BENGAL ENGINEERING & SCIENCE UNIVERSITY, SHIBPUR

B.E. (ETCE) Part-III 5th Semester Final Examination, 2012-13

Transmission Lines and Waveguides
(ET-504)

Time : 3 Hours | Full Marks : 70

Answer **Question no.1 and any FOUR** from the rest

(Extra Answers will be discarded)

Smith Chart would be provided on request

1. Select the most appropriate alternative(s) (any **Six**). $1\times6=6$

(a) For a lossy transmission line, the characteristic impedance does not depend on the
(i) operating frequency of the line (ii) length of the line (iii) load terminating the line
(iv) conductivity of the conductors (v) conductivity of dielectric separating the conductors

(b) In an air line, adjacent maxima are found at 12.5 cm and 37.5 cm. The operating frequency is
(i) 1.5 GHz (ii) 600 MHz (iii) 300 MHz (iv) 1.2 GHz

(c) In Smith chart problems, anti-clockwise movement along constant-S circles indicates
(i) travel towards load (ii) travel towards generator (iii) none of the above

(d) Which of the following conditions will not guarantee a distrotionless transmission line?
(i) $R = 0 = G$ (ii) $RC = GL$ (iii) Very low frequency range ($R>>\omega L$, $G>>\omega C$)
(iv) Very high frequency range ($R<<\omega L$, $G<<\omega C$)

(e) Input impedance of an short-circuited loss-less line of length λ is
(i) infinity (ii) zero (iii) finite inductive reactance (iv) finite capacitive reactance

(f) Which of the modes does not exist in a rectangular resonant cavity?
(i) TE_{110} (ii) TE_{011} (iii) TM_{110} (iv) TM_{111}

(g) The boundary condition satisfied at a perfect metallic interface is that
(i) electric field parallel to the surface is infinite
(ii) magnetic field parallel to the surface is zero
(iii) electric field parallel to the surface is zero
(iv) magnetic field normal to the surface is zero

(h) Under conditions of reflection, reflection coefficient is found to be $0.5\angle 10^0$ in a line. VSWR under this condition will be
(i) 3 (ii) 0.3 (iii) 2 (iv) 5

2. (a) Neatly draw and label the equivalent circuit of a uniform transmission line. State the reasons of occurrence of the two shunt parameters of the line. By applying KVL and KCL to this equivalent circuit derive the general time-domain differential transmission line equations. Find their time-harmonic form. Solve these equations to get the transmission line equations in exponential form. Interpret all the symbols you use.

(b) Considering a forward traveling wave, find the expressions for the propagation constant, attenuation constant and phase constant if $V_1\angle\phi_1$ and $V_2\angle\phi_2$ are the voltages at z = 0 and z = 1 distance where | V1 | > | V2 |. Write the relationship between Neper and deciBel units.

12+4=16

3. (a) Explain how can a complex load be matched to a line by using a quarter-wave transformer. What is a stub? With the help of suitable and neat diagram, describe its working in general in impedance matching.

(b) A line has $R = 30$ Ω/km, $L = 100$ mH/km, $G = 0$, and $C = 20$ µF/ km. At f = 1 kHz, obtain: (i) characteristic impedance of the line, (ii) propagation constant, (iii) phase velocity. Show all the complex number calculations in details.

9+7=16

4. (a) Define voltage reflection coefficient & voltage transmission coefficient. Relate them at the load. Derive that the reflection coefficient $\Gamma(l)$ at a distance 'l' measured from the load toward the generator is given by $\Gamma(l) = \Gamma_L e^{-2\gamma l}$ where Γ_L is the reflection coefficient at the load and γ is the propagation constant.

(b) A lossless 60 Ω line is terminated by a 60 + j60 Ω load. (a) Find Γ, S, $Z_{in,max}$ and $Z_{in,min}$ by both analytically and using a Smith chart. Describe the procedure while using the Smith Chart.

Solve using the Smith chart only: How far (in terms of λ) is the first maximum voltage from the load? If Z_{in} = 120 – j60 Ω, how far (in terms of wavelengths) is the load from the generator? Describe the procedure in obtaining your results.

6+10=16

5. (a) Distinguish between characteristic impedance and input impedance of a transmission line. By using the transmission line equations in time-harmonic form and exponential form derive that the characteristic impedance is given by $Z_0 = \frac{V_0^+}{I_0^+} = -\frac{V_0^-}{I_0^-} = \frac{R + j\omega L}{\gamma} = \frac{\gamma}{G + j\omega C}$ where, the symbols have their usual meaning.

(b) Define VSWR. From this definition derive a relation between it and the magnitude of reflection coefficient. Also show that $Z_{max} = Z_0 \times$ VSWR and $Z_{min} = Z_0 /$ VSWR.

A lossless line of characteristic impedance 50 Ω is terminated in a pure resistive load of 100 Ω and the voltage at the load is 100 V. Draw the voltage and current standing wave patterns versus distance in wavelength with labeling of maximum and minimum values.

8+8=16

6. (a) Define phase velocity and group velocity. What is the relation between them? Prove mathematically along with a neat figure that a propagating TE_{10} wave in a parallel-plate waveguide can be regarded as the superposition of two uniform plane waves bouncing back and forth obliquely between the two conducting plates (guide walls).

(b) With the help of appropriate diagram explain that the wavelength and phase velocity in the direction of propagation in a rectangular waveguide is greater than equal to the wavelength and phase velocity of the incident wave, respectively. Under what circumstances those quantities reach a value of infinity?

10+6=16

7. (a) What is the significance of two subscripts of a mode (TE/TM) in a rectangular waveguide? Illustrate. Neatly plot the E-field patterns for TE_{10} and TM_{21} modes in a rectangular waveguide (on x-y plane and y-z plane for z-direction propagation).

(b) The separation between parallel plates of a parallel plate waveguide is 3 cm. It is filled with a dielectric with relative permittivity of 4. The signal frequency is up to 6 GHz. Find the propagating modes. For each propagating mode calculate (i) cut-off frequency f_c, (ii) cut-off wavelength λ_c. Also calculate (iii) guide wavelength λ_g at 6 GHz, (iv) phase velocity v_{ph} for 6 GHz.
8+8=16

8. (a) At UHF and higher frequencies what are the reasons of replacing ordinary lumped-parameter *RLC* resonant circuits by cavity resonators? Neatly sketch a rectangular cavity resonator with dimensions. Write the boundary conditions for each component of *E* and *H* fields on the walls of this resonator assuming perfect conductivity. For a TM_{mnp} wave write only the expressions of variations of associated field components in the *x*-, *y*-, and *z*-directions. Ignore derivations and magnitudes. What is the range of values of *m*, *n*, and *p*?

(b) An air-filled resonant cavity with dimensions $a = 5$ cm, $b = 4$ cm, and $d = 10$ cm is made of copper. Find the resonant frequencies for three lowest order modes. Identify the dominant mode.
10+6=16

9. (a) Enumerate the differences between waveguides and coaxial lines. A common rule of thumb is that a cable or wire should be treated as a transmission line if the length is greater than 1/10 of wavelength. Justify this concept.

(b) Neatly plot the voltage standing wave patterns (two to three cycles) against λ starting right from the load position for load conditions: (i) resistive ($>Z_0$), (ii) resistive ($<Z_0$), (iii) inductive and (iv) capacitive. Z_0 is the characteristic impedance of the line to which the load is connected.

(c) Find the values of reflection coefficient and standing wave ratio for open load, short load and matched load. Explain how you will determine unknown *R* from the standing wave measurements.
4+6+6=16

The Complete Smith Chart

Black Magic Design