

NATIONAL RADIO ASTRONOMY OBSERVATORY  
Green Bank, WV

MEMORANDUM

March 20, 1990

To: GBT Memo Series  
From: Roger D. Norrod  
Subj: GBT Focal Length

The following tabulates estimated GBT performance at the prime focus as the paraboloid F/D ratio is varied, where D is the projected aperture diameter (100 meters). The calculations were done at 1 GHz using an aperture integration program, and with the aperture center offset a constant 54 meters. The assumed feed pattern was a circularly symmetric  $\cos^N \theta$  function.

Table 1 considers circular polarization.  $\psi_s$  is the LCP squint angle, expressed as a fraction of the HPBW. RCP is deflected in a direction opposite to LCP, so the separation between the two circular polarization beams is  $2\psi_s$ .  $G_{\max}$  is the LCP peak gain, and  $\Delta G$  is the amount the gain is down, relative to  $G_{\max}$ , at boresight.  $E_{CP}$  is  $\Delta G$  expressed as a relative efficiency. If a point source were observed with, for example,  $F/D = 0.60$ , in both polarizations at boresight, the antenna efficiency is 98.4% of that achievable at the gain peak of either circular polarization. Note that  $G_{\max}$  decreases as the focal length is reduced. This effect is probably due to the increased path length difference between the main reflector near and far rim causing a reduction in the illumination efficiency.

Linear polarization is tabulated in Table 2.  $G_{\max}$  is the peak gain which occurs for both linear polarizations at the boresight. Note that the linear  $G_{\max}$  is equal to the gain at boresight in circular polarization, not the circular polarization peak gain.  $X_{pol}$  is the maximum crosspolarization level, relative to the copolar peak, which occurs in the pattern cut of constant elevation.  $E_F$  is  $G_{\max}$  expressed as an efficiency relative to  $(\pi D/\lambda)^2$ .

The F/D ratio affects the dimensions of the main reflector, as illustrated in Table 3.  $\theta_0$  is the angle that bisects the main reflector subtended angle, measured relative to the paraboloid axis. As the focal length is shortened, this tilt angle increases making the main reflector rim more elliptical as shown in the third column.

The field-of-view is a performance measure that is strongly affected by the focal ratio. Figures 1-4 are pattern plots at wavelength 21.1 cm,  $F/D = 0.6$ , and for 0, 1, 2, and 3 HPBW beam offsets in the elevation plane. Note the beam broadening (which occurs in the plane of offset), and the decrease in gain as the feed is scanned off. Figure 5 shows two pattern cuts for the 2 HPBW offset case.

Figures 6-9 show patterns for  $F/D = 0.55$  and for 0, 1, 2, and 3 BW offsets. Table 4 lists the gain change as the beam is scanned off-axis.

At the prime focus of the  $F/D = 0.60$  case, the beam scan/feed offset is approximately 1.3 BW/wavelength. Probably the minimum acceptable feed aperture with today's feed technology is  $2\lambda$ . Therefore, a 7-feed array, with one feed on axis and six surrounding, would have beams separated by about 2.6 BW. The gain of the outboard feeds would be about 71% of the on-axis feed.

For the  $F/D = 0.55$  case, the beam scan/feed offset coefficient is larger, but the feeds can be smaller because the reflector subtended angle is larger, so the minimum beam separation is about the same, 2.6 BW. However, because the field-of-view is less, the outboard feed gain would be about 65% of the on-axis gain.

TABLE 1  
Circular Polarization

F/D	$\psi_s$	$G_{\max}$ (dBi)	$\Delta G$ (dB)	$E_{cp}$
.75	.051	59.11	-0.04	99.1%
.65	.065	59.05	-0.05	98.9%
.60	.074	58.99	-0.07	98.4%
.55	.083	58.92	-0.08	98.2%
.50	.097	58.86	-0.11	97.5%

TABLE 2  
Linear Polarization

F/D	$G_{\max}$ (dbi)	$E_F$	$X_{pol}$ (dB)
.75	59.07	73.6	-23.9
.65	59.00	72.4	-21.8
.60	58.92	71.1	-20.6
.55	58.84	69.8	-19.4
.50	58.75	68.4	-18.0

TABLE 3

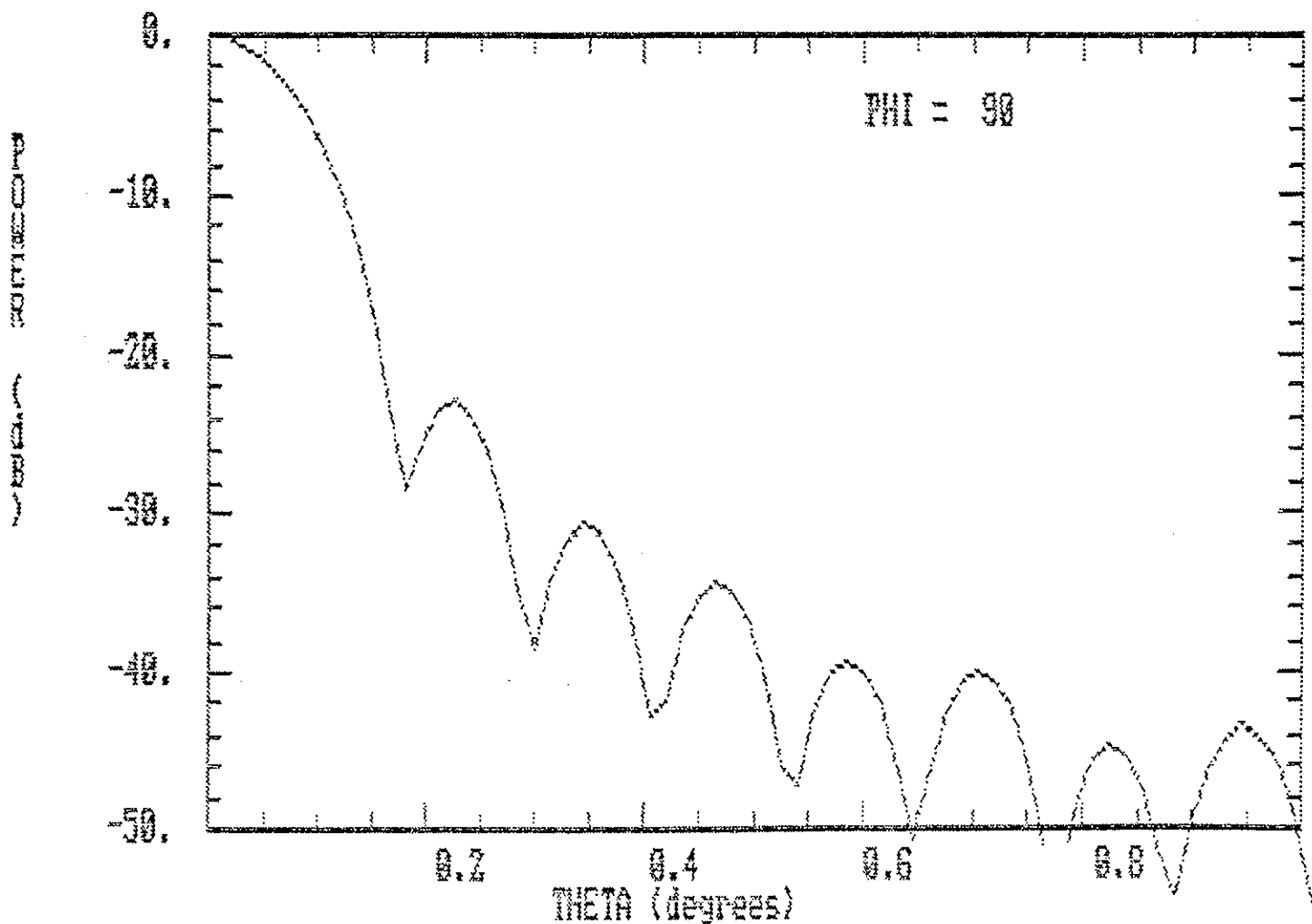
## Main Reflector

F/D	$\theta_0$ (°)	Main Reflector
.75	36.3	100 x 106
.65	40.4	100 x 108
.60	42.8	100 x 110
.55	45.5	100 x 112
.50	48.4	100 x 114

TABLE 4

## Gain Change vs. Beam Offset

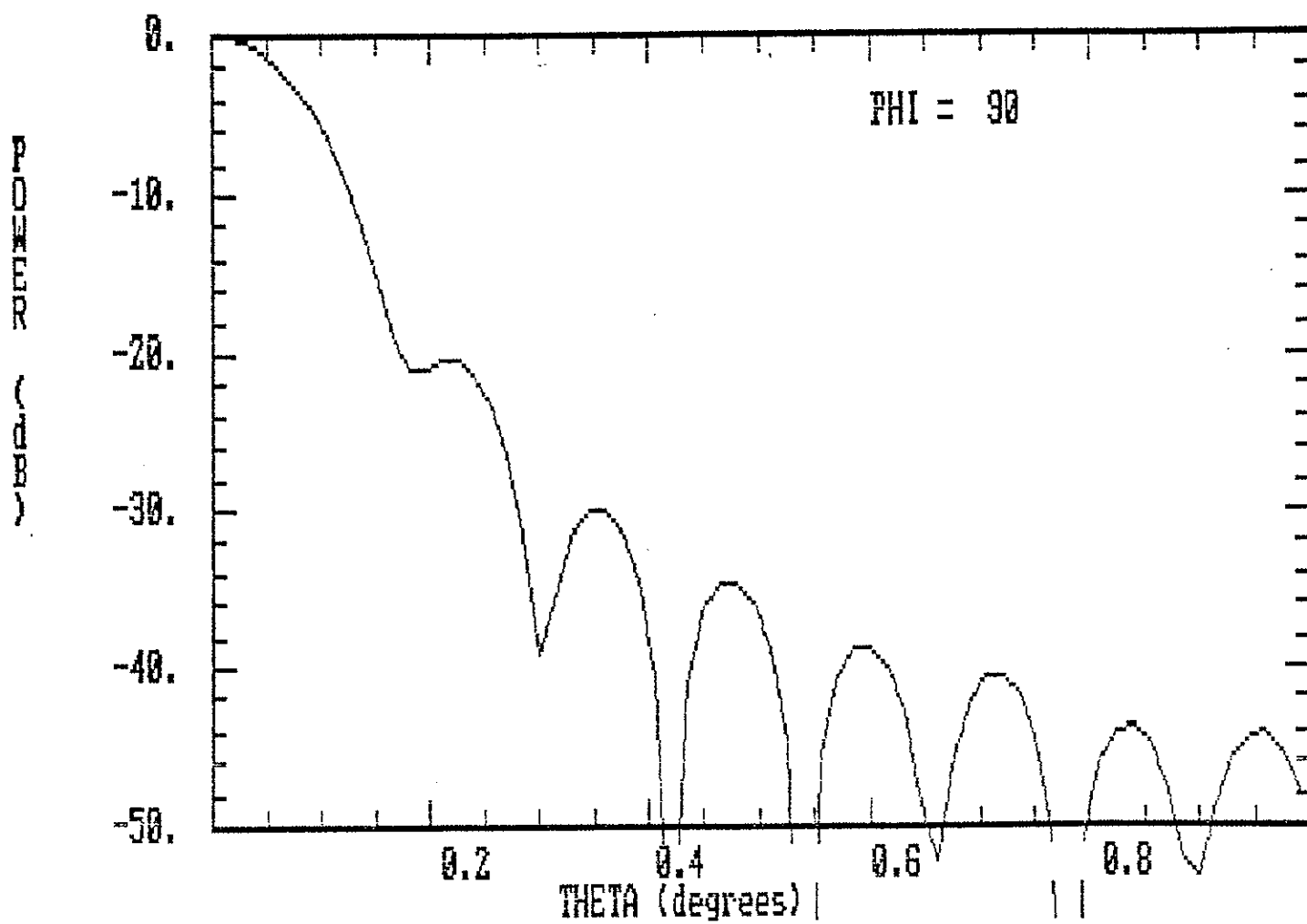
F/D	$\Delta G$ - 1 BW (dB)	$\Delta G$ - 2 BW (dB)	$\Delta G$ - 3 BW (dB)
0.60	-0.21 (95%)	-0.82 (83%)	-1.97 (64%)
0.55	-0.26 (94%)	-1.16 (77%)	-2.40 (58%)



$\lambda = 21.1$   
Zero Offset  
Gain = 62.81

$f = 60$  m  
 $D = 100$  m

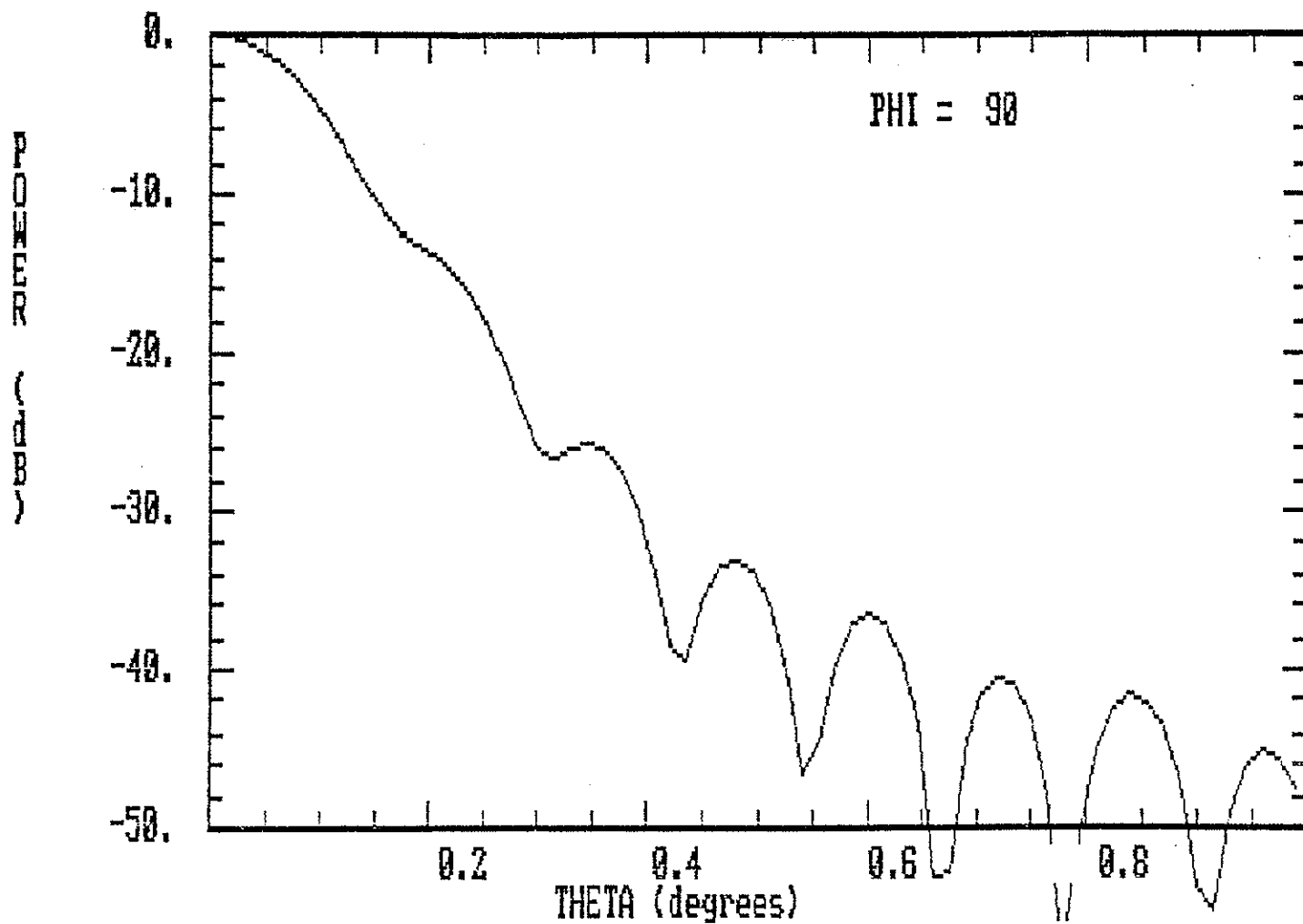
FIGURE 1



$\lambda = 21.1$  cm  
Az = 0  
El = 0.144  
1 BW Offset  
Gain = 62.60  
 $\Delta = -0.21$

f = 60 m  
D = 100 m

FIGURE 2

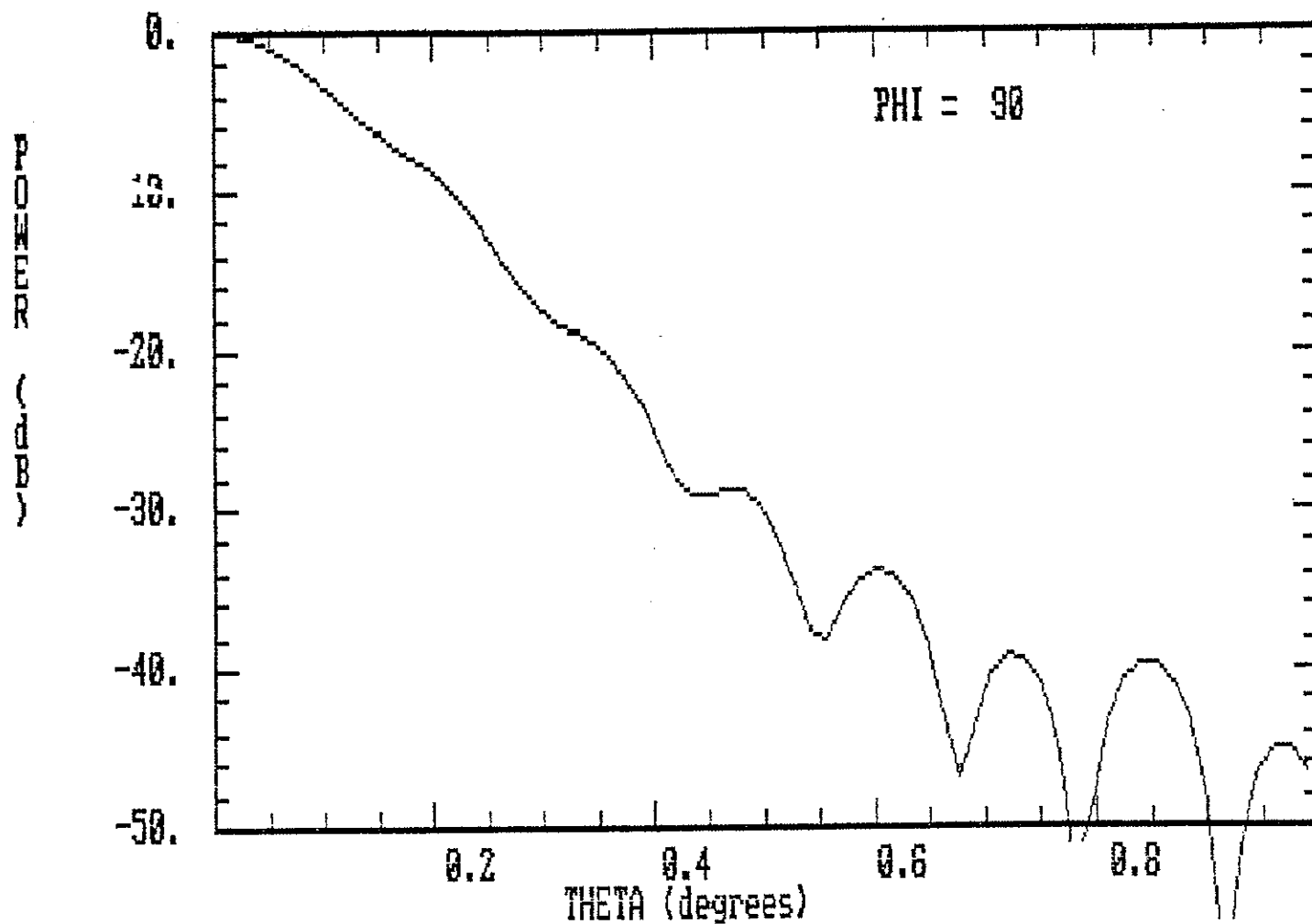


$\lambda = 21.1$   
Az = 0  
El = 0.287  
 $\Delta G = 0.82$   
2 BW Offset

Gain = 61.99

f = 60 m  
D = 100 m

FIGURE 3



$\lambda = 21.1$   
Az = 0  
El = 0.431°  
3 BW Offset

$\Delta G = 1.97$   
Gain = 60.84

f = 60 m  
D = 100 m

FIGURE 4



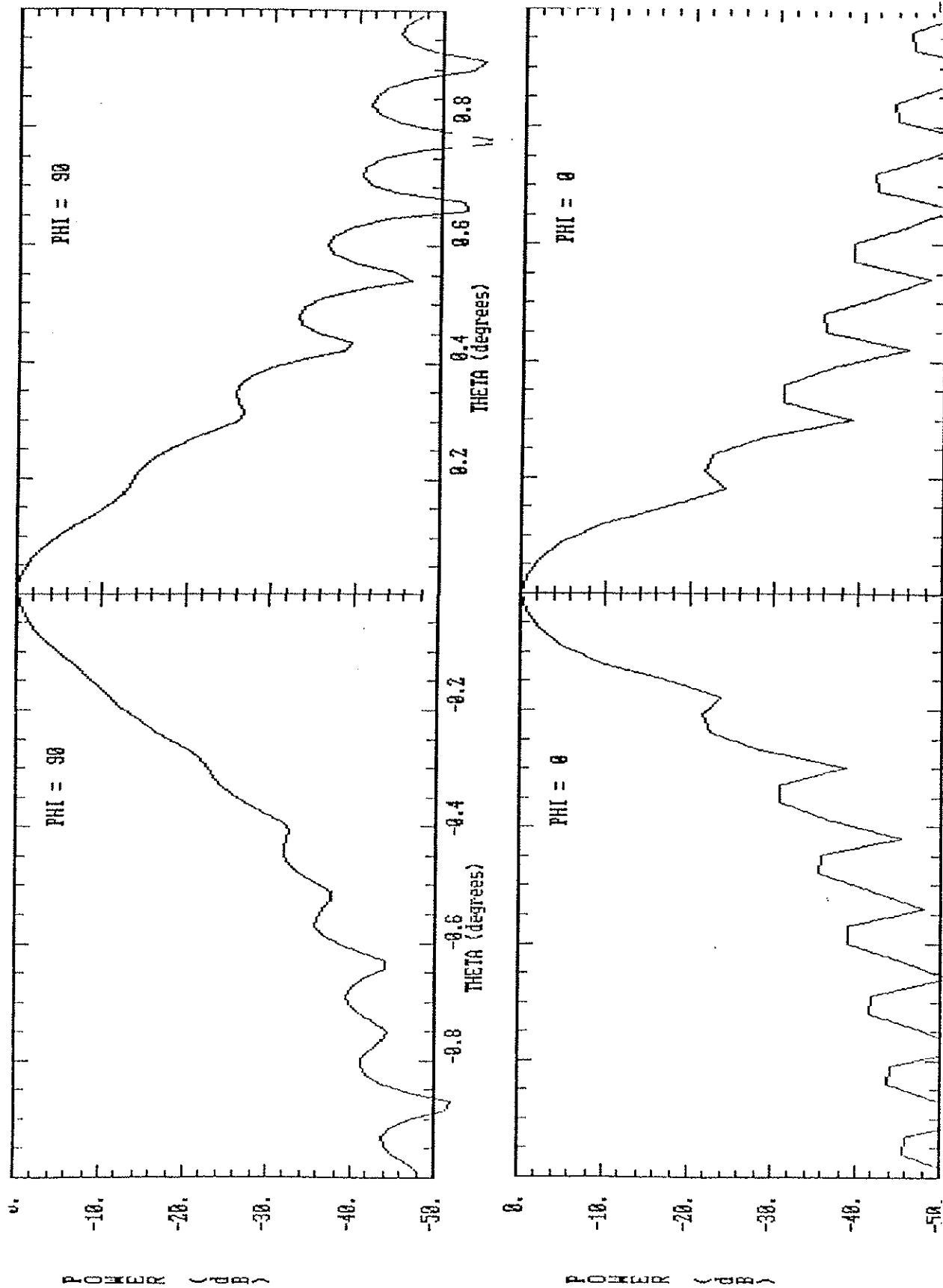
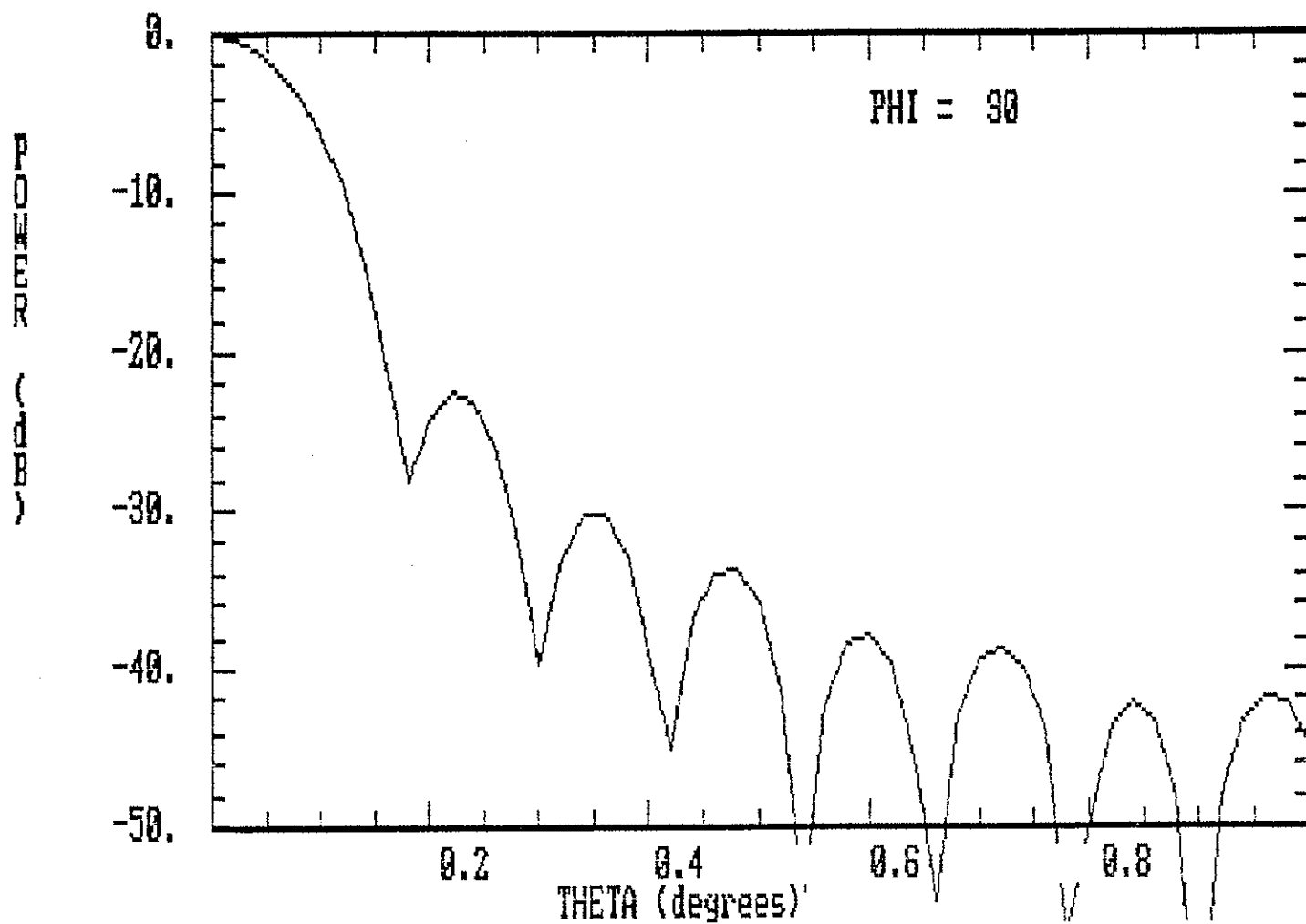


FIGURE 5

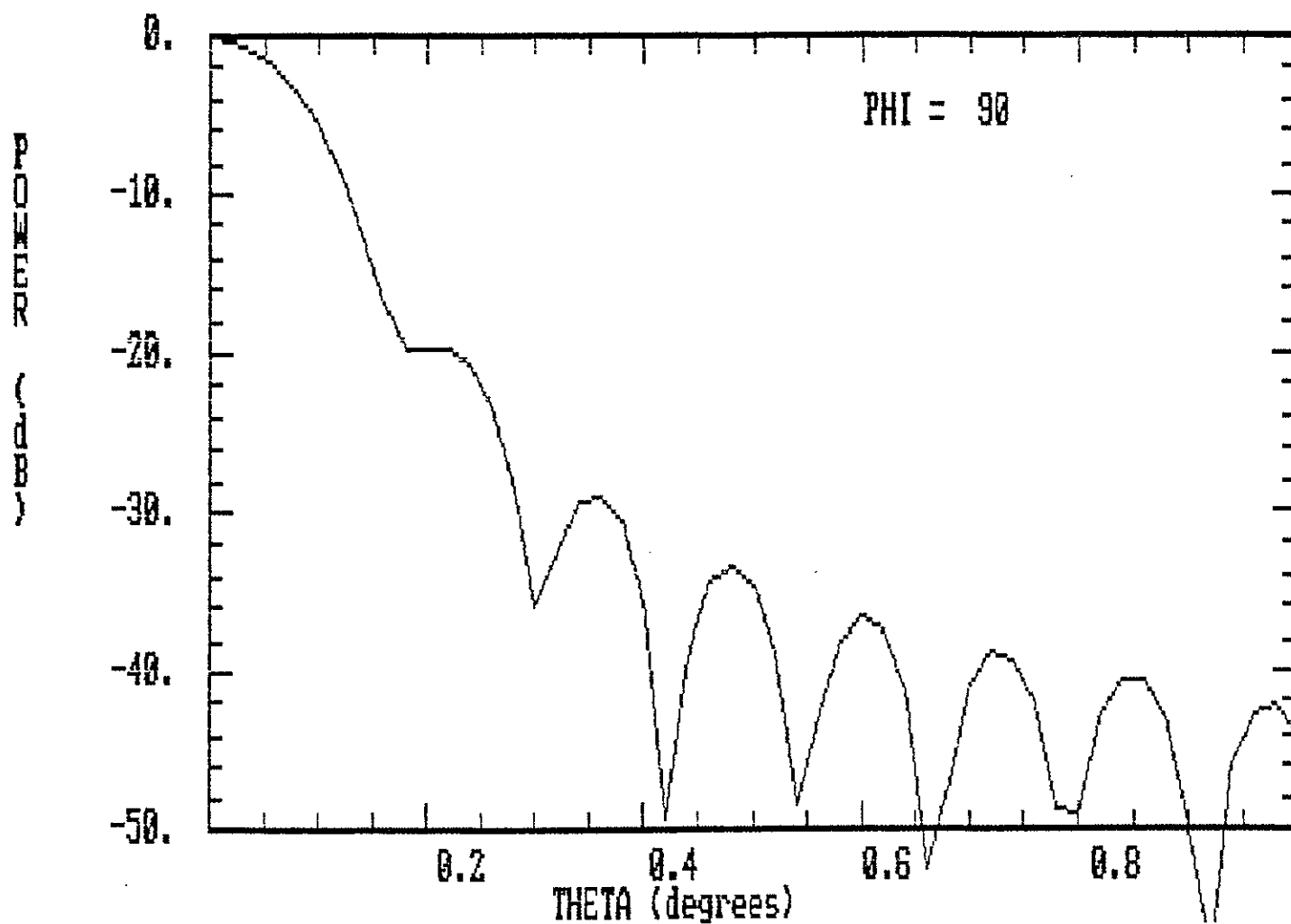
Two Pattern Cuts for 2 BW Offset and  $F = 60$ .



$\lambda = 21.1$  cm  
Zero Offset  
Gain = 62.76

$f = 55$  m  
 $D = 100$  m

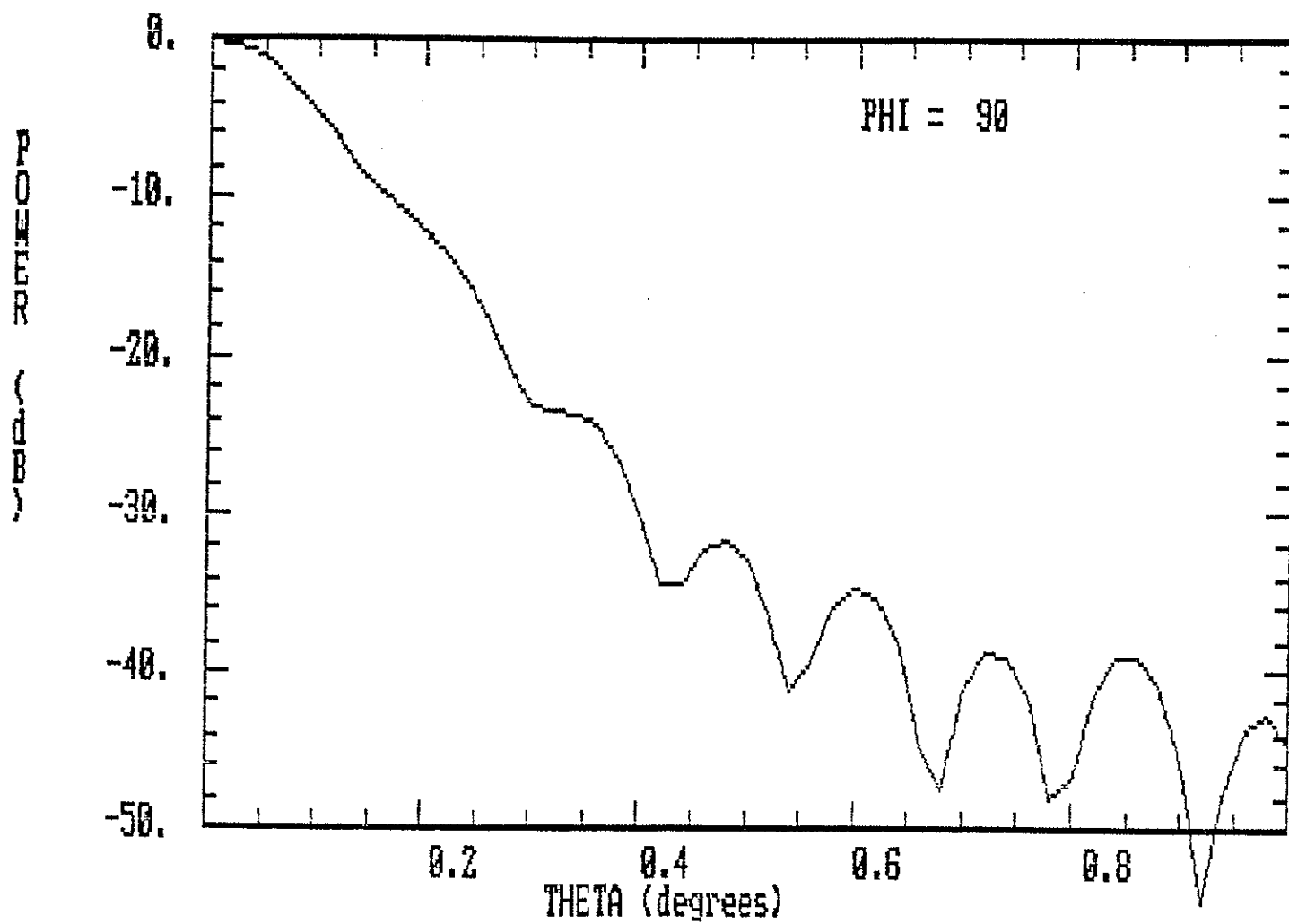
FIGURE 6



$\Delta G = 0.26$   
1 dB Offset  
Gain = 62.50

$f = 55$  m  
 $D = 100$  m

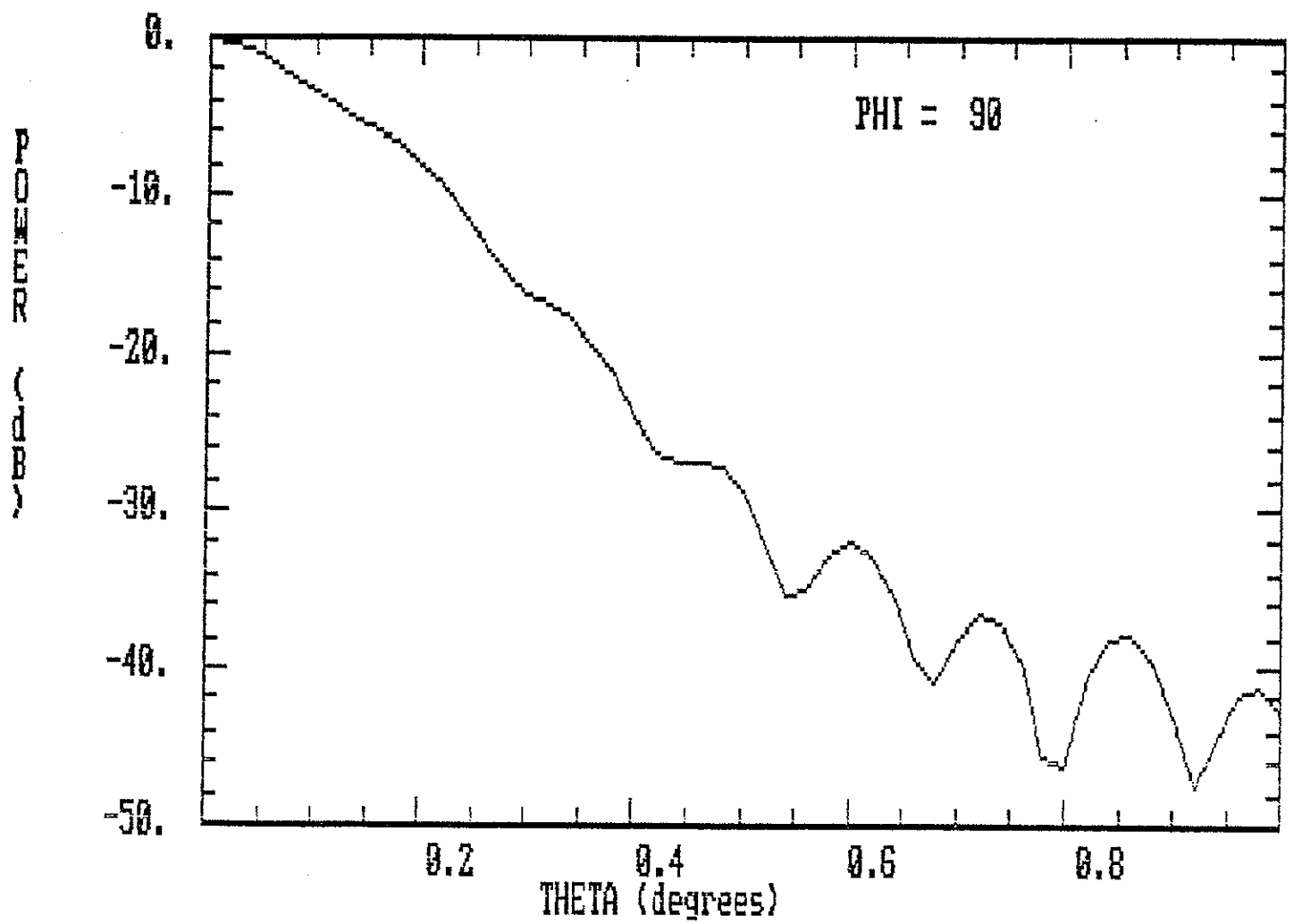
FIGURE 7



$\Delta G = -1.16$  dB  
2 BW Offset  
Gain = 61.60

$f = 55$  m  
 $D = 100$  m

FIGURE 8



$\Delta G = 2.41$   
3 BW Offset  
Gain = 60.35

$f = 55$  m  
 $D = 100$  m

FIGURE 9