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## 2 Microwave 2

① Introduction

② MW components

↳ E-plane Tee

↳ H-plane Tee

↳ Magic Tee [ E-H plane Tee ] [3 Marks]  
↳ S-Matrix [ Hybrid Tee ]

↳ Rat race Junction

↳ Directional coupler [15 Marks]

↳ Ferrite device

⇒ Isolator

⇒ Gyralix

⇒ circulator [6 Marks]

③ MW signal generation & application

↳ MW Tubes

↳ Limitation of conventional tubes [8 Marks]

↳ Two cavity klystron

↳ Multi cavity klystron

↳ Reflex klystron → oscillator

[15 Marks] → Amplifier

↳ TWT [15 Marks] → Amplifier

↳ BWO → oscillator

↳ Magnetron [15 Marks] → oscillator

④ Solid state device.

↳ Gunn Diode [15 Marks]

↳ Tunnel diode [10 Marks]

↳ Avalanche transit time device

⇒ IMPATT [Read Diode] [20 Marks]

⇒ TRAPATT

⇒ BARITT

↳ Parametric Amplifier [15 marks]

↳ MASER & LASER

↳ Cavity Resonator

⑤ MW measurement [10 marks]

⑥ MW communication

↳ Terrestrial comm.

↳ Satellite comm. [15 marks]

⑦ Microwave Antenna

⑧ microstrip [8 marks]

## ↳ Introduction

→ MW Frequency range

300 MHz to 300 GHz

MW devices can be used upto  $10^6$  GHz. i.e.  $10^{15}$  Hz

$$c = \lambda f$$

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

$$c = 3 \times 10^8 \text{ m/sec}$$

↳ case-1

$$f = 300 \text{ MHz}$$

$$\lambda_1 = \frac{3 \times 10^8}{300 \times 10^6} = 1 \text{ m}$$

↳ case-2

$$f = 300 \text{ GHz}$$

$$\lambda_2 = \frac{3 \times 10^8}{300 \times 10^9} = 1 \text{ mm}$$

↳ case-3

$$f = 10^6 \text{ GHz}$$

$$\lambda_3 = \frac{3 \times 10^8}{10^6 \times 10^9} = 0.3 \mu\text{m}$$

In case-3  $\lambda_3 = 0.3 \mu\text{m}$  (in the range of  $\mu\text{m}$ )  
hence the name microwave.

⇒ MW are so called because they are defined in terms of their wavelength.

⇒ Advantage of MW

gt Res. B.W. availability.

B.W. is some % of center frequency

Let B.W. is 1% of center frequency

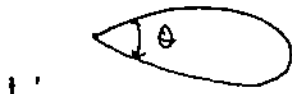
B.W. of T.V. channel in India = 7 MHz.

Audio signal - FM

Video signal - VSB (AM)

| carrier freq. | BW      | No. of TV channel |
|---------------|---------|-------------------|
| 70 MHz        | 0.7 MHz | 0                 |
| 700 MHz       | 7 MHz   | 1                 |
| 7 GHz         | 70 MHz  | 10                |
| 70 GHz        | 700 MHz | 100               |

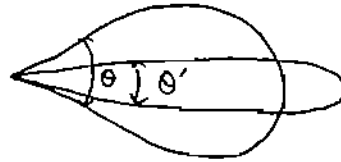
↳ Improved directive property



$\theta \rightarrow$  Beam width

$$\text{Directivity} \propto \frac{1}{\theta}$$

$$\theta \propto \lambda$$

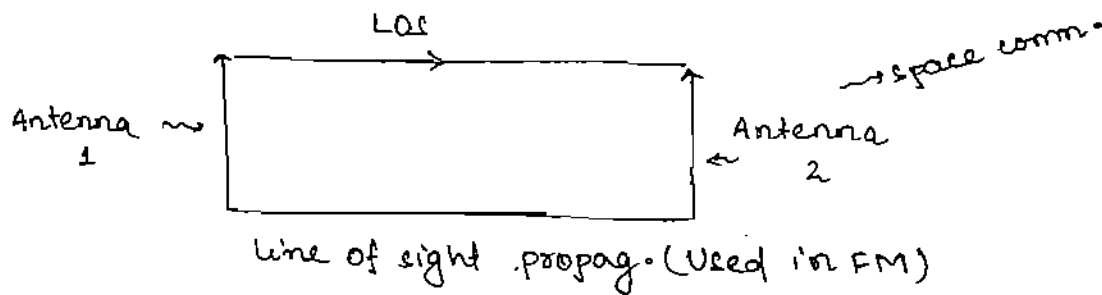


$$\theta' < \theta$$

$$f \uparrow \quad \lambda \downarrow \quad \theta \downarrow \quad D \uparrow$$

so, high gain & directive antenna can be designed & fabricated more easily at MW frequency.

→ Fading effect and Reliability



Due to line of sight propagation & high freq. there is less fading effect & MW comm. is more reliable.

→ Power requirements

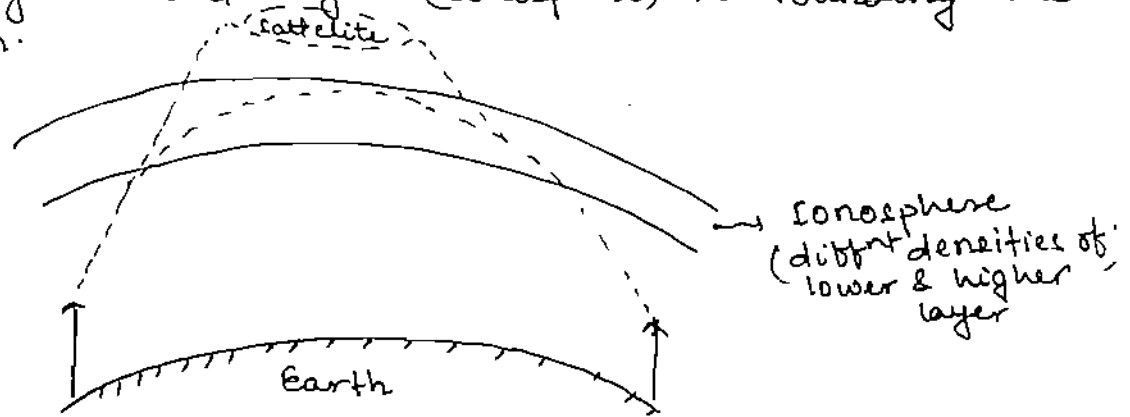
Tx & Rx power requirements is very low at MW frequency.

$$P_0 \propto \frac{1}{f}$$

↳ Receiving power requirements

## → Transparency property of MW

MW frequency bands are capable of free propagation through ionised layer (ionosphere) surrounding the earth.



$\epsilon$ -wave can penetrate ionospheric layer.

Ionospheric comm. (sky wave propagation).

→ Size of component is directly proportional to wavelength, therefore smaller system is possible.

## ⇒ Application

↳ Telecommunication

↳ Intercontinental Telephone & TV, space comm., telemetry comm. link for railways.

↳ Radar

↳ Commercial & Industrial application uses heating property of  $\epsilon$ -wave

eg. -  $\epsilon$ -wave oven

- Drying machine

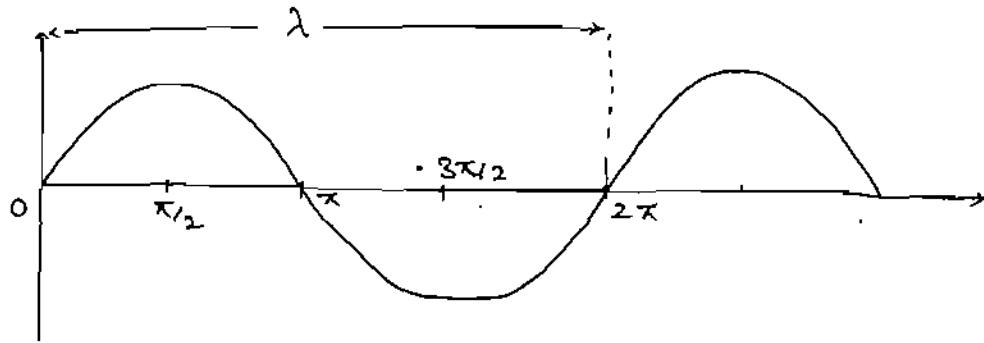
- Machine / Public works

- Food processing industry

↳ Biomedical application

↳ Electronic warfare

⇒ Relation between path travelled and phase change



| Path travelled | Phase change                   |
|----------------|--------------------------------|
| $\lambda$      | $2\pi$                         |
| $\lambda/2$    | $\pi$                          |
| $\lambda/4$    | $\pi/2$                        |
| $l$            | $\frac{2\pi}{\lambda} \cdot l$ |

Rate of change of phase  $\rightarrow \omega = \frac{d\theta}{dt} = 2\pi f = \frac{2\pi}{T}$

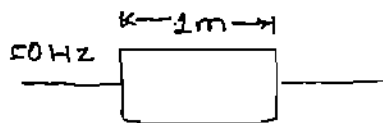
$$f = \frac{1}{T}$$

eg  $f = 50 \text{ Hz}$  ;  $T = \frac{1}{f} = 20 \text{ msec}$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{50} = 6 \times 10^6 \text{ m} = 6000 \text{ km}$$

& if  $f = 10^6 \text{ GHz}$  ;  $\lambda = 0.3 \text{ m}$

$$\phi = \frac{2\pi}{\lambda} \cdot l = \frac{2\pi}{6 \times 10^6} \times 1 \approx 0$$

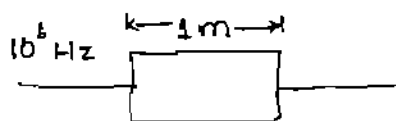


$$\phi = \frac{2\pi}{6 \times 10^6} \times 1 \approx 0$$

[lumped parameter]

R, L, C

because rate of change of phase is very low



$$\phi = \frac{2\pi}{0.3 \times 10^{-6}} \times 1$$

[distributed parameter]

$\Omega/\text{m}$ ,  $\text{farad}/\text{m}$ ;  $\text{H}/\text{m}$

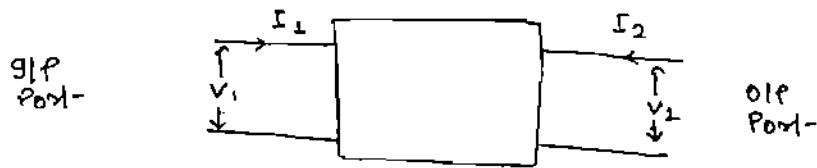
when  $\lambda$  is large there is negligible phase variation across the components so lumped parameter or simple ckt. theory is applicable for small  $\lambda$  there is high phase variation across the components therefore  $\pi$ -wave components are represented as distributed parameter.

### ↳ Band designation

IEEE : Institute of electrical & electronics eng.

| Band | Freq. range |
|------|-------------|
| L    | 1-2 GHz     |
| S    | 2-4 GHz     |
| e    | 4-8 GHz     |
| X    | 8-12 GHz    |
| KU   | 12-18 GHz   |
| K    | 18-27 GHz   |
| Ka   | 27-40 GHz   |

⇒ q-wave components

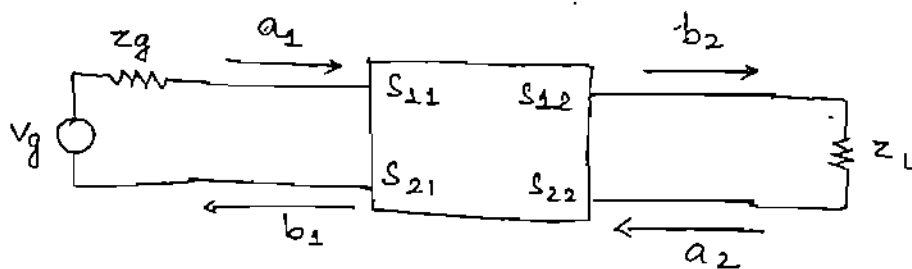


$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

If the frequencies are in q-wave range then h, Y, Z-parameters can't be used for following reasons:-

- ↳ Equipment is not readily <sup>available</sup> to measure total voltage & total current at the port of network.
- ↳ sc & oc are difficult to achieve over broad band of frequency.
- ↳ Active device such as power transistors, tunnel diode etc frequently will not have stability for sc or oc.

⇒ S-parameter [Scattering]



$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$