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MICROWAVE ENGINEERING

TOPIC :-

1) Microwave Components

1) a) Microwave Power transmission-guides - Rectangular
- 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 Ring / Directional coupler
- Non Reciprocal - Isolators - Circulators

2) Microwave Solid-State Devices (Low Power)

a) TED → Transferred Electron Devices

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

b) ATTs → Avalanche Transit time Devices

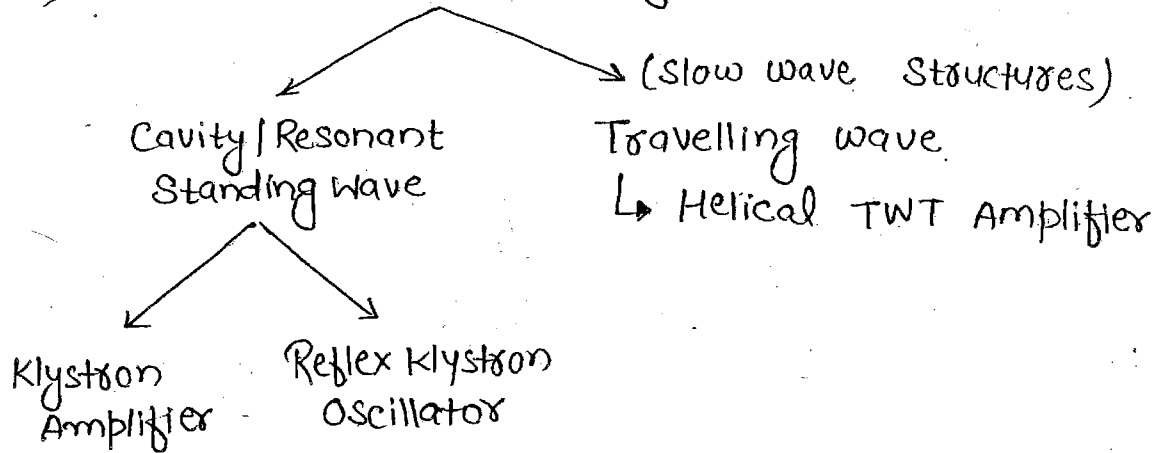
- Breakdown Diodes - Switches
- IMPATT diodes - Read Diode
- TRAPATT
- BARITT

c) Study of Microwave vs RF devices

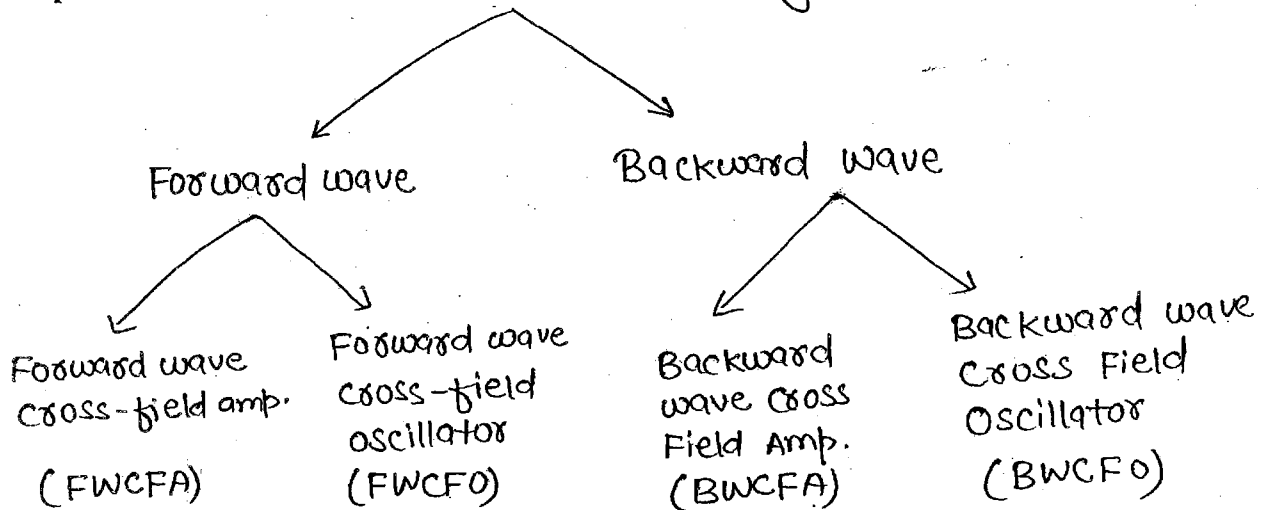
BJTs ——— vs ——— HBJTs MOSFETs ——— MESFETs
JFETs ——— HEMFETs

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

a) Linear Beam Tubes \rightarrow D-type tubes



b) Cross-Field Structures \rightarrow M-type tubes



4) Miscellaneous 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 \rightarrow A few GHz to few 100GHz
($10^9 - 10^{11}$ Hz)
 λ Range is few cm to few mm
- waves \rightarrow AF (20-20kHz)
 \downarrow
RF-waves - MHz
(mini)
 \downarrow
Microwaves \rightarrow GHz. PANs - 2.4GHz

Imp Microwave Bands \rightarrow

- L \rightarrow (1-2)GHz Eg:- GSM - 1800/1900 MHz (cellphones)
- S \rightarrow (2-4)GHz Ex:- Bluetooth, WiFi - 2.4GHz - 2400MHz
- C \rightarrow (4-8)GHz
- X \rightarrow (8-12)GHz
- K_u \rightarrow (12-18)GHz $f > 45$ GHz mm Bands.
- K \rightarrow (18-27)GHz
- K_a \rightarrow (27-45)GHz

• Frequency Hopping Spread Spectrum :-

Bluetooth \rightarrow 2.417 - 2.412

WiFi \rightarrow 2.418 - 2.419

FHSS

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

• Microwave Applications :-

$$J_d = \epsilon \frac{\partial E}{\partial t}$$

Rate of change should be large and J_d 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

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

EX: → • RF - FM radio

$$f_c = 98.3 \text{ MHz} \rightarrow f = 98.31 \text{ MHz}$$

$$98.29 \text{ MHz}$$

$$\text{BW} = 0.02 \text{ MHz} = 20 \text{ KHz}$$

Human Voice → 1 KHz

- 20 audio channels.

• Microwave · $f_c = 2.4 \text{ GHz}$

$$f \rightarrow (2.41 \text{ GHz})$$

$$2.39 \text{ GHz}$$

$$\text{BW} = 0.02 \text{ GHz} = 20 \text{ MHz}$$

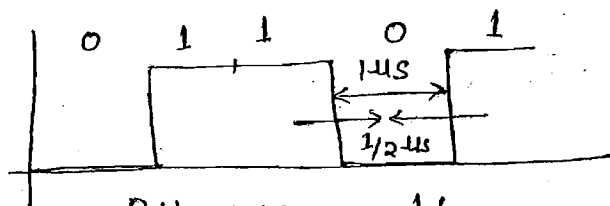
* 20,000 audio channel ⇒ That is used in Satellite Communication



10000 telephone lines 100 TV channels.

• ↳ It is used in Satellite communication for launching telephone / TV links.

EX:-

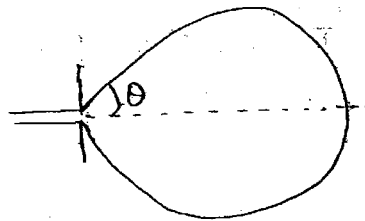


$$\text{Bit rate} = 1/1 \mu\text{sec} = 10^6 \text{ Mbps}$$

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

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

RF antenna



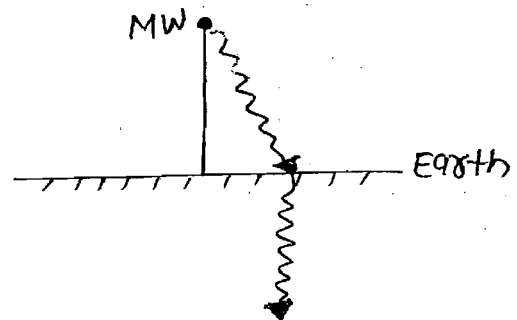
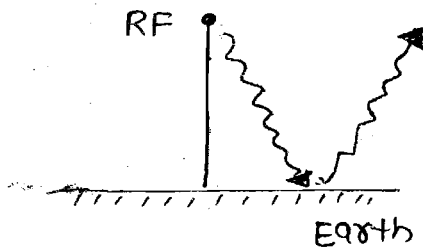
M/W Antenna



$\lambda \downarrow \theta_{HBW} \downarrow D \uparrow$

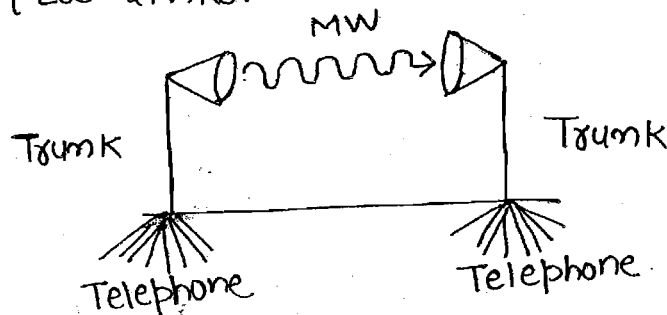
$$A_e = \frac{\lambda^2}{4\pi} D \propto \frac{1}{\Omega_A}$$

- 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.



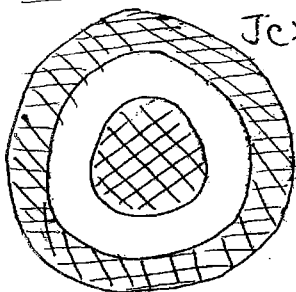
3.) Microwaves Cannot be used in Ground wave guiding but is most often in aerial links/terrestrial links | LOS links.

EX: →



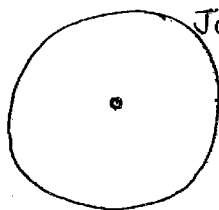
RECTANGULAR WAVEGUIDES

Power Line 50Hz



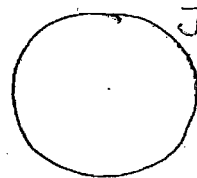
$J_c \gg J_d$
 3 Conductors
 99% Power - V-I
 1% Power - E/H
 Free space
 TEM Mode

RF Line MHz



$J_c \approx J_d$
 50% - V/I
 50% - E/H
 TEM Mode

GHz MW Guide

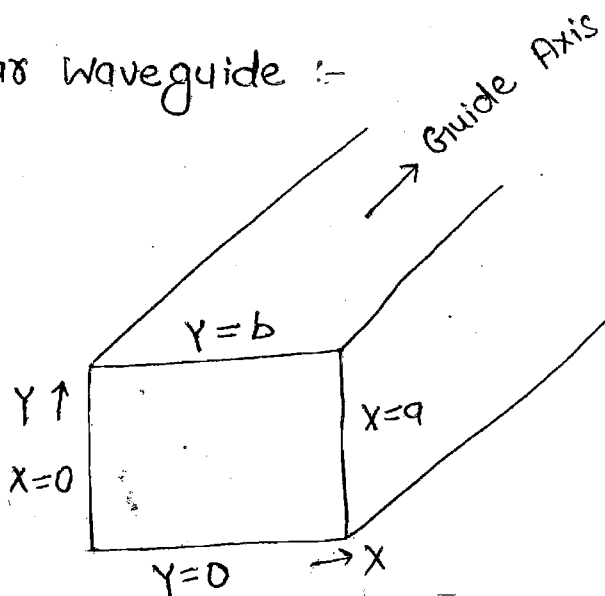


$J_d \gg J_c$
 99% E/H
 1% V/I
 TE/TM
 (High Freq.)

WaveGuide :-

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

Rectangular waveguide :-



- Rectangular waveguide is a similar single conductor structure with walls at $x=0, x=a, y=0, y=b$
- Guiding Mechanism involves confinement of the E/H fields or satisfying Boundary Conditions.

$$1) E_{\text{tang}} = 0$$

$$2) E_{\text{normal}} = E_{\text{max}}$$

$$3) H_{\text{tang}} = H_{\text{max}}$$

$$4) H_{\text{normal}} = 0$$

(7)

- 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 $\beta_x = \frac{m\pi}{a}$

$$\gamma_y \text{ or } \beta_y = \frac{n\pi}{b}$$

$$H/E(x, y, z, t) (x, y, z)$$

$$\downarrow \sin/\cos\left(\frac{n\pi}{b}y\right)$$

$$\sin/\cos\left(\frac{m\pi}{a}x\right)$$

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

Applying the basic Helmholtz eqⁿ

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

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

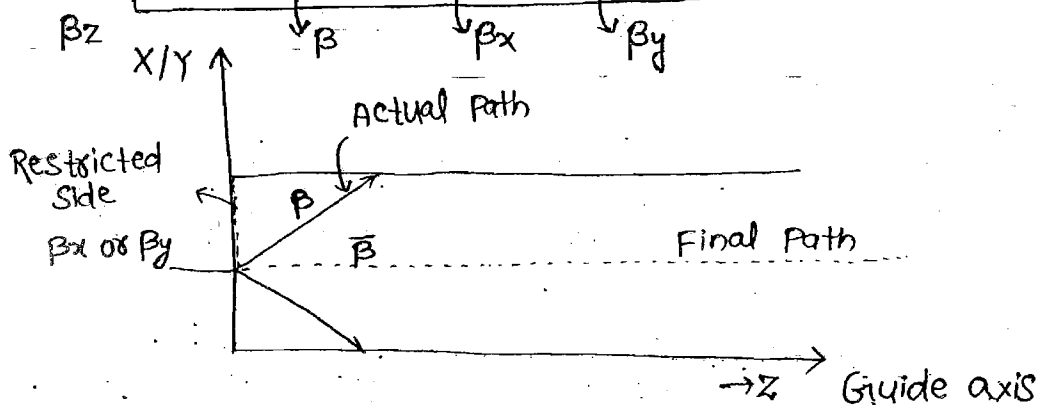
$$\frac{\partial^2 E}{\partial x^2} + \frac{\partial^2 E}{\partial y^2} + \frac{\partial^2 E}{\partial z^2} = -\omega^2 \mu \epsilon E$$

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

Finally,

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

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



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

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

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

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

$$\sin\theta = f_c/f = \omega_c/\omega$$

- V_p , Phase Velocity = $\frac{\omega}{\beta} = \frac{c}{\cos\theta}$ Give
 $= \frac{c}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}} > c$

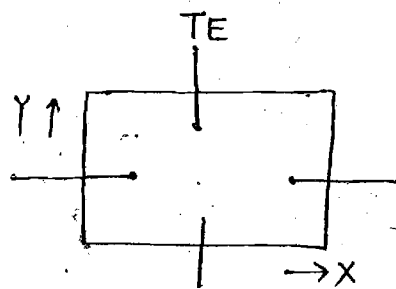
- \bar{v}_g = Group Velocity = $d\omega/d\bar{\beta}$
 $\bar{v}_g = c \cdot \cos\theta < c$

Dispersive Beams with β -vs- ω (Non linear)

v_g is physically velocity but not v_p .

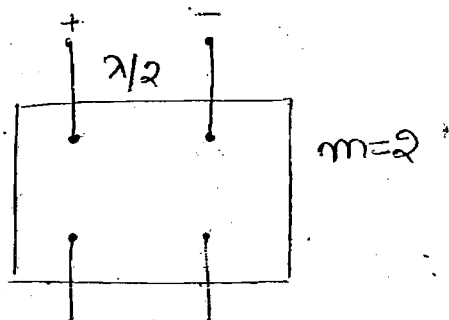
- TE/TM MODES: \rightarrow

TE Mode: -

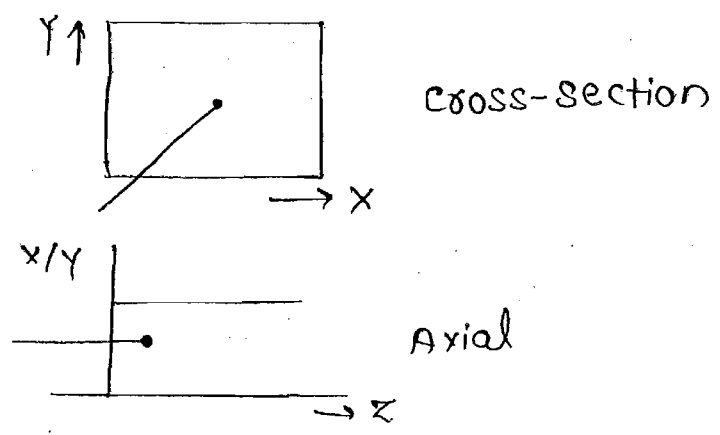


E_y or E_x
but $E_z = 0$

Cross-section



- TE Feed:-
 - Horizontal/vertical polarization of the feed antennas as seen in the cross-section results in $E_z=0$ which is TE Mode.
 - m/m stands for out of phase feed connections in x/y direction respectively.
 - Spacing should be $\lambda/2$ as two antennas are out of phase
- TM Connections:-



Lateral feed connection resulting in cross-sectional circular magnetic fields.
 i.e., H_x and H_y circles with $H_z=0$ which is TM mode feed.

TM WAVE SOLUTIONS :- ($H_z=0$)
 The axial field E_z is the basic for all other field components.

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

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

