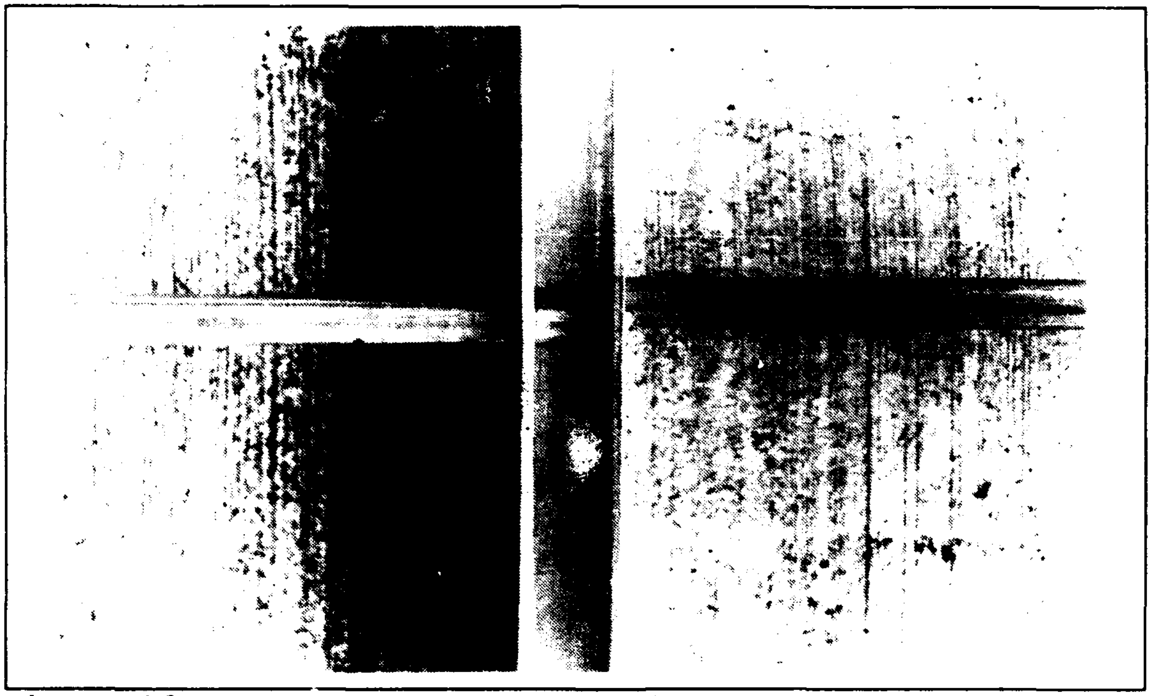

Figure 16. Element Attachment to the Feeder (Top View).

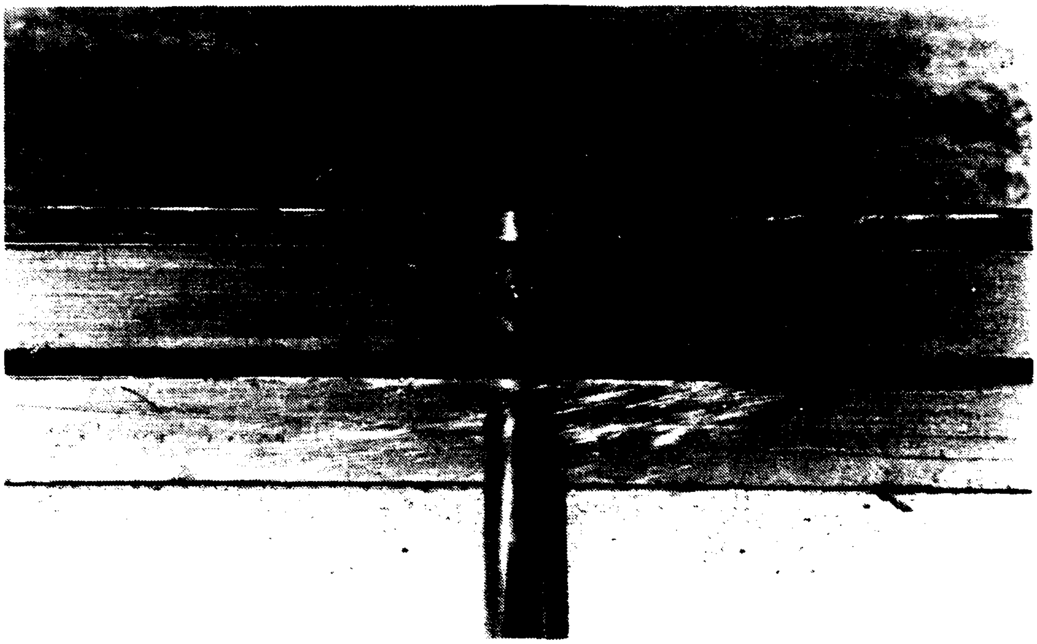

Figure 17. Element Attachment to the Feeder (Side View).

IV. NEC ANALYSIS AND MEASUREMENTS

A. THE NUMERICAL ELECTROMAGNETICS CODE

1. Introduction

The Numerical Electromagnetics Code (NEC)-Method of Moments is a user-oriented computer code for analysis of the electromagnetic response of thin-wire antennas and closed metal structures. It is based on the numerical solution of integral equations for the currents induced on the structure by sources of incident fields or by local sources on the structure. This approach avoids many of the simplifying assumptions required by other solution methods and provides a highly accurate, versatile tool for electromagnetic analysis.

The code combines an integral equation for smooth surfaces with one specialized for wires to provide convenient, accurate modeling of a wide range of structure shapes. A model may include non-radiating networks and transmission lines connecting parts of the structure, perfect or imperfect conductors, and lumped element loading. A structure may also be modeled over a ground plane which is either a perfect or imperfect conductor.

The excitation can be either voltage sources on the structure or an incident plane wave of linear or elliptic polarization. The output may include induced currents or charges, near electric or magnetic fields, and radiated fields. Hence, the program is suited to either antenna analysis or scattering and EMP studies.

The integral equation approach is best suited to structures with dimensions up to several wavelengths. Although there is no theoretical size limit, the numerical solution requires a matrix equation of increasing order as the structure size is increased relative to wavelength. Modeling very large structures may require more computer time and file storage than is practical on a particular computing machine. In such cases standard high frequency approximations such as Geometrical Optics, Physical Optics, or the Geometrical Theory of Diffraction may be more suitable than the integral equation method of NEC. The code also contains a "Numerical Green's Function" for a partitioned-matrix solution and also has a treatment for lossy grounds which is accurate for antennas very close to the ground surface. NEC also includes an option to compute maximum coupling between antennas.

2. Background

NEC solves both Electric Field Integral Equations (EFIE) and Magnetic Field Integral Equations (MFIE) via the method of moments.

For the current, two approximation options are available: the thin-wire kernel and the extended thin-wire kernel. For the thin-wire kernel, the current on the surface of a segment is reduced to a filament of current on the segment axis. Using the extended thin-wire kernel, the current is uniformly distributed around the segment surface. The EFIE used in NEC is given as [Ref. 3]:

$$-\hat{s}\cdot\overline{E}^{i}(\overline{r}) = -\frac{j}{4\pi\omega\varepsilon}\int_{c(\overline{r})} I(s')\cdot\left(\hat{s}\cdot\hat{s}'\cdot\kappa^{2}-\frac{\partial^{2}}{\partial_{s}\partial'_{s}}\right)\cdot g(\overline{r},\overline{r}')\,ds' \,, \quad (12)$$

where:

$\hat{s}$	=unit vector along the wire axis
s'	=distance along the wire axis
$\overline{E}^{i}(\overline{r})$	=incident electric field at r
ω	$=2\pi f$, where f is the frequency
$I(s')$	=axial current
ε	=permittivity
κ	$=\omega(\mu\varepsilon)^{1/2}$ = phase constant
$\overline{r}$	=observation point
$\overline{r}'$	=source point
$g(\overline{r},\overline{r}')$	$=\exp[-j\kappa r/R]$ =free space Green's function
R	$=(\overline{r}-\overline{r}')$.

NEC includes a patch option for modeling surfaces using the MFIE. The formulation is restricted to closed surfaces with non-vanishing enclosed volume. The MFIE used in NEC is given as [Ref. 3]:

$$\overline{J}_{s}(\overline{r}) = 2\hat{n}\times\overline{H}^{inc}(\overline{r}) + \frac{1}{2\pi}\int_{S}\hat{n}\times\left[\overline{J}_{s}(\overline{r}')\times\nabla' g(\overline{r},\overline{r}')\right]dA' \,, \quad (13)$$

where:

$\bar{J}_s(\bar{r})$ =surface current density

$\bar{H}^{inc}(\bar{r})$ =incident magnetic field at the observation point

$\hat{n}$ =unit vector normal to the surface.

3. Wire Modeling Guidelines

Short straight segments for wires and flat patches for surfaces are basic elements for modelling structures in NEC. Since only wire antennas were investigated in this thesis, guidelines for these are the only ones presented.

An antenna and any other conducting object in the vicinity of a test antenna that affect its performance must be modelled with strings of segments following the paths of the wires. Proper choice of segmentation is the most critical step in obtaining accurate results. For accuracy and efficient run-time, the number of segments should be the minimum required.

A wire segment is defined by the coordinates of its two end points and its radius. Geometrical and electrical guidelines for segments are given below [Ref. 4]:

- Geometrically, segments should follow the paths of conductors as closely as possible.
- Each wire must be broken into segments of length Δ, where $0.1\lambda<\Delta<0.001\lambda$, for each corresponding frequency.
- The segment length Δ should be 0.05λ or less when modelling critical regions of an antenna, such as near multiple wire junctions or near feed points.
- Using segments less than about $10^{-3}\lambda$, should be avoided because it may lead to numerical inaccuracy.

- The wire radius must be small compared to the segment length Δ. For the thin-wire kernel approximation, Δ/*a* must be greater than about 8 to obtain errors of less than 1%.

- For the extended thin-wire kernel approximation, the diameter of the wire can be increased up to Δ/*a* = *2* to obtain the same accuracy as the thin-wire kernel approximation, but applies only to segments connected in a straight line.

- If the distance between the ends of two segments is greater than about 10^{-3} times the length of the shortest segment, NEC will not allow the current to flow from one segment to the other.

- Identical coordinates should be used for connected segment ends.

- The end of one wire must be connected to the junction of two segments on another wire, not to the mid-point of a single segment.

- Large changes in radius between the two adjacent connected wires should be avoided. The change in radius between adjacent segments should be limited to a factor of two or less. It is also important that the largest radius not violate previously mentioned guidelines for the radius versus segment length.

- A segment is required at each point where a network connection or a voltage source is located.

- Any changes in segment length between two adjacent connected wires may be modelled using tapered segment lengths as long as the lengths of two adjacent segments are held to a ratio of 2:1 or less.

B. LPDA MODELLING

Using these guidelines and calculations of Chapter III, a log-periodic dipole antenna model was created. The U-shaped aluminum channel feeder was represented by a transmission line connected to the mid-point of each element; thus an odd number of segments was used for each element of the antenna. The distance between the channels of the feeder corresponds to the calculated value of the characteristic impedance Z_0 of the feeder.

C. NEC RESULTS

Data sets used in the NEC LPDA model meet the following criteria:

- The antennas were analyzed in free space environment.
- A frequency step of 100 MHz was used for the 200-800 MHz and 100-800 MHz LPDAs.
- A step of 10 MHz was chosen for the 60-150 MHz LPDA.

All data sets are illustrated in Appendix A. These data sets were used in calculating input impedance, gain, and radiation patterns (azimuth and elevation planes) of the LPDAs.

Based on the calculated input impedance the VSWR was also computed by using the formulas [Ref. 6]:

$$VSWR=\frac{1+|\overline{\Gamma}_L|}{1-|\overline{\Gamma}_L|}, \tag{14}$$

$$\overline{\Gamma}_L=\frac{Z_L-Z_0}{Z_L+Z_0}, \tag{15}$$

where:

$\overline{\Gamma}_L$ =reflection coefficient

Z_0 =characteristic impedance of transmission line

Z_L = input impedance of the LPDA.

A sample of the radiation patterns is shown in Figures 18 and 19. The total set of patterns is in Appendix B. Input impedance, gain, and VSWR are summarized in Tables 4, 5 and 6.

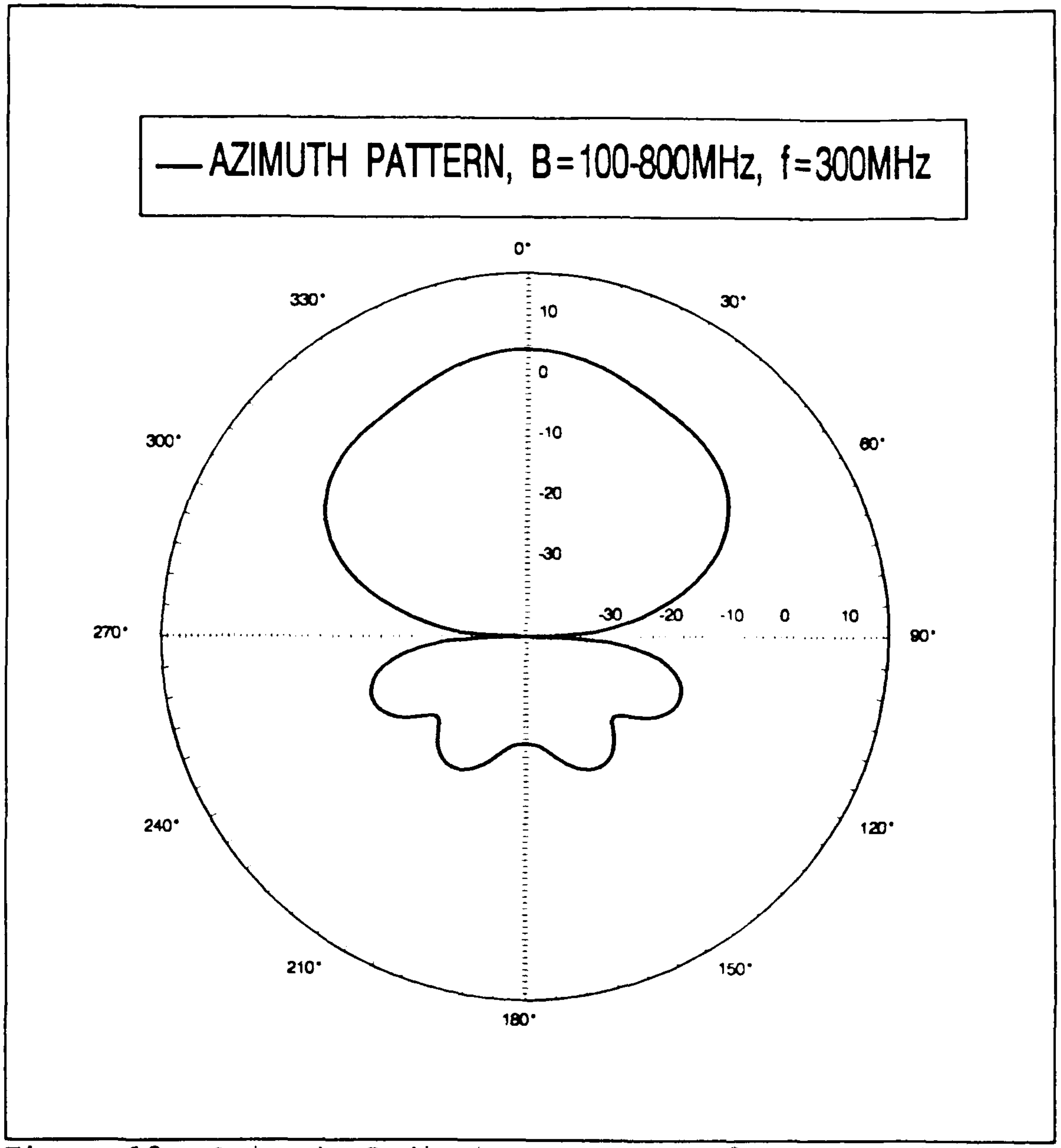

Figure 18. Azimuth Radiation Pattern (θ=90°), f=300 MHz, 100-800 MHz LPDA.

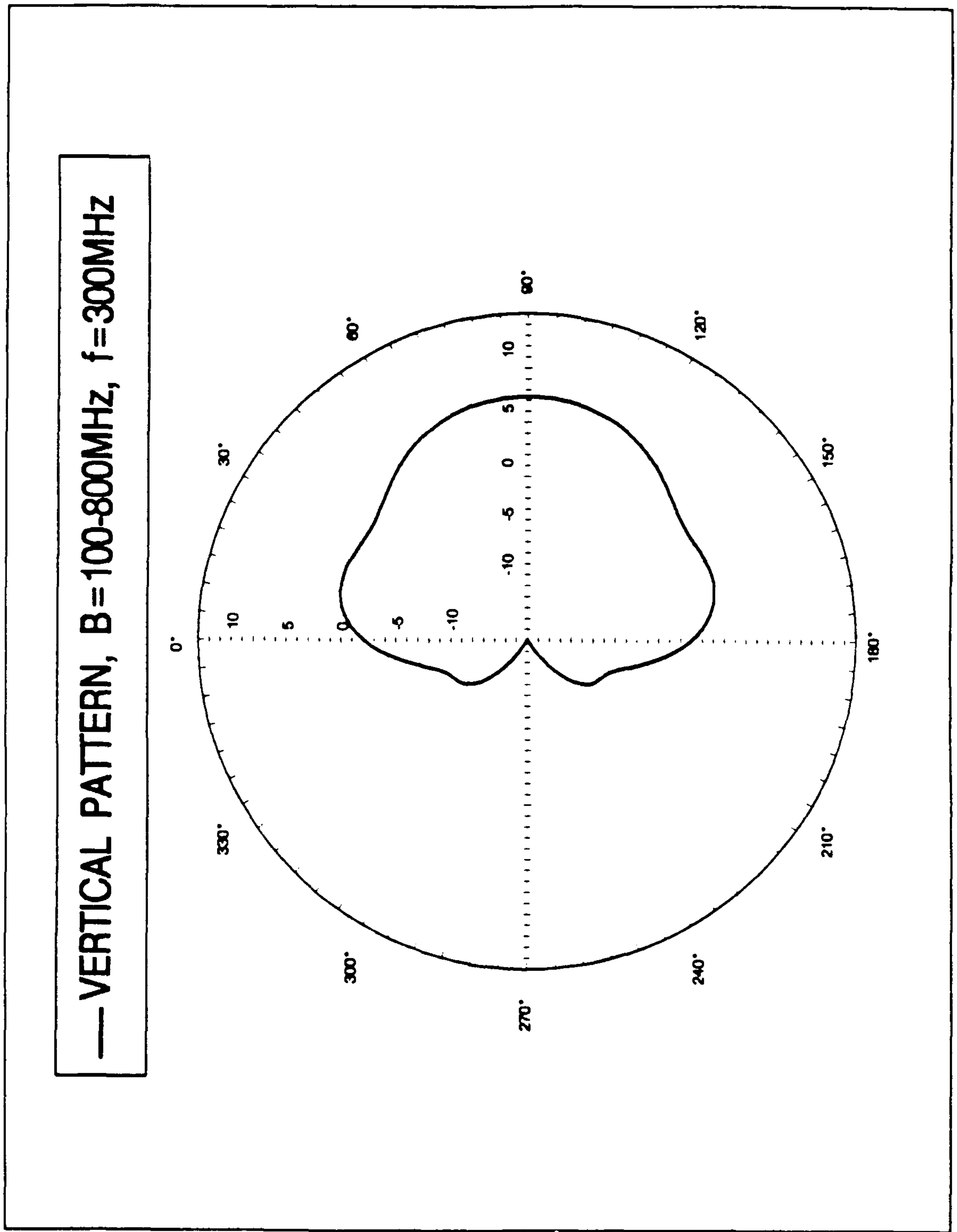

Figure 19. Elevation Radiation Pattern ($\phi=0°$), f=300 MHz, 100-800 MHz LPDA.

TABLE 4

INPUT IMPEDANCE, GAIN, AND VSWR VERSUS FREQUENCY

200-800 MHz LPDA

f [MHz]	Z_0 [Ω]	G [dB]	VSWR
200	42.4+j4.2	7.95	1.21
300	50.3-j0.7	8.11	1.01
400	48.4-j1.1	8.01	1.04
500	38.9+j4.2	7.78	1.31
600	45.3-j7.0	7.53	1.19
700	41.4+j8.5	6.91	1.30
800	46.0-j3.1	7.05	1.11

TABLE 5

INPUT IMPEDANCE, GAIN, AND VSWR VERSUS FREQUENCY

100-800 MHz LPDA

f [MHz]	Z_0 [Ω]	G [dB]	VSWR
100	48.4-j13.5	6.80	1.32
200	45.0+j2.1	7.22	1.12
300	49.8+j3.1	7.36	1.06
400	62.7+j3.1	7.54	1.26
500	30.3-j4.8	7.41	1.67
600	50.0-j6.0	7.29	1.13
700	62.0-j2.1	7.22	1.24
800	54.4-j17.8	7.20	1.42

TABLE 6

INPUT IMPEDANCE, GAIN, AND VSWR VERSUS FREQUENCY

60-150 MHz LPDA

f [MHz]	Z_0 [Ω]	G [dB]	VSWR
60	74.2-j6.6	7.08	1.51
70	45.7+j2.6	7.22	1.11
80	54.7-j9.1	7.34	1.22
90	56.5-j6.8	7.25	1.19
100	72.7-j16.3	7.30	1.58
110	34.6+j0.5	7.37	1.45
120	46.7-j0.6	7.14	1.07
130	44.2+j8.7	6.93	1.25
140	61.8-j3.1	6.77	1.24
150	33.8-j20.5	7.37	1.87

D. LPDA MEASUREMENTS

An HP-8409B automatic network analyzer was used with an HP-9845T desktop computer for measurements at 200-800 MHz. The antennas under measurement were connected to the analyzer and a standard reflection calibration sequence was followed. Scattering parameters were measured over the bandwidth of interest in 10 MHz steps, and were converted to input impedance by:

$$Z_{22}=Z_0\,\frac{(1-s_{11})\cdot(1+s_{22})+s_{12}\cdot s_{21}}{(1-s_{11})\cdot(1-s_{22})-s_{12}\cdot s_{21}}\,. \qquad \textbf{(16)}$$

The measured s_{22} parameter is the output reflection coefficient. Since the antenna is a one-port network, all other terms in Equation (16) vanish.

For 60-200 MHz, a programmable HP-3577A network analyzer was used. Measured s_{22} parameters were automatically converted into input impedance in steps of 2 MHz for the 60-150 MHz LPDA, and in steps of 10 MHz for the 100-800 MHz LPDA. From the input impedance data, Equations (14) and (15) were used to compute VSWR.

For comparison purposes, only the measured input impedance values and VSWR corresponding to the computed values are illustrated in Tables 7, 8, and 9.

TABLE 7

MEASURED INPUT IMPEDANCE AND VSWR VERSUS FREQUENCY

200-800 MHz LPDA

f [MHz]	Z_0 [Ω]	VSWR
200	35.4+j12.30	1.42
300	53.3+j8.10	1.12
400	49.8-j0.10	1.00
500	49.5-j0.95	1.05
600	51.6-j0.46	1.03
700	45.6+j5.23	1.10
800	103.0+j47.0	2.00

TABLE 8

MEASURED INPUT IMPEDANCE AND VSWR VERSUS FREQUENCY

100-800 MHz LPDA

f [MHz]	Z_0 [Ω]	VSWR
100	95.0+j21.0	1.90
200	45.6+j1.3	1.10
300	53.7+j0.8	1.06
400	47.3+j2.8	1.08
500	46.8-j0.1	1.02
600	44.4-j1.9	1.15
700	42.9-j2.7	1.18
800	34.1-j3.9	1.50

TABLE 9

MEASURED INPUT IMPEDANCE AND VSWR VERSUS FREQUENCY

60-150 MHz LPDA

f [MHz]	Z_0 [Ω]	VSWR
60	43.7+j52.5	2.80
70	64.8+j6.3	1.32
80	58.9-j14.3	1.37
90	61.3-j25.0	1.61
100	64.9-j21.1	1.58
110	23.8+j8.2	2.10
120	30.9+j8.2	1.63
130	33.0+j4.0	1.52
140	52.5+j17.5	1.05
150	129.0+j46.0	2.60

E. NEC/MEASURED DATA COMPARISON

To illustrate the comparison between the computed and measured impedance and VSWR, a graphical, rather than tabular, form is used.

A Smith chart shows the input impedance. The plot is rough due to the large 10 MHz steps used. Because data points are concentrated in a small area, magnified versions of the areas of interest are provided. Figures 20 through 24 illustrate all sets of impedance data. Figure 25 shows the continuously measured input impedance for the 60-150 MHz LPDA, obtained from a plotter connected to the HP-3577A network analyzer (the HP-8409B network analyzer does not have this capability). Figures 26 through 28 show the comparison between computed and measured VSWR versus frequency.

Comparison of the measured and NEC results illustrates the similarity of the two approaches. The VSWR, in most cases, is less than two, which is the desired value. The input impedance values are close to the desired 50Ω value as is shown in the Smith charts.

F. FIELD TRIALS

Field trials were conducted to determine the effectiveness of the log-periodic antennas in locating sources among complex power-line configurations. The first trial was held on a 12.8 kV distribution line located near Morgan Hill, California. A noise source was known to be in the vicinity of

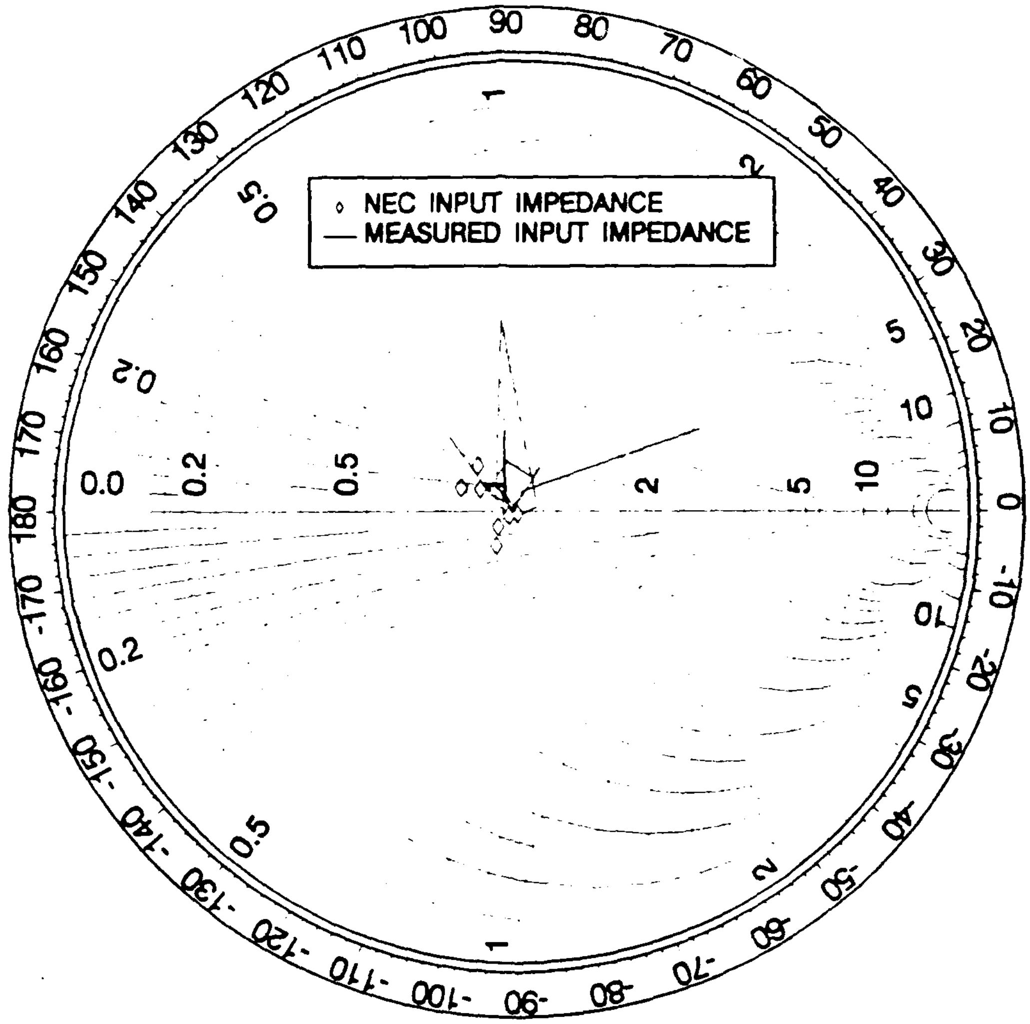

Figure 20. Computed and Measured Input Impedance; 200-800 MHz LPDA.

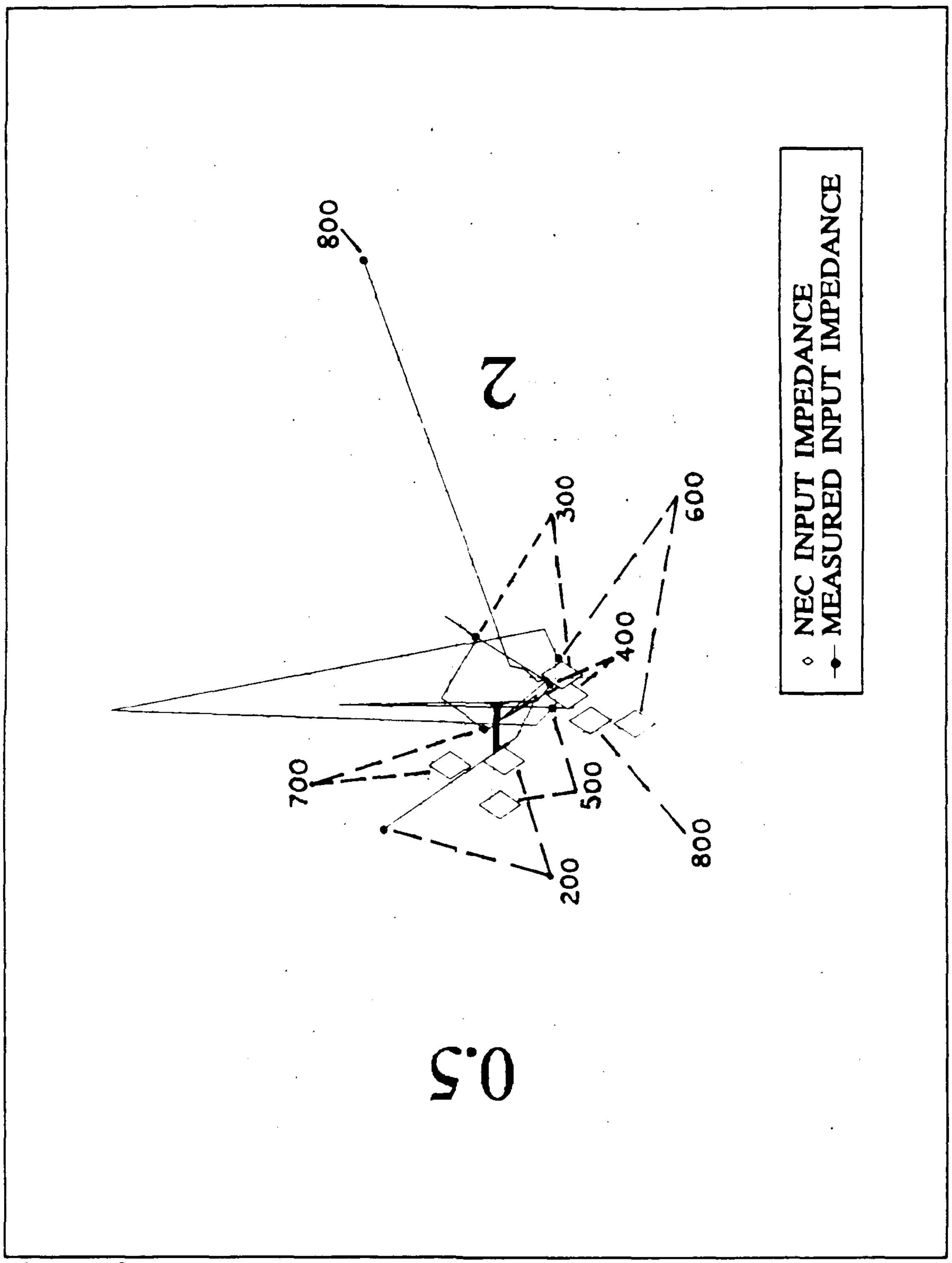

Figure 21. Expanded Input Impedance Data; 200-800 MHz LPDA.

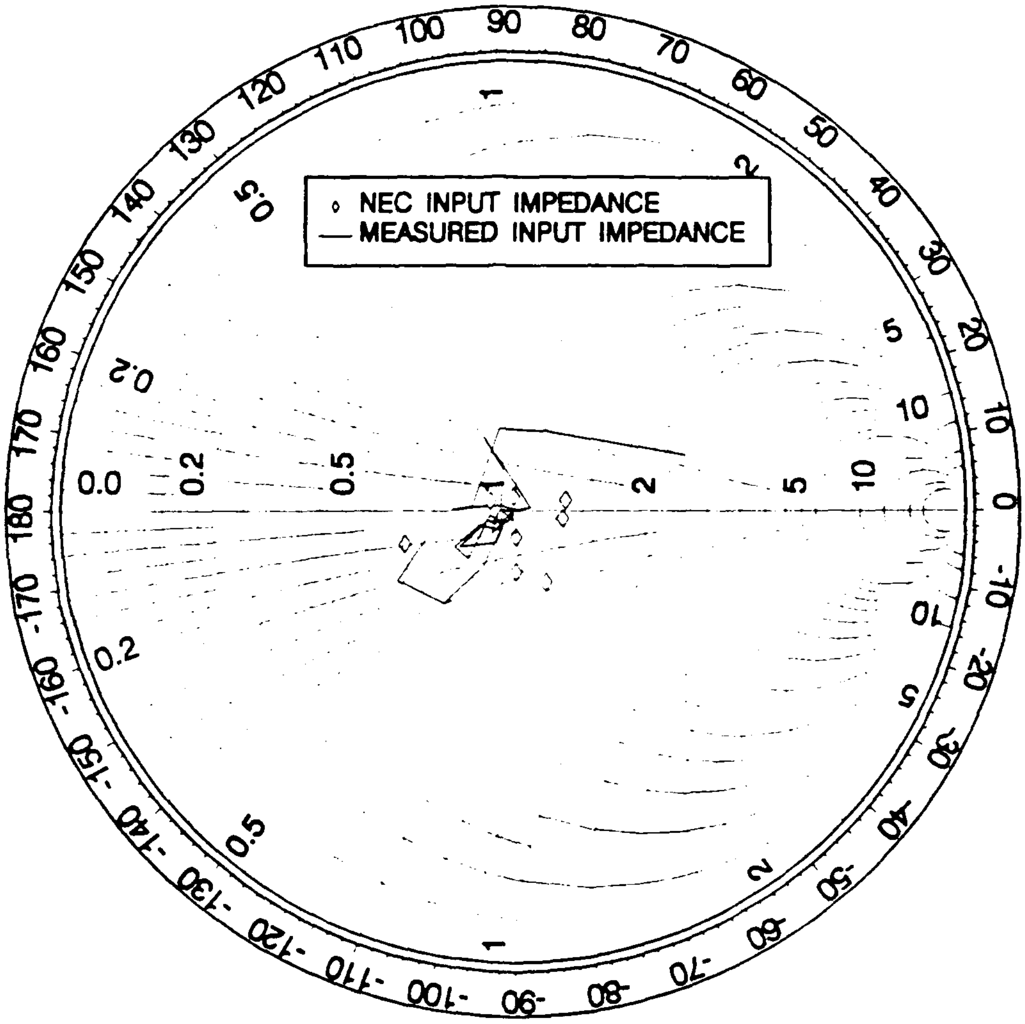

Figure 22. Computed and Measured Input Impedance; 100-800 MHz LPDA.

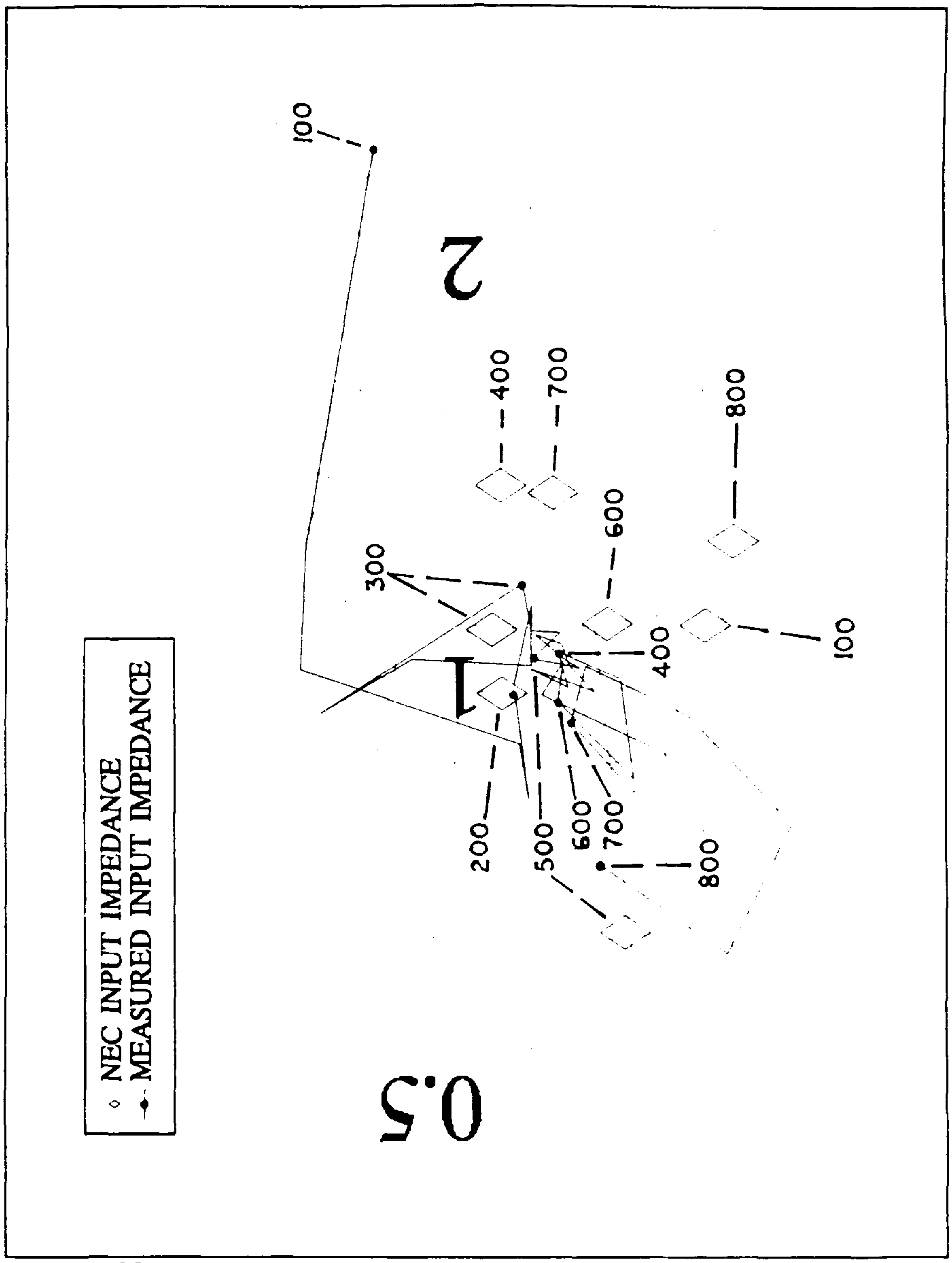

Figure 23. Expanded Input Impedance Data; 100-800 MHz LPDA.

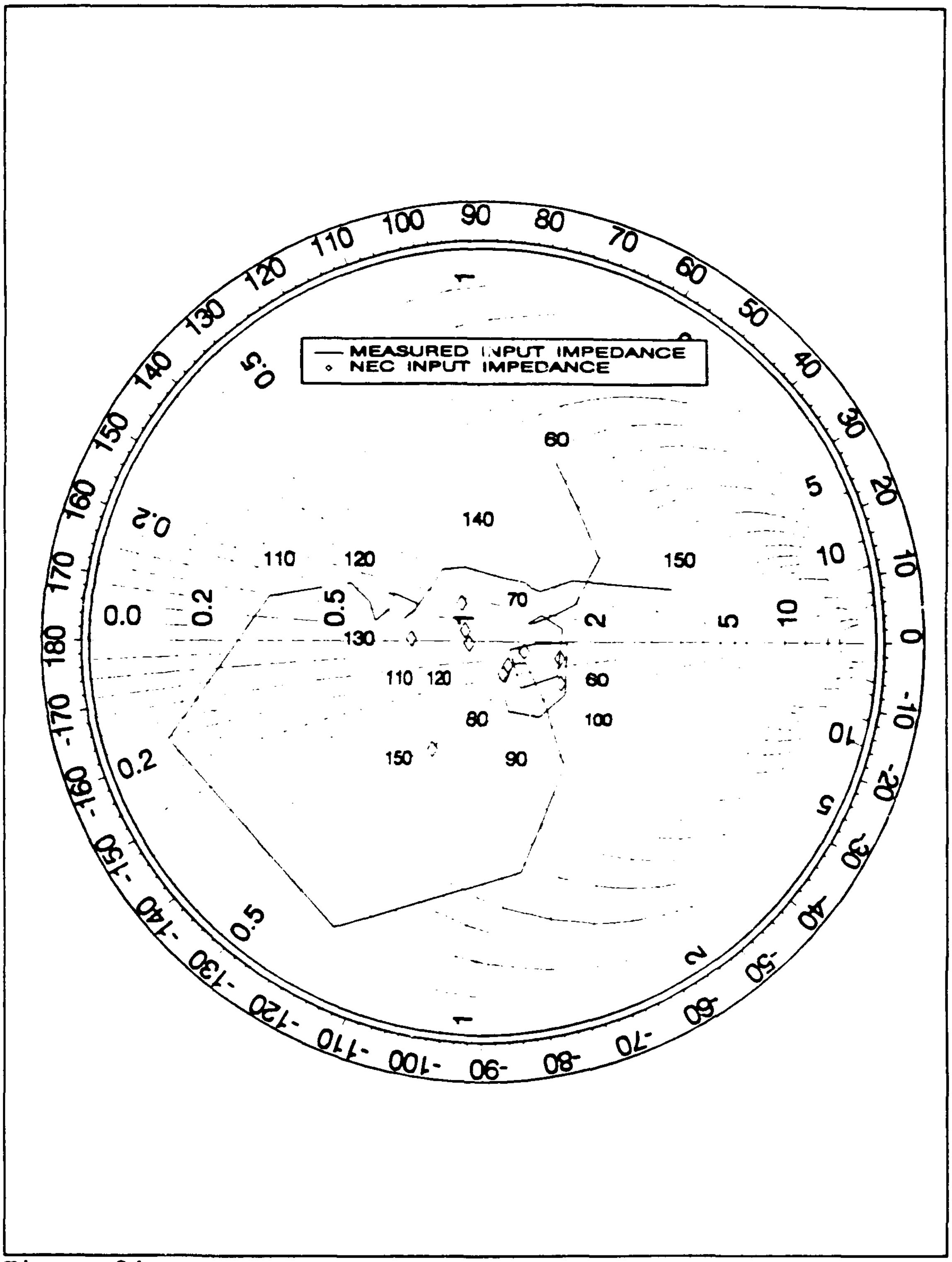

Figure 24. Computed and Measured Input Impedance; 60-150 MHz LPDA.

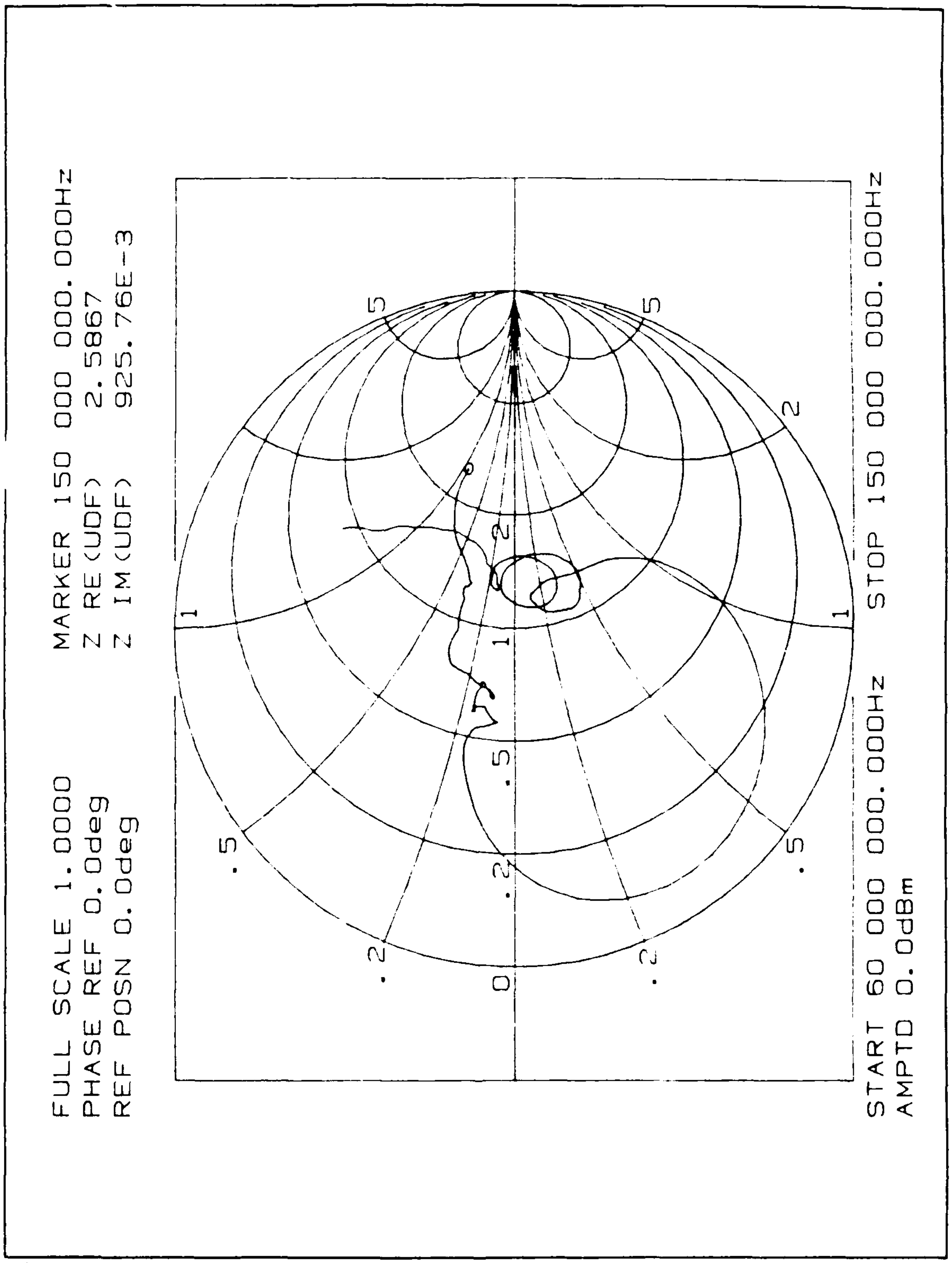

Figure 25. Measured Input Impedance; 60-150 MHz LPDA.

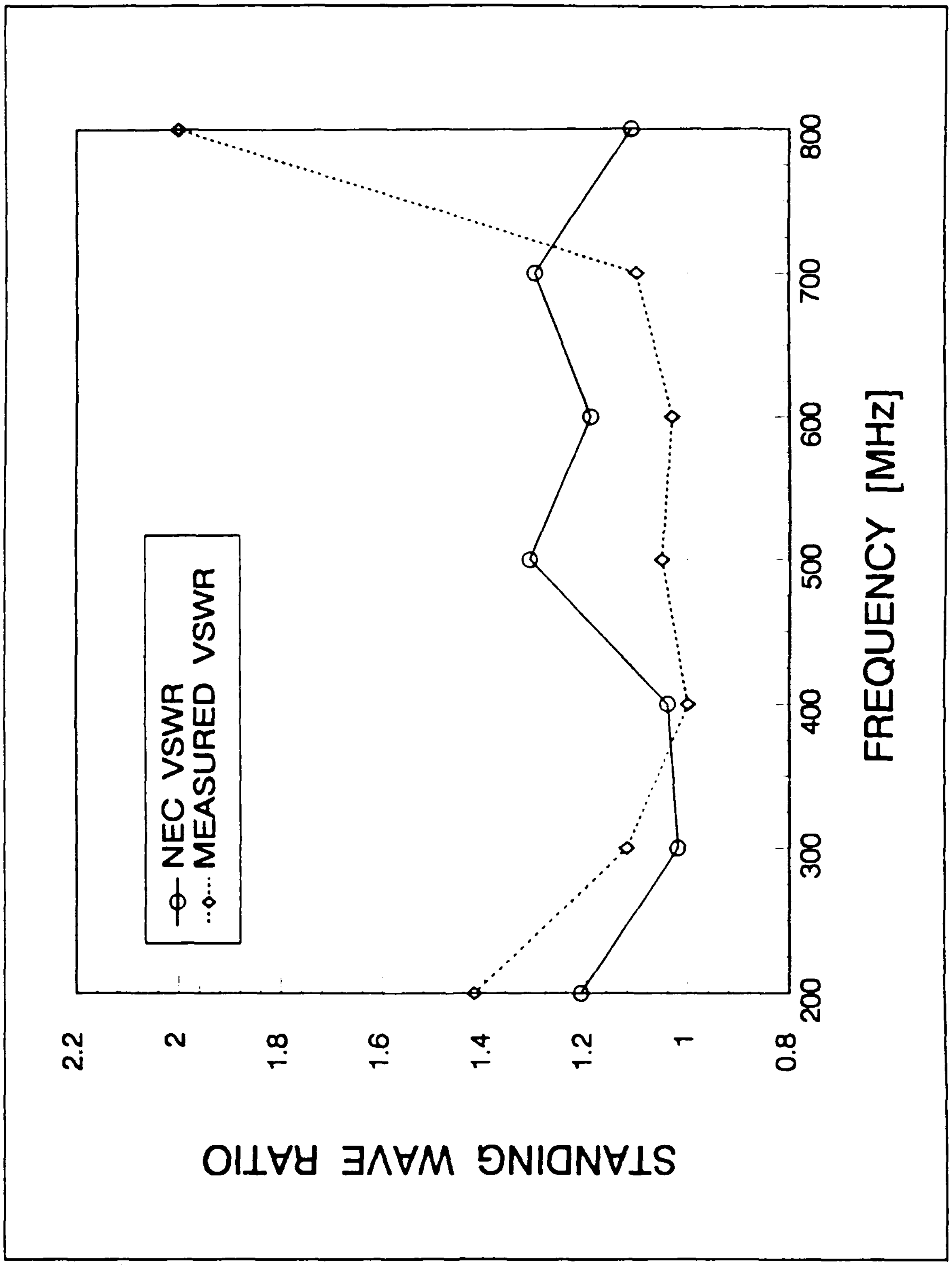

Figure 26. Computed and Measured VSWR; 200-800 MHz LPDA.

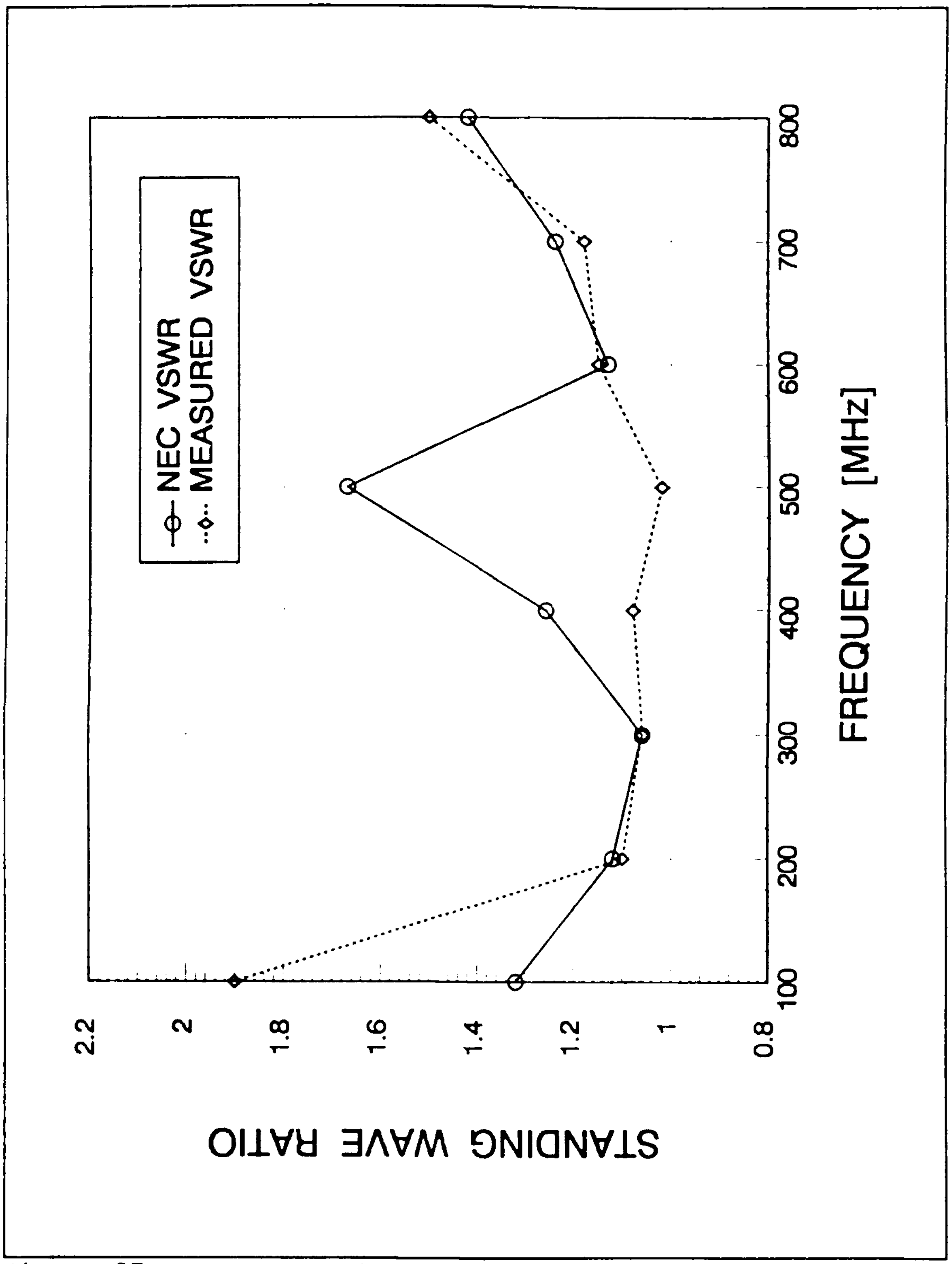

Figure 27. Computed and Measured VSWR; 100-800 MHz LPDA.

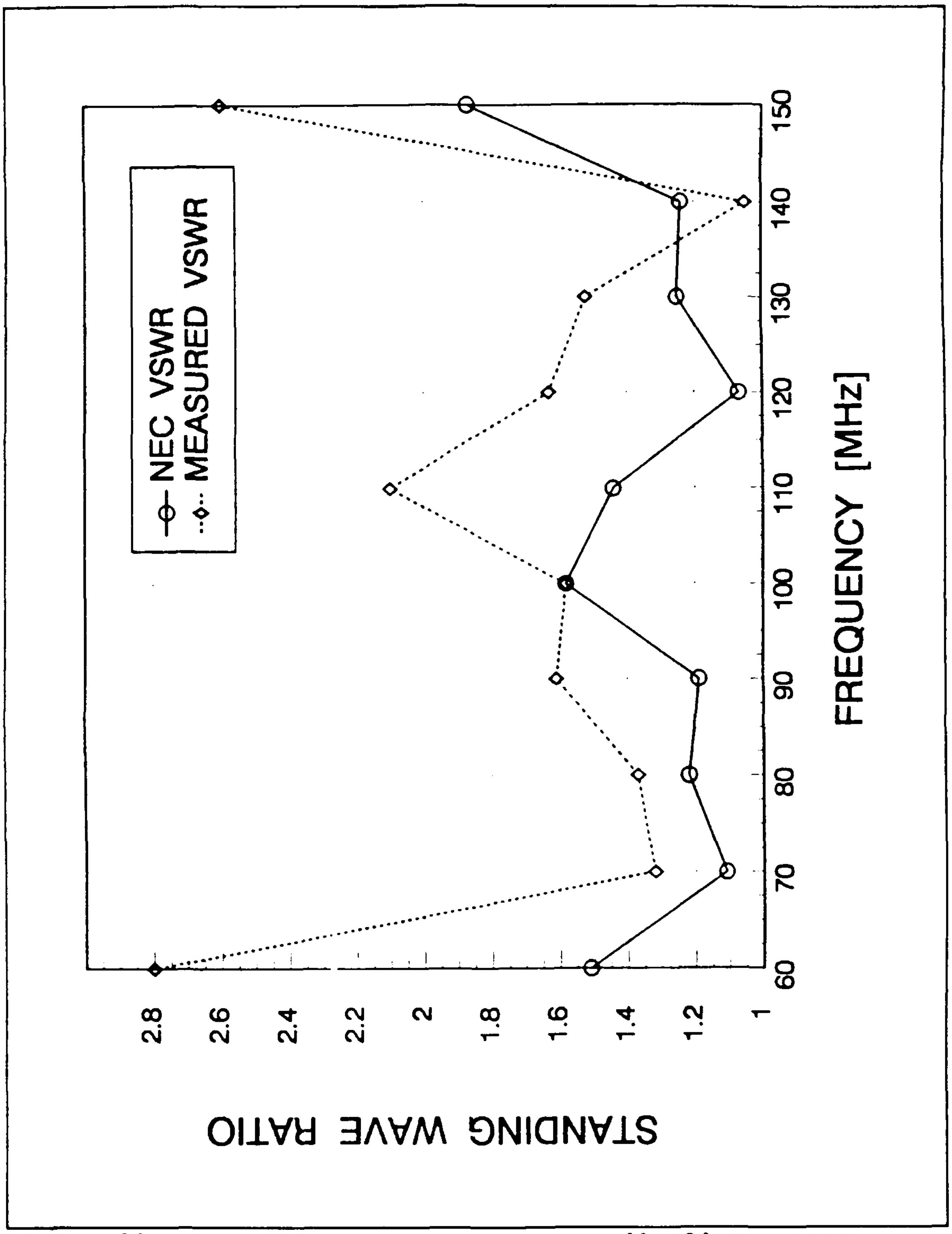

Figure 28. Computed and Measured VSWR; 60-150 MHz LPDA.

a junction in the line, but the pole containing the source had not been identified. The 200-800 MHz antenna was used since it was the first unit available for testing. Because the spectral content of the particular noise source was very low at frequencies below 150 MHz, the frequency range of the 200-800 MHz model was not suitable for the location of this particular source. Emphasis was placed on the completion of the 60-150 MHz and 100-800 MHz versions of the antenna to provide lower frequency operation.

The next field trial was an operational noise source location exercise held in the vicinity of a U.S. Navy receiving site at Hanza, Okinawa, Japan. A noise source was found where a 12 kV distribution line ran along a street and two short spans from this line crossed to the other side of the street. The 100-800 MHz antenna was used to determine which pole contained the noise source. The source was isolated to a specific pole in a few minutes by scanning each pole. In this case the spectral content of the noise source extended to above 500 MHz, and the smaller 200-800 MHz antenna also was effective. The 60-150 MHz log-periodic antenna was not suitable for the specific noise source found at Hanza as contrasted to its critical need at the Morgan Hill site.

The two field trials indicate that the smaller 200-800 MHz log-periodic will be useful in most source location cases. However, some sources require lower-frequency antennas. The 100-800 MHz antenna covers the frequency range of noise of noise emissions for a larger number of cases, and the physically large 60-150 MHz antenna is required for some special cases where the spectral content of the noise source is unusually low in frequency.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

A Signal-to-Noise Enhancement Program (SNEP) was established to identify and mitigate sources of radio noise affecting the performance of Naval receiving sites. In this thesis, three log-periodic dipole antennas (LPDAs) have been designed, constructed, analyzed, measured and tested to support instrumentation used by SNEP teams to locate sources of power-line noise. Specific uses are to locate utility poles containing sources of noise in situations where:

1. Poles are closely spaced.
2. The hardware is complex and distributed across several nearby poles.
3. Multiple sources exist on several adjacent and close poles.
4. Complex substation configurations.
5. Equipment used by a power customer.

These antennas can also be used as general purpose communication antennas over their frequency bandwidth. Specific observations are:

1. The design is based on previously obtained theoretical results [Ref. 2], but differs in two major points; first, U-shaped aluminum channels are used instead of round tubes as feeders of the antenna, and second, transmission line theory is used to compute the value of the characteristic impedance of the feeder.

2. Predicted values of input impedance of the antennas were computed based on a modified formula for the characteristic impedance of the feeder. The NEC analysis and measurements of input impedance showed that Equation (11) can be used with good agreement.

3. Because standard aluminum stock sizes do not correspond with desired element diameter sizes, an average element length-to-diameter ratio was used instead of the computed one. It did not significantly affect the performance of the antenna, provided the transition between adjacent groups of constant element length-to-diameter ratio is smooth.

4. NEC analysis was performed in a free-space environment. In all cases it provided nearly constant values of gain, deviating from the theoretical value by less than 1 dB.

5. The comparison between NEC results and actual measurements of the input impedance and standing wave ratio, illustrate close agreement between values. The predicted performance of the antennas was satisfactory.

6. Radiation patterns indicate good performance of the antennas with a small distortion of the main beam at high frequencies. This distortion does not significantly affect the desired operation of the LPDAs.

7. The method of attaching elements to the feeder is very efficient because it provides for easy portability and ease replacement in case of damage during field tests.

B. RECOMMENDATIONS

The computation of the characteristic impedance of the feeder using Equation (11) showed satisfactory results. However, a more refined equation resulting from extended study may yield more accurate results.

The placement of the short circuit at the end of the LPDA dramatically affects the value of the input impedance, especially in the lower frequencies of the operation bandwidth. The optimum position of the short circuit can not be theoretically determined. Before constructing more LPDAs, the optimum position must be found by several iterations using NEC modelling.

New geometrical structures of LPDAs can be created and modelled based on the performance of antennas in this study.

APPENDIX A. NEC DATA SETS

```
CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=200 MHz.85 SEGMENTS.
GW1,11,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,11,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,11,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,7,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,7,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,5,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,5,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,5,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,5,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,5,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,3,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,3,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,3,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,3,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,3,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,3,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.00075,0.0,-0.1,-0.00075,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,200.0,0.0,
PT-1,1,1,1,
TL17,1,1,6,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,6,2,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,6,3,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,6,4,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,4,5,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,4,6,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,3,7,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,3,8,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,3,9,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,3,10,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,3,11,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,2,12,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,2,13,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,2,14,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,2,15,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,2,16,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,2,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
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RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN


CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9  dB,  DIPOLE  LENGTH  TO  DIAMETER  RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=300 MHz. 99 SEGMENTS.
GW1,11,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,11,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,11,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,11,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,11,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,5,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,5,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,5,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,5,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,5,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,3,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,3,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,3,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,3,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,3,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,3,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.0005,0.0,-0.1,-0.0005,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,300.0,0.0,
PT-1,1,1,1,
TL17,1,1,6,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,6,2,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,6,3,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,6,4,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,6,5,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,6,6,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,3,7,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,3,8,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,3,9,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,3,10,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,3,11,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,2,12,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,2,13,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,2,14,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,2,15,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,2,16,2,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,2,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=400 MHz. 127 SEGMENTS.
GW1,11,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,11,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,11,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,11,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,11,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,9,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,9,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,9,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,7,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,7,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,5,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,5,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,5,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,5,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,5,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,5,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-1.0,0.00038,0.0,-0.1,-0.00038,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,400.0,0.0,
PT-1,1,1,1,
TL17,1,1,6,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,6,2,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,6,3,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,6,4,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,6,5,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,6,6,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,5,7,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,5,8,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,5,9,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,4,10,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,4,11,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,3,12,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,3,13,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,3,14,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,3,15,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,3,16,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,3,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=500 MHz. 161 SEGMENTS.
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GW1,15,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,15,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,15,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,15,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,15,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,11,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,11,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,11,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,11,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,11,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,5,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,5,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,5,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,5,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,5,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,5,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.0003,0.0,-0.1,-0.0003,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,500.0,0.0,
PT-1,1,1,1,
TL17,1,1,8,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,8,2,8,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,8,3,8,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,8,4,8,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,8,5,8,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,8,6,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,6,11,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,3,12,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,3,13,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,3,14,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,3,15,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,3,16,3,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,3,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=600 MHz. 185 SEGMENTS.
GW1,17,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,17,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,17,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,17,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
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GW5,17,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,11,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,11,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,11,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,11,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,11,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,9,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,9,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,7,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,7,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,7,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,7,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.00025,0.0,-0.1,-0.00025,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,600.0,0.0,
PT-1,1,1,1,
TL17,1,1,9,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,9,2,9,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,9,3,9,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,9,4,9,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,9,5,9,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,9,6,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,6,11,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,5,12,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,5,13,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,4,14,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,4,15,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,4,16,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,4,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=700 MHz. 197 SEGMENTS.
GW1,19,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,19,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,19,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,19,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,19,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,11,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,11,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,11,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
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GW9,11,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,11,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,9,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,9,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
GW13,7,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,7,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,7,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,7,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.00021,0.0,-0.1,-0.00021,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,700.0,0.0,
PT-1,1,1,1,
TL17,1,1,10,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,10,2,10,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,10,3,10,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,10,4,10,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,10,5,10,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,10,6,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,6,11,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,5,12,5,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,5,13,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,4,14,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,4,15,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,4,16,4,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,4,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 16 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.09, TAU=0.89,
CM GAIN=6.9 dB, DIPOLE LENGTH TO DIAMETER RATIO=87,
CE BOOM IMPEDANCE=65 OHMS. FREQUENCY=800 MHz. 237 SEGMENTS.
GW1,21,0.0,0.375,0.0,0.0,-0.375,0.0,0.00476,
GW2,21,0.135,0.334,0.0,0.135,-0.334,0.0,0.00476,
GW3,21,0.255,0.297,0.0,0.255,-0.297,0.0,0.00476,
GW4,21,0.362,0.2645,0.0,0.362,-0.2645,0.0,0.00476,
GW5,21,0.457,0.2355,0.0,0.457,-0.2355,0.0,0.00476,
GW6,13,0.542,0.2095,0.0,0.542,-0.2095,0.0,0.00397,
GW7,13,0.617,0.1865,0.0,0.617,-0.1865,0.0,0.00397,
GW8,13,0.684,0.166,0.0,0.684,-0.166,0.0,0.00397,
GW9,13,0.744,0.1475,0.0,0.744,-0.1475,0.0,0.00397,
GW10,31,0.797,0.1315,0.0,0.797,-0.1315,0.0,0.00397,
GW11,11,0.844,0.117,0.0,0.844,-0.117,0.0,0.00317,
GW12,11,0.886,0.104,0.0,0.886,-0.104,0.0,0.00317,
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GW13,11,0.923,0.0925,0.0,0.923,-0.0925,0.0,0.00317,
GW14,11,0.956,0.0825,0.0,0.956,-0.0825,0.0,0.00317,
GW15,11,0.986,0.0735,0.0,0.986,-0.0735,0.0,0.00317,
GW16,11,1.012,0.0655,0.0,1.012,-0.0655,0.0,0.00317,
GW17,1,-0.1,0.00018,0.0,-0.1,-0.00018,0.0,0.00001,
GP
GE0,0,0.0,
FR0,1,0,0,800.0,0.0,
PT-1,1,1,1,
TL17,1,1,11,-65.0,1000000.0,0.0,0.000001,0.0,
TL1,11,2,11,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,11,3,11,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,11,4,11,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,11,5,11,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,11,6,7,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,7,7,7,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,7,8,7,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,7,9,7,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,7,10,7,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,7,11,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,6,12,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,6,13,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,6,14,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,6,15,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,6,16,6,-65.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,16,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=100 MHz. 115 SEGMENTS.
GW1,15,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,15,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,15,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,7,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,7,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,5,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,5,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,5,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,5,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,5,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,3,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,3,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,3,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,3,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,3,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
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GW16,3,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,3,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,3,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,3,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,3,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.0015,0.0,-0.1,-0.0015,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,100.0,0.0,
TL21,1,1,8,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,8,2,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,8,3,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,8,4,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,4,5,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,4,6,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,3,7,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,3,8,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,3,9,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,3,10,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,3,11,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,2,12,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,2,13,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,2,14,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,2,15,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,2,16,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,2,17,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,2,18,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,2,19,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,2,20,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,2,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=200 MHz. 151 SEGMENTS.
GW1,15,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,15,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,15,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,15,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,15,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,9,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,9,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,9,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,9,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,9,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,3,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
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GW12,3,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,3,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,3,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,3,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,3,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,3,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,3,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,3,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,3,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.00075,0.0,-0.1,-0.00075,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,200.0,0.0,
TL21,1,1,8,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,8,2,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,8,3,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,8,4,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,8,5,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,8,6,5,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,5,7,5,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,5,8,5,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,5,9,5,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,5,10,5,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,5,11,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,2,12,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,2,13,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,2,14,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,2,15,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,2,16,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,2,17,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,2,18,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,2,19,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,2,20,2,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,2,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=300 MHz. 181 SEGMENTS.
GW1,15,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,15,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,15,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,15,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,15,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,11,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,11,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
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GW8,11,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,11,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,11,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,5,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,5,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,5,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,5,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,5,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,5,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,5,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,5,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,5,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,5,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.0005,0.0,-0.1,-0.0005,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,300.0,0.0,
TL21,1,1,8,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,8,2,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,8,3,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,8,4,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,8,5,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,8,6,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,6,11,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,3,12,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,3,13,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,3,14,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,3,15,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,3,16,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,3,17,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,3,18,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,3,19,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,3,20,3,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,3,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=400 MHz. 237 SEGMENTS.
GW1,21,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,21,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,21,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
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GW4,21,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,21,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,11,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,11,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,11,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,11,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,11,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,13,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,13,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,13,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,7,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,7,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,7,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,7,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,7,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,7,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,7,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.00037,0.0,-0.1,-0.00037,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,400.0,0.0,
TL21,1,1,11,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,11,2,11,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,11,3,11,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,11,4,11,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,11,5,11,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,11,6,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,6,11,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,6,12,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,6,13,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,6,14,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,4,15,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,4,16,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,4,17,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,4,18,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,4,19,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,4,20,4,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,4,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
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CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=500 MHz. 311 SEGMENTS.
GW1,25,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,25,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,25,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,25,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,25,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,15,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,15,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,15,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,15,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,15,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,11,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,11,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,11,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,11,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,11,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,11,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,11,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,11,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,11,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,11,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.0003,0.0,-0.1,-0.0003,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,500.0,0.0,
TL21,1,1,13,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,13,2,13,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,13,3,13,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,13,4,13,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,13,5,13,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,13,6,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,8,7,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,8,8,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,8,9,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,8,10,8,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,8,11,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,6,12,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,6,13,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,6,14,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,6,15,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,6,16,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,6,17,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,6,18,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,6,19,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,6,20,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=600 MHz. 371 SEGMENTS.
GW1,31,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,31,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,31,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,31,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,31,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,17,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,17,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,17,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,17,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,17,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,13,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,13,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,13,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,13,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,13,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,13,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,13,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,13,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,13,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,13,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.00025,0.0,-0.1,-0.00025,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,600.0,0.0,
TL21,1,1,16,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,16,2,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,16,3,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,16,4,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,16,5,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,16,6,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,9,7,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,9,8,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,9,9,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,9,10,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,9,11,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,7,12,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,7,13,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,7,14,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,7,15,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,7,16,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,7,17,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,7,18,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,7,19,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,7,20,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,7,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
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RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN


CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=700 MHz. 351 SEGMENTS.
GW1,31,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,31,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,31,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,31,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,31,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,17,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,17,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,17,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,17,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,17,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,11,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,11,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,11,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,11,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,11,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,11,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,11,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,11,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,11,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,11,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.00021,0.0,-0.1,-0.00021,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,700.0,0.0,
TL21,1,1,16,-81.0,0.0,1[illegible]0.0,0.0,0.000001,0.0,
TL1,16,2,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,16,3,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,16,4,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,16,5,16,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,16,6,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,9,7,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,9,8,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,9,9,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,9,10,9,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,9,11,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,6,12,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,6,13,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,6,14,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL14,6,15,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,6,16,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,6,17,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,6,18,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
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TL18,6,19,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,6,20,6,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN
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CM 20 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.06, TAU=0.884,
CM GAIN=6.3 dB, DIPOLE LENGTH TO DIAMETER RATIO=100,
CE BOOM IMPEDANCE=81 OHMS. FREQUENCY=800 MHz. 441 SEGMENTS.
GW1,39,0.0,0.75,0.0,0.0,-0.75,0.0,0.00714,
GW2,39,0.18,0.663,0.0,0.18,-0.663,0.0,0.00714,
GW3,39,0.339,0.586,0.0,0.339,-0.586,0.0,0.00714,
GW4,39,0.479,0.518,0.0,0.479,-0.518,0.0,0.00714,
GW5,39,0.603,0.458,0.0,0.603,-0.458,0.0,0.00714,
GW6,23,0.713,0.405,0.0,0.713,-0.405,0.0,0.00635,
GW7,23,0.81,0.358,0.0,0.81,-0.358,0.0,0.00635,
GW8,23,0.896,0.3165,0.0,0.896,-0.3165,0.0,0.00635,
GW9,23,0.972,0.2795,0.0,0.972,-0.2795,0.0,0.00635,
GW10,23,1.039,0.2475,0.0,1.039,-0.2475,0.0,0.00635,
GW11,13,1.098,0.2185,0.0,1.089,-0.2185,0.0,0.00397,
GW12,13,1.15,0.193,0.0,1.15,-0.193,0.0,0.00397,
GW13,13,1.196,0.171,0.0,1.196,-0.171,0.0,0.00397,
GW14,13,1.237,0.151,0.0,1.237,-0.151,0.0,0.00397,
GW15,13,1.273,0.1335,0.0,1.273,-0.1335,0.0,0.00397,
GW16,13,1.305,0.118,0.0,1.305,-0.118,0.0,0.00238,
GW17,13,1.333,0.1045,0.0,1.333,-0.1045,0.0,0.00238,
GW18,13,1.358,0.092,0.0,1.358,-0.092,0.0,0.00238,
GW19,13,1.38,0.0815,0.0,1.38,-0.0815,0.0,0.00238,
GW20,13,1.399,0.072,0.0,1.399,-0.072,0.0,0.00238,
GW21,1,-0.1,0.00018,0.0,-0.1,-0.00018,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,800.0,0.0,
TL21,1,1,20,-81.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,20,2,20,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,20,3,20,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,20,4,20,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,20,5,20,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,20,6,12,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,12,7,12,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,12,8,129,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,12,9,12,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,12,10,12,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL10,12,11,76,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL11,7,12,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL12,7,13,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL13,7,14,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
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TL14,7,15,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL15,7,16,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL16,7,17,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL17,7,18,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL18,7,19,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
TL19,7,20,7,-81.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,20,7,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,
EN


CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=60 MHz. 91 SEGMENTS.
GW1,11,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,11,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,11,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,11,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,11,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,7,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,7,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,7,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,7,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,7,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0025,0.0,-0.15,-0.0025,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,60.0,0.0,
TL11,1,1,6,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,6,2,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,6,3,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,6,4,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,6,5,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,6,6,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,4,7,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,4,8,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,4,9,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,4,10,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,4,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN


CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=70 MHz. 111 SEGMENTS.
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GW1,15,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,15,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,15,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,15,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,15,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,7,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,7,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,7,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,7,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,7,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0021,0.0,-0.15,-0.0021,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,70.0,0.0,
TL11,1,1,8,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,8,2,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,8,3,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,8,4,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,8,5,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,8,6,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,4,7,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,4,8,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,4,9,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,4,10,4,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,4,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=80 MHz. 131 SEGMENTS.
GW1,17,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,17,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,17,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,17,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,17,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,9,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,9,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,9,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,9,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,9,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0018,0.0,-0.15,-0.0018,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,80.0,0.0,
TL11,1,1,9,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
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TL1,9,2,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,9,3,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,9,4,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,9,5,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,9,6,5,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,5,7,5,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,5,8,5,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,5,9,5,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,5,10,5,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,5,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=90 MHz. 141 SEGMENTS.
GW1,17,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,17,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,17,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,17,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,17,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,11,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,11,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,11,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,11,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,11,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0016,0.0,-0.15,-0.0016,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,90.0,0.0,
TL11,1,1,9,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,9,2,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,9,3,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,9,4,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,9,5,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,9,6,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=100 MHz. 141 SEGMENTS.
GW1,17,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,17,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,17,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,17,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,17,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,11,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,11,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,11,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,11,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,11,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0015,0.0,-0.15,-0.0015,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,100.0,0.0,
TL11,1,1,9,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,9,2,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,9,3,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,9,4,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,9,5,9,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,9,6,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=110 MHz. 151 SEGMENTS.
GW1,19,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,19,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,19,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,19,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,19,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,11,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,11,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,11,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,11,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,11,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0013,0.0,-0.15,-0.0013,0.0,0.0001,
GP
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GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,110.0,0.0,
TL11,1,1,10,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,10,2,10,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,10,3,10,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,10,4,10,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,10,5,10,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,10,6,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,6,7,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,6,8,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,6,9,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,6,10,6,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,6,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN

CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=120 MHz. 171 SEGMENTS.
GW1,21,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,21,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,21,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,21,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,21,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,13,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,13,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,13,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,13,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,13,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0012,0.0,-0.15,-0.0012,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,120.0,0.0,
TL11,1,1,11,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,11,2,11,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,11,3,11,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,11,4,11,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,11,5,11,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,11,6,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,7,7,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,7,8,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,7,9,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,7,10,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,7,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
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RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=130 MHz. 181 SEGMENTS.
GW1,23,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,23,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,23,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,23,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,23,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,13,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,13,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,13,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,13,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,13,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0011,0.0,-0.15,-0.0011,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,130.0,0.0,
TL11,1,1,12,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,12,2,12,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,12,3,12,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,12,4,12,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,12,5,12,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,12,6,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,7,7,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,7,8,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,7,9,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,7,10,7,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,7,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=140 MHz. 201 SEGMENTS.
GW1,25,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,25,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,25,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,25,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,25,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,15,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,15,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,15,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
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GW9,15,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,15,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.001,0.0,-0.15,-0.001,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,140.0,0.0,
TL11,1,1,13,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,13,2,13,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,13,3,13,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,13,4,13,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,13,5,13,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,13,6,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL6,8,7,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL7,8,8,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL8,8,9,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL9,8,10,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,8,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
RP0,361,1,1000,0.0,0.0,1.0,0.0,0.0,0.0,
EN
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CM 10 ELEMENT LOG-PERIODIC DIPOLE ANTENNA IN FREE SPACE.
CM RECEIVING AND TRANSMITTING PATTERNS. SIGMA=0.08, TAU=0.87,
CM GAIN=6.0 dB, DIPOLE LENGTH TO DIAMETER RATIO=150,
CE BOOM IMPEDANCE=70 OHMS. FREQUENCY=150 MHz. 211 SEGMENTS.
GW1,27,0.0,1.25.0.0,0.0,-1.25,0.0,0.0159,
GW2,27,0.4,1.0875,0.0,0.4,-1.0875,0.0159,
GW3,27,0.748,0.946,0.0,0.748,-0.946,0.0,0.0159,
GW4,27,1.051,0.823,0.0,1.051,-0.823,0.0,0.0095,
GW5,27,1.314,0.716,0.0,1.314,-0.716,0.0,0.0095,
GW6,15,1.544,0.623,0.0,1.544,-0.623,0.0,0.0095,
GW7,15,1.744,0.542,0.0,1.744,-0.542,0.0,0.00635,
GW8,15,1.917,0.4715,0.0,1.917,-0.4715,0.0,0.00635,
GW9,15,2.069,0.4105,0.0,2.069,-0.4105,0.0,0.00635,
GW10,15,2.201,0.357,0.0,2.201,-0.357,0.0,0.00635,
GW11,1,-0.15,0.0009,0.0,-0.15,-0.0009,0.0,0.0001,
GP
GE0,0,0.0,
PT-1,1,1,1,
FR0,1,0,0,150.0,0.0,
TL11,1,1,14,-70.0,0.0,1000000.0,0.0,0.000001,0.0,
TL1,14,2,14,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL2,14,3,14,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL3,14,4,14,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL4,14,5,14,-70.0,0.0,0.000001,0.0,0.000001,0.0,
TL5,14,6,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
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TL8,8,9,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
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TL9,8,10,8,-70.0,0.0,0.000001,0.0,0.000001,0.0,
EX0,10,8,10,1.0,0.0,
RP0,1,361,1000,90.0,0.0,0.0,1.0,0.0,0.0,
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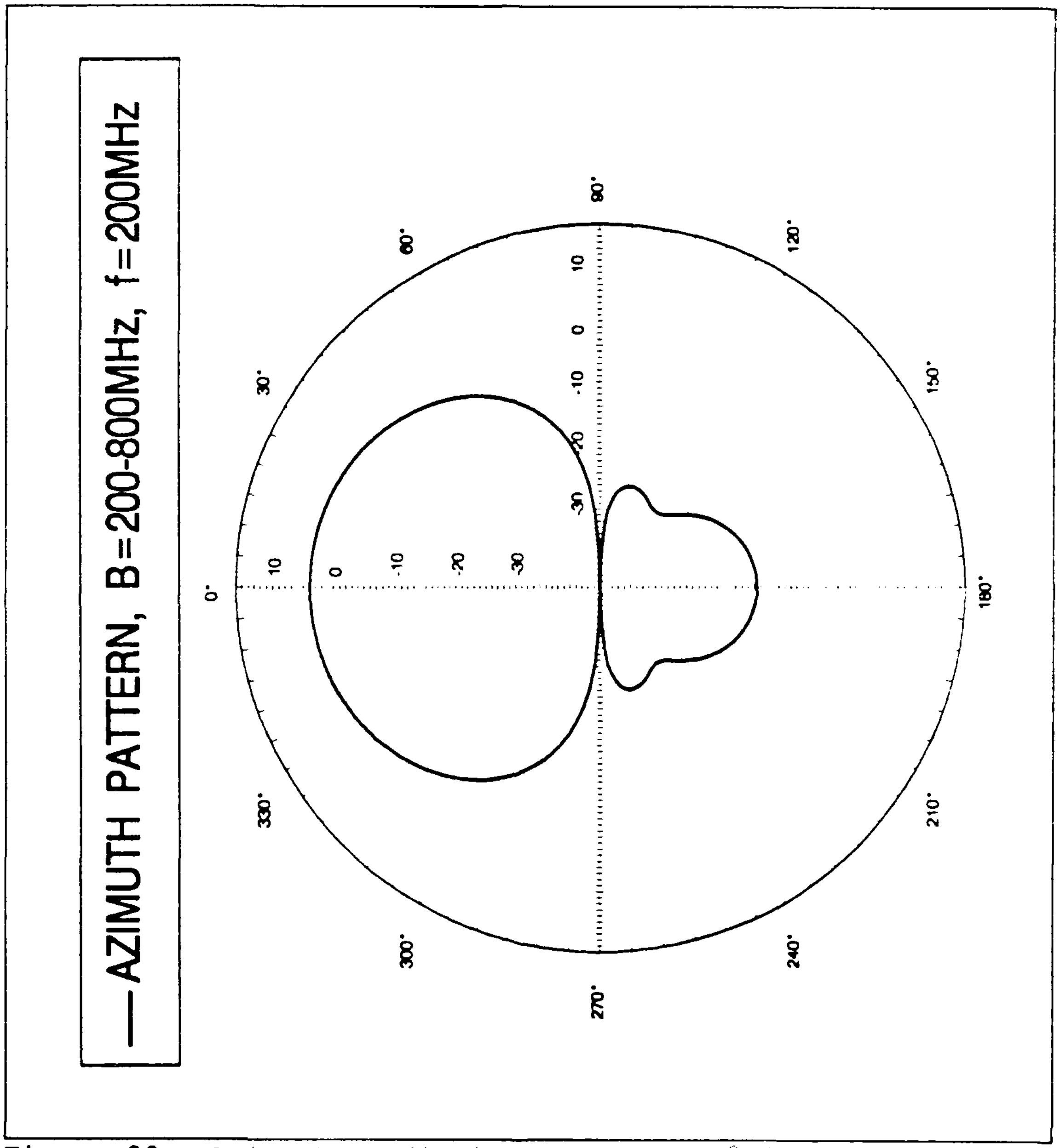

Figure 29. Azimuth Radiation Pattern (θ=90°), f=200 MHz; 200-800 MHz LPDA.

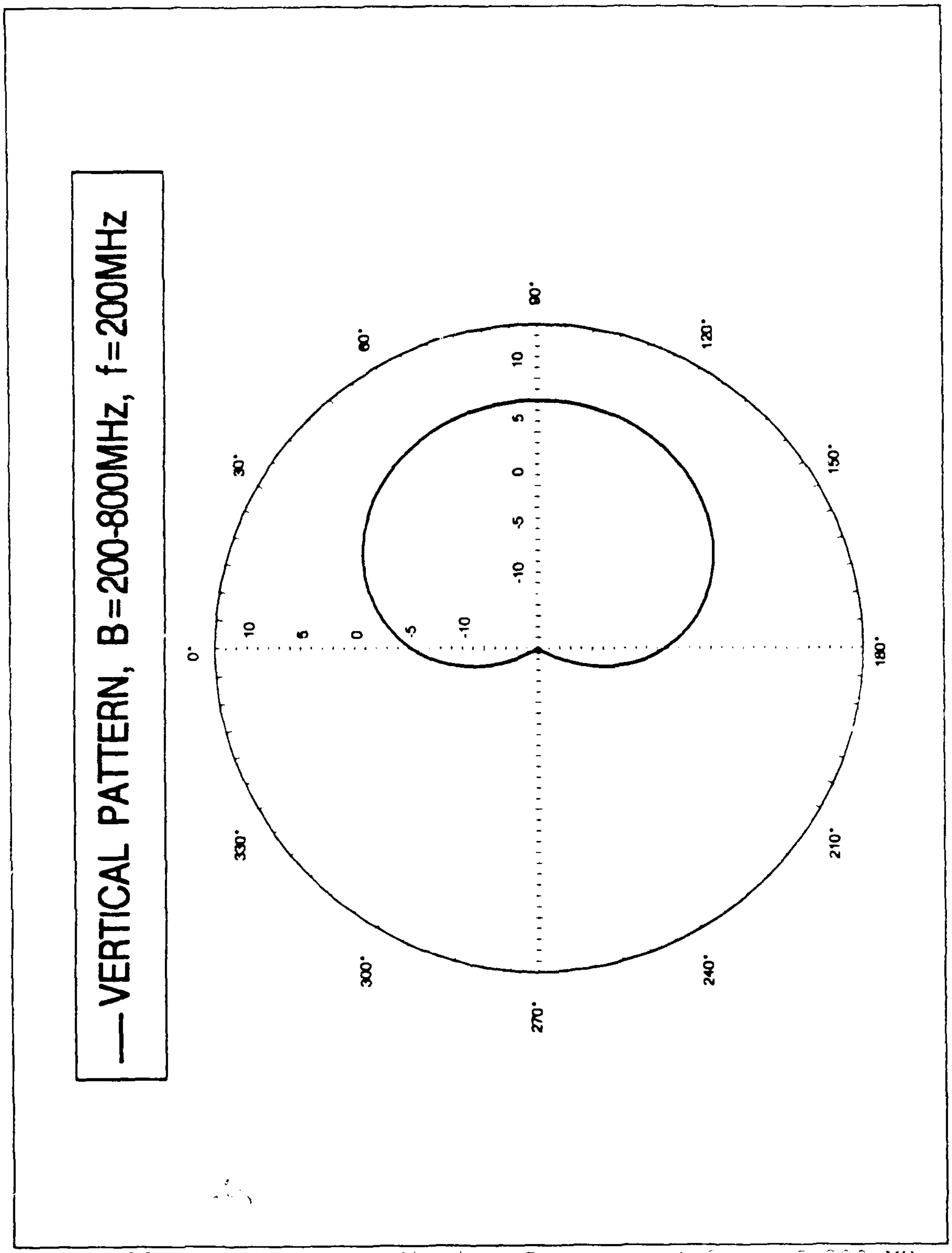

Figure 30. Elevation Radiation Pattern (Φ=0°), f=200 MHz; 200-800 MHz LPDA.

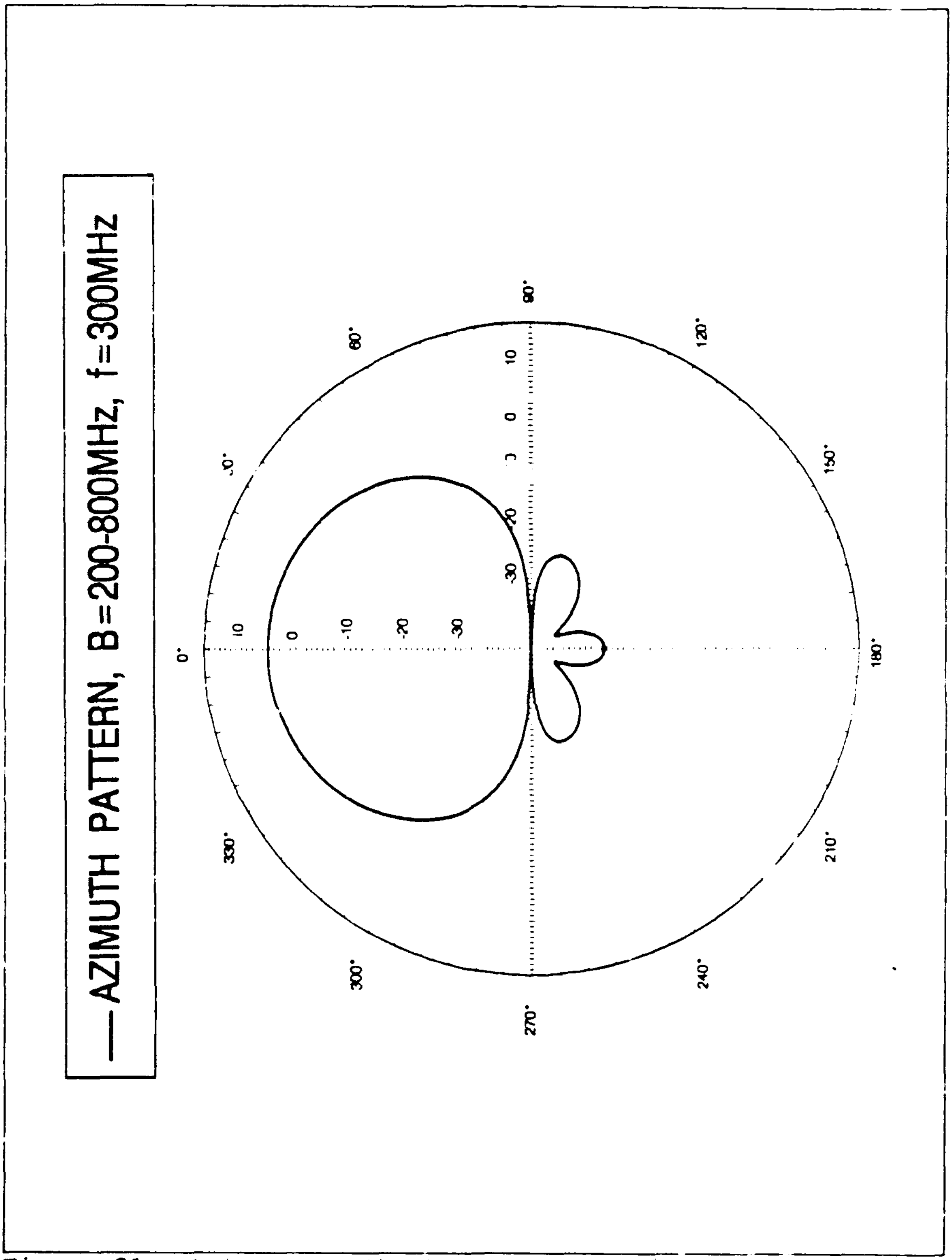

Figure 31. Azimuth Radiation Pattern (θ=90°), f=300 MHz; 200-800 MHz LPDA.

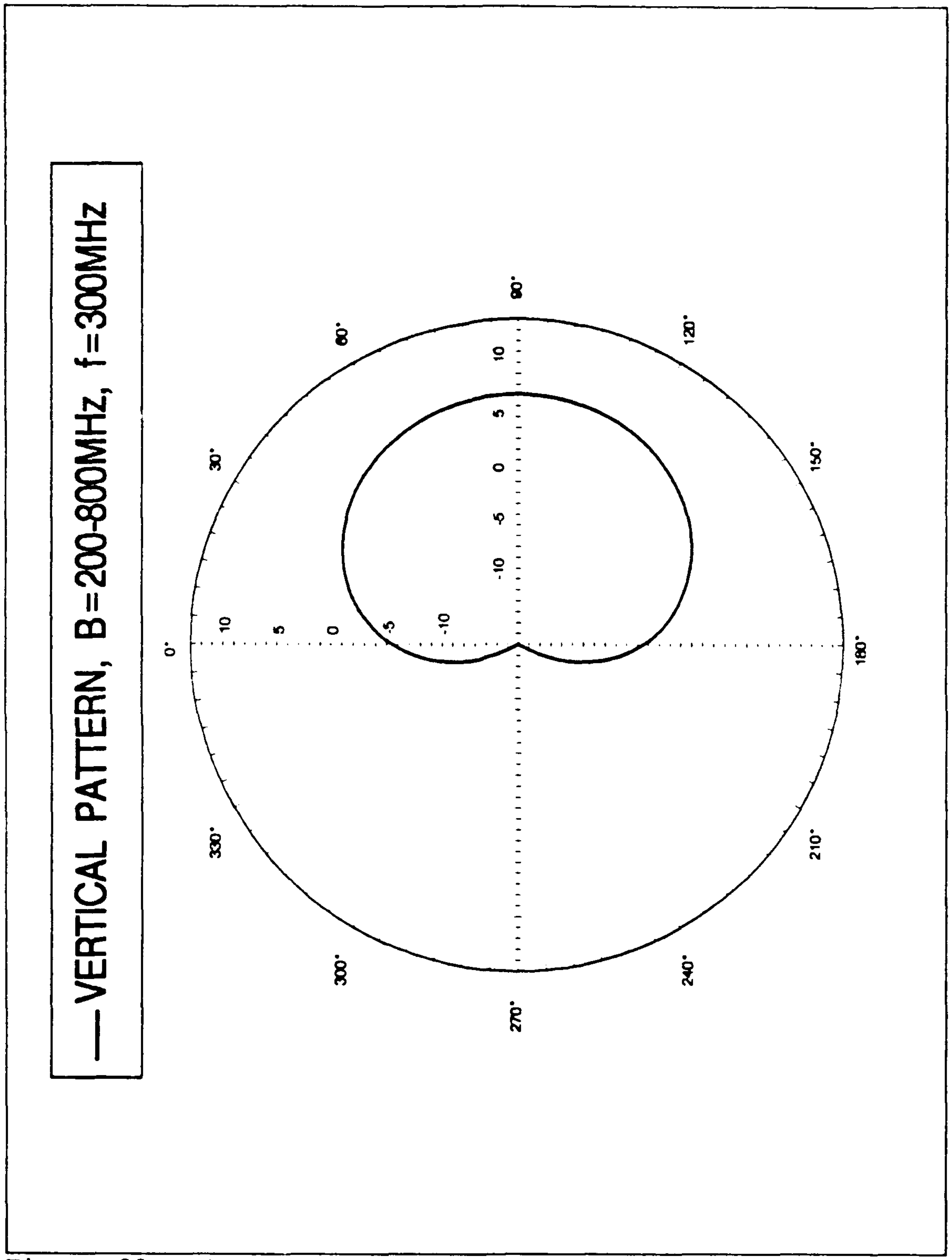

Figure 32. Elevation Radiation Pattern ($\phi=0°$), f=300 MHz; 200-800 MHz LPDA.

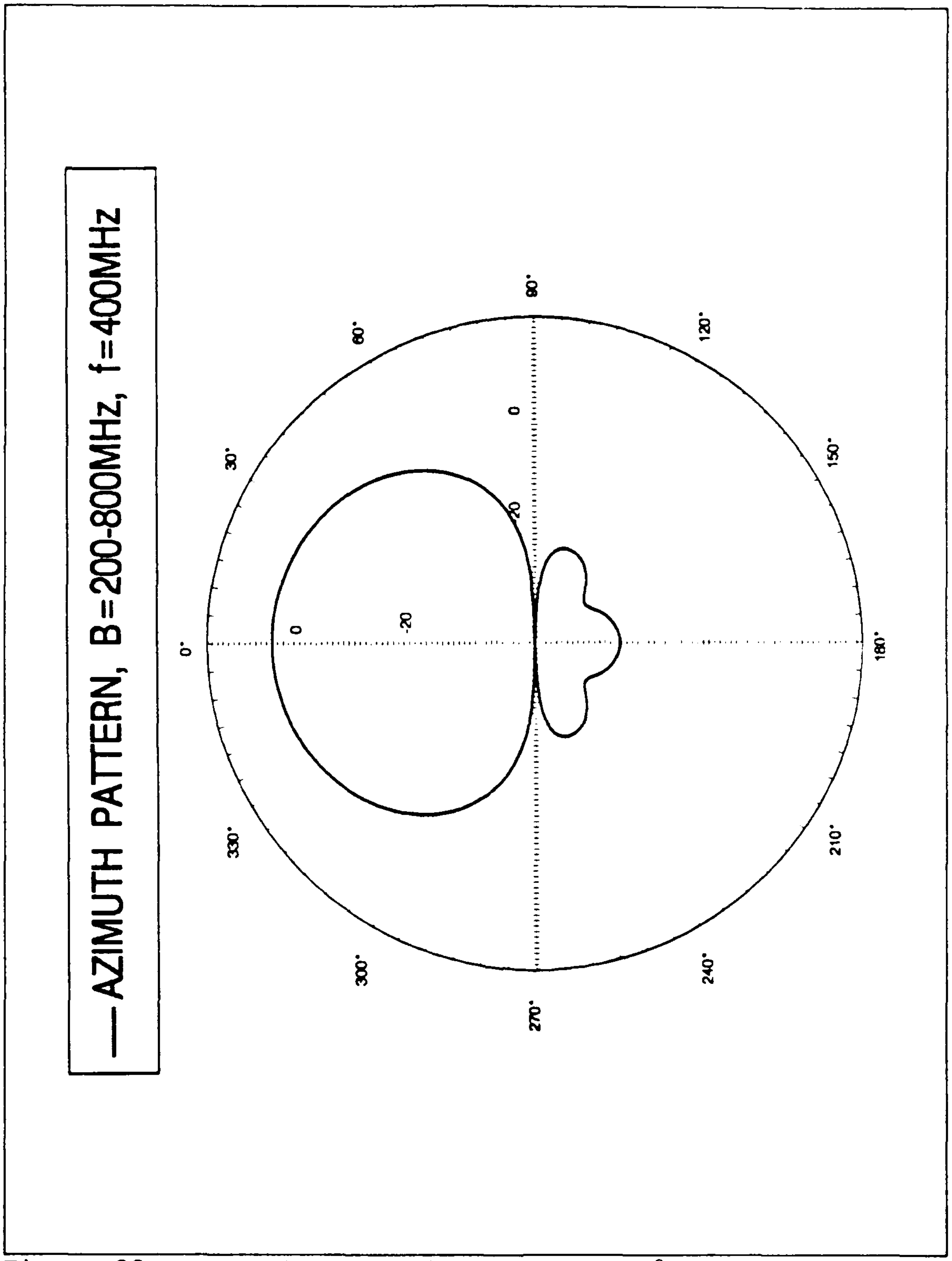

Figure 33. Azimuth Radiation Pattern ($\theta=90°$), f=400 MHz; 200-800 MHz LPDA.

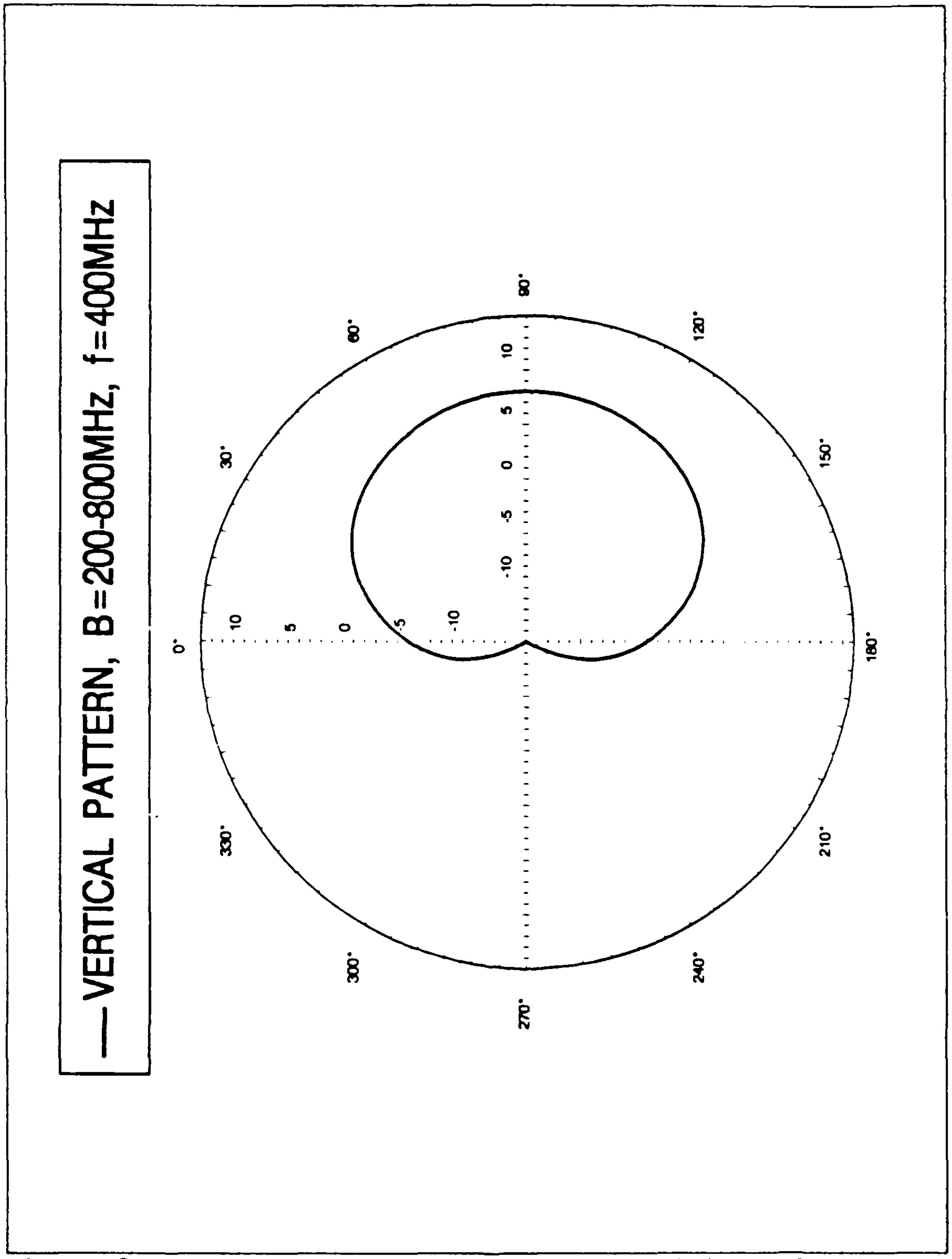

Figure 34. Elevation radiation Pattern (Ø=0°), f=400 MHz; 200-800 MHz LPDA.

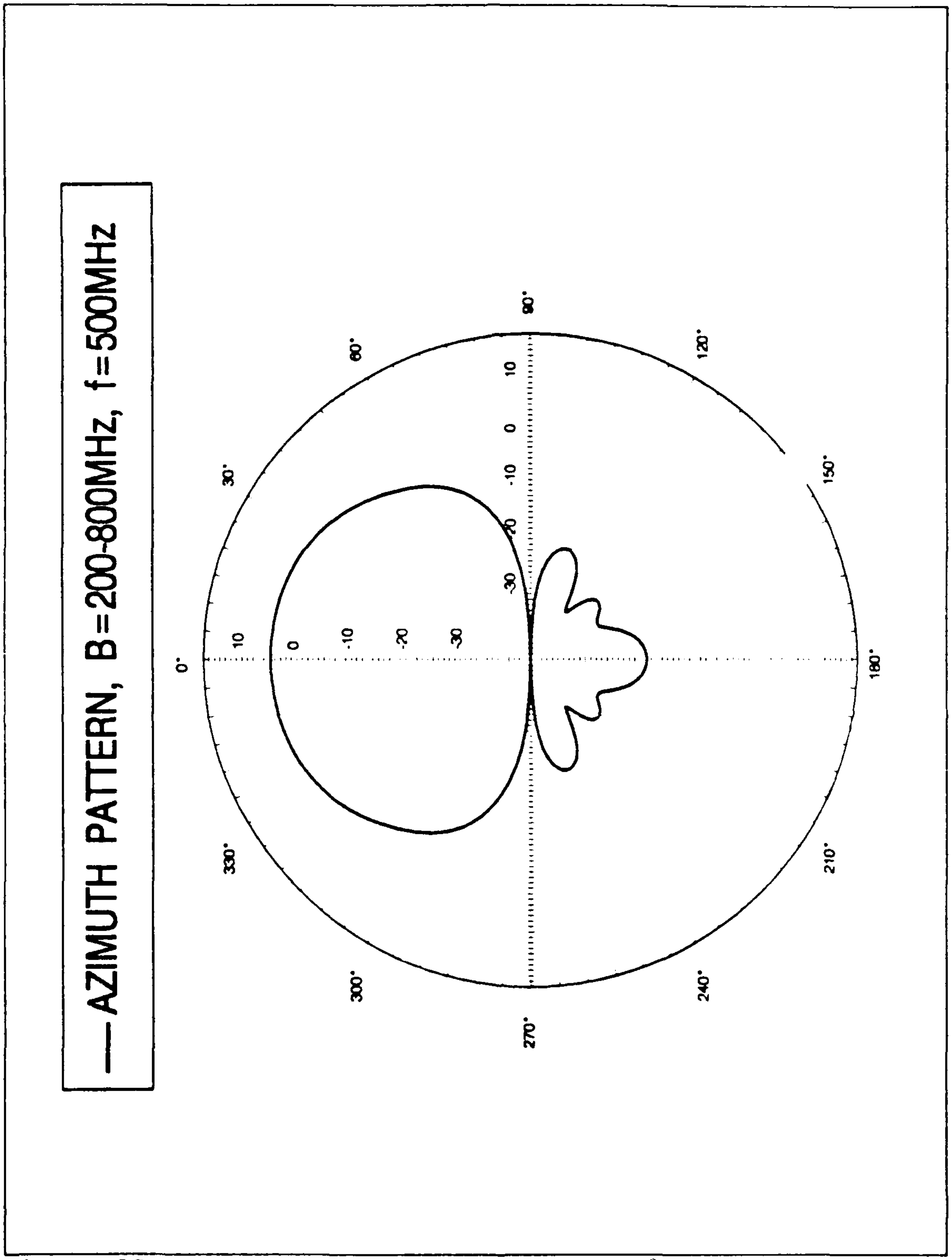

Figure 35. Azimuth Radiation Pattern ($\theta=90°$), f=500 MHz; 200-800 MHz LPDA.

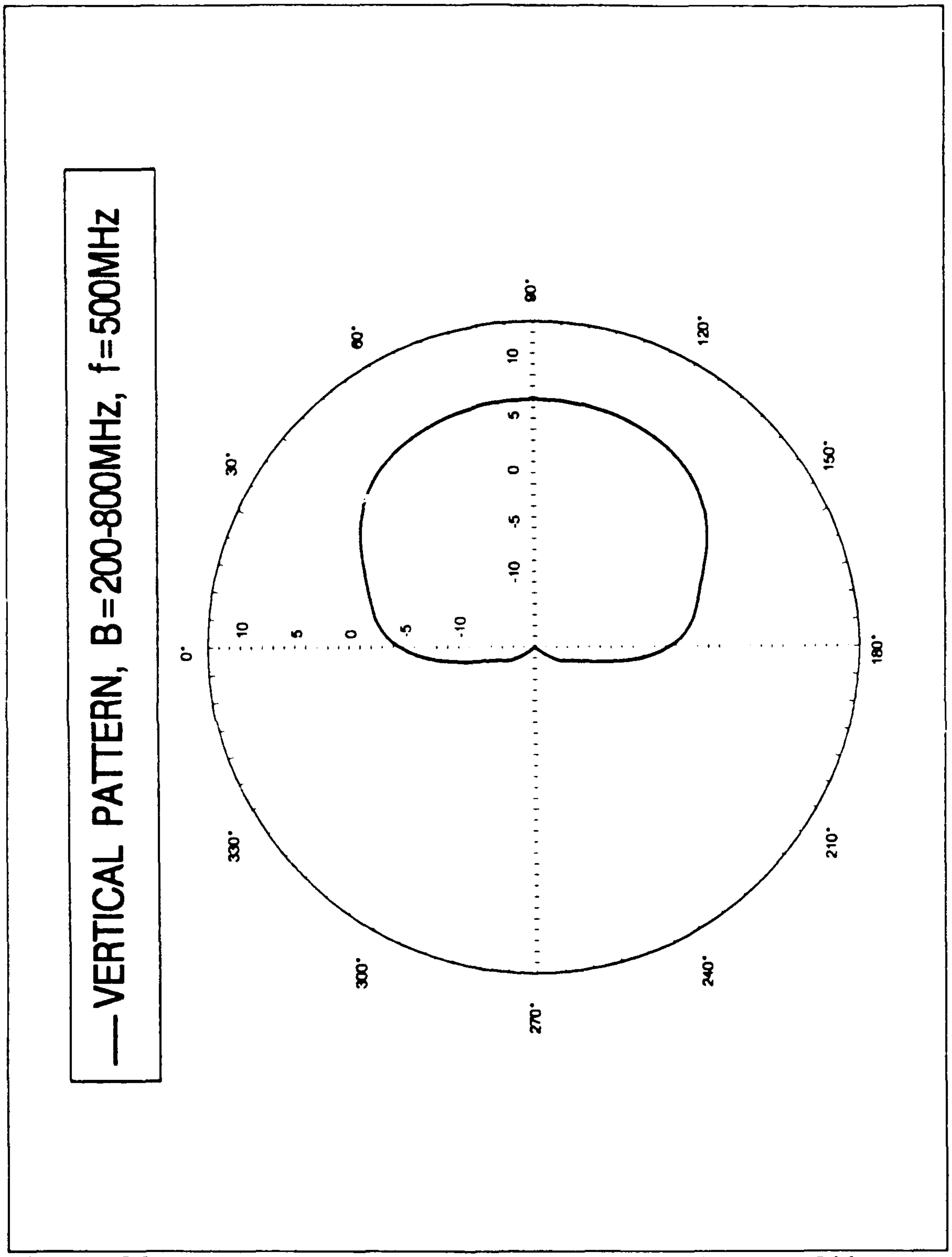

Figure 36. Elevation Radiation Pattern (Φ=[illegible]), f=500 MHz; 200-800 MHz LPDA.

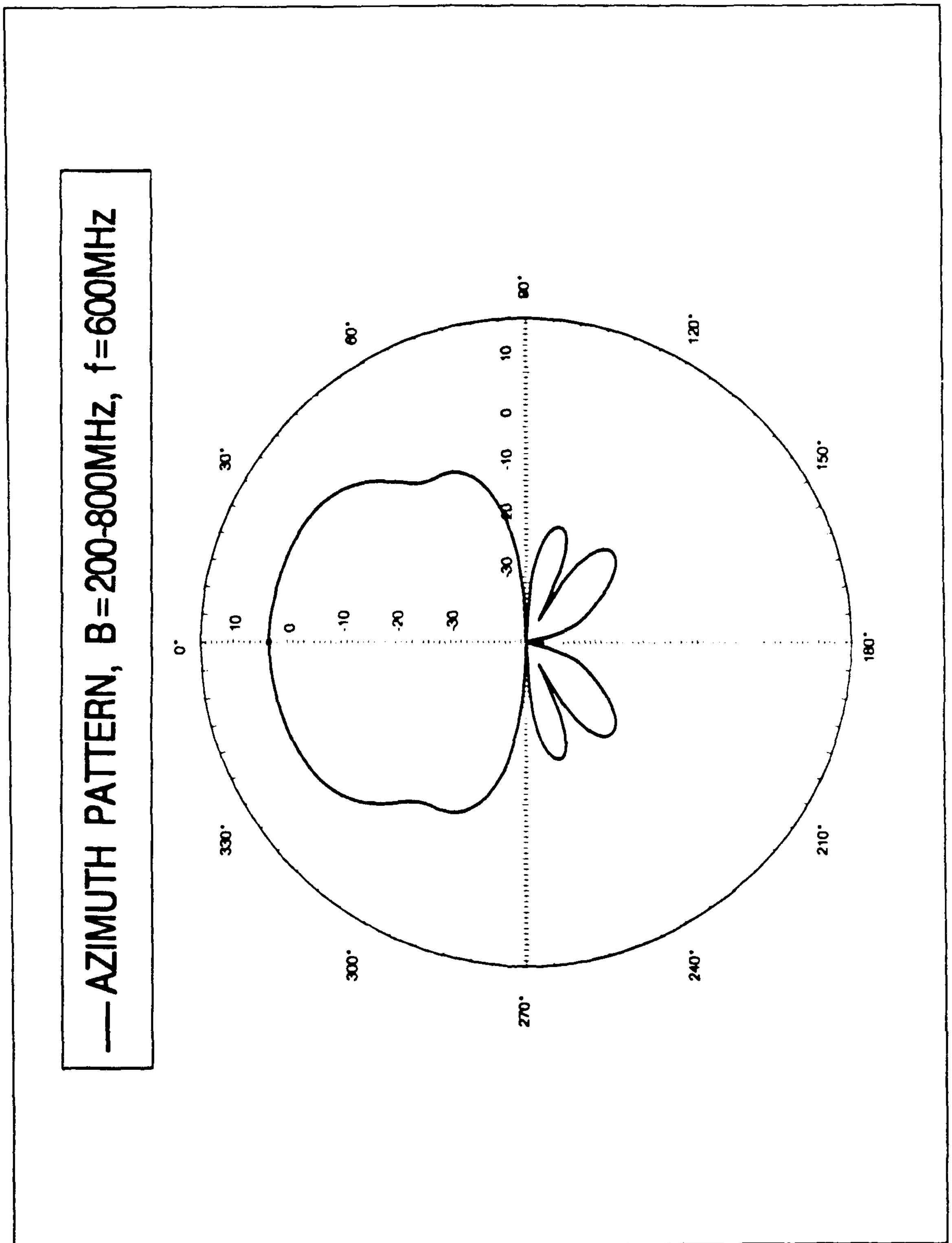

Figure 37. Azimuth Radiation Pattern (θ=90°), f=600 MHz; 200-800 MHz LPDA.

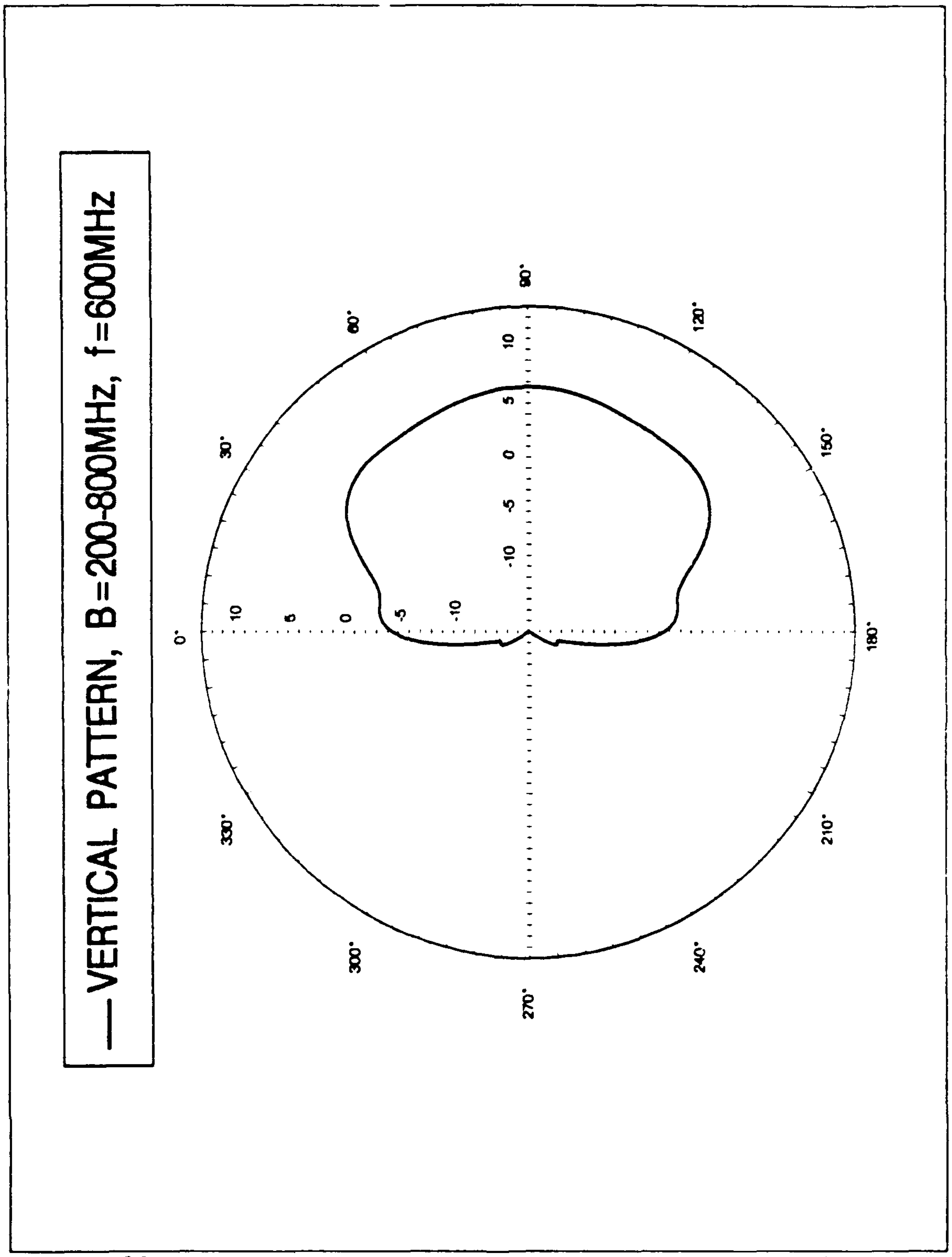

Figure 38. Elevation Radiation Pattern ($\Phi=0°$), f=600 MHz; 200-800 MHz LPDA.

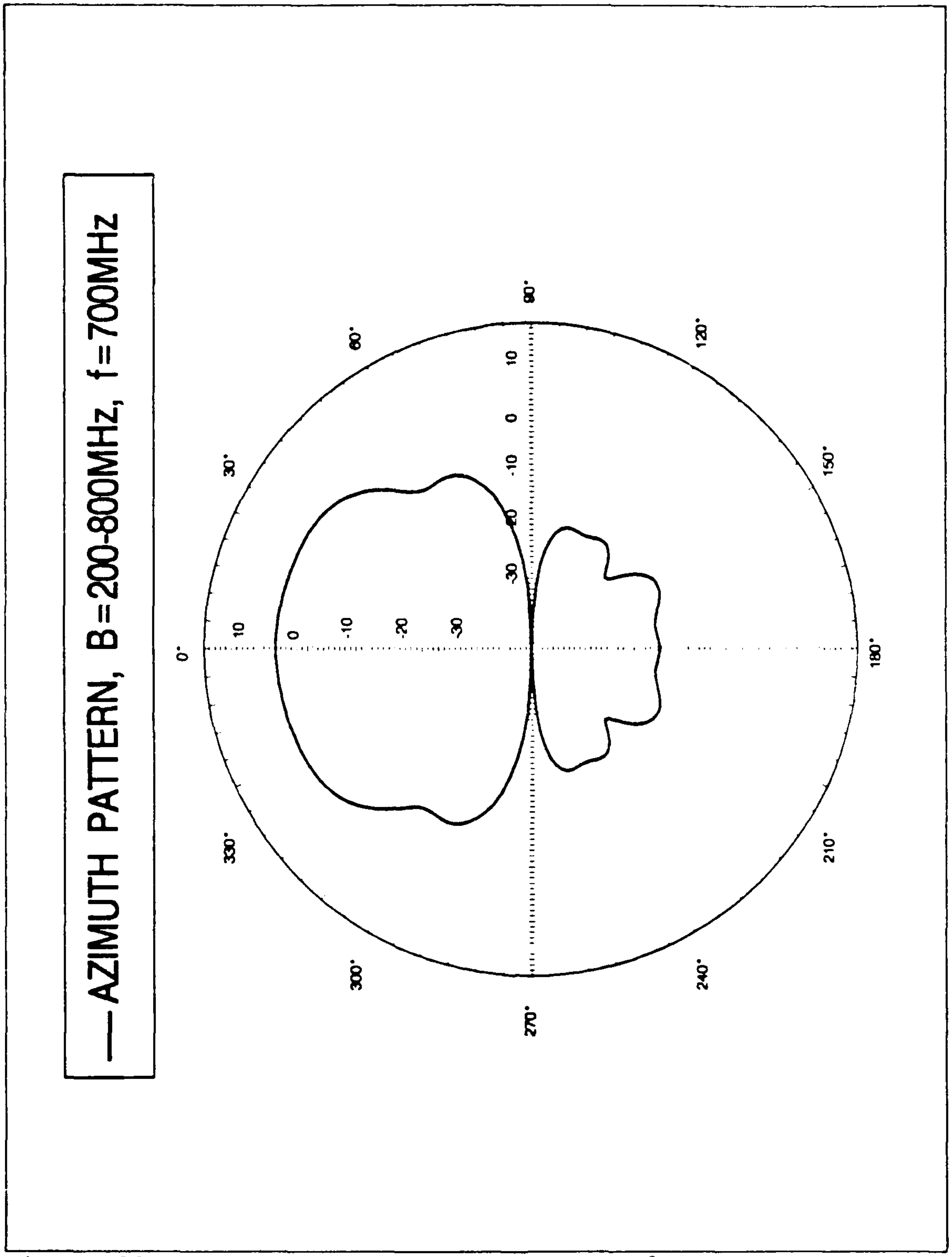

Figure 39. Azimuth Radiation Pattern (θ=90°), f=700 MHz; 200-800 MHz LPDA.

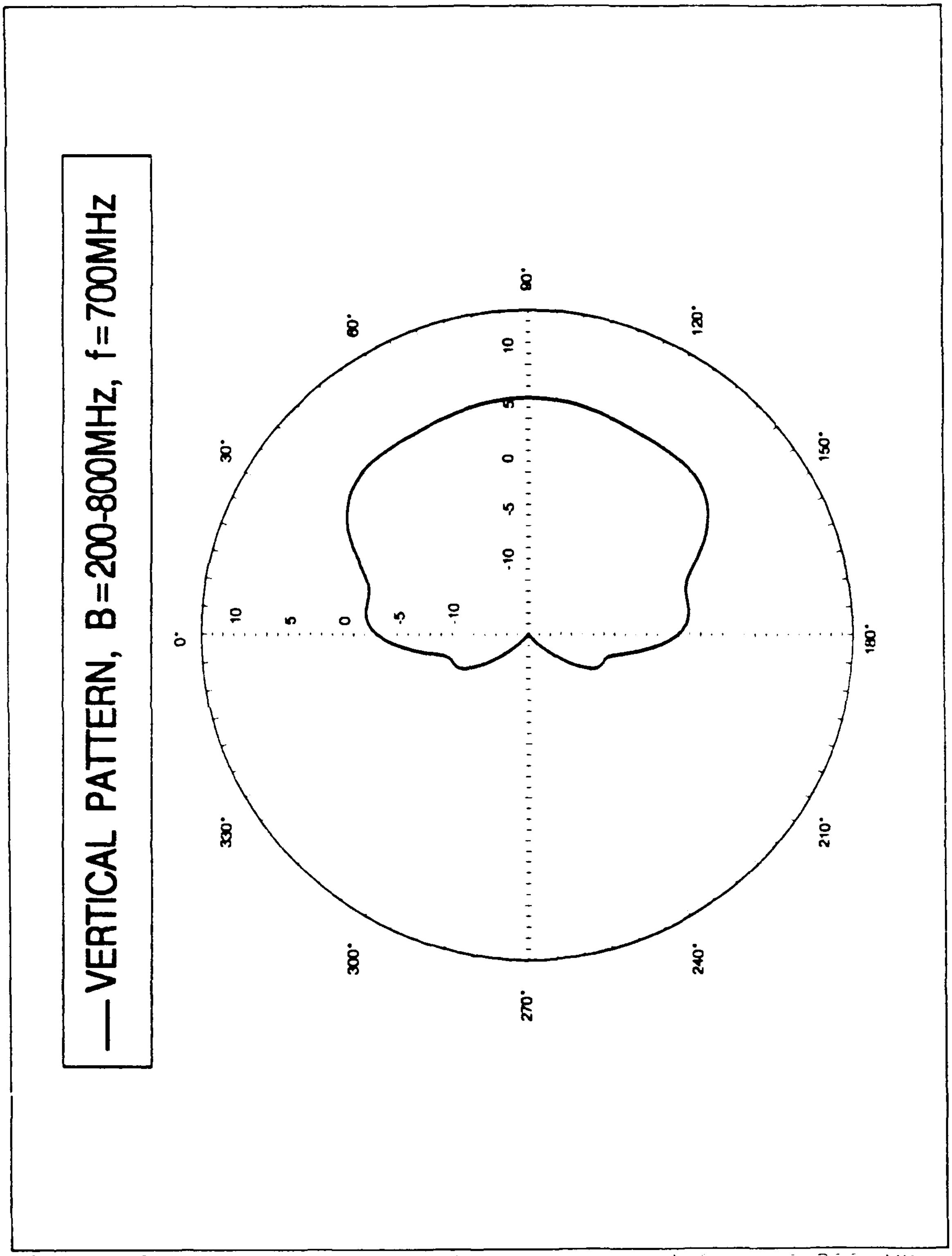

Figure 40. Elevation Radiation Pattern (ϕ=[illegible]), f=700 MHz; 200-800 MHz LPDA.

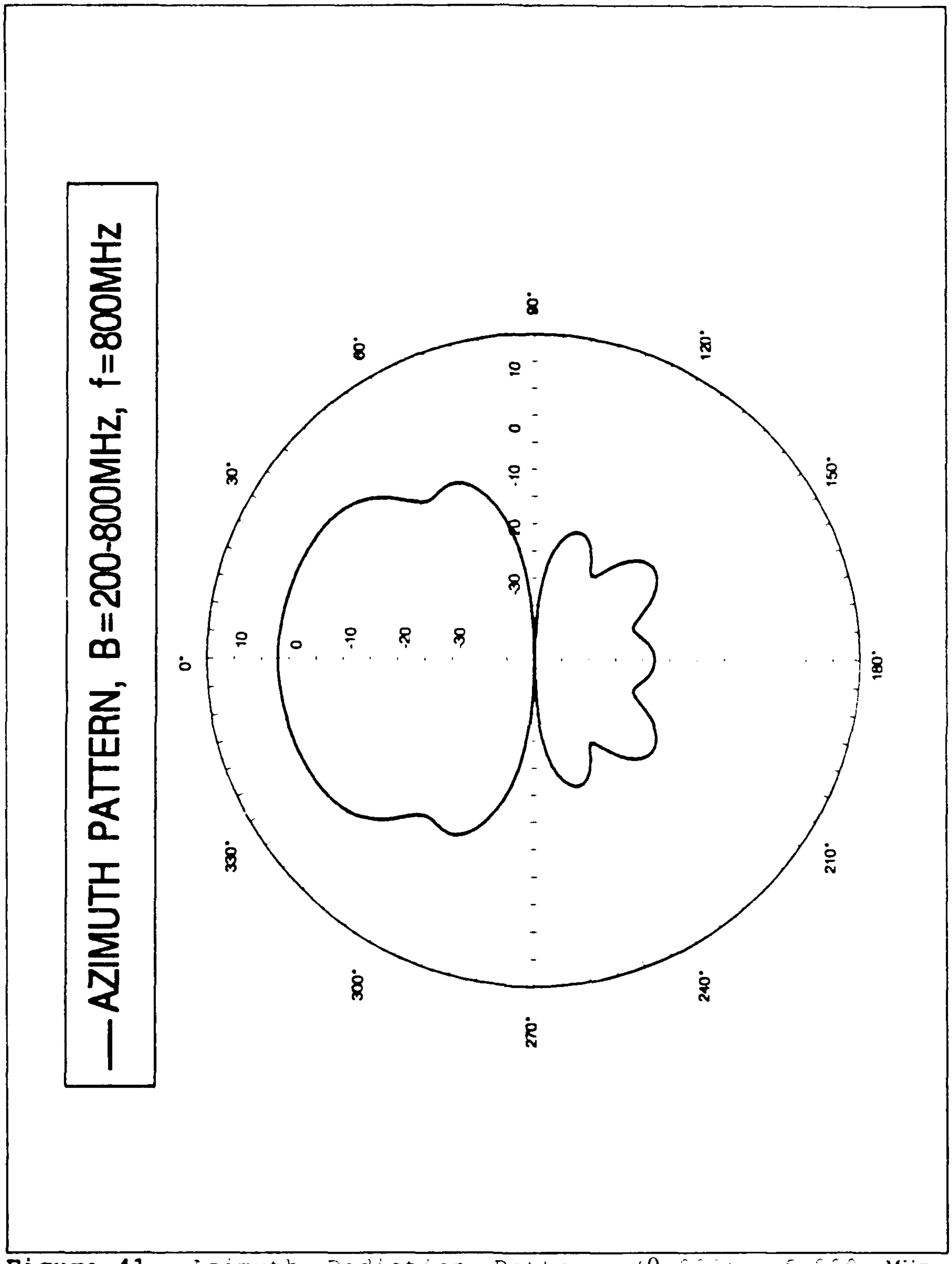

Figure 41. Azimuth Radiation Pattern ($\theta=90°$), f=800 MHz; 200-800 MHz LPDA.

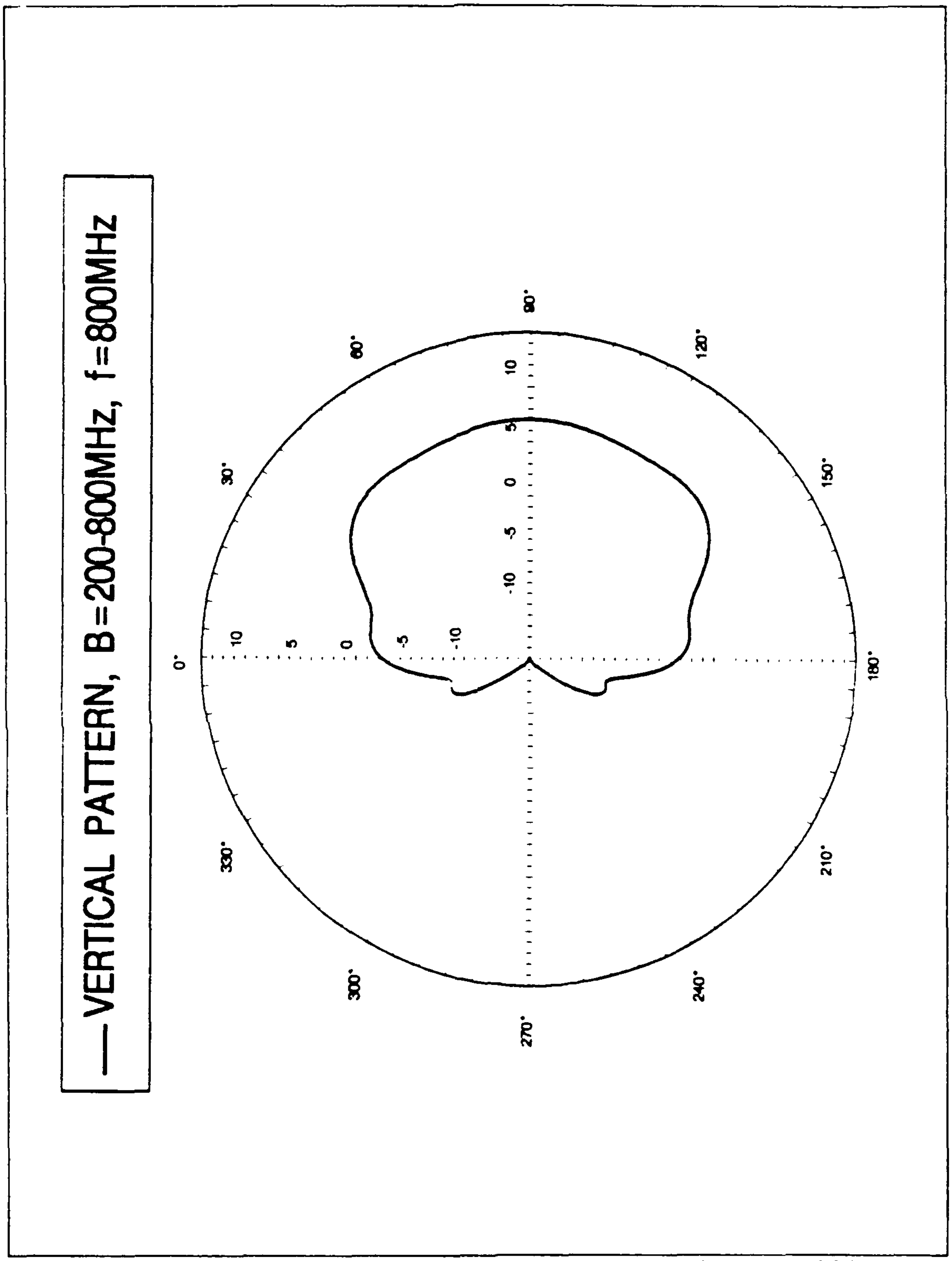

Figure 42. Elevation Radiation Pattern (Φ=0°), f=800 MHz; 200-800 MHz LPDA.

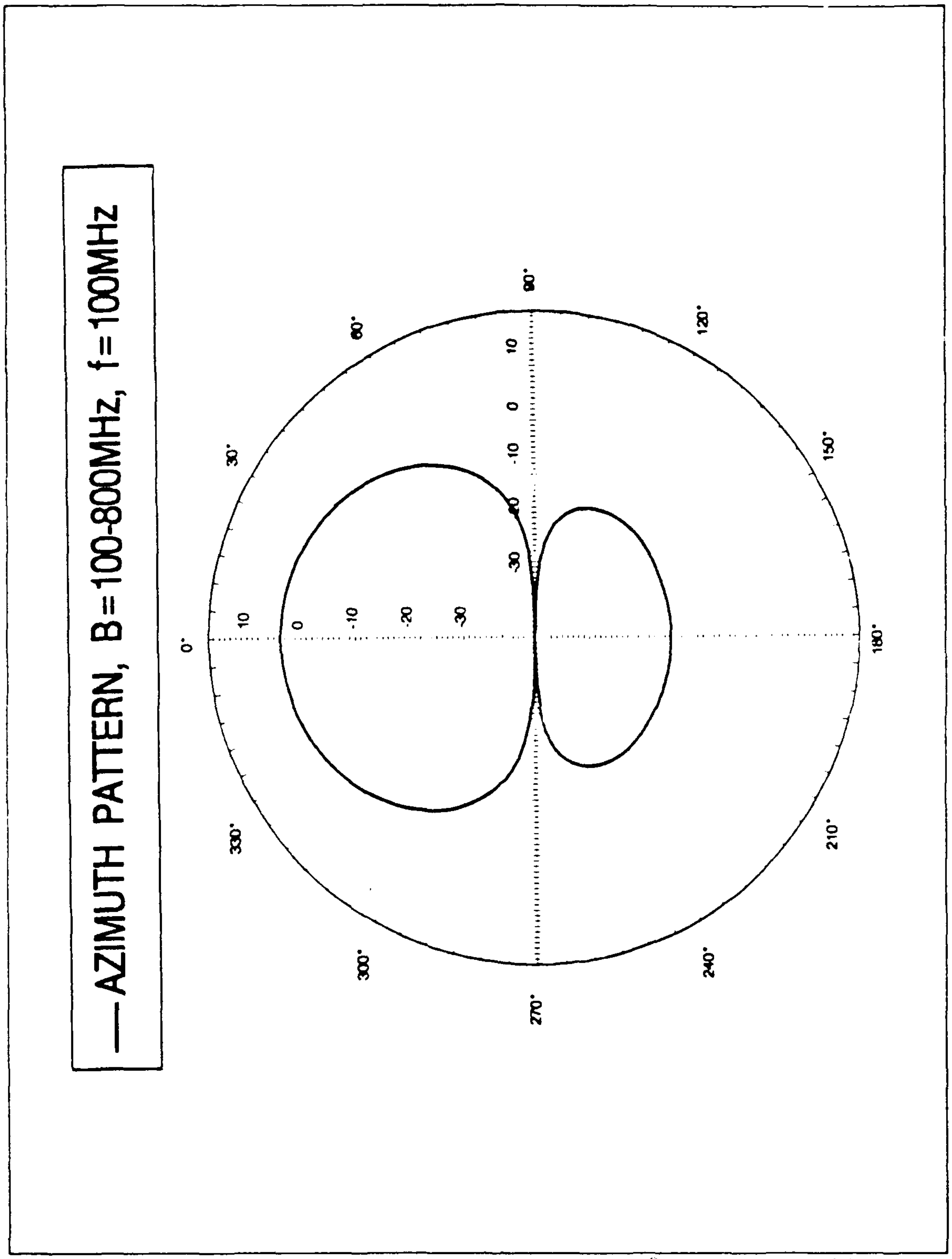

Figure 43. Azimuth Radiation Pattern (θ=90°), f=100 MHz; 100-800 MHz LPDA.

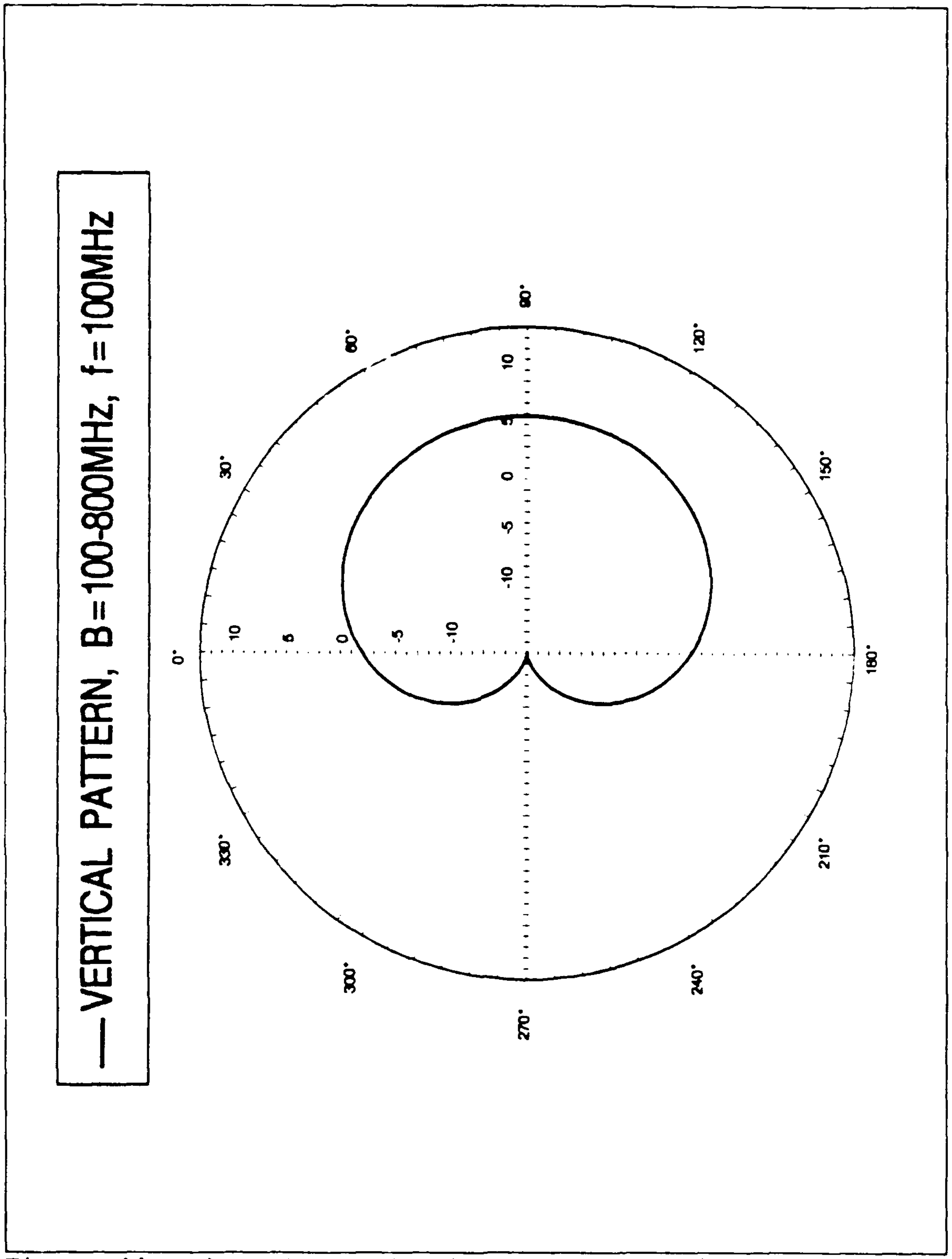

Figure 44. Elevation Radiation Pattern (Φ=0°), f=100 MHz; 100-800 MHz LPDA.

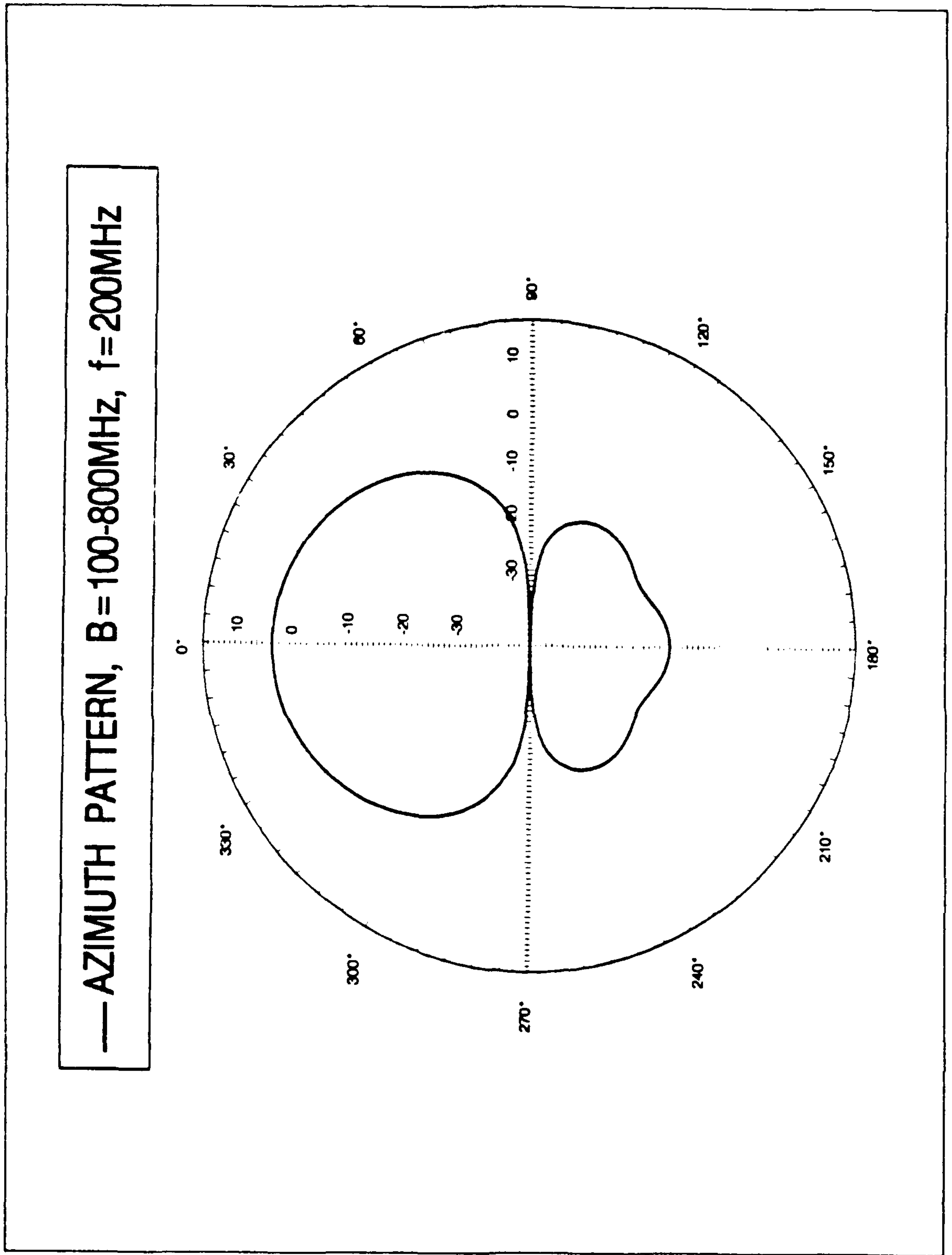

Figure 45. Azimuth Radiation Pattern ($\theta=90°$), f=200 MHz; 100-800 MHz LPDA.

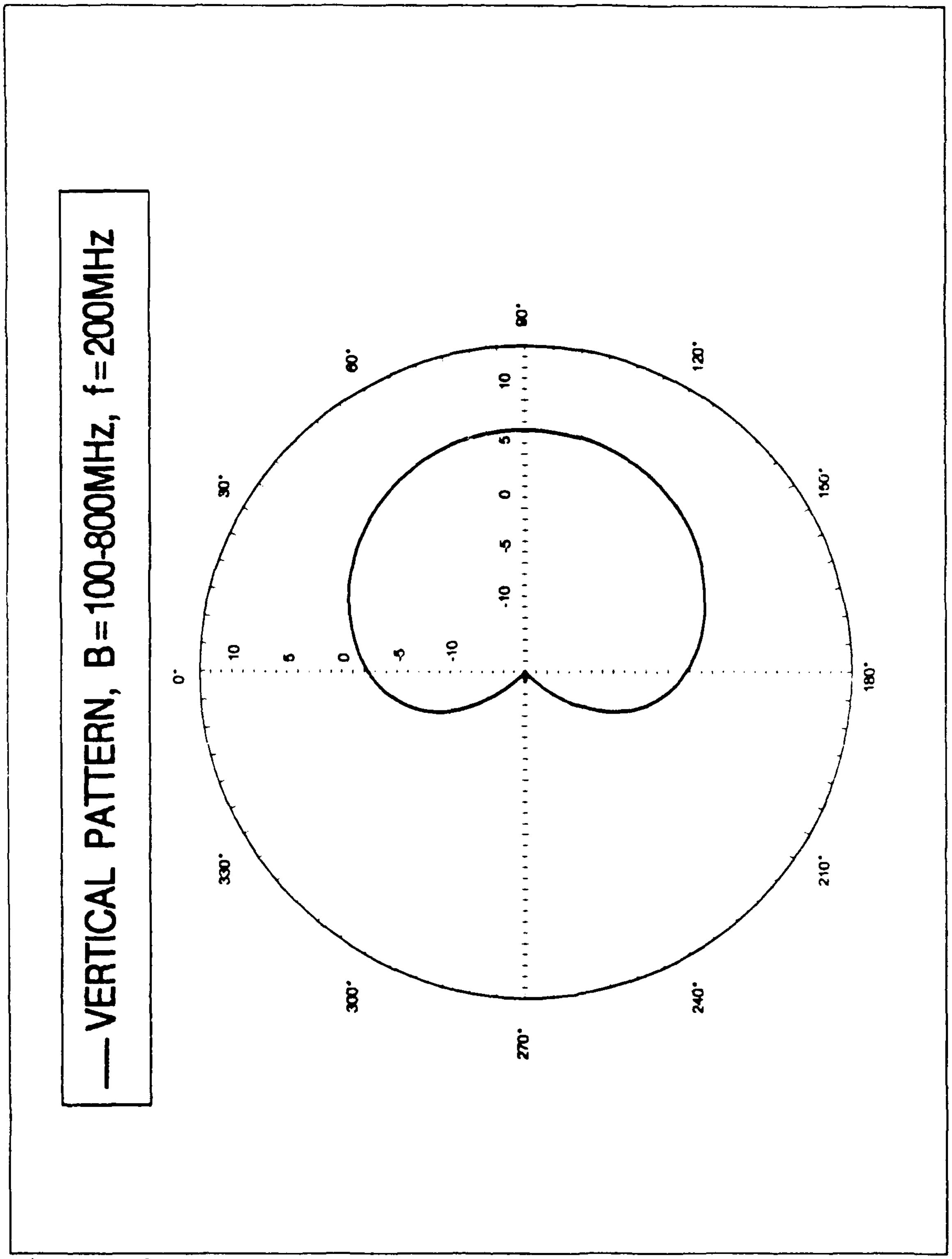

Figure 46. Elevation Radiation Pattern (ϕ=[illegible]), f=200 MHz; 100-800 MHz LPDA.

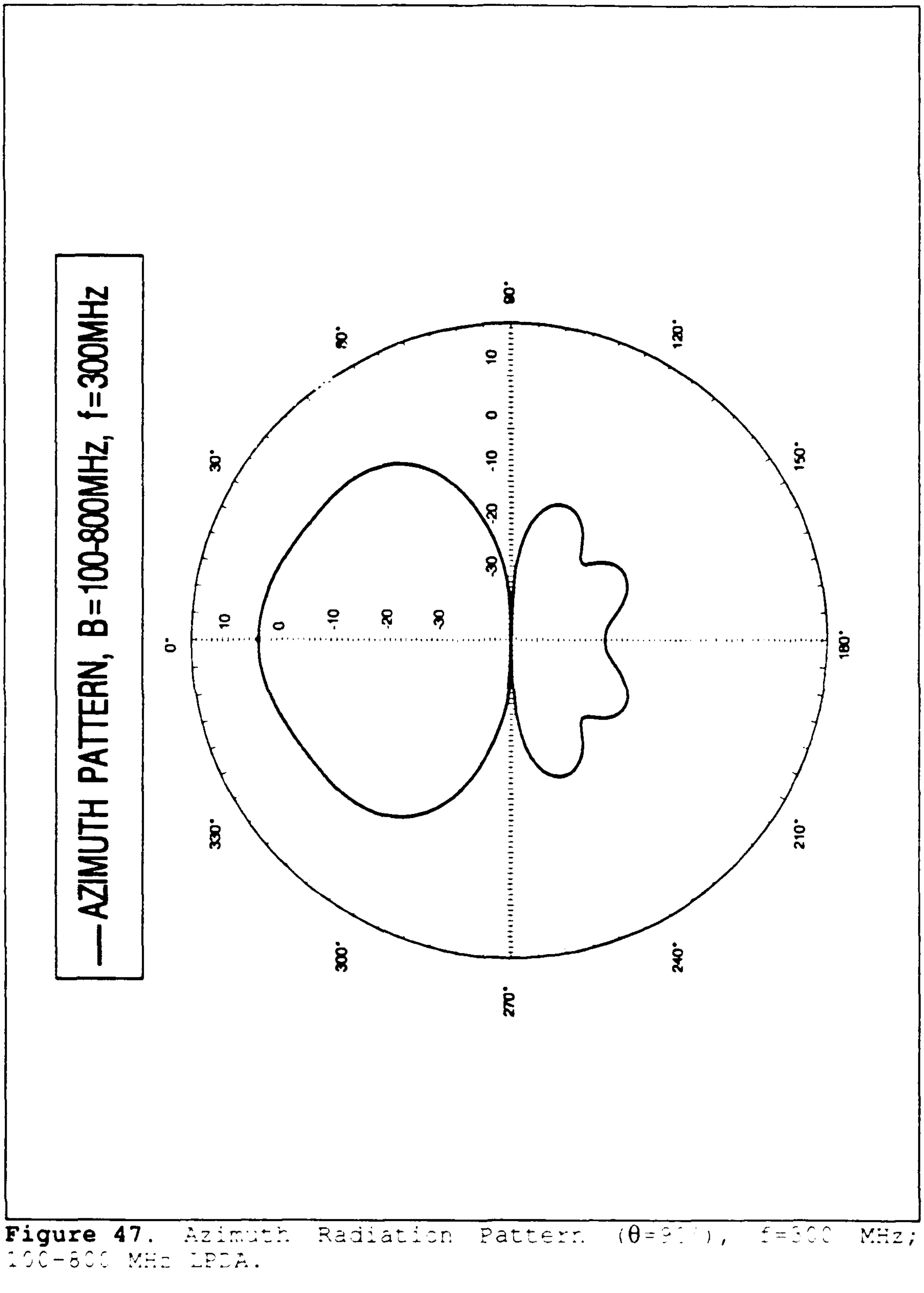

Figure 47. Azimuth Radiation Pattern ($\theta=90°$), f=300 MHz; 100-800 MHz LPDA.

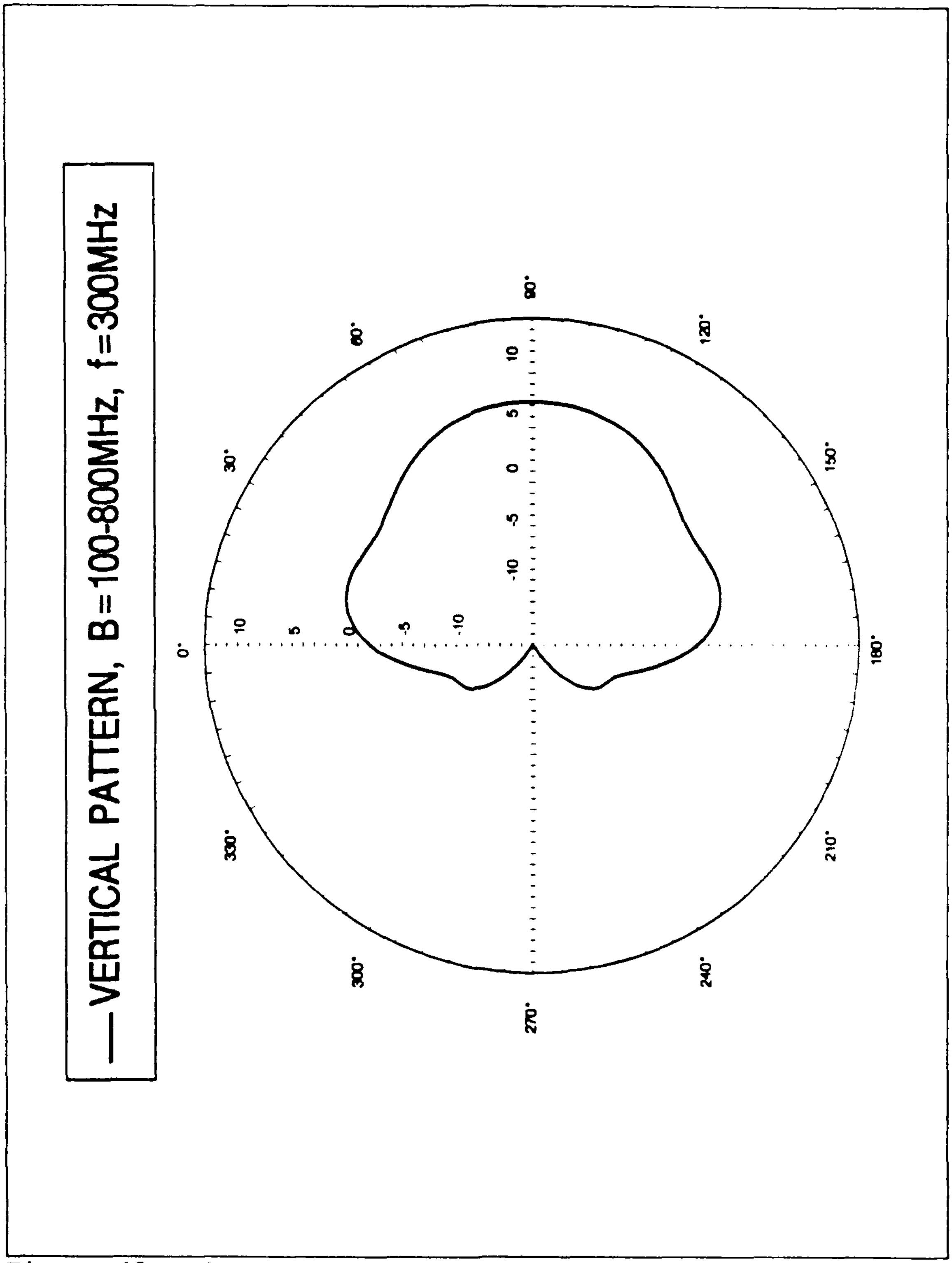

Figure 48. Elevation Radiation Pattern (Φ=0°), f=300 MHz; 100-800 MHz LPDA.

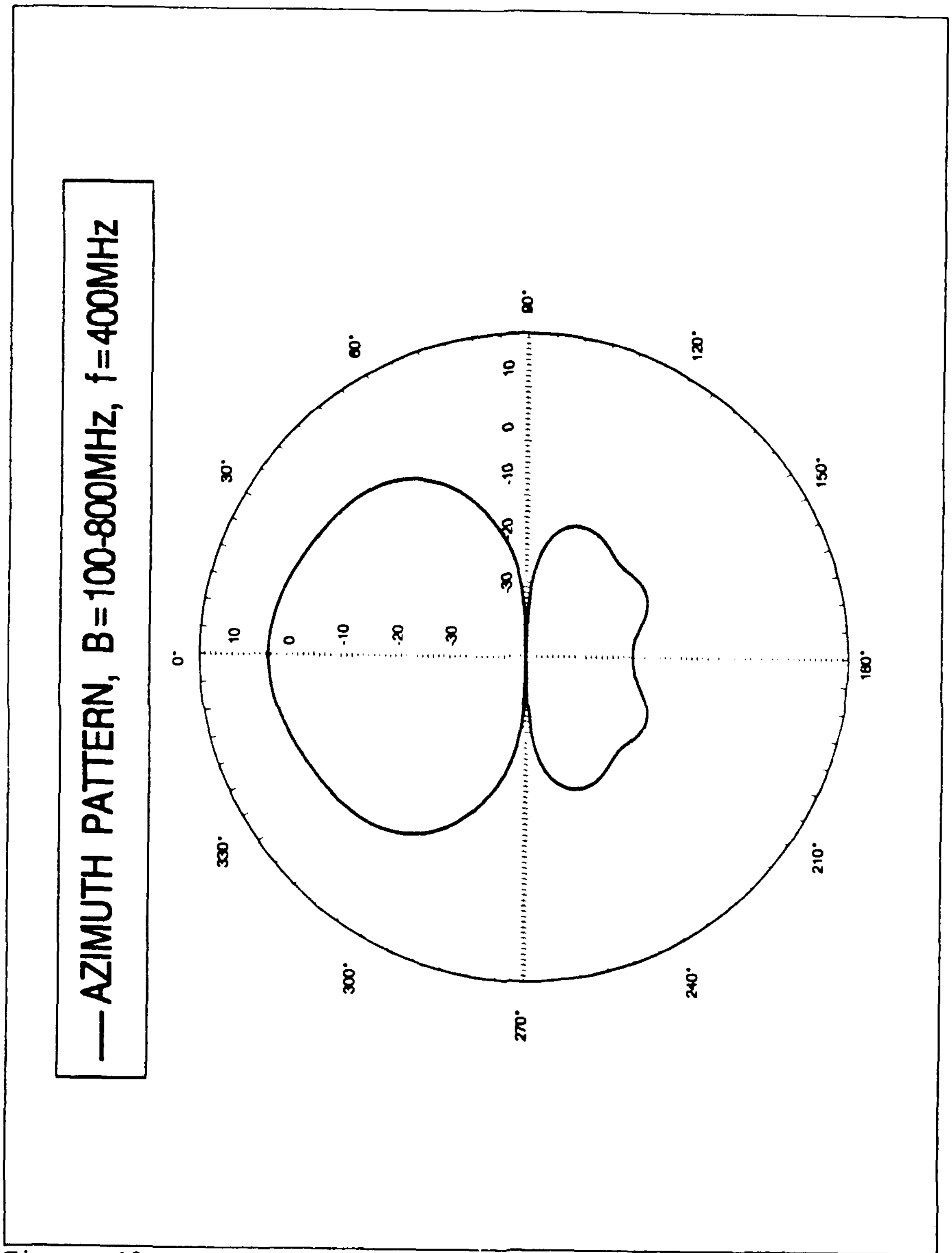

Figure 49. Azimuth Radiation Pattern (θ=90°), f=400 MHz; 100-800 MHz LPDA.

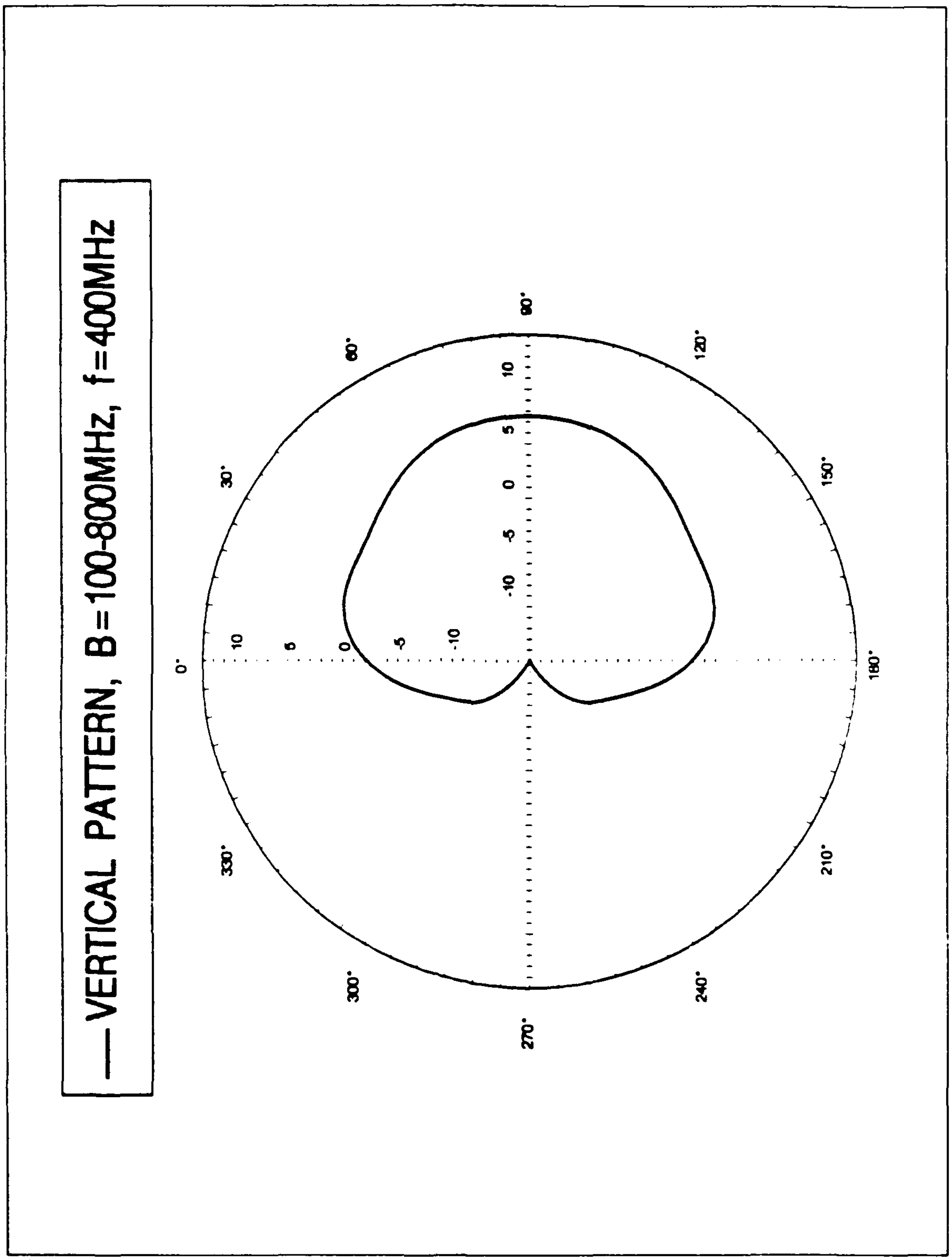

Figure 50. Elevation Radiation Pattern (Φ=[illegible]), f=400 MHz; 100-800 MHz LPDA.

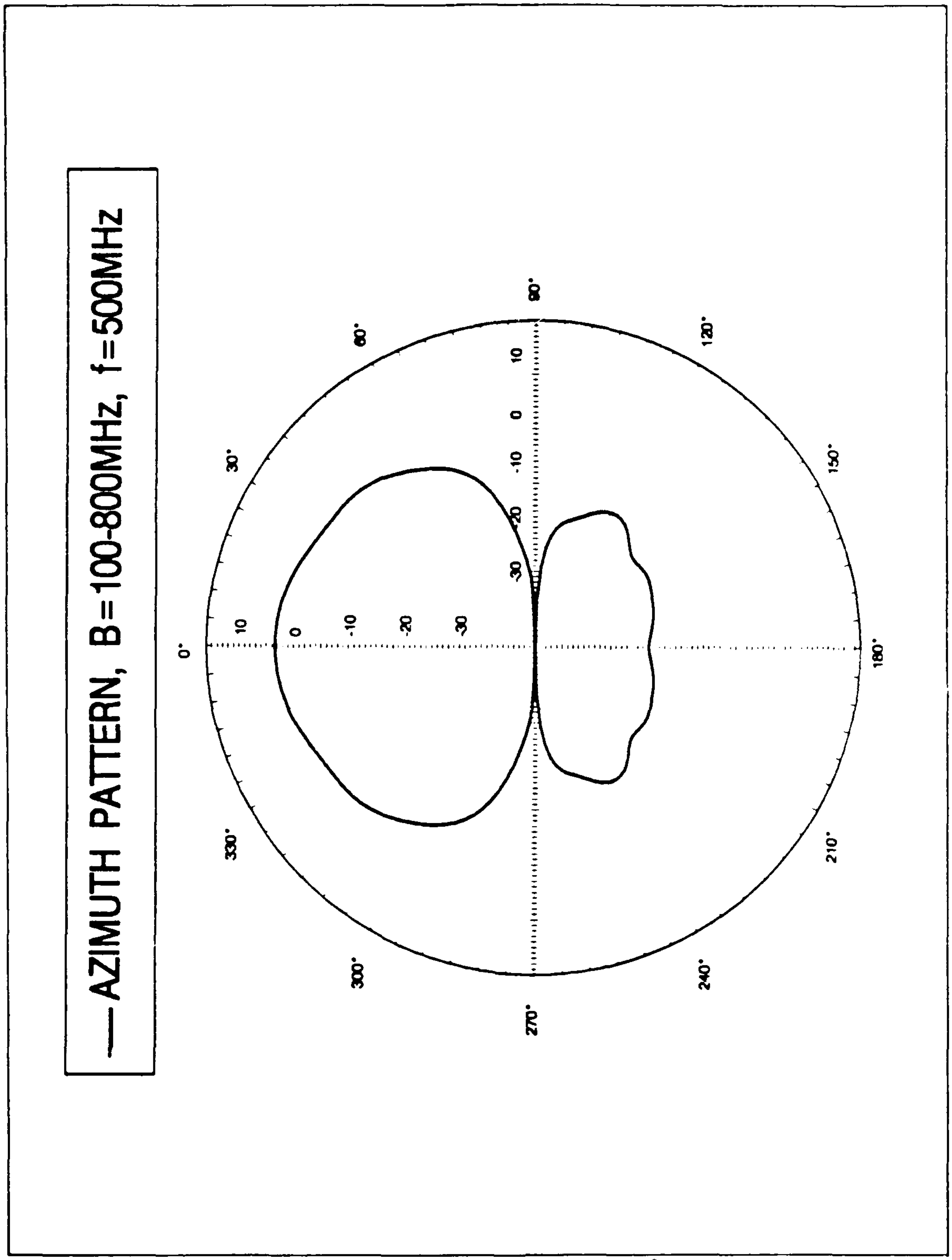

Figure 51. Azimuth Radiation Pattern (θ=[illegible]), f=500 MHz; 100-800 MHz LPDA.

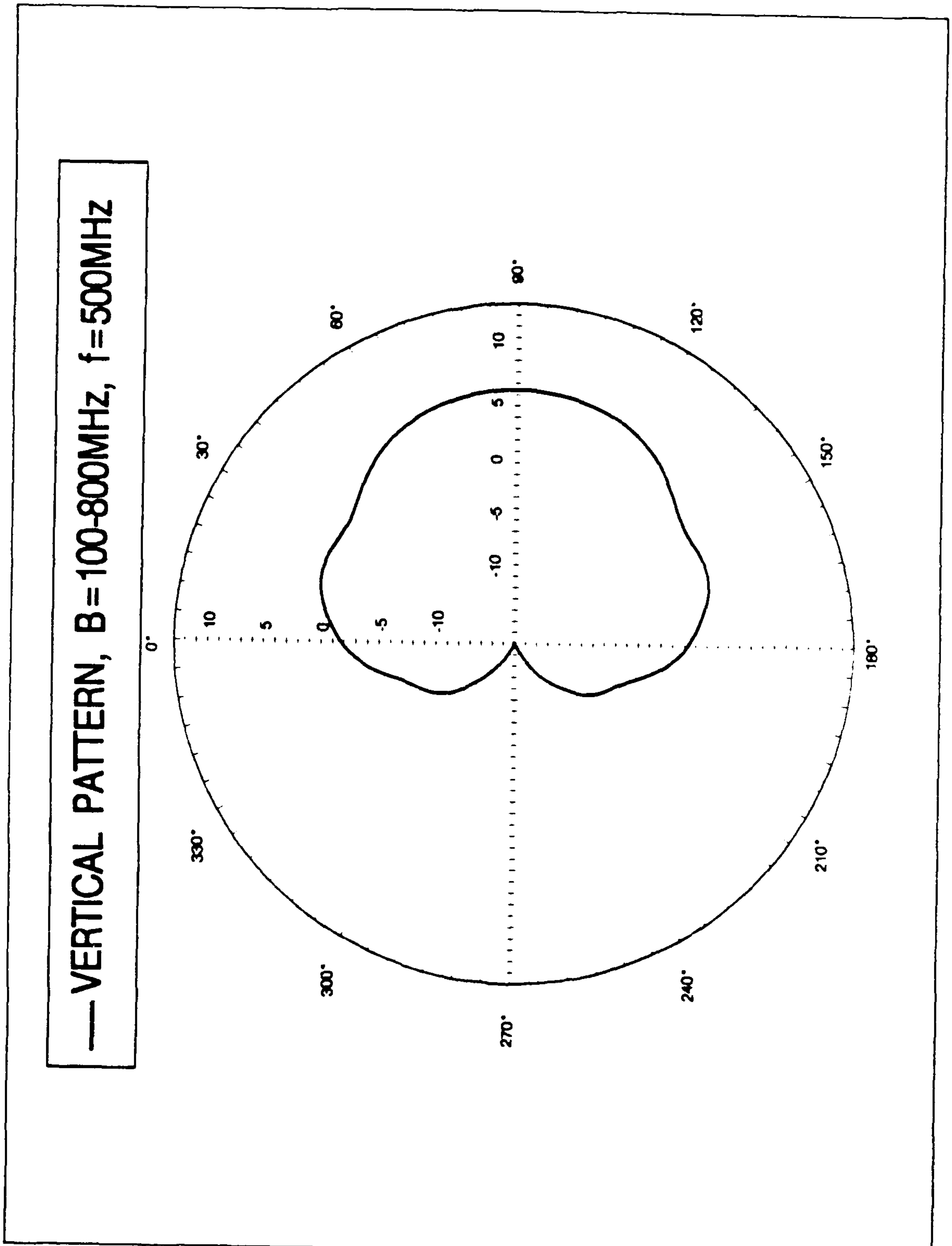

Figure 52. Elevation Radiation Pattern (ϕ=0°), f=500 MHz; 100-800 MHz LPDA.

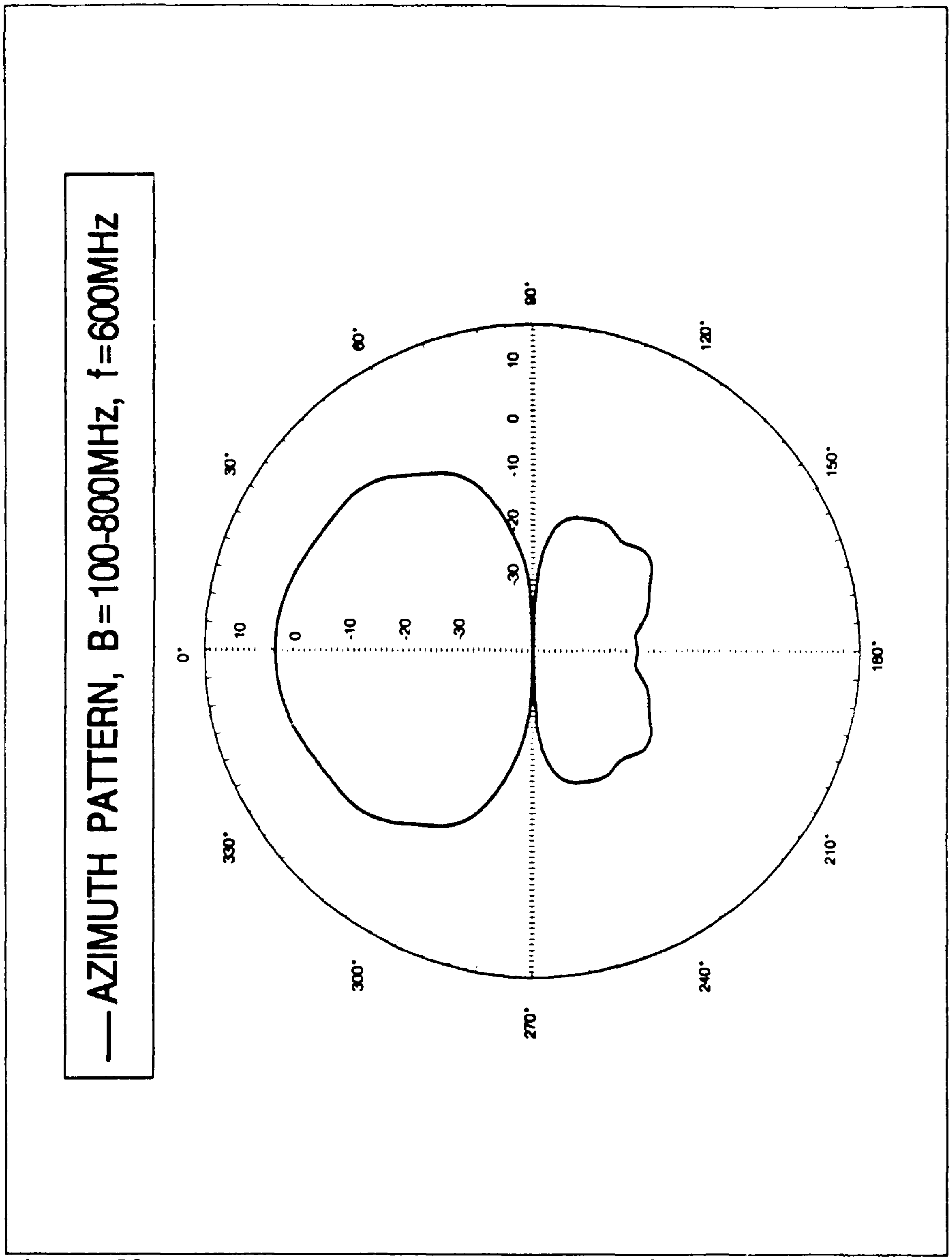

Figure 53. Azimuth Radiation Pattern ($\theta=90°$), f=600 MHz; 100-800 MHz LPDA.

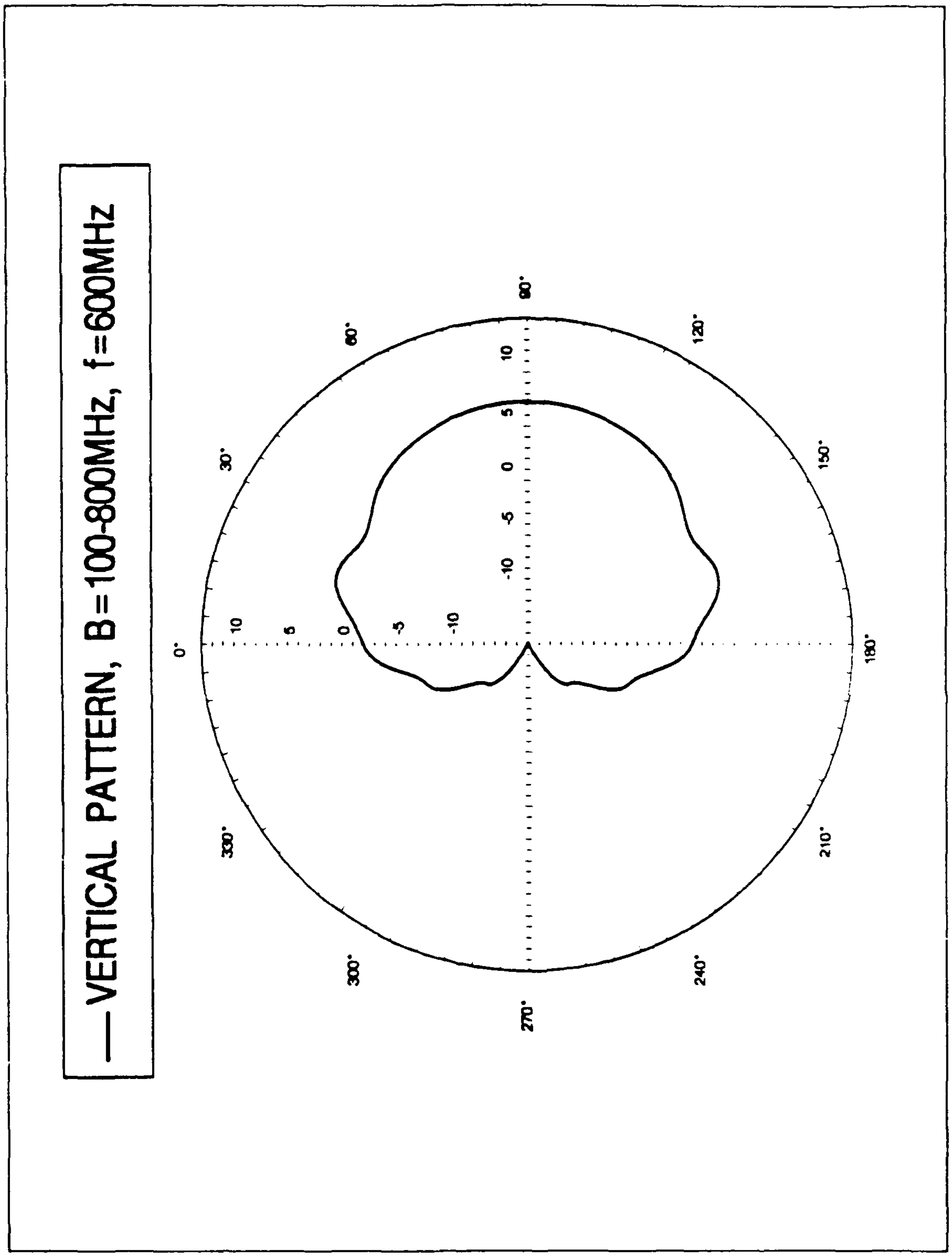

Figure 54. Elevation Radiation Pattern (Φ=0°), f=600 MHz; 100-800 MHz LPDA.

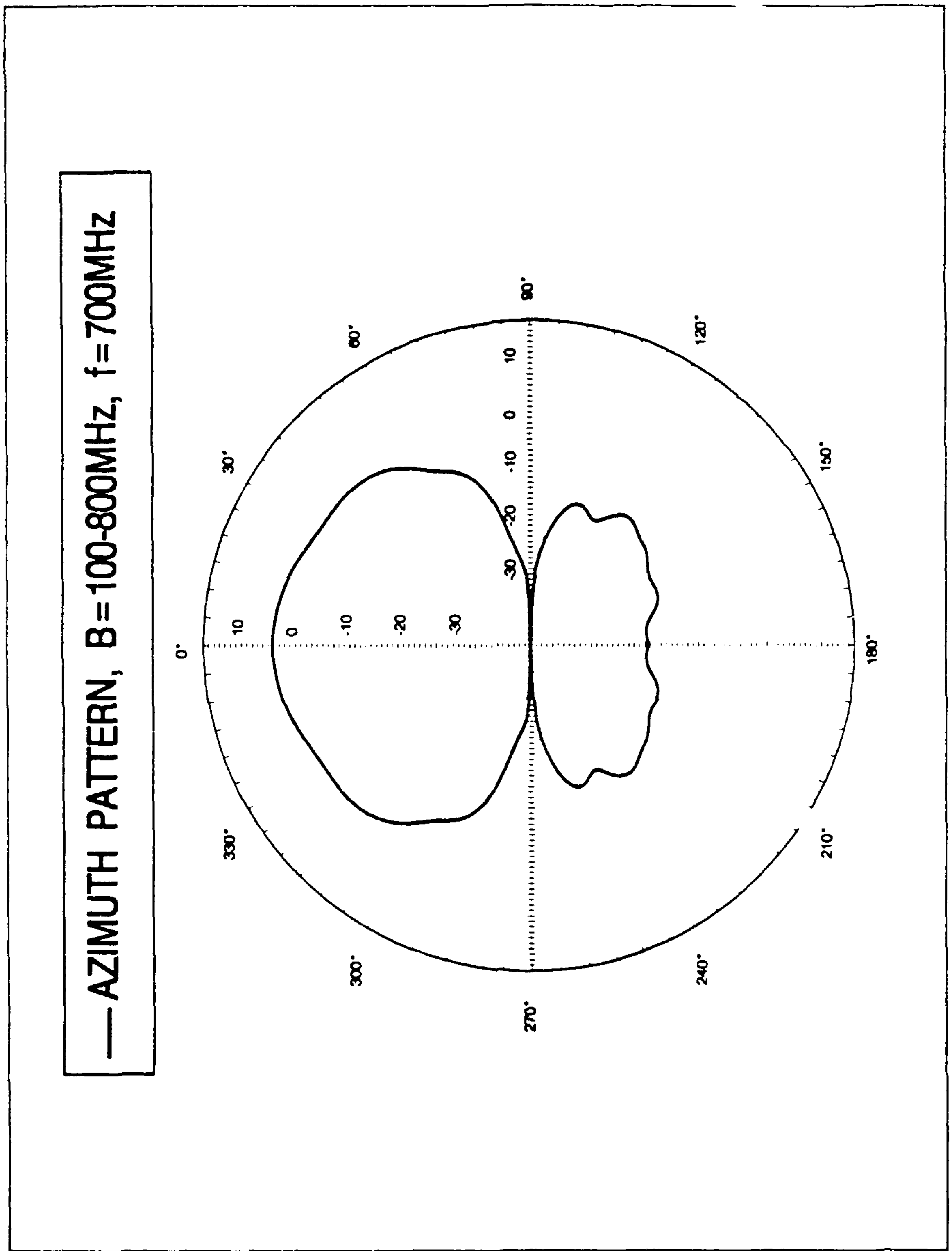

Figure 55. Azimuth Radiation Pattern (θ=90°), f=700 MHz; 100-800 MHz LPDA.

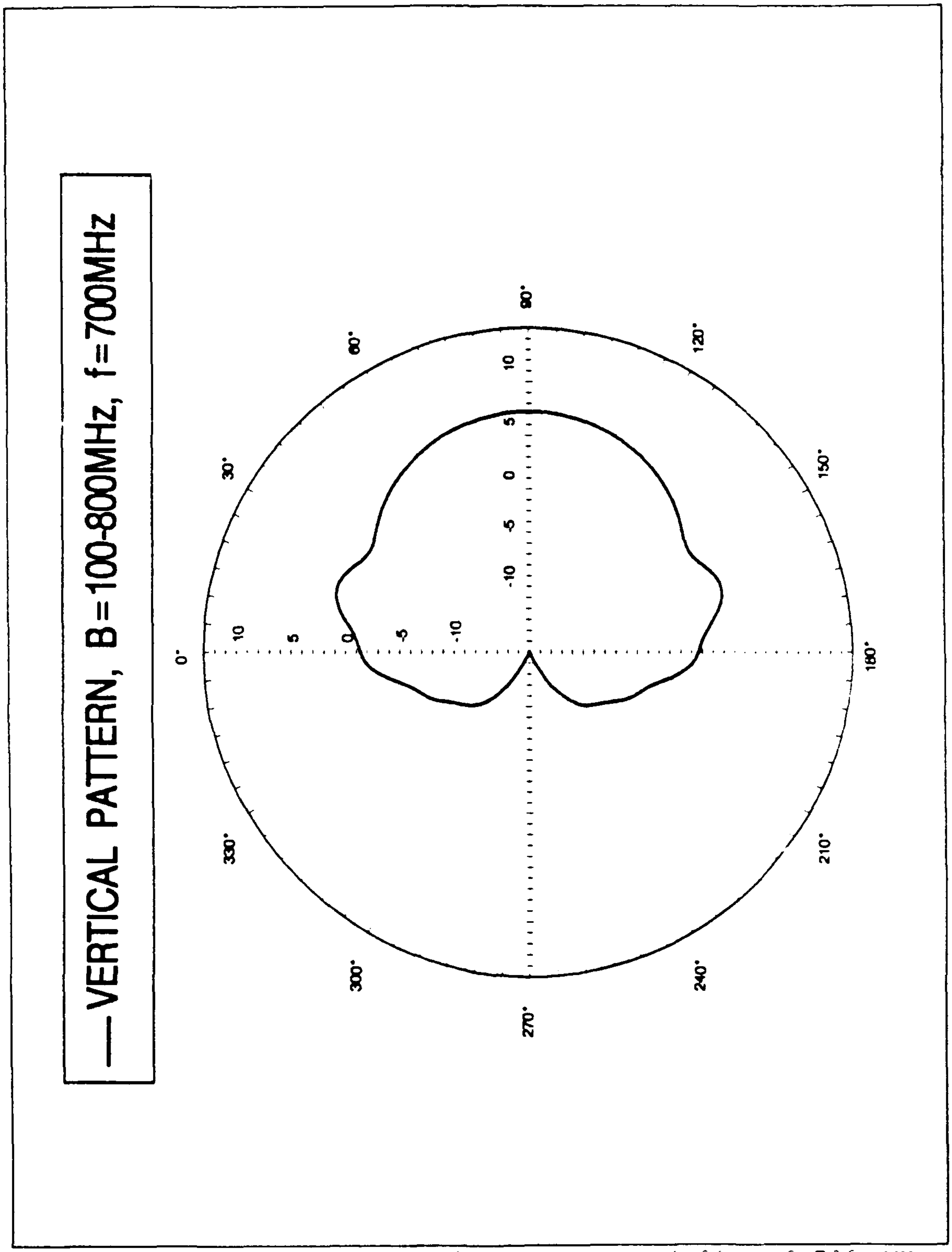

Figure 56. Elevation Radiation Pattern (ϕ=0°), f=700 MHz; 100-800 MHz LPDA.

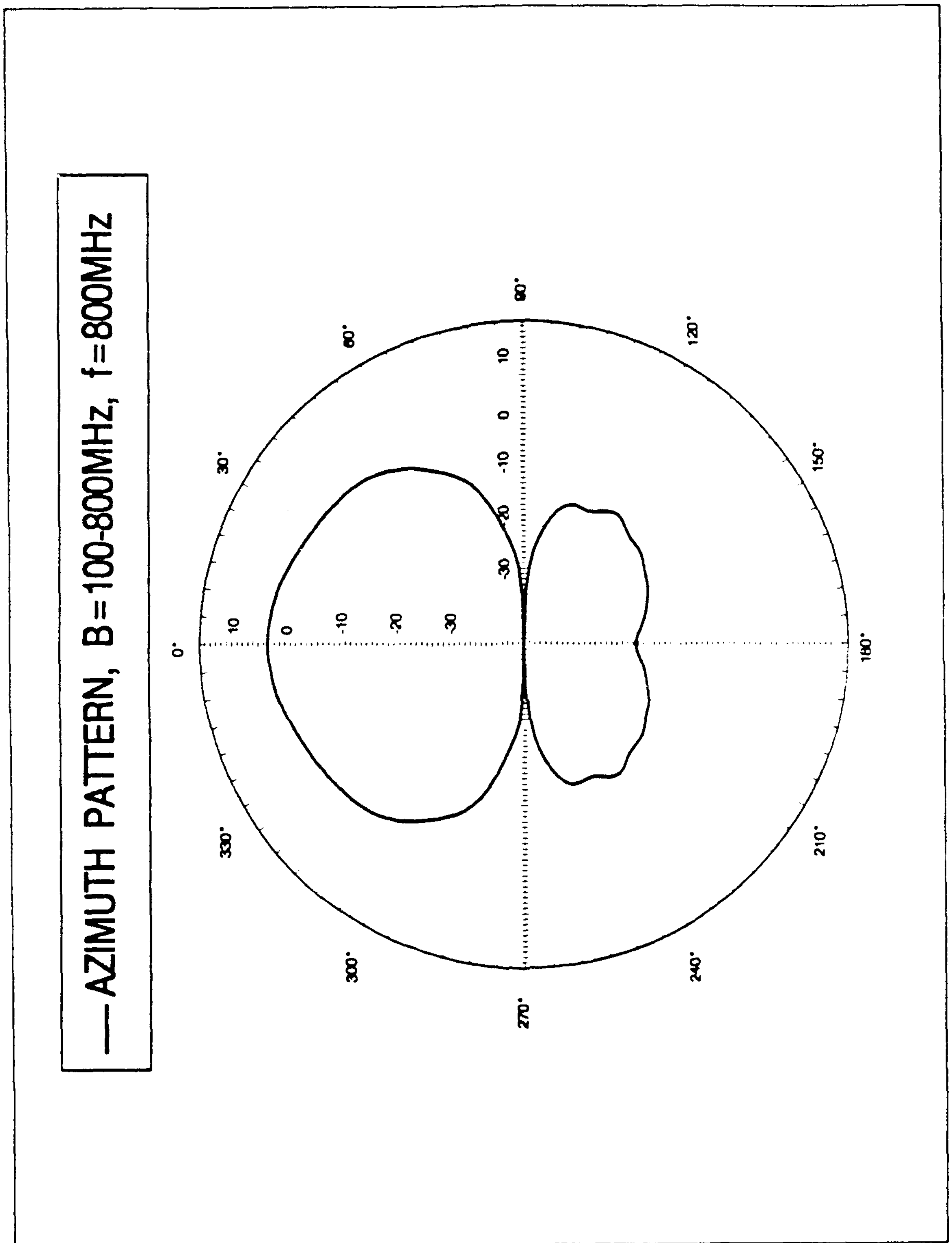

Figure 57. Azimuth Radiation Pattern (θ=90°), f=800 MHz; 100-800 MHz LPDA.

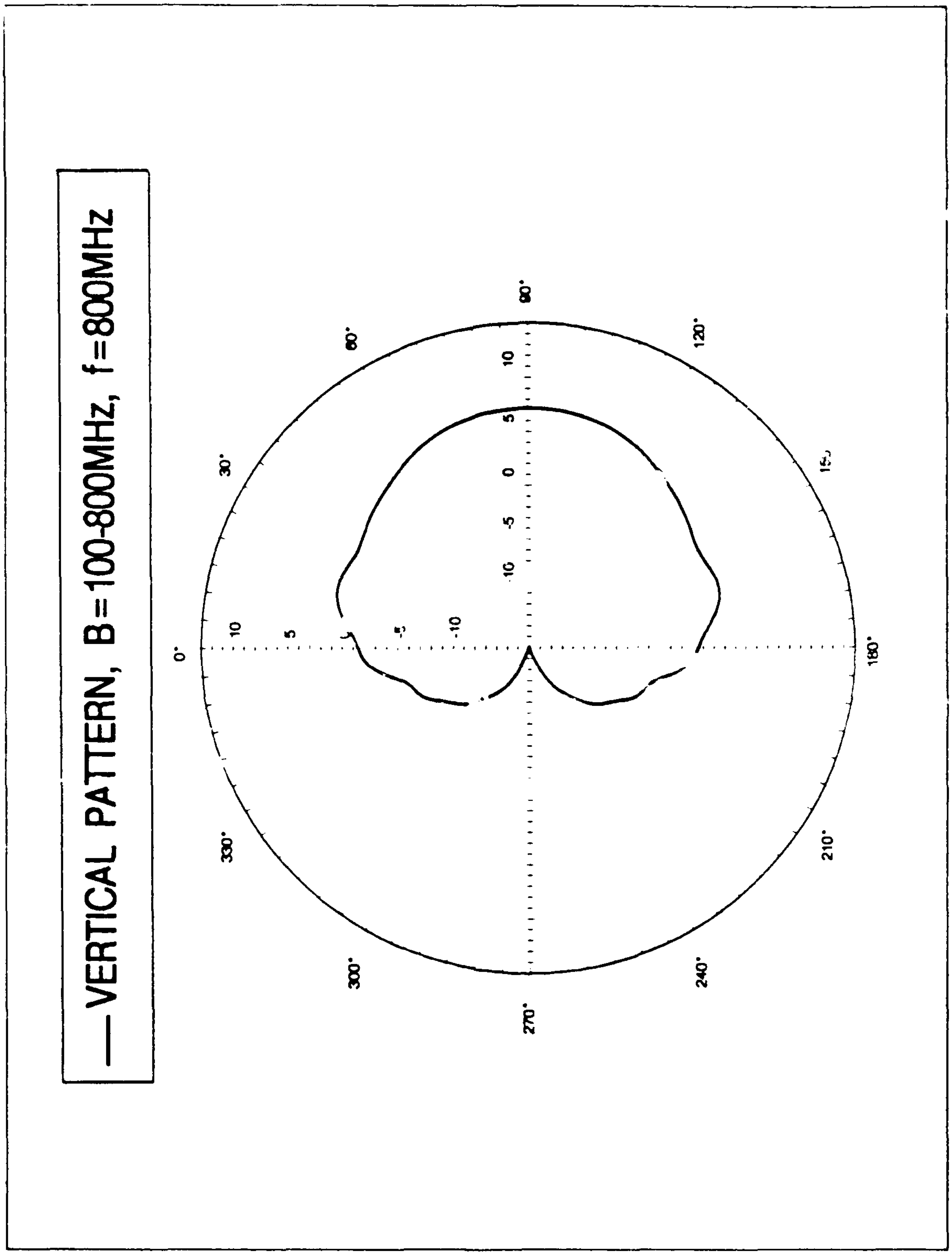

Figure 58. Elevation Radiation Pattern (Φ=0°, f=800 MHz; 100-800 MHz LPDA.

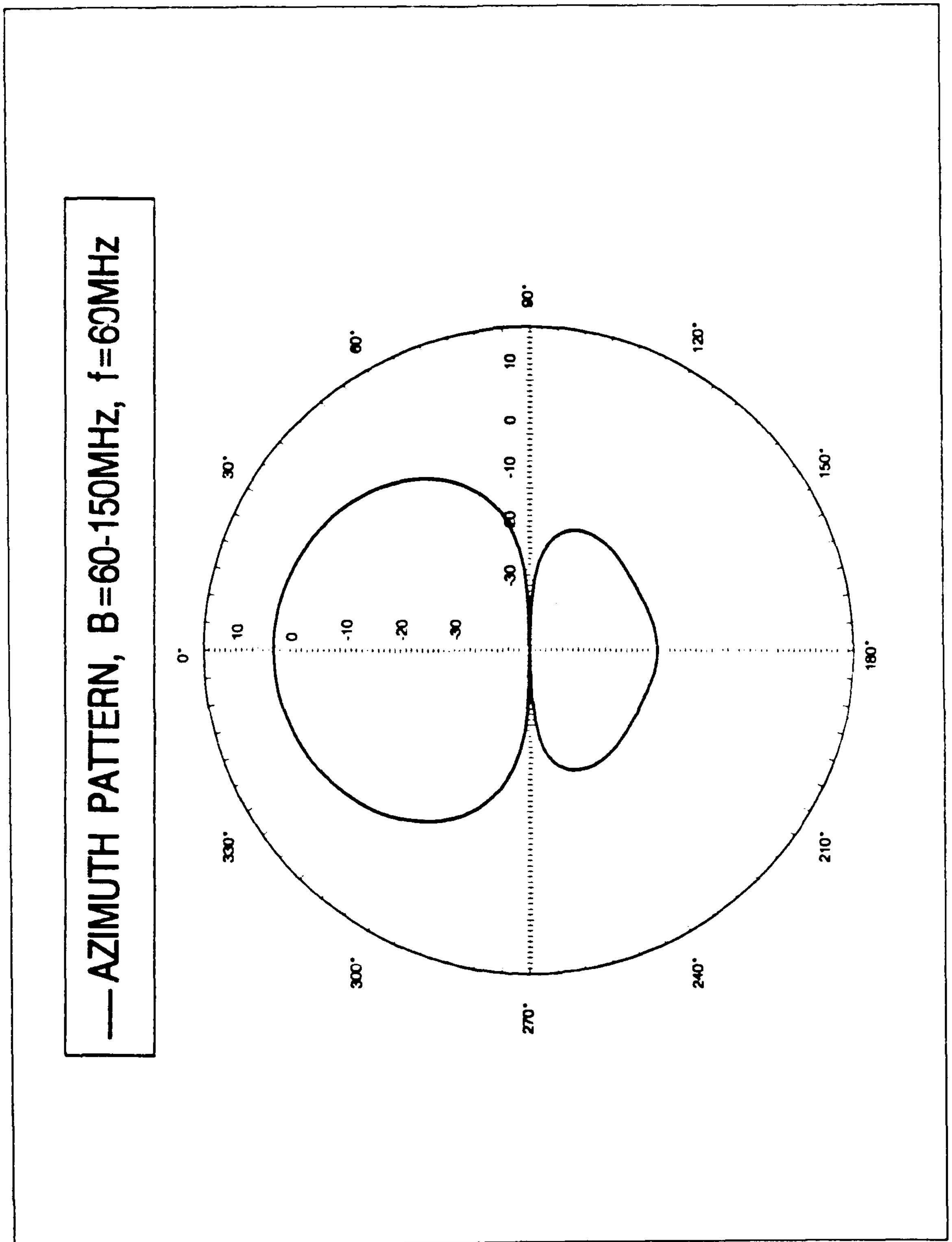

Figure 59. Azimuth Radiation Pattern (θ=90°), f=60 MHz; 60-150 MHz LPDA.

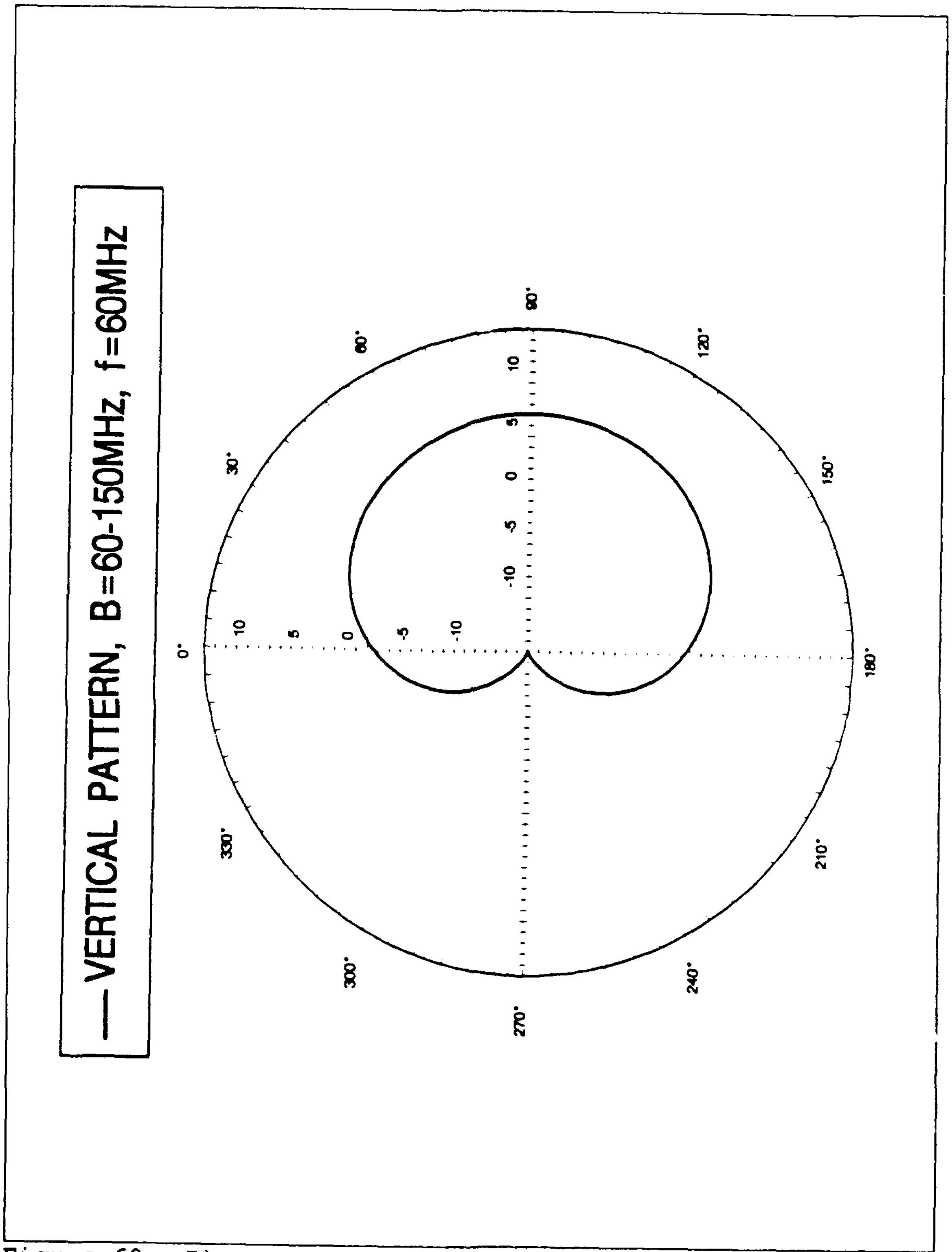

Figure 60. Elevation Radiation Pattern (Φ=0°, f=60 MHz; 60-150 MHz LPDA.

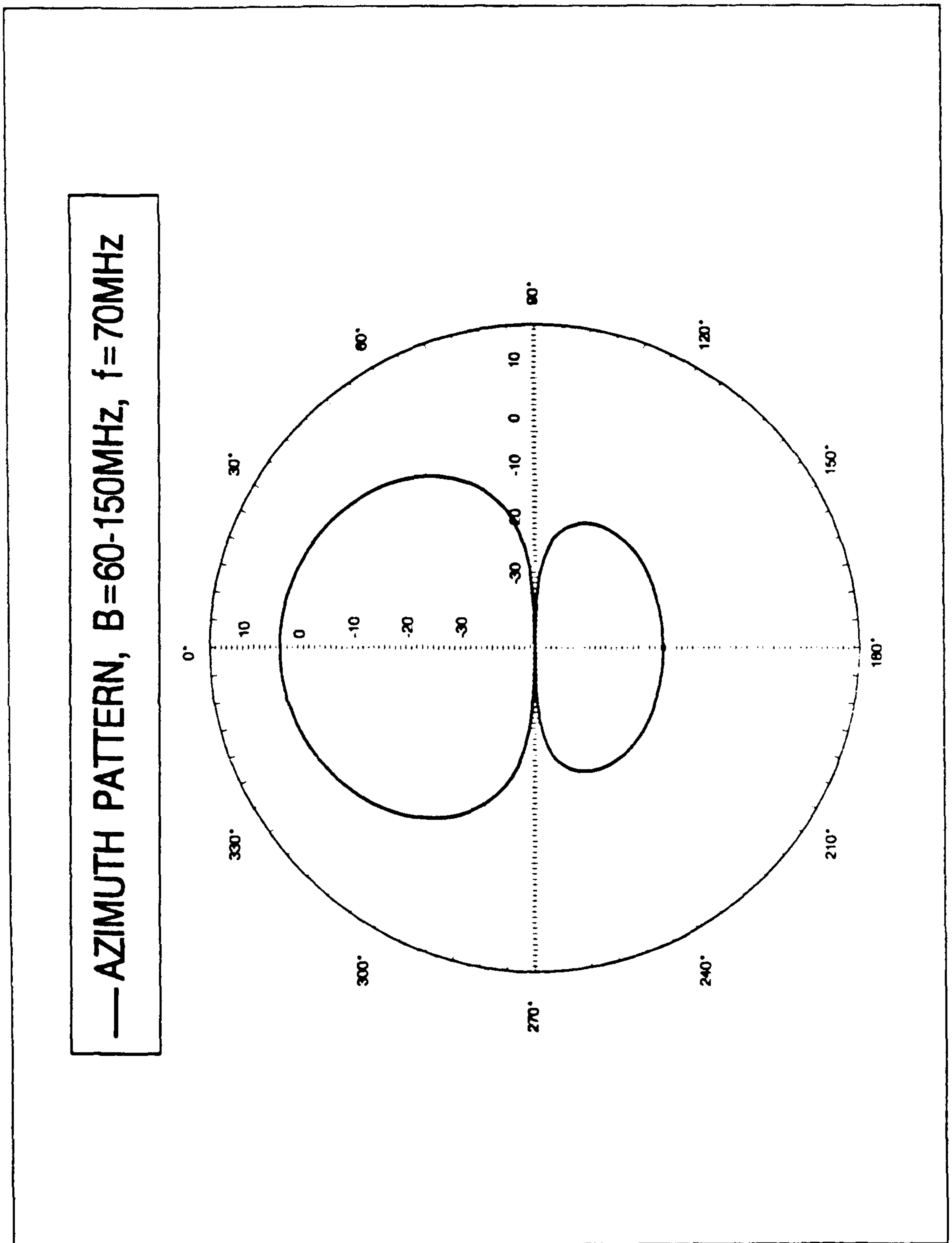

Figure 61. Azimuth Radiation Pattern (θ=90°, f=70 MHz; 60-150 MHz LPDA.

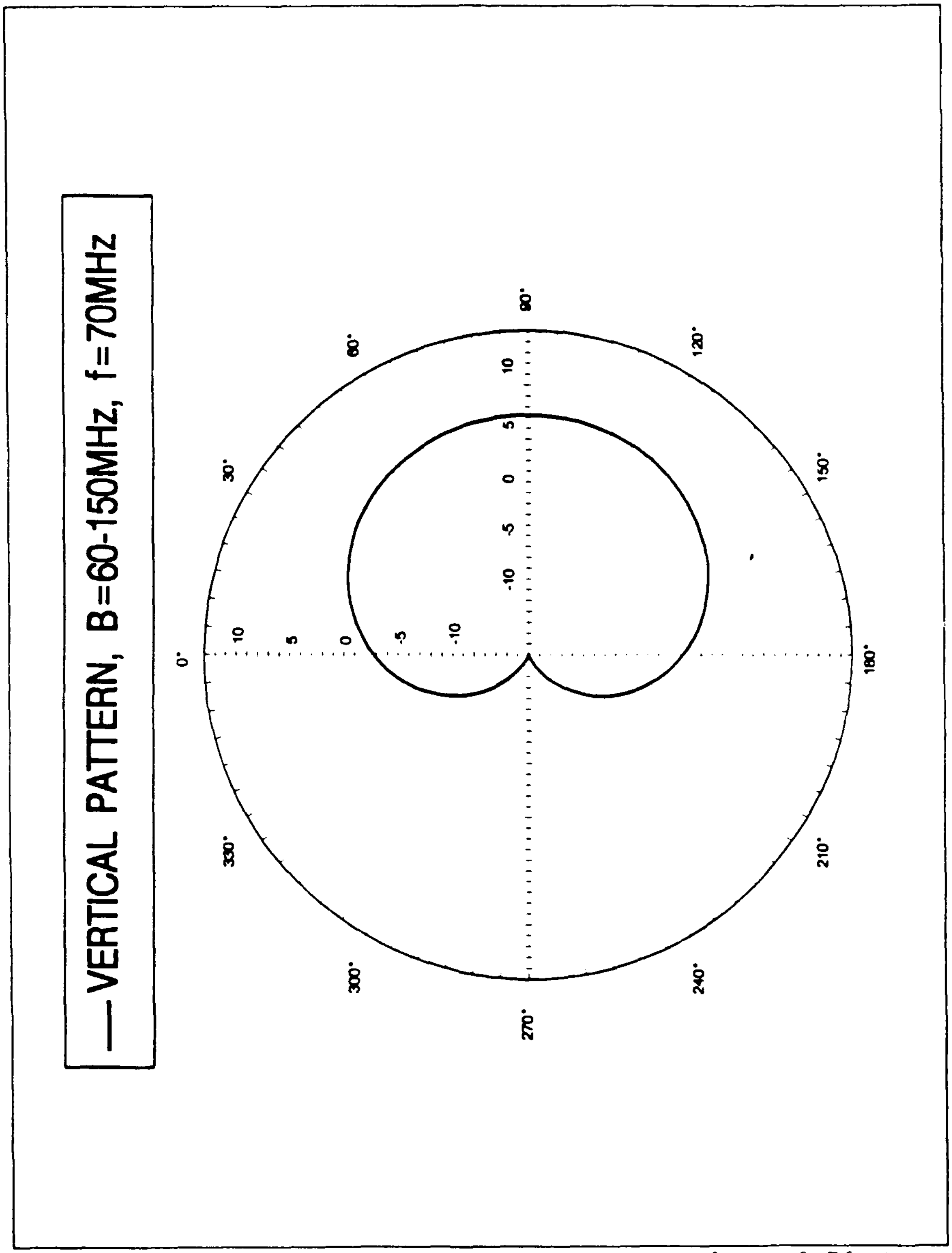

Figure 62. Elevation Radiation Pattern (Φ=0°, f=70 MHz; 60-150 MHz LPDA.

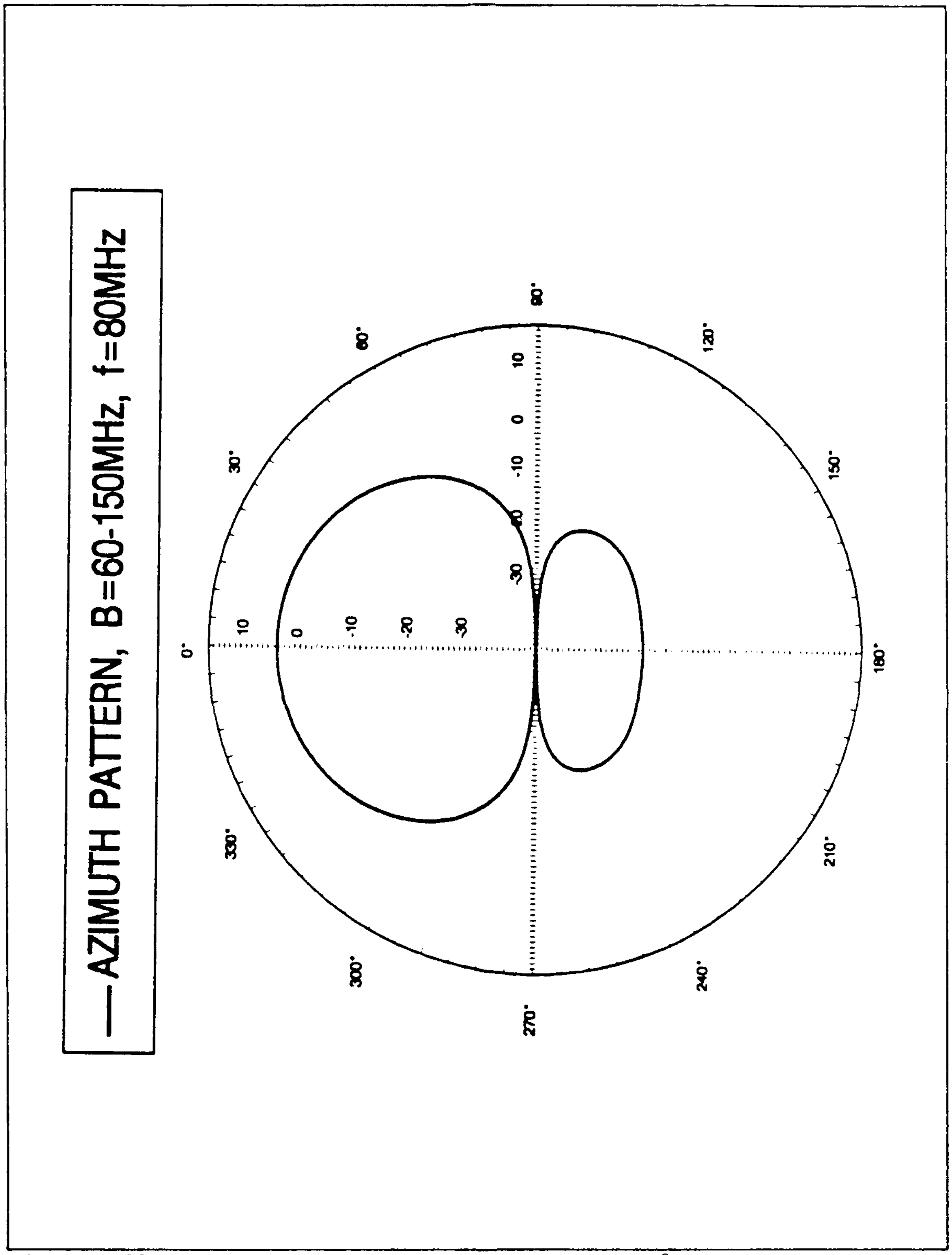

Figure 63. Azimuth Radiation Pattern (θ=90°), f=80 MHz; 60-150 MHz LPDA.

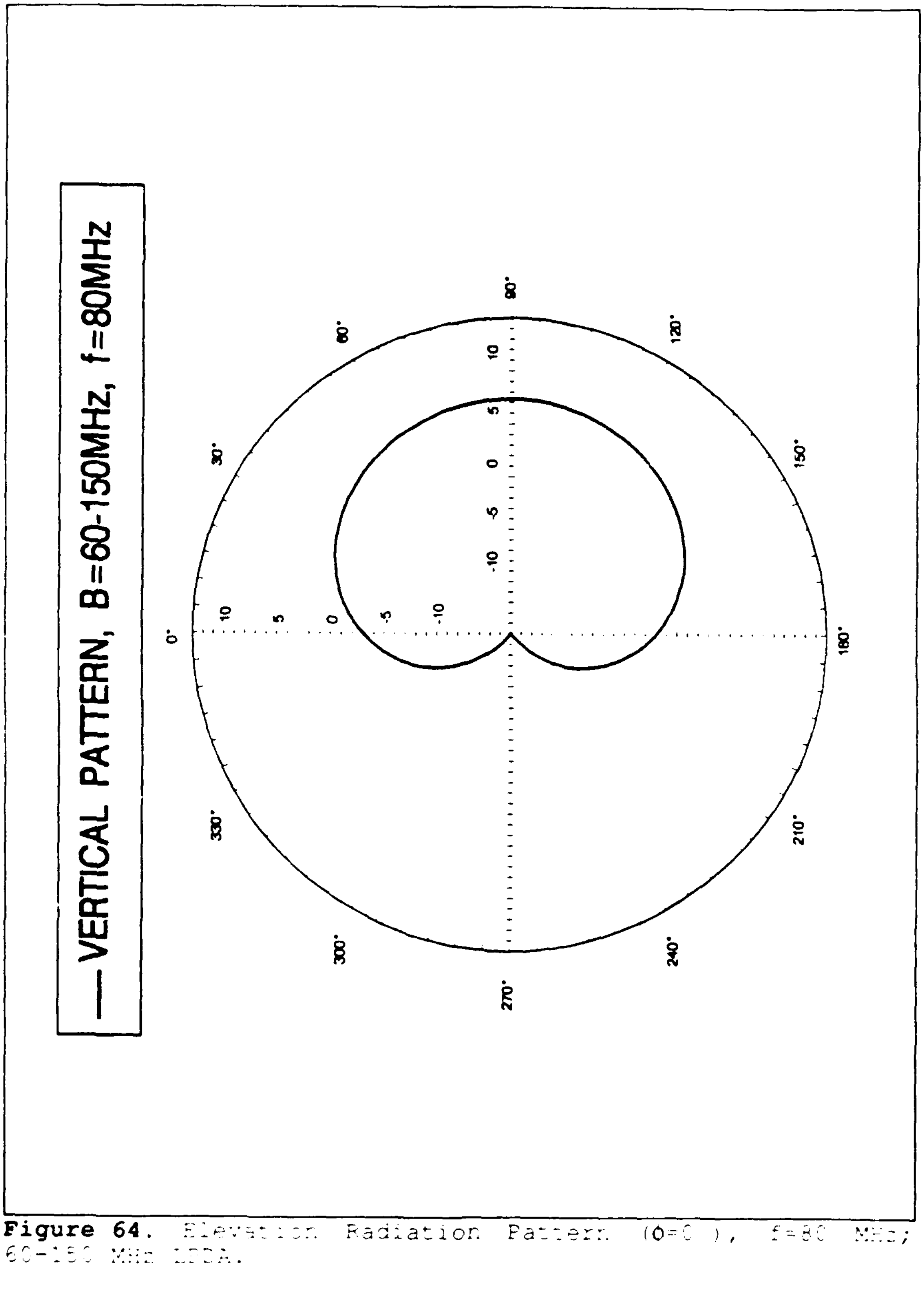

Figure 64. Elevation Radiation Pattern ($\phi=0^\circ$), f=80 MHz; 60-150 MHz LPDA.

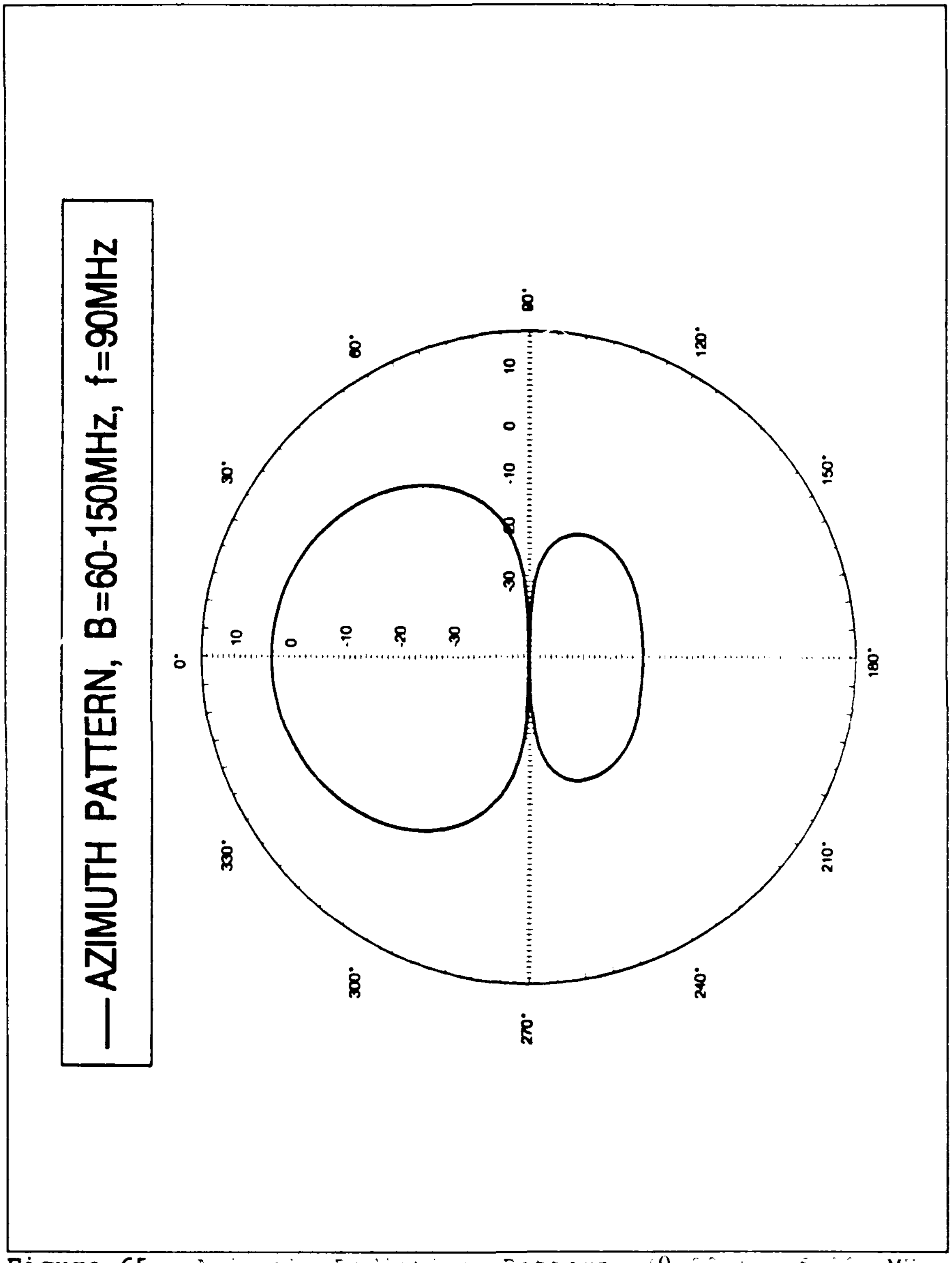

Figure 65. Azimuth Radiation Pattern (θ=90°), f=90 MHz; 60-150 MHz LPDA.

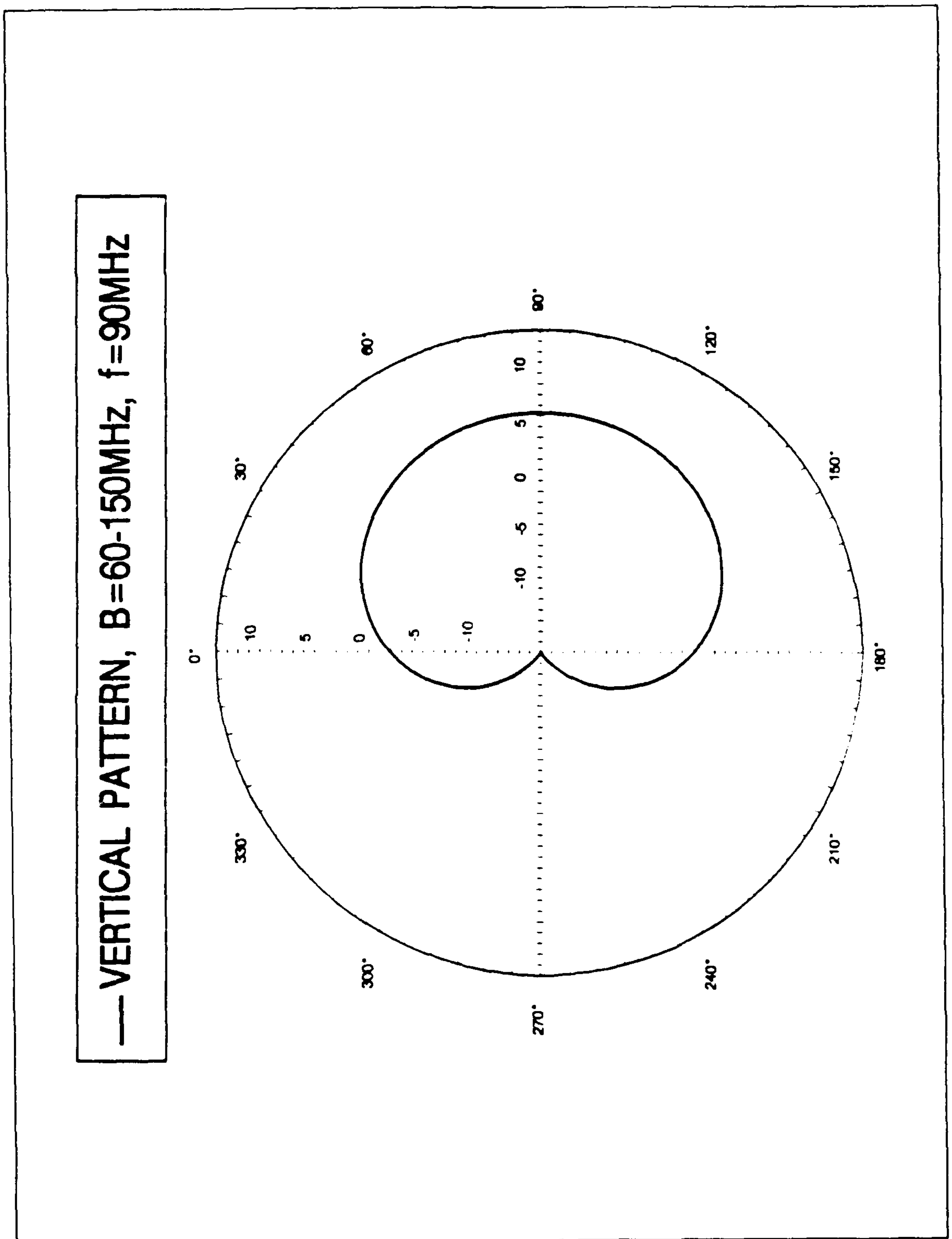

Figure 66. Elevation Radiation Pattern (φ 0°), f=90 MHz; 60-150 MHz LPDA.

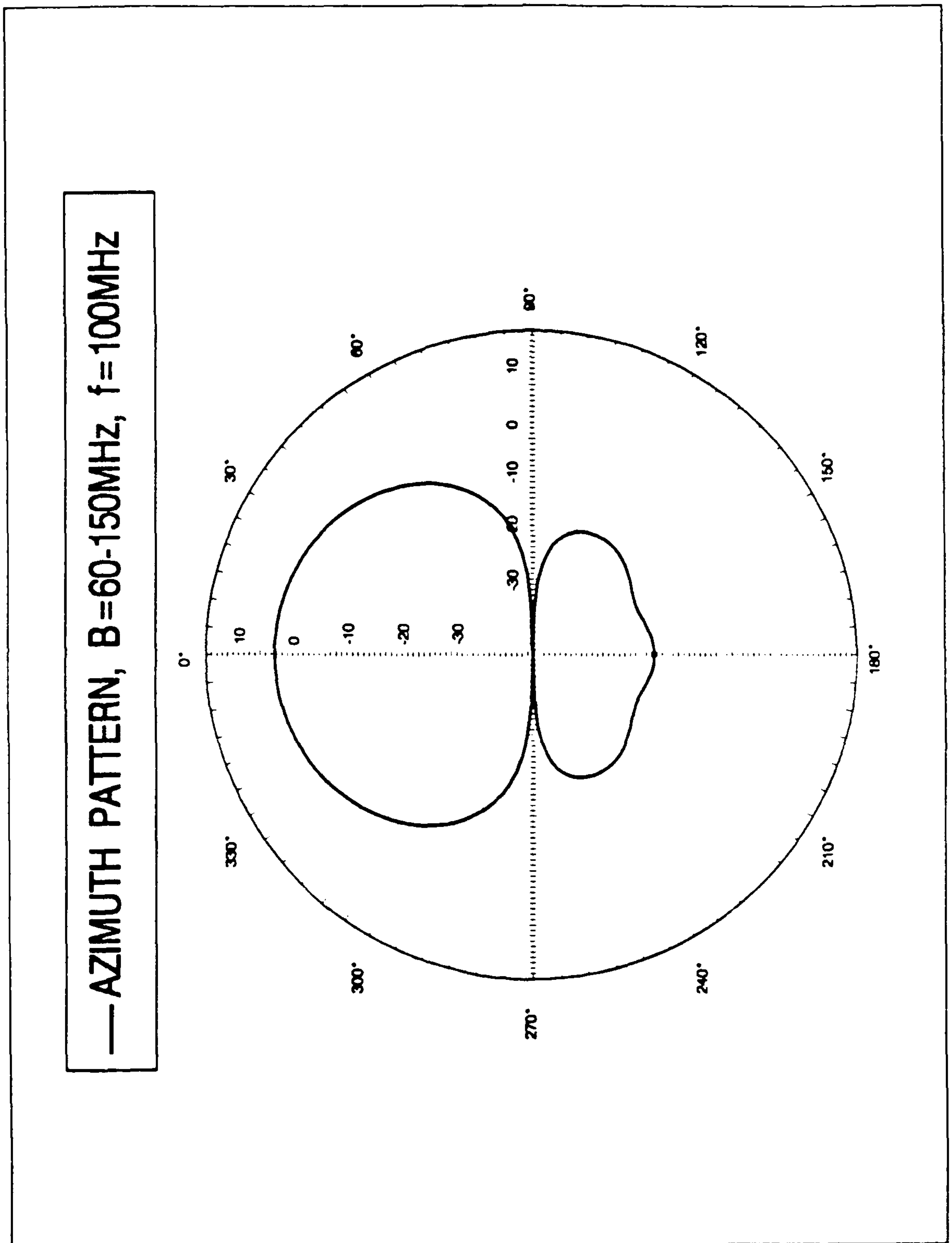

Figure 67. Azimuth Radiation Pattern ($\theta=90°$), f=100 MHz; 60-150 MHz LPDA.

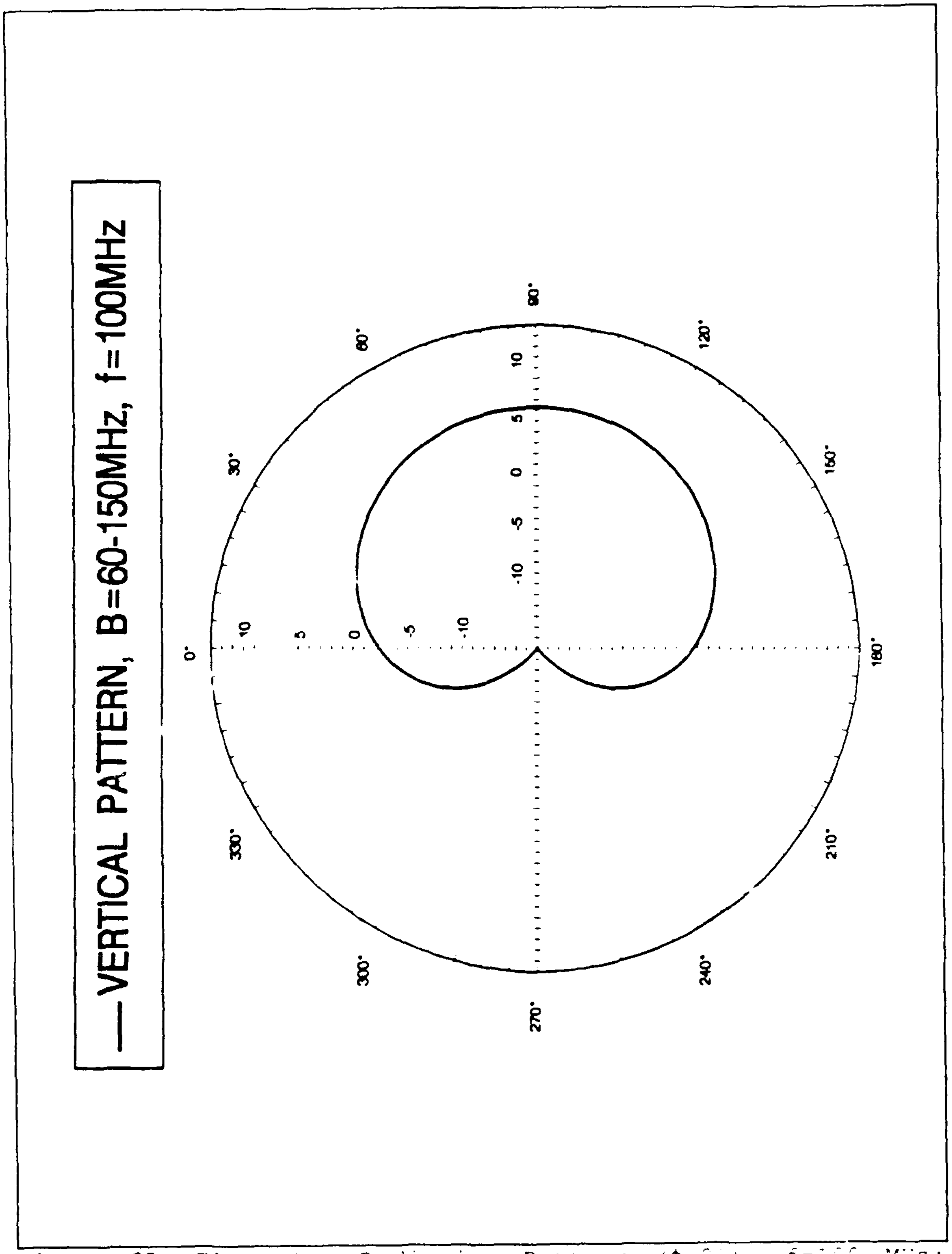

Figure 68. Elevation Radiation Pattern ($\phi=0°$), f=100 MHz; 60-150 MHz LPDA.

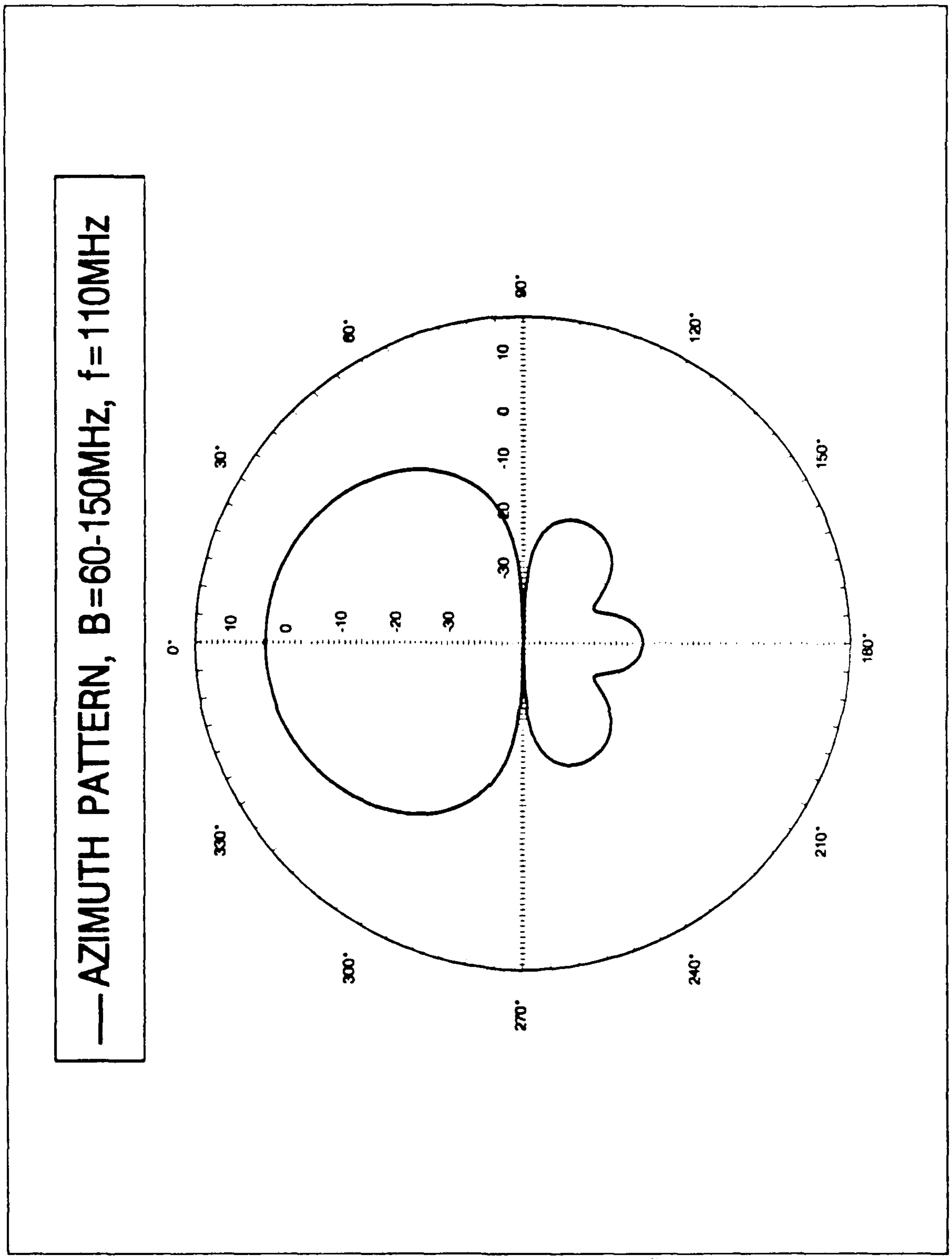

Figure 69. Azimuth Radiation Pattern (θ=[illegible]), f=110 MHz; 60-150 MHz LPDA.

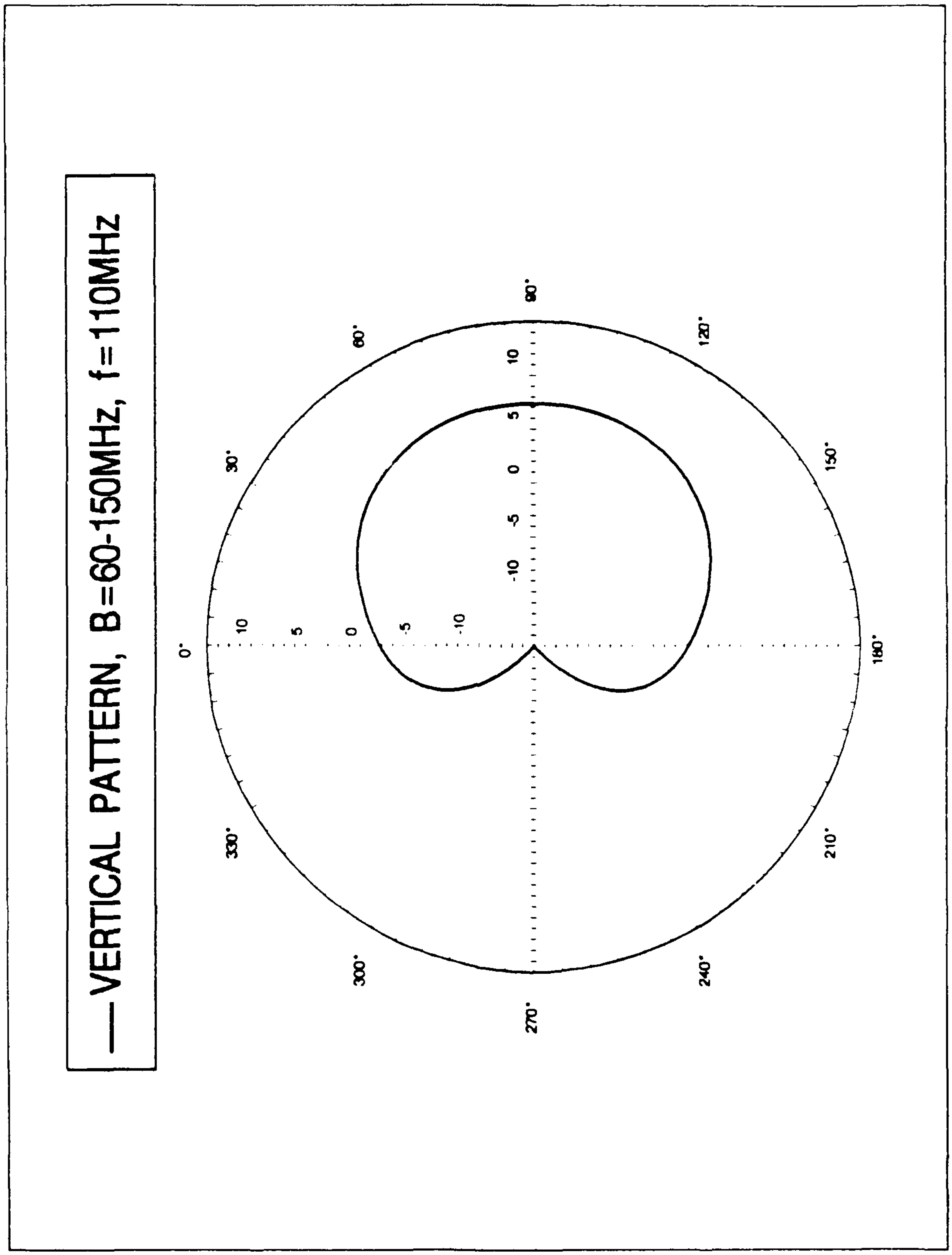

Figure 70. Elevation Radiation Pattern (Φ=0°), f=110 MHz; 60-150 MHz LPDA.

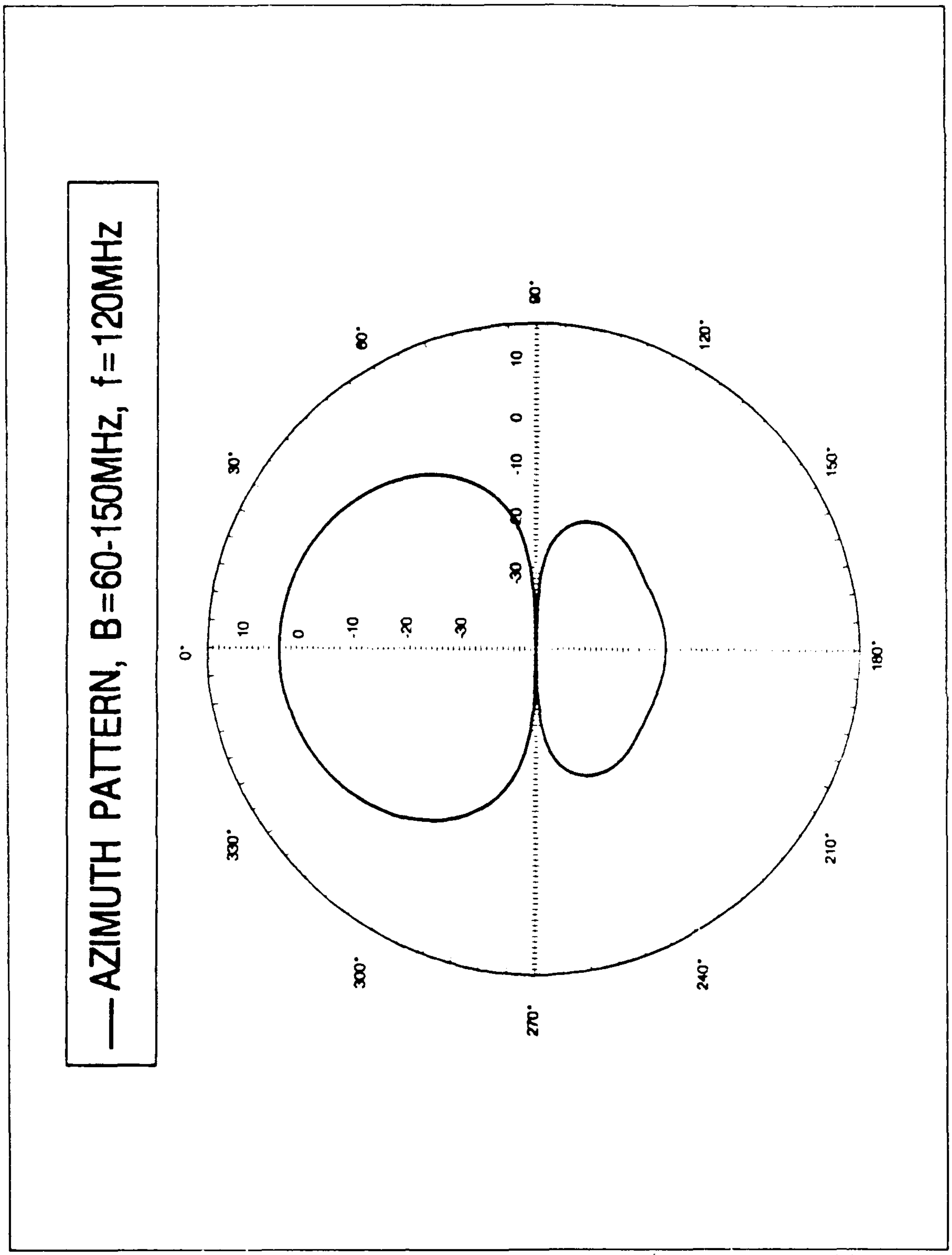

Figure 71. Azimuth Radiation Pattern ($\theta=90°$), f=120 MHz; 60-150 MHz LPDA.

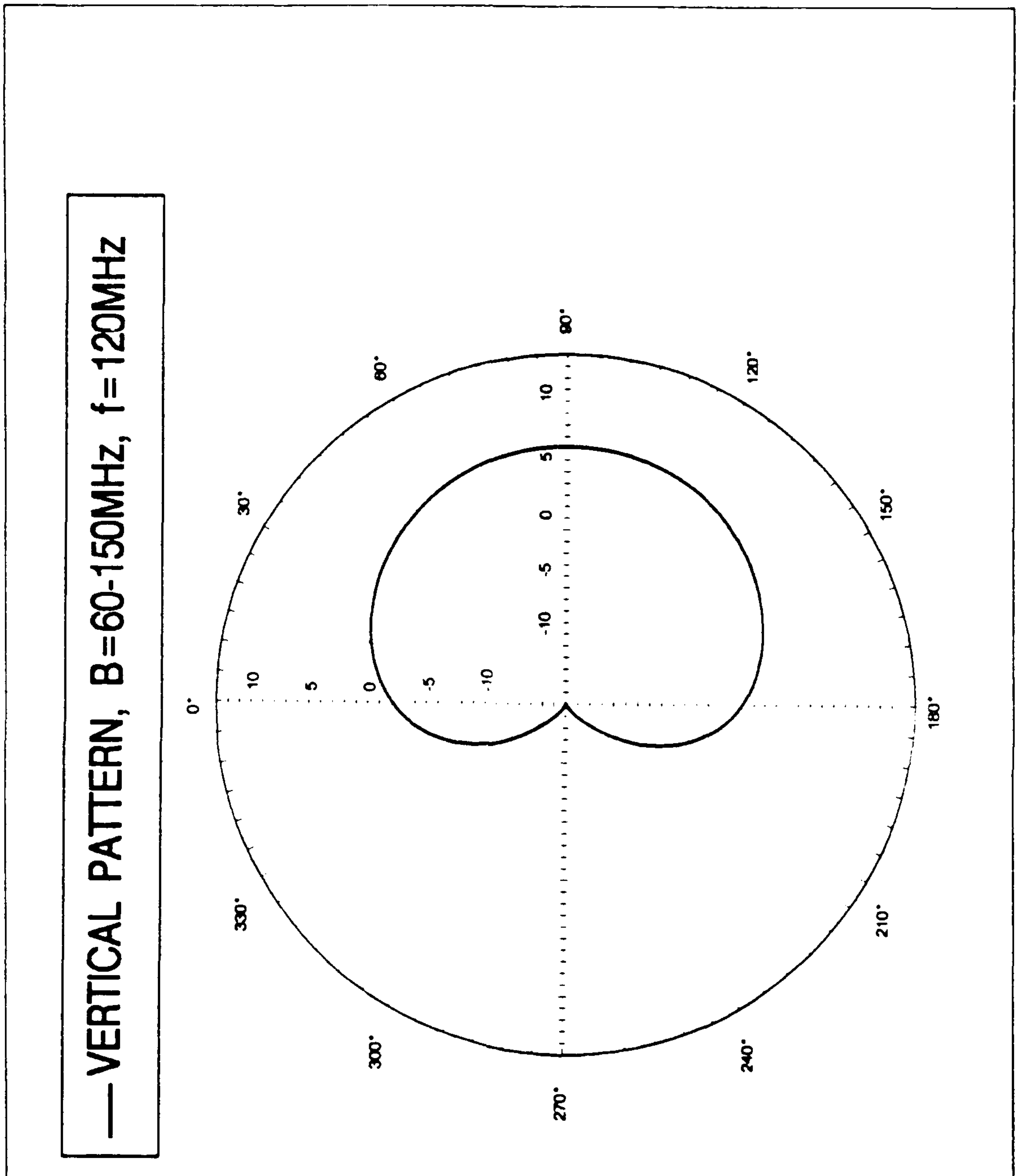

Figure 72. Elevation Radiation Pattern (O=[illegible]), f=120 MHz; 60-150 MHz LPDA.

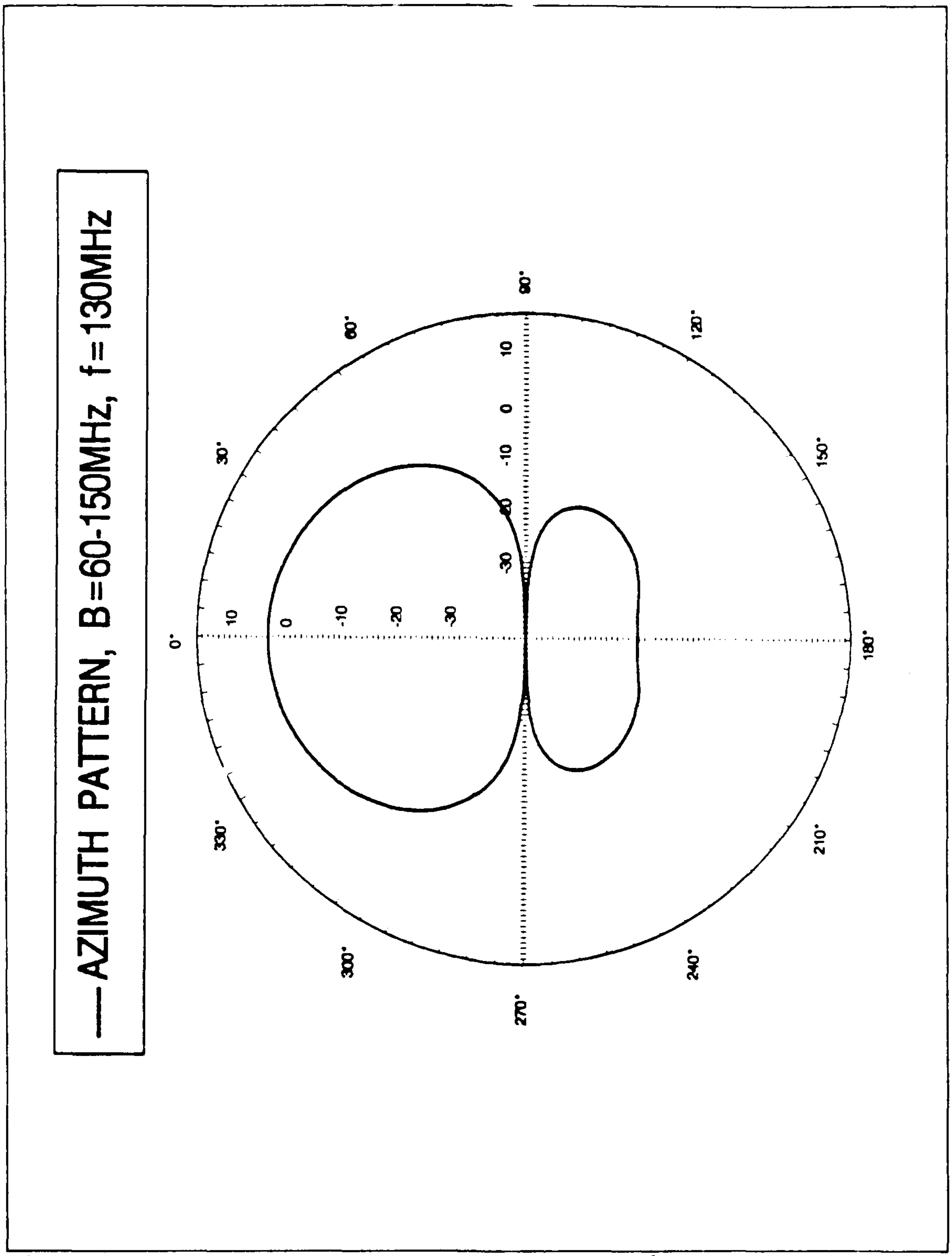

Figure 73. Azimuth Radiation Pattern ($\theta=90°$), f=130 MHz; 60-150 MHz LPDA.

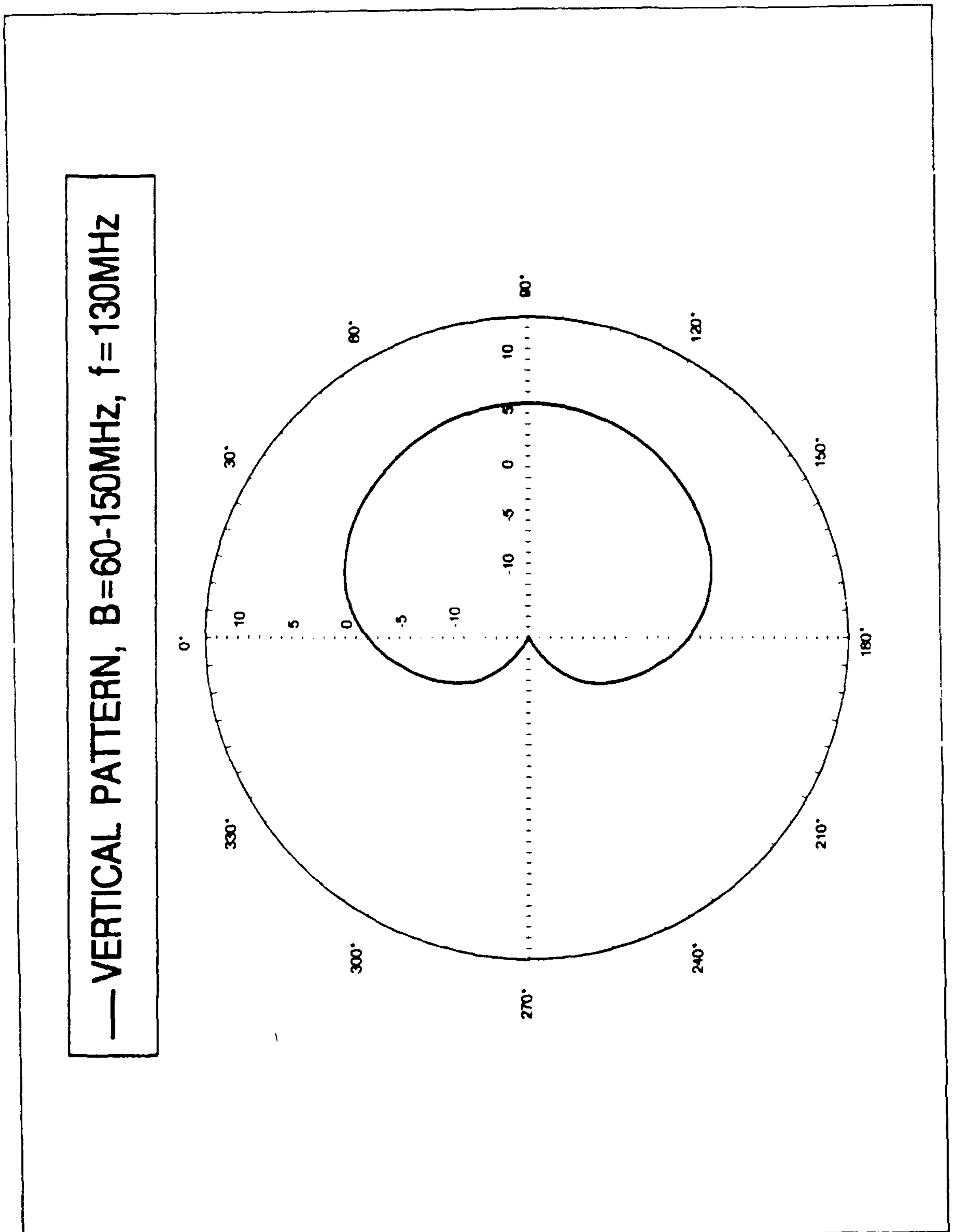

Figure 74. Elevation Radiation Pattern (Φ=0°), f=130 MHz; 60-150 MHz LPDA.

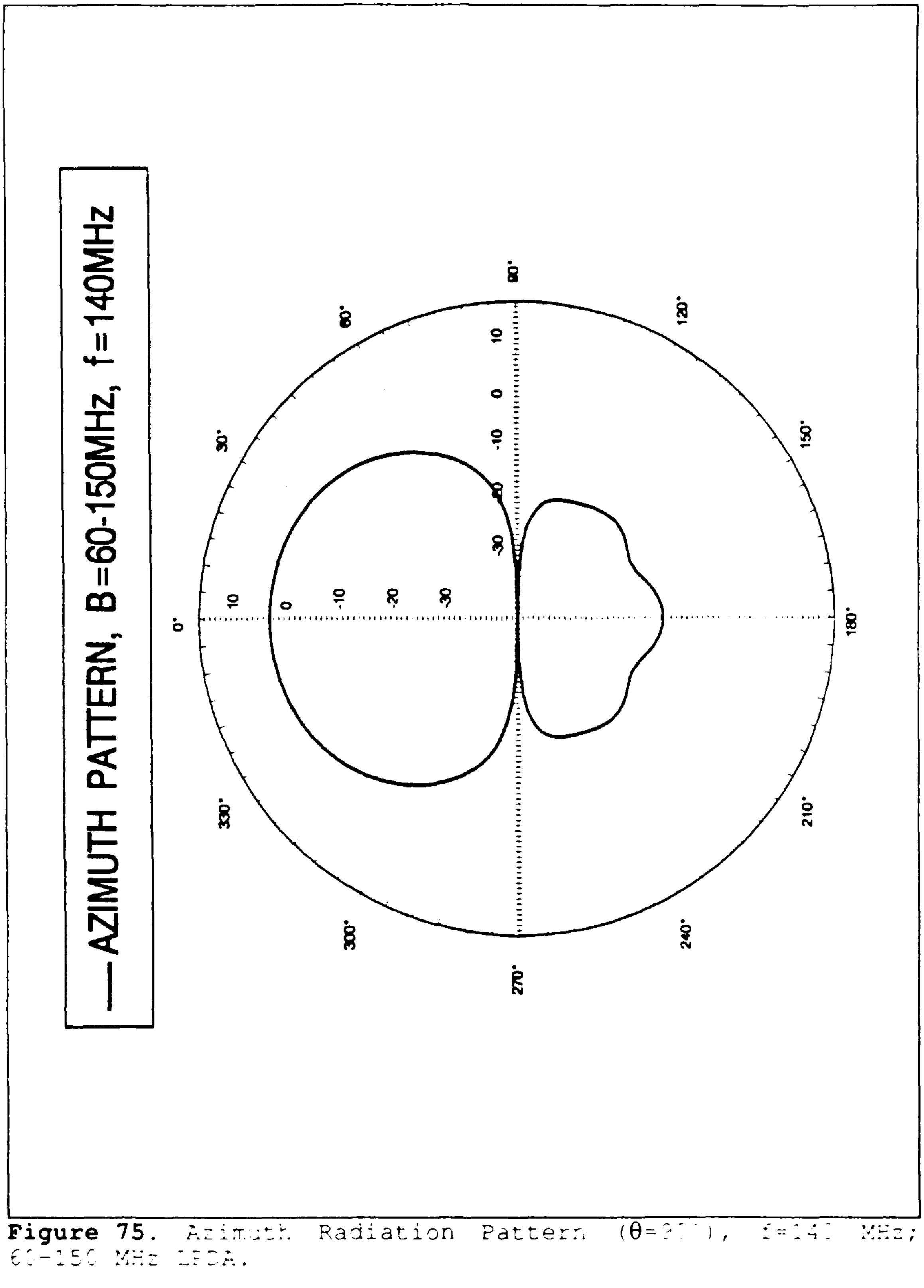

Figure 75. Azimuth Radiation Pattern (θ=90°), f=140 MHz; 60-150 MHz LPDA.

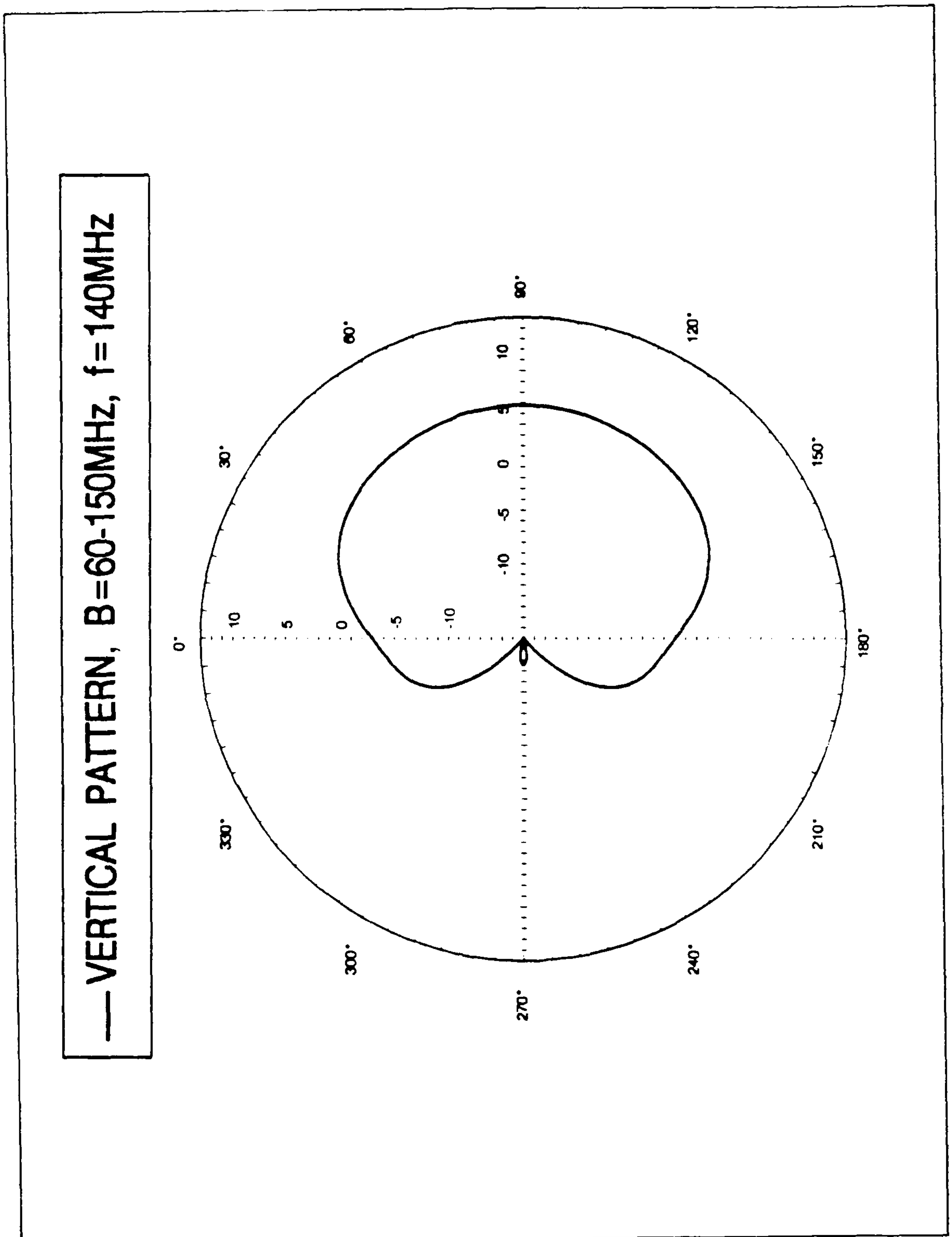

Figure 76. Elevation Radiation Pattern (Φ=0°), f=140 MHz; 60-150 MHz LPDA.

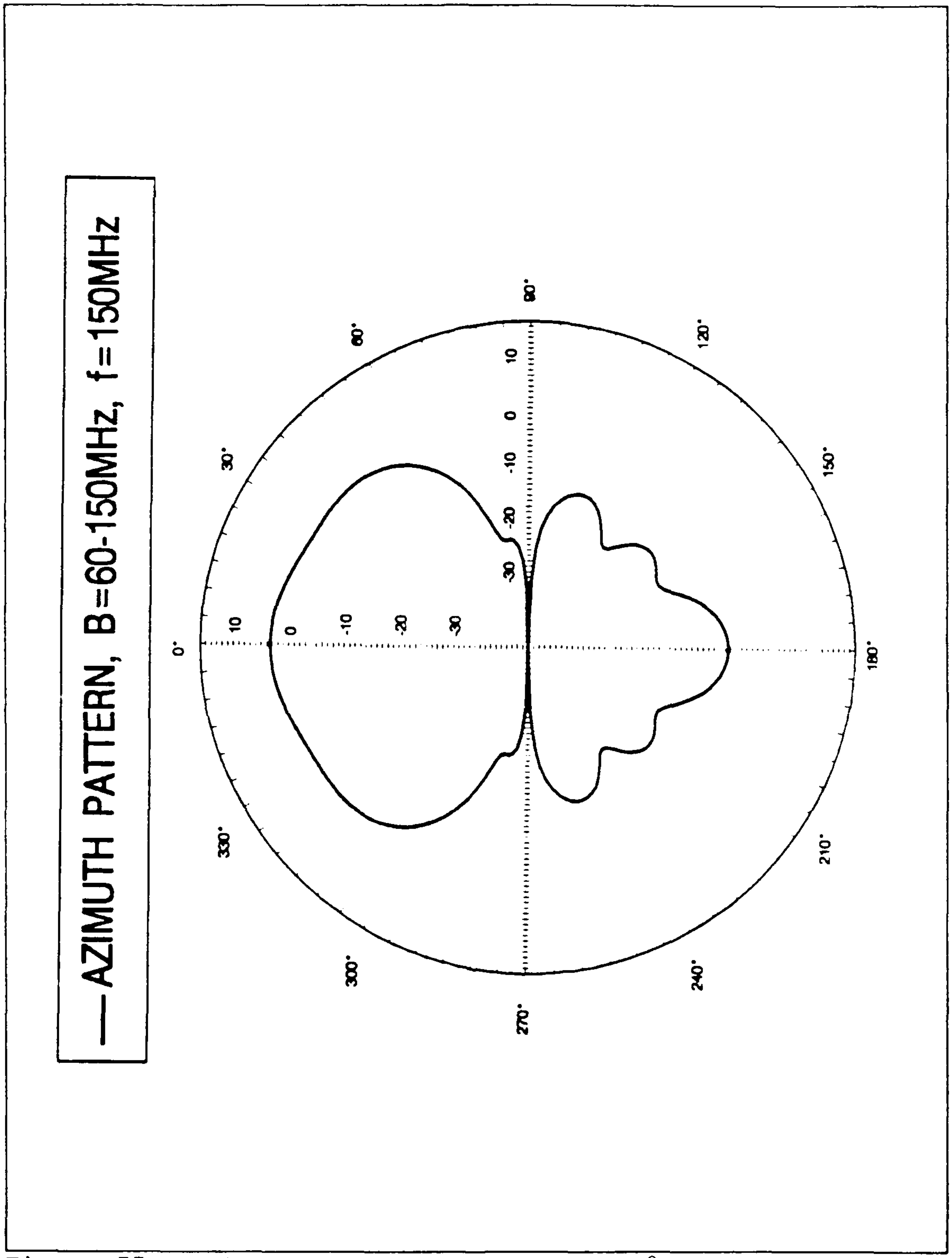

Figure 77. Azimuth Radiation Pattern ($\theta=90°$), f=150 MHz; 60-150 MHz LPDA.

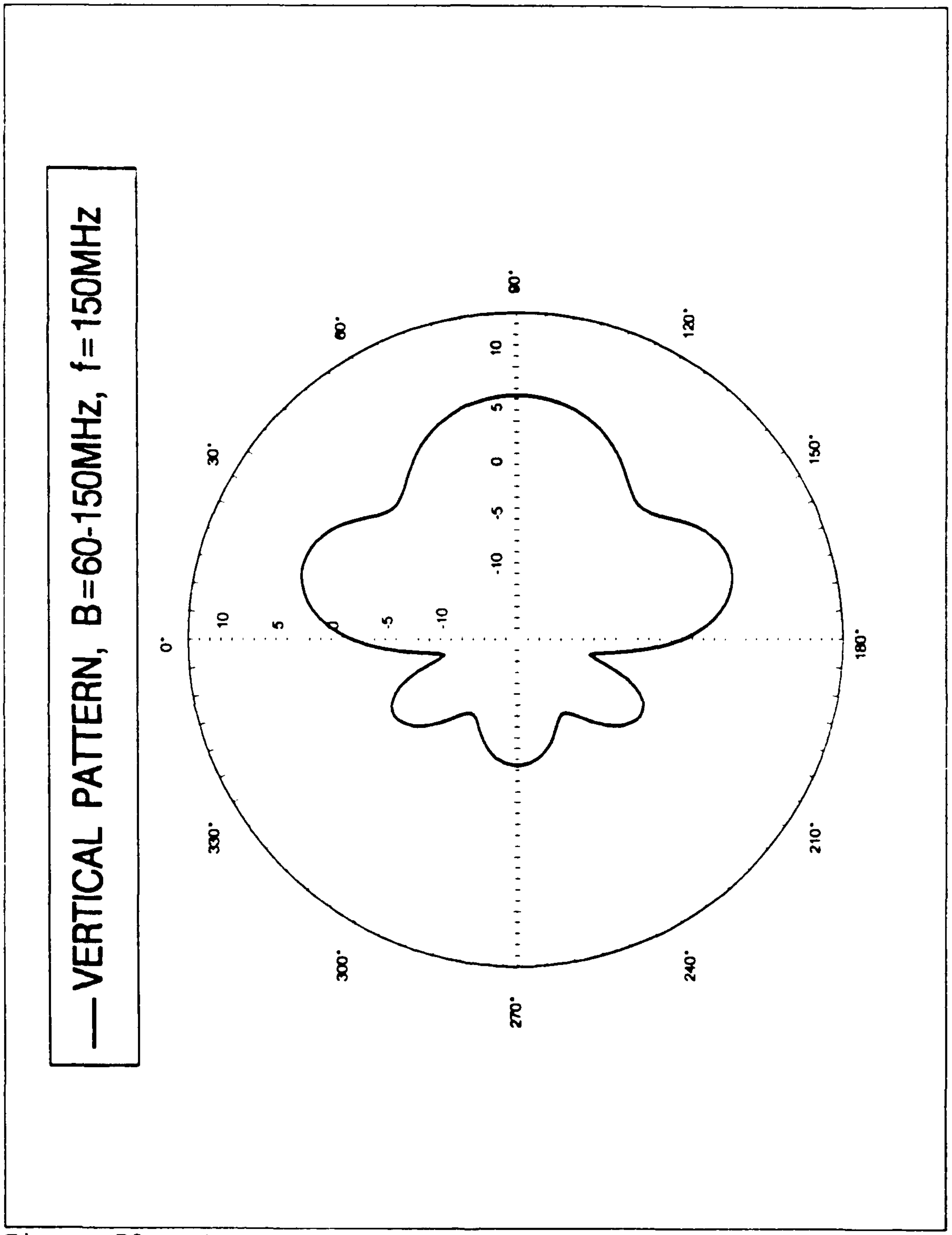

Figure 78. Elevation Radiation Pattern (0-180°, f=150 MHz; 60-150 MHz LPDA.

LIST OF REFERENCES

1. Adler, R.W., Jauregui, S., Vincent, W., *Performance Evaluation at Cryptologic Sites*, Technical Manual, April 1991.

2. Carrel, R.L., *Analysis and Design of the Log-Periodic Dipole Antenna*, PhD Dissertation, University of Illinois, June 1961.

3. Naval Ocean Systems Center Technical Document 116, Volume 2, *Numerical Electromagnetics Code (NEC) Method of Moments*, January 1981.

4. Naval Ocean Systems Center, *The Numerical Electromagnetic Engineering Design System (NEEDS)-Version 2.0*, June 1989.

5. Pozar, D.M., *Microwave Engineering*, Addison Wesley Co., April 1990.

6. Carrel, R.L., *An Analysis of Log-Periodic Antennas*, 10th Annual Symposium, USAF Antenna Research and Development Program, University of Illinois, October 1960.

7. Lo, Y.T., Lee, S.W., *Antenna Handbook*, Van Nostrand Reinhold Co., February 1988.

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