ECEG 497 **Wireless System Design** **Spring 2025**

Homework Assignment #8 – due via Moodle at 11:59 pm on Monday, May 5, 2025

***Instructions, notes, and hints*:**

You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems, but review their solutions and make sure that you understand the concepts incorporated into them.

***Graded Problems*:**

1. Consider a linear phased array that consists of 12 half-wave dipole antennas spaced along the *z*-axis with the dipoles parallel to the *x*-axis. Neglecting the effects of mutual coupling between the elements, find the interelement phase shift δ in degrees required to steer the main beam in the *yz*-plane to the direction $\theta_0 = 60°$ for the following element spacings:

- **a.** $d = 0.5\,\lambda$
- **b.** $d = 0.8\,\lambda$
- **c.** $d = 1.5\,\lambda$

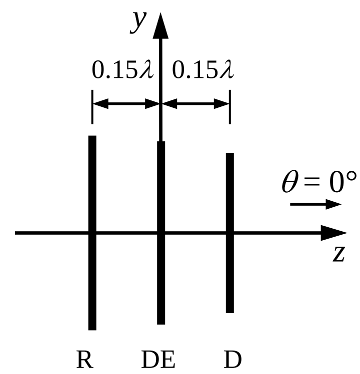
2. A *grating lobe* is a sidelobe in a radiation pattern that has a maximum value equal to that of the main lobe. Grating lobes are usually undesirable since the typical application of a phased array is to direct most of the radiated energy (or enhance the sensitivity in reception mode) in one direction only. If the interelement phase shift is δ and the element spacing is d, grating lobes appear at those angles θ_G that satisfy $\psi = \delta + kd\cos\theta_G = \pm n2\pi$, where n = 1, 2, 3, … (The main beam appears at the angle θ_0 that satisfies $\psi = 0$, which corresponds to $n = 0$.) Physically meaningful angles must fall within the range $0 \leq \theta \leq 180°$ since θ is not defined outside that range; that is, any θ_G values that fall outside that range are not "visible." Suppose that the main beam of the 12-element array considered in the previous problem is steered to $\theta_0 = 60°$. For the following interelement spacings, determine the number (if any) of grating lobes and the directions in which they appear.

- **a.** $d = 0.5\,\lambda$
- **b.** $d = 0.8\,\lambda$
- **c.** $d = 1.5\,\lambda$

(*continued on next page*)

3. A three-element Yagi-Uda array has the geometry shown below. An *EZNEC* simulation reveals that the current magnitudes and phases at the element centers have the values shown below left when the driven element is excited with a voltage of 1 $\angle$ 0° V. The current distribution along each element is approximately sinusoidal. If the gain in the $\theta = 0°$ direction is 7.14 dBi, find the gain in the $\theta = 90°$ and 180° directions in the *xz*-plane (in which $\phi = 0°$). *Hint #1*: Express the ratio of the relative E-field magnitudes in the $\theta = 90°$ and 180° directions to the magnitude in the $\theta = 0°$ direction in dB and then subtract each result from 7.14 dBi. *Hint #2*: The isolated element pattern in the *xz*-plane is uniform, so any variation in gain is due only to the array factor.

$I_R = 11.36 \angle 126°$ mA
$I_{DE} = 22.16 \angle 0°$ mA
$I_D = 9.92 \angle -106°$ mA



Ungraded Problems:

The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. You will be responsible for knowing the material referred to in these problems.

1. Use Matlab to plot the radiation patterns (in dB, array factor only) in the *yz*-plane for the phased arrays considered in Graded Problems 1 and 2 for all three element spacings. The patterns should be normalized to 0 dB. For each pattern, identify the main lobe and the grating lobe(s), if any.

2. Use *EZNEC* to simulate a two-element Yagi-Uda array in which the parasitic element has a varying length. First simulate a single nominally half-wave dipole operating at 90.5 MHz (WVBU). The wire diameter should be 3/16" (about 4.76 mm), and the dipole should be aligned along the *z*-axis and centered on the origin. Adjust the length until the input impedance indicates resonance (a reactance of less than an ohm or so in magnitude). Now add a parallel parasitic element 0.2λ away along the *y*-axis. Use *EZNEC* to calculate the gain in the two endfire directions for parasitic element lengths from 0.43λ to 0.52λ in 0.005λ increments. The endfire directions correspond to $\phi = 90°$ and 270° in the $\theta = 90°$ (*xy*) plane, but you will need to convert those angles to the elevation and azimuth angles used by *EZNEC*. Plot the gain in both directions vs. length (19 data points per plot) on the same graph using a legend to indicate each curve. Determine the length of the parasite for which it is optimized to act as a director and the length for which it is optimized to act as a reflector.