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Designation: Professor

Department: EC

Subject: Antennas & Wave Propagation

Unit: 3

Topic: Types of Antenna

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PAGE NO.:

Unit-3

Types of Antenna

7/3/19

Antenna is an essential device in all communication and radar system. It act as a transducer, impedence matching device, radiator and reciever of electro-magnetic waves. With a well designed antenna, it is possible to have communication from one point to other point of entire globe. There are many types of antennas. The choice of antenna depends upon the frequency operation, polarization, gain requirements and application. Antenna are classified into different categories

1) Isotropic radiator
2) Directional antenna
3) Omnidirectional antenna

Isotropic radiator

It is defined as hypothetical element which radiates equally in all direction It is useful as reference antenna.

Directional antenna

These antennas which radiate or recieve electromagnetic waves more effectively in some directions than in others eg. dipoles, horns, ~~pa~~ paraboloid

Omni directional Antenna

It is defined as an antenna which has a non-directional pattern in azimuth and has a directional pattern in elevation.

eg. vertical hertz antenna, marconi antenna, quarter wave monopole, circular loop and so on.

Resonant Antenna

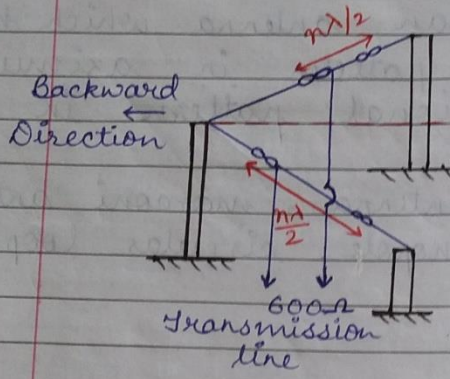
1) Length of resonant antenna is in exact multiples of $\lambda/2$. It is periodic antenna
2) These antenna are open at the both ends
3) These are not terminated in any resistance
4) A standing wave exist in these antenna
5) They are used at fixed frequency

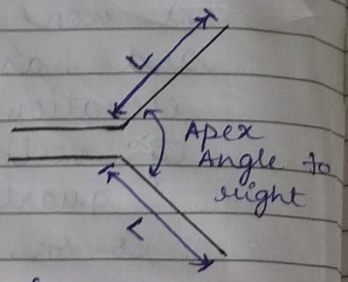
Non-Resonant Antenna

1) The length of non resonant antenna is other than in multiples of $\lambda/2$.
2) At one end is excited and other is terminated
3) There are no standing waves.
4) It operates over a range of frequencies
5) It is aperiodic antenna

8/3/19

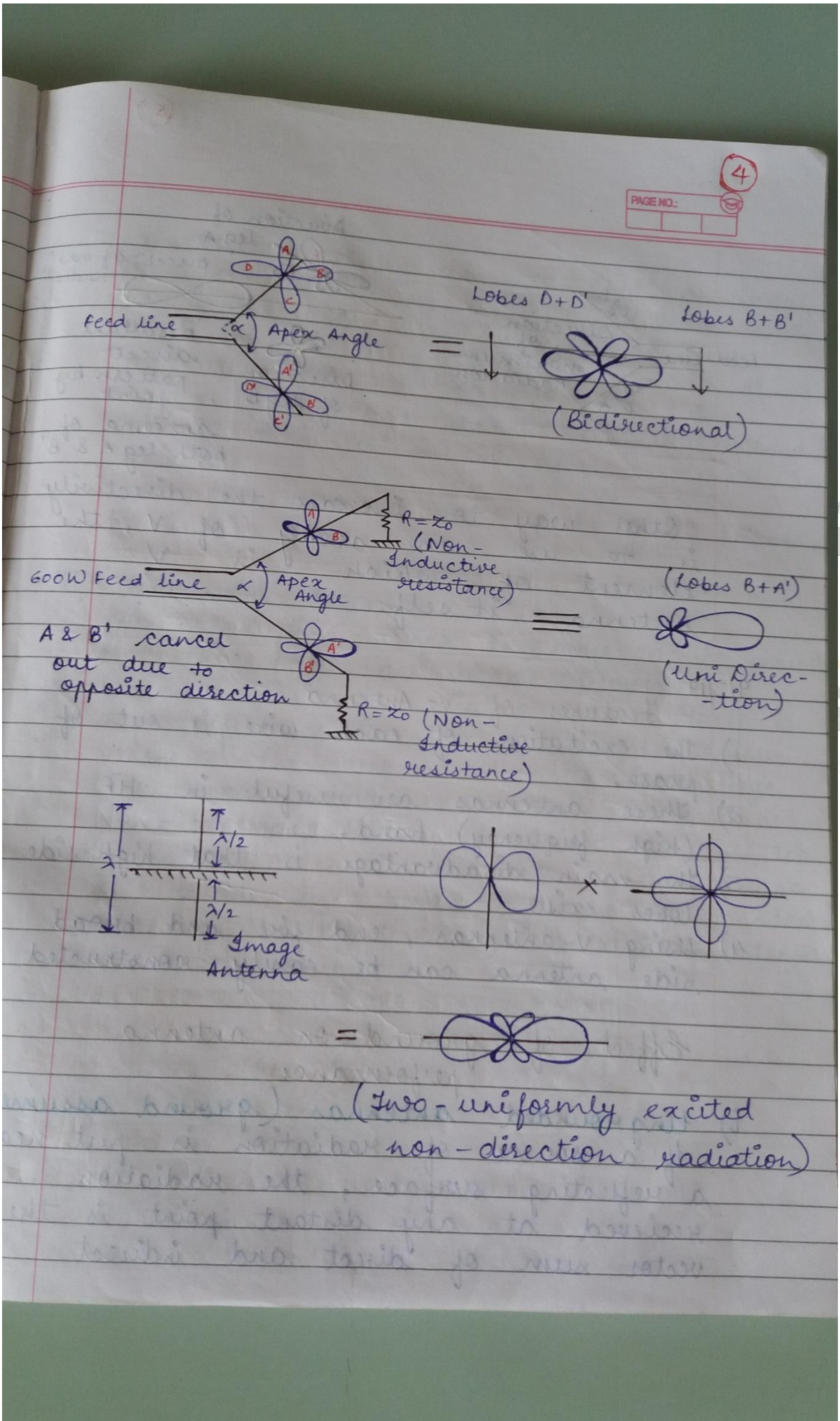
* The V-Antenna

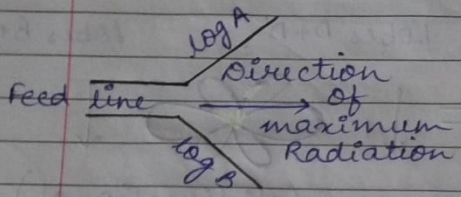


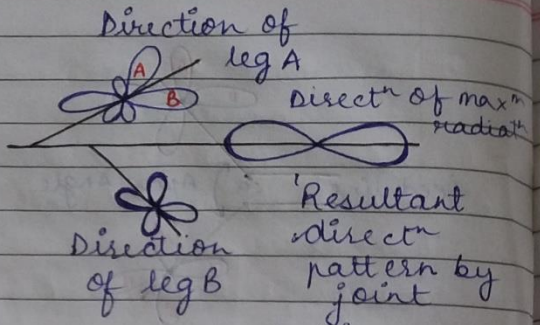


"A high frequency tuned or resonant V- antenna"

The V- antenna is an extension of a long wire antenna. The 2 long wire antennas (called legs) are arranged in the form of horizontal V, fed at the apex. The 2 wires are fed 180° out of phase with each other. This provides gain and directivity. These are achieved by cancelling oppositely & erected corresponding radiation lobes in each legs & by adding the similarly erected corresponding lobes in each leg. One way to convert the V directional pattern into uni direction is termination with a non-inductive resistance of value equal to characteristic impedence of the leg.


4
PAGE NO.:
A
B
C
D
A'
B'
C'
D'
Feed line
α
Apex Angle
Lobes D+D'
Lobes B+B'
(Bidirectional)
A
B
R=Z0
(Non-Inductive resistance)
600Ω Feed line
α
Apex Angle
A & B' cancel out due to opposite direction
A'
B'
R=Z0 (Non-Inductive resistance)
(Lobes B+A')
(Uni Direc-tion)
λ
λ/2
λ/2
Image Antenna
×
=
(Two-uniformly excited non-direction radiation)





Other way to increase the directivity is to use an array of V, the element of which is V antenna itself.

9/3/19

Features of V-Antenna

1) The excitation of each wire is out of phase.
2) These antennas are useful in HF (high frequency) band.
3) The main disadvantage is that high side lobes exist.
4) Using V-antennas, end fire and broad side antenna can be easily constructed

Effect of ground on antenna performance

i) **Ungrounded antennas (ground assumed)**
If a source of radiation is put near a reflecting surface, the radiation recieved at any distant point is the vector sum of direct and indirect

radiation. It is assumed that an image antenna is existing below the ground and is mirror image of actual antenna. Now the resulting radiation recieved at a distant point is considered to be coming from the actual and image antenna. The direction of current flow in vertical antennas is same as that of actual antenna while in case of horizontal antenna, it is in opposite phase.

ii) Grounded Antenna

When the antenna is close to the ground that the earth act as a mirror and becomes part of radiating system. There is one difference in the resulting behaviour whereas the ungrounded with its image forms an array. while in the grounded antenna, the bottom is joined to the top of image antenna and act as an antenna of double size hence in case of grounded antenna, the effective size of actual antenna is just doubled.

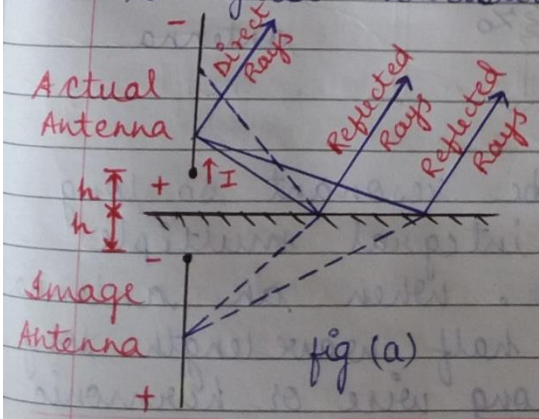


fig (a)

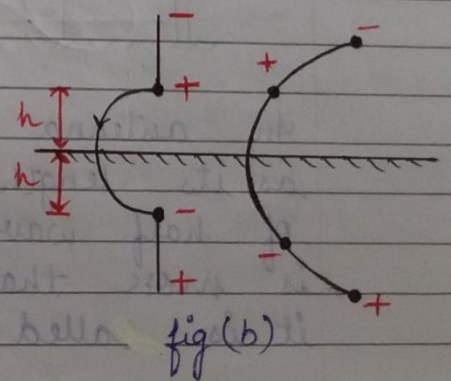
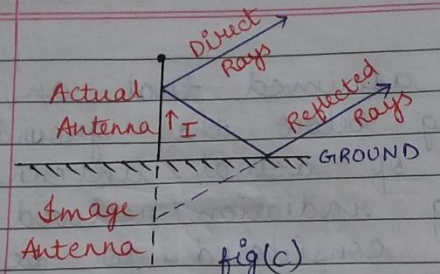


fig (b)

7

PAGE NO.:



fig(c)

fig(a) :- Ungrounded Antenna and its image (vertical)

fig(b) :- Vertical Antenna (same phase)

fig(c) :- Actual & image antenna

★ Long Wire or Harmonic Antenna

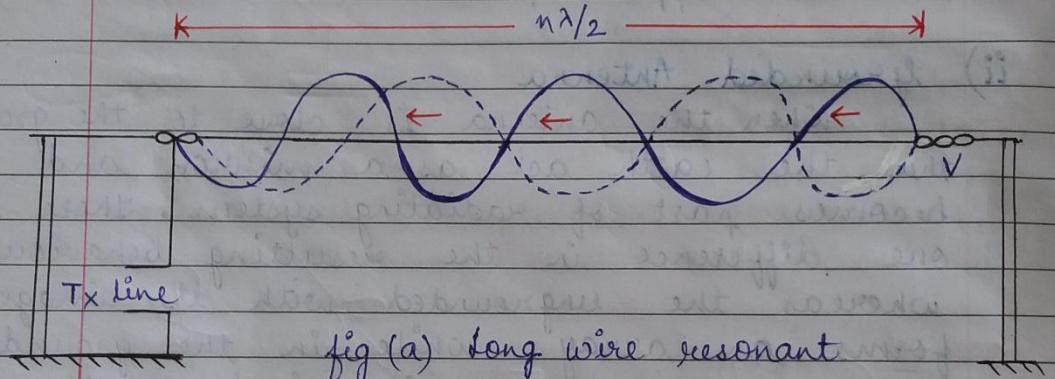


fig (a) Long wire resonant antenna

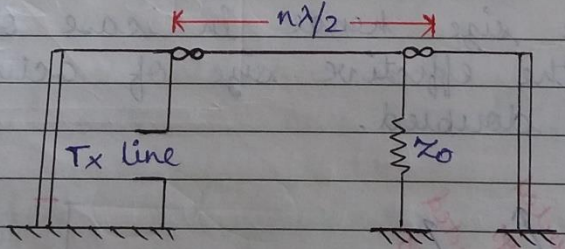
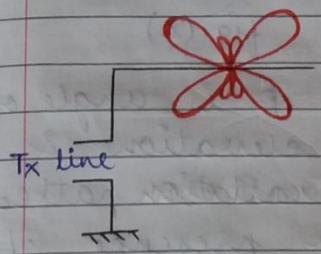


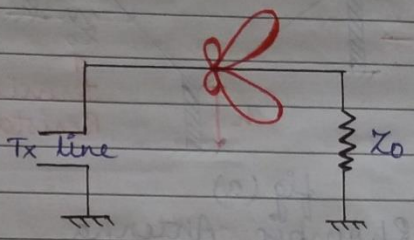
fig (b) Long wire non-resonant antenna

An antenna will be resonant so long as its length is integral multiple of half wave length. When an antenna is more than a half wavelength long, it is called as long wire or harmonic

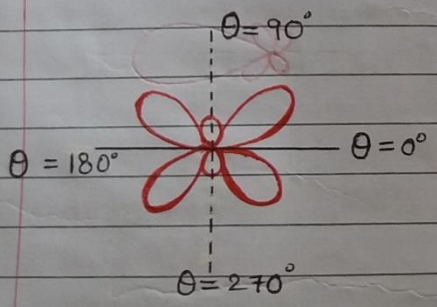
antenna. Thus the long wire antenna is a single long wire. Generally 2 or more wavelength i.e., $4\lambda/2$ or more $\lambda/2$ long at operating frequency. The higher no. of $\lambda/2$ produces better directivity. The long wire antenna is generally made a half wavelength at the lowest frequency of operation and fed at the end.



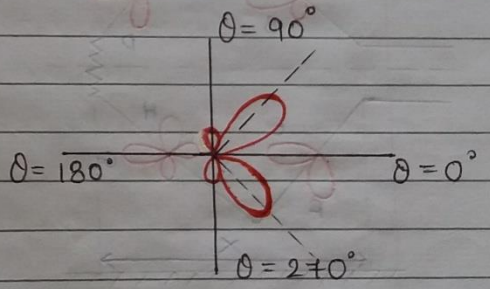
(a) Bi-directional pattern due to resonant antenna



(b) Uni-directional pattern due to non-resonant



(a) $n = 3$
Bidirectional pattern (non-terminated)



(b) $n = 3$
Uni-directional pattern (terminated)

Long-wire Pattern

9
PAGE NO.:

11/3/19

★ Rhombic Antenna

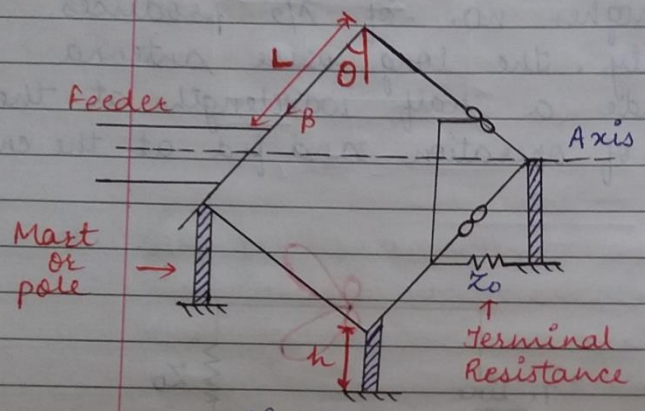


fig (a)
Rhombic Antenna

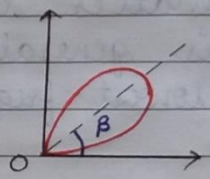


fig (c)

β is angle of elevation & radiation pattern in presence of Earth

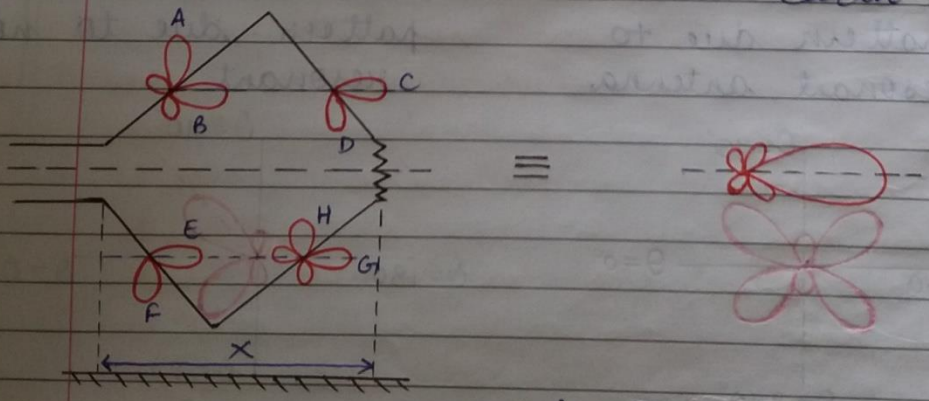
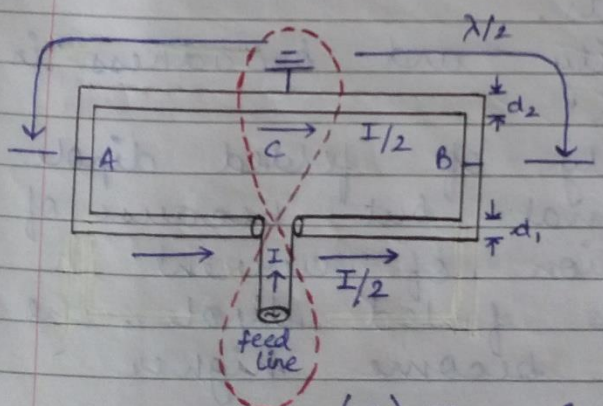


fig (b)
Radiation pattern over perfectly conducting plane

The Rhombic antenna is based on the principle of travelling wave radiator by the application of return conductor & ~~wire~~ wires are

pulled apart at one point so that diamond or rhomus shape is founded. A Rhombic antenna is very effecient antenna of broad frequency capabilities. It is prominant all radio communication facilities where the shape is necessary for its large structure is easily available. It consists of 4 straight wire arrangement in the form of rhombus suspended horizontally above surface of the earth. It can be regarded as 2 inverted V-antenna connected in a series or 2 V- antenna connected end-to-end forming obtuse angle. It is also called diamond antenna. It is ideally suitable for high frequency transmission and reception in commercial point-to-point communication.

* Folded Dipole Antenna



AB → minimum current point
C → maximum current point
Minimum voltage pt. = $d_1 = d_2$

(a) Two-wire folded dipole with current distribution & Radiation Pattern

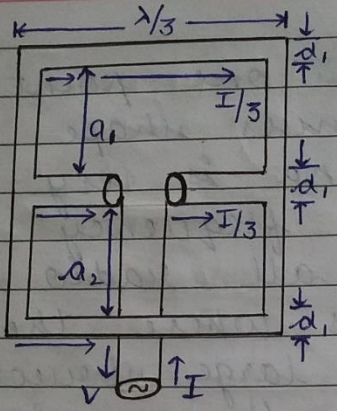


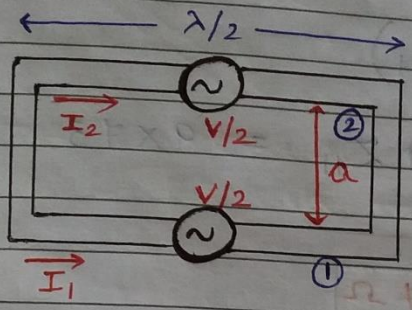
fig (b) Three wire-folded dipole

A very important variation of conventional half wave dipole is the folded dipole in which 2 half wave dipoles, 1 continuous and other split at the center have been folded and joined together in parallel at the ends. The split dipole is fed at center by a balance transmission line. The radiation pattern of folded dipole & a conventional half wave dipole is same but the input impedance of folded dipole is higher. It differs from the conventional dipole mainly in two respects.

Eg. directivity and broadness in band width

The directivity of folded dipole is bi directional but because of the distribution of current in the parts of folded dipole, the i/p impedance become higher

Equation of input impedence



Equivalent fig of two-wire folded dipole

Voltage in each dipole = V/2

NODAL ANALYSIS :-

$$\frac{V}{2} = I_1 Z_{11} + I_2 Z_{12}$$

I_1 & I_2 → current of dipole no. ① & ②

Z_{11} & Z_{12} → self impedence of dipole ① & ②

But $I_1 = I_2$

$$\frac{V}{2} = I_1 (Z_{11} + Z_{12})$$

$Z_{11} \cong Z_{12}$ (Two dipole in system very close to each other)

$$\frac{V}{2} = I_1 (2Z_{11})$$

$$\frac{V}{I_1} = 4Z_{11} \quad [\because Z_{11} = 73\Omega]$$

$$Z = 4 \times 73$$

$$\boxed{Z = 292\ \Omega}$$

Similarly for 3 wire folded dipole

$$\frac{V_1}{I_1} = 3(3Z_{11})$$

$$\frac{V}{I_1} = 9Z_{11} = 9 \times 73$$

$$\boxed{Z = 657\,\Omega}$$

When n no. of half wave dipole

$$\therefore \boxed{Z = n^2 \times 73}$$

Uses

In conduction with parasitic elements, folded dipole is used in wide band operation such as in television. In Yagi antenna, the driven element is folded dipole and remaining are reflector and director. Grounding is made at point B (The mid point of unbroken arm).

Advantages

→ High i/p impedence
→ wide band in frequency
→ Act as build in reactance compensation network.

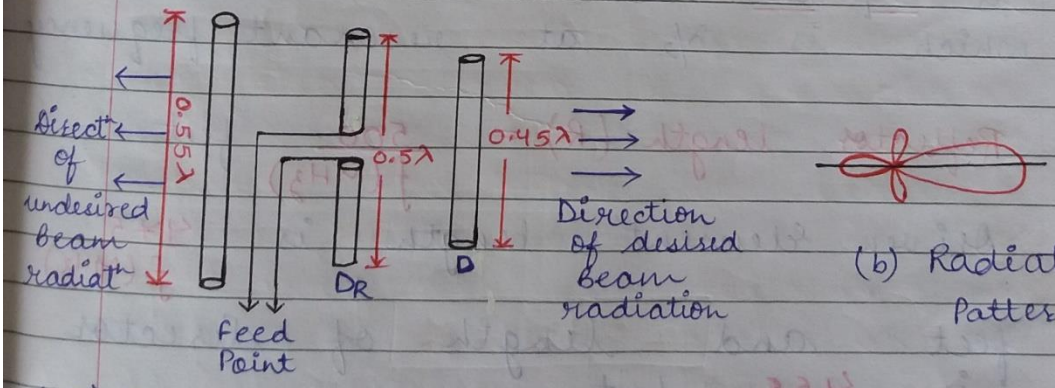
14

PAGE NO.:

14/3/19

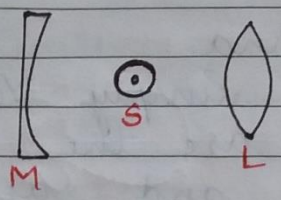
★ Yagi Uda Antenna

Yagi Uda or simply Yagi antennas or Yagis are the most high gain antennas and are known after the names of proffessor S. Uda and H. Yagi. It consists of driven element (operator), a reflector and one or more directors. That is Yagi Uda antenna is an array of driven element or active element and one or more parasitic elements or passive elements. The driven element is a resonant half wave dipole usually metallic rod at the frequency of operation. The parasitic elements of continuous metallic rods are arranged parallel to the driven element and at the same line of sight level. They are arranged collinearly and closed together with one reflector and one director



(a) Yagi Uda Antenna Structure

(b) Radiation Pattern



(c) Its optical Equivalent

M → Mirror , S → source , L → lens
R → reflector , D → director
Parasitic Elements

D_R → driven Element → Active Element

The parasitic element recieve their excitation from the voltages induced in them by current flow in the driven element. The phase & current flowing due to induced voltage depend on the spacing b/w the elements and length
The spacing b/w driven & parasitic elements that are usually used in practice are the order of 0.10λ to 0.15λ. The length of reflector is 5% more & director is 5% less than the driven element which is λ/2 at resonant frequency

Reflector length (R) = $\frac{500}{f(MHz)}$ feet

Driven Element length is $\frac{475}{f(MHz)}$ feet and length of director is $\frac{455}{f(MHz)}$ feet. $\approx \frac{451.25}{f(MHz)}$

16

PAGE NO.:

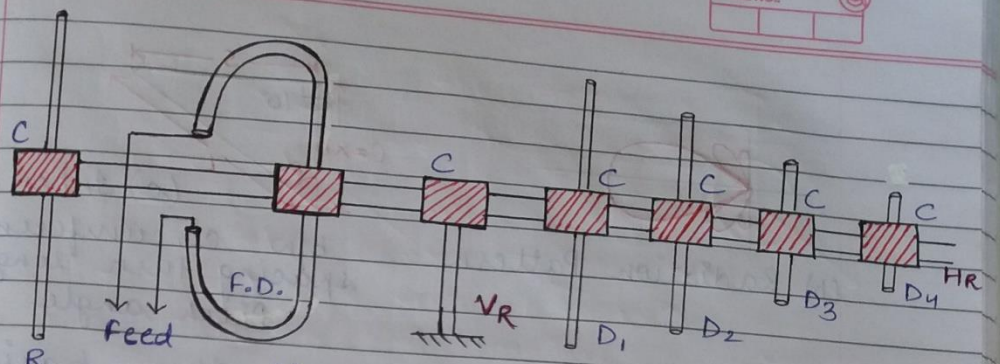


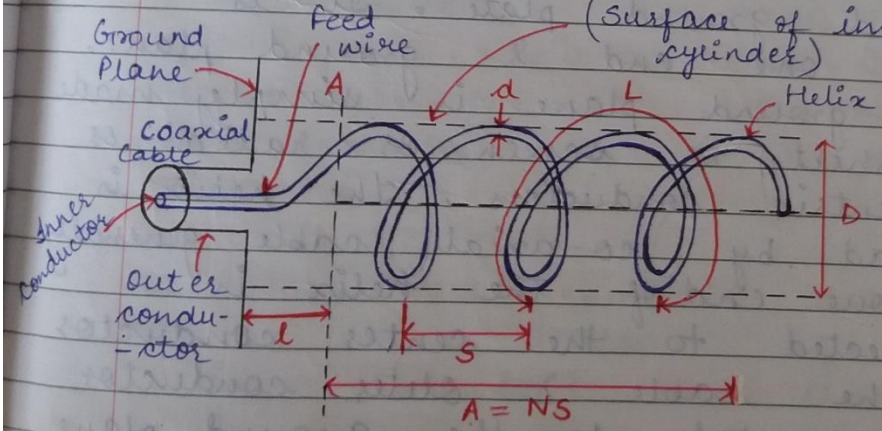
fig. 6- Element Yagi Antenna with folded dipole (FD)

V_R → Vertical Rod
H_R → Horizontal Rod

It is also known as High gain or super directive antenna due to high gain & beam width per unit area of the array.

15/3/19

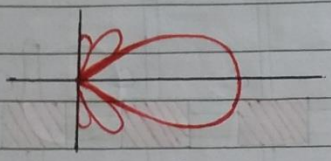
★ Helical Antenna



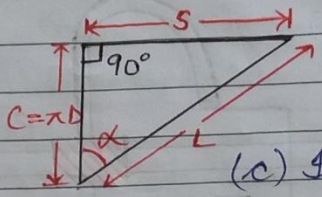
(a) Helical Antenna

D → diameter of Helix

S → center to center of Helix spacing



(b) Radiation Pattern



(c) Inter Relat^{n} b/w circumference spacing turn length & Pitch angle

Helical Antenna is another basic type of radiator and simplest antenna to provide circularly polarized wave which are used in extra terrestrial communication in which satellite rays are involved Helical antenna is broadband VHF and UHF antenna to provide circular polarisation characteristic. It consist of helix of a thick copper wire in the shape of screw spread with a flat metal plate called ground plate. It is b/w one end & ground plane. The ground plane is simply made of sheet or screen or radial or concentric conductors. The helix is spread by co-axial cable generally The one end of the helix is connected to the center conductor of the cable & outer conductor is connected to the ground plane The radiation pattern depends on the parameters → diameter of

helix D and → turn spacing S
(center to center)

$$\tan\alpha = \frac{S}{C} = \frac{S}{\pi D}$$

C → circumference of helix = πD
D → diameter of helix conductor
l → spacing of helix from ground plane
α → Pitch angle

$$\tan^{-1}\left(\frac{S}{\pi D}\right) = \alpha$$

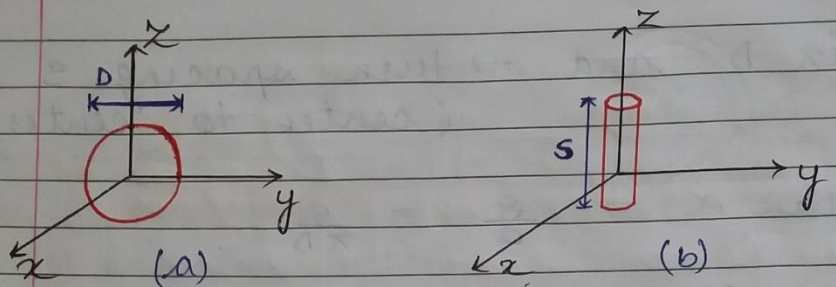
L → length of one turn

Normal mode of Radiation

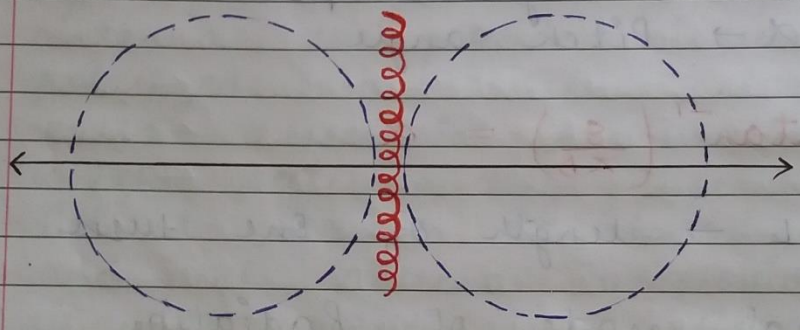
In normal mode of radiation, the radiation field is maximum is broad way that is in the direct^{n} normal to the helix axis. This mode of radiation is obtained if the dimension of helix is small as compared with wavelength i.e., $NL << \lambda$

If $S \to 0$, helix collapse to a loop

If S = constant and $D \to 0$, helix becomes a linear conductor (straight)



The Radiation pattern of these two equivalent radiator are same



Radiation pattern of normal mode (circular polarization)

16/3/19

* Slot Antenna

The slot antenna is simply an opening cut in a sheet of conductor which is energised in some appropriate manner. Such as via a coaxial cable or waveguide (used for high frequency transmission). One simple type of slot antenna is a half wavelength long with narrow width and excited through a 50 Ω co-axial cable normally connected. About 0.05λ

22
PAGE NO.:

★ Turnstile Antenna

In the turnstile antenna, 2 half wave dipole placed at right angle to each other in the same plane excited 90° out of phase with each other.

The dipoles carry equal current in magnitude but in phase quadrature. Here two dipoles pattern combining in the manner and produce almost circular pattern in the plane of turnstile. It is also called as George down Turnstile antenna

$$E = \frac{\cos\left(\frac{\pi}{2}\sin\theta\right)}{\cos\theta}\sin\omega t + \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{\cos\theta}\cos\omega t$$

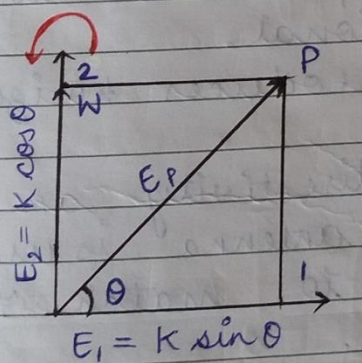


fig. Vector diagram at point 'P'

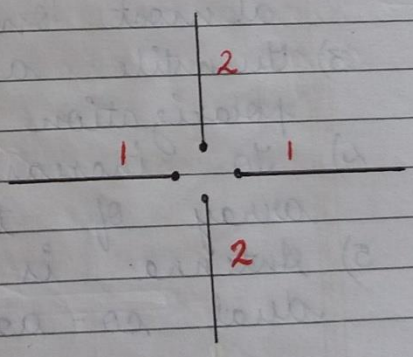


fig. "Two short cross dipole"
∴ A plane view of Turnstile antenna

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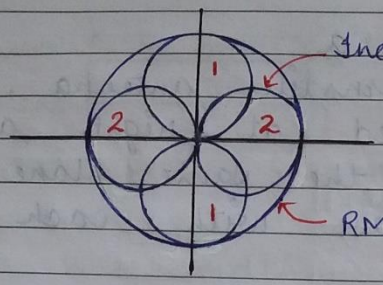

fig. Radiation Pattern

Use of Turnstile antenna

A turnstile antenna used to form transmission of FM and TV broadcast signal in VHF and UHF band.

Features of Turnstile Antenna

1) Turnstile antenna is formed by placing two half wave dipoles perpendicular to each other.
2) Radiation pattern produced is almost Omni directional.
3) Turnstile antenna produces horizontal polarization
4) To increase the directivity an array of turnstile antenna is used.
5) Antenna is useful to match 70 Ω dual co-axial line.

★ Horn Antenna

A horn antenna may be regarded as flared out or opened out waveguide. In waveguide, a small portion of the incident wave is radiated and the large

Assignment Question of Unit -3:

Q. 1) Explain the working & construction of Log- Periodic Antenna?

Q.2) Describe Loop Antenna also write down its features?

Q.3) Explain the working & construction of Yagi-Uda Antenna with application.

Q.4) Explain the working construction of Travelling –Wave Antenna.

Q.5) Write short note :-

a) Lens Antenna b) Trunstile Antenna c) Rhombic Antenna

LNCT SM GROUP OF COLLEGES "WORKING TOWARDS BEING THE BEST"

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Subject: Antennas & Wave Propagation

Unit: 4

Topic: Aperture & Slot Antennas

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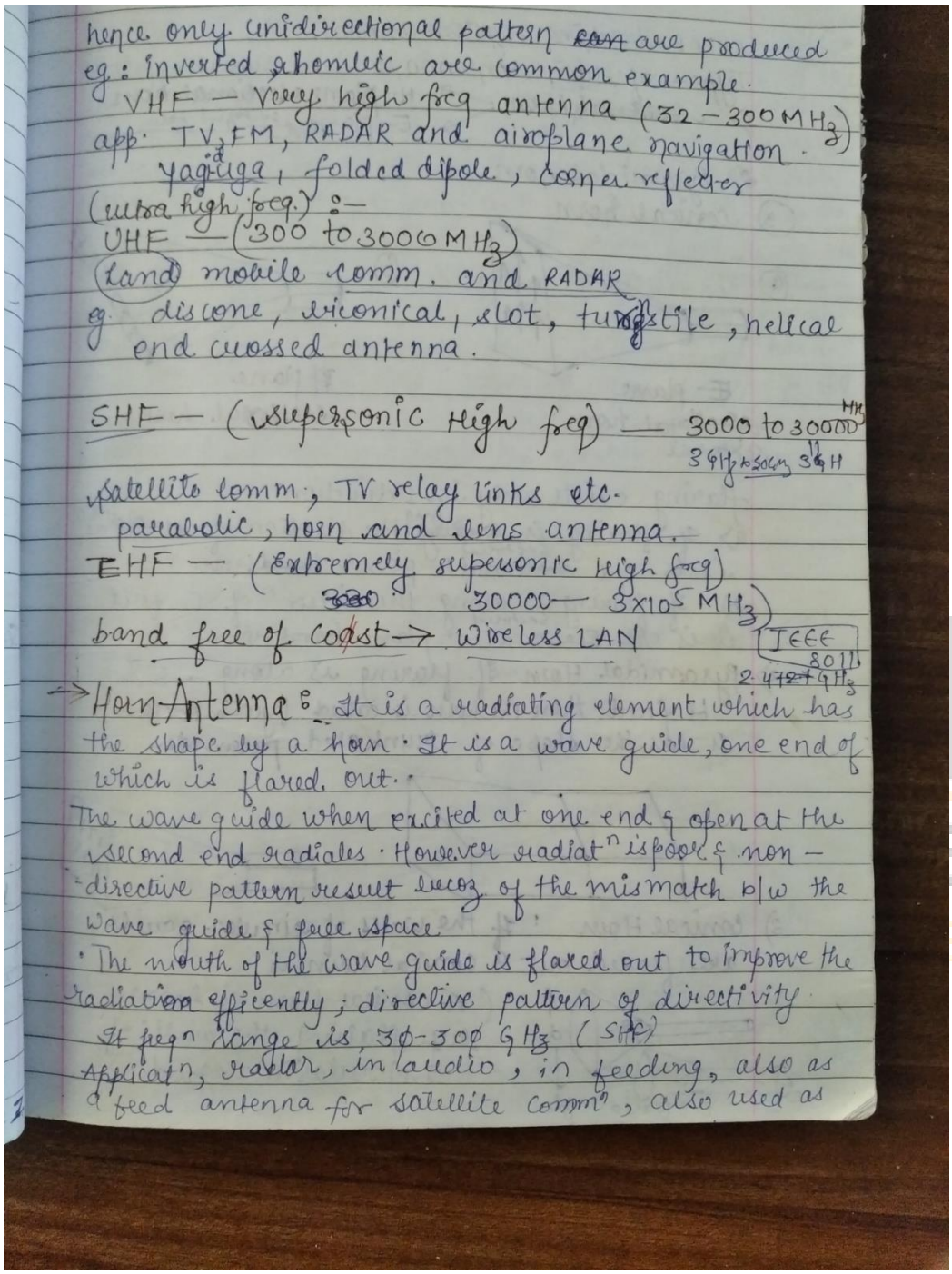
Horn Antenna



hence only unidirectional pattern ~~can~~ are produced
eg: inverted rhombic are common example.
VHF — Very high freq antenna (32 – 300 MHz)
app. TV, FM, RADAR and airoplane navigation.
yagiuga, folded dipole, corner reflector
(ultra high freq.) :-
UHF — (300 to 3000 MHz)
land mobile comm. and RADAR
eg. discone, biconical, slot, turnstile, helical
end crossed antenna.

SHF — (supersonic High freq) — 3000 to 30000 MHz
3 GHz to 30 GHz 3 GH

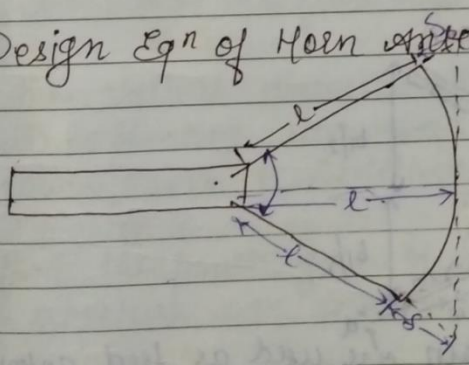
satellite comm., TV relay links etc.
parabolic, horn and lens antenna.
EHF — (Extremely supersonic High freq)
~~3000~~ 30000 — 3×10^5 MHz)
band free of coast → Wireless LAN
IEEE 8011
2.47 GHz

→ Horn Antenna :- It is a radiating element which has the shape by a horn. It is a wave guide, one end of which is flared out.
The wave guide when excited at one end & open at the second end radiates. However radiatⁿ is poor & non-directive pattern result becoz of the mismatch b/w the wave guide & free space.
• The mouth of the wave guide is flared out to improve the radiation efficently; directive pattern of directivity.
It freqⁿ range is 30-300 GHz (SHF)
Applicatⁿ, radar, in audio, in feeding, also as a feed antenna for satellite commⁿ, also used as

Working of horn Antenna :

The EM wave propogat^n is a wave guide is diff from that of freespace. In a wave guide propogat^n is restricted by the conducting walls & the waves will not spread. After reach the mouth wave spread laterally of wave front become spherical. At the mouth of the waveguide their exist near field region where the wavefront is complicated. This is considered to be transit^n region where change of propogat^n from waveguide to free space take place as the wave guide imp & free space imp. do not match the wall of the waveguide are flared out. This flared out structure is c/d horn. The flaring provides imp. matching, more directivity & narrow beam width. Horn produces a uniform beam wavefront with larger aperture as aperture is very large the directivity is high.

Design Eq^n of Horn Antenna :→



$$\theta = 2\tan^{-1}\left(\frac{d}{2l}\right)$$

$$\theta = 2\cos^{-1}\left(\frac{l}{l+\delta}\right)$$

$$(l+\delta)^2 = l^2 + \left(\frac{d}{2}\right)^2$$

$$l = \frac{d^2}{8\delta}$$

HPBW

$$\phi_E = \frac{56\lambda}{d_E} \qquad \phi_H = \frac{67\lambda}{d_H}$$

Directivity

$$D = \frac{7.5\,A_a}{\lambda^2}$$

power gain

$$g_p = \frac{4.5\,A_a}{\lambda^2}$$

Where $A_a = d_E d_H$

ϕ_H = HPBW in H plane
ϕ_E = HPBW in E plane

δ = path difference
l = excess length
d = aperture diamen^n
θ = flare angle

RADAR tracking system antenna.

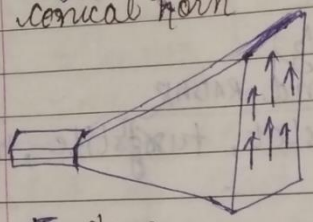
Types of Horn Antenna :

1) Sectoral horn → H-plane sectoral horn
                 → E-plane sectoral horn

2) Pyramidal horn

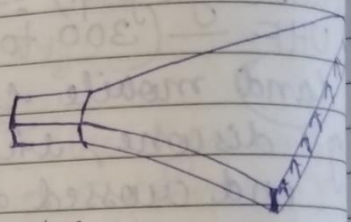
3) Conical horn

(a)



E-plane sectoral horn

(b)



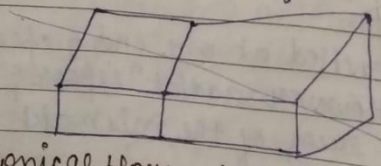
H plane sectoral horn

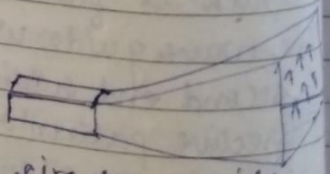
flaring exists only in 1 direction

a) If flaring is along the direction of H-plane it is c/d sectoral H-plane horn

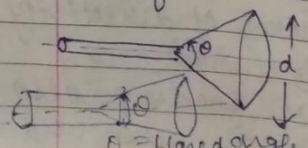
b) If flaring is along the direct^{n} of E-field it is c/d sectoral E-plane horn

2) Pyramidal Horn If flaring is along E & H field then the horn is called pyramidal It has the shape of trunketed paramuter





3) Conical Horn : If the walls of circular gauide are flared out a conical horn is

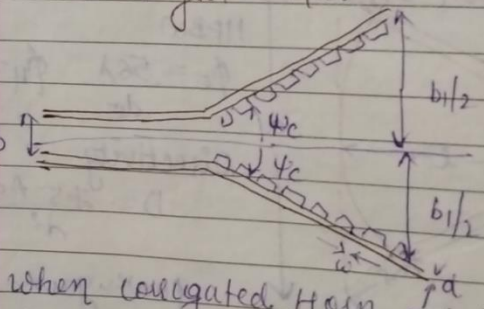


(A conical horn is formed by flaring the walls of a circular waveguide)

d_E = aperture in E-plane in free space wavelength
d_H = aperture in H plane in free space wavelength
A_a = aperture area or physical area.

Applicatⁿ of Horn antenna :→
It is used at microwave frequency (3 to ...
where moderate gains are sufficients.
II they are used feed elements.
III they are often used in laboratories for measurement of different parameter.
Horn antenna is used as feed element in parabolic ele... at satellite statⁿ or Ground
boundary conditⁿ H = 0
"Corrugatⁿ ↓es edge deflect, directivity ↑es by 2...
teeth

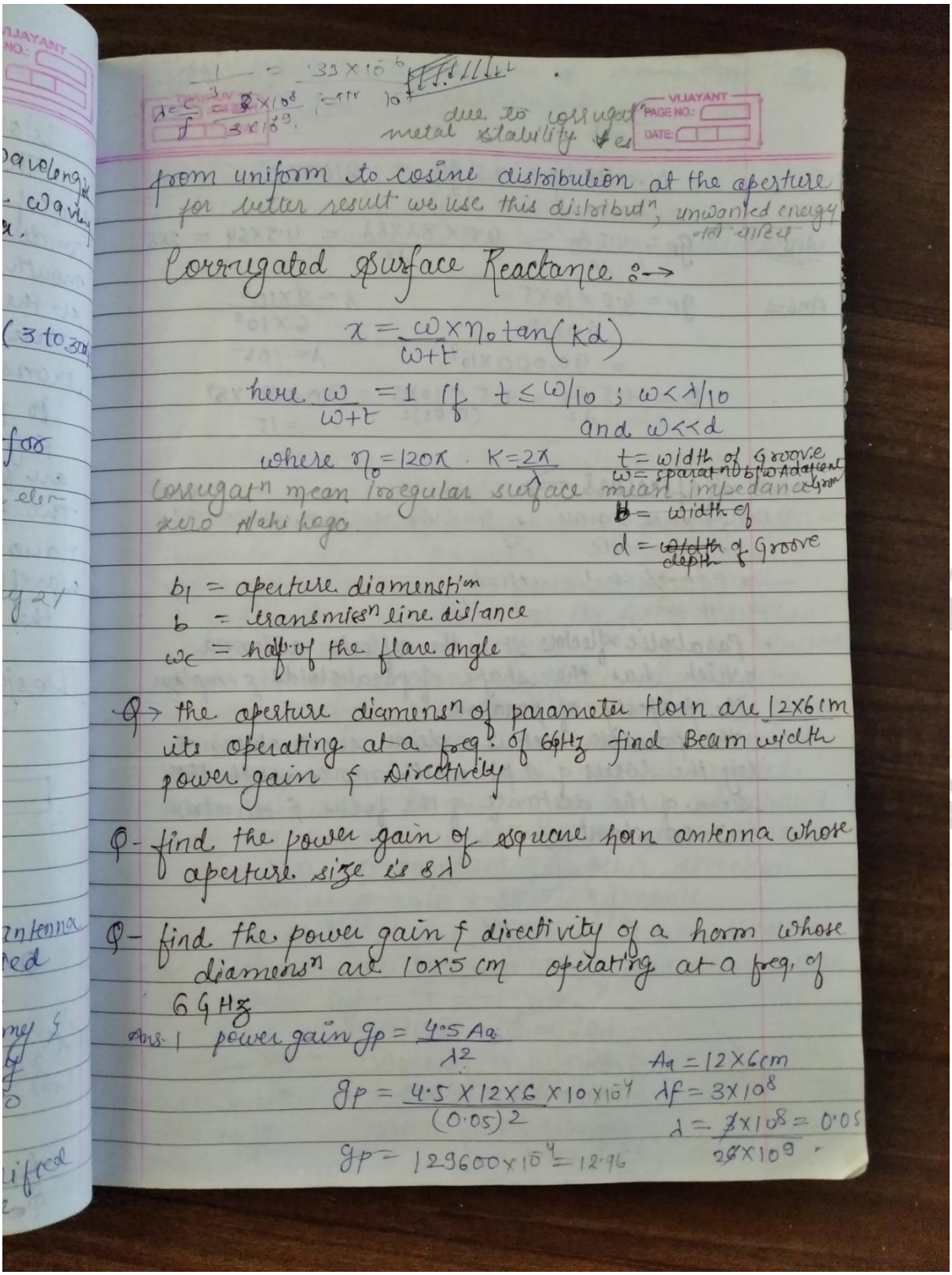
Corrugatⁿ Horn



When corrugated Horn are used as feed antenna for paraboloids. aperture effeciency is ↑ed and cross polarization are ~~used~~ reduced. these system are used in radia astronomy & satellite comm. this aperture efficiency 50-60% for conventional Horn & 70-80

the corrugatⁿ on the wall horn modified the E-field distribution in the E-plane

$\frac{1}{3} = 33 \times 10^{-6}$



$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9}$

due to corrugat metal stability

from uniform to cosine distribution at the aperture for better result we use this distribut^n, unwanted energy नहीं चाहिए

Corrugated Surface Reactance :→

$$x = \frac{\omega}{\omega + t} \times \eta_0 \tan(Kd)$$

here $\frac{\omega}{\omega+t} = 1$ if $t \le \omega/10$; $\omega < \lambda/10$ and $\omega << d$

where $\eta_0 = 120\pi$. $K = \frac{2\pi}{\lambda}$

t = width of Groove
ω = sparat^n b/w Adjacent Groove
b = width of
d = ~~width~~ depth of Groove

Corrugat^n mean irregular surface mean impedance zero Nahi hoga

b_1 = aperture diamenstion
b = transmiss^n line distance
ω_c = half of the flare angle

Q→ the aperture diamens^n of parameter Horn are 12×6 cm its operating at a freq. of 6GHz find Beam width power gain & Directivity

Q- find the power gain of square horn antenna whose aperture size is 8λ

Q- find the power gain & directivity of a horn whose diamens^n are 10×5 cm operating at a freq. of 6 GHz

Ans. 1 power gain $g_p = \frac{4.5 A_a}{\lambda^2}$

$A_a = 12 \times 6 cm$

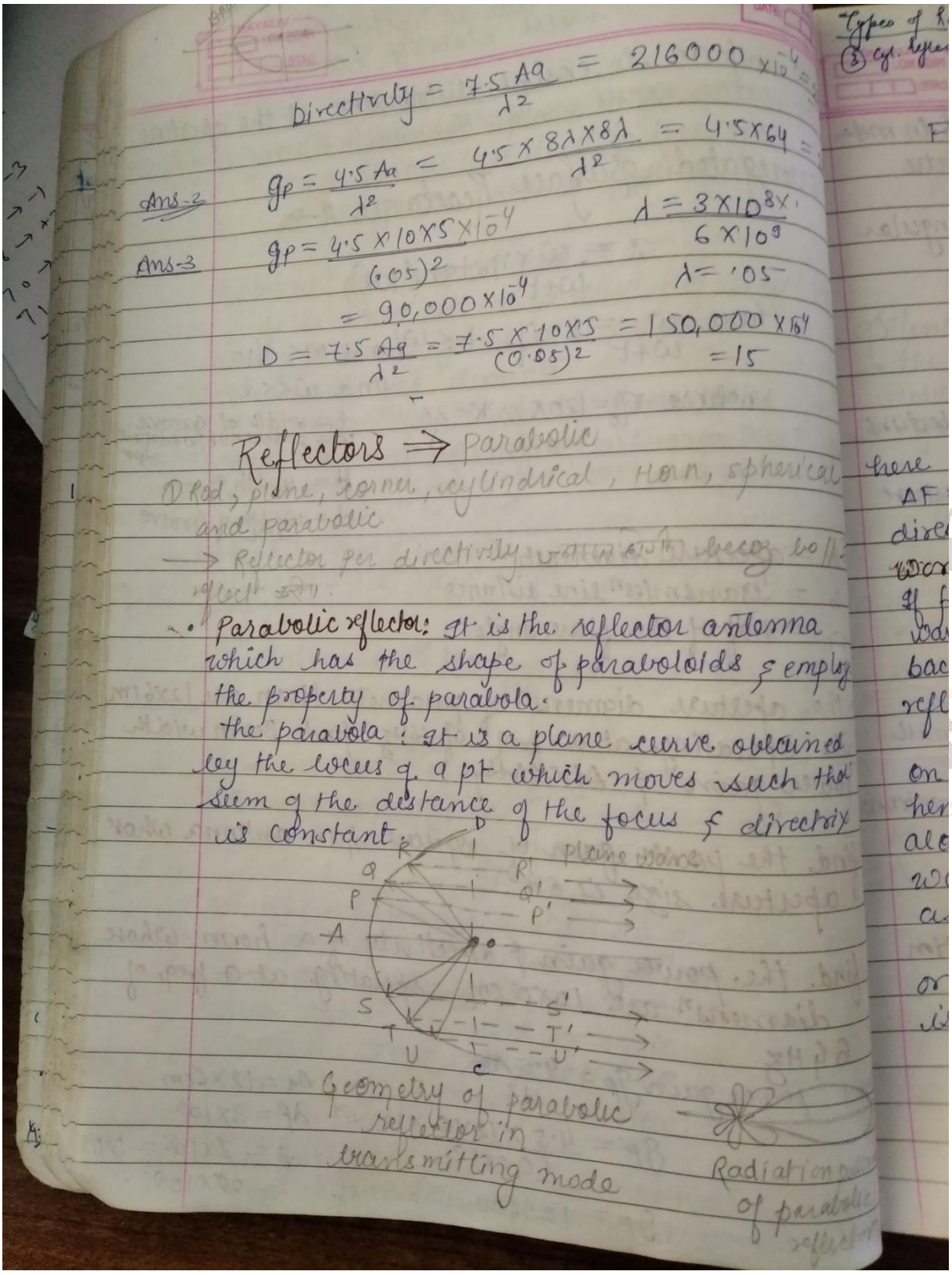
$g_p = \frac{4.5 \times 12 \times 6 \times 10 \times 10^{-4}}{(0.05)^2}$

$\lambda f = 3 \times 10^8$

$\lambda = \frac{3 \times 10^8}{2 \times 10^9} = 0.05$

$g_p = 129600 \times 10^{-4} = 12.96$

Parabolic Reflector Antenna:



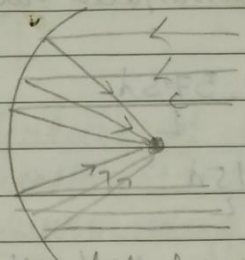
Types of Reflectors:- 1) plane reflector 2) [illegible]
3) cyl. reflector 4) parabolic reflector

VIJAYANT PAGE NO.: DATE:

$FP + PP' = FQ + QQ' = \text{Constant}$

$y^2 = 4fx$ eqn of parabola

$y^2 + z^2 = 4fx$ eqn of paraboloid



receiving parabola

Geometry of parabolic reflector in receiving mode

here AB is axis of parabola, CD mouth of dia.
AF = focal length of A is vertex, F = focus, CD = directrix, CAD is parabola.

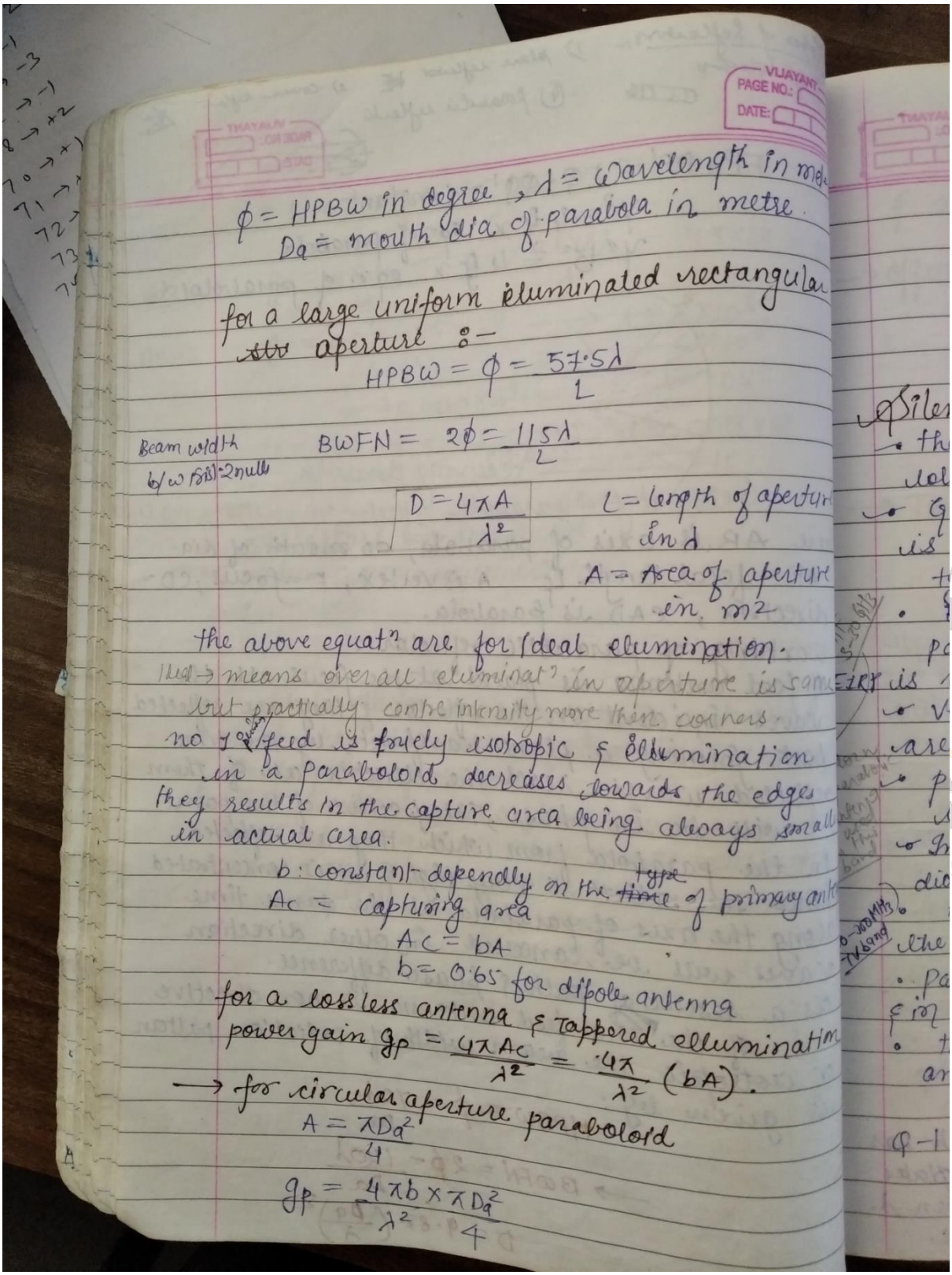
Working of parabolic reflector:
If feed antenna is placed at the focus all the waves incident on the reflector & they are reflected back forming a plane wavefront, by the time reflected waves reach the directrix all of them will be in phase, irrespective of the point on the parabola from which they are reflected. hence the radiatn is very high & it is concentrated along the axis of parabola at the same time waves will be cancelled in other direction as a result of path & phase difference.

If the 1° or feed antenna is non directive or isotropic the beam width of radiation pattern is given by:

$$HPBW = \phi = \frac{70\lambda}{Da}$$

$$\longrightarrow BWFN = 2\phi = \frac{140\lambda}{Da}$$

$$D = 9.87\left(\frac{Dq}{\lambda}\right)^2$$



ϕ = HPBW in degree, λ = wavelength in metre
D_a = mouth dia of parabola in metre.

for a large uniform illuminated rectangular aperture :-

$$HPBW = \phi = \frac{57.5\lambda}{L}$$

Beam width b/w first 2 null

$$BWFN = 2\phi = \frac{115\lambda}{L}$$

$$\boxed{D = \frac{4\pi A}{\lambda^2}}$$

L = length of aperture in d

A = Area of aperture in m^2

the above equat^n are for ideal elumination.
Ideal → means overall eluminat^n in aperture is same but practically centre intensity more then corners.
no feed is truely isotropic & illumination in a paraboloid decreases towards the edges they results in the capture area being always small in actual area.

b : constant dependly on the type of primary ant^n
A_c = capturing area

$$A_C = bA$$

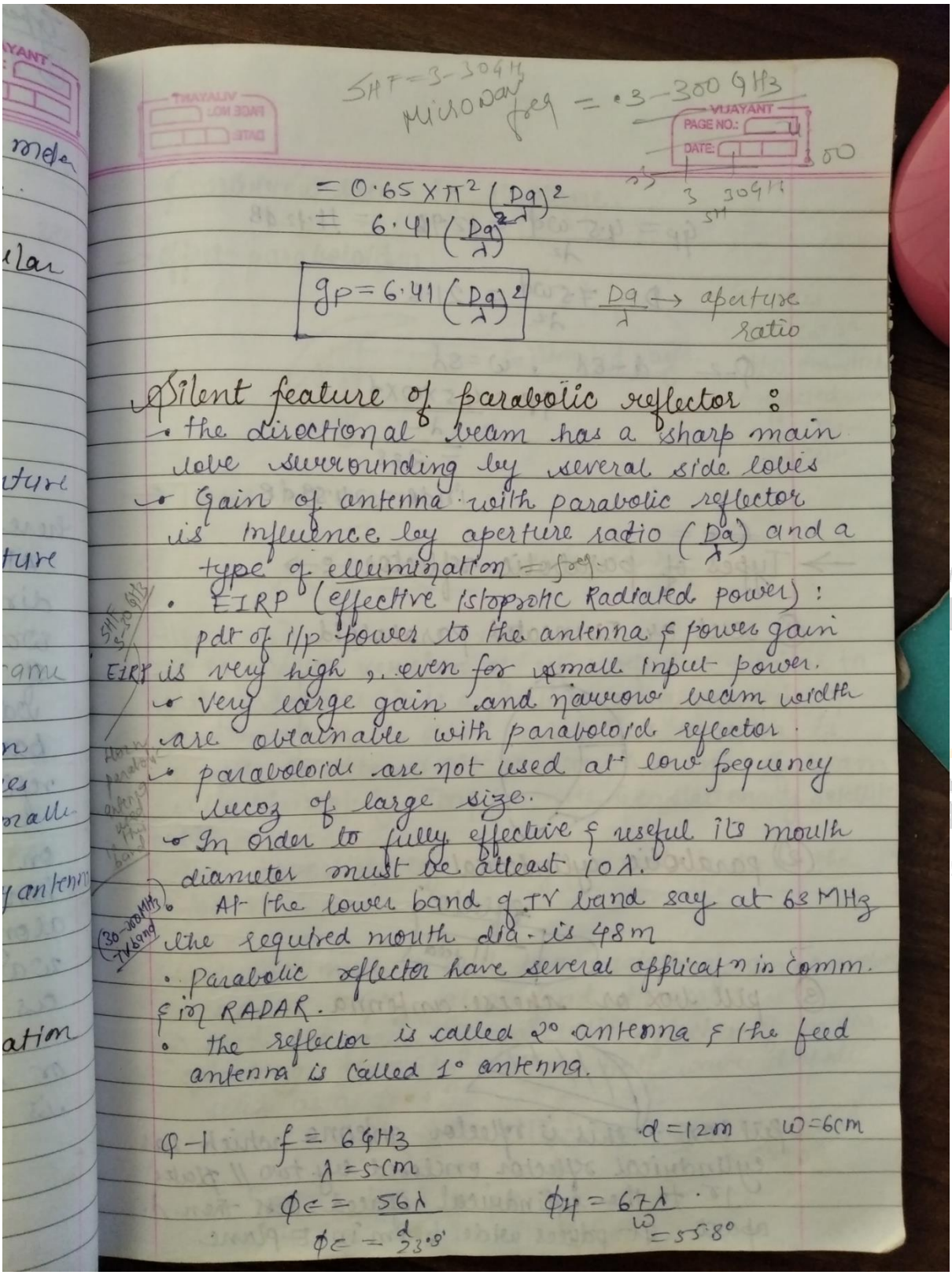
$b = 0.65$ for dipole antenna

for a lossless antenna & tappered elumination
power gain $g_p = \frac{4\pi A_c}{\lambda^2} = \frac{4\pi}{\lambda^2}(bA)$.

→ for circular aperture paraboloid

$$A = \frac{\pi D_a^2}{4}$$

$$g_p = \frac{4\pi b \times \pi D_a^2}{\lambda^2 \quad 4}$$



SHF = 3-30 GHz
Microwave freq = .3-300 GHz

$= 0.65 \times \pi^2 \left(\frac{Dq}{\lambda}\right)^2$

$= 6.41 \left(\frac{Dq}{\lambda}\right)^2$

$\boxed{g_p = 6.41 \left(\frac{Dq}{\lambda}\right)^2}$ $\frac{Dq}{\lambda}$ → aperture ratio

Silent feature of parabolic reflector :
- the directional beam has a sharp main lobe surrounding by several side lobes
- Gain of antenna with parabolic reflector is influence by aperture ratio $\left(\frac{Dq}{\lambda}\right)$ and a type of illumination = freq.
- EIRP (effective isotropic Radiated power) : pdt of i/p power to the antenna & power gain
- EIRP is very high, even for small input power.
- very large gain and narrow beam width are obtainable with paraboloid reflector.
- paraboloids are not used at low frequency bcoz of large size.
- In order to fully effective & useful its mouth diameter must be atleast 10λ.
- At the lower band of TV band say at 63 MHz the required mouth dia. is 48m
- Parabolic reflector have several applicatn in comm. & in RADAR.
- the reflector is called 2° antenna & the feed antenna is called 1° antenna.

Q-1 $f = 6$ GHz, $\lambda = 5$ cm, $d = 12$m, $w = 6$cm

$\phi_E = \frac{56\lambda}{d}$ $\phi_H = \frac{67\lambda}{w}$

$\phi_E = \frac{}{23.3^\circ}$ $= 55.8^\circ$

$G_p = \frac{4.5\,\omega d}{\lambda^2} = 12.96 = 11.12\ dB$

$D = \frac{7.5\,\omega d}{\lambda^2} = 21.6$

Q-2 $d = 8\lambda$, $\omega = 8\lambda$

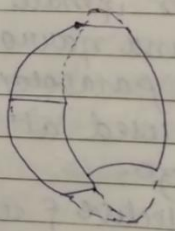
$G_p = \frac{4.5 \times \omega \times d}{\lambda^2}$

$= 288$

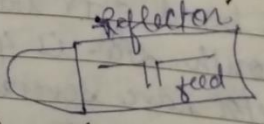
$in\ dB = 24.59\ dB$.

→ Types of parabolic reflector :→

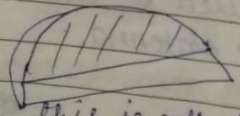
① cut or Truncated paraboloid



② parabolic cylindrical.



③ pill box or cheese antenna.

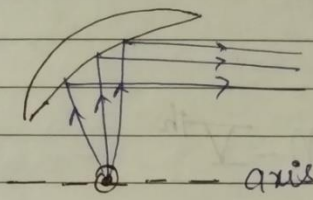


pill box : this is reflector antenna which has cylindrical reflector enclosed by two // plates ⊥r to the cylindrical spaced less than λ apart. It provides wide beam in E plane.

VIJAYANT PAGE NO.: DATE:

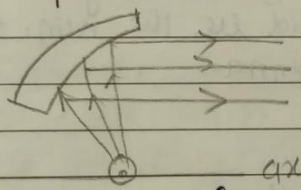
f narrow beam in H-plane.

→ offset paraboloid :



In this the collisn b/w emmitted & reflected wave does not occur

→ Torus antenna :



It is better version of offset reflector similar to cut paraboloids, it is a parabola along one axis & circular along the other axis. This antenna is useful to transmit or receive a no. of beam simultaneously. Two f80 are Geostationary satellite orbit

This is possible by placing several feeds at the focus.

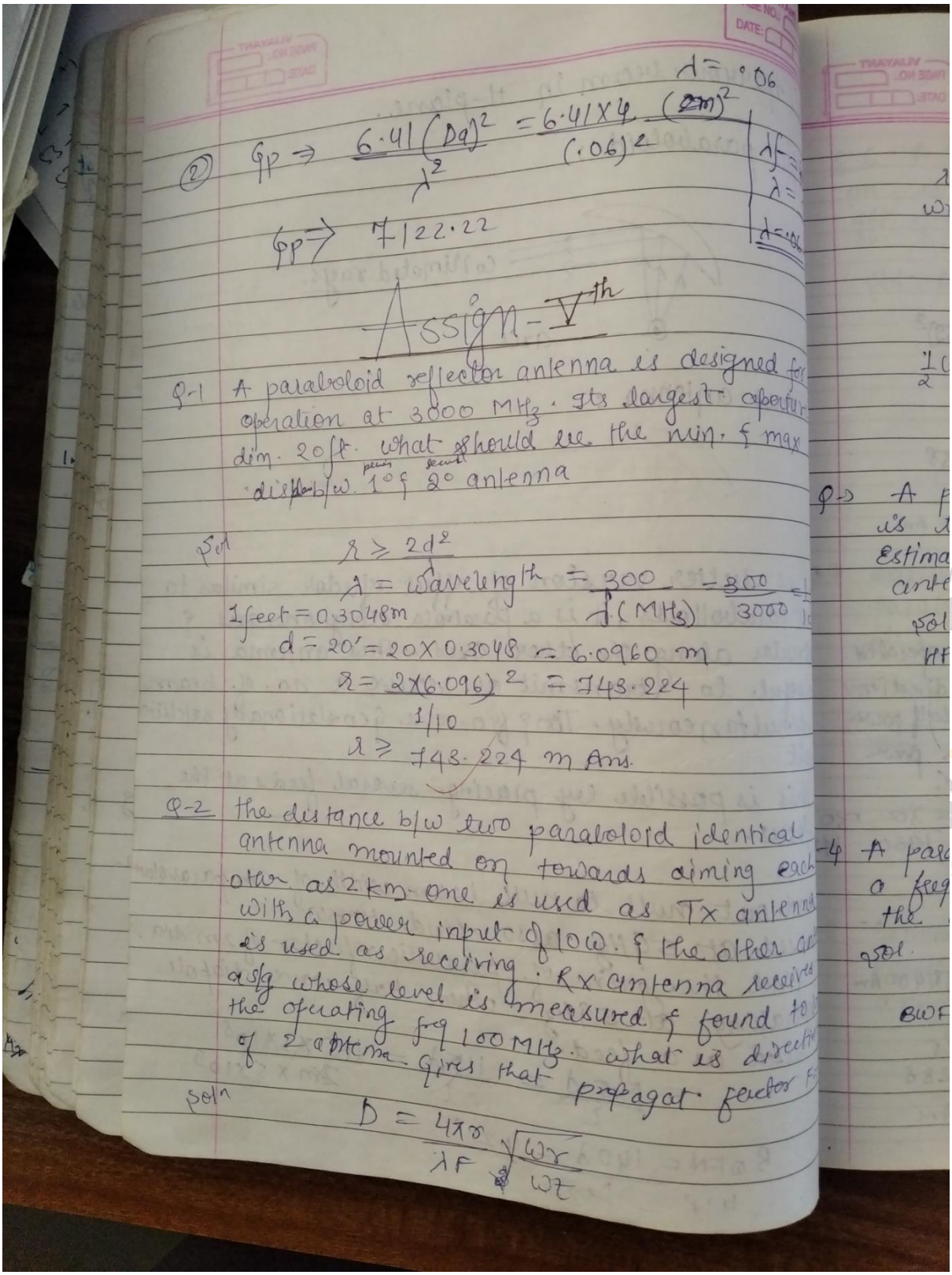
① find out null to null beam width of 2m paraboloid used at 5GHz also find HPBW.

② find the gain of parabolic reflector of 2m dia. operating at 5GHz when Half wave dipole used as a feed.

$$= \frac{115\lambda}{D} = \frac{115\lambda}{2m} = \frac{115 \times 3 \times 10^8}{2m \times 5 \times 10^9}$$

$$BWFN = \frac{140\lambda}{Da} = 4.2°$$

$$H.P. = \frac{2.1}{}$$



② $\phi_p \Rightarrow \frac{6.41(Dq)^2}{\lambda^2} = \frac{6.41 \times 4}{(.06)^2}$ (cm)^2

$\phi_p \Rightarrow 7122.22$

$\lambda = .06$

Assign - Vth

Q-1 A paraboloid reflector antenna is designed for operation at 3000 MHz. Its largest aperture dim. 20 ft. what should be the min. & max distance b/w 1° & 2° antenna

Sol $R \geq \frac{2d^2}{\lambda}$

λ = wavelength $= \frac{300}{f(MHz)} = \frac{300}{3000} = \frac{1}{10}$

1 feet = 0.3048 m

$d = 20' = 20 \times 0.3048 = 6.0960$ m

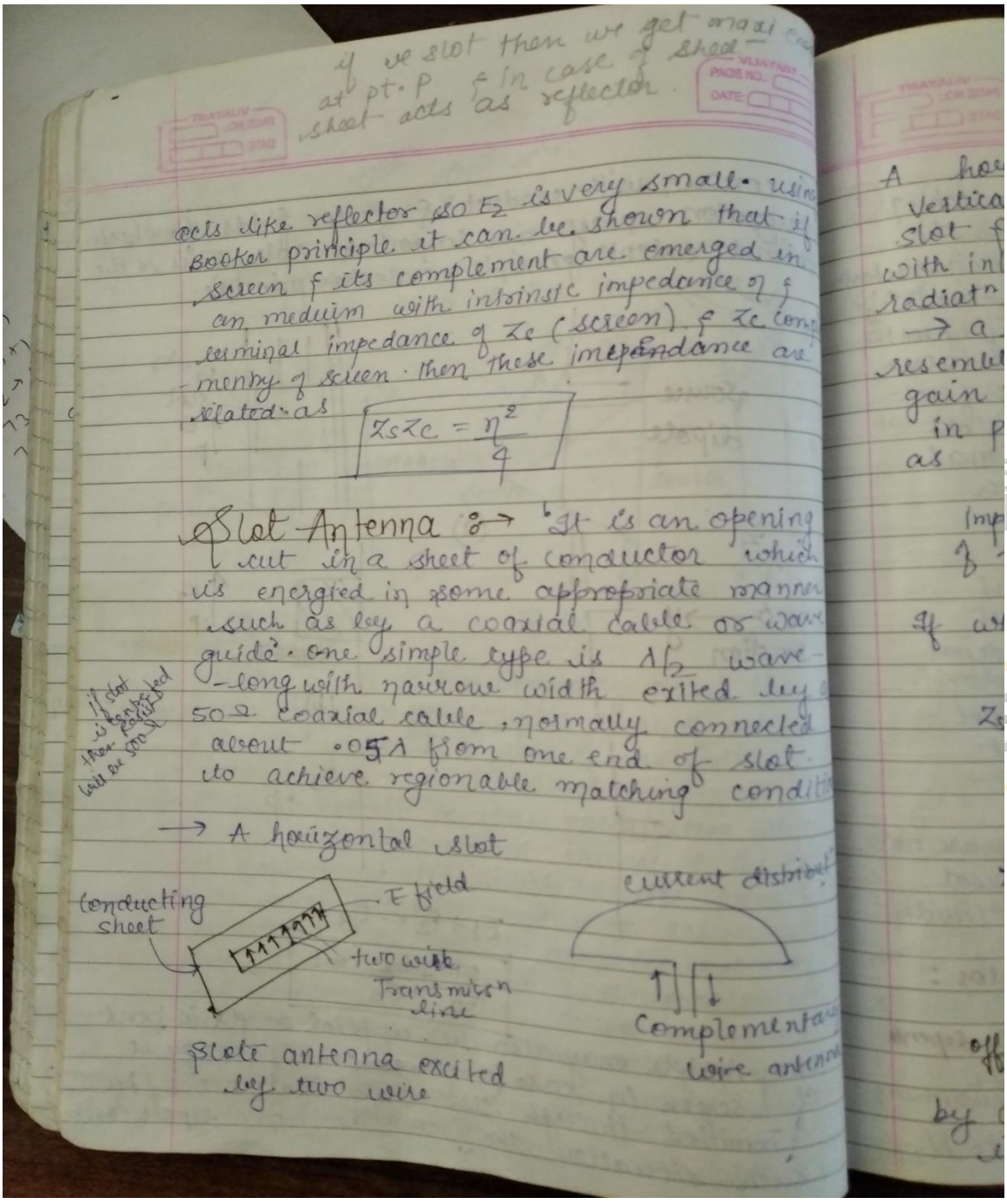
$R = \frac{2 \times (6.096)^2}{1/10} = 743.224$

$R \geq 743.224$ m Ans.

Q-2 the distance b/w two paraboloid identical antenna mounted on towards aiming each other as 2 km one is used as Tx antenna with a power input of 10 W & the other antenna is used as receiving. Rx antenna receives a sig whose level is measured & found to be the operating freq 100 MHz. what is directive of 2 antenna gives that propagat. factor F

Soln $D = \frac{4\pi}{\lambda F} \sqrt{\frac{W_r}{W_t}}$

Slot Antenna:



Horizontal slot ka polarizat^n Vertical hoga or vice-versa.

VIJAYANT PAGE NO.: DATE:

A horizontal slot iso energised produces vertical polarizat^n in a direction normal to slot & vice-versa. but if a slot is boxed with internal dimens of depth $d = \lambda/4$ then a radiat^n is outward from the opening of the box.

→ a single half wavelength slot in many ways resembles the half wave dipole in terms of of gain & radiation. Except their is a difference in polarization. The slot & dipole is related as

$$Z_s \cdot Z_d = \eta^2/4$$

(Z_s: impd. of slot; Z_d: imped. of dipole; η: free space impedance)

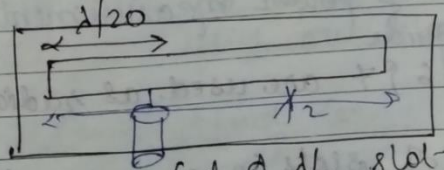
If width of the dipole is very small then

$$Z_d = 73 + j42.5\ \Omega$$

$$Z_s \cdot Z_d = \frac{(377)^2}{4}$$

$$Z_s = \frac{(377)^2}{4} \left[\frac{1 \times (73 - j42.5)}{73 + j42.5 \times (73 - j42.5)} \right]$$

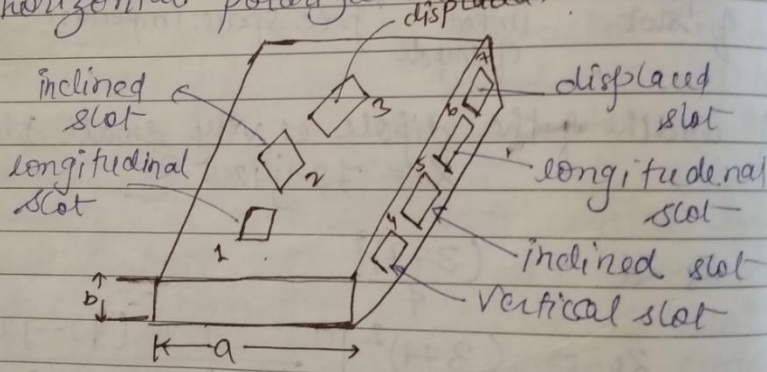
$$Z_s = 363 - j211\ \Omega$$



off center fed of $\lambda/2$ slot antenna

by changing the f/b pt. from one end of slot its impedance can be changed.

centre fed is not suitable for matching with conventional coaxial cable as the impedance of centre fed slot is characterized by high impedance. However off centre is suitable to match 50 Ω cable by choosing approxiamate feed points in order to increase the gain & directivity array of slot is used. cylindrical array of slots are found to produce omnidirectional radiation in horizontal plane with horizontal polarization.



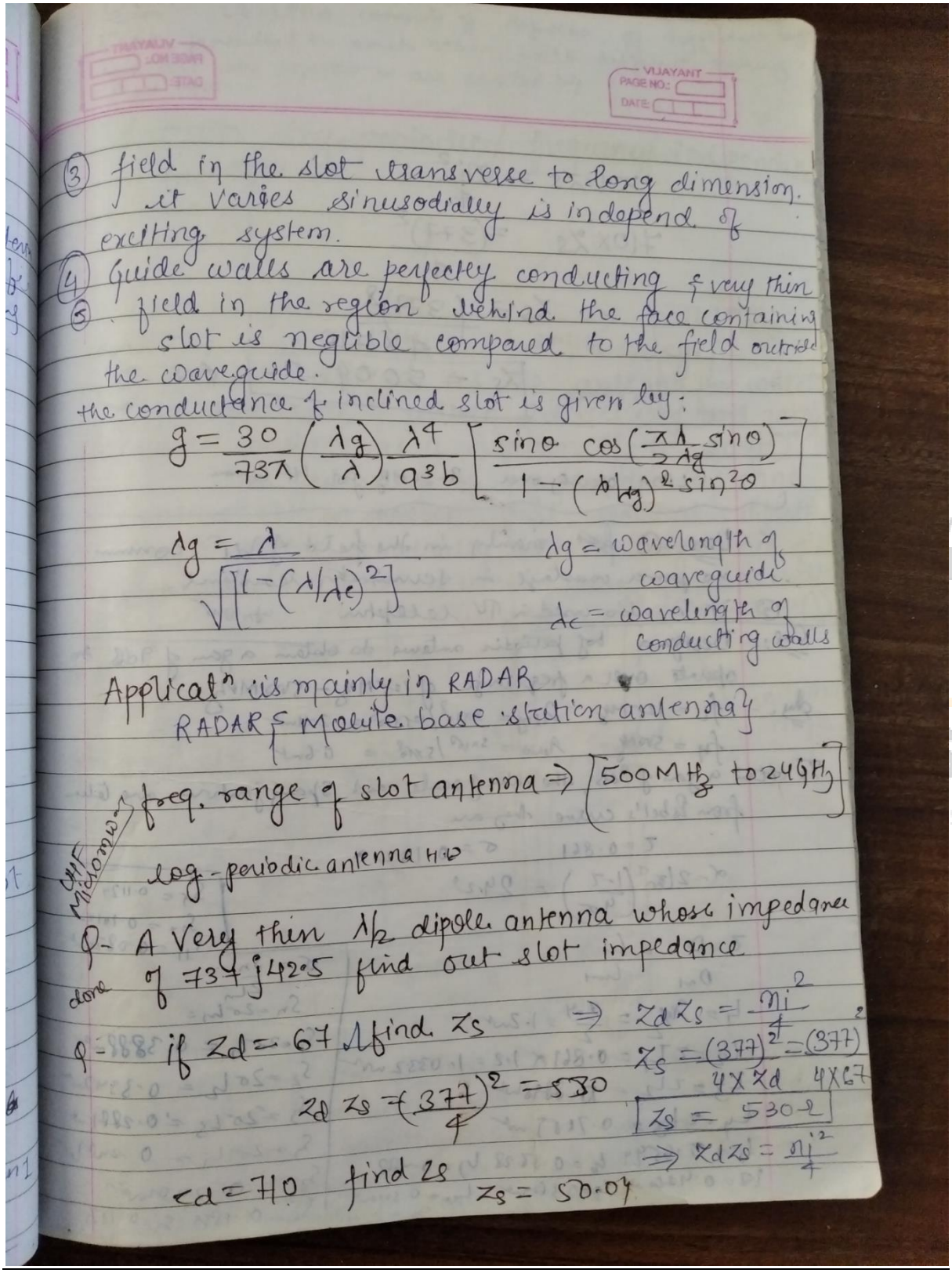
Slot Antenna

Slot 1 & 4 do not radiates hence they are not used as radiators. But they can used for the field of power measurement inside the wave guide

Slot 2, 3 5, 6 & 7 are used as radiator:

→ The theory of slots in a wave guide depends on following assumption:

1. slots are narrow $\left[\frac{L}{W}\right.$ should be greater than Very-2
2. slot length is approxia. equal to $\lambda/2$



③ field in the slot transverse to long dimension. it varies sinusodially is independ of exciting system.

④ Guide walls are perfectly conducting & very thin

⑤ field in the region behind the face containing slot is neglible compared to the field outside the waveguide.

the conductance of inclined slot is given by:

$$g = \frac{30}{73\lambda}\left(\frac{\lambda_g}{\lambda}\right)\frac{\lambda^4}{a^3 b}\left[\frac{\sin\theta\ \cos\left(\frac{\pi\lambda}{2\lambda_g}\sin\theta\right)}{1-\left(\lambda/\lambda_g\right)^2\sin^2\theta}\right]$$

$$\lambda_g = \frac{\lambda}{\sqrt{\left[1-(\lambda/\lambda_c)^2\right]}}$$

λ_g = wavelength of waveguide

λ_c = wavelength of conducting walls

Applicat^n is mainly in RADAR

RADAR & Mobile base station antenna

freq. range of slot antenna ⇒ [500MHz to 24GHz]

UHF Microwave

log-periodic antenna H.W

Q- A very thin λ/2 dipole antenna whose impedance of 73+j42.5 find out slot impedance done

Q- if $Z_d = 67\Omega$ find Z_s

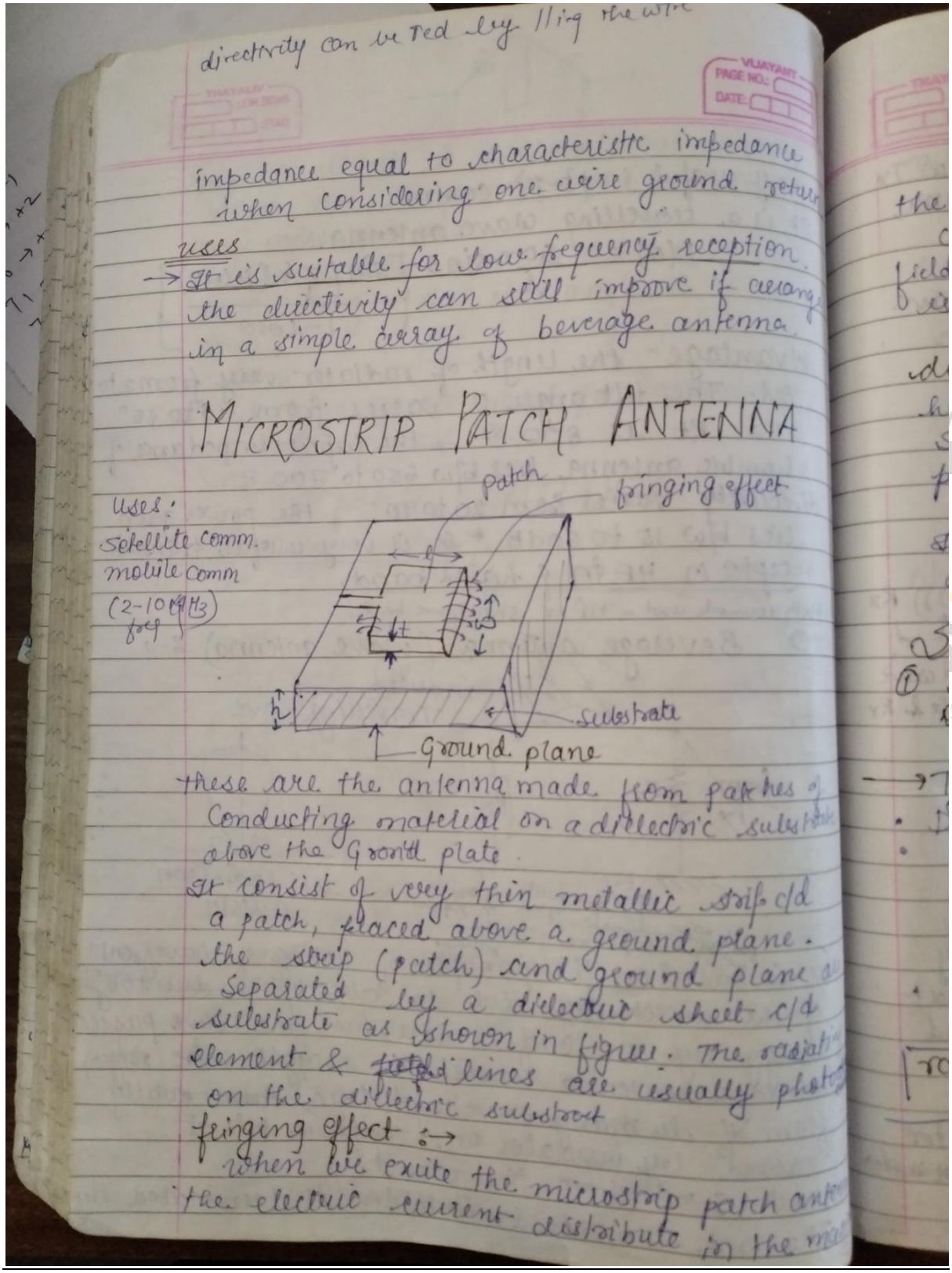
$$Z_d Z_s = \frac{\eta_i^2}{4} \Rightarrow Z_s = \frac{(377)^2}{4\times Z_d} = \frac{(377)^2}{4\times 67}$$

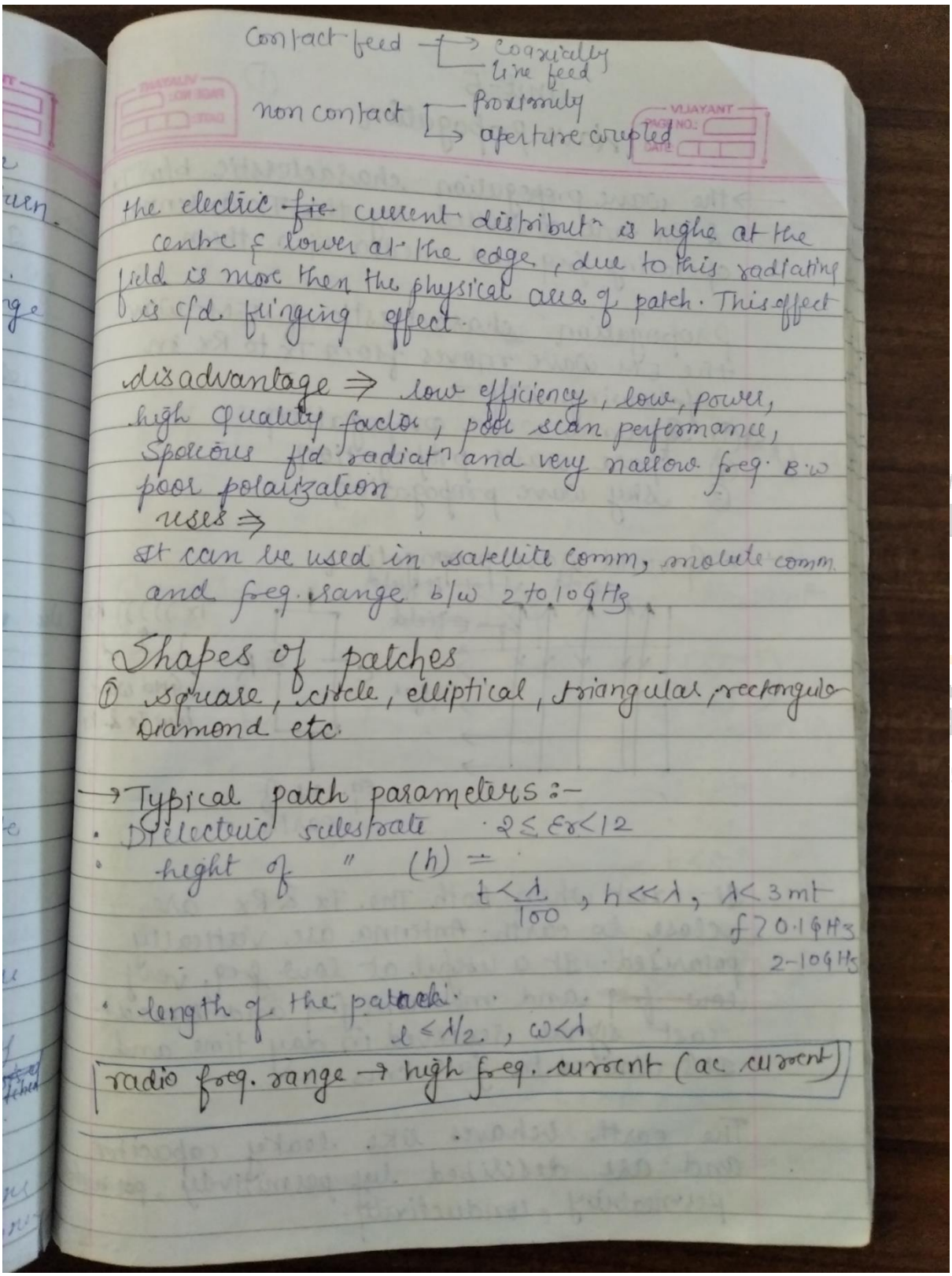
$$Z_d Z_s = \left(\frac{377}{4}\right)^2 = 530 \qquad \boxed{Z_s = 530\Omega}$$

$Z_d = 74\Omega$ find Z_s $\Rightarrow Z_d Z_s = \frac{\eta_i^2}{4}$

$Z_s = 50.07$

Microstrip Antenna:





Contact feed → coaxially line feed
non contact → Proximity, aperture coupled

the electric ~~fie~~ current distribut^n is highe at the centre & lower at the edge, due to this radiating field is more then the physical area of patch. This effect is cfd. fringing effect.

disadvantage ⇒ low efficiency, low power, high quality factor, poor scan performance, Spurious fld radiat^n and very narrow freq. B.W poor polarization

uses ⇒
It can be used in satellite comm, mobile comm. and freq. range b/w 2 to 10 GHz.

Shapes of patches
① square, circle, elliptical, triangular, rectangular, diamond etc.

→ Typical patch parameters :-
- Dielectric substrate $2 \le \varepsilon_r < 12$
- height of " (h) =

$$t < \frac{\lambda}{100}, \quad h \ll \lambda, \quad \lambda < 3\text{ mt}$$

f ? 0.1 GHz
2-10 GHz

- length of the patch

$$l \le \lambda/2, \quad \omega < \lambda$$

radio freq. range → high freq. current (ac current)

Assignment Questions of Unit-4:

Q1:What is Parabolic Reflector Antenna and Write its different type of Feeding Techniques also.

Q2: What is Horn antenna also write its Advantages and Disadvantages.

Q3:Explain slot antenna with neat and Labeled diagram.

Q4:What is Microstrip Patch antenna ,also write its designing Equation.

Q5:Write Advantages and disadvantages of Microstrip patch Antenna.

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Name of Faculty: Rajdeep Shrivastava, Saiyed Tazen Ali, Dr. Bharti Gupta

Designation: Professor

Department: Electronics & Communication

Subject: Antenna & Wave Propagation

Unit: 5

Topic: Propagation of Waves

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Unit-5
Wave Propagation

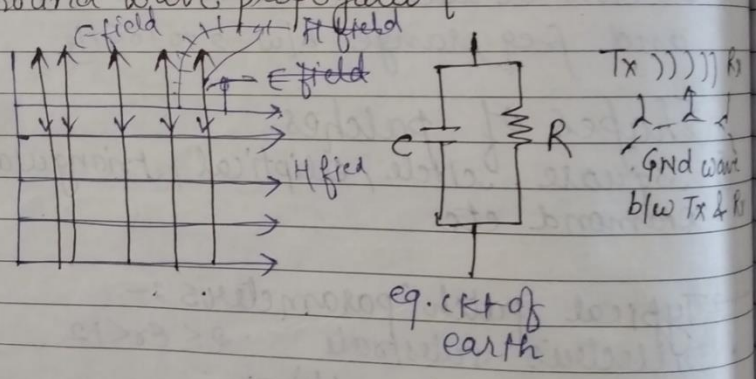
VIJAYANT PAGE NO.: DATE:

→ the wave propogation characteristic b/w Tx & Rx are controlled by the Tx antenna, operating freq. and media b/w them

propogation characteristic of EM-wave
the EM wave moves from Tx to Rx in following ways ⇒

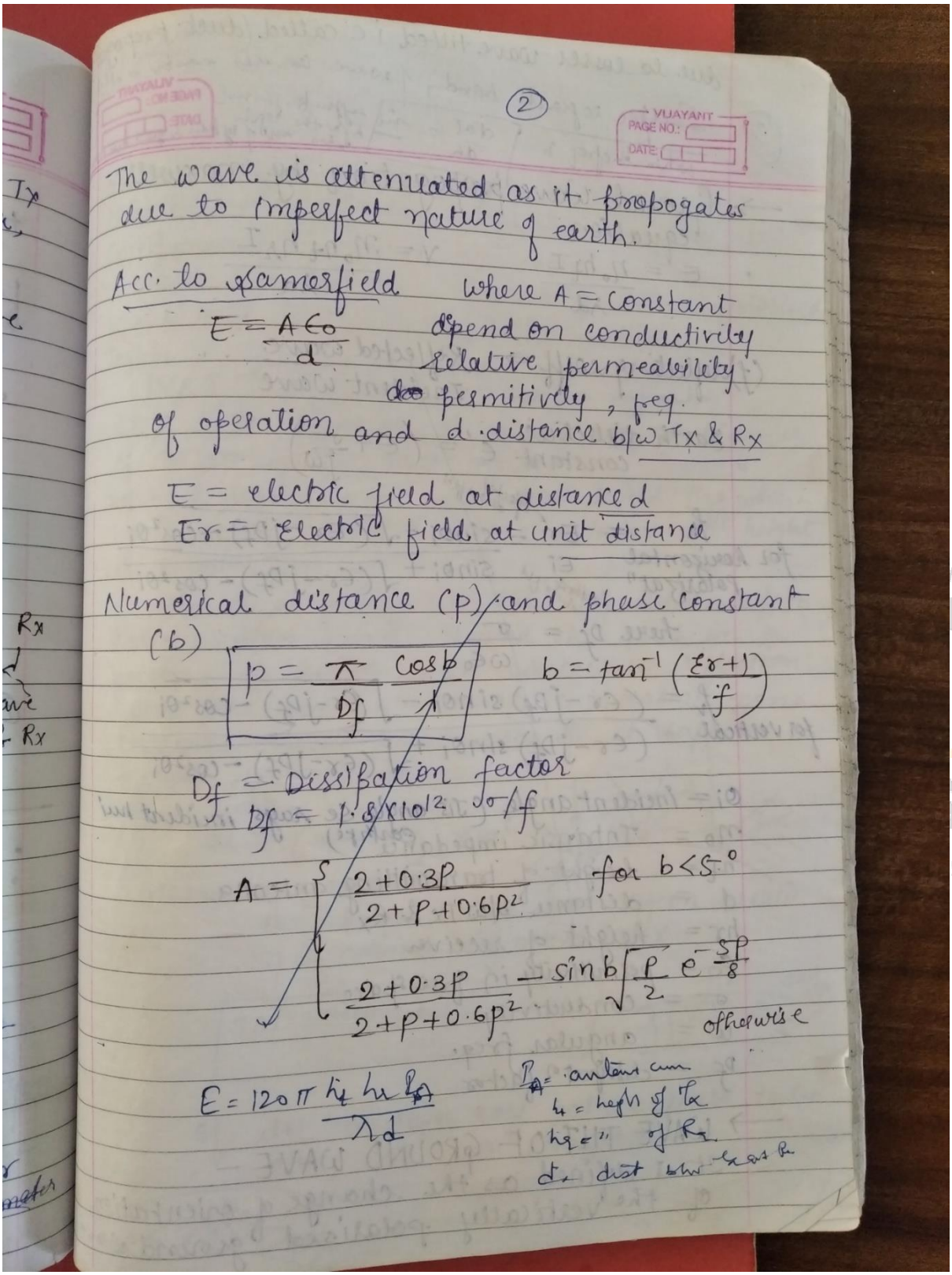
① Ground wave propogation
② Space wave propogation
③ sky wave propogation.

→ Ground wave propogation



It exist when both the Tx & Rx are close to earth. Antenna are vertically polarised. It is useful at low freq, very ~~low freq~~ and medium freq and broad-cast signal recieved in day time and It's limited in few kms

The earth behaves like leaky capacitor and are described by permitivity, ~~per~~ permeabilty, conductivity.



(2)

The wave is attenuated as it propogates due to imperfect nature of earth.

Acc. to Sommerfield $E = \frac{A \epsilon_0}{d}$ where A = constant depend on conductivity relative permeability permitivity, freq. of operation and d distance b/w Tx & Rx

E = electric field at distance d
Er = electric field at unit distance

Numerical distance (p) and phase constant (b)

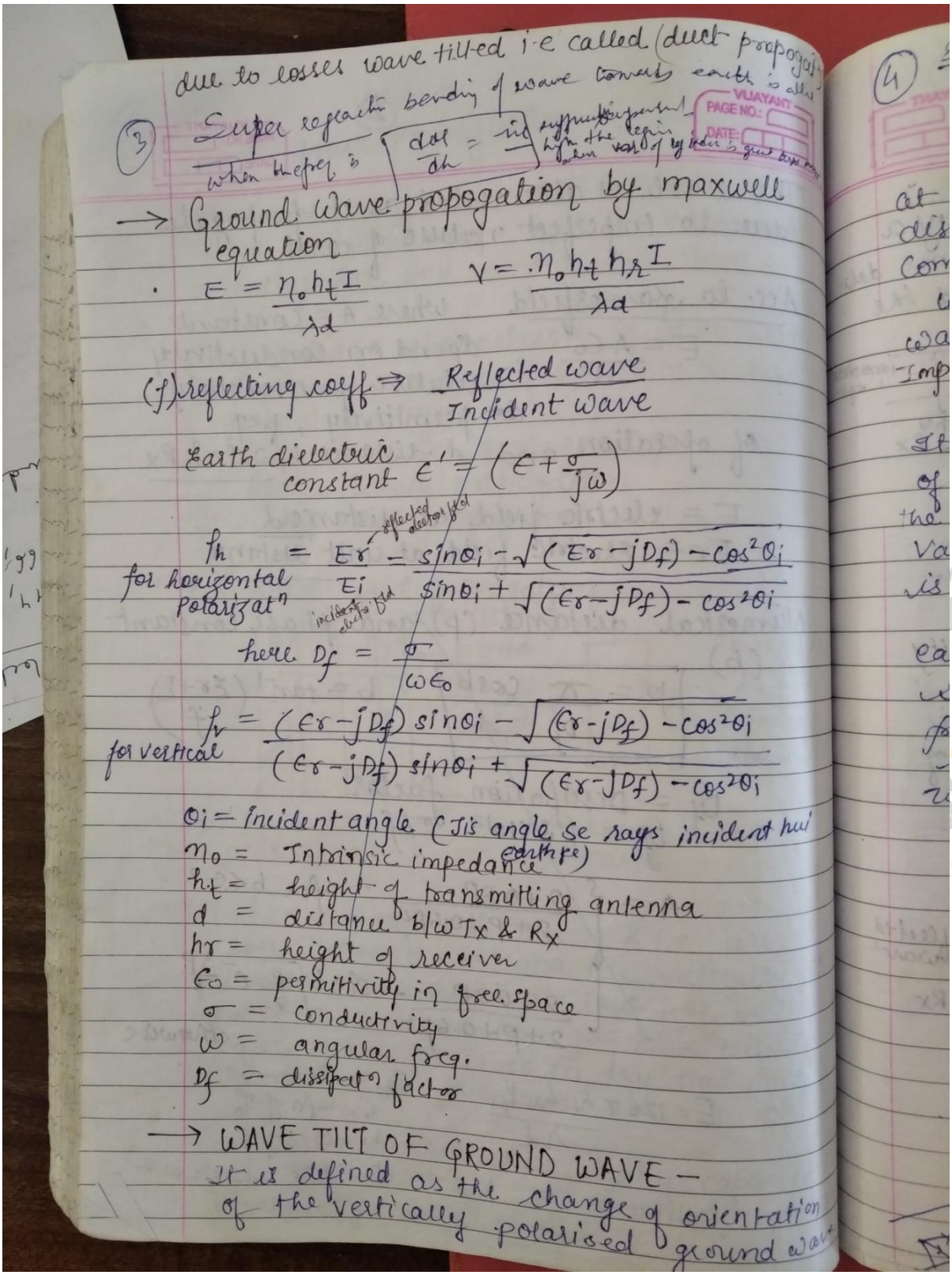
$$p = \frac{\pi}{D_f} \cos b \qquad b = \tan^{-1}\left(\frac{\epsilon_r + 1}{f}\right)$$

D_f = Dissipation factor
$D_f = 1.8 \times 10^{12} \sigma_0 / f$

$$A = \begin{cases} \frac{2 + 0.3p}{2 + p + 0.6p^2} & \text{for } b < 5^\circ \\ \frac{2 + 0.3p}{2 + p + 0.6p^2} - \sin b \sqrt{\frac{p}{2}} e^{-\frac{5p}{8}} & \text{otherwise} \end{cases}$$

$$E = \frac{120 \pi h_t h_r P_A}{\lambda d}$$

P_A = antenna gain
h_t = height of Tx
h_r = " of Rx
d = dist b/w Tx & Rx



due to losses wave tilted i.e called (duct propogation)

(3) Super refraction bending of wave towards earth is called when the freq is $\boxed{\frac{dd}{dh} = \frac{-ve}{}}$ suffice to be expressed high the region when var of ref index is great [illegible]

→ Ground wave propogation by maxwell equation

$$E = \frac{\eta_0 h_t I}{\lambda d} \qquad V = \frac{\eta_0 h_t h_r I}{\lambda d}$$

(f) reflecting coeff ⇒ $\frac{\text{Reflected wave}}{\text{Incident wave}}$

Earth dielectric constant $\epsilon' = \left(\epsilon + \frac{\sigma}{j\omega}\right)$

$$\rho_h = \frac{E_r}{E_i} = \frac{\sin\theta_i - \sqrt{(E_r - jD_f) - \cos^2\theta_i}}{\sin\theta_i + \sqrt{(E_r - jD_f) - \cos^2\theta_i}}$$

for horizontal polarizatⁿ

reflected electric field

incident electric field

here $D_f = \frac{\sigma}{\omega\epsilon_0}$

$$\rho_v = \frac{(E_r - jD_f)\sin\theta_i - \sqrt{(E_r - jD_f) - \cos^2\theta_i}}{(E_r - jD_f)\sin\theta_i + \sqrt{(E_r - jD_f) - \cos^2\theta_i}}$$

for vertical

θ_i = incident angle (Jis angle se rays incident hui earth pe)
η_0 = Intrinsic impedance
h_t = height of transmitting antenna
d = distance b/w Tx & Rx
h_r = height of receiver
ϵ_0 = permitivity in free space
σ = conductivity
ω = angular freq.
D_f = dissipatⁿ factor

→ WAVE TILT OF GROUND WAVE –
It is defined as the change of orientation of the vertically polarised ground wave

(4) Effective radius of Earth is defined as equivalent radius of the earth used to correct atmospheric refraction approx. as $r \propto h$

at the surface of the earth. It causes power dissipation exist both horizontal and vertical components of electric field.

Wave tilt changes originally vertical polarised wave into elliptically polarised wave.

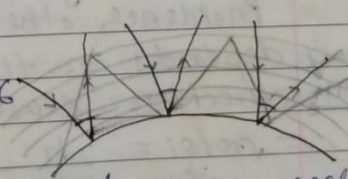
Imp –

DUCT PROPOGATION ⇒ Super refraction

It is a phenomenon of propogation making use of the atmospheric duct region.

the duct region exist b/w two levels the where variation of modified refractive index with height is minimum.

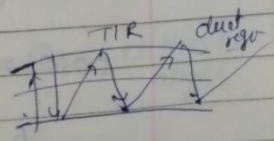
In duct propogation the ray which is // to earth surface travels around the earth in a series of hopes with succesive reflection from the earth. Temperature inversion zone creates duct phenomenon & it happens when $\frac{dM}{dh}$ is –ve



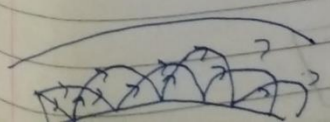
$$M = \left(n - 1 + \frac{h}{a}\right) \times 10^6$$

where a = radius
h = height where duct region creates
n = normal refractive index

$$\boxed{\text{Std. value } \frac{dM}{dh} = 0.036}$$



If $\frac{dM}{dh} = 0$ then ray path appears to be a straight line.

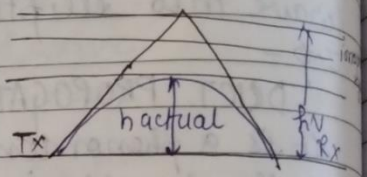


$\angle i = 0$, $N = N_{max}$ & $f = f_c$

(5)

(1) Virtual height —

It's defined as the height is reached by a short pulse of energy which has the same time as the original wave. It is useful to find the the incident angle (α_i). or θ_i required for the wave to return the earth at a specified point.



(2) Critical - frequency ⇒

It is defined as the heighest freq. that will reflected to earth by that layer at vertical incidence

$u = \frac{\sin\theta}{\sin r} = \sqrt{1 - \frac{81N}{f^2}}$

$f_c = 9\sqrt{N}$; N = electron density

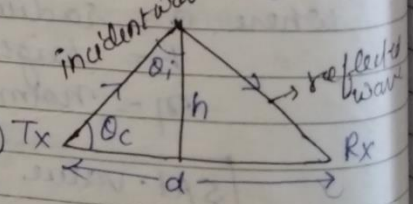
Max^m usable frequency ⇒

It is the highest freq of wave that is reflected by the layer at an angle of incidence other than normal MUF depends on time of day, distance, direction, season & solar activity.

MUF range 8-30 MHz

$\cos\theta_i = \frac{h}{\sqrt{h^2 + d^2/4}}$ ($\theta_i = 90 - \theta_c$)

$\sin\theta_c = \frac{h}{\sqrt{h^2 + d^2/4}}$



$\cos\theta_i = \frac{f_c}{MUF}$

$\frac{h}{\sqrt{h^2 + d^2/4}} = \frac{f_c}{MUF}$

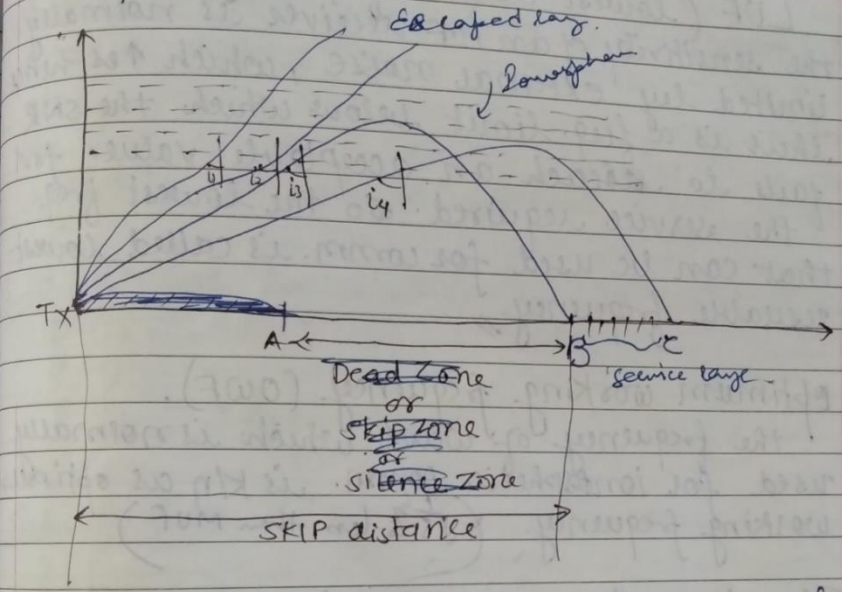
$MUF = \frac{f_c\sqrt{h^2 + \frac{d^2}{4}}}{h}$

$$\boxed{MUF = f_c\sqrt{\frac{d^2}{4h^2} + 1}}$$

6

VIJAYANT PAGE NO.: DATE:

skip distance ⇒



the distance at which the surface wave become negligible and the distance at which first wave return to earth from the ionospheric layer → their is a zone which is not covered by any wave (neither GND wave nor sky wave), so zone is called skip zone. & the distance across it is the skip distancing.

Relation b/w MUF & skip distance ⇒

$$\text{skip distance } ds = \frac{2h}{\tan\theta_c}$$

θ_c = critical angle

$$ds = 2h\sqrt{\left(\frac{f_{muf}}{f_c}\right)^2 - 1}$$

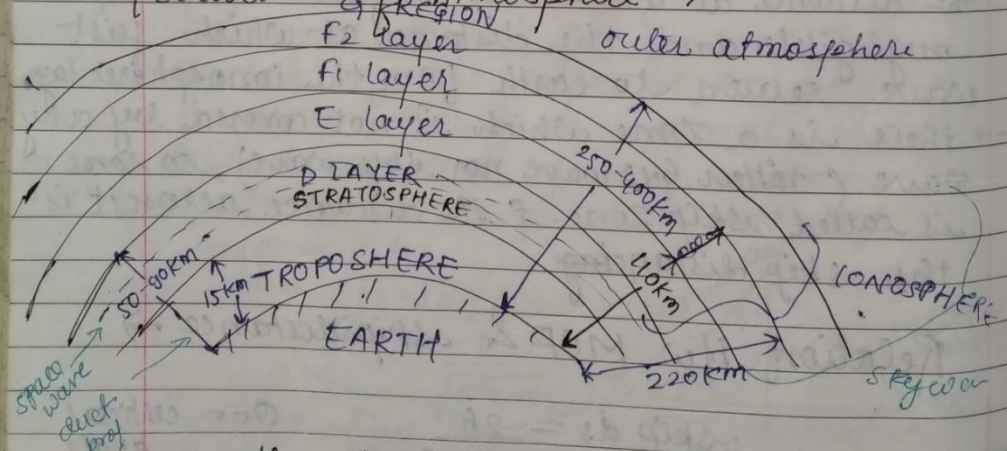
or when operating freq. is reduced from MUF the absorption of the wave in ionosphere increases, and the Rx signal strength become less.

VIJAYANT PAGE NO.: DATE:

LUF (lowest usable frequency) :→
the sensitivity of an HF receiver is normally limited by external noise, which ↑es hence there is a freq. limit below which the SNR fails to reach an acceptable value for the service required. So the lowest freq. that can be used for comm. is called lowest usable frequency.

Optimum working frequency (OWF).
the frequency of wave which is normally used for ionospheric comm. is K/n as optimum working frequency. (15% less than MUF)

Structure of Atmosphere ⇒



Q → If critical freq. of ionised layer is 9.5 MHz find the e⁻ density of the layer

Sol ⇒ $f_c = 9.5$ MHz

$f_c = 9\sqrt{N}$

$(1.5 \times 10^6)^2 = 81\ N$

$N = 27 \times 10^9$ e⁻/cm³

Assignment Questions of Unit-5:

Q1: What is Ground Wave Propagation?

Q2: Explain the concept of Sky Wave Propagation.

Q3: Write short notes on:

(a)MUF (b) LUF.

Q4: Write short notes on:

(a)Skip distance (b) Critical Frequency.

Q5: What do you understand by Duct Propagation?

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