Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2015-2016 (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.** Briefly describe the following types of radar system:
i) Primary surveillance radar
ii) Secondary surveillance radar
iii) Mono-static radar
iv) Bi-static radar
(4)

b. A long range surveillance radar operates at 1.3GHz and uses a common transmit/receive antenna that is 11.9m wide and 6.9m high with a linear efficiency factor of 0.707. The antenna rotates at 5 revolutions per minute. The peak transmitter power is 56kW, the pulse duration is 140μs and the radar operates at a maximum unambiguous range of 490km.

i) What is the transmitter duty cycle and mean transmitter power? What is the power gain of the antenna?
ii) For how long is a point target illuminated each antenna revolution and how many 'hits' are there on a point target each revolution?
iii) What is the Doppler resolution and velocity resolution each time the target is illuminated?
(10)

c. In Figure 1, **A** denotes a moving police car with an on-board CW Doppler radar operating at 10GHz. The radar detects returns from each of the targets **B** to **F** simultaneously and without obstruction. Sketch a graph of the frequency spectrum of the radar receive signal indicating the features that correspond to each of the targets **B** to **F**. Assume that the *magnitude* of the received signals from each target is identical. The speed of each target (km per hour) is given in the table below and the direction of travel is indicated by the arrows in Figure 1.

Object	Description

(6)

A	Police car with 10GHz radar travelling at 80km/hr
B	Car travelling at 130km/hr
C	Car travelling at 60km/hr
D	Car travelling at 100km/hr
E	Car travelling at 100km/hr
F	Stationary road sign

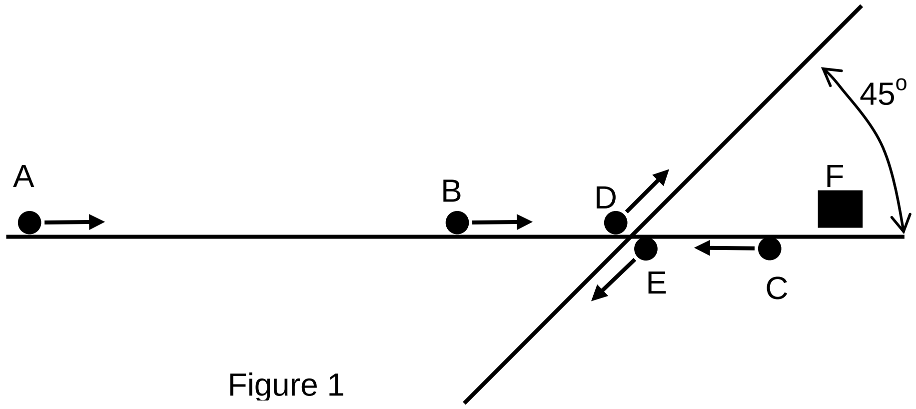


Figure 1

(6)

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

b. A radar system operating at 9.4GHz uses a common transmit/receive antenna with an effective aperture size of 3.4m (horizontal) by 0.75m (vertical) and a first sidelobe level of –20dB relative to the main beam. Calculate the approximate azimuth and elevation beamwidth and estimate the antenna gain. **(4)**

c. If the transmit power is 10kW, the noise level is –140dBW and the total losses are 5dB, calculate the maximum range at which an aircraft with an RCS of $1m^2$ could be detected with a SNR of 13dB. **(5)**

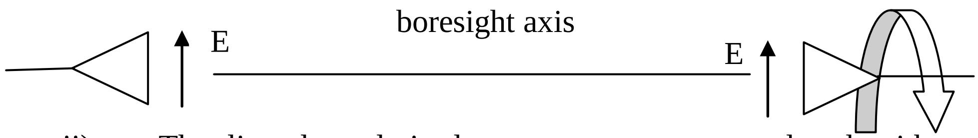
d. Calculate the RCS of a target that would produce a similar output level at half this range if detected by the antenna's first sidelobe. **(5)**

3. **a.** 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? **(4)**

b. Explain how polarisation diversity may be used to increase the capacity of a communications link. **(4)**

c. A communications link consists of two antennas aligned on boresight such that they respectively transmit and receive perfect linear polarisation. One of the antennas is now rotated through 360 degrees about the boresight axis;

i) sketch the variation of the normalised received signal as a function of rotation angle.



ii) The linearly polarised antennas are now replaced with matched, circularly polarised antennas and the experiment is repeated. Sketch the variation of the normalised received signal as a function of rotation angle. **(6)**

d. A 2.4GHz Bluetooth hands-free kit transmits to a smart phone with a power level of 5 mW. Assuming line-of-sight transmission, isotropic transmit and receive antennas and a separation distance of 50cm, calculate the received power (in dBm) at the phone. **(6)**

4. An antenna has a far-field directivity pattern given by

$$D(\theta,\emptyset) = D_0 sin^3\theta$$

a. Sketch the normalised 2-D directivity pattern for $\theta = 0$ to $\theta = 180$. Indicate on the sketch the main beam, nulls and half-power beamwidth **(4)**

b. Sketch the normalised 2-D directivity pattern for $\emptyset = 0$ to $\emptyset = 360$ and $\theta = 90$ **(2)**

c. Calculate the elevation angle that gives peak gain. **(2)**

d. In which directions do the pattern nulls occur? **(2)**

e. Calculate the value of D_0 **(6)**

f. If the antenna is lossless and operates at 1GHz calculate the maximum power received by an isotropic receive antenna 1km away due to 100W input transmit power **(4)**

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

AT