Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2010-2011 (2 hours)

Antennas, Radar and Navigation 3

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 antenna design define the terms: gain, directivity, efficiency and effective area. **(4)**

b. An electrically large aperture antenna has 3dB far-field principal plane beamwidths of β_x and β_y respectively. Derive an approximate expression for the gain of the antenna, stating any assumptions you make.

Estimate the gain of an antenna with azimuth and elevation 3dB beamwidths of 3 degrees **(6)**

c. A 10GHz satellite communications link consists of a 3.6m diameter dish transmit antenna with an aperture efficiency of 0.7, and a receive dish antenna of 1.5m diameter with an aperture efficiency of 0.65. The transmit and receive antennas are both linearly polarised and polarisation matched. If the distance between the link is 37000km and the transmit power is 200W, calculate the magnitude of the received power. If the transmit antenna is modified to transmit a circularly polarised signal what will be the change in received power? **(10)**

2. **a.** Derive the 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, located at point A, illuminates a rotating spherical target as shown in Figure 1. 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. Assuming that the target is in the far-field of the radar, derive an expression for the Doppler shift detected by the radar. 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.

In a second experiment the signal scattered from the target, due to illumination from point A, is recorded by a separate radar receive antenna located at point B (also in the far-field). Derive a new expression for the Doppler shift detected by the radar at point B.

(10)

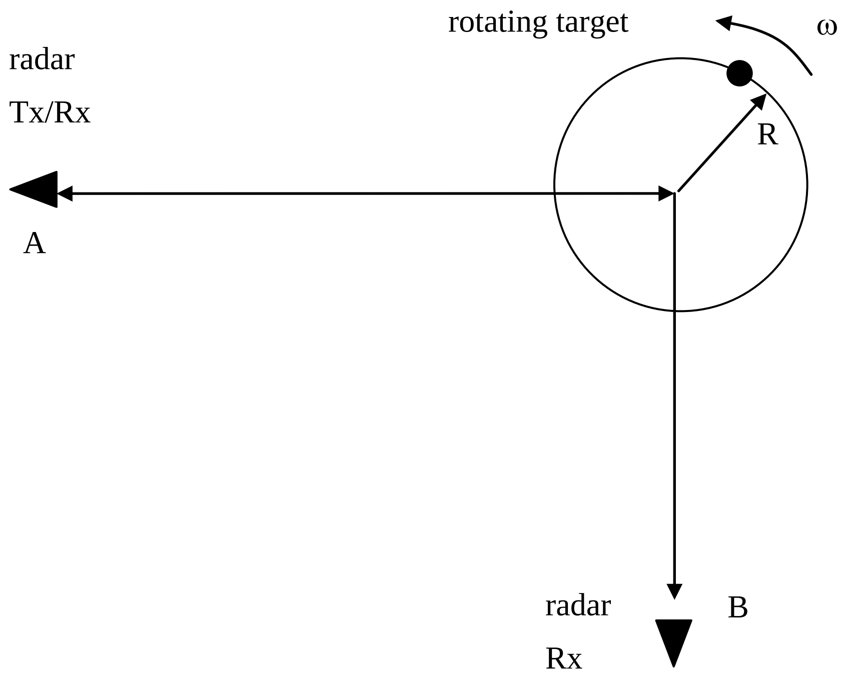
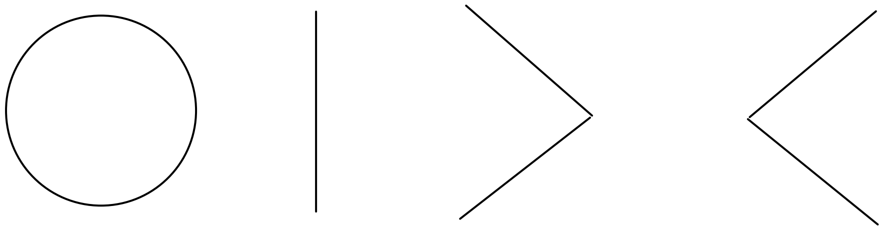


Figure 1

3. **a.** The Figures below show the cross section of four objects (a, b, c and d). If the objects are illuminated from the left by a plane-wave, list the objects in order of the decreasing magnitude of their RCS. Note that the dimension **a** is assumed to be several wavelengths.



a) sphere of diameter **a** | b) flat plate of side **a** | c) corner reflector of side **a** | d) corner reflector of side **a**

(4)

b. A 8GHz radar with a boresight gain of 40dB and a peak transmit power of 200kW is used to track a target with an RCS of 1.4m^2. The radar antenna also receives a jamming signal in a sidelobe which has a gain of 15dB. The jammer operates at a distance of 100km from the radar and has an antenna gain of 30dB and a transmit power level of 1.5kW. Calculate the burnthrough range. **(8)**

c. A radar system operating at 10.0GHz uses a common transmit/receive antenna with an effective aperture size of 2m^2. The radar is used to detect a square plate of side length 1m at a distance of 10km. The plate is illuminated at normal incidence. If the transmit power is 1kW calculate the magnitude of the received power at the radar.

A second identical plate is placed adjacent to the first but at a distance 11.25mm behind it. Estimate the change in received power.

Note the RCS of a flat plate of area A at normal incidence is given by $\sigma = \dfrac{4\pi A^2}{\lambda^2}$ **(8)**

4. **a.** With the aid of simple sketches, explain how the radiation pattern of an array can be expressed in terms of the element pattern and an array factor **(4)**

b. Show that the normalised array factor of a 2 element array with inter-element spacing d can be expressed as **(4)**

$$f(\theta) = \frac{1 + e^{jkdsin\theta}}{2}$$

c. If the spacing, d, is a half wavelength, plot $f(\theta)$ over the range $-\pi/2 \leq \theta \leq +\pi/2$ and calculate the value of $f(\theta)$ for $\theta = 0 \; and \; \theta = \pm\pi/2$ **(4)**

d. Figure 3 shows a schematic diagram of a simple two-element time-switched array which is driven by a generator operating at a frequency f_0. The output from the generator is sequentially switched between the two elements of the array using a SPDT switch such that each element radiates for 50% of the switching period. The separation distance between the elements is a half wavelength at the operating frequency and the switching frequency is f_s.

Sketch the form of the **time domain** output signal from the array in the boresight ($\theta = 0$) and endfire ($\theta = 90$) directions.

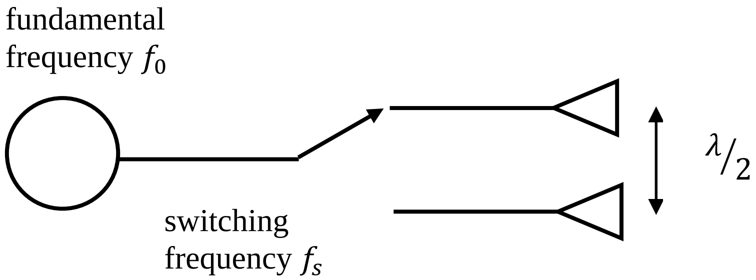


Figure 3

(4)

e. Sketch the form of the **frequency domain** output signal from the array in the boresight ($\theta = 0$) and endfire ($\theta = 90$) directions **(4)**

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