Engineering 9816 Assignments 4 **Due: Fri., April 1, 2016**

1. A uniform linear array of $\lambda/2$ dipoles used in an iceberg detection experiment is to be designed to operate in endfire mode in the VHF band at 100 MHz. It is required that the maximum directivity of the array be about 8.45 dB. The elements are to be aligned on a raised platform with the platform itself being 4.5 metres long as shown. There is an element at each end of the platform. Ignore all ground effects and the height of the platform, and take the line of the array to be along the x axis.

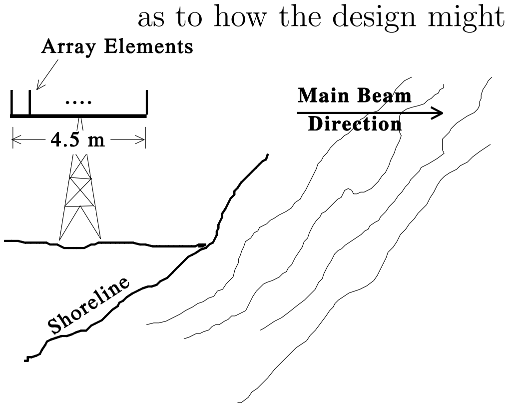
   (a) Determine that the required number of elements is 7 and that their spacing is $\lambda/4$ if the array is exactly the same length as the platform.

   (b) Determine the resultant H-plane pattern of the array. Be sure to calculate all nulls and maxima and make a neat sketch.

   (c) What change would have to be made, without moving the antenna elements, so that the array could scan 20° from endfire?

   (d) When the array is operating in endfire mode, what would the maximum error be in the azimuthal position of an iceberg which is located in the main lobe at a distance of 5 km from the platform? Use the half-power beamwidth in answering this question. How does this error compare to what it would be if the array operated in broadside mode?

   (e) You should notice that perhaps a re-design is in order! Given that the physical size of the installation cannot be changed, make one suggestion as to how the design might be altered to give better detection resolution.



2. A 10-by-8 array of vertical dipole elements in the x-y plane has element spacing in both the x and y directions of $\lambda/4$. Determine the current phasings which will give a single beam maximum (a) along the x-axis and (b) along the direction $\phi = 30°$ in the x-y plane. (c) For part (a) write down the normalized value of

the array factor magnitude. (d) Could this array be phased to detect an aircraft flying directly overhead? Explain.

3. It has been deduced that when a resonant long-wire antenna used in HF (3-30 MHz) communications has a length which is $m\lambda/2$ where m is an odd natural number, then the angle of maximum radiation as measured from the wire axis is given by

$$\Psi_{\max} = \cos^{-1}\left(\frac{m-1}{m}\right)$$

while the radiation resistance and maximum directivity are given by

$$R_r = 73 + 69\log_{10}(m) \qquad \text{and} \qquad D_0 = \frac{120}{R_r \sin^2 \Psi_{\max}} ,$$

respectively. (a) In a particular skywave radar operating at 20 MHz, for which such an long wire may be used as a transmitting antenna, determine (i) the approximate length (in metres) of such an antenna along with (ii) its radiation resistance and (iii) maximum directivity if it is required that $\Psi_{\max} = 36.87°$. (b) Also, determine the direction of all the nulls. (c) Next, compare the given $\Psi_{\max}$ with that obtained using an otherwise identical antenna operating in travelling wave mode. (d) Repeat part (c) if $\Psi_{\max} = 10.475°$. Comment on the relative differences between the resonant and travelling wave maxima when the antenna length is many half-waves.

4. (a) Determine the input impedance of a $3\lambda/2$ dipole in free space. You'll have to find some means of numerically determining the value of the resulting sine and cosine integrals.

   (b) If this dipole is resonant at 900 MHz, by approximately how much should it's length be "trimmed" to effectively remove the reactive portion of the answer in (a)? (Obtain the answer using the curves on page 7a of the class notes.)

   (c) An identical $3\lambda/2$ element is placed side-by-side, at a distance of $\lambda/4$ away, with that in part (a) and the two are connected to a transmitter cable by means of pieces of lossless two-wire line that have a velocity factor of 80% (see diagram on page 11 of the class notes). At 900 Mz, determine the minimum lengths of line so that no extra impedance is added to the array. (You'll need the Term 6 notes on transmission lines for this.) Also, determine the driving point impedance of the array.

   (d) If one of the elements in part (c) is disconnected from the transmission line, determine the new driving point impedance.

   (e) Suppose it were possible to remove the reactive part of the answer in part (c) by adding a series reactance. What is the nature (i.e., capacitive or inductive) and value of such a reactance?

5. (a) Determine and plot the total vertical plane far-field pattern for a vertical Hertzian dipole placed at a height of $\lambda/4$ over perfect ground. (b) Repeat (a) if the antenna is moved to ground level, the operating frequency is 100 MHz and the perfect ground is replaced by ground with conductivity of 10^{-2} ℧/m and $\epsilon_r = 16$.

6. Two lossless X-band (8.2–12.4 GHz) horn antennas are separated by a distance of 100λ. The reflection coefficients at the terminals of the transmitting and receiving antennas are 0.1 and 0.2, respectively. The maximum directivities of the transmitting and receiving antennas (over isotropic) are 18 dB and 22 dB, respectively. Assuming that the input power in the lossless transmission line connected to the transmitting antenna is 4 W, and the antennas are aligned for maximum radiation between them and are polarization matched (are aligned so that the E-field vector from the transmitter can be maximumly received by the receiver), find the power delivered to the load of the receiver.

7. Two spacecraft are separated by 10,000 km. Each has a lossless antenna operating at 2.5 GHz and having a directivity of 1000 . The receiver on one craft requires a minimum signal power of 30 dB over 1 pW. What is the required transmitting power from the other craft if this power level is to be achieved?

8. Problem 6.19, page 332, Ed. 2 of text (6.24, page 374 of Ed. 3).

9. Problems 6.24 and 6.25, page 333, Ed. 2 of text (6.31 and 6.32, page 376 of Ed. 3).