UNIVERSITY OF SURREY©

Department of Electronic Engineering

MSc EXAMINATION

EEM.Ant

Antennas and Propagation

Duration: 2 Hours Spring 2003/04

READ THESE INSTRUCTIONS

Answer **THREE** questions from six, one from each section.

USE A SEPARATE ANSWER BOOK FOR EACH SECTION
On the front sheet of EACH answer book, complete the list of questions attempted **in that book** in the order they appear. Then draw a line below this list and add the question numbers you have attempted in the *other* answer books.

SECTION A

A1 (a) Write definitions and notes on the terms

Isotropic
Radiation resistance
Polarisation
Power radiation pattern
Side lobe

in the context of antenna design and construction. **[25%]**

(b) Give an example of a linearly polarised antenna, and of a circularly polarised antenna, and state the advantages and disadvantages of each on an earth-to-satellite communications link. **[15%]**

(c) A turnstile antenna is constructed from a pair of dipoles. Sketch the construction and indicate the phasing of the currents in the elements. For this antenna,

(i) indicate a direction where the polarisation is circular

(ii) Estimate the maximum-to-minimum radiated power level around the radiation sphere

(iii) Explain how the sense of circular polarisation may be chosen.

[25%]

(d) An antenna is constructed from two such turnstiles, stacked one above the other in a vertical line. The separation of the turnstiles is one half wavelength. The turnstiles are fed in-phase. Estimate the azimuth-plane gain in dBi, and indicate what the vertical-direction radiation properties are likely to be. **[25%]**

(e) Explain how the presence of a perfectly conducting ground under such a stacked antenna might change its radiation properties. **[10%]**

A2 (a) Write down the formula relating the gain of an aperture antenna to its effective area for the capture of radiation, and to the wavelenth of the radiation. **[15%]**

(b) Estimate the diameter of a dish designed for a 45dBi gain antenna at a frequency of 20GHz. **[10%]**

(c) Define the terms

spillover
tapered illumination
aperture efficiency

and discuss these terms in relation to the sidelobe performance of a Cassegrain reflector dish antenna. **[25%]**

(d) A certain spacecraft to Earth communications link at 15GHz is specified to work at a maximum range of 400,000 km with a bandwidth of 30MHz. The satellite dish size is limited to 1.5 metres circular dish diameter equivalent. Estimate, showing your reasoning, the minimum size of the earth ground station dish which would be needed. Assume a noise temperature of 290K for the downlink. **[35%]**

(e) Calculate what the required pointing accuracy would be for this earth station dish. **[15%]**

SECTION B

B3 (a) Define the terms:-

(i) Radiation Resistance

(ii) Antenna Bandwidth (with respect to input impedance)

(iii) Antenna Pattern Bandwidth.

[30%]

(b) An antenna has an input impedance of 50 ±j50:-

(i) Find the reflection coefficient on a 50 ohm line feeding the antenna.

(ii) Find the VSWR on the feeder

(iii) Explain how this relates to part (a) above

[30%]

(c) The electric field at a distance *r* from, and at an angle θ to, a current element *idl* along a wire antenna, is given by

$$E = j\pi Z_0 \lambda^{-1} \int r^{-1} \sin\theta \, e^{-jkr} \; idl$$

where $Z_0 = 120\pi$

(i) Explain why any short dipole has a directivity of 1.5

(ii) Find the input radiation resistance of a short dipole of total length l, and explain your method

[40%]

B4 (a) For ionospheric propagation, briefly define (at least eight of) the following terms and give any inter-relationships between them:-

(i) Critical Frequency, and f_0F1, f_0F2, etc

(ii) MUF (Maximum Usable Frequency)

(iii) OWF

(iv) Plasma frequency and plasma resonance

(v) Ordinary wave

(vi) X-wave

(vii) Gyro-magnetic frequency

(viii) 'Luxembourg effect'

(ix) D-layer absorption

(x) LUF

[70%]

(b) For an MUF of 28MHz and a Critical Frequency of 8MHz

(i) Estimate the 'virtual height' of the operative ionospheric layer, given that the radius of the earth is 20,000/π km. (Hint;- use the 'secant law' and assume 'grazing incidence' for MUF propagation).

(ii) Estimate the maximum single-hop path length for this layer.

[30%]

SECTION C

C5 (a) Figure C5 shows an outdoor transmitter (Tx) at 1800MHz and an indoor receiver (Rx) placed exactly in the middle of a square building. Both the transmitter and receiver are on the ground floor and both have the same antenna heights. Show how you would estimate the path loss (L_{dB}) at the receiver by identifying the relevant ray path and the parameters involved when using COST231 outdoor to indoor model. Hence calculate the received signal for a transmitted power of 0dBW, a receiver antenna gain of 0dBd and transmitter antenna gain of 5dBi. Assume all feeder losses to be negligible.

[35%]

Parameter	Material	Approximate value
L_e	External concrete wall with windows External wood wall with windows	7dB 4dB
L_i	Internal concrete wall Internal wood and plaster wall	7dB 4dB
L_g	-	20dB
α	-	0.6 dB/m

Table C5

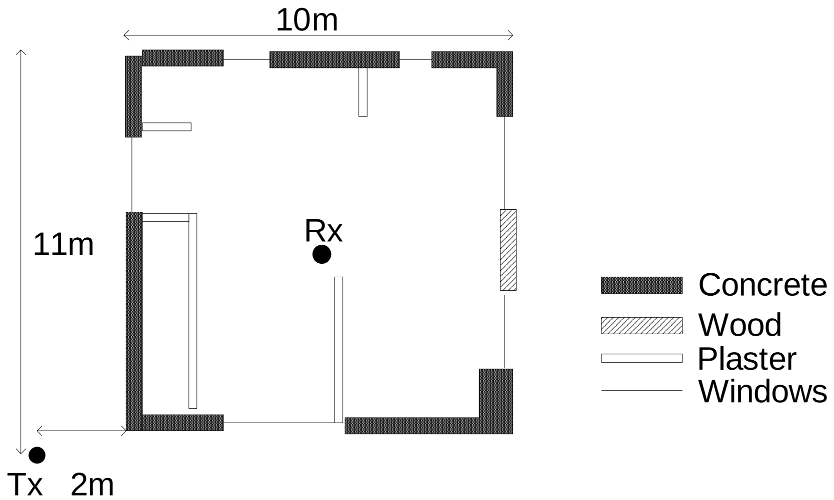

Figure C5

COST231:

$$L_{dB} = 32.4 + 20\log\left(f_{GHz}\right) + 20\log(r_e + r_i) + L_e + L_g\left(1-\cos\theta\right)^2 + \max\left(L_1, L_2\right)$$

$$L_1 = L_i n_w$$

$$L_2 = a\left(r_i - 2\right)\left(1-\cos\theta\right)^2$$

Question C5 continues on the next page

Question C5 continued

(b) A radio propagation campaign is carried out for comparison purposes to check the theoretical results produced by the above model. Do you expect to see any differences between the measured data and the theoretical predictions produced by the above model and why? **[10%]**

(c) Is there any room for improvement to the modelling process of part (a) and why? **[20%]**

(d) Explain what we mean by the term of "smooth" and " rough" surface in the context of radio wave propagation. In the latter case how can we account for the reduction in amplitude of a reflected wave? **[20%]**

(e) Name the parameters/factors that can influence radio wave propagation through building interfaces like external and internal walls, windows etc. **[10%]**

(f) Define ionospheric, tropospheric and local radio wave propagation effects. **[15%]**

C6 The link budget parameters for a satellite to ground fixed link, operating at 8GHz, with a satellite altitude of 35000 km, are shown below:

Satellite parameters	Receiver parameters
Transmit power: 10dBW	Required signal power: 150dBm
Transmitter antenna gain: 45dBd	Receiver antenna gain: 50dBi
Feeder losses: 3dB	Feeder losses: 3dB

(a) Calculate the free space loss for this link **[5%]**

(b) Calculate the available fade margin **[5%]**

(c) What are the steps for predicting propagation loss over terrestrial fixed links? **[20%]**

(d) Define linear, circular, elliptical and random polarisation **[20%]**

(e) What steps are involved when using Geometrical optics to calculate the received field? What are the assumptions made and limitations when using this method? What other method can we use to overcome these limitations? **[25%]**

(f) How would you expect the transmission loss to vary in:

(i) a relatively thick, homogeneous, high loss dielectric layer?

(ii) a relatively thin, homogeneous, low loss dielectric layer?

if the thickness of the dielectric layer progressively increases. **[25%]**

Examiners: D.Jefferies
M.Underhill
S.Stavrou
External Examiners: I.Wilson
S.McLaughlin