UNIVERSITY OF SWAZILAND
FACULTY OF SCIENCE
SUPPLEMENTARY EXAMINATION JULY 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 6 PAGES INCLUDING THIS PAGE.

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USEFUL INFORMATION

Electronic charge $e = 1.6\times10^{-19}$ C,
permittivity of free space $\epsilon_o = 8.85 \times 10^{-12}$ F/m
electronic mass $m = 9 \times 10^{-31}$ kg.

Effective radius of the earth, $R_e = 8500$ km

Antenna efficiency factor, $k = 0.55$

Gain for $\lambda/2 = 1.64$

Power at receiving antenna, $P_r = (P_t G_t G_r \lambda^2) / (16 \pi^2 r^2)$

Total radiated power from the antenna, $P_{rad} = (\pi\eta I_o^2 l^2) / (3 \lambda^2)$

The magnitude of the electric field strength in air $|E| = (60\pi I_o l \sin\theta) / (\lambda r)$
Spread angle, $\tan(\alpha/2) = (1 - \tau) / (4\sigma)$
General gain expression = (4π) (effective area) / λ^2

Frii's transmission formula

$$p_r = \left(\frac{p_{rad} G_t \ G_r}{\left(\frac{4\pi r}{\lambda}\right)^2} \right)$$

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

QUESTION 1

(a) Derive a simple equation which can be used to estimate the magnitude of the electric field at d km from a transmitting station on the sea. The sea-land path consists of d_1 km of sea and d_2 km of land. Use well labelled sketches where necessary. Explaining all terms in the equation.

(13 marks)

(b) Consider an ionospheric layer whose relative permittivity $\varepsilon_r = 1 - \frac{Ne^2}{\varepsilon_o m\omega^2}$.

N is the density of electrons/m^3, e and m are the electron charge and mass respectively.

(i) Develop an expression for the critical frequency of the layer.

(5 marks)

(i) A signal is incident on the bottom of a layer at an angle of 25° to the normal. Determine the frequency which should be used to ensure the signal returns if the electron density for the layer is $1.44 \times 10^{12}/m^3$.

(3 marks)

(ii) Briefly explain the meaning of the terms

(i) virtual height (2 marks)

(ii) skip distance (2 marks)

QUESTION 2

The National Swaziland FM broadcast radio operates over the frequency band 88 MHz to 108 MHz. The radio channels in the range 88 MHz to 92 MHz are educational while the remaining commercial ones occupy the rest of the band from 92 MHz. The Ministry of Education desires to tune onto anyone of the two types of broadcast using a single FM antenna.

Design such an antenna, ensuring good coverage at the band edges. Include a well labeled geometrical structure. Let the spacing and scale factors be σ = 0.18 and T = 0.92, respectively.

(25 marks)

QUESTION 3

A 5 - GHz microwave communication link operates through two repeater towers. If the minimum detectable receiver power, Pr = - 46.0 dBm, the transmitter power Pt = 50dBm and the antenna diameter d = 2.0 m, compute

(i) the maximum possible spacing between the two repeater towers

(11 marks)

(ii) the minimum height of both the transmitting and receiving antennas that will effectively make use of the range capability in (i).

(5 marks)

(iii) If the receiver noise temperature is 200 K, compute the signal - to - noise ratio at the receiver output assuming a bandwidth of 10 MHz.

(9 marks)

QUESTION 4

(a) A 20 MHz incident plane wave has an rms electric field strength of 5 mV/m. Compute the received power by a properly terminated $\lambda/2$ dipole.

(8 marks)

(b) A research Satellite operating at a frequency of 136 MHz, is at a range of 500 km form a receiving earth station. The satellite transmitter supplies 0.75 W into a 3 dB aerial with reference to an isotrope. For free space propagation with an impedance of 120 Π, compute

(i) the field strength at the earth station (5 marks)

(ii) the power flux density. (3 marks)

(iii) The effective absorbing area of an isotropic antenna is $\lambda^2/4\pi$. Compute the received signal power if the earth station antenna has a gain of 30 dB.

(6 marks)

(iv) If the receiving antenna has an effective length of 1.5 m and a radiation resistance of 50 Ω, determine the voltage induced in the antenna.

(3 marks)

QUESTION 5

(a) The transmission from a new TV station is to reach customers up to 80 km away. How tall must the antenna be raised ?

(3 marks)

(b) Due to local ordinances, the highest tower possible on this site is 320 m. Roof heights are 3.3 m and 1 m poles are available for mounting antennas. Are there any solutions that will let the original viewing area be maintained ?

(7 marks)

(c) A spherical target has a diameter of 3.57 m and radar cross-sectional area approximately 0.025% of its actual cross-sectional area. Given that the transmitted power is 1 MW, at an operating frequency of 5 GHz, a gain of 45 dB, the minimum detectable signal power of -115 dBm,

(i) compute the maximum range for detecting the target.

(5 marks)

(ii) How much increase in antenna gain is needed to double the range capability of a radar which uses a common antenna for transmitting and receiving? (2 mark)

(iii) Estimate the electric field strength at d = 50 km from a short vertical monopole (FM = 300) radiating power P_t = 10 kW at frequency f = 900 kHz over ground with mean conductivity σ = 10 mS/m.

(8 marks)