A Simulator for the LWA

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The University of New Mexico

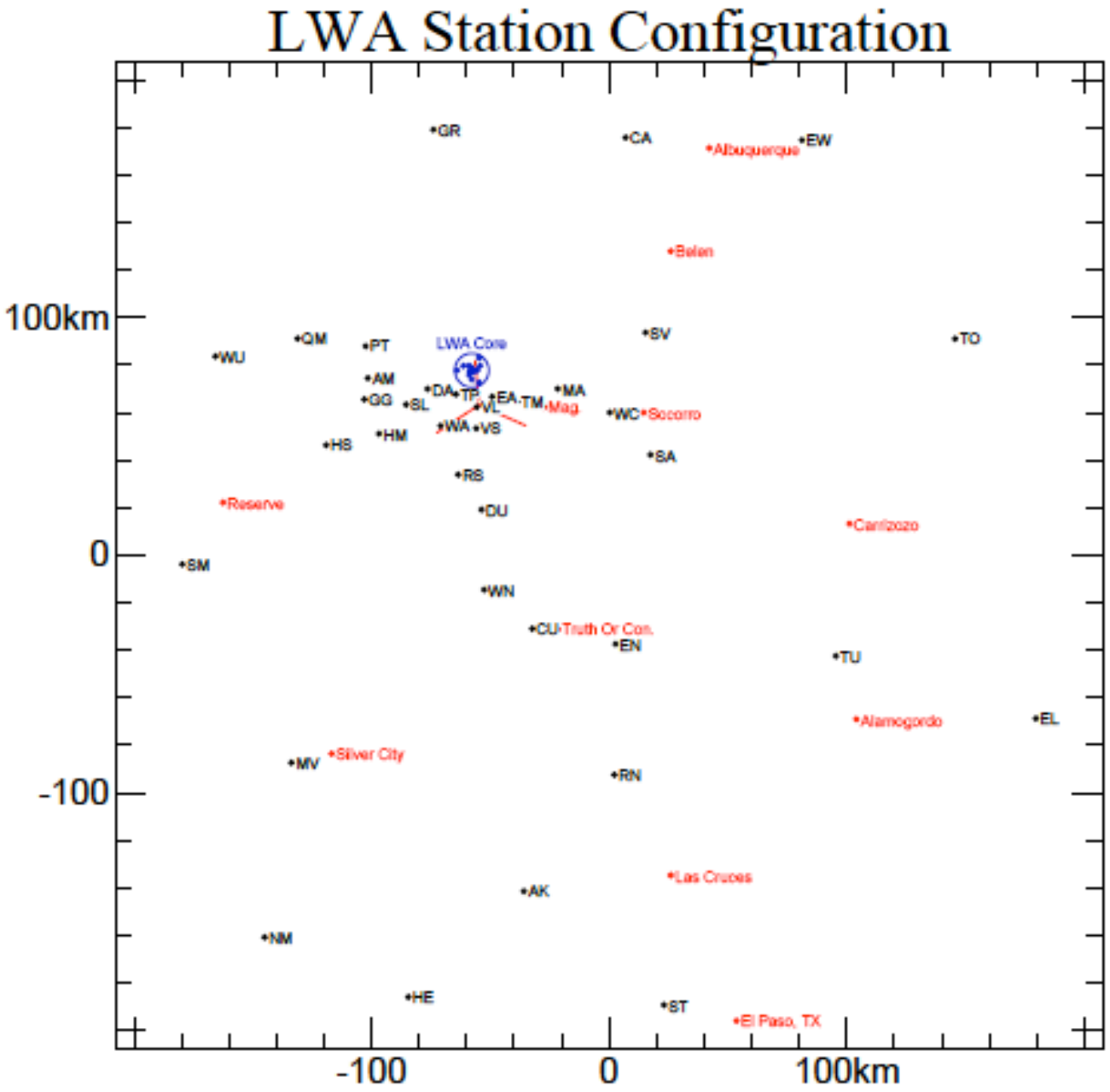
Outline

1.Station Beam Model

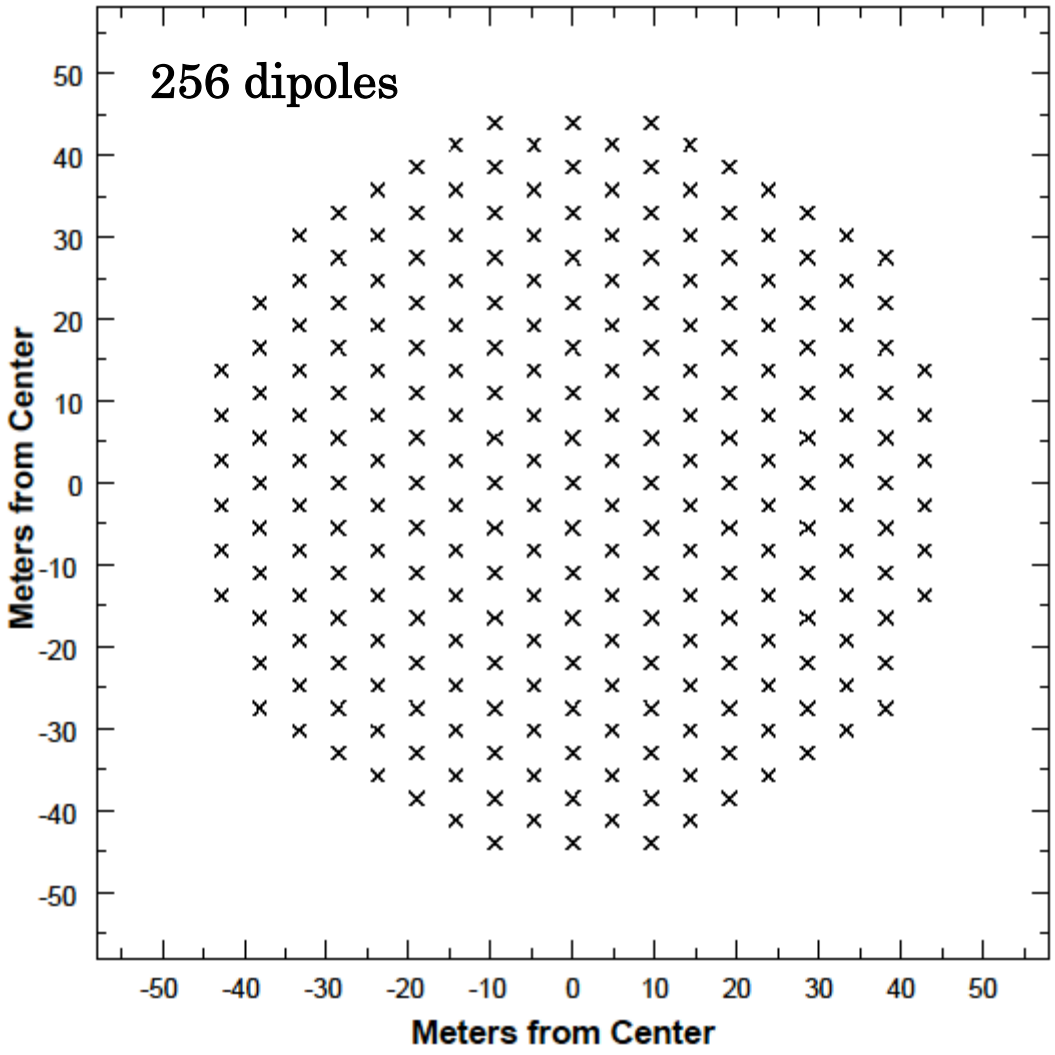
2.Asymmetry Station Beam

3.Station Beam Error

4.Summary



(Aaron Cohen LWA Memo Series [55])



(Leonid Kogan LWA Memo Series [21])

Simulation model for a station beam

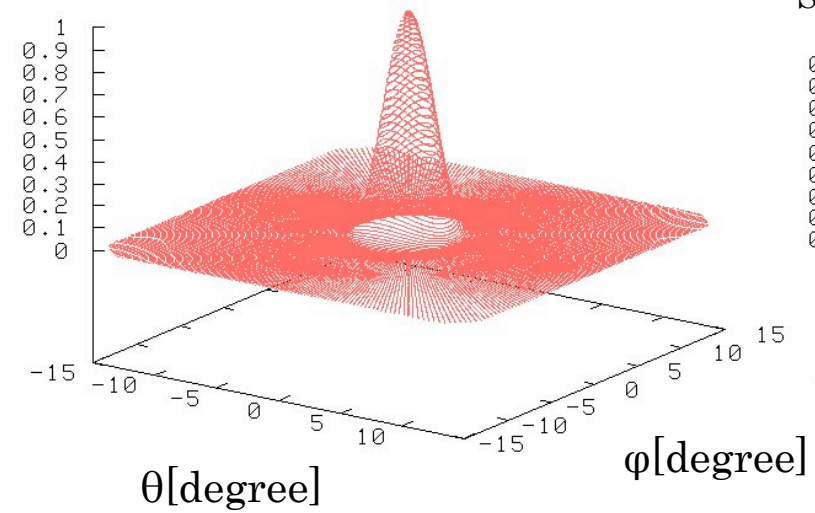
$$E(\theta,\varphi)=\sum_{J=0}^{255} Gaussian(\theta,\varphi)\exp(iP_j)\exp(\Psi-\Phi_j)+Noise_j$$

Gaussian(θ,φ) = individual primary beam

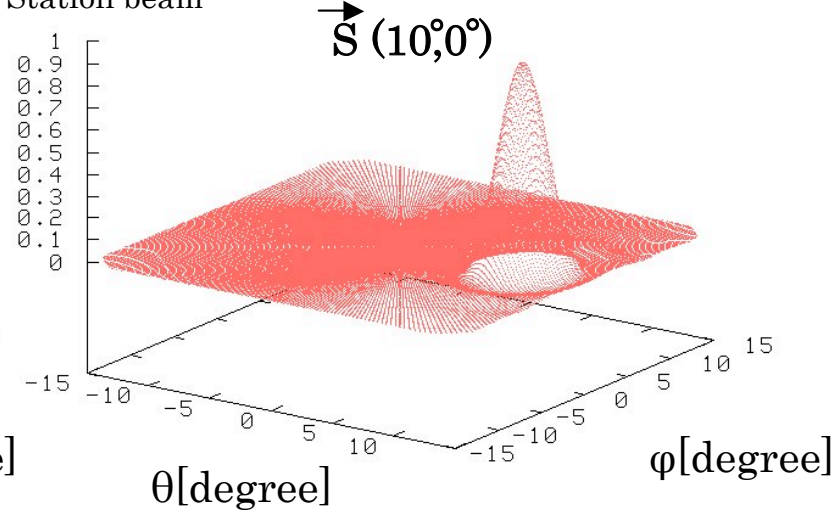
$$\Psi_j = \frac{2\pi}{\lambda}(\vec{D}_j \cdot \vec{u})$$

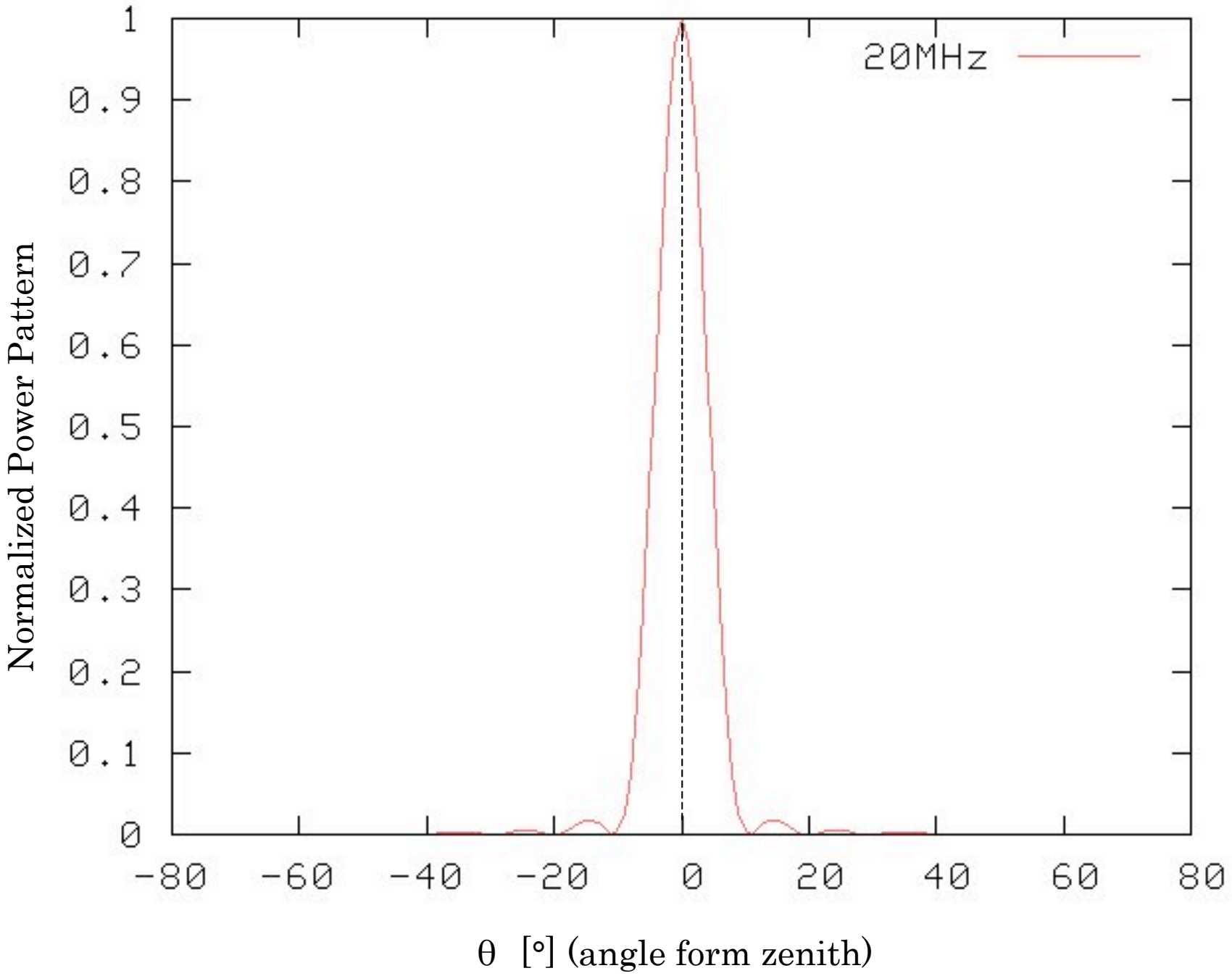
$$\Phi_j = \frac{2\pi}{\lambda}(\vec{D}_j \cdot \vec{S})$$

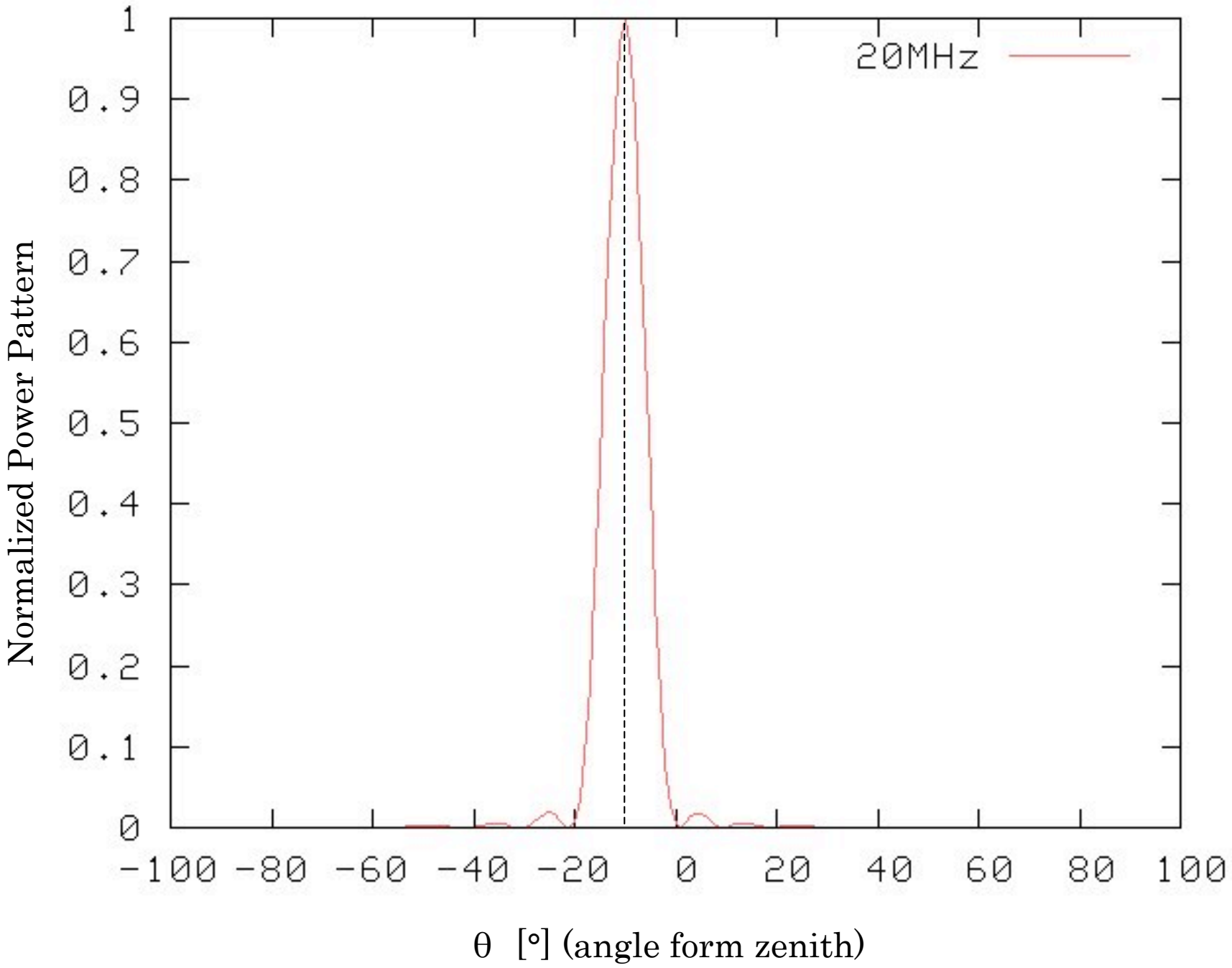
Station beam $\vec{S}(0°,0°)$ = Zenith



Station beam $\vec{S}(10°,0°)$




20MHz
Normalized Power Pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80
θ [°] (angle form zenith)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-100 -80 -60 -40 -20 0 20 40 60 80 100
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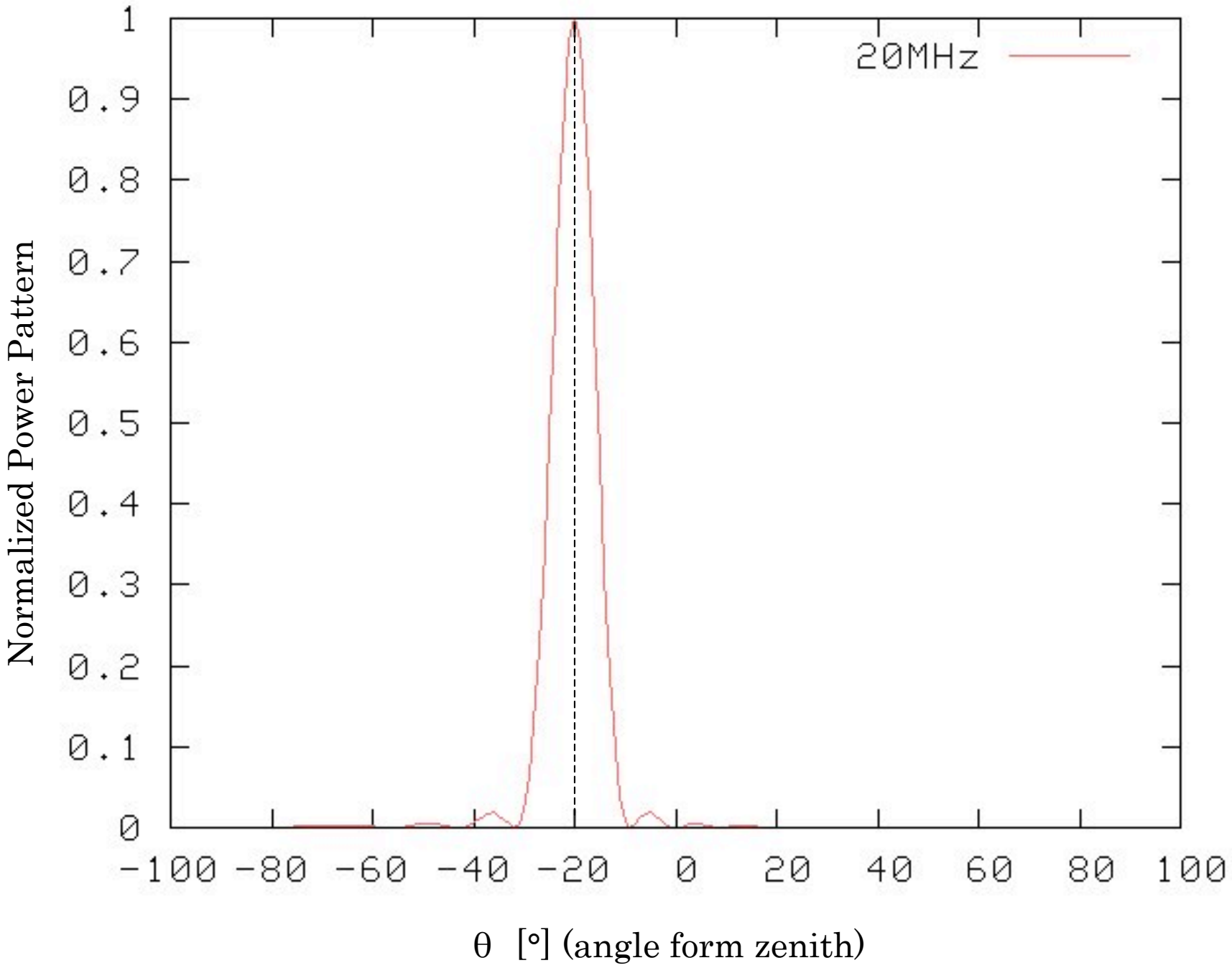
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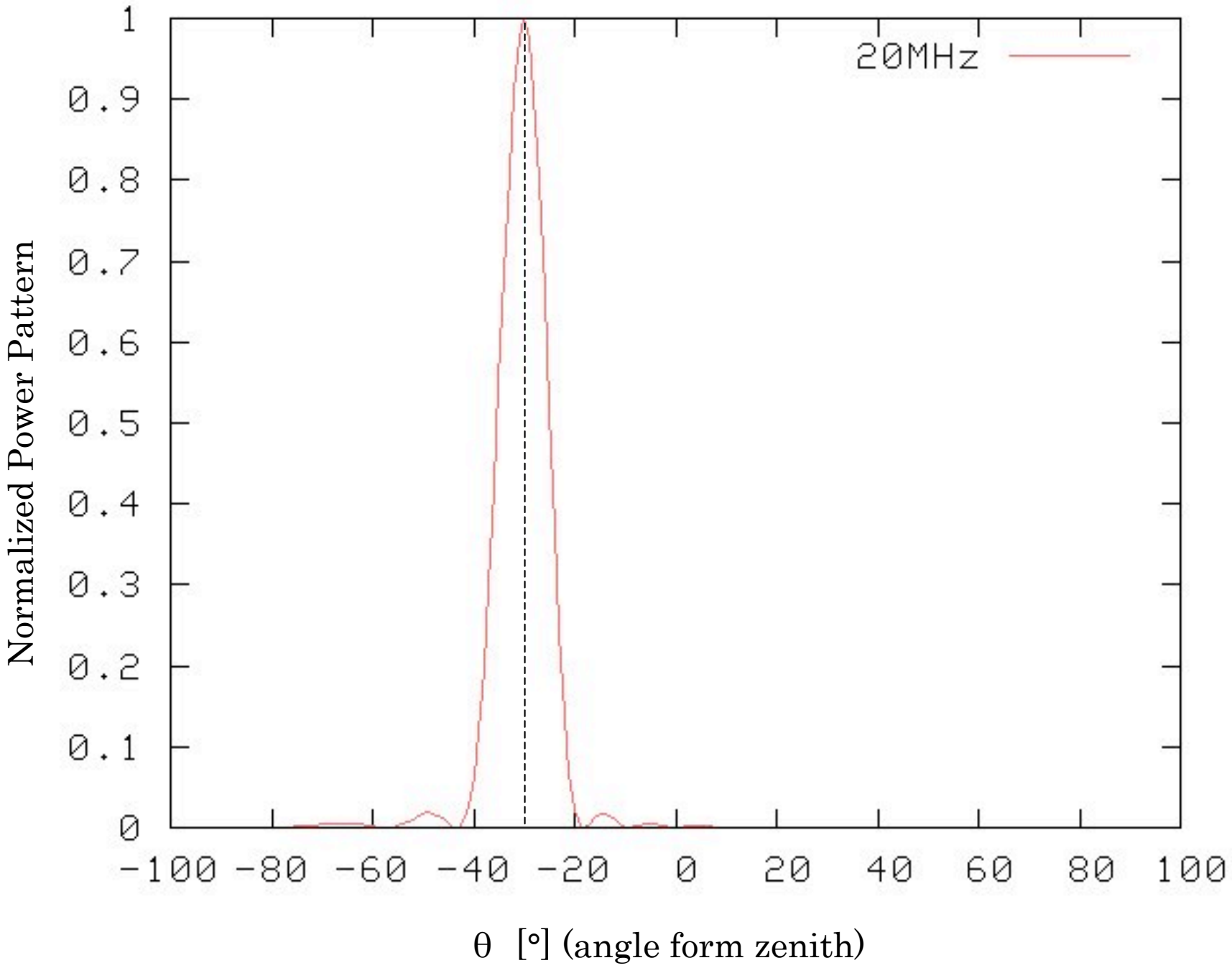
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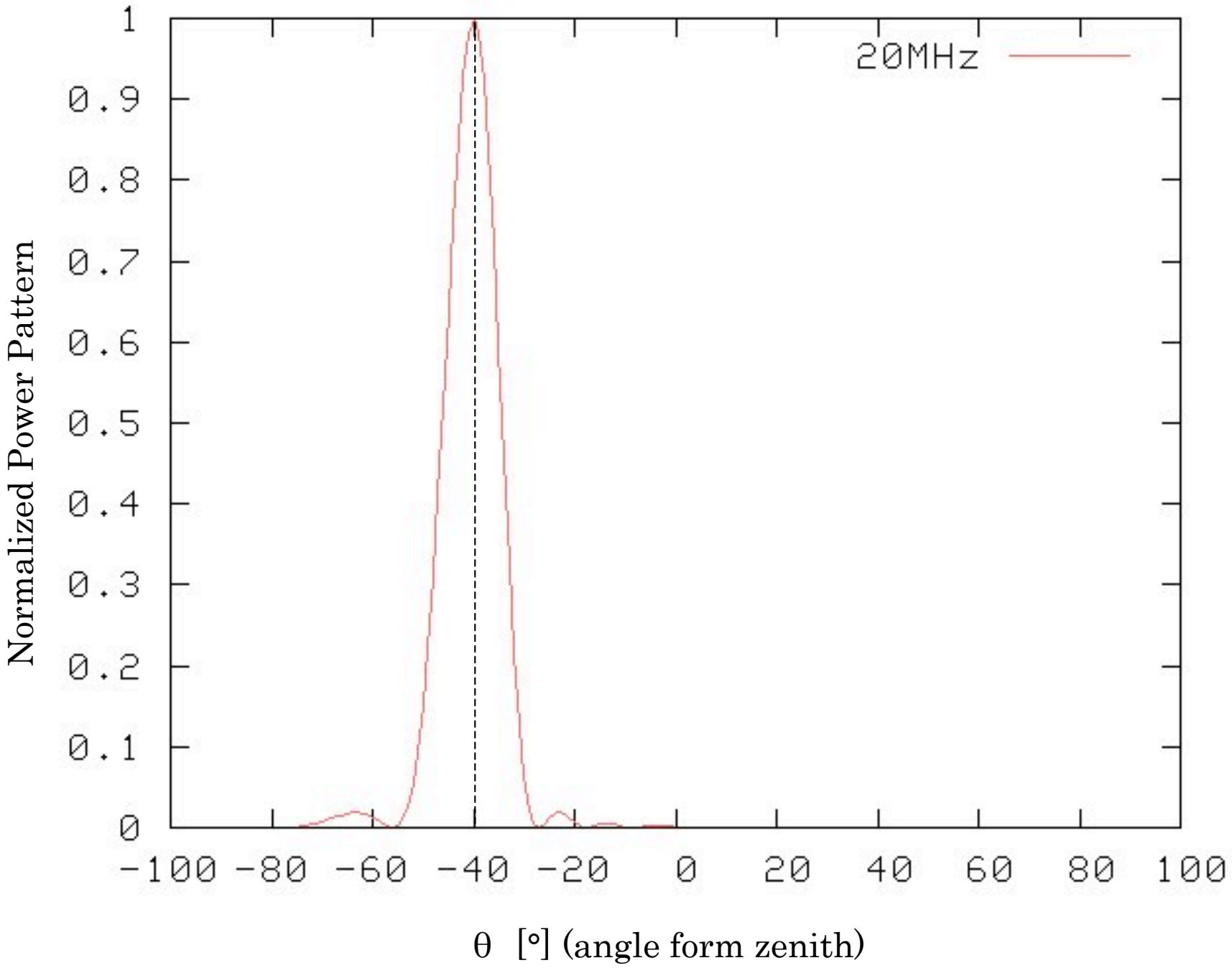
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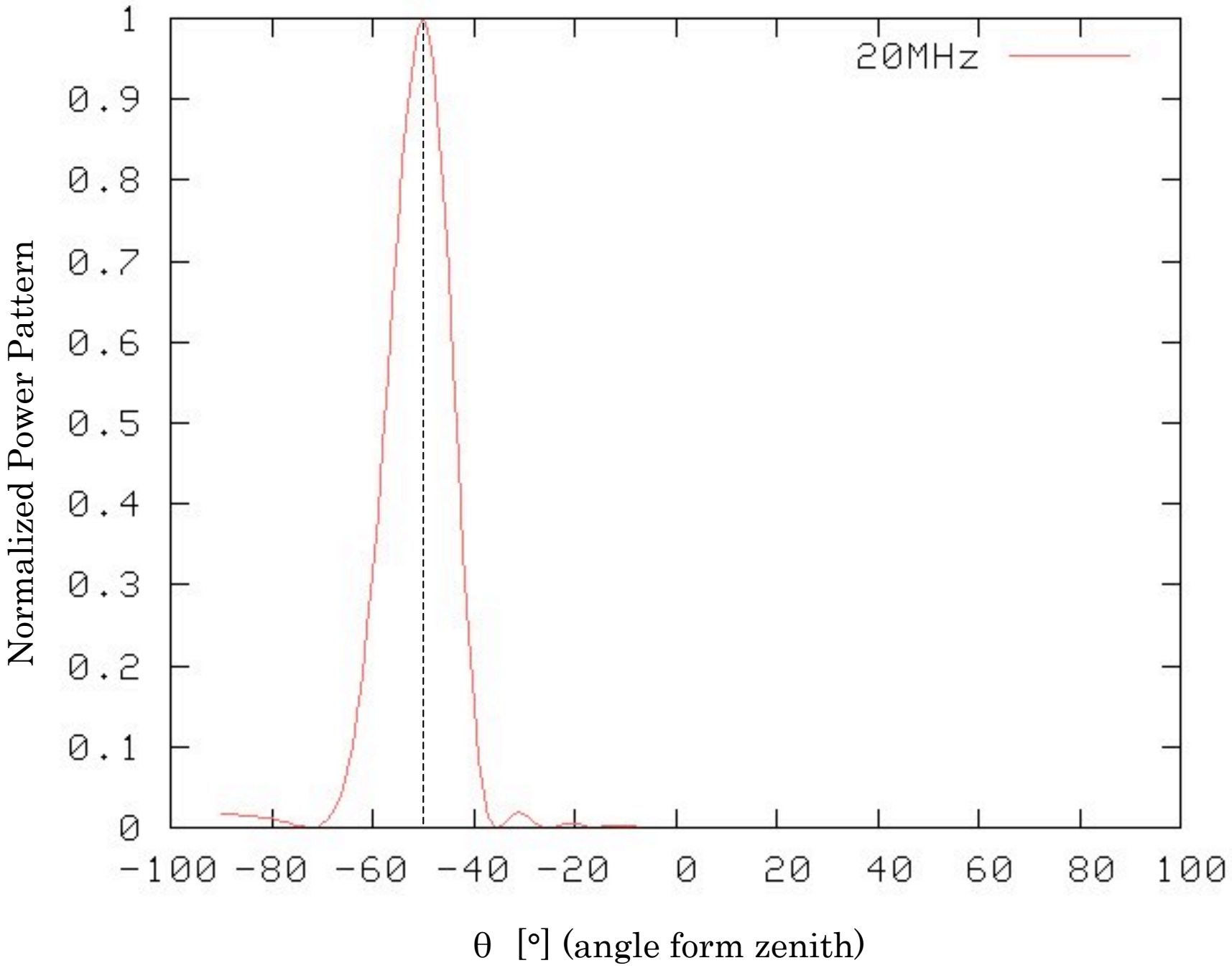
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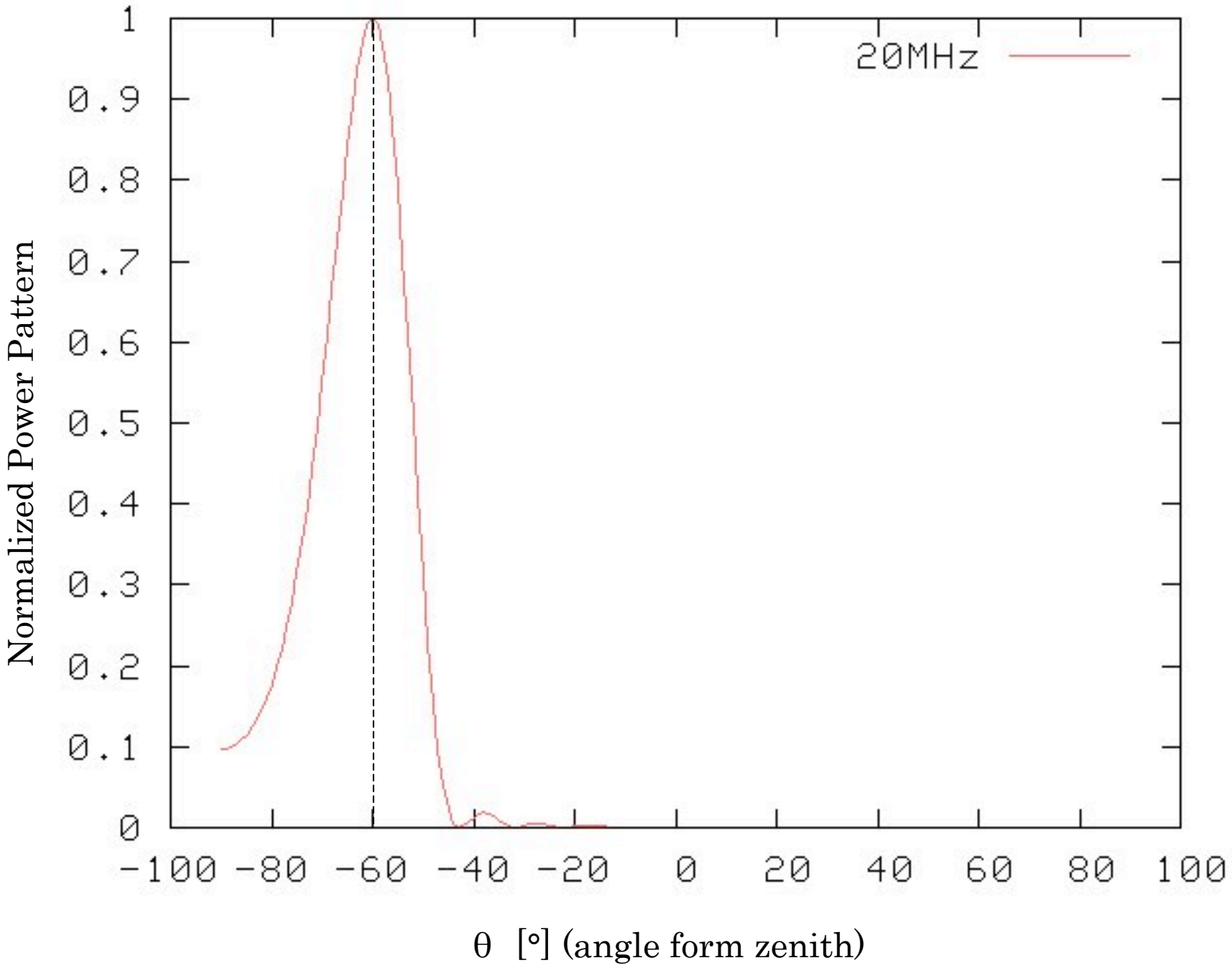
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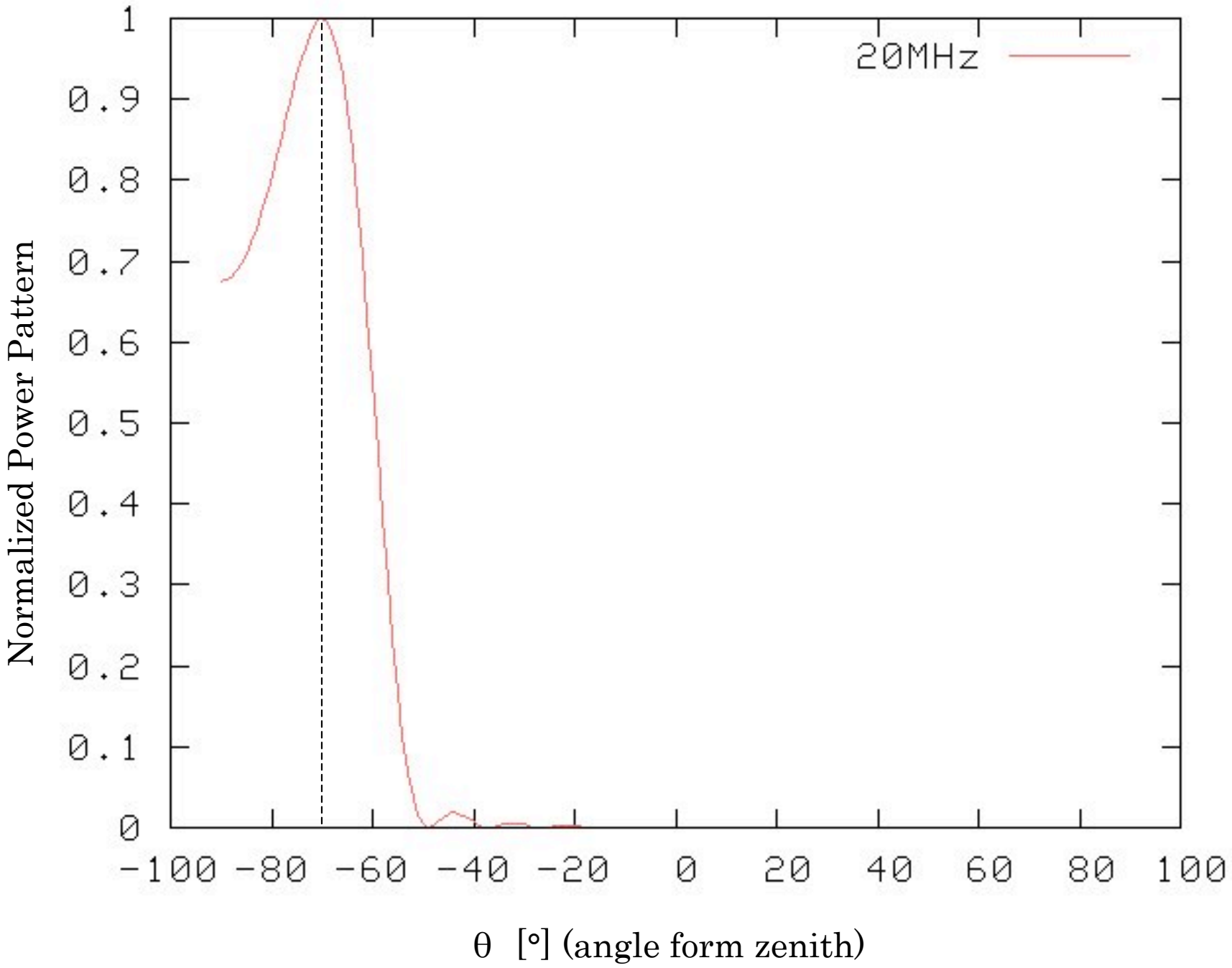
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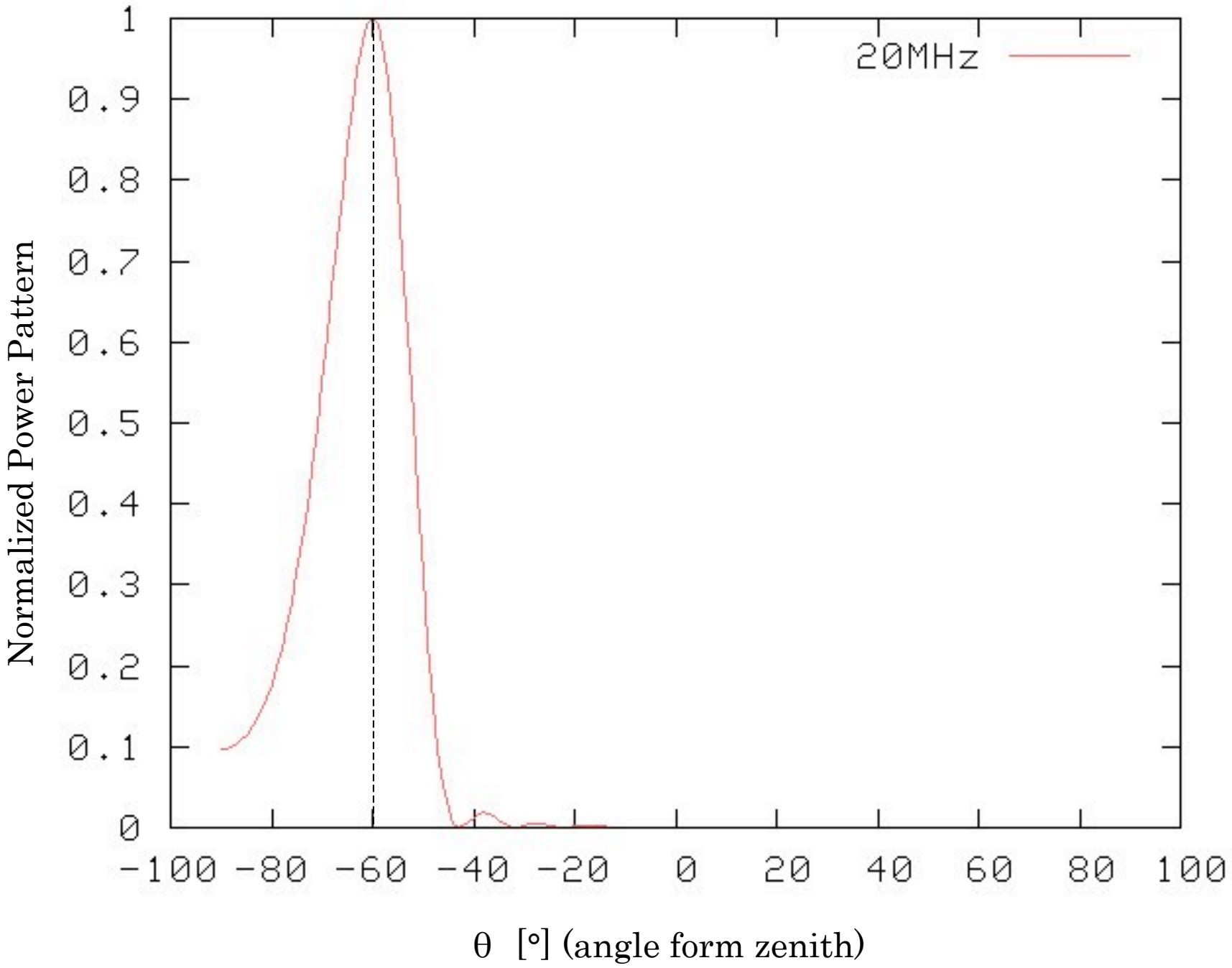
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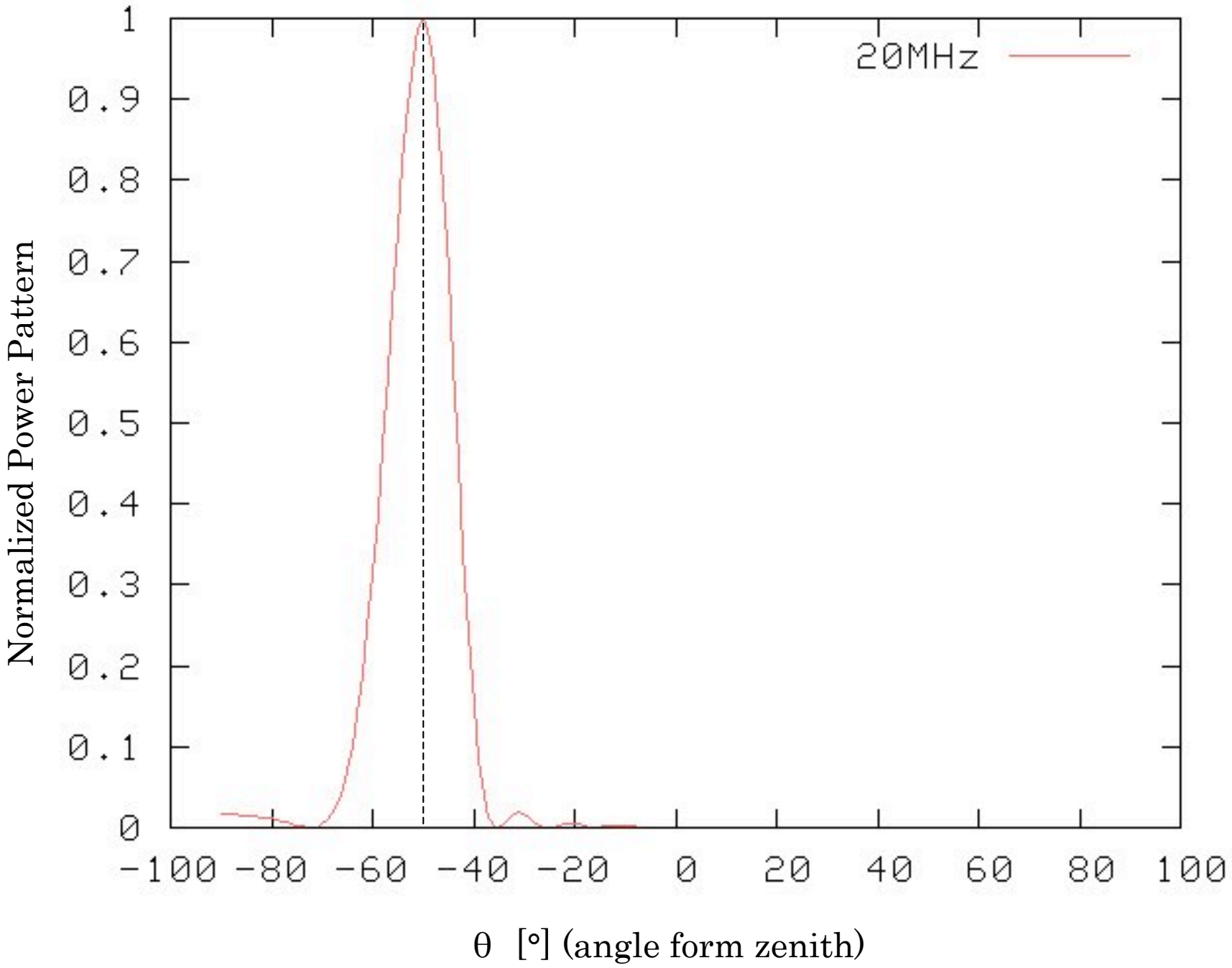
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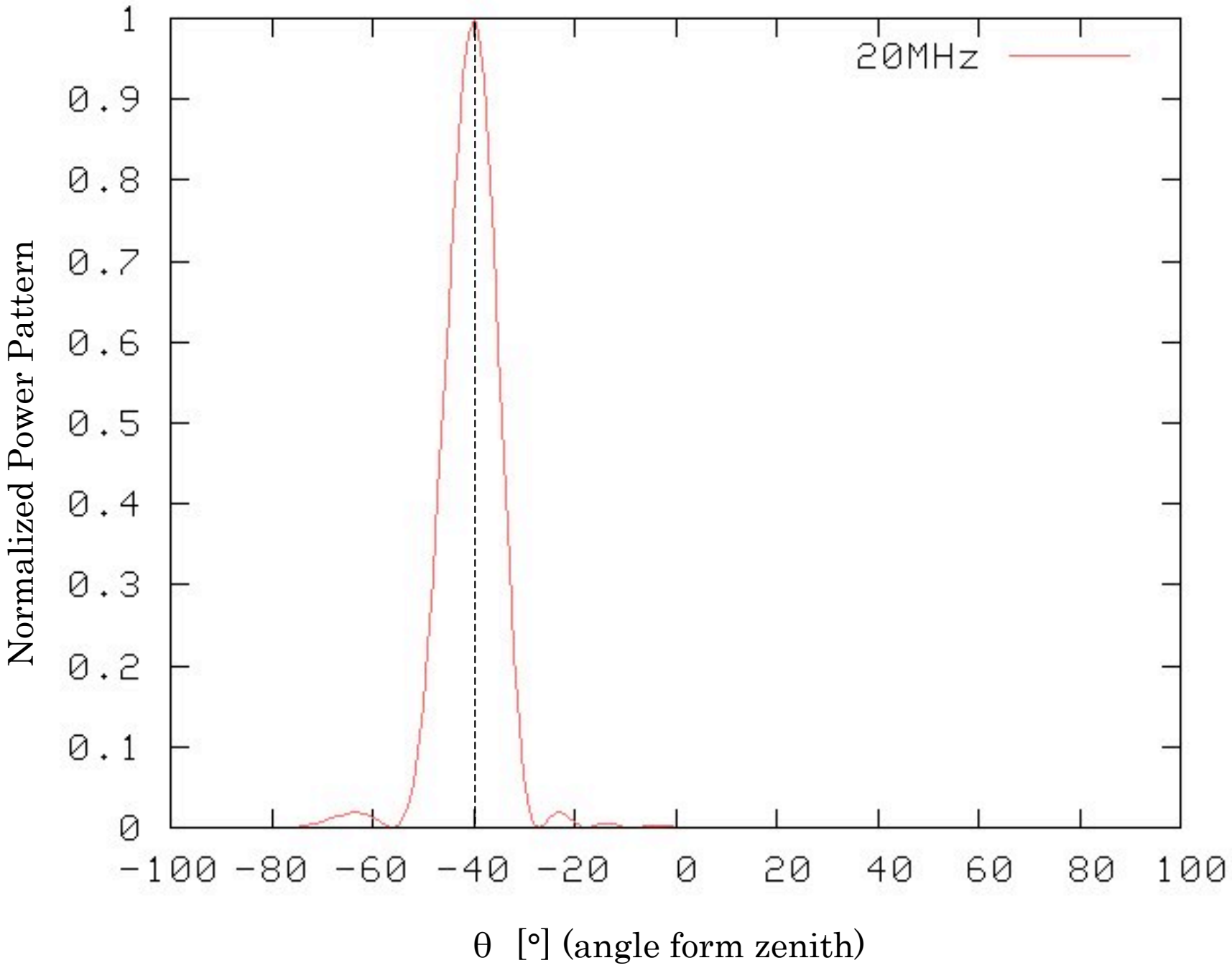
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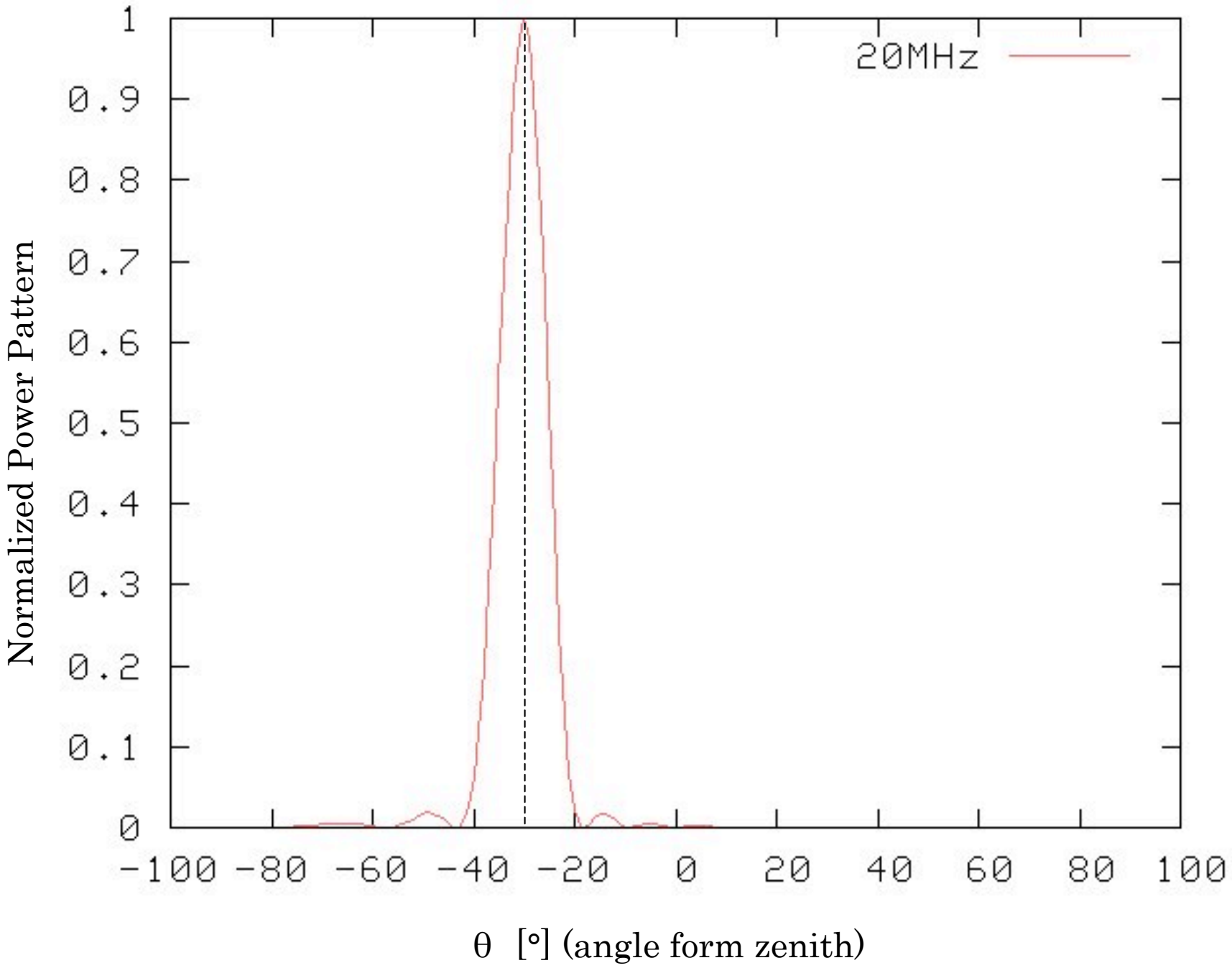
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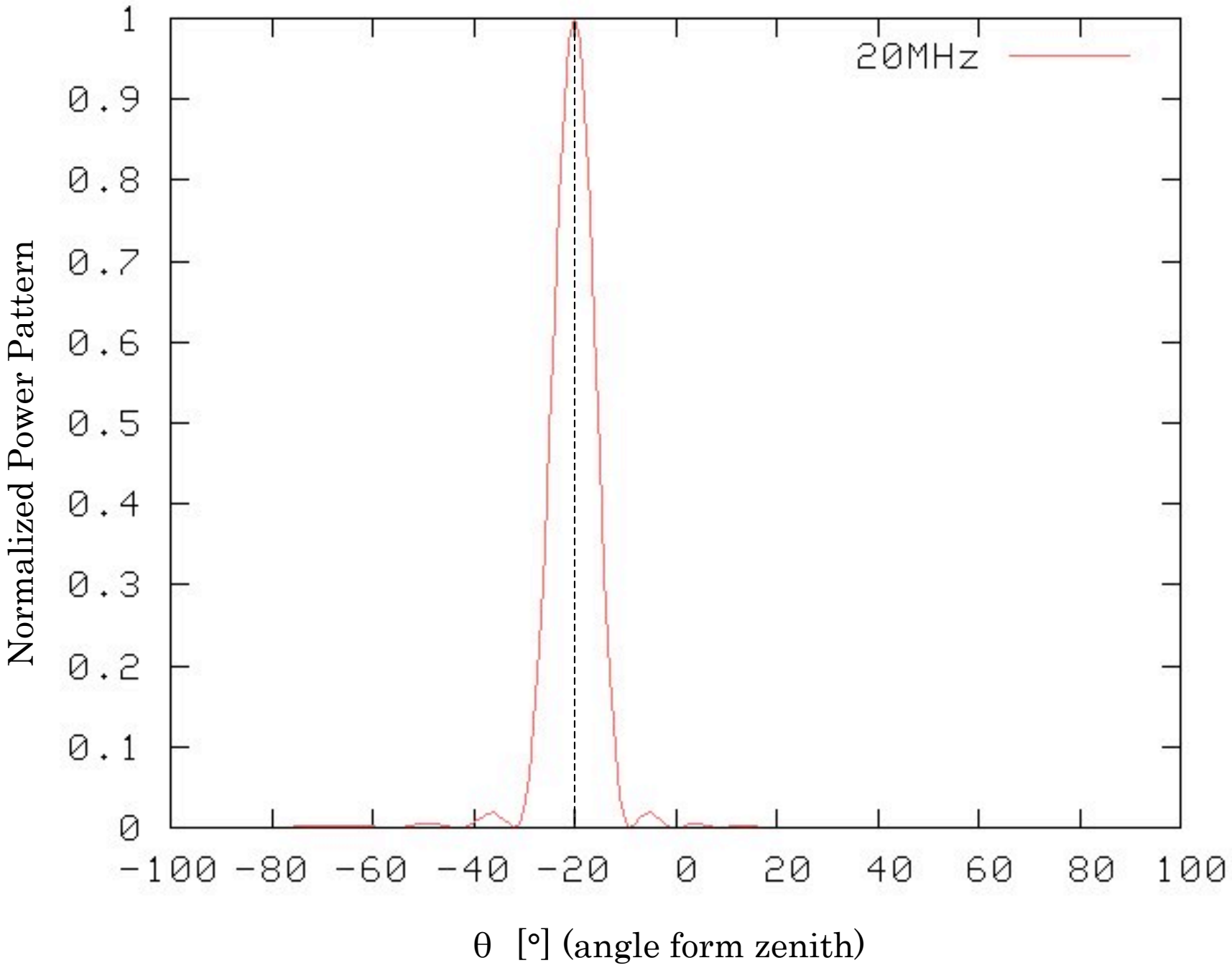
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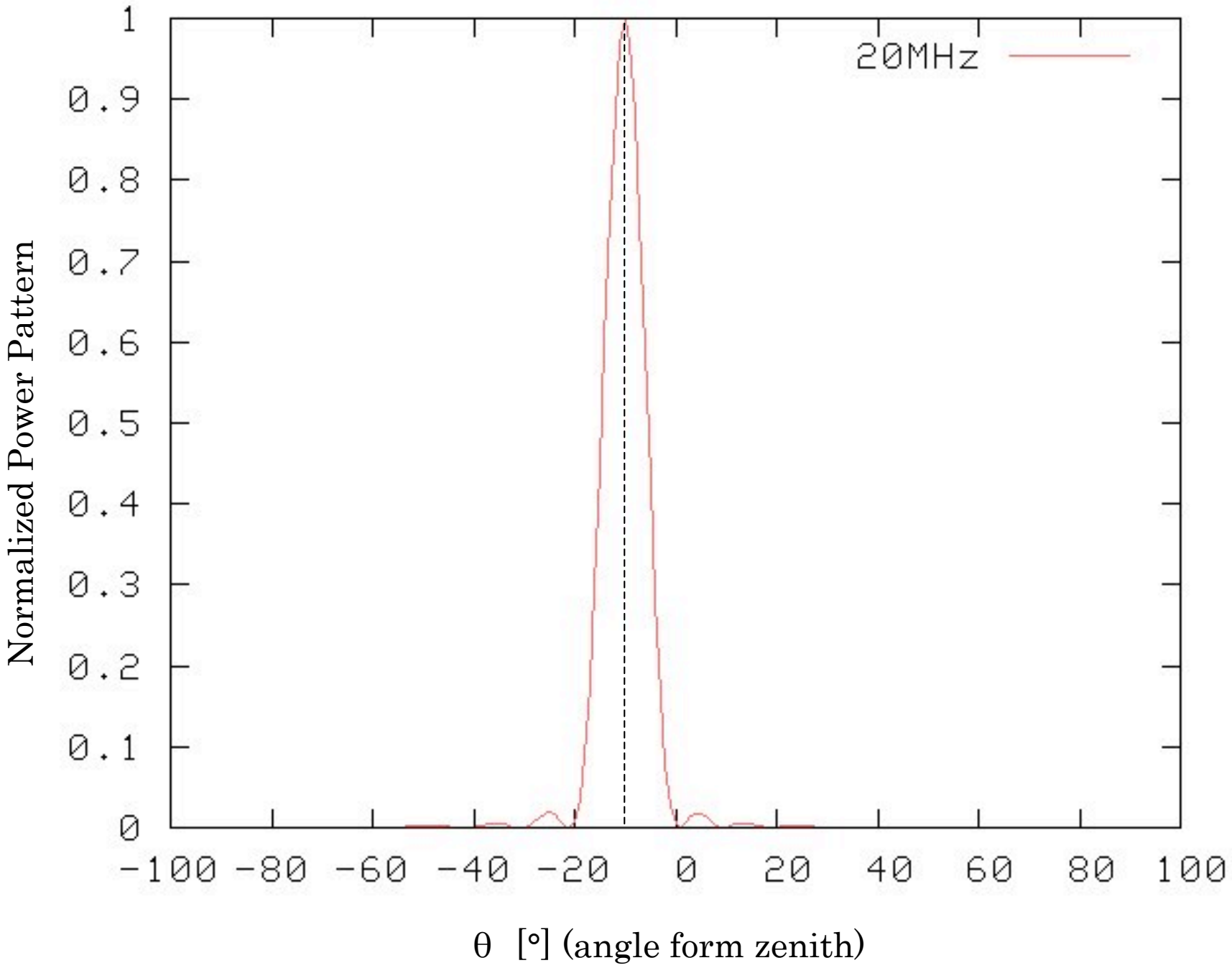
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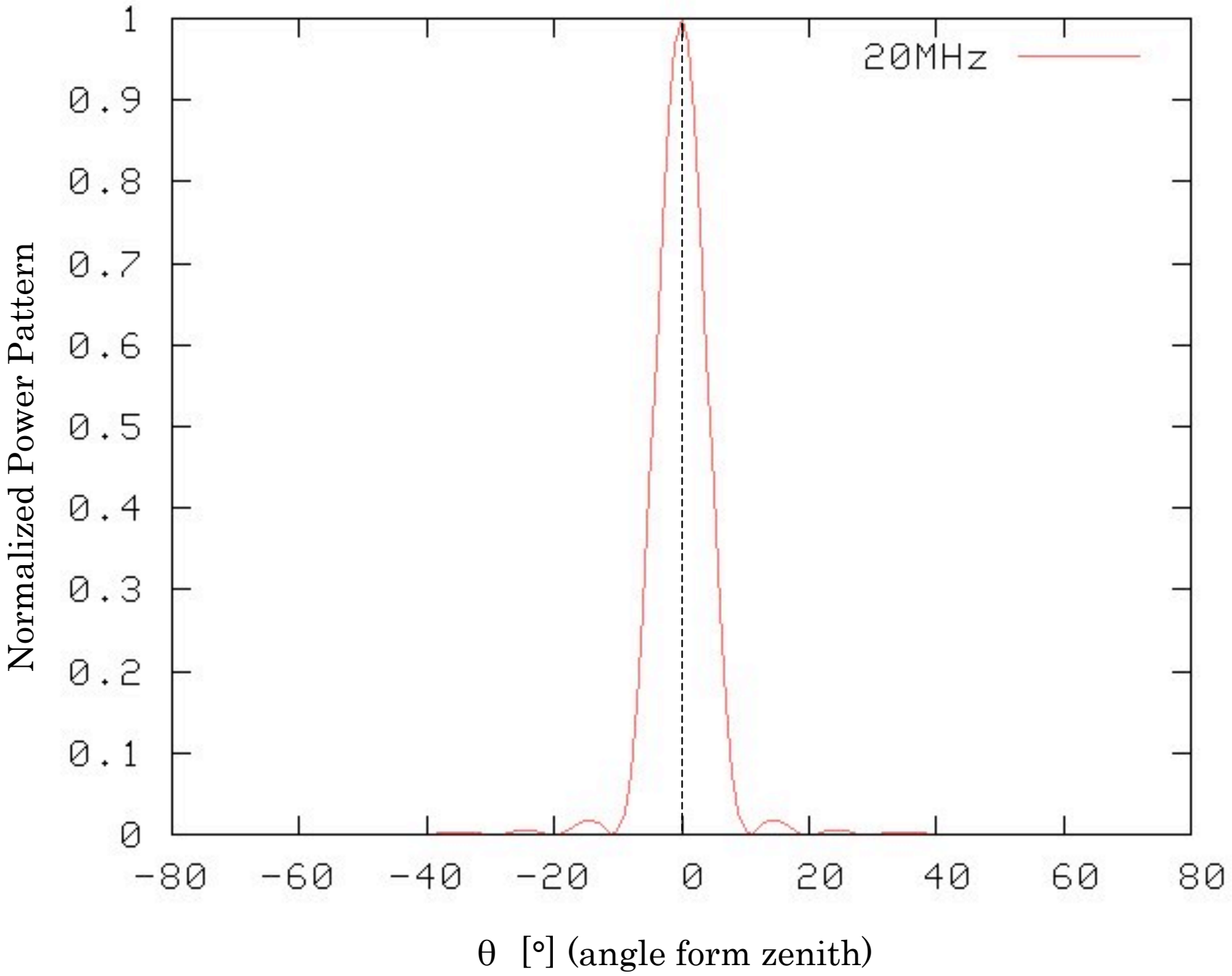
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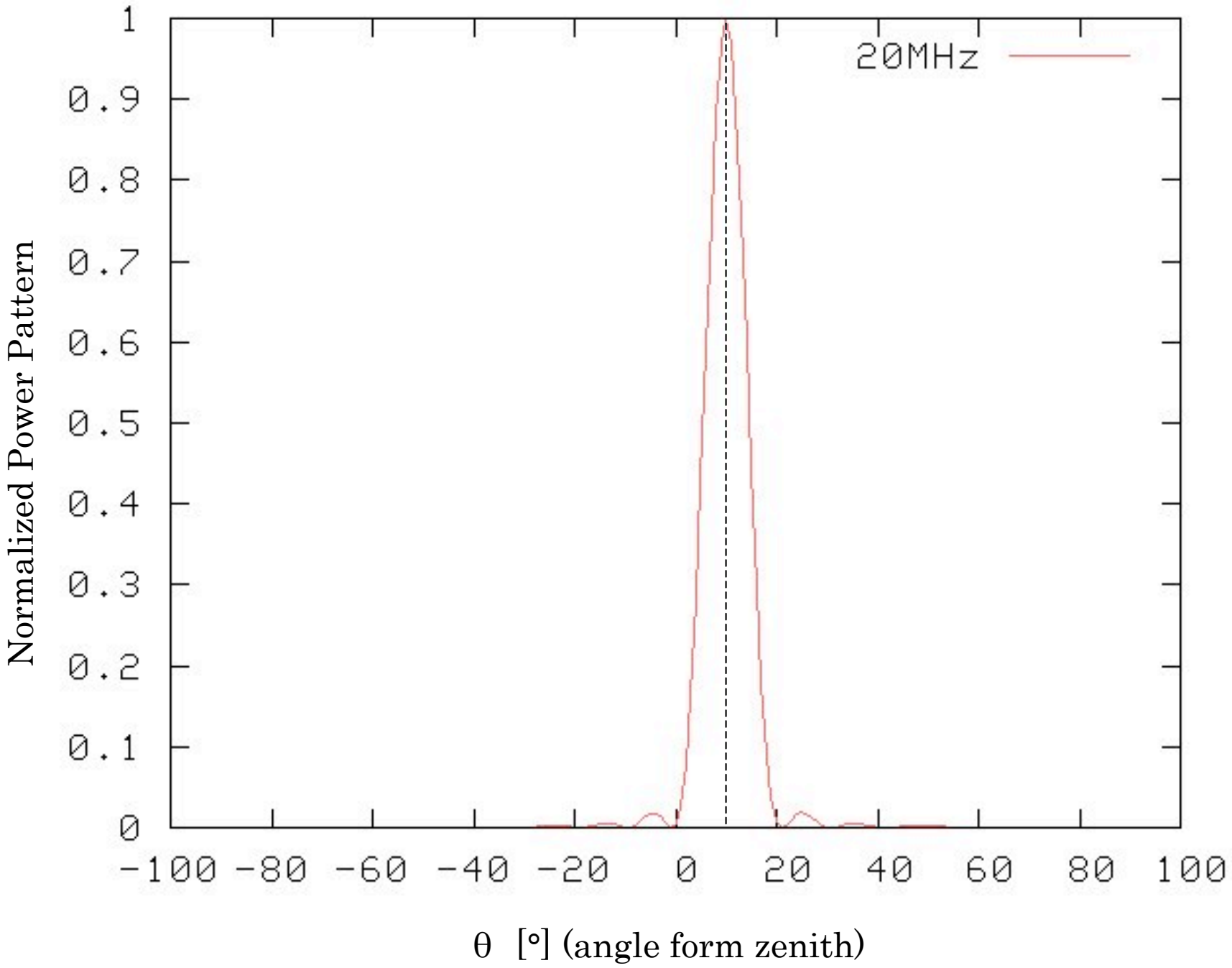
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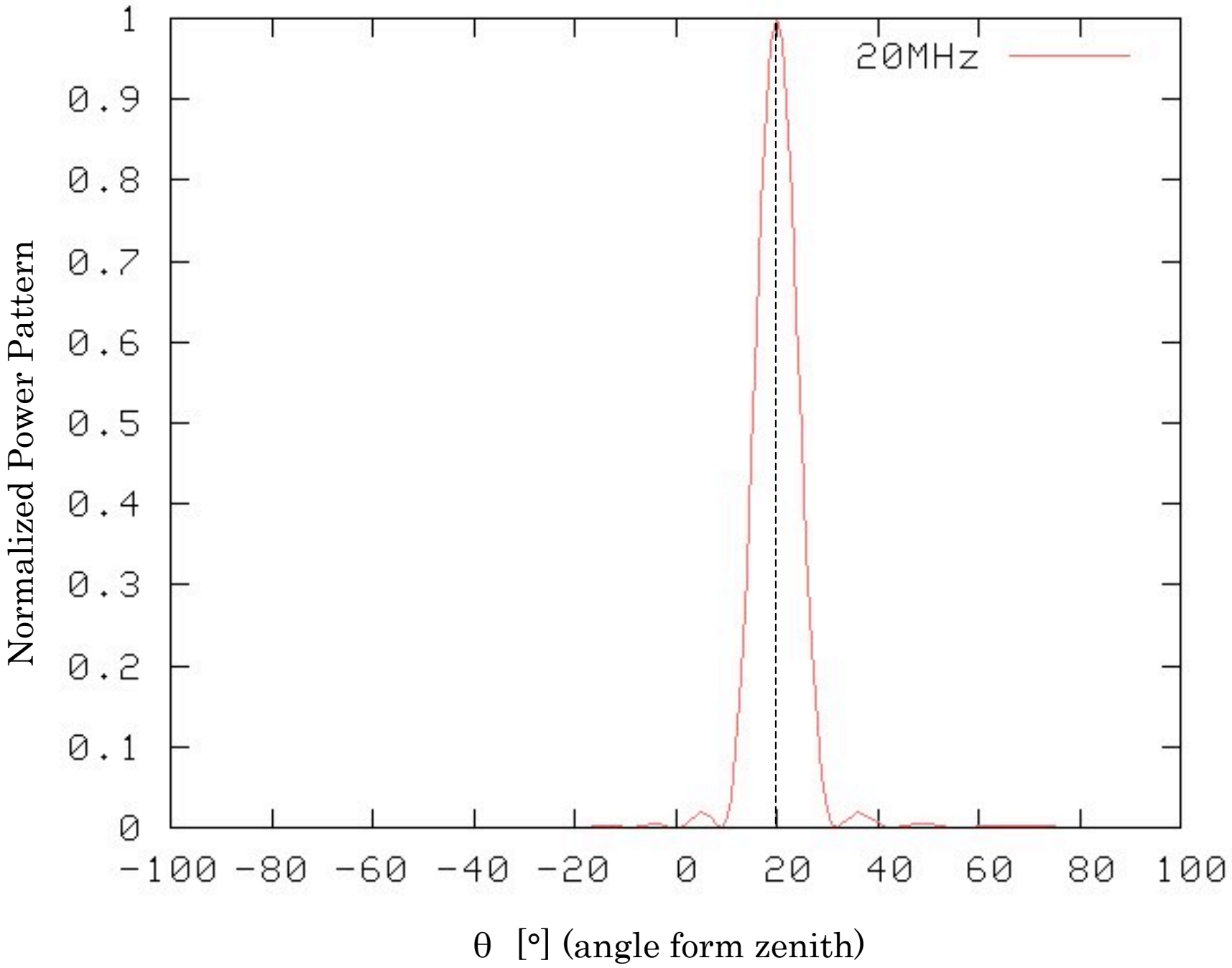
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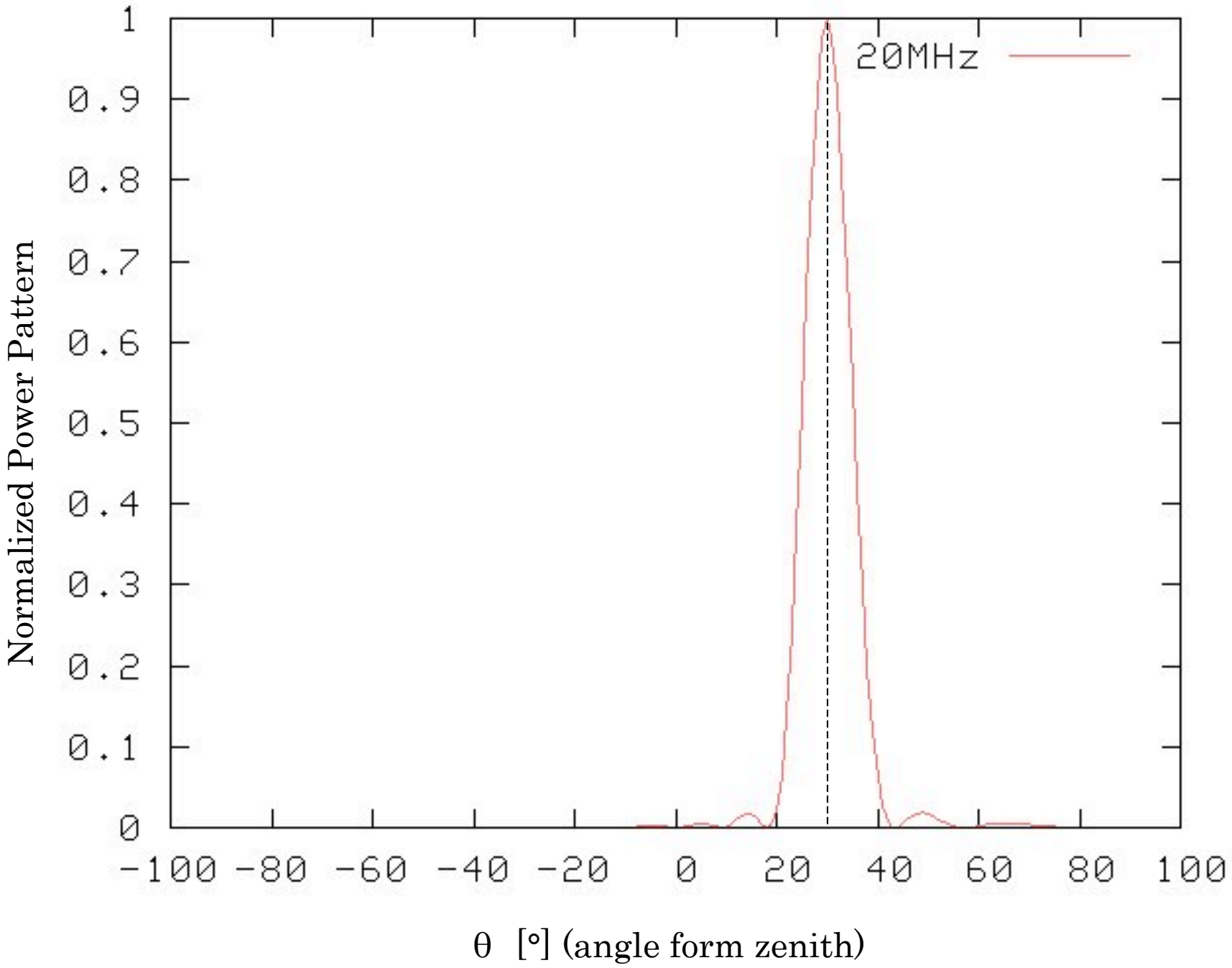
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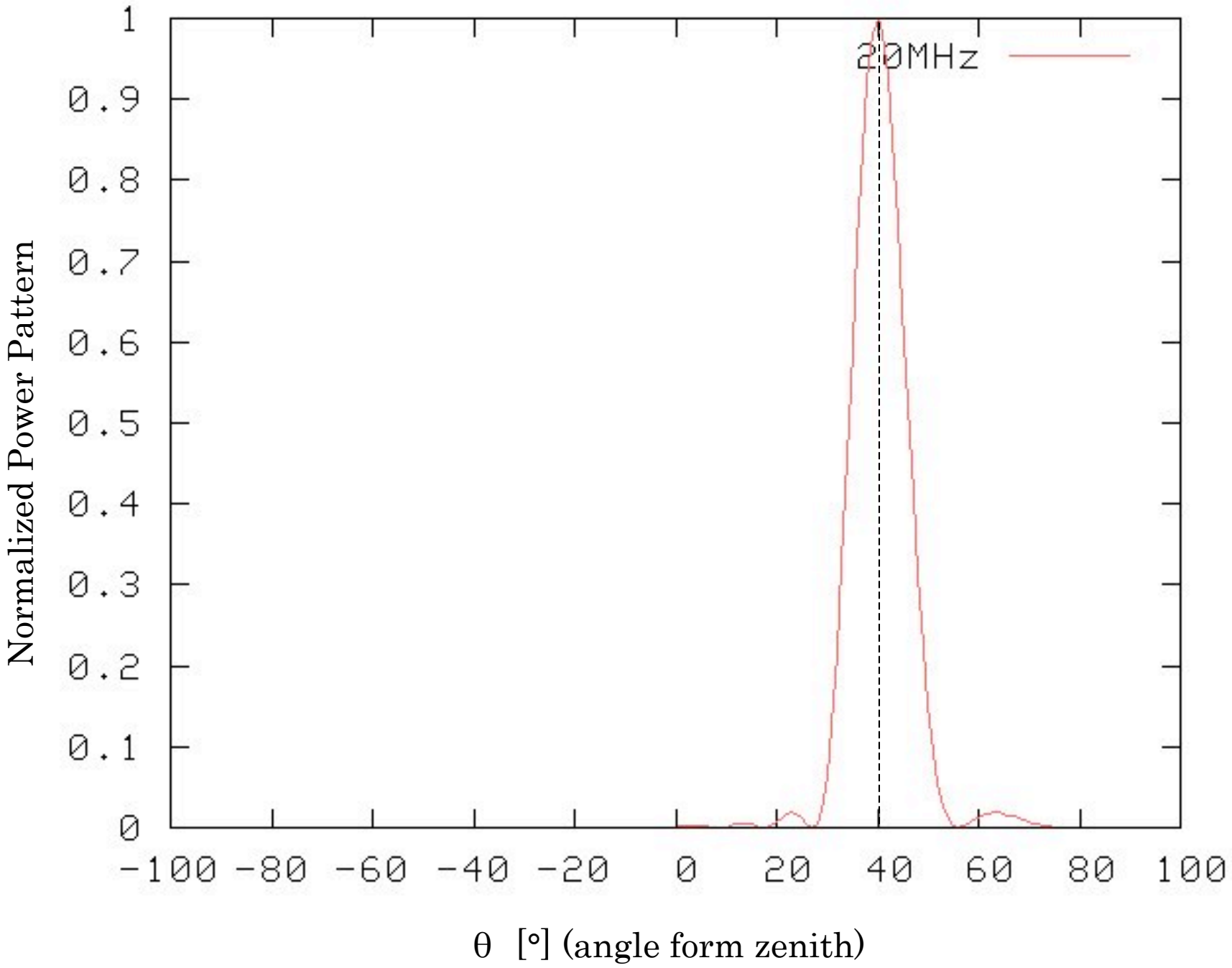
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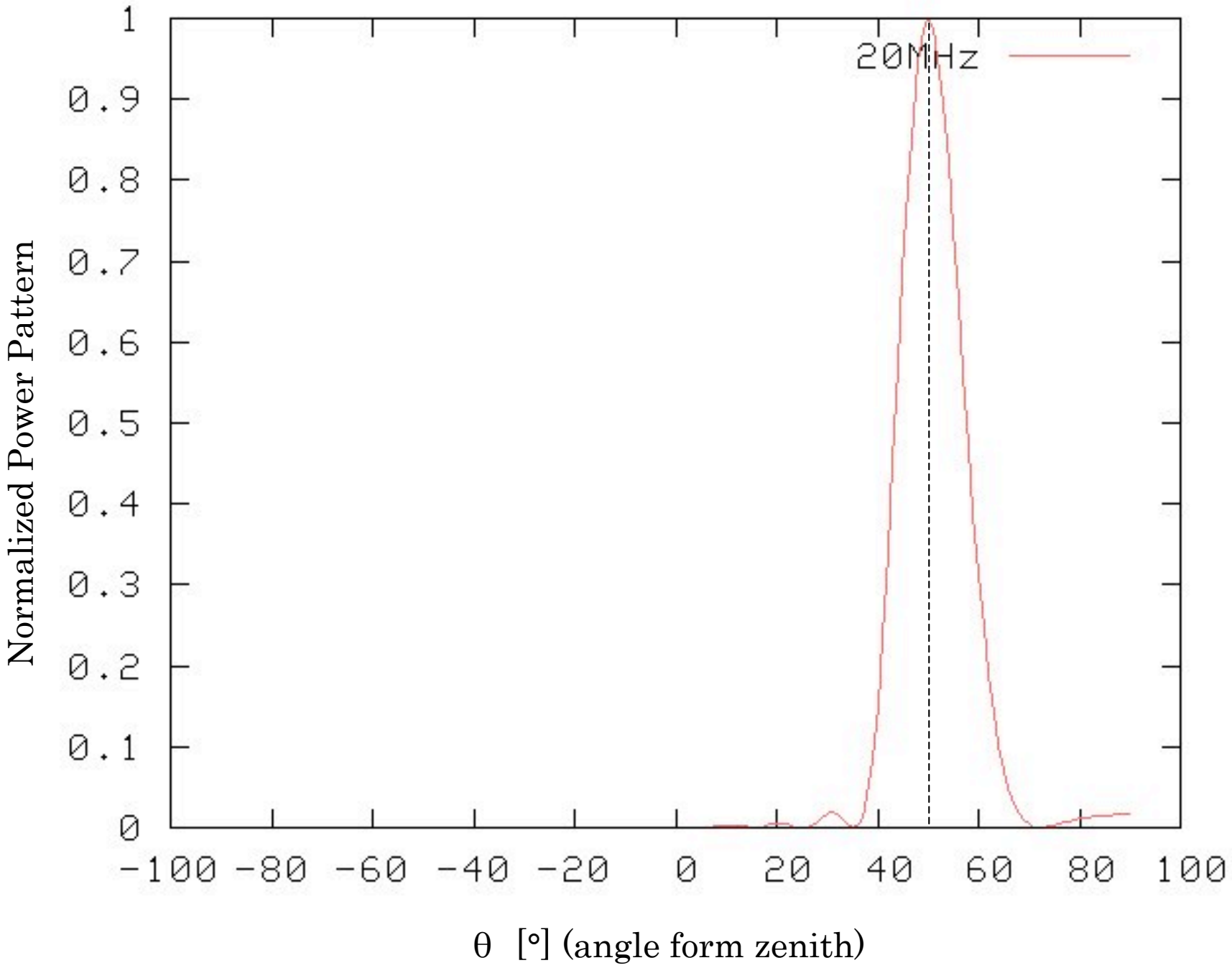
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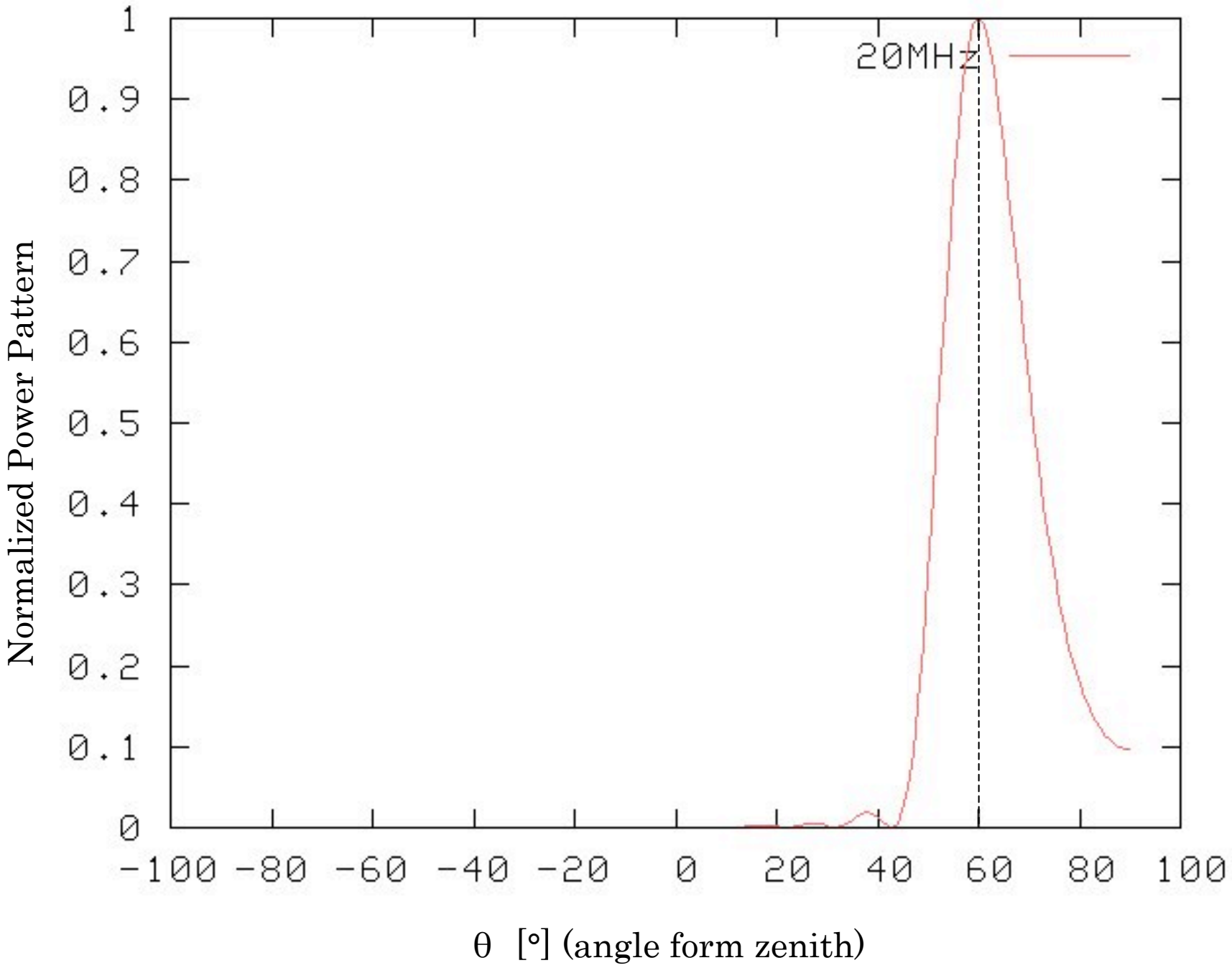
20MHz
Normalized Power Pattern
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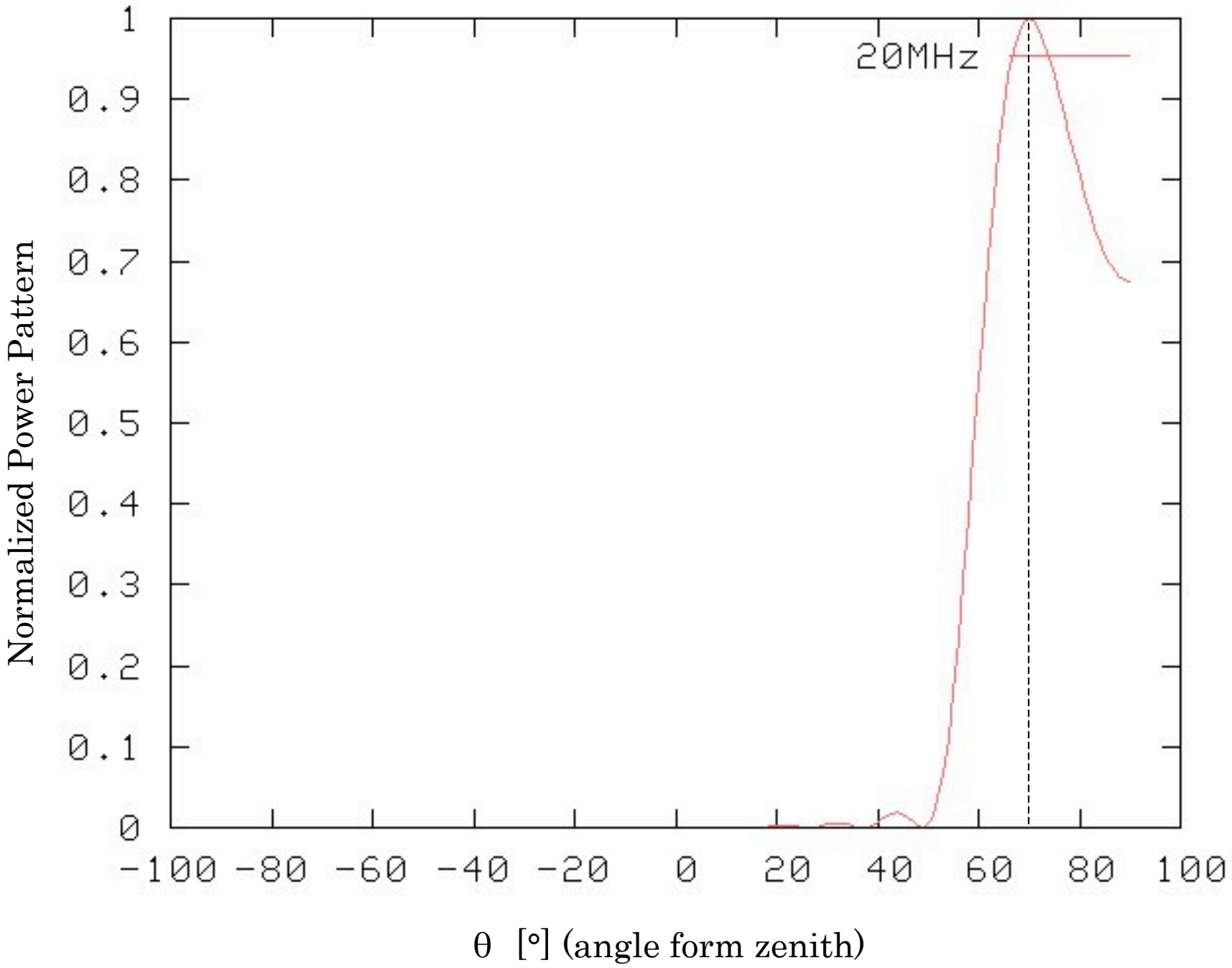
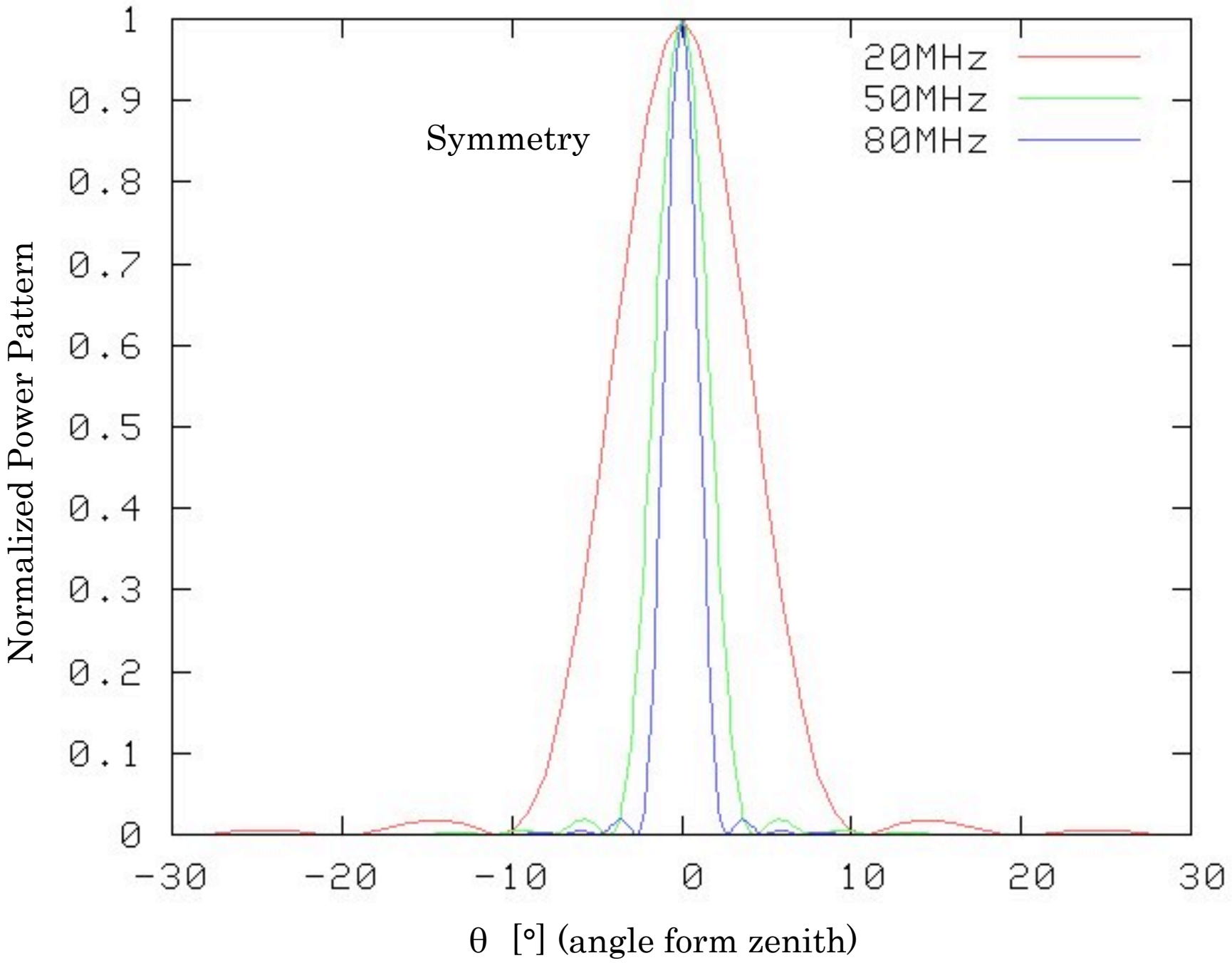
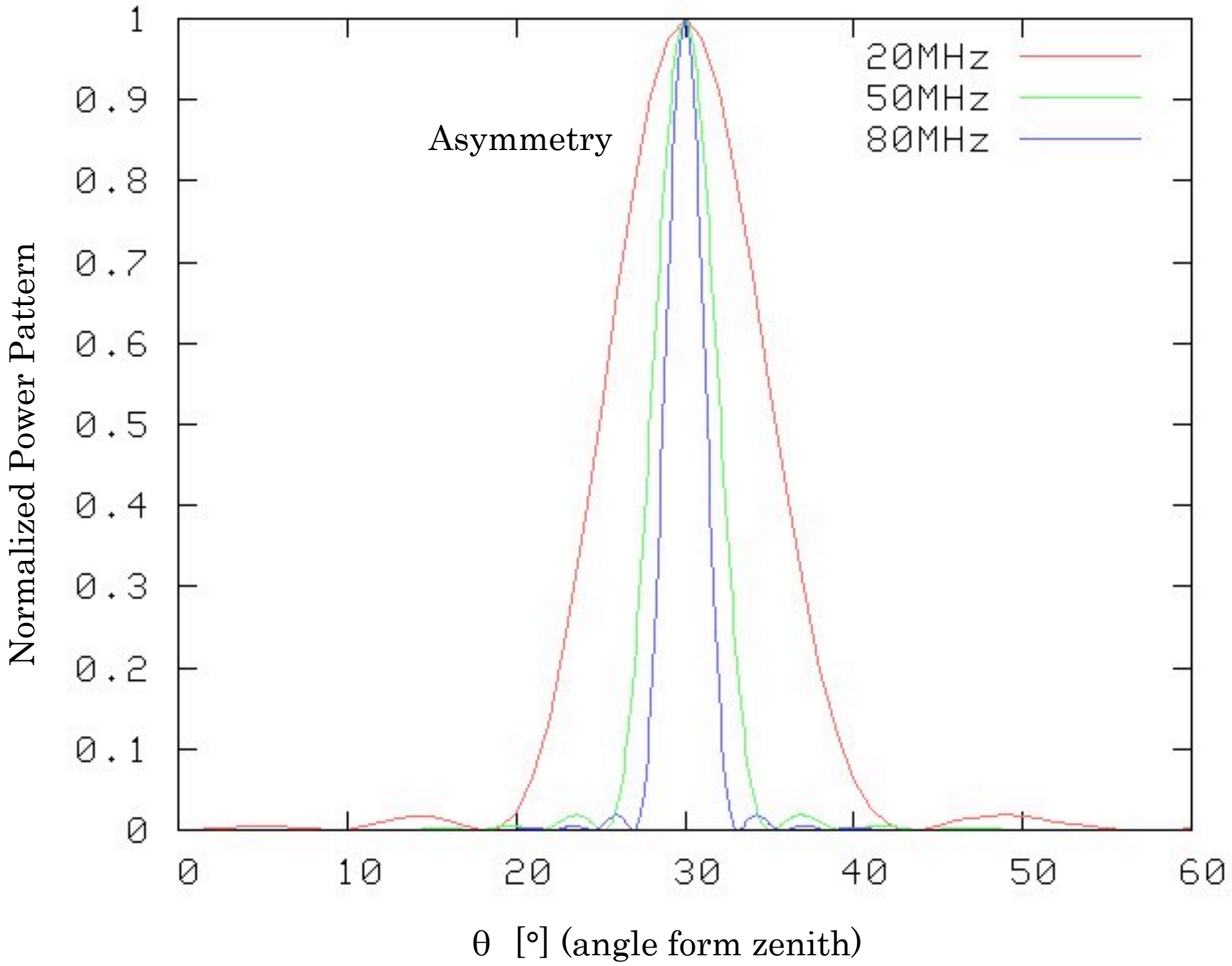
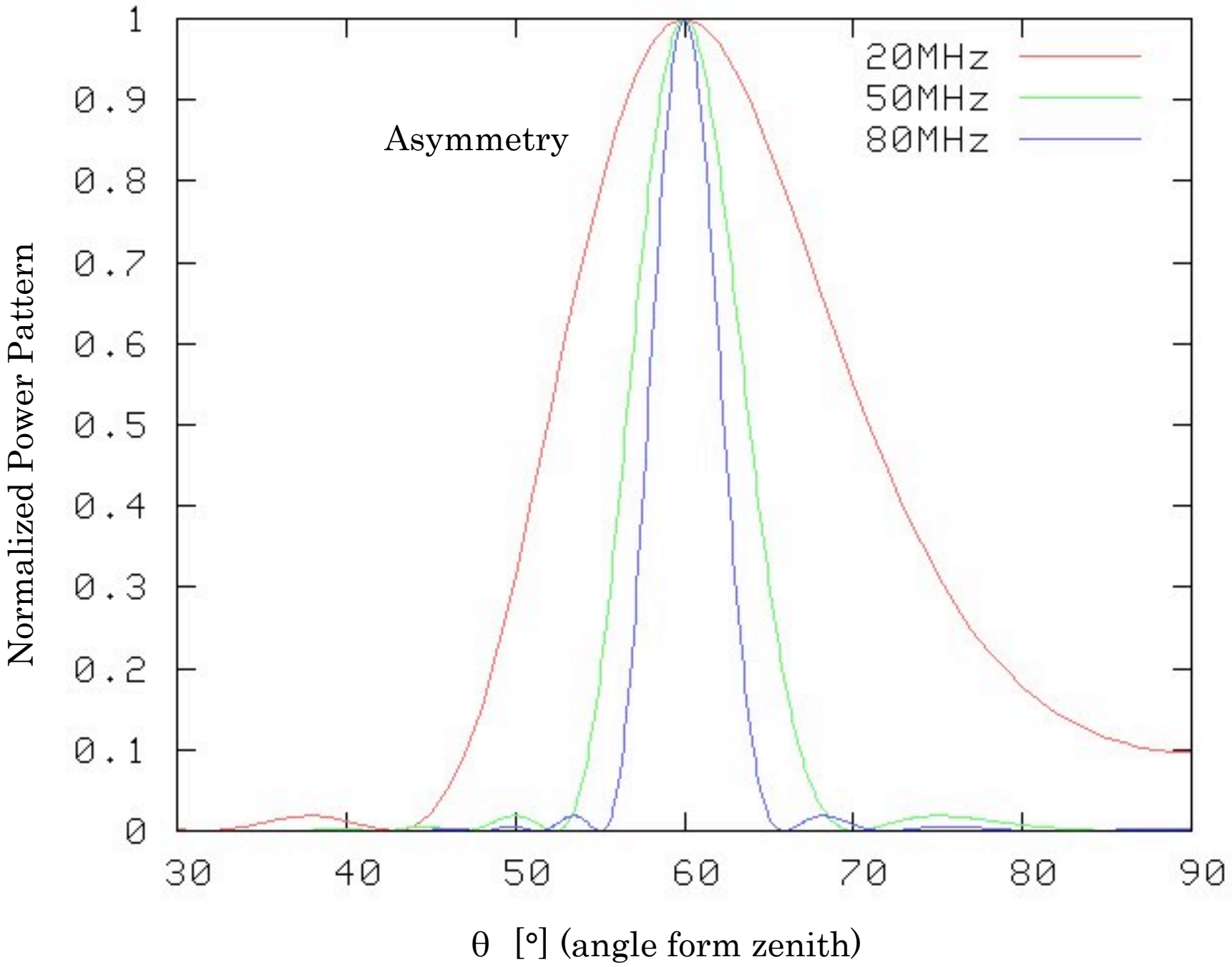
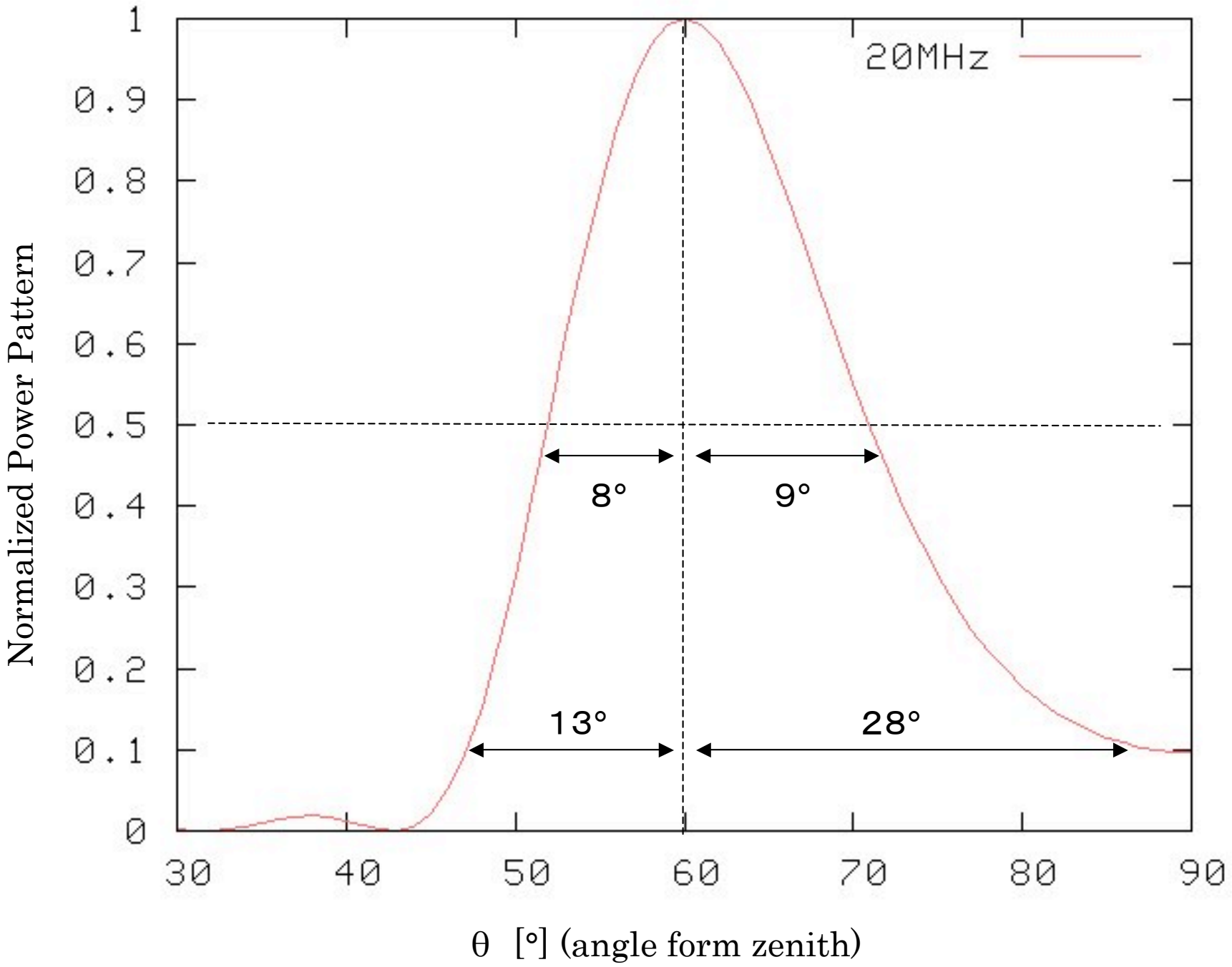
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-100 -80 -60 -40 -20 0 20 40 60 80 100
θ [°] (angle form zenith)


20MHz
Normalized Power Pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-100 -80 -60 -40 -20 0 20 40 60 80 100
θ [°] (angle form zenith)

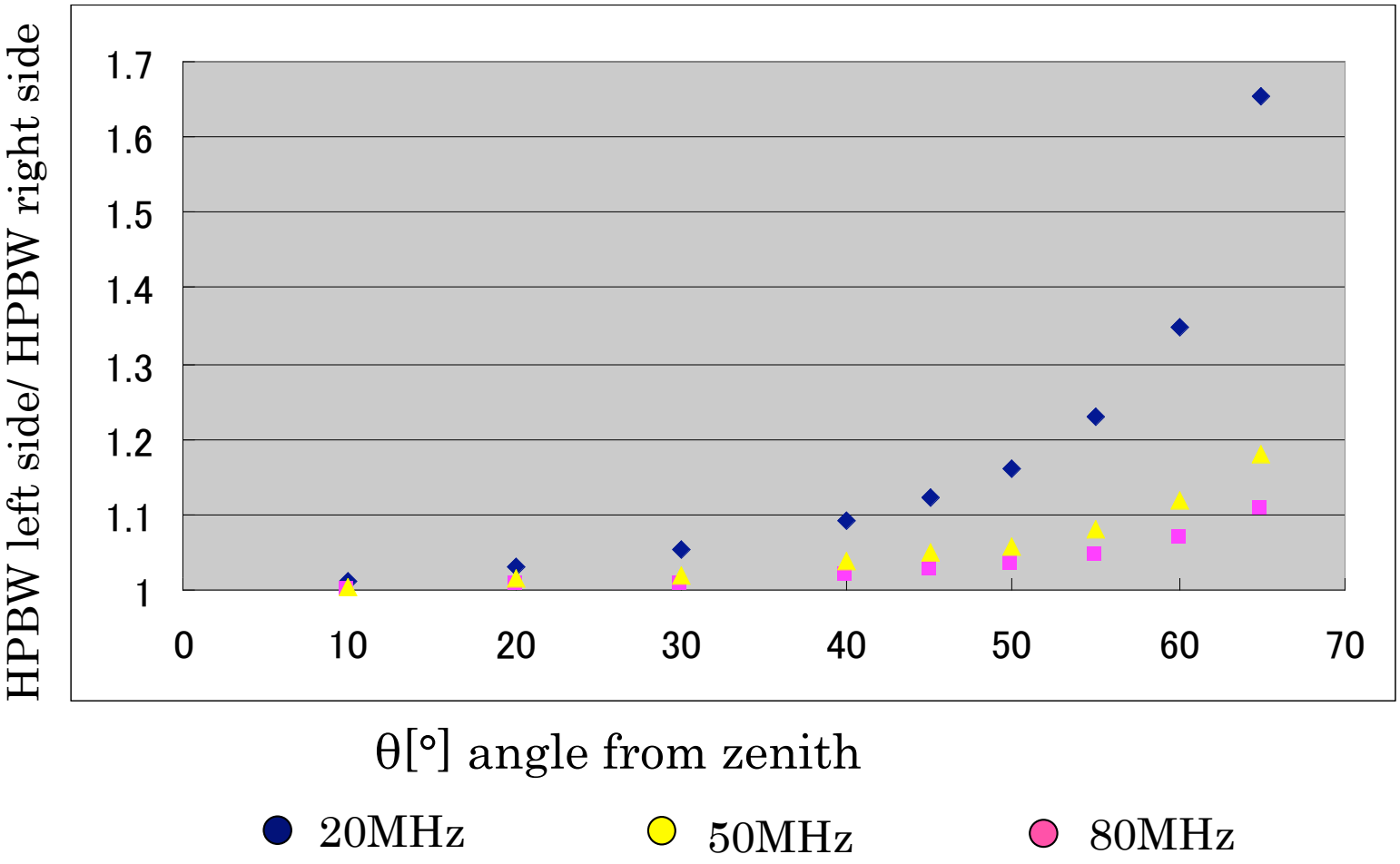

Symmetry
20MHz
50MHz
80MHz
Normalized Power Pattern
θ [°] (angle form zenith)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-30
-20
-10
0
10
20
30

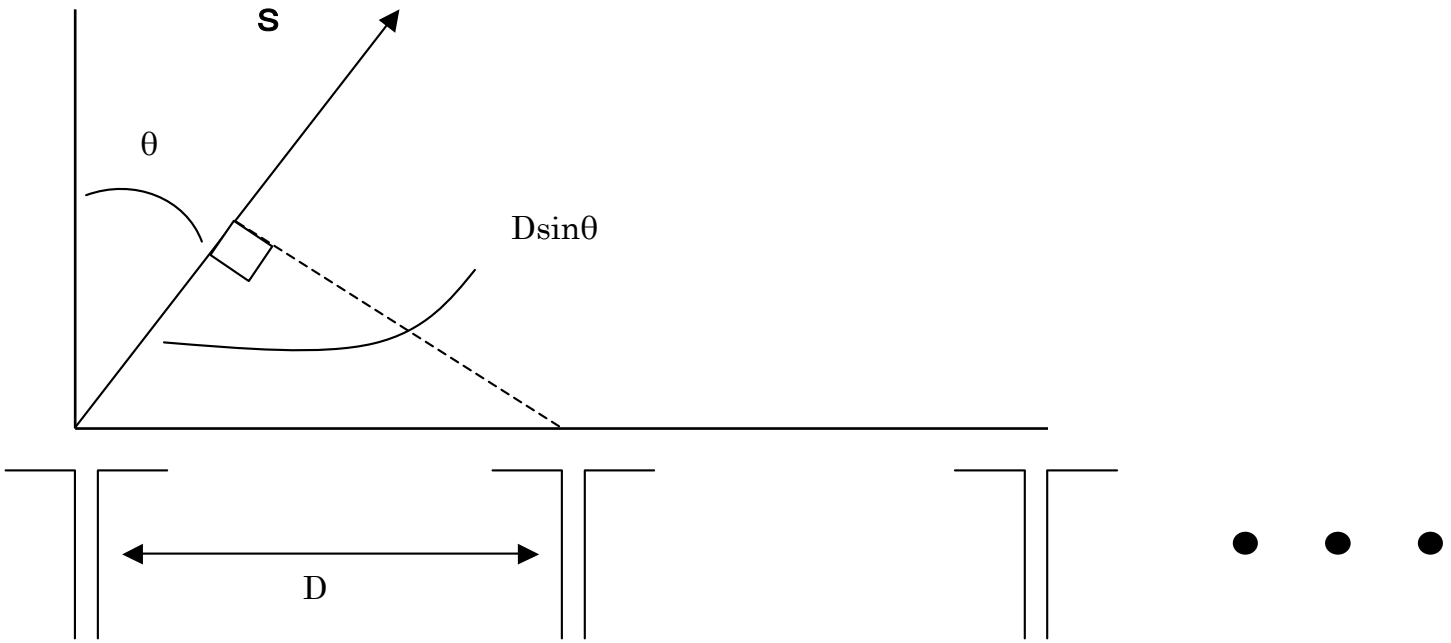

Asymmetry
20MHz
50MHz
80MHz
Normalized Power Pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
θ [°] (angle form zenith)


Asymmetry
20MHz
50MHz
80MHz
Normalized Power Pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90
θ [°] (angle form zenith)

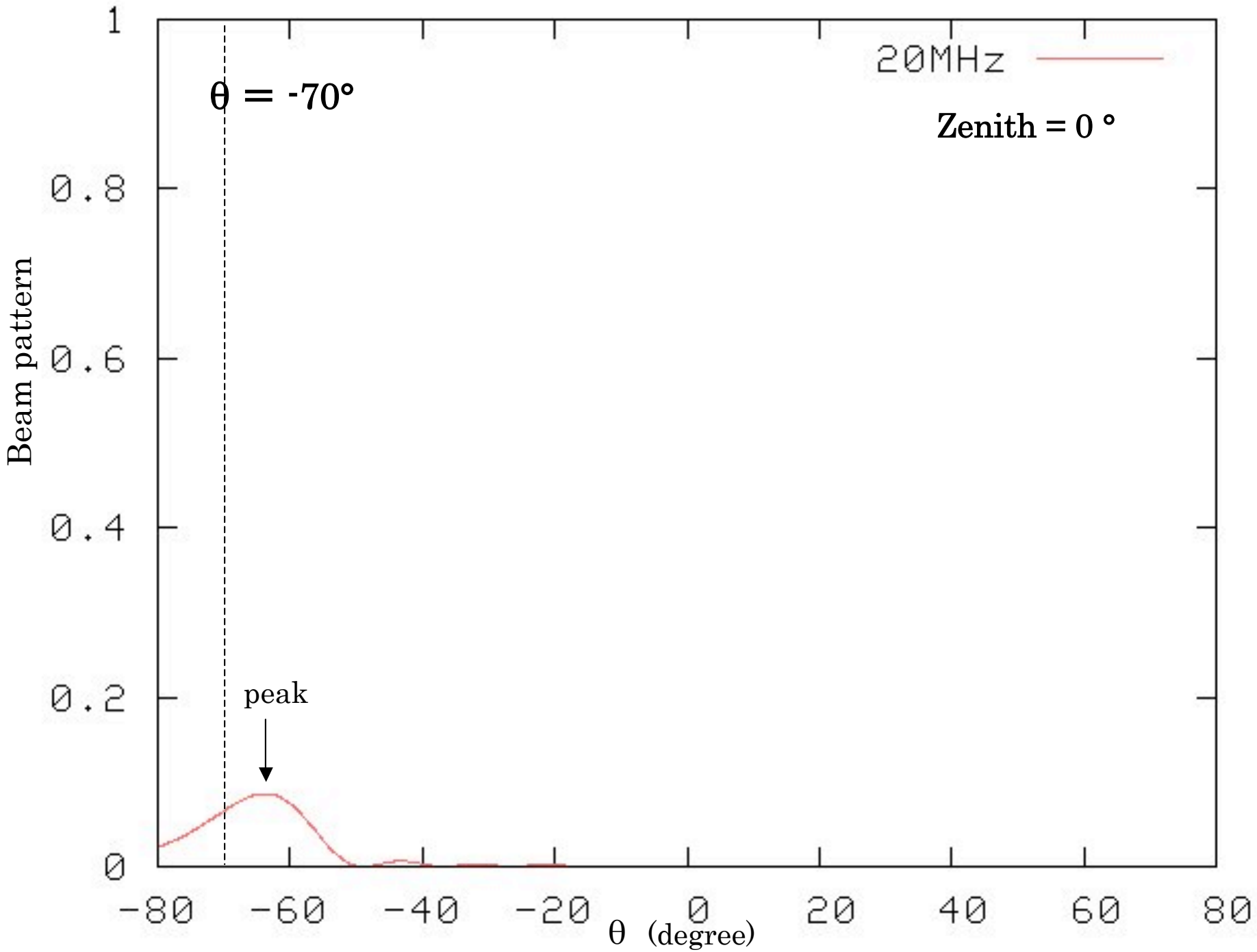

20MHz
Normalized Power Pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90
8°
9°
13°
28°
θ [°] (angle form zenith)

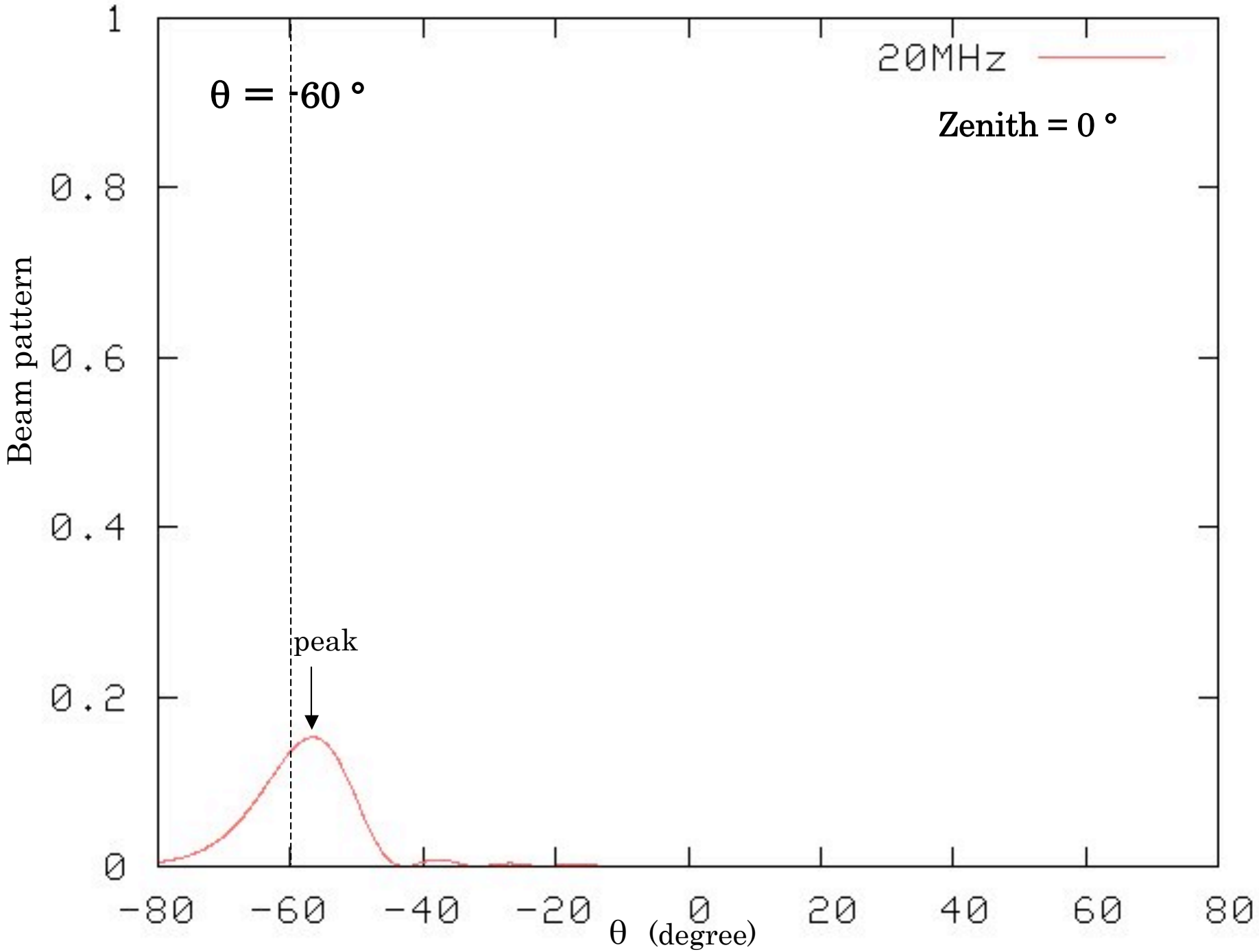
Asymmetry rate

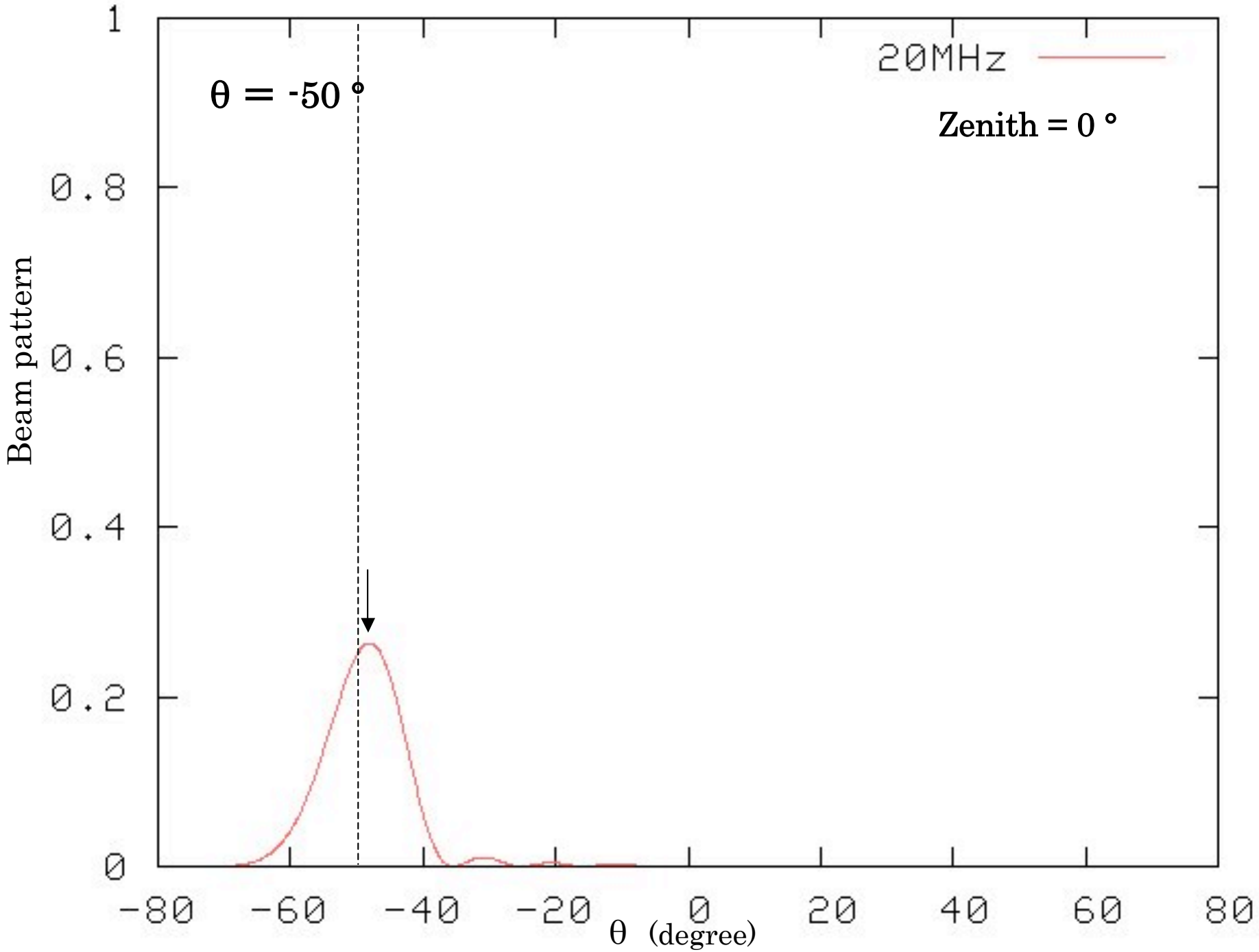


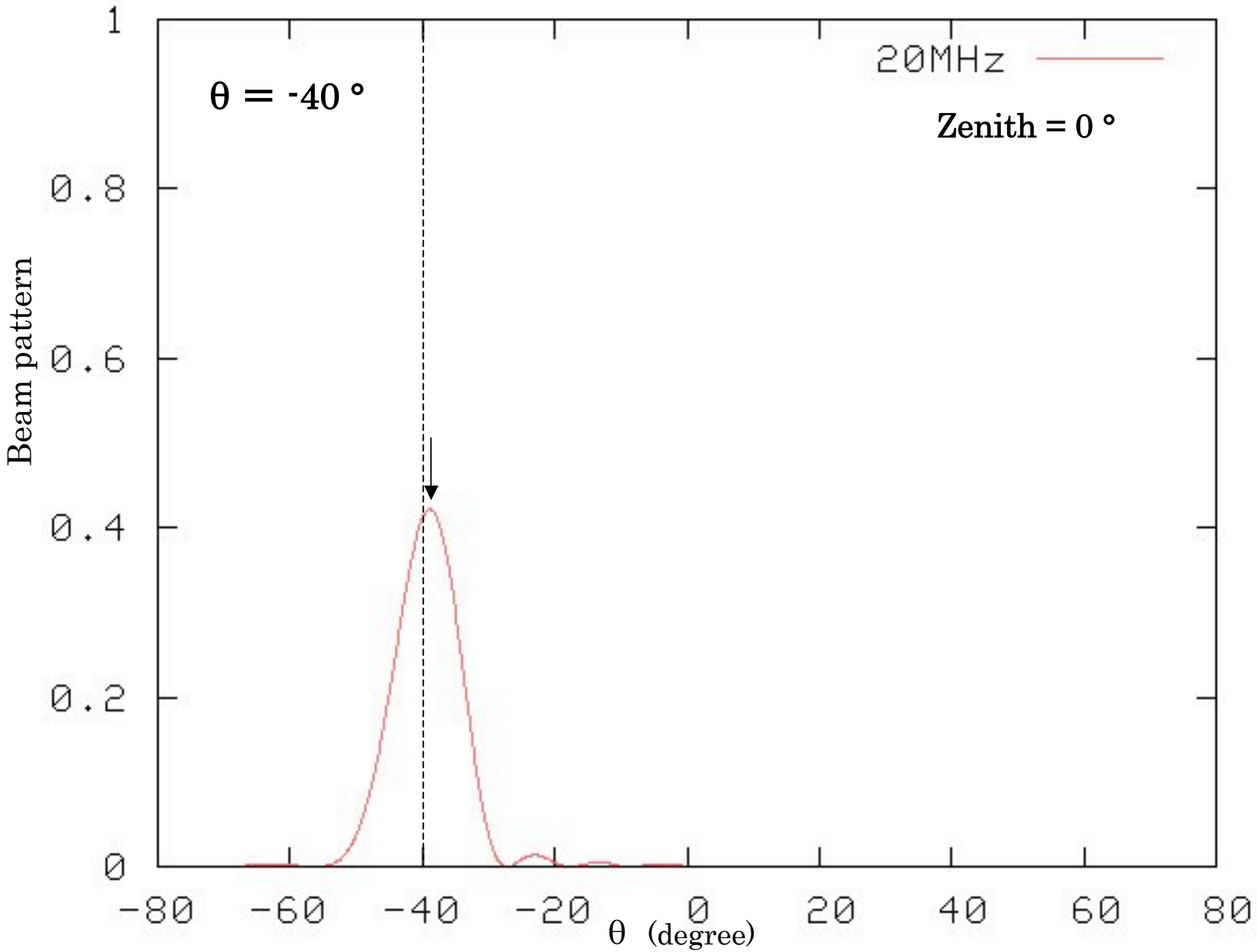


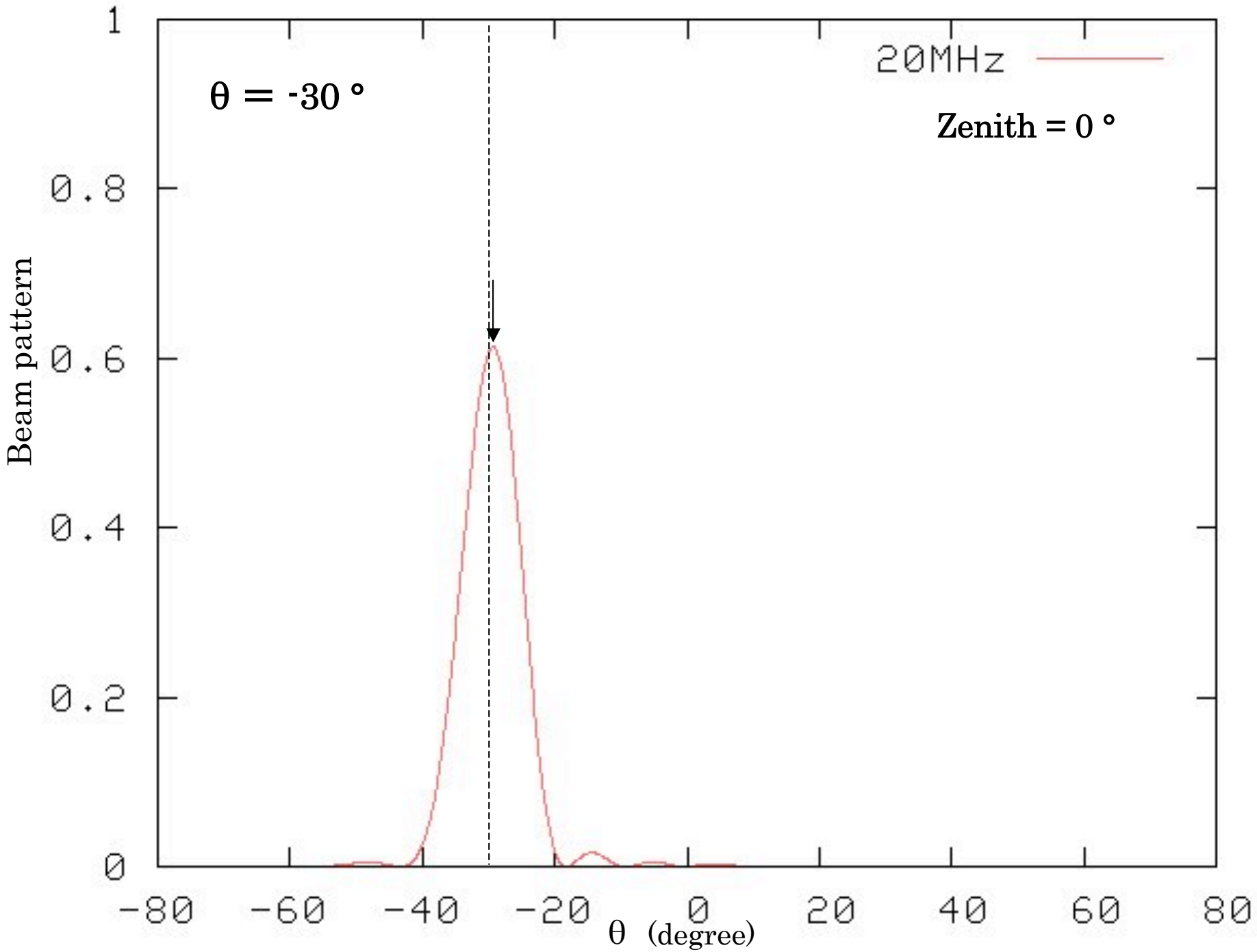
As the angle θgoes from 0 to π/2,
the value of cosθ(differentiation of sinθ) gets smaller.
As a result, the beam becomes asymmetric.
This effect increases as the frequency decreases.

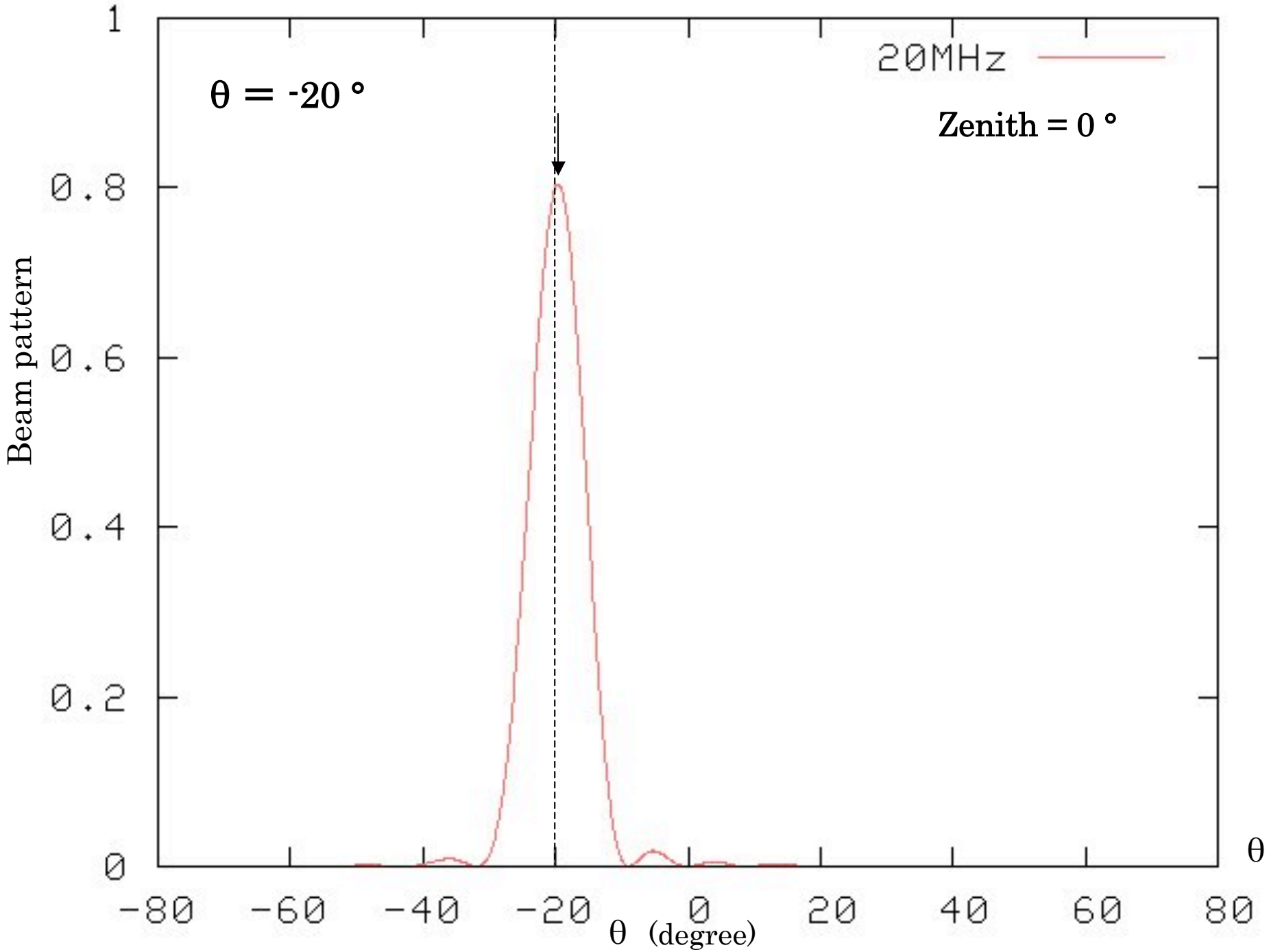

20MHz
θ = -70°
Zenith = 0 °
peak
Beam pattern
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

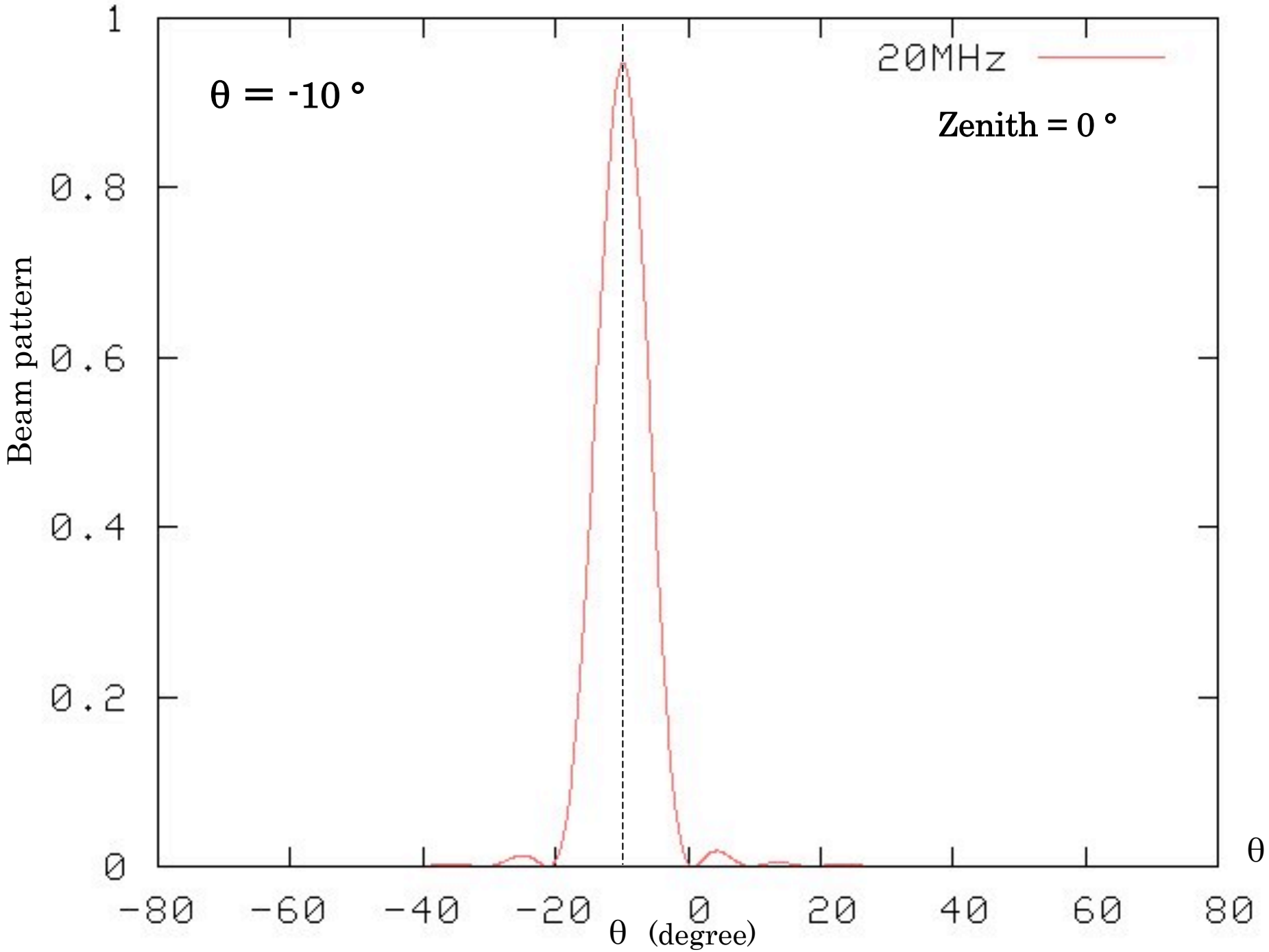

20MHz
θ = -60 °
Zenith = 0 °
peak
Beam pattern
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

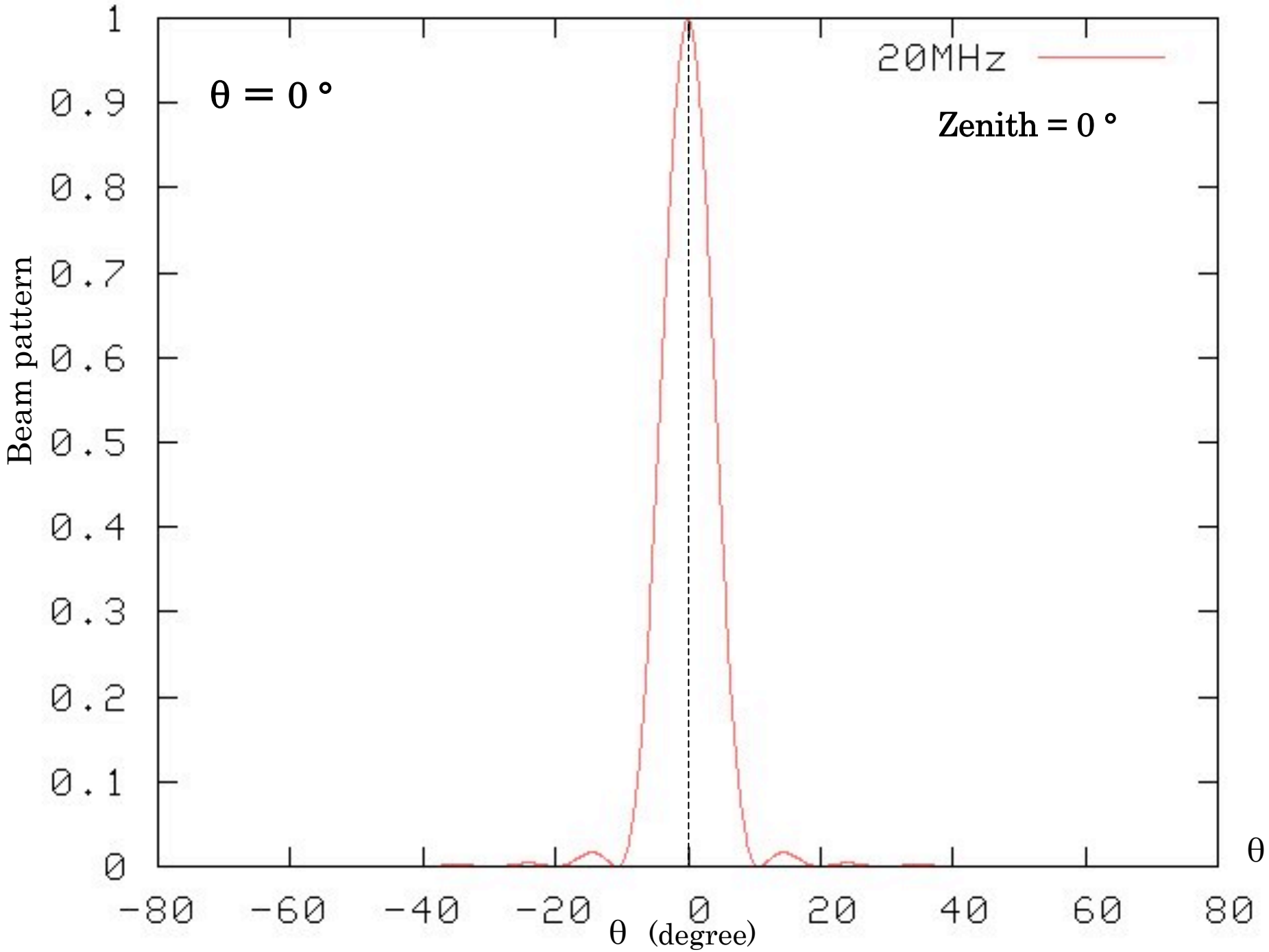

20MHz
θ = -50 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

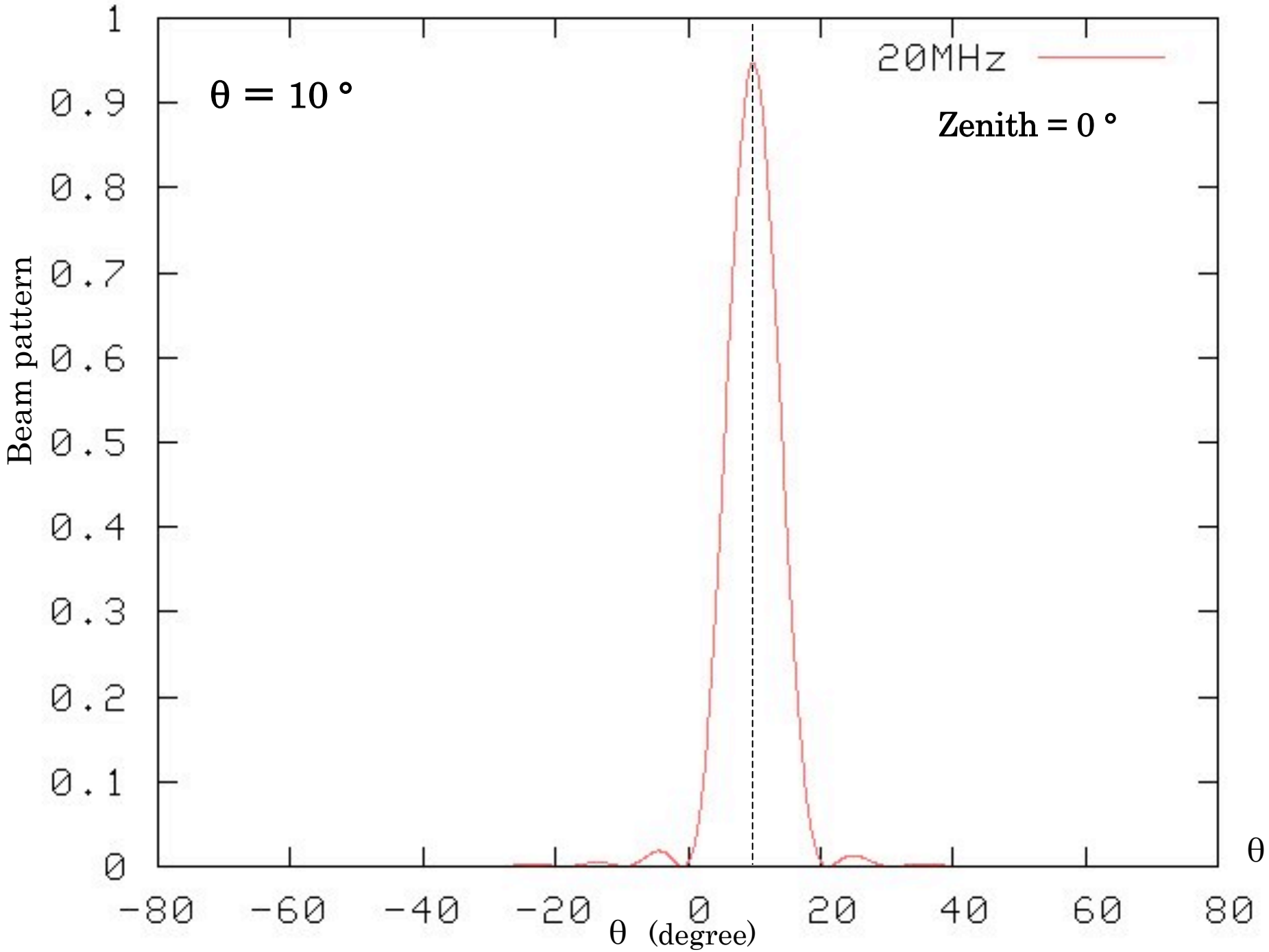

20MHz
θ = -40 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

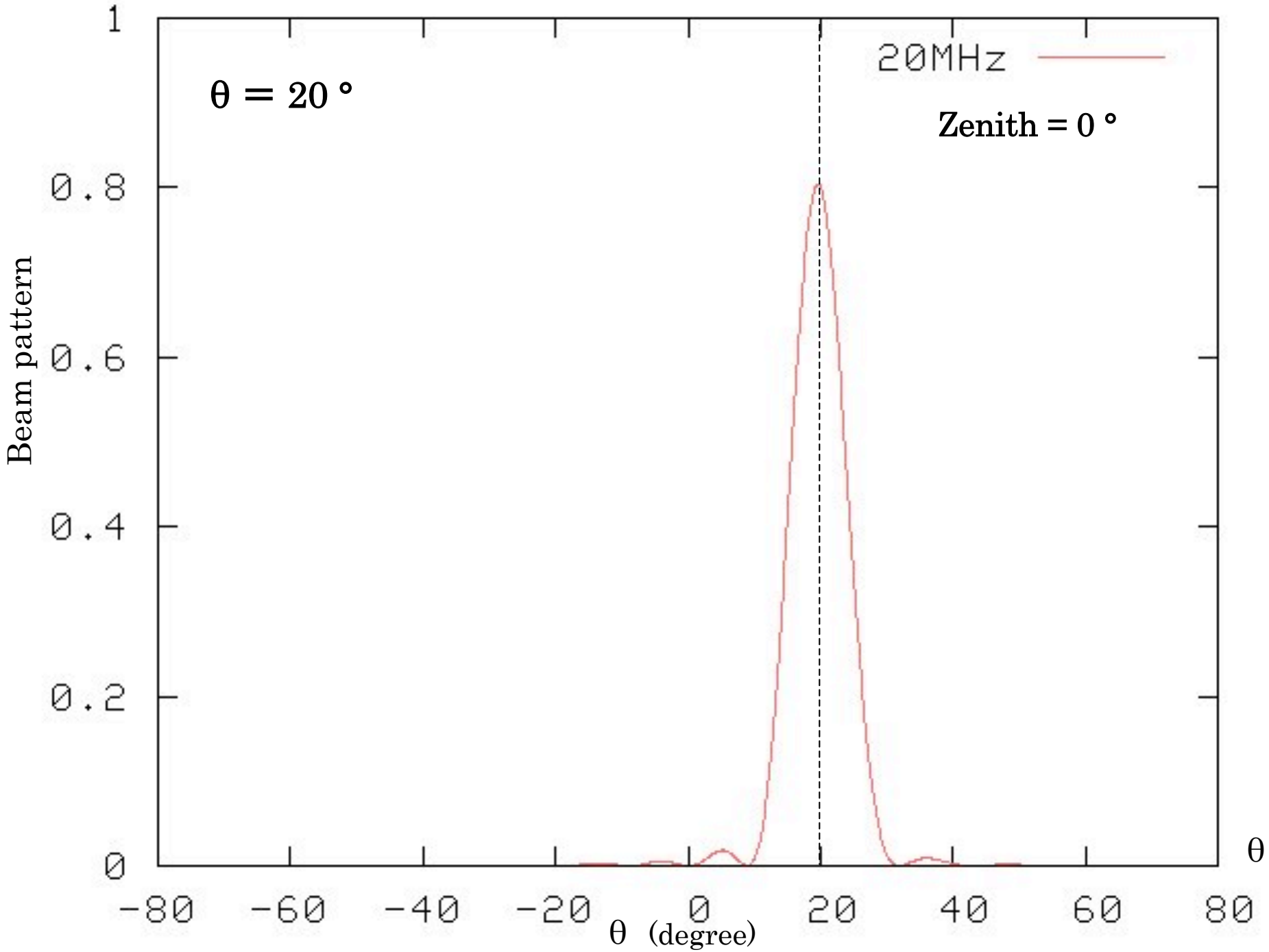

20MHz
θ = -30 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

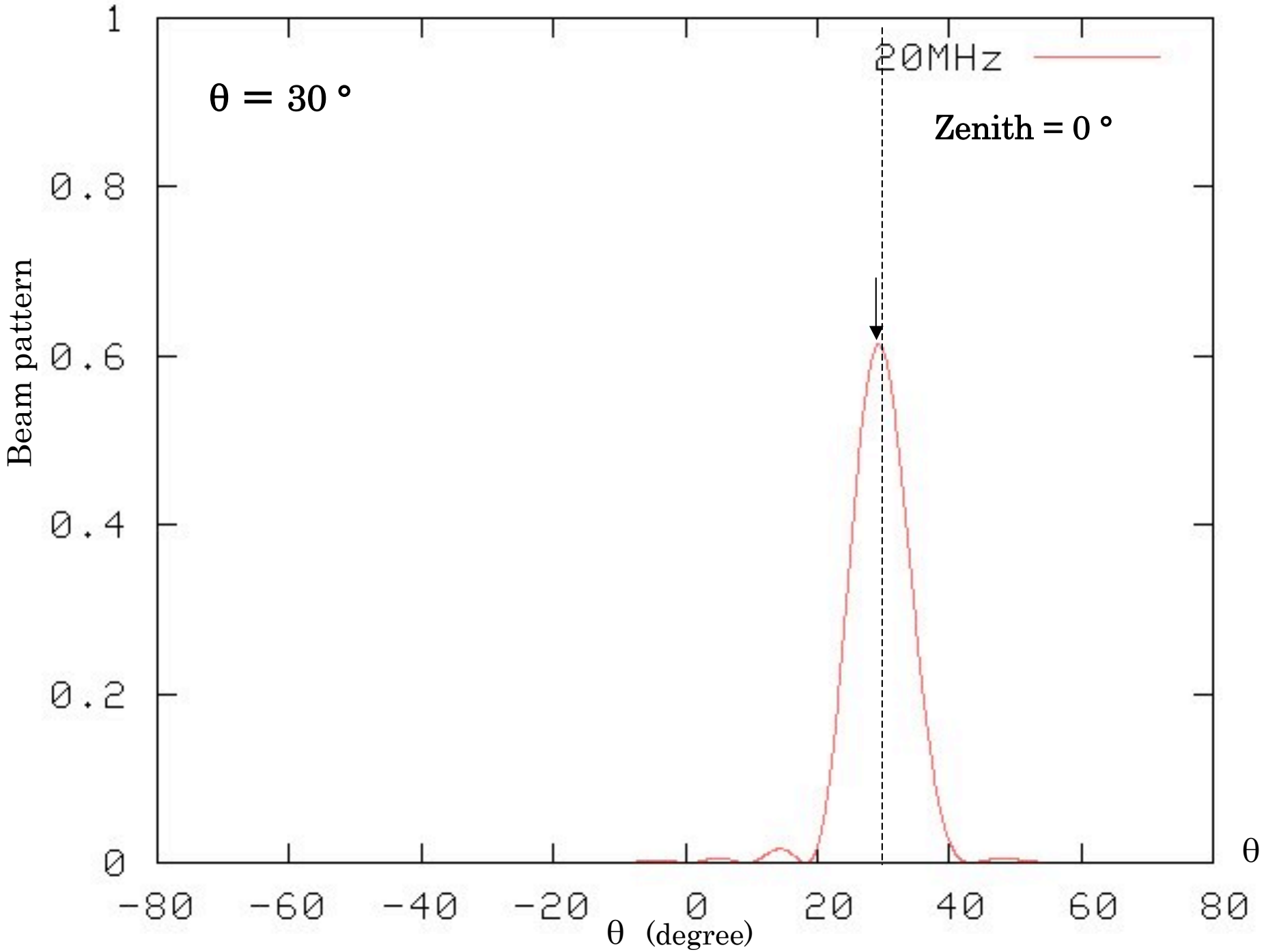

θ = -20 °
20MHz
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ
θ (degree)

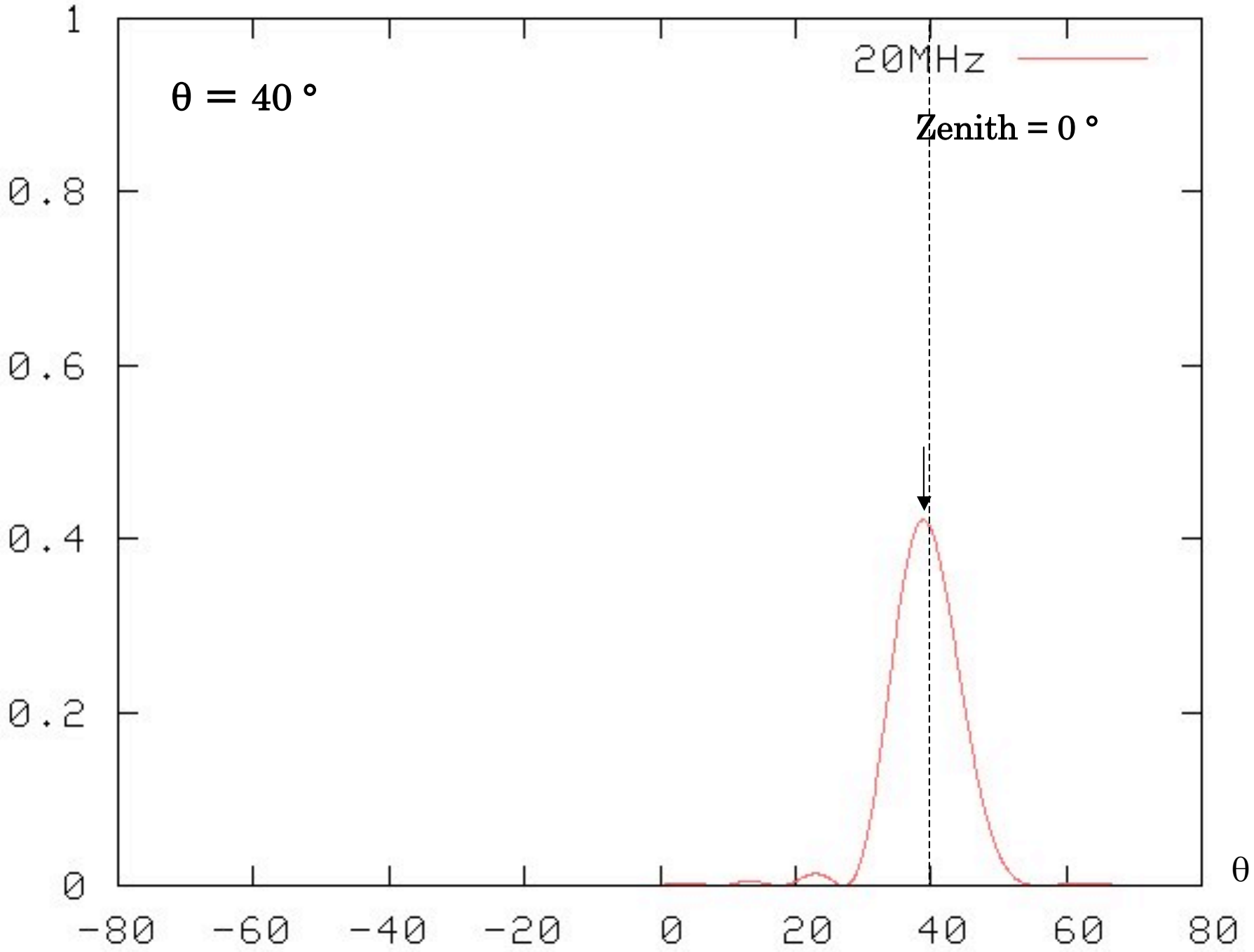

θ = -10 °
20MHz
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ
θ (degree)

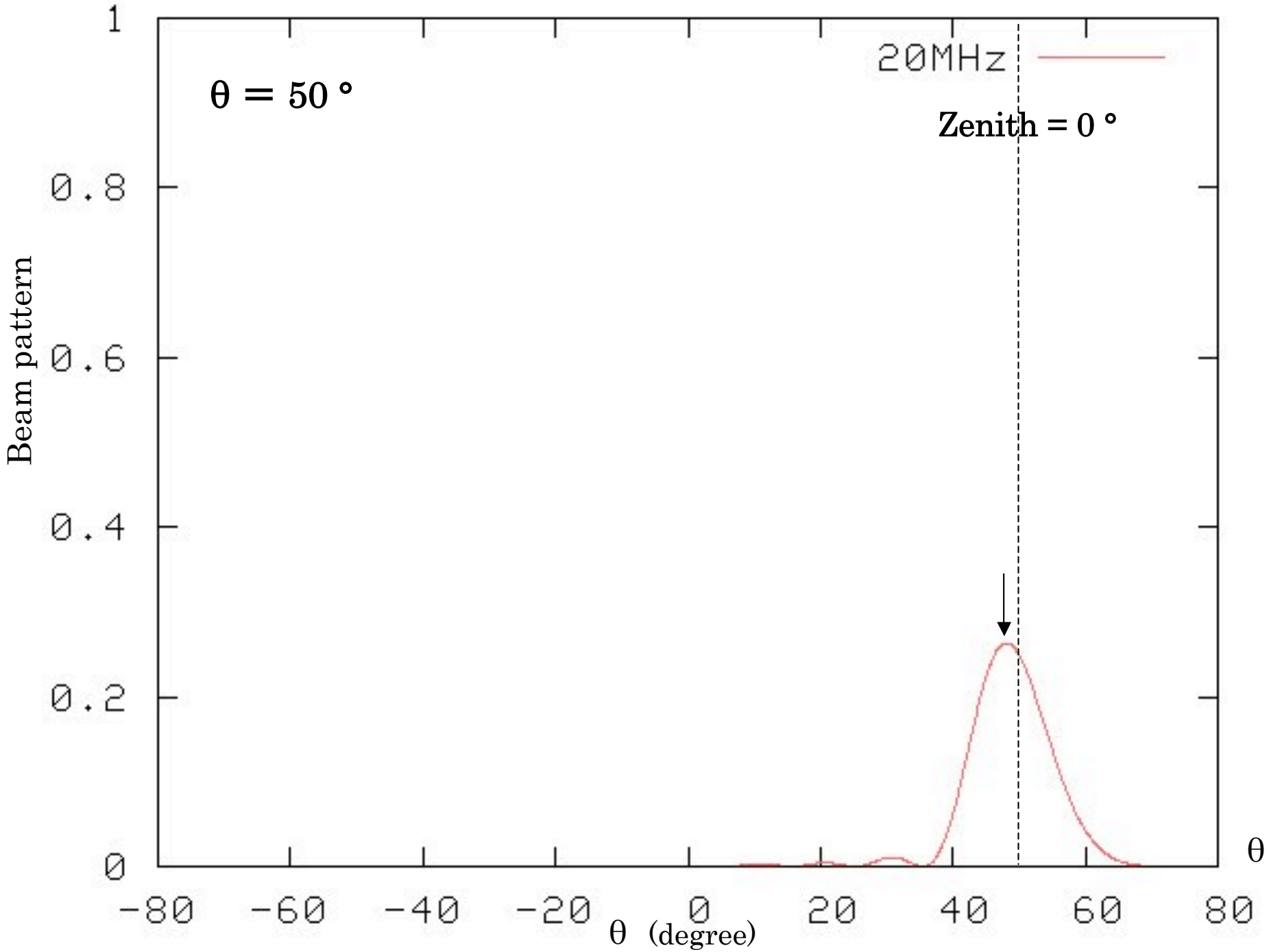

θ = 0 °
20MHz
Zenith = 0 °
Beam pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)
θ

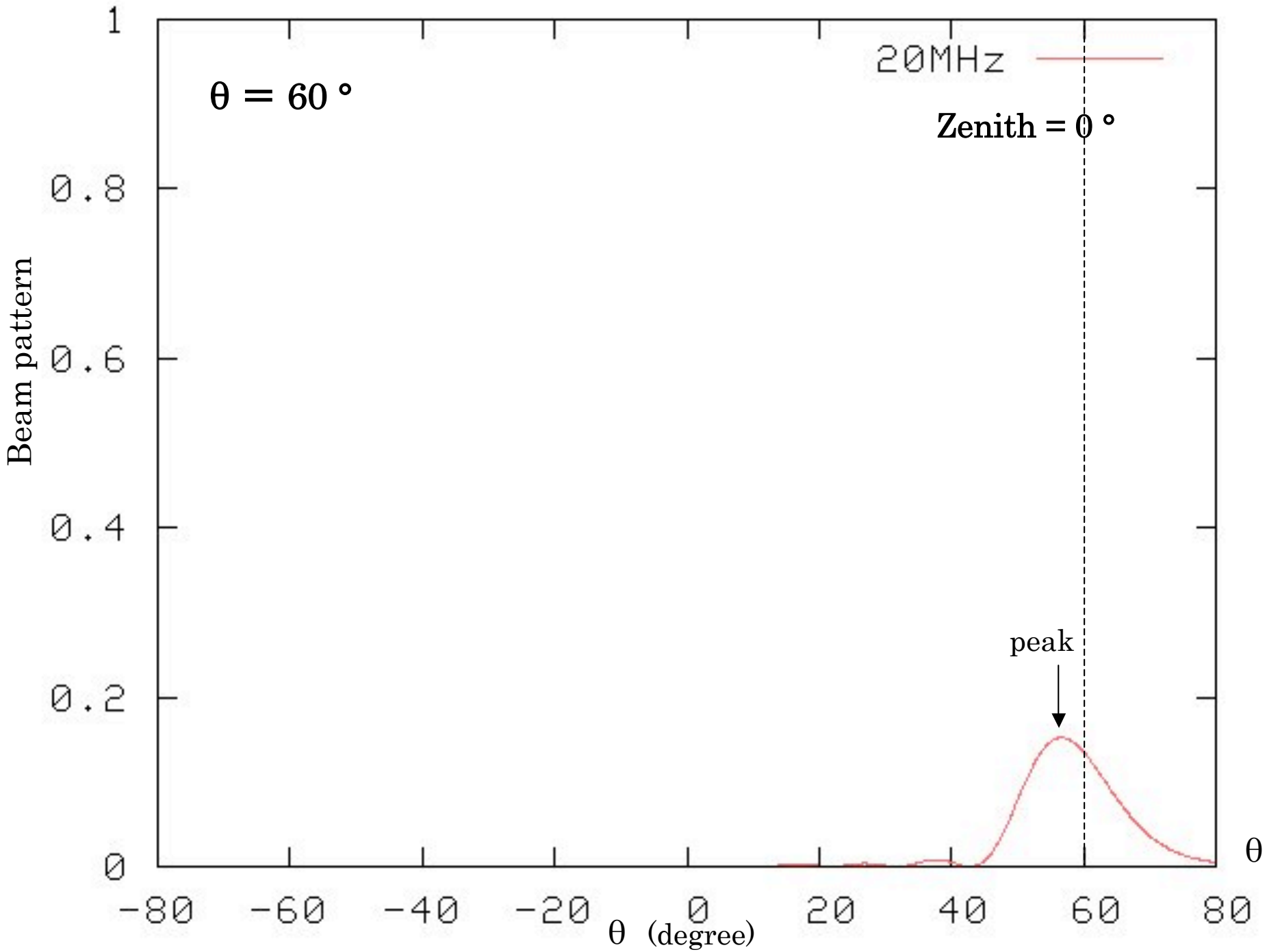

θ = 10 °
20MHz
Zenith = 0 °
Beam pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)
θ

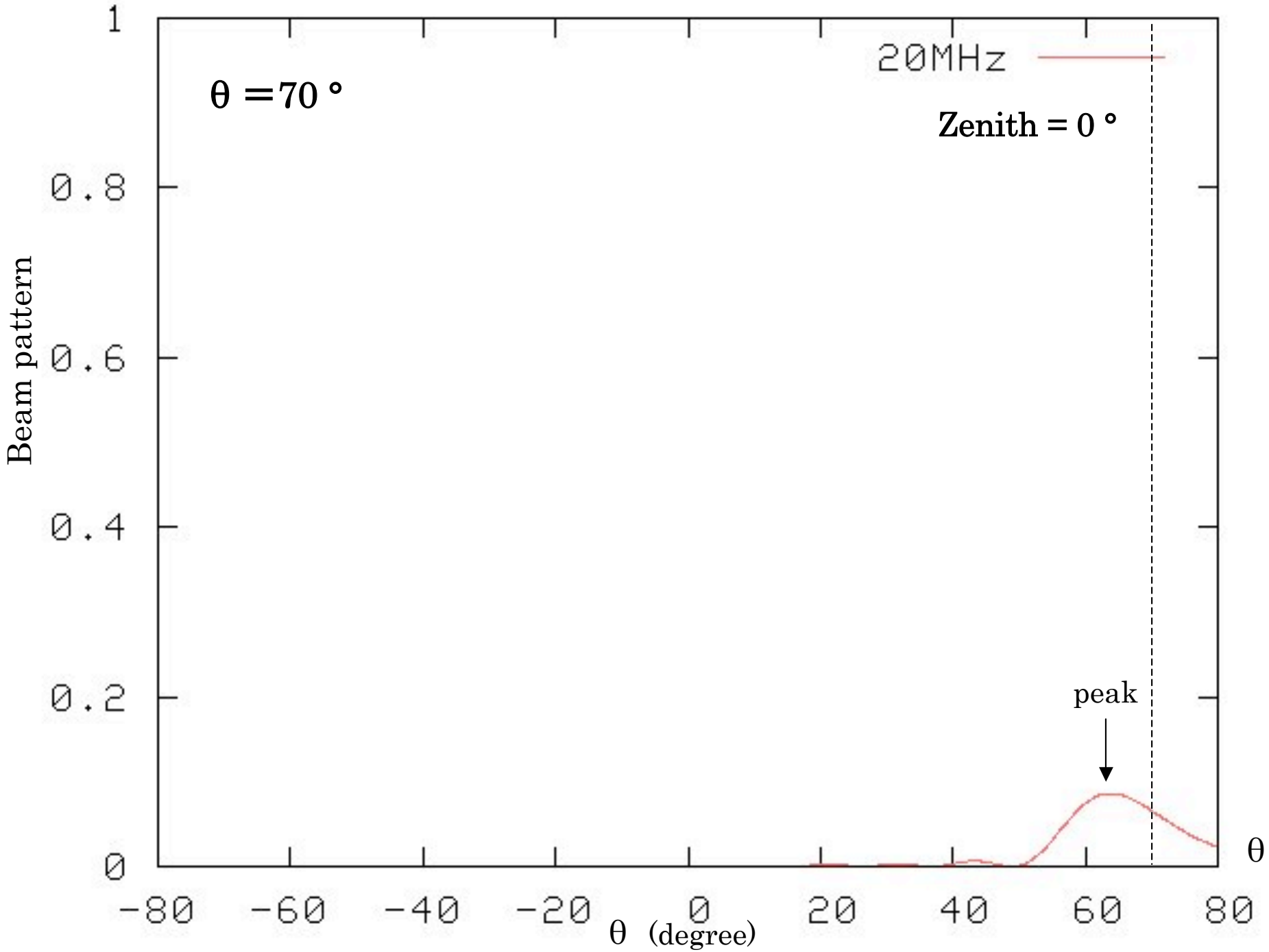

20MHz
θ = 20 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ
θ (degree)

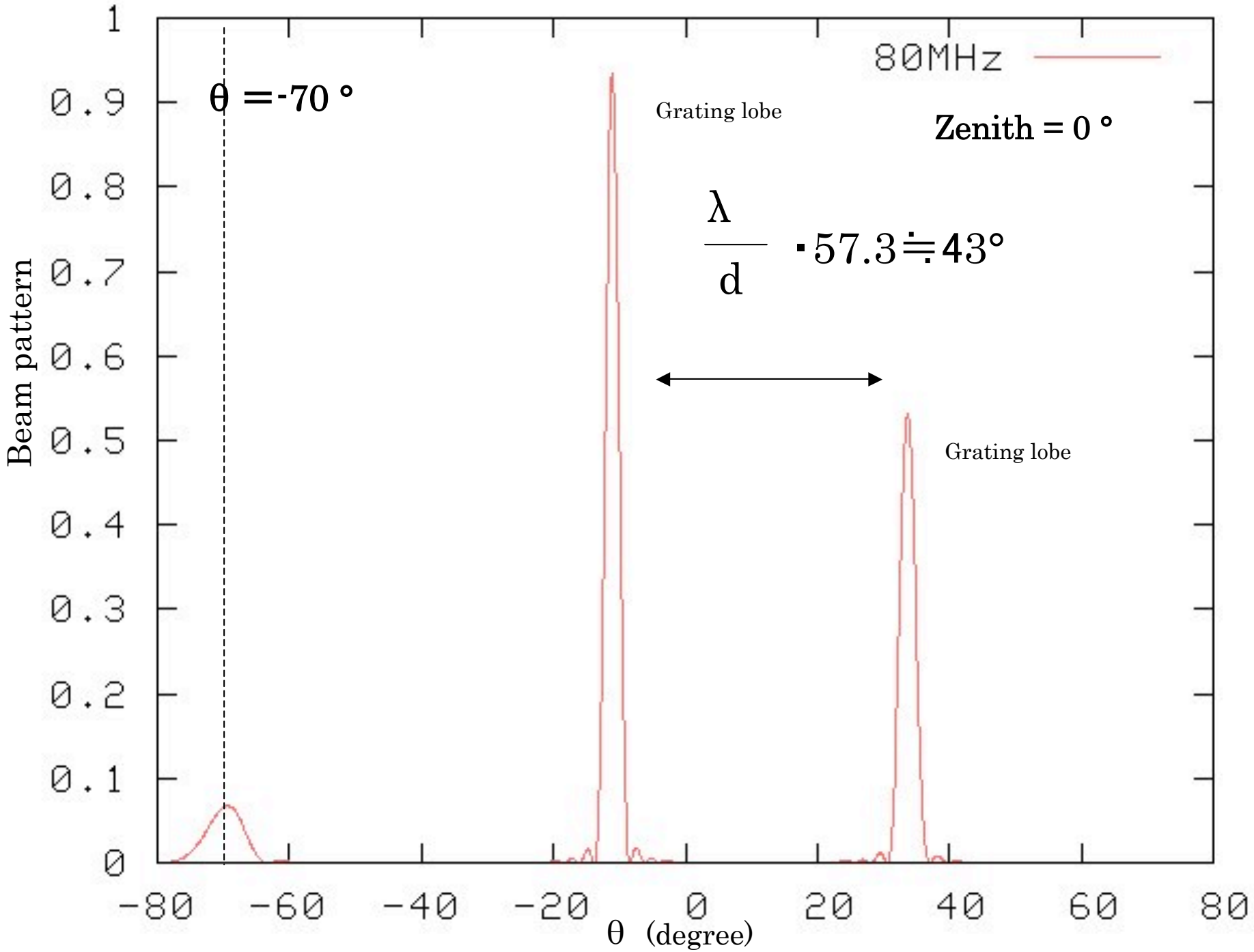

20MHz
θ = 30 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ
θ (degree)

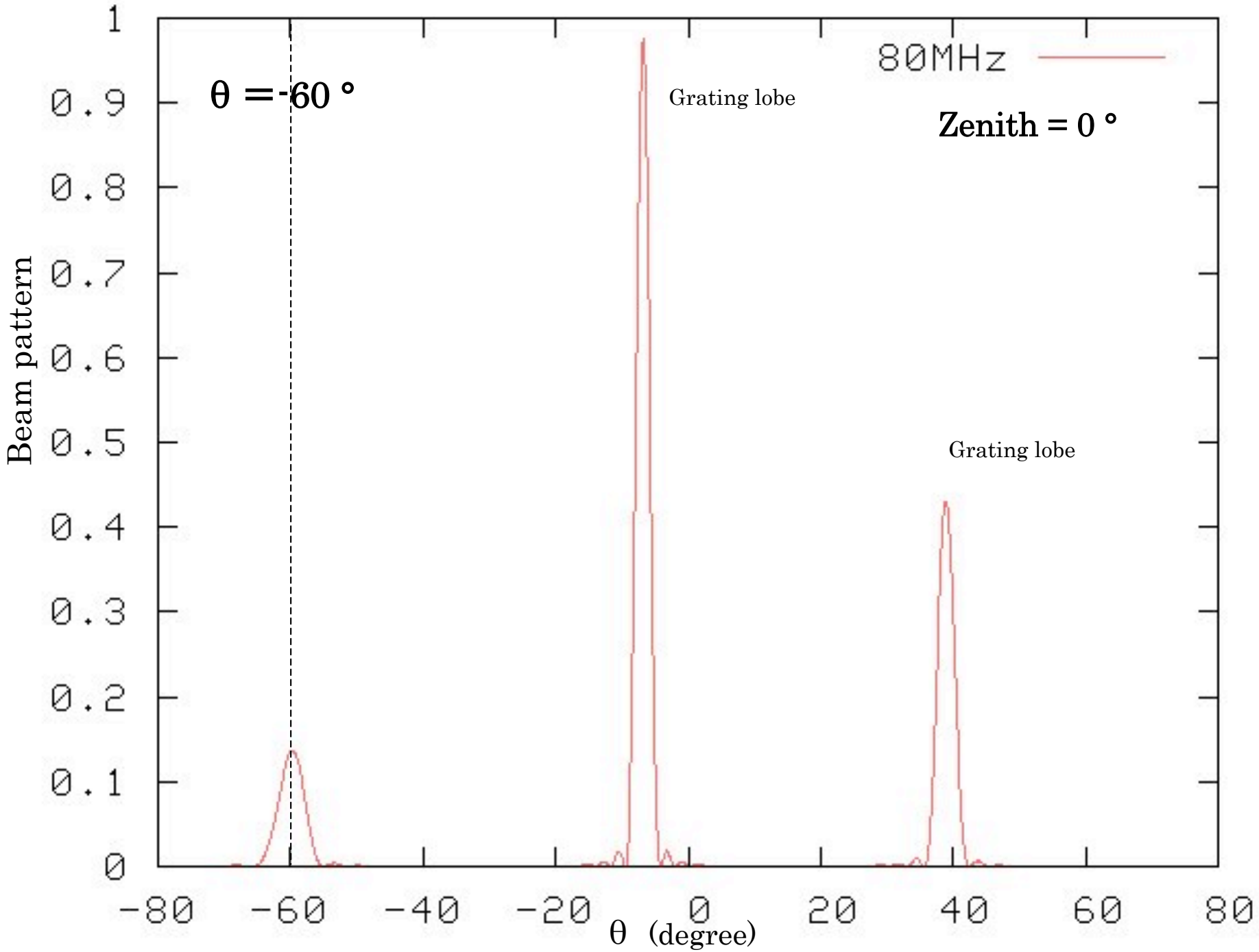

20MHz
θ = 40 °
Zenith = 0 °
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ

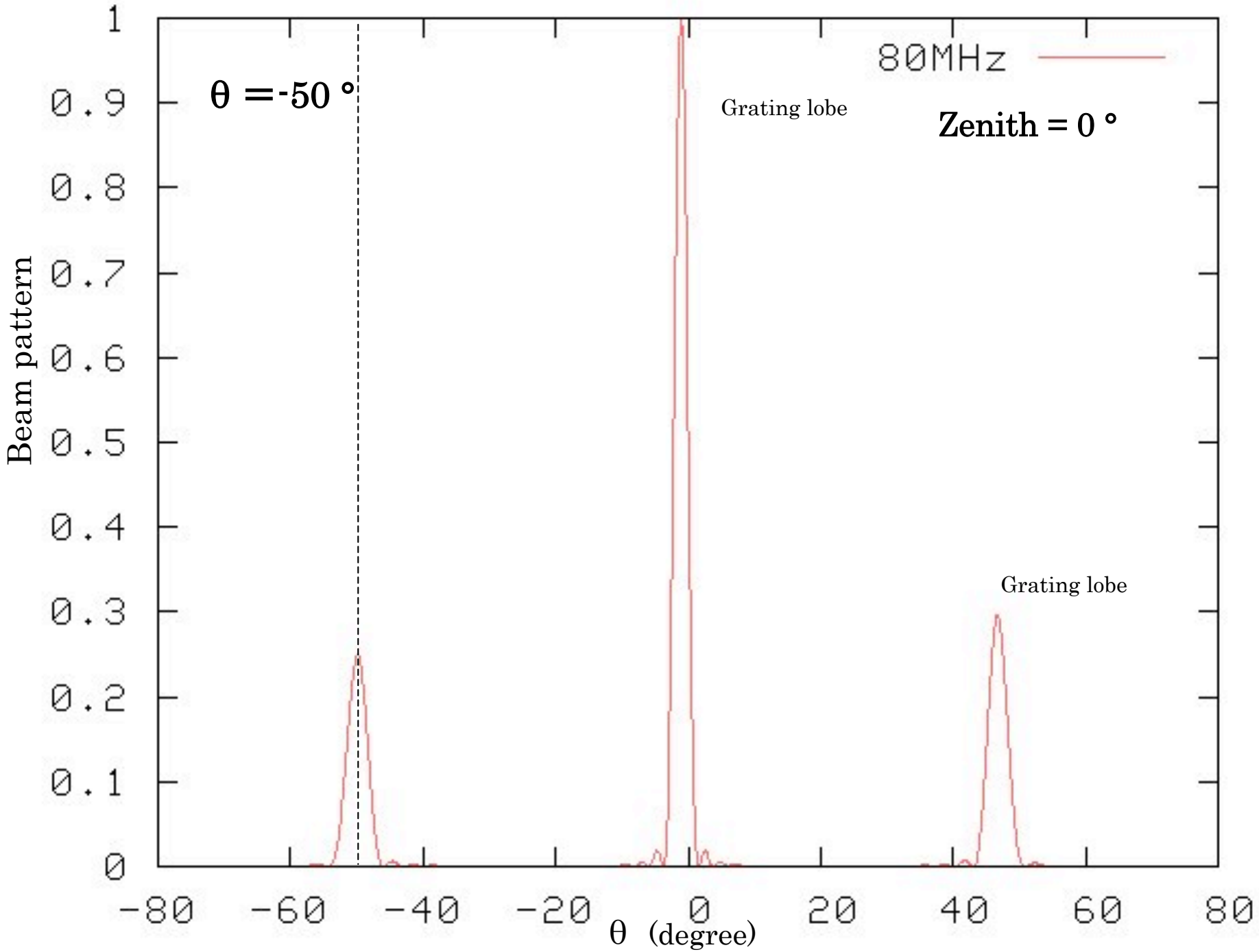

20MHz
θ = 50 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)
θ

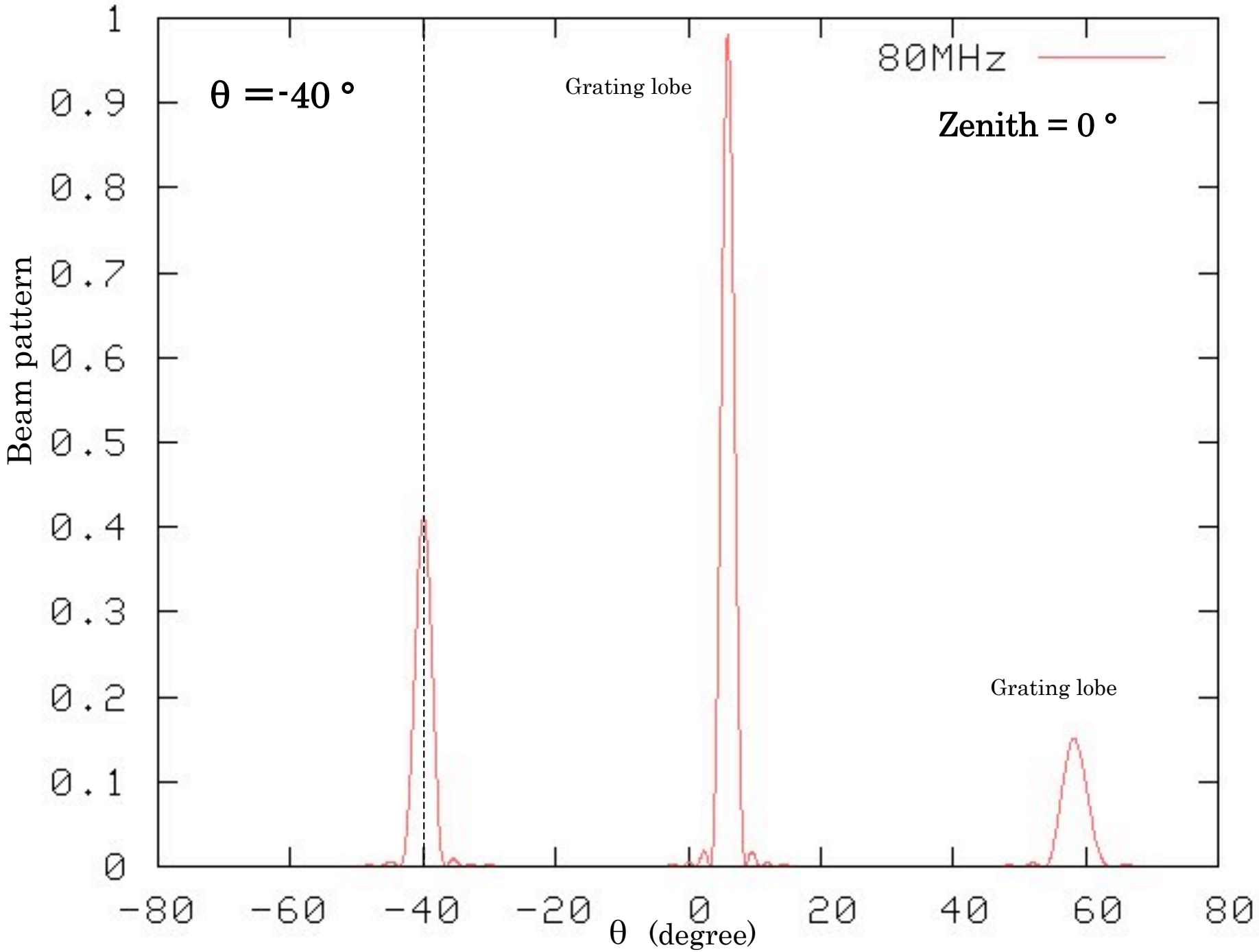

20MHz
θ = 60 °
Zenith = 0 °
peak
Beam pattern
θ
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

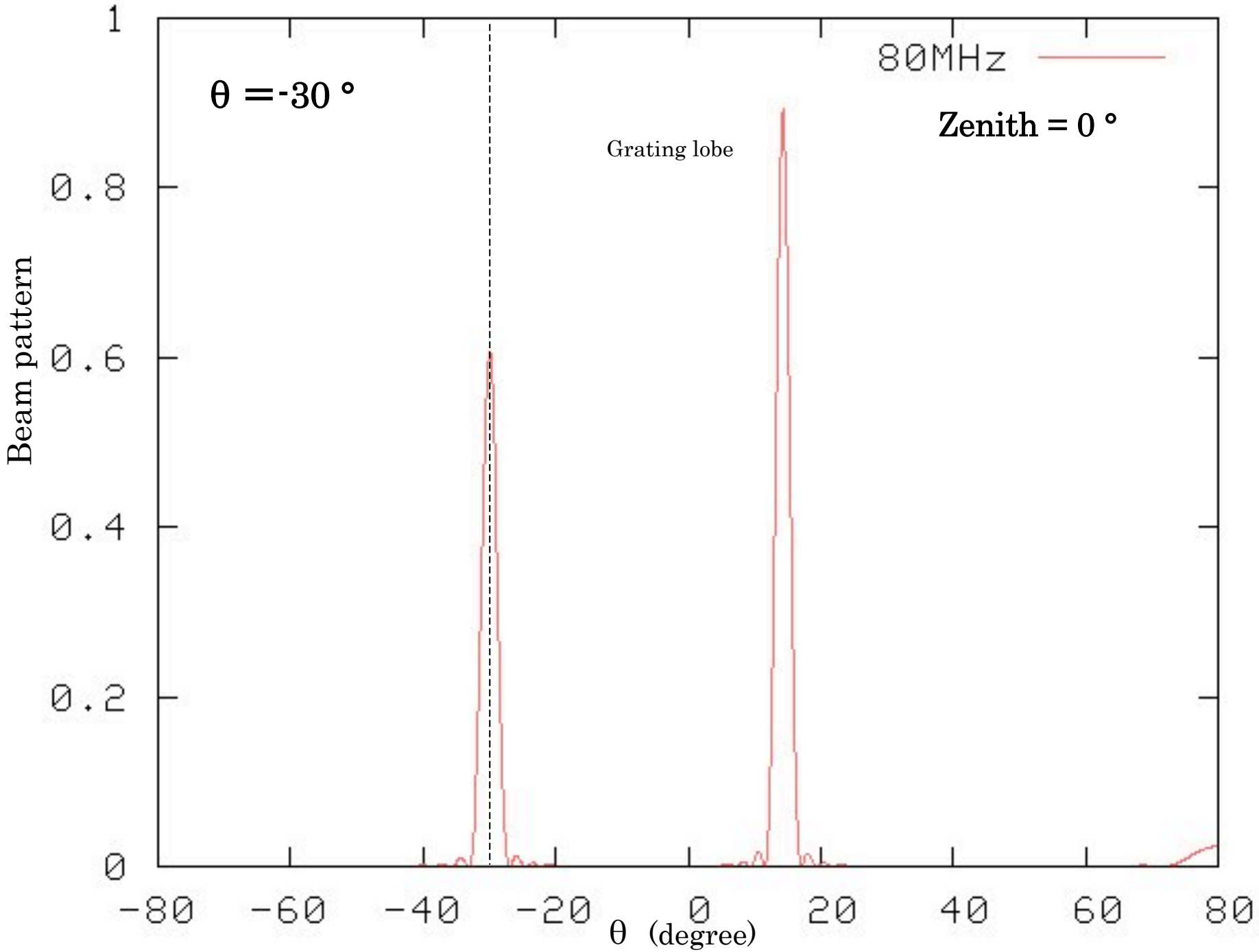

20MHz
θ =70 °
Zenith = 0 °
Beam pattern
1
0.8
0.6
0.4
0.2
0
peak
θ
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

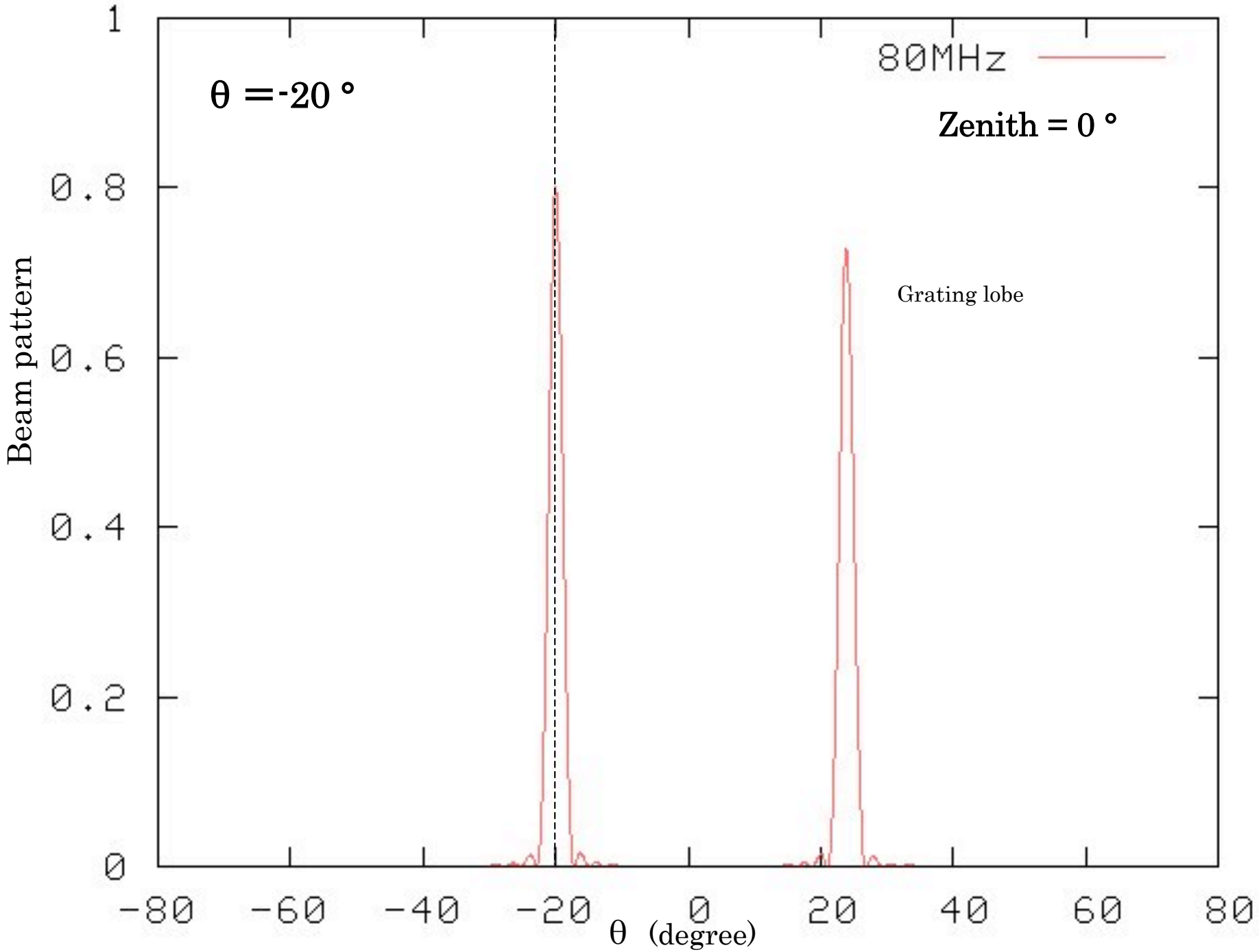

80MHz
θ =-70 °
Grating lobe
Zenith = 0 °
λ/d ・57.3≒43°
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

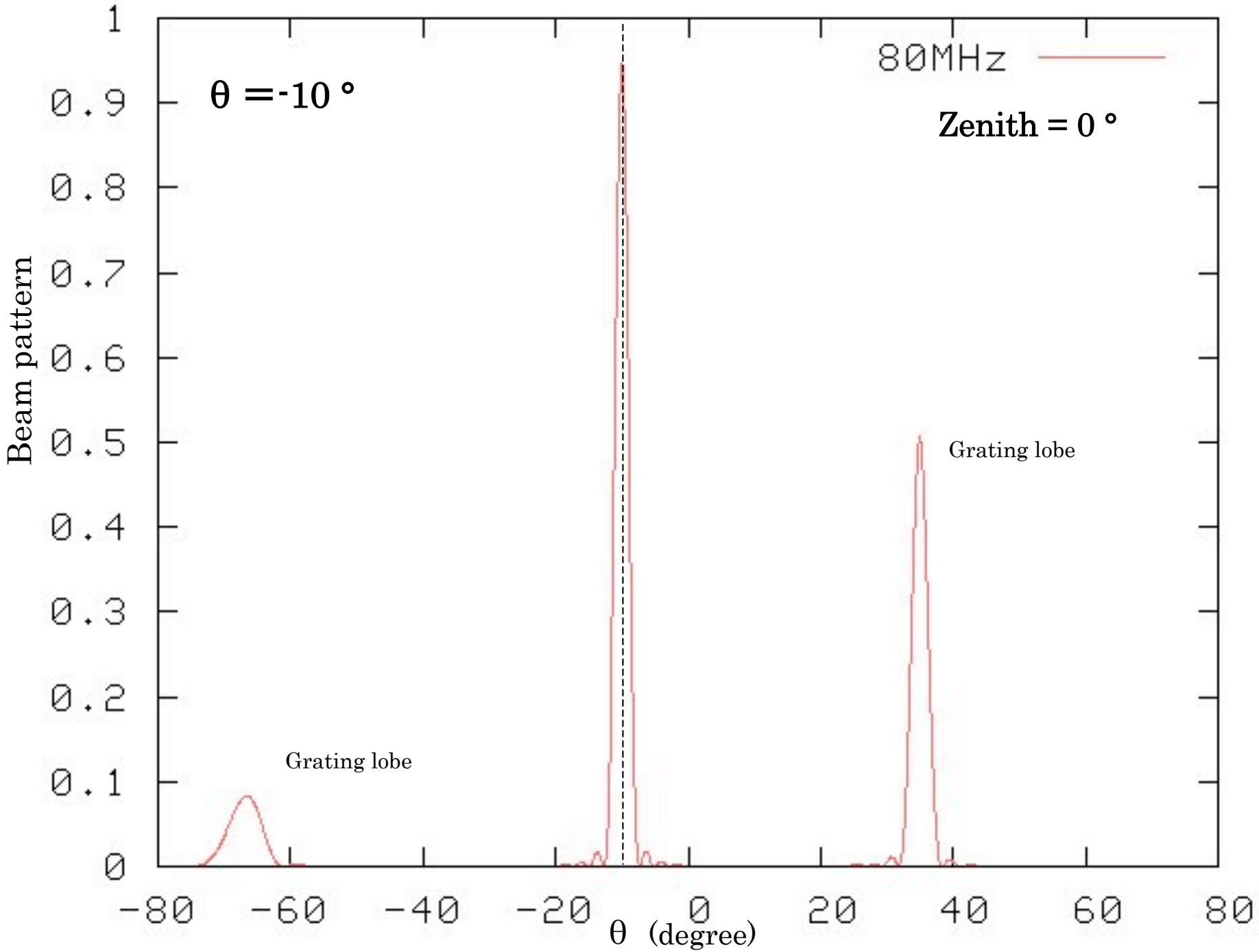

80MHz
θ = -60 °
Grating lobe
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

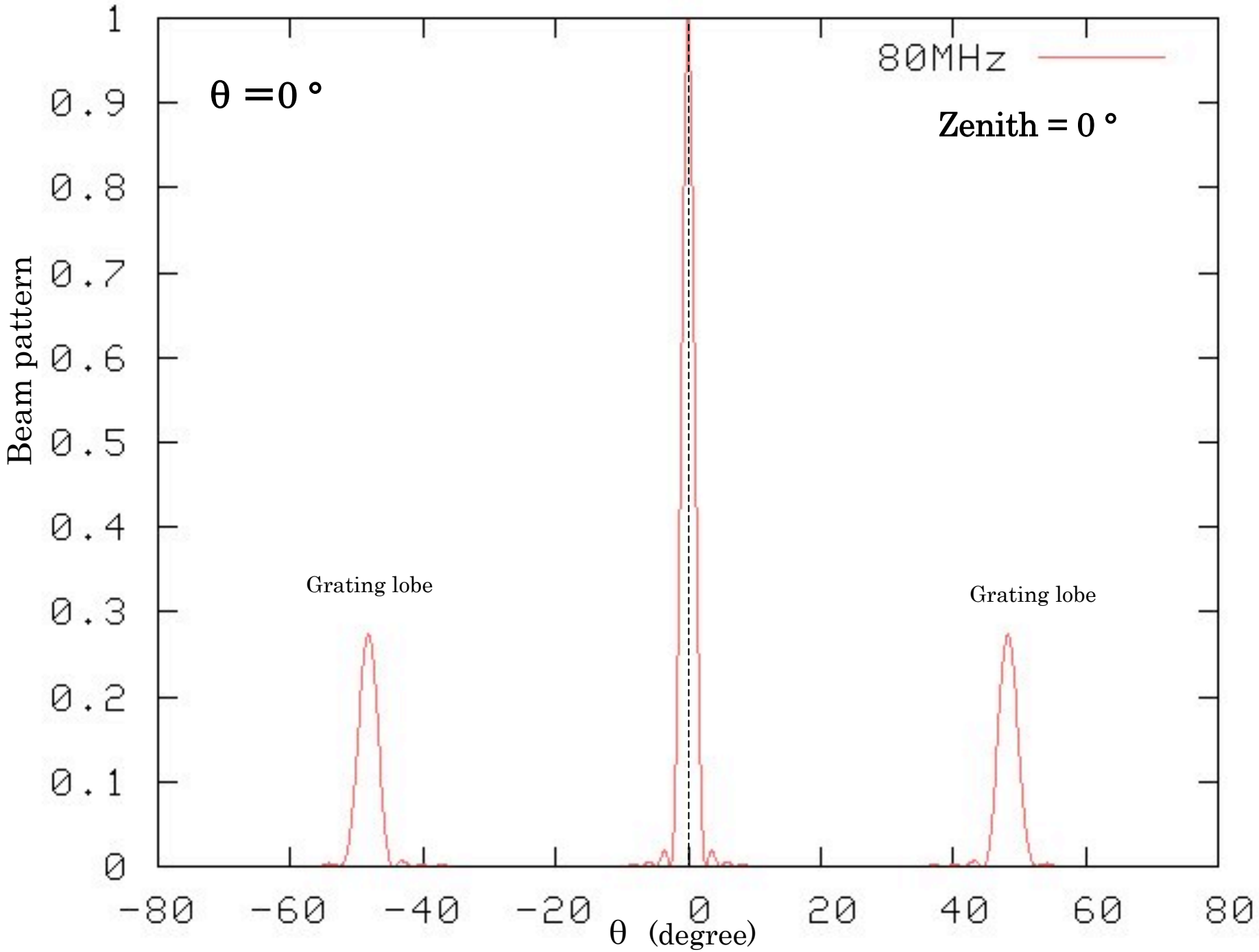

θ =-50 °
80MHz
Grating lobe
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

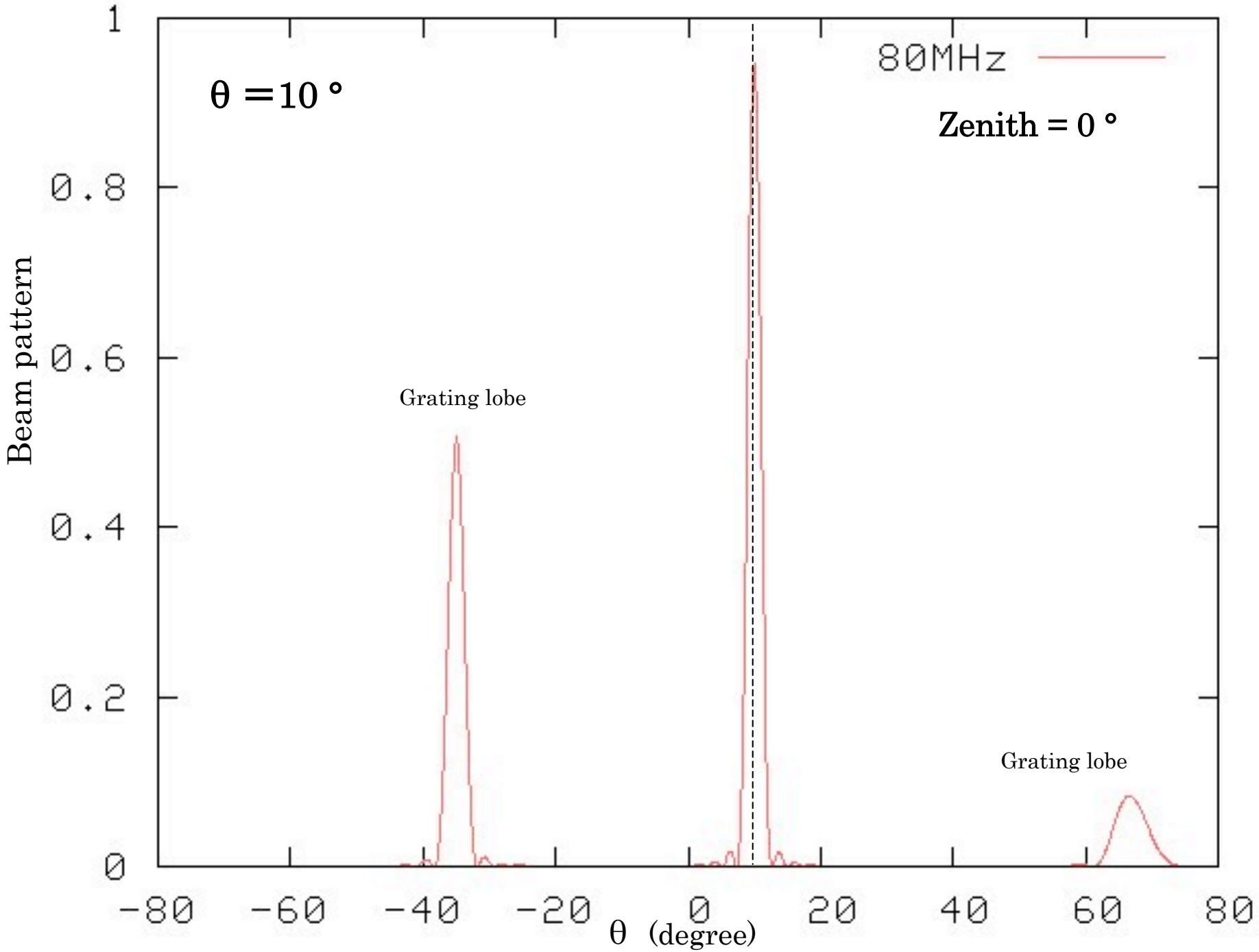

θ =-40 °
Grating lobe
80MHz
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

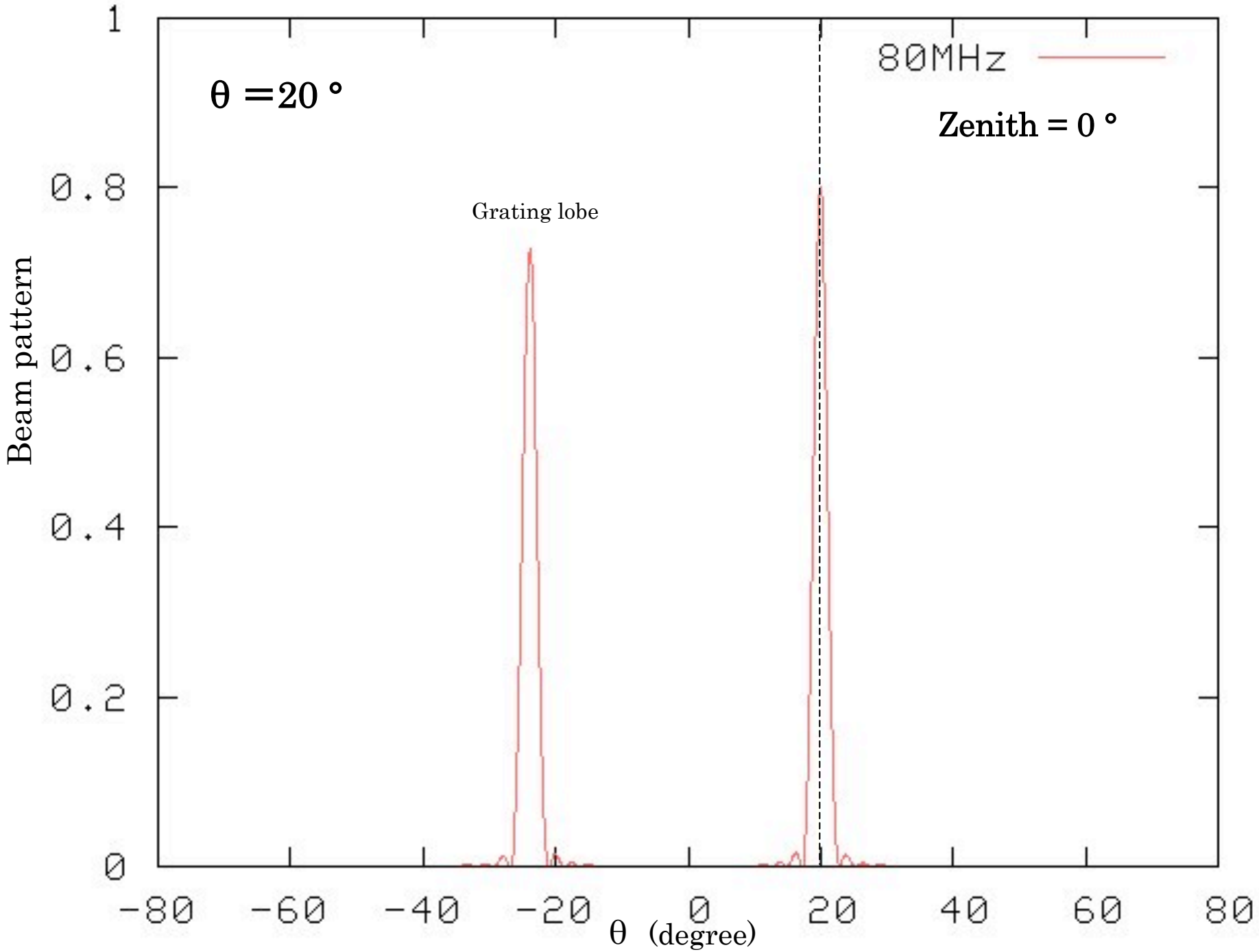

80MHz
θ =-30 °
Zenith = 0 °
Grating lobe
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

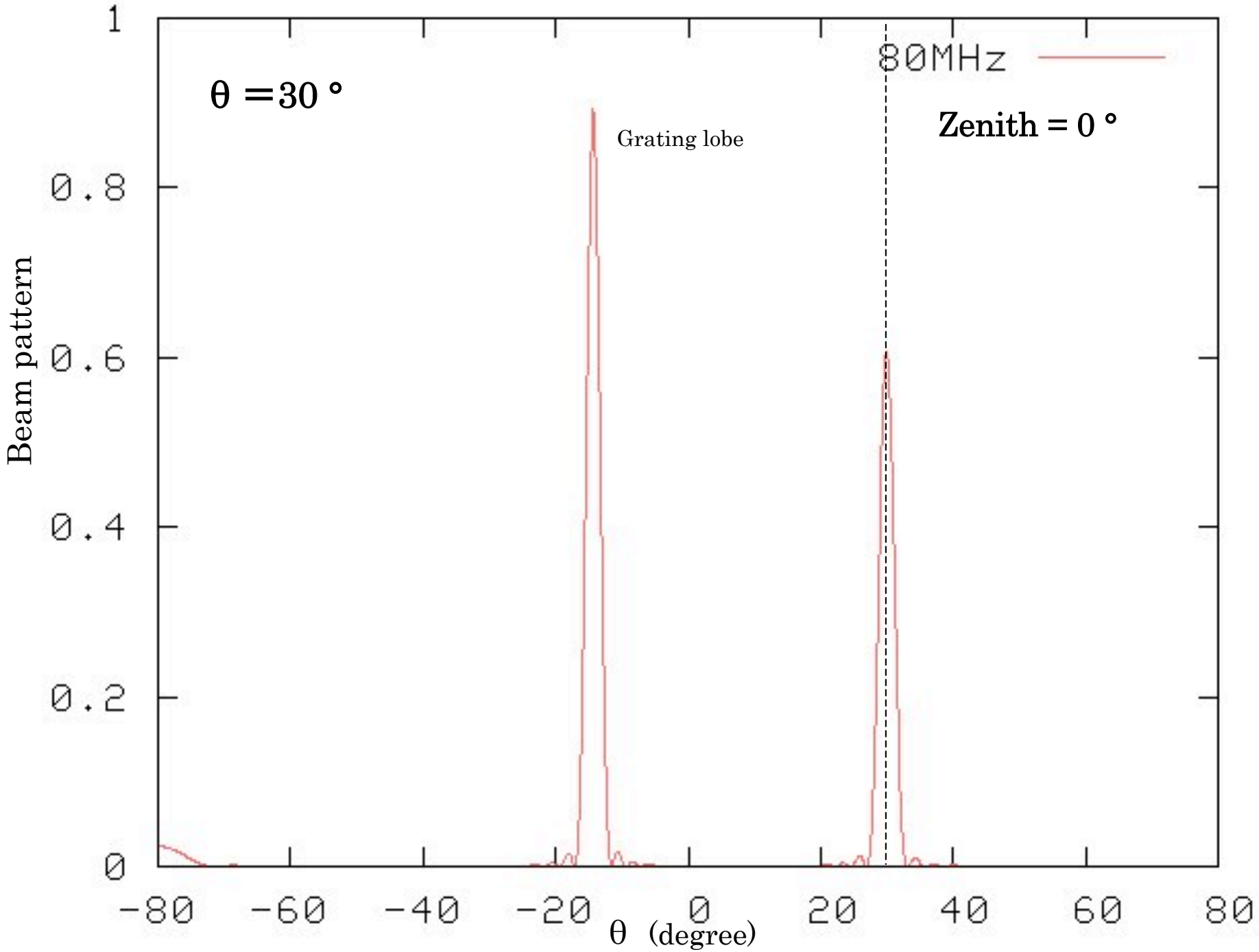

80MHz
θ =-20 °
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

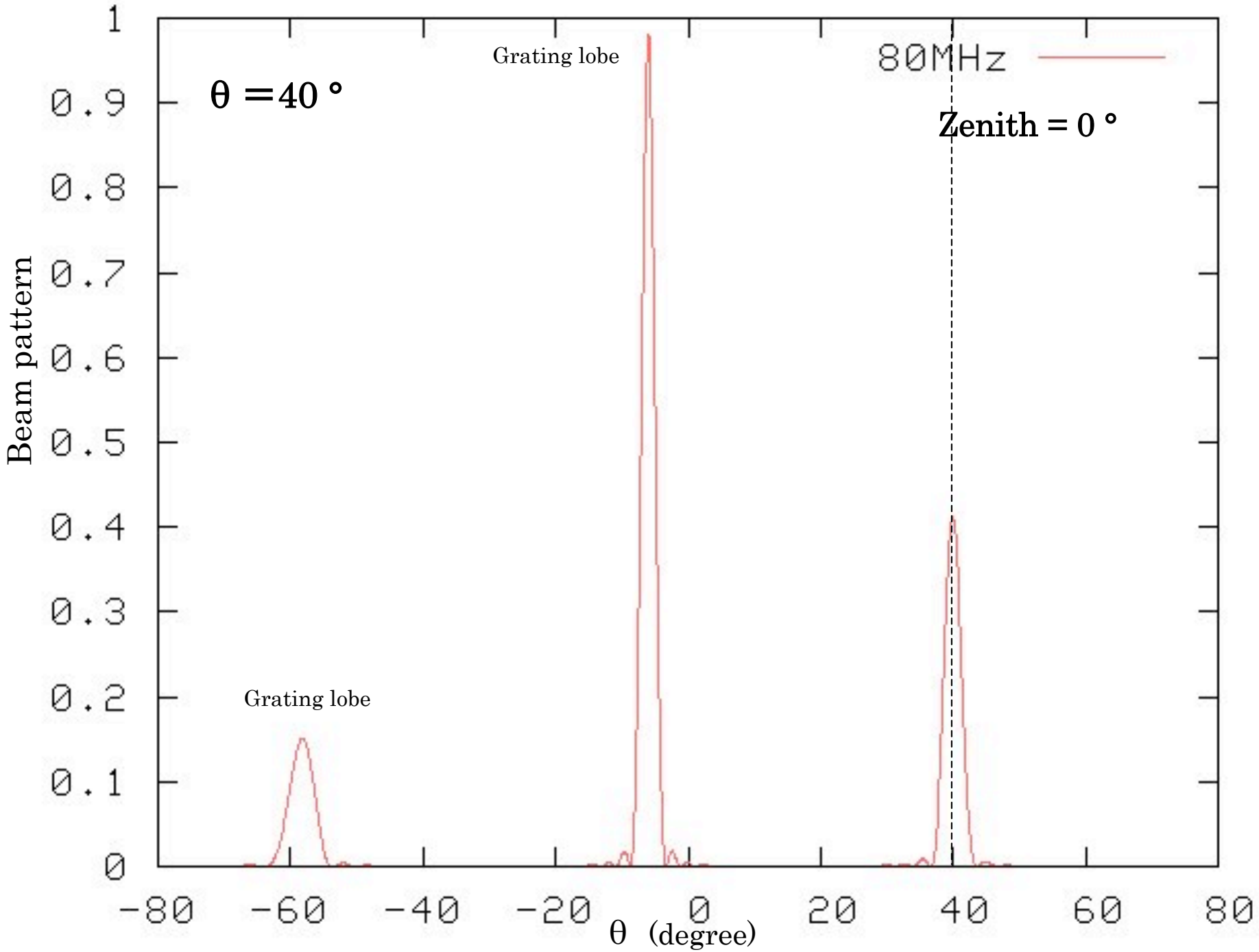

θ =-10 °
80MHz
Zenith = 0 °
Grating lobe
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

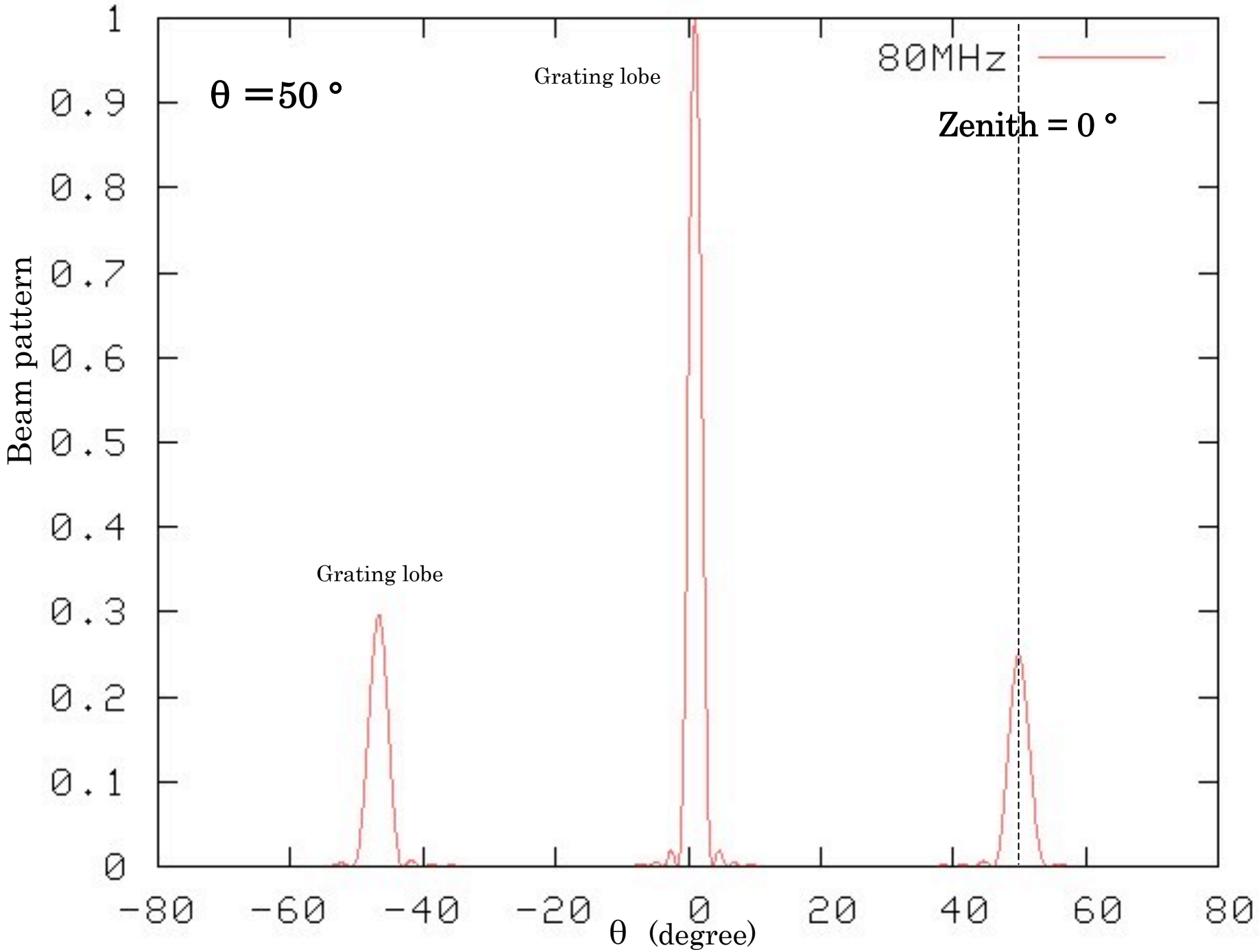

80MHz
θ =0 °
Zenith = 0 °
Grating lobe
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

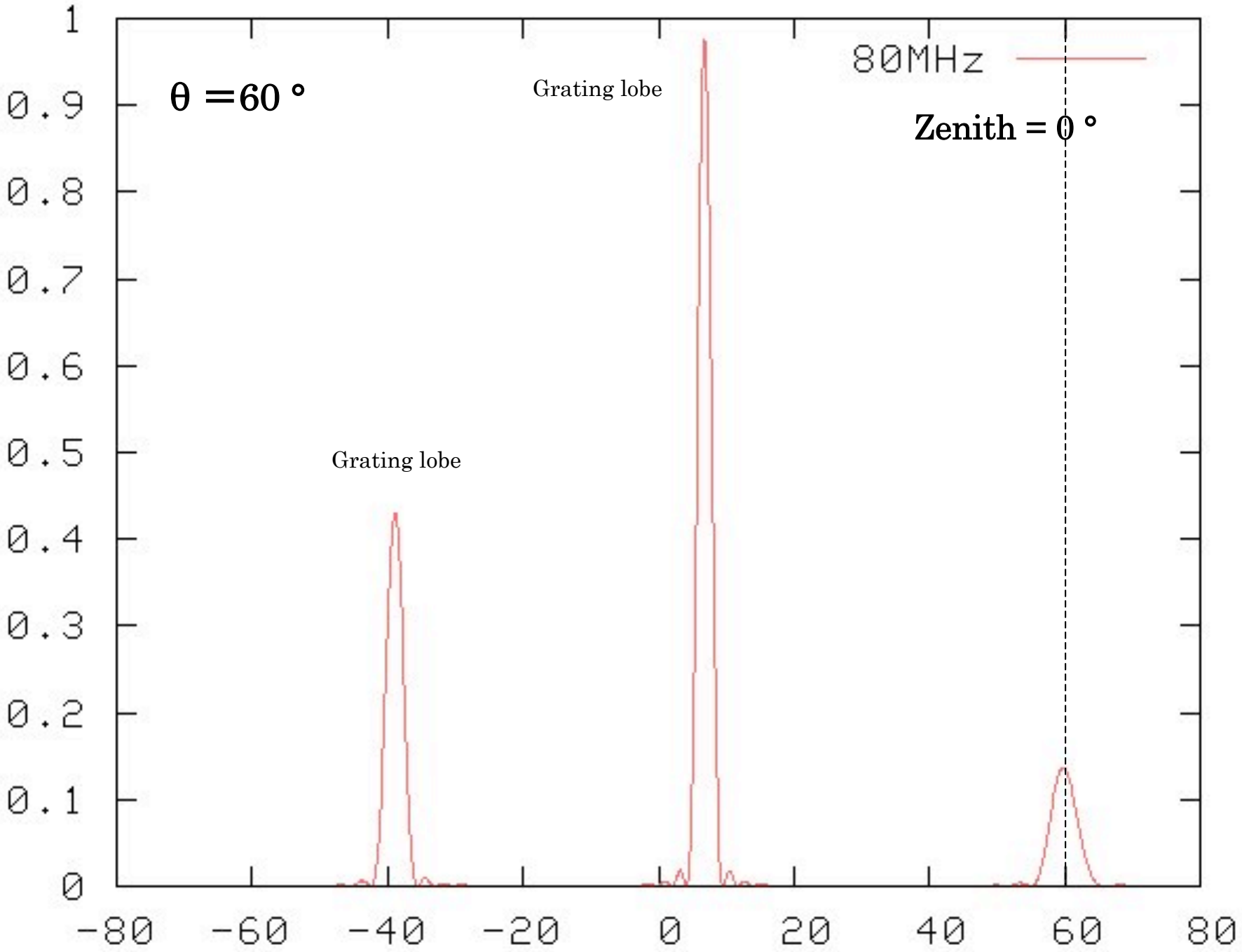

θ =10 °
80MHz
Zenith = 0 °
Grating lobe
Grating lobe
Beam pattern
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

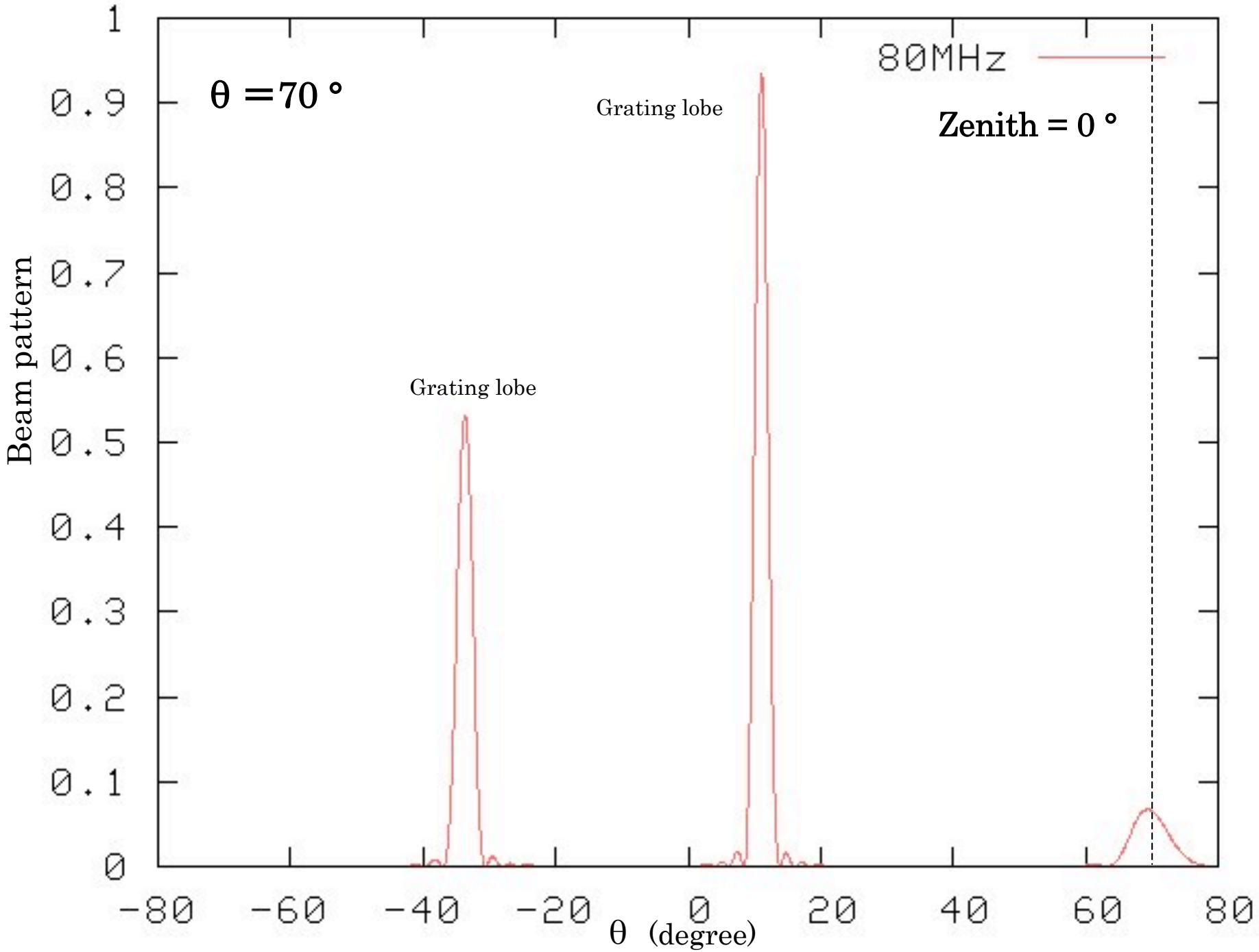

θ =20 °
80MHz
Zenith = 0 °
Grating lobe
Beam pattern
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)


θ =30 °
80MHz
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

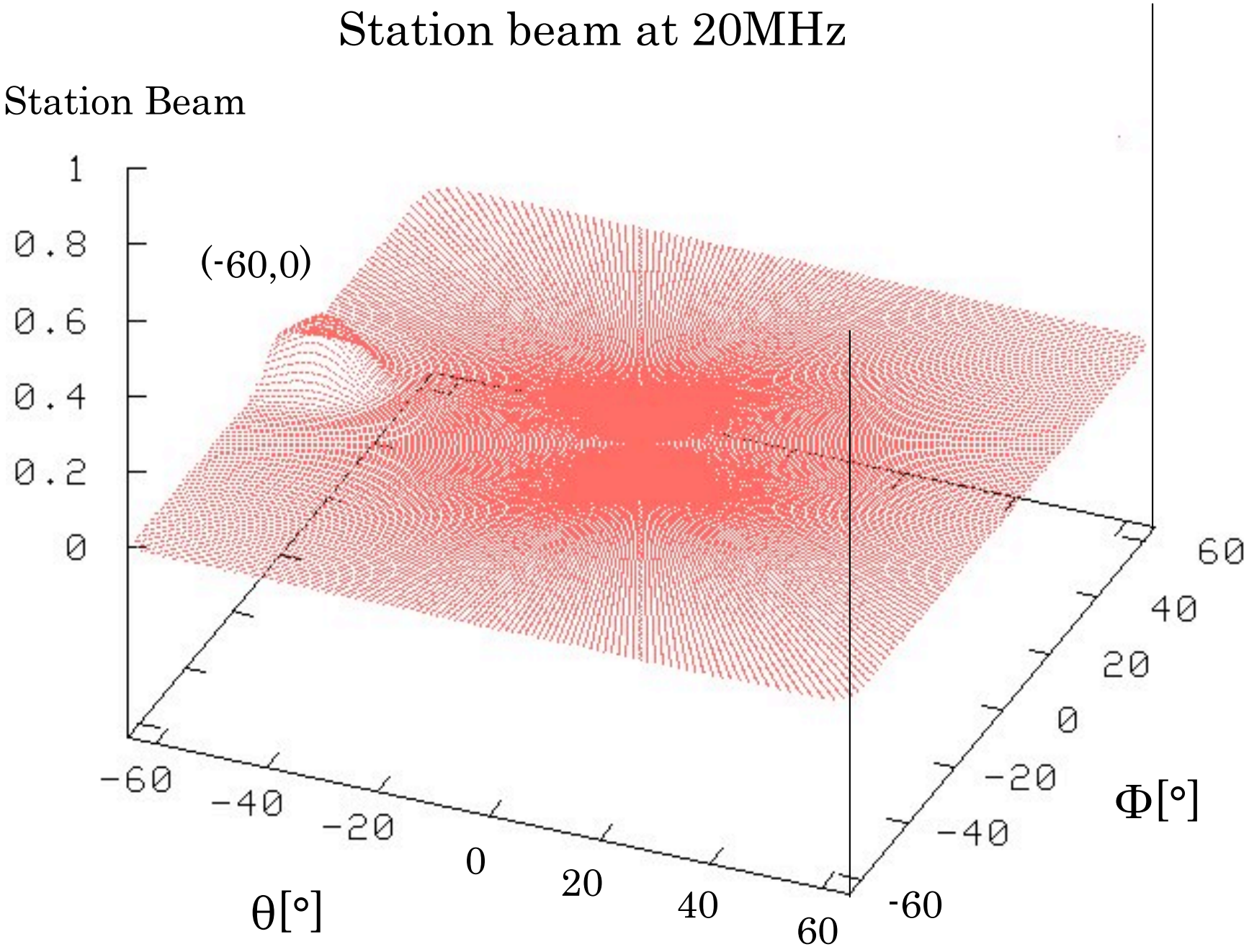

θ =40 °
Grating lobe
80MHz
Zenith = 0 °
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80


θ =50 °
Grating lobe
80MHz
Zenith = 0 °
Grating lobe
Beam pattern
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80
θ (degree)

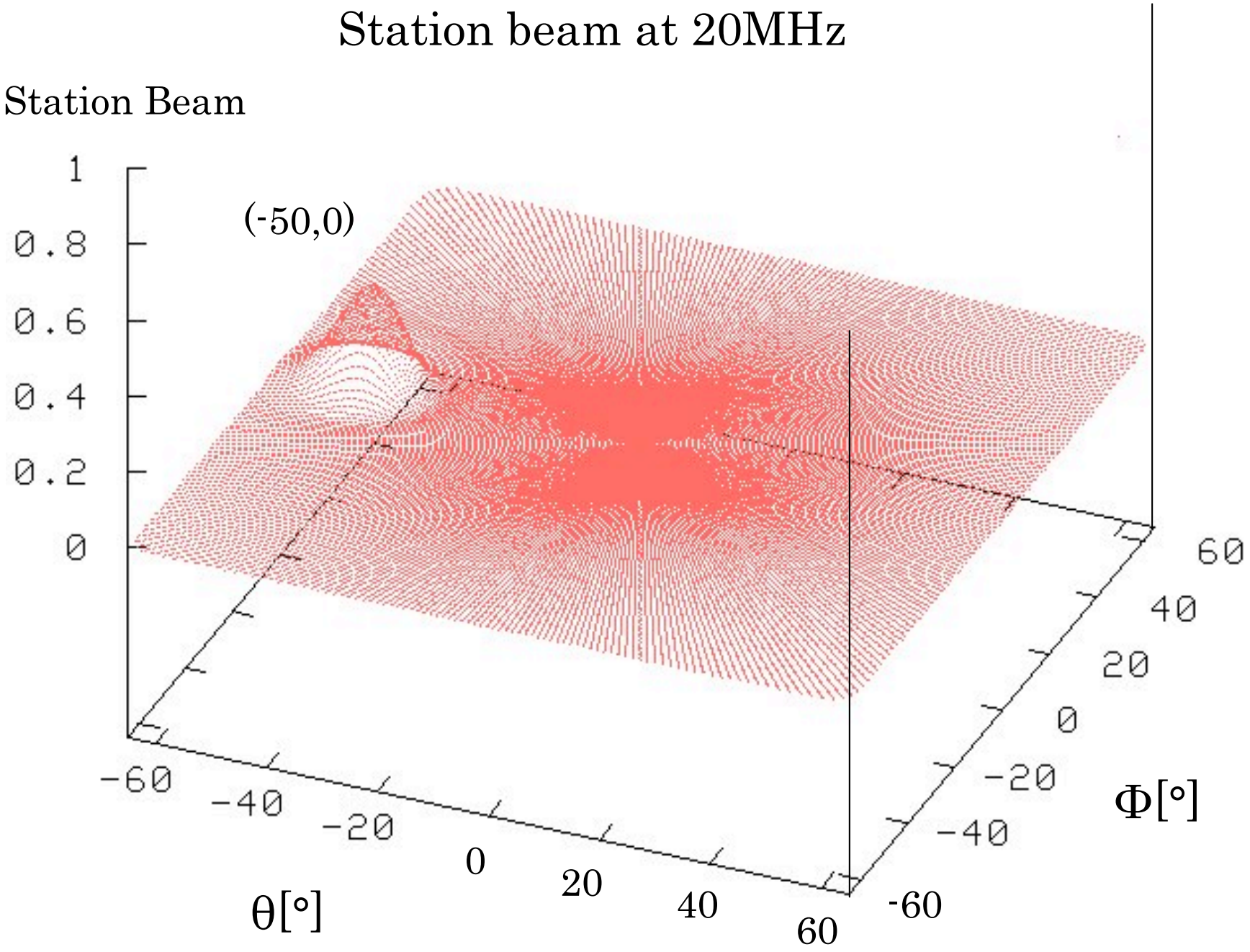

θ =60 °
Grating lobe
80MHz
Zenith = 0 °
Grating lobe
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80


θ =70 °
80MHz
Zenith = 0 °
Grating lobe
Grating lobe
Beam pattern
θ (degree)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80

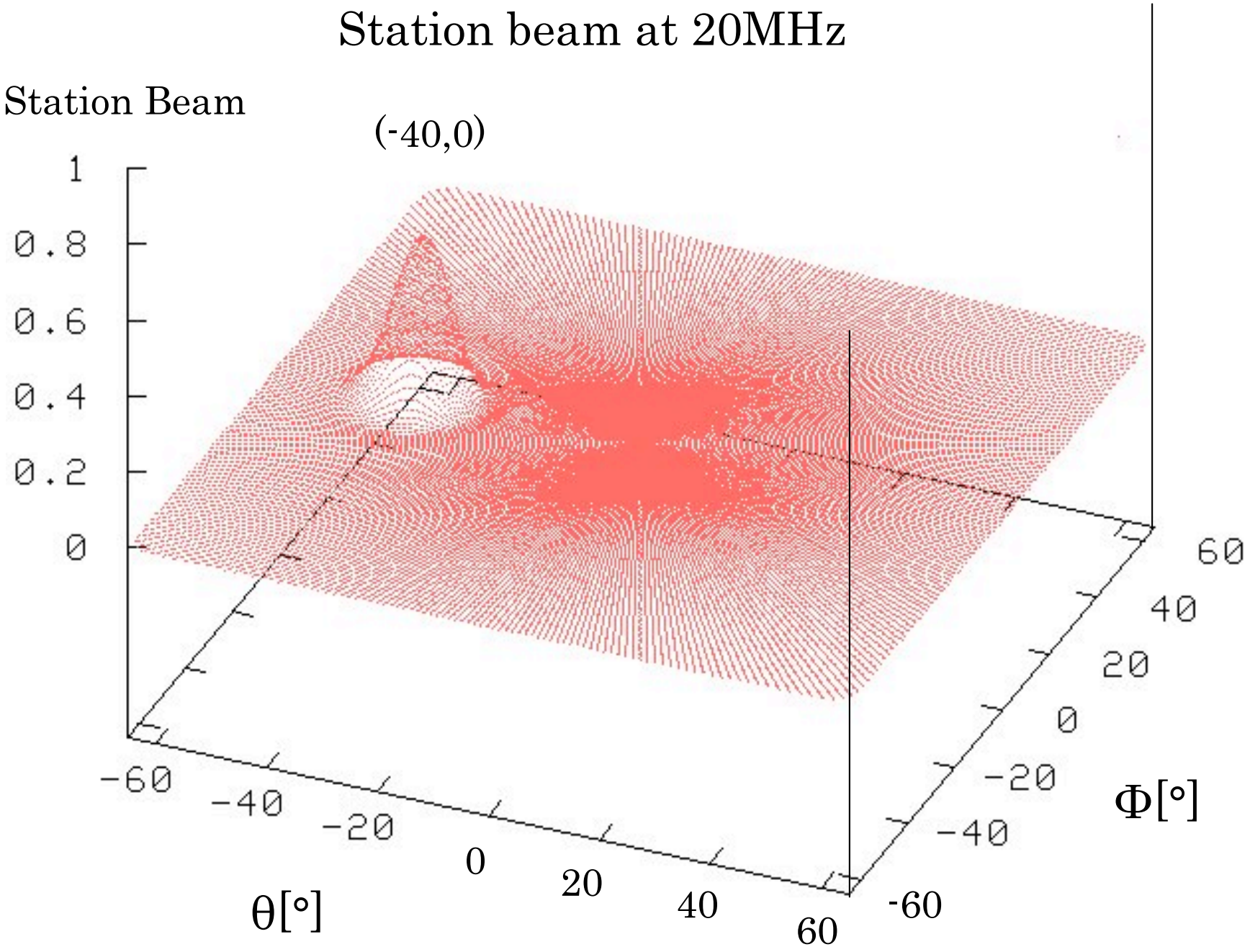
Station beam at 20MHz



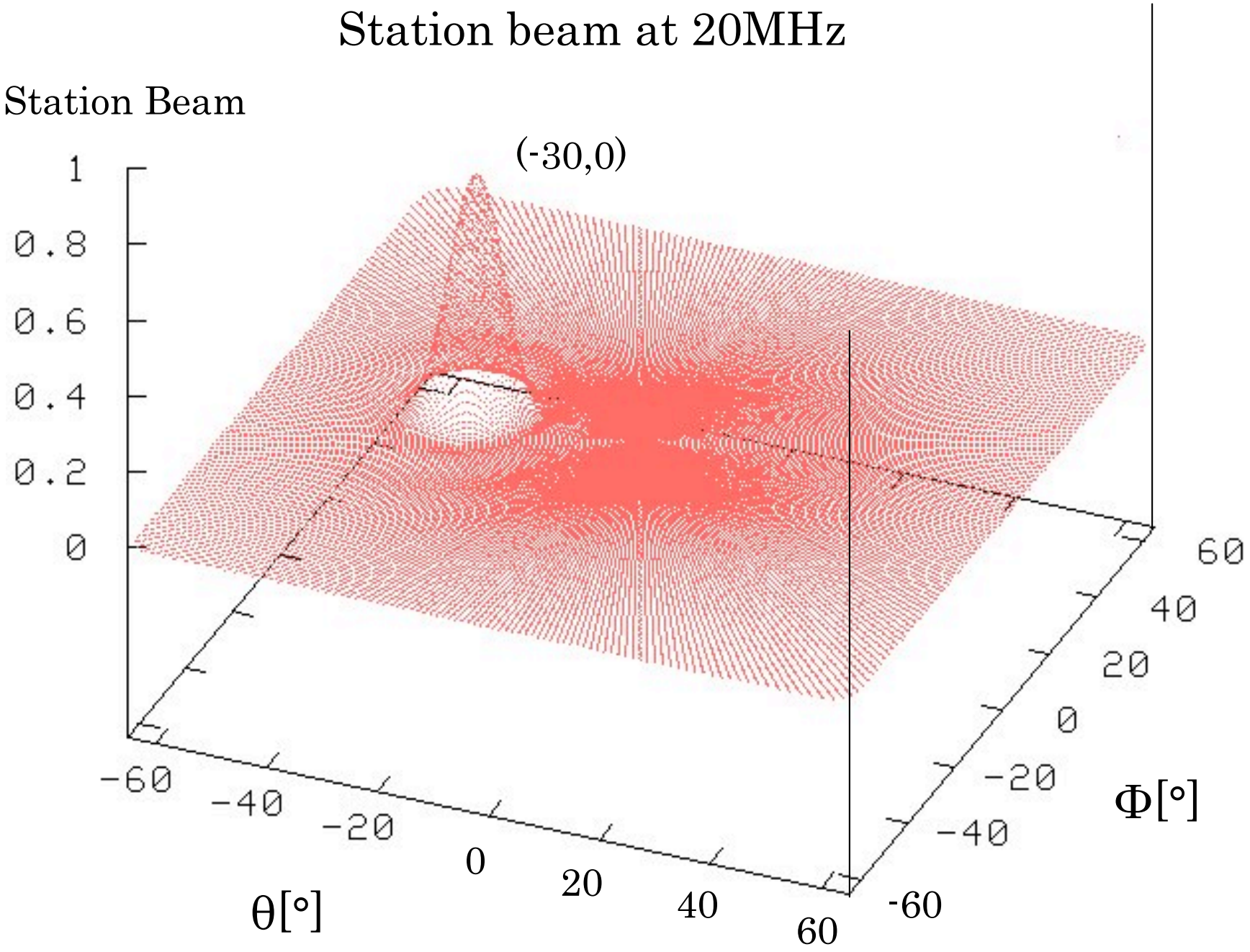
Station beam at 20MHz



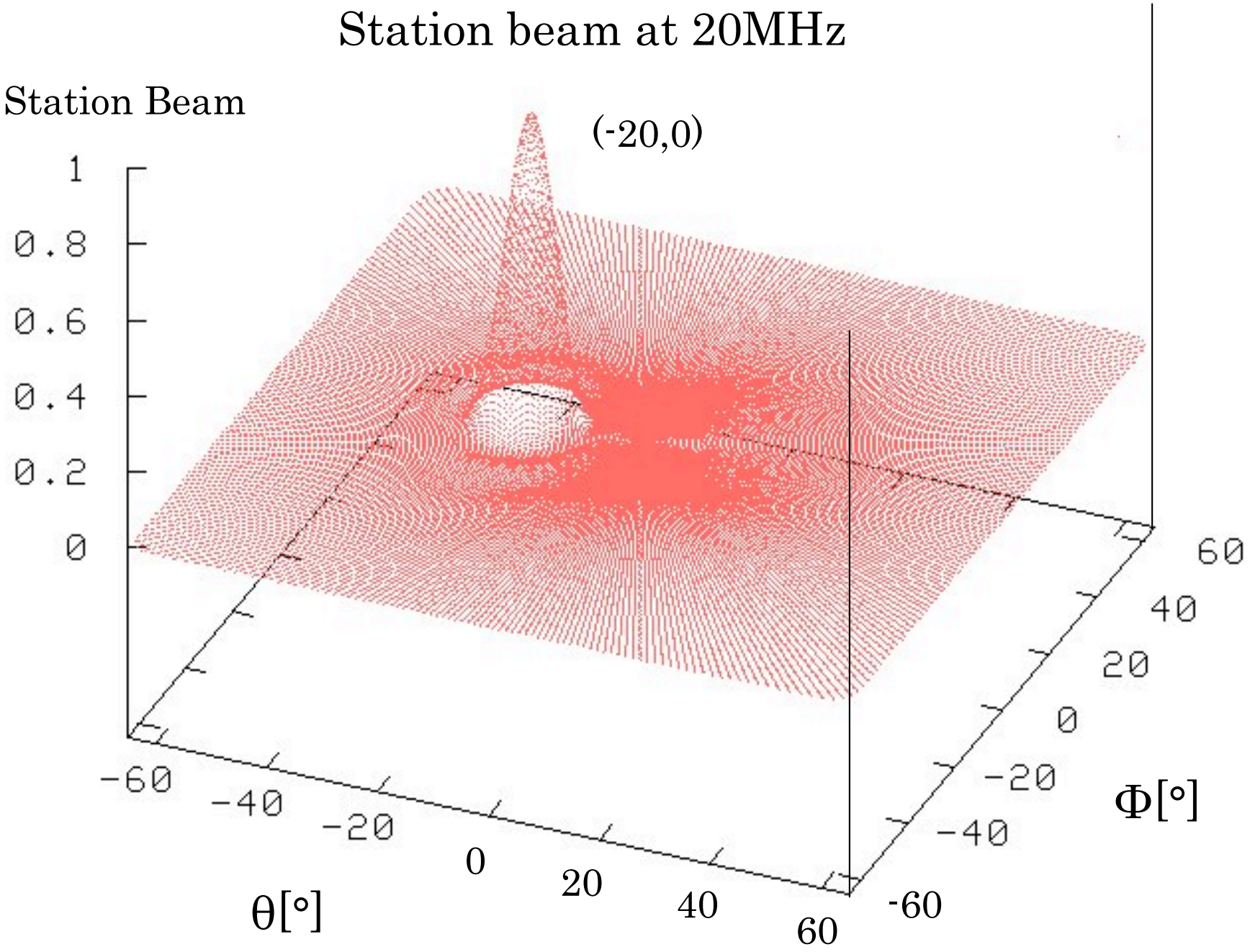
Station beam at 20MHz

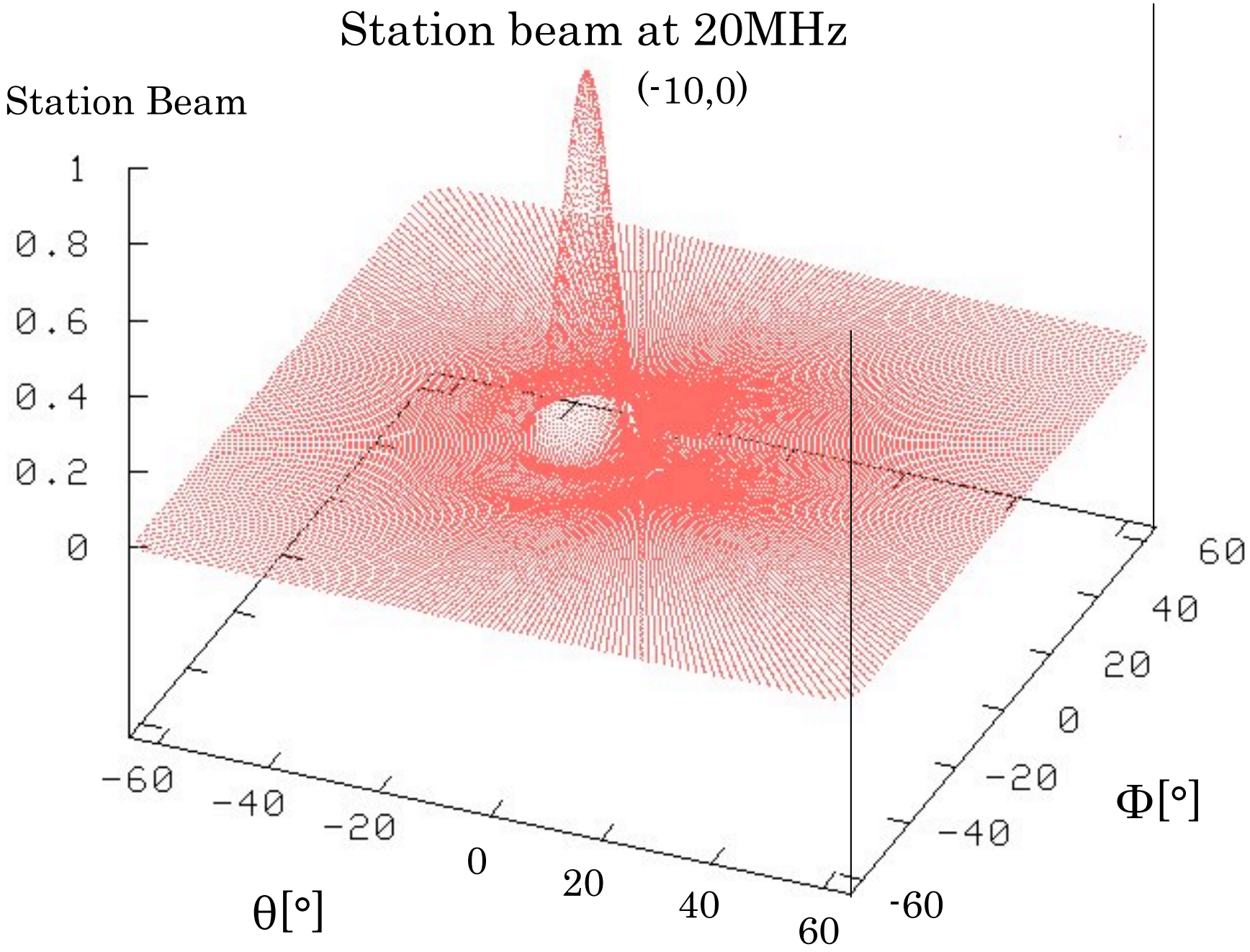


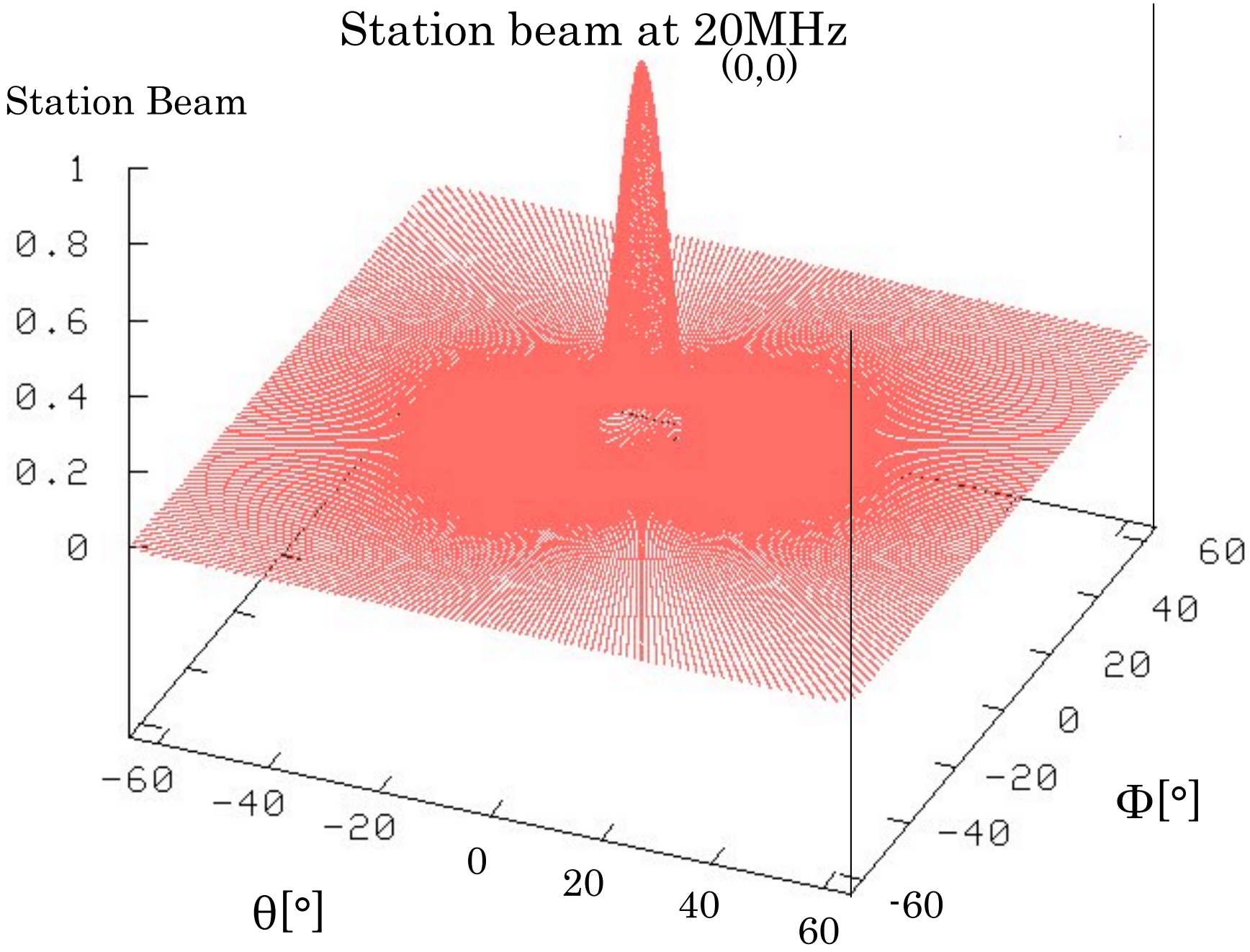
Station beam at 20MHz



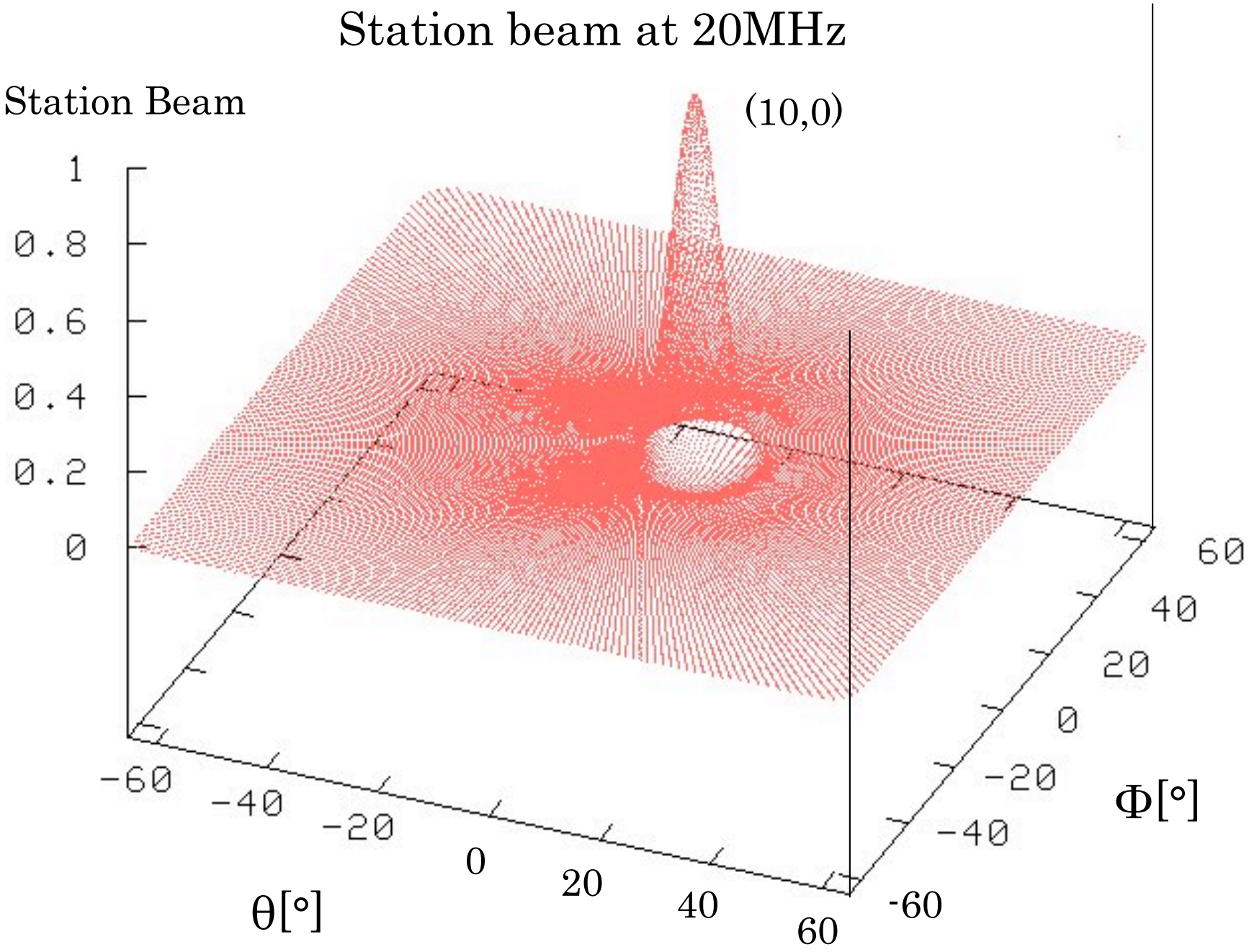
Station beam at 20MHz



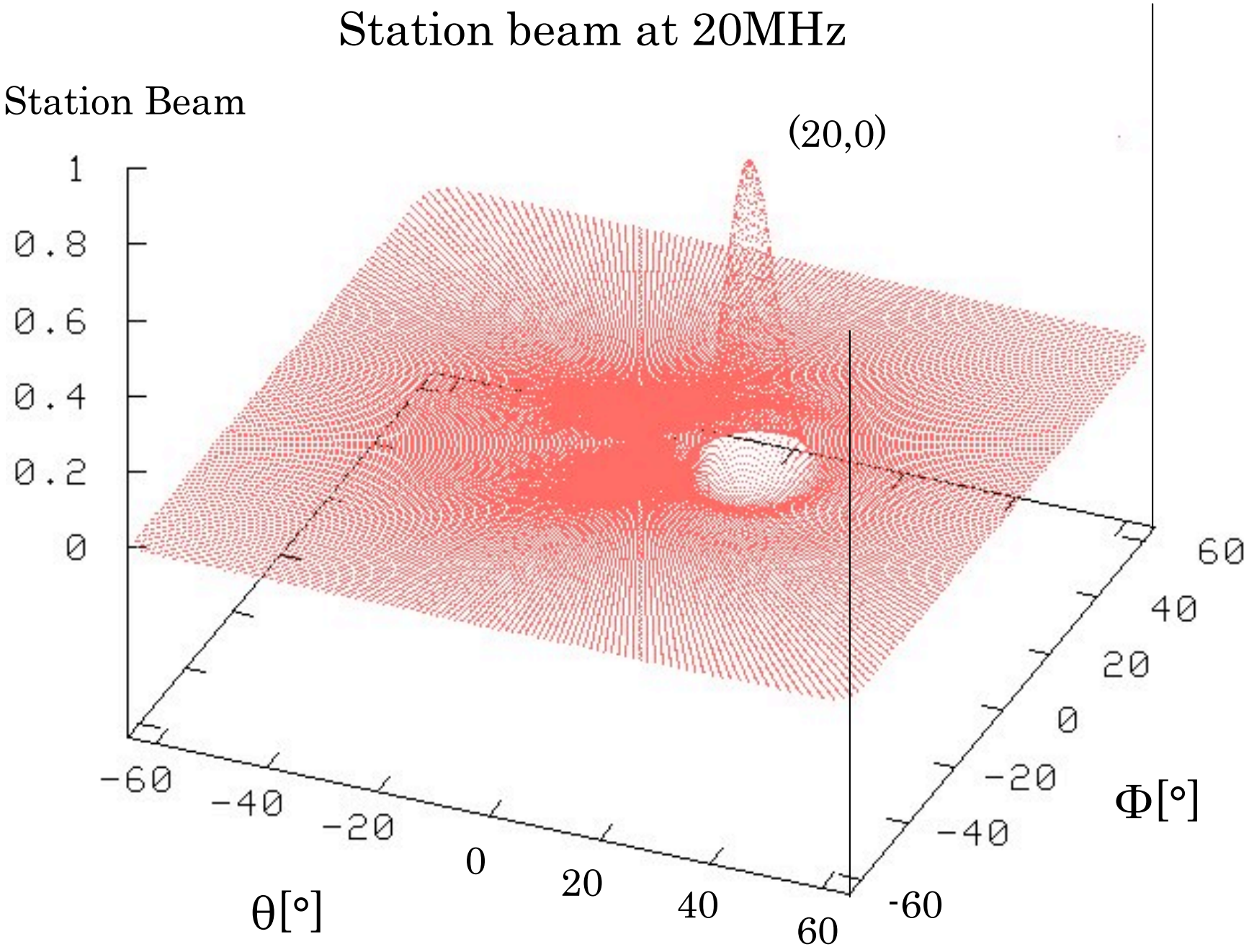

Station beam at 20MHz
(-10,0)
Station Beam
1
0.8
0.6
0.4
0.2
0
-60
-40
-20
0
20
40
60
θ[°]
60
40
20
0
-20
-40
-60
Φ[°]


Station beam at 20MHz
(0,0)
Station Beam
1
0.8
0.6
0.4
0.2
0
-60
-40
-20
0
20
40
60
θ[°]
60
40
20
0
-20
-40
-60
Φ[°]

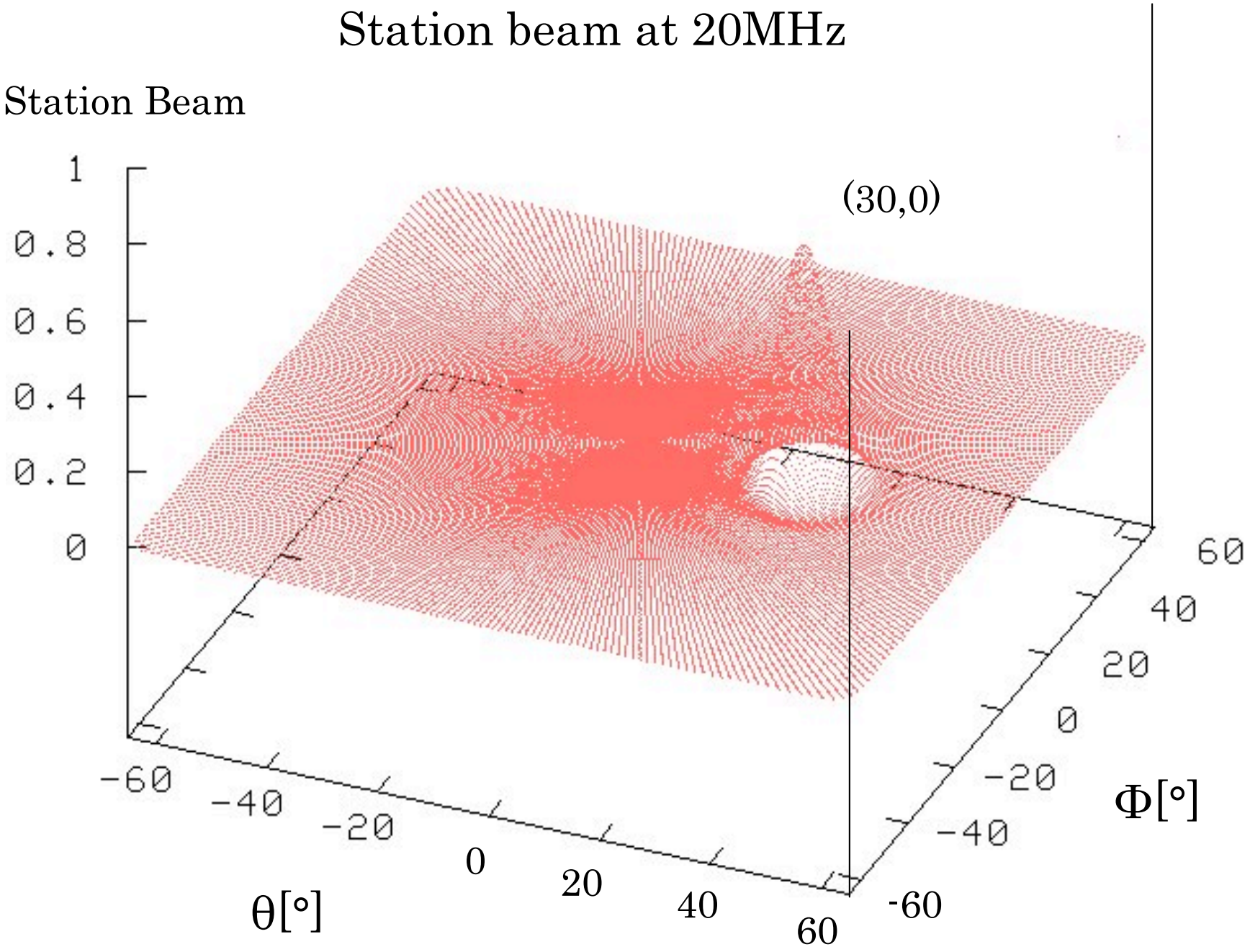
Station beam at 20MHz



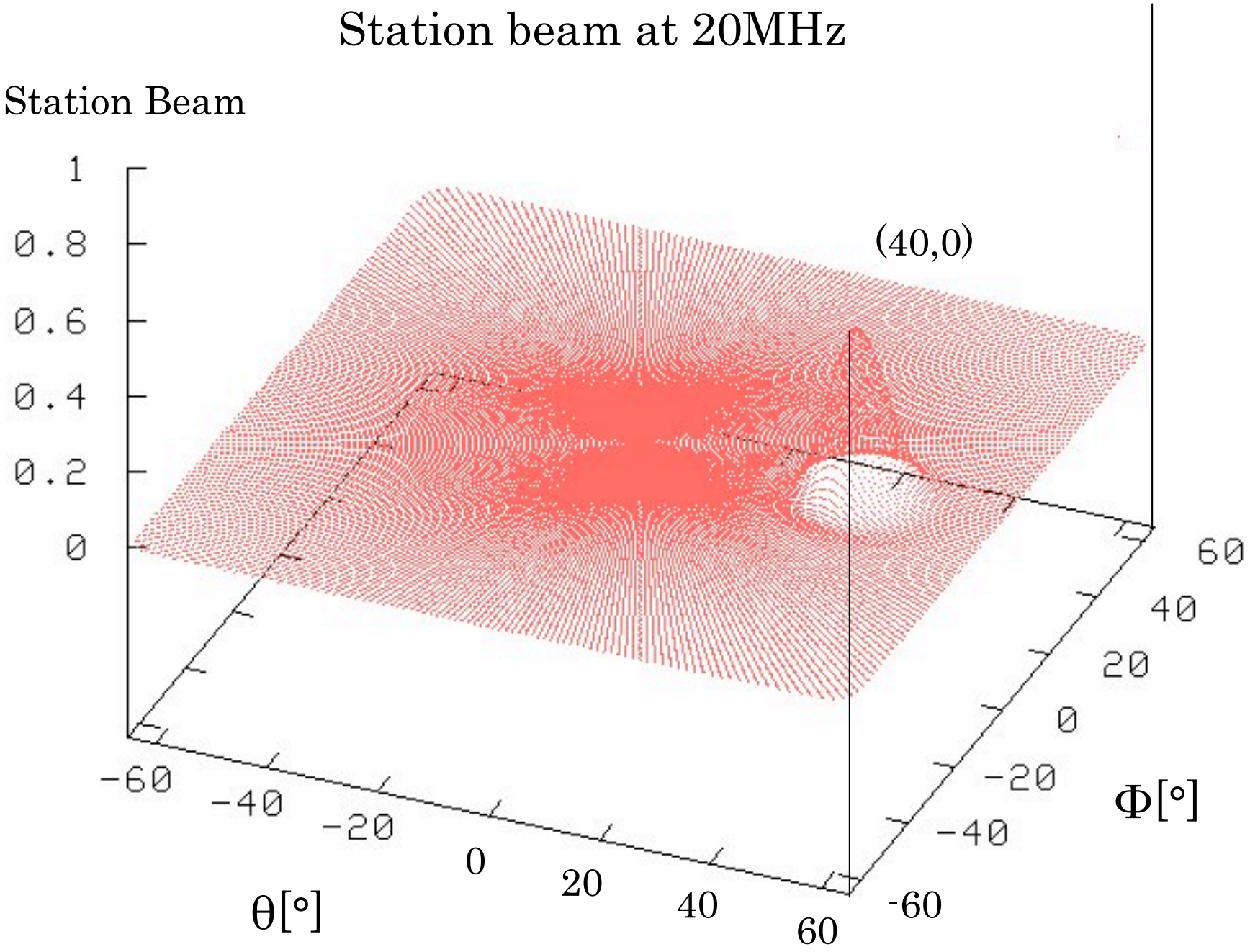
Station beam at 20MHz



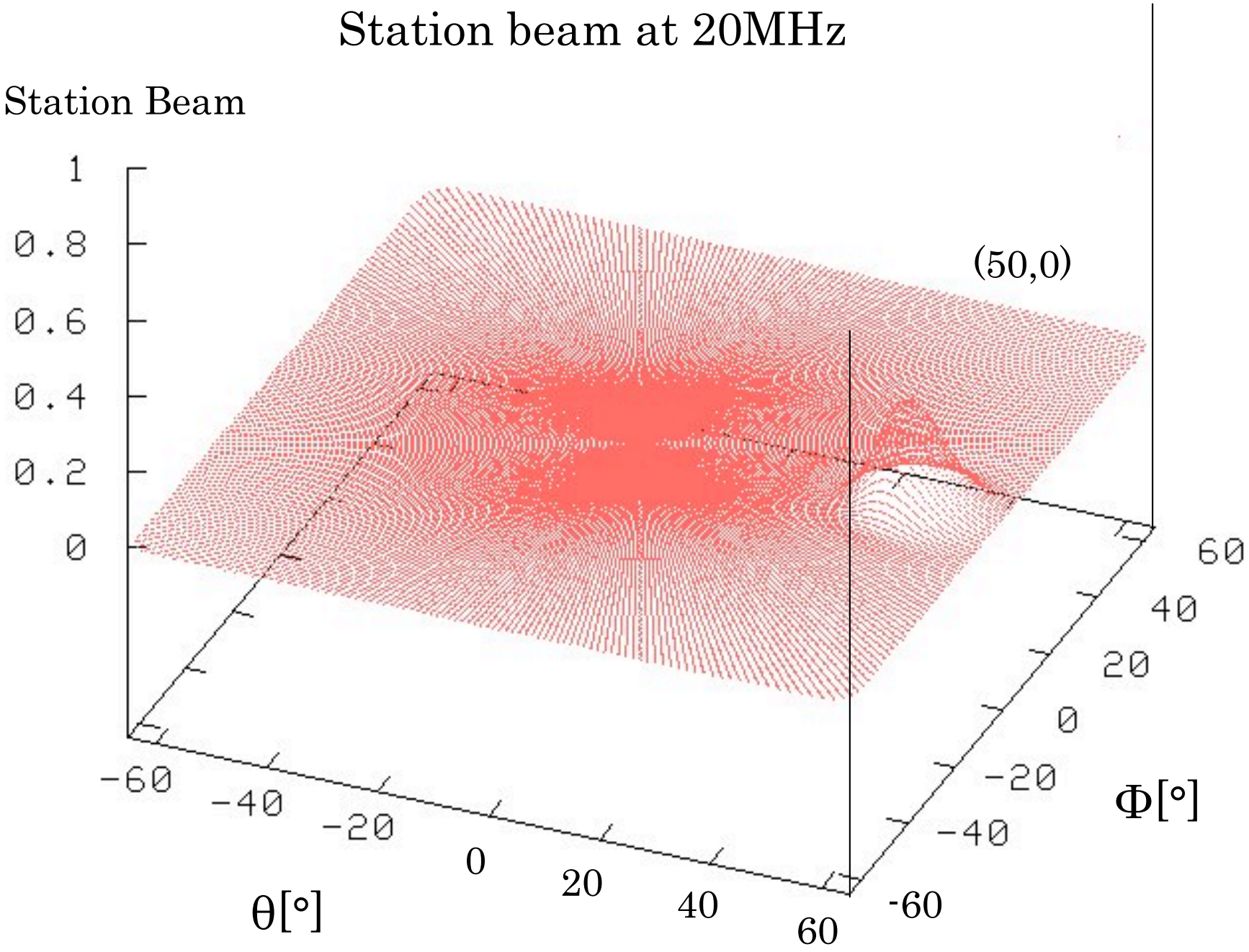
Station beam at 20MHz



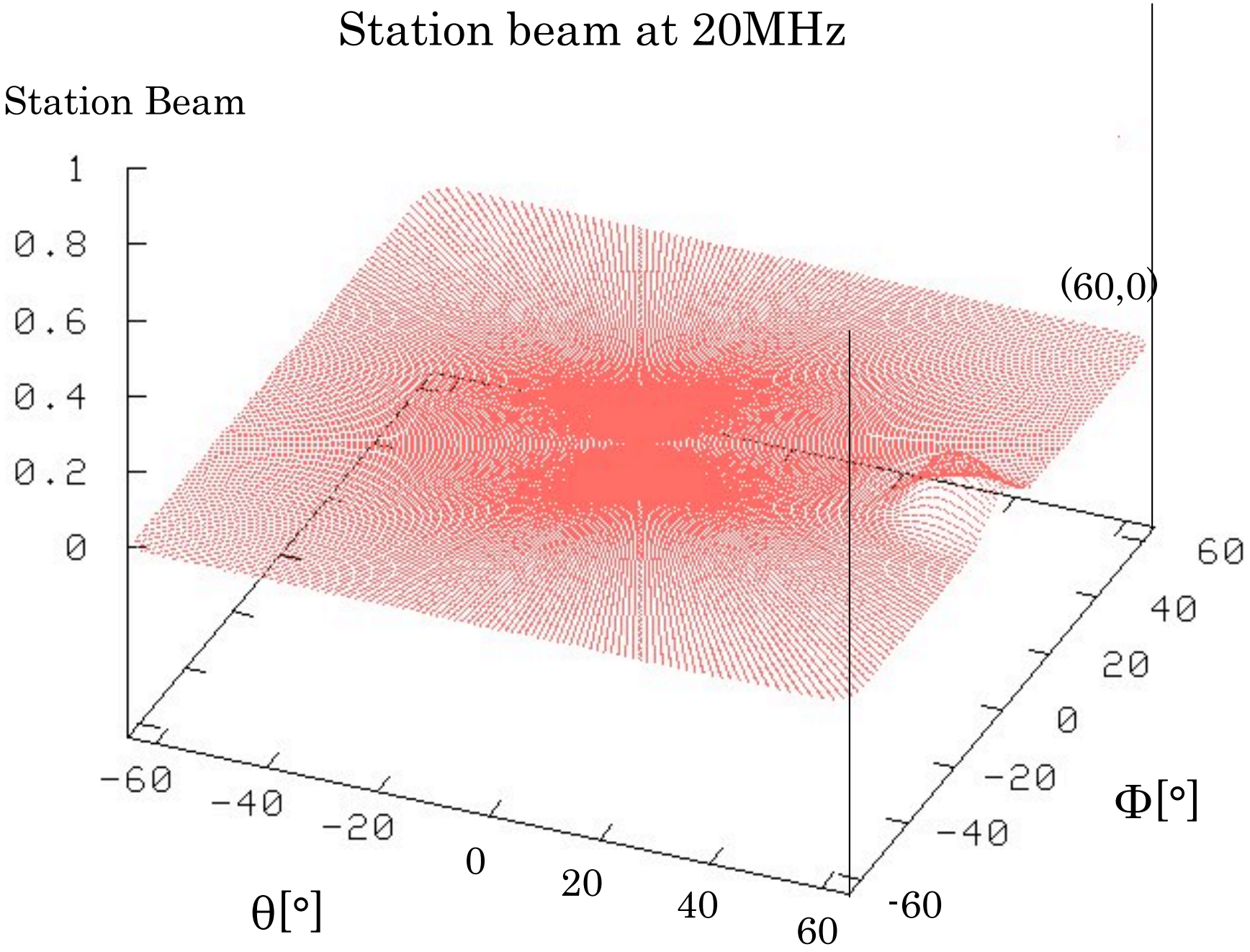
Station beam at 20MHz



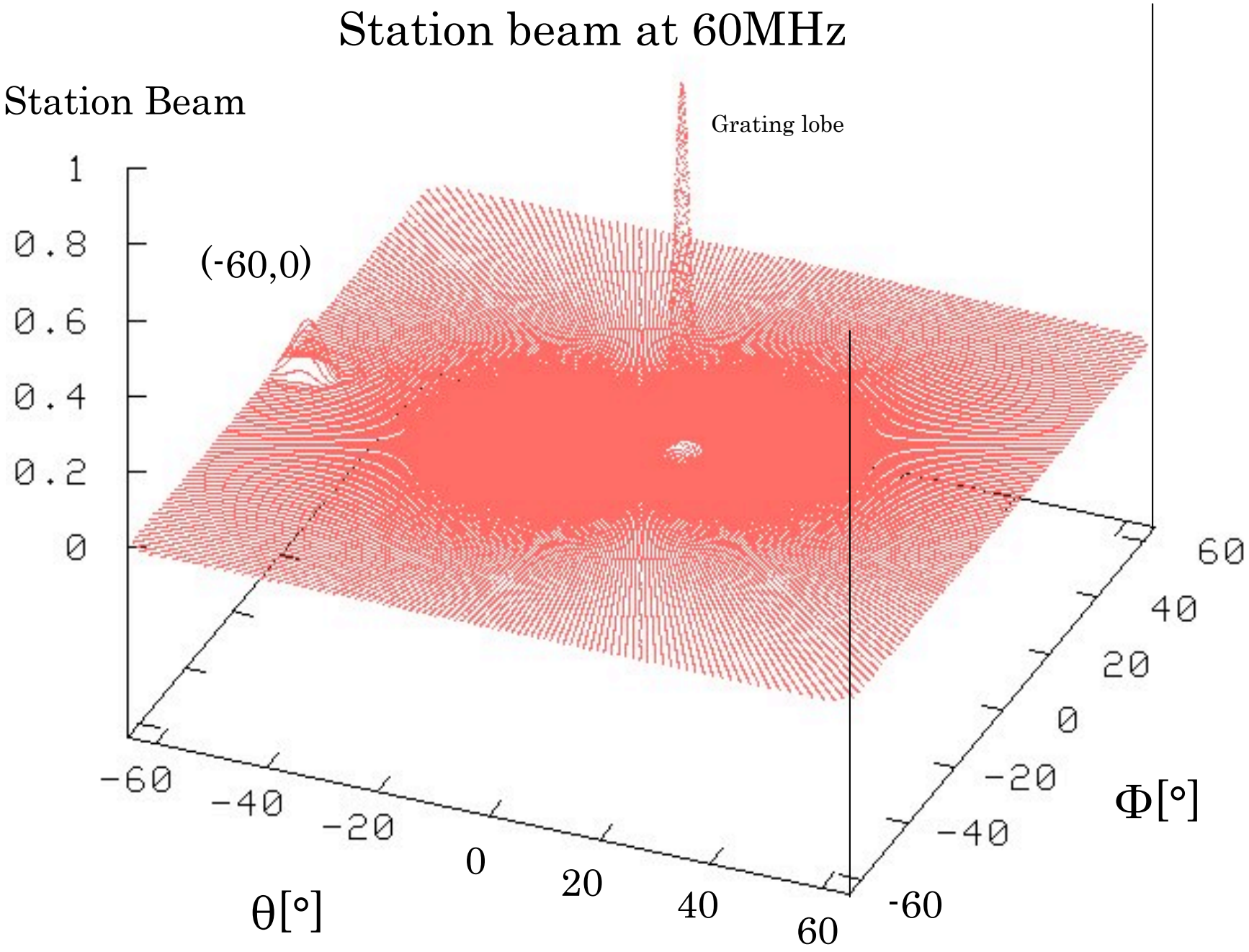
Station beam at 20MHz



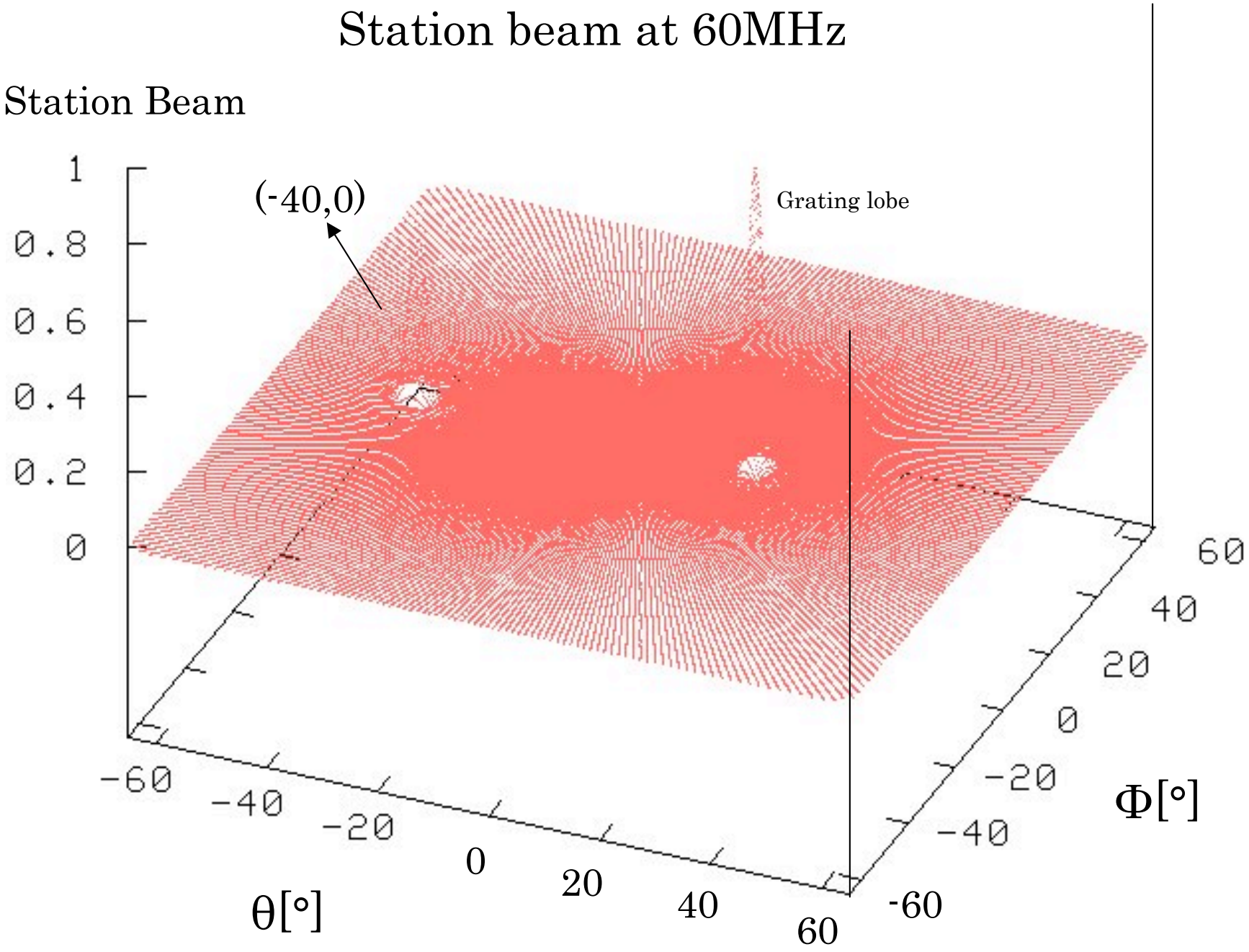
Station beam at 20MHz



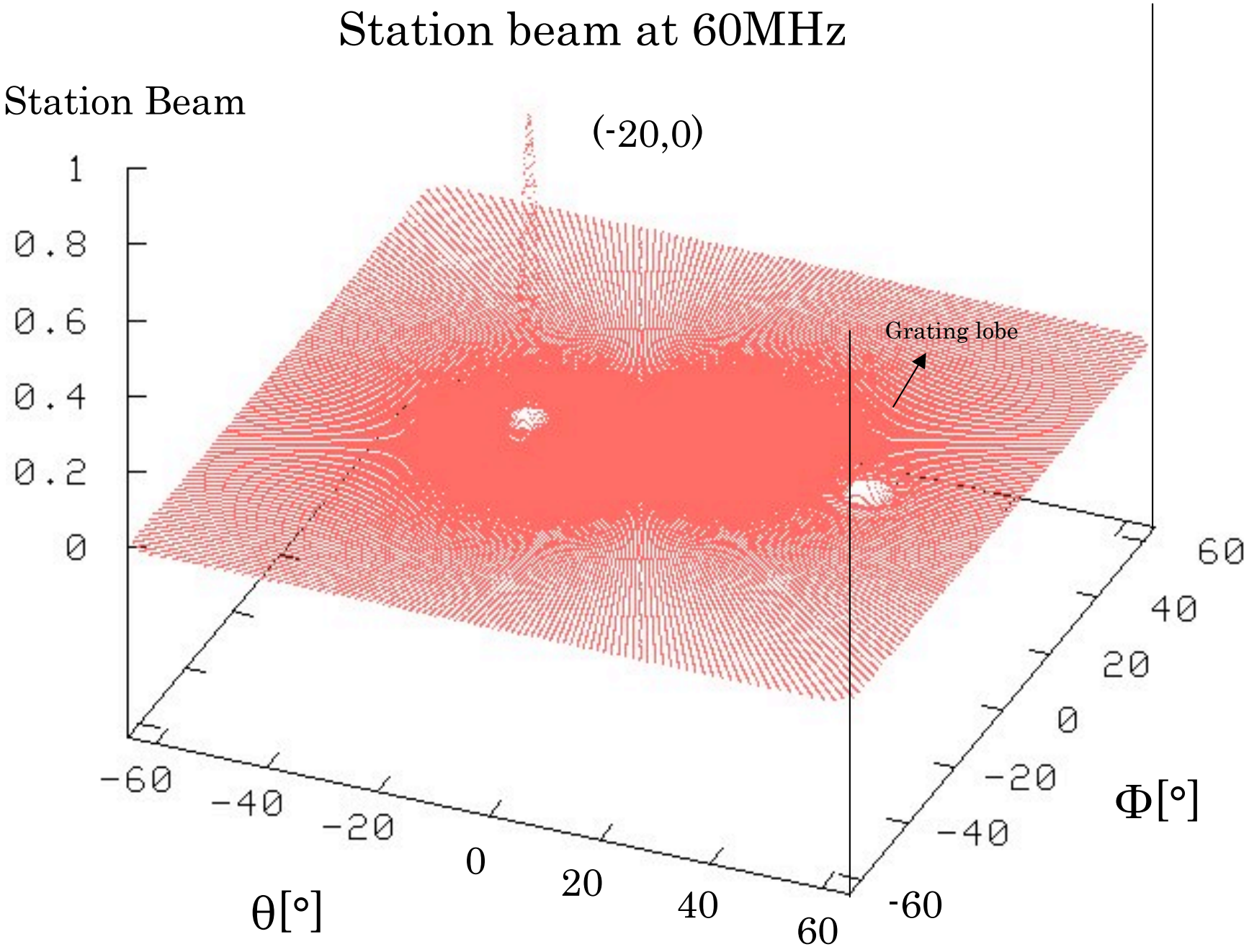
Station beam at 60MHz



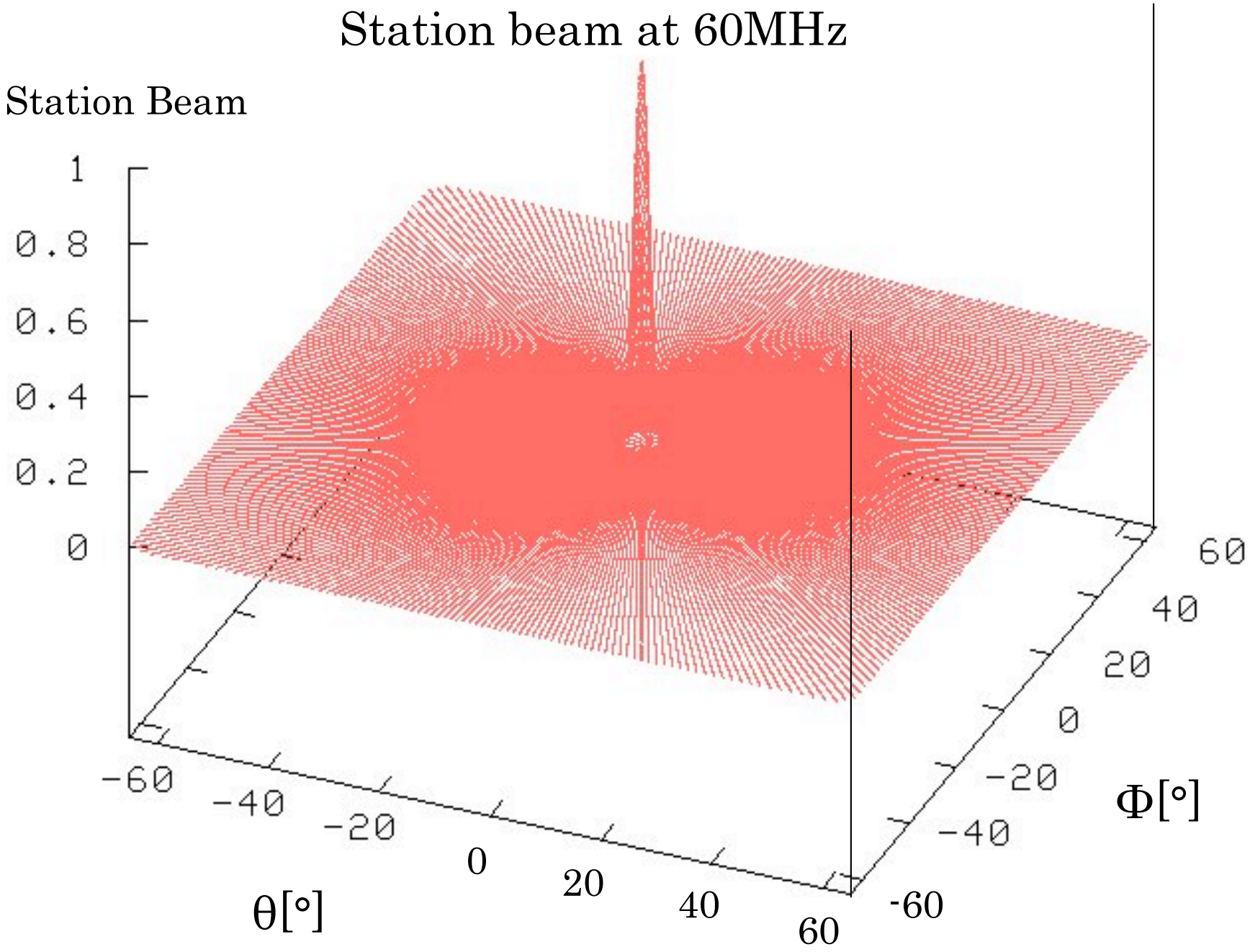
Station beam at 60MHz



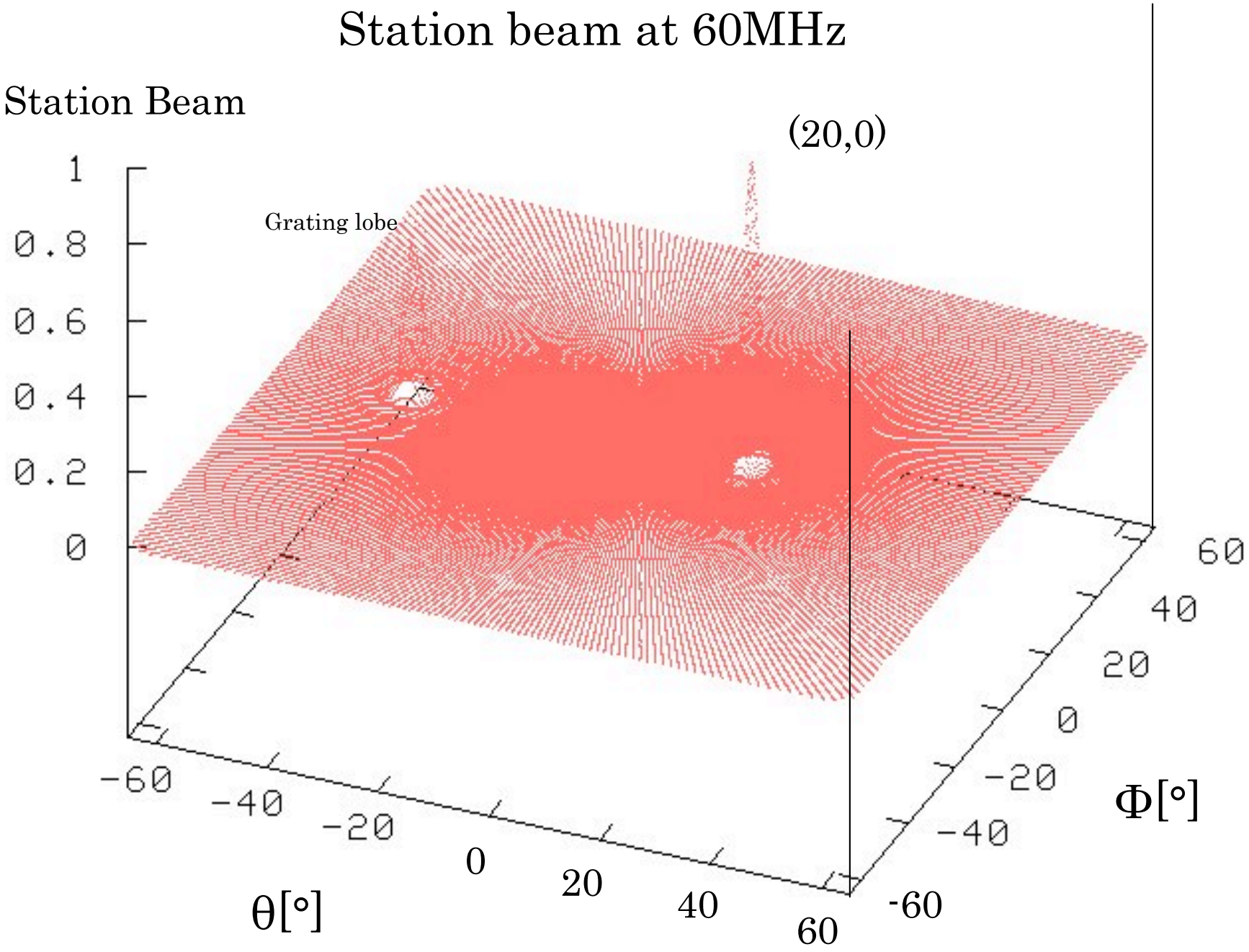
Station beam at 60MHz



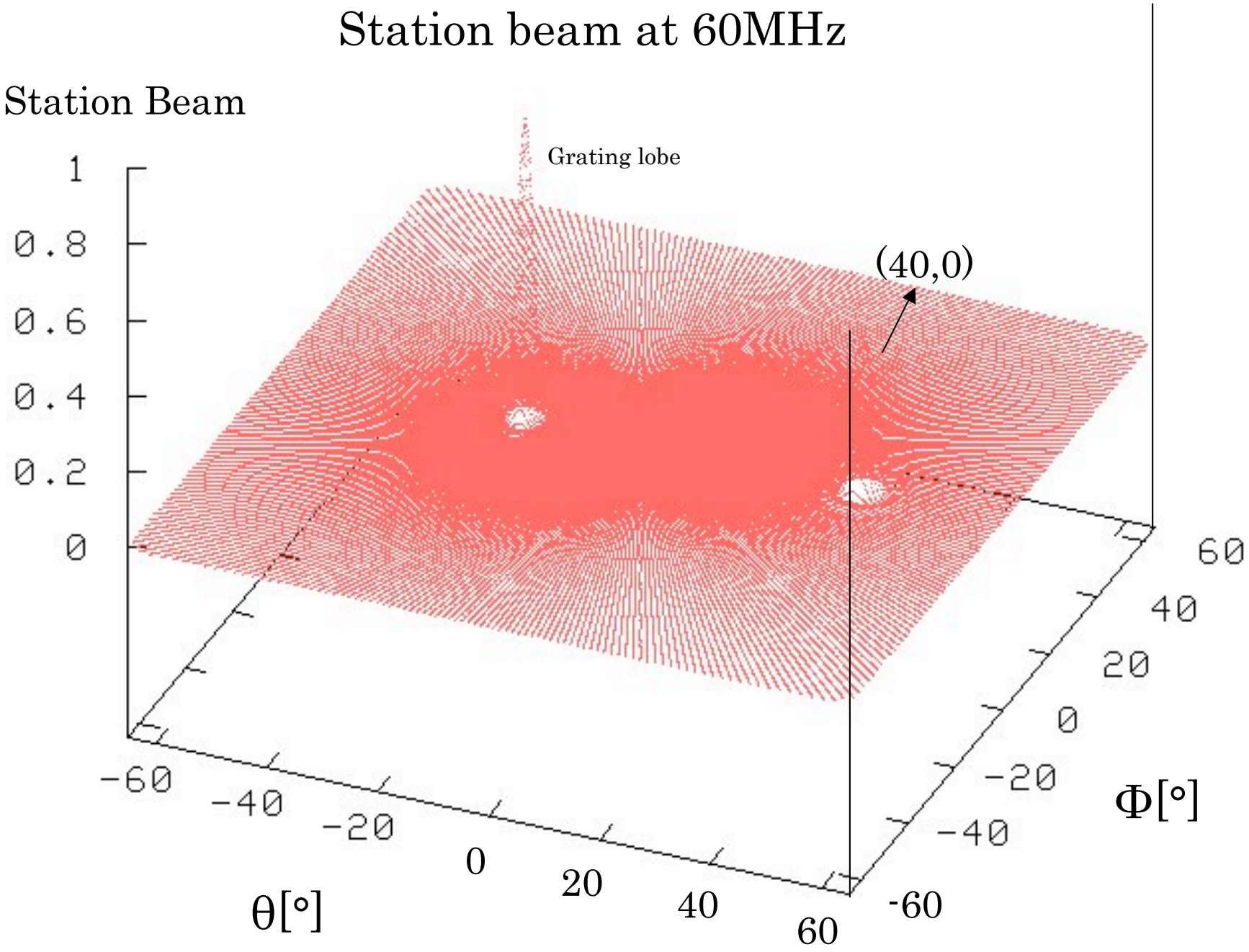
Station beam at 60MHz



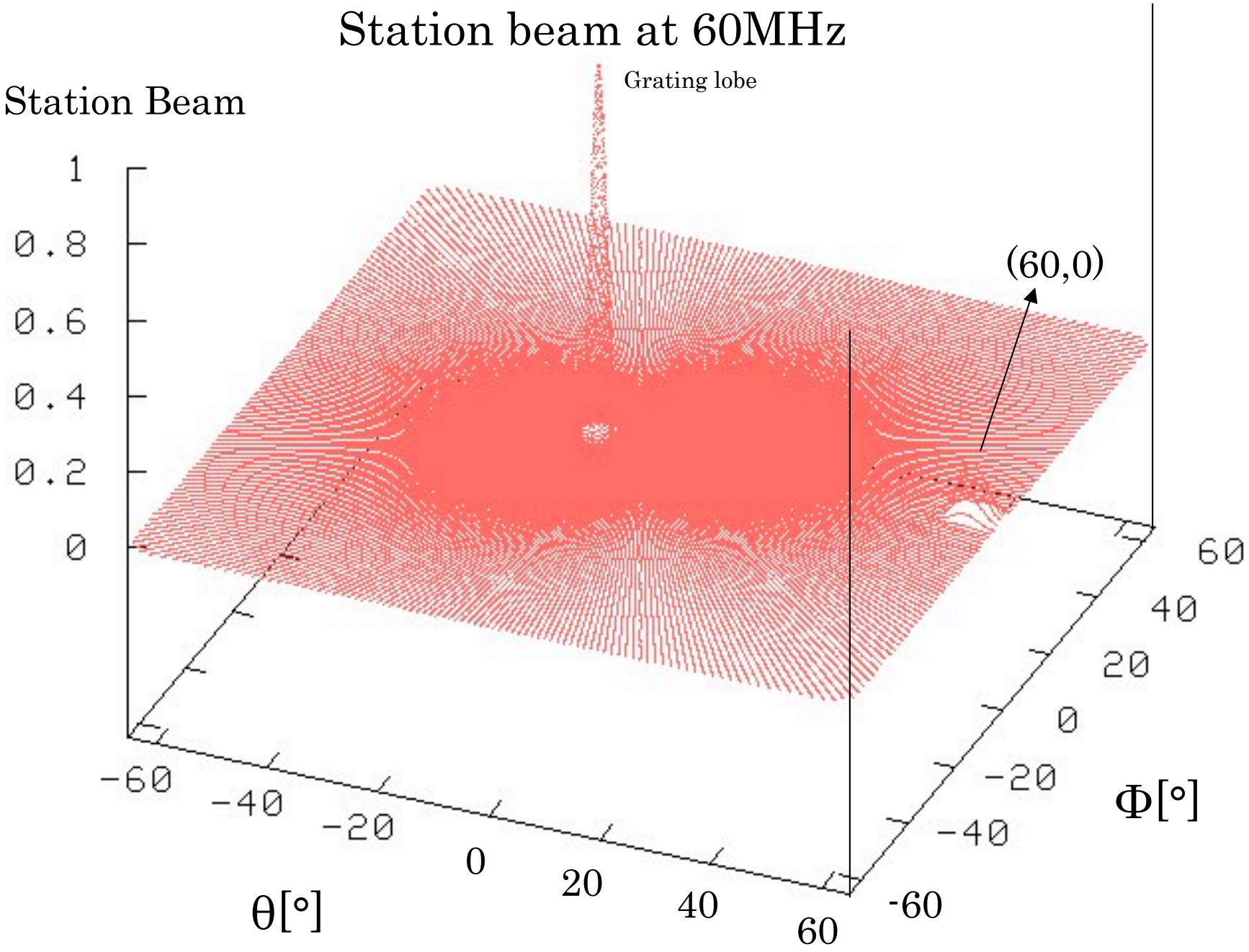
Station beam at 60MHz



Station beam at 60MHz



Station beam at 60MHz



Summary

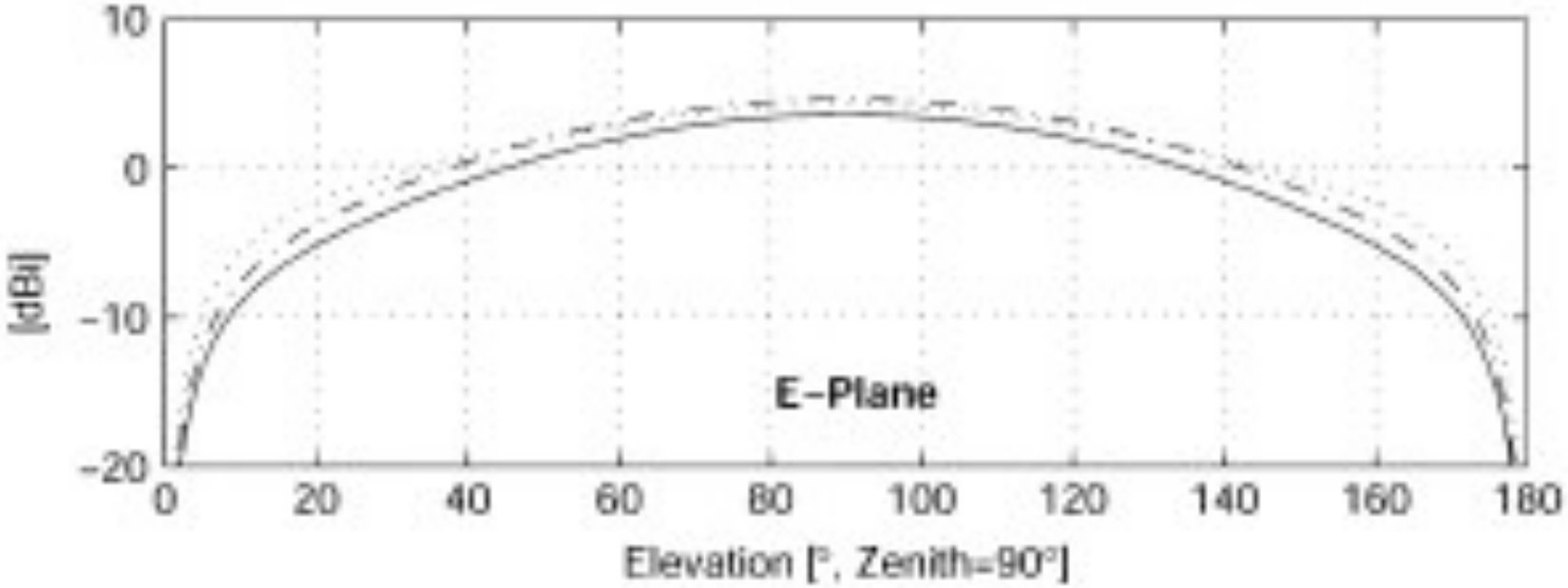
1. Asymmetry rate of a station beam → beam elevation & observing frequency
2.The direction error of a station beam → beam elevation & primary beam

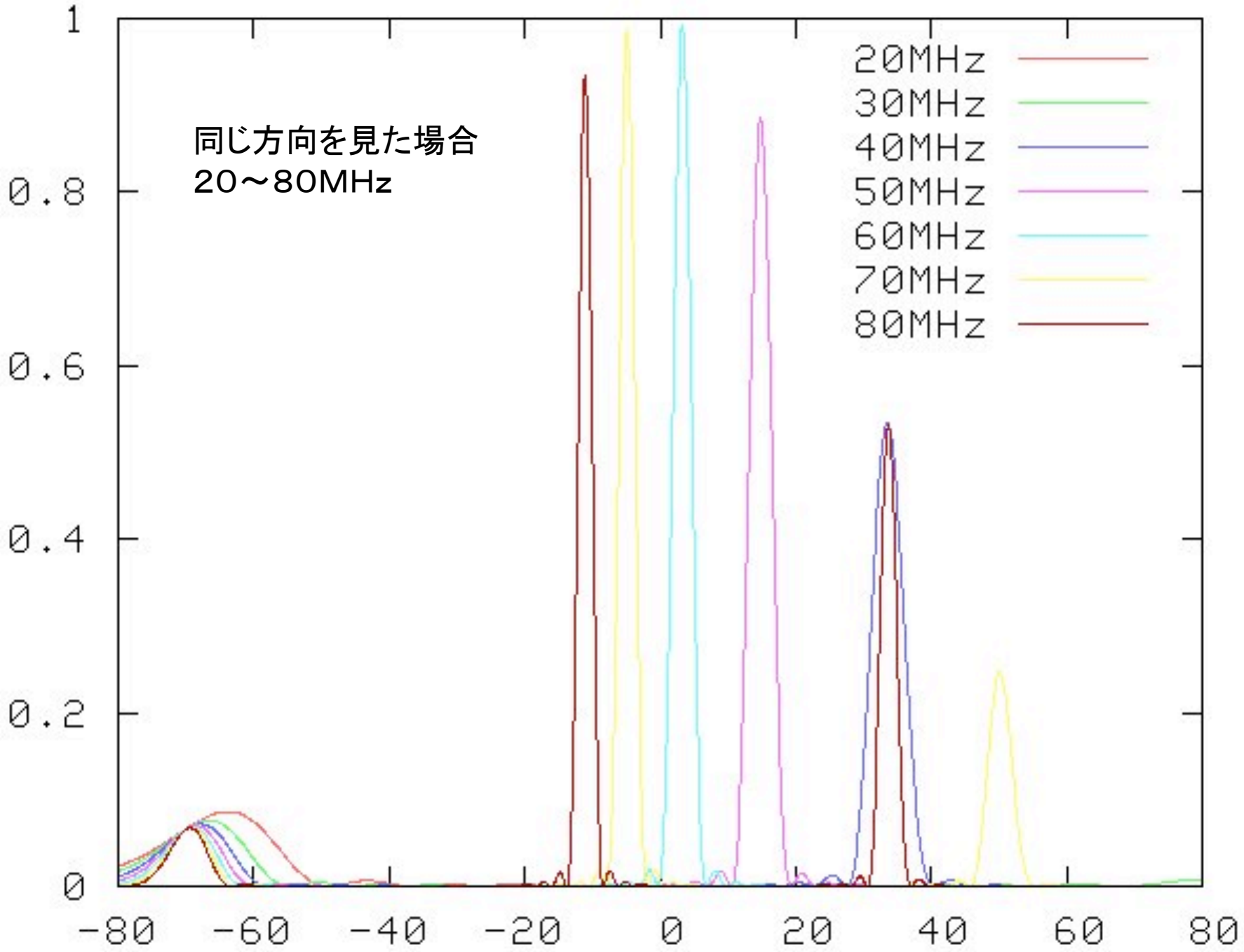
Future Plan

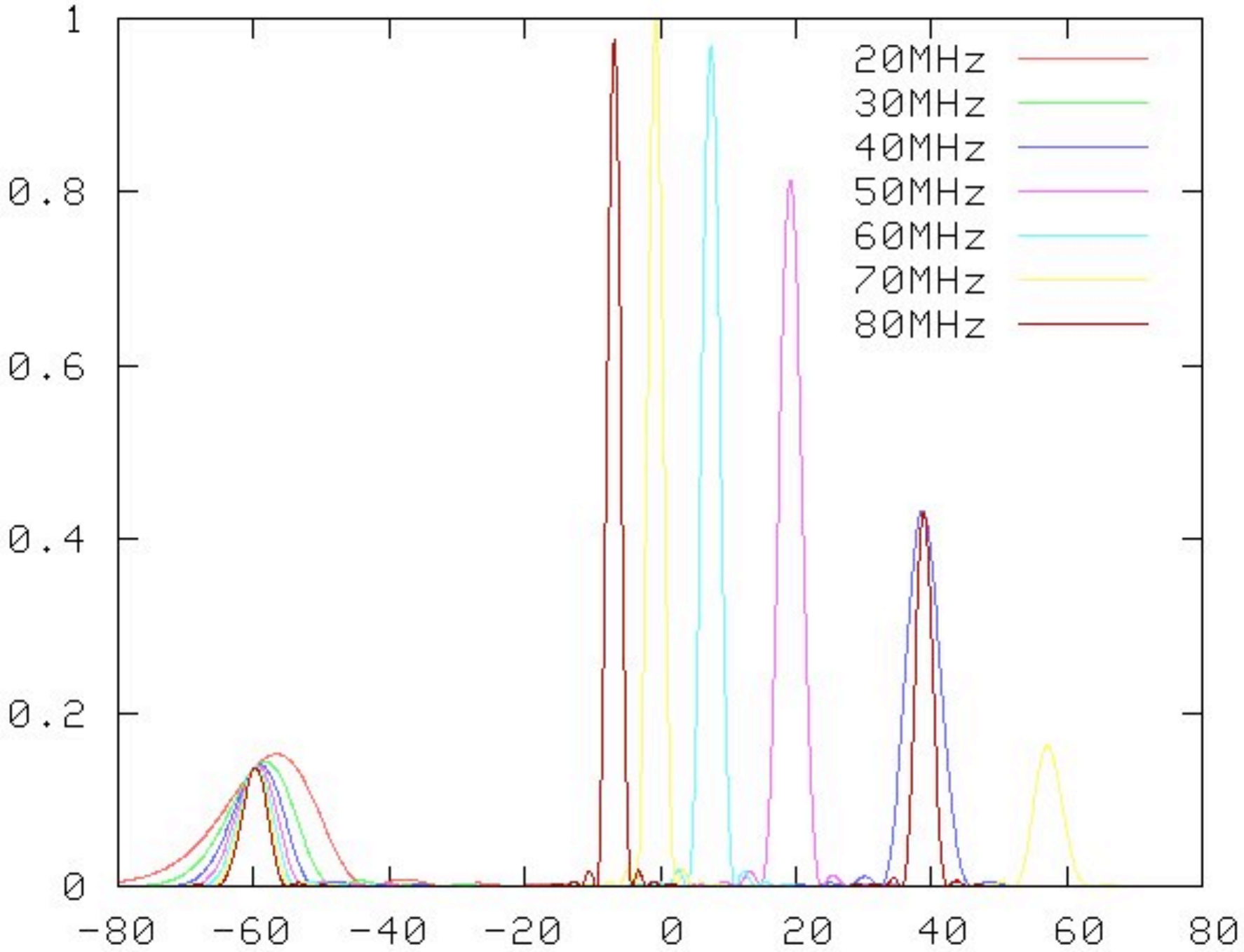
@ Addition of a real dipole beam pattern to the simulator
@ Addition of band widths to the simulator
@ Dipole configuration to remove the grating lobes
@
@

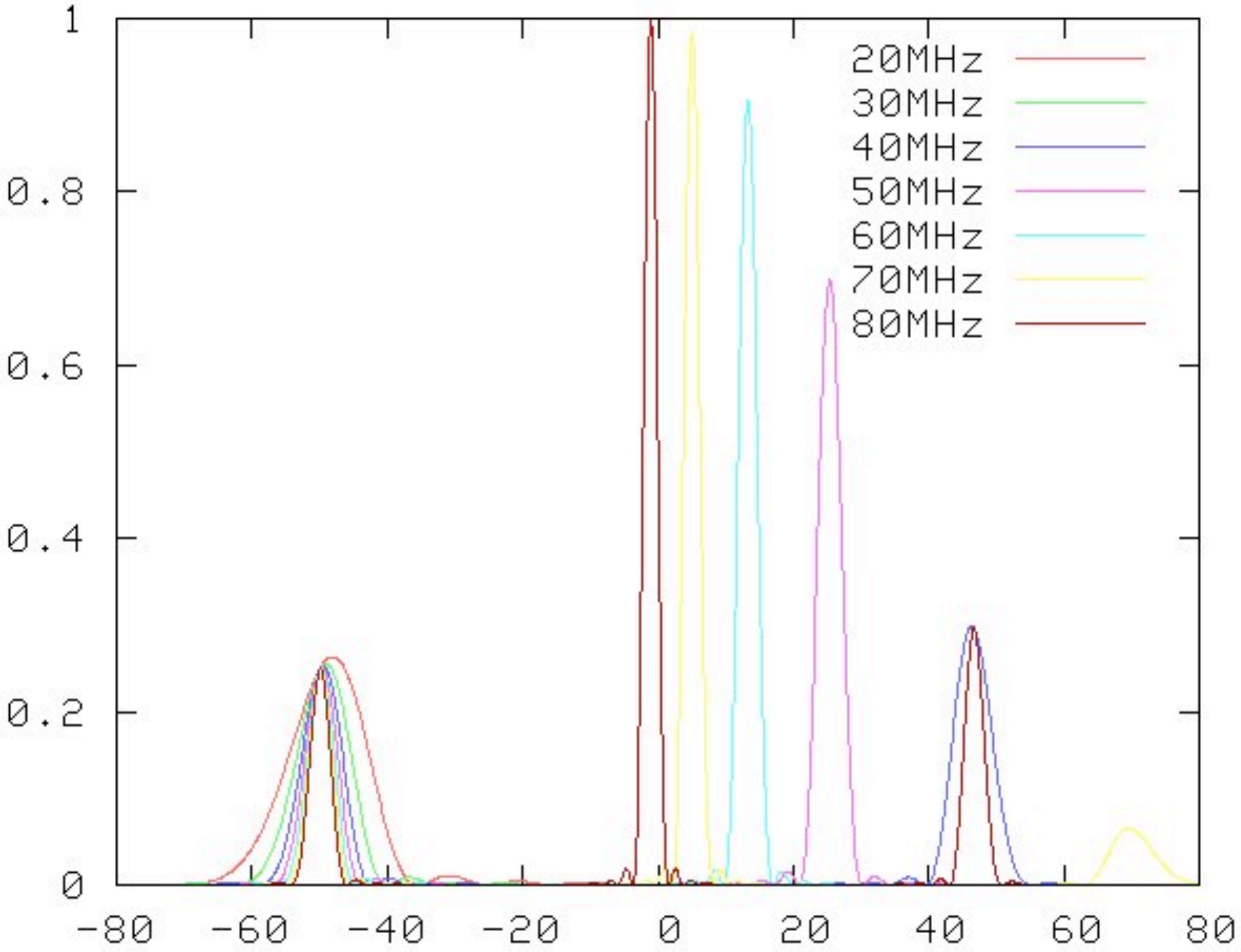
.
.
.

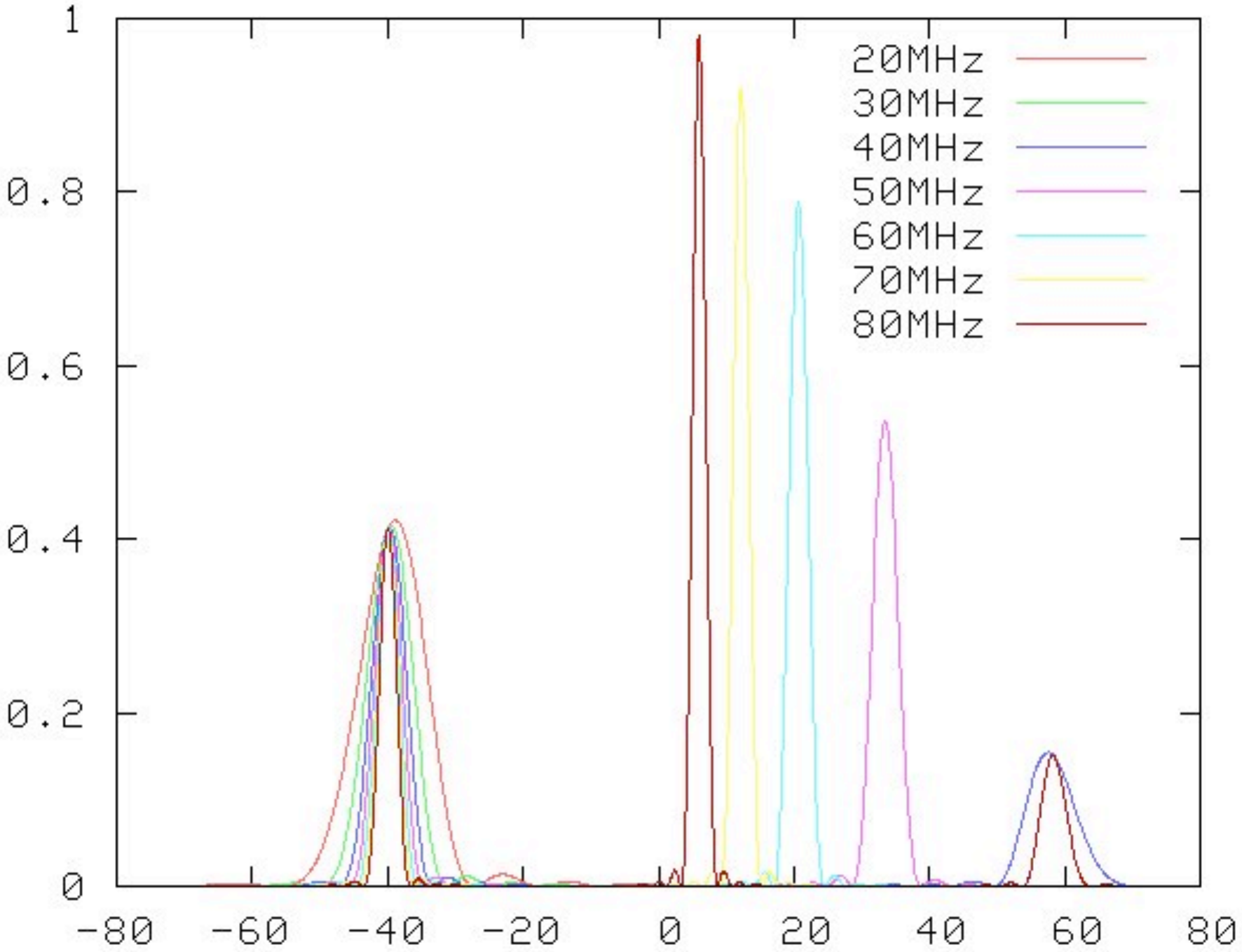
★Completion of the simulator for the LWA

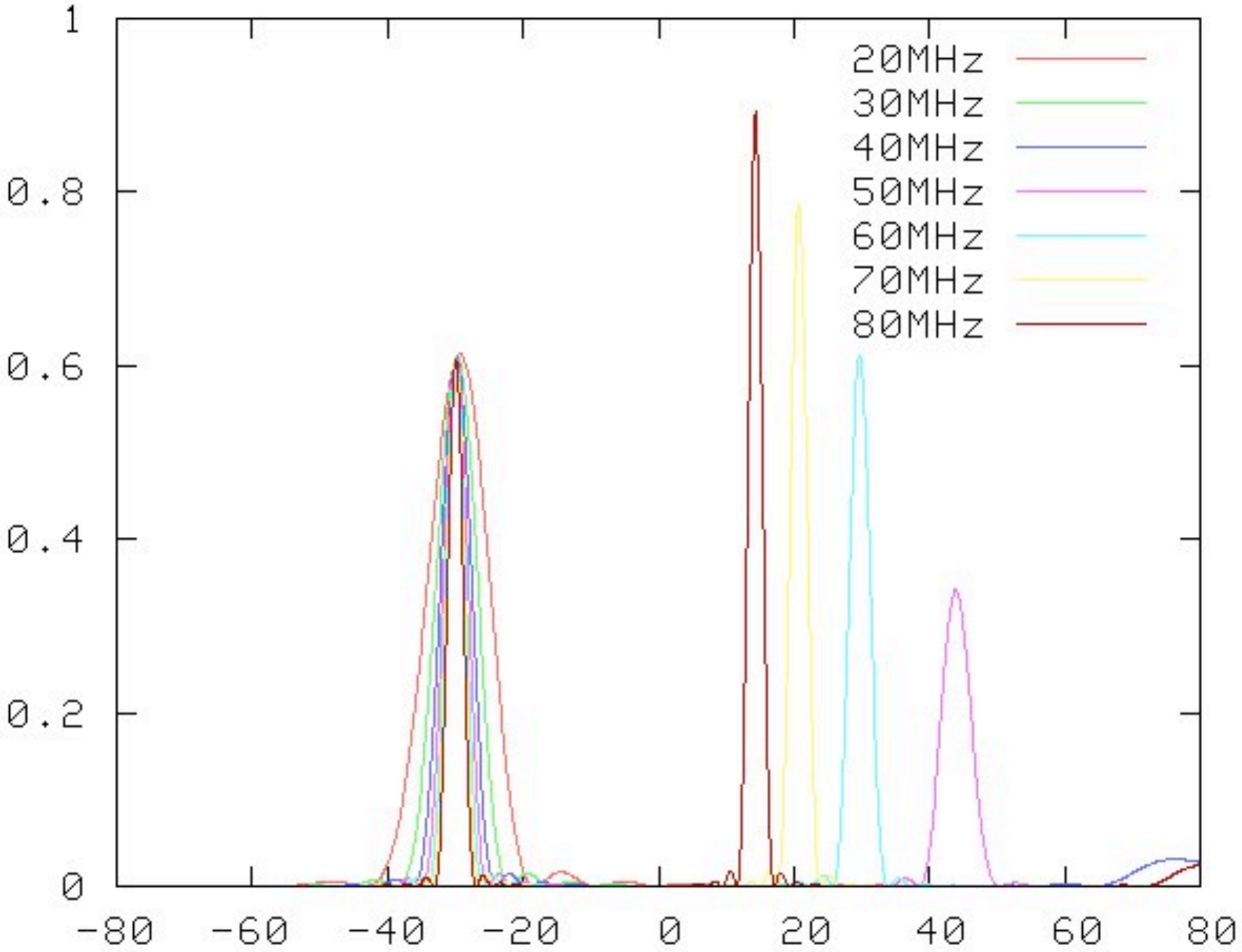

10
0
-10
-20
[dBi]
E-Plane
0
20
40
60
80
100
120
140
160
180
Elevation [°, Zenith=90°]

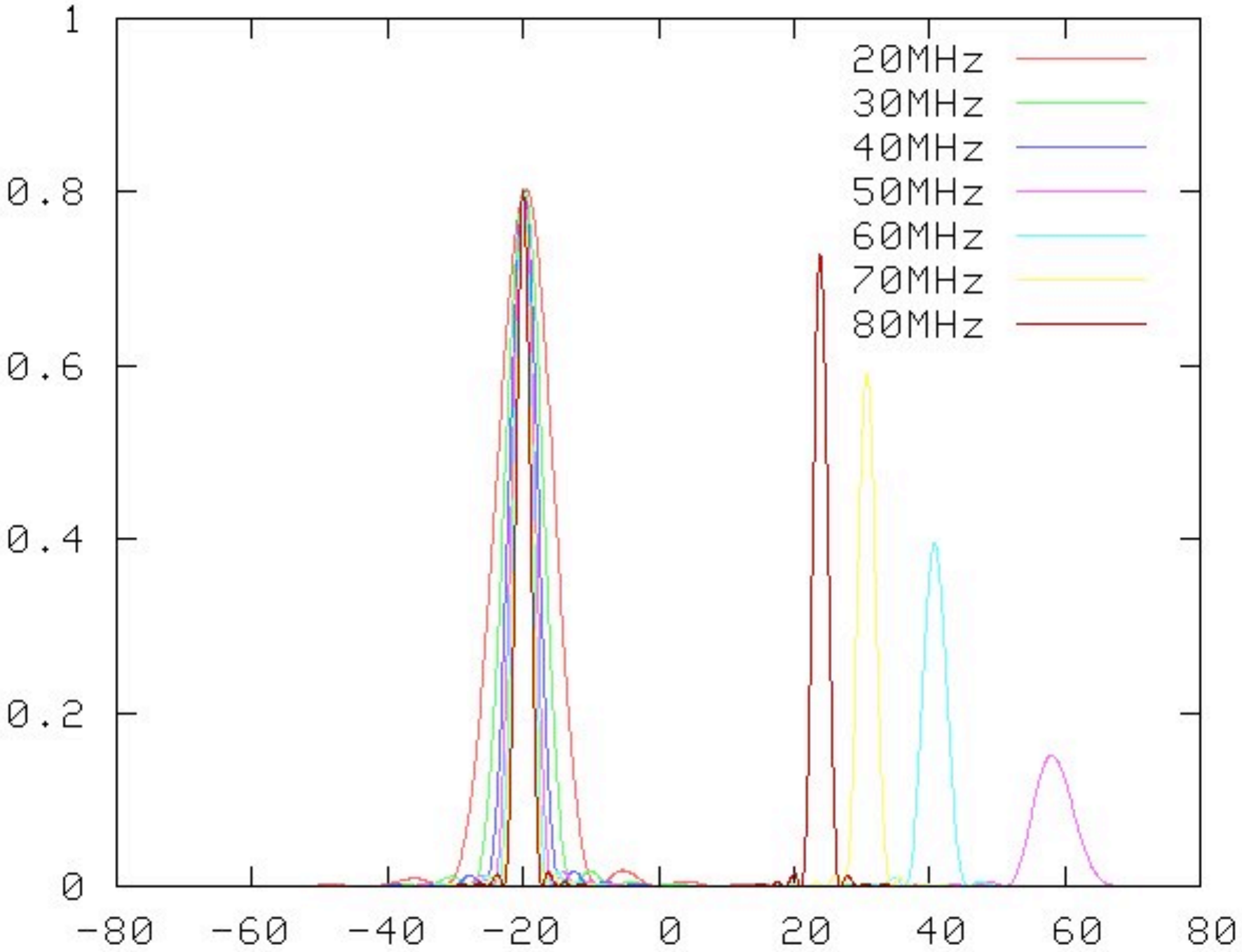

同じ方向を見た場合
20～80MHz
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz
1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80

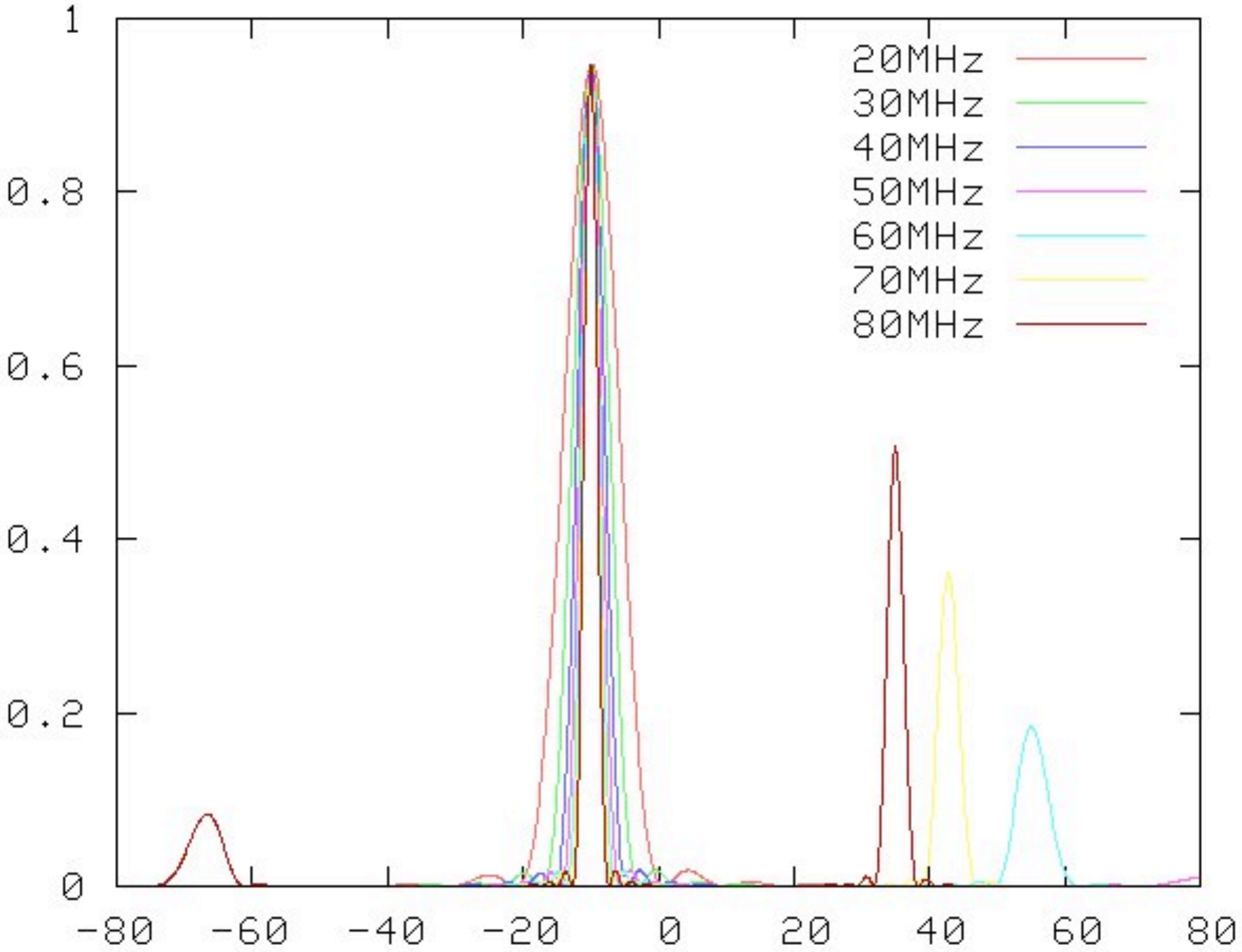

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

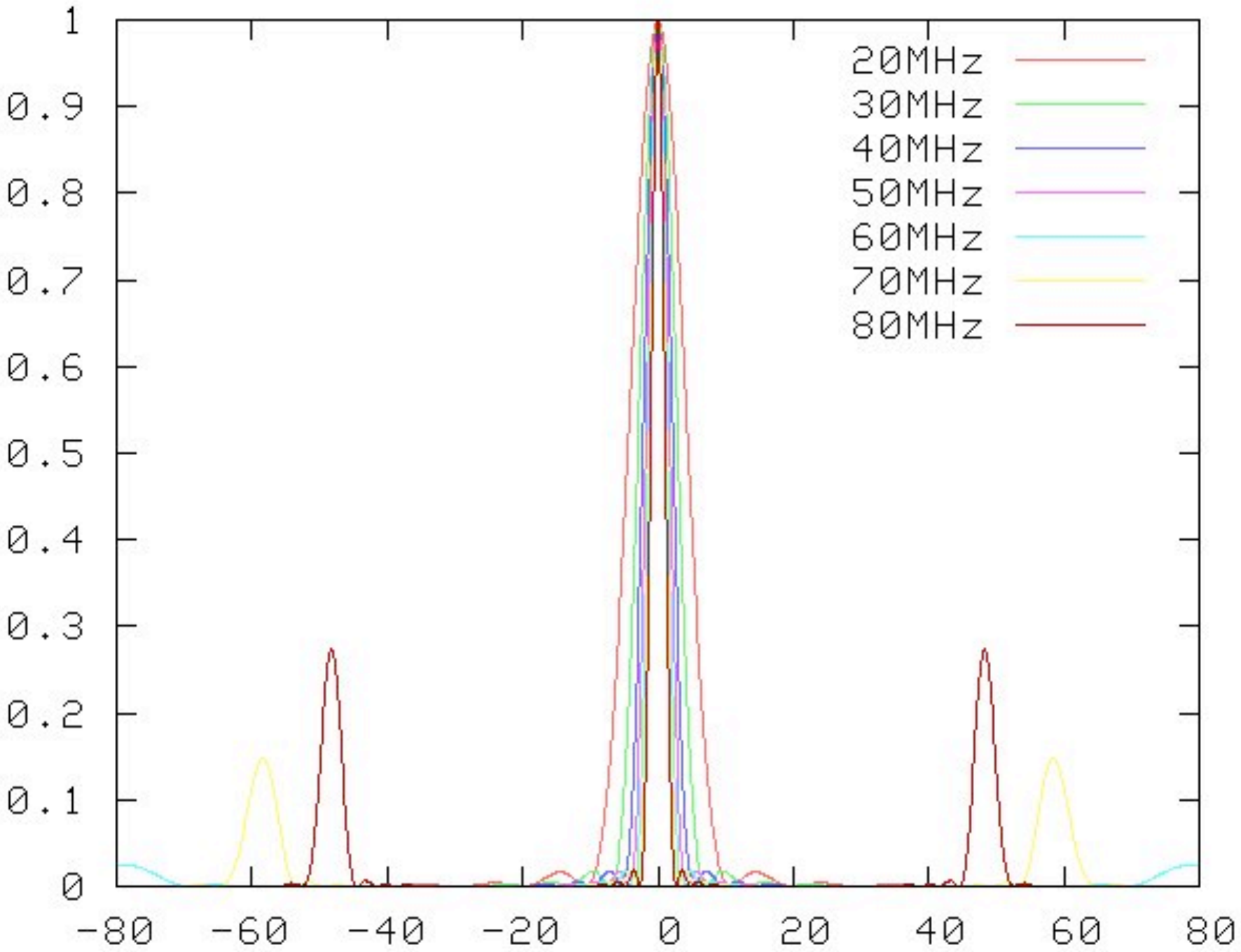

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

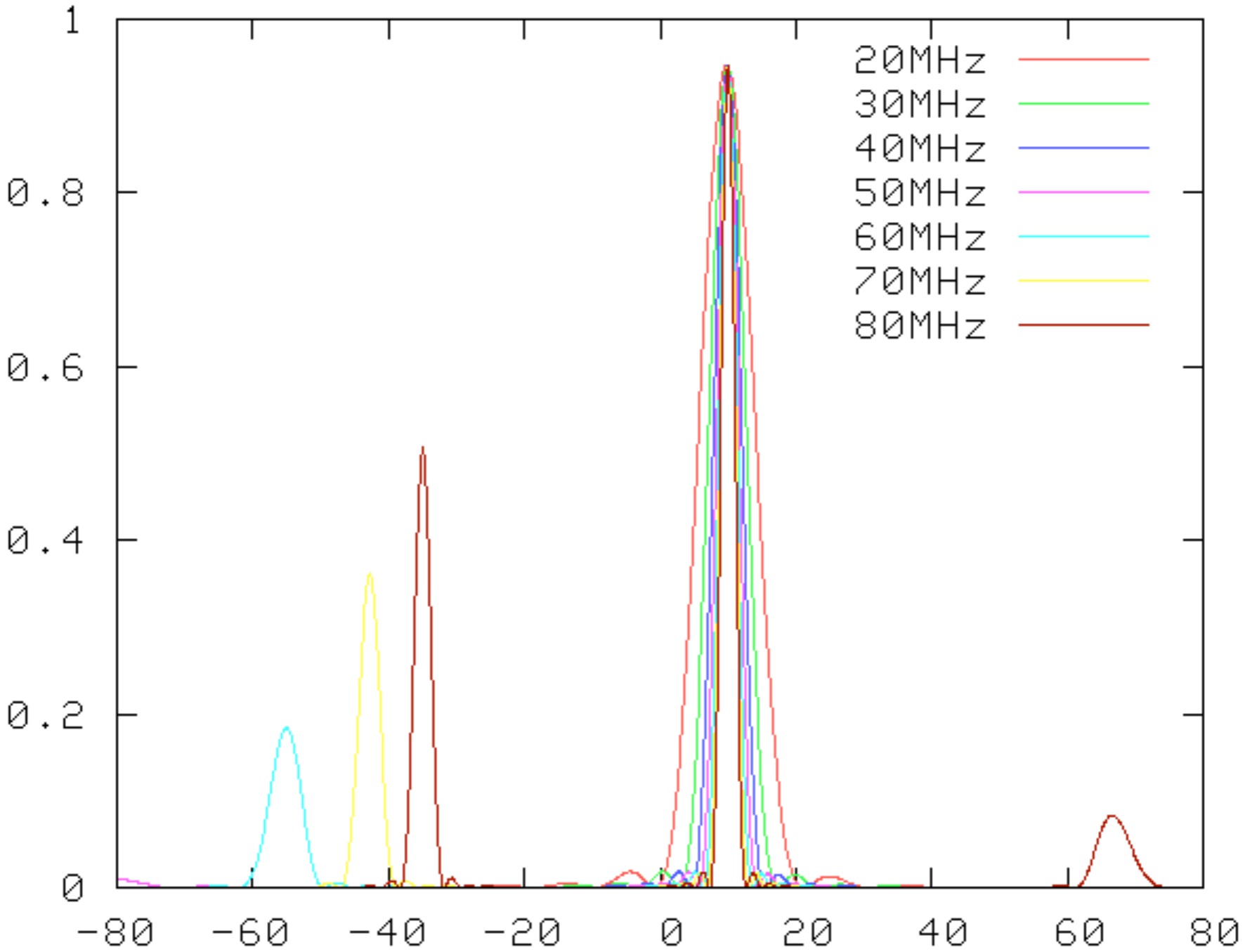

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

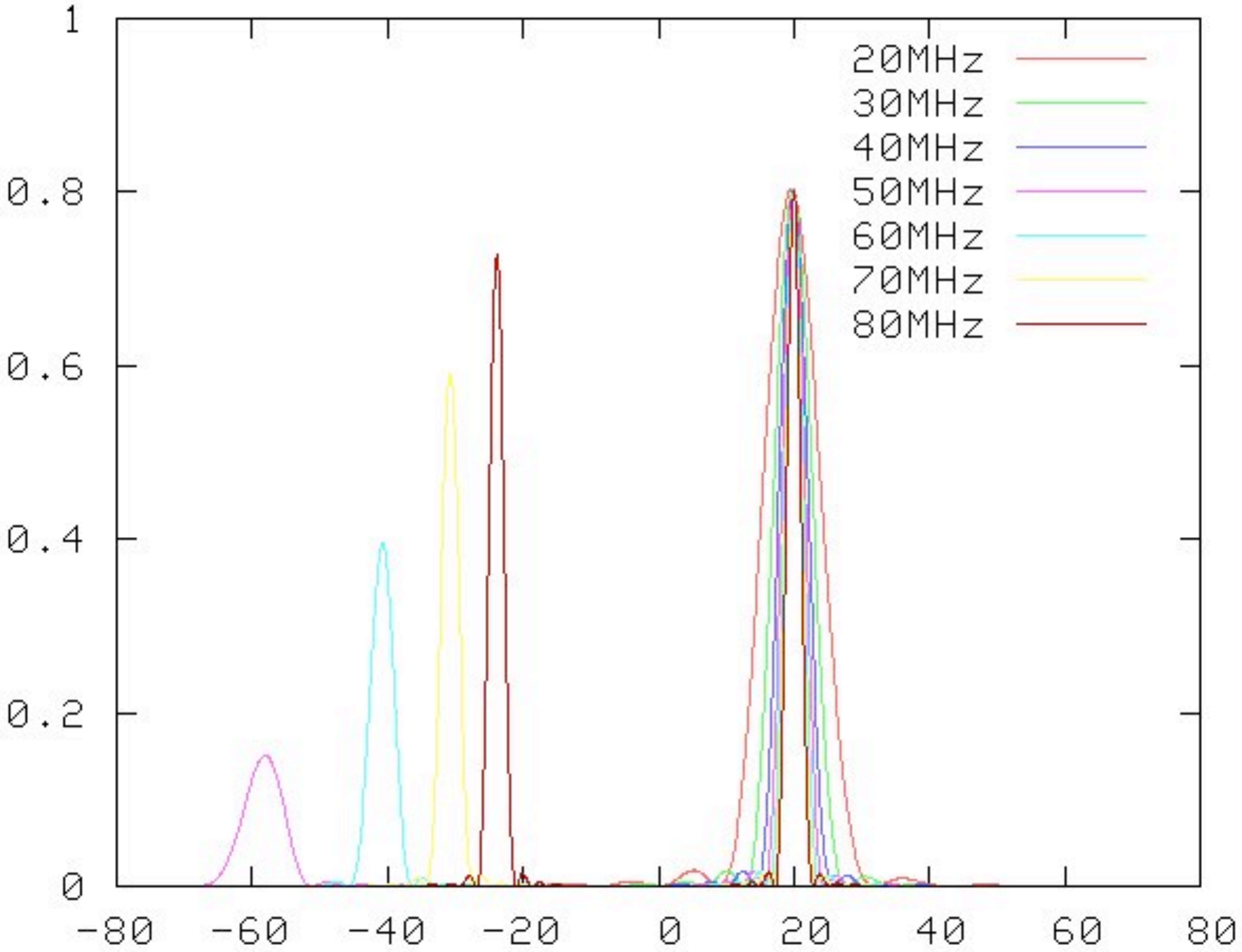

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

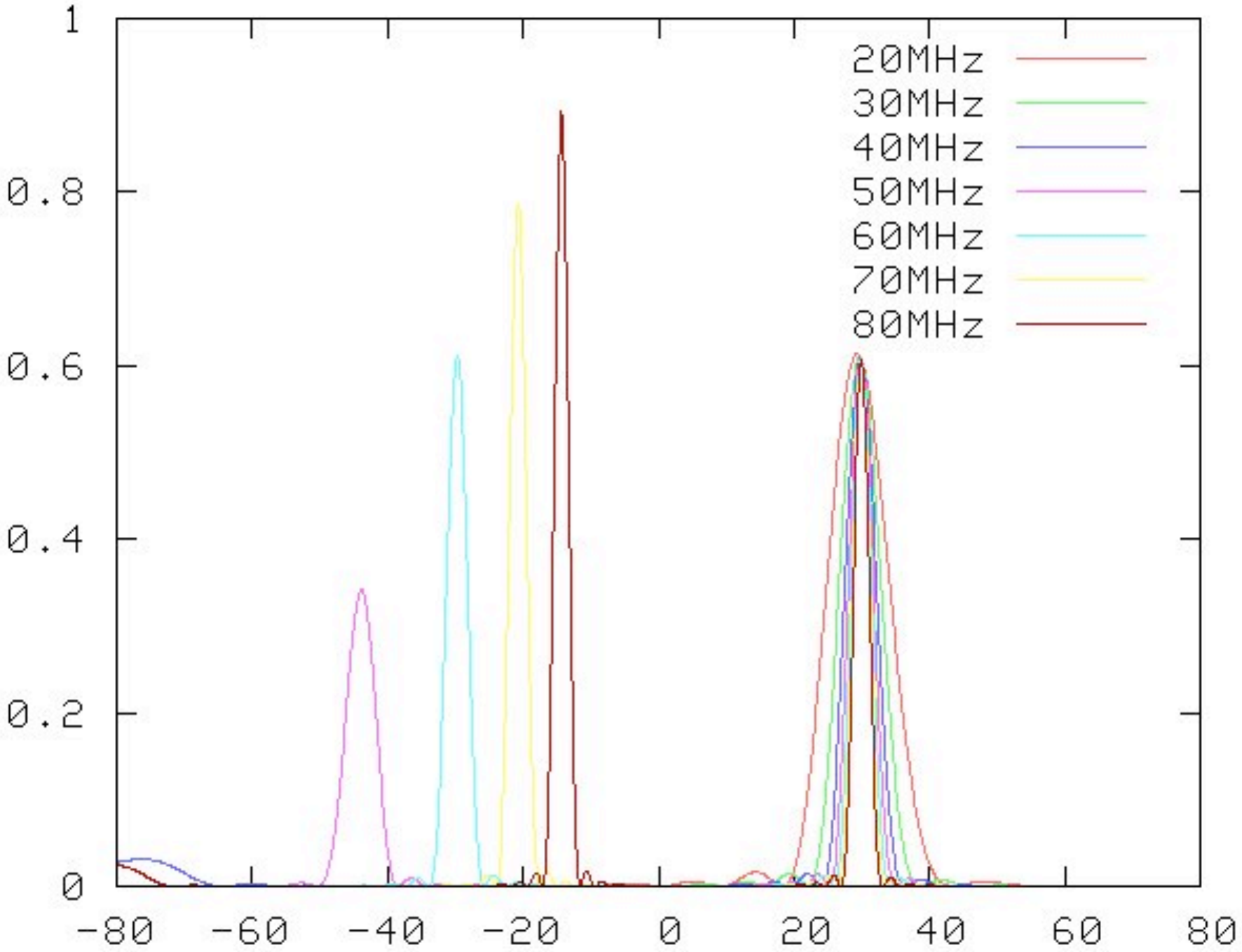

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

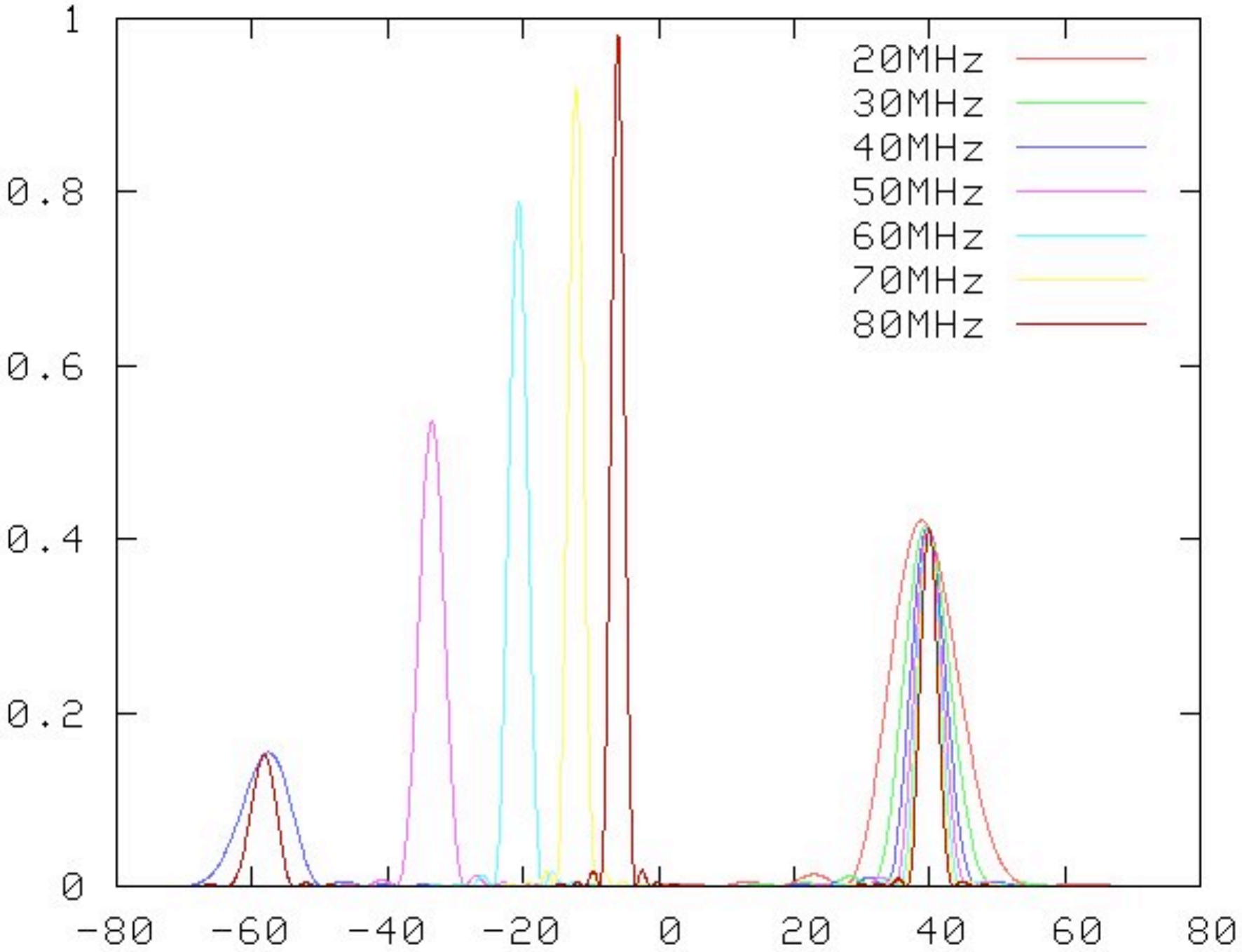

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

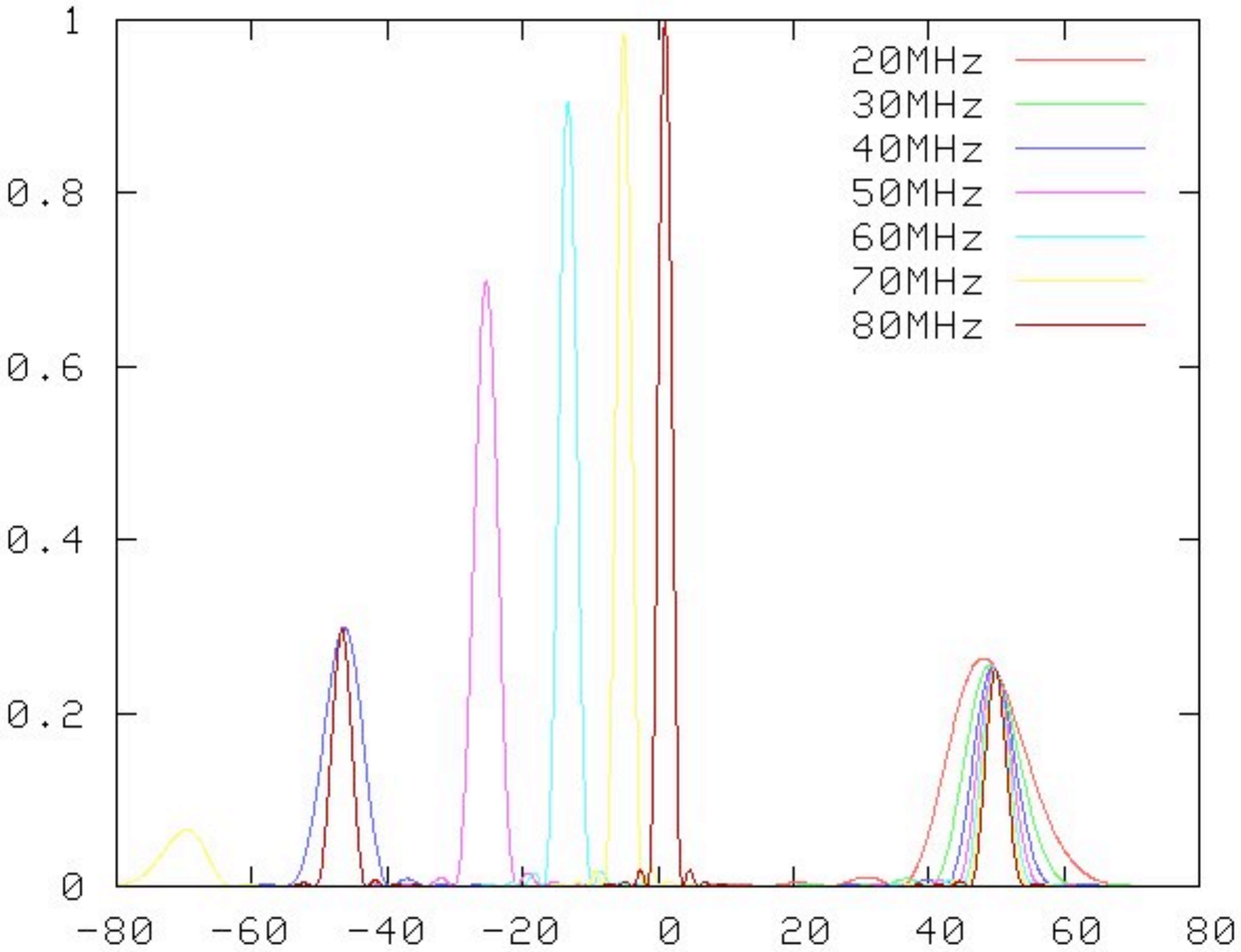

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

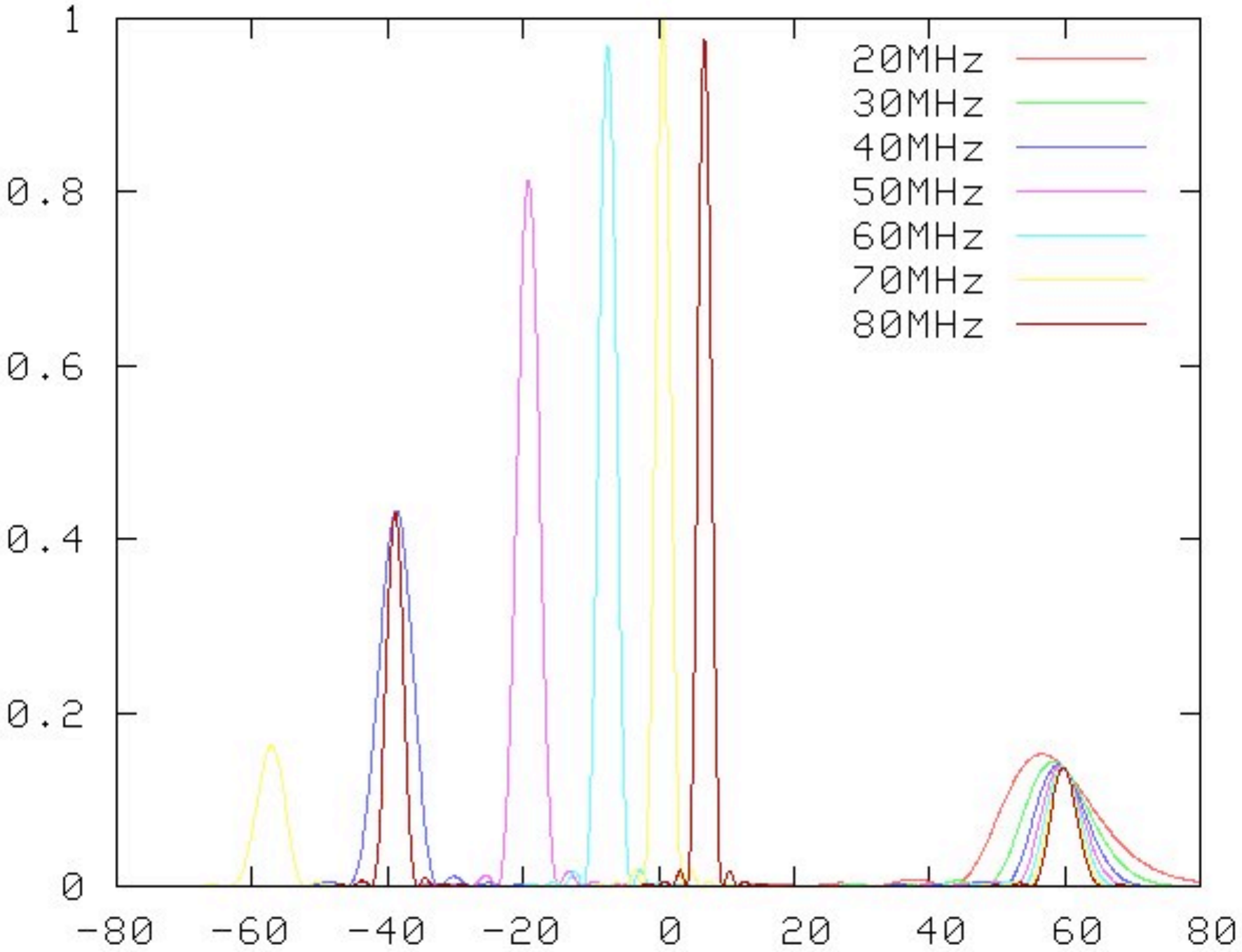

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

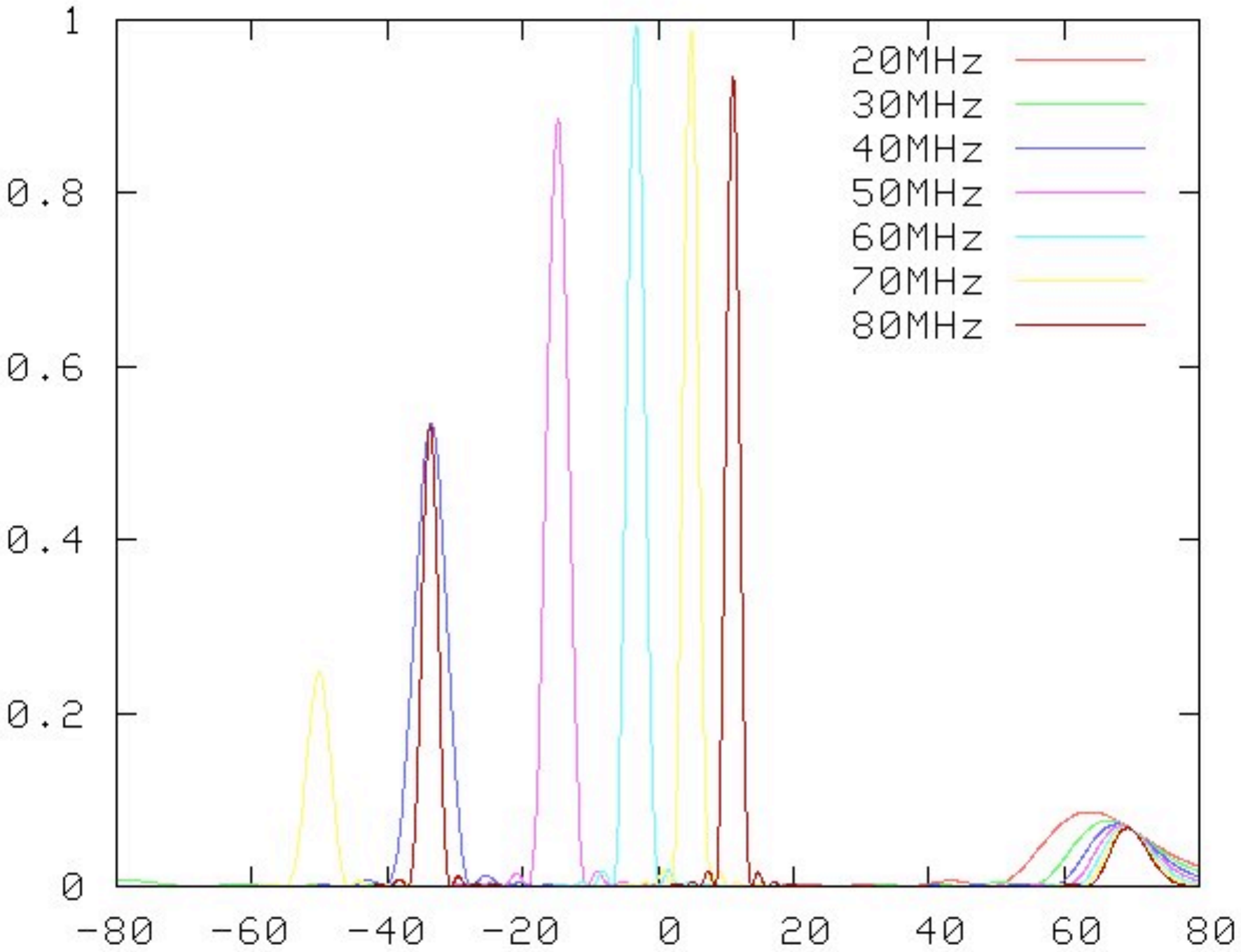

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz


1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz


1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz


1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

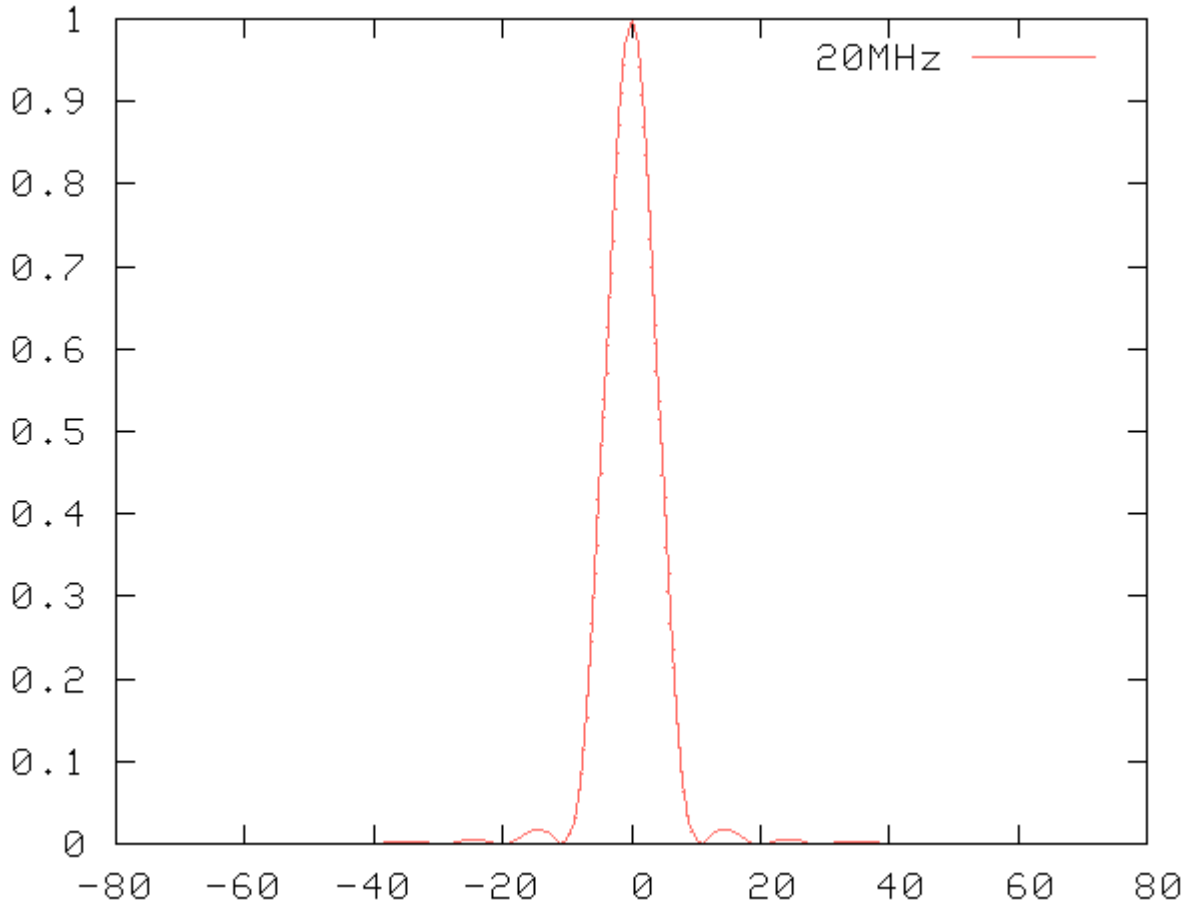

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

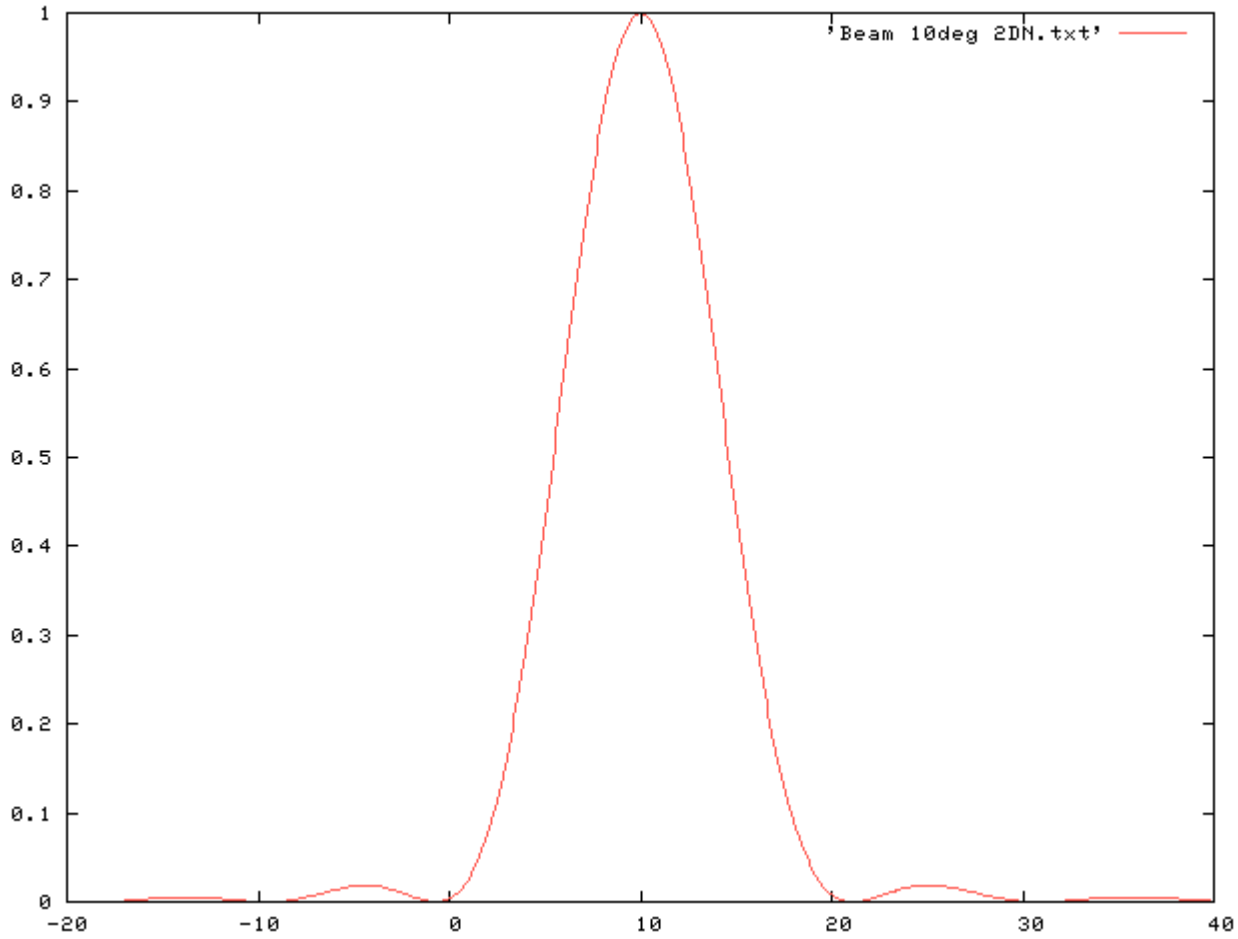

1
0.8
0.6
0.4
0.2
0
-80
-60
-40
-20
0
20
40
60
80
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

The gap between beams.

29MHz ->172 degrees
30MHz -> 115 degrees
40MHz -> 86 degrees
50MHz -> 69 degrees
60MHz -> 57 degrees
70MHz -> 49 degrees
80MHz -> 43 degrees

20MHz Station Beam

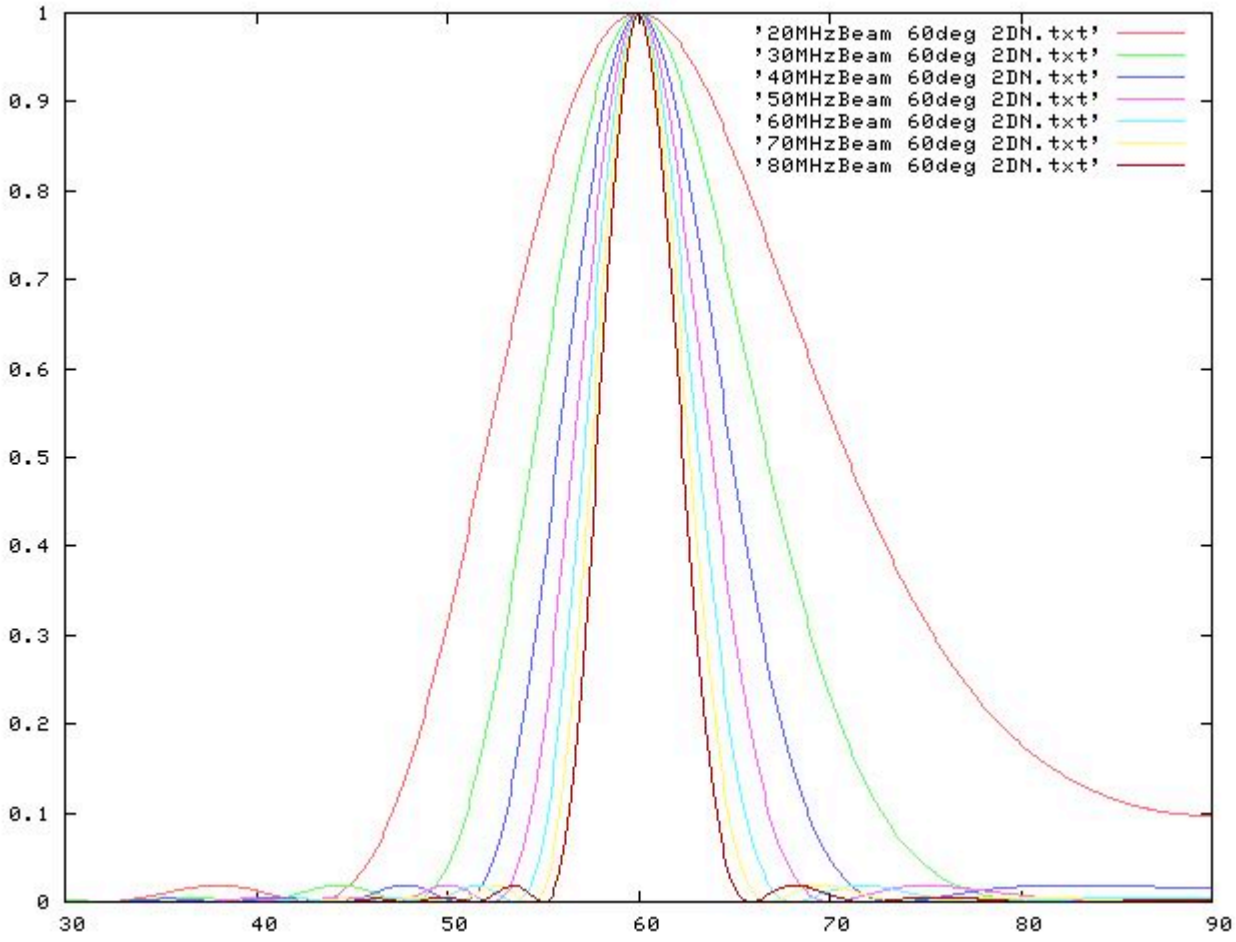



'Beam 10deg 2DN.txt'
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-20
-10
0
10
20
30
40

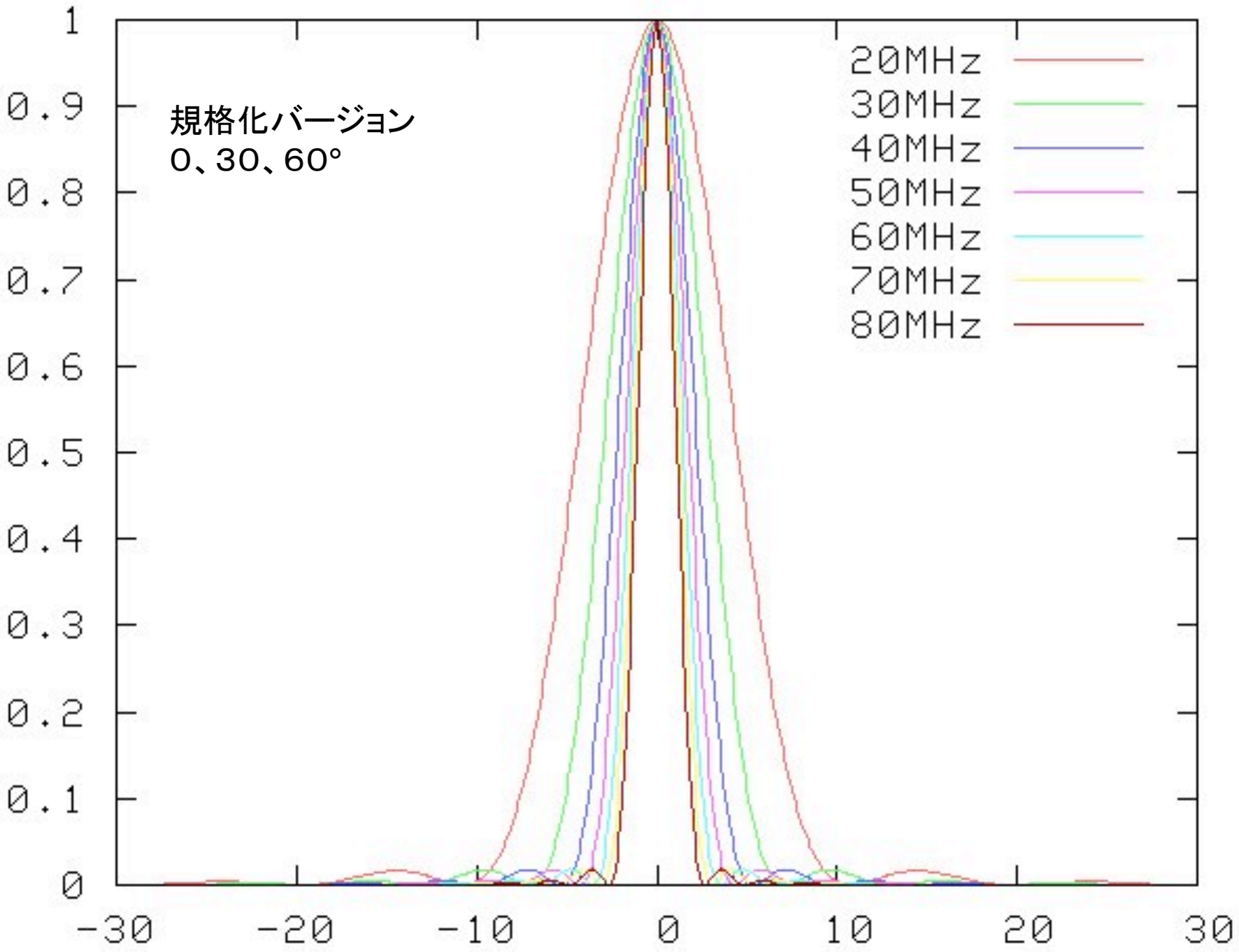
3D one station beam figure
20MHz 0deg 20deg 40deg 60deg

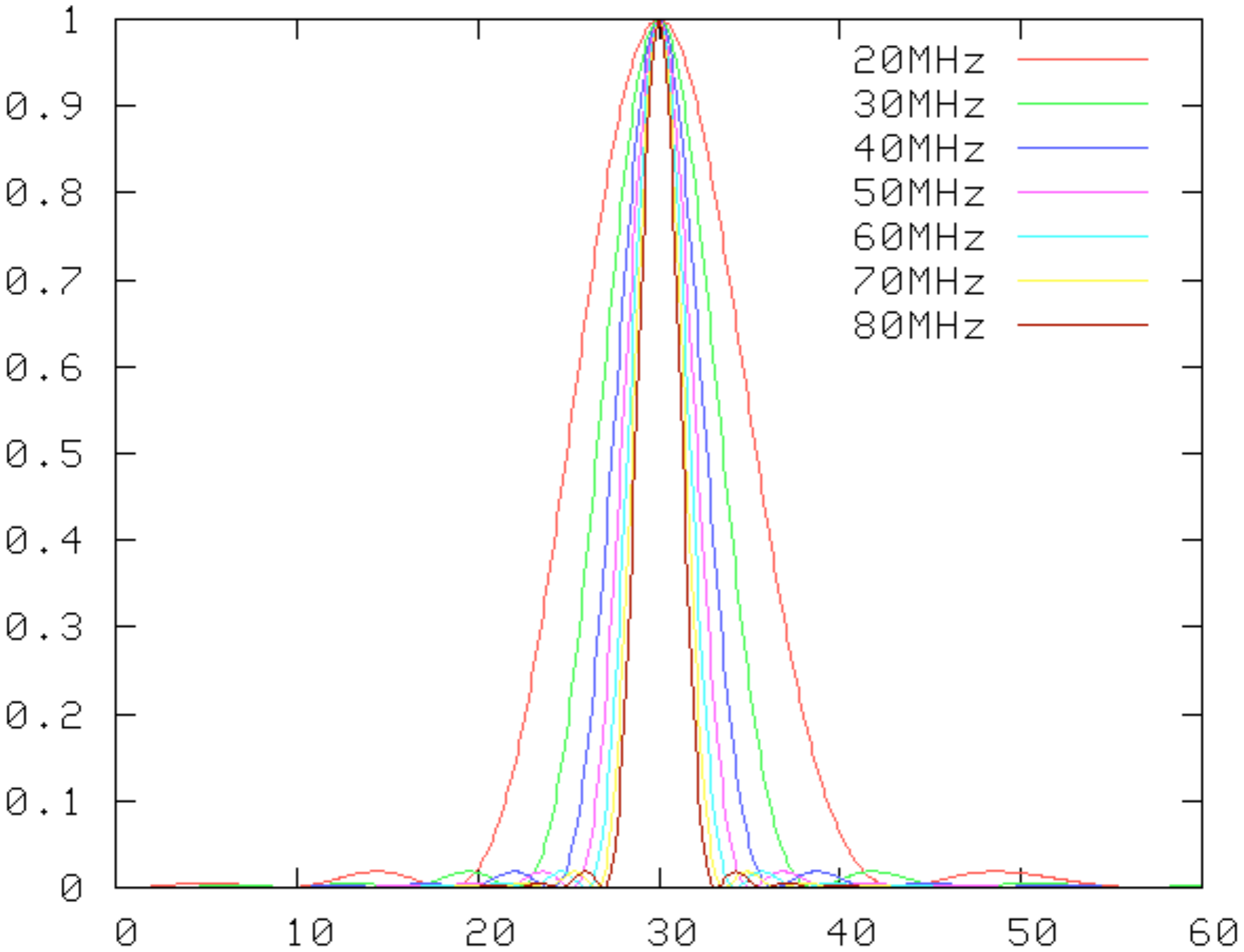
HPBW

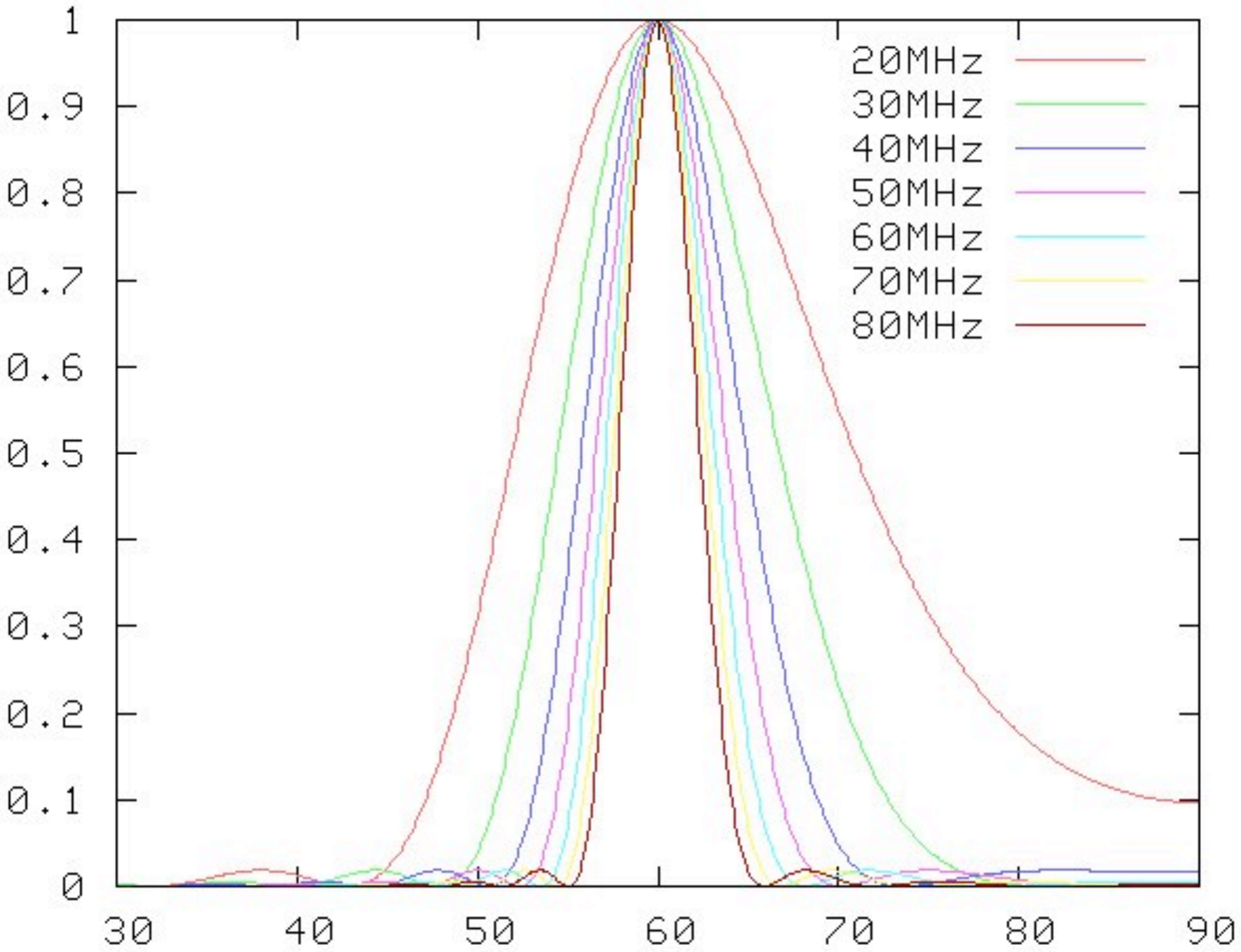
∝ P

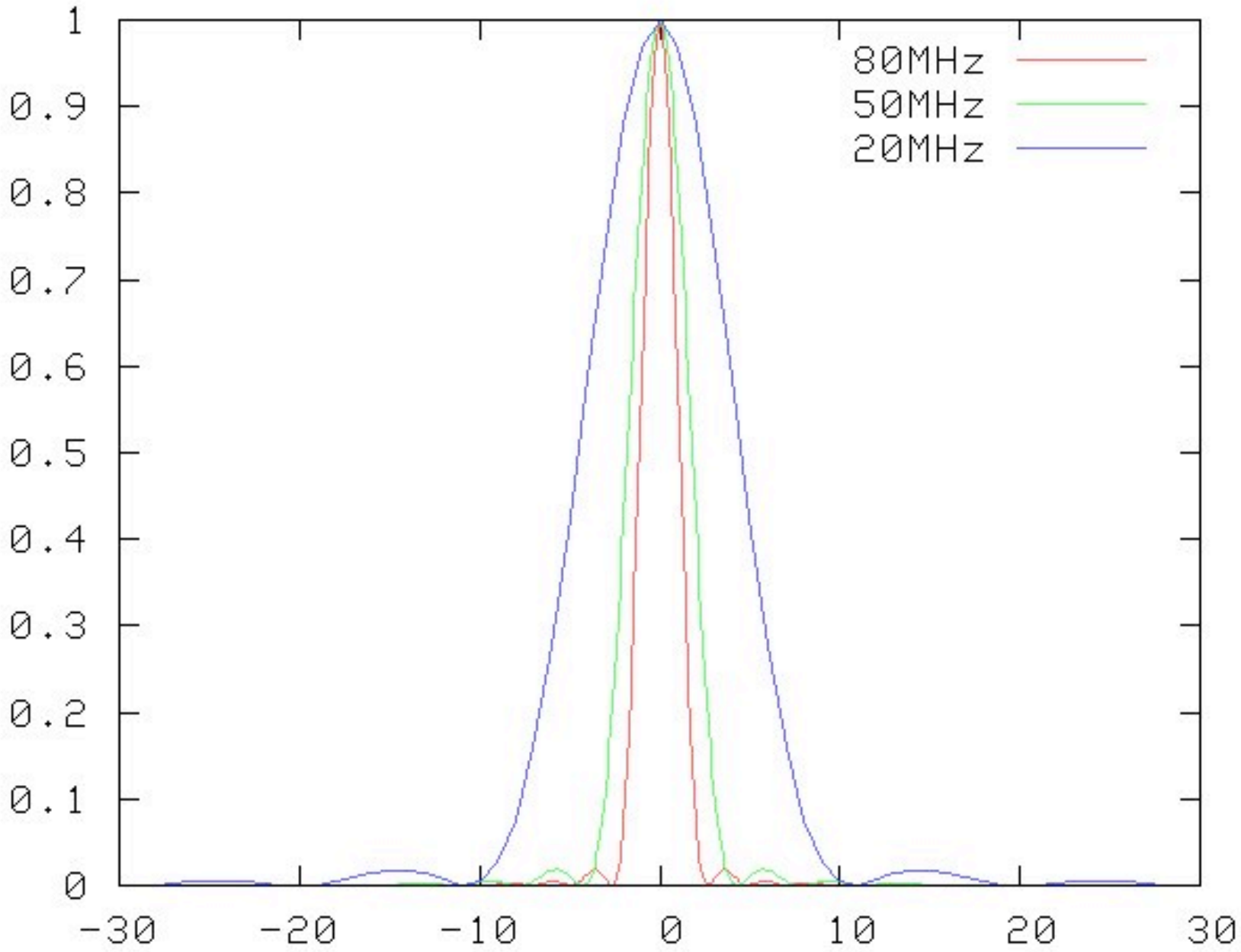

'20MHzBeam 60deg 2DN.txt'
'30MHzBeam 60deg 2DN.txt'
'40MHzBeam 60deg 2DN.txt'
'50MHzBeam 60deg 2DN.txt'
'60MHzBeam 60deg 2DN.txt'
'70MHzBeam 60deg 2DN.txt'
'80MHzBeam 60deg 2DN.txt'
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90

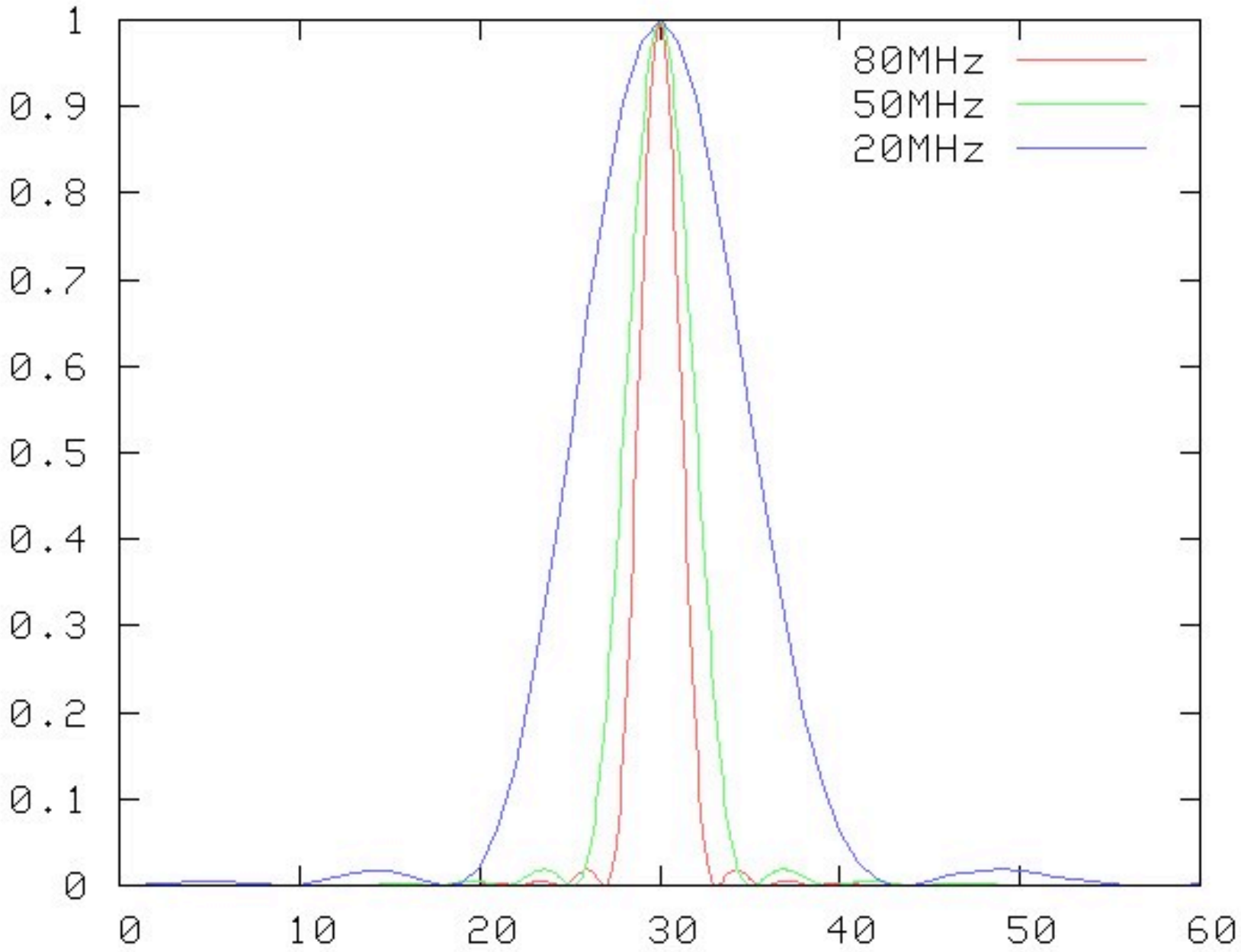
θ

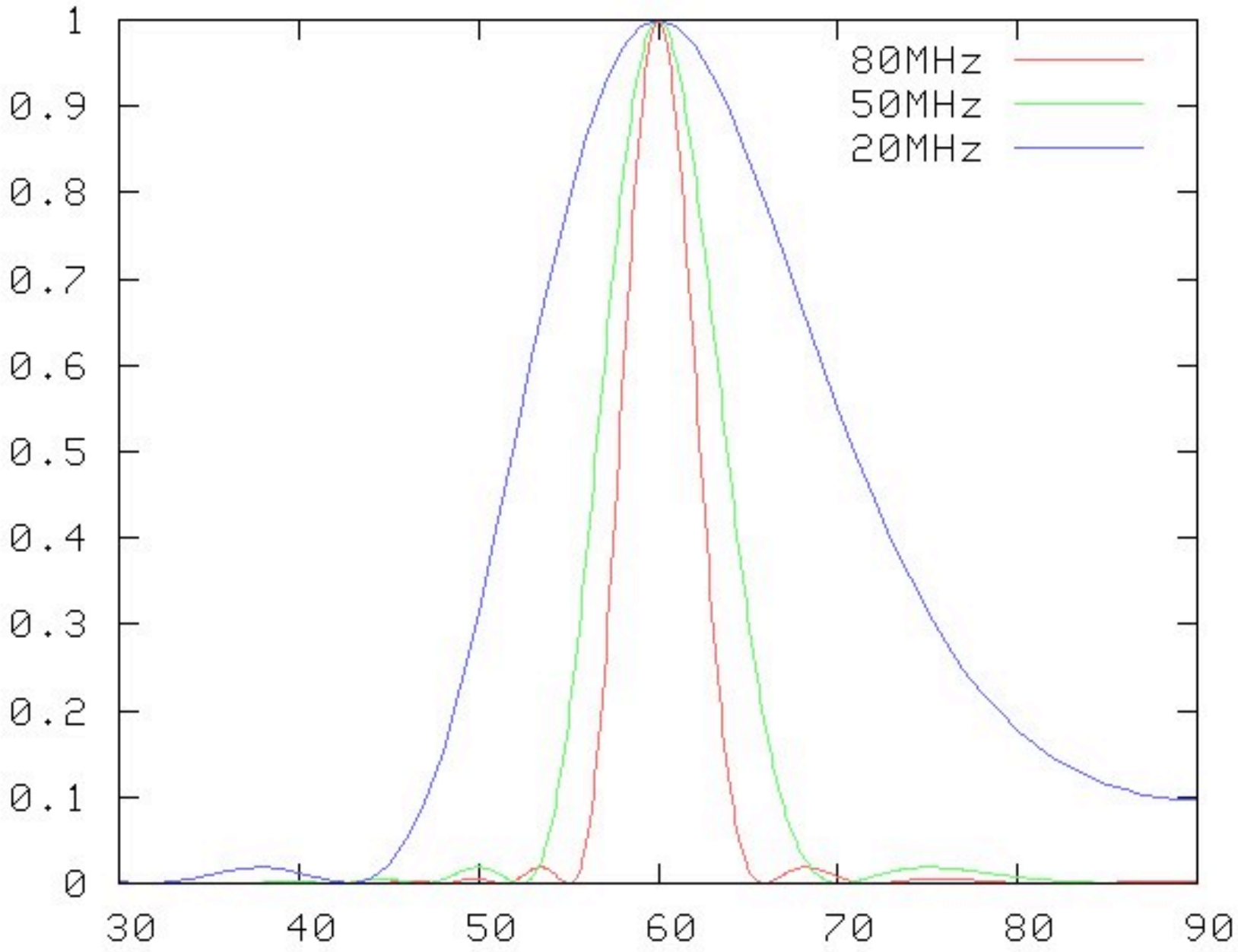

規格化バージョン
0、30、60°
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-30
-20
-10
0
10
20
30

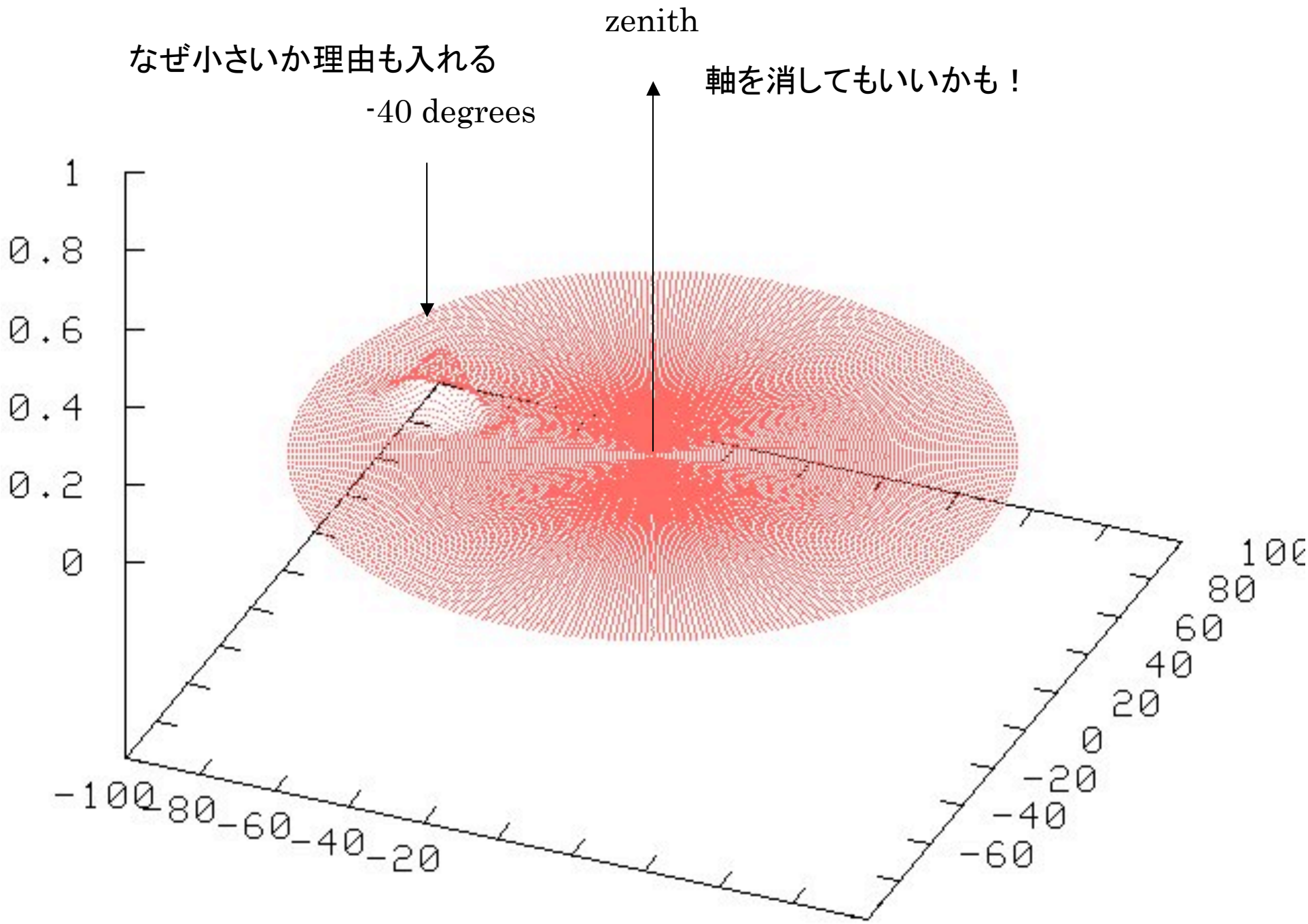

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

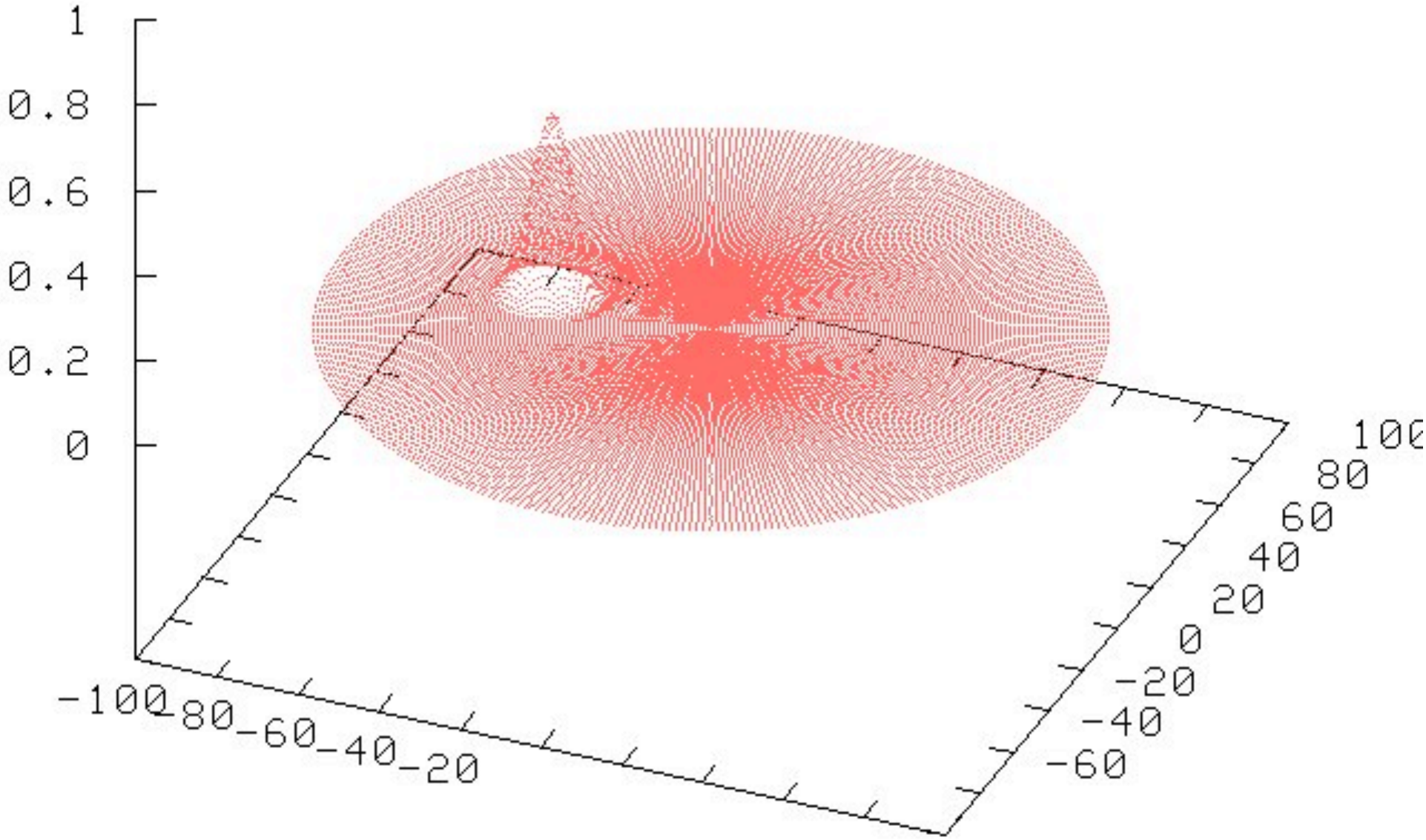

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90
20MHz
30MHz
40MHz
50MHz
60MHz
70MHz
80MHz

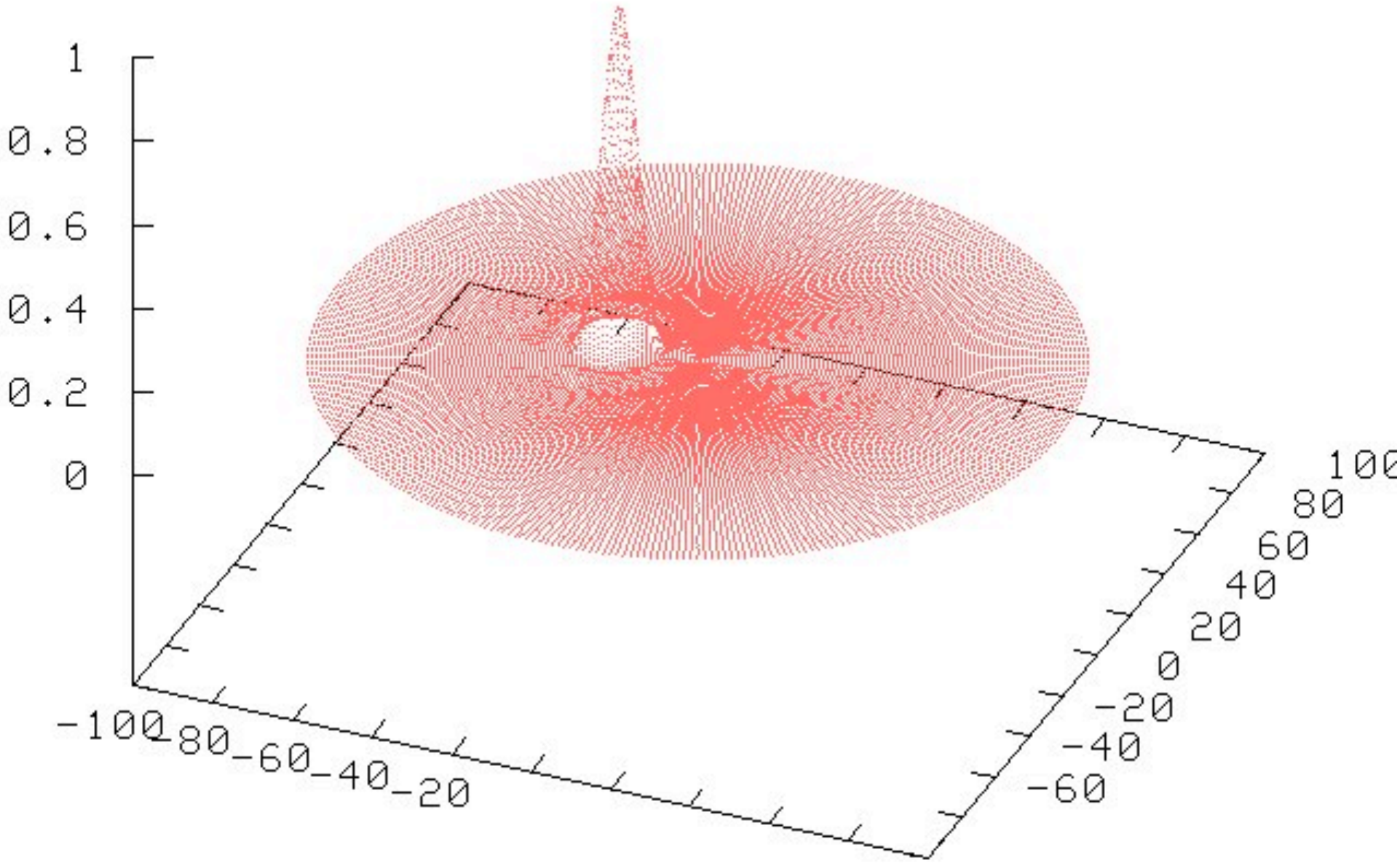

80MHz
50MHz
20MHz
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-30
-20
-10
0
10
20
30

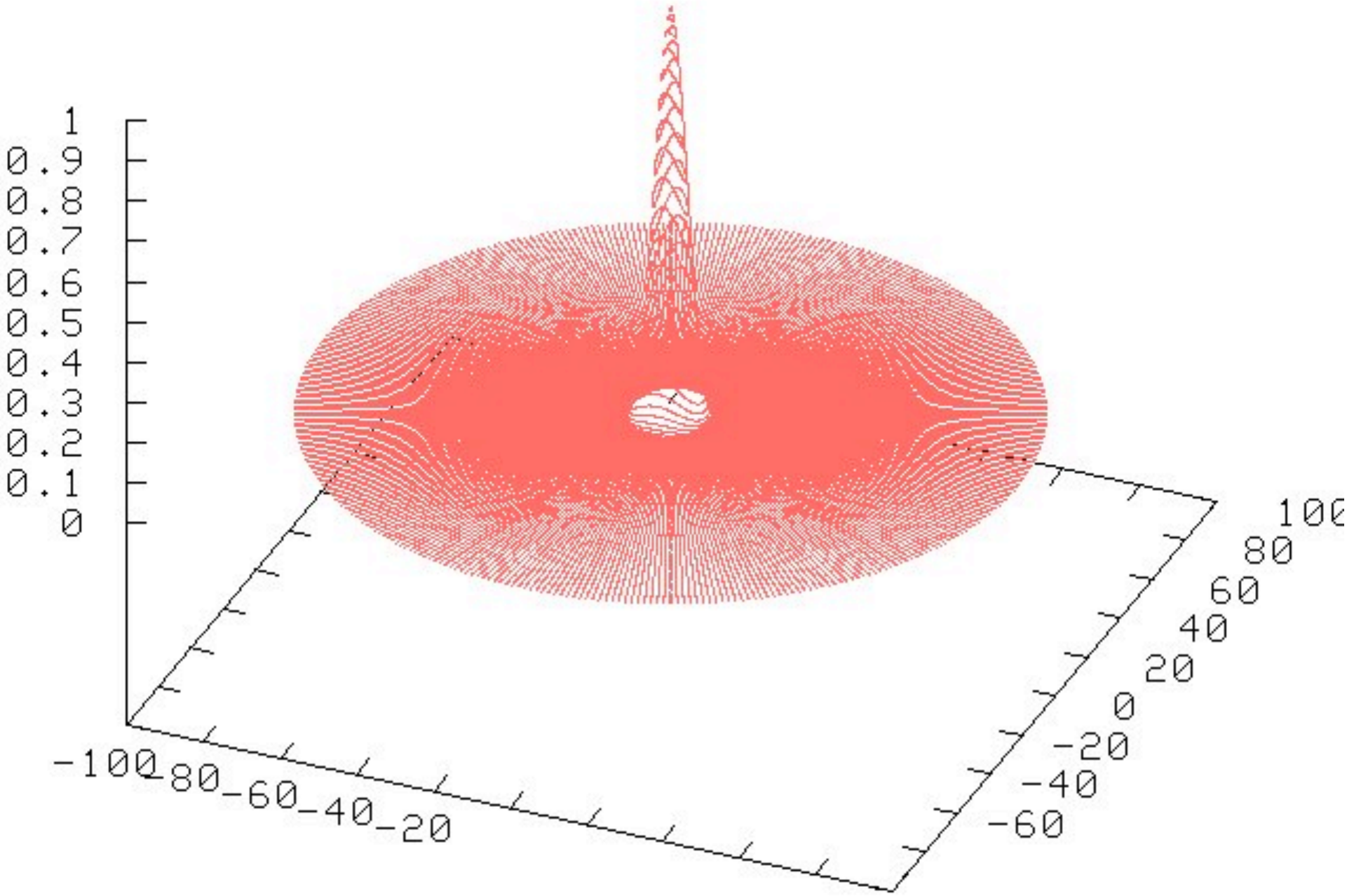

80MHz
50MHz
20MHz
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60

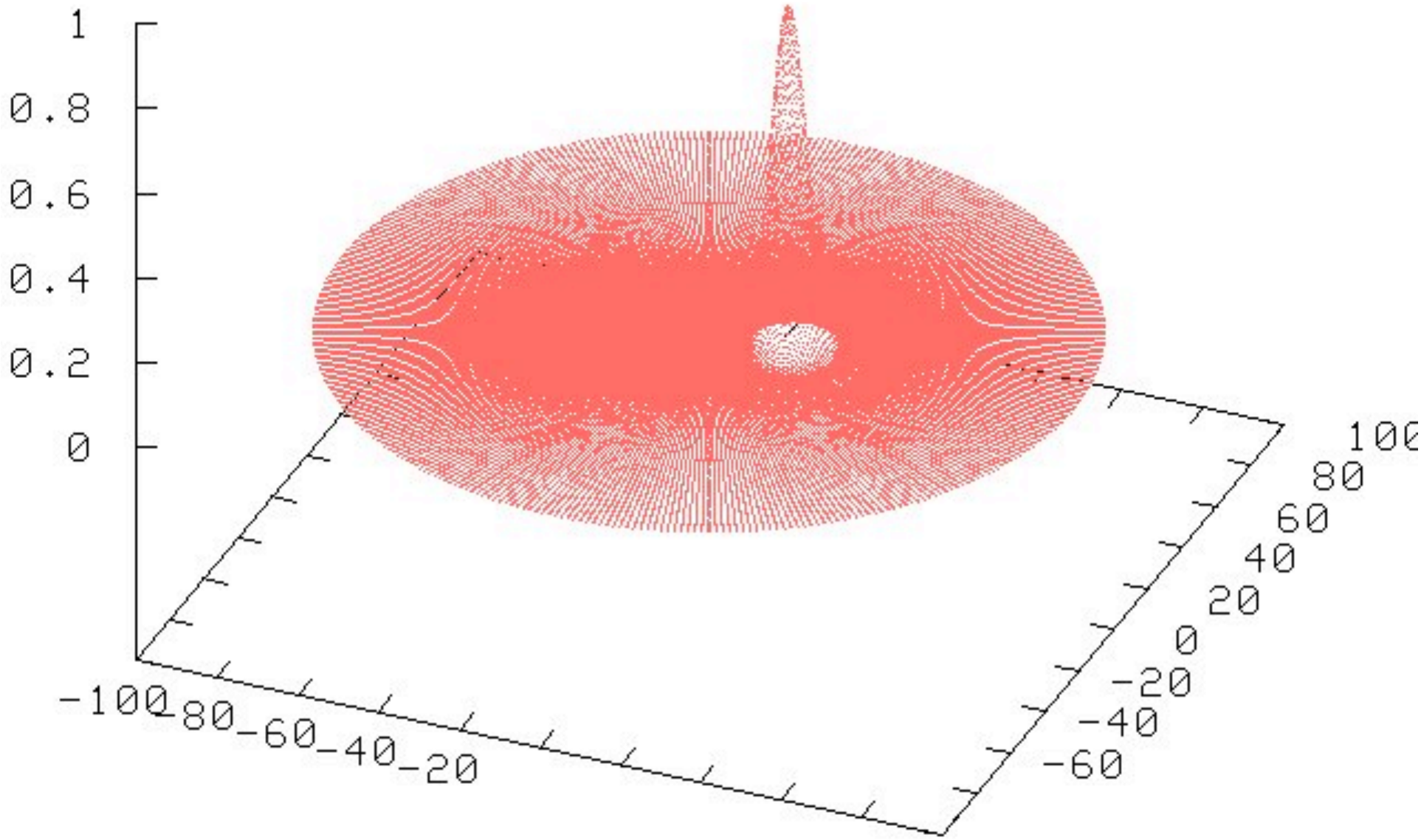

80MHz
50MHz
20MHz
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
40
50
60
70
80
90

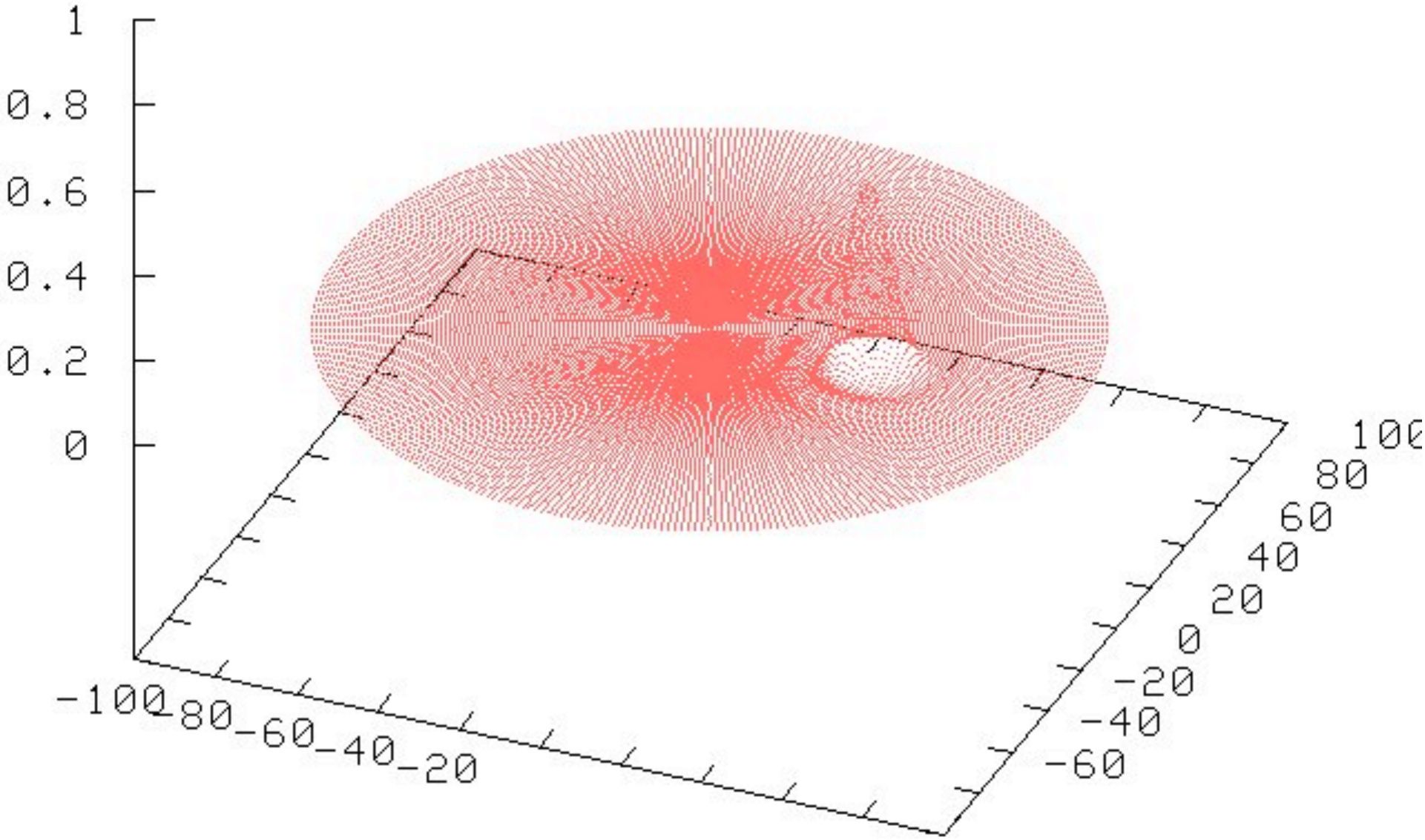

zenith
なぜ小さいか理由も入れる
軸を消してもいいかも！
-40 degrees
1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100

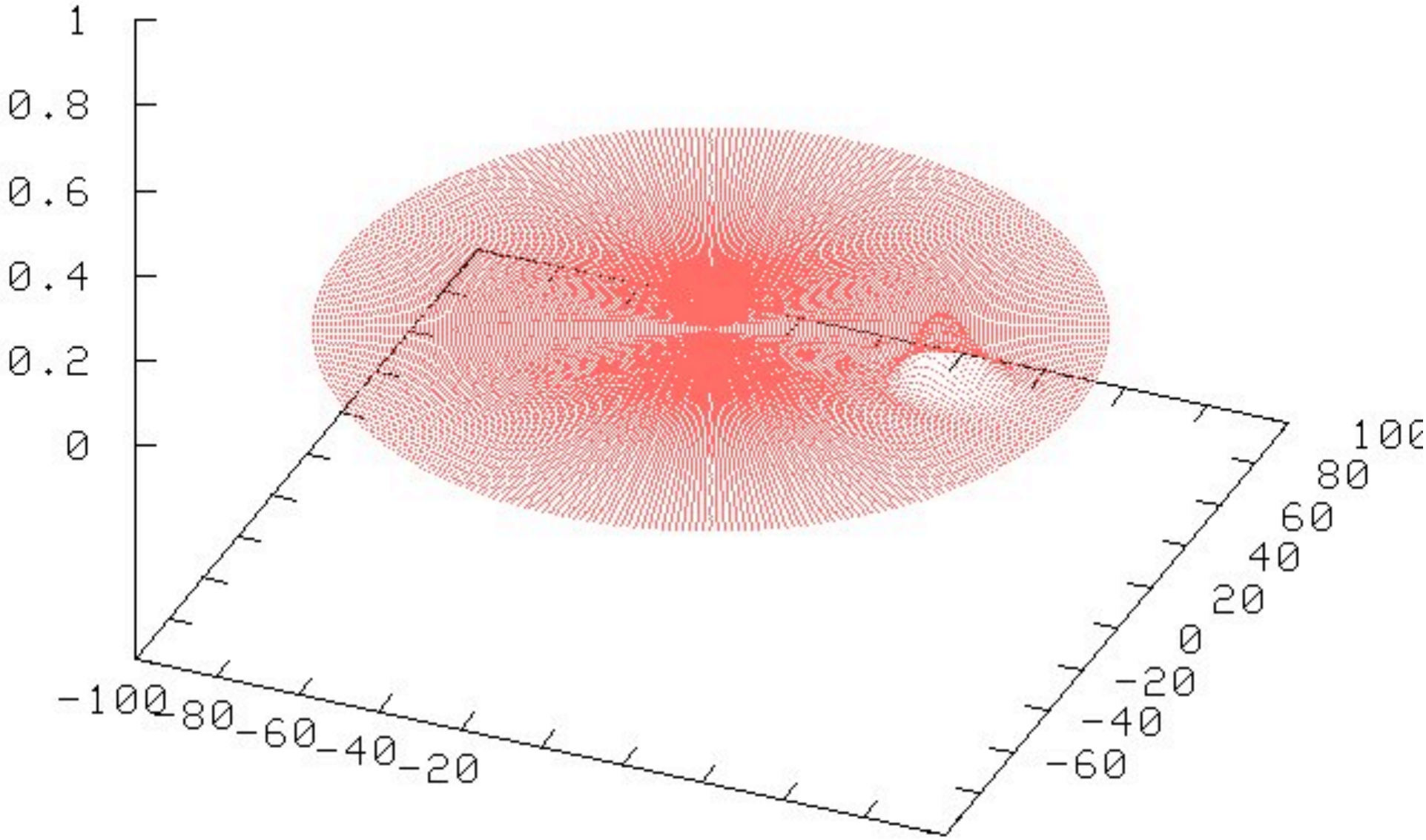

1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0

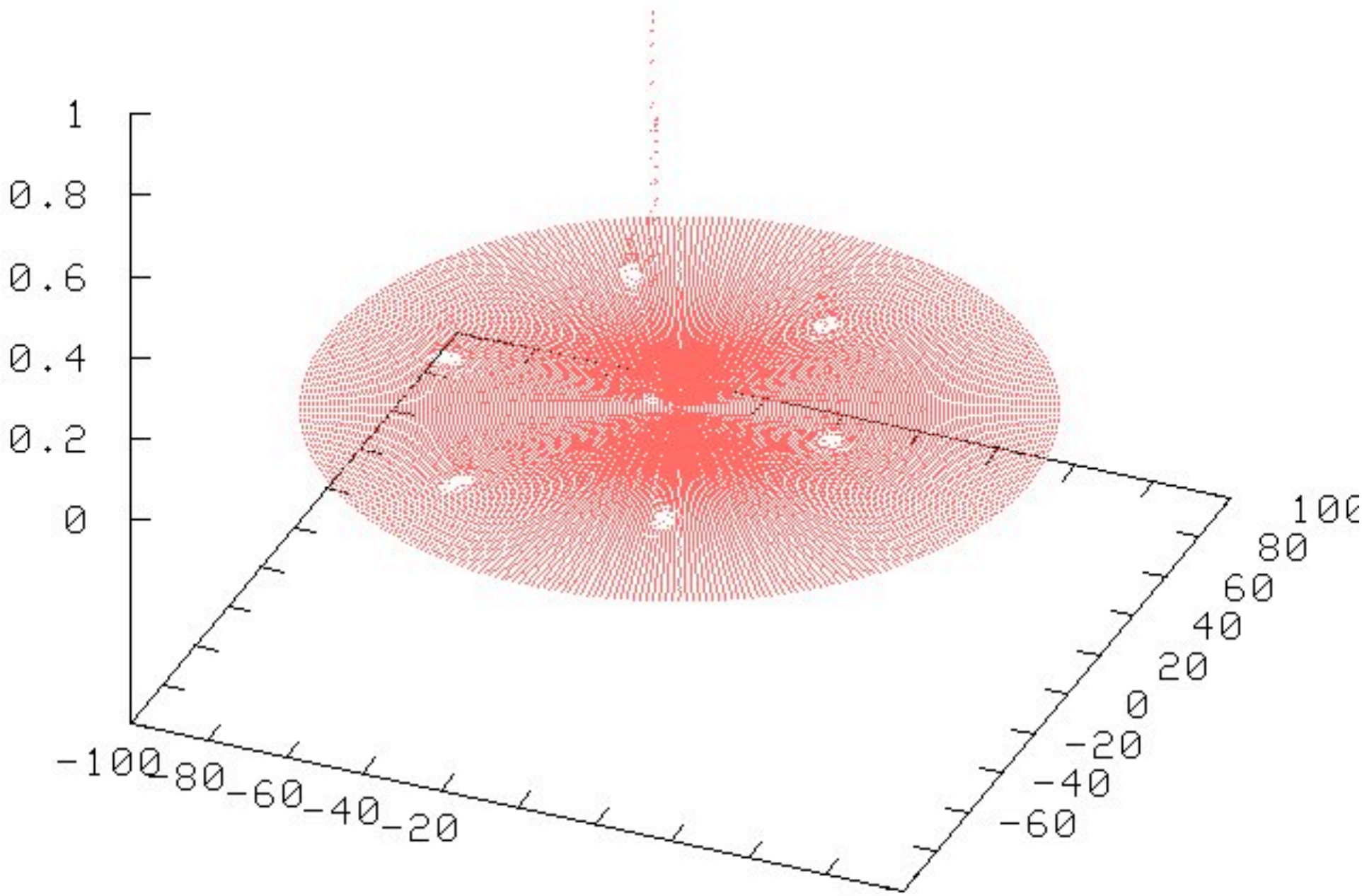

1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0

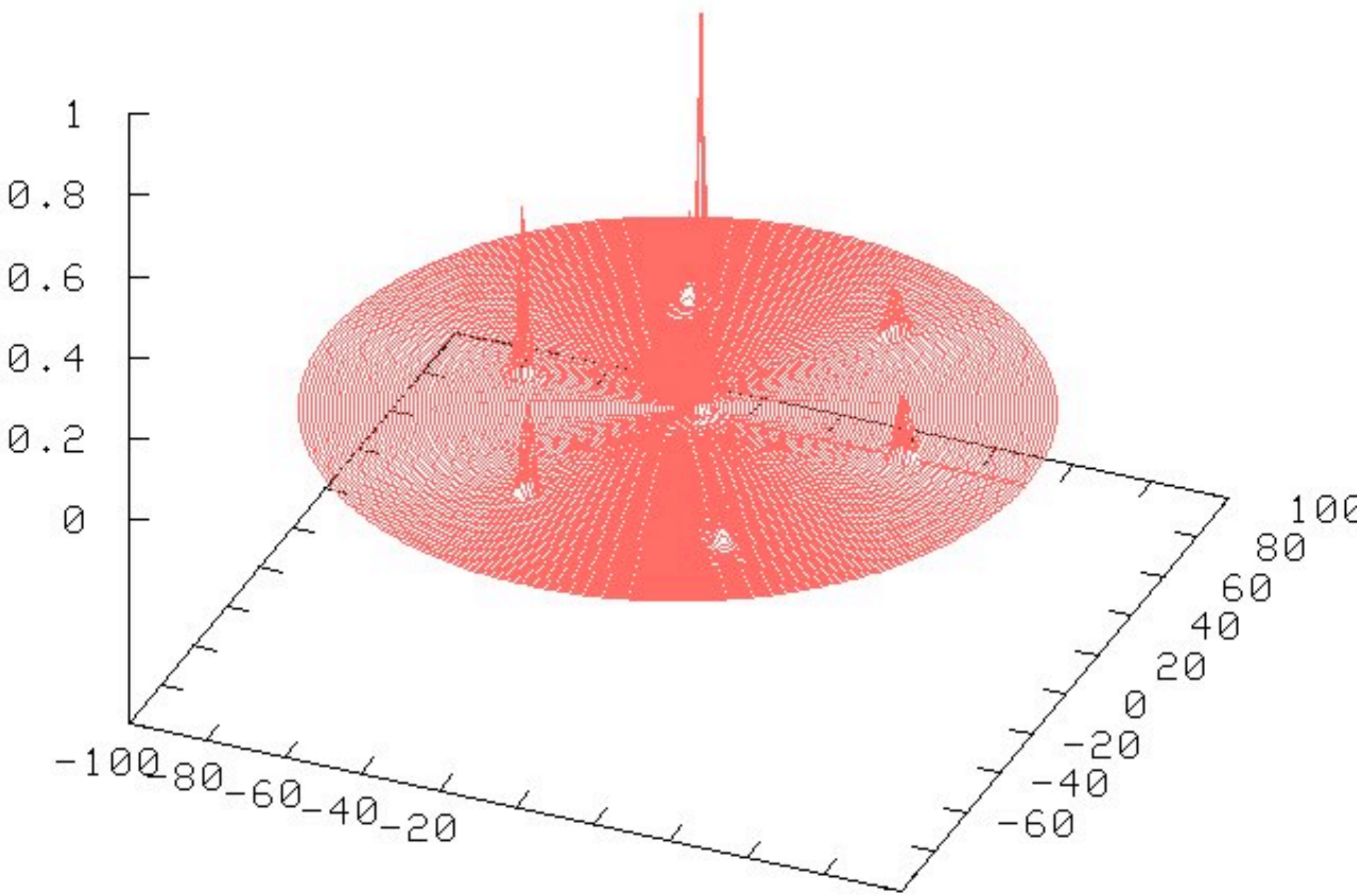

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-100
-80
-60
-40
-20
0
-20
-40
-60
80
60
40
20
0

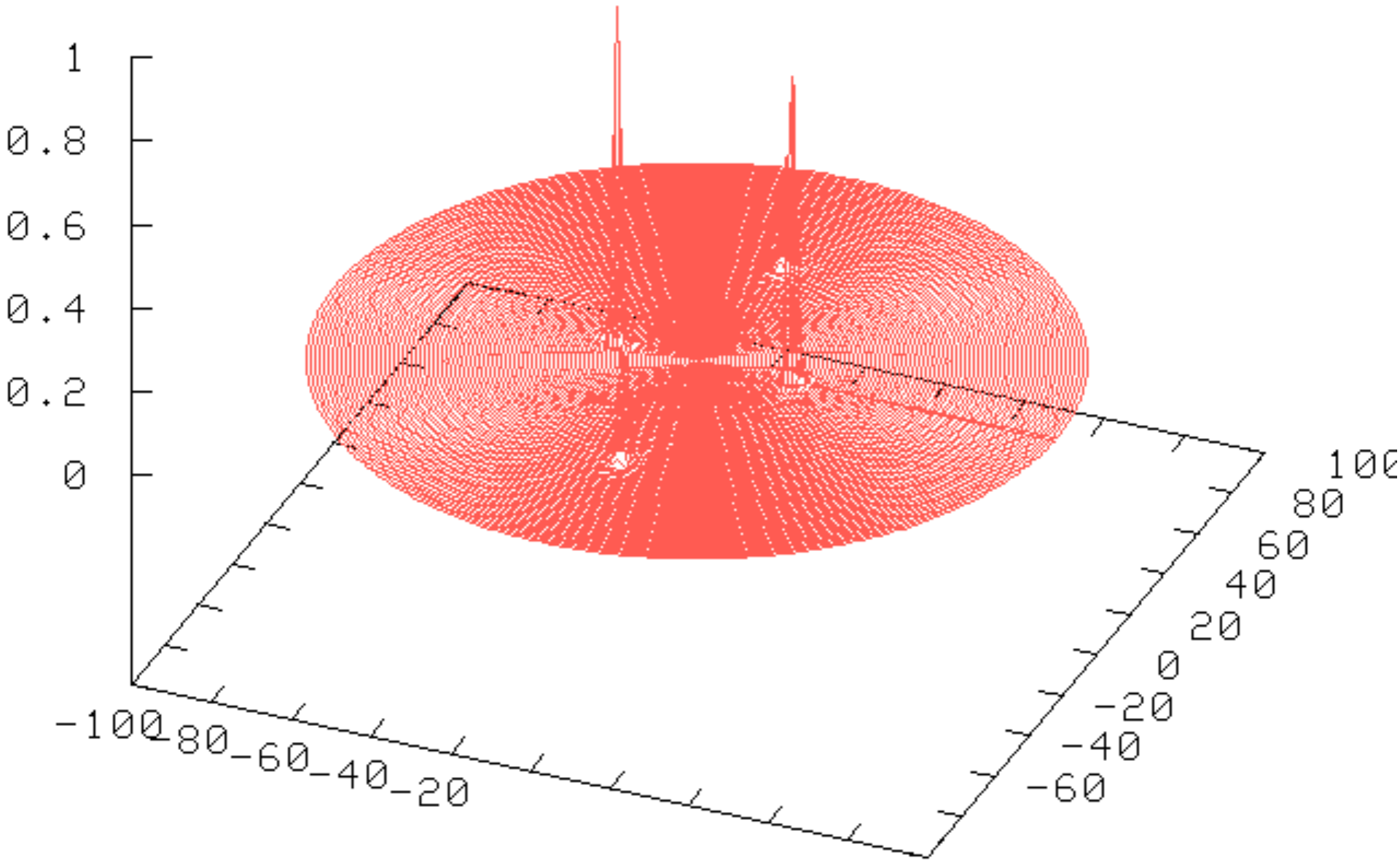

1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0


1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0


1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0


1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0


1
0.8
0.6
0.4
0.2
0
-100
-80
-60
-40
-20
0
20
40
60
80
100
-60
-40
-20
0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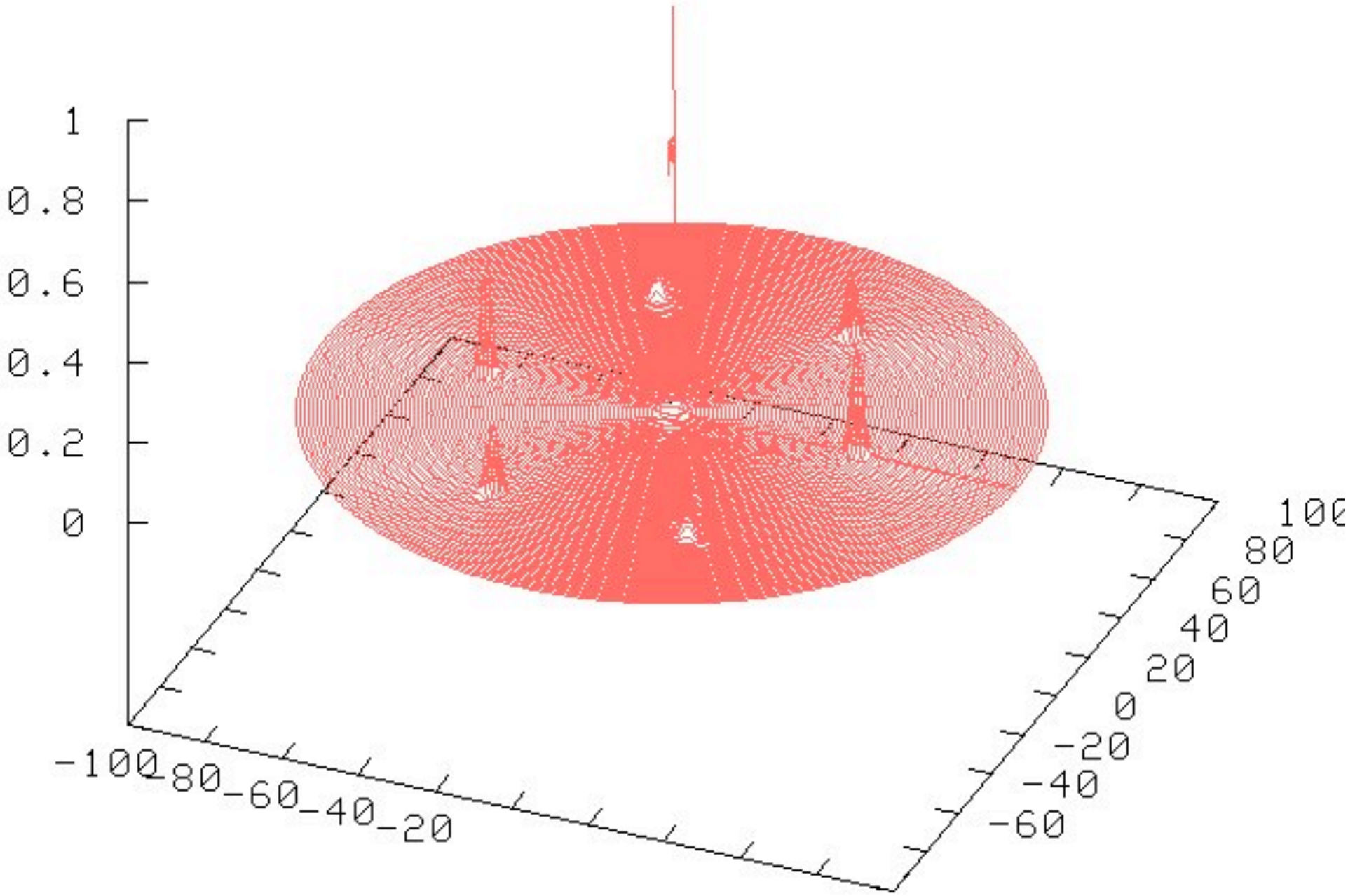
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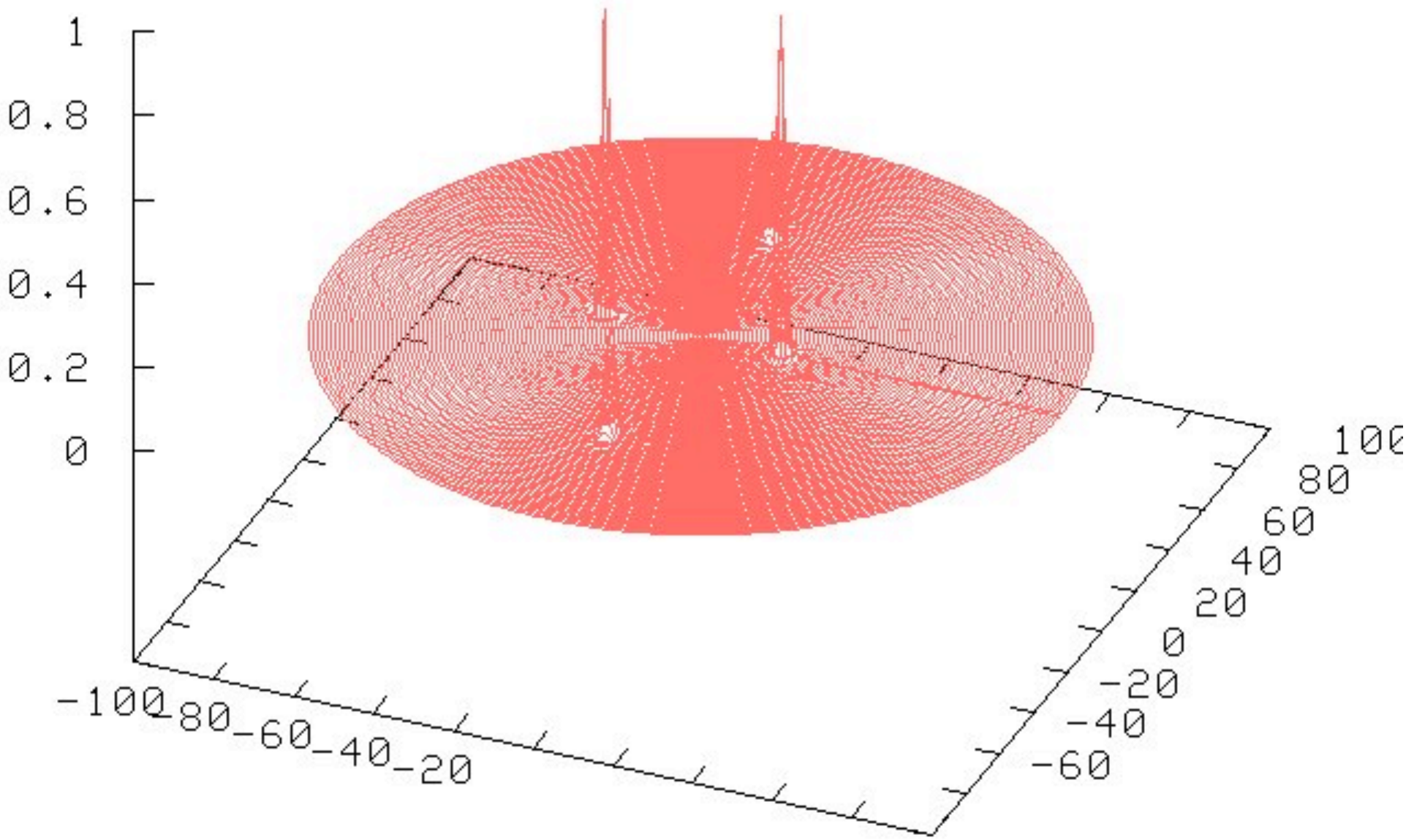
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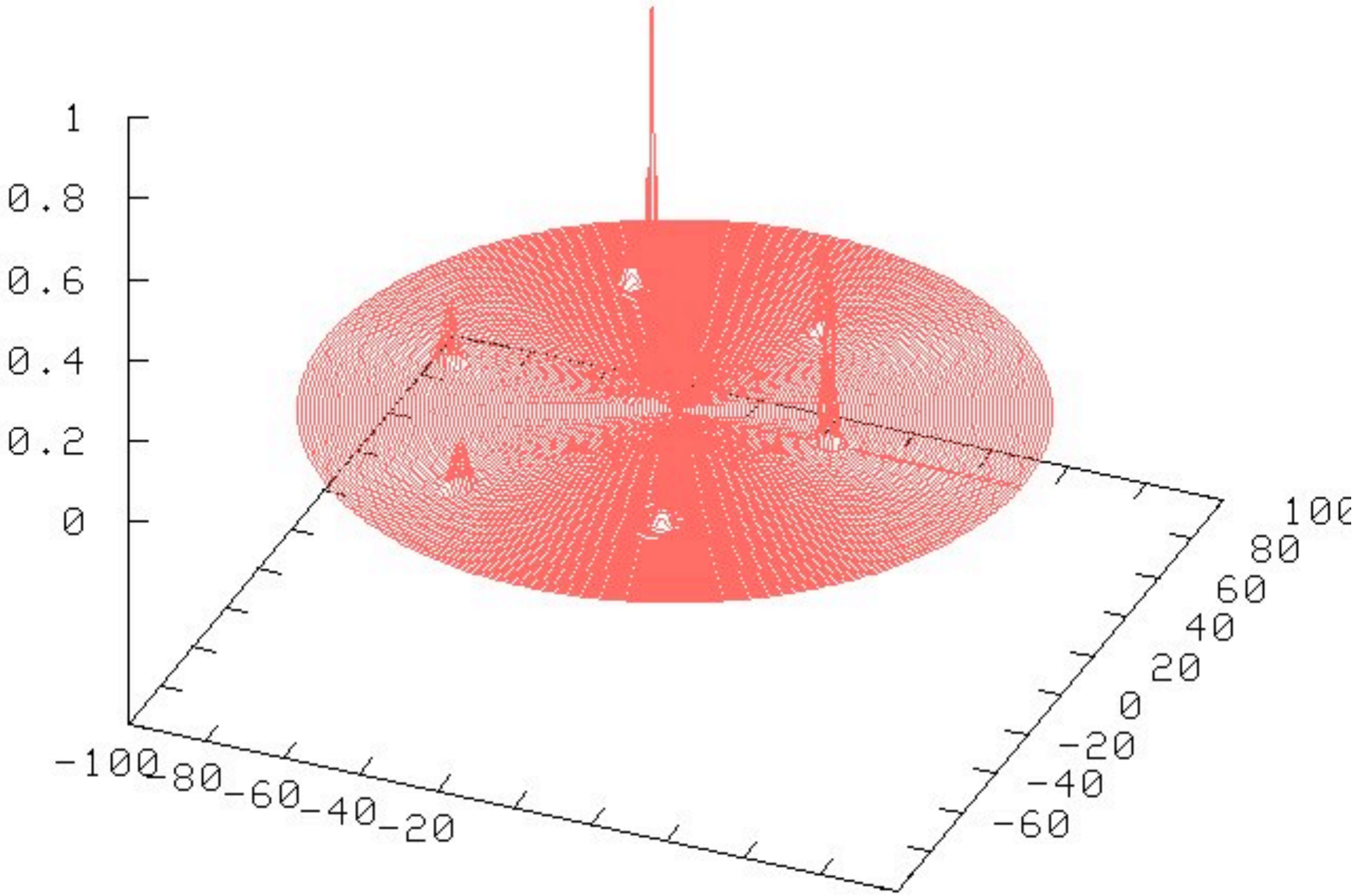
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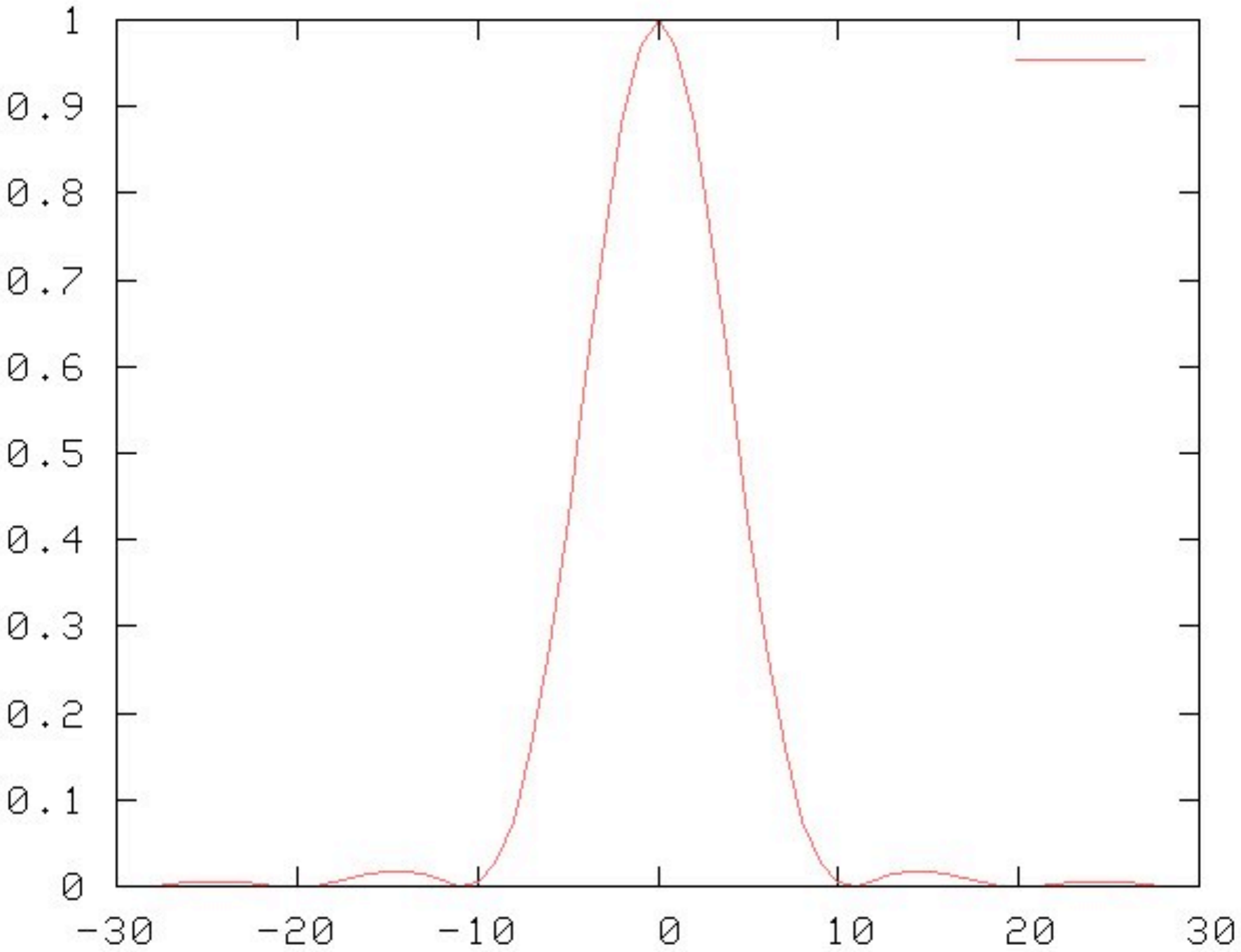
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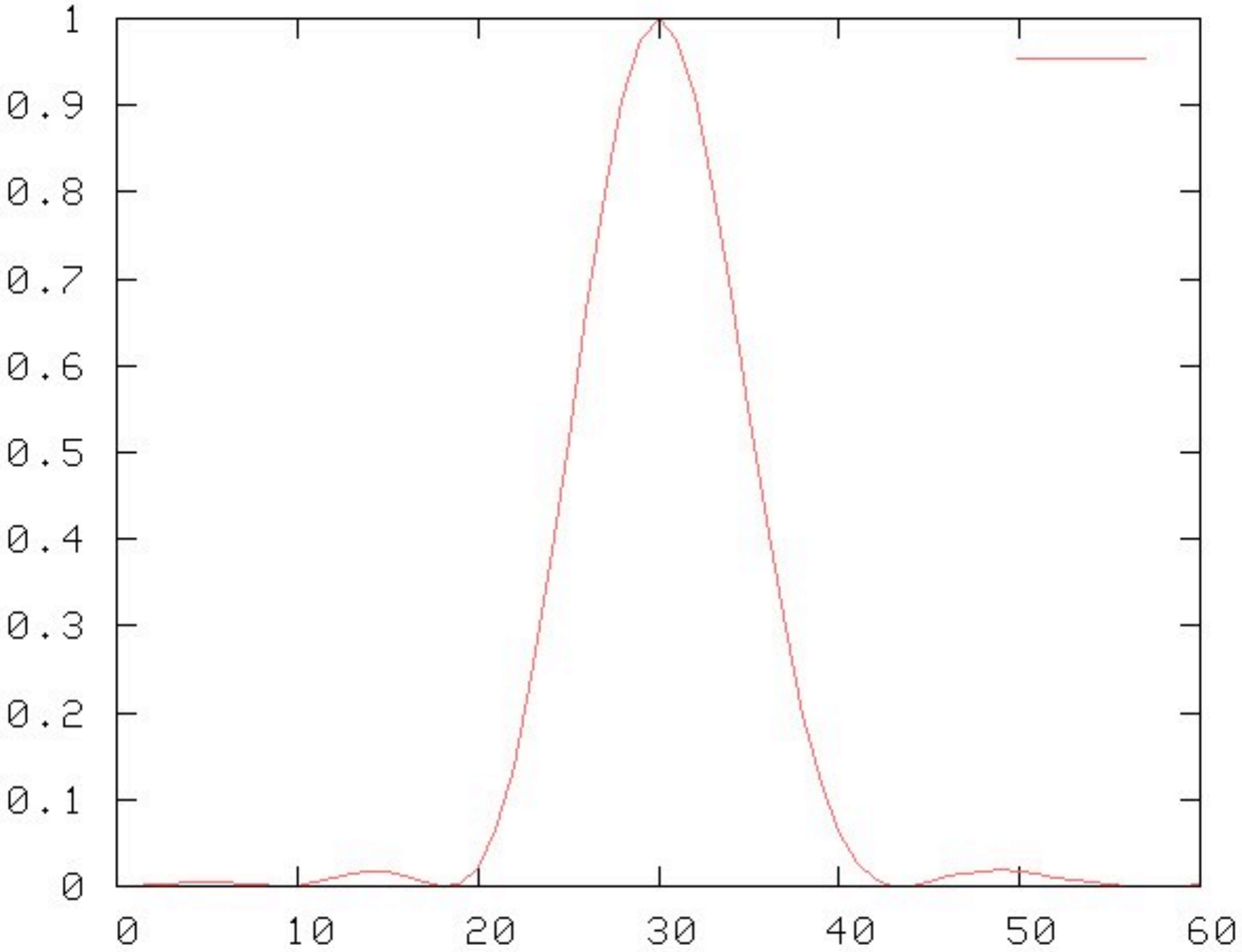
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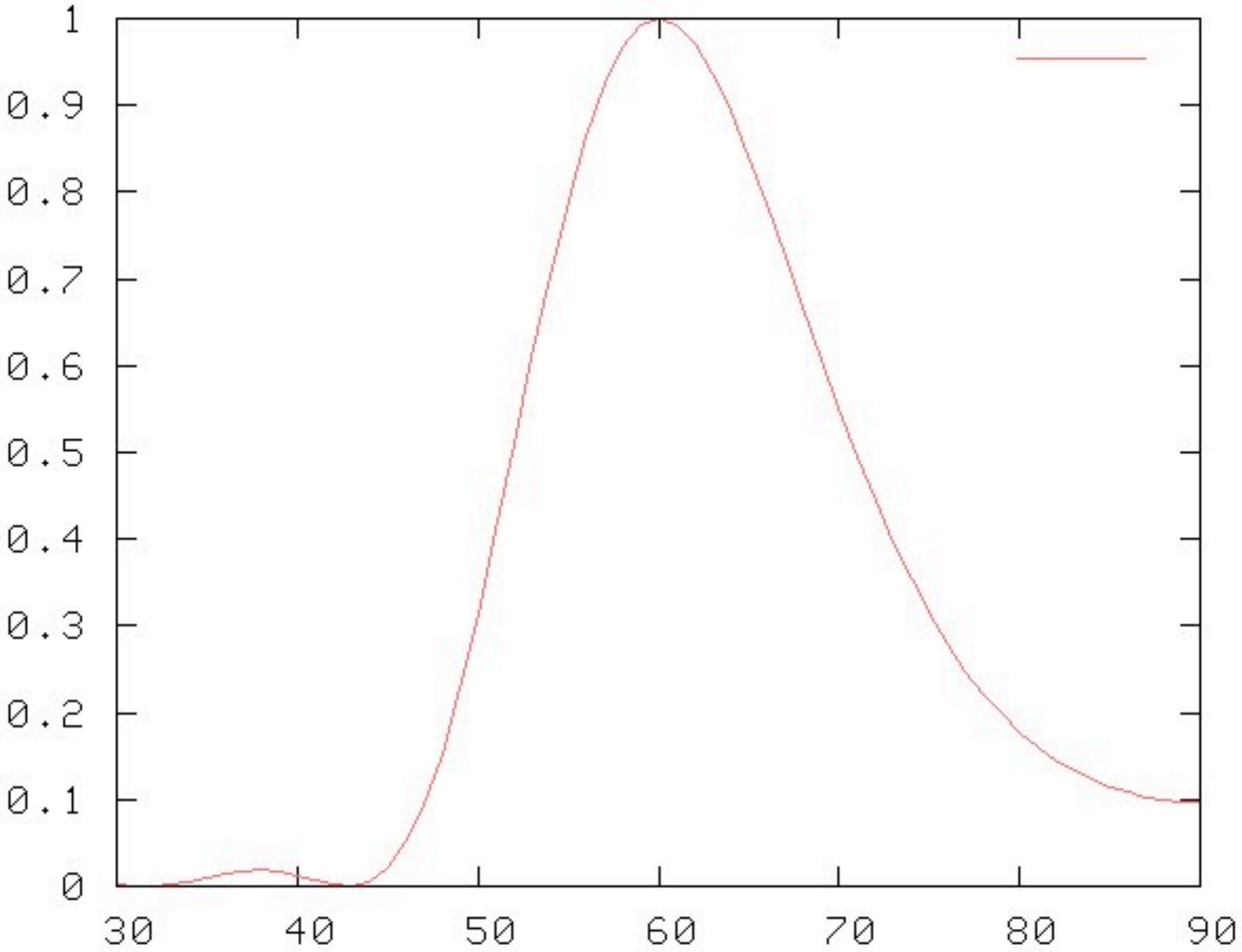
50
60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40
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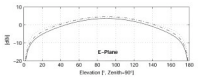
70
80
90

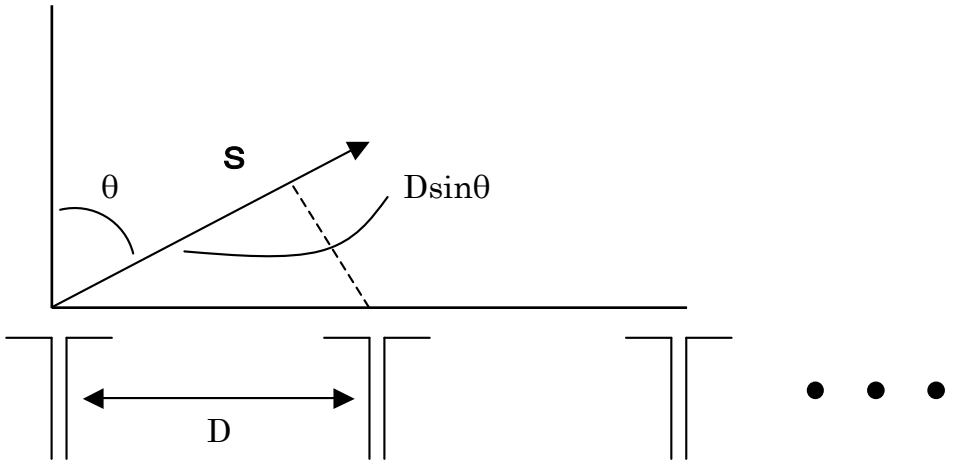
We need a simulator because there is no LWA station.
If you get the simulator, you could find some problems in LWA before the construction.

ここにkumarからもらったシミュレーションソフトを
改造してLWA100mバージョンにした
最終的な（クリーン後）を入れる

最終的にこのようなソフトを作りたい
しかし、これは1ステーションを100mと
考えた時の、実際のステーションの位置
を入れたデータである。

実際に256ダイポールからなるステーションビーム
でシミュレーションソフトを作成することが目的。


E-Plane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