# UNIVERSITY OF SWAZILAND
# FACULTY OF SCIENCE

## DEPARTMENT OF ELECTRONIC ENGINEERING
## MAIN EXAMINATION 2005/2006

TITLE OF PAPER : ANTENNAS AND WAVE PROPAGATION

COURSE NUMBER : ECO510

TIME ALLOWED : THREE HOURS

INSTRUCTIONS : READ EACH QUESTION CAREFULLY
ANSWER ANY **FOUR** OUT OF **SIX** 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.

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

## USEFUL INFORMATION

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|---|---|
| $R_r$ - radiation resistance | $R_r = 790\left(\frac{\ell}{\lambda}\right)^2$ |
| The effective relative permittivity of a dielectric | $\epsilon = 1 - \frac{e^2 N}{m\omega^2 \varepsilon_0}$ |
| 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 | $k = 0.55$ |
| Gain for $\lambda/2$ | 1.64 |
| General expression for gain | $(4\pi k)$ (effective area) / $\lambda^2$ |
| The radar equation | $P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 r^4}$ |
| Figure of merit for a $\lambda/2$ dipole antenna | 222 |

## QUESTION 1

(a) The power density of an isotropic radiator, fed with power *P* watts is measured at distance r away. Derive expressions for the magnitudes of both the electric and magnetic field intensities at *r* from the radiator. ( 7 marks )

(b) The point source of (a) is replaced by a transmitting antenna of power gain 20 dB in the direction of maximum radiation and radiation resistance of 50 Ω. A receiver is placed at r = 50 km from the transmitter. For an excitation current of 0.5 A in the transmitting antenna, determine:

(i) the power density

( 5 marks )

(ii) the electric field intensity at the receiver.

( 3 marks )

(iii) The induced voltage in the receiving antenna is 4 mV and its radiation resistance is 73 Ω, what is its effective length? ( 3 marks )

(iv) Determine the total power available to a receiver under matched conditions.

( 3 marks )

(c) A 720 kHz radio station transmits from the Medium Wave band using a horizontally polarized half-wave antenna. How can the same station effectively transmit from a vertically polarized antenna?

( 4 marks )

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## QUESTION 2

(a) A small community which lives in a mountainous area, has asked your company to carry out some research and advice them on the best location for a small but effective transmitting station to cater for all the residents over a radius of 4 km.. Present a short report of how you will determine the best location for the transmitting antenna, include diagrams, derived expressions, etc. ( 8 marks )

(b) In a simple model of space wave propagation, the received field strength is the resultant of the field strengths of the direct and reflected waves. For a transmitting antenna, *d* meters from a receiving one, derive an expression for the possible phase lag between the reflected and direct waves arriving at the receiver. Assume a flat and horizontal boundary. ( 7 marks )

(c) An electromagnetic wave of field strength $E = E_o Sin(\omega t)$ is incident on an ionized medium with *N* free electrons per $m^3$ available for conduction. Taking the total force on the electron to include that due to collisions between gas molecules and electrons, and neglecting the effect of the earth's magnetic field,

(i) derive expressions for both the conductivity $\sigma$ and the relative permittivity $\epsilon_r$ of the medium if the total current density can be expressed as $J = \sigma E + j\omega\varepsilon E$, where $\varepsilon$ is the permittivity of the material. ( 7 marks )

(ii) Develop an expression for the critical frequency using results of (i) above. ( 3 marks )

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**QUESTION 3**

(a) The working class in a small town plan to operate a Medium Frequency broadcasting station. Which mode of wave propagation and times of transmission will be best? Briefly explain. ( 3 marks )

(b) The radiation pattern of a horizontally polarized half - wavelength dipole antenna is bidirectional. This can be greatly improved to give a radiation pattern where most of the energy is concentrated towards one direction only. Explain, using diagrams where necessary, a simple inexpensive way of achieving this using a second half - wavelength dipole antenna. ( 10 marks )

(c) A communication link is established between two systems. The transmitting and receiving antennas are separated by 120 km. The point of reflection, located between the two antennas, is 80 km from the transmitter. The height of the receiving antenna $h^1_r$ =100 m above mean terrain level. Assuming that the effective radius of the earth plus the mean terrain level total to 8500 km, determine the antenna heights $h_t$, $h_r$, and the transmitting antenna height $h^1_t$ above mean terrain level. ( 12 marks )

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**QUESTION 4**

(a) A transmitter operating at 1 MHz with $E_1$ = 3000 mV $m^{-1}$ is used for communication with a receiver situated 300 km away. The ground path consists of 100 km of ground with parameters $\sigma$ = 10 mS $m^{-1}$ and $\epsilon_r$ = 4, and then a further 200 km of sea with parameters $\sigma$ = 4000 mS $m^{-1}$ and $\epsilon_r$ = 80. With reference to Figure 4, estimate the field strength at the receiver. ( 15 marks )

(b) A 100 m high transmitting antenna is located 60 km from a receiver. Calculate the required height of the receiving antenna which will enable line - of - sight reception. ( 6 marks )

(c) Explain the following terms

(i) Multipath fading ( 2 marks )

(ii) Virtual height of an ionospheric layer. ( 2 marks )

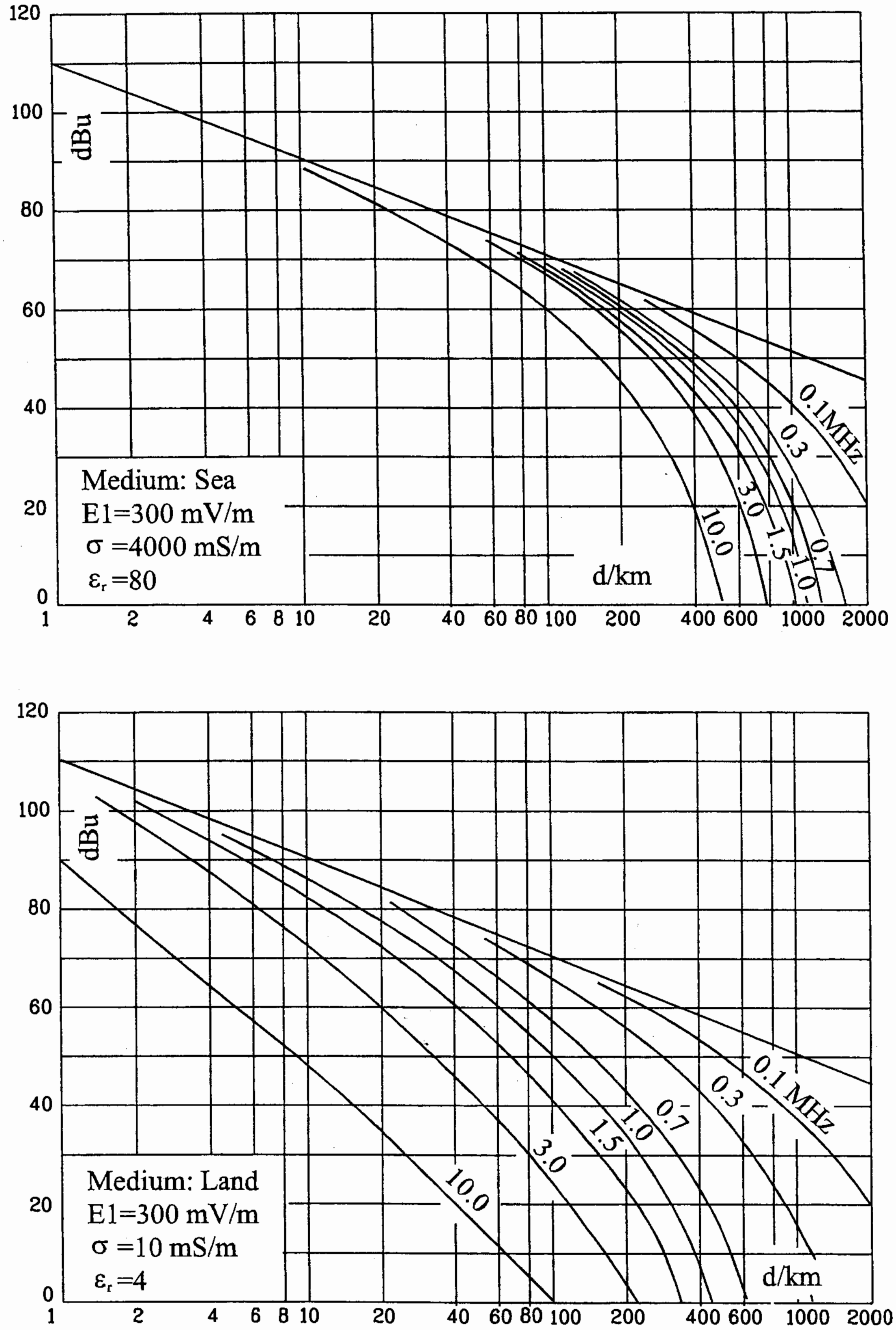


Figure 4 Ground propagation paths

## QUESTION 5

(a) An electromagnetic wave follows a downward path from medium 1 with refractive index $n_{x+1}$ to medium 2 with refractive index $n_x$ , where $n_{x+1} < n_x$ . Snell's law, under the given conditions states that $n_{x+1} \sin r_{x+1}$ = constant. The em wave will be refracted such that the resulting radius of curvature R at any point is inversely proportional to the gradient of the refractive index ( the rate of decrease of refractive index with height ) $\frac{-dn}{dh}$ . Derive an expression which relates R to $\frac{-dn}{dh}$ using appropriate diagrams.

( 11 marks )

(b) (i) The ionosphere may be generally seen as a region of ionized layers each characterized by different electron densities, *N* (the number of free electrons per cubic meter). Define the refractive index *n* of the ionosphere and compute a simple expression for *n* in terms of *N* and frequency of propagation *f*. ( 8 marks )

(ii) It is desired to use an ionospheric layer with an electron density of $2 \times 10^{12}$ $m^{-3}$ to reflect vertically launched signals propagating at 11 MHz. back to earth. Show by way of calculations if this will be possible. ( 4 marks )

(c) Explain the following with reference to radio communication.

(i) Tropospheric scatter ( 1 mark )

(ii) Define the maximum usable frequency. ( 1 mark )

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**QUESTION 6**

(a) A radar system consists of a transmit and receive antenna at distances of $r_t$ and $r_r$ respectively from a target object. Both antennas are pointed such that the pattern maxima are directed toward the target which has an echoing area δ. If the power reaching the target is isotropically scattered, deduce an expression for the power scattered by the target as a function of the echoing area, δ.

( 5 marks )

(b) A target of 0.02 $m^2$ echoing area at a range of 100 km, is being tracked by a 9 GHz tracking radar. The gain of the common transmitting and receiving antenna is 45 dB. If a 1 MW transmitter is used with a low noise receiver system(T = 60 K, noise bandwidth = 1 MHz), determine

(i) the received signal power in dBm and ( 6 marks )

(ii) the received signal - to - noise ratio in dB. ( 6 marks )

(iii) How much increase in antenna gain is needed to double the range capability of the radar using a common antenna for transmitting and receiving?

( 2 marks )

(c) A λ/2 dipole antenna operating at 300 kHz is supplied with 1 mA rms current, what is the unattenuated field at 1 km from the antenna? ( 6 marks )

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