UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
DEPARTMENT OF ELECTRONIC ENGINEERING
DECEMBER EXAMINATION 2008

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.

THIS PAPER HAS 7 PAGES INCLUDING THIS PAGE.

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USEFUL INFORMATION

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

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

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

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

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

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

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

Antenna efficiency factor $\quad k = 0.55$

Figure of merit for shot vertical monopole $\quad 300$

General expression for gain $\quad (4\pi k)$ (effective area) / λ^2

$p = 0.582 df^2 / \sigma$,

$\frac{p}{A} = 0.582 f^2 E_1 / \sigma E_m$

$A = (2 + 0.3p) / (2 + p + 0.6p^2)$,

Friis equation

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

QUESTION 1

(a) A 10 GHz tracking radar uses a common 2.0 m diameter dish antenna. The efficiency of the antenna is 0.7 for both transmission and reception. The average power re-radiated by the target is 10^{-13} W. Determine

(i) the power received by the receiver in dBm, (7 marks)

(ii) the range at which a target of 4.0 m^2 echoing area will first be detected if the transmitter average power output is 10 kW and (7 marks)

(iii) the gain of the dish antenna. (3 marks)

(b) (i) Under what conditions is maximum power transferred from the transmitter to the transmitting antenna? (2 marks)

(ii) At the receiving terminal, if the induced voltage on the receiving antenna is V_{rms} , deduce an expression which relates the maximum power P_{max}, transferred from the antenna to its receiver, and the induced voltage. (6 marks)

QUESTION 2

(a) The local television transmission is to cover a community living over a radius of 35 km. Due to some local ordinances, the highest receiving antenna is restricted to 5 m above ground.
How high should the local television station pitch their antenna for the signal to cover the whole community?

(8 marks)

(b) Explain the term maximum usable frequency with reference to a given ionospheric layer. (1 mark)

(c) The bending of electromagnetic waves as they pass through a medium with varying permeability or refractivity is governed by Snell's law. Consider an electromagnetic wave following a downward path from a medium with refractive index n_{x-1} to another with refractive index n_x .The em wave will be refracted such that the radius of curvature at any point is inversely proportional to the gradient of the refractive index.
If the downward path makes an angle θ with the vertical and $n_{x-1} < n_x$, using a clear diagram, derive an expression relating the radius of curvature of the earth at any point to the gradient of the refractive index, ***dn/dh,*** where ***h*** is the height.

(12 marks)

(d) An electromagnetic signal propagating at 14 MHz and incident on the bottom of a layer with $N = 1.96 \times 10^{12}$ electrons/ m^3 is refracted parallel to the earth's surface. Which angle of incidence will satisfy this condition?

(4 marks)

QUESTION 3

(a) Explain what is meant by

(i) the properties power gain G and effective receiving area A, of an antenna. (2 marks)

(ii) reciprocity and radiation resistance as applied to antennas. (3 marks)

(b) A point source, fed with power P_i radiates isotropically. The radiation is observed to decrease with distance away from the source. Derive an expression for the electric field E, a distance r away from the source in terms of the input power.

(5 marks)

(c) A space research satellite operating at 136 MHz, transmits signals to an earth receiver station 500 km away. The satellite antenna, with input impedance 50 Ω is energized by a 0.1 A current and has a gain of 3 dB with reference to an isotropic antenna. Compute the electric field at the point of reception.

(6 marks)

(d) With reference to part (c) above, what is the received signal power if the antenna at the earth station, has a gain of 20 dB with reference to an isotropic antenna?

(9 marks)

QUESTION 4

(a) Explain what you understand by the recovery effect with reference to electromagnetic wave propagation over mixed land - sea paths?

(2 marks)

(b) (i) Explain why a Forestry company, situated about 400 km from both, a non-synchronized medium frequency radio transmitter and the wanted transmitter, experiences night-time interference between the two stations. The two are operating at the same frequency but broadcasting different programmes.

(4 marks)

(ii) What is the probable range of good reception from an AM radio broadcasting transmitter with E_1 = 1500 mV/m over surrounding land with mean conductivity σ = 10 mS/m? Assume that the minimum level for good reception is 10 mV/m in a city, given the numerical distance of 2.0.

(9 marks)

(c) (i) Explain what is meant by tropospheric scatter in relation to beyond - the - horizon transmission. (2 marks)

(ii) A 5 GHz receiving aerial of a tropospheric scatter link has gain of 50 dB. The incident signal of power density 1.76×10^{-27} W/m^2 yields a signal-to-noise ratio of 12 dB in a bandwidth of 10 kHz at the aerial terminals.
Compute the equivalent noise temperature of the antenna.

(8 marks)

QUESTION 5

The newly established Eswatini Royal inn wants to install an inexpensive but very efficient broadband antenna for use by its customers. They should be able to tune into anyone of the available programmes in the 54 MHz to 216 MHz frequency band.

You are tasked with designing such an antenna for optimum performance using a spacing factor and scale factor of $\sigma = 0.822$ and $\tau = 0.787$, respectively.

The design must include a well labeled geometrical structure of the antenna.

(25 marks)