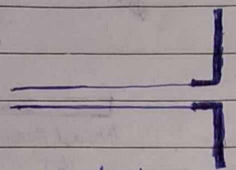
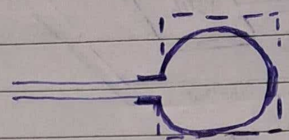
Insem 2

Ans3:- (a) Types of antennas:-

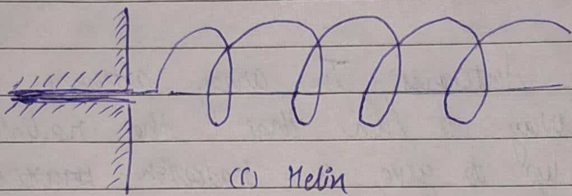
① **Wire Antennas:-** Wire Antennas are used on automobiles, buildings, ships, aircraft, spacecraft, etc. They are of various shapes such as straight wire (dipole), loop and helix. Loop antennas can take form other than circular also like rectangle, square, ellipse, etc. (Circular loop most common because of simplicity in construction.)



(a) dipole



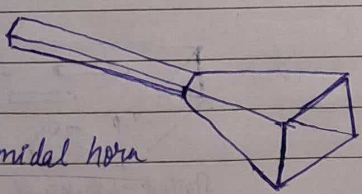
(b) Circular (Square) loop



(c) Helix

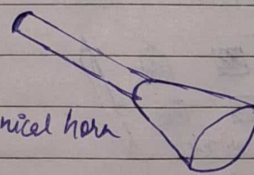
② **Aperture Antennas:-** Aperture Antennas are very useful for aircraft and spacecraft applications, bcoz they can be very conveniently flush-mounted on the skin of the aircraft or spacecraft. Also, they can be covered with a dielectric material to protect them from hazardous conditions of the environment.

(a)



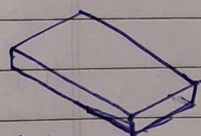
Pyramidal horn

(b)



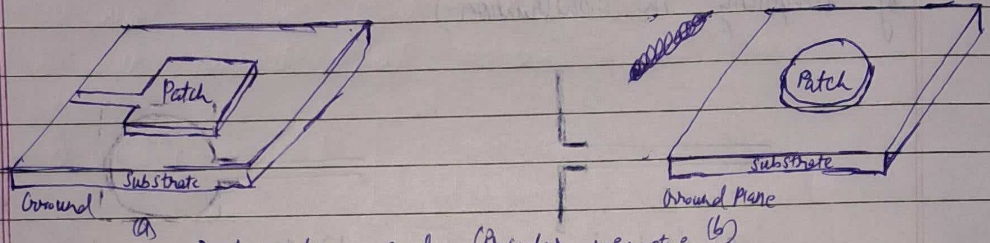
Conical horn

(C)



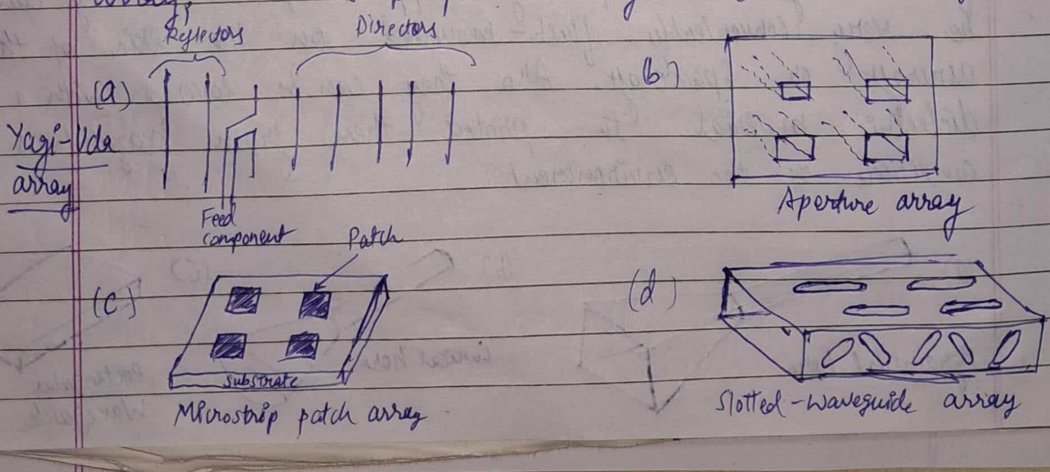
Rectangular Waveguide

(3) Microstrip Antennas:- They are used for spaceborne applications, government and commercial applications. It consist of a metallic patch on a grounded substrate. They are low-profile, comformable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology and very versatile in terms of resonant frequency and polarization. They can be mounted on the surface of high performance aircraft, space craft, satellites, missiles, etc.

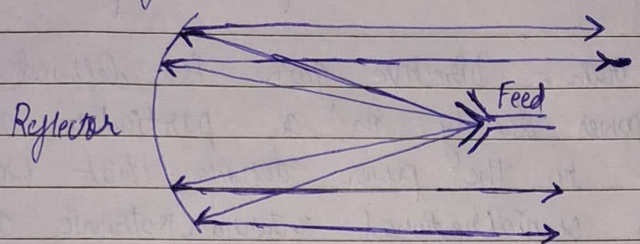


Rectangular and Circular microstrip (patch) antennas.

(4) Array Antennas:- In array antennas, the arrangement of the array is such that the radiation from the elements adds up to give a radiation ~~maxim~~ maximum in a particular direction, minimum in others or as desired. Examples of array ~~antennas~~ are:- Yagi-Uda array, Aperture array, microstrip patch array and slotted-waveguide array.

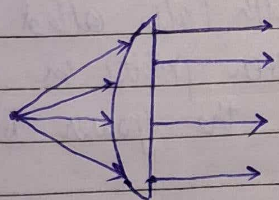


(5) <u>Reflector Antennas</u>:- Reflector antennas are needed for communicating over great distances and to transmit and receive signals that had to travel millions of miles. They generally have diameter as large as 305m. Large diameter required to achieve high gain.
Ex:- Parabolic Reflector.

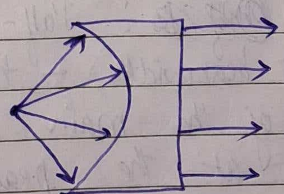


Parabolic ~~ref~~ reflector with front feed.

(6) <u>Lens Antennas</u>:- Lens are primarily used to collimate incident divergent energy to prevent ~~it~~ it from spreading in undesired directions. By properly shaping the geometrical configuration and material, they can transform various forms of divergent energy into plane waves. They are mostly used at higher frequencies.



<u>Convex-plane</u>



<u>Concave-plane</u>

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(b) • Radiation Pattern:- An antenna radiation pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, it is determined in the far-field region and represented as a function of the directional coordinates.

• Directive Gain:- Directive gain is defined as the ratio of the power density in a particular direction of one antenna to the power density that would be radiated by an omnidirectional antenna (isotropic antenna).

$$D(dBi) = 10 \log \left[\frac{\text{(power density in the direction of maximum radiation)}}{\text{(power density due to isotropic antenna or isotropic radiator)}} \right]$$

• $$D(dBd) = 10 \log \left[\frac{\text{(power density in the direction of maximum radiation)}}{\text{(power density due to half-wave dipole)}} \right]$$

$$D(dBi) = D(dBd) + 2.15\ dB$$

• HPBW :- Half-Power BeamWidth (also called 3db or -3dB beamwidth) — the angle between points on either side of the main lobe where the power is half that at the peak.

• FNBW:- First Null BeamWidth - angle between the first nulls in the pattern on either side of the main lobe.

• Bandwidth:- The term bandwidth refers to the range of frequencies the antenna will radiate effectively. When the antenna power drops to ½ (3 dB), the upper and lower extremities of these frequencies have been reached and antenna no longer performs satisfactorily.

- Polarization:- Polarization of an antenna refers to the direction in space of the E-field (electric vector) portion of the electromagnetic wave being radiated by the transmitting system.

Q4 (a) 3 field regions of an antenna are:-

(i) 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 exist at a $R < 0.62\sqrt{D^3/\lambda}$ from antenna surface, where λ is wavelength and D is the largest dimension of the antenna. (For a very short dipole outer boundary exist at $\frac{\lambda}{2\pi}$ from the antenna surface.)

$(D > \lambda)$

(ii) 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. Inner boundary taken as $R \geq 0.62\sqrt{D^3/\lambda}$ and outer boundary as $R < 2D^2/\lambda$.

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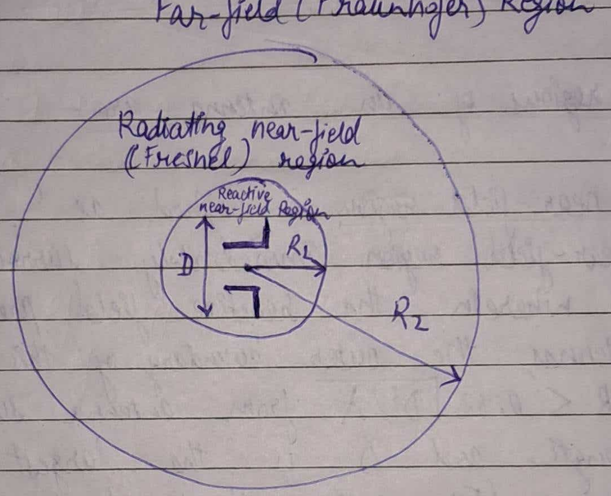
(iii) Far-field (Fraunhofer) region is defined as "that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna. The far-field region commonly exist at distance greater than $\frac{2D^2}{\lambda}$ from the antenna.

~~the antenna.~~



Field regions of an antenna

$$R_1 = 0.62\sqrt{D^3/\lambda}$$

$$R_2 = \frac{2D^2}{\lambda}$$

P.T.O

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(b) • <u>Omni directional Antenna</u>:- It is defined as one 'having an essentially non directional pattern in a given plane and a directional pattern in any orthogonal plane. It is a special type of a directional pattern.

• <u>Isotropic Antenna</u>:- It is defined as "a hypothetical lossless antenna having equal radiation in all directions." It is taken as reference for expressing the directive properties of actual antennas.

• <u>Directive Antenna</u>:- It is defined as one "having the property of radiating or receiving electromagnetic waves more effectively in some directions than in others." Antenna whose maximum directivity is significantly greater than that of a half-wave dipole.

• <u>E-plane pattern of antenna</u>:- The radiation pattern of an antenna in the plane containing the electric-field vector and the direction of maximum radiation.

• <u>H-plane pattern of antenna</u>:- The radiation pattern of an antenna in the plane containing the magnetic field vector and the direction of maximum radiation.

<u>P.T.O</u>

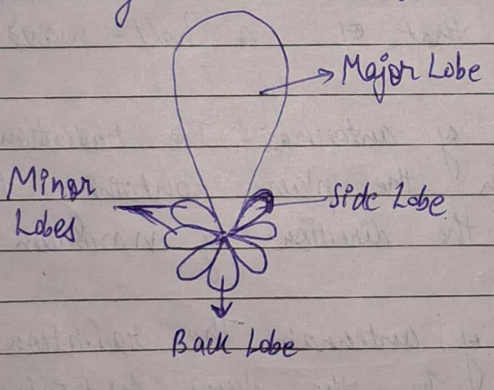
(C) • <u>Radiation Lobe</u>:- A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation ~~intent~~ intensity.

• <u>Major lobe (Main beam)</u>:- It is defined as the radiation lobe containing the direction of maximum radiation.

• <u>Minor lobe</u>:- All the lobes with the exception of the major lobe are classified as minor lobes.

• <u>Side Lobe</u>:- It is 'a radiation lobe in any direction other than the intended lobe.'

• <u>Back Lobe</u>:- It is 'a radiation lobe whose axis makes an angle of approximately 180° with respect to the beam of an antenna.'



Endsem

Q1 (a) For reactive near-field region:-

$kr << 1$ $\left(k = \frac{2\pi}{\lambda}\right)$

(b) For radiating near field:-

$kr > 1$

(c) For Far-Field:-

$kr >> 1$

(b) Range of 3-dB beamwidths as length varies from infinitesimal to one wavelength:-

$l << \lambda$	3-dB beamwidth = 90°
$l = \lambda/4$	〃 = 87°
$l = \lambda/2$	〃 = 78°
$l = 3\lambda/4$	〃 = 64°
$l = \lambda$	〃 = 47.8°

(C) • Resonant Antennas:- When the voltage and current distribution form standing wave patterns, then such types of antennas are called standing wave antennas or resonant antennas. They have travelling waves propagating in forward and backward directions.

• Non-Resonant Antennas:- Non-Resonant Antennas or travelling wave antennas are configurations of antennas where voltage and current can be represented as one or two travelling waves moving in the same-direction. So also known as unidirectional travelling wave antennas.

→ The difference b/w the radiation patterns of resonant and non-resonant wire antennas is that radiation pattern of non-resonant antenna is unidirectional where as radiation pattern of resonant antenna is bidirectional.

- For infinitesimal antenna:-

  dBi gains = 1.76 dB

- For half-wave dipole:-

  In resonant antennas dBi gains = 2.15 dB
  In non-resonant antennas " = 5.05 dB

- For eight-wave dipole:-

  In resonant antennas dBi gains = 8.51 dB
  In non- " = 12.4 dB

(d)

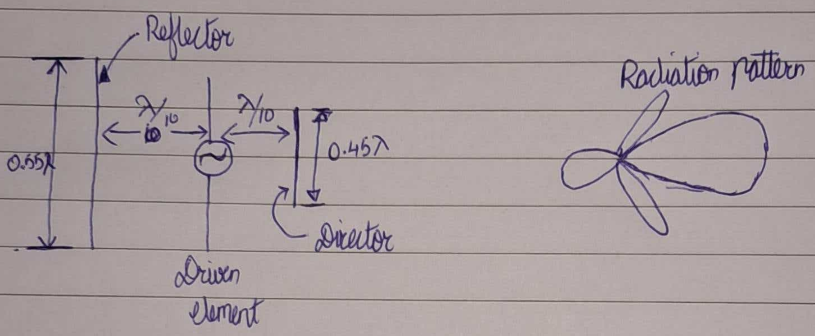
RF

<u>Endsem</u>

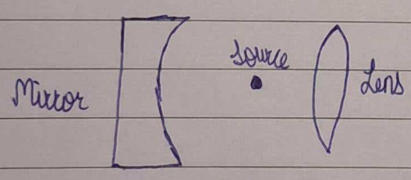
Q.2

(a) ~~The~~ A Yagi-Uda antenna is an array consisting of a driven element and one or more parisitic elements.

They are arranged collinearly and close together with the optical equivalent and the radiation pattern.



(a)



(b)

Yagi Antenna (a) Antenna and pattern (b) optical equivalent.

(i) Driven element : This is the active element that is connected to the transmitter or receiver.

(ii) Reflector : Positioned behind the driven element, the reflector is slightly longer than the driven element. It reflects the radio waves back toward the driven element, enhancing the antenna's directivity.

(iii) Director : Positioned in front of the driven element, directors are shorter than the driven element. They focus the radiation in forward direction.

Advantages of the Yagi-Uda antenna in receiving VHF broadcast television :

(i) Directionality : The Yagi antenna is unidirectional, meaning it focuses its sensitivity in one direction and rejects signals from other directions. ~~This~~ This is beneficial for receiving television signals from a specific transmitting tower.

(ii) Gain : The Yagi ~~antenna~~ array provides gain over a dipole antenna, which means it can receive weaker signals more effectively. The addition of directors and reflectors enhances the antenna's gain.

(b) $f = 6GHz$ Diameter $(D) = 2m$

Half power beamwidth $(HPBW) = 70 \times \left(\frac{\lambda}{D}\right)$

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

$$= \frac{3 \times 10^8}{6 \times 10^9}$$

$$= \frac{1}{2} \times 10^{-1}$$

$$= 0.05m$$

$$HPBW = 70 \times \frac{0.05}{2}$$

$$= 7\cancel{0} \times \frac{5}{10\cancel{0}} \times \frac{1}{2}$$

$$\boxed{HPBW = 1.75}$$

Antenna Gain

$$D(dB_i) = 10 \log \left[\frac{(\text{power density in the direction of max. radiation})}{(\text{power density due to isotropic antenna or isotropic radiator})}\right]$$

$$D(dB_d) = 10 \log \left[\frac{(\text{power density in the dir}^n \text{ of max. radiation})}{(\text{power density due to half-wave dipole})}\right]$$

$$D(dB_i) = D(dB_d) + 2.15dB$$

Q

$\frac{2 \times \overset{20}{\cancel{100}}}{\cancel{5}} = 40$

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YOUVA

D(dBi) of Parabolic Reflector Antennas $= 10 \log \left(\pi^2 \left(\frac{D}{\lambda}\right)^2\right)$

D(dBd) of Parabolic Reflector Antenna $= 10 \log \left(6 \left(\frac{D}{\lambda}\right)^2\right)$

$D(dBi) = 10 \log \left(9.8 \times \left(\frac{2}{0.05}\right)^2\right)$

$= 10 \log (9.8 \times 1600)$

$= 10 \log (15775.36)$

$= 41.979 \sim \boxed{41.98 \text{ dB}}$

$D(dBd) = 10 \log (6 \times 1600)$

$= \boxed{39.82 \text{ dB}}$

$41.98 - 39.82 = \boxed{2.15 \text{ dB}}$

(c) The 5 variables for control of radiation pattern of array antenna of identical elements are:

(i) The geometrical configuration of the overall array (linear, circular, rectangular, spherical, etc.).

(ii) The relative displacement between the elements.

(iii) The excitation amplitude of the individual elements.

(iv) The excitation phase of the individual elements.

(V) The relative pattern of the individual elements.

(d) The array factor is a func^n of the geometry of the array and the excitation phase.

In normalized form, it can be written as :

$$\boxed{(AF)_n = \cos\left[\frac{1}{2}(kd\cos\theta + \beta)\right]}$$

Q.3

(a) The directivity of an antenna is defined as the ratio of the radiation intensity in a given dir^n from the antenna to the radiation intensity averaged over all directions.

The directivity of a non-isotropic source is equal to the ratio of its radiation intensity in a given dir^n over that of an isotropic source. Mathematically,

$$\boxed{D = \frac{U}{U_0} = \frac{4\pi U}{P_{rad}}}$$

D = Directivity (dimensionless)
U = radiation intensity (w/unit solid angle)
U_0 = radiation intensity of isotropic source (w/unit solid angle)
P_{rad} = total radiated power (W)

If the direction is not specified, it implies the direction of maximum radiation intensity (maximum directivity):

$$\boxed{D_{max} = D_0 = \frac{U_{max}}{U_0} = \frac{4\pi U_{max}}{P_{rad}}}$$

D_0 : Maximum directivity
U_{max} : maximum radiation intensity (w/unit solid angle)

(v) The total antenna efficiency e_0 is used to take into account losses at the input terminals and within the structure of the antenna. Such losses may be due to:

(i) reflections because of the mismatch b/w the transmission line and the antenna

(ii) I^2R losses (conduction & dielectric).

In general, overall efficiency can be written as

$$\boxed{e_0 = e_r e_c e_d}$$

where

e_0 = total efficiency
e_r = reflection (mismatch) efficiency = $(1-|\Gamma|^2)$
e_c = conductivity efficiency
e_d = dielectric efficiency
Γ = voltage reflection coefficient at the input terminals of the antenna. $[\Gamma = (Z_{in}-Z_0)/(Z_{in}+Z_0)]$.

e_c, e_d are very difficult to compute, ~~[illegible]~~ so

$$\boxed{e_0 = e_r e_{cd} = e_{cd}(1-|\Gamma|^2)}$$

- Reflection efficiency (e_r):

→ It is a measure of how well the antenna structure reflects incident power back into free space.

Given by : $e_r = 1 - |\Gamma|^2$ where Γ is the reflection coefficient.

- Conductivity efficiency (e_c) :

→ Represents the portion of the incident power that is converted into useful radiation by the conduction currents on the antenna structure.

- Dielectric efficiency (e_d)

→ Accounts for losses in the dielectric materials used in the antenna system.

(c) The 3 basic propagation mechanisms for propagation of space waves are:

Reflection, diffraction & scattering

(i) Reflection occurs when a propagating electromagnetic wave impinges upon an object which has very large dimensions when compared to the wavelength of the propagating wave.

(ii) Diffraction occurs when the radio path between the transmitter and receiver is obstructed by a surface that has sharp irregularities. At high frequencies, diffraction depends on the geometry of the object, as well as the amplitude, phase & polarization of the incident wave at the point of diffraction.

(iii) Scattering occurs when the medium through which the wave travels consist of objects with dimensions that are small compared to the wavelength, and where the no. of obstacles per unit volume is large.

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End sem

Q7 (a) Measurement of radiation pattern of antenna.

Diagram from 1st pdf

- Radiation pattern is representation of radiation characteristics of the antenna as a fxn of elevation angle θ & azimuthal angle ϕ for constant radial distance & frequency.

- The 3-D pattern is decomposed into two orthogonal 2-D patterns in $\vec{E}$ & $\vec{H}$ field planes where z-axis is the line joining the transmitting & receiving antennas & $\perp$ to the radiating aperture.

- Due to reciprocal characteristics of antennas, the measurements are performed with test antenna placed in its receiving node.

- Source antenna - fed by stable source
+ Received signal - measured using receiver.

- O/P of receiver - fed to Y-axis input of XY-recorder

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- The receiving antenna positioner controller plane & the angle information is fed to X-axis I/P of the XY recorder.

- Thus, amplitude vs angle plot is obtained from the recorder O/P.

(b) Measurement of absolute gain of antenna using two-antenna method: 2 antennas separated by distance R.
Procedure to measure gain using Friis transmission formula with eqns.

→

- Gain is the most important figure-of-merit that describes performance of a radiator.
- Absolute-gain method is used to calibrate antennas that can then be used as standards for gain measurements, & requires no a-priori knowledge of gains of antennas.

- All absolute-gain measurement methods are based on Friis transmission formula which assumes that measuring system employs, each time, two antennas - separated by dist. R & it must satisfy far-field criterion of each antenna.

- Equation:

$$(G_{0t})_{dB} + (G_{0r})_{dB} = 20\log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10\log_{10}\left(\frac{P_r}{P_t}\right)$$

$(G_{ot})_{dB}$ = gain of transmitting antenna (dB)

$(G_{or})_{dB}$ = gain of receiving antenna (dB)

P_r = received power (W)

P_t = transmitted power (W)

R = antenna separation (m)

λ = operating wavelength (m)

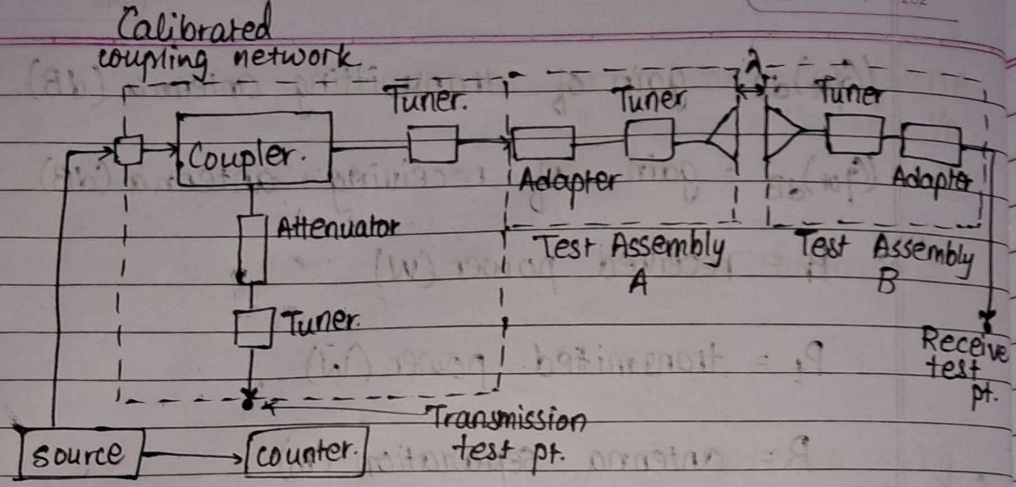
- If transmitting & receiving antennas are identical ($G_{ot} = G_{or}$), eqn reduces to:

$$(G_{ot})_{dB} = (G_{or})_{dB} = \frac{1}{2}\left[20 \log_{10}\left(\frac{4\pi R}{\lambda}\right) + 10 \log_{10}\left(\frac{P_r}{P_t}\right)\right]$$

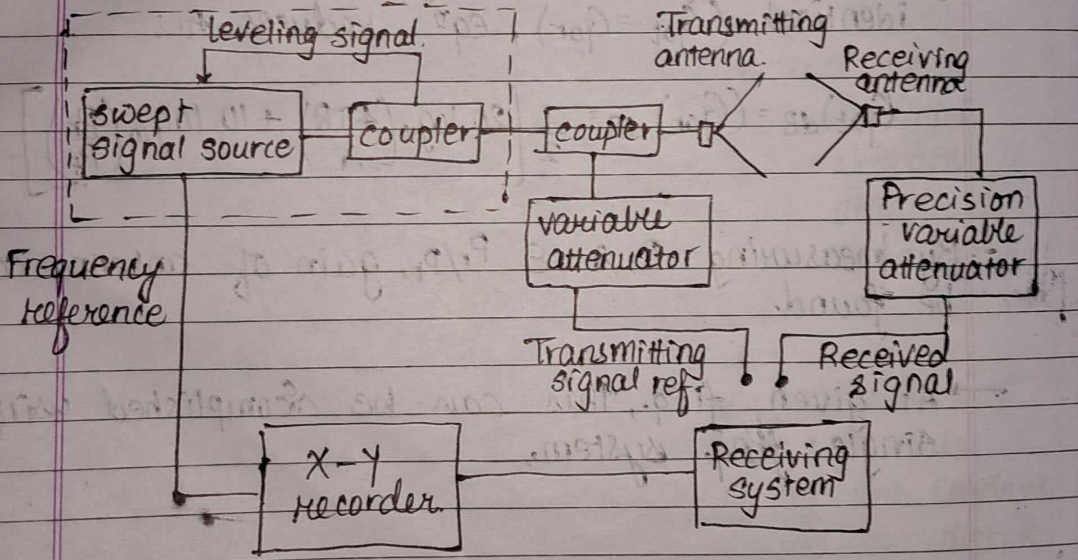
- By measuring R, λ & P_r/P_t, gain of antenna can be found.

→ At given freq., this can be accomplished using single freq. system.

Diag. ⟶ NEXT PAGE.



- For continuous multifreq. measurements like broadband antennas, the swept freq. instrumentat^n can be utilized:



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(c) Numerical: signals travel at speed of light

$f = 10\,GHz = 10 \times 10^9\,Hz$

Two identical antennas. so ($G_{0t} = G_{0r}$)

$R = 60\,cm = 0.6\,m$

$\frac{P_r}{P_t} = -15\,dB = 10\log_{10}\left(\frac{P_r}{P_t}\Big|_W\right)$

$\frac{P_r}{P_t}\Big|_W = \cancel{10^{\left(\frac{-15}{10}\right)}}\ 10^{\wedge}(-1.5)$

$\frac{P_r}{P_t}\Big|_W = 0.0316$

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

$= \frac{3\times10^8}{10\times10^9}$

$= 3\times10^{-2}$

$\lambda = 0.03\,m$

so $G_{0t} = G_{0r} = \frac{1}{2}\left[20\log_{10}\left(\frac{4\pi\times0.6}{0.03}\right) + 10\log_{10}(0.0316)\right]$

$G_{0t} = G_{0r} = 10\log_{10}(251.3274) + 5\log_{10}(0.0316)$

$= 24.002 + (-7.501)$

$\boxed{G_{0t} = G_{0r} = 16.5\,dB}$