Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2013-2014 (2 hours)

Antennas, Radar and Navigation3

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** In the context of surveillance radar, explain how the beamwidth of the antenna affects the performance of the radar.

(2)

b. An antenna with azimuth and elevation beamwidths of $\Delta\phi$ and $\Delta\theta$ is required to scan a hemisphere of sky. Determine a relationship between the gain of the antenna and the number of beam positions required to fully scan the hemisphere. If an antenna has a gain of 30dB and the hemisphere of sky needs to be fully scanned every 6s, determine the dwell time per position.

(4)

c. A rotating pulsed radar system has the following parameters: frequency = 560MHz; pulse width = 1.3μS; peak power = 279kW; duty cycle = 8.3 x 10^{-4} ; antenna rotation rate = 16 RPM; vertical beamwidth = 4^0; number of hits on a point target per rotation = 9.9.

Determine the following parameters:

Wavelength; pulse repetition frequency (PRF); pulse repetition time (PRT); average power; horizontal antenna beamwidth; antenna gain; maximum unambiguous range and the range resolution.

(8)

d. The cost of operating a radar system may be expressed as $C = C_P + C_A$ where the power consumption is C_P and the cost of building/maintaining the antenna hardware is C_A. Assume that these two costs are given by $C_P = PC_{kW}$ and $C_A = AC_{sm}$ where P is the total transmit power (kW), C_{kW} is the power cost per kW, A (m^2) is the area of the antenna and C_{sm} is the per square meter cost of building/maintaining the antenna. When designing a radar system there is therefore a trade-off between C_A and C_P as a large antenna will have greater gain and require less transmit power for the same range. Derive a relationship between C_A and C_P to minimise the total cost C. State any assumptions that you make. **(6)**

2. **a.** Derive the bi-static radar range equation **(6)**

b. With the aid of a block diagram, describe the basic operation of a continuous wave Doppler radar system. **(4)**

c. A CW Doppler radar illuminates a rotating spherical target as shown in Figure1. The target rotates at an angular velocity of ω radians per second around a circular path of radius R. The radar operates at a frequency of f_0 Hz and is located a distance d away from the target.

i) Assuming that $d \gg R$ derive an approximate expression for the Doppler shift detected by the radar.

ii) If $f_0 = 10GHz$, $R=1m$ and the target rotates at 30rpm, sketch a graph of the variation in Doppler shift during one complete rotation of the target.

iii) If the condition $d \gg R$ does NOT apply derive a new expression for the detected Doppler shift in terms of the parameters ω, α, R, θ and f_0

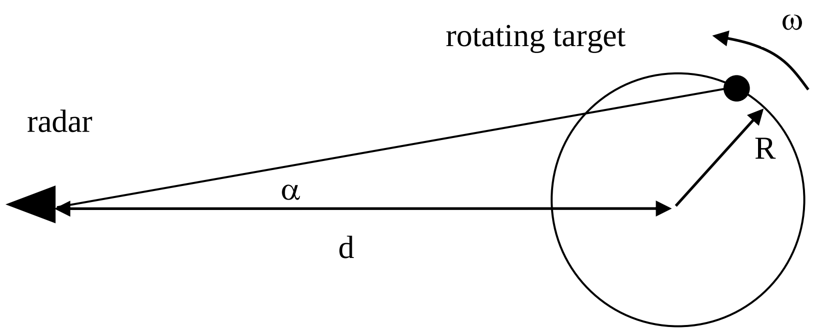

Figure 1

(10)

3. **a.** With the aid of a diagram explain the terms: main-beam, boresight direction, sidelobes, nulls, back-lobes, half-power beamwidth and first-nulls beamwidth, as applied to an antenna's far-field radiation characteristics. **(3)**

b. Sketch the approximate far-field radiation patterns that would be produced by the four 1D aperture distributions shown in Figure 2

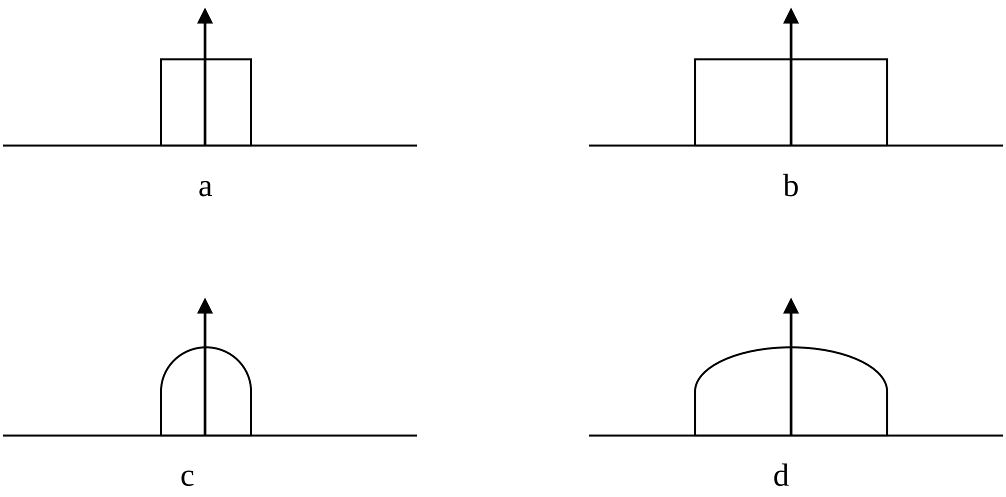

Figure 2

(4)

c. A 10.8GHz communications link consists of a 2.1m diameter dish transmit antenna with an aperture efficiency of 0.75, and a receive dish antenna of 1.8m diameter with an aperture efficiency of 0.65. If the distance between the link is 150km, calculate the magnitude of the transmit power required to produce a received power level of 500nW **(5)**

d. Derive an expression for the normalised array factor of a simple 2-element array with element spacing d and uniform, equal phase excitation.

i) Plot the array factor for an element spacing of $\lambda/2$.

ii) If the elements are now driven in anti-phase, plot the new array factor. **(8)**

4. **a.** Explain why and under what circumstances a wireless communication system is more power efficient than a cable based system. **(4)**

b. i) With the aid of a diagram, define the term *axial ratio* with regard to the polarisation of the field radiated by an antenna. What are the numerical limits on the value of axial ratio and what types of polarisation do these limits correspond to?

ii) Explain how polarisation diversity may be used to increase the capacity of a communications link.

iii) With the aid of a diagram, explain how circular polarisation may be generated by two suitably phased dipole antennas. **(8)**

c. A resonant, lossless half-wavelength dipole antenna has a radiation pattern given by $U = \sin^3(\theta)$. The antenna has an input impedance of 73Ω and is connected to lossless 50Ω transmission line. If the antenna is illuminated by a plane-wave with a power density of 5μW/m^2 at a frequency of 10MHz, calculate the power available at the end of the transmission line.

You may find the following expression useful $\int \sin^4 ax\,dx = \frac{3x}{8} - \frac{\sin 2ax}{4a} + \frac{\sin 4ax}{32a}$

(8)

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