UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2018

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

[Three Hours]

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

All notations have their usual meanings.

Q1 a) i) What is meant by characteristic impedance of a transmission line?

ii) Explain briefly why it is required to match the impedance of a load to the characteristic impedance of a transmission line when they are connected together.

[3.0 Marks]

b) A lossless transmission line is matched to a load using a single stub tuner as shown in Figure Q1. The length of the short-circuited stub is 0.12λ. The distance from the stub to the load is 0.12λ. Use the given Smith chart to evaluate the followings by stating all the steps clearly.

i) Determine the normalized admittance at AA without the stub.

ii) Determine the admittance and impedance of the load.

iii) Is the load inductive or capacitive?

iv) If the stub is removed, what is the VSWR (Voltage Standing Wave Ratio) of the transmission line and the reflection coefficient at the load end?

[7.0 Marks]

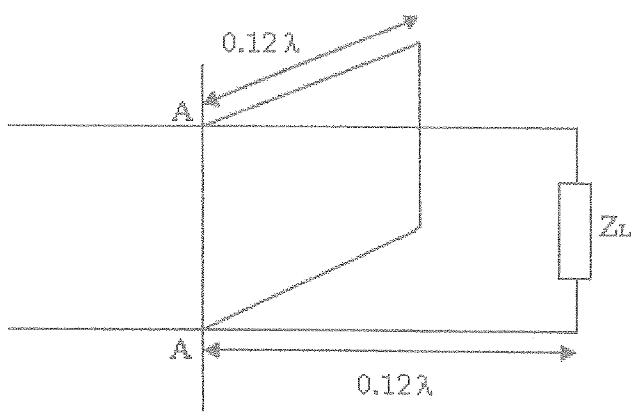


Figure Q1.

Q2 a) i) Write an expression to determine the propagation constant for an evanescent mode of a rectangular waveguide.

ii) Explain why the evanescent mode cannot be used for propagating electromagnetic waves through a waveguide.

[3.0 Marks]

b) An air-filled rectangular waveguide has dimensions $a = 5$ cm and $b = 2$ cm. The waveguide operates at 8 GHz in TM_{21} (Transverse Magnetic) mode.

i) Show that there is no propagation at this frequency (i.e., in evanescent mode).

ii) If the maximum amplitude of the longitudinal component of the electric field, E_z is 1 kV/m at $z = 0$, determine the distance z such that the amplitude of E_z is half of its $z = 0$ value.

iii) Assume that the waveguide operating frequency changes to 12 GHz. Determine the guided wavelength for TM_{21} mode.

[5.0 Marks]

c) Draw the field patterns of a rectangular waveguide for TM_{21} mode in a plane perpendicular to the waveguide axis.

[2.0 Marks]

Q3 a) The refractive index of the lower part of the atmosphere (troposphere) changes with the height. Using illustrations, explain how the following parameters are introduced in propagation analysis.

i) Radio horizon

ii) Effective radius of earth

[3.0 Marks]

b) In an ionospheric propagation problem, the ionosphere is modeled as a single layer located at an altitude of 200 km. The electron density of the layer is 10^{12} electrons per cubic meter. The radius of the earth is 6367 km.

i) If the transmission mode is single hop, determine an expression for the minimum distance of communication achievable.

ii) If the skip distance is 800 km, calculate the maximum usable frequency assuming the earth is a flat surface.

[5.0 Marks]

<u>Hint</u>:

The refraction coefficient of an ionospheric layer is given by

$$n = \sqrt{1 - \frac{81N}{f^2}}$$

where N is the electron density in electrons per cubic meter and f is the frequency in Hz.

c) If the transmitting and receiving antennas are separated by a distance of 2400 km in part b), sketch all possible propagation paths.

[2.0 Marks]

Q4 a) What is meant by the beam solid angle of an antenna?

[1.5 Marks]

b) The radiation intensity of the major lobe of an antenna is given by

$$P_n(\theta,\phi) = B_0 \cos\theta$$

where B_0 is the maximum radiation intensity. The radiation intensity exists only in the upper hemisphere $\left(0 \le \theta \le \frac{\pi}{2},\ 0 \le \phi \le 2\pi\right)$ as shown in Figure Q4. Determine the followings.

i) Beam solid angle

ii) Maximum directivity of the antenna

[3.5 Marks]

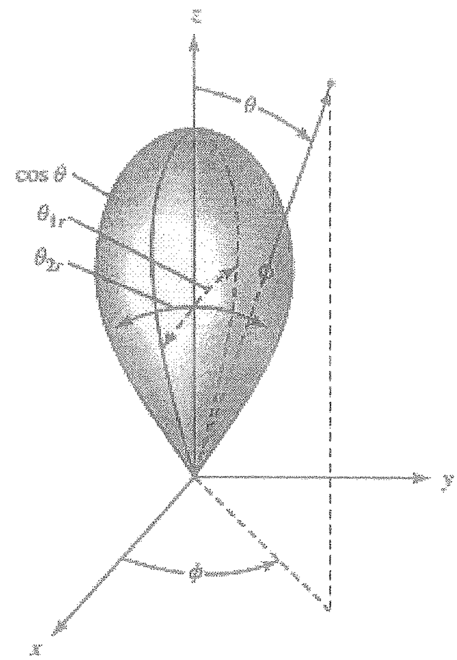


Figure Q4.

c) Consider a monostatic pulse radar operating at a frequency of 8 GHz with a peak transmission power of 6 MW with a gain of 36 dB. The pulses have a pulse width of 2 μs with a pulse repetition frequency of 1 kHz. Consider speed of light as 3×10^{8} ms^{-1}.

i) Find the average power transmitted by the radar.

ii) Find the minimum range resolution.

iii) Calculate the unambiguous range.

iv) If the minimum detectable power of the radar is 0.5 nW, calculate the maximum range using the radar equation for a target having a radar cross section of 15 m^2.

v) Determine the maximum possible range of the radar using the results obtained in part iii) and part iv).

[5.0 Marks]

Q5 a) Draw the block diagram of a typical satellite transponder and briefly explain the function of the low noise amplifier.

[2.0 Marks]

b) Explain the use of an intermediate frequency for a satellite base station.

[1.0 Mark]

c) The sub-satellite point of a satellite operating in Ku band is located 2000 km from the transmitter and 1500 km from the receiver. The angle of elevation of the satellite from the transmitter is 78.463^0. This satellite communicates with a transmitting base station that has a transmit power of 52 dBm and antenna gain of 44 dB. Uplink and downlink losses are negligible. The system noise bandwidth and system noise temperature for both uplink and downlink are 56 MHz and 420 K respectively. The Boltzmann constant is 1.38×10^{-23} J/K.

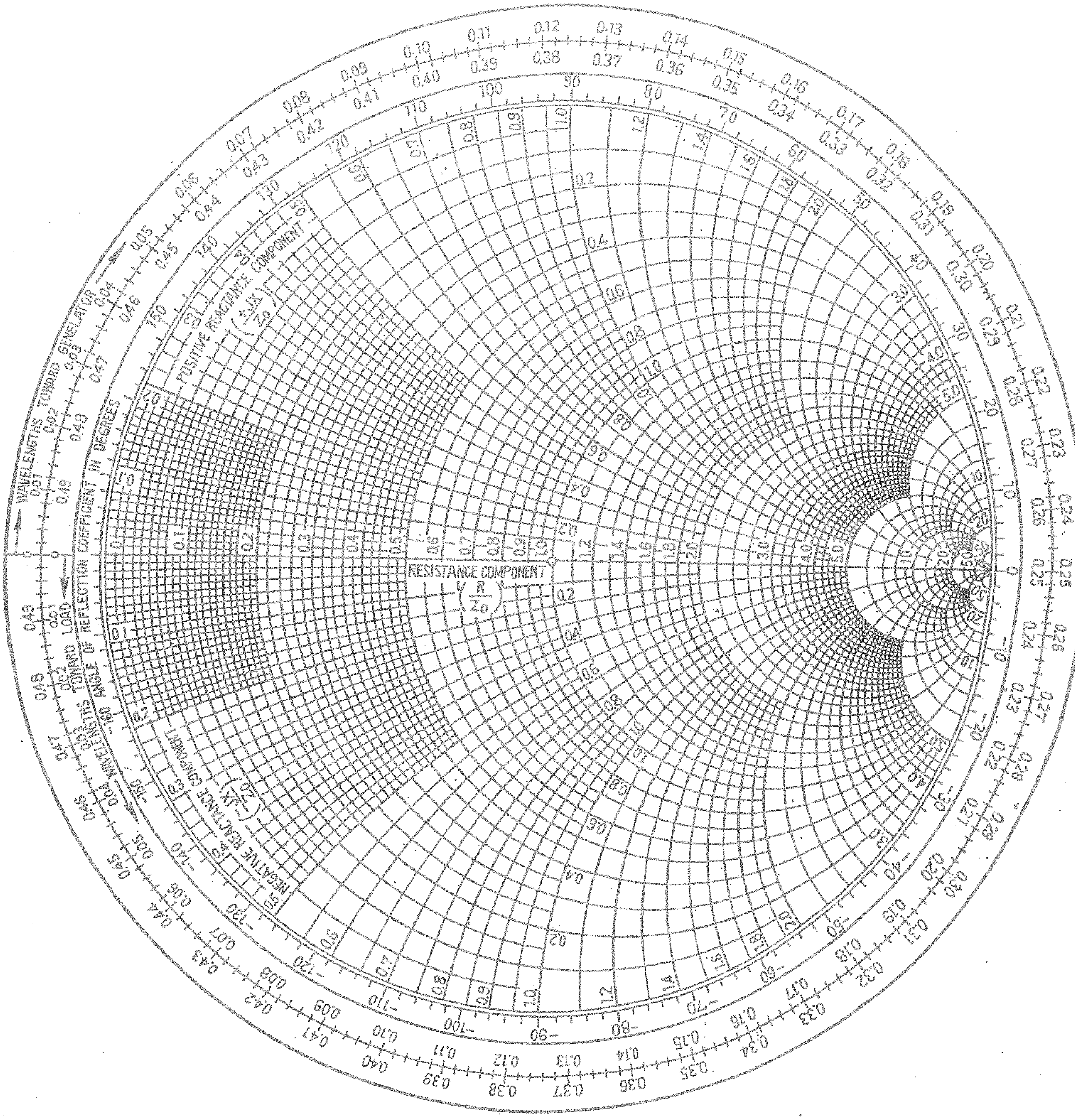
i) Find the uplink and downlink slant ranges of the satellite assuming the earth is flat.

ii) If the gain of the receiver antenna of the transponder is 35 dB, calculate the Carrier-to-Noise Ratio (CNR) at the output of the receiver antenna of the satellite.

iii) If the saturated Effective Isotropic Radiated Power (EIRP) of the satellite transponder is 400,000 W and the receiver base station has an antenna gain of 44 dB, calculate the CNR for the downlink.

iv) Assuming that the satellite transponder is having a noise figure of 2.5, calculate the overall CNR for the whole satellite communication system.

[7.0 Marks]



The Smith Chart