UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: February 2020

Module Number: EE6301 **Module Name: Communication Systems**

[Three Hours]

[Answer **all questions,** each question carries **10 marks]**

All notations have their usual meaning.

Q1 a) Obtain an expression for the voltage reflection coefficient at any point on a lossless transmission line, distance l away from the load end.

Hint:

Consider the general solution for the voltage wave equation of a transmission line is given by

$$v(z) = V^{+}e^{-\gamma z} + V^{-}e^{\gamma z}$$

where z is the distance measured from the source end of the transmission line.

[2.0 Marks]

b) A transmission line shown in Figure Q1 feeds two parallel load impedances $Z_{R1} = (200 + j200)\ \Omega$ and $Z_{R2} = (100 - j100)\ \Omega$ through a half wavelength section and a quarter wavelength section respectively. The characteristic impedance of the two sections is $200\,\Omega$. Use the provided Smith Chart to determine the followings.

i) Impedance at the terminals AB.

ii) Position and length of the short circuited shunt stub that will match the line to the load at terminals AB.

Note:

Give only one solution and attach the Smith Chart to the answer script.

[8. 0 Marks]

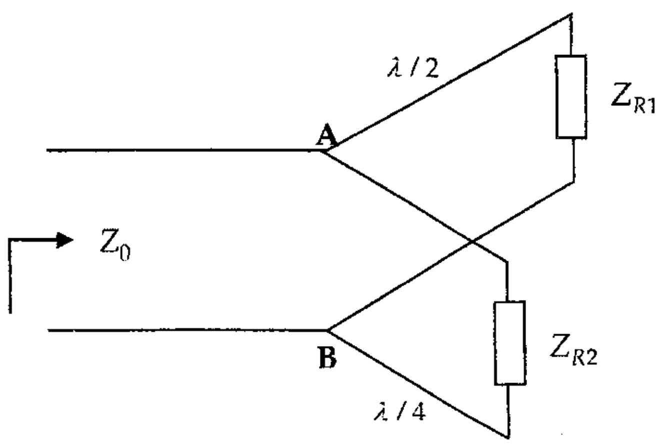


Figure Q1

Q2 a) Explain what is meant by the dominant mode of a rectangular waveguide.

[1.0 Mark]

b) A sinusoidal wave propagating in a rectangular waveguide has the following field components in the z-direction (direction along the axis of the waveguide).

$$H_z = H_0 \cos\left(\frac{\pi z}{a}\right) e^{j(\omega t - \beta z)}$$
$$E_z = 0$$

Obtain an expression for the average power density of the waveguide.

Hint:

The transverse components of a rectangular waveguide are

$$E_x = \frac{1}{h^2}\left[-\gamma\frac{\partial E_z}{\partial x} - j\omega\mu\frac{\partial H_z}{\partial y}\right], \quad E_y = \frac{1}{h^2}\left[-\gamma\frac{\partial E_z}{\partial y} + j\omega\mu\frac{\partial H_z}{\partial x}\right],$$
$$H_x = \frac{1}{h^2}\left[j\omega\varepsilon\frac{\partial E_z}{\partial y} - \gamma\frac{\partial H_z}{\partial x}\right] \quad \text{and} \quad H_y = \frac{1}{h^2}\left[-j\omega\varepsilon\frac{\partial E_z}{\partial x} - \gamma\frac{\partial H_z}{\partial y}\right].$$

Moreover, the time-average Poynting vector in a rectangular waveguide is

$$P = \frac{1}{2}\mathrm{Re}[\mathbf{E} \times \mathbf{H}].$$

[6.0 Marks]

c) Hence, draw the electric and magnetic field patterns for the mode mentioned in part b) of the rectangular waveguide.

[3.0 Marks]

Q3 a) A two-ray ground reflection model is shown in Figure Q3. If E_0 is the free space Electric field (in V/m) at a reference distance d_0 from the transmitting antenna, electric field components in the direct path and the reflected path are $E_D = \frac{E_0 d_0}{r_1}$ and $E_R = \frac{\alpha E_0 d_0}{r_1}$ respectively, where $\alpha = \left(\frac{G_R}{G_D}\right)^{1/2} \frac{r_1}{r_2} \rho D$.

i) Explain why it is used two factors ρ and D in deriving the aforementioned electric field components.

ii) Show that the total electric field is given by $E_T = \frac{2E_0 d_0}{d}\frac{2\pi h_t h_r}{\lambda d}$, when $d \gg r_1, r_2$.

[4.0 Marks]

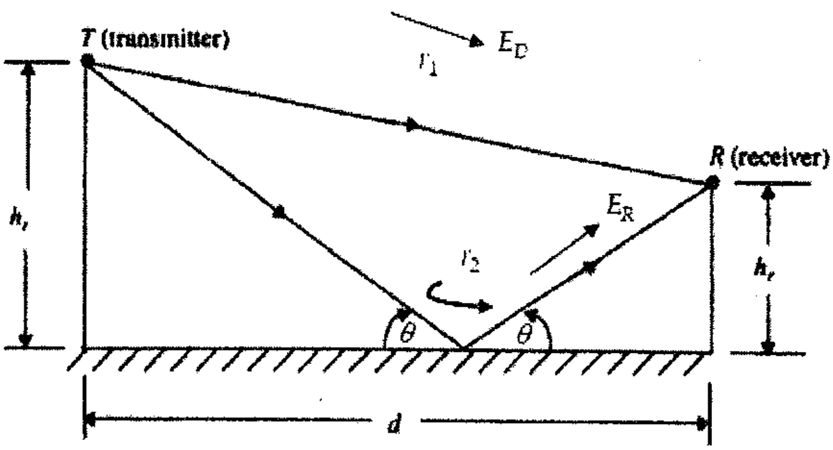


Figure Q3

b) A mobile located 5 km away from a base station, uses a vertical $\lambda / 4$ monopole antenna with a gain of 2.55 dB to receive cellular radio signals. The electric field at 1 km away from the transmitter is measured to be 10^{-3} V/m. The carrier frequency used for this system is 900 MHz.

i) Determine the effective aperture of the receiving antenna.

ii) Determine the received power at the mobile using the two-ray ground refection model assuming the heights of transmitting and receiving antennas 50 m and 1.5 m respectively.

[6.0 Marks]

Q4 a) Briefly explain the following terms related to an antenna.

i) Directive Gain

ii) Power Gain

[2.0 Marks]

b) A Hertzian dipole at length l ($l << \lambda$), placed at the origin and oriented along z-axis has following non-zero electric and magnetic field components for a spherical coordinate system.

$$E_\theta = \frac{I_0\, l \sin\theta\, e^{j\omega t} e^{-j\beta r}}{4\pi\omega\varepsilon} \left\{ \frac{j\beta^2}{r} + \frac{\beta}{r^2} - \frac{j}{r^3} \right\}$$

$$E_r = \frac{I_0\, l \cos\theta\, e^{j\omega t} e^{-j\beta r}}{4\pi\omega\varepsilon} \left\{ \frac{\beta}{r^2} - \frac{j}{r^3} \right\}$$

$$H_\phi = \frac{I_0 l \sin\theta e^{j\omega t} e^{-j\beta r}}{4\pi r} \left\{ j\beta + \frac{1}{r} \right\}$$

Suppose that I_0 is the constant current along the length of the dipole.

i) Modify the given expression by neglecting the higher order terms of parameter r, when $r \gg \lambda$.

ii) Show that $\frac{E_\theta}{H_\phi}$ gives the characteristic impedance of the free space.

[5.0 Marks]

c) Figure Q4 shows the spatial variation of the three fields, radiation field (with $1/r$ terms), induction field (with $1/r^2$ terms) and electro-static field (with $1/r^3$ terms). Using the figure, explain the difference between the near-field and the far-field of a Hertzian dipole antenna.

[3.0 Marks]

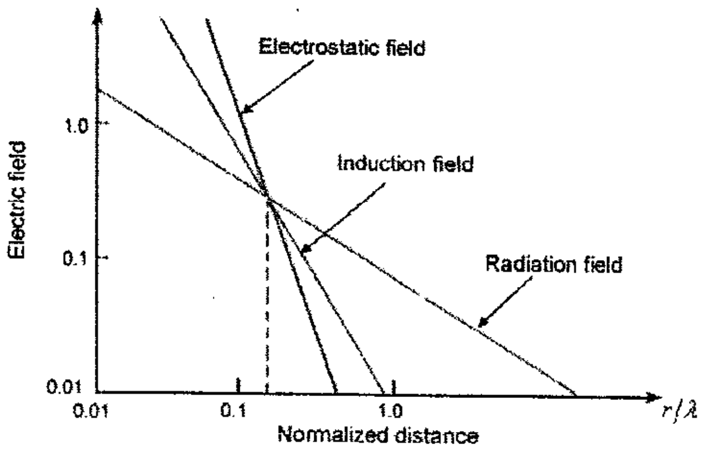


Figure Q4

Q5 a) A block diagram of a satellite transponder is shown in Figure Q5. Briefly explain the purpose of each block to identify the basic operations of the transponder.

[3.0 Marks]

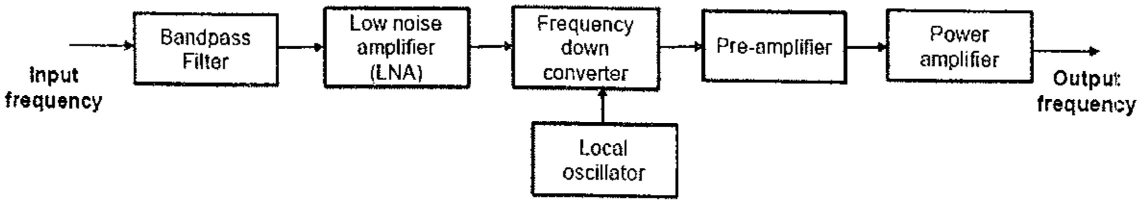


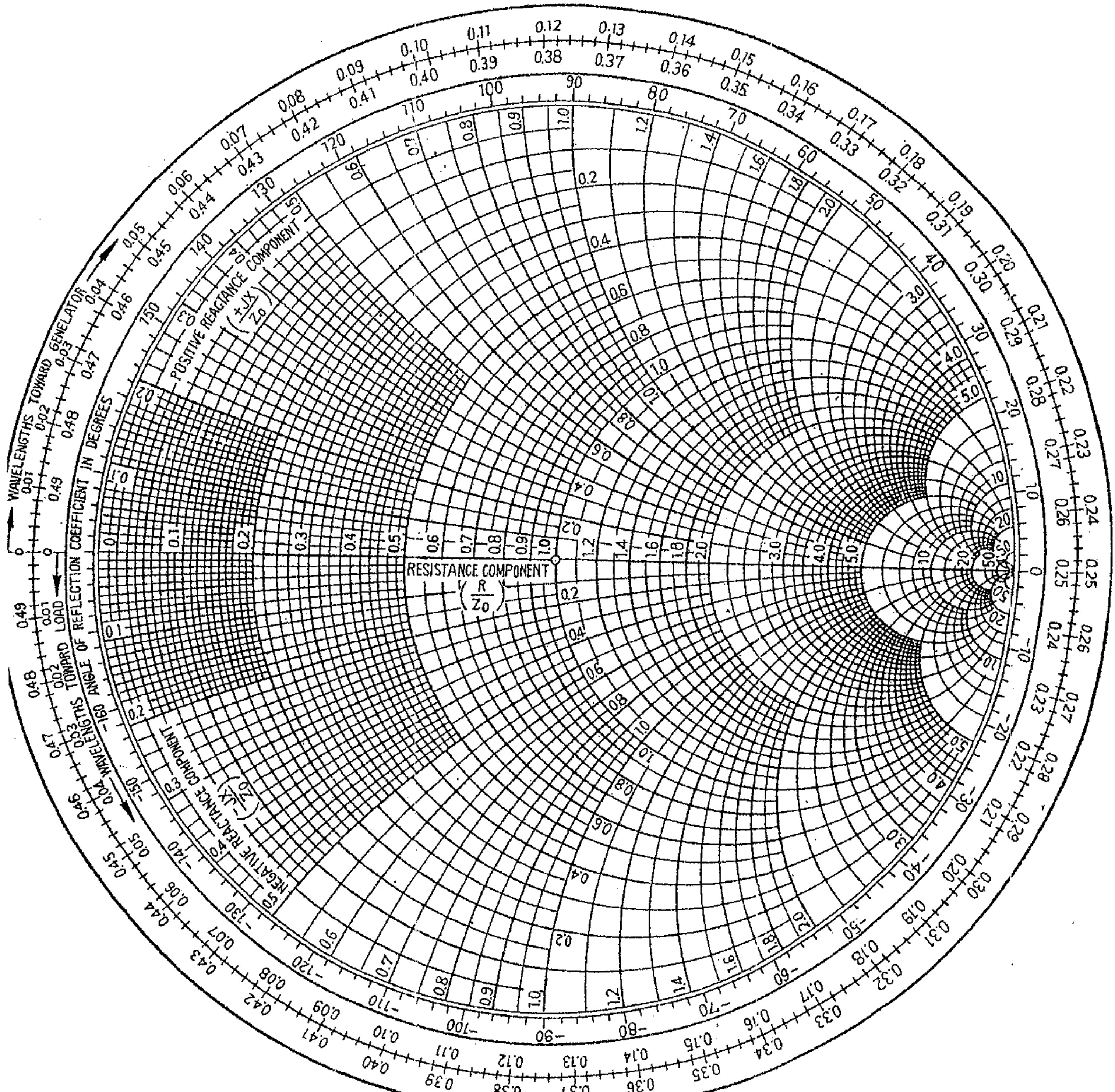
Figure Q5

b) A 14/11 GHz digital satellite, transparent transponder and communication link has the following specifications.

Uplink Saturating Flux Density	-83.2 dBW/m^2
Input Back-off Loss	8.0 dB
Satellite Gain-to-Noise Temperature Ratio	1.8 dB/K
Transponder Bandwidth	36 MHz
Uplink Slant Range	41000 km
Saturated Satellite Effective Isotropic Radiated Power (EIRP)	45 dBW
Output Back-off Loss	2.8 dB
Downlink Slant Range	39000 km
Earth Station Gain-to-Noise Temperature Ratio	31 dB/K
Downlink Earth Station Fixed Losses	3.5 dB

If the uplink and downlink earth station elevations angles are 5.6^0 and 20.3^0 respectively, estimate the overall link, clear sky, carrier-to-noise (CNR) ratio. Assume pure TDMA operation such that there is no intermodulation noise and interference is negligible. Further, the characteristic impedance of the free space is 120π.

[7.0 Marks]



The Smith Chart