Antenna :-

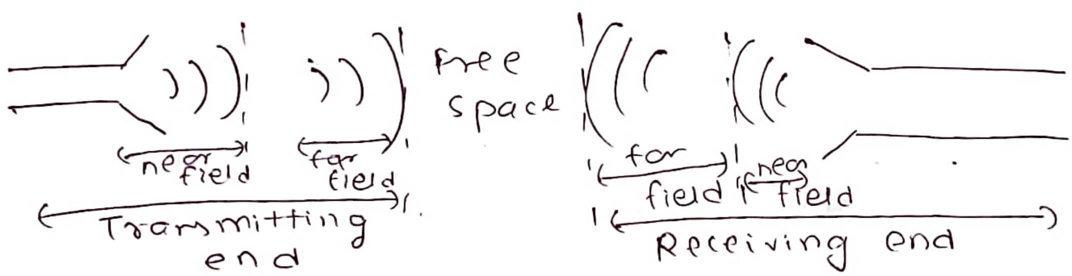
- In telecommunication systems, antenna is electronic device which radiate electromagnetic signal and receiving antenna receive the same signal from space.

- when an electric current passes through an antenna it converts current into radio waves which are transmitted to free space. At receiving end, it converts electromagnetic radiation received from free space in electric current.

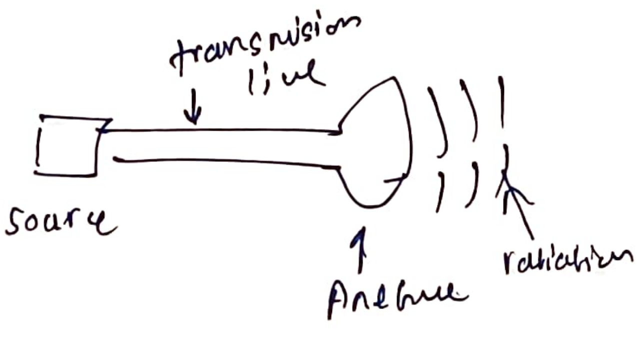
Transmitter :- Electric current ⟹ Radio waves

Receiver :- Radio waves ⟹ Electric current.

- Antenna may be isotropic or directional.



- Antenna is also called transducer.



Types of Antennas:-

	Examples	Applications
1. wire Antenna	Dipole Antenna, monopole Antenna, Helix antenna, Loop antenna.	personal application, ships, automobiles
2. Aperture Antennas	waveguide, Horn antenna.	Flush-mounted application, air-craft, space craft.
3. Reflector Antennas	Parabolic reflectors, corner reflectors	microwave communication, satellite tracking, radio astronomy.
4. Lens Antennas	Convex-plane, concave-plane, convex-convex, concave-concave lenses	used for very high freq. applications
5. Microstrip Antenna.	circular-shaped, Rectangular-shaped metallic patch above ground plane	Air-craft, space-craft, satellites, missiles, cars, mobile phones
. Array Antennas	Yagi-Uda antenna, micro strip patch array, Aperture array, slotted wave guide array	used for very high gain applications, mostly when needs to control the radiation.

. wire Antenna:-

- basic type of antennas., well known and widely used.
- subdivided into four types:-
  - ipole Antenna
  - short Dipole antenna
  - monopole Antenna
  - Loop Antenna.

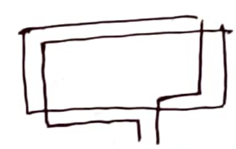
1. Dipole Antenna :-

ⓐ Dipole

- It is made up of two conductors in same axis and the length of wire need to small compare a to wavelength.
- For short dipole antenna, the length of wire less than the tenth of worelength of frequency.

2. Loop Antenna :-

- A loop antenna is formed by single or multiple turn of wire forming a loop. ~~The radiation~~

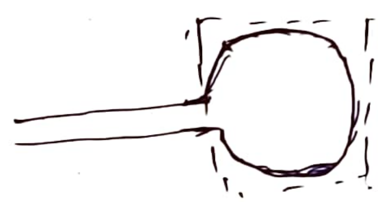


Loop.

3. monopole Antenna :-

- Special case of Dipole antenna is monopole.
- it is half of dipole antenna.

ⓑ Helix



circular loop

2. Aperture Antennas :-

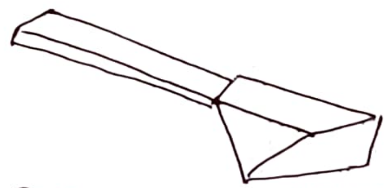
- It has two types :-
  - Slot Antenna
  - Horn Antenna.
- It has directional antenna, aperture antenna have opening in surface.
- It consists of dipole or loop antenna in guiding structure with opening to emit radio waves.

1. Slot Antenna:-

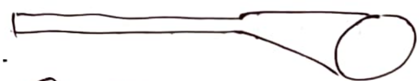
- Type of aperture antenna which contains one or more slots cut on surface of waveguide.
- Used in microwave frequ.
- Have an omnidirectional radiation pattern.

2. Horn Antenna:-

- most populer antennas.
- Operate in microwave freq.
- End of antenna is widened or in horn shape. Therefore, there is larger directivity. to emit signal to long distances.



(a) Pyramidal Horn



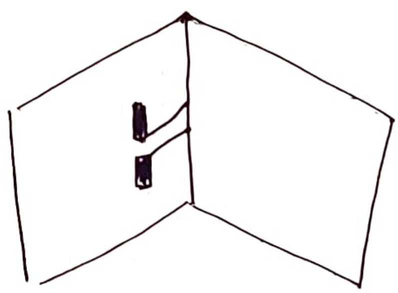
(a) Conical horn.

3. Reflector Antennas:-

1. Corner Reflecter.
2. Parabolic Reflector.

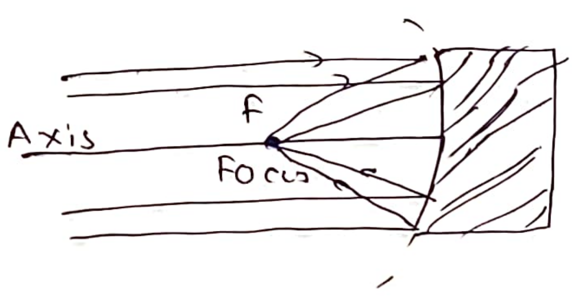
1. Corner Reflecter:-

- It comprises of one or more dipole elements placed in front of corner reflecter, is known as corner-reflecter antenna.
- The directivity of antenna can be increased by using reflecters.



2. Parabolic Reflecter:-

- The radiating surface of parabolic antenna has very large dimensions compared to its wavelength



Parabolic Antenna.

Performance Parameters:-

1. Radiation Pattern:-

- It is defined as "a mathematical function or graphical representation of radiation properties of antenna as a function of space coordinates.

- In most case, the radiation pattern is determined in far field region

- Radiation properties includes radiation intensity, field strength, directivity and polarization.

-

2. Antenna ~~Bandwidth~~ Directivity

- The directivity is defined as the ratio of the radiation intensity in a given direction from antenna to radiation intensity average over all direction

$$D(\theta,\phi) = \frac{U(\theta,\phi)}{U_0} = \frac{4\pi\, U(\theta,\phi)}{P_{rad}}.$$

max :-

$$D_{max} = D_0 = \frac{U_{max}}{U_0} = \frac{4\pi\, U_{max}}{P_{rad}}.$$

3. Gain :-

- The ratio of radiation intensity in a given direction to radiation intensity that would be ~~accepted~~ obtained if power accepted by antenna were radiated isotropically.

$$G = \frac{4\pi\, U(\theta,\phi)}{P_{\cancel{rad}.in}}$$

$$G(\theta,\phi) = e_{cd}\, D(\theta,\phi)$$

max :-

$$G_0 = e_{cd}\, D_0.$$

4. Efficiency:-

- For antenna its efficiency is ratio of radiated antenna power to power fed to antenna. Ideally, it should be equal.

- Various losses are:-
  1. Losses due to reflection.
  2. Power loss due to conductor
  3. Dielectric losses.

- $e_0 = e_r \, e_c \, e_d$

  ↓

  efficiency

  e_r = reflection efficiency

  e_c = conduction efficiency

  e_d = dielectric efficiency.

5. Half Power beam width:-

- Beam width ~~of~~ is the aperture angle from where the most of power is radiated.

- Two types:- Half Power Beam width (HPBW), First Null Beam width.

- HPBW:- The angular separation in which the magnitude of radiation pattern decreases by 50% from peak of main beam.

- HPBW is angle in which relative power is more than 50% of peak power, in effective radiated field of antenna.

$$HPBW = \frac{70\lambda}{D}$$

D → Diameter
λ → wavelength

unit :- radian or degree

5. Bandwidth:-

- Bandwidth describes the range of frequencies over which antenna can properly radiate or receive energy.

- The desired ~~antenna~~ bandwidth is one of determining parameters used to decide upon an antenna.

- Typically quoted in term of VSWR in bandwidth.

- Antenna can be described as operating at 100-400 MHz with VSWR < 1.5.

- It can be specified as Fractional Bandwidth. FBW is ratio of frequency range divide by center freq.

6. Effective Length:-

- The ratio of open-circuit voltage at the terminals of antenna to magnitude of electric field strength in direction of antenna polarization.

$$V_{oc} = E \cdot l_e$$

$E \rightarrow$ incident electric field.
$l_e \rightarrow$ effective length.
$V_{oc} \rightarrow$ open-circuited voltage.

7. Effective Area:-

- The ratio of available power at terminal of a receiving antenna to power flux density of plane wave incident polarization matched on antenna.

$$A_e = \frac{P_T}{W_i} \quad \begin{matrix} \rightarrow \text{power delivered to load} \\ \rightarrow \text{power density.} \end{matrix}$$

8. Radiation Efficiency:- The ratio of total power radiated by antenna to net power received by antenna.

$$\varepsilon_R = \frac{P(\text{radiated})}{P(\text{input})}.$$

Friis Transmission Equation:-

- It is used to calculate the power received from one antenna when transmitted from another antenna, separated by distance R. and operating at frequeny f or wavelength λ.

- It is given as:-

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi R)^2} \quad -(1)$$

P_T → Power Transmitted.
G_T → Gain of Transmitter Antenna.
G_T → Gain of Receiver Antenna
λ → wavelength.
R → distance betw. two antennas

- $\lambda = \frac{c}{f}$

$$\therefore \quad P_R = \frac{P_T G_T G_R c^2}{(4\pi R f)^2} \quad -(2)$$

- Eqn (2) clearly shows that power received will be highest at lower frequencies.

- Path loss is higher for higher frequencies.

- $\frac{P_R}{P_T} = \frac{G_T G_R}{\left(\frac{4\pi d}{\lambda}\right)^2}$, $\underbrace{L_S = \left(\frac{4\pi d}{\lambda}\right)^2}_{\text{transmission path loss}}$

Microwaves:-

- Microwaves are form of electromagnetic radiation with wavelengths ranging from about one meter to one millimeter. with freq betw 300 MHz (1m) and 300 GHz (1mm)

- Freq. in microwave range are often referred as: S, C, X, Ku, K, or Ka band.

- ~~UHF, SHF - 30 to 300 m~~
  ~~300 MHz to 3000 GHz~~

UHF	-	300 MHz to 3000 MHz	- Cellphone WLAN, GPRS
SHF	-	3 to 30 GHz	← Satellite 5G mobile
EHF	-	30 to 300 GHz	- Imaging ~~detection~~ application

→

L	-	1 to 2 (GHz)
S	-	2 to 4
C	-	4 to 8
X	-	8 to 12
Ku	-	12 to 18
K	-	18 to 27
Ka	-	27 to 40
Millimeter	-	40 - 300. (GHz)

Advantages of microwaves:-

1. Increased Bandwidth Availability
2. Lower power requirement.
3. Less fading effect and more reliable.
4. Improved Directive propeties
5. Transparency propetis of microwaves

Applications:-

1. Commercial :-
   - Microwave ovens
   - Drying machines
   - Biomedical appilcation
   - Rubber / plastic process industry

2. Electronic warfare

3. Telecommunication
   - Space commun.

4. Radars

5. Object Identification.

Formula

* ~~Comparsion betw Transmission line and waveguide:-~~

* Wave guide:-

- A hallow metallic tube of uniform cross sectn for ~~electr~~ transmitting EM waves by successive reflections from inner walls of tube is called wave guide.

- The waves propagating inside the metal waveguide may be characterized by reflections from conducting walls.

- modes of waveguides:

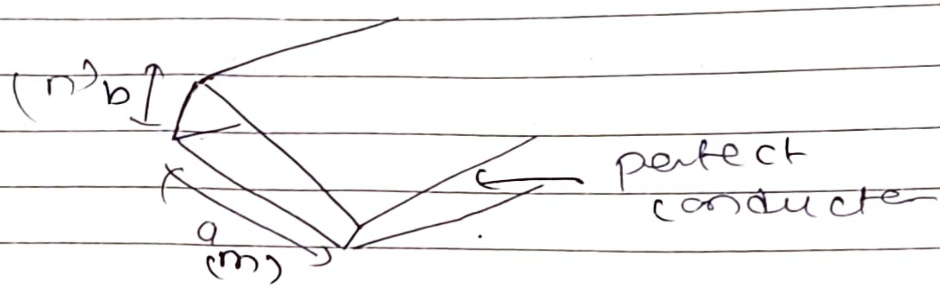
1. TEM wave:- Here both electric and magnetic field is tranverse to direction of propagation
   $E_z = 0, H_z = 0$.

2. TM wave :- Only magnetic field is tranverse to direction of propagation, , $H_z = 0$.

3. TE wave :- only Electric field is tranverse to direction of propagatn , $E_z = 0$.

1. ~~Cut off frequency~~ :-

* Rectangular waveguide ·



- TE mode or TM mode, not TEM mode.
- Rectangular in structure.

→ TE_{mn} or TM_{mn}

→ Dominant mode TE_{10}, $m=1$, $n=0$.

→ $\lambda_c > \lambda_0$, $f_c < f_0$

cut-off wavelength, operating wave ; cut-off freq, operating freq.

$$\lambda_c = \frac{2ab}{\sqrt{n^2 b^2 + m^2 a^2}} , \quad f_c = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}$$

$$\lambda_{c_{TE_{10}}} = 2a , \quad f_{c_{TE_{10}}} = \frac{c}{2a}$$

② ~~Modes of propagation~~ :.

phase velocity ; group velocity

$$V_p = \frac{c}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} , \quad V_g = c\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$$V_p V_g = c^2$$

Cut-off freq:-

- It is possible to propagate several modes of em waves with waveguide

- The physical dimension of waveguide determines the cutoff freq. of each mode

- If frequency of signal is above cutoff frequency for given mode, the wave can be transmitted through the guide without attenuation.

- Otherwise freq. ~~of~~ below cutoff will attenuate the signal.

$$f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

for air as dielectric medium

$$c = \frac{1}{\sqrt{\mu\varepsilon}}$$

$$f_{c\,TM_{11}} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2}$$

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

$$f_{c\,TE_{10}} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \left(\frac{\pi}{a}\right).$$

$$f_{c\,TE_{11}} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \left(\frac{\pi}{b}\right).$$

Dominant mode:-

- ~~fo~~ The dominant mode in particular waveguide is mode having lowest cut-off frequency.

- In Rectangular w, It is TE_{10}.

- So, cut-off frequency for TE_{10},

Let take air as dielectric medium

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

$m = 1, \; n = 0$

$$= \frac{c}{2\pi}\sqrt{\left(\frac{\pi}{a}\right)^2}$$

$$= \frac{c}{2\pi} \times \frac{\pi}{a}$$

$$\boxed{f_c = \frac{c}{2a}} \leftarrow \text{when } TE_{10}.$$

Waveguide parameters:-

1. Guide wavelength:-

- Distance travelled by wave in order to undergo phase shift of 2π radians.

given by,

$$\lambda_g = \frac{\lambda}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

2. Phase velocity:-

- Velocity with which the wave changes it's phase in terms of guide wavelength.

$$V_p = \frac{c}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

$$V_p = \frac{c}{\sqrt{1 - \left(\frac{\lambda_0}{\lambda_c}\right)^2}}$$

3. Group velocity:-

- rate at which wave propagates through waveguide.

$$v_g = c\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$$v_g = c\sqrt{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}$$

$$v_p * v_g = c^2$$

4. Wave Impedance:-

- ratio of strength of electric field in one transverse direction to strength of magnetic field along other transverse direction.

$$Z = \frac{E_x}{H_y}$$

$$Z_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} \Rightarrow \frac{\eta}{\sqrt{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}}$$

$$Z_{TM} = \eta\sqrt{1-\left(\frac{f_c}{f}\right)^2} \Rightarrow \eta\sqrt{1-\left(\frac{\lambda_o}{\lambda_c}\right)^2}$$

* Comparsion betw Coaxial cable and waveguide :-

Waveguide	Coaxial cable.
- Less loss due to air filled	- more Loss-no air filled
- Handle high power	- Cannot Handle High power
- metallic structure, heavy, expensive	- smaller in size, lighter in weight.
- Bandwidth is smaller	- Higher than waveguide..
- Easy to manufacture	- complex to manufacture
- cross sectional area should be maintained	- need not to be maintained.

Stripline	microstrip line
- TEM	- Quasi- TEM
- No Dispersion	- low dispersion
- size medium	- size :- small
- component Integration is fairly complex	- Component Integration is easy.

waveguide	Transmission line
- ~~Two or more~~ metal waveguides are typically one enclosed conductor filled with an insulating medium.	- Two or more conductors separated by some insulating medium.
- TE or TM mode	- Mode:- TEM or quasi- TEM. mode
- Lower attenuation at higher freq. than trans. line	- Higher attenuation at high freq.
- should maintain freq. above resp. TE or TM mode cut off freq.	- No cutoff freq. for TEM mode
- large cross-section are impractical due to large size and high cost	- large cross section trans line can transmit high power
- ~~Small cross~~ metal waveguide can transmit high power level.	- small cross sect can transmit ~~s~~ low power levels

0.9 inch × 0.4 inch , $f = 9.2$ GHz.

a ↑ b ↑

$$\lambda = \frac{c}{f} = \frac{3\times10^{10}\ (cm/s)}{9.2\times10^{9}}$$

$a = 0.9$ inch $= 2.286$ cm.

$b = 0.4$ inch $= 1.016$ cm

$\lambda = 3.26$ cm.

ⓐ In Rectangular wave guide, Dominant mode is TE_{10} (TE_{mn}).

ⓑ cut-off freq for TE_{10} :- $f_c = \frac{c}{2a} = \frac{3\times10^{10}\ (cm/s)}{2\times2.286}$

$$f_c = 6.562\ \text{GHz}$$

ⓒ Guided wavelength :-

$$\lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{3.26}{\sqrt{1-\left(\frac{6.562\times10^9}{9.2\times10^9}\right)^2}}$$

$= 4.65$ cm

ⓓ Phase velocity.

$$v_p = \frac{3\times10^8}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = 4.28\times10^8\ m/sec$$

ⓔ Impedance.

$$Z_{TE} = \frac{\eta}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{377}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

$= 537.88.$

PUNE INSTITUTE OF COMPUTER TECHNOLOGY, PUNE - 411043

Department of Electronics & Telecommunication Engineering

UNIT TEST – I

Class : BE E&TC

Date : 12/09/2022
Day : Monday

Subject : Radiation and Microwave Theory(RMT)
Time : 3PM-4PM
Max Marks : 30

- *All the questions are compulsory.*
- *Neat diagrams must be drawn wherever necessary.*
- *Assume suitable data if necessary.*

Q. NO.	QUESTION STATEMENT	MARKS	CO
Q.1	a) A wave originating from the transmitting antenna with 10 dB gain and 150 W Radiating power at 100 MHz. It is received by an antenna with 18 dB gain located at 25 Km distance, Calculate the received power, Path loss (free space transmission loss) and E-field strength?	5	CO1
	b) Define and explain following antenna parameters: i) Directivity ii) Effective Area iii) Gain iv) Radiation Pattern v) Half Power Beam Width	5	
	c) Explain radiation mechanism of antenna.	5	
Q.2	a) State different types of strip line. Distinguish between strip line and micro strip line.	5	CO2
	b) A rectangular air-filled copper waveguide with dimensions 0.9-inch x 0.4-inch cross section and 12-inch length is operated at 9.2GHz with a dominant mode. Find i) Dominant mode ii)Cutoff frequency iii) Guided wavelength iv) Phase velocity v) Characteristics impedance	5	
	c) Compare transmission line and wave guide.	5	

****

Formula

* Cut-off freq :-

$$f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}$$

For air-filled,

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

For f_c TE_{10} in ~~air medium~~ $\quad f_c = \frac{c}{2a}$ $\leftarrow 3 \times 10^{10}$ cm/s

* Cut-off wavelength $\quad \lambda_c = \frac{2ab}{\sqrt{m^2b^2 + n^2a^2}}$ cm

* Guided wavelength :-

$$\lambda_g = \frac{\lambda \rightarrow \text{cm}}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

* Phase velocity :-

$$v_p = \frac{c \leftarrow 3 \times 10^8}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

* Group velocity :

$$v_g = c\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

* Impedance :

$$Z_{TE} = \frac{\eta \rightarrow 377}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$$

$$Z_{TM} = \eta\sqrt{1 - \left(\frac{f_c}{f}\right)^2}$$

(i) Dominant mode for rectangular waveguide is for TE_{10}, $m=1$, $n=0$

(ii) cut-off freq. $f_c = \frac{c}{2a}$

$= \frac{3 \times 10^{10}}{2 \times 2.286}$

$= 6.5$ GHz.

(iii) Guided wavelength $\lambda_g = \frac{c/f}{\sqrt{1 - \left(\frac{6.5}{9.2}\right)}}$

$= \frac{3 \times 10^8 / 9.2 \times 10^9}{\sqrt{1 - \left(\frac{6.5}{9.2}\right)}}$

$= \cancel{0.06\,cm}$ 0.033 $= 0.05$ cm

(iv) phase velocity $v_p = \frac{c}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} = \frac{3 \times 10^8}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}$

$= \cancel{5.5 \times 10^8\ m/s}$ 4.24×10^8

(v) $Z_{TE} = \frac{377}{\sqrt{1 - \left(\frac{6.5}{9.2}\right)^2}} = 532.72\ \Omega$