UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE

DEPARTMENT OF ELECTRONIC ENGINEERING
MAIN EXAMINATION, DECEMBER 2007

TITLE OF PAPER : ANTENNAS AND WAVE PROPAGATION

COURSE NUMBER : ECO510

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : READ EACH QUESTION CAREFULLY
ANSWER ANY **FOUR** OUT OF **FIVE** QUESTIONS.
EACH QUESTION CARRIES **25 MARKS.**
MARKS FOR EACH SECTION ARE SHOWN
ON THE RIGHT-HAND MARGIN.
USEFUL INFORMATION IS ATTACHED.

THIS PAPER HAS 7 PAGES INCLUDING THIS PAGE.

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR.

USEFUL INFORMATION

Radar equation $P_r = P_t G_t G_r \lambda^2 \sigma / (4\pi)^3 r^4$

The effective relative permittivity of a dielectric $\epsilon = 1 - e^2 N / m\omega^2 \varepsilon_0$

Electronic charge $e = 1.6 \times 10^{-19}\ C$

Permittivity of space $\varepsilon_0 = 8.85 \times 10^{-12}\ F/m$

Electronic mass $m = 9 \times 10^{-31}$ kg.

Effective radius of the earth plus the mean terrain level $R_e = 8500$ km

Antenna efficiency factor $k = 0.55$

General expression for gain (4Πk) (effective area) / λ^2

Conductivity of No. 20 AWG copper wire $\sigma = 5.7 \times 10^7$ mhos/m

Permeability of free space $\mu o = 4\Pi \times 10^{-7}$ H/m

R_r -radiation resistance $R_r = 790\left(\frac{\ell}{\lambda}\right)^2$,

surface resistance $R_s = \sqrt{\frac{\omega\mu}{2\sigma}}$

QUESTION 1

(a) Two point sources energized by in - phase current, are spaced a distance r apart in the horizontal plane. The field strengths of each, are approximately equal at a distant point 0, which is at θ to the line joining the centres of the two point sources. The field strength due to a single source when energized by power P_i is Eo.

(i) What is the phase difference between the two signals? (3 marks)

(ii) If the two element array is energized by the same power as that of a single source, derive an expression for the resultant field E_R at point 0. (7 marks)

(iii) Give reasons why the signal strength received by a VHF aerial vary with height above ground. (4 marks)

(b) An ideal copper wire antenna of effective length 60 cm, operates at a frequency of 1 MHz. The radius of the wire is 4.06×10^{-4} m.

(i) Compute the radiation efficiency of the antenna. (10 marks)

(ii) How can the efficiency of the antenna be modified, if there is need to? (1 mark)

QUESTION 2

(a) Consider the ionosphere as an ionized medium with N free electrons per cubic meter available for conduction. It can thus be defined in terms of the primary parameters: the conductivity σ and the permittivity ϵ. If a sinusoidally varying electromagnetic wave is incident on the layer and the total current density is $J_T = \sigma E + j\omega\epsilon E$, derive an expression for the refractive index of the layer. Assume the total force on the electron includes that due to collisions.

(11 marks)

(b) Explain the phenomenon of radio horizon in relation to electromagnetic radiation.

(3 marks)

(c) Television channels are allocated a bandwidth of 6 MHz in the Ultra High Frequency range. Channel 30 occupies a frequency span, 566 - 572 MHz. Design a $\lambda/2$ Yagi antenna with 3 directors for reception of Channel 30.

(11 marks)

QUESTION 3

(a) In the microwave range of frequencies, communication links are designed on the basis of direct ray propagation. The high frequencies of the microwave region offer wideband capability allowing simultaneous transmission of many voice and picture channels. For point-to-point terrestrial transmissions, the maximum range is limited by the curvature of the Earth.

(i) Derive an expression for maximum range of a microwave link.

(9 marks)

(ii) An aircraft flying at an altitude of 20 km above the ground transmits signals to a military base antenna pitched on a 100 m - high tower. Assuming both physical and polarization discrimination, determine the maximum distance of signal reception.

(3 marks)

(iii) The receiving antenna on the tower has a gain of 12 dB in the direction of the receiver. The output power is 500 W. Compute the electric field strength at the receiving antenna.

(4 marks)

(vi) Explain what is meant by virtual height. (3 marks)

(vii) Develop an equation for the received power as a function of the electric field and magnetic field intensities at a large distance r from a $\lambda/2$ dipole antenna in the direction of maximum radiation. The antenna has power gain G in that direction, a radiation resistance R_{rad} and an excitation current I.

(6 marks)

QUESTION 4

(a) The total predicted electric field strength, 100 km from a 1 MHz, elementary doublet antenna, radiating 9 kW of power into space, is found to be 61.54 dBμ. Propagation charts of field strength against distance for specified values of contributory ground parameters and operating frequencies can be used to estimate the electric field strength. Compute the value of the estimated electric field at 100 km from the transmitter if propagation charts were used.

(8 marks)

(b) Consider a satellite communication system operating at a wavelength of 6 cm with a spherical balloon of equivalent echoing area 10 m^2 and identical aerials of 50 dB gain for transmission and reception. The transmitter power is 10 kW. The receiving aerial noise temperature is 20 K and the receiver noise temperature is 30 K. The distance from the balloon to the transmitting and receiving aerials are 2000 and 3000 km respectively. Calculate the

(i) received signal in dBm. (11 marks)

(ii) the input signal - to - noise at the receiver assuming a bandwidth of 10 kHz. (7 marks)

QUESTION 5

Signals from a 10 MHz vertically polarized radiator, placed over a reflecting plane ground surface, travel along the sky, ground and direct paths, in the vicinity of ionospheric layers with a maximum free electron density of 10^{10} m^{-3} .

(i) Which signals will reach a receiver placed at a distance **d** from the radiator?

(5 marks)

(ii) Derive an expression (in terms of the transmitting and receiving antenna heights, h_t and h_r respectively) for the difference in path length between all signals reaching the receiver.

(10 marks)

(iii) What is the phase difference between the signals for a 16 m high receiver, 60 km from the 10 MHz radiator?

(7 marks)

(iv) Determine the magnitude of the peak received electric field strength.

(3 marks)