ECC 203 : Electromagnetics and Radiating Systems

Antenna Array 3 : Uniform N Element Planar Array

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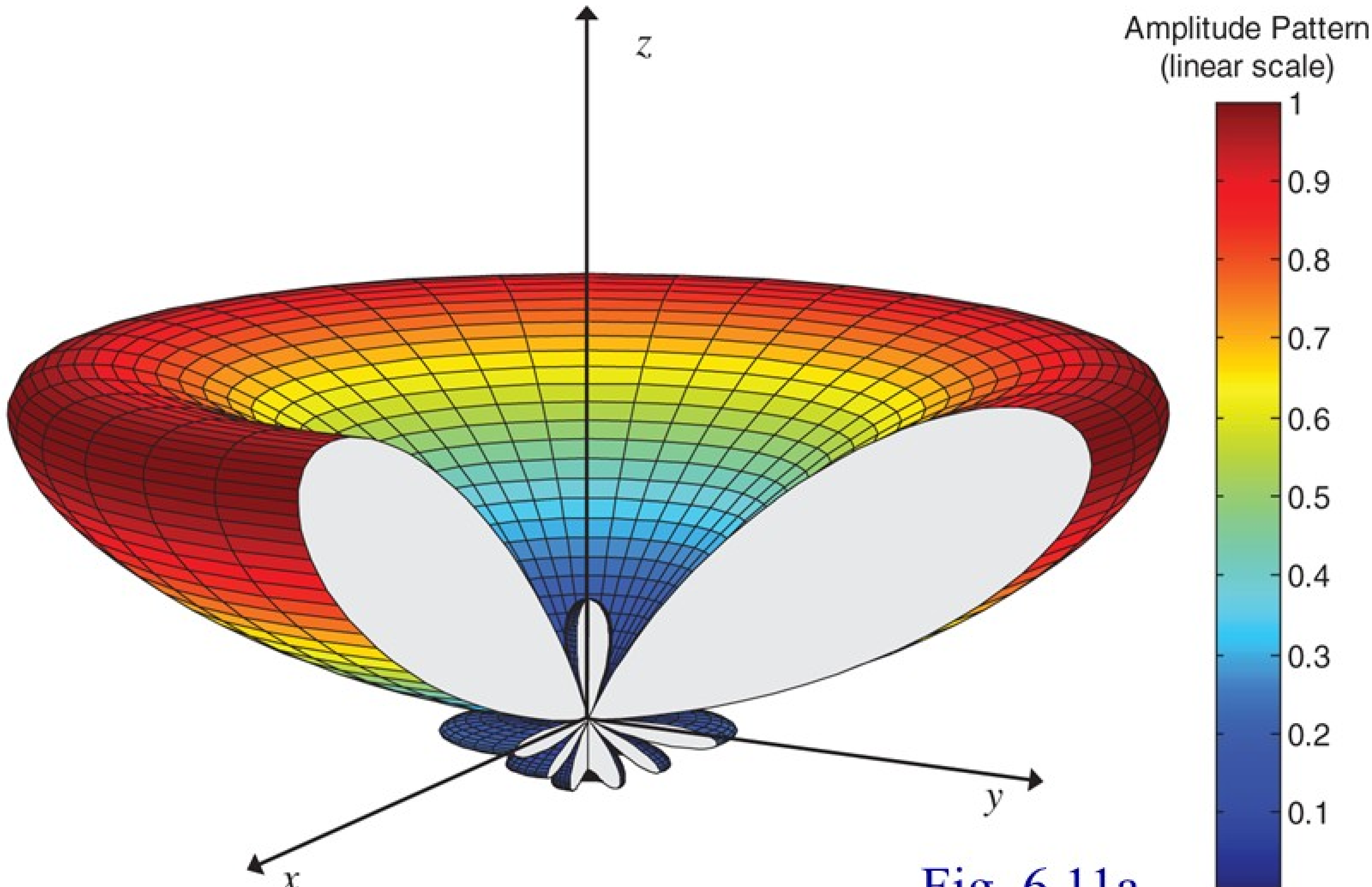
Three-Dimensional



(a) Three-dimensional

Fig. 6.11a

Planar Arrays

1. Linear arrays (one-dimensional) can scan the beam only in one plane.

2. To scan the beam in any direction, two-dimensional array geometries are needed, such as elements placed along a circle and planar, cubical, cylindrical, spherical, etc., surfaces.

AWACS Array

Airborne Warning and Control System (AWACS)

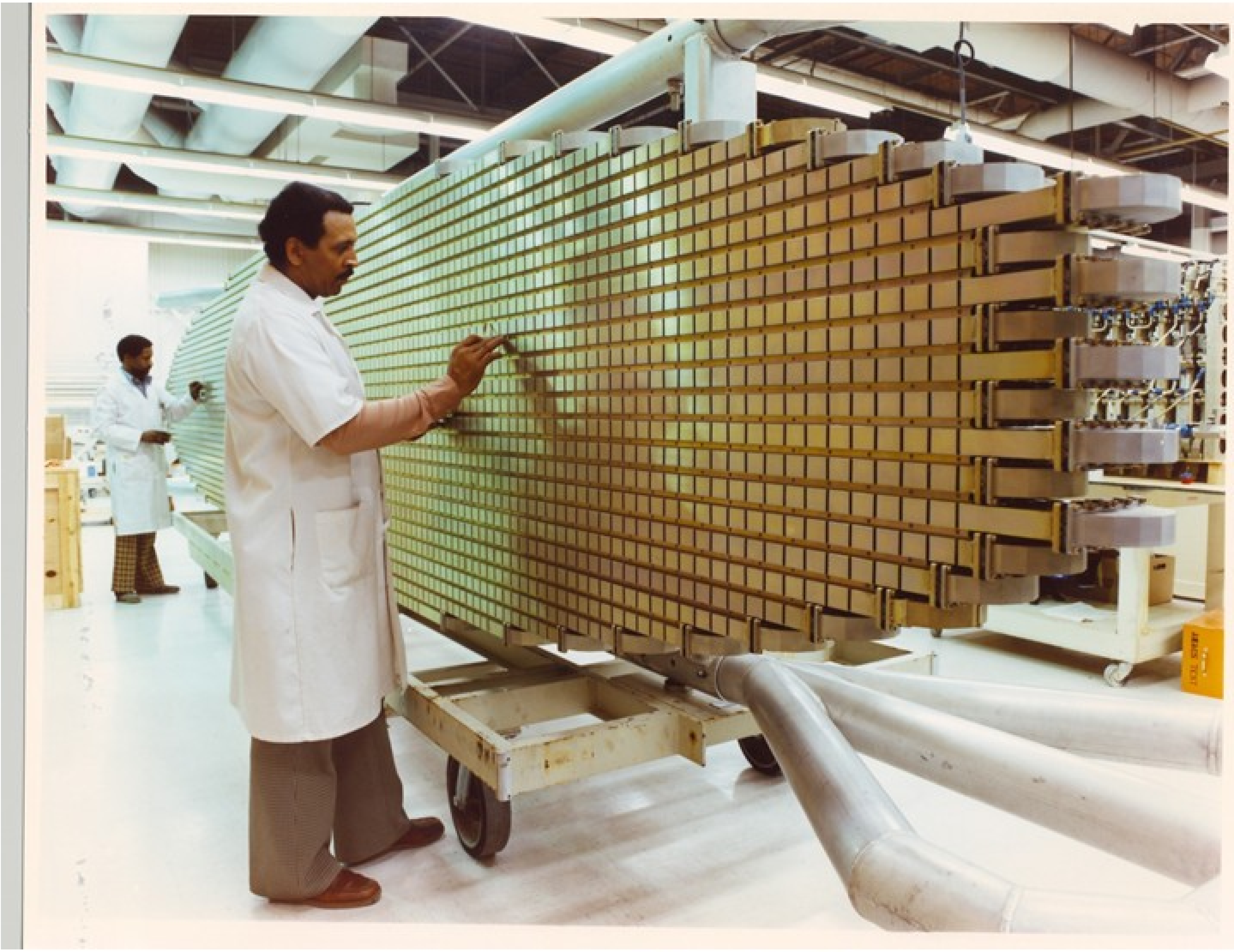
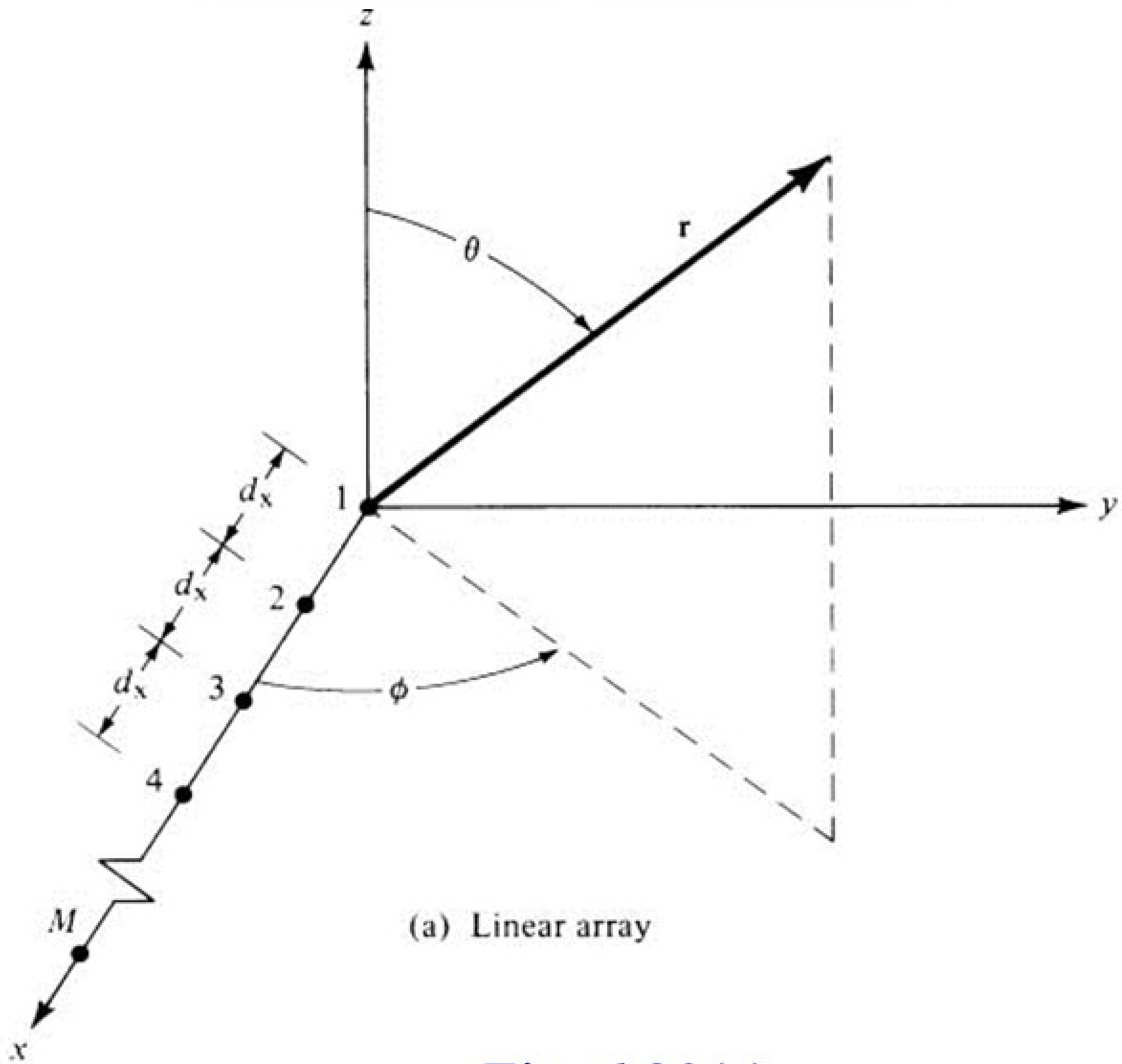


Fig. 6.29

Linear Array Geometry



(a) Linear array

Fig. 6.30(a)

Rectangular Planar Array Geometry

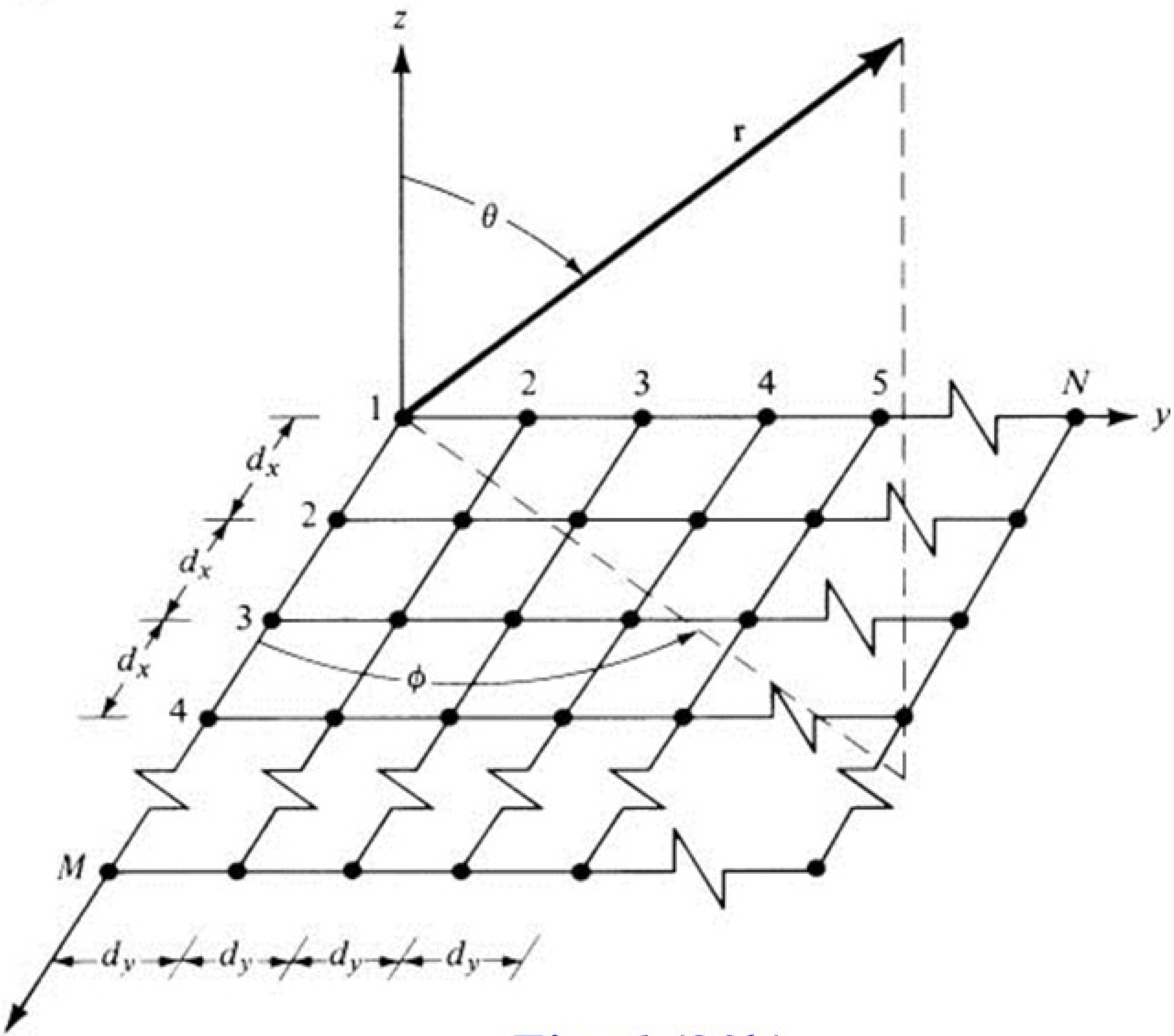


Fig. 6.(30b)

Normalized Array Factor

$$|\mathrm{AF}|_n = \begin{cases} \dfrac{1}{N}\left|\displaystyle\sum_{n=1}^{N} e^{j(n-1)\psi}\right| \\[2ex] \dfrac{1}{N}\left|\dfrac{\sin\left(\dfrac{N}{2}\psi\right)}{\sin\left(\dfrac{\psi}{2}\right)}\right| \overbrace{\approx}^{\psi\to 0} \left|\dfrac{\sin\left(\dfrac{N}{2}\psi\right)}{\left(\dfrac{N}{2}\psi\right)}\right| \end{cases}$$

$$\psi = kd\cos\theta + \beta$$

Axis: $\psi = kd\cos\gamma + \beta$ (6-52a)

z: $\psi_z = kd_z \cos\theta + \beta_z$ (6-53)

x: $\psi_x = kd_x \sin\theta\cos\phi + \beta_x$ (6-54a)

y: $\psi_y = kd_y \sin\theta\sin\phi + \beta_y$ (6-55)

Nonuniform Linear/Planar Array

Planar:

$$(AF)_{xy} = \sum_{n=1}^{N} \{(AF)_x\} \times [I_{n1} e^{j(n-1)(kd_y \sin\theta \sin\phi + \beta_y)}]$$

$$(AF)_{xy} = \sum_{n=1}^{N} \left\{ \underbrace{\sum_{m=1}^{M} \left[I_{m1} e^{j(m-1)(kd_x \sin\theta \cos\phi + \beta_x)} \right]}_{(AF)_x} \right\} \quad \text{(6-87a)}$$

$$\times \left[I_{n1} e^{j(n-1)(kd_y \sin\theta \sin\phi + \beta_y)} \right]$$

Uniform Planar Array

$$\text{If} \quad I_{mn} = I_{m1} I_{1n} = I_0 = \text{Constant}$$

$$(\text{AF})_{xy} = I_0 \left[\sum_{m=1}^{M} e^{j(m-1)(kd_x \sin\theta\cos\phi + \beta_x)} \right] \times \left[\sum_{n=1}^{N} e^{j(n-1)(kd_y \sin\theta\sin\phi + \beta_y)} \right] \tag{6-90}$$

Array Factor (Uniform Array)

$$(\mathrm{AF})_n = \left[\frac{1}{M}\frac{\sin\left(\frac{M}{2}\psi_x\right)}{\sin\left(\frac{\psi_x}{2}\right)}\right]\left[\frac{1}{N}\frac{\sin\left(\frac{N}{2}\psi_y\right)}{\sin\left(\frac{\psi_y}{2}\right)}\right] \quad (6\text{-}91)$$

$$\psi_x = kd_x \sin\theta\cos\phi + \beta_x \quad (6\text{-}91a)$$

$$\psi_y = kd_y \sin\theta\sin\phi + \beta_y \quad (6\text{-}91b)$$

M = number of elements in x direction

N = number of elements in y direction

3-D Antenna Pattern of a Planar Array of Isotropic Elements and Equal Amplitude and Phase Excitations

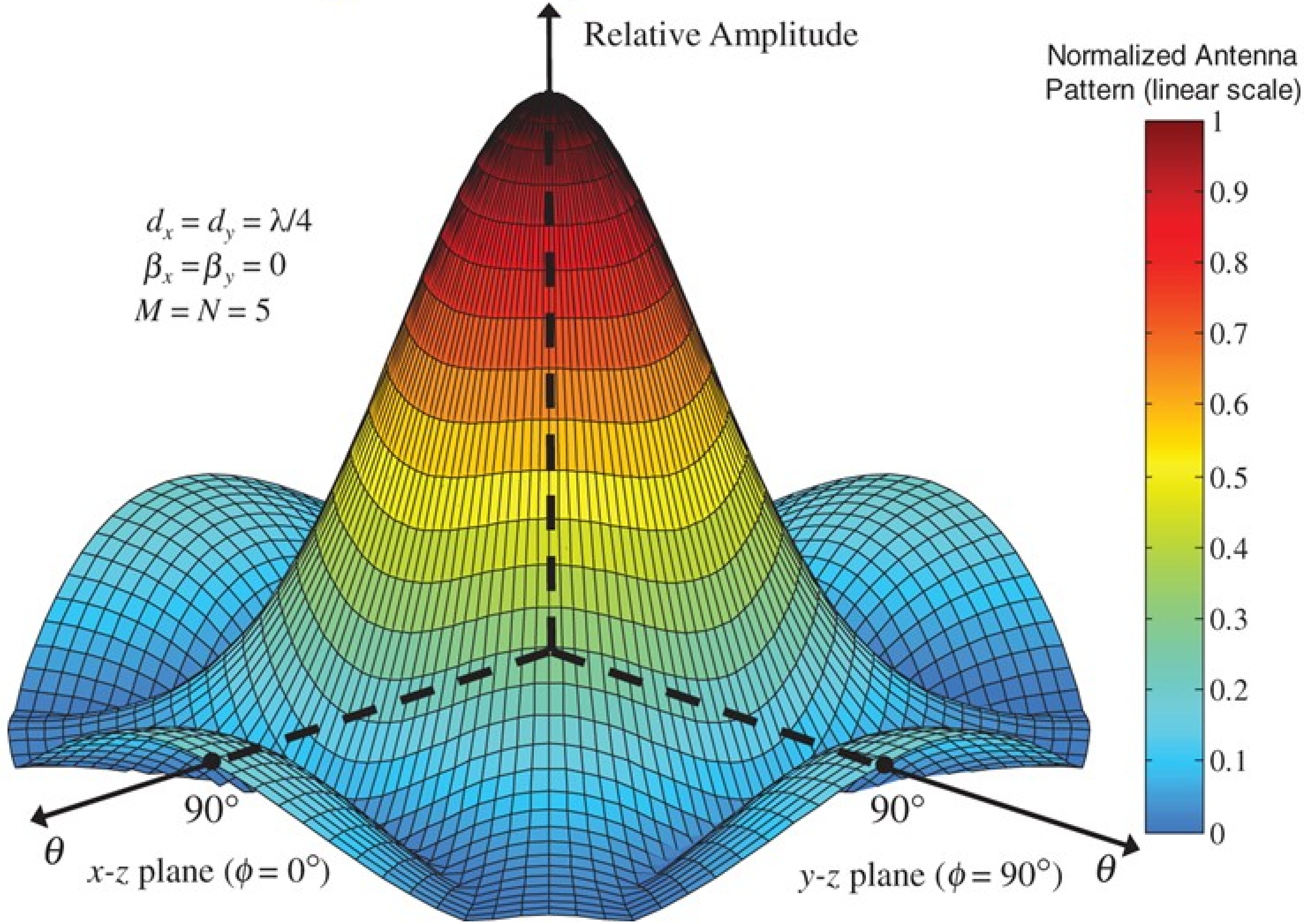


Fig. 6.31

3-D Antenna Pattern of a Planar Array of Isotropic Elements and Equal Amplitude and Phase Excitations

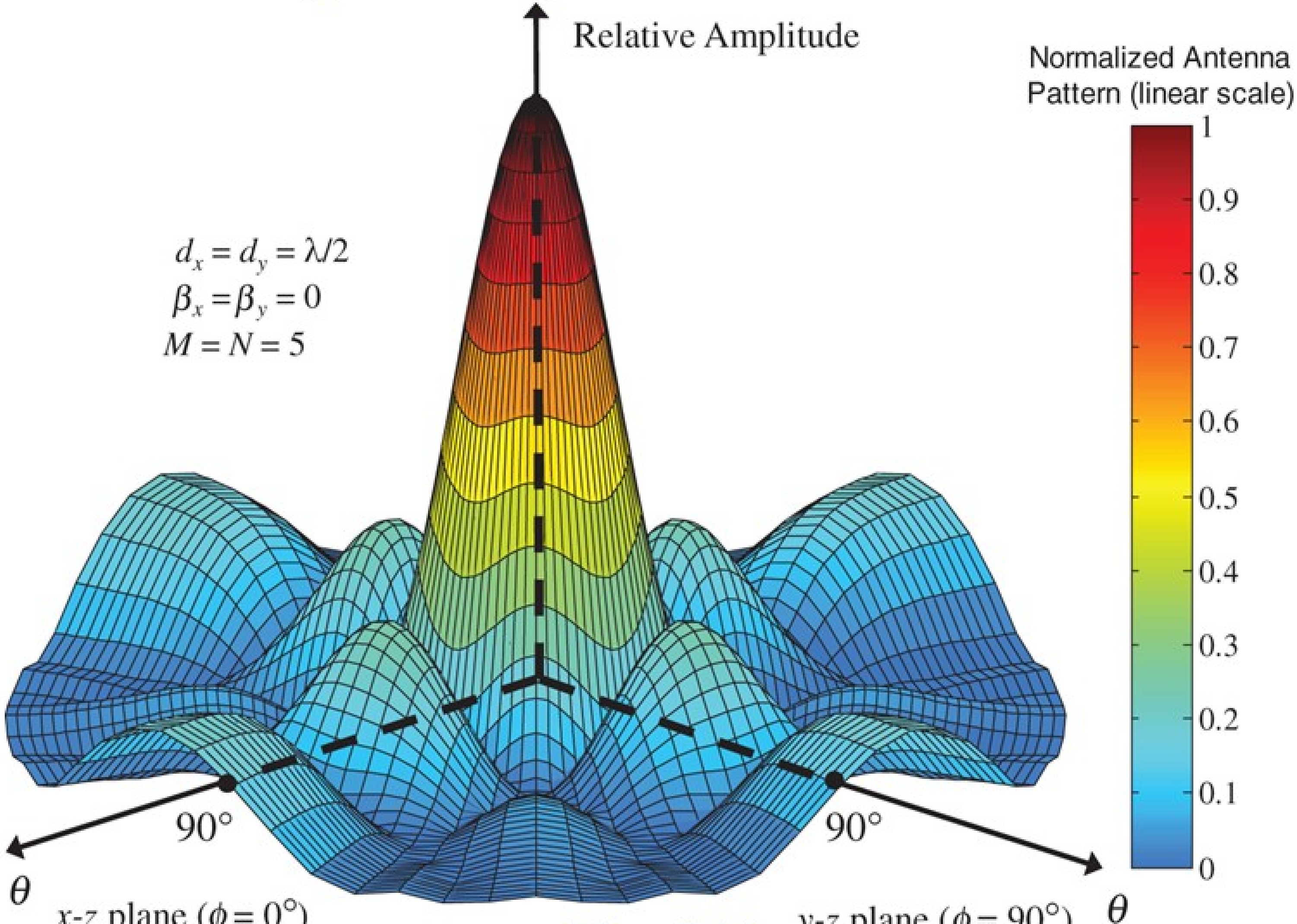


Fig. 6.32

3-D Antenna Pattern of a Planar Array of Isotropic Elements and Equal Amplitude and Phase Excitations

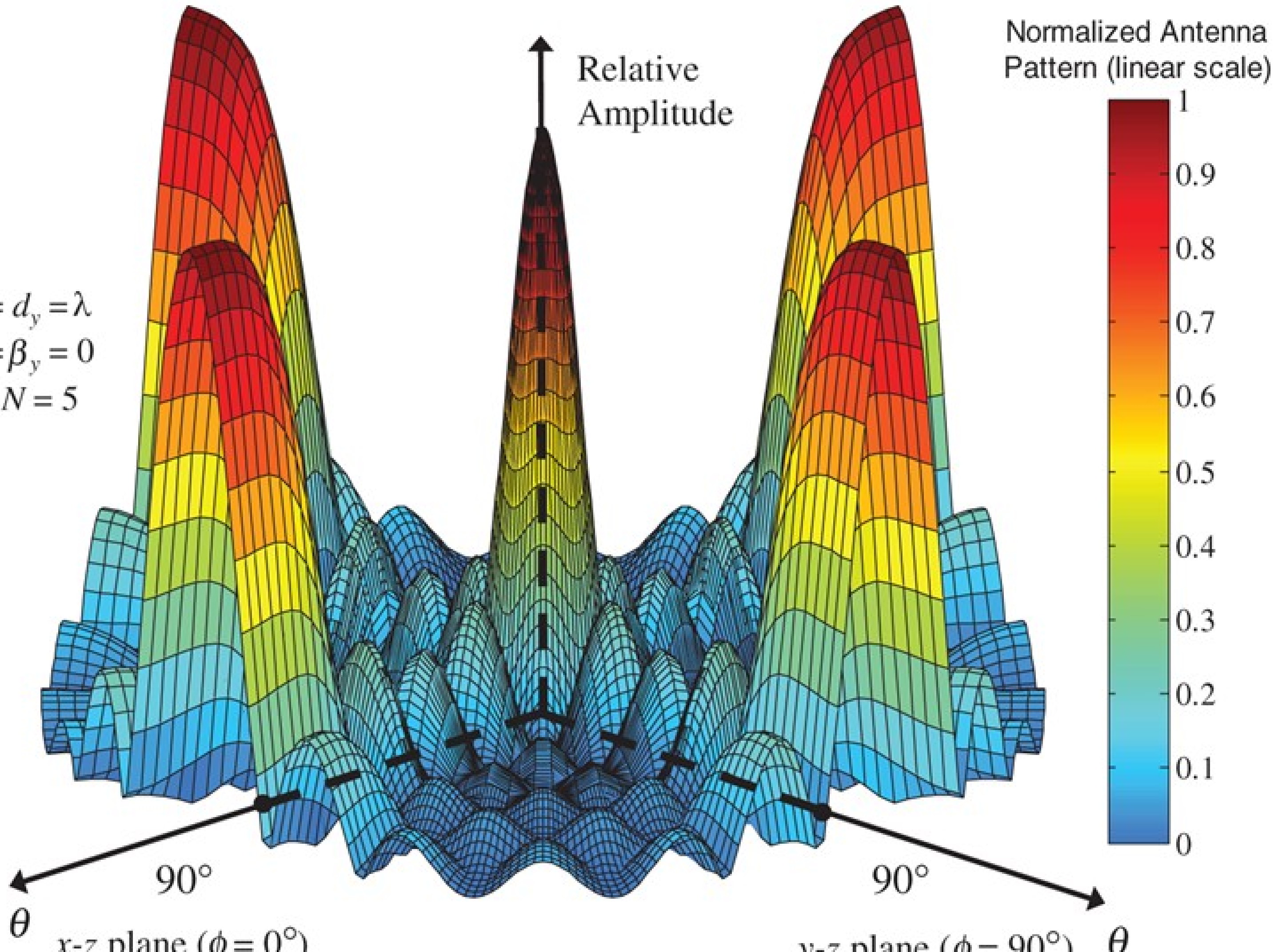


Fig. 6.36

Maxima

$$\psi_x = kd_x \sin\theta\cos\phi + \beta_x = \pm 2m\pi, \quad m = 0,1,2,\ldots \qquad (6\text{-}92a)$$

$$\psi_y = kd_y \sin\theta\sin\phi + \beta_y = \pm 2n\pi, \quad n = 0,1,2,\ldots \qquad (6\text{-}92b)$$

First main maximum

$(m=0,\ n=0)$ @ $\theta = \theta_0\ ,\ \phi = \phi_0$

$$\psi_x = kd_x \sin\theta_0 \cos\phi_0 + \beta_x = 0 \Rightarrow \beta_x = -kd_x \sin\theta_0 \cos\phi_0 \qquad (6\text{-}93a)$$

$$\psi_y = kd_y \sin\theta_0 \sin\phi_0 + \beta_y = 0 \Rightarrow \beta_y = -kd_y \sin\theta_0 \sin\phi_0 \qquad (6\text{-}93b)$$

Main Maximum ($m=n=0$)

$$\beta_x = -kd_x \sin\theta_0 \cos\phi_0 \qquad (6\text{-}93a)$$

$$\beta_y = -kd_y \sin\theta_0 \sin\phi_0 \qquad (6\text{-}93b)$$

When these two equations are solved simultaneously for θ_o and ϕ_o, they lead to

$$\tan\phi_0 = \frac{\beta_y d_x}{\beta_x d_y} \qquad (6\text{-}94a)$$

$$\sin^2\theta_0 = \left(\beta_x / kd_x\right)^2 + \left(\beta_y / kd_y\right)^2 \qquad (6\text{-}94b)$$

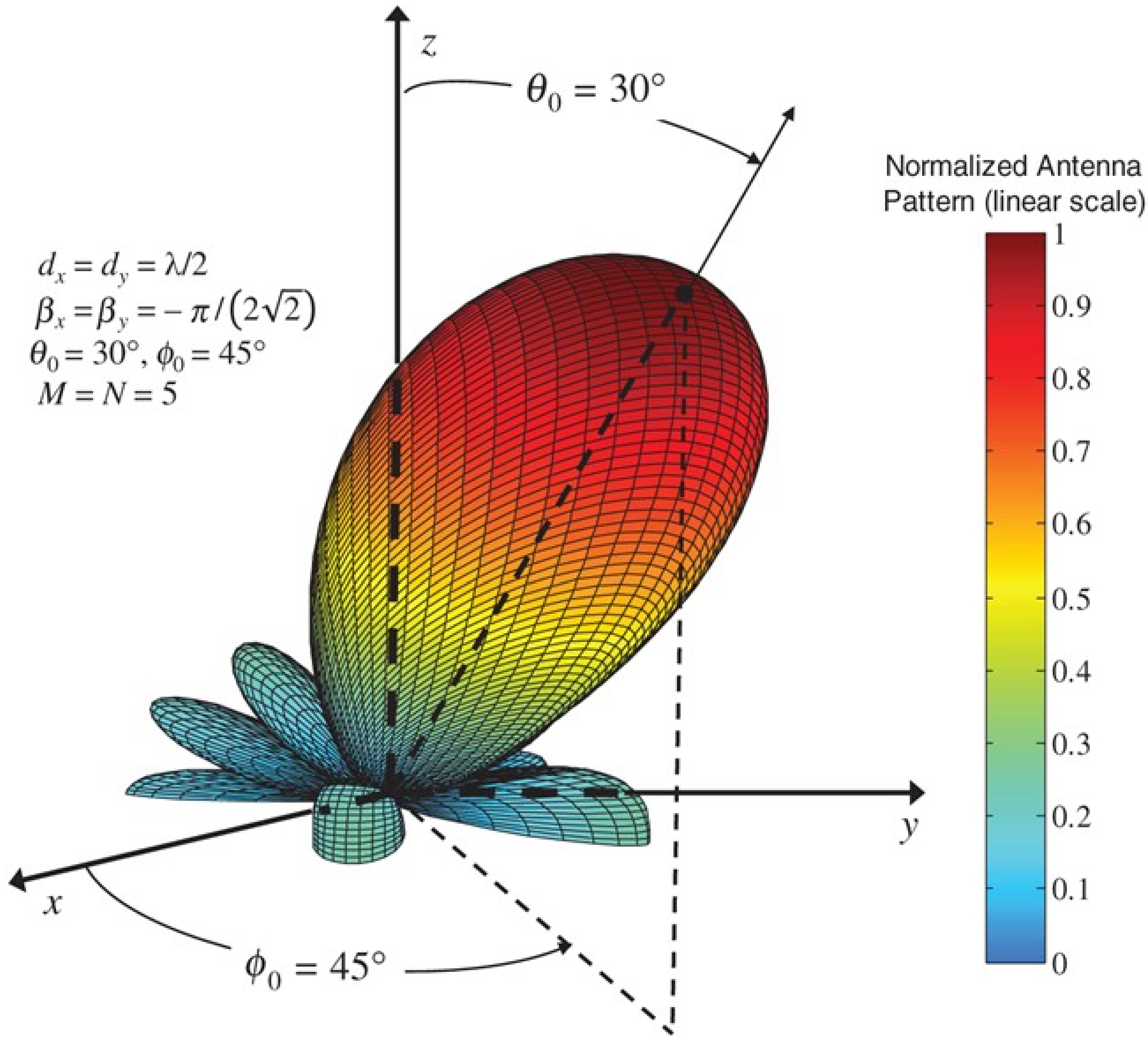

z
$\theta_0 = 30°$
Normalized Antenna Pattern (linear scale)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$d_x = d_y = \lambda/2$
$\beta_x = \beta_y = -\pi/(2\sqrt{2})$
$\theta_0 = 30°, \phi_0 = 45°$
$M = N = 5$
y
x
$\phi_0 = 45°$

Figure 6.34(b)

Half-Power Beamwidth

$$\Theta_h = \sqrt{\frac{1}{\cos^2\theta_0\left[\left(\frac{\cos\phi_0}{\Theta_{x0}}\right)^2 + \left(\frac{\sin\phi_0}{\Theta_{y0}}\right)^2\right]}}$$

Θ_{x0} = HPBW of corresponding broadside linear array of M elements

Θ_{y0} = HPBW of corresponding broadside linear array of N elements

Directivity

$$D_0 = \pi \cos\theta_0 D_x D_y \qquad (6\text{-}103)$$

D_x, D_y = corresponding directivities of linear broadside arrays, respectively, with lengths & elements $(L_x, M), (L_y, N)$

$$D_0 \cong \frac{\pi^2}{\Omega_A(\text{rads}^2)} = \frac{32{,}400}{\Omega_A(\text{degrees}^2)} \qquad (6\text{-}104)$$

Thank You