CSE311 Microwave Engineering

Lec (01) - Chapter (01)
Microwave fundamentals

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LECTURE OUTLINES

1 – Microwave definitions

2 – Electromagnetic frequency spectrum

3 – What is MW devices

4 – Advantages of MW

5 – Disadvantages and limitations of MW

6 – industrial Applications of MW

7- History of microwave devices

8- Typical Examples of MW devices

9- summary of microwave sources

1- MICROWAVE DEFINITIONS

MICROWAVE SIGNAL & SPECTRUM

- **Microwaves are electromagnetic waves whose frequencies range from about 300 MHz (some ref. 1GHz) – 300 GHz (or wavelengths in air ranging from 100 cm – 1 mm.**

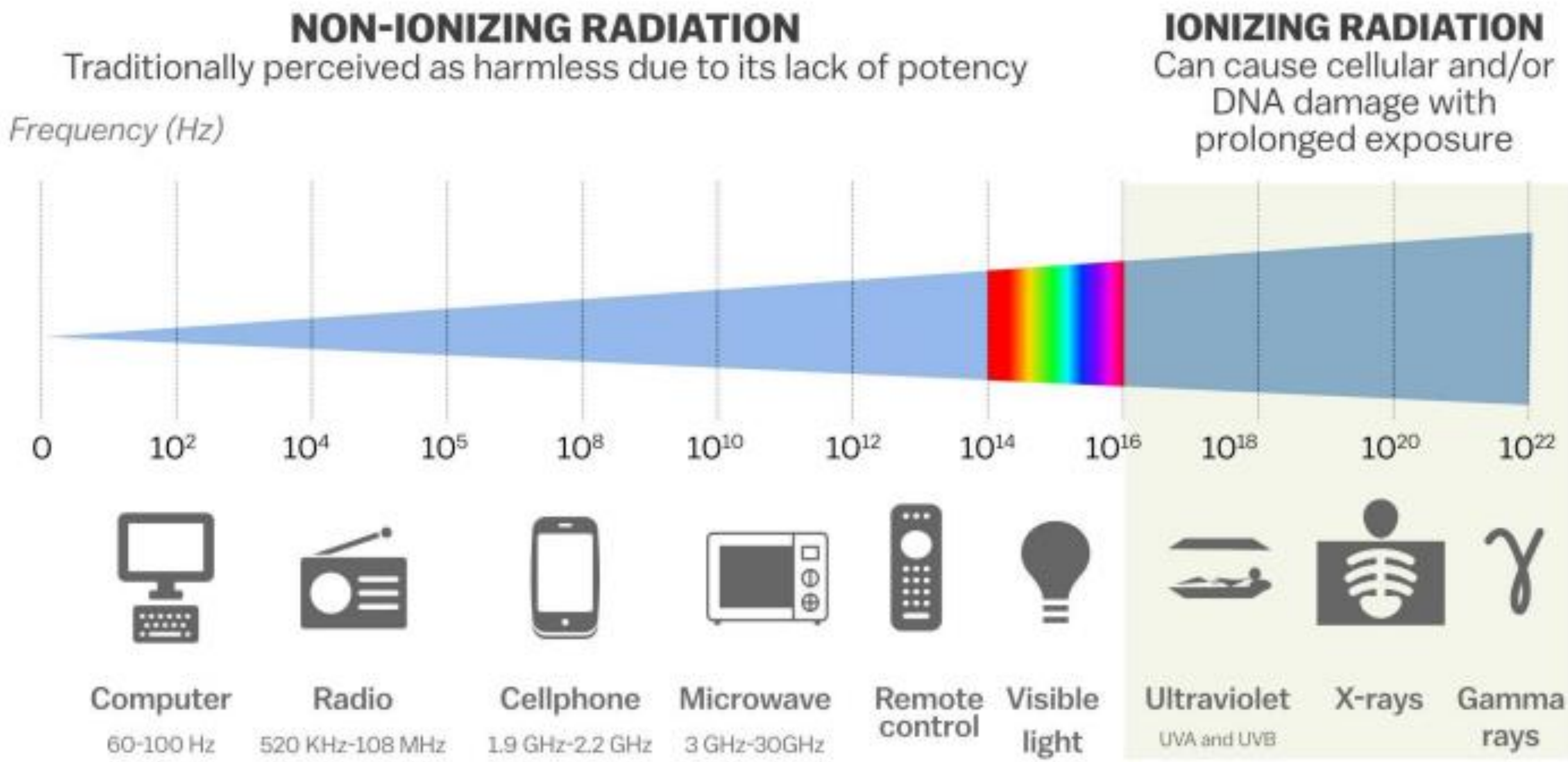
  f = 30 GHz ,,, $\lambda = 3 * 10^8 / 30 * 10^9 = 10$ mm

  f = 300 GHz ,,, $\lambda = 3 * 10^8 / 300 * 10^9 = 1$ mm

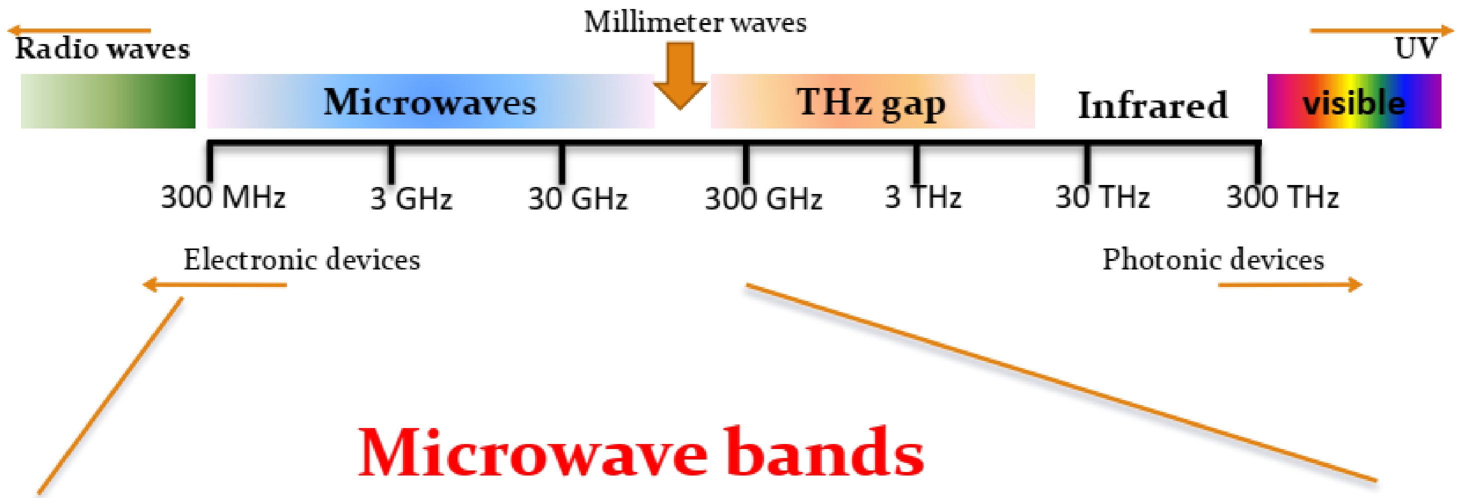
- **The word Microwave means very short wave (electromagnetic radiation of short wavelength), which is the shortest wavelength region of the radio spectrum and a part of the electromagnetic spectrum.**
- **They can reflect by conducting surfaces just like optical waves since they travel in straight line.**

2 - EM FREQUENCY SPECTRUM

EM FREQUENCY SPECTRUM



Electromagnetic spectrum



Microwave bands

Band	P	L	S	C	X	Ku	K	Ka
Freq (GHz)	0.23-1	1-2	2-4	4-8	8-12.5	12.5-18	18-26.5	26.5-40

EM FREQUENCY SPECTRUM

Freq. Bands	Freq. Range	wavelength	Uses
ELF	3-30Hz	100Mm-10000Km	Medical applications
SLF	30-300Hz	10000Km-1000Km	
ULF	300-3000Hz	1000Km-100Km	Military uses/voice
VLF	3K-30KHz	100Km - 10Km	long distance Communication.
LF	30K-300KHz	10Km-1km	Marine Communication.
MF	300K-3000KHz	1Km - 100m	AM Radio broadcasting.
HF	3M-30MHz	100-10m	long distance Communication (ship/aircraft)
VHF	30M-300MHz	10-1m	FM Radio, Television broadcasting.
UHF	300M-3000MHz	1m-10cm	For Mobiles/pagers /UHF channels.
SHF	3G-30GHz	10-1cm	Satellite communication.
EHF	30G-300GHz	1cm-1mm	Radar communication.
THF	300 GHz & > 3 THz		Medical imaging, remote sensing, terahertz communication

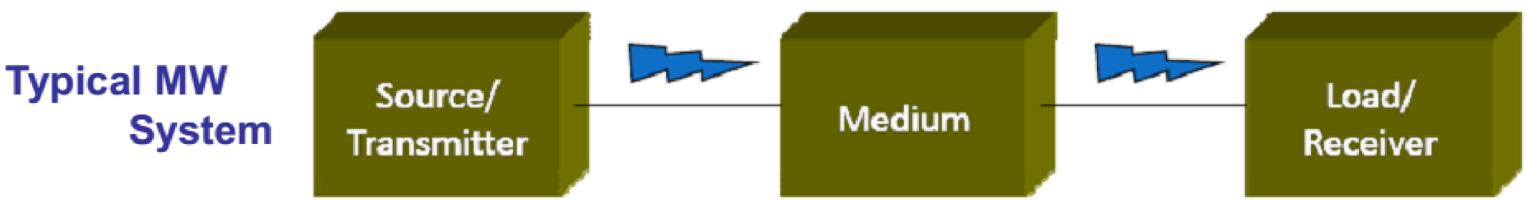
3 – WHAT IS MW DEVICES

What is the Microwave Devices?

The microwave devices are used to generate or amplify Microwave signals.

Why we use Microwave signals? → Microwave System

A Microwave System is **a system of equipment used in broadcasting and telecommunications transmissions**. The microwave system includes antennas located high atop microwave towers, which are used for the transmission of microwave communications **using line of sight microwave radio technology.**



4 - ADVANTAGES OF MW

ADVANTAGES OF MW

1 Increased bandwidth availability:

Band width of microwaves is larger than the low frequency signals so more information can be transmitted using single carrier). For example, the microwaves extending from $\lambda = 1$ cm - $\lambda = 10$ cm (i.e) from 30,000 MHz – 3000 MHz, this region has a bandwidth of 27,000 MHz.

2 Improved directive properties:

At microwave frequencies, it is easier to design and fabricate a high gain antenna as compared to low frequency signals.

Beam width bet. Half power $\Phi=\lambda/4\pi D=c/4\pi fD$

Φ is beam width ,λ is wavelength ,D is Directivity ,c is velocity of light

This is because of the fact that as the frequency increases ,directivity increases and beam width decreases.

3 Lower Power Requirement :

The power required by the microwaves is very less as compared to low frequency signals.

Advantages of Microwaves

3. Improved directive properties:

$\Phi = \lambda / 4\pi D = c / 4\pi f D$ Φ is beam width, λ is wavelength, D is Directivity, c is velocity of light

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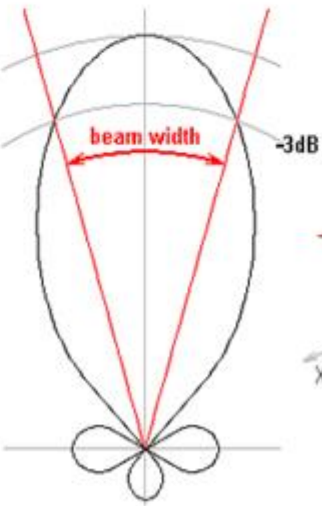
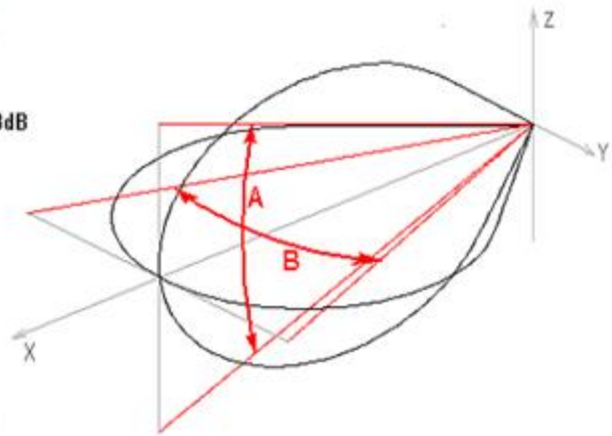
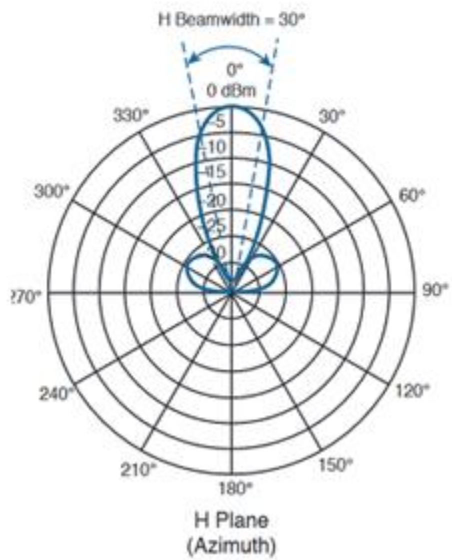
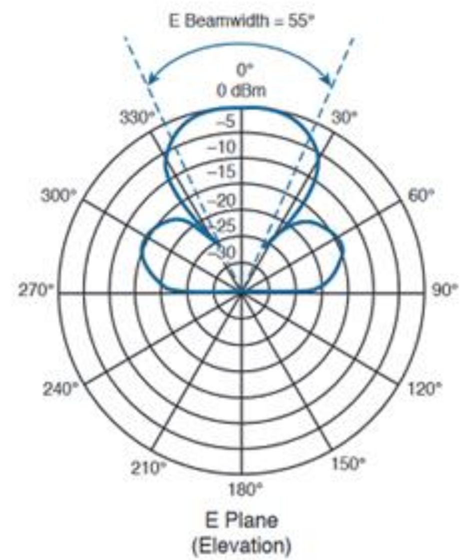
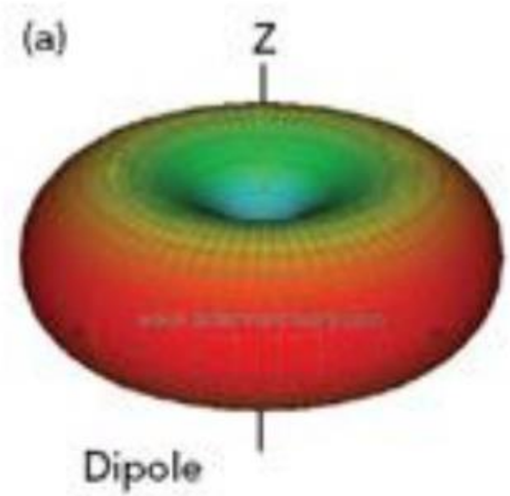


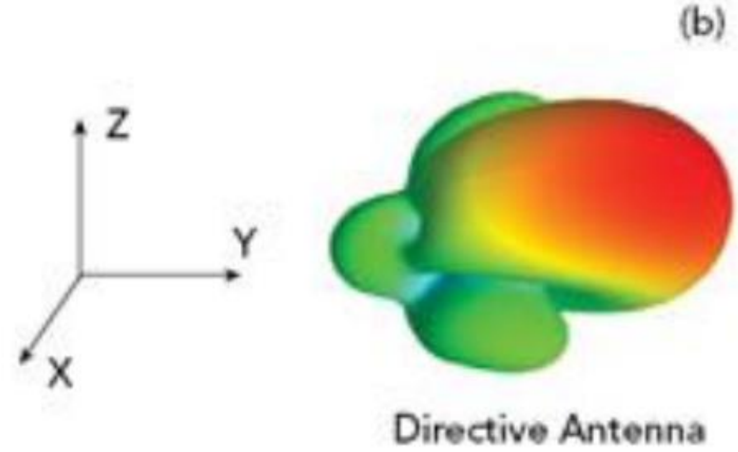




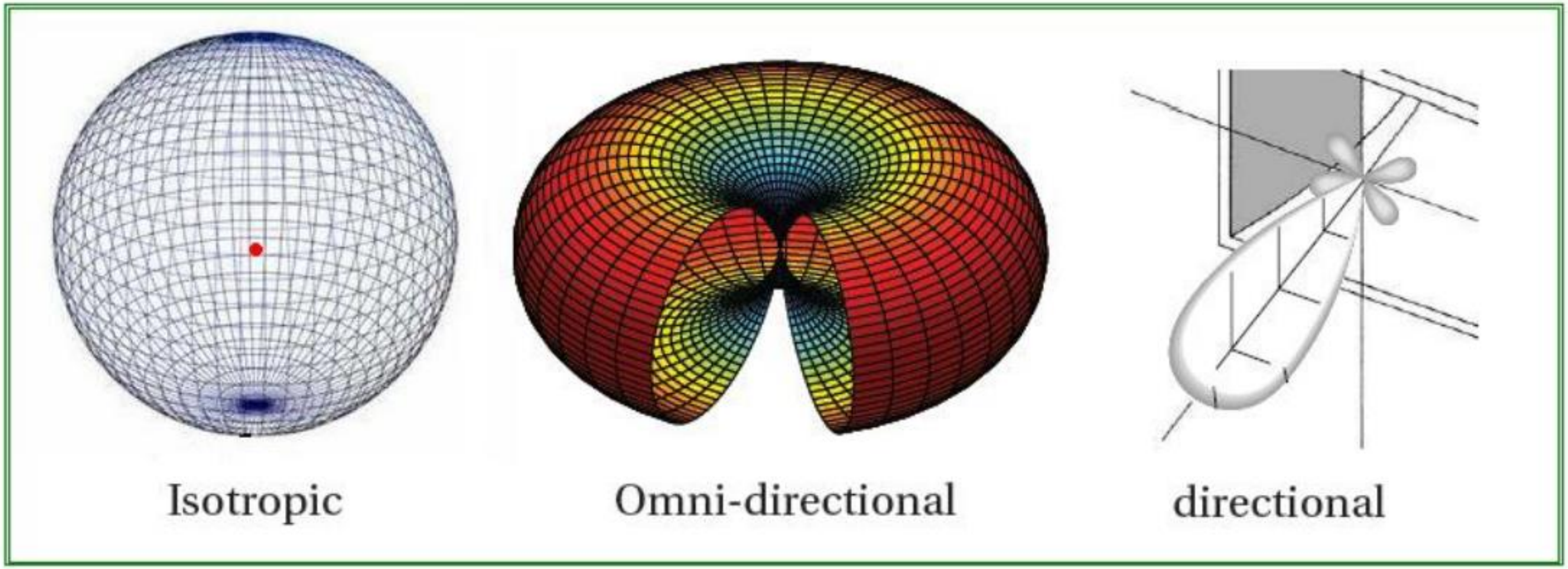


Difference between Omnidirectional & Directive Antennas





❑ RADIATION PATTERNS



TYPES OF ANTENNAS

Dipole

Building , automobile

Dish (Reflector)

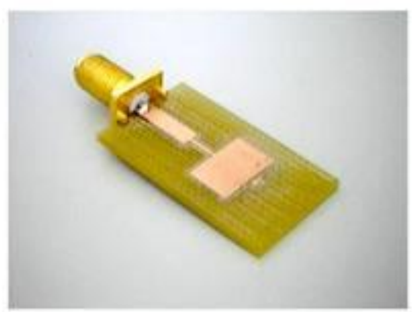
Helix

Yagi Atenna

Pyramidal Horn

Conical Horn

aircraft and spacecraft applications

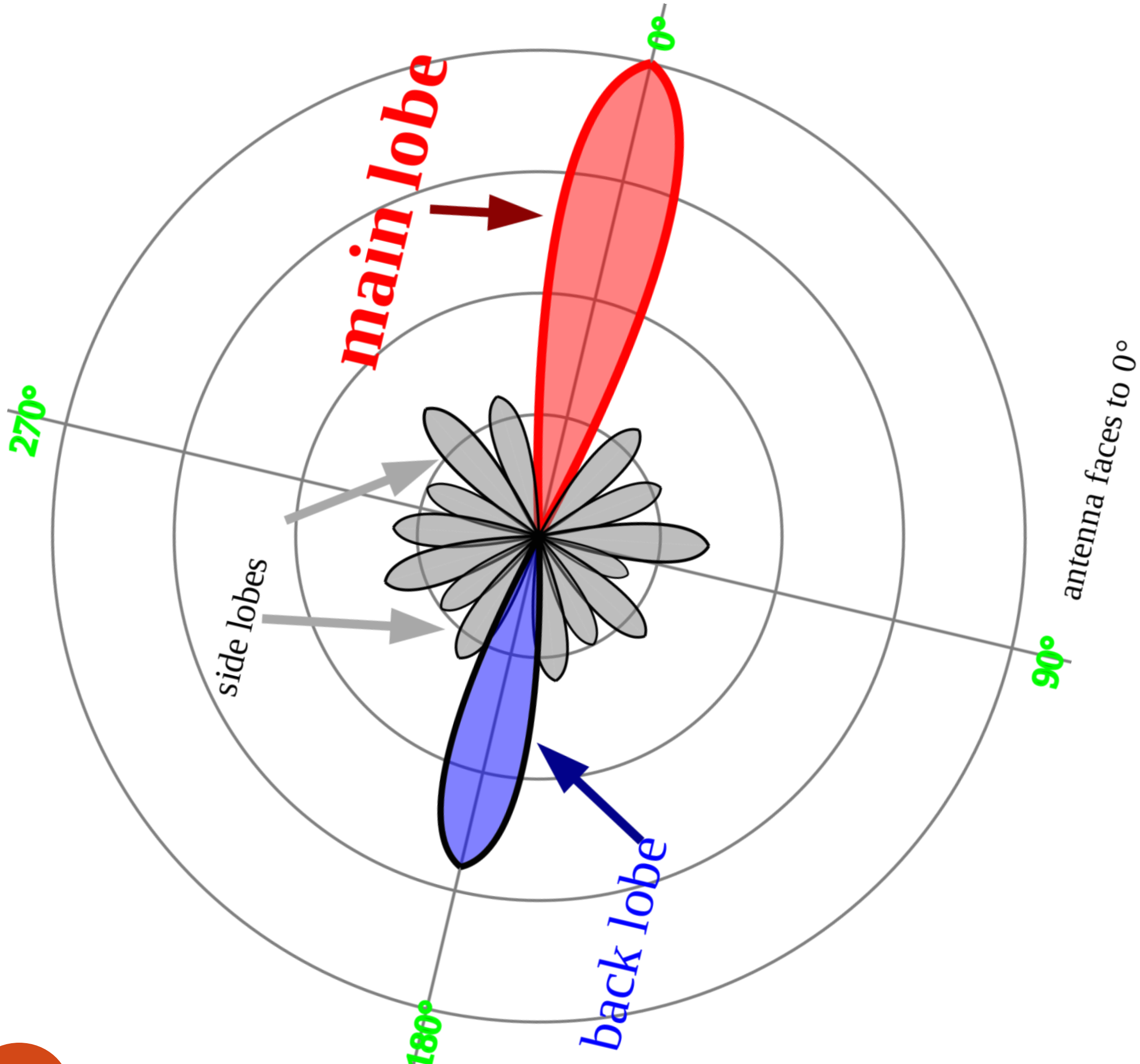


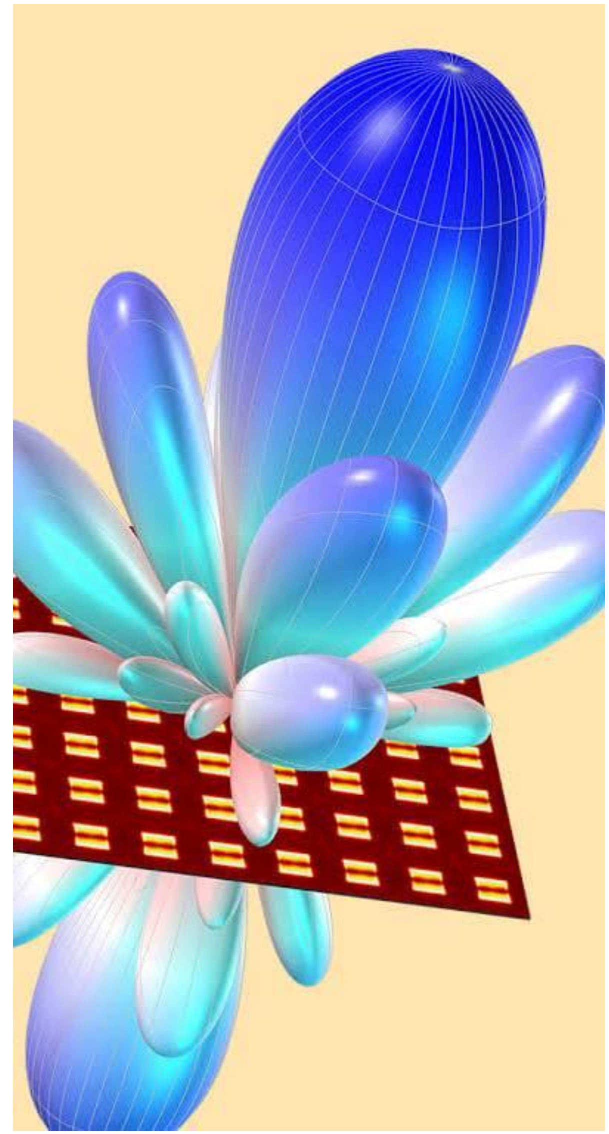
Microstrip patch

Loop Atenna

Arrays

❑ EXAMPLES FOR RADIATION PATTERNS





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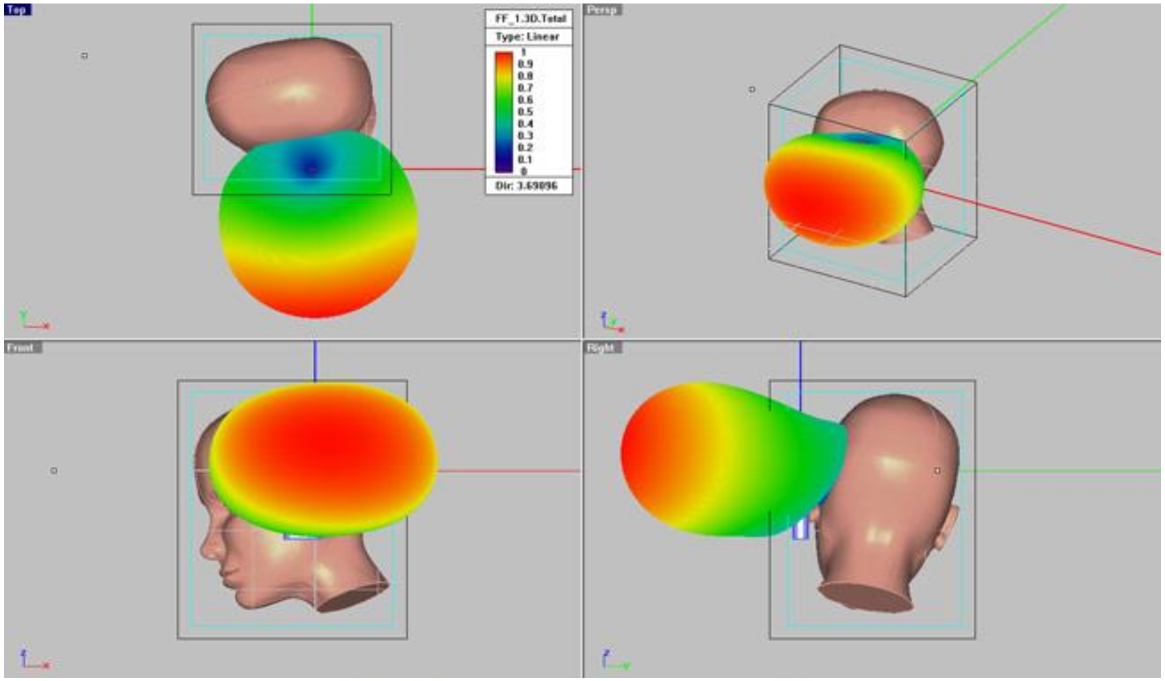
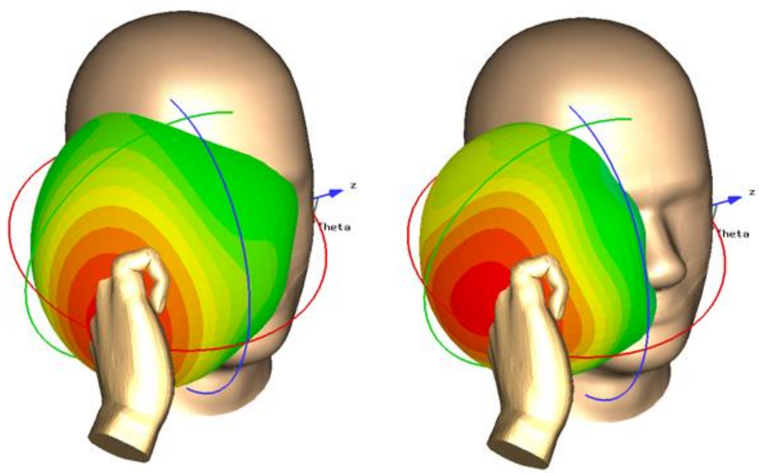
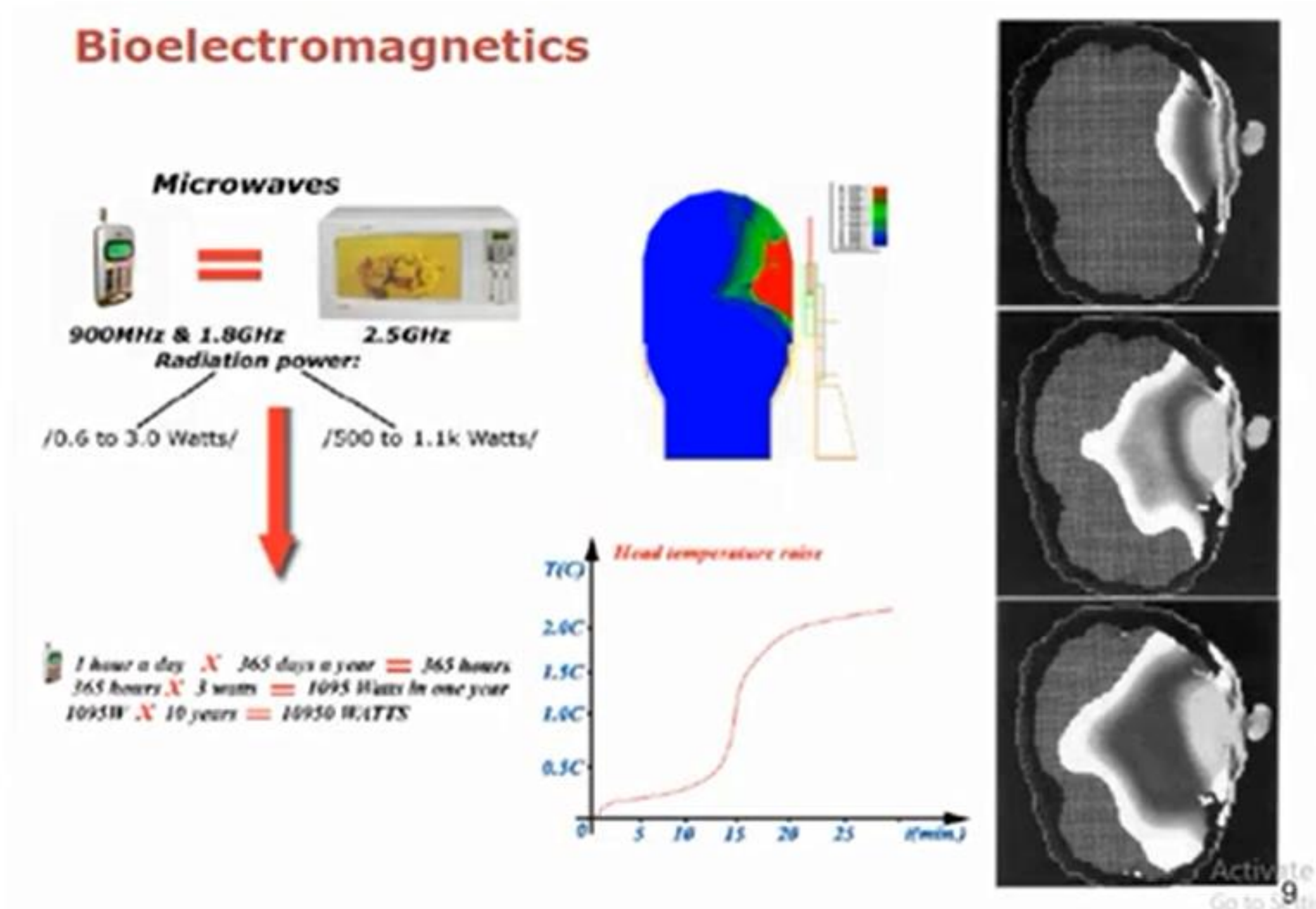




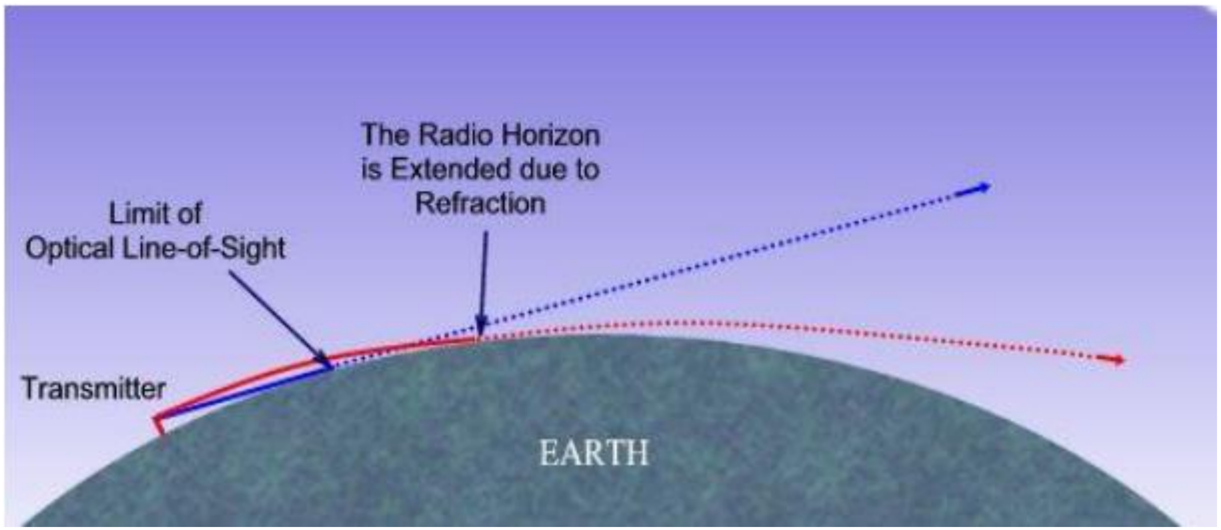


Bioelectromagnetics
Microwaves
900MHz & 1.8GHz
2.5GHz
Radiation power:
/0.6 to 3.0 Watts/
/500 to 1.1k Watts/
1 hour a day X 365 days a year = 365 hours
365 hours X 3 watts = 1095 Watts in one year
1095W X 10 years = 10950 WATTS
Head temperature raise
T(C)
2.0C
1.5C
1.0C
0.5C
0
5
10
15
20
25
t(min.)
9

5 - DISADVANTAGES AND LIMITATIONS

DISADVANTAGES AND LIMITATIONS

1- Short surface (need many antennas , distance between each two according to earth surface curvature)



2- Expansive cost for MW circuits

3- MW affected by weather.

6 - INDUSTRIAL , SCIENTIFIC AND MEDICAL (ISM) APPLICATIONS OF MW

INDUSTRIAL APPLICATIONS OF MW

1. **Consumer markets;**

- **Broadcast media transmission (TV, radio), Satellite communications, Cellular (wireless) communications**
  - Wireless Communications (space, cellular phones, cordless phones (wireless home phones), WLANs, Bluetooth, satellites etc.)
  - Microwaves is used in broadcasting and Telecom. transmission, due to their short wavelength, highly directional antennas are smaller . Mobile phone networks, like GSM, use the low microwave/UHF frequencies around 1.8 and 1.9GHz .
  - Microwaves are used in television signal to transmit a signal from a remote location to a television station from a specially equipped van.
  - Microwave are used for comm. from one point to another via satellite.
  - Satellite TV either operates in the C band for the traditional large dish or Ku band for direct –broadcast satellite.
- **Radar, e.g., Air traffic control, Weather, Global Positioning System (GPS)**
  - The most important application of remote sensing is RADAR, that uses a transmitter to illuminate an object and a receiver to detect its position and velocity.
  - **Animal Tracking**

INDUSTRIAL APPLICATIONS OF MW

- ❑ **MW_oven ➔ cooking**
- ❑ **Drying machines**

2. **Scientific;**
   - ☐ Atmospheric radar, Radio astronomy الفلك, Deep space communications
   - ☐ Medical/Biomedical (**Diagnostics)**
   - ☐ Ground penetrating radar

3. **Industrial;**
   - ☐ Testing and instrumentation, Materials processing
   - ☐ Industrial plasmas, especially for semiconductor, manufacture

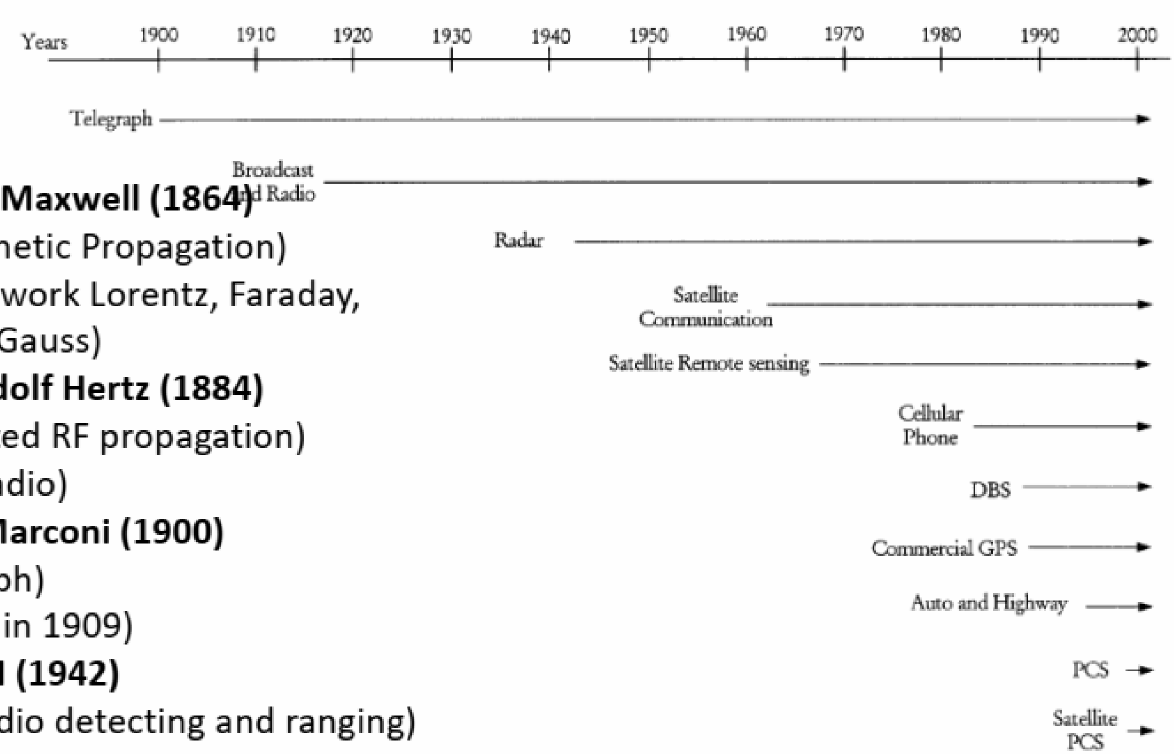
4. **Military;**
   - ☐ Radar, e.g., Search, Track, Missile صواريخ –seeker/finder , Weather Testing
   - ☐ Electronic countermeasures انظمة الدفاع المضادة (ECM)
   - ☐ High-power microwave (HPM) weapons

7 - HISTORY OF MICROWAVE DEVICES

HISTORY OF MICROWAVS

Microwave

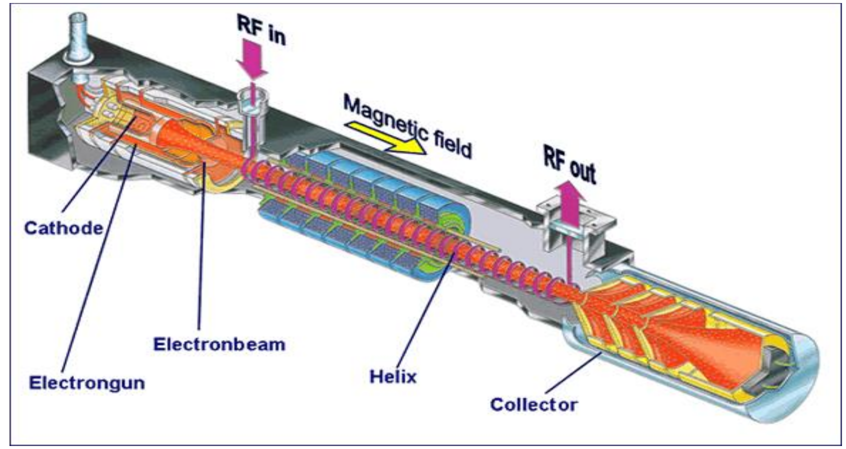
James Clark Maxwell (1864)
(Electromagnetic Propagation)
(Unified the work Lorentz, Faraday, Ampere's & Gauss)
Heinrich Rudolf Hertz (1884)
(Demonstrated RF propagation)
(Father of Radio)
Guglielmo Marconi (1900)
(The telegraph)
(Nobel Prize in 1909)
World War II (1942)
(Radar == radio detecting and ranging)



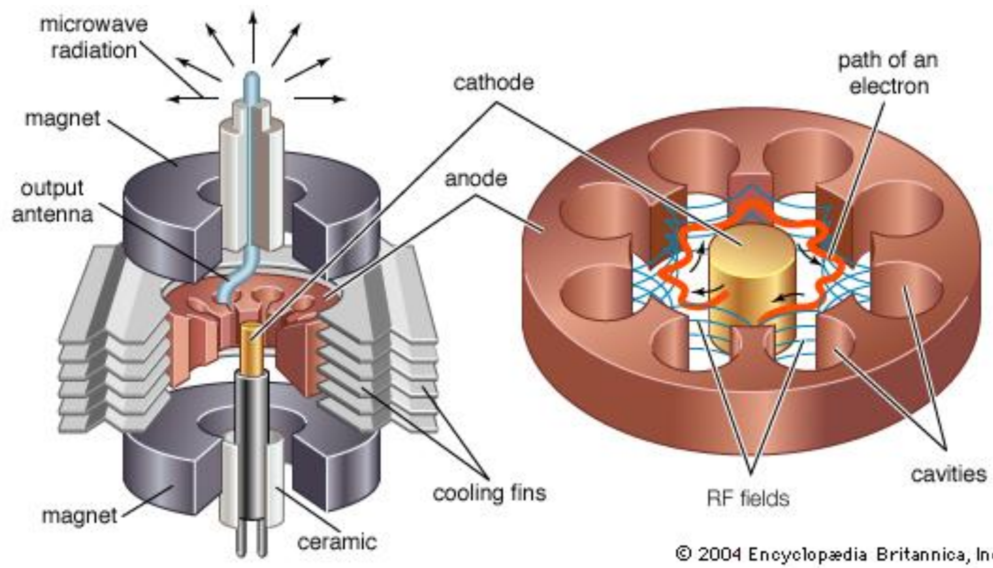
HISTORY OF MICROWAVE DEVICES

- In 1887 , Hertz discovered electromagnetic waves.
- In 1921 , Albert Hull invented the 1st microwave oscillator (Magnetron) , it generates VHF.
- In 1937 ,Varian && Siguard , invented (Klystron) .. A tube for both oscillation and amplification.
- In 1942 , invention of Travelling wave tube (TWT) to be used as an amplifier in satellite systems.

REFLEX KLYSTRON



TWT

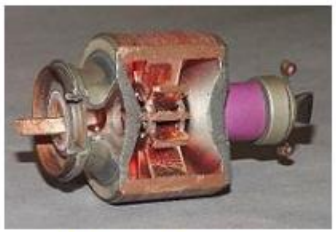


Magnetron

8 – TYPICAL EXAMPLES OF MW DEVICES

Microwave Devices

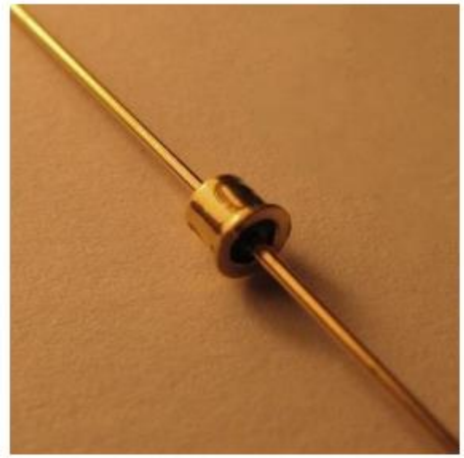
Microwave vacuum tubes



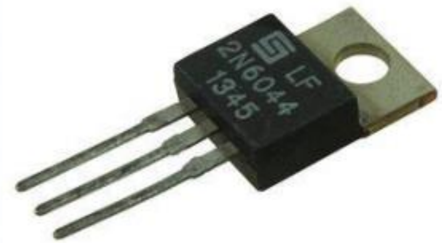
Magnetron

Vacuum tube

Microwave solid state devices



Tunnel diode

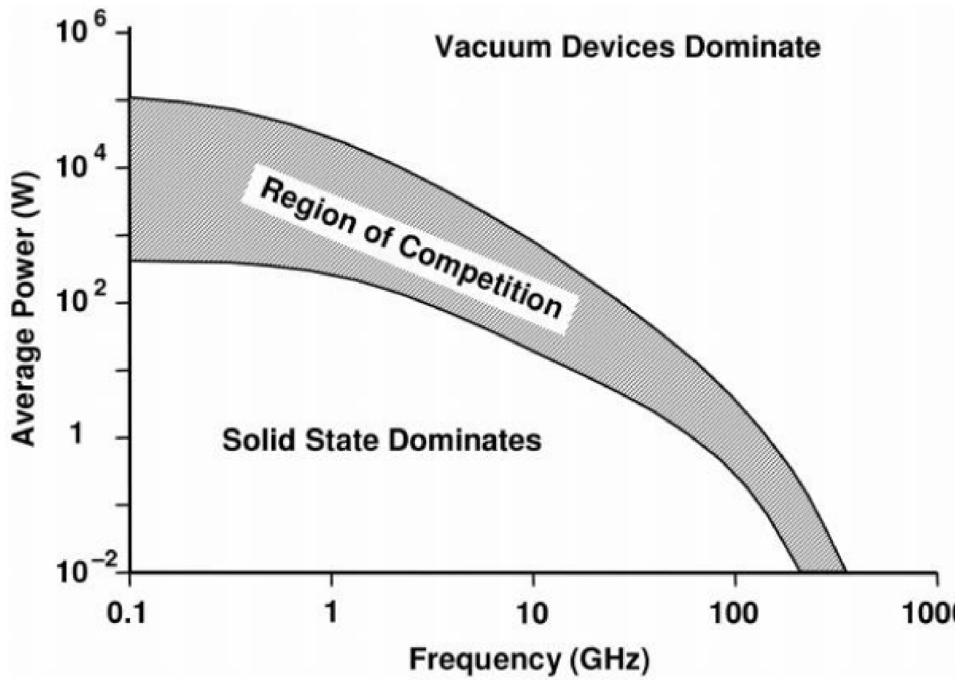


BJT transistor

- What is the difference between conventional tubes & MW tubes ?

Solid-state and vacuum device average power capabilities

- It can be seen that tubes have a very high power handling capability compared to that of solid state devices.
- Therefore, the choice of a particular type of device for a given application depends on the ability of the device to meet the power and frequency requirement.
- In the region of competition both microwave vacuum tubes and solid state devices can be used to generate the microwave signal with a competition between them in the performance.

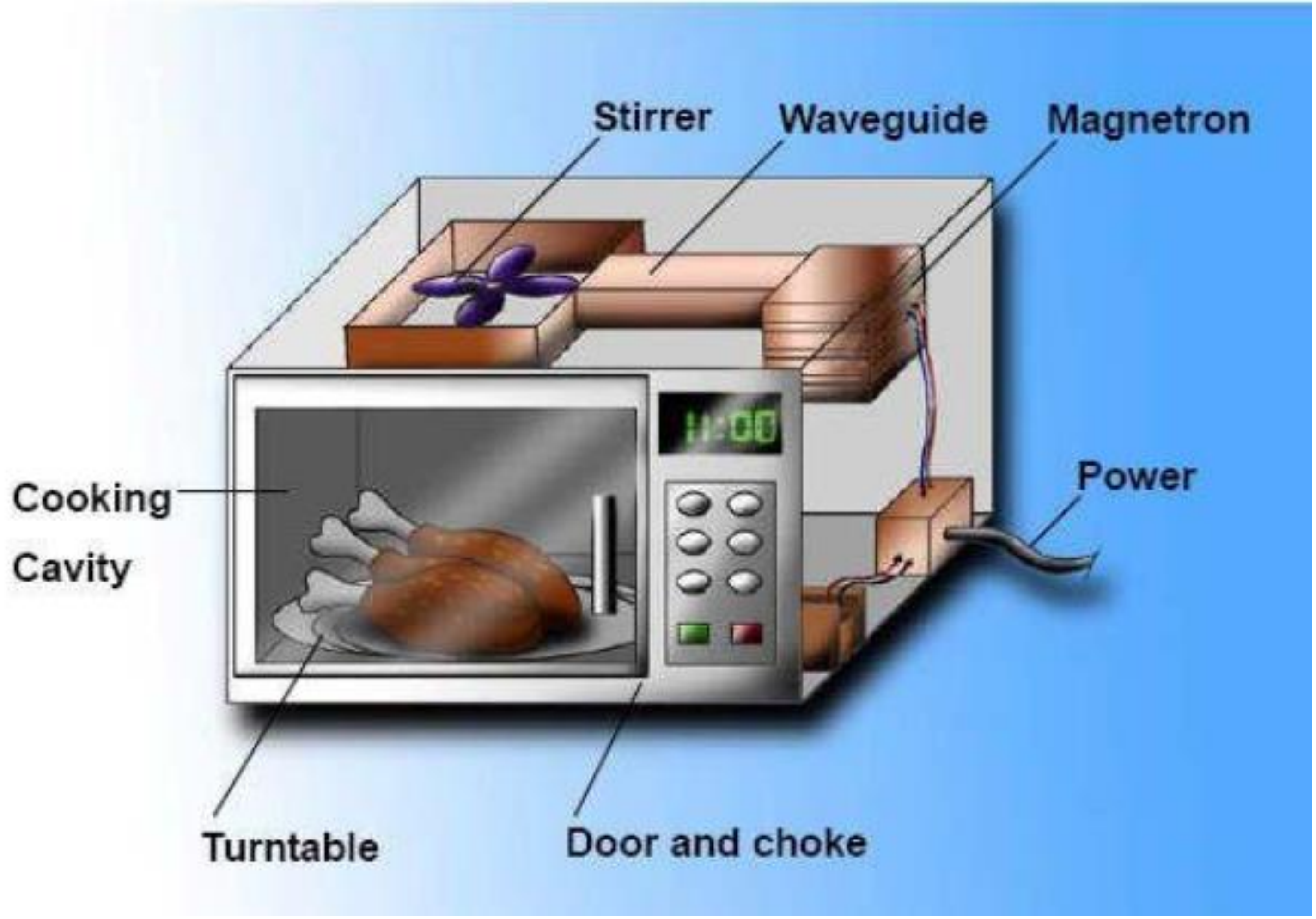


- Microwave tubes are preferred over vacuum tubes. At microwave frequency range, the conventional tubes become less effective when used as an amplifier and oscillator. Microwave tubes usually operate on the theory of velocity modulation, a concept that avoids the problems encountered in conventional tubes. Conventional oscillators (valves and tubes) can't generate frequencies above 100MHz , also can't generate high power for radar uses.
- In conventional oscillators, the interconnections in the electronic circuits acts as an antenna which diffracts الحيود and Disperses التشتت the oscillations.
- Coils , parasitic capacitors are also factors that faces conventional oscillators and hinders يعوق it in satellite and radar systems
- Microwave signals are very short signals (cm) , so traditional wires can't carry these waves , it will radiates all the power (ac as dipole antenna) through a small distance. Also coaxial cables can't carry all types of microwaves (just the lowest of them). So, waveguides is the replacement of normal wires.
- Also, wire antennas can't be used with microwave transmission, we use aperture antennas (dish & horn)

HISTORY OF MICROWAVE DEVICES

- Magnetron , Klystron and TWT based on :
  - Electron beam generated within a resonant cavity with dimensions according the operating frequency of oscillator/amplifier
  - Energy transferred from Electron beam to the required wave to be generated or amplified so the energy of the required wave increased.
- Magnetron , Klystron and TWT used in Radar systems during 2^{nd} world war.
- Unlike satellite systems , communication systems doesn’t require high power , so a microwave transistors invented and developed to operate as oscillators & amplifiers in microwave ranges.
- Nowadays , Microwave electronic devices are used in Mobile systems, Microwave oven and Diagnosis and treatment of diseases

Microwave Oven



- Microwave ovens operate at the frequency 2,450.00 MHz
- Microwave output power in the range of 1000 Watts

o Typical Example: Solid State Device

- Low noise block (LNB) attached to a satellite receiving dish, I/P frequency band 10.7 GHz to 11.8 GHz, O/P 950 MHz to 1950 MHz

o Typical Example: Solid State Radar

Radar Characteristics

General Characteristics
Multi-Role Radar System
Frequency Band (D/L) - 1215 to 1400 MHz
Active Electronic Elevation Scanning Array
Solid State Transmitters

Multi-Role Characteristics
Performance Designed to Meet Customer Requirements
Highly Configurable Performance due to Flexible Time Energy Management
Operator Mission Selection by Azimuth

Configurable Parameters

Instrumented Ranges and Height	Rotation Rate
Maximum Elevation Coverage	Transmit Power

Example Missions

Surveillance Radar	Terminal Control Radar
Gap Filler Radar	Customer Unique

Antenna Characteristics

RF Power	9.1 kW
Average RF Power	1.6 kW
Antenna Aperture Size	14.3 m2 (153.9 ft2)
Number of Active Rows	18
Dual Scan Rates	Configurable from 5 to 15

Surveillance Mission

Coverage Volume

Range	10 - 4
Azimuth	360°
Height Coverage	0 - 30
Elevation Coverage	0° - +
Scan Rate	5 RPM

Performance

Target Size	2m²
Probability of Detection	80%
PD Range	259
PD Height	up to

Accuracies - up to 15.2 km (50 kft)

Range	< 50
Azimuth	< 0.2
Height	< 915

Terminal Control Mission

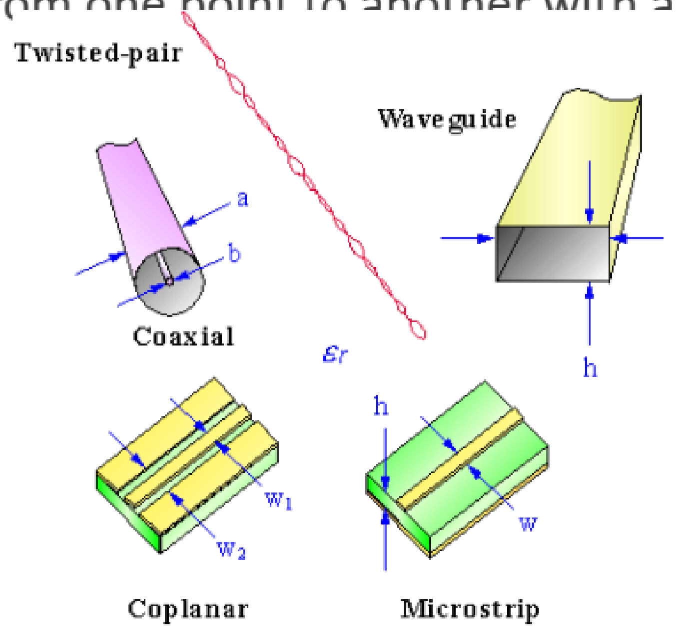
Coverage Volume

Range	2 - 1
Azimuth	360°
Height Coverage	0 - 1
Elevation Coverage	0° - +

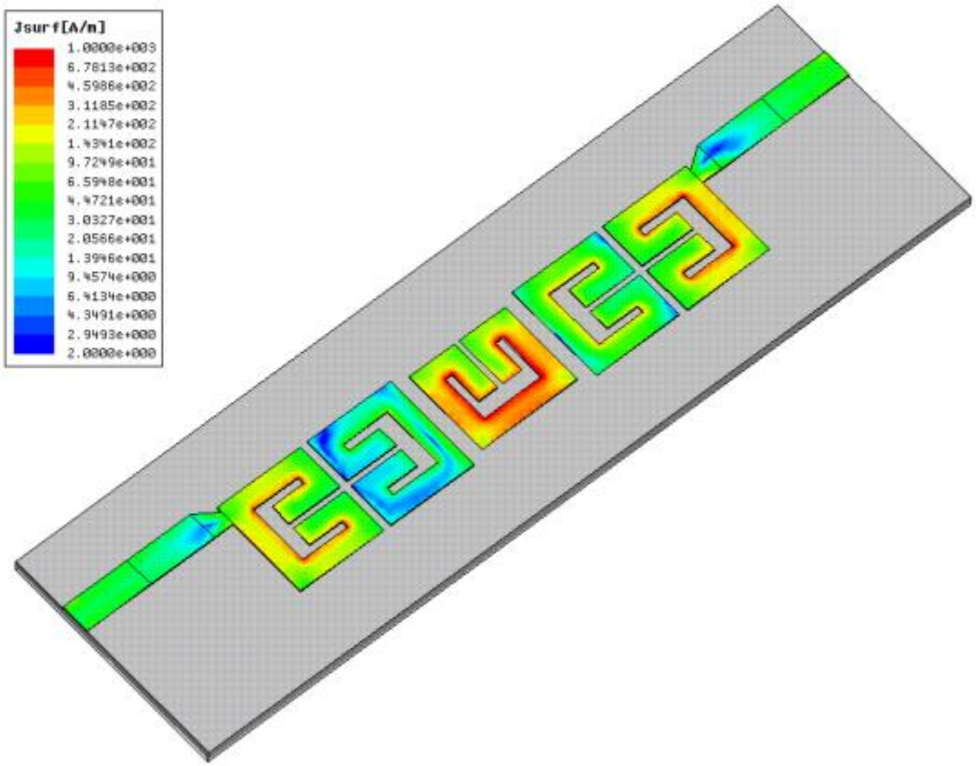
Transmission lines

Transmission lines

- A device that transfers energy from one point to another with a minimum loss.
- Forms:
  - Twisted pair
  - Coaxial cable
  - Stripline
  - Microstrip
  - Waveguide

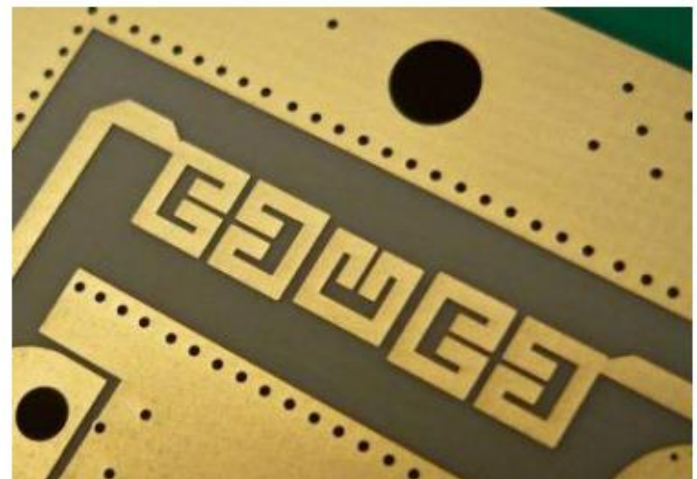


Microwave Filters



Compact Hairpin Band Pass Filter

Based on the traditional hairpin design, this 7GHz filter was made compact for a microwave backhaul company.



10 – WHY MICROWAVES

Waveguiding Structures

A waveguiding structure is one that carries a signal (or power) from one point to another.

There are three common types:

- Transmission lines
- Waveguides
- Fiber-optic guides

Transmission Line

Properties

- Has two conductors running parallel (one can be inside the other)
- Can propagate a signal at any frequency (in theory)
- Becomes lossy at high frequency
- Can handle low or moderate amounts of power
- Does not have signal distortion, unless there is loss (but there always is)
- May or may not be immune to interference (shielding property)
- Does not have E_z or H_z components of the fields (TEM_z)

Coaxial cable (coax)

Twin lead
(shown connected to a 4:1 impedance-transforming balun)

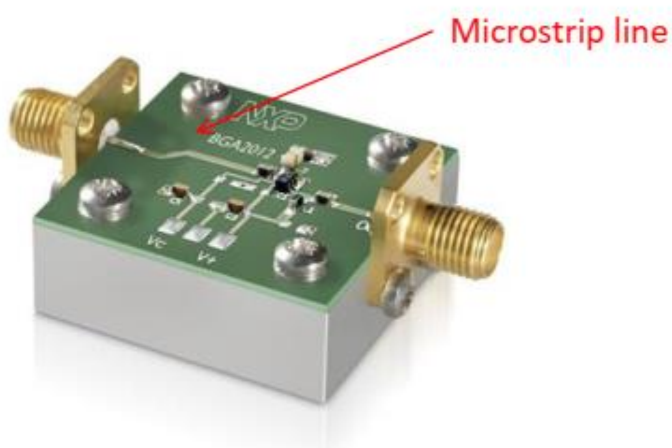
Transmission Line (cont.)

CAT 5 cable
(twisted pair)

The two wires of the transmission line are twisted to reduce interference and radiation from discontinuities.

Transmission Line (cont.)

Transmission lines are commonly met on printed-circuit boards.



A microwave integrated circuit.

Thank you for your attention