2.5 Circular Array

Module:2 Linear and Planar Arrays

Course: BECE305L – Antenna and Microwave Engineering

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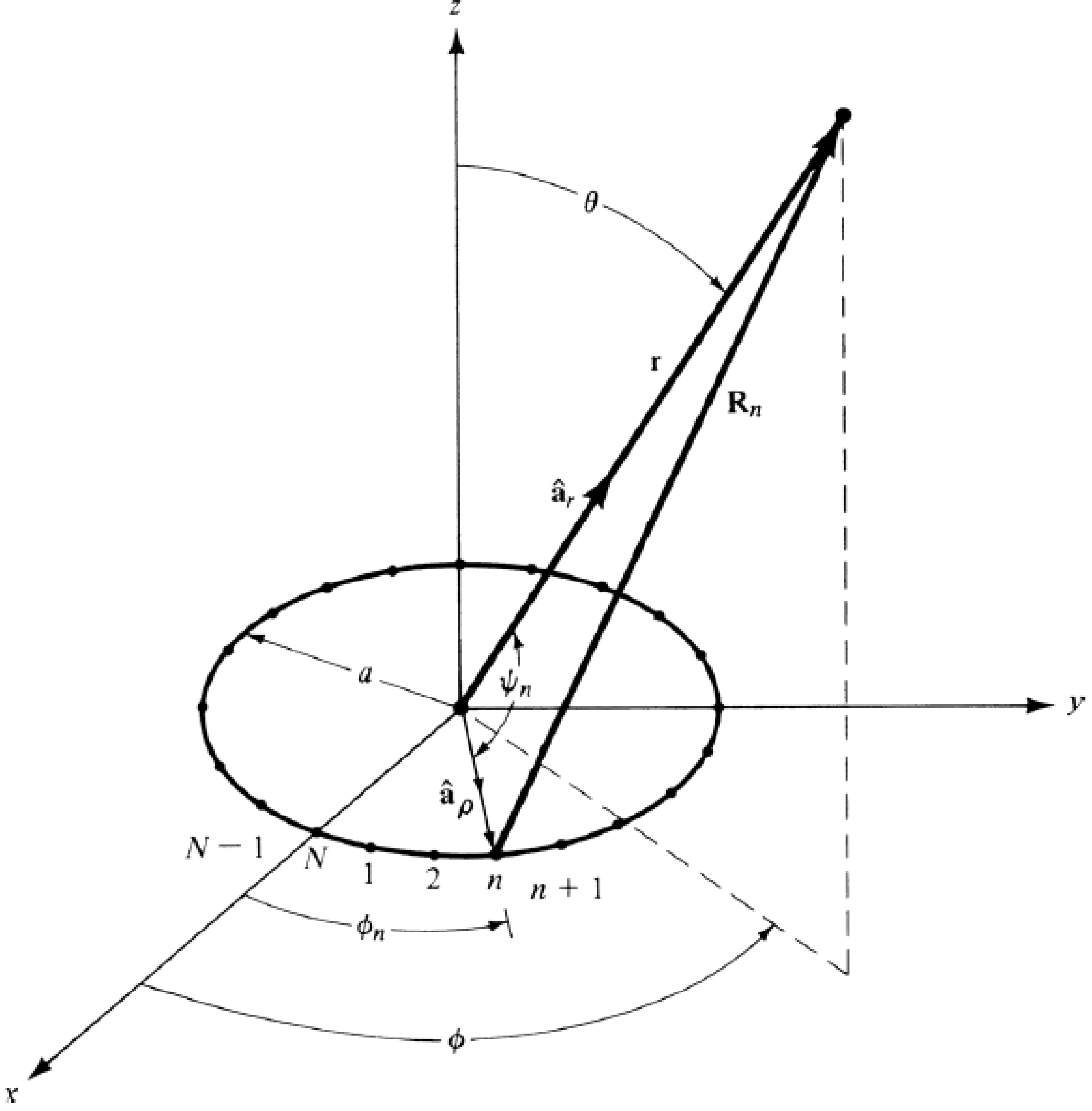
Module:2 Linear and Planar Arrays

- Two element array, N-element linear array - broadside array, End fire array - Directivity, radiation pattern, pattern multiplication. Non-uniform excitation - Binomial, Chebyshev distribution, Arrays: Planar array, circular array, Phased Array antenna (Qualitative study).

- Source of the contents: Constantine A. Balanis - Antenna theory analysis and design (2016)

1. Circular array

- The circular array, in which the elements are placed in a circular ring.
- Applications : radio direction finding, air and space navigation, underground propagation, radar, sonar, wireless communication, and in particular for smart antennas
- *N* isotropic elements are equally spaced on the *x*-*y* plane along a circular ring of the radius *a*.



- normalized field of the array R_n is the distance from the nth element to the observation point

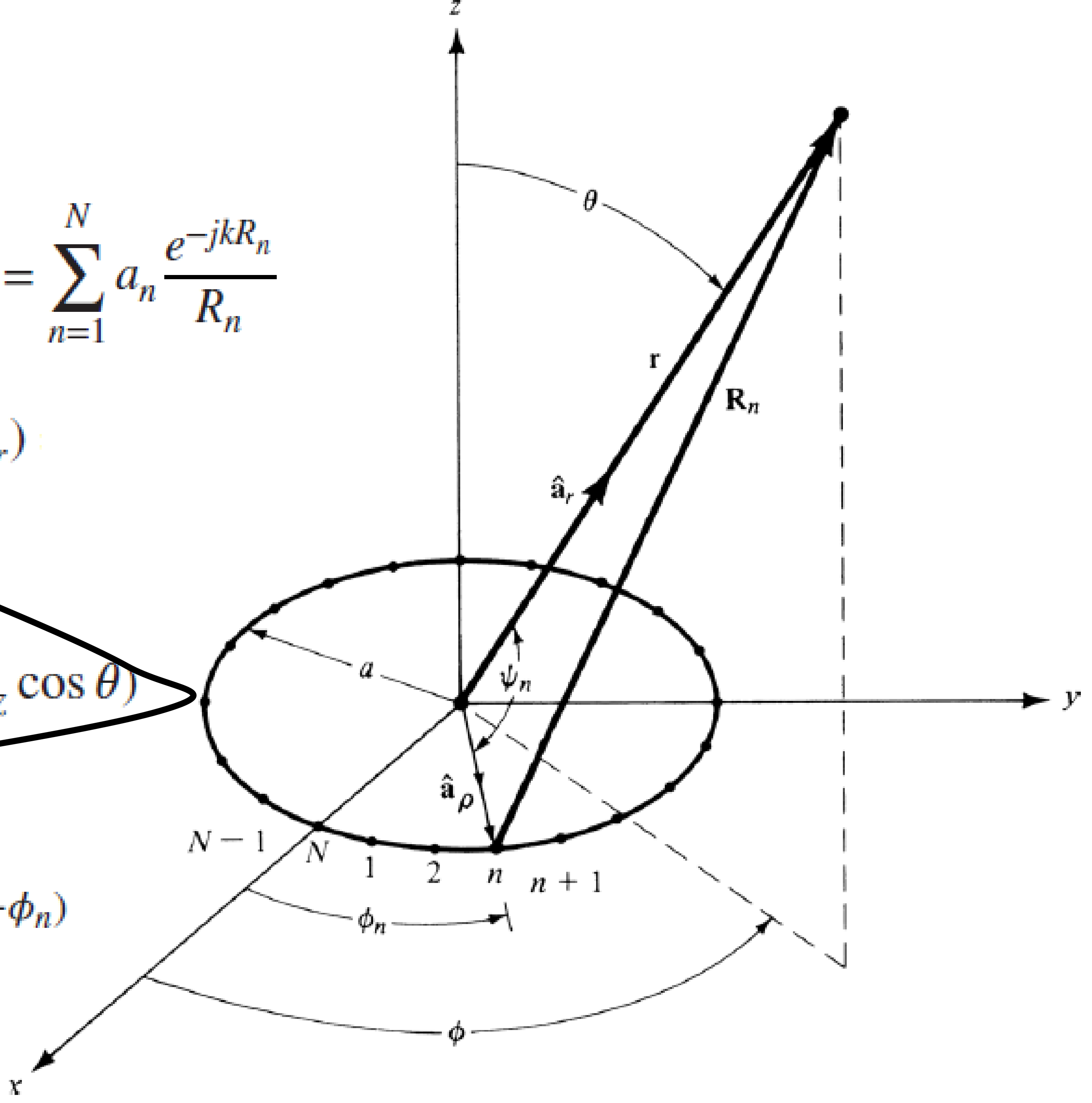
$$E_n(r,\theta,\phi) = \sum_{n=1}^{N} a_n \frac{e^{-jkR_n}}{R_n}$$

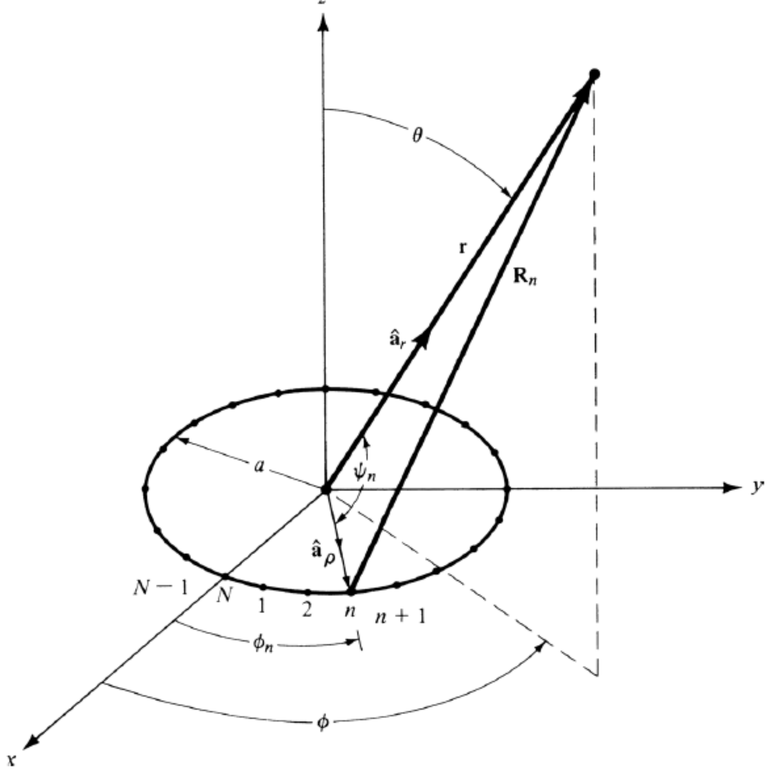
- for $r \gg a$

$$R_n \simeq r - a\cos\psi_n = r - a(\hat{\mathbf{a}}_\rho \cdot \hat{\mathbf{a}}_r) = r - a\sin\theta\cos(\phi - \phi_n)$$

$$\hat{\mathbf{a}}_\rho \cdot \hat{\mathbf{a}}_r = (\hat{\mathbf{a}}_x \cos\phi_n + \hat{\mathbf{a}}_y \sin\phi_n) \cdot (\hat{\mathbf{a}}_x \sin\theta\cos\phi + \hat{\mathbf{a}}_y \sin\theta\sin\phi + \hat{\mathbf{a}}_z \cos\theta) = \sin\theta\cos(\phi - \phi_n)$$

$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r} \sum_{n=1}^{N} a_n e^{+jka\sin\theta\cos(\phi-\phi_n)}$$





$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r}\sum_{n=1}^{N} a_n e^{+jka\sin\theta\cos(\phi-\phi_n)}$$

a_n = excitation coefficients (amplitude and phase) of nth element

$\phi_n = 2\pi\left(\frac{n}{N}\right)$ = angular position of nth element on x-y plane

- With excitation coefficient $a_n = I_n e^{j\alpha_n}$

I_n = amplitude excitation of the nth element

α_n = phase excitation (relative to the array center) of the nth element

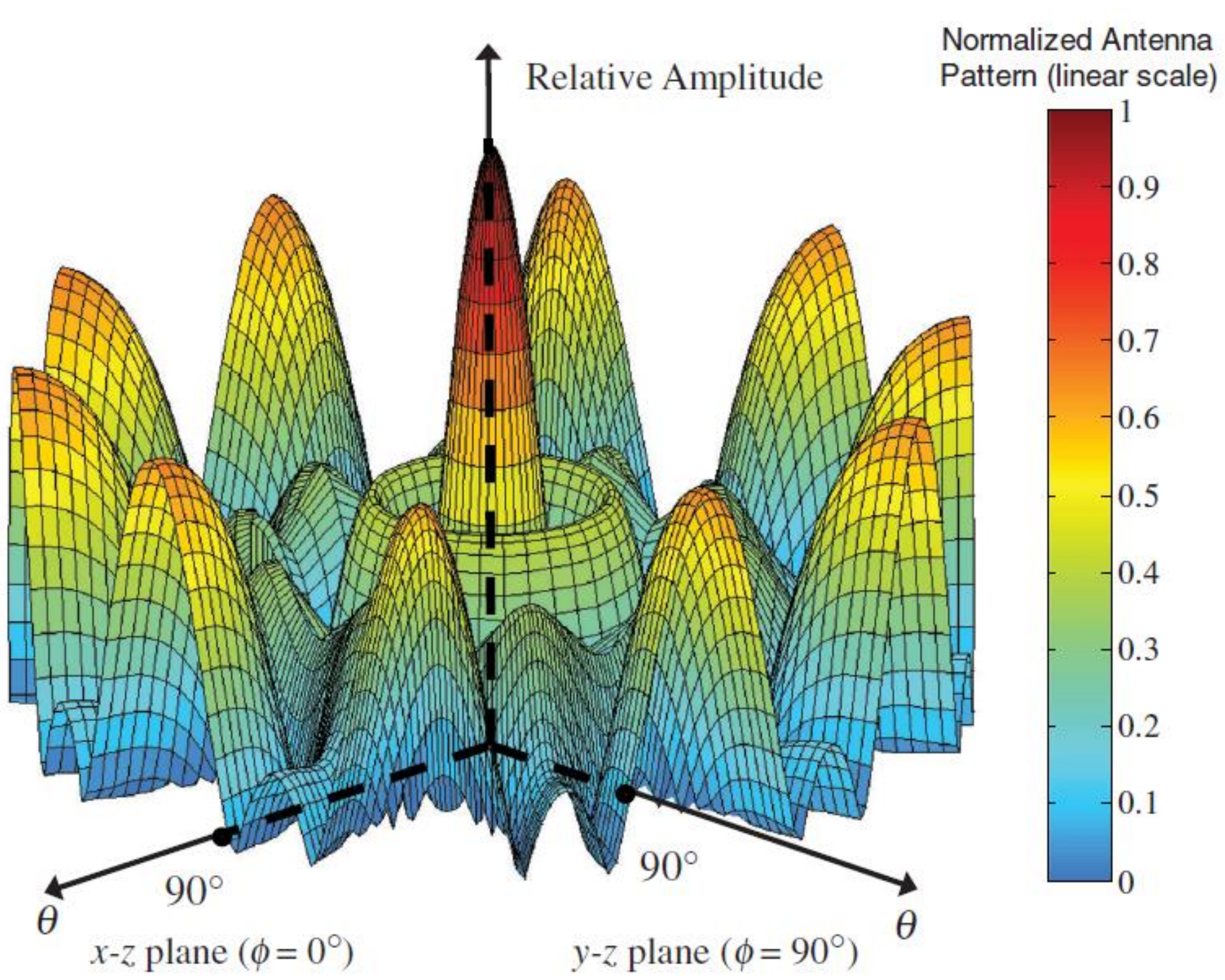
$$E_n(r,\theta,\phi) = \frac{e^{-jkr}}{r}[\mathrm{AF}(\theta,\phi)]$$

$$\xi = \tan^{-1}\left[\frac{\sin\theta\sin\phi - \sin\theta_0\sin\phi_0}{\sin\theta\cos\phi - \sin\theta_0\cos\phi_0}\right]$$

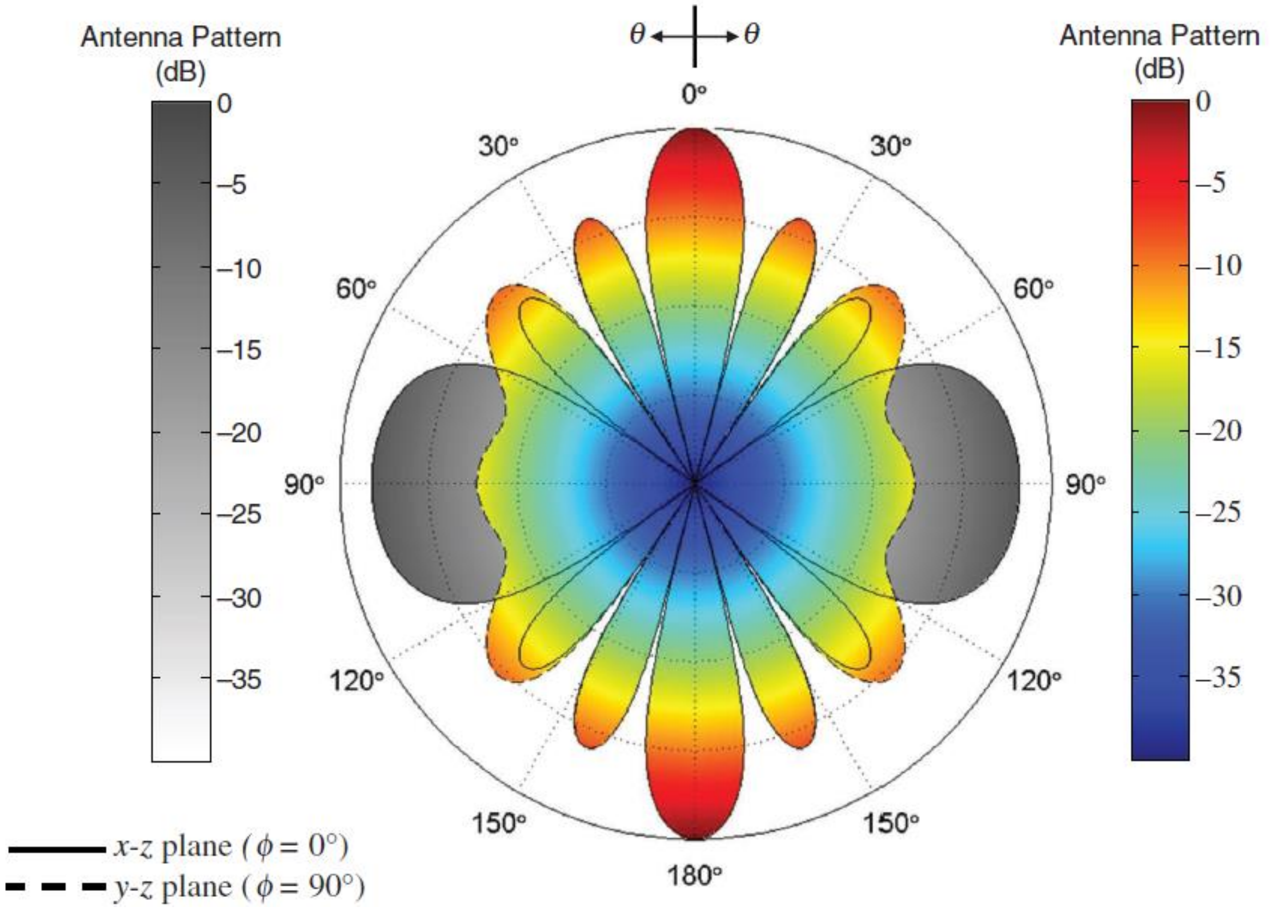
$$\mathrm{AF}(\theta,\phi) = \sum_{n=1}^{N} I_n e^{j[ka\sin\theta\cos(\phi-\phi_n)+\alpha_n]} = \sum_{n=1}^{N} I_n e^{jka(\cos\psi-\cos\psi_0)} = \sum_{n=1}^{N} I_n e^{jk\rho_0\cos(\phi_n-\xi)}$$

$$\rho_0 = a[(\sin\theta\cos\phi - \sin\theta_0\cos\phi_0)^2 + (\sin\theta\sin\phi - \sin\theta_0\sin\phi_0)^2]^{1/2}$$

Three-dimensional amplitude pattern of the array factor for a uniform circular array of N = 10 elements ($C/\lambda = ka = 10$).



Principal-plane amplitude patterns of the array factor for a uniform circular array of N = 10 elements ($C/\lambda = ka = 10$).



- For a uniform amplitude excitation of each element ($I_n = I_0$),

$$\mathrm{AF}(\theta, \phi) = N I_0 \sum_{m=-\infty}^{+\infty} J_{mN}(k\rho_0) e^{jmN(\pi/2-\xi)}$$

- $J_p(x)$ is the Bessel function of the first kind
- The part of the array factor associated with the zero order Bessel function $J_0(k\rho_0)$ is called the *principal term* and the remaining terms are noted as the *residuals*.
- For a circular array with a large number of elements, the term $J_0(k\rho_0)$ alone can be used to approximate the two-dimensional principal-plane patterns. The remaining terms contribute negligibly because Bessel functions of larger orders are very small