UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: January 2022

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

[Three Hours]

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

Notes:

- **All notations have their usual meaning.**
- **Use the provided Smith chart to answer Q1.**
- **State any assumption made in calculations clearly.**
- **Use the following parameters, if required.**
  - **Permittivity of the free space,** $\varepsilon_0 = \frac{1}{36\pi \times 10^9}$ F/m
  - **Permeability of the free space,** $\mu_0 = 4\pi \times 10^{-7}$ H/m
  - **Boltzmann constant,** $k = 1.380649 \times 10^{-23}$ J/K

Q1 a) Obtain an expression for the voltage reflection coefficient at the load and the voltage standing wave ratio (VSWR) of a lossless transmission line.

[2.0 Marks]

b) A transmission line is formed by two parallel wires rooted in a dielectric medium with a relative permittivity of $\varepsilon_r = 9$. The characteristic impedance of the transmission line is 50 Ω and it is terminated by a load impedance $(50 + j50)\ \Omega$. The signal frequency is 100 MHz.

i) Determine the wavelength in meters.

ii) Calculate the distance from the load to the nearest impedance of the voltage maximum and VSWR.

iii) If the impedance matching is to be used by single stub matching technique, determine the smallest distance from the load (in meters) in which the short circuited stub may be attached in parallel to the main transmission line. Also determine the stub length. Assume that stub also has a characteristic impedance of 50 Ω.

[8. 0 Marks]

Q2 a) For a rectangular waveguide having dimensions $a \times b$, it can be shown that

$$h^2 = \left(\frac{n\pi}{a}\right)^2 + \left(\frac{m\pi}{b}\right)^2$$

where n and m denote the mode numbers used to classify the propagating modes. Discuss the three criteria for propagation of electromagnetic waves inside the rectangular waveguide.

[3.0 Marks]

b) Consider a rectangular waveguide with dimensions $2.25 \times 1.00\ \text{cm}^2$.

i) Calculate the ratio of the wavelength of the waveguide and wavelength of free space at the frequency 10 GHz.

ii) How do you modify the propagation coefficient expression $\beta^2 = k^2 - h^2$, if the waveguide is completely filled with a dielectric material that has a relative permittivity ε_r?

iii) Calculate the relative permittivity of a dielectric material which needs to be filled in order to make the waveguide wavelength equal to the free space wavelength at the frequency 10 GHz.

[7.0 Marks]

Q3 a) Show that the maximum transmission range allowed between the transmitter and receiver for line of sight free space propagation (without having the effect of refraction), shown in Figure Q3, is

$$d_{max} = \sqrt{2R_e h_t} + \sqrt{2R_e h_r}$$

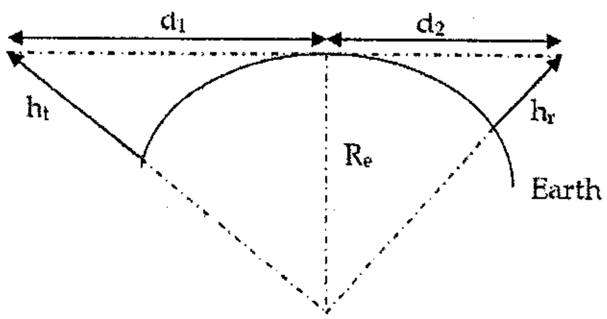


Figure Q3

i) Determine the number of microwave towers of 100 m height required to be installed in order to cover the perimeter of the earth. Assume that the radius of earth is 6000 km.

ii) If there is refraction effect of free space propagation with a standard atmosphere, determine the total number of towers required similar to part ii).

[6.0 Marks]

b). i) Explain the difference between space wave propagation and ionospheric propagation.

ii) A high frequency radio link has to be established between two points at a distance of 2500 km on earth surface. Considering the ionospheric height of 200 km and critical frequency of 5 MHz, calculate the maximum usable frequency (MUF) of the given path. Obtain an expression to perform the above calculation.

[4.0 Marks]

Q4 a) Explain the difference between following parameters related to an antenna.

i) Half Power Beam Width (HPBW) and Beam Width between First Nulls (FNBW)

ii) Directivity and Gain

iii) Directive Gain and Power Gain

[3.0 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.

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

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

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

where I_0 is the constant current along the length of the dipole. Simplify the above expression for a far-field scenario.

[3.0 Marks]

c) i) A Hertzian dipole is excited by a current of 5 A in amplitude. If the length of the dipole is $l = 0.001\lambda$, determine the average power radiated per unit area.

Hint:

$P = \frac{1}{2}\mathrm{Re}[\mathbf{E} \times \mathbf{H}]$ (Poynting Theorem)

ii) Determine the radiation resistance of the Hertzian dipole.

[4.0 Marks]

Q5 a) i) Briefly explain various elements used at an earth station of a satellite communication system.

ii) Why is it desirable to place the low-noise amplifier of the antenna at the end of the feeder cable?

[2.0 Marks]

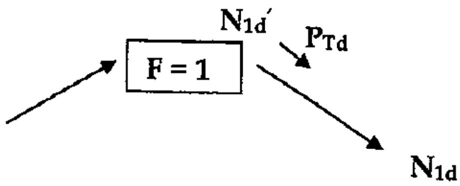
b) Taking the Carrier-to-Noise Ratio of the uplink of a satellite communication link as

$$(CNR)_u = \frac{(EIRP)_u}{L_u} \frac{\lambda_u^2}{(4\pi d_u)^2} \left(\frac{G_u}{T_u}\right)\left(\frac{1}{kB}\right),$$

derive an expression for Carrier-to-Noise Ratio (CNR) of the entire satellite communication link.

Hint:

For the downlink, consider the noise contribution comes from the uplink and noise introduced by the downlink itself separately.



[3.0 Marks]

c) Using the obtained expression in part b), calculate the overall CNR of the following satellite communication link.

Satellite Parameters

Transponder EIRP at saturation: 53 dBW

G/T ratio of the satellite transponder = 4 dB/K

Transponder BW = 36 MHz

High-Power Amplifier (HPA) compression = 2.7 dB

Earth Station Parameters

Peak transmit gain = 33.5 dB

Block Up-converter (BUC) operating power = 12 dBW

Hub G/T = 30 dB/K

Channel BW = 1 MHz

Other Parameters

Uplink frequency = 14.25 GHz

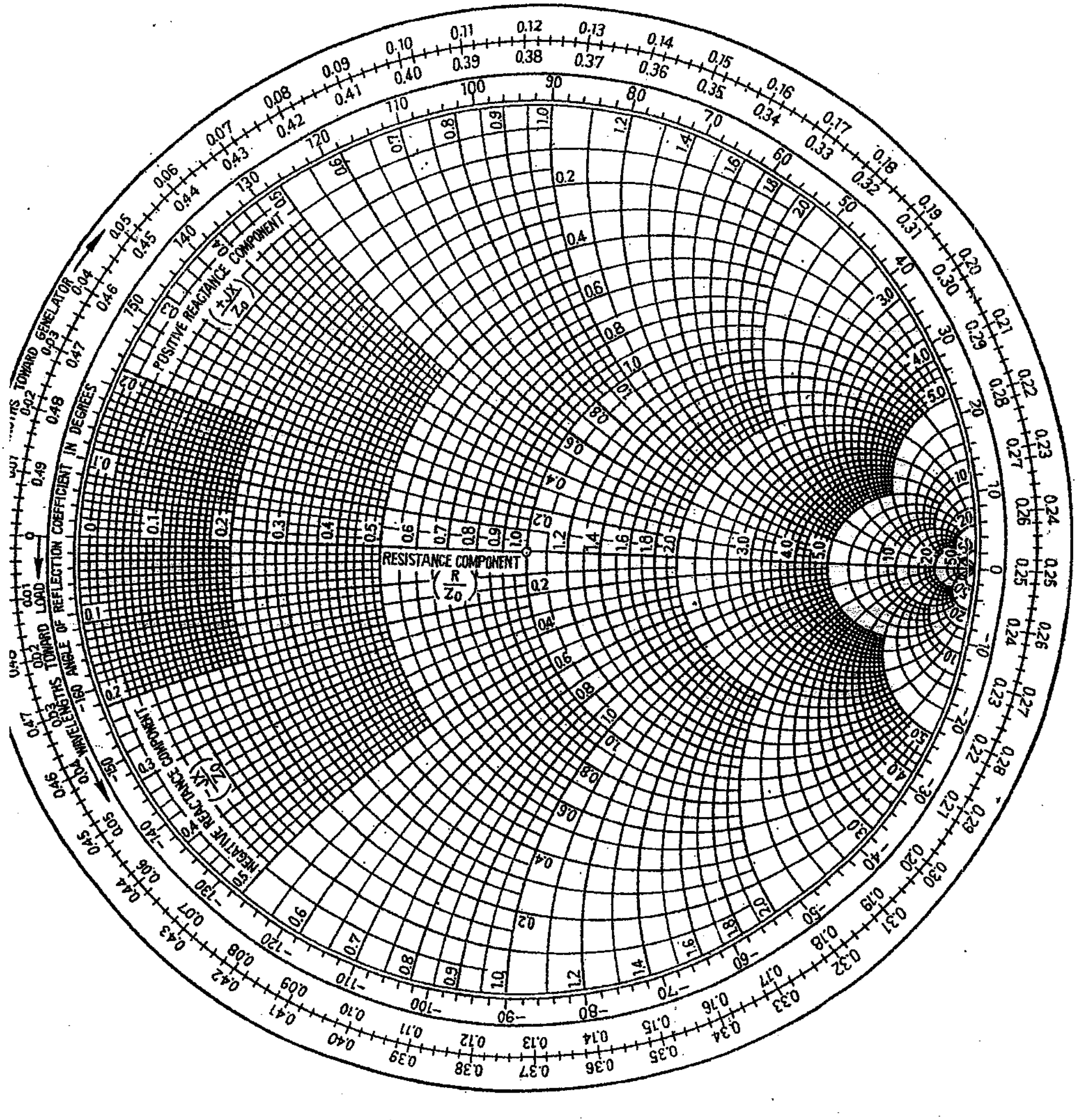
Downlink frequency = 11.45 GHz

Path distance = 38,000 km

Boltzmann constant = -228.6 dB

Atmospheric loss = 0.35 dB

[5.0 Marks]



The Smith Chart