Phased Array Antenna

1 Learning Objectives:

- *Students will learn about the antenna pattern for linear and planar phased array.*
- *Students will learn about the design of linear array antenna (uniform and non-uniform spacing, aperture, and tapering function)*
- *Students will learn about the tradeoff in the design of linear array antenna (mainlobe beamwidth, sidelobe level, and grating lobes).*
- *Students will learn about the SPY-1A Phased Array Radar on the OU north campus.*

2 Introduction

A phased array antenna is a directive antenna made of a number of individual radiation element. It can steer the radar beam electronically by varying the phase of each element for both transmission and receiving. Electronically steered phased array radar was developed in mid-1960s mainly for military applications. It has the capability of instantaneously and adaptively controlling beam position on a pulse-to-pulse basis, which allows a single radar to perform multiple tasks such as surveillance, target tracking, and weapon controls.

In this module, we will learn and exercise the fundamental of phased array antenna. The antenna pattern is defined by the product of array factor and element factor. Here we assume that each element is isotropic to simply the problem. The electrical field produced by a number of sub-array and pointing at $\mathbf{a}_0$ can be obtained by the following equation.

$$E(\theta_x, \theta_y) = \sum_{n=0}^{N-1} w(n) e^{jk(\mathbf{a}_r - \mathbf{a}_0)\cdot \mathbf{d}_n} \tag{1}$$

where $w(n)$ is the tapering function, $k = 2\pi/\lambda$ is the wavenumber, $\mathbf{d}_n = \mathbf{a}_x d_{nx} + \mathbf{a}_y d_{ny} + \mathbf{a}_z d_{nz}$ is the location of the nth sub-array, $\mathbf{a}_r = \mathbf{a}_x \sin\theta\cos\phi + \mathbf{a}_y \sin\theta\sin\phi + \mathbf{a}_z \cos\theta$ is the angular location where $E(\theta_x, \theta_y)$ to be calculated, and $\theta_x = \sin\theta\cos\phi$, $\theta_y = \sin\theta\sin\phi$, $\theta_z = \cos\theta$. The array factor is obtained by $|E(\theta_x, \theta_y)|^2$. Note the general representation of (1) can be applied to both 2D and 1D array. It is suggested to use this equation for the following hands-on activities.

3 Hands-On Activities

You are required to write computer codes to plot the antenna pattern and analyze the results. You should turn in your code, discussions of the results, and figures. Proper labels are required for all figures. **Prob. 3** is required for those who take the course as ECE 5663 but is optional for those who are in ECE 4663 (i.e., extra credit). ***The report is due on March 5, 2008***.

1. **Prob 1.** Plot the antenna pattern of an equally spaced linear array with 25 elements for various tapering functions (rectangular, Hamming, Hanning). The spacing between elements is half wavelength (a) Discuss the effect of tapering function on antenna pattern in terms of mainlobe beamwidth, sidelobe levels, and grating lobe locations. (b) Plot and discuss the two-dimensional pattern of the rectangular tapering function for $-50^\circ \leq \theta_x \leq 50^\circ$ and $-50^\circ \leq \theta_y \leq 50^\circ$. (4 points)

2. **Prob 2.** You are tasked to design an X-band (10 GHz) linear array antenna with the following different requirements. (a) scenario 1: 13 radiating elements are used and spaced equally within a dimension of 36 cm; (b) scenario 2: somehow due to the cost constraint, now only 5 elements can be afforded. The 5 elements are still spaced equally within the 36 cm; (c) scenario 3: The 5 elements are spaced unevenly to produce non-redundant spacing. In other words, the spacing between elements is .1.3.5.2. The numerical number Plot the 1D antenna pattern for (a), (b), and (c) and discuss the tradeoff of mainlobe beamwidth, sidelobe levels, and grating lobe locations. (6 points)

3. **Prob 3.** This problem is aiming at the Antenna pattern for the S-band (3 GHz) Phased Array Radar (PAR) at the National Weather Radar Testbed (NWRT). First you need to download antenna configuration "NWRT_ARRAY.mat" from the course website (learn@ou.edu). The variable is d(4352,3) with the first dimension of the number of elements and the second dimension of the coordinates of Cartesian. (a) Plot the all antenna elements on a x-y plane. (b) Plot the 2D antenna pattern pointing at the broadside. (c) Plot the 1D antenna pattern in the azimuthal plane with pointing angle of zero and 45 degree (similar to the figure shown in the class). What is the half power beamwidth for both cases?