EC8701 ANTENNAS AND MICROWAVE ENGINEERING

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OBJECTIVES:

- To enable the student to understand the basic principles in antenna and microwave system design
- To enhance the student knowledge in the area of various antenna designs
- To enhance the student knowledge in the area of microwave components and antenna for practical applications.

UNIT I INTRODUCTION TO MICROWAVE SYSTEMS AND ANTENNAS 9

Microwave frequency bands, Physical concept of radiation, Near- and far-field regions, Fields and Power Radiated by an Antenna, Antenna Pattern Characteristics, Antenna Gain and Efficiency, Aperture Efficiency and Effective Area, Antenna Noise Temperature and G/T, Impedance matching, Friis transmission equation, Link budget and link margin, Noise Characterization of a microwave receiver.

UNIT II RADIATION MECHANISMS AND DESIGN ASPECTS 9

Radiation Mechanisms of Linear Wire and Loop antennas, Aperture antennas, Reflector antennas, Microstrip antennas and Frequency independent antennas, Design considerations and applications.

UNIT III ANTENNA ARRAYS AND APPLICATIONS 9

Two-element array, Array factor, Pattern multiplication, uniformly spaced arrays with uniform and non-uniform excitation amplitudes, Smart antennas.

UNIT IV PASSIVE AND ACTIVE MICROWAVE DEVICES 9

Microwave Passive components: Directional Coupler, Power Divider, Magic Tee, attenuator, resonator, Principles of Microwave Semiconductor Devices: Gunn Diodes, IMPATT diodes Schottky Barrier diodes, PIN diodes, Microwave tubes: Klystron, TWT, Magnetron.

UNIT V MICROWAVE DESIGN PRINCIPLES 9

Impedance transformation, Impedance Matching, Microwave Filter Design, RF and Microwave Amplifier Design, Microwave Power amplifier Design, Low Noise Amplifier Design, Microwave Mixer Design, Microwave Oscillator Design

OUTCOMES:

The student should be able to:

- Apply the basic principles and evaluate antenna parameters and link power budgets
- Design and assess the performance of various antennas
- Design a microwave system given the application specifications.

TEXTBOOKS:

1. John D Krauss, Ronald J Marhefka and Ahmad S. Khan, “Antenna and Wave Propagation: Fourth Edition, Tata McGraw –Hill, 2006. (UNITI, II, III)

2. David M.Pozar, “Microwave Engineering”, Fourth Edition, Wiley India, 2012. (UNIT I, IV, V).

REFERENCES:

1. Constantine A.Balanis,”Antenna Theory Analysis and Design”, Third edition, John Wiley India Pvt Ltd., 2005.

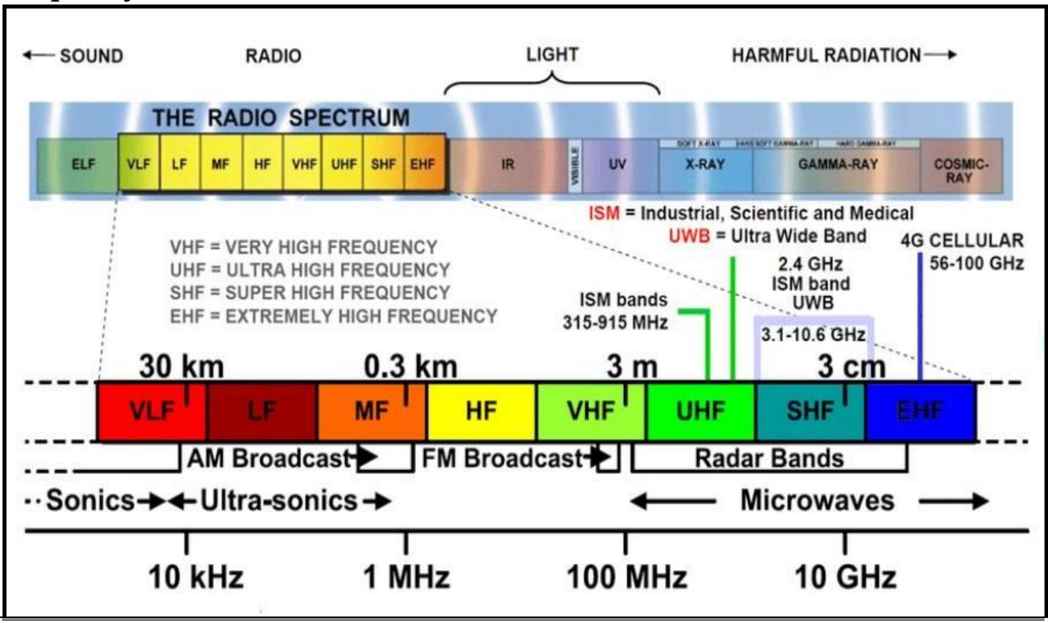
2. R.E.Collin, “Fundamentals for Microwave Engineering”, Second edition, IEEE Press, 2001.

UNIT I INTRODUCTION TO MICROWAVE SYSTEMS AND ANTENNAS

Microwave frequency bands, Physical concept of radiation, Near- and far-field regions, Fields and Power Radiated by an Antenna, Antenna Pattern Characteristics, Antenna Gain and Efficiency, Aperture Efficiency and Effective Area, Antenna Noise Temperature and G/T, Impedance matching, Friis transmission equation, Link budget and link margin, Noise Characterization of a microwave receiver.

UNIT-I / PART-A

1. **Sketch electromagnetic frequency spectrum showing the location of RF and Microwave frequency bands.**



2. **What are microwaves?(NOV/DEC 2021)**

Microwaves are electromagnetic waves (EM) with wavelengths ranging from 1mm to 1m. The corresponding frequency range is 300MHz to 300 GHz.

3. **List the conditions under which wire radiates.**

(i) If charge is moving with a uniform velocity(current created):

a. There is no radiation if the wire is straight, and infinite in extent.

b. There is radiation if the wire is curved, bent, discontinuous, terminated, or truncated.

(ii) If charge is oscillating in a time-motion, it radiates even if the wire is straight.

4. **Define reactive near field region of antenna.**

Reactive near-field region is defined as "that portion of the near-field region immediately surrounding the antenna wherein the reactive field predominates." For most antennas, the outer boundary of this region is commonly taken to exist at a distance $R < 0.62\sqrt{D^3/\lambda}$ from the antenna surface, where λ is the wavelength and D is the largest dimension of the antenna.

5. **Define radiating near field region(Fresnel region) of antenna.**

Radiating near-field (Fresnel) region is defined as "that region of the field of an antenna between the reactive near-field region and the far-field region wherein radiation fields predominate and wherein the angular field distribution is dependent upon the distance from the antenna.

The inner boundary is taken to be the distance $R \geq 0.62\sqrt{D^3/\lambda}$ and the outer boundary is taken to be the distance $R < 2D^2/\lambda$ where D is the largest dimension of the antenna.

6. **Define far field(Fraunhofer) region of antenna**

Far-field (Fraunhofer) region is defined as "that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. If the antenna has a maximum overall dimension D, the far-field region is commonly taken to exist at distances greater than $2D^2/\lambda$ from the antenna, λ being the wavelength.

7. **A parabolic reflector antenna used for reception with the direct broadcast system (DBS) is 18 inches in diameter and operates at 12.4 GHz. Find the far-field distance for this antenna.**

The operating wavelength at 12.4 GHz is $\lambda = c/f = (3 \times 10^8)/(12.4 \times 10^9) = 2.42$ cm.

D= 18 inches= 18x0.0254=0.457m

The far-field distance is $R_{ff} = 2D^2/\lambda = 2(0.457)^2/0.0242 = 17.3$ m.

8. **Define Radiation Intensity. What is it's significance?**

Radiation Intensity $U(\theta, \emptyset)$ in given direction is defined as the power per unit solid angle in that direction.

- The power radiated per unit area in any direction is given by pointing vector P.
- For distant field for which E and H are orthogonal in a plane normal to the radius vector,

The power flow per unit area is given by $P = \frac{E^2}{\eta_v}$ *watts / sqm*

- There are r^2 square meters of surface area per unit solid angle(or steradian).
- $U(\theta, \emptyset) = r^2 P = \frac{r^2 E^2}{\eta_v} watts/unit\ solid\ angle$

The radiation intensity gives the variation in radiated power versus position around the antenna. We can find the total power radiated by the antenna by integrating the Poynting vector over the surface of a sphere that encloses the antenna. This is equivalent to integrating the radiation intensity over a unit sphere.

$$P_{rad} = Power\ radiated = \int_{\emptyset=0}^{2\pi} \int_{\theta=0}^{\pi} U(\theta, \emptyset) sin\theta d\theta d\emptyset$$

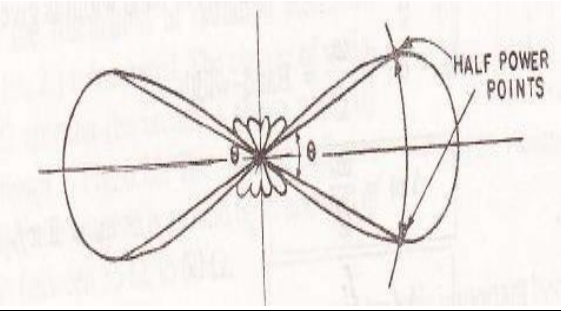
9. **Define Radiation pattern.**

The radiation pattern of an antenna is a plot of the magnitude of the far-zone field strength versus position around the antenna, at a fixed distance from the antenna.

Thus the radiation pattern can be plotted from the pattern function $F_\theta(\theta,\varphi)$ or $F_\varphi(\theta,\varphi)$, versus either the angle θ (for an elevation plane pattern) or the angle φ (for an azimuthal plane pattern). The choice of plotting either F_θ or F_φ is dependent on the polarization of the antenna.

10. **Define Half Power Beam Width (HPBW) of an antenna.**

Half Power Beam Width is a measure of directivity of an antenna. It is an angular width in degrees, measured on the radiation pattern (main lobe) between points where the radiated power has fallen to half its maximum value.



11. **Define beam solid angle.**

The beam area or beam solid angle Ω_A for antenna is given by integral of the normalized power pattern over a sphere.

$$\Omega_A = \int_0^{2\pi} \int_0^{\pi} P_n(\theta,\phi)\ d\Omega \qquad steradian$$

$$P_n(\theta,\phi) = Normalized\ \ power\ \ pattern$$

Beam solid angle is also given approximately by

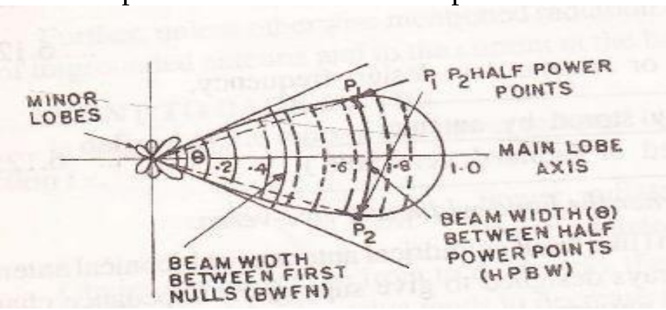
$\Omega_A = \theta_{HP}\ \phi_{HP}$ *steradian*

$\theta_{HP} = HPBW\ in\ E - plane\ or\ \theta\ \ plane$

$\phi_{HP} = HPBW\ in\ H - plane\ or\ \phi\ \ plane$

12. **Define Beam Width between First Null.**

Beam width between first null (BWFN) is the angular width in degrees, measured on the radiation pattern between first null points on either side of the main lobe.



13. **Define main lobe, side lobe, minor lobe and back lobe with reference to antenna radiation pattern.**

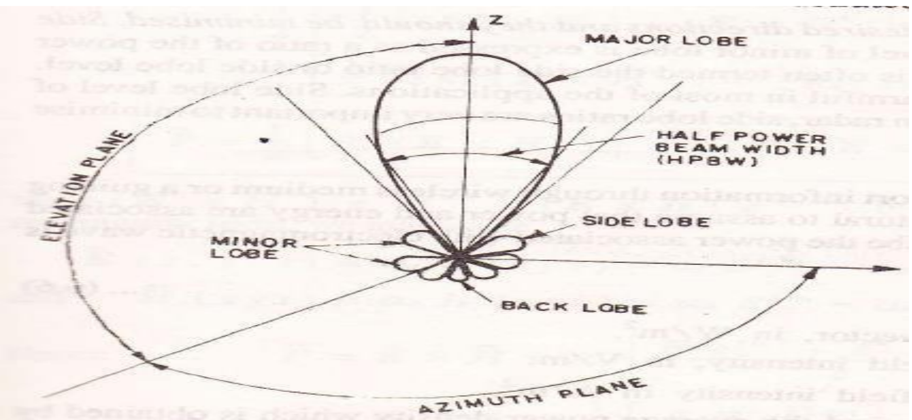
<u>Major Lobe</u>: Major lobe is also called as main beam and is defined as "the radiation lobe containing the direction of maximum radiation". In some antennas, there may be more than one major lobe.

<u>Minor lobe:</u> All the lobes except the major lobes are called minor lobe.

<u>Side lobe:</u> A side lobe is adjacent to the main lobe.

<u>Back lobe</u>: Normally refers to a minor lobe that occupies the hemisphere in a direction opposite to that of the major(main) lobe .

Minor lobes normally represents radiation in undesired directions and they should be minimized.



14. **Define directivity of an antenna.**

The directivity(D) of an antenna is defined as the ratio of the maximum value of the power radiated per unit solid angle to the average power radiated per unit solid angle.

That is, directivity is ratio of the maximum radiation intensity in the main beam to the average radiation intensity over all space.

$$D = \frac{U_{max}}{U_{avg}} = \frac{U_{max}}{P_{rad}/4\pi} = \frac{4\pi U_{max}}{\int_{\emptyset=0}^{2\pi}\int_{\theta=0}^{\pi} U(\theta,\emptyset) sin\theta d\theta d\emptyset}$$

Thus, the directivity measures how intensely the antenna radiates in its preferred direction than an isotropic radiator would when fed with the same total power.

Directivity is a dimensionless ratio of power, and is usually expressed in dB as D(dB) = 10 log(D)

15. **What do you mean by an isotropic radiator? What is the directivity of isotropic radiator?**

An isotropic radiator is a hypothetical loss less radiator having equal radiation in all directions.

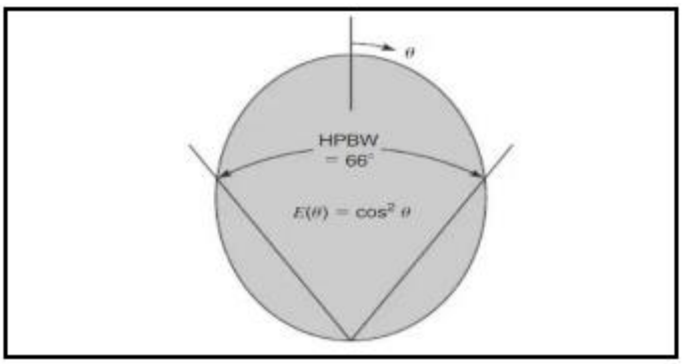
U(θ,φ) = 1 for isotropic antenna. Applying the integral identity, $\int_{\emptyset=0}^{2\pi}\int_{\theta=0}^{\pi} sin\theta d\theta d\emptyset = 4\pi$, we have,

$$D = \frac{4\pi U_{max}}{\int_{\emptyset=0}^{2\pi}\int_{\theta=0}^{\pi} U(\theta,\emptyset) sin\theta d\theta d\emptyset} = 1$$

The directivity of an isotropic antenna is D = 1, or 0 dB.

16.	**What is the Relationship between Directivity and beamwidth?** Beamwidth and directivity are both measures of the focusing ability of an antenna. An antenna pattern with a narrow main beam will have a high directivity, while a pattern with a wide beam will have a lower directivity. Approximate relation between beam width and directivity that apply with reasonable accuracy for antennas with pencil beam patterns is the following: $D \cong \frac{32,000}{\theta_1 \theta_2}$ where θ_1 and θ_2 are the beam widths in two orthogonal planes of the main beam, in degrees. This approximation does not work well for omnidirectional patterns because there is a well-defined main beam in only one plane for such patterns.
17.	**Define omnidirectional antenna. Give its appliccations.** Antennas having a constant pattern in the azimuthal plane are called omnidirectional, and are useful for applications such as broadcasting or for hand-held wireless devices, where it is desired to transmit or receive equally in all directions.
18.	**Define pencil beam antenna and give its applications.** Antennas with radiation pattern that have relatively narrow main beams in both planes are known as pencil beam antennas. Pencil beam antenna are useful in applications such as radar and point-to-point radio links.
19.	**Define radiation efficiency of antenna.** Radiation efficiency of an antenna is defined as the ratio of the radiated output power to the supplied input power. $\eta_{rad} = \frac{P_{rad}}{P_{in}} = \frac{P_{in} - P_{loss}}{P_{in}} = 1 - \frac{P_{loss}}{P_{in}}$ where P_{rad} is the power radiated by the antenna, P_{in} is the power supplied to the input of the antenna, and P_{loss} is the power lost in the antenna(dissipative losses) due to metal conductivity or dielectric loss with in the antenna.
20.	**Define gain of an antenna. What is the significance of gain of an antenna?/** **Relate the gain and directivity of an antenna through proper expression.(NOV/DEC 2021)** The gain of the antenna is closely related to the directivity, it is a measure that takes into account the efficiency of the antenna as well as its directional capabilities. **A**ntenna gain is defined as the product of directivity and efficiency: $Gain = G = \eta_{rad} \times D.$ Thus, gain is always less than or equal to directivity.
21.	**Define aperture efficiency.** Aperture efficiency is defined as the ratio of the actual directivity of an aperture antenna to the maximum directivity of aperture antenna. The maximum directivity that can be obtained from an electrically large aperture of area A is given as, $D_{max} = \frac{4\pi A}{\lambda^2}$ $\eta_{ap} = \text{aperture efficieny} = \frac{D}{D_{max}}$
22.	**Define effective aperture area. What is the relation between effective aperture area and Directivity(gain)?** Received power is proportional to the power density, or Poynting vector, of the incident wave. Since the Poynting vector has dimensions of W/m^2, and the received power, P_r, has dimensions of W, the proportionality constant must have units of area. We have, $P_r = A_e \times S_{avg}$ where A_e is defined as the effective aperture area of the receive antenna. The effective aperture area has dimensions of m^2, and can be interpreted as the "capture area" of a receive antenna, intercepting part of the incident power density radiated toward the receive antenna. The maximum effective aperture area of an antenna is related to the directivity of the antenna as, $A_e = \frac{D\lambda^2}{4\pi}$ The maximum effective aperture area as defined above does not include the effect of losses in the antenna, which can be accounted for by replacing D with G, the gain, of the antenna.

23.	**Define Antenna Brightness temperature** When the antenna beam width is broad enough that different parts of the antenna pattern see different background temperatures, the effective brightness temperature seen by the antenna can be found by weighting the spatial distribution of background temperature by the pattern function of the antenna. Mathematically we can write the brightness temperature T_b seen by the antenna as $T_b = \frac{\int_{\emptyset=0}^{2\pi}\int_{\theta=0}^{\pi} T_B(\theta,\emptyset)D(\theta,\emptyset)sin\theta d\theta d\emptyset}{\int_{\emptyset=0}^{2\pi}\int_{\theta=0}^{\pi} D(\theta,\emptyset)sin\theta d\theta d\emptyset}$ Where $T_B(\theta,\emptyset)$ is the distribution of the background temperature, and $D(\theta,\emptyset)$ is the directivity (or the power pattern function) of the antenna. Antenna brightness temperature is referenced at the terminals of the antenna. Observe that when T_B is a constant, $T_b = T_B$
24.	**What is the significance of G/T ratio?** Useful figure of merit for receive antennas is the G/T ratio, defined as 10 log(G/ T_A) dB/K, where G is the gain of the antenna, and T_A is the antenna noise temperature. This quantity is important because, the signal-to-noise ratio (SNR) at the input to a receiver is proportional to G/T_A. The ratio G/T can often be maximized by increasing the gain of the antenna, since this increases the numerator and usually minimizes reception of noise from hot sources at low elevation angles. Of course, higher gain requires a larger and more expensive antenna, and high gain may not be desirable for applications requiring omnidirectional coverage (e.g., cellular telephones or mobile data networks), so often a compromise must be made.
25.	**State why impedance matching(tuning) is important.** Impedance matching or tuning is important for the following reasons: (i) Maximum power is delivered when the load is matched to the line (assuming the generator is matched), and power loss in the feed line is minimized. (ii) Impedance matching sensitive receiver components (antenna, low-noise amplifier, etc.) may improve the signal-to-noise ratio of the system. (iii) Impedance matching in a power distribution network (such as an antenna array feed network) may reduce amplitude and phase errors.
26.	**Give the Friis radio link formula.** $P_r = \frac{G_r P_t G_t \lambda^2}{(4\pi r)^2}$ P_r= Received power (antenna matched) in W P_t= power in to transmitting antenna in W A_{et}= Effective aperture of transmitting antenna, m^2 A_{er}= Effective aperture of Receiving antenna , m^2 r=distance between transmitting and receiving antenna , m λ= wave length, m
27.	**Define EIRP. What is the significance of this quantity?** The product $P_t G_t$ is defined as the Effective Isotropic Radiated Power (EIRP). EIRP = $P_t G_t$ W For a given frequency, range, and receiver antenna gain, the received power is proportional to the EIRP of the transmitter and received power can only be increased by increasing the EIRP. This can be done by increasing the transmit power, or the transmit antenna gain, or both.
28.	**Define path loss.** Path loss is the quantity that account for the free-space reduction in signal strength with distance between the transmitter and receiver. Path loss= Transmitted power- Received power=P_t - P_r Assuming unity gain antennas, path loss is given as (using Friis formula) $path\ loss\ (dB) = 20\ log\left(\frac{4\pi r}{\lambda}\right)$

29.	**Define link margin** In practical communications systems it is usually desired to have the received power level greater than the threshold level required for the minimum acceptable quality of service (usually expressed as the minimum carrier-to-noise ratio (CNR), or minimum SNR). This design allowance for received power is referred to as the link margin, and can be expressed as the difference between the design value of received power and the minimum threshold value of receive power: Link margin (dB) = LM = $P_r - P_r(\text{min}) > 0$, where all quantities are in dB. Link margin should be a positive number; typical values may range from 3 to 20 dB. Having a reasonable link margin provides a level of robustness to the system to account for variables such as signal fading due to weather, movement of a mobile user, multipath propagation problems, and other unpredictable effects that can degrade system performance.
30.	**Define fade margin.** Signal fading occur due to weather, movement of a mobile user, multipath propagation problems, and other unpredictable effects that can degrade system performance and quality of service. Link margin that is used to account for fading effects is sometimes referred to as fade margin.
31.	**How link margin for a given communication system can be improved?** Link margin for a given communication system can be improved by increasing the received power (by increasing transmit power or antenna gains), or by reducing the minimum threshold power (by improving the design of the receiver, changing the modulation method, or by other means)
32.	**32. What is point-to-point communication. Mention some of its application.** • In a point-to-point radio system a single transmitter communicates with a single receiver. Such systems generally use high-gain antennas in fixed positions to maximize received power and minimize interference with other radios that may be operating nearby in the same frequency range. • Point-to-point radios are typically used for satellite communications, dedicated data communications by utility companies, and backhaul connection of cellular base stations to a central switching office.
33.	**An antenna has a field pattern given by E(θ) = $\cos^2\theta$ for 0° < θ < π. Find Half Power Beam Width (HPBW). (Nov 20)** E(θ) at half power = 0.707. $\cos^2\theta = 0.707$ so, $cos\theta = \sqrt{0.707}$ and $\theta = 33^o$ HPBW =2θ =66^o 

34.	**What is Link Budget ? Mention a simple Link Budget equation.** The link budget is a summary of the transmitted power along with all the gains and losses in the communication system and this enables the strength of the received signal to be calculated. Using this knowledge, it is possible to determine whether power and gain levels are sufficient, too high, or too low and then apply corrective action to ensure the system will operate satisfactorily. **Simple link Budget equation**: $P_r(\text{dBm}) = P_t - L_t + G_t - L_0 - L_A + G_r - L_r$ Where, Transmit power P_t Transmit antenna line loss $(-)L_t$ Transmit antenna gain G_t Path loss (free-space) $(-)L_0$ Atmospheric attenuation $(-)L_A$ Receive antenna gain G_r Receive antenna line loss $(-)L_r$ Receive power P_r
	UNIT-I / PART-B
1.	Explain in detail, the physical concept of radiation. Illustrate with necessary diagrams, how the electromagnetic fields guided within the transmission line and antenna, finally get "detached" from the antenna to form a free-space wave.
2.	Explain in detail the field regions of antenna. What is the significance of Fraunhofer zone?
3.	Define and explain in detail the terms Gain, Directivity, beam width, Bandwidth and Polarization of an antenna.
4.	Define and describe the following parameters of an antenna: (i)Radiation Pattern (ii)Radiation intensity (iii)Directivity (iv)Effective aperture
5.	Define and explain the significance of the following antenna parameters: (i) Antenna brightness temperature (ii) Antenna noise temperature (iii) Antenna Efficiency (iv)Half Power Beam width
6.	(i) How are antennas classified based on radiation characterstics? Explain with an example, the radiation pattern characteristics of omnidirectional antenna. (ii) Explain in detail about:1)Radiation pattern lobes 2) Aperture efficiency 3) Beam solid angle
7.	(i) Derive FRIIS transmission formula. **(ii)** A radio link has a 20 W transmitter connected to an antenna of 2.5 m^2 effective aperture at 5 GHz. The receiving antenna has an effective aperture of 0.5m^2 and is located at a 15 Km line of sight distance from the transmitting antenna. Assuming lossless, matched antennas, find the power delivered to the receiver**. (Nov 2019)**
8.	Explain the various loss and gain terms considered in the microwave link budget. Also discuss on the significance of link margin and fade margin of a communication system.
9.	Define and explain the various parameters used to analyse the noise characteristics of a microwave receiver.
10.	Discuss on the noise analysis of a Microwave receiver front end, including antenna and transmission line contributions.
11.	Obtain expression for the field and power radiated by an oscillating dipole and calculate the radiation resistance. **(Nov 2020)**

12. i) What is impedance matching ? Explain about the techniques used to solve the impedance matching problems.
ii) Using Friss transmission formula find the maximum power received at a distance of 1 Km over a free space. A 100 MHz circuit consisting of a transmitting antenna of 30 dB gain and a receiving antenna with a 25 dB gain is used. The power input to the transmitting antenna is 150 W. **(Nov 2020)**

13. (i)Define and explain the significance of the following antenna parameters:
a. Radiation resistance b. Antenna temperature
(ii)How are antennas classified based on radiation characteristics? Illustrate with examples**.(NOV/DEC 2021)**

14. Examine the Noise Characterization of a microwave receiver**.(NOV /DEC 2021)**

UNIT II RADIATION MECHANISMS AND DESIGN ASPECTS

Radiation Mechanisms of Linear Wire and Loop antennas, Aperture antennas, Reflector antennas, Microstrip antennas and Frequency independent antennas, Design considerations and applications.

UNIT-II / PART-A

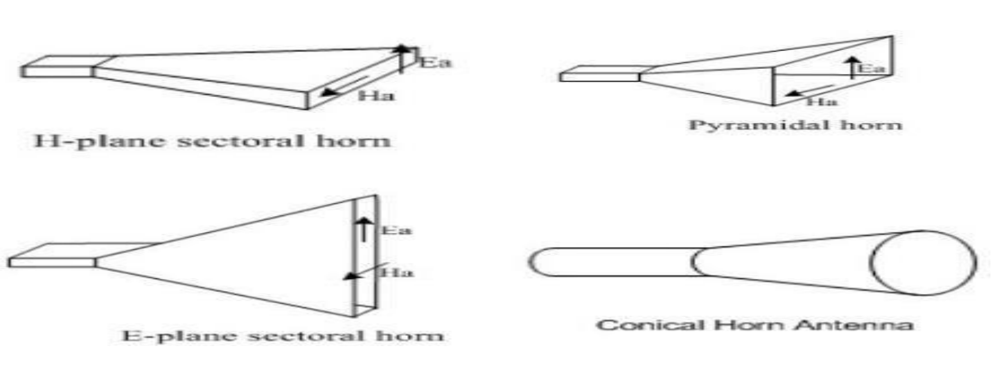
1. **State Huygen's Principle.**
Huygens' principle states that "each point on a primary wave front can be considered to be a new source of a secondary spherical wave and that a secondary wave front can be constructed as the envelope of these secondary spherical waves ."

2. **State Babinet's principle and how it gives rise to the concept of complementary antenna?**
Babinet's principle states that the sum of the field at a point behind a plane having a screen and the field at the same point when a complimentary screen is substituted, is equal to the field at the point when no screen is present. This principle can be applied to slot antenna analysis.

3. **State uniqueness theorem (May 2012)**
Uniqueness theorem states that, for a given set of sources and boundary conditions in a lossy medium, the solution to Maxwell's equations is unique.

4. **What is field equivalence principle? (May 2014)**
The field equivalence principle is based on the uniqueness theorem which states that "a field in a lossy region is uniquely specified by the sources within the region plus the tangential components of the electric field over the boundary, or the tangential components of the magnetic field over the boundary, or the former over part of the boundary and the latter over the rest of the boundary ."

5. **Draw various types of Horn antenna.**
Different types of horn antenna are**:** E-Plane sectoral horn, H-plane sectoral horn, Pyramidal horn, Conical horn



6. **Distinguish between sectorial horn and pyramidal horn.**
   - Horn antenna is a wave guide one end of which is flared out. In pyramidal horn, the flaring is along E and H. It has the shape of a truncated pyramid.
   - In sectoral horn, the flaring is along E or H. If flaring is along the direction of electric field, it is called sectoral E-plane horn. If flaring is along the direction of magnetic field, it is called sectoral H-plane horn.

7.	**The aperture dimensions of a pyramidal horn are 12x6 cm and operating at a frequency of 10 GHz. Find the beam width and directivity. (May 2013)** Frequency = 10 GHz $\lambda = \frac{3\times10^8}{10\times10^9} = 3cm$ $d = 12cm$ and $w = 6cm$ $Beamwidth: \phi_E = 56\frac{\lambda}{d} = 14^0$ $\phi_H = 67\frac{\lambda}{w} = 33.5^0$ $power\ gain = \frac{4.5wd}{\lambda^2} = 36 = 15.56dB$ $Directivity = \frac{7.5wd}{\lambda^2} = 60$
8.	**What are secondary antennas? Give two examples.** **Secondary antennas** are one that needs a primary antenna to excite it. Eg: Reflector antenna, Lens antenna.
9.	**What is a corner reflector?** **A corner reflector** is made up of two flat-plate reflectors joined together to form a corner. The corner reflector is generally used in conjunction with a dipole or dipole array kept parallel to the corner line. Corner reflector gives a higher directivity.
10.	**What is the main advantage of Cassegrain reflector configuration?** The main advantage is that the primary feed horn and the associated receiver or transmitter can be located conveniently behind the main reflector. • The necessity of running long transmission lines or waveguides is also eliminated. • Since the horn feed is kept behind the main reflector, one can afford to have a much larger aperture for the horn.
11.	**What is the main disadvantage of Cassegrain reflector configuration?** The main disadvantage of Cassegrain reflector configuration is the large aperture blockage by the sub-reflector. Hence, Cassegrain reflector configuration is used only for very large aperture antennas having gain greater than 40dB.
12.	**What is slot radiator? What is its operating principle?** When a slot in a large metallic plane is coupled to an R.F source, it behaves like a diploe antenna mounted over a reflecting surface. The slot is coupled to a feed line in such a manner that E-field lies along the short axis of the slot.
13.	**Write any two differences between slot antenna and its complementary dipole antenna.** (i) First, the electric and magnetic fields are interchanged. In case of the dipole antenna the electric lines are horizontal while the magnetic lines form loops in the vertical plane. But in case of slot antenna, the magnetic lines are horizontal and the electric lines are vertical. The electric lines are built up across the narrow dimensions of the slot. As a result, the polarization of the radiation produced by a horizontal slot is vertical and vertical slot is horizontal. (ii) Second, the direction of the lines of electric and magnetic force abruptly reverse from one side of the metal sheet to the other. In case of the dipole, the electric lines have the same direction while the magnetic line forms continuous loops.
14.	**The impedance of an infinitesimally thin λ/2 antenna is 73+j42.5 Ω. Calculate the terminal impedance of an infinitesimally thin λ/2 slot antenna.(Nov/Dec 2015)** $Z_S = \frac{\eta_0^2}{4Z_C} = \frac{(377)^2}{4(73+j42.5)} = \frac{35532.25}{(73+j42.5)} = 363.52 - j\,211.64\ \Omega$

15.	**What is a microstrip antenna?** A microstrip patch antenna is an antenna consisting of a thin metallic patch etched on the dielectric substrate using PCB technology. It is also referred as printed antenna. Its performance depends on shape (can be square, rectangular, triangular, circular) and size.
16.	**What are the features of microstrip antennas?** • Micro strip antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and when the particular patch shape and mode are selected, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance. • In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed.
17.	**What are the major operational disadvantages of microstrip antennas?/** **Point out the limitations of microstrip patch antennas.(NOV/DEC 2021)** Major operational disadvantages of microstrip antennas are their low efficiency, low power, high Q (sometimes in excess of 100), poor polarization purity, poor scan performance, spurious feed radiation and very narrow frequency bandwidth.
18.	**List the different methods of feeding Microstrip antenna.** (i) microstrip line feed (ii) coaxial probe feed (iii) aperture coupling (iv) proximity coupling
19.	**Define the bandwidth of an antenna.** The band width of antenna is defined as "The range of frequencies within which the performance of the antenna, with respect to some characteristics [input impedance, beam, width, polarization, side lobe level, gain etc.] confirms to a specified standard''.
20.	**What is wide band antenna? Give an example.** Antennas which maintain certain required characteristics like gain, front to back ratio, SWR, Polarization, input impedance and radiation pattern over wide range of frequencies are called wide band or broad band antennas. Log periodic antenna is a broadband antenna.
21.	**State Rumsey principle on frequency independence.(April/May 2017)** **Rumsey's principle** states that the impedance and radiation pattern properties of an antenna will be frequency independent if the antenna shape is specified only in terms of angles. Example: Planar log spiral antenna.
22.	**What is LPDA?** **LPDA** is log periodic dipole array. It is unidirectional broadband, multi element, narrow beam, frequency independent antenna that has impedance and radiation characteristics that are regularly repetitive as a logarithmic function of frequency.
23.	**Why is log periodic antennas called so?** Log periodic antennas are called so, because**,** it is an array antenna which has structural geometry such that its impedance and radiation characteristics are periodic with the logarithm of the frequency.
24.	**Calculate the beam width between first nulls of a 2.5 m paraboloid reflector used at 6 GHz. (Nov 20)** $f = 6GHz$ $\lambda = \frac{3 \times 10^8}{6 \times 10^9} = 0.05m$ $BWFN = 140 \times \frac{\lambda}{D} = \frac{140 \times 0.05}{2.5} = 2.8^o$
25.	**What is aperture blockage ? Give one example. (Nov 20)** Aperture blockage is the effect of antenna parts lying in the path of rays arriving at or departing from a radiating element or the aperture of an antenna. For example, the **feed, sub-reflector, or support structure** may produce aperture blockage for a reflector antenna.

26.	**Discuss the merits and applications of offset feed reflector antenna.(NOV/DEC 2021)** • Offset feed arrangement, reduce aperture block which reduces the antenna gain. • It is used as domestic satellite TV receiving antenna
	UNIT-II / PART-B
1.	Derive the expression for the field quantities radiated from a $\lambda/2$ dipole and prove that the radiation resistance to be 73 Ohms**.**
2.	(i) Compare uniform and tapered aperture antennas. Give examples. (ii)With neat diagrams, explain parabolic reflector antenna and its Cassegrain feeding system.
3.	Discuss the principle working of Parabolic reflectors. Explain the various feed techniques their relative merits and demerits. Discuss the role of f/d ratio in the parabolic reflectors (f- focal length, D – diameter of reflector). **(May 2019)**
4.	(i) Explain the radiation mechanism of Microstrip antenna. **(ii)** Write short notes on Slot antenna. **(Nov 2019) (Nov 17)**
5.	Design a 50 to 200 MHz log periodic dipole antenna for gain corresponds to scale factor 0.8 and space factor 0.15. Assume the gap spacing at the smallest dipole is 3.6 mm. **(May 18)**
6.	Explain in detail about log periodic antennas. What is the need for feeding from end with shorter dipoles and the need for transposing the lines? Also discuss the effects of decreasing α. **(Nov/Dec 2016)**
7.	Design a Log-Periodic dipole array with 7 dBi gain and a 4 to 1 bandwidth. Specify apex angle α, scale constant k and the number of elements. **(Nov/Dec 2015)**
8.	Explain the design procedure for the construction of log periodic antenna. (**May 2016)**
9.	Explain the principle of operation of Log periodic antenna with neat schematic diagram. **(Nov/Dec 2016) (May 2019)**
10.	Discuss in detail how a spiral antenna behaves as a frequency independent antenna. (**May 2014)**
11.	(i) What is Log periodic antenna? Explain the principle of Log periodic antenna. **(ii)** Design a 50 – 200 MHz log – periodic antenna to obtain a gain corresponds to scale factor 0.8 and space factor 0.15**(Nov 2019)**
12.	Explain in detail the radiation from a slot antenna and their feed systems. **(Nov/Dec 2016)**
13.	(i) Explain the principle of parabolic reflector antenna and discuss on different types of feed used with neat diagram. (ii) The diameter of a parabolic reflector is 2m. For operation at 6GHz, find the beam width between first nulls and the gain. **(Nov 17)**
14.	Explain the principles of operation of Horn antenna and discuss the various forms of Horn antenna. Obtain the design equations of Horn antenna. **(May 18) (May 2019)**
15.	Explain the radiation mechanism of a microstrip antenna with suitable illustrations. With suitable figures explain the various feed techniques. **(May 18)**
16.	Explain the principle of operation and applications of loop antenna.
17.	i) Explain in detail about Loop antenna. Derive the expression for fields at Far region. **ii)** Explain how a Loop antenna is utilized for determining the direction of an incoming radio signal. **(Nov 2020)**
18.	i) With neat necessary diagrams, explain parabolic reflector antenna and its different types of feeding system. **ii)** Briefly explain about frequency independent planar Log spiral antenna. **(Nov 2020)**
19.	Discuss the parabola geometry that makes it suitable for antenna reflectors. Develop an antenna employing a parabolic reflector that is likely to be a highly directive receiving antenna**.(NOV/DEC 2021)**
20.	Illustrate the radiation characteristics of microstrip antenna with different types of feeding structures and mention its applications**.(NOV/DEC 2021)**

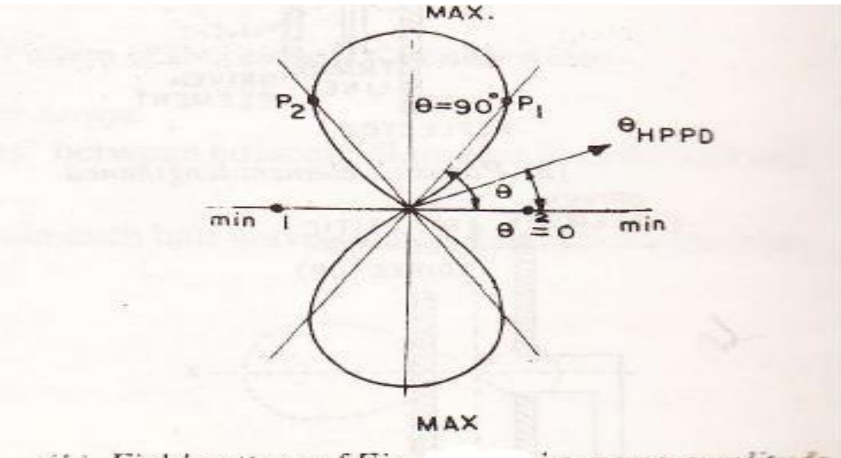
21.	Explain in detail about Loop antenna. Derive the expression for fields at Far region.**(NOV/DEC 2021)**

UNIT III ANTENNA ARRAYS AND APPLICATIONS

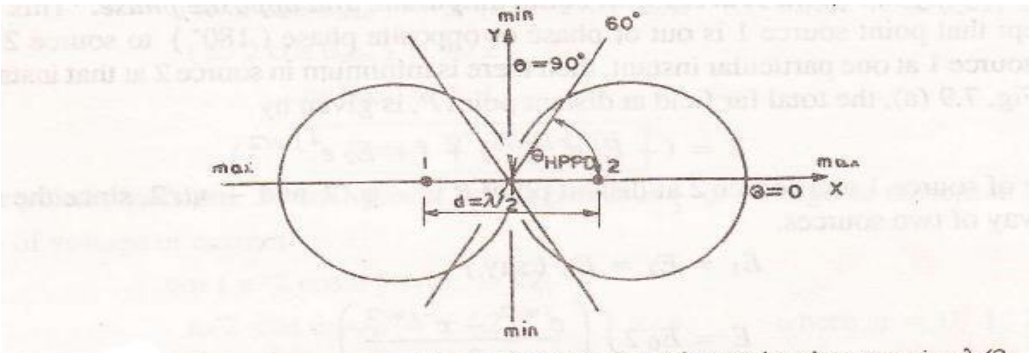
Two-element array, Array factor, Pattern multiplication, uniformly spaced arrays with uniform and non-uniform excitation amplitudes, Smart antennas.

UNIT-III / PART-A

1.	**What is an antenna array?** • **Antenna array is system** of a similar antennas oriented similarly to get greater directivity in a desired direction. • Antenna array is a radiating system consisting of several spaced and properly phased (current phase) radiators.
2.	**What is a Linear Array?** An antenna array is said to be linear if the individual antennas of the array are equally spaced along a straight line.
3.	**Define uniform linear array**. **Uniform linear array** is defined as the one in which the elements are fed with a current of equal amplitude (magnitude) with uniform progressive phase shift along the line. The individual antennas of the array are equally spaced along a straight line.
4.	**Why we go for non-uniform amplitude distribution?** We go for non- uniform amplitude distribution to reduce side lobe levels.
5.	**Distinguish between uniform and non-uniform arrays**. • Uniform linear array is one in which the elements are fed with a current of equal amplitude. • Non-uniform linear array is one in which the elements are fed with currents of un equal amplitude
6.	**What is uniform Array?** An array of identical elements all of identical magnitude and each with a progressive phase is referred to as a uniform array. In other words, Uniform Array is an Array in which the array elements are fed with a current of equal amplitude (magnitude) with uniform progressive phase shift along the line.
7.	**What are the factors that decide the radiation characteristics of array?** In an array of identical elements, there are at least five controls that can be used to shape the overall pattern of the antenna. These are: 1. the geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.) 2. the relative displacement between the elements 3. the excitation amplitude of the individual elements 4. the excitation phase of the individual elements 5. the relative pattern of the individual elements
8.	**Define Grating lobes** Lobes with maxima in other directions, in addition to the main maximum is referred to as Grating lobes.
9.	**What is end-fire array?** End-fire array is defined as an array in which the principal radiation direction is along the array axis. i.e., maximum radiation is along the axis of the array.
10.	**Give the condition to have only one end-fire maximum.** To have only one end-fire maximum and to avoid any grating lobes, the maximum spacing between the elements should be less than half the wave length. i.e, $d_{max} < \lambda/2$.

11.	**What is broad-side array?** Broadside array is defined as an array in which the principal radiation direction is perpendicular to the array axis.
12.	**A uniform linear array contains 50 isotropic radiators with an inter element spacing of $\lambda/2$. Find the directivity of broadside forms of arrays. (May 2013)** N=50 d= $\lambda/2$ Array length=N d= $l = 25\lambda$ Directivity of Broadside array = $2\left(\frac{l}{\lambda}\right)$=50
13.	**What is tapering of arrays? (May 2019)** The techniques used in reduction of side lobe level are called as tapering. It is found that minor lobes are reduced if the center source radiates more strongly than the end sources (non-uniform current distribution). Hence tapering is done from center to end according to some prescription.
14.	**What are the advantages of antenna arrays? (May 2014)** **The advantages of antenna arrays are**: (i) It offers high directivity. Also, the directivity can be varied by choosing a proper number of elements according to the need. (ii) The strength of the transmitted signal significantly increased. (iii) It offers beam steering electronically. Thus, the direction of the beam can be changed from one point to another. (iv) It provides a better signal to noise ratio. (v) With the application of non-uniform input to each element, the radiation pattern can be shaped according to the requirement. (vi) The design of the antenna array supports better antenna performance.
15.	**Draw the radiation pattern for a linear array of two isotropic elements spaced λ/2 apart and with equal current fed in phase. (April/May 2017) (May 2019)**  *(b). Field pattern of Fig. i.e. same amplitude and phase with d = λ/2.* Normalized total field of two element array of isotropic point sources of same amplitude and same phase that are $\lambda/2$ apart is $E_{nor} = \cos\left(\frac{\frac{2\pi}{\lambda}\times\frac{\lambda}{2}\cos\theta}{2}\right) = \cos\left(\frac{\pi}{2}\cos\theta\right)$

16. **Draw the radiation pattern of an isotropic point sources of same amplitude and opposite phase that are $\lambda/2$ apart along X-axis symmetric with respect to origin. (May 2016)**



Two point sources with equal amplitude and opposite phase spacing λ/2.

Normalized total field of two element array of isotropic point sources of same amplitude and opposite phase that are $\lambda/2$ apart is,

$$E_{nor} = \sin\left(\frac{\frac{2\pi}{\lambda}\times\frac{\lambda}{2}\cos\theta}{2}\right) = \sin\left(\frac{\pi}{2}\cos\theta\right)$$

17. **A uniform linear array of 4 isotropic elements with an inter element spacing of $\lambda/2$. Find the BWFN and directivity of end fire arrays.**

n=4 , d= $\lambda/2$

Array length= nd $= l = 2\lambda$

$$BWFN = 2\sqrt{\frac{2\lambda}{nd}} = 2$$

Directivity of end fire array $= 4\left(\frac{l}{\lambda}\right) = 8$

18. **How number of array elements effect directivity?**

As number of array element increases; the beam width will be lesser and this will result better directivity.

19. **What is the advantage of pattern multiplication?**

The advantage of pattern multiplication is it is a simple method for obtaining radiation pattern of arrays which makes it possible to sketch rapidly, the radiation pattern of complicated arrays without making lengthy calculations, almost by inspection.

20. **State the principle of pattern multiplication (Nov 20)**

The field pattern of an array of non-isotropic but similar sources is the product of the pattern of the individual source and the pattern of an array of isotropic point sources having the same locations, relative amplitudes, and phase as the non- isotropic sources.

The total field pattern of an array of non-isotropic but similar sources is the product of individual source pattern and the pattern of an array of isotropic point sources each located at the phase center of the individual source and having the same relative amplitude and phase, while the total phase pattern is the sum of the phase patterns of the individual source and the array of isotropic point sources.

$$E = f(\theta,\varphi)F(\theta,\varphi)\angle\left(f_p(\theta,\varphi) + F_p(\theta,\varphi)\right)$$

$f(\theta,\varphi)F(\theta,\varphi) = fieldpatternofarray$

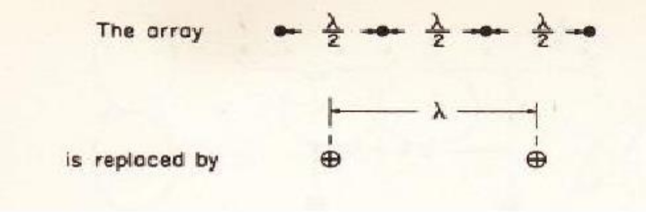
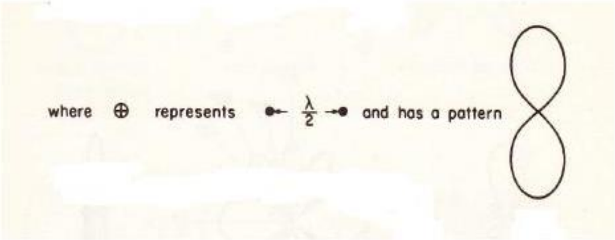
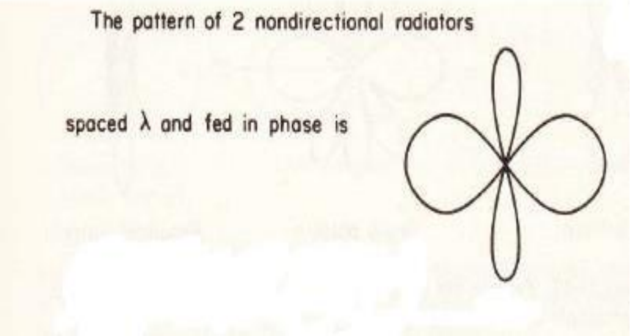
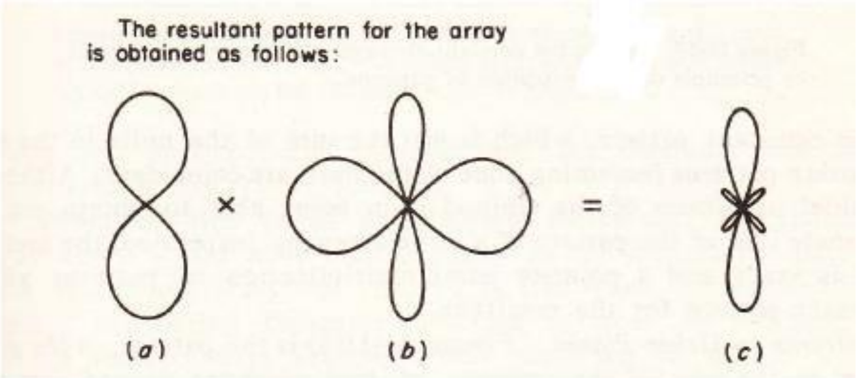
$\left(f_p(\theta,\varphi) + F_p(\theta,\varphi)\right) = phasepatternofarray$

$f(\theta,\varphi) = fieldpatternofindividualsource$

$f_p(\theta,\varphi) = phasepatternofindividualsource$

$F(\theta,\varphi) = fieldpatternofarrayofisotropicsources$

$F_p(\theta,\varphi) = phasepatternofarrayofisotropicsources$

21.	**Using pattern multiplication find the radiation pattern for the broadside array of 4 elements, spacing between each element is λ/2./ Illustrate the pattern multiplication principle.(NOV/DEC 2021)**    
22.	**What is the practical major disadvantage of Binomial array?** A major practical disadvantage of binomial arrays is the wide variations between the amplitudes of the different elements of an array, especially for an array with a large number of elements. This leads to very low efficiencies for the feed network, and it makes the method not very desirable in practice. For example, the relative amplitude coefficient of the end elements of a 10-element array is 1 while that of the center element is 126. Practically, it would be difficult to obtain and maintain such large amplitude variations among the elements. They would also lead to very inefficient antenna systems.

23.	**What is the main advantage of Binomial array?** Binomial arrays usually possess the smallest side lobes when compared to Dolph-Tschebyscheff and uniform arrays. Binomial arrays with element spacing equal or less than λ/2 have no side lobes. The main advantage of Binomial array is the absence or no side lobes in the radiation pattern of Binomial array when the element spacing is equal to or less than λ/2.
24.	**What is binomial array?** **Binomial array** is an array whose elements are excited according to the current distribution determined by the coefficients of Binomial series. Binomial series: $(1+x)^{m-1} = 1+(m-1)x+\frac{(m-1)(m-2)}{2!}x^2+\frac{(m-1)(m-2)(m-3)}{3!}x^3+............$ For example, For m =3 $(1+x)^{3-1} = 1+(3-1)x+\frac{(3-1)(3-2)}{2!}x^2+\frac{(3-1)(3-2)(3-3)}{3!}x^3+............$ $= 1+2x+x^2$ Current distribution for 3 element binomial array is 1:2:1
25.	**What are the advantages of Dolph-Tschebyscheff array?** **The advantages of Dolph-Tschebyscheff array are** • It provides a minimum beam width for a specified side lobe level. • It provides pattern which contains side lobes of equal level. • The amplitude distribution is not highly tapered and hence it is more practical.
26.	**What is Phased arrays ? (APR/MAY 18)** • In antenna theory, a **phased array** usually means an **electronically scanned array**; a computer-controlled array of antennas which creates a beam of radio waves which can be electronically steered to point in different directions, without moving the antennas. • In an array antenna, the radio frequency current from the transmitter is fed to the individual antennas with the correct phase relationship so that the radio waves from the separate antennas add together to increase the radiation in a desired direction, while cancelling to suppress radiation in undesired directions. • In a phased array, the power from the transmitter is fed to the antennas through devices called *phase shifters*, controlled by a computer system, which can alter the phase electronically, thus steering the beam of radio waves to a different direction.
27.	**Define adaptive array(smart antennas). /** **Illustrate the features of smart antennas.(NOV/DEC 2021)** • Adaptive arrays are antenna array that can steer the beam to any direction of interest while simultaneously nulling interfering signals. • **Smart antennas** (also known as adaptive array antennas, digital antenna arrays) are antenna arrays with smart signal processing algorithms used to identify spatial signal signatures such as the direction of arrival (DOA) of the signal, and use them to calculate beamforming vectors which are used to track and locate the antenna beam on the mobile/target. • Smart antenna techniques are used notably in acoustic signal processing, track and scan radar, radio astronomy and radio telescopes, and mostly in cellular systems like W-CDMA, UMTS, and LTE. • Smart antennas have many functions: DOA(Direction of Arrival) estimation, beamforming, interference nulling, and constant modulus preservation.
28.	**What is reconfigurable antenna ?(Nov 20)** • A reconfigurable antenna is an antenna capable of modifying its frequency and radiation properties dynamically, in a controlled and reversible manner. • **Reconfigurable** antennas can provide various functions in operating frequency, beam pattern, polarization, etc. The dynamic tuning can be achieved by manipulating a certain switching mechanism through controlling electronic, mechanical, physical or optical switches.

UNIT-III / PART-B	
1.	(i) Write a note on binomial array? (ii) Draw the pattern of 10 element binomial array with spacing between the elements of $3\lambda/4$ and $\lambda/2$.
2.	Derive the expressions for field pattern of broad side array of *n* point sources.**(May 2013)(Nov 2019)**
3.	Two identical radiators are spaced $d = 3\lambda/4$ meters apart and fed with currents of equal magnitude but with 180^0 phase difference. Evaluate the resultant radiation and identify the direction of maximum & minimum radiation. **(May 2015)**
4.	For a 2 element linear antenna array separated by a distance $d = 3\lambda/4$, derive the field quantities and draw its radiation pattern for the phase difference of 45^0. **(Dec 2012)**
5.	Derive the expressions for field pattern of end-fire array of *n* sources of equal amplitude and spacing. **(May 2012)**
6.	An antenna array consists of two identical isotropic radiators spaced by a distance of d= $\lambda/4$ meters and fed with currents of equal magnitude but with a phase difference β. Evaluate the resultant radiation for $\beta = 0^0$ and thereby identify the direction of maximum radiation. **(Dec 2011)**
7.	Describe a broadside array. Deduce an expression for the radiation pattern of a broadside array with two point sources.
8.	Plot the radiation pattern of a linear array of 4 isotropic elements spaced λ/2 apart and fed out of phase with equal currents.
9.	**(i)** Derive Array factor of an Uniform linear array of n sources. Explain the significance of array factor. **(Dec 2013)** **(ii)** Compare End fire and Broadside array. **(May 2014)**
10.	Explain in detail about: 1) adaptive arrays 2) Phased arrays**.(Nov 2019)**
11.	Obtain the expression for the field and the radiation pattern produced by a N element array of infinitesimal with distance of separation $\lambda/2$ and currents of unequal magnitude and phase shift 180 degree. **(May 2016)**
12.	(i) Using pattern multiplication determine the radiation pattern for 8 element array separated by the distance $\lambda/2$. **(ii)** Write short notes on tapered array and phased array. **(May 2016)**
13.	Develop a treatise on the following forms of arrays: **(Nov/Dec 2015)** (i)Linear array (ii)Two-element array (iii)Uniform array (iv)Binomial array
14.	Derive and draw the radiation pattern of 4 isotropic sources of equal amplitude and same phase. **(April/May 2017)**
15.	(i) Describe the principle of phased arrays and explain how it is used in beam forming. **(April/May 2017)(Nov/Dec 2016)** **(ii)** Write short notes on binomial arrays. **(April/May 2017)(Nov/Dec 2016)**
16.	Derive the expression for the array factor of a linear array of four isotropic element spaced λ/2 apart fed with signals of equal amplitude and phase. Obtain the directions of maxima and minima.**(Nov17)**
17.	(i) Explain in detail the Binomial array and derive the expression for the array factor. Also obtain the excitation coefficients of a seven element binomial array. **(ii)**What is phased array?**(Nov 17)**
18.	Derive the expression for the array factor of a linear array of four isotropic element spaced λ/2 apart fed with signals of equal amplitude and phase. Obtain the directions of maxima and minima. **(May 18)**

19.	Design a broadside Dolph-Tschebyscheff array of 10 elements with spacing'd' between the elements and with a major-to-minor lobe ratio of 26 dB. Find the excitation coefficients and form the array factor. **(May 18)**
20.	i) What is broad side array ? Deduce the expression for the Radiation pattern of a broadside array with n- vertical dipoles. **ii)** Design a 4 element broadside array of λ/2 spacing between elements.**(Nov 20)**
21.	i) What is non-uniform excitation amplitudes ? Draw the pattern of 10 elements binomial array with spacing's between the elements of λ/2. **ii)** Write short notes about Active antenna.**(Nov 20)**
22.	i) A broad casting station (500 to 1000 KHz band) requires a pattern in the horizontal plane fulfilling the conditions as given below. The max. field intensity with as little variation as possible, is to be radiated in the 90° sector between NE and WE. No nulls in the pattern can occur in this sector. The nulls must be present in the due east and due SW directions in order to prevent interference with other stations in these directions. **ii)** What is the need of smart antennas ? Briefly explain about Adaptive arrays.**(Nov 20)**
23.	Determine the field pattern of an array of n-elements characterized by in-phase sources. **(NOV/DEC 2021)**
24.	Describe in detail about smart antennas and its applications. **(NOV/DEC 2021)**
25.	A uniform linear array consists of 16 isotropic point sources with a spacing of λ/4. If the phase difference is -90° . Determine the directivity, HPBW, beam solid angle and effective apertures**.(NOV/DEC 2021)**

UNIT IV PASSIVE AND ACTIVE MICROWAVE DEVICES

Microwave Passive components: Directional Coupler, Power Divider, Magic Tee, attenuator, resonator, Principles of Microwave Semiconductor Devices: Gunn Diodes, IMPATT diodes Schottky Barrier diodes, PIN diodes, Microwave tubes: Klystron, TWT, Magnetron.

UNIT-IV / PART-A

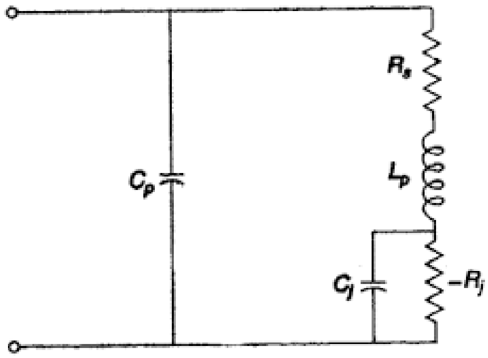
1.	**Define any two performance factors of directional couplers. List out the different types of directional couplers.** The two performance factors of DC are the Coupling Factor and Directivity. Coupling Factor defines the ratio of the amount of power coupled in coupled port to that of power at input port in decibels. Directivity is defined as the ratio of powers at the isolated port and the incident ports at decibels. **Types:** Bethe hole DC, 2 hole, crossed guide DC, coupled line couplers, branch line couplers, and Lange DC are the different types of directional couplers.
2.	**Name some uses of waveguide Tees. What are the two different types of waveguide Tees?** It is used to connect a branch or section of the waveguide in series or parallel with the main waveguide transmission line for providing means of splitting and also of combining power in a waveguide system. **Types:** (i) E-plane tee (series) and (ii) H-plane tee (shunt).
3.	**Write the application of magic Tee. (Nov 2012 & May 2017)** Measurement of impedance, (ii) As duplexer (iii) As mixer and (iv) As an isolator.
4.	**What is hybrid ring or Rat-Race junctions? (May 2013)** The hybrid ring is a four-port junction .The four ports are connected in the form of an angular ring at proper intervals by means of series (or parallel) junction. It also called Rat-race circuits. It is mainly used to combining two signals (or) dividing a single signal into two equal halves.
5.	**What is negative resistance in Gunn diode? (May 2014)(Nov 2019)** The carrier drift velocity is linearly increased from zero to a maximum when the electric field is varied from zero to a threshold value. When the electric field is beyond the threshold value of 3000v/cm, the drift velocity is decreased and the diode exhibits negative resistance. The diode in the negative resistance will act as a source.

6.	**A Directional coupler is having coupling factor of 20dB and directivity of 40dB. If the incident power is 900mW, what is the coupled power? (May 2013)** Coupling Factor (C) in dB = 10 log $_{10}$ (P_1/P_3) = 20 Power supplied to port 1 is coupled to port 3 (the ***coupled port***) P_1/P_3 = 100 ; P_1= 900 mW ; $P_3 = P_1 / 100$ = 9 mW Coupled power = 9 mW
7.	**What are the various materials used for Gunn diodes? What are the four different modes of operation of GUNN diode?** GaAs, InP, CdTe, InAs are materials used in Gunn diode. Gunn oscillation mode, stable amplification mode, LSA oscillation and bias current oscillation mode.
8.	**Mention the applications of IMPATT diode.** Microwave generators, Receiver local oscillators, parametric amplifier
9.	**What is Gunn Effect? (May 2013) (Nov 2014)** Above some critical voltage corresponding to an electric field of 2000-4000 v/cm the current in every specimen became a fluctuating function of time. The frequency of oscillation was determined mainly by the specimen and not by the external circuit. The length of the specimen is inversely proportional to the frequency of oscillation. Some of materials like GaAs, InP, CdTe exhibit a negative differential mobility when biased above a threshold value of the electric field.
10.	**Compare PIN and PN diode. (Nov 2016)**

S.No	PIN Diode	PN Diode
1.	A PIN diode is a diode with a wide, undoped intrinsic semiconductor region between a p-type & an n-type semiconductor region.	P-N junction diode is the most fundamental and the simplest electronics device.
2.	The p-type and n-type regions are typically heavily doped because they are used for ohmic contacts.	When one side of an intrinsic semiconductor is doped with acceptor i.e, one side is made p-type by doping with n-type material; a p-n junction diode is formed. This is a two terminal device.

11\. **Draw the equivalent circuit of a Gunn diode.**

The equivalent circuit of Gunn diode



C_j, R_j – Diode capacitance, Diode resistance
R_s- total resistance of lead ohmic contacts, bulk resistance
C_p, L_p – package capacitance and inductance

12.	**List out the different types of Magnetrons.** Negative Resistance magnetrons, Cyclotron frequency magnetron, Travelling wave magnetron
13.	**Explain Hull Cut-off condition.** Hull cut-off condition gives the cut-off magnetic field in a magnetron such that the electron grazes the anode and returns back to the cathode.
14.	**What is the purpose of slow wave structures in TWT? Name them. (May 2018)** Slow wave structures are used to reduce the phase velocity of the wave in certain direction so that the electron beam and signal wave can interact. Helical, Feedback line, Zig-Zag, Interdigital line, corrugated wave guide.

15. **List the advantages of Reflex klystron over multi-cavity klystrons.**
Reflex klystrons can be used as an oscillator without any complex feedback circuitry as required in multi-cavity klystrons. As it is a narrow bandwidth device it can be tuned to operate at a single desired frequency in resonant circuits.

16. **Explain the need for attenuators in TWT.**
Attenuators are used to attenuate the unwanted signal traveling towards the input end due to reflections arising from impedance mismatch.

17. **What is meant by velocity modulation? (May 2018)**
The change in the velocity of the electrons under the influence of an alternating field is termed as velocity modulation

18. **Define transit time in a Reflex klystron.**
The time taken by electron to travel into the repeller space and come back toward the cavity is called the transit time in Reflex klystron.

19. **Bring out the differences between the TWT & Klystron (May 2015 & 2017)**

TWT	Klystron
High BW More gain Use non-resonant structures Continuous interaction between electron beam and RF voltage	Narrow BW Less gain Use cavity resonators Discontinuous interaction between electron beam and RF voltage

20. **What do you meant by bunching?**
The electrons traveling with different velocities join together at their transit towards the output end. This collection of different velocity modulated electrons is called bunching

21. **Write the application of Reflex klystron**
Local oscillator in microwave receiver (ii) Microwave signal source (iii) pump oscillator for parametric amplifier (iv) as an oscillator, in frequency modulation of low power microwave link.

22. **What are the classifications of Microwave tubes and explain the difference between them.**

Linear beam tubes (O –type)	Cross field tubes (M- type)
In O-Type tube , a magnetic field whose axis coincides with the electron beam is used to hold the beam together as it travels the length of the tube Reflex Klystron, TWT are Linear beam tubes Low power device	In M-Type tube, electric field is in the radial direction & magnetic field is in the axial direction. Magnetron is M-type beam tubes Low power device

23. **Write the application of backward wave oscillator.**
(1) Signal source sources in instrument and transmitters.
(2) Broad band noise source
(3) Noise less oscillator with good bandwidth in frequency range 3-9 GHz.

24. **Define Electronic Admittance.**
It is defined by the ratio of induced bunch beam current and cavity gap voltage.

25. **What is drift space?**
The separation between buncher and catcher grids is called drift space.

26. **What is magnetron? (NOV 2016)**
Magnetron is an electron tube for amplifying or generating microwaves, with the flow of electrons controlled by an external magnetic field.

27. **What do you mean by O type tube? Name some O type tubes.**
In O-type tube a magnetic field whose axis coincides with the electron beam is used to hold the beam together as it travels the length of the tube. It's also called as linear beam tube. TYPES - Helix travelling wave tube and coupled cavity TWT.

28. **How to minimize the lead inductance and inter electrode capacitance. (NOV 2018)**
The lead inductance and inter electrode capacitance can be minimized by reducing the lead length and electrode area.

29. Distinguish between O-type and M-type tubes. (NOV 2018)

Sl.No.	O Type tubes	M Type tubes
1.	Linear beam tube	Crossed field tubes
2.	DC magnetic field is in parallel with dc electric field is used to focus the electrons beam.	DC magnetic field and dc electric field are perpendicular to each other
3.	Electron receive potential energy from the dc beam voltage before they arrive in the microwave interaction region and converted into kinetic energy	Dc magnetic field plays a direct role in the RF interaction process.
	Example: Klystron ,TWT	Magnetron

30. Give two examples for reciprocal microwave passive device.(Nov 20)

Passive power splitter, Attenuator

31. A Reflex Klystron is operated at 10 GHz with a dc beam voltage of 600 V for 1 3/4 mode, repeller space length of 1 mm and dc beam current of 12 mA. The beam coupling co-efficient is assumed to be 1. Calculate the repeller voltage.(Nov 20)

$$|V_R| = \left[6.74 \times 10^{-6} \times f \times \frac{L}{N} \times \sqrt{V_o}\right] - V_o$$

L=1mm; N= 1.75; V_o=600; f =10GHz

$$|V_R| = \left[6.74 \times 10^{-6} \times 10 \times 10^9 \times \frac{1\times10^{-3}}{1.75} \times \sqrt{600}\right] - 600 = -343.4V$$

32. A directional coupler is having coupling factor of 20 dB and directivity of 40 dB. If the incident power is 800 mW, what is the coupled power?(NOV/DEC 2021)

Coupling Factor (C) in dB = 10 $\log_{10}$ (P_1/P_3) = 20

Power supplied to port 1 is coupled to port 3 (the ***coupled port***)

P_1/P_3 = 100 ; P_1= 800 mW ; $P_3 = P_1 / 100$ = 8 mW

Coupled power = 8 mW

33. Specify the scattering matrix of a multi hole directional coupler.(NOV/DEC 2021)

1. Symmetric Coupler: $\boldsymbol{\theta = \phi = \pi/2}$,

$$[S] = \begin{bmatrix} 0 & \alpha & j\beta & 0 \\ \alpha & 0 & 0 & j\beta \\ j\beta & 0 & 0 & \alpha \\ 0 & j\beta & \alpha & 0 \end{bmatrix}$$

2. Antisymmetric Coupler: $\boldsymbol{\theta = 0, \phi = \pi}$,

$$[S] = \begin{bmatrix} 0 & \alpha & \beta & 0 \\ \alpha & 0 & 0 & -\beta \\ \beta & 0 & 0 & \alpha \\ 0 & -\beta & \alpha & 0 \end{bmatrix}$$

UNIT-IV / PART-B

1.	Explain how Directional coupler can be used to measure reflected power. Also Derive scattering Matrix for Two hole Directional coupler. **(Nov2012) (May 2013 & 2015) (Nov 2019)**
2.	Derive and explain the properties of H-plane tee and give reasons why it is called shunt Tee. **(Nov 2012) (May 2017)**
3.	Derive and explain the properties of E-plane tee and give reasons why it is called series Tee. **(Nov 2014) (Dec 2015) (May 2013) (May 2017)**
4.	**(i)** Derive the equation for scattering matrix of magic Tee.**(Nov 2013) (Nov 2017)** **(ii)** Find the directivity in db for a coupler if the same power is applied in turn to input and output of the coupler with output terminated in each case in matched impedance. The auxiliary output readings are 450mW and 0.710µW. **(May 2014)**
5.	Explain the working of Attenuators with neat diagram. **(May 2014)(Dec 2015)**
6.	Explain Physical structure, negative resistance, power output & efficiency of IMPATT Diode. **(Nov 2013) (May 2013) (Dec 2015) (May 2015)**

7.	Briefly Explain Gunn Effect & modes of operation of the Gunn Diode. Explain the working principle of Gunn diode with two valley model and plot its characteristics. **(Dec 2015) (May 2015) (Nov 2019)**
8.	Derive the S matrix for a directional coupler and also verifying the properties of it **(May 2018)**
9.	(i) Derive the S matrix H plane TEE. **(ii)** Explain the mode of oscillation of gunn diode. **(May 2018)**
10.	**(i)** Explain the construction of Magic Tee and derive its S-matrix.**(Nov 2019)** **(ii)** Derive the scattering matrix for a directional coupler. **(Nov 2018)**
11.	Describe the Gunn effect with the aid of two valley model theory
12.	Explain the working principle and operation of multi-cavity Klystron amplifier and derive the expression for its output power. **(Nov 2016)**
13.	Explain the working principle of Reflex klystron oscillator and derive output power & Efficiency. **(Nov 2013) (Dec 2015) (Nov 2017)**
14.	Explain the operation of TWT Amplifier & write its characteristics. **(Dec 2015) (Nov & May 2017)**
15.	Explain π mode of operation of Magnetron Oscillators mention few high frequency limitations. **(May 2015)**
16.	A Reflex klystron is to be operated at frequency of 10 GHz, with dc beam voltage 300V, repeller space 0.1 cm for $1\frac{3}{4}$ mode. Calculate P_{RFmax} and corresponding repeller voltage for a beam current of 20 mA.
17.	A Reflex klystron is to be operated at frequency of 9 GHz, with dc beam voltage 600V, repeller space 1 cm for $1\frac{3}{4}$ mode. Calculate electronic efficiency, output power and corresponding repeller voltage for a beam current of 10 mA. The beam coupling coefficient is assumed to be 1.
18.	A two-cavity klystron amplifier is tuned at 3 GHz. The drift space length is 2cm and beam current is 25mA. The catcher voltage is 0.3 times the beam voltage. It is assumed that the gap length of the cavity << the drift space so that the input and output voltages are in phase (β = 1). Compute (a) Power output and efficiency for N= $5\frac{1}{4}$ (b) Beam voltage, input voltage and output voltage for maximum power output of N= $5\frac{1}{4}$ mode.
19.	A two-cavity klystron amplifier operates at 5GHz with a dc beam voltage of 10KV and a 2 mm cavity gap. For a given input RF voltage, the magnitude of the gap voltage is 100 volts. Calculate the transit time at the cavity gap, the transit angle, and the velocity of the electrons leaving the gap.
20.	An X- band pulsed conventional magnetron has the following operating parameters: Anode Voltage Vo = 5.5 KV, Beam current is 4.5 mA, Operating frequency 9GHz, Resonator conductance 2×10^{-4} mho, Loaded conductance 2.5×10^{-4} mho, Vane capacitance is 2.5 PF, Duty cycle 0.002, Power loss is 18.5 KW. Compute 1) Angular resonant frequency, 2) Unloaded quality factor 3) loaded quality factor, 4) external quality factor 5) circuit efficiency 6) electronic efficiency
21.	A 250kw pulsed cylindrical magnetron has the following parameters. Anode voltage = 25Kv, peak anode current = 25 A, Magnetic field = 0.35Wb/m^2, Radius of the cathode = 4CM, Radius of the Anode = 8CM, Calculate efficiency of the magnetron, cyclotron angular frequency, Cutoff magnetic field. **(May 2013)**

22.	Write a detailed note on cylindrical magnetron **(Nov 2013) (Nov 2017)(Nov 2019)**
23.	A traveling wave tube (TWT) operates under the following parameters: Beam Voltage V_0=3Kv; Beam Current I_0=30ma; Characteristics impedance of helix =Z_0=10Ω; Circuit length =N=50m; Frequency f=10GHz. Determine: (i) gain parameters C (ii) Output power gain A_p in decibels. (iii) All four propagation constants. **(Nov 2016)**
24.	With neat diagram explain the operation of two cavity Klystron amplifier and derive the equations for velocity modulation process. **(May 2017)(Nov 2019)**
25.	(i) Draw a neat sketch showing the constructional features of a cavity magnetron and explain why magnetron is called as crossed field device. **(ii)** Derive an expression for cut off magnetic field for a cylindrical magnetron. **(Nov 2019)**
26.	A reflex klystron is operated at 8 GHz with dc beam voltage of 600 V for 1.75 mode, repeller space length of 1mm, and dc beam current of 9 mA. The beam coupling coefficient assumed to be 1. Calculate the repeller voltage, electronic efficiency and output power. V_o =600 V, L= 1mm,I_O =9mA B_0 = 1, f=8 GHz, n =2 or $1^{3/4}$ mode. **(May 2018)**
27.	(i) Draw the schematic of two cavity Klystron amplifier and explain the process of velocity modulation and bunching .Also derive the equation of velocity modulation. **(ii)** With neat diagram, explain how amplification of RF wave is accomplished in Helix type TWT. **(Nov 2018)**
28.	(i)Draw the cross sectional view of Magnetron tube and explain the process of bunching. Derive the expression for Hull cut off voltage. (ii) Compare TWT and Klystron**(Nov 2018)**
29.	A two cavity Klystron amplifier has the following specifications. Beam Voltage V_o= 900V;Beam current I_o=30mA;Frequency f= 8 GHz. Gap spacing in either cavity d= 1mm ;Spacing between center of cavities L= 4cm Effective shunt impedance R_{th} = 49kΩ. Determine (i)Electron velocity(ii) Dc transit time of electron (iii)Maximum input voltage (iv)Voltage gain**(Nov 2018)**
30.	Write short notes on the following Microwave passive devices along with S parameters. i) Directional Couplers. ii) Attenuator. **(Nov 20)**
31.	i) With the help of two valley theory, explain how negative resistance is created in Gunn diodes. **ii)** Describe the construction and operation of a basic magnetron. **(Nov 20)**
32.	i) Describe with neat sketch the construction details and principle of operation of Klystron amplifier and derive the expression for its optimum bunching distance Lopt. **(Nov 20)**
33.	Discuss the working principle of Gunn diode as a transferred electron device with two valley model. Also draw the structure, equivalent circuit and V-I characteristics of Gunn diode**.(NOV/DEC 2021)**
34.	Illustrate the operation and properties of power divider; also derive the S-parameters**.(NOV 2021)**

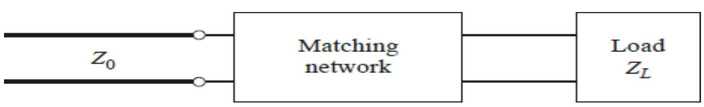
UNIT V MICROWAVE DESIGN PRINCIPLES

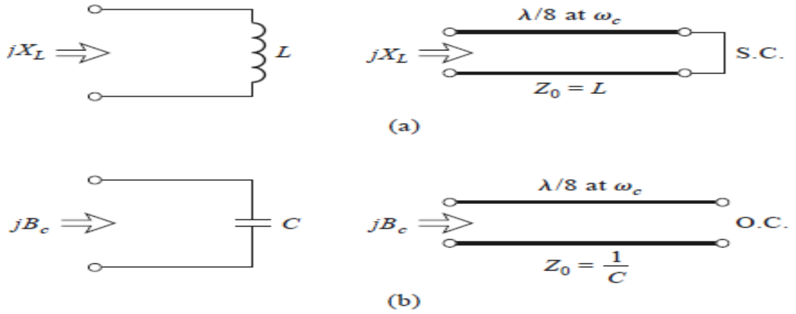
Impedance transformation, Impedance Matching, Microwave Filter Design, RF and Microwave Amplifier Design, Microwave Power amplifier Design, Low Noise Amplifier Design, Microwave Mixer Design, Microwave Oscillator Design

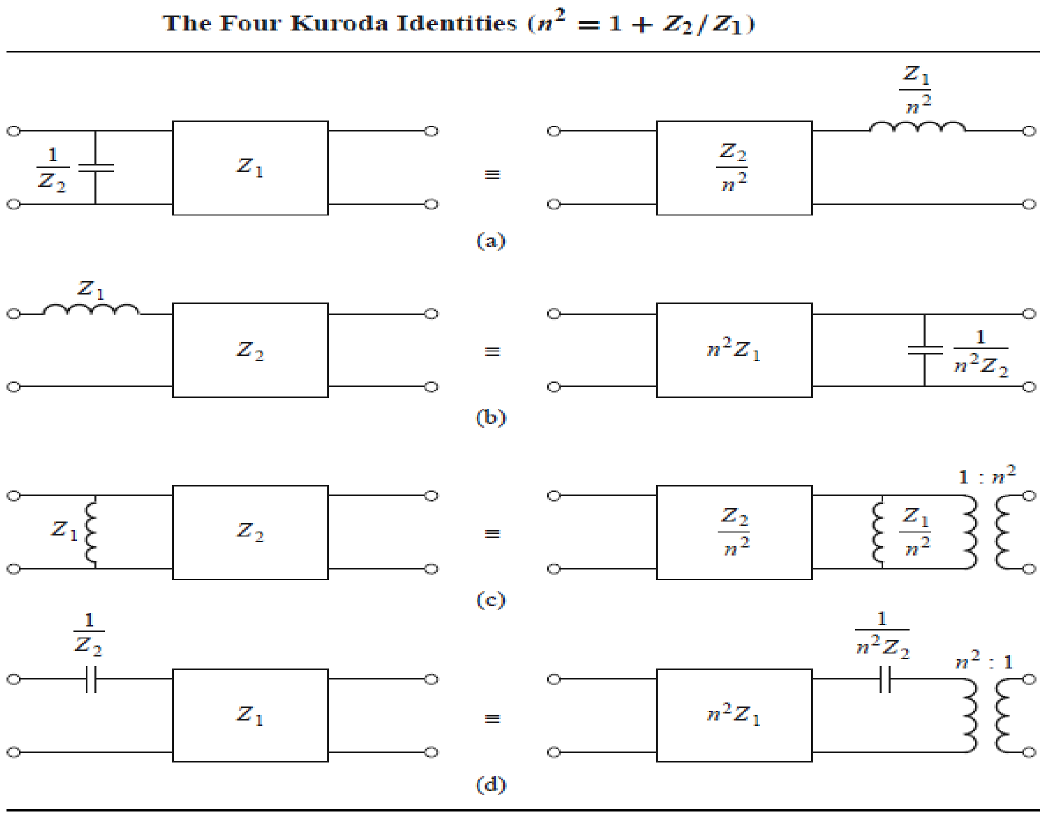
UNIT-V / PART-A

1. **What do you mean by impedance matching? (May 2018)**

The basic idea of impedance matching is illustrated in the following figure, which shows an impedance matching network placed between a load impedance and a transmission line. The matching network is ideally lossless, to avoid unnecessary loss of power, and is usually designed so that the impedance seen looking into the matching network is Z_0. Then reflections will be eliminated on the transmission line to the left of the matching network, although there will usually be multiple reflections between the matching network and the load. This procedure is sometimes referred to as tuning.

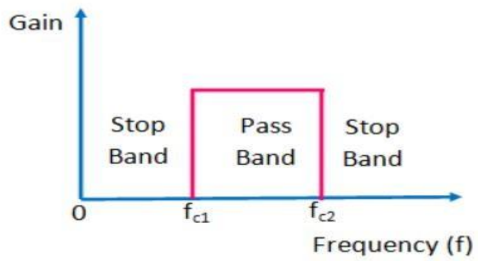
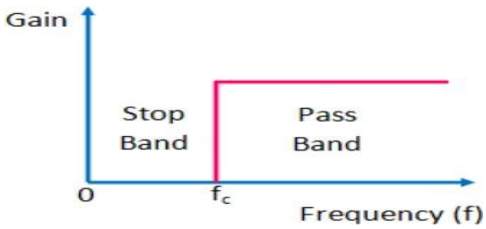


2.	**Why impedance matching is significant in a microwave system? (May 2015)** ▪ Maximum power is delivered when the load is matched to the line (assuming the generator is matched), and power loss in the feed line is minimized. ▪ Impedance matching sensitive receiver components (antenna, low-noise amplifier, etc.) may improve the signal-to-noise ratio of the system. ▪ Impedance matching in a power distribution network (such as an antenna array feed network) may reduce amplitude and phase errors.
3.	**List out the factors that may be important in the selection of a particular matching network? (Nov 2019)** Complexity, Bandwidth, Implementation and Adjustability
4.	**Define a filter.** A filter is a two-port network used to control the frequency response at a certain point in an RF or microwave system by providing transmission at frequencies within the passband of the filter and attenuation in the stopband of the filter. Typical frequency responses include low-pass, high-pass, bandpass, and band-reject characteristics. Applications can be found in virtually any type of RF or microwave communication, radar, or test and measurement system.
5.	**Write about microwave filter implementation.** The lumped-element filter designs generally work well at low frequencies, but two problems arise at higher RF and microwave frequencies. First, lumped-element inductors and capacitors are generally available only for a limited range of values, and can be difficult to implement at microwave frequencies. Distributed elements, such as open-circuited or short-circuited transmission line stubs, are often used to approximate ideal lumped elements. In addition, at microwave frequencies the distances between filter components is not negligible. The first problem is treated with Richards' transformation, which can be used to convert lumped elements to transmission line sections. Kuroda's identities can then be used to physically separate filter elements by using transmission line sections. Because such additional transmission line sections do not affect the filter response, this type of design is called redundant filter synthesis. It is possible to design microwave filters that take advantage of these sections to improve the filter response; such nonredundant synthesis does not have a lumped-element counterpart.
6.	**State the principle behind Richards' transformation.** Richards' transformation allows the inductors and capacitors of a lumped-element filter to be replaced with short-circuited and open-circuited transmission line stubs, as illustrated in following figure. Since the electrical lengths of all the stubs are the same ($\lambda/8$ at ω_c), these lines are called commensurate lines.
7.	**What is the role of Kuroda's Identities in filter implementation?** The four Kuroda identities use redundant transmission line sections to achieve a more practical microwave filter implementation by performing any of the following operations: • Physically separate transmission line stubs • Transform series stubs into shunt stubs, or vice versa • Change impractical characteristic impedances into more realizable values
8.	**Sketch Richard's transformation**  Richards' transformation. (a) For an inductor to a short-circuited stub. (b) For a capacitor to an open-circuited stub.

9.	**Sketch the four Kuroda Identities.** 
10.	**Mention the significance of Microwave transistor amplifiers.** Most RF and microwave amplifiers today use transistor devices such as Si BJTs, GaAs or SiGe HBTs, Si MOSFETs, GaAs MESFETs, or GaAs or GaN HEMTs. Microwave transistor amplifiers are rugged, low-cost, and reliable and can be easily integrated in both hybrid and monolithic integrated circuitry. Transistor amplifiers can be used at frequencies in excess of 100 GHz in a wide range of applications requiring small size, low noise figure, broad bandwidth, and medium to high power capacity. Although microwave tubes are still useful for very high power and/or very high frequency applications, continuing improvement in the performance of microwave transistors is steadily reducing the need for microwave tubes.
11.	**List out the usual microwave amplifier design goals.** i. Maximum power gain. ii. Minimum noise figure for the first stage. iii. Stable gain, i.e., no oscillations. iv. Input and Output VSWR as close to unity as possible. v. Adequate gain and uniformity of gain over a specified frequency band. vi. Phase response that is a linear function of ω (no distortion, only group delay). vii. Insensitivity to nominal changes or variations in the device S_{ij} parameters.
12.	**Define Power gain.** *Power gain* = $G = P_L/P_{in}$ is the ratio of power dissipated in the load Z_L to the power delivered to the input of the two-port network. This gain is independent of Z_S, although the characteristics of some active devices may be dependent on Z_S.
13.	**Define Available power gain. (Dec 2015) (Nov 20)** *Available power gain* = $G_A = P_{avn}/P_{avs}$ is the ratio of the power available from the two-port network to the power available from the source. This assumes conjugate matching of both the source and the load, and depends on Z_S, but not Z_L.
14.	**Define Transducer power gain. (Nov 2013 & May 2017)/** **Define transducer power gain of amplifier.(NOV/DEC 2021)** *Transducer power gain* = $G_T = P_L/P_{avs}$ is the ratio of the power delivered to the load to the power available from the source. This depends on both Z_S and Z_L.

15.	**State the conditions that are necessary and sufficient for unconditional stability.(May 2019)** In K-Δ test, it can be shown that a device will be unconditionally stable if Rollet's condition, defined as $K = \frac{1 - \|S_{11}\|^2 - \|S_{22}\|^2 + \|\Delta\|^2}{2\|S_{12}S_{21}\|} > 1$ along with the auxiliary condition that $\|\Delta\| = \|S_{11}S_{22} - S_{12}S_{21}\| < 1$ are simultaneously satisfied.
16.	**What is the idea behind LNA design?** Besides stability and gain, another important design consideration for a microwave amplifier is its noise figure. In receiver applications especially it is often required to have a preamplifier with as low a noise figure as possible since the first stage of a receiver front end has the dominant effect on the noise performance of the overall system. Generally, it is not possible to obtain both minimum noise figure and maximum gain for an amplifier, so some sort of compromise must be made. This can be done by using constant-gain circles and circles of constant noise figure to select a usable trade-off between noise figure and gain.
17.	**Define noise figure. (Nov 20)** Noise figure of the component is a measure of the degradation in the signal-to-noise ratio between the input and output of the component. The signal-to-noise ratio is the ratio of desired signal power to undesired noise power, and so is dependent on the signal power. When noise and a desired signal are applied to the input of a noiseless network, both noise and signal will be attenuated or amplified by the same factor, so that the signal-to-noise ratio will be unchanged. However, if the network is noisy, the output noise power will be increased more than the output signal power, so that the output signal-to-noise ratio will be reduced. The noise figure, F, is a measure of this reduction in signal-to-noise ratio, and is defined as $F = \frac{signal - to - noise\ ratio\ at\ input}{signal - to - noise\ ratio\ at\ output} = \frac{S_i/N_i}{S_0/N_o} \geq 1$ where S_i , N_i are the input signal and noise powers, and S_o, N_o are the output signal and noise powers.
18.	**Give the noise figure expression for a cascaded system.** $F_{cas} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots$
19.	**What is role of power amplifiers in transmitters?** Power amplifiers are used in the final stages of radar and radio transmitters to increase the radiated power level. Typical output powers may be on the order of 100–500 mW for mobile voice or data communications systems, or in the range of 1–100 W for radar or fixed-point radio systems.
20.	**List out the types and characteristics of power amplifiers.** ▪ Class A amplifiers are inherently linear circuits, where the transistor is biased to conduct over the entire range of the input signal cycle. Because of this, class A amplifiers have a theoretical maximum efficiency of 50%. Most small-signal and low-noise amplifiers operate as class A circuits. ▪ In contrast, the transistor in a class B amplifier is biased to conduct only during one-half of the input signal cycle. Usually two complementary transistors are operated in a class B push-pull amplifier to provide amplification over the entire cycle. The theoretical efficiency of a class B amplifier is 78%. ▪ Class C amplifiers are operated with the transistor near cutoff for more than half of the input signal cycle, and generally use a resonant circuit in the output stage to recover the fundamental. Class C amplifiers can achieve efficiencies near 100% but can only be used with constant envelope modulations. ▪ Higher classes, such as class D, E, F, and S, use the transistor as a switch to pump a highly resonant tank circuit, and may achieve very high efficiencies

21.	**Define a mixer.** A mixer is a three-port device that uses a nonlinear or time-varying element to achieve frequency conversion. An ideal mixer produces an output consisting of the sum and difference frequencies of its two input signals. Operation of practical RF and microwave mixers is usually based on the nonlinearity provided by either a diode or a transistor. As we have seen, a nonlinear component can generate a wide variety of harmonics and other products of input frequencies, so filtering must be used to select the desired frequency components.
22.	**The IS-54 digital cellular telephone system uses a receive frequency band of 869– 894 MHz, with a first IF frequency of 87 MHz and a channel bandwidth of 30 kHz. What are the two possible ranges for the LO frequency? If the upper LO frequency range is used, determine the image frequency range. Does the image frequency fall within the receive passband?** The two possible LO frequency ranges are $f_{LO} = f_{RF} \pm f_{IF} = (869 \text{ to } 894) \pm 87$ =956 to 981 MHz and 782 to 807 MHz Using the 956–981 MHz LO, we find that the IF frequency is $f_{IF} = f_{RF} - f_{LO} = (869 \text{ to } 894) - (956 \text{ to } 981) = -87$ MHz, The RF image frequency range is $f_{IM} = f_{LO} - f_{IF} = (956 \text{ to } 981) + 87 = 1043 \text{ to } 1068$ MHz, which is well outside the receive passband
23.	**Define conversion loss in a mixer.** Conversion Loss (CL) of a mixer is generally defined in dB as the ratio of supplied input power P_{RF} over the obtained IF power P_{IF}. When dealing with BJTs and FETs, it is preferable to specify a conversion gain (CG) defined as the inverse of the power ratio. $$\text{CL} = 10\log\left(\frac{P_{RF}}{P_{IF}}\right)$$
24.	**How are oscillators designed for microwave frequencies?** A solid-state oscillator uses an active nonlinear device, such as a diode or transistor, in conjunction with a passive circuit to convert DC to a sinusoidal steady-state RF signal. Basic transistor oscillator circuits can generally be used at low frequencies, often with crystal resonators to provide improved frequency stability and low noise performance. At higher frequencies, diodes or transistors biased to a negative resistance operating point can be used with cavity, transmission line, or dielectric resonators to produce fundamental frequency oscillations up to 100 GHz. Alternatively, frequency multipliers, in conjunction with a lower frequency source, can be used to produce power at millimeter wave frequencies.
25.	**Compare and contrast diode-based and transistor-based oscillators.** Transistor oscillators generally have lower frequency and power capabilities than diode sources (e.g., tunnel, Gunn, or IMPATT diodes), but offer several advantages over diodes. First, oscillators using transistors are readily compatible with monolithic integrated circuitry, allowing easy integration with transistor amplifiers and mixers, while diode devices are often less compatible. In addition, a transistor oscillator circuit is much more flexible than a diode source. This is because the negative resistance oscillation mechanism of a diode is determined and limited by the physical characteristics of the device itself, while the operating characteristics of a transistor can be adjusted to a greater degree by the bias point, as well as the source or load impedances presented to the device. Transistor oscillators usually allow more control of the frequency of oscillation, temperature stability, and output noise than do diode sources. Transistor oscillator circuits also lend themselves well to frequency tuning, phase or injection locking, and various modulation requirements. Transistor sources are relatively efficient but usually are not capable of very high-power outputs.

26.	**Why is it necessary to go for microstrip line matching networks? (Nov 2018)** Design of matching networks involves discrete components. However, with increasing frequency and correspondingly reduced wavelength, the influence of parasitics in the discrete elements become more noticeable. The design now requires us to take these parasitics into account, thus significantly complicating the component values computation. This, along with the fact that discrete components are only available for certain values, limits their use in high frequency circuit applications. As an alternative to lumped elements, distributed components are widely used when the wavelength becomes sufficiently small compared with the characteristic circuit component length.
27.	**Sketch the frequency response characteristics of ideal Band pass filter and ideal High pass filter.(NOV/DEC 2021)** An ideal band pass filter transmits all the signals of frequencies within a certain frequency band (fc2−fc1) without any distortion and completely blocks all the signals of frequencies outside this frequency band. The frequency band (f2−f1) is called the pass band of the band-pass filter.  An ideal high pass filter transmits all the signals of frequencies above fc without any distortion and completely blocks all the signals of frequencies ranging from dc to fc . 

UNIT-V / PART-B

1.	What is a matching network? Why is this required? Briefly explain T &π matching networks. **(Nov 2012& 2013)**
2.	Explain in detail about Microstrip line matching network with neat diagram. **(May 2017)**
3.	Discuss the smith chart approach to design the L section and T section matching networks
4.	i)Explain the significance of impedance matching and tuning. **ii)** What are the design issues in T and Pi matching network and explain. **(Nov 2019)**
5.	Design an L-section matching network to match a series RC load with an impedance Z_L= (200-j100) Ω to 100Ω line at frequency of 500 MHz. (use smith chart).
6.	Design a matching network to match a Z_L= (10+j10) Ω to 50Ω line. Specify the values of L and C at frequency of 1GHz. (use smith chart). **(May 2014)**
7.	Using smith chart design any two possible configurations of discrete two element matching networks to match the source impedance Z_s= (50+j25) Ω to the load Z_L = (25-j50) Ω. Assume Z_o= 50Ω, f=2GHz. **(May 2015)**
8.	Design a T-type matching network that transforms a load impedance $Z_L = 60 - j30\Omega$ into a $Z_{in} = 10 + j20\Omega$ input impedance and that has a maximum nodal quality factor of 3. Compute the values for the matching network components, assuming that matching is required at $f = 1$GHz.

9.	Discuss in detail the steps involved in microwave filter design.
10.	**(i)** Write mathematical analysis of amplifier stability **(Nov/Dec 2018, April/May 2019)** **(ii)** A microwave amplifier is characterized by its S parameters. Derive equations for power gain, available gain and transducer gain. **(May 2018) (May 2019) (Nov 2019)**
11.	An RF Amplifier has the following S-parameters: $S_{11} = 0.3\angle{-70^0}$, $S_{12} = 0.2\angle{-10^0}$, $S_{21} = 3.5\angle{85^0}$ *and* $S_{22} = 0.4\angle{-45^0}$. Furthermore, the input side of the amplifier is connected to a voltage source with $V_S = 5V\angle{0^0}$ and source impedance $Z_S = 40\Omega$. The output is utilized to drive an antenna which has an impedance of $Z_L = 73\Omega$. Assuming that the S-parameters of the amplifier are measured with reference to a $Z_0 = 50\Omega$ characteristic impedance, find the following quantities: (a) Transducer gain G_T, Unilateral transducer gain G_{TU}, available gain G_A, operating power gain G and (b) Power delivered to the load P_L, available power P_A and incident power to the amplifier P_{inc}. **(Nov 2017) (Nov 2019)**
12.	Investigate the stability regions of a transistor whose S-parameters are recorded as follows: S_{12}=0.2 ∟-10˚;S_{11}=0.7∟ -70 ˚;S_{21}=5.5 ∟85 ˚;S_{22}=0.7∟ -45 ˚; at 750 MHz. **(Nov 2016)**
13.	Explain in detail noise figure in an amplifier.
14.	Discuss in brief steps involved in the design of Low Noise Amplifiers.
15.	Elaborate on Microwave Power amplifiers and their efficiencies.
16.	Explain in detail the types of mixers in microwave circuits.
17.	Write a detailed note on microwave oscillator design.
18.	i) Write the mathematical analysis of amplifier stability. **ii)** Design a microwave amplifier for maximum transducer power gain. **(Nov 20)**
19.	Discuss various aspects of amplifier power relation for RF transistor amplifier design. **(NOV/DEC 2021)**
20.	Explain the various stabilization methods and stability considerations for RF transistor amplifier design.**(NOV/DEC 2021)**