EC6503 TRANSMISSION LINES AND WAVEGUIDES

UNIT –I TRANSMISSION LINE THEORY
PART A - C303.1

1. Distinguish lumped parameters and distributed parameters.

Lumped parameters are individually concentrated or lumped at discrete points in the circuit and can be identified definitely as representing a particular parameter.

Distributed parameters are distributed along the circuit, each elemental length of the circuit having its own values and concentration of the individual parameters is not possible.

2.What are the different types of transmission lines?

The different types of transmission lines are

1.Open wire line 2. Cable 3. Coaxial line 4. Waveguide

3.Describe the different parameters of a transmission line.

(1)The parameters include resistance, which is uniformly distributed along the length of the conductors. Since current will be present, the conductors will be surrounded and linked by magnetic flux, and this phenomena will demonstrate its effect in distributed inductance along the line.(2)The conductors are separated by insulating dielectric, so that capacitance will be distributed along the conductor length.(3)The dielectric or the insulators of the open wire line may not be perfect, a leakage current will flow, and leakage conductance will exist between the conductors.

4. Give the general equations of a transmission line.

The general equations are,

$E = E_R \cosh\sqrt{ZY}\, s + I_R Z_o \sinh \sqrt{ZY}\, s$

$I = I_R \cosh\sqrt{ZY}\, s + (E_R / Z_o) \sinh \sqrt{ZY}\, s$ where $Z= R + j\omega L$ = series impedance, ohms per unit length of line and $Y = G + j\omega C$ = shunt admittance, mhos per unit length of line.

5. What is the advantage in terminating a line with its characteristic impedance?

A line of finite length, terminated in a load equivalent to its characteristic impedance, appears to the sending end generator as an infinite line.

6. Define wavelength of the line. (Jan 2016)

The distance the wave travels along the line while the phase angle is changing through 2π radians is called a wavelength.

7. What is the relationship between characteristic impedance and propagation constant.

$Z_o = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$ and $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$. On multiplying Z_o, characteristic impedance and γ, propagation constant, we get, $Z_o X \gamma = R + j\omega L$ and $\frac{\gamma}{Z_o} = G + j\omega C$

8. What is meant by distortion less line?&Give the condition for a distortion less line? (Nov 2017).

A distortion less line is one which has neither frequency nor delay distortion. The attenuation constant and velocity of propagation cannot be functions of frequency.

The condition for a distortion less line is, LG = RC

9. Find the characteristic impedance of the line at 1600 Hz if $Z_{oc} = 750\angle -30^{\circ}\,\Omega$ and $Z_{sc} = 600\angle -20^{\circ}\,\Omega$ (Nov 2016).

Solution: Characteristic impedance, $Z_o = \sqrt{Z_{oc}Z_{sc}}$

$$= \sqrt{750\angle -30^{\circ}\, X\, 600\angle -20^{\circ}}$$

$$= 670.8\angle -25^{\circ}\,\Omega$$

10. Define frequency distortion.

Attenuation constant α is a function of frequency. All frequencies transmitted on a line will then not be attenuated equally. A complex applied voltage, such as a voice voltage containing many frequencies, will not have all frequencies transmitted with equal attenuation, and the received waveform will not be identical with the input waveform at the sending end. This variation is known as frequency distortion.

11. Define delay or phase distortion.

All frequencies applied to a transmission line will not have the same time of transmission, some
frequencies being delayed more than others. For an applied voice voltage wave the received waveform will not be identical with the input waveform at the sending end, since some frequency components will be delayed more than those of other frequencies. This phenomenon is known as delay or phase distortion.

12. How can you reduce frequency distortion?

Frequency distortion is reduced in the transmission of high quality radio broadcast programs over wire lines by use of equalizers at the line terminals. These circuits are networks whose frequency and phase characteristics are adjusted to be inverse to those of the lines, resulting in an over-all uniform frequency response over the desired frequency band.

13. How can you overcome delay distortion?

Coaxial cables are used to overcome delay distortion. In such cables, the internal inductance is low at high frequencies because of skin effect, the resistance is small because of the large conductors, and capacitance and leakages are small because of the use of air dielectric with a minimum of spacers. The velocity of propagation is raised and made more nearly equal for all frequencies.

14. Give the expressions for attenuation constant, phase constant and velocity of propagation in a telephone cable.

Attenuation constant, $\alpha = \sqrt{(\omega RC) / 2}$ Phase constant, $\beta = \sqrt{(\omega RC) / 2}$

Velocity of propagation, $v_p = \omega/ \beta = \sqrt{(2\omega) / RC}$

15. What is the need for inductance loading of telephone cables?

The condition for a distortion less line is, LG = RC. In order to achieve this condition, L/C ratio has to be increased. To increase this ratio, the value of L must be increased which in turn is increased by adding lumped inductors spaced at regular intervals along the telephone cables.

16. What do you mean by reflection factor?

The change in current in the load due to reflection at the mismatched junction is called the reflection factor and is given by reflection factor, k = $\left|\frac{2\sqrt{Z_R Z_O}}{Z_R + Z_O}\right|$

17. Define reflection loss.

Reflection loss is defined as the number of nepers or decibels by which the current in the load under image matched conditions would exceed the current actually flowing in the load. Reflection loss, nepers = 10 log$\left(\frac{|Z_R + Z_o|^2}{4Z_R Z_O}\right)$, Reflection loss, dB = 20 log $\left(\frac{|Z_R + Z_o|}{2\sqrt{Z_R Z_O}}\right)$

Where Z_R = Receiving end impedance, Z_o = characteristic impedance

18. Define insertion loss of a line. (May 2015)

The insertion loss of a line or network is defined as the number of nepers or decibels by which the current in the load is changed by the insertion.

19. What are the primary&secondary constants of a transmission line?

The primary constants of a transmission line are resistance R, ohm/unit length, inductance L, henry/unit length, capacitance C, farad/unit length and conductance G, mho/unit length.

The secondary constants of a transmission line are characteristic impedance and propagation constant.

20. A transmission line has $Z_o = 745\angle -12^\circ$ ohms and is terminated by $Z_R = 100$ ohms. Calculate the reflection loss in dB and reflection factor. (May 2017)

Solution: Reflection loss, dB = 20 log $\left(\frac{|Z_R + Z_o|}{2\sqrt{Z_R Z_O}}\right)$ = 3.776 dB

Reflection factor, k = $\left|\frac{2\sqrt{Z_R Z_O}}{Z_R + Z_O}\right|$ = 0.648

21. When does a finite line appear as an infinite line?

A line of finite length, terminated in a load equivalent to its characteristic impedance appears to the sending end generator as an infinite line.

22. Write the equation for the input impedance of a transmission line.

The equation for the input impedance of a transmission line is

$$Zin = Z_o\left[\frac{Z_R \cosh\gamma l + Z_o \sinh\gamma l}{Z_o \cosh\gamma l + Z_R \sinh\gamma l}\right]$$

23. A 50 ohms coaxial cable feeds a 75+j20 ohms dipole antenna. Find reflection coefficient and standing wave ratio.

Solution: Given Z_o = 50 ohms, Z_R = 75+j20 ohms

Reflection co-efficient, K = $\frac{Z_R - Z_o}{Z_R + Z_o}$

$$= \frac{75 + j20 - 50}{75 + j20 + 50} = \frac{25 + j20}{125 + j20} = \frac{32\angle 38.65^\circ}{126.58\angle 9.09^\circ}$$

$$= 0.25\angle 29.56^\circ \qquad SWR, S = \frac{1+|K|}{1-|K|} \frac{1+0.25}{1-0.25} = 1.666$$

24. Find the reflection coefficient of a 50 ohm transmission line when it is terminated by a load impedance of 60+j40 ohm.(Nov 2015)

Solution: Given Z_o = 50 ohms, Z_R = 60+j40 ohms

Reflection co-efficient, K = $\frac{Z_R - Z_o}{Z_R + Z_o}$

$$= \frac{60 + j40 - 50}{60 + j40 + 50} = \frac{10 + j40}{110 + j40} = \frac{41.23\angle 75.9^\circ}{117.047\angle 19.98^\circ}$$

$$= 0.3523\angle 55.9169^\circ$$

$$\text{Standing wave ratio, S} = \frac{1+|\text{K}|}{1-|\text{K}|}$$

$$= \frac{1+0.3523}{1-0.3523} = 2.08$$

25.What is the drawback of using ordinary telephone cables?(May 2015)

The drawback of using ordinary telephone cables is the attenuation and velocity are functions of frequency and there will be very considerable frequency and delay distortion.

26. Find the attenuation constant and phase constant of a wave propagating along the line Whose $\gamma = 1.048\text{x}10^{-4}\angle 88.8^\circ$

Solution: Propagation constant**,** $\gamma = \alpha + j\beta$

that is**,** $\gamma = 1.048\text{x}10^{-4}\angle 88.8^\circ$

In rectangular form**,** $\gamma = 2.194\text{x}10^{-6} + j1\text{x}10^{-4}$**,** Equating the real and imaginary parts, we get, $\alpha = 2.194\text{x}10^{-6}$ nepers per unit length and $\beta = 1\text{x}10^{-4}$ rad per unit length.

27. What is characteristic impedance? (Nov 2017)

The characteristic impedance of a uniform transmission line is the ratio of the amplitudes of voltage and current of a single wave propagating along the line; that is, a wave travelling in one direction in the absence of reflections in the other direction.

28.A lossless line hasan characteristic impedance of 400Ω. Determine the standing wave ratio if the receiving impedance is 800+j0.0Ω. (May 2017)

Reflection co-efficient, K = $\frac{Z_R - Z_o}{Z_R + Z_o}$

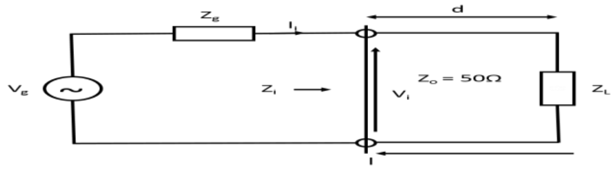
$$= \frac{800 - 400}{800 + 400} = \frac{400}{1200} = \frac{1}{3} = 0.33$$

$$\text{Standing wave ratio, S} = \frac{1+|\text{K}|}{1-|\text{K}|}$$

$$= \frac{1+0.3333}{1-0.3333} = 1.999 = 2$$

PART B- C303.1

1. (i) Derive the transmission line equation and hence obtain the expression for voltage and current on a transmission line.
   (ii) Prove that an infinite line equal to finite line terminated in its characteristic impedance.**(May 2016,Nov 2017)**
2. A communication link has R = 10.4 ohm/km, L = 3.67 mH/km, G = 0.08 µmho/km and C = 0.0083µF/km. Determine the characteristic impedance, propagationconstant, phase constant, velocity of propagation, sending end current and receiving end current for given frequency f = 1kHz, sending end voltage is 1 volts and transmission line length is 100km.**(May 2017)**
3. Derive the expressions for attenuation constant, phase constant.
4. Derive the expressions for input impedance of open &short circuited lines.(**Nov 2015)**
5. Discuss in detail about lumped loading and derive the Campbell's equation. (**May 2017)**
6. A telephone cable 64 km long has a resistance of 13 ohms/km and a capacitance of 0.008 micro farad/km. Calculate attenuation constant, velocity and wavelength of the line at 1000 HZ.**(Nov 2015)**
7. A parallel – wire transmission line is having the following line parameters at 5 KHZ. Series resistance R = 2.59 x 10^{-3} ohm/m, Series inductance L = 2 micro H/m, Shunt conductance G = 0 mho/mand capacitance between conductors C = 5.56 nF/m. Find the characteristic impedance, attenuation constant, phase shift constant, velocity of propagation and wavelength. **(Nov 2015)**
8. A 2 meter long transmission line with characteristic impedance of 60+j40 ohm is operating at $\omega = 10^6 \text{ rad/sec}$ has attenuation constant of zero neper/m. If the line is terminated by a load of 20+j50ohms, determine the input impedance of this line. **(May 2017)**
9. For a transmission line terminated in Z_0, prove that $Z_o = \sqrt{Z_{oc}Z_{sc}}$. The following Measurements are made on a 25km line at a frequency of 796 Hz,
$$Z_{SC} = 3220\angle -79.29°, Z_{OC} = 1301\angle 76.67° .$$
   Determine the primary constants of the line.
10. Characteristic impedance of a uniform transmission line is 2309.6 ohms at 800 HZ. At this frequency, the propagation constant is 0.054(0.0366+j0.999) per km. Determine R and L.
11. (i) Derive the conditions for minimum attenuation in the distortion less transmission line.**(Nov 2016)**
    (ii) Explain in detail about the reflection on a line not terminated in its characteristic impedance Z_o.**(Nov2017).**
12. (i) Explain the concept of loading and different types of loading of transmission lines
    (ii) A transmission line has L =10mH/m, C=10^{-7} F/m, R = 20 ohm/m and G = 10^{-5}mhos/m. Find theinput impedance at a frequency of $\left(\frac{500}{2\pi}\right)$Hz, if the line is very long.
13. (i)The constants of line are are R=6 ohm/Km.L=2.2mH/Km.C=0.005µF/Km and G=0.25*10^-3 mhos/Km. Calculate the attenuation constant and phase constant at 1000Hz.
    (ii) A transmission line has a characteristic impedance of (683-j138).The propagation constant is ((0.0074+j0.0356)per Km. Determine the values of R and L of this line if thefrequency is 1000Hz.
14. A lossless transmission line with Z_o=50Ω and d=1.5m connects a voltage V_g Source to a terminal load of Z_l=50+j50Ω, find the distance first voltage maximum l_M from the load and what is the power delivered to the load P_L? Assume the speed of the wave along the transmission line equal to the speed of light C. **(Nov 2017)**



UNIT- II HIGH FREQUENCY TRANSMISSION LINES
PART A- C303.2

1. What are the standard assumptions made for RF line? (May 2016)
Very considerable skin effect, so that currents may be assumed as flowing on conductor surfaces, internal inductance then being zero. Assume ωL>> R. this assumption is justifiable because it is found that the R increases because of skin effect with $(f)^{1/2}$ while the line reactance increases directly with frequency f.The lines are well enough constructed that G may be considered zero.

2. What is called a line of small dissipation and a line of zero dissipation?
Line of small dissipation: If resistance R is small, the line is considered as one of small dissipation and this concept is useful when lines are employed as circuit elements or where resonance properties are involved.
Line of zero dissipation: If resistance R is completely negligible, the line is considered as one of zero dissipation. This concept is useful in applications where losses may be neglected as in transmission of power at high efficiency.

3. What is known as a standing wave?
The actual voltage at any point on the transmission line is the sum of the incident and reflected wave voltages at that point. The resultant total voltage wave appears to stand still on the line, oscillating in magnitude with time but having field positions of maxima and minima. . Such a wave is known as a standing wave.

4. What are nodes and antinodes on a line?(Nov 2017).
Node: Nodes are points of zero voltage or current in the standing wave systems.
Antinodes: Antinodes or loops are points of maximum voltage or current.

5. Define smooth line. (May 2017)
A line terminated in R_o has no standing waves and thus no nodes or loops and this is called a smooth line.

6. Define SWR. (May 2017)
The ratio of the maximum to minimum magnitudes of current or voltage on a line having standing waves is called the standing wave ratio SWR S.

$$S = \frac{|E_{max}|}{|E_{min}|} \quad \text{or} \quad S = \frac{|I_{max}|}{|I_{min}|}$$

7. Give the relationship between SWR and the magnitude of reflection co-efficient.(May2016)

$$VSWR = \frac{1+|K|}{1-|K|}$$

8. Name the devices used for the measurement of standing waves.
Slotted line section and directional coupler are the devices used for the measurement of standing waves.

9. Define reflection coefficient.

The ratio of amplitudes of the reflected and incident voltage waves at the receiving end of the line is frequently called the reflection coefficient.

10. Give the expression for the input impedance of the dissipation less line (Nov 2017).

$Z_{in} = R_o\left(\frac{Z_R + jR_o \tan \beta l}{R_o + jZ_R \tan \beta l}\right)$, ohm

11. Explain the similarity of performance of open circuited and short circuited lines to that of series resonant or antiresonant circuits.

The similarity suggests the use of lines as reactive circuit elements or as tuned circuits. The input of the quarter wave short circuited line appears similar to that of a parallel resonant circuit, and the input of the quarter wave open line as that of a series resonant circuit.

12. A 50 ohms line is terminated in load Z_R = 90+j60 ohms. Determine the reflection coefficient.

Solution: Reflection co-efficient, K = $\frac{Z_R - Z_o}{Z_R + Z_o}$ = $0.473\angle 33.11^\circ$

13. Calculate standing wave ratio and reflection coefficient on a line having the characteristic impedance Z_o= 300 ohms and the terminating impedance Z_R is 300+j400 ohms. (Nov 2016).

Solution: $VSWR = \frac{1+|K|}{1-|K|}$ **;**To find the magnitude of the reflection coefficient, use

K = $\frac{Z_R - Z_o}{Z_R + Z_o}$ = $0.55\angle 56.31^\circ$.Therefore, SWR $S = \frac{1+0.55}{1-0.55}$ = 3.49

14. Write the expressions for the input impedance of open and short circuited dissipation less line(Nov 2016).

$Z_{oc} = -jR_o \cot \beta l$ and $Z_{sc} = jR_o \tan \beta l$

15. For the line of zero dissipation, what will be the values of attenuation constant and characteristic impedance.

For the line of zero dissipation, series arm impedance Z = $j\omega L$ and shunt arm admittance

Y = $j\omega C$. $Z_o = \sqrt{\frac{j\omega L}{j\omega C}} = \sqrt{\frac{L}{C}}$ = and $\gamma = \sqrt{(j\omega L)(j\omega C)} = j\omega\sqrt{LC}$. But, Propagation constant, $\gamma = \alpha + j\beta$. This implies that, attenuation constant, $\alpha = 0$ and $\beta = \omega\sqrt{LC}$

16. Write the conditions to be satisfied by dissipation less line.

The standard assumptions for a dissipation less line at a high frequency are ωL >> R and ωC >> G.

The value of characteristic impedance is real and resistive, it is represented by symbol

$$R_o = \sqrt{\frac{L}{C}}$$

Similarly, the propagation constant is found to be purely imaginary.

17. Give the minimum and maximum value of SWR and reflection co-efficient.

Min value ofSWR = 1; Max. Value of SWR = infinity, Min. value of K = 0 and Max. Value of K =1

18. Find the characteristic impedance of the line with following constants L = 9 micro henry/m, C = 16pico farad/m working at radio frequencies.

Solution: $Z_o = \sqrt{\frac{L}{C}}$ = 866 ohms.

19. Write the expression for VSWR in terms of
(a) The reflection coefficient (b)ZR & Z0 (Jan 2016)

Solution: (a)$VSWR = \frac{1+|K|}{1-|K|}$

$$VSWR = \frac{1+\left(\frac{Z_R - Z_o}{Z_R + Z_o}\right)}{1-\left(\frac{Z_R - Z_o}{Z_R + Z_o}\right)} = \frac{Z_R + Z_o + Z_R - Z_o}{Z_R + Z_o - Z_R + Z_o} = \frac{2Z_R}{2Z_o} = \frac{Z_R}{Z_o}$$

20. What is the significance of reflection coefficient?

Reflection coefficient gives the ratio of reflected voltage/current to incident voltage/current. The value of reflection coefficient is a measure of mismatch of impedance between the line and the load.

21. A line having characteristic impedance 50 Ω is terminated with a load 75 + j 75Ω. Calculate the reflection coefficient.

Reflection co-efficient K = $\frac{Z_R - Z_o}{Z_R + Z_o}$

22. A lossless transmission line has a shunt capacitance of 100 pF/m and a series inductance of 4 micro Henry/m. Determine the characteristic impedance.(Nov 2015)

Solution: $Z_o = \sqrt{\frac{L}{C}} = \sqrt{\frac{4x10^{-6}}{100x10^{-12}}}$ =200 ohm

23. For the line of zero dissipation, what will be the values of attenuation constant and characteristic impedance? (Nov 2015).

For the line of zero dissipation, Series impedance, Z = jωL and shunt admittance, Y = jωC Propagation constant, $\gamma = \sqrt{ZY} = \sqrt{j\omega L \times j\omega C} = \sqrt{j^2\omega^2 LC} = j\omega\sqrt{LC}$, since $\gamma = \alpha + j\beta$, attenuation constant, $\alpha = 0$ and phase constant, $\beta = \omega\sqrt{LC}$

PART B-C303.2

1. (i) Derive an expression for the input impedance of a dissipation less line and also find the input impedance is maximum and minimum at a distance ‘s’.**(Nov 2016)**

(ii)Find the sending end line impedance for a HF line having characteristic impedance of 50 Ω. The line is of length (1.185 λ) and is terminated in a load of (110 + j80) Ω. **(May 2017)**

2. (i) Derive the line constants for a line of zero dissipation.**(May 2016)**
   (ii) A line with zero dissipation has R = 0.006 ohm/m, C = 4.45 pF/m, L = 2.5 µH/m. if the line is operated at 10 MHz find R_0, α, β, v, λ
3. A transmission line is terminated in Z_L. Measurements indicate that the standing wave minima are 102cm apart and that the last minimum is 35cm from the load end of the line. Thevalue of standing wave ratio is 2.4 and R_o = 250 ohm. Determine wavelength andload impedance.
4. (a)A 30m long lossless transmission line with Z_o = 50 ohms operating at 2 MHZ is terminated witha load Z_L = 60+j40 ohms. If u= 0.6c on the line, find (i) Reflection co-efficient (ii) Standing wave ratio (iii) Input impedance. (b) Draw the input impedance pattern of lossless line when short circuited and open circuited. **(Nov 2017)**
5. The input impedances of a $\frac{\lambda}{8}$ long, 50 ohms transmission line are Z_1 = 25+j100 ohms Z_2 = 10-j50 ohms, Z_3 = 100+j0 ohms and Z_4 = 0+j50 ohms, when various load impedances are connected at the other end. In each case, determine the load impedance and the reflection coefficient at the input and load ends.
6. (i) Discuss in detail about the variation of input impedance along open and short circuit lines with relevant graphs**. (May 2016)**
   (ii)A loss less line has a SWR of 4. The R_0 is 150 ohms and the maximum voltage measured in the line is 135V. Find the power delivered to the load. **(May 2016)**
7. (i) Describe an experimental set up for the determination of VSWR of an RF transmission.
   (ii) Briefly explain on a) Standing wave b) Reflection loss. **(Nov 2016)**
8. Derive the expression that permit easy measurements of power flow on a line of negligible losses. **(May 2017)**
9. Draw and explain the voltage and current waveforms for the following cases: (1) Open circuited line (ii) Short circuited line (iii) $Z_R = Z_o$ (iv) $Z_R = 3Z_o$ and $Z_R = Z_o/3$
10. Mention the parameters of open wire line and coaxial cable at RF. Mention the standard assumptions made for radio frequency line.**(Nov 2015)**
11. A lossless line in air having a characteristic impedance of 300 ohms is terminated by unknown impedance. The first voltage minimum is located at 15cm from the load. The standing wave ratio is 3.3. Calculate the wavelength and terminating impedance.**(Nov 2015)**
12. Calculate the average input power at a distance from the load ‘l’ and find the impedance when the load is short circuited, open circuited and matched line. **(Nov 2017)**
13. Discussin detail aboutthe voltages and current on the dissipation less line. (**May 2017)**

UNIT III- IMPEDANCE MATCHING IN HIGH FREQUENCY LINES
PART A - C303.3

1. State the uses of the quarter wave line.(May 2017)

The expression for input impedance of the quarter wave line is given by $Z_s = R_o^2 / Z_R$

(1)It may be thought of as a transformer to match a load of Z_R to a source of Z_s. It may be considered as an impedance inverter in that it can transform low impedance into high impedance and vice versa.

(2)It may be used to couple a transmission line to a resistive load such as an antenna.

(3)It can be used as an insulator to support an open-wire or the center conductor of a coaxial line Such lines are sometimes referred to as copper insulators.

2. Why is a quarter wave linecalled an impedance inverter? (Nov 2017)
A quarter wave line may be considered as an impedance inverter in that it can transform a low impedance into a high impedance and vice versa.

3. Design a quarter wave transformer to match a load of 200ohms to a source resistance of 500 ohms. The operating frequency is 200 MHz.
Solution: The characteristic impedance of a quarter wave transformer, $R_0^{'} = \sqrt{R_A R_0}$

$$R_0^{'} = \sqrt{200\text{x}500} = 316.227\,\text{ohms}$$

4. What is an impedance matching in stub? (Nov 2017)
If maximum power has to transfer between the source and the load, the resistance of the load should be equal to that of the source and the reactance of the load should be equal to that of the source but opposite in sign (ie) if the source is inductive, the load should be capacitive and vice versa. When this condition is achieved, it is commonly referred to as impedance matching.

5. Give some of the impedance matching devices.
The quarter wave line or transformer, exponential line and the use of an open or closed stub line of suitable length are some of the impedance matching devices.

6. Define stub matching. (May 2016)
A section of transmission line can be used as matching section by inserting them between the load and the source. It is also possible to connect sections of open or short circuited line called stub in shunt with the main line at some point or points to effect impedance matching. This is called stub matching.

7. What are the advantages of stub matching?
The advantages of stub matching are the length and characteristic impedance of the line remain unaltered. From mechanical stand point, adjustable susceptances are added in shunt with the line so that impedance matching can be achieved.

8. Why a short circuited stub is preferred to an open circuited stub?(May 2017)
A short circuited stub is preferred to an open circuited stub because of greater ease in construction and because of the inability to maintain high enough insulation resistance at the open circuited point to ensure that the stub is really open circuited. A short circuited stub also has a lower loss of energy due to radiation since the short circuit can be definitely established with a large metal plate, effectively stopping all field propagation.

9. What are the drawbacks of impedance circle diagram?
Though the circle diagram is very useful in calculating the line impedance and admittance it has the following drawbacks. 1.Constant S and βs circles are not concentric, making interpolation difficult.2.Only a limited range of impedance values can be accommodated in a chart of reasonable size.

10. Define Smith chart.
Smith chart is a special polar diagram containing constant resistance circles, constant reactance circles, circles of constant standing wave ratio and radius lines representing line-angle loci; used in solving transmission line and waveguide problems.

11. What are the properties of Smith Chart?

The properties of Smith chart are as follows: (a) Normalizing impedance. (b) Plotting of an impedance. (c) Determination of Standing wave ratio(d) Determination of reflection co-efficient K in magnitude and direction. e) Location of voltage maxima and voltage minima. f) Movement along the periphery of the chart. g) Matched load.

12. Write down the basic difference between circle diagram and Smith chart.

The basic difference between circle diagram and Smith chart is that in the circle diagram the impedance is represented in a rectangular form while in the Smith chart the impedance is represented in a circular form.

13. Write down the application of circle diagram.

The circle diagram may be used to find the input impedance of a line of any chosen length.

14. Mention the applications of Smith Chart. (May 2015)

Smith chart can be used

1. as an admittance diagram to convert impedance into admittance
2. to determine the sending end impedance.
3. to determine the load impedance.

15.Match a load with impedance Z_A=100 Ohms to be 50 Ohms using a quarter-wave transformer.

$R_0' = \sqrt{Z_A R_0}$

$=\sqrt{(100x50)}=70.7$ohms

16. Design a coaxial quarter wave transformer to match a 10 ohm load to a 80 ohm line at 3000 MHZ.

$R_0' = \sqrt{Z_A R_0} = \sqrt{10x80} = 28.28$ ohms

17. Write down the expression to determine the length of the short circuited stub.

$$L = \frac{\lambda}{2\pi}\tan^{-1}\frac{\sqrt{1-|K|^2}}{2|K|}$$

18. Give the names of circles on smith chart.

The names of circles on smith chart are (i) Constant – R circles and (ii) constant – X circles

19. What are constant - S circles?

The input impedance equation for a dissipation less line if expressed in terms of SWR S, results in the form of a circle. These circles are called as constant – S circles.

20. Distinguish between single stub and double stub matching. (Nov 2016)

Single stub matching: Single-stub impedance matching requires that the stub be located at a definite point on the line. This requirement frequently calls for placement of the stub at an undesirable place from a mechanical view point. For a co-axial line, it is not possible to determine location of a voltage minimum without a slotted section, so that placement of a stub at the exact required point is difficult.

21. Double stub matching.

Double stub matching is one in which two short circuited stubs, whose lengths are adjustable independently are fixed. The locations of the two stubs are arbitrary. The spacing between the two stubs is frequently made as $\frac{\lambda}{4}$. Half-wave spacing should be avoided because it places the two stubs in parallel, resulting in only one effective adjustment being available. The same difficulty arises if the stubs are closely spaced.

22. Give the application of eighth-wave line. (Nov 2016)

It is used to transfer any resistance to an impedance with a magnitude equal to R_0 of the line, or to obtain a magnitude match between a resistance of any value and R_0, the internal source resistance.

PART B - C303.3

1.(i) Find the sending end impedance of a line with negligible losses when Characteristic impedance is 55Ω, the load impedance is 115 + j75Ω and thelength if the line is 1.183 λ by using smith chart. **(Nov 2016)**

(ii) Explain the significance of smith chart and its application in a transmission line.

2.A 30m long lossless transmission line with characteristic impedance of 50 ohm is terminated by a load impedance Z_L = 60 + j40 ohm. The operating wavelength is 90m. Find the reflection coefficient, SWR and input impedance using Smith Chart.

3.Explain the procedure of double stub matching on a transmission line.**(Nov 2015)**

4. (i)Determine the length and location of a single short circuited stub to produce an impedance match on a transmission line with R_o of 600Ω & terminated in1800 Ω. (ii) Explain the operation of quarter wave transformer and mention its important applications. **(Nov 2016)**

5.A 50 ohm transmission line is connected to a load impedance Z_L = 60 + j80 ohm. The operating frequency is 300MHZ. A double stub tuner spaced an eighth of a wavelength apart is used to match the load to the line. Find the required lengths of the short circuited stubs using Smith Chart.

6. Explain in detail about single stub matching and its drawbacks.

7. (i) Prove that the input impedance of a quarter wave line is $Z_{in} = R_0^2/Z_R$.**(May 2016)**

(ii) Design a quarter wave transformer to match a load of 200 ohms to a source resistance of 500 ohms, operating frequency is 200 MHz.**(May 2017)**

8.Discuss the following: (i) Impedance matching (ii) single & double stub matching

9.VSWR on a lossless line is found to be 5 and successive voltage minima are 40 cm apart. The first voltage minima is observed to be 15cm from load. The length of the line is 160 cm and the characteristic impedance is 300 Ω. Using Smith chart determine (a) load impedance (b) sending end impedance.

10.An RF transmission line with a characteristic impedance of 300∠0°Ω is terminated in an impedance of 100∠-45°. The load is to be matched to the transmission line by using a short circuited stub. With the help of Smith chart, determine the length of the stub and distance from the load.

11.For a load of normalized load impedance 0.8 + j 1.2 Ω, design a double stub tuner making the distance between the stubs 3λ/8. Specify the stub length and distance from the load to the first stub. The stubs are short circuited.

12.(i) What is quarter wave line? (ii) A 75 ohm lossless transmission line is to be matched with a 100-j80 ohm load using single stub. Calculate the stub length and its distance from the load
corresponding to the frequency of 30 MHZ using Smith chart.**(Nov 2015)**

13.A 300 ohm transmission line is connected to a load impedance of 450-j600 ohm at 10 MHZ. Find the position and length of a short circuited stub required to match the line using Smith chart.**(May 2017)**

14.A load (50 – j100) ohms is connected across a 50 ohms line. Design a short circuited stub to provide matching between the two at a signal frequency of 30 MHz using smith chart. **(May 2017)**

15. An antenna with impedance of 40+j30Ω is to be matched to a 100Ω lossless line with a short circuited stub. Determine the following using Smith chart. (i) The required stub admittance (ii) The distance between the stub and antenna (iii)The stub length (iv) The standing wave ratio on each of the system. **(Nov 2017)**

16. Design a double-stub tuner to match a loadimpedance Z_L=60-j80Ω to 50Ω line. The stubs are to be short circuited and are spaced λ/8 apart. Find the lengths of the two stubs using smith chart. **(Nov 2017)**

UNIT – IV PASSIVE FILTERS
PART A - C303.4

1. For a symmetrical network, define propagation constant and characteristic impedance. (Nov 2016)

For a symmetrical network, the image impedances Z_{1i} and Z_{2i} are equal to each other, and the image impedance is then called the characteristic impedance or the iterative impedance, Z_o. That is, if a symmetrical T network is terminated in Z_o, its input impedance will also be Z_o, or its impedance transformation ratio is unity. Under the condition of Z_o termination, propagation constant γ is defined as the natural logarithm of the ratio of input to output currents or input to output voltages. γ is a complex number defined as γ = α + jβ, where α is known as the attenuation constant, since it determines the magnitude ratio between input and output quantities, or the attenuation produced in passing through the network.

2. What is the significance of propagation constant in symmetrical network?

The propagation constant being a function of frequency can supply information on the ability of the filter to perform as desired. That is, by definition, $\frac{I_1}{I_2} = e^{\alpha + j\beta}$, where $I_1 and I_2$ are the input and output currents of a symmetrical network. If $I_1 = I_2 ; \alpha = 0$; there is no attenuation only a phase shift, in transmitting a signal through the filter and the operation is in a pass band of frequencies. If $|I_1| < |I_2|$, then α has a positive value, attenuation has occurred and operation is in an attenuation or stop band of frequencies.

3. What are called constant k filters? (Nov 2017)

If Z_1 and Z_2 of a reactance network are unlike reactance arms, then $Z_1 Z_2 = k^2$ where k is a constant independent of frequency. Networks or filter sections for which this relation holds are called constant-k filters.

4. How to obtain constant-k high pass filter?

For a constant-k high pass filter, $Z_1 = -jX_C$ and $Z_2 = jX_L$, then $Z_1 Z_2 = k^2 = L/C$, where k is a constant independent of frequency.

5.What are the demerits of constant – k filters? (May 2017)

There are two major demerits in the constant – k filters. They are,

1.The attenuation does not rise very rapidly at cutoff, so that frequencies just outside the pass band are not appreciably attenuated with respect to frequencies just inside the pass band.

2. The characteristic impedance varies widely over the pass band, so that a satisfactory impedance match is not possible.

6. What are m-derived filters?
The m-derived filters attempt to raise the attenuation near cutoff frequencies.

7.Define neper.
Neper is defined as the natural logarithm of the ratio of the input to output currents or input to output voltages. Ie. N nepers = ln (V_1 / V_2) = ln (I_1 / I_2)

8.Define decibel.(Nov 2017)
The bel is defined as the logarithm of a power ratio, number of bels = log (P_1/P_2). It has been found that a unit one-tenth as large is more convenient, and the smaller unit is called the decibel, abbreviated "db" defined as db = 10 log(P_1/P_2).

9.Write down the relationship between neper and dB.
1 Neper = 8.68 dB.
1 dB= 0.1151 nepers

10. What do you mean by symmetrical networks?
When Z_1 = Z_2 or the two series arms of a T network are equal, or Z_a = Z_c and the shunt arms of a π network are equal, the networks are said to be symmetrical.

11. What are called cut-off frequencies in the design of filters?
The frequencies at which the network changes from a pass network to a stop network, or vice versa, are called cutoff frequencies.

12. What is meant by the terms pass band and stop band as applied to filters?
Pass band: Pass band is a band of frequencies in which the signal is allowed to pass where the attenuation of the signal is zero for an ideal filter.
Stop band: Stop band is a band of frequencies in which the signal is not allowed to pass where the attenuation of the signal is infinity for an ideal filter.

13. What is the use of crystal filters?
Crystal filters are quite generally used to separate the various channels in Carrier telephone circuits, in the range above 50 kilocycles.

14. What are the characteristics of an ideal filter?
The characteristics of an ideal filter are zero attenuation in the pass band and infinite attenuation in the stop band.

15. A constant-K, T-section high pass filter has a cut-off frequency of 10KHz and the design impedance is 600ohms. Determine the value of shunt inductance L and series capacitance C. (Nov 2016)
Solution: For a prototype high pass filter, R= R_o

$$L = \frac{R}{4\pi f_c} = \frac{600}{4\pi x 10000} = 4.77\text{mH}; \; C = \frac{1}{4\pi f_c R} = 132.6\mu\text{F}$$

16. What are composite filters? (May 2016)
Filters designed using one or more m-derived sections following a proto type filter are called composite filters. The m derived section is designed following the design of the proto type T section. (ie) the use of a prototype and one or more m- derived sections in series results in a composite filter.

17. How can you realize a band stop filter?

A band stop or band elimination filter can be realized by connecting a low pass filter in parallel with a high pass section in which the cut-off frequency of low pass filter is below that of a high pass filter.

18. How do you obtain a band pass filter?

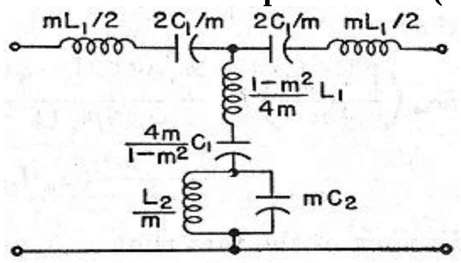
A band pass filter may be obtained by using a low pass filter followed by a high pass filter in which the cut-off frequency of the low pass filter is above the cut-off frequency of the high pass filter, the overlap thus allowing only a band of frequencies to pass.

19. Give the characteristic impedance of constant k low pass filter (both pi and T sections).

The characteristic impedance of constant k low pass filter (both pi and T sections) is,

$$Z_{oT} = R_k\sqrt{1-\left(\frac{f}{f_c}\right)^2} \text{ and } Z_{o\pi} = \frac{R_k}{\sqrt{1-\left(\frac{f}{f_c}\right)^2}}$$

20.Sketch an m-derived band-pass section.(May 2017)



21.Give the characteristic impedance of a symmetrical T-section and symmetrical π section.

Characteristic impedance of a symmetrical T-section, $Z_{oT} = \sqrt{Z_1 Z_2\left(1+\frac{Z_1}{4Z_2}\right)}$

Characteristic impedance of a symmetrical π section, $Z_{o\pi} = \sqrt{\frac{Z_1 Z_2}{1+4Z_1 Z_2}}$

22.Determine the value of L required by a constant k T section HPF with a cut-off frequency of 1 KHZ and design impedance of 600 ohms. Determine the value of L.

Solution: L = $\frac{R}{4\pi f_c}$ =0.0477H

23. What are the advantages of m-derived filters?(Nov 2015)

There are two major advantages in the m-derived filters. They are,

1. The attenuation does rise very rapidly at cutoff, so that frequencies just outside the pass band are appreciably attenuated with respect to frequencies just inside the pass band.
2. The characteristic impedance remains uniform widely over the pass band, so that a satisfactory impedance match is possible.

24. Give some applications of filters.

Filter networks are widely used in communication systems to separate various voice channels in carrier frequency telephone circuits. Filters also find applications in instrumentation, telemetering equipment etc. where it is necessary to transmit or attenuate a limited range of frequencies.

25. Design a prototype low pass filter T and π section of design impedance R_o = 500ohms and cut-off frequency is 2000HZ.

Solution: For a prototype low pass filter, R= R_o

$$L = \frac{R}{\pi f_c} = 0.0796 \text{ henry} ;C = \frac{1}{\pi f_c R} = 3.184 \times 10^{-7} \text{ farad}$$

PART B - C303.4

1.Explain the design of constant-K LPF & HPF (both pi and T sections) with necessary equations and diagrams.

2.Design a low pass filter (both pi and T sections) having a cut-off frequency of 2 KHZ to operate with a terminal load resistance of 500 ohms.**(May 2017)**

3.Explain the theory of proto type band elimination filter for both T and pi configurations and also plot the variation of reactance with respect to frequency.**(Nov 2015)**

4.i)Sketch the reactance curve and design a constant – k low pass filter.Determine attenuation constant and phase constant in pass band and stop band and plot it. **(Nov 2017)**(ii) A π – section filter network consists of a series arm inductance of 20mH and two shunt arm capacitance of 0.16μF each. Calculate the cut-off frequency and attenuation constant and phase shift constant at 15 KHz. What is the value of nominal impedance in the pass band?**(May 2016)**

5.What is m-derived filter? Draw a m-derived T-section and π-section LPF and explain the analysis of m-derived LPF with respect to attenuation, phase shift and characteristic impedance with frequency profile respectively.**(Nov 2016)**

6.The series arm impedance of a filter consists of a 0.5 micro farad capacitor in series with an inductor of 0.35 H. If R_0 = 500 ohms, determine the elements in the shunt arm and the manner in which they may be connected. Find the frequency of resonance f_0.

7.Design a constant K band pass filter (both t and pi sections) having a design impedance of 600 ohms and cut-off frequencies of 1 KHZ and 4 KHZ.**(Nov 2015)**

8.Design a composite filter to meet the following specifications f_c = 2000 Hz, f_∞ = 2050 Hz and R_K = 500 Ω. **(May 2016)**

9.Derive the design equation of constant – k BPF.

10. Design an m-derived LPF for cut-off frequency of 1KHZ, Design impedance is 400 ohms and the resonant frequency is 1100HZ.**(Nov 2015)**

11. Derive the equations for the characteristic impedance of symmetrical T and pi networks.**(Nov 2015)**

12. What is composite filter? Design a composite-K-low pass filter (T and pi sections) and having cut-off at which 2.5kHz and design resistance 700 ohms.Also find the frequency at which this filter produces attenuation of 19.1 dB. Find its characteristic impedance and phase constant at pass band and stop band. **(Nov 2016)**

13. Design a T and a pi section low pass filter which has series inductance 80 mH& shunt capacitance 0.022 μF. Find the cut-off frequency & design impedance**(Nov 2017)**

14. What are the advantages of m derived filter? Design an m derived low pass filter (T andpi section) having design resistance R_o = 500 ohms, cut-off frequency =1500 HZ and infinite attenuation frequency =2000 HZ. **(May 2017)**

15. Draw and explain the design and operation of m-derived T-section band pass filter with necessary equations and diagrams.**(May 2015)**

16. Design constant K band stop filters (both T and π sections) for the cutoff frequencies of 2 KHz and 6KHz .The design impedance is 500 Hz.
17. Discuss the properties of symmetrical network in terms of characteristic impedance and propagation constant.**(Nov 2015)**

UNIT V WAVE GUIDES AND CAVITY RESONATORS

PART-A - C303.5

1. What are guided waves? Give examples.

The electromagnetic waves that are guided along or over conducting or dielectric surface are called guided waves. Examples: The waves along ordinary Parallel wire co-axial transmission lines.

2. Define TEM wave.

The transverse electromagnetic waves are waves in which both electric and magnetic fields are transverse entirely but have no components of E_z and H_z. It is referred to as principal wave.

3. Mention the characteristics of TEM waves. (Nov 2015)

(a)TEM waves are special type of TM wave. (b) It does not have either E_z or H_z component. (c) Its velocity is independent of frequency. (d) Its cut-off frequency is zero.

4. Define skin depth.

In a medium which has conductivity the wave is attenuated as it progress owing to the losses which occur. In a good conductor at radio frequencies the rate of attenuation is very great and the wave may penetrate only a short distance before being reduced to a negligibly small percentage of its original strength. Such circumstance is called depth of penetration or skin depth defined as δ, the depth the wave has been attenuated to 1/e or approximately 37% of its original value.

5. Write down the expression for the wave impedance for TM,TE and TEM wave.

Wave impedance for TM wave, $Z_{TM}= \eta\sqrt{1-\left(\frac{f_c}{f}\right)^2}$; For TE wave, $Z_{TE} = \dfrac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$

Wave impedance for TEM wave, $Z_{TEM} = \eta_o = \sqrt{\frac{\mu_o}{\varepsilon_o}} = 120\pi$ ohms

6.Define phase velocity and group velocity.(May 2015)

The rate at which the wave changes its phase as the wave propagates inside the region between planes is defined as phase velocity v_p and is given by ,$v_p = \frac{\omega}{\beta}$;

$$\beta = \varpi\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

The actual velocity with which the wave propagates inside the region between the planes is defined as group velocity v_g, given by $v_g = \frac{d\omega}{d\beta}$

7. Two conducting planes have a distance of separation of 6 cm in air. At a frequency of 6 GHZ with TM_2 mode being excited, find the cut-off wavelength.

Solution:

$$\lambda_c = \frac{2a}{m} = \frac{2x0.06}{2} = 0.06m$$

8.The electric field in free space is given by $\vec{E} = 50\cos\left(10^8 t + \beta x\right)\vec{a}_y$, v/m. find the direction of wave propagation and phase constant.

Solution: Direction of wave propagation = negative x direction

Phase constant $\beta = \omega\sqrt{\mu\varepsilon}$; since the electric field is in free space, $\mu = \mu_o and \varepsilon = \varepsilon_o$

= $\omega\sqrt{\mu_o\varepsilon_o}$; We know that $\frac{1}{\sqrt{\mu_o\varepsilon_o}}$ = 3 X 10^8 m/sec

From the given electric field vector, $\omega = 10^8$; => $\beta = \frac{10^8}{3x10^8} = 0.33 rad$

9. Compare TE and TM mode.

TM wave: Transverse magnetic wave is a wave in which magnetic field strength H is entirely transverse. It has an electric field strength E_z in the direction of propagation and no component of magnetic field strength H_z in the same direction.**TE wave:** Transverse electric wave is a wave in which electric field strength E is entirely transverse. It has a magnetic field strength H_z in the direction of propagation and no component of electric field strength E_z in the same direction.

10. What is meant by dominant mode? What is the dominant mode for parallel plate waveguides?(Nov 2017)

Dominant mode is the mode which has the lowest cut-off frequency. For parallel plate waveguides, it is $TE_{10.}$

11. What is degenerate mode in rectangular waveguide? (Jan 2016)

Some of the higher order modes, having the same cut-off frequency, are called degenerate modes. It is seen that in a rectangular waveguide possible TE_{nm} and TM_{mn} modes (both m≠ 0 and n ≠0) are always degenerate.

12. A wave is propagated in a parallel plane waveguide. The frequency is 6 GHz and the plane separation is 3 cm. Determine the group and phase velocities for the dominant mode. (Nov 2013) Solution: f = 6 GHz, a = 3cm, Dominant mode = TE_1

Cut-off frequency = $\frac{m}{2a\sqrt{\mu\varepsilon}}$ =(1x3x10^8)/(2x0.03) =5GHz

$$v_p = \frac{\omega}{\beta} \; ; \; \beta = \varpi\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

13. Why rectangular waveguides are preferred over circular waveguide?

Rectangular waveguides are preferred over circular waveguides because of the following reasons.

Rectangular waveguide is smaller in size than a circular waveguide of the same operating frequency. It does not maintain its polarization through the circular waveguide.

The frequency difference between the lowest frequency on dominant mode and the next mode of a rectangular waveguide is bigger than in a circular waveguide.

14. What is known as evanescent mode in a rectangular waveguide?

When the operating frequency is lower than the cut-off frequency the propagation constant becomes real ie $\gamma = \alpha$ .The wave cannot be propagated. This non-propagating mode is known as evanescent mode.

15. What is meant by the dominant mode of a waveguide?(May 2016)

The cut-off frequency $f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$ shows that the physical size of the waveguide will determine the propagation of the modes of specific orders determined by m and n. The minimum cut-off frequency is obtained for a guide having dimension a > b, for m = 1,n = 0 Since for TM_{mn} modes, m $\neq 0$ or n $\neq 0$, the lowest order mode possible is TE_{10} and TM_{11} mode, called the dominant mode in a rectangular waveguide for a >b

16. Explain the impossibility of TEM wave in waveguide.

Suppose a TEM wave is assumed to exist within a hollow guide of any shape. Then lines of H must lie entirely in the transverse plane. Also in a nonmagnetic material, $\nabla . H = 0$ which requires that the lines of H be closed loops. Therefore, if a TEM exists inside the guide, the lines of H will be closed loops in plane perpendicular to the axis. Now by Maxwell's first equation the magnetomotive force around each of these closed loops must equal the axial current (J_C or J_D). In the case of a guide with an inner conductor, example, a coaxial transmission line, this axial current through the H loops is the conduction current in the inner conductor. However, for a hollow waveguide having no inner conductor, this axial current must be a displacement current. But an axial displacement current requires an axial component of E, something not present in a TEM wave. Therefore the TEM wave cannot exist in a single conductor waveguide.

17. A circular waveguide operated at 11 GHZ has the internal diameter of 4.5 cm. for a TE_{01} mode propagation, calculate free space wavelength and cut-off wavelength. ($(ha)_{01}$= 2.405)

Solution: $\lambda_o = \frac{C}{f} = \frac{3x10^8}{11x10^9}$ **= 0.02 m**

$\lambda_C = \frac{C}{f_c}$ **;** $f_c = \frac{h_{nm}}{2\pi\sqrt{\mu\varepsilon}}$ **= 5.1 GHZ ;** $\lambda_C = \frac{3x10^8}{5.1x10^9}$ **= 0.0588 m**

18.Why is TM_{01} mode preferred to the TE_{01} mode in a circular waveguide?

TM_{01} mode is preferred to theTE_{01} mode, since it requires a smaller diameter for the same cut-offwavelength.

19. A rectangular waveguide of cross section 5 cm X 2 cm is used to propagate TM_{11} mode at 10 GHZ. Determine the cut-off wavelength. (Nov 2015)

Cut-off frequency, $f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

Here, a = 0.05m and b = 0.02m, m = 1 and n = 1, f = 10 GHZ

If air is the dielectric within the rectangular waveguide, $\frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3x10^8 \, m/sec$

Therefore, $f_c = \frac{1}{2\sqrt{\mu_0\varepsilon_0}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} = \frac{C\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}{2}$

$$\frac{C}{f_c} = \frac{2}{\sqrt{\left(\frac{1}{0.05}\right)^2 + \left(\frac{1}{0.02}\right)^2}} = 0.037m$$,Cut-off wavelength, $\lambda_C = 0.037\text{m}$

20What is a microwave cavity resonator?

Microwave resonator is a tunable circuit used in microwave circuits. It is a metallic enclosure that confines the electromagnetic energy. When the resonator resonates at resonant frequency, the peak energies stored in the electric and magnetic fields are equal.

21. Define the quality factor Q of a resonator.

The quality factor Q is a measure of frequency selectivity of the resonator. It is defined as Q = 2π X (maximum energy stored)/ Energy dissipated per cycle)

X=> ω W/P where W is the maximum stored energy, P is the average power loss.

22. Why rectangular or circular cavities can be used as microwave resonators? And why transmission line resonator is not used?

Rectangular or circular cavities can be used as microwave resonators because they have natural resonant frequency and behave like a LCR circuit. At very high frequencies transmission line resonator does not give very high quality factor Q due to skin effect and radiation loss in braided cables. So, transmission line resonator is not used as microwave resonator.

23. What is the dominant mode for rectangular resonator and circular cavity resonator?

The dominant mode of a rectangular resonator depends on the dimensions of the cavity. For b<a<d, the dominant mode is TE_{101}. In circular cavity resonator, for d<2a, the dominant mode is TM_{010} and for d>2a, TE_{111}.

24. What is the dominant TE and TM mode in rectangular waveguide?

TE_{10} and TM_{11} mode, are called the dominant mode in a rectangular waveguide for a >b

25. Write the applications of cavity resonators.(Nov 2015)

Cavity resonators are useful as filters and tuners in microwave circuits, as LC resonators in RF circuits. They can also be used to measure the frequency of an electromagnetic signal.

26.An air-filled rectangular waveguide of inner dimensions 2.286 cm X 1.016 cm in the dominant TE_{10} modes. Calculate the cut-off frequency and phase velocity of a wave in the guide at a frequency of 7 GHz.(Nov 2016).

Cut-off frequency, $f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

Here, a = 2.286 cm and b = 1.016 cm, m = 1 and n = 0, f = 7 GHz

If air is the dielectric within the rectangular waveguide, $\frac{1}{\sqrt{\mu\varepsilon}} = \frac{1}{\sqrt{\mu_0\varepsilon_0}} = 3x10^8\, m/\sec$

Therefore, $f_c = \frac{1}{2\sqrt{\mu_0\varepsilon_0}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2} = \frac{C\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}{2} = 1.98GHz$

$$V_p = \frac{\omega}{\beta} \; ; \; \beta = \varpi\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2} \qquad V_p = \frac{C}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = 3.127x10^8 m/\sec$$

27. Justify, why TM_{01} and TM_{10} modes in a rectangular waveguide do not exist. (Nov 2016).

TM_{01} and TM_{10} do not exist in a rectangular wave guide. Because no fields are present if neither 'm' or 'n' be zero. (i.e., $E_z = E_y = H_x = H_y = 0$).

28. How is cavity resonator is formed? (May 2016)

Waveguide cavity resonators are formed by shorting the two ends of a section of a waveguide. The electromagnetic fields inside the cavity should satisfy Maxwell's equations, subject to the boundary conditions that the electric field tangential to and the magnetic field normal to the metal walls must vanish.

29.Write the expression for cut-off wavelength of the wave which is propagated in between parallel planes. (Nov 2017)

$$\lambda_C = \frac{2a}{m}$$

30.Calculate the cut-off frequency of rectangular waveguide whose inner dimensions are a=2.5cm and b=1.5cm operating at TE_{10} mode. (May 2017)

Cut-off frequency, $f_c = \frac{1}{2\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$

Here, a = 2.5cm and b = 1.5cm, m = 1 and n = 0, f = 6 GHZ

31. Enumerate the parameters describing the performance of a cavity resonator.(May2017)

(i) Quality factor (ii) Dimensions of the resonator cavity (iii) Skin depth of the conducting walls of resonator.

PART B - C303.5

1. Derive the components of electric and magnetic field strength between a pair of parallel perfectly conducting planes of infinite extend in the 'Y' and 'Z' directions. The planes are separated in X direction by "a".**(May 2015)**
2. Derive the expressions for the field components of TM and TE waves between parallel plates, propagating in Z direction.**(Nov 2016)**
3. Two perfectly conducting planes are separated by 7.5 cm and filled with a dielectric material of dielectric constant ε_r = 2.5. For a frequency of 4000 MHZ with TM_2 mode excited, find the following: (a) cut-off frequency (b) cut-off wavelength (c) phase velocity (d) group velocity (e) phase constant (f) wave impedance (g) guide wavelength and (h) Is it possible to propagate TM_1 mode?**(May 2016)**
4. Discuss the characteristics of TE and TM waves and also derive the cut-off frequency and phase velocity from the propagation constant.**(May 2015)**
5. Derive the expressions for the field components of TM and TE waves in rectangular waveguides.**(Nov 2017)**
6. (i)Derive the expressions for the field components of TM and TE waves in circular waveguides.

(Nov 2015)

(ii) Derive the wave impedance for TM and TE waves between parallel planes.**(May 2015)**

7. (i) Prove that TEM wave does not exist in hollow waveguides.

(ii)A TEM wave is propagated in the region between the conducting planes at a frequency of 2.5 GHZ. This region between planes is filled with polysterene material for which $\varepsilon_r = 2.56$ and $\mu_r = 1$. Find (a) phase constant (b) Wave impedance and (c) guide wavelength.

9. (i) Explain the concept of excitation of waveguides. (ii) Discuss the structure, advantages and disadvantages of resonant cavities.**(May 2015).**

(ii) An air filled circular waveguide having an inner radius of 1 cm is excited in dominant mode at 10 GHZ. Find (i) cut-off frequency (ii) guide wavelength (iii) wave impedance and (iv) attenuation constant for wall surface resistance of 20 milliohm.

10. A rectangular air-filled copper waveguide with dimension 0.9 inch x 0.4 inch cross section and 12 inch length is operated at 9.2 GHZ with a dominant mode. Find the cut-off frequency, guide wavelength, phase velocity, characteristic impedance and the loss**.(Nov 2015)**

11.Calculate the resonant frequency of an air filled rectangular resonator of dimensions a = 2cm, b = 4 cm and d = 6 cm operating in TE_{101} mode. **(Nov 2015).**

12. (i) Write a brief note on circular cavity resonator and its application. **(Nov 2016)**

(ii) A TE_{11} wave is propagating through a circular waveguide. The diameter of the guide is 10 cm and the guide is air-filled. Given $X_{11} = 1.842$.(1)Find the cut-off frequency (2) Find guide wavelength in the guide for a frequency of 3 GHz. (3) Determine the wave impedance in the guide. **(Nov 2016)**

13.An air-filled resonant cavity with dimensions a=5cm, b=4cm and c=10cm is made of copper (σ_c=5.8x10^7mhos/m). Find the resonant frequencies of (a) The first lower order modes (b) the quality factor TE_{101} mode. **(Nov 2017)**

14.Examine the effectiveness of Bessel’s differential equation and Bessel function with reference to waveguides. **(Nov 2017)**

15.When dominant mode is transmitted through a circular waveguide, the wavelength measured is to be 13.33cm. The frequency of the microwave signal is 3.75GHz. Calculate a) Cut-off frequency b) Inner radius of guide c) Phase velocity d) Group velocity e) Phase constant f) Wave impedance g) Bandwidth for operation in dominant mode only. **(May 2017)**