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Baseline Antenna Design for Space Exploration Initiative

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Chapter 1

INTRODUCTION

A key element of future NASA Space Exploration Initiative (SEI) mission is the lunar and Mars telecommunication system. This system will provide voice, image, and data transmission to monitor unmanned missions, to conduct scientific experiments, and to provide radiometric data for navigation.

In the later half of 1991, a study [1] was conducted on antennas for the Mars Exploration Communication. Six antenna configurations were examined: Three reflector and three phased array. The conclusion was that due to wide-angle scan requirement, and multiple simultaneous tracking beams, phased arrays are more suitable.

For most part, this report studies phased array antenna designs for two different applications for Space Exploration Initiative. It also studies one design for a tri-reflector type antenna. These antennas will be based on a Mars orbiting satellite, as shown in Fig. 1. The baseline requirements for these different applications are [2]–[4]:

- **Application A**
  1. Mission: the antenna is at MRS (Mars Relay Satellite), to set up communication links between MRS and Habitat, Rover, Science Instruments on Mars.
  2. Diameter: 1 m.
  3. Scan angle: $\pm$ 8 degrees.
  4. Frequency: 32 GHz.
  5. Number of beams: 10 independently controlled simultaneous beams.
  6. EIRP (Effective Isotropically Radiated Power) $\geq$ 45 dBW for all beams.

7. Peak side lobe level: -25 dB.
8. Cross Polarization level: -25 dB.

- **Application B**

1. Mission: the antenna is at MRS, to setup communication links between MRS, MPV (Mars Piloted Vehicle)and, MTV (Mars Transfer Vehicle).
2. Diameter: 1 m.
3. Scan angle: $\pm$ 30 degrees.
4. Frequency: 32 GHz.
5. Number of beams: 1 tracking beam.
6. EIRP $\geq$ 45 dBW.
7. Peak side lobe level: -25 dB.
8. Cross Polarization level: -25 dB.

For both these applications, the design requirements can be realized by the phased arrays only. For Application A, although it may be possible to achieve the relatively narrow field of view ($\pm 8°$) through a reflector antenna. However, the requirement of 10 independently controlled simultaneous beams rules out this choice.

For Application B, although only one beam is required, the field of view is $\pm 30°$ cone and, therefore, unrealizable by the reflector antennas. As a result both applications will be based on phased array antennas.

During the first year of the present grant, a computer code named *PARCOM1* (Pattern of Array Computation, Version 1) was developed for analysis and design of phased arrays. The program has been improved to increase its capability. The new version called *PARCOM2* is used to obtain baseline designs for phased array antennas in both the above applications. For each application, two antennas are studied. First antenna uses high gain circular waveguide as array element and the second uses microstrip subarray as array element.

Chapter 2 discusses the design considerations. Chapters (3-4) discuss the antennas studied for both applications. Chapter 5 studies a array based on a MMIC subarray developed at Texas Instruments for NASA. Chapter 6 dicusses the tri-reflector antenna. Chapter 7 draws conclusions based on these studies.

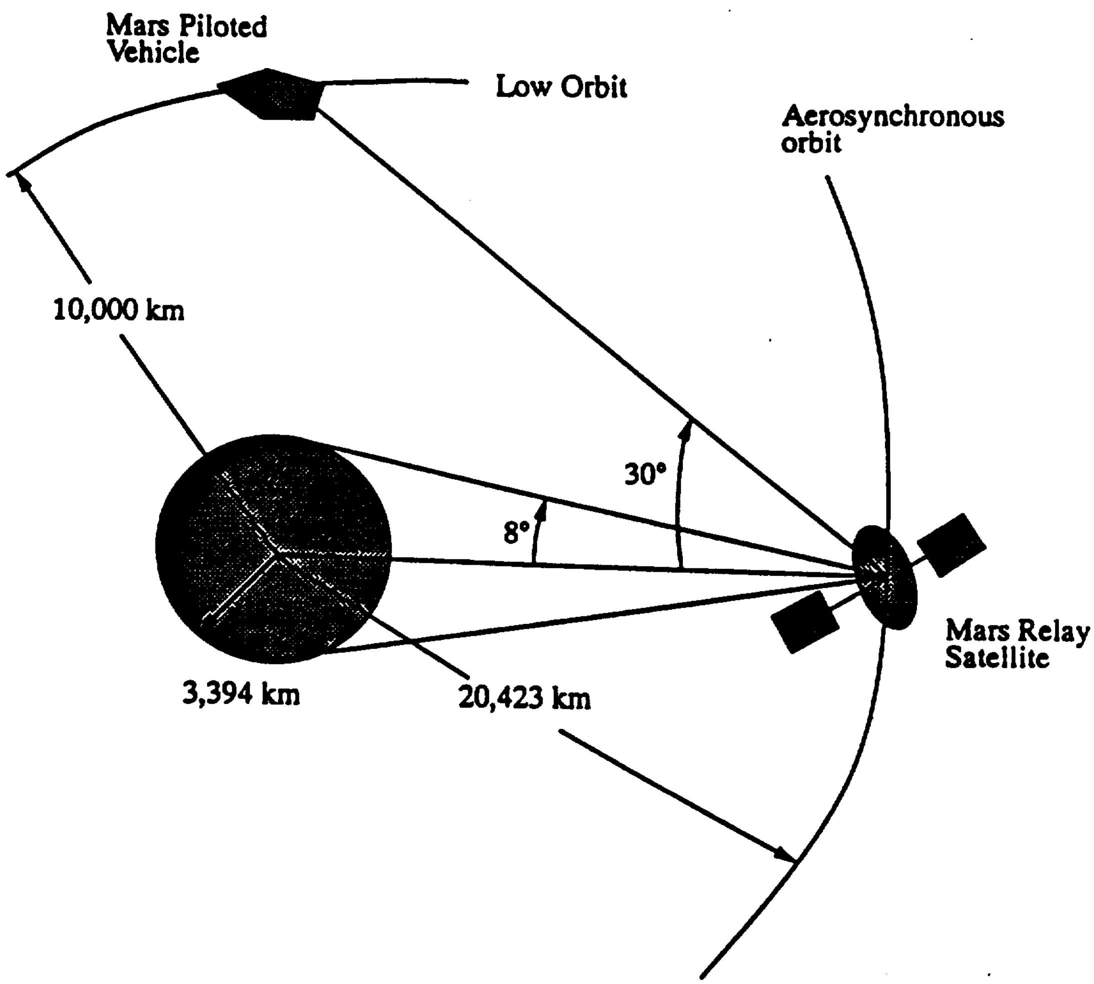


Figure 1. Intra Mars Communications Setup

Chapter 2

DESIGN CONSIDERATIONS

The baseline design of phased arrays for both applications was based on the following design considerations.

2.1 Array Lattice Selection

There are two kinds of lattice arrangements commonly used: rectangular lattice and triangular lattice. The number of elements needed for equilateral triangular lattice is 13.4% lower than that of square lattice array for the same grating lobe free area [5]. Due to this reason triangular lattice was used for Design A and Design B, Design C uses square lattice.

2.2 Array Radiation Element Selection

The choice of array elements is usually based on: the required antenna performance, physical packaging constraints, environmental requirements, and cost. Some commonly used array elements are:

- Open-ended rectangular/circular waveguide or horn.
- Dipole.

- Waveguide slot
- Microstrip patch.

Dipole and microstrip patches are usually used for x-band and lower frequencies. Waveguide radiators are used for s-band or higher frequency. The impedance match frequency bandwidth for different types of radiators is:

- Waveguide radiator $\sim$ 20% to an Octave,
- Dipole $\sim$ 10%,
- Microstrip 3 $\sim$ 5%,

compared to a dipole or microstrip patch, waveguide radiator can have higher element gain, higher efficiency and higher power capability.

For designs A and B the array spacings are 3.69λ and 1.08λ, respectively. Waveguide and microstrip subarray are the two most promising candidates for array elements. Waveguide elements have much wider impedance match frequency bandwidths, higher efficiency and gain. Microstrip subarray is suitable for MHMC (Monolithic Hybrid Microwave Circuit) and MMIC (Monolithic Microwave Integrated Circuit) technologies. Particularly, the slot feed microstrip patch subarray eliminates the need for large number of coaxial connectors, and need for feed-throughs in multiple layer configuration. In other words, microstrips will reduce plumbing, promote weight reduction, reduce assembly labor, and increase reliability.

Due to these considerations, circular waveguide and microstrip patch subarray have been chosen for both design applications.

2.3 Common Design Parameters

The following parameters are common to both Design A and B antennas.

f = 32 GHz.
element efficiency = 0.84 for circular waveguide.

element efficiency = 0.73 for microstrip subarrays.
design side lobe level = -35 dB Taylor taper, with 6 equal side lobes.
VSWR $\leq$ 2.0.

2.4 Effect of Component errors on Array Performance

These errors are mainly caused by manufacturing tolerances of the components and variations in material consistency. These errors can be identified and grouped in to two types: system errors, and random errors. The system errors are deterministic and can be trimmed out. The random errors, on the other hand, are not deterministic.

Therefore, we will address the effect of random errors on antenna performance. The effect of component errors on array performance can be expressed in terms of the rms errors as follows [8]–[10]:

(1) The rms side lobe power

$$\text{rms sl} \simeq \frac{\sigma^2}{\mathrm{p_e}\eta_a\mathrm{N_e}}$$

where,

$\sigma^2 = \sigma_a^2 + \sigma_p^2$
σ_a = rms amplitude error
σ_p = rms phase error
η_a = aperture efficiency
p_e = probability of survival for array elements
N_e = number of array elements

(2) Peak side lobe level (amplitude)

$$\text{psl} = |\mathrm{S_0}| + \frac{2\sigma}{\sqrt{\eta_a\mathrm{N_e}}}$$

where S_0 is the amplitude of the design side lobe without errors.

(3) Gain loss

$$\frac{G}{G_0} = \frac{1}{1 + (3\pi/4)(a/\lambda)^2\sigma^2}$$

where G_0 is the array gain without errors and a is the array spacing. It may be noted that the gain loss depends on the array spacing a and, therefore, It will be same for different types of array elements. Fig. 2.4.1 shows gain reduction as a function of component errors for Design A and Fig. 2.4.2 shows gain reduction for Design B.

(4) Beam pointing error δ_ψ

$$\frac{\delta_\psi}{\Delta\theta} = \sqrt{\frac{3}{N_e}}\frac{\sigma}{0.88\pi}$$

where $\Delta\theta$ is 3 dB beam width in radians.

2.5 Effect of Phase Quantization on Array Performance

In the case of a digitally controlled phase shifter, a p bit phase shifter has 2^p phase states. The minimum phase step is $2\pi/2^p$. The staircase phase variation is used to approximate the desired linear phase progress. The array gain loss due to the triangular phase error distribution is [6],

$$\Delta G = \frac{1}{3}\frac{\pi^2}{2^{2p}}$$

where p is the number of bits of the phase shifter. In addition to gain loss, the periodic variation of triangular phase error across the array aperture is of great significance. It causes the so-called phase-quantization side lobes (pqsl), which are much larger than rms side lobes, pqsl can be expressed as,

$$\text{pqsl} = \frac{1}{2^p}$$

It may be noticed that the effect of phase quantization depends only on the phase shifter bits and therefore, are common to all array designs. An example is shown in table below.

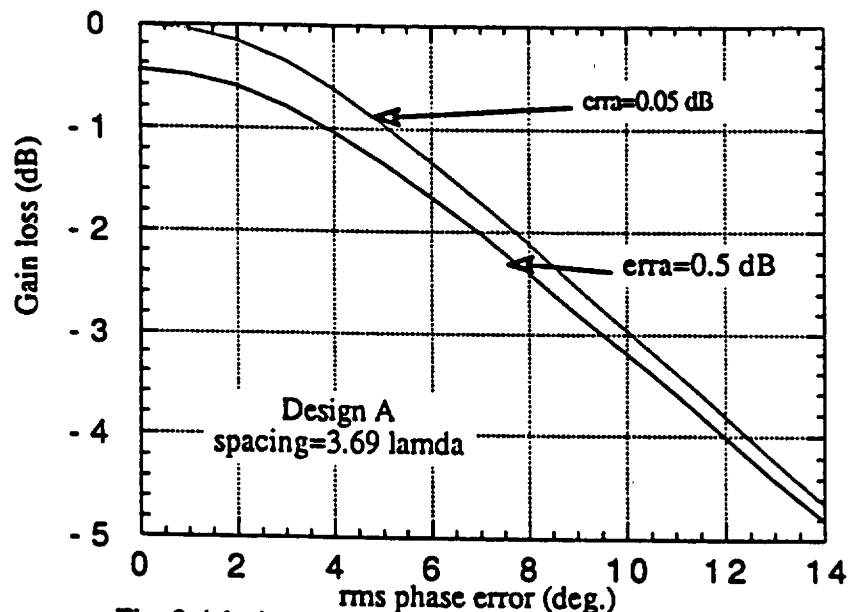


Fig. 2.4.1 Array gain loss as a function of random errors

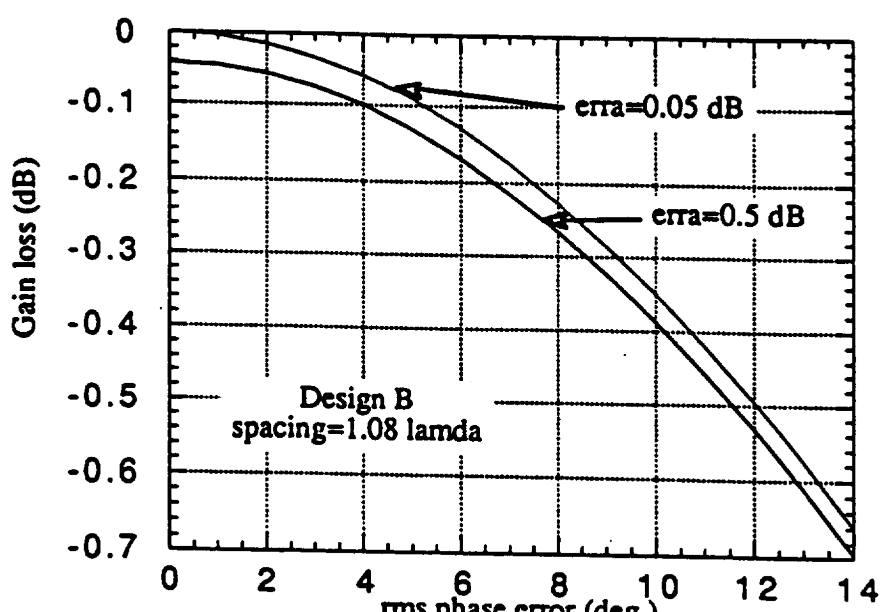


Fig. 2.4.2 Array gain loss as a function of random errors

Table 1

p	2	3	4	5
ΔG dB	-1.00	-0.23	-0.06	-0.01
pqsl dB	-12.04	-18.06	-24.08	-34.10

2.6 Instantaneous Frequency Bandwidth Limitation

In an array that is steered by phase shifter, rather than time delay, beam will scan as frequency is changed [7]. When it is set, the criteria is that for edge frequency spectral components, array beam scan $\pm 1/4$ beamwidth. The instantaneous frequency bandwidth limitation is,

$$\frac{\Delta f}{f} = 0.886B\frac{\lambda_0}{Lsin\theta_0}$$

where:

$L =$ length of array in scan plane,
$B =$ beam broadening factor= 1.12, 1.29, and 1.43 for -20, -30, and -40 dB sidelobe level
$\theta_0 =$ maximum scan angle.

an example of this is shown in Table 2 below:

Table 2

	Design A	Design B	Design C
$\frac{\Delta f}{f}$	0.088	0.023	0.048

Chapter 3

APPLICATION A

The arrays will be used to set up communication links between Mars Relay Satellite (MRS) and Habitat on Mars (Fig. 1). As shown, the required scan coverage is $\pm 8°$ cone. The antenna will be based on MRS. Other specifications are detailed in Chapter 1.

Two array designs are studied for this application. The design using the open-ended circular waveguide elements, will be called A1, and the design using 4×4 microstrip subarray modules, will be called A2. These studies are carried out by using *PARCOM2* which is an improved version of *PARCOM1*.

3.1 Design A1

In this design, the array element is chosen to be an open-ended circular waveguide with a radius,r, of $1.71cm$. The elements are arranged in a hexagonal lattice, as shown in Fig. 3.1. A total of 631 elements are arranged in 14 concentric rings. The element spacing, a, is $3.46cm$ and $a/\lambda = 3.69$. The diameter of the antenna turns out to be $96.88cm$.

The individuals element gain is 19.74 dB. E plane element pattern is shown in figure 3.1.7 and the H plane pattern is shown in Fig. 3.1.8.

From the exact computation the directivity is 45.84 dB at boresight, the radiation pattern in E plane over the entire $\pm 90°$ visible range is plotted in Fig. 3.1.1. The grating lobes are at

$\pm 35°$(well outside the scan region). However, due to the highly directive nature of array elements, the grating lobes are below -23.27 dB from the main beam and do not significantly reduce the directivity for the entire array. Fig. 3.1.2 shows the side lobes to be -27.29 dB. and the bandwidth to be 0.72° .

Fig. 3.1.3 shows the radiation pattern in H plane over the entire visible range. The grating lobes are now closer at $\pm 18°$; still outside the scan area but are stronger to -10.75 dB. Fig. 3.1.4 shows the side lobes of -30.32 dB. and the beamwidth of 0.72°.

At a scan angle of 8° (Fig. 3.1.5) the directivity reduces to 43.26 dB. and the grating lobes increase to -16.35 dB. Fig. 3.1.6 shows that the side lobe level is -26.49 dB.

3.2 Design A2

Design A2 uses square 4×4 microstrip subarrays to form higher directivity elements. The subarray spacing is 0.73 *cm*. A total of 631 subarrays are used in 14 concentric hexagonal rings, as shown in Fig. 3.2. The element spacing, a, and a/λ are the same as in Design A1.

The subarray gain is 16.28 dB. The subarray pattern is shown in Fig. 3.2.7 and Fig. 3.2.8.

The overall pattern in E plane is shown in Fig. 3.2.1. The directivity is 41.58 dB. The grating lobes are located at $\pm 34°$; well outside the scan region and are -15.35 dB. Fig. 3.2.2 shows the side lobes at -27.3 dB and a 0.72° beam width.

Fig. 3.2.3 shows the directivity pattern in H plane over the entire visible range. The Directivity is 41.58 dB and grating lobes are at $\pm 18°$, well out side the scan area. The level of grating lobes is -28.86 dB. Side lobe level is -29.72 dB as shown in Fig. 3.2.4, the beam width is 0.72°.

At 8° scan angle the directivity goes down to 39.79 dB. and the grating lobes are at $\pm 48°$ at a level of -11.54 dB. the radiation pattern over the entire visible range is shown in Fig. 3.2.5. Side lobes are -26.49 dB and the beam width is 0.72°(see Fig.3.2.6).

DESIGN A1

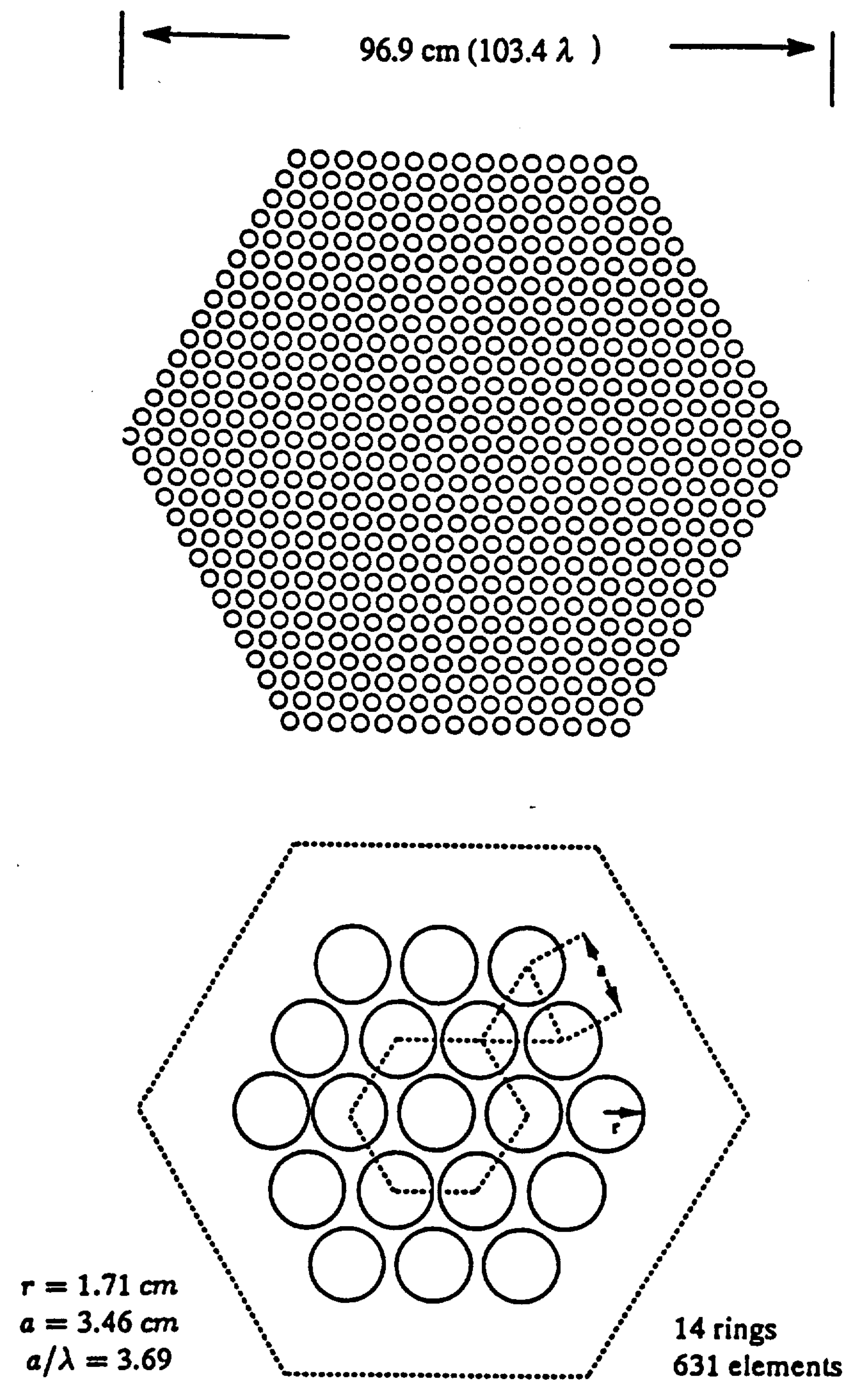


Figure 3.1. Geometry of Design A1 with high-gain open-ended circular waveguide elements.

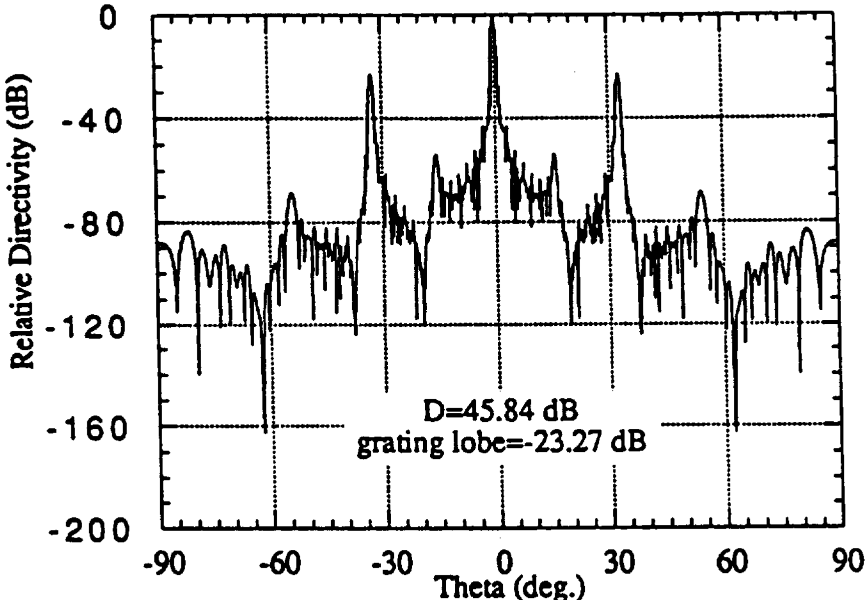


Fig. 3.1.1 E plane pattern of Design A1, scan=0 deg.

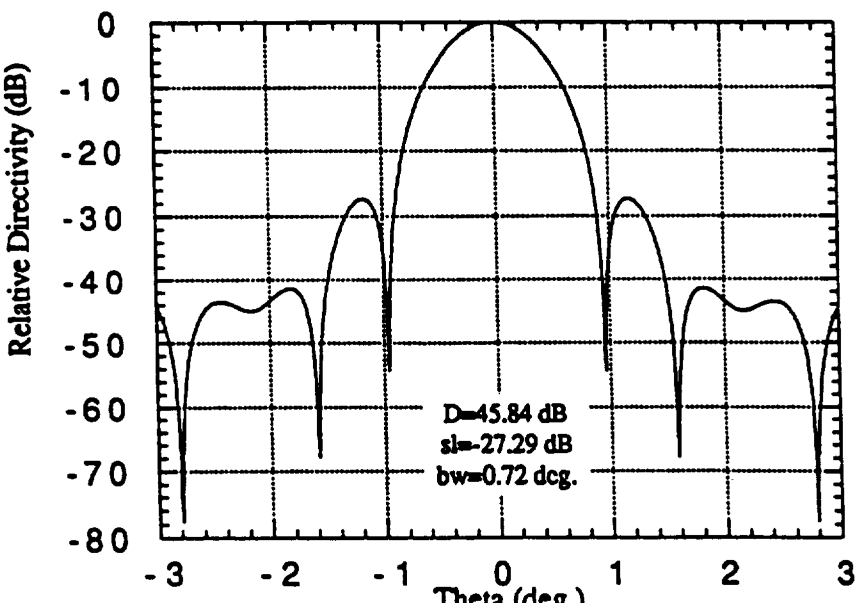


Fig. 3.1.2 E plane pattern of Design A1. scan=0 deg.

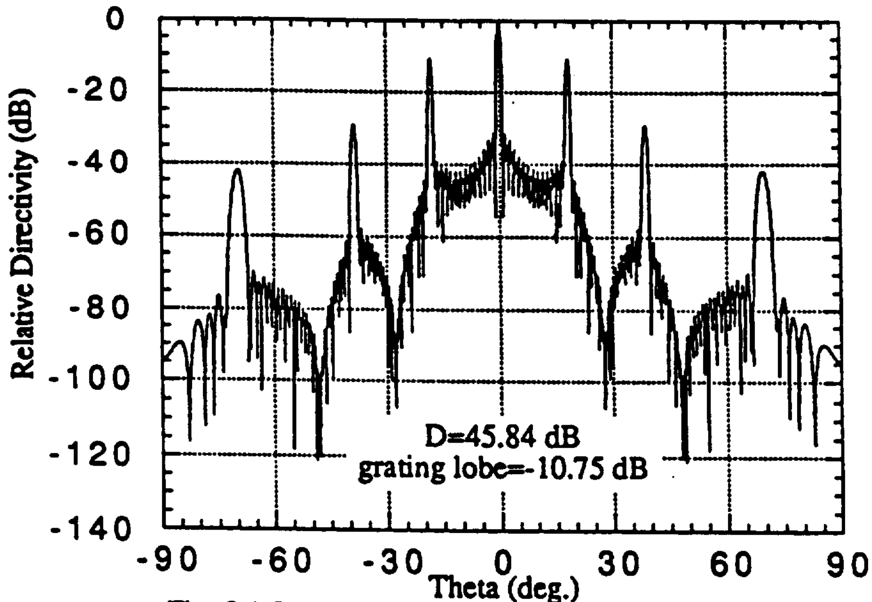


Fig. 3.1.3 H palne pattern of Design A1, scan=0 deg.

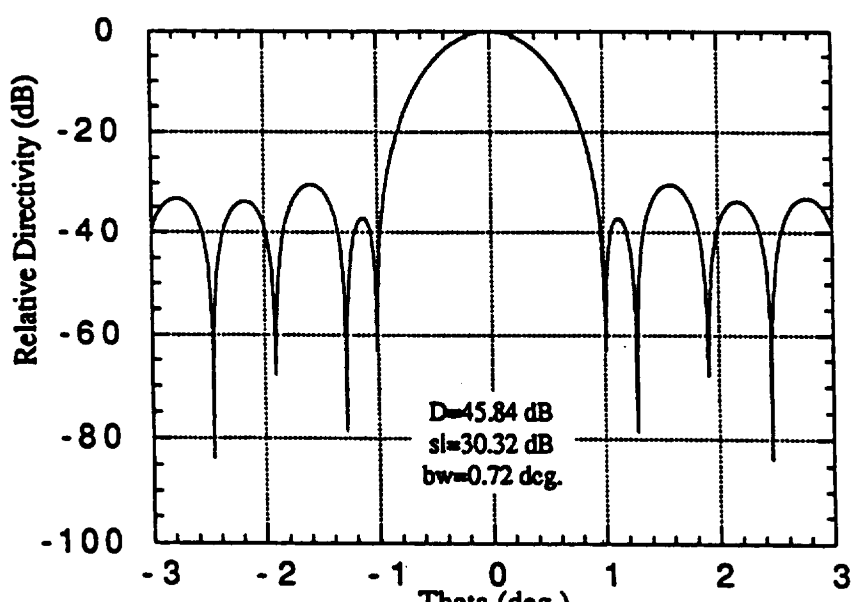


Fig. 3.1.4 H plane pattern of Design A1. scan=0 deg.

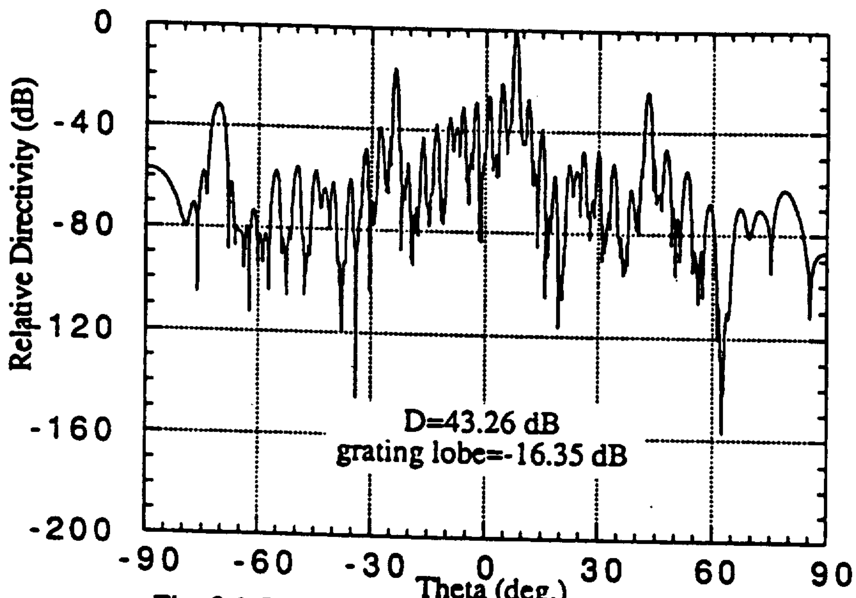


Fig. 3.1.5 E plane pattern of Design A1, scan=8 deg.

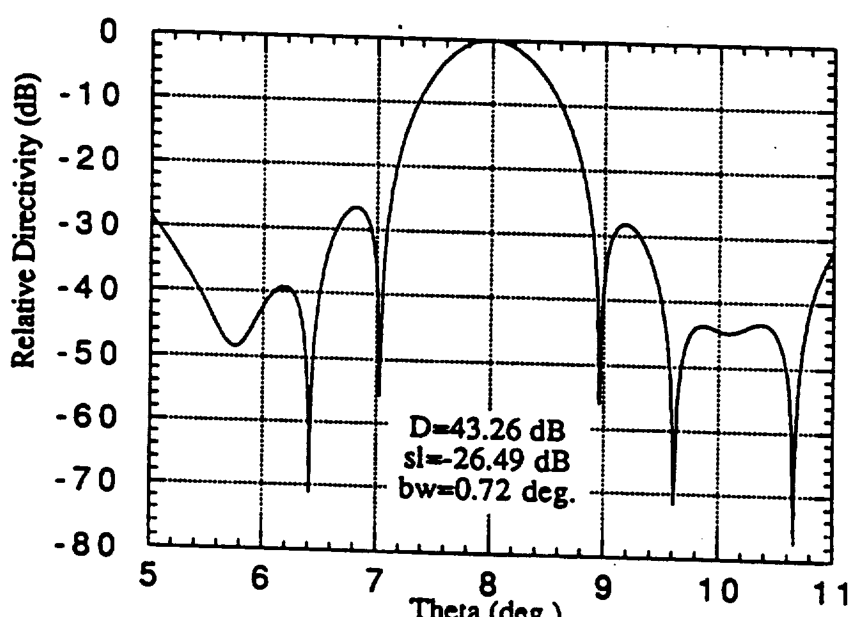


Fig. 3.1.6 E plane pattern of Design A1, scan=8 deg.

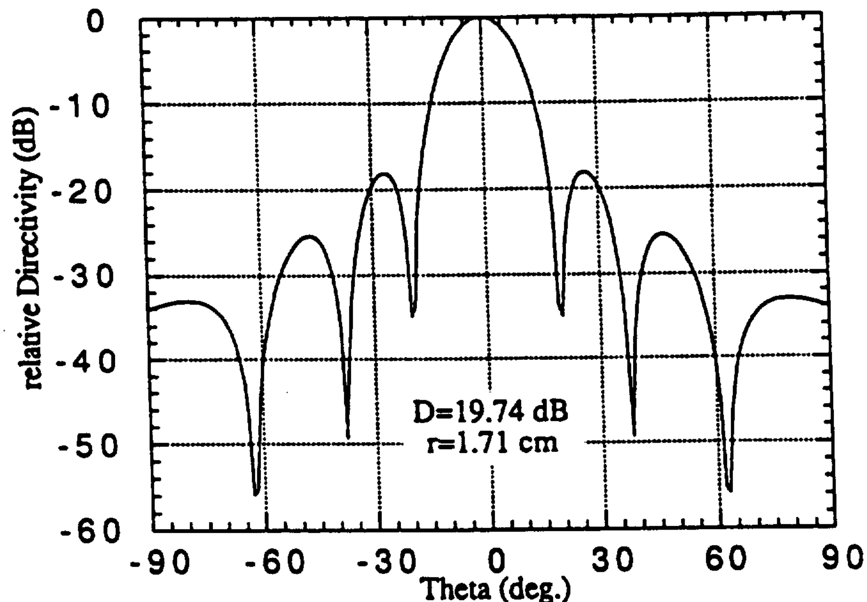


Fig. 3.1.7 E plane pattern of a single open circular guide.

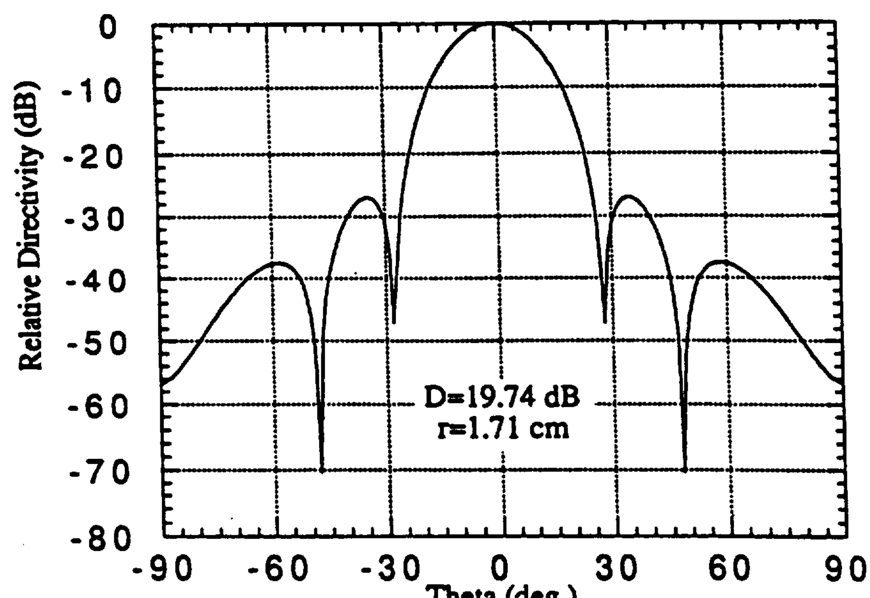


Fig. 3.1.8 H plane pattern of a single open circular guide

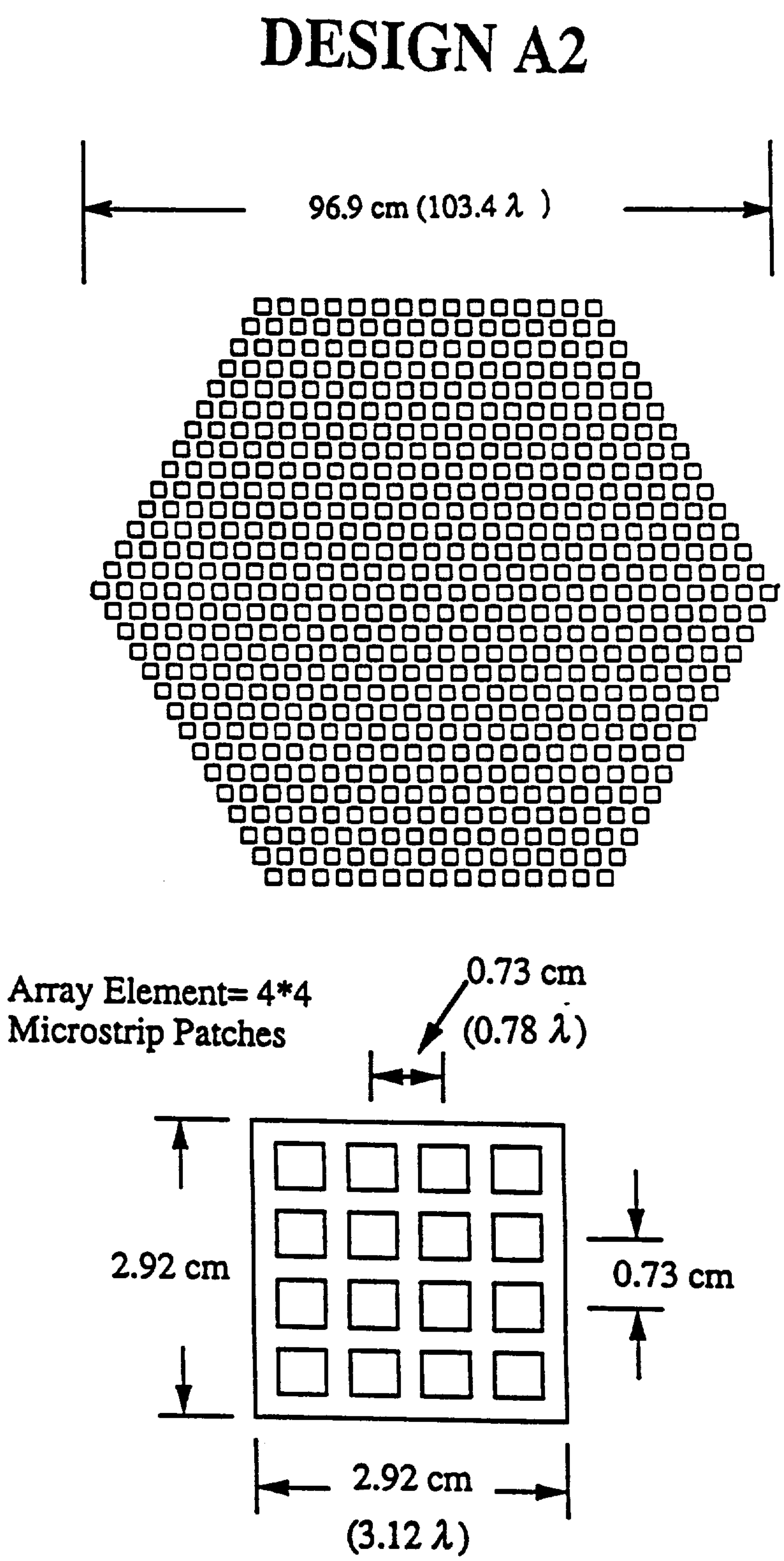


Figure 3.2. Geometry of Design A2 with 4 × 4 Microstrip patch modules.

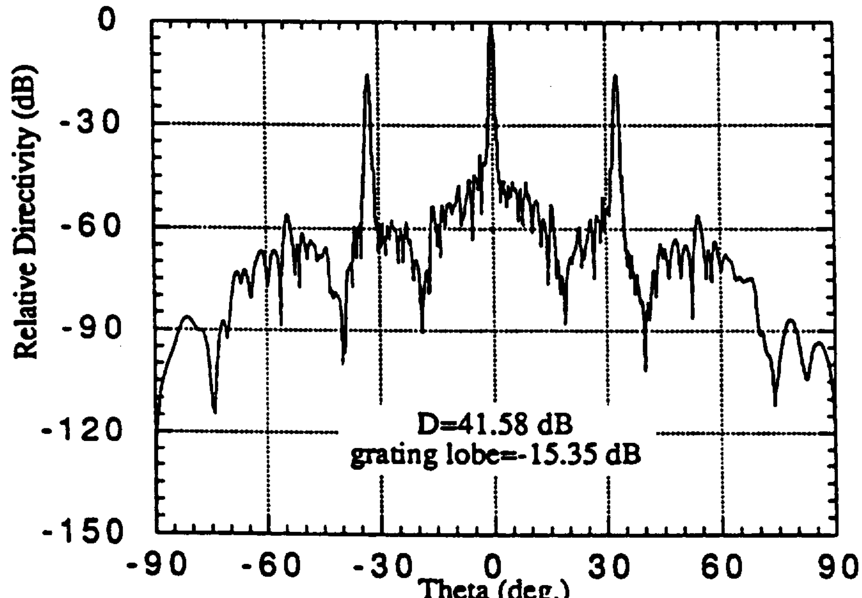


Fig. 3.2.1 E plane pattern of Design A2, scan=0 deg.

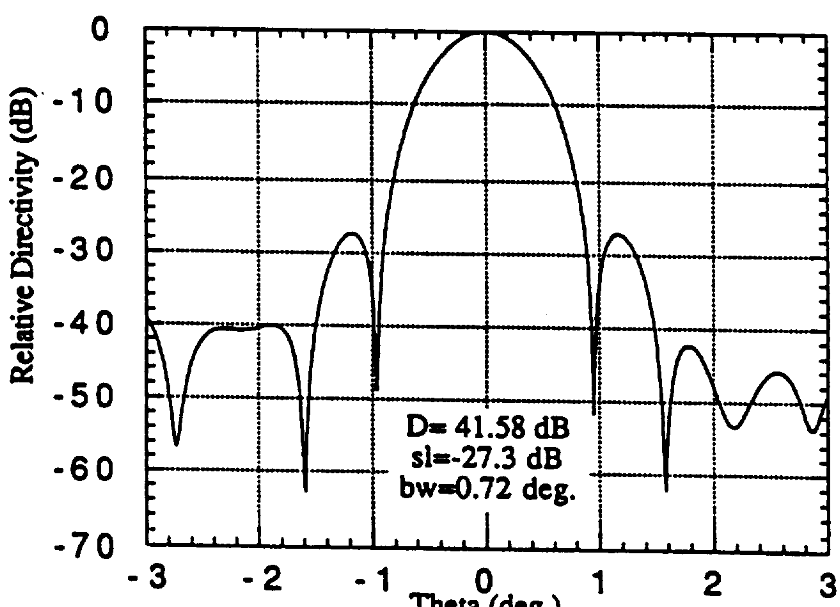


Fig. 3.2.2 E plane pattern of Design A2, scan=0 deg.

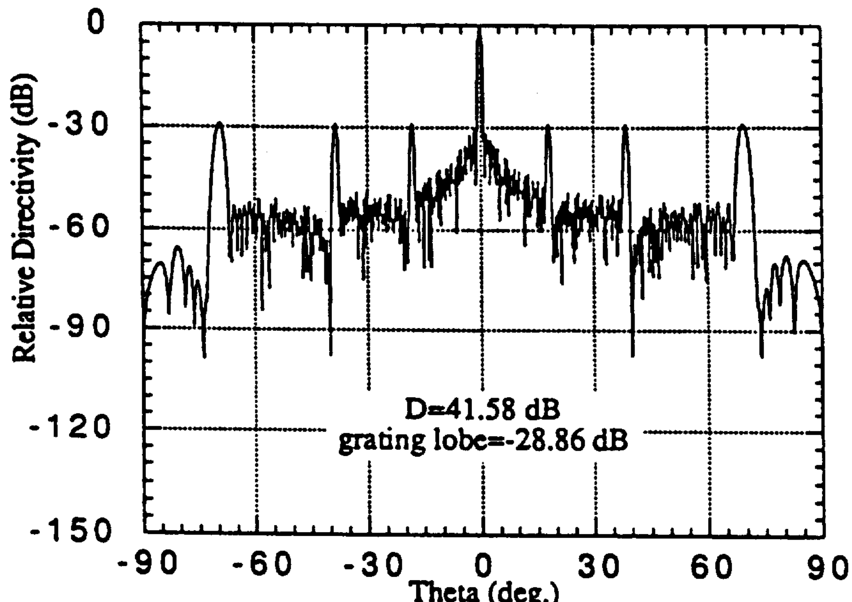


Fig. 3.2.3 H plane pattern of Design A2, scan=0 deg.

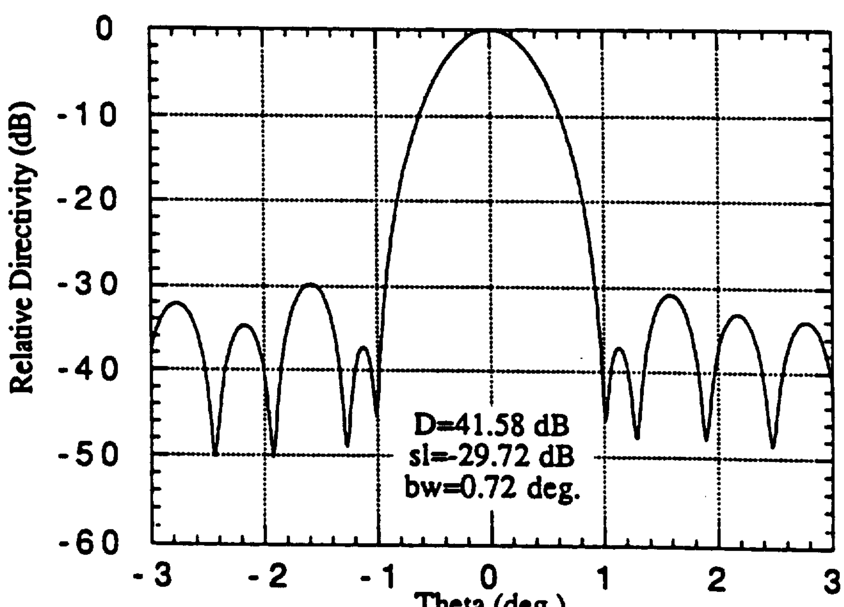


Fig. 3.2.4 H plane pattern of Design A2, scan=0 deg.

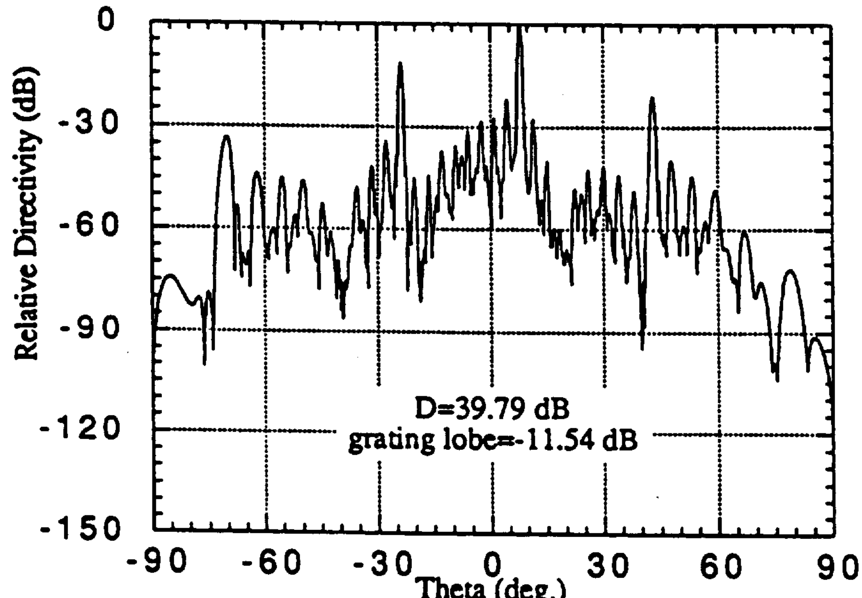


Fig. 3.2.5 E plane pattern of Design A2, scan=8 deg.

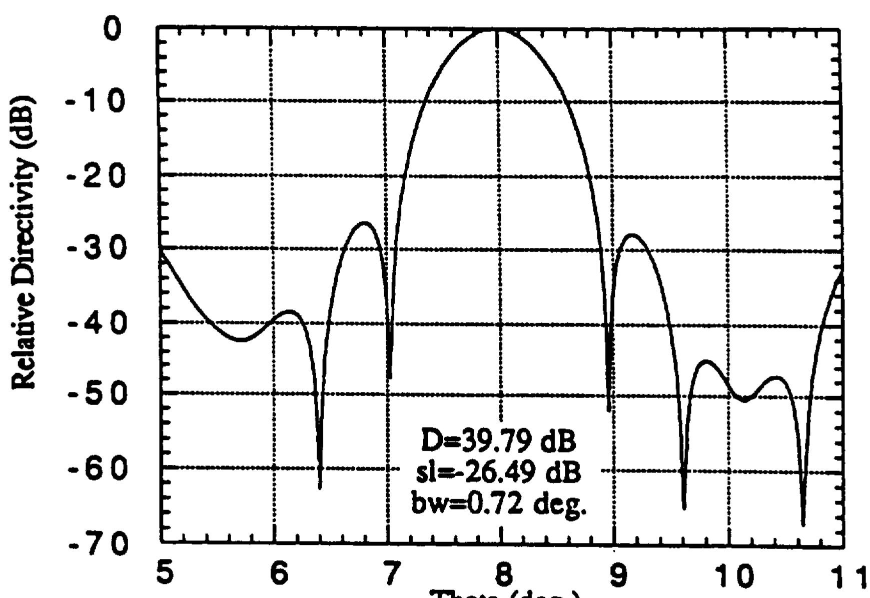


Fig. 3.2.6 E plane pattern of Dwsign A2, scan=8 deg.

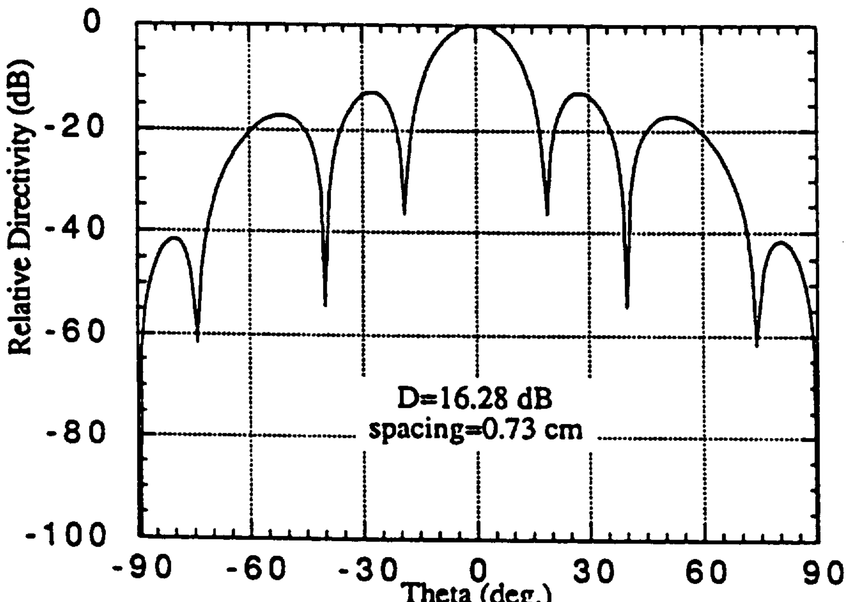


Fig. 3.2.7 E plane pattern of 4*4 microstrip patch subarray

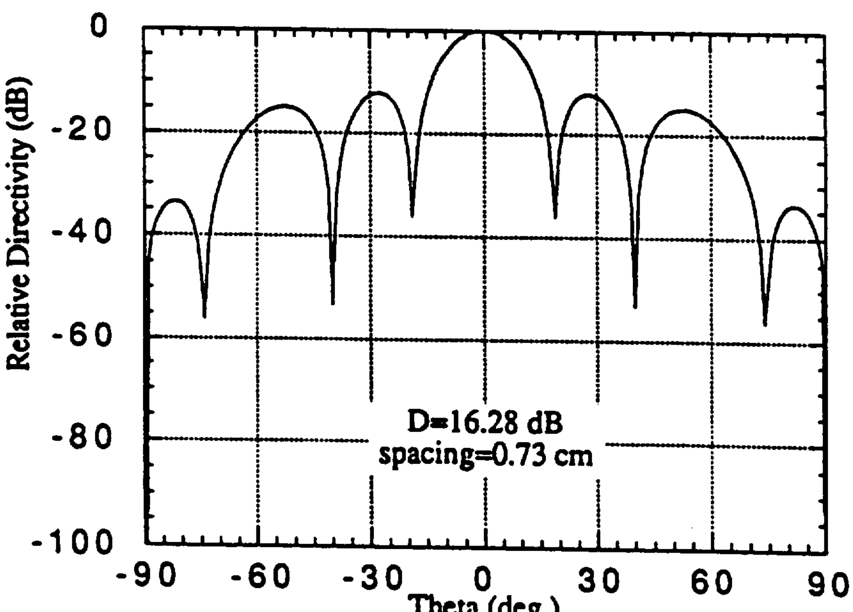


Fig. 3.2.8 H plane pattern of 4*4 microstrip patch subarray.

Chapter 4

APPLICATION B

The array will be used for communication links between MRS and MPV(Mars Piloted Vehicle) or MTV (Mars Transfer Vehicle). This is shown in Fig. 1. The required scan coverage is $\pm 30^\circ$ cone. This antenna will be based on MRS too, it is required to have only one tracking beam. The detailed specifications are given in Chapter 1.

Again, two possible antenna configurations are studied. First configuration, called B1, uses open-ended circular waveguide elements. Second configuration, called B2, uses 2×2 microstrip subarray modules as array elements. *PARCOM2* is used to carry out these studies.

4.1 Design B1

As noted above this design uses open-ended circular waveguide as array elements. The radius of the waveguide is, $r = 0.49cm$. There are a total of 7651 elements arranged in concentric hexagonal lattice. There are a total of 50 rings (See Fig. 4.1). The spacing between the elements,a, is $1.01cm$, and a/λ is 1.08.

The single element E plane pattern is plotted in Fig. 4.1.7 and has a gain of 9.08 dB. The H plane pattern is shown in Fig. 4.1.8.

At boresight, the array directivity is 46.99 dB. The E plane radiation pattern over the entire $\pm 90^\circ$ visible range is plotted in Fig. 4.1.1. As can be seen, the grating lobes are too far and too small to be of any significance. Fig. 3.1.2 shows the side lobes at -26.47 dB and the beam width of 0.7°.

Fig. 4.1.3 shows the overall H plane radiation pattern. Again, the grating lobes are insignificant. The sides lobs are observed to be -30.18 dB. and the beam width is 0.7° (Fig. 4.1.4).

The radiation pattern at a scan angle of 30° is plotted in Fig. 4.1.5. The Directivity is 43.17 dB. and grating lobes are more noticeable now. The side lobe level of -26.09 dB. can be seen in Fig. 4.1.6. The beam width is 0.8°.

4.2 Design B2

Design B2 uses low-gain 2×2 microstrip subarray modules as its basic array element. The subarray spacing is 0.42 cm. There a 50 concentric rings of elements arranged in a hexagonal lattice. There are a total of 7651 elements. The array spacing, $a = 1.01cm$. and $a/\lambda = 1.08cm$. This configuration is shown in Fig. 4.2. The diameter is $101cm$.

The E plane subarry pattern in Fig. 4.2.7 and the H Plane pattern is shown in Fig. 4.2.8. The gain is 6.69 dB.

The E plane radiation pattern for the entire array is plotted in Fig. 4.2.1. It is noted that the directivity is 44.75 dB. The grating lobes are insignificant. Fig. 4.2.2 shows the side lobe level and beam width to be -26.6 dB and 0.7°, respectively.

It can be seen in Fig. 4.2.3 that the grating lobes are insignificant in the H plane radiation plot as well. Side lobe level is seen to be -29.88 dB in Fig.4.2.4 and the beam width is 0.7°.

At a scan angle of 30° the entire visible range pattern is plotted in Fig. 4.2.5. The directivity is seen to be 41.92 dB. the grating lobes appear at -19.54 dB. Fig. 4.2.6 shows the side lobes are -25.96 dB. The beam width is broadened to 0.8°.

DESIGN B1

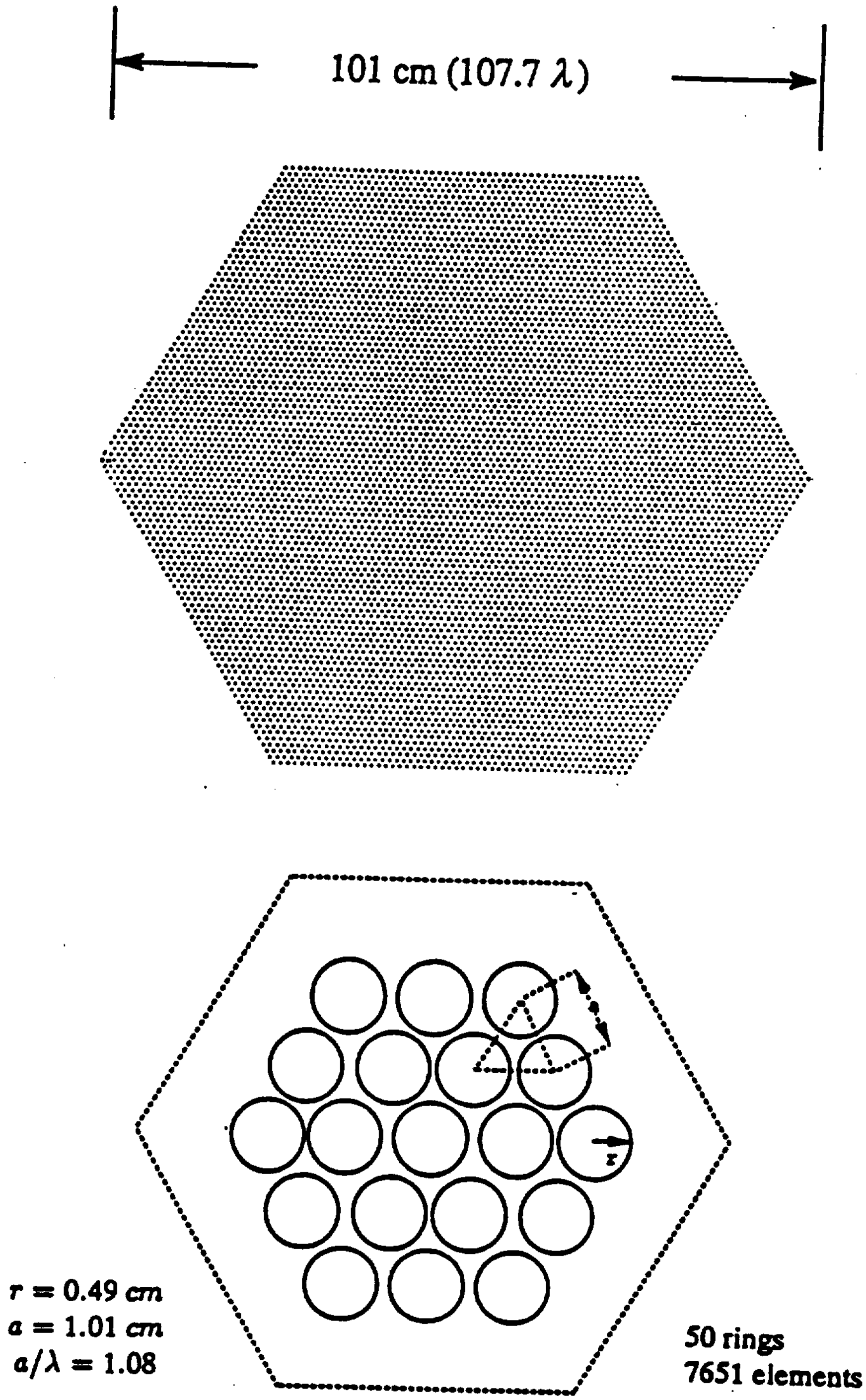


Figure 4.1. Geometry of Design B1 with open-ended circular waveguide elements.

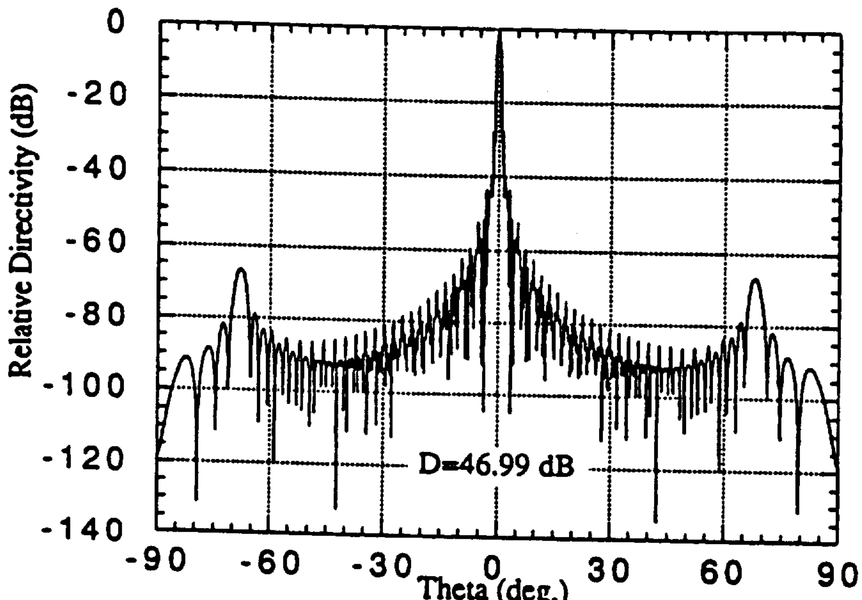


Fig. 4.1.1 E plane pattern of Design B1, scan=0 deg.

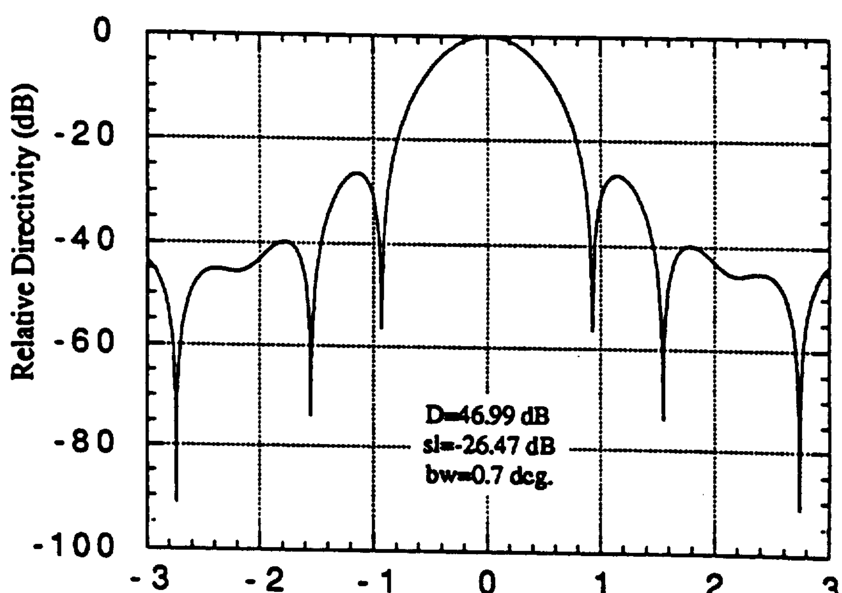


Fig. 4.1.2 E plane pattern of Design B1, scan=0 deg.

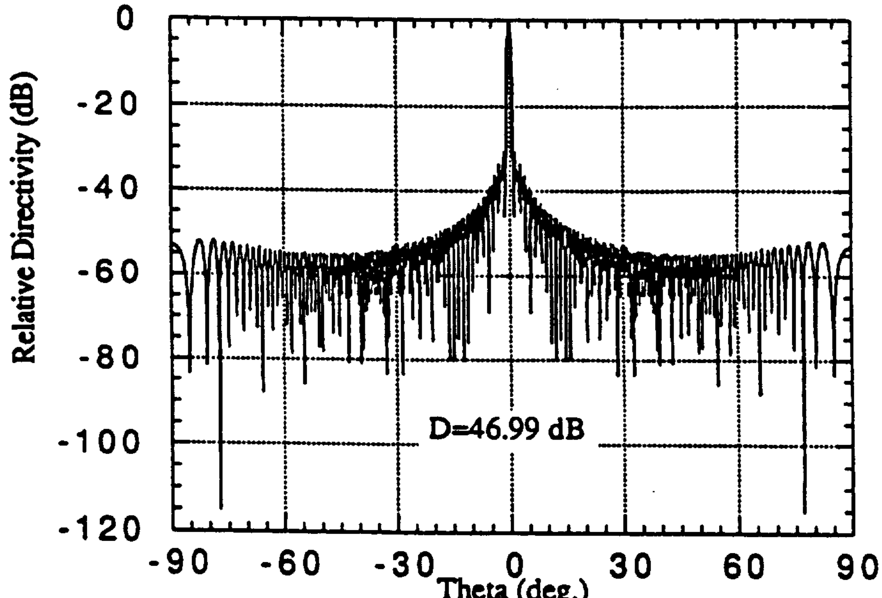


Fig. 4.1.3 H plane pattern of Design B1, sscan=0 deg.

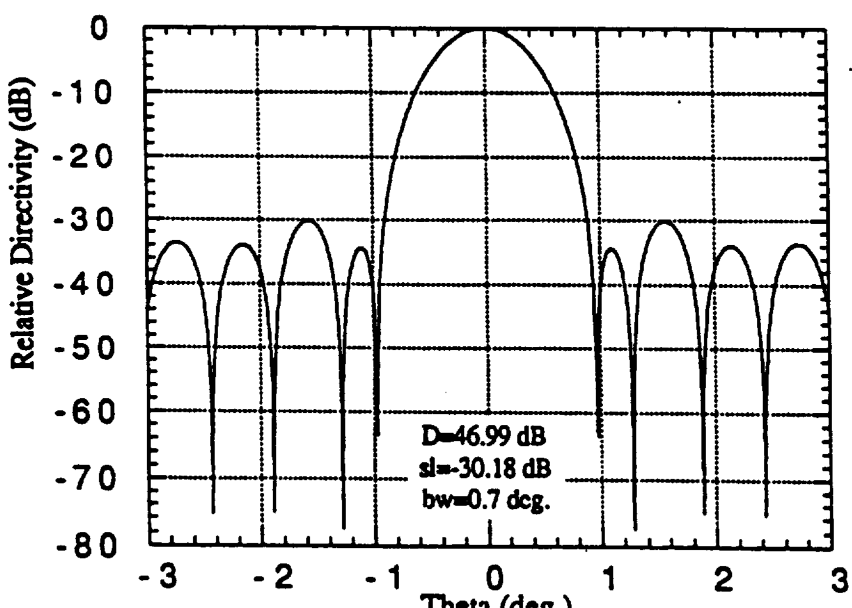


Fig. 4.1.4 H plane pattern of Design B1, scan=0 deg.

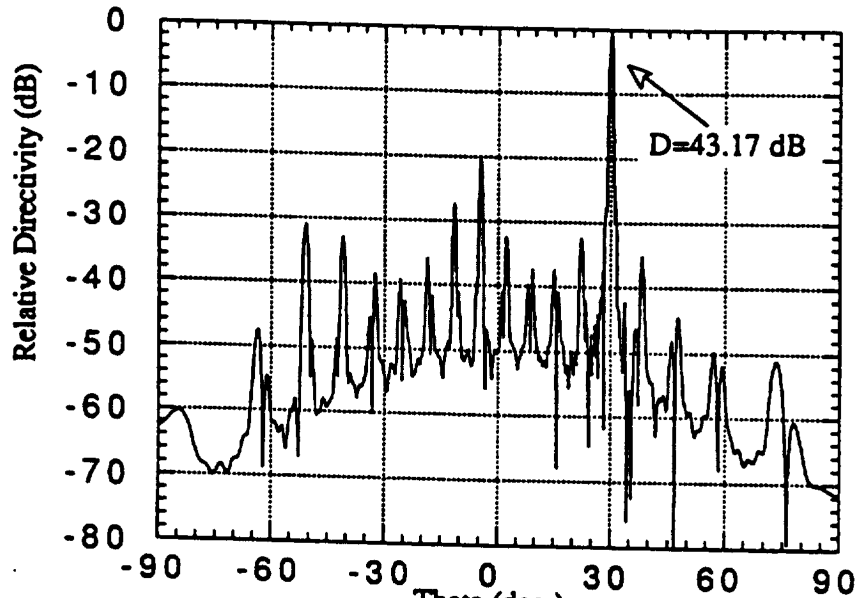


Fig. 4.1.5 E plane pattern of Design B1, scan=30 deg.

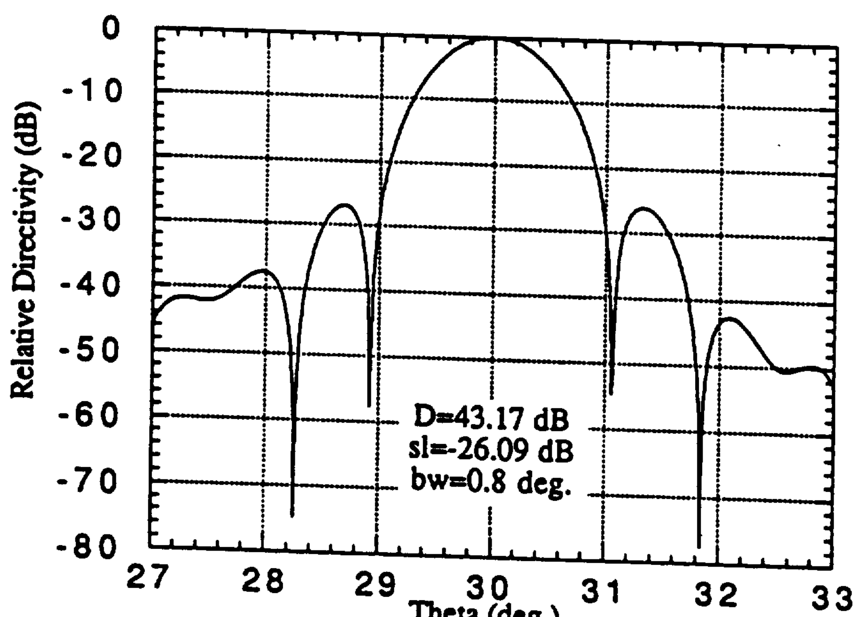


Fig. 4.1.6 E plane pattern of Design B1, scan=30 deg.

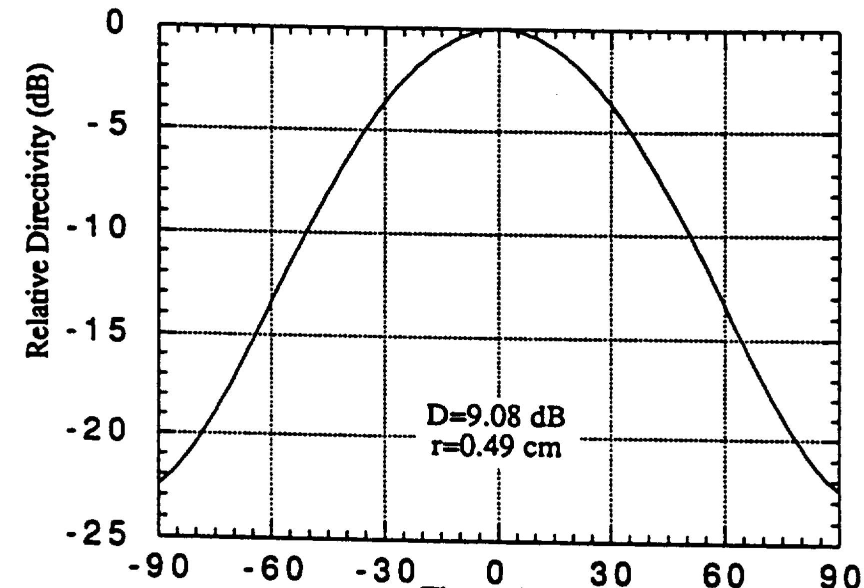


Fig. 4.1.7 E plane pattern of a single open circular guide.

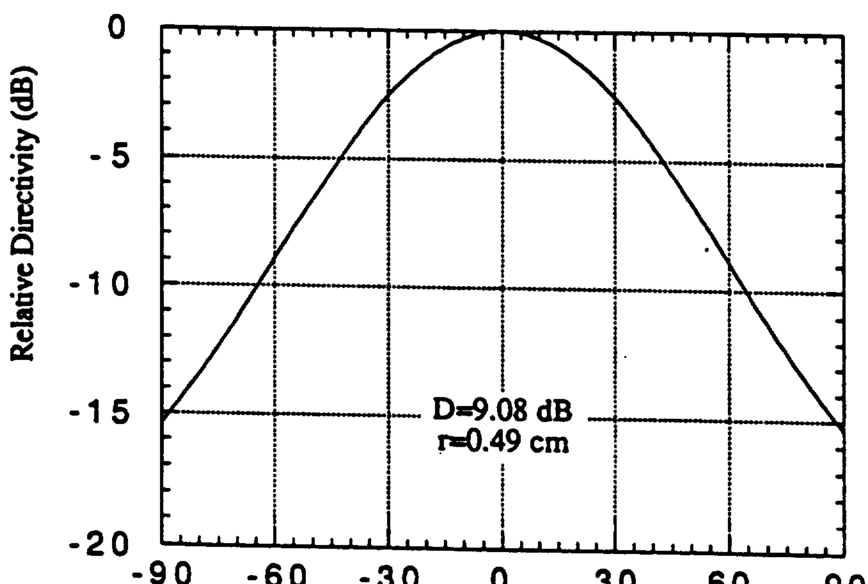


Fig. 4.1.8 H plane pattern of a single open circular guide.

DESIGN B2

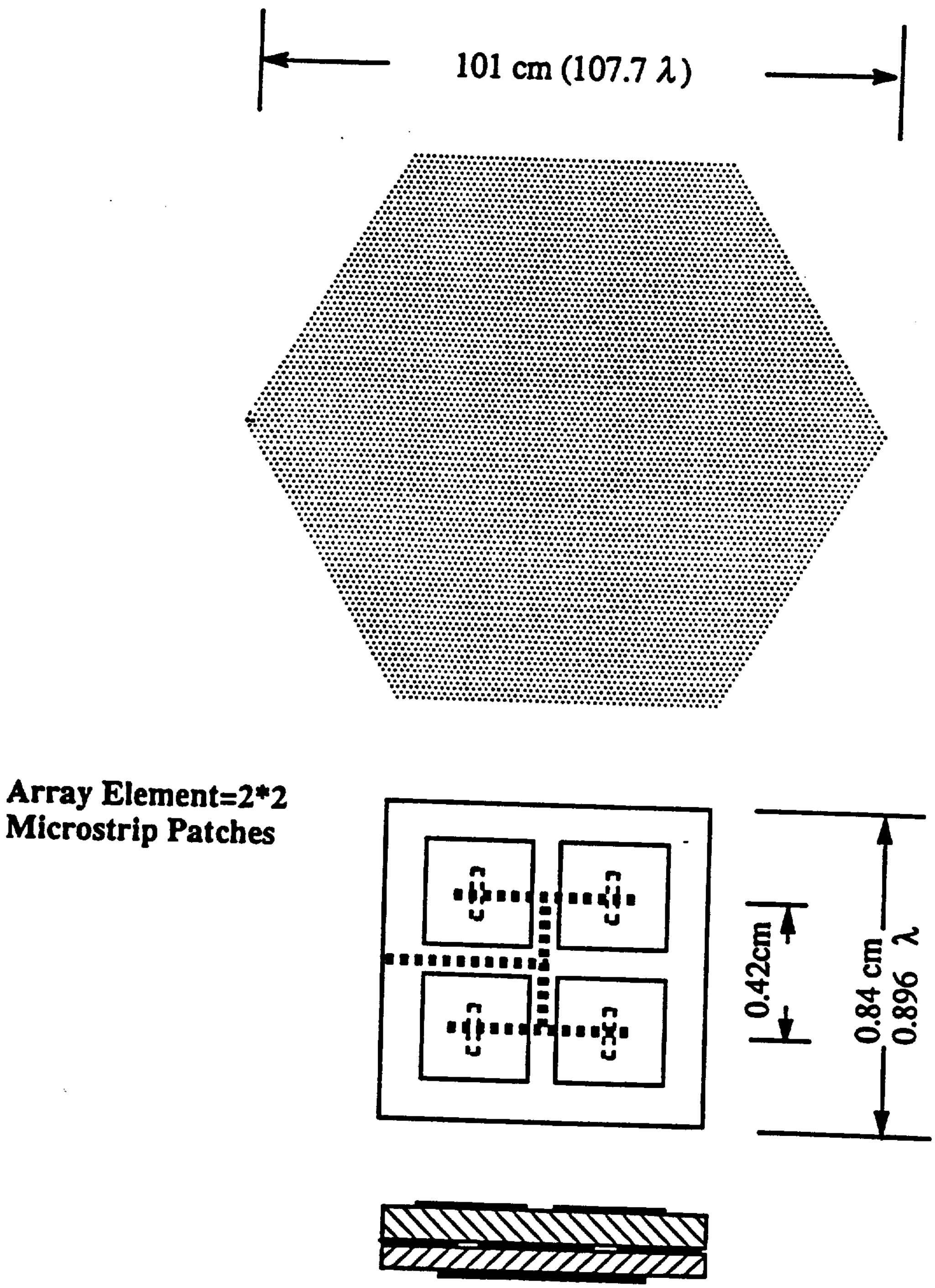


Figure 4.2. Geometry of Design B2 with 2 × 2 microstrip patch modules.

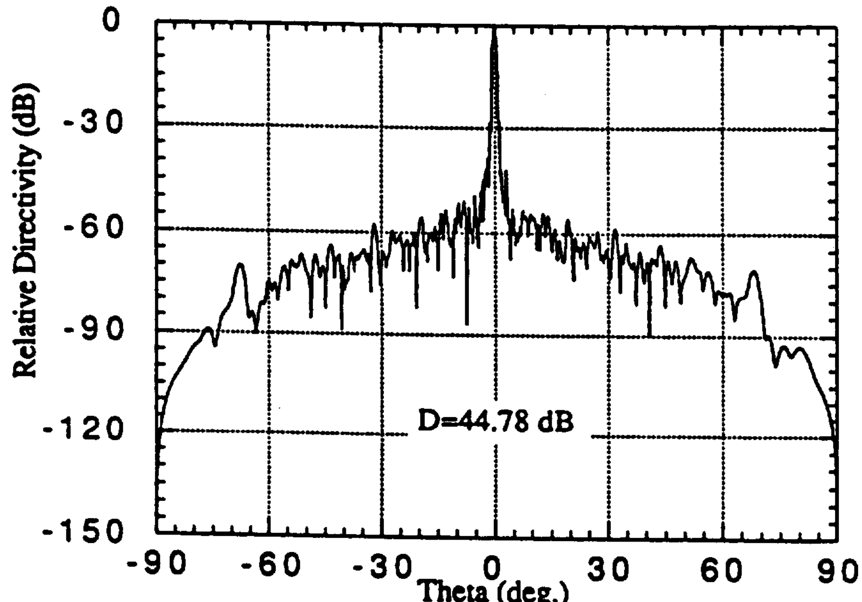


Fig. 4.2.1 E plane pattern of Design B2, scan=0 deg.

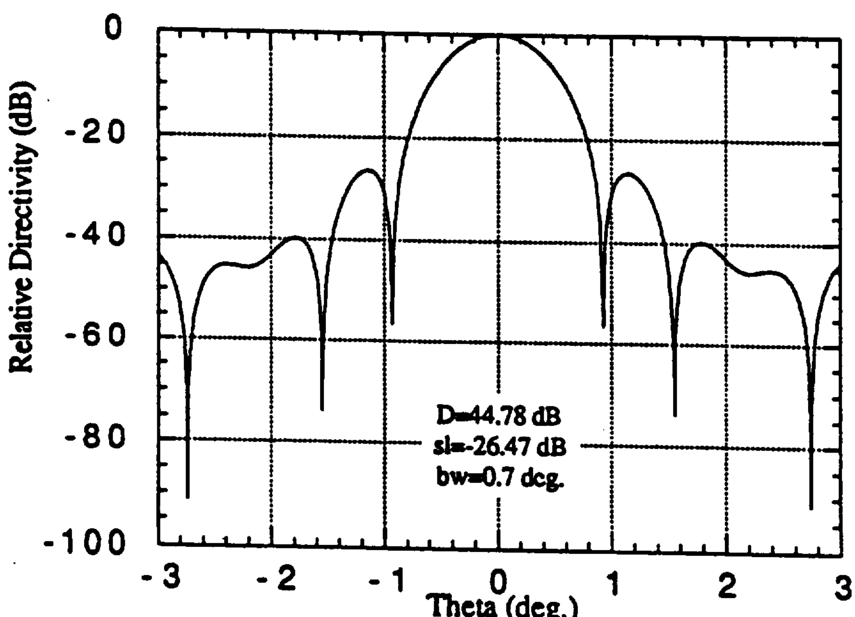


Fig. 4.2.2 E plane pattern of Design B2, scan=0 deg.

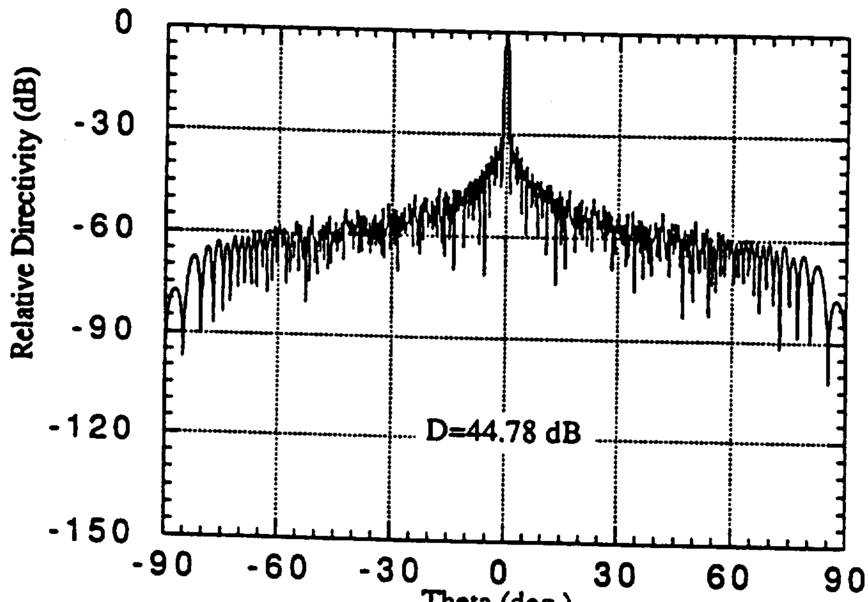


Fig. 4.2.3 H plane pattern of Design B2, scan=0 deg.

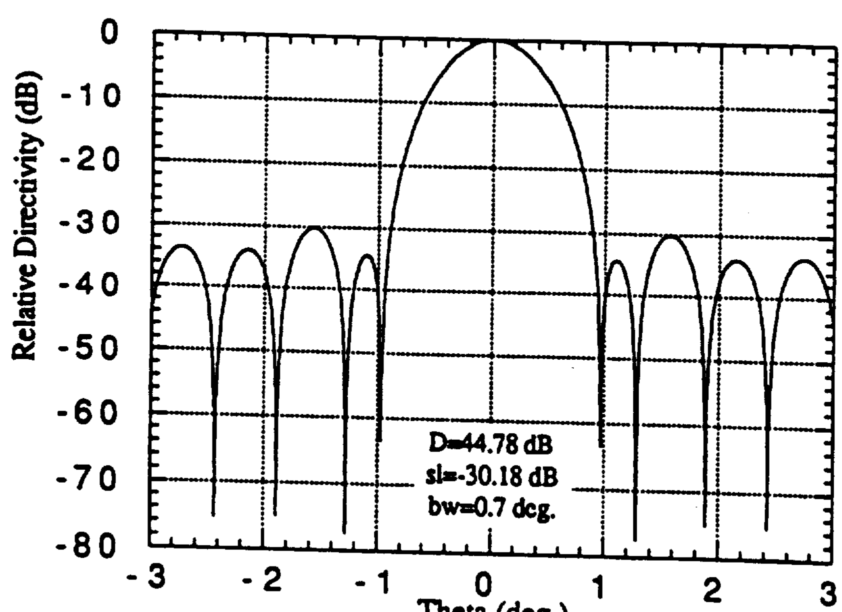


Fig. 4.2.4 H plane pattern of Design B2, scan=0 deg.

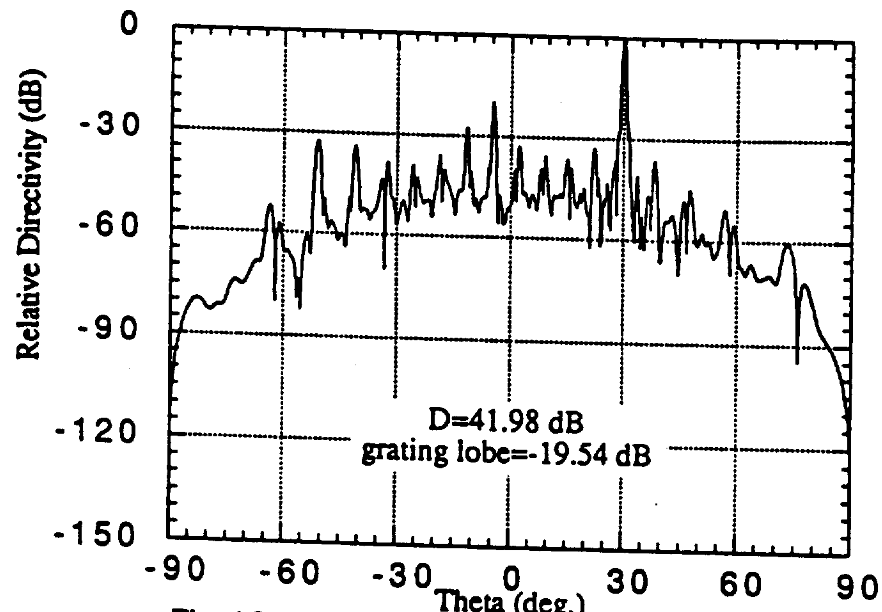


Fig. 4.2.5 E plane pattern of Design B2, scan=30 deg.

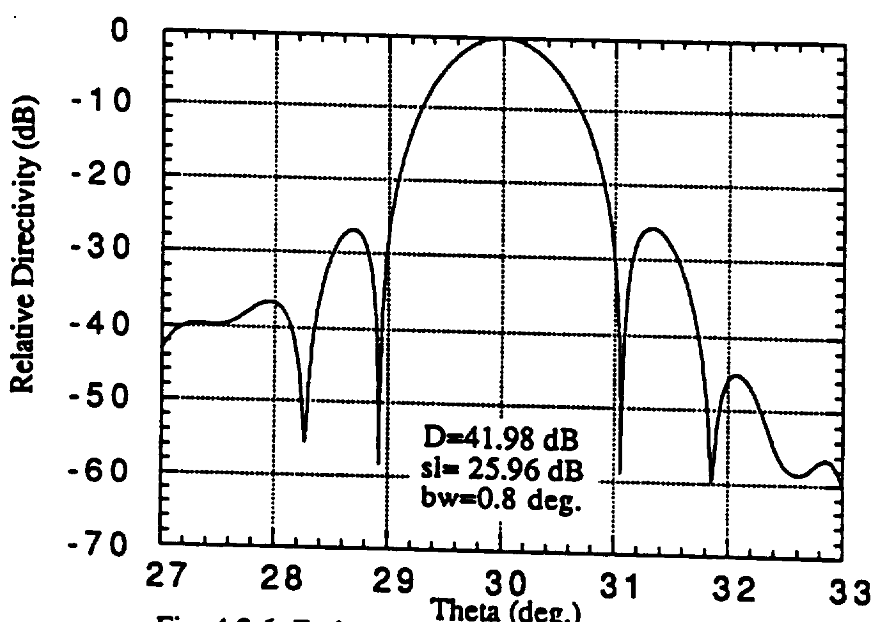


Fig. 4.2.6 E plane pattern of Design B2, scan=30 deg.

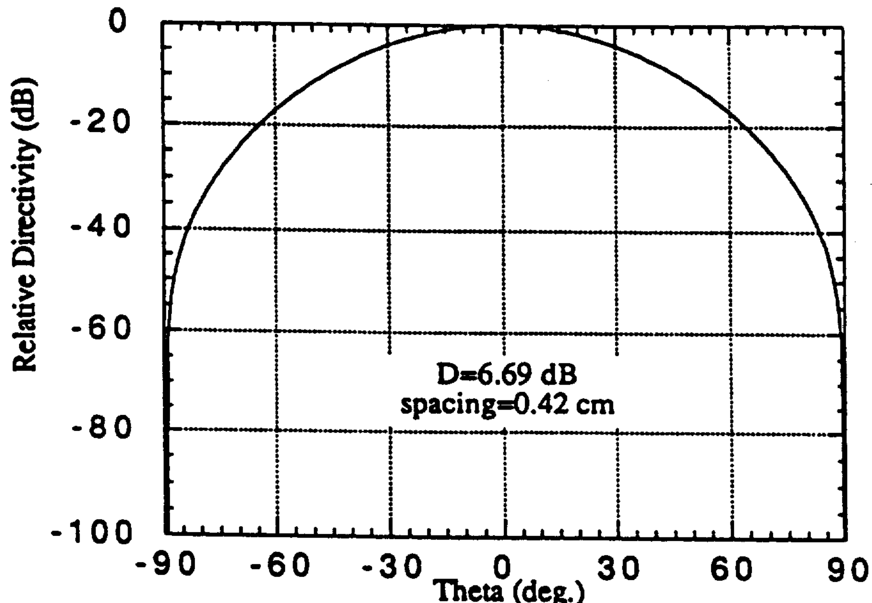


Fig. 4.2.7 E plane pattern of 2*2 microstrip patch subarray.

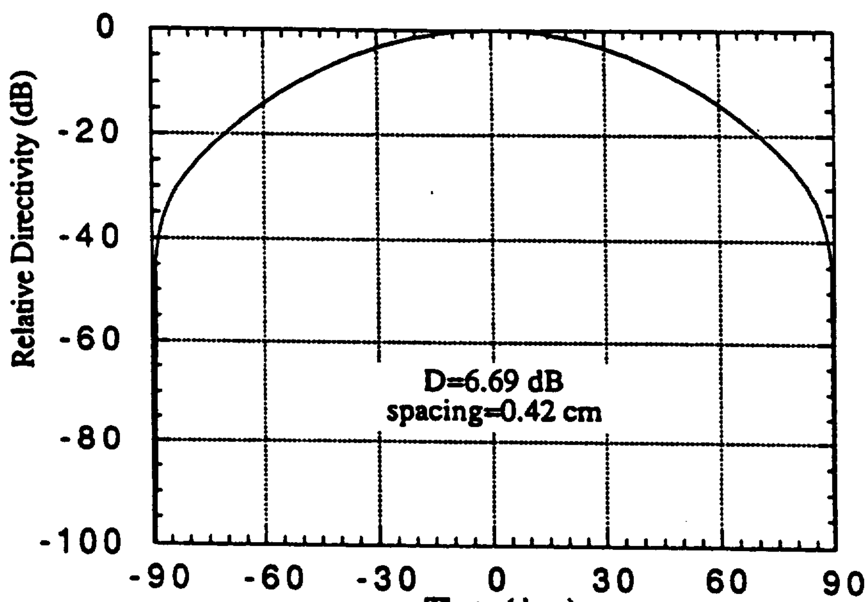


Fig. 4.2.8 H plane pattern of 2*2 microstrip patch subarray.

Chapter 5

DESIGN C

NASA has an ongoing contract with Texas Instruments to develop a modular Ka-band MMIC microstrip subarray (NAS 3–25718). Our Design C matches the dimensions of this subarray [11].

Design C uses square lattice, the spacing, $dx = dy$, is 0.82 cm, number of rows in both x and y direction are, $Nx = Ny = 60$, and the number of elements are 3600. The overall array size is $49.2 \times 49.2\ cm^2$

The subarray pattern for E plane is shown in Fig. 5.1.7 and the H plane pattern is plotted in Fig. 5.1.8. The single element gain is 3.43 dB.

At boresight, the array directivity is 40.17 dB. The E plane radiation pattern over the entire visible range is plotted in Fig. 5.1.1. Figure 5.1.2 shows the side lobe level at -20.81 dB. The beamwidth is 1.12°.

Figs. 5.1.3 and 5.1.4 show the H plane characteristics at boresight. Fig. 5.1.5 shows that at 30° scan although the grating lobe is at -1.39 dB, yet it is 40° apart from the main beam. The side lobe is about the same as at boresight (Fig. 5.1.6) and the beam width increases by about 0.17°.

DESIGN C

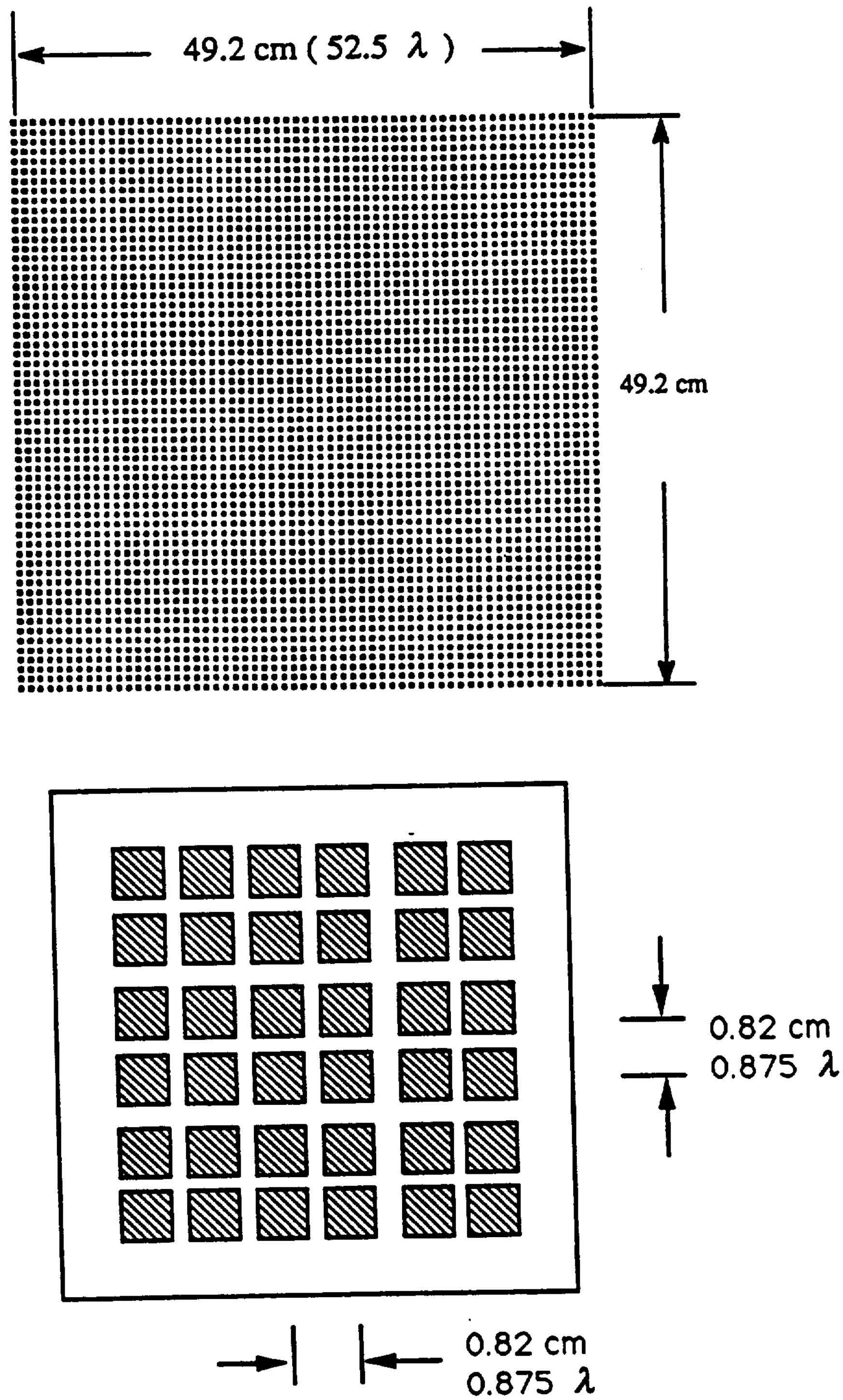


Figure 5.1. Geometry of Design C with 60 × 60 MMIC microstrip patches.

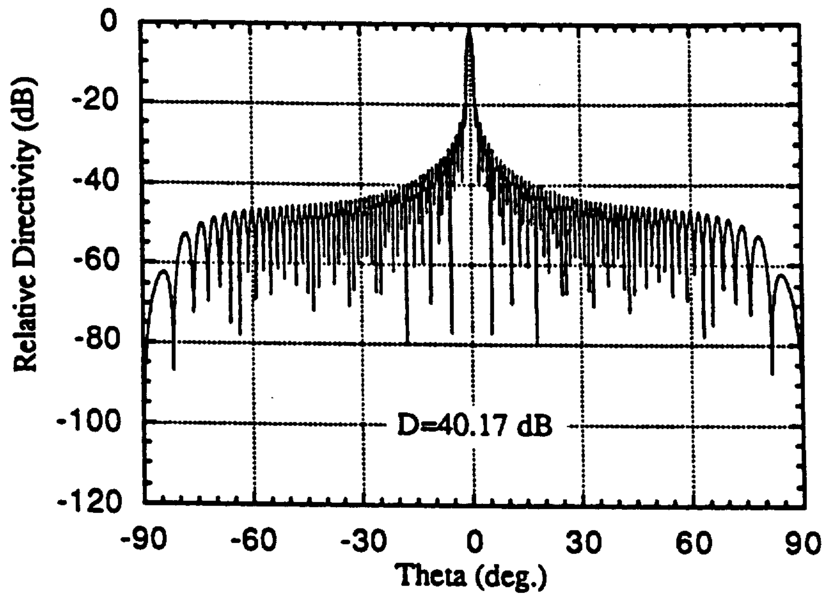


Fig. 5.1.1 E plane pattern of Design C, Scan=0 deg.

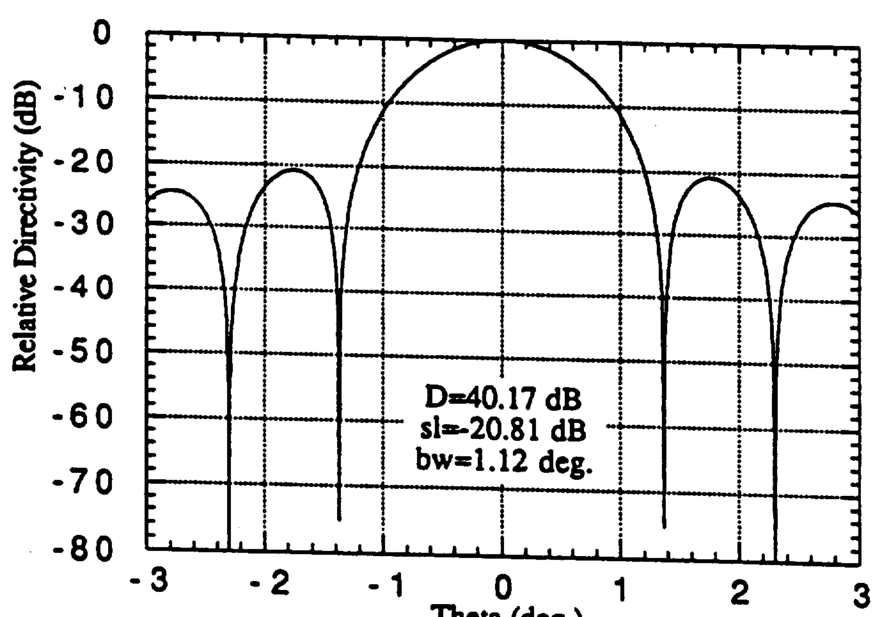


Fig. 5.1.2 E plane pattern of Design C, scan=0 deg.

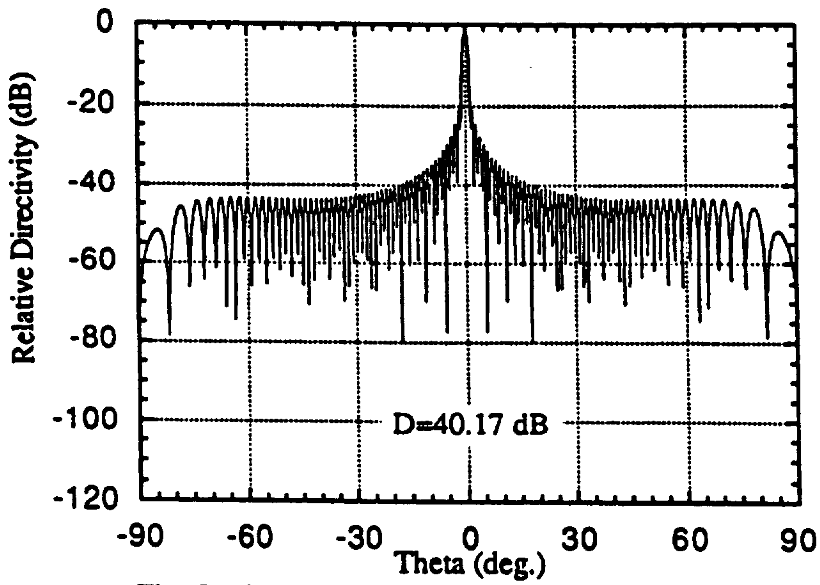


Fig. 5.1.3 H plane pattern of Design C, scan=0 deg.

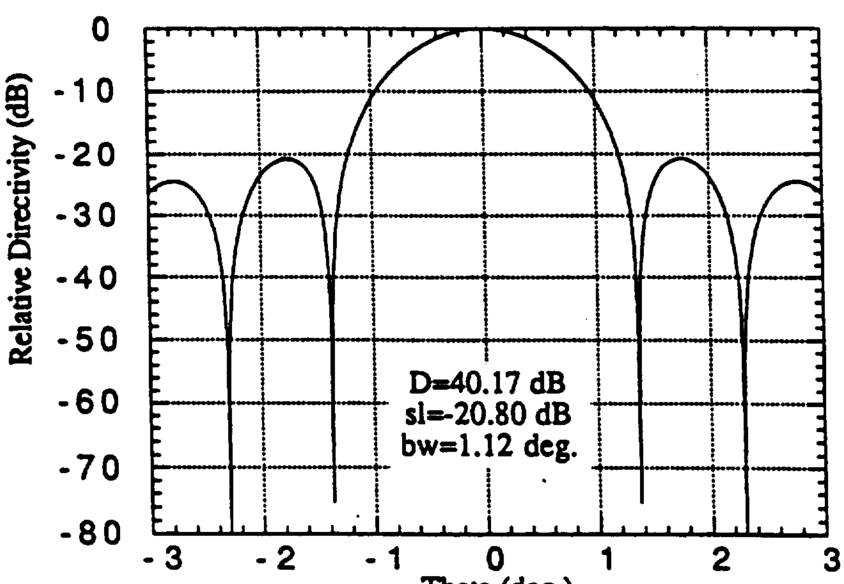


Fig.5.1.4 H plane pattern of Design C,scan=0 deg.

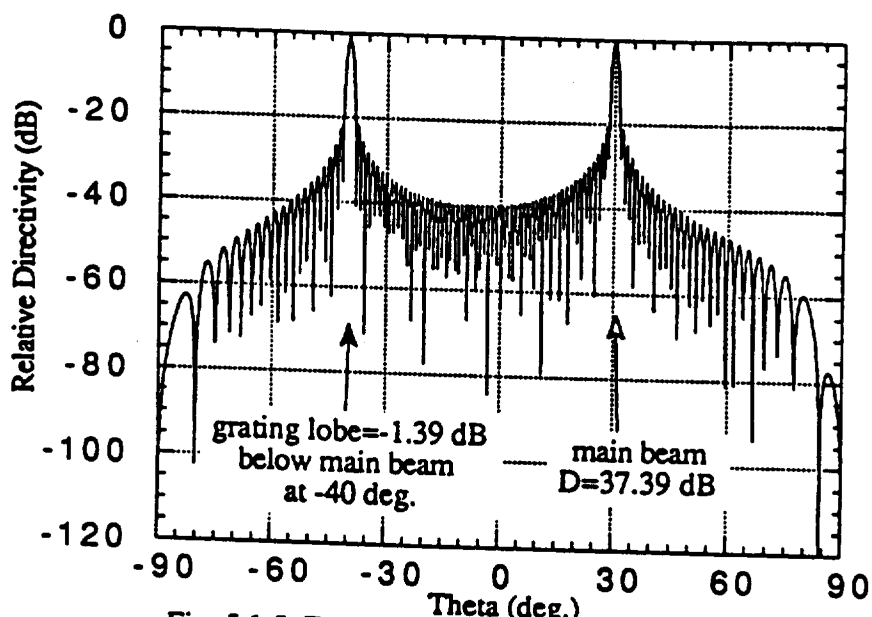


Fig. 5.1.5 E plane pattern of Design C, scan=30 deg.

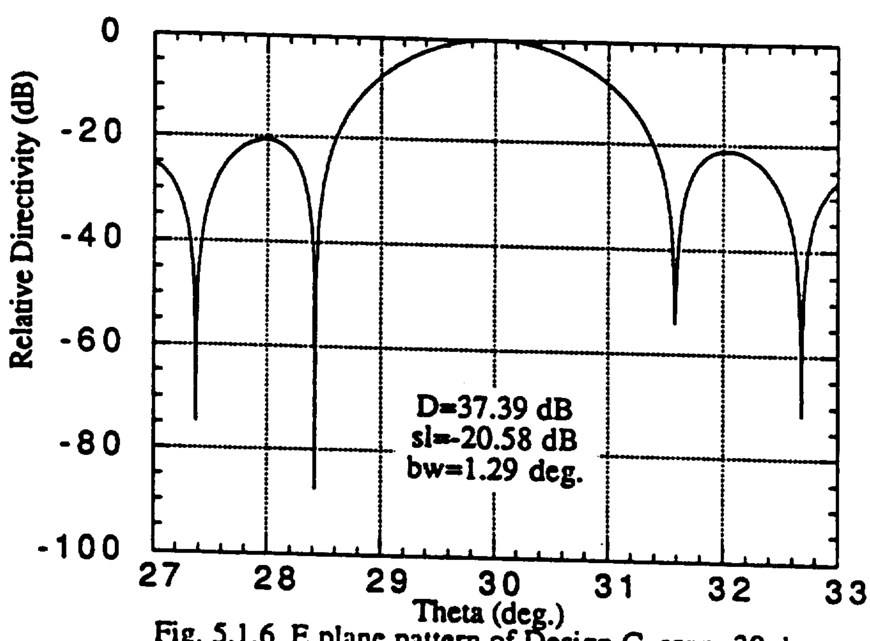


Fig. 5.1.6 E plane pattern of Design C, scan=30 deg.

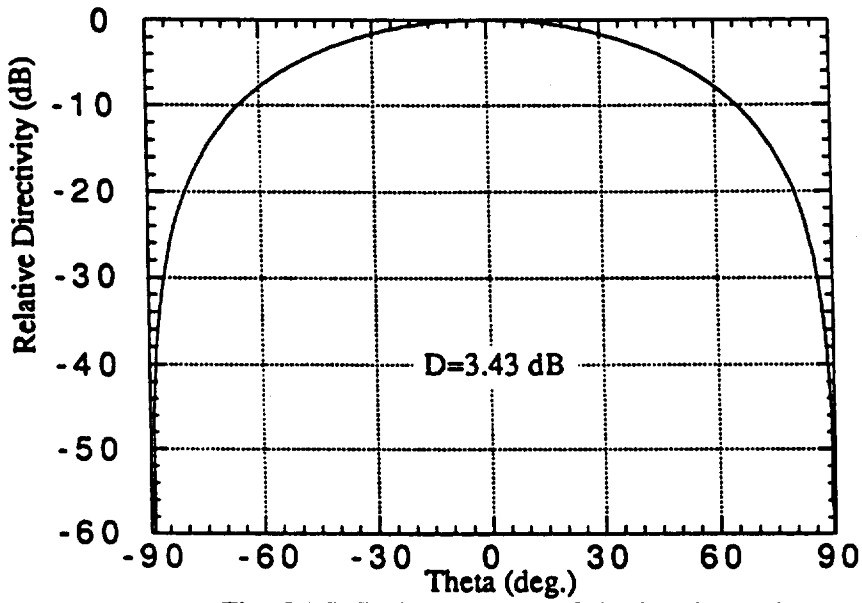


Fig. 5.1.7 E plane pattern of single microstrip

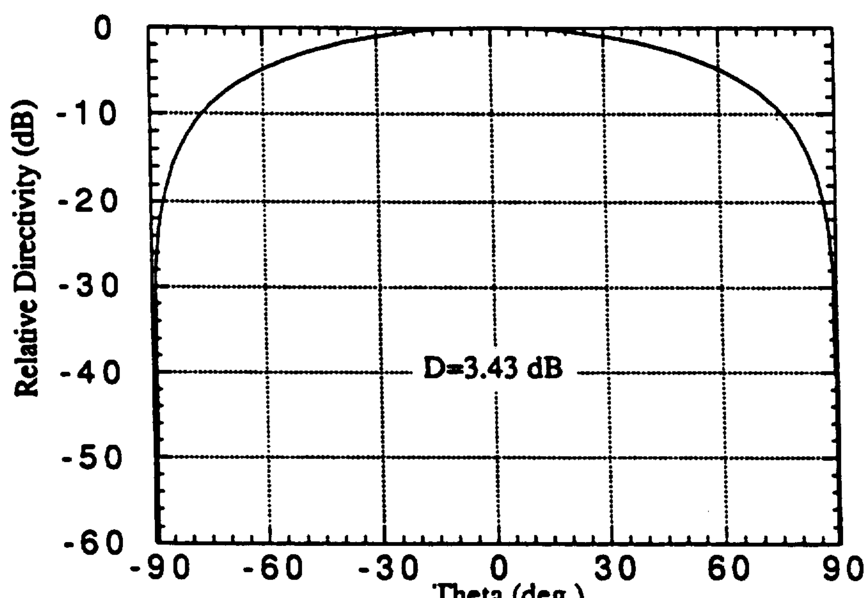


Fig. 5.1.8 H plane pattern of single microstrip

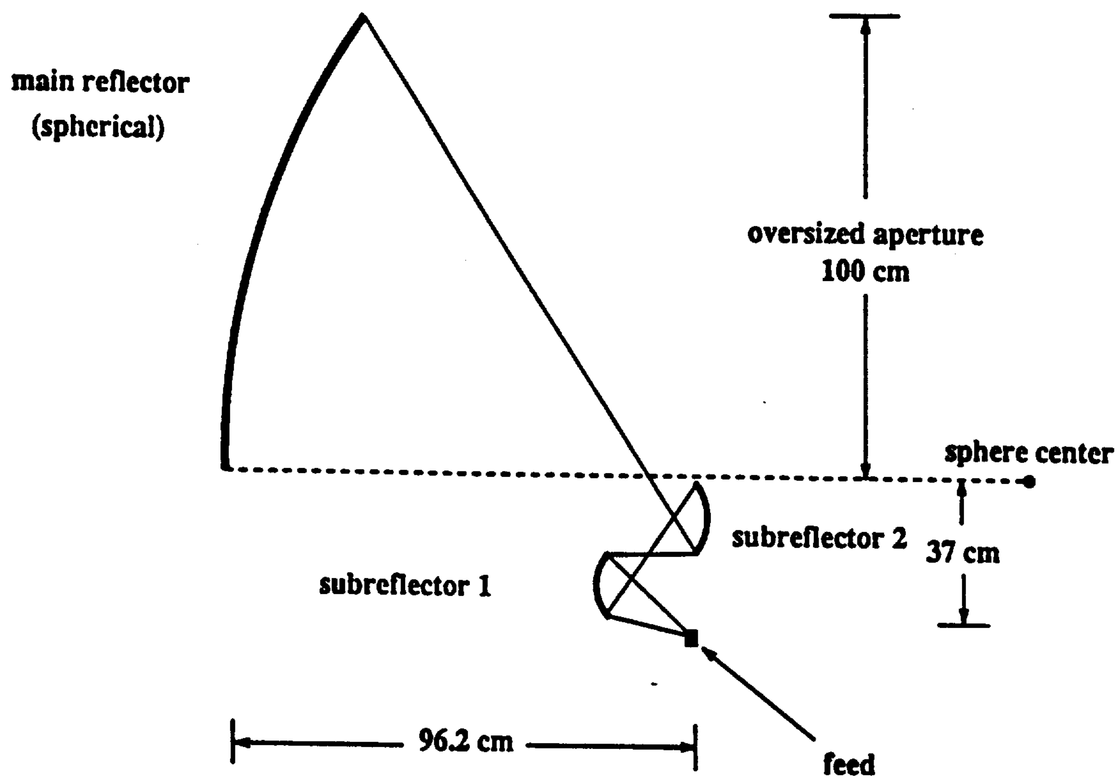
Chapter 6

DESIGN D

Design D is a Watanabe type [12]-[13] Tri-Reflector design. Two computer codes **shape3** and **sbrwn3** are used to design the Tri-Reflector antenna for scanning 8° cone. The designed Tri-Reflector Antenna geometry is shown in Fig. 6.1 and the computed secondary radiation patterns are shown in Figs. 6.1.1 to 6.1.4. The geometry design parameters are:

1. Actual diameter of the spherical main reflector is 100 cm. It's effective aperture is 74 cm. The aperture oversize is necessary for an 8° scan.
2. Radius of the main spherical reflector is 177.6 cm. Coordinate origin is at the center of the sphere. The location of the center of main reflector aperture is $x = 37.74$cm. and $y = 0.0$cm.
3. The location of feed is $x = -37.0$, $y = 0.0$,and $z = -81.4$
4. First sub-reflector center is located at $(-14.8, 0.0, -103.6)$, it's size is about 13.5×11.7 in x, y direction.
5. The center of second sub-reflector is located at $y = 0.0$ and $z = -81.4$, the size is about 15.3×11.1 in x, y direction.

To steer a beam, two sets of motion are necessary. First, the sub-reflectors rotate on an arc with respect to the center of sphere. Second, several small beam waveguides rotate or slide slightly, so that the image of feed horn is relocated to a new position in accordance with the motion of sub-reflectors. In order to implement 10 simultaneous beams, 10 sets of primary radiator systems are arranged around the center of the spherical reflector.



Fifure 6.1a. Geometry of Design D, Tri-Reflector Antenna.

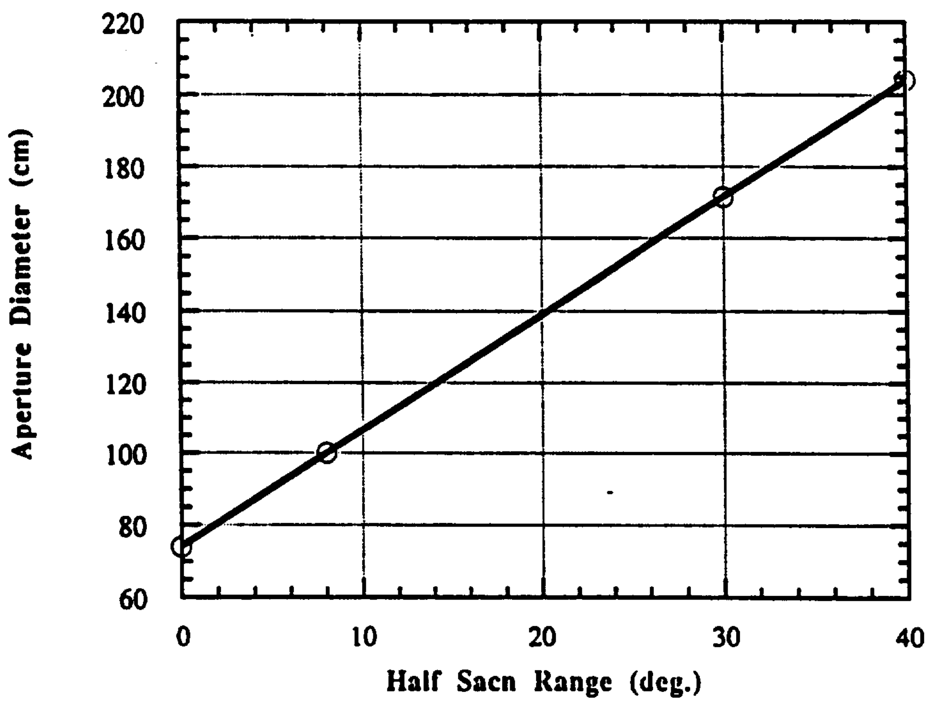


Figure 6.1b Oversized operture to scan angles for tri-reflector antenna.

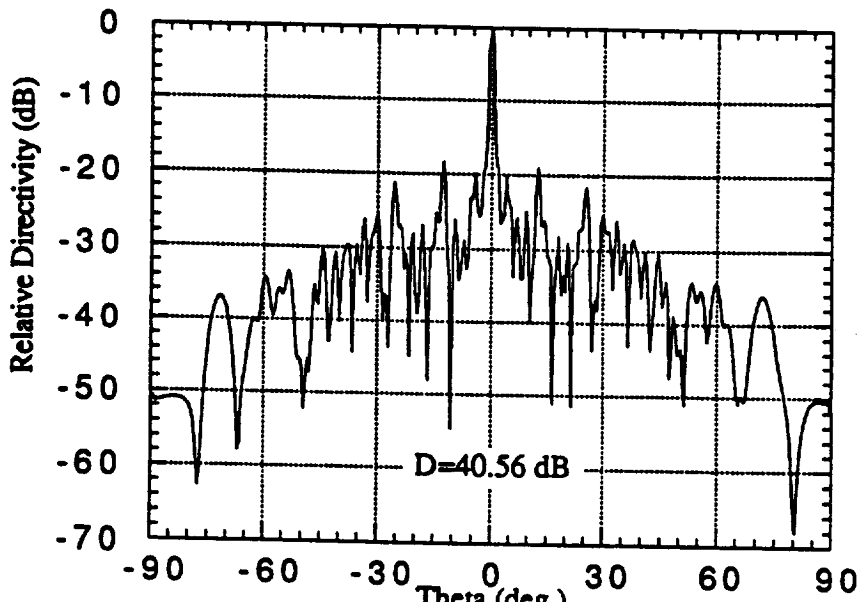


Fig. 6.1.1 Eplane pattern of Design D

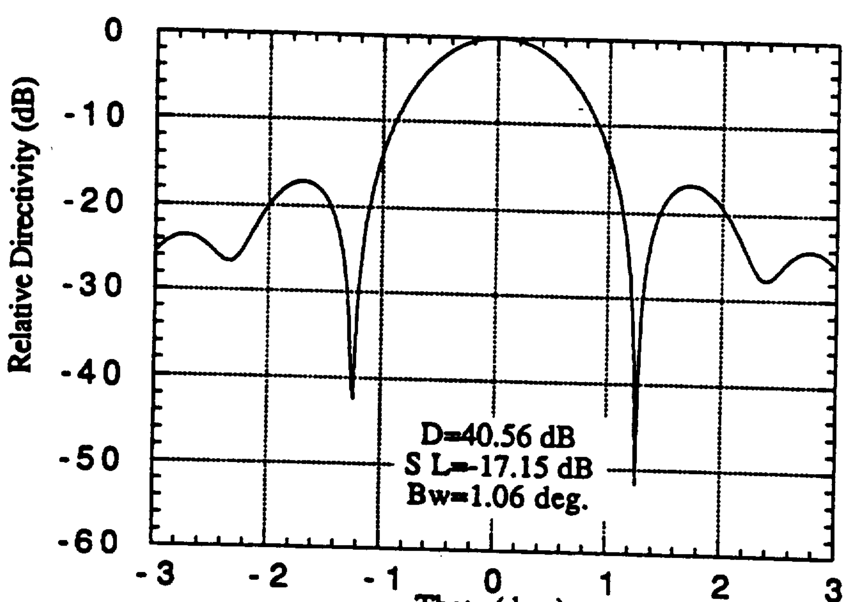


Fig. 6.1.2 E plane pattern of Design D

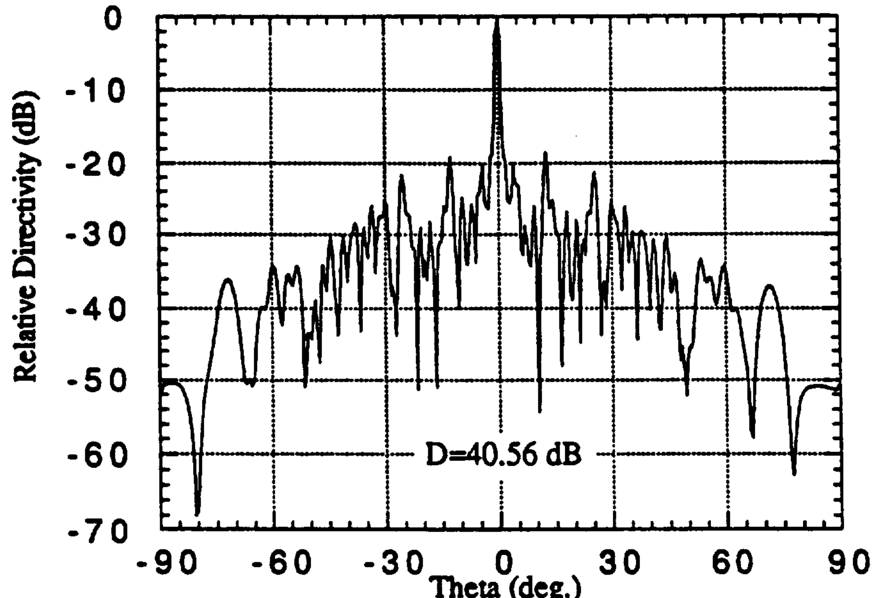


Fig. 6.1.3 H plane pattern of Design D

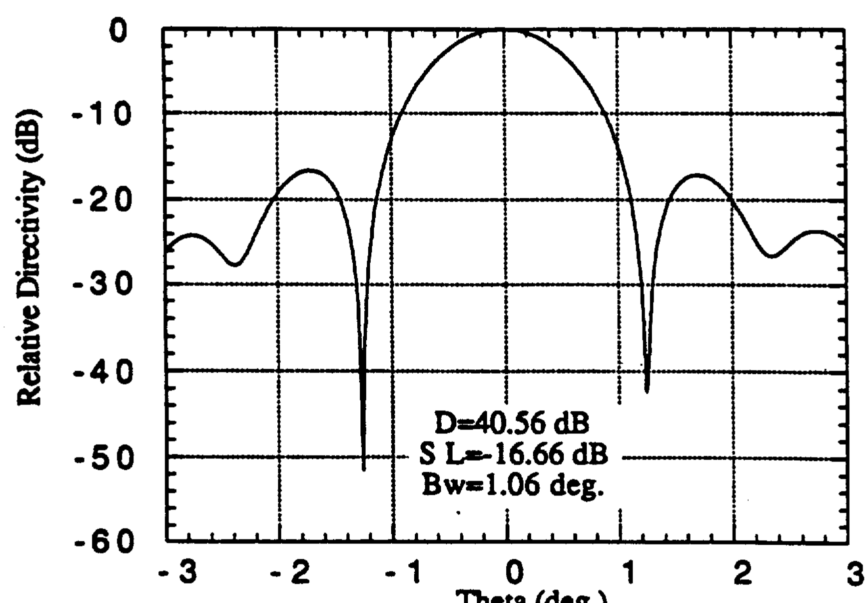


Fig. 6.1.4 H plane pattern of Design D

Chapter 7

CONCLUSIONS

Four planar phased arrays have been studied in this report. The computed results are summarized in Table 3.

1. Design A meets Application A's requirements, but grating lobes are rather high (-11.5 dB). The obvious advantage of Design A is that it uses much less array elements (631) compared with Design B (7651). When array element output power is 90 mW [11], the array output power is 56.79 W, the Array EIRP will be at least 57.5 dBW.

2. Design B meets all the requirements stipulated by the user, including requirements in both Design A and Design B. The grating lobes are below -20 dB. The side lobes are below -25 dB and array EIRP are greater than 70 dBW in the grating lobe free scan region (±30° cone).

3. Design B1 uses open-ended circular waveguide (Diameter =$1.01 cm. = 1.08\lambda$) as array element. It has rather wide grating lobe free scan area and wider impedance match frequency bandwidth (cab be greater than 20 %), higher element efficiency, and higher gain and power capability compared to microstrip patch. Design B2 uses 2×2 microstrip subarray as array elements. Its disadvantage is narrow frequency bandwidth (about $3 \sim 5$ %), slightly lower element efficiency and gain. On the other hand, it is suitable for MHMC and MMIC technology, and will promote weight and assembly Labor reduction, and increase reliability.

4. Design C is a square lattice array. It has 3600 elements, the array size is $49.2 \times 49.2\ cm^2$. Design C meets part of the requirements for applications A and B. EIRP is greater than 62.5 dBW, side lobe level less than -20 dB, but grating lobe as high as -1.39 dB to the main beam is the most discouraging factor.

5. Design D is the Tri-Reflector design. Although, it will give good scan performance, still, the size and multiple feeds which need to be mechanically tuned will increase the size and weight to unacceptable degree.

TABLE 3

Design	θ	N_r	N_e	Element type	Array Size cm	D dB	EIRP dBW	θ_{bw}	sidelobe dB	grt lobe dB	grt lobe θ
Baseline							≥ 45		-25.00		
A1	0°	14	631	Conical Horn	96.88	45.84	63.38	e: 0.72°	-27.29	-23.27	35.0°
				$r = 1.71cm$				h: 0.72°	-30.32	-10.75	17.5°
	8°			$(\lambda = 1.8)$		43.26	60.80	e: 0.72°	-26.49	-16.25	35.0°
A2	0°	14	631	4×4 Microstrip	96.88	41.58	59.12	e: 0.72°	-27.30	-15.35	35.0°
				$a = 0.73cm$				h: 0.72°	-29.72	-28.86	17.5°
	8°			$(\lambda = .78)$		39.79	57.33	e: 0.72°	-26.49	-11.54	35.0°
Baseline							≥ 45		-25.00		
B1	0°	50	7651	Conical Horn	101.0	46.99	75.37	e: 0.7°	-26.47	≤ 60	—
				$r = 0.49cm$				h: 0.7°	-30.18	None	—
	30°			$(\lambda = .52)$		43.26	71.64	e: 0.8°	-26.09	-16.25	35.0°
B2	0°	50	7651	2×2 Microstrip	101.0	44.75	73.13	e: 0.7°	-26.60	≤ -50	—
				$a = 0.42cm$				h: 0.7°	-29.88	None	—
	30°			$(\lambda = .44)$		41.98	70.36	e: 0.8°	-25.96	-19.54	35.0°
C	0°		3600	MMIC Microstrip	49.2×49.2	40.17	65.28	e: 1.12°	-20.81	None	—
				$0.82 \times 0.82cm^2$				h: 1.12°	-20.80	None	—
	30°			$(\lambda = .87)$		37.39	62.50	e: 1.29°	-20.58	-1.39	70.0°

Chapter 8

REFERENCES

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[11] R. Q. Lee et. al.,"Ka-band MMIC Microstrip Array for High Rate Communications", *AIAA 91–3421*, Sept. 1991.

[12] C. S. Lee and S. W. Lee, " Extrapolation Technique for Shaping Tri-Reflectors", *Journal of Electromagnetic Waves and Applications*, vol. 6, No. 2, pp 157-168, 1992.

[13] Fumio Watanabe, " An Offset Spherical Tri-Reflector Antenna", *The Transection of the IECE of Japan*, vol. E66, No. 2, Feb. 1983.

Appendix A

INPUT PARAMETERS

This appendix has copies of input files used for various designs.

Input file " parcom2.dat " for Design A1. scan 0 deg., theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
*************************************************************
Enter following data in feed coordinates.
*************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
 --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
 --     ENTER THE ELEMENT RADIUS "a",
 --     THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
92, 1.71, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
84.0
*************************************************************************
Enter following data in array coordinates
*************************************************************************
----     ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:    20; NUMBER OF ELEMENTS, JUNK,
  --              21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:    30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 14.0, 0.0
3.46,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
****************************************************************************
Enter following data in main coordinates.
****************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                 2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 721
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
"parcom2.dat" 100 lines, 4482 characters
rel3 220% Input data file "parcom2.dat" for Design A1, scan 0 deg.
```

Input file " parcom2.dat " for Design A1. scan 0 deg., theta: -3 to 3 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
****************************************************************
Enter following data in feed coordinates.
****************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
 --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
92, 1.71, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
84.0
**********************************************************************
Enter following data in array coordinates
**********************************************************************
----     ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:      0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
 --                  1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:     20; NUMBER OF ELEMENTS, JUNK,
  --               21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:    30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 14.0, 0.0
3.46,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
****************************************************************************
Enter following data in main coordinates.
****************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI              2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-3.00, 3.00, 601
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design A1. scan 8 deg. , theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
*****************************************************************
Enter following data in feed coordinates.
*****************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --      IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
92, 1.71, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
84.0
**********************************************************************
Enter following data in array coordinates
**********************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:    20; NUMBER OF ELEMENTS, JUNK,
  --              21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
58   --- HEXAGONAL:    30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
59  30, 14.0, 0.0
60  3.46,.3290,90.
61  ---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
62   --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
63  0
64  2,3
65  ---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
66   --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
67   --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
68   --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
69   --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
70   --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
71   --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
72   --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
73  4
74  35.0, 6.0
75  ---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
76  4
77  ---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
78    -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
79    -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
80  0
81  7.0,0.0,-345
80  0
81  7.0,0.0,-345
88  **********************************************************************
89  Enter following data in main coordinates.
90  **********************************************************************
91  ---- CHOOSE OBSERVATION VARIABLES
92       1 = THETA,PHI                2 = ELEVATION, AZIMUTH
93  1
94  ---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
95  8.0, 00.00
96  ---- RANGE OF FAR-FIELD ANGLES
97   --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
98  -90.00, 90.00, 721
99   --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
100 00.00, 90.00, 2
```

Input file " parcom2.dat " for Design A1. circular guide element, theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
**************************************************************
Enter following data in feed coordinates.
**************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --      IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A PÓSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
92, 1.71, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
84.0
************************************************************************
Enter following data in array coordinates
************************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:      20; NUMBER OF ELEMENTS, JUNK,
  --                21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 0.0, 0.0
3.46,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
1.0, 0.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
0
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:        1=ANALYTICAL FORMULA FOR Q-FEED
                        2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                        3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                        4=NUMERICAL INTEGRATION
4
1.17E9
**************************************************************************
Enter following data in main coordinates.
**************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI               2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 181
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design A2. scan 0 deg., theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
****************************************************************
Enter following data in feed coordinates.
****************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --     ENTER THE ELEMENT RADIUS "a",
  --     THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS; 1=TE11, 2=TE21,DUMMY
40, 1.71, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
100.0
**********************************************************************
Enter following data in array coordinates
**********************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:    0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --               1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:    20; NUMBER OF ELEMENTS, JUNK,
  --              21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:    30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 14.0, 0.0
3.46,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
************************************************************************
Enter following data in main coordinates.
************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI              2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 721
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design A2. 4*4 microstrip patch subarray, theta: -90 to 90

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
************************************************************
Enter following data in feed coordinates.
************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
 --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
 --      ENTER THE ELEMENT RADIUS "a",
 --      THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
31, 1.3, 0.8, 1.0
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
73.0
*******************************************************************
Enter following data in array coordinates
*******************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:    0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --               1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:    20; NUMBER OF ELEMENTS, JUNK,
  --              21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
10, 4.0, 4.0
0.73, 0.73, 90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
0
1.0, 0.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
0
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
*******************************************************************************
Enter following data in main coordinates.
*******************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 181
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design B1. scan 0 deg., theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
**************************************************************
Enter following data in feed coordinates.
**************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --      IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
92, 0.49, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
84.0
*************************************************************************
Enter following data in array coordinates
*************************************************************************
----     ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:    20; NUMBER OF ELEMENTS, JUNK,
  --              21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
--- HEXAGONAL:    30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 50.0, 0.0
1.01,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY  1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:       1=ANALYTICAL FORMULA FOR Q-FEED
                       2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                       3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                       4=NUMERICAL INTEGRATION
4
1.17E9
**************************************************************************
Enter following data in main coordinates.
**************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 721
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design B2. scan 0 deg. , theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
************************************************************
Enter following data in feed coordinates.
************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
 --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
 --     ENTER THE ELEMENT RADIUS "a",
 --     THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
40, 0.49, 1,1
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
100.0
*********************************************************************
Enter following data in array coordinates
*********************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
 --                 1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:      20; NUMBER OF ELEMENTS, JUNK,
 --                21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 50.0, 0.0
1.01,.3290,90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH .
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:        1=ANALYTICAL FORMULA FOR Q-FEED
                        2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                        3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                        4=NUMERICAL INTEGRATION
4
1.17E9
******************************************************************************
Enter following data in main coordinates.
******************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 721
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design B2. 2*2 microstrip patch subarray,theta: -90 to 90

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
****************************************************************
Enter following data in feed coordinates.
****************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
31, 1.3, 0.8, 1.0
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
73.0
**************************************************************************
Enter following data in array coordinates
**************************************************************************
----     ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:     20; NUMBER OF ELEMENTS, JUNK,
  --               21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
10, 2.0, 2.0
0.42, 0.42, 90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) {DEF=1}
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. {DEFAULT= 1, 0}
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
0
1.0, 0.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
0
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
**************************************************************************
Enter following data in main coordinates.
**************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 181
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design C . scan 0 deg. , theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
  0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
**************************************************************
Enter following data in feed coordinates.
**************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
  --        IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --    ENTER THE ELEMENT RADIUS "a",
  --    THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
31, 1.3, 0.8,1.0
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
73.0
************************************************************************
Enter following data in array coordinates
************************************************************************
----    ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:     0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:     20; NUMBER OF ELEMENTS, JUNK,
  --               21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
10, 60.0, 60.0
0.82, 0.82, 90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG= 0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) {DEF=1}
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
4
35.0, 6.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
4
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
**************************************************************************
Enter following data in main coordinates.
**************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 721
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " parcom2.dat " for Design C . microstrip patch element, theta: -90 to 90 deg.

```
---- INPUT FILE FOR PROGRAM parcom2 (GENERAL PHASED ARRAY ANT.)
     THE OUTPUT FILE IS THE SCREEN.
---- INPUT LENGTH UNIT (all angles in degrees)
 --- 1=INCH, 2=CENTIMETER, 3= MILIMETER
2
---- SPECIFY FREQUENCY IN GHZ OF WAVELENGTH
 --- IF FREQUENCY, ENTER 1, FREQUENCY VALUE
 --- IF WAVELENGTH, ENTER 2, WAVELENGTH VALUE
1, 32.0
---- ARRAY COORD. CENTER IN MAIN COORDINATES
   0.00,  0.00,  0.00
---- EULERIAN MATRIX FOR CONV FROM MAIN TO ARRAY COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660, 0.5000
 0.0000 ,-0.5000, 0.8660
---- EULERIAN MATRIX FOR CONV FROM ARRAY TO FEED COORDINATES.
 1.0000 , 0.0000, 0.0000
 0.0000 , 0.8660,-0.5000
 0.0000 , 0.5000, 0.8660
*************************************************************
Enter following data in feed coordinates.
*************************************************************
---- ELEMENT POLARIZATION
 ---  1 = X-POLARIZATION
 ---  2 = Y-POLARIZATION
 ---  3 = RIGHT-HAND CIRCULAR POLARIZATION
 ---  4 = LEFT-HAND CIRCULAR POLARIZATION
 ---  5 = ELLIPTICAL POLARIZATION
 --       IF 5, ENTER "A","B","PSI"(DEG) ON NEXT LINE
1
---- FEED ELEMENT TYPE
 ---  1 = CLOSED FORM DIST = C + (1-C) 1-(r/a) **P
  --     ENTER THE ELEMENT RADIUS "a",
  --     THE EDGE TAPER IN DB = 20logC (AS A POSITIVE NUMBER),& "P".
 --- 10 = ISOTROPIC POINT SOURCE:NO OTHER INFO. NEEDED
 --- 20 = INFIN. DIPOLE: ORIENTATED AT ANGLE ALPHA FROM X-DIR.
 --- 31 = COS(THETA)**Q: QE, QH, DUMMY
  -- 32 = QE-QH APPROACH FOR RECT. GUIDE: X-WIDTH, Y-WIDTH, DUMMY
  -- 33 = QE-QH APPROACH FOR CIRCULAR GUIDE:X-WIDTH, Y-WIDTH, DUMMY
 --- 40 = NUMERICAL DATA: E-PLANE IN UNIT 30, H-PLANE IN UNIT 31.
 --- 91 = REAL RECTANGULAR GUIDE CALC. BY PO: X-WIDTH,Y-WIDTH, DUMMY
  -- 92 = REAL CIRC GUIDE: RADIUS, 1=TE11, 2=TE21,DUMMY
31, 1.3, 0.8,1.0
----  ENTER THE FEED EFFICIENCY IN PERCENT (100 SHOULD BE DEFAULT)
73.0
**********************************************************************
Enter following data in array coordinates
**********************************************************************
----     ARRAY TYPE: TYPE # ON FIRST LINE FOLLOWED BY 1ST 2 PARAMETERS.
 --- ARBITRARY:      0; NUMBER OF ELEMENTS,FOLLOWING LINES ENTER Xi, Yi
  --                 1; # OF ELEMENTS, THEN JUNK LINE. DATA IN LOC.D (15)
 --- RECTANGULAR: 10; NUMBER OF ROWS IN X DIR., Y DIR.
  -- (INC.LINEAR) 11; APERTURE SIZE IN X-DIM, Y-DIM
  -- NEXT LINE LATTICE VECTOR ELEMENTS "a1" (X DIR), "a2", ANGLE "OMEGA"
 --- CIRCULAR:      20; NUMBER OF ELEMENTS, JUNK,
  --                21; ELEMENT SPACING (IN LENGTH), JUNK
  -- NEXT LINE MAJOR AXIS RAD., AXIAL RATIO, ANGLE FROM X TO MAJOR AXIS.
```

```
 --- HEXAGONAL:   30; NUMBER OF RINGS, ROTATION ANGLE, SPACING, JUNKx2
30, 0.0, 0.0
0.82, 0.82, 90.
---- SUBARRAY:ENTER "IFLAG". NEXT LINE  # ELEM. IN X, Y DIRECTIONS
 --- IFLAG=  0-NO SUBARRAY   1-PHASE   2-MAGNIT.   3-BOTH
0
2,3
---- CURRENT EXCITATION COEFFICIENTS (MAGNITUDE AND PHASE) (DEF=1)
 --- 0 = UNIFORM: TWO LINES, ON 2ND LINE ENTER EXC. (DEFAULT= 1, 0)
 --- 1 = ARBITRARY: TWO LINES, 2ND JUNK (INPUT IN EXCIT.D=UNIT 14)
 --- 2 = ARBITRARY: BEGIN ENTERING EXC. ON 2nd LINE
 --- 3 = C+(1-C)(1+(R/A)**2)**P TAPER, ON 2nd LINE, EDGE TAPER, P
 --- 4 = TAYLOR TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- 5 = BAYLISS TAPER, ON 2nd LINE SL LEVEL (>0), # EQUAL SLs.
 --- SPACE TAPER = 10+(NUMBER OF TAPER) e.g. Taylor space = 14
0
1.0, 0.0
---- PHASE DISCRETIZATION - 0 IF NONE, ELSE NUMBER OF BITS IN PH. SHFT.
0
---- ERRORS - 0 IF NONE, ELSE 1 : NEXT LINE PHASE, AMP ERRORS,ISEED
  -- RMS PHASE ERROR IN DEGREES, RMS AMPLITUDE ERROR IN DB.
  -- ISEED IS NEGATIVE INTEGER, CHANGE EACH TIME! (NORMAL DIST.)
0
7.0,0.0,-345
---- POWER CALC:      1=ANALYTICAL FORMULA FOR Q-FEED
                      2=USE 1 WATT FOR 1 ELEMENT, AND NUMERICAL FOR MORE.
                      3=USE INPUT VALUE GIVEN ON FOLLOWING (2ND) LINE
                      4=NUMERICAL INTEGRATION
4
1.17E9
*************************************************************************
Enter following data in main coordinates.
*************************************************************************
---- CHOOSE OBSERVATION VARIABLES
     1 = THETA,PHI                2 = ELEVATION, AZIMUTH
1
---- SCAN ANGLE (THETA,PHI) OR (ELEVATION,AZIMUTH)
0.0, 00.00
---- RANGE OF FAR-FIELD ANGLES
 --- ENTER LEFT BOUND, RIGHT BOUND AND # OF PTS OF THETA OR ELEVATION
-90.00, 90.00, 181
 --- ENTER LEFT BOUND, RIGHT BOUND, AND # OF PTS OF PHI OR AZIMUTH
00.00, 90.00, 2
```

Input file " shape3.d " for Design D

```
---NUMBER OF RADIAL DIVISIONS (OR RINGS) (N)
   100
---NUMBER OF EXTRA RINGS (NEX)
   07
---RATIO OF NUMBERS OF RADIAL DIVISIONS, COMPUTED AND PRINTED (NF)
   1
--- NUMBER OF LAST LINES UNAFFECTED BY NF (NX)
   1
---DIAMETER OF MAIN REFLECTOR APERTURE (XYM)
   74.
---Q-INDEX OF FEED(0.5*NNP)
   67.5
---MAXIMUM FEED ANGLE (ANM)
   11.
---CROSS POINT BETWEEN TWO SUBREFLECTORS: YES=1, NO=2 (ICROSS)
   1
---APERTURE FIELD TAPER: TAR=1, UNIFORM=2 (ITAPER)
   2
---EDGE TAPER IN DB (DB)
   00.0
---RADIUS OF SPHERICAL MAIN REFLECTOR (RR)
  177.6
---LOCATION OF FEED IN MAIN REFLECTOR COORD., X AND Z (XF AND ZF)
   -37.0   -81.4
---LOCATION OF FIRST SUBREFLECTOR CENTER, X AND Z (XSR1 AND ZSR1)
   -14.8   -103.6
---LOCATION OF CENTER OF MAIN REFLECTOR APERTURE, X COMPONENT (XA)
  37.74
---LOCATION OF SECOND SUBREFLECTOR CENTER, Z COMPONENT (ZSR2)
   -81.4
---IPLOT=1 FOR PLOTING,  =2 FOR REGULAR COMPUTATION
2
```

Input file " sbrwn3.d " for Design D

```
***sbrwn3 : SBR FOR 3 REFLECTORS WITH NUMERICAL SURFACES
--- UNIT :  1 = INCH, 2= CM, 3 = MM, 4=METER
    2
--- FREQ (GHZ)
032.000
--- IEFF=1 if calculating beam eff,   =2 if regular pattern calcu
2
--- OBSERVATION PHI: START, END, STEP-SIZE (DEGREES)
   315.00  315.00  100.00
--- OBSERVATION THETA: START, END, STEP-SIZE (DEGREES)
   -90.00  90.00  00.5
--- INTEGRATION PLANE: AT Z=Zout, (THETA9,PHI9) OF NORMAL
      Normal(theta9,phi9) should be in main beam direction
     -133.20,   0.0,    90.0
--- IONERAY=1 IF JUST SHOOT 1 RAY,  =2 IF MORE RAYS
     If =1, then also enter xin, yin for the ray
2,   -28.120, 00.000
--- # OF RAYS IN X AND Y GRID
40   40
--- IDIVFAC=1 if use DF calculated numerically
             2 if assume uniform field at the exit aperture
2
--- For the case IDIVFAC=2, enter half cone angle of feed, q-power
       of feed, exit aperture area (pi*a**2)
11.,   67.5, 4060.96
--- For case of IDIVFAC=1, SHRUNK FACTOR OF UNIT CELL IN DF CALCU
          (Normally 1.0)
1.500
--- MAX DISTANCE ALONG Z THAT MUST BE SEARCHED FOR INTERSECTION
222.
--- RADOME? COATING ON REFL SURFACES? DEBUG PRINTOUT? 1=YES 0=NO
    0                0                 0
--- HUYGEN'S PRINCIPLE: 1=E,  2=H,  3=EH FORMULATION
3
**************************
*** REFLECTOR SURFACE****
**************************
---3 reflectors: 2 subs ane 1 main
**SUB REFLECTOR 1: numerical data in tape61
---PUNCH CYLINDER:IAXIS(1=X,2=Y,3=Z), PT ON AXIS:CPUNCHX,CPUNCHY,CPUNCHZ
3,        -15.18,  0.,  000.
---  RADIUS OF PUNCH CYLINDER: RPUNCHX, RPUNCHY,RPUNCHZ
6.74,  5.86, 6.66
---  BLOCKAGE:IIBLOCK(1=YES,0=NO), PT ON AXIS:CBLOCKX,CBLOCKY,CBLOCKZ
0,              0.,    0.,  0.
---  RADIUS OF BLOCKAGE CYLINDER: RBLOCKX, RBLOCKY, RBLOCKZ
0.00,  0.00,  0.00
**SUB REFLECTOR 2: numerical data in tape62
---PUNCH CYLINDER:IAXIS(1=X,2=Y,3=Z), PT ON AXIS:CPUNCHX,CPUNCHY,CPUNCHZ
3,          -7.71,  0.000,  -000.
---  RADIUS OF PUNCH CYLINDER: RPUNCHX, RPUNCHY,RPUNCHZ
147.85, 147.85, 147.85
---  BLOCKAGE:IIBLOCK(1=YES,0=NO), PT ON AXIS:CBLOCKX,CBLOCKY,CBLOCKZ
0,              0.,    0.,  0.
---  RADIUS OF BLOCKAGE CYLINDER: RBLOCKX, RBLOCKY, RBLOCKZ
```

```
1.33,  1.33, 1.33
**MAIN REFLECTOR 3 (ANALYTICAL SURFACE)
     MUNORM=1 IF SURF NORMAL TOWARD +Z , =-1 IF OTHERWISE
+1
     D0,          D1,          D2,           D3,          D4
     0.00         0.0          0.0           0.0           0.00
     D5,          D6,          D7
     0.0         -1.0         0.500
     S1,          S2,          S3,           S4,          S5
    31541.76       0.0         -0.00          0.0          -1.0
     S6,          S7,          S8,           S9,          S10
     -1.00        0.0         -0.00          0.0          0.0
     S11,         S12,         S13,          S14,         S15
     -00.00       0.0         -0.00          0.0           0.0
---PUNCH CYLINDER:IAXIS(1=X,2=Y,3=Z), PT ON AXIS:CPUNCHX,CPUNCHY,CPUNCHZ
3,          71.74  ,000.,  -000.
---  RADIUS OF PUNCH CYLINDER: RPUNCHX, RPUNCHY,RPUNCHZ
37.0,  37.0,  37.0
---  BLOCKAGE:IIBLOCK(1=YES,0=NO), PT ON AXIS:CBLOCKX,CBLOCKY,CBLOCKZ
0,             0.,   0.,  0.
---  RADIUS OF BLOCKAGE CYLINDER: RBLOCKX, RBLOCKY, RBLOCKZ
1.33,  1.33,  1.33
**SURFACE 8: RADOME (dummies if there is no radome)
     D0,          D1,          D2
     1.776        0.0         -0.00
     D6
     1.00
     S1,          S2,          S3,           S4,          S5
     66.26        0.0         -0.00          0.0         -1.0
     S6
     -1.000
---PUNCH CYLINDER:IAXIS(1=X,2=Y,3=Z), PT ON AXIS:CPUNCHX,CPUNCHY,CPUNCHZ
3,             0.,    0.,  -0.00
---  RADIUS OF PUNCH CYLINDER: RPUNCHX, RPUNCHY,RPUNCHZ
8.14,  8.14,  8.14
---  BLOCKAGE:IIBLOCK(1=YES,0=NO), PT ON AXIS:CBLOCKX,CBLOCKY,CBLOCKZ
0,             0.,    0.,  0.
---  RADIUS OF BLOCKAGE CYLINDER: RBLOCKX, RBLOCKY, RBLOCKZ
0.00,  0.00,  0.00
*************
****FEED****
*************
---- FEED CORD CENTER IN MAIN CORD.
-36.97,     -0.00,     -81.34
----EULERIAN ANGLES:GAMMA1,GAMMA2,GAMMA3 (DEG)
090.00,135.0,270.00
---- FEED POLARIZATION IN FEED CORDINATE SYSTEM
    1=X-POLARIZATION
    2=Y-POLARIZATION
    3=RIGHT-HAND CIRCULAR POLARIZATION
    4=LEFT-HAND CIRCULAR POLARIZATION
    5=ELLIPTICAL POLARIZATION
    IF 5, THEN ENTER A,B,PSI(DEG) ON NEXT LINE
1
---- FEED ELEMENT
      DIPOLE(FULL SPACE): 0, DUMMY, DUMMY
      USER INPUT: 1, QE, QH
```

```
        QE-QH RECT GUIDE: 2, X-WIDTH, Y-WIDTH
        QE-QH CIRCULAR GUIDE: 3, RADIUS, DUMMY
        PO REAL RECT GUIDE:91, X-WIDTH,Y-WIDTH
        PO REAL CIRCULAR GUIDE:92, RADIUS, 1=TE11 AND 2=TE21
1,67.5,67.5
--- TOAL NO. OF ELEMENTS IN ARRAY
1
--- FOR EACH FEED,ENTER X,Y IN FEED CORD,EXCITATION(MG,PHASE)
    THE ARRAY MUST BE ON X-Y PLANE OF FEED COORD
+0.000,+0.000,  1.00,  0.0
--- FOR REAL GUIDE: 1=NUMER INTEGRATION FOR FEED RADIATED POWER
                    2= USE 1 WATT FOR 1 ELEMENT,AND NUMER FOR MORE
                    3= USE INPUT VALUE GIVEN NEXT
    FOR Q-GUIDE: dummy
2
--- FOR 3 ABOVE, ENTER  RADIADED POWER FROM FEED( dummy otherwise)
3.213554
***********
***COAT****
***********
--START ENTER COATING FOR 7 PEC-BACKED,PLUS ONE HALF SPACE
   *1ST LAYER IS FARTHST FR INCID. FIELD
   *ONLY COAT 8 IS HALF-SPACE:1ST LAYER HAS SAME (EP,MU) AS
      HALF SPACE. BY DEFAULT IT HAS ZERO THICNESS
--- NO. OF DIFFERENT COATING,NOT COUNTIG COAT 8 (THE HALF SPACE)
2
**COAT 1: NO. OF LAYERS (1-20)
1
---THICK,EPSILON(C),MU(C),RESISTIVITY(OHM)
0.00000,(1.000,-0.00),(1.,0.),1.E+30
**COAT 2: NO. OF LAYERS (1-20)
1
---THICK,EPSILON(C),MU(C),RESISTIVITY(OHM)
0.000,(1.0,0.),(1.,0.),1.E+30
****COAT 8=HALF SPACE: NO. OF LAYERS (2-20, MIN 2)
 1ST LAYER HAS SAME (EP,MU) AS HALF SAPCE,MUST HAVE ZERO THICK.
2
---THICK,EPSILON(C),MU(C),RESISTIVITY(OHM)
0.00000,(1.000,-0.0),(1.0,-0.0),1.E+30
0.07400,(4.000,-0.002),(1.0,-0.0),1.E+30
---FOR 8 SURFACES, SPECIFY TYPES OF COATING
1, 2, 1, 1, 1, 1, 1, 8
```