Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2014-15 (3.0 hours)

EEE6223 Antennas, Propagation and Satellite Systems

Answer **FOUR** questions. **No marks will be awarded for solutions to a fifth 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. Where a symbol or abbreviation is not defined it can be assumed to have its usual meaning with which candidates should be familiar. ANSWER AT LEAST ONE QUESTION FROM EACH SECTION. NO MARKS WILL BE GIVEN FOR SOLUTIONS TO A FOURTH QUESTION FROM SECTION A.** ***ANSWERS TO SECTION A SHOULD BE IN A SEPARATE ANSWER BOOK TO THOSE FOR SECTION B. LABEL EACH ANSWER BOOK CLEARLY AS 'SECTION A' OR 'SECTION B'***

SECTION A - Antennas and Propagation

1. a. Explain how an HF radio wave can be ‘reflected’ back to earth by the ionosphere, and hence show that

$$\cos i_o = \frac{\omega_c}{\omega}.$$ **(8)**

b. If an *8MHz* signal takes *2.5ms* to be reflected back to earth, calculate the electron density and height of the reflection layer, and identify it. Assume the speed of propagation of radio waves is $3\times 10^8 m/s$. **(6)**

c. A signal is transmitted at zero elevation angle and is reflected by this layer. What must the frequency of this transmission therefore be? Assuming this is the sole ionospheric layer, what can be said about the propagation of signals with frequencies higher and lower than this? Assume the radius of the earth is *6000km*. **(6)**

2. **a.** The E-plane radiation pattern of a co-linear array of half wave dipoles positioned axially along the *z* axis is given by

$$E_\theta = C\frac{\cos\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)} \times \frac{I\sin\left(\frac{Nkd}{2}\cos(\theta)\right)}{\sin\left(\frac{kd}{2}\cos(\theta)\right)}$$

Write down an expression for

(i) The individual dipole radiation pattern

(ii) The array factor.

(iii) The excitation current I of each dipole if the transmitter is delivering a total current I_o

(iv) The approximate input impedance of the array before any matching **(5)**

b. For an *11* element array with inter-element spacing of 0.7λ calculate

(i) The antenna gain

(ii) The position and height (with respect to the main lobe) of the 1st sidelobe

(iii) The *3dB* beamwidth of the main lobe

(12)

c. Explain how the main beam could be electronically steered, and how one might obtain an asymmetric sidelobe distribution in the E-plane pattern either side of the main lobe. Why might such asymmetry be useful? **(3)**

Useful relation for this question:

$$\left.\frac{\sin(Nx)}{N\sin(x)}\right|_{N=11,x=0.127} = 0.71$$

3. **a.** Show that the gain of a centre fed full wave dipole antenna ($L = \lambda$) in free space is *3.8dBi*. The following expressions should be of use:

$$|E_\theta| = \frac{2\eta I_o}{4\pi r}\left[\frac{\cos\left(k\frac{L}{2}\cos(\theta)\right) - \cos\left(k\frac{L}{2}\right)}{\sin(\theta)}\right]$$

$$\int_0^\pi \frac{\cos^2(\pi\cos(\theta)+1)}{\sin(\theta)}\,d\theta = 3.318$$

where $\eta = 377\Omega$. **(12)**

b. Explain the advantages and disadvantages of using a full wave dipole instead of a half wave dipole in a radio communication link. **(2)**

c. Calculate the power received by a full wave dipole from a distant *800MHz* transmitter producing a co-polar *75mV/m* incident electric field. **(4)**

d. What is the power received by a full wave dipole receiving the same incident field strength at *1600MHz*? **(2)**

4. **a.** Sketch the current distributions and E-plane radiation patterns of the following monopoles fed against an infinite groundplane:

(i) A $\lambda / 4$ long monopole,

(ii) A $\lambda / 2$ long monopole,

(iii) A $3\lambda / 4$ long monopole.

Assume all conductors are perfect. **(6)**

b. If the radiation pattern of the $\lambda / 4$ monopole in the half space above the groundplane is given by

$$|E_\theta| = \frac{\eta I_o}{2\pi r} \frac{\cos\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)}$$

where $\eta = 377\Omega$, calculate the monopole's

(i) radiation resistance

(ii) gain over isotropic in the direction $\theta = 90^o$.

The following relation may be of use:

$$\int_0^{\pi/2} \frac{\cos^2\left(\frac{\pi}{2}\cos(\theta)\right)}{\sin(\theta)} d\theta = 0.61$$

(12)

c. Compare your values for **b.**(i) and **b.**(ii) with those for a half wave dipole. **(2)**

SECTION B - Satellite Systems

5. **a.** Discuss the orbits available to satellite system designers and typical uses for each. **(6)**

b. What advantages do satellite communications have over terrestrial systems and what are the key challenges faced by designers? **(6)**

c. Explain the terms:

(i) Noise power

(ii) Noise factor

(iii) Noise figure **(3)**

d. An antenna with a noise temperature of 105K is connected to a receiver using a cable with a loss of 2 dB. If the receiver noise figure is 2dB what is the overall noise temperature of the system? Assume the cable temperature is 290 K. **(5)**

6. **a.** Briefly describe the challenges facing a communications satellite from launch to life in orbit and how these are alleviated in spacecraft design. **(6)**

b. A satellite receiver operating at 12 GHz has a noise figure of 2 dB. If it is directly connected to an antenna/pre-amplifier with a gain of 7 dB and a noise temperature of 100 K, estimate the overall system noise figure.

If the antenna/pre-amplifier is now connected to the receiver via a 5m length of coaxial cable with an attenuation of 3dB, estimate the new system noise figure. **(7)**

c. Derive an expression for the noise figure of a cascade of three amplifier stages in a receiver. Comment on the design of the first amplifier (Pre-amplifier) that would be suitable for use in a satellite receiver. **(7)**

GGC/JMRIG/JZ