MADE EASY

ELECTRONICS ENGINEERING

Microwave

By- Suresh Sir

- Theory
- Explanation
- Derivation
- Example
- Shortcuts
- Previous Years Question With Solution

MICROWAVE ENGINEERING

TOPIC :-

1.) Microwave Compoments

1) a) Microwave Power transmission-guides – Rectangula
– Cylindrical

b) Microwave – Power Oscillations
'Resonators'
– Rectangular Cavities
– Cylindrical Cavities

c) Microwave – Power distribution
Tees.

- E-plane tee – series
- H-plane tee – shunt
- Magic tee / Hybrid Rings / Directional coupler
- Non Reciprocal – Isolators – Circulator

2.) Microwave Solid-State Devices (Low Power)

a) TED → Transfered Electron Devices

- Crystal Oscillators
- Gunn Diode (GaAs
- Cd-Te
- In-P

b) ATTs → Avalenche Transit time Devices

- Breakdown Diodes – Switches
- IMPTT diodes – Read Diode
- TRAPATT
- BARITT

c) Study of Microwave vs RF devices

BJTs —— vs —— HBJTs MoSFETs —— MESFETs

JFETs ———— HEMFETS

3.) Microwave - Vacuum Tube Devices. (High Power)

a) Linear Beam Tubes → D-type tubes

- Cavity | Resonant Standing wave
  - Klystron Amplifier
  - Reflex Klystron Oscillator
- (Slow wave Structures) Travelling wave
  - ↳ Helical TWT Amplifier

b) Cross-Field Structures → M-type tubes

- Forward wave
  - Forward wave cross-field amp. (FWCFA)
  - Forward wave cross-field oscillator (FWCFO)
- Backward wave
  - Backward wave cross Field Amp. (BWCFA)
  - Backward wave Cross Field Oscillator (BWCFO)

4.) Miscelleneous Topics

a) Microwave Measurements.

b) MASERS

c) Microstrip lines

d) Parametric Amplifiers.

e) Practical Antennas.

Book: Samuel. Y. Liao

MICROWAVE FREQUENCIES - BANDS & APPLICATION

- Frequency Range of M/W → A few GHz to few 100GHz ($10^9 - 10^{11}$ HZ)

  λ Range is few Cm to few mm

- waves —— AF (20-20KHZ)
  ↓
  RF-waves - MHZ
  (mini)
  ↓
  Microwaves ⟶ GHZ.

  PANs - 2.4GHZ

imp
- Microwave Bands :→

L →	(1-2)GHZ	Eg:- GSM - 1800/1900 MHZ (cellphones)
S →	(2-4)GHZ	Ex:- Bluetooth, WiFi - 2.4GHZ - 2400MHZ
C →	(4-8)GHZ	
X →	(8-12)GHZ	
Ku →	(12-18)GHZ	f > 45GHZ mm Bands.
K →	(18-27)GHZ	
Ka →	(27-45)GHZ	

- Frequency Hoping Spread Spectrum :-

  Bluetooth → 2.417 - 2.412
  WIFI → 2.418 - 2.419
  FHSS

  Due to FHSS, Bluetooth & wifit work at a same time without overlapping.

- Microwave Applications :-

  $J_d = \epsilon \frac{\partial E}{\partial t}$ Rate of change should be large and Jd will also be large.

Microwave : It is an EM wave existing in the free space and rarely it has a V/I component existing in conductors.
counterpart

1.) It has High frequency & High Bandwidth as compared to RF technology & hence suited for High speed data transfer.

EX:→ • RF – FM radio

$f_c = 98.3\,MHz \longrightarrow f = 98.31\,MHz$

$98.29\,MHz$

$BW = 0.02\,MHz. = 20\,KHz.$

Human Voice → 1 KHZ

– 20 audio channels.

• Microwave. $f_c = 2.4\,GHz$

$f \to (2.41\,GHz)$

$2.39\,GHz$

$BW = 0.02\,GHz = 20\,MHz.$

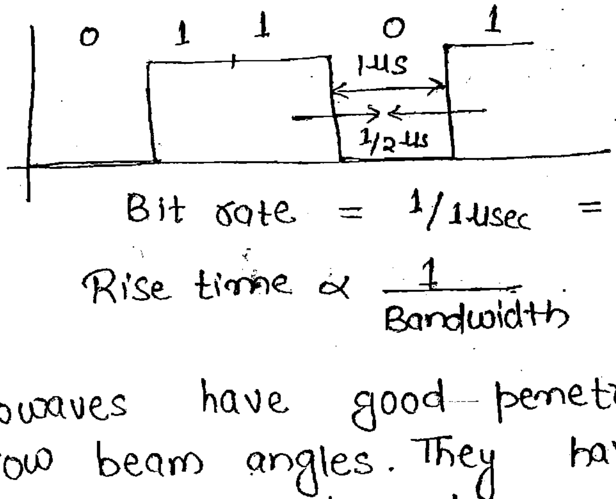
* 20,000 audio channel ⇒ That is used in Sattellite Communication

⇓

10000 telephone lines 100 TV channels.

•.) It is used in satellite communication for launching telephone / TV links.

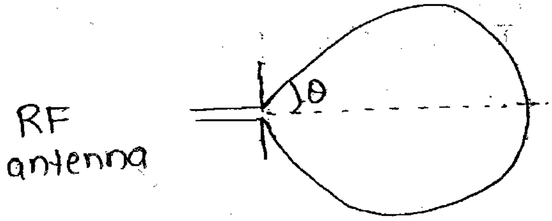
EX:-

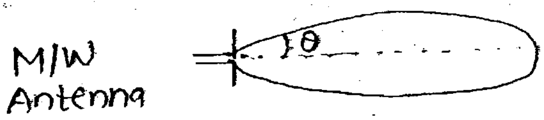


$\text{Bit rate} = 1/1\mu sec = 10^6\,Mbps.$

$\text{Rise time} \propto \frac{1}{\text{Bandwidth}}$

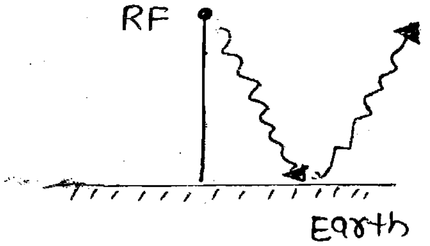
2.) Microwaves have good penetration due to narrow beam angles. They have high directivity & reduced scattering losses.

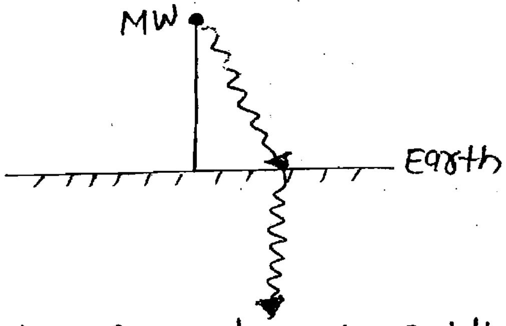




$\lambda \downarrow \quad \theta_{HBW} \downarrow \quad D \uparrow \qquad A_e = \frac{\lambda^2}{4\pi} D \propto \frac{1}{\Omega_A}$

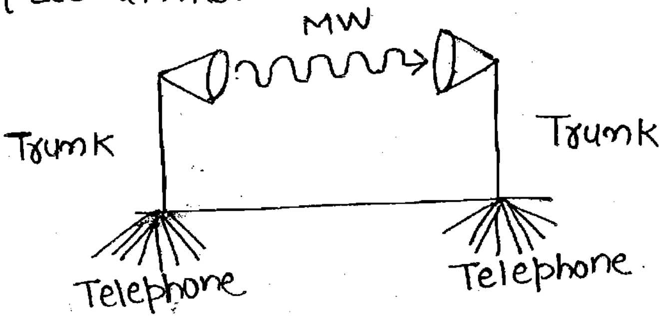
- They can penetrate into clouds/waters/Rain Ionosphere/ Earth.
- It makes ideal to be used in Radars for Air Traffic Control in GPS System for Navigations.
- It is used in remote sensing & Satellite Imaging.





3.) Microwaves Cannot be used in Ground wave guiding but is most often in aerial links/terrestrial links | LOS links.

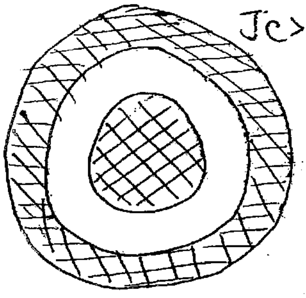
EX:→



RECTANGULAR WAVEGUIDES

Power Line 50Hz

Jc>>Jd



2Conductor

99% Power - V-I

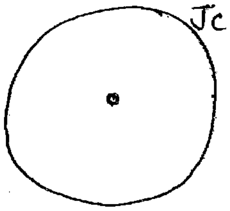
1% Power - E/H

Freespace

TEM Mode

RF Line MHz

Jc≅Jd



50% - V/I

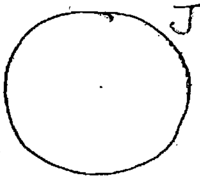
50% - E/H

TEM Mode

GHz ~

MW Guide

Jd>>Jc



99% E/H

1% V/I

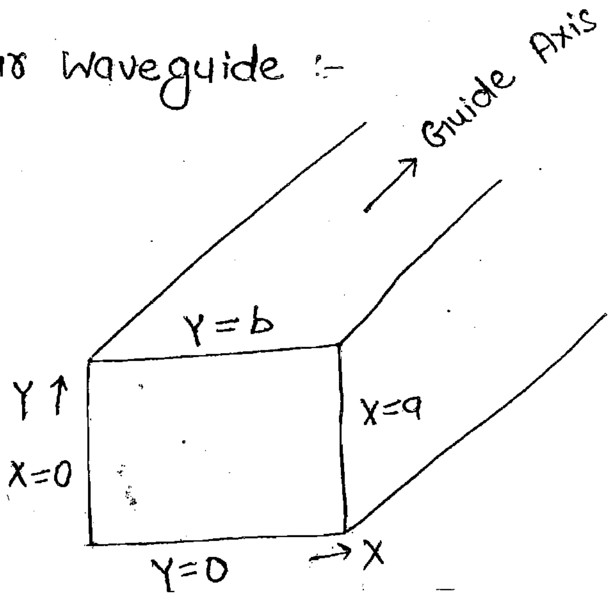
TE/TM

(High Freq.)

WaveGuide :-

- A waveguide is a simple conductor structure for E/H every transfer for using high frequencies TE/TM modes, i.e, the second conductor in transmission lines is replaced with axial field Ez/Hz.

Rectangular Waveguide :-



- Rectangular waveguide is a similar single conductor structure with walls at X=a, X=a, Y=0, Y=b

- Guiding Mechanism involves confinement of the E/H fields or Satisfying Boundary Conditions.

1.) $E_{tang} = 0$ 3.) $H_{tang} = H_{max}$
2.) $E_{normal} = E_{max}$ 4.) $H_{normal} = 0$

- The harmonic propagation in X/Y sides has to be strictly Sin/Cos Harmonics with well defined maximas/ minimas.
- The wave has a restriction with γ_x or $\beta_x = \frac{m\pi}{a}$

γ_y or $\beta_y = \frac{n\pi}{b}$

$$\begin{tikzcd}[column sep=tiny] H/E\,(x, & y, & z, t)\,(x, y, z) \\ & \sin/\cos\left(\frac{n\pi}{b}y\right) & \\ \sin/\cos\left(\frac{m\pi}{a}x\right) & & \arrow[from=1-1, to=3-1] \arrow[from=1-2, to=2-2] \end{tikzcd}$$

β_z or $\bar{\beta}$ un-restricted along the Guide axis.

Applying the basic Helmholtz eqn

$$\nabla^2 E = \gamma^2 E = (j\beta)^2 E$$

$$\nabla^2 E = -\omega^2 \mu \epsilon E$$

$$\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + \frac{\partial^2 E}{\partial z^2} = -\omega^2 \mu \epsilon E$$

$$-\left(\frac{m\pi}{a}\right)^2 E - \left(\frac{n\pi}{b}\right)^2 E + \bar{\gamma}^2 E = -\omega^2 \mu \epsilon E.$$

Finally,

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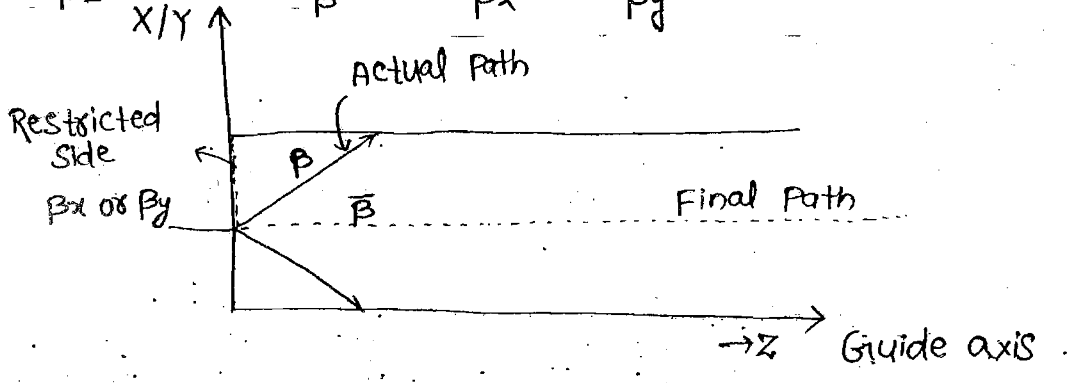
$$\boxed{\bar{\gamma} = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2 \mu \epsilon}}$$

$$\boxed{\bar{\beta} = \sqrt{\underset{\beta}{\omega^2 \mu \epsilon} - \underset{\beta_x}{\left(\frac{m\pi}{a}\right)^2} - \underset{\beta_y}{\left(\frac{n\pi}{b}\right)^2}}}$$

β_z



- At exact $\bar{\gamma}=0$ for cut-off frequencies,

$$\boxed{\begin{array}{l} \omega_c = \left(\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2}\right)c \\ \hline f_c = \left(\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}\right)\frac{c}{2} \end{array}}$$

- If θ is the zig-zag path angle or wave angle.

$$\boxed{\sin\theta = f_c/f = \omega_c/\omega}$$

- V_p, Phase Velocity $= \frac{\omega}{\beta} = \frac{c}{\cos\theta}$ Give

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

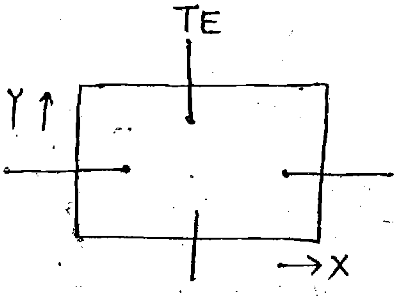
- $\vec{V_g}$ = Group Velocity $= d\omega/d\vec{\beta}$

$$\vec{V_g} = c\cdot\cos\theta < c$$

Dispersive Beams with β-vs-ω (Non linear)
V_g is physically velocity but not V_p.

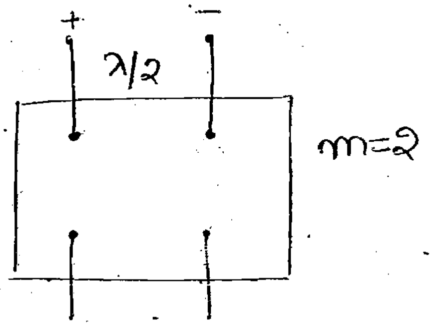
- **TE/TM MODES :→**

TE Mode :-



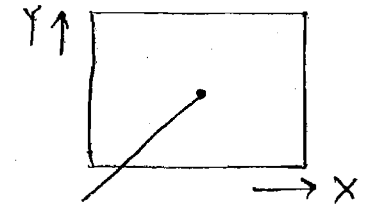
E_y or E_x
but $E_z = 0$

Cross- Section

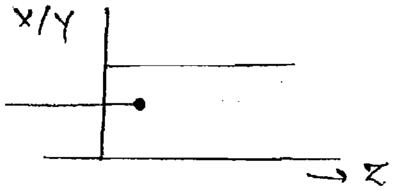


- TE Feed:-
- Horizontal / vertical polarization of the feed antennas as seen in the cross-section results in $Ez=0$ which is TE Mode.
- m/n stands for out of phase feed ~~come~~ connections in X/Y direction respectively.
- Spacing should be $\lambda/2$ as two antennas are out of phase

TM Connections:-



Cross-section



Axial

Lateral feed connection resulting in cross-sectional circular Magnetic fields.
i.e., Hx and Hy circles with $Hz=0$ which is TM mode feed.

TM WAVE SOLUTIONS :- $(Hz=0)$

The axial field Ez is the basic for all other field components.

The wave is $E(x,y,z,t)$ (x,y,z)
$H(x,y,z,t)$ (x,y)

$E(x,y,z,t)z =$ ___