





ELECTOMAGNETIC WAVES



ELECTROMAGNETIC WAVES

• A WAVE IS A CARRIER OF ENERGY OR INFORMATION, WHICH IS A FUNCTION OF TIME AND SPACE.

• MAXWELL PREDICTED THE EXISTENCE OF EM WAVES AND ESTABLISHED IT THROUGH MAXWELL'S EQUATION.

••EXAMPLES : RADIO, RADAR BEAMS, TV SIGNALS etc.



ELECTROMAGNETIC WAVES

•OSCILLATIONS WHICH PROPAGATE THROUGH FREE SPACE WITH THE VELOCITY OF LIGHT (i.e.3x10⁸ m/s)

•THESE ARE TRANSVERSE WAVES (OSCILLATIONS PERPENDICULAR TO DIRECTION OF PROPAGATION)

•IT HAS ELECTRIC FIELD AND MAGNETIC FIELD WHICH ARE HENCE PERPENDICULAR TO DIRECTION OF PROPAGATION AND ALSO MUTUALLY PERPENDICULAR.







EM WAVES SPREAD UNIFORMLY IN ALL DIRECTIONS IN FREE SPACE FROM A POINT SOURCE.

THE PLANE JOINING ALL THE POINTS OF IDENTICAL PHASE AT A PARTICULAR INSTANT IS CALLED A WAVE FRONT.

IN FREE SPACE, IT IS SPHERICAL.



DEFINITIONS



ELECTROMAGNETIC RADIATION

POWER ESCAPING INTO SPACE IS SAID TO BE RADIATED & IS GOVERNED BY THE CHARACTERISTICS OF FREE SPACE.

FREE SPACE

SPACE THAT DOES NOT INTERFERE WITH THE NORMAL RADIATION & PROPAGATION OF RADIO WAVES.

IT DOES NOT HAVE MAGNETIC OR GRAVITATIONAL FIELDS, SOLID BODIES OR IONISED PARTICLES.



• **ISOTROPIC SOURCE** :- WHICH RADIATES EQUALLY IN ALL DIRECTIONS IN SPACE.

• ISOTROPIC MEDIUM :- IN WHICH VELOCITY OF RADIATION IS CONSTANT AT ALL POINTS (AS IN FREE SPACE). THIS MAKES THE WAVE FRONT SPHERICAL.



WAVES IN FREE SPACE



WAVES IN FREE SPACE





P & Q are the two wave fronts. The power ' P_t ' at point 'O' is transmitted in all directions and is called isotropic radiation.

The power density of a wave front 'P' is different from the power density of the wave front 'Q'



POWER DENSITY = RATIO OF RADIATED POWER PER UNIT ARC. α 1/(SQUARE OF

DISTANCE

FROM SOURCE) (INVERSE SQUARE LAW)

$\rho = P_t/4\pi r^2$

WHERE r= POWER DENSITY AT A DISTANCE 'r' FROM AN ISOTROPIC SOURCE

 $P_t = TRANSMITTED POWER$



ELECTRIC FIELD α SQUARE ROOT OF
 INTENSITY OF AN POWER DENSITY
 EM WAVE AT THAT POINT.

(SIMILAR TO: VOLTAGE α SQUARE ROOT OF POWER)

•IT MAY BE SHOWN $\epsilon = \frac{\sqrt{30} P_t}{r}$ VOLTS /m



•IN ANALOGY TO THE RELATION BETWEEN POWER AND VOLTAGE, IT MAY BE SHOWN $\rho = \frac{\epsilon^2}{z}$ WHERE z = CHARACTERISTICIMPEDANCE OF FREE SPACE

$$\therefore \mathbf{z} = \underline{\varepsilon^2} = (\underline{30 P_t}) / (Pt/4\pi r^2)$$

$$\rho r^2$$

or $z = 120 \pi$

or z = 377 ohms





- IN ALL COMMUNICATIONS LIKE
- POLICE RADIO TV
 SATELLITE IONOSPHE
 TROPOSPHERIC WIRELESS
 CELLULAR MOBILE CO

TV IONOSPHERIC WIRELESS MOBILE COMMUNICATIONS

IN ALL TYPES OF RADARS LIKE

- DOPPLER RADAR
- AIRPORT SURVEILLANCE RADAR
- WEATHER FORECASTING RADAR
- REMOTE SENSING RADAR
- GROUND MAPPING RADAR
- FIRE CONTROL RADAR

ALSO USED IN RADIO THERAPY, MW OVENS etc.



FREQUENCY ALLOCATIONS

FREQUENCY	DESIGNATION	
30 TO 300 HZ	EXTREMELY LOW FREQUENCY	
300 TO 3000 HZ	VE FREQUENCY (VF)	
3 TO 30 KHZ	VERY LOW FREQUENCY (VLF)	
30 TO 300 KHZ	LOW FREQUENCY (LF)	
300 TO 3000 KHZ	MEDIUM FREQUENCY (MF)	
3 TO 30 MHZ	HIGH FREQUENCY (HF)	
30 TO 300 MHZ	VERY HIGH FREQUENCY (VHF)	
300 TO 3000 MHZ	ULTRA HIGH FREQUENCY (UHF)	
3 TO 30 GHZ	SUPER HIGH FREQUENCY (SHF)	
30 TO 300 GHZ	EXTREMELY HIGH	
FREQUENCY(EHF)		



Propagation mechanism

Frequency	Mechanism of propagation
< 500 kHz	Surface wave
500 kHz – 1.5 MHz	Surface wave for short distance
	Ionospheric wave for longer distance
1.5 MHz – 30 MHz	Ionospheric wave
> 30 MHz	Space wave (line of sight)



Radio frequency bands used in Railways

Frequency range	Band	Application	
VHF	30 MHz – 300 MHz	Walkie-talkie	
UHF	300 MHz – 3 GHz	2 GHz UHF links,	
		Train radio through leaky coaxial cable in tunnels, GSM & GSM-R	
SHF (MW)	3GHz – 30 GHz	7 GHz MW,	
		18 GHz MW	
HF communication (3 MHz-30 MHz band) was once used in Railways; Now obsolete			



GSM & GSM-R

Туре	Up link	Down link
	(MS to BTS)	(BTS to MS)
GSM-900	890-915 MHz	935-960 MHz
GSM-1800	1710-1785 MHz	1805-1880 MHz
GSM-1900	1850-1910 MHz	1930-1990 MHz
GSM-R	876-915 MHz	921-960 MHz



POLARISATION OF A WAVE



POLARISATION OF A WAVE

THE POLARISATION OF A WAVE IS DEFINED AS THE DIRECTION OF THE ELECTRIC FIELD AT A GIVEN POINT OF TIME

TYPES OF POLARISATION

- LINEAR POLARISATION

 i) HORIZONTAL POLARISATION
 ii) VERTICAL POLARISATION
 iii) THETA POLARISATION
- CIRCULAR POLARISATION
- ELLIPTICAL POLARISATION



A WAVE IS SAID TO BE LINEARELY POLARISED IF THE ELECTRIC FIELD LIES WHOLLY IN ONE PLANE CONTAINING THE DIRECTION OF PROPAGATION.

IF $E_y=0$ and E_x is present, when a wave travels in z-direction with e-field lying in XY-plane, it is said to be horizontally polarised.

IF $E_x=0$ and ey is present, then the wave is vertically polarised.

IF E_x AND E_y ARE PRESENT AND ARE IN PHASE, THEN THE WAVE IS THETA POLARISED.



FOR HORIZONTALLY POLARISED WAVE, THE ELECTRIC FIELD LIES IN A PLANE PARALLEL TO EARTH'S SURFACE.

ALL THE ELECTRIC INTENSITY VECTORS ARE VERTICAL FOR A VERTICALLY POLARISED WAVE.

THE DIRECTION OF POLARISATION IS SAME AS THE DIRECTION OF ANTENNA.

THUS, VERTICALLY POLARISED WAVE IS RADIATED BY VERTICAL ANTENNA.

HORIZONTALLY POLARISED WAVE IS RADIATED BY HORIZONTAL ANTENNA.



PROPAGATION CHARACTERISTICS OF EM WAVES



PROPAGATION CHARACTERISTICS OF EM WAVES

- THE WAVE PROPAGATION CHARACTERISTICS BETWEEN TRANSMITTER AND RECEIVER ARE CONTROLLED BY

 TRANSMITTING ANTENNA
 OPERATING FREQUENCIES
 MEDIA BETWEEN TX AND RX
- THE EM WAVE RADIATED BY THE TX ANTENNA IS A TRANSVERSE WAVE.



IT MOVES FROM TX TO RX IN THE FOLLOWING WAYS

- A PART OF THE WAVE TRAVELS ALONG OR NEAR THE SURFACE OF THE EARTH. THIS IS GROUND WAVE.
- SOME WAVES NEITHER FOLLOWS THE EARTH, NOR MOVES TOWARD THE SKY, BUT TRAVELS DIRECTLY FROM THE TX TO THE RX ANTENNA. THESE ARE <u>SPACE OR</u> <u>TROPOSPHERIC WAVES</u>.
- 3. SOME WAVES TRAVEL UPWARDS TOWARDS THE SKY AND GET REFLECTED BACK TO THE RECEIVER.

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• **GROUND WAVES** ARE USEFUL FOR COMMUNICATION AT VLF, LF & MF RANGES (BROADCAST SIGNALS RECEIVED DURING DAY)

• **SPACE WAVES** ARE USEFUL ABOVE THE FREQUENCY OF 30 MHZ (FM RECEPTION IS NORMALLY BY SPACE WAVE PROPAGATION)

• **SKY WAVES** ARE USEFUL FOR FREQUENCIES BETWEEN 2 TO 30 MHZ (RESPONSIBLE FOR LONG DISTANCE COMMUNICATION)



FACTORS INFLUENCING EM WAVE PROPAGATION



FACTORS INFLUENCING EM WAVE PROPAGATION

- 1. EARTH'S CURVATURE IN TERMS OF CONDUCTIVITY, PERMITTIVITY AND PERMEABILITY.
- 2. FREQUENCY OF OPERATION.
- 3. POLARISATION OF TRANSMITTING ANTENNA.
- 4. HEIGHT OF TRANSMITTING ANTENNA.
- 5. TRANSMITTER POWER.
- 6. CURVATURE OF THE EARTH.



- 8. ELECTRICAL CHARACTERISTICS OF THE ATMOSPHERE IN THE TROPOSPHERIC REGION.
- 9. MOISTURE CONTENT IN THE TROPOSPHERE.
- 10.CHARACTERISTICS OF THE IONOSPHERE.
- 11.EARTH'S MAGNETIC FIELD.
- 12.REFACTIVE INDEX OF TROPOSPHERE AND IONOSPHERE.
- 13.DISTANCE BETWEEN TRANSMITTER AND RECEIVER.

14.ROUGHNESS AND TYPE (HILLY, FOREST, SEA OR RIVER) OF THE EARTH.



GROUND WAVE



GROUND WAVE

- IT PROPAGATES FROM TRANSMITTER TO RECEIVER BY GLIDING OVER THE SURFACE OF THE EARTH.
- IT EXISTS WHEN 1) BOTH TRANSMITTING AND RECEIVING ANTENNAS ARE CLOSE TO THE SURFACE OF THE EARTH.
 - 2) THE ANTENNAS ARE VERTICALLY POLARISED.



- IT IS OF IMPORTANCE AT MF (BROADCAST) AND LF
- IT IS LIMITED TO ONLY A FEW KM.

- •FIELD STRENGTH VARIES WITH CHARACTERISTICS
- OF THE EARTH AND IS INVERSELY PROPORTIONAL
- TO THE SQUARE OF THE DISTANCE AND THE FREQUENCY



• REQUIRES RELATIVELY HIGH TRANSMITTER POWER.

- •NOT AFFECTED BY THE CHANGES IN ATMOSPHERIC CONDITIONS.
- •CAN BE USED TO COMMUNICATE BETWEEN SHIP-
 - TO-SHIP, SHIP-TO-SHORE, MARITIME MOBILE COMMUNICATION AND RADIO NAVIGATION.
- •HORIZONTALLY POLARISED ANTENNAS ARE NOT PREFFERED, AS THE HORIZONTAL COMPONENT OF

THE ELECTRIC FIELD IN CONTACT WITH THE



SKY WAVES OR

IONOSPHERIC WAVES


SKY WAVES OR IONOSPHERIC WAVE PROPAGATION

• IT IS THE UPPER PORTION OF THE ATMOSPHERE (BETWEEN APPROX.50KM AND 400KM ABOVE THE EARTH)

•IN THIS REGION, GASES GET IONISED BY ABSORBING LARGE QUANTITIES OF RADIATION AND FORM DIFFERENT LAYERS.

• IONISATION INCREASES WITH ALTITUDE.

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•The amount of ionization depends upon the rate of formation of the ions and the rate of recombination.

•At lower altitudes since the atmospheric pressure is large the rate of combination is large so that ionization is small.

•At higher altitudes since the atmospheric pressure is low the rate of re-combination is small so that ionization



<u>D-Layer</u> 50Km – 90Km above the earth's surface. It will disappear at night..

- <u>E-Layer</u> 110Km above the earth's surface.
- F1 & F2 220Km and 250-350Km
 respectively. At night these two layers make one layer. The ionization of all the layers is maximum at day time and minimum at night











MECHANISM OF IONOSPHERIC PROPAGATION

- As the wave passes through the ionosphere, the ionisation density increases, and the refractive index of the layer decreases.
- Hence, the incident wave is gradually bent away from the normal.
- At a certain point, it finally becomes parallel to the layer and then bends downwards and returns from the ionised layer.
- The bending of a wave by the ionosphere follows optical laws (Snell's Law):

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 \mu = (\sin i)/(\sin r) 
where i = angle of incidence at the lower edge
of the atmosphere
r = angle of refraction.
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CHARACTERISTIC PARAMETERS OF IONOSPHERIC PROPAGATION

 <u>Virtual height</u>: It is defined as the height that is reached by a short pulse of energy which has the same time delay original wave. Virtual height of a layer is always greater than actual height.





2. <u>Critical Frequency</u>: F_c for a given layer is defined as the highest frequency that will be reflected to earth by that layer at vertical incidence.

It is the limiting frequency below which a wave is reflected and above which it penetrates through an ionospheric layer at normal incidence.

Refractive Index, by definition, is equal to square root of dielectric constant, i.e.

$$\mu = \sqrt{\epsilon_r}$$

i.e (sin i)/(sin r) = 1- (81N/F²)

Here N = Electron Density

F = Frequency in KHz



For the wave to be reflected back, r=90° i.e. sin i = $\sqrt{1-(81N/F^2)}$ or, $\sin^2 i = 1 - (81N/F^2)$ or, $1 - \sin^2 i = 81 \text{N/F}^2$ or, $\cos^2 i = 81 \text{N/F}^2$ or, $F = (81N)/\cos i$ = 9(N)/cos i $= 9(\sqrt{N})$ sec i

If i=0°, then $F=9\sqrt{N}=F_c$

This is the critical frequency.



Above this frequency, the wave will not be reflected back to earth.

At any other angle, the frequency which will be capable of being reflected back will be

$$F = F_c \text{ sec } i$$

This is referred to as the **SECANT RULE** and gives the **MAXIMUM USABLE FREQUENCY** at various angles of incidence.

MAXIMUM USABLE FREQUENCY : It is the highest frequency of wave that is reflected by the layer at an angle of incidence other than normal.



<u>SKIP DISTANCE</u>: It is the shortest distance from the transmitter that is covered by a fixed frequency (F_c)



Large angle of incidence Ray returns to ground at a long distance from TX.

Angle of incidence reduced Ray returns to ground at a shorter distance.

Ultimately, possibility of a certain distance not being covered exists, since ray escapes.



SKIP FREQUENCY:

It is the maximum frequency above which it is not possible for a signal to reach a point via lonospheric Reflection.

OPTIMUM WORKING FREQUENCY (OWF):

•The frequency of wave which is normally used for ionospheric communication is known as OWF.

•It is generally chosen to be about 15% less than the MUF.

•It is always desirable to use as high a frequency as possible (but not too near the skip frequency or MUF), since any slight variation in the ionosphere condition may cause a loss of signal.



SPACE WAVE OR

TROPOSPHERIC WAVE



SPACE WAVE OR TROPOSPHERIC WAVE PROPAGATION

- Troposphere is the region of atmosphere within 16 Km above the surface of the earth.
- The EM wave that propagates from the transmitter to the
- receiver in the earth's troposphere is called Space Wave
 - or Tropospheric Wave.
- Space Wave propagation is useful at frequencies above 30MHz.
- ➢It is useful for FM, TV and Radar applications.



The space wave field strength is affected by

2. <u>Curvature of the earth:</u>

- The field strength at the receiver becomes small as the direct ray may not reach the receiving antenna. The ground reflected rays diverge after their incidence on the earth.
- The curvature of the earth creates <u>shadow zones</u>, also called diffraction zones. These are the regions where no signal reaches.
- Reduces the possible distance of communication.
- Field strength available at receiver becomes small.







<u>2. Effect of Earth's Imperfections and</u> <u>Roughness</u>

- Earth is basically imperfect and rough
- For perfect earth, reflection coefficient is unity. But actual earth makes it different.
- For reflection from perfect earth, phase change is 180°. But actual earth makes it different.
- Amplitude of ground reflected ray is smaller than that of Direct ray.
- The field strength at receiver is reduced due to the roughness.



3. Effect Of Hills, Buildings and Other Obstacles

- These create Shadow Zones.
- Hence possible distance of transmission is reduced.

4. <u>Height Above Earth</u>

- Field varies with height above earth.
- Field variation is characterised by maxima, minima

and nulls

Maximas, minimas depend on frequency, height of transmitting antenna, ground characteristics and polarisation of the wave.







5. Transition between Ground Wave and Space Wave

When the transmitting antenna is close to earth, Ground Wave exists and the field strength is independent of height of antenna.

Antenna height has an effect on field strength, which depends upon frequency, polarisation and constants of earth.

> At higher heights, Space Wave dominates.



<u>Atmospheric Effects in Space Wave</u> <u>Propagation</u>

- Atmosphere consists of gas molecules and water vapour.
- So, density is higher compared to free space.
- For standard atmosphere; Pressure, Temperature, Humidity decrease linearly with altitude.
- Thus Refractive Index of air depends upon height.
- This gives rise to phenomenon like
- Reflection
- Refraction
- Scattering



REFLECTION

Occurs when waves strike smooth surface, such as water, smooth earth, etc.

Both Reflected and Direct wave reaching the receiver ensures reduced signal strength.

These may arrive either in phase, or out of phase, or partially out of phase.

For perfectly smooth surface, and under condition of amplitude being equal and exactly out of phase at receiver, the received wave may get completely **cut off**.

This is **FADING**.

Hence care should be taken during survey that there



DIFFRACTION

• Obstacle (like tall buildings or hill tops) in the path of the wave, increases transmission loss.

• Wave arrives at the receiver by the process of diffraction.



REFRACTION

Due to the varying refractive indices with height, the wave does not follow a straight path from Transmitting to Receiving antennas.

It follows a bent path, i.e. follows the curvature of the earth.

<u>Hence radius of the earth seems to be larger</u> than actual for the beam

Also the path varies during various hours of day and at various place.



K-FACTOR



<u>K-Factor</u>

To correlate between earth's curvature and the

curvature of the MW beam path, it is customary to take one of the curvatures to be a straight line (generally MW beam).

- Due to this assumption, the actual curvature of the beam will also have to be modified to keep the earlier correlation same.
- The modification of earth's curvature is done by multiplying actual earth's curvature by <u>K-Factor.</u>
- K-Factor depends upon atmospheric conditions.

Hance Modified earth's surveiture also changes with



The amount and direction of bending subjected by the MW beam is defined

- either by the Refractive Index Gradient dN/dh (where N is the Radio Refractivity and h is the height of the layer above the surface of the earth)
- or very often by the Effective Earth's Radius Factor
 K.

Definition

K is a factor which when multiplied by the actual earth's radius, gives the value of the modified earth's radius employed in profile chart to make the MW beam a straight line.



It can be Shown that

K-Factor= 157/(157+dN/dh)

Here, N (Radio Refractivity) = $77.6(P/T)+3.73\times10^{5}(e/T^{2})$

- Where, P = Total Atmospheric Pressure in Millibar
 - T = Absolute Temperature in ^oKelvin.
 - e = Water Vapour Pressure in Millibar.



CONDITIONS

- 2. When dN/dh = -40 UNITS/Km; K = 4/3 (This is Standard Atmospheric Condition)
- 3. When dN/dh = -157 UNITS/Km; K = infinity.(This is Super Refractive Atmospheric Condition)
- 4. When dN/dh = 0 UNITS/Km; K = 1 (This is Sub Refractive Atmospheric Condition)
- 5. When dN/dh = +79 UNITS/Km; K = 2/3 (This is Sub Refractive Atmospheric Condition)



Atmospheric condition	dM/dh (units per meter)	dn/dh (units per meter)	dN/dh (units per km)	K	MW propagation
Sub refractive	0.377 to 0.157	0.22 to 0 X 10 ⁻⁶	+220 to 0	5/12 to 1	Sub-normal refraction
Typical sub- refractive	0.235	0.078 X 10 ⁻⁶	+78	2/3	Sub-normal refraction
Standard	0.157 to 0.1	0 to -0.058 X 10 ⁻⁶	0 to -58	1 to 1.6	Standard Refraction
Typical Standard	0.118	-0.039 X 10-6	-39	4/3 (1.33)	Standard Refraction
Super refractive	0.1 to 0	-0.058 to -157 X 10 ⁻⁶	-58 to -157	1.6 to Infinity	Reflection
Extreme super std. (Flat earth)	0	-157 X 10-6	-157	Infinity	Ducting



□ Change in the value of K from 1 to infinity have less influence upon the received signal (excepting multipath fading).

 \Box For K<1, the path is vulnerable to extreme multipath fading.

 \Box For K= -ve, path is susceptible to blackout fading.



•n is Atmospheric Refractive Index . Variation of 'n' w.r.t. height is low i.e. of the order <u>10⁻⁶ per</u> <u>meter</u>. Hence, we consider certain scaled parameters.

•<u>dN/dh = 1000. dn/dh</u> i.e. N parameter variation gives variation of RI per km. We can use convenient ranges of integer-values for dN/dh corresponding to normal, sub-normal & supernormal conditions of atmosphere.

•M Vs. h graph gives convenient graphical representation of normal, sub-normal & supernormal conditions of atmosphere. Since M = (n-1) 10⁶ + 0.157 h, we have interpolated curvature of earth into M. Hence, <u>M vs.h plot gives modified</u> <u>RI profile.</u>

•K is 'Effective earth radius factor' i.e. factor to



Significance of 0.157

 $1/Earth radius = 1/6378 \text{ km} = 157 \text{ X} 10^{-6} / \text{ m} = 0.157 / \text{ km}$

i.e. 0.157 is Earth curvature factor.

Variation of RI causes curving of beam.

Curvature of beam can be expressed in terms of curvature of earth i.e. a scaling factor X 0.157 to have a 'feel' of various refractive conditions.

Condition Variation of RI (Curvature of beam) expressed in terms of curvature of earth

Sub-normal(2.4 to 1) X 0.157Typical sub-normal1.5 X 0.157Normal(1 to 0.64) X 0.157Typical normal0.75 X 0.157Super-normal(0.64 to 0) X 0.157Extreme super-normal0 X 0.157 i.e. constant or straight



Super Standard Refraction

Arises due to reduction in atmospheric density with increased height.

K increases– Results in flattening of the effective Earth's curvature.

Condition causing it– Passage of cool air over warm body of water.

- Atmospheric density increases near the surface (due to low temperature & high humidity).
- High downward bending of wave is caused.
- > In moderate conditions, K^{\rightarrow} infinity, and wave is propagated parallel to earth.

In extreme cases, K=-ve and causes a blackout fade.



SUB - STANDARD REFRACTION

Arises due to increase in atmospheric density with height.

Condition causing it– When fog is formed with the passage of warm air over cool air or moist surface.

Causes upward bending of beam (Earth's bulge).





Earth appears to be increasingly flat as the value of of K increases.

For K=infinity, the earth appears to be perfectly flat for the MW beam, since the beam curves at the same rate as earth.

The curvature for various values of K can be calculated by

 $h=d_1d_2/(12.75K)$

- where, h= Change in vertical distance from a horizontal reference line.
 - d₁= Distance from a point to one end of the path (in Km)

 d_2 = Distance from same point to other end of the path (in Km)


How to plot path profiles

Ideally, we have to plot the path taken by the rays for normal, sub-normal & super-normal conditions.

If we plot the path profile (using details obtained from Survey maps) on plain graph paper, curvature of Earth is not accounted for.

Hence, for convenience of analysis, bending of radio path to be interpolated in earth curvature for all conditions (normal, subnormal & super-normal) and using such curvedabscissa graph sheets, path profiles to be plotted



Profile Charts

 Profile charts for various values of K available

Send of radio path 'transferred' to earth radius as per value of K

 Mark the terrain specific details from Survey maps on these charts

Mark the tower / antenna



Profile Chart for K= 4/3 (Normal





P<u>rofile Chart for K= 2/3 (Sub-normal condition</u>) Η E G Η Τ in m Distance in km



Profile Chart for K= Infinity (Super-normal condition)





M-PROFILES



The characteristics of troposphere is studied by another term called Modified Refractive Index

It is defined in terms of the mean sea level elevation as

M = N + 15.75h

When a graph is plotted with height in Y-axis and M in X-axis, the plot is called M-PROFILE.

The slope of M-Profile determines the degree of bending of MW beam in relation to earth.



M- profile





M-profile : Sub-normal condition



dM/dh = 0.235 per meter at the heights under consideration

At higher values of h, dM/dh reaches normal profile



M- profile : Super-normal condition



dM/dh 0.1 to 1 at heights of consideration

At higher values of h, dM/dh reaches normal profile



<u>uper-normal condition with ground-based duc</u>



Extreme case of superstandard condition, when there is temperature inversion

Signal gets trapped in the duct and may cause over-reach problems



<u>Super-normal condition with elevated</u> <u>duct</u>



Duct not close to ground, but elevated

Signal gets trapped in duct in atmosphere



Essential clearances for Radio path



By clearance of radio path, we mean

- Clearance of 'zone' of constructive arrival rays to the full extent in 'Normal' condition
- Clearance of 'zone' of constructive arrival rays to sufficient extent in 'Sub-normal' condition
- Clearance of reflection point from reflective bodies to avoid ground reflected rays' interference and consequent fading



Clearance in 'Normal' & 'Sub-normal' Clearance of 'zone^C of constructive arrival rays to the required extent –

•Zone of constructive arrival means ' First Fresnel Zone'

•For normal condition, take typical value K = 4/3

•For sub-normal condition, take typical value K = 2/3

Let us understand Fresnel Zone & computation of it's



<u>Concept of 'Fresnel Zone'</u>

When MW beam is transmitted from an antenna, the beam gradually spreads conically (Huygen's Principle).

The total MW energy reaching antenna B is the sum of the energies passing through various zones called FRESNEL'S ZONES.

Maximum energy (primary energy) is concentrated in the central zone, called FIRST FRESNEL'S ZONE.





The successive zones have a path difference of $\lambda/2$ and are 180° out of phase when reaching antenna B.

Thus, 1st, 3rd, 5th, etc Fresnel Zone are in phase

2nd, 4th, 6th, etc Fresnel Zone are in phase

Vector Diagram Of Energy Contents In Fresnel





Thus we see that the energies are getting diminished with the higher Fresnel Zones.

The transmitted MW will have maximum energy if only the 1st Fresnel Zone is cleared.

The strength of the MW signal reaching B will depend upon the no. of Fresnel Zone cleared. (More Fresnel Zone, less strength of signal).

Practically, it is not possible to make an antenna receive only the 1st Fresnel Zone.

So, we limit the the height of TX and RX antenna so that the 2nd Fresnel Zone is obstructed on the lower side at a certain lower value of K.



If full 1^{st} Fresnel Zone is available for K=4/3, at least 2/3rd of 1^{st} Fresnel Zone should be cleared for K=1.

Radius of the 1st Fresnel Zone is calculated as

F1= 17.3
$$(d_1d_2/F_{GHz}D_{Km})^{1/2}$$

where, F1= Radius of 1st Fresnel Zone $d_1 \& d_2$ = Distances in Km of the towers at the point where radius is to be calculated.

- Eroquoncy ir



Radius of nth Fresnel zone

 $F_n = F_1 (n)^{1/2}$

where, n is the no. of Fresnel Zone for which radius is to be calculated.

While clearing the 1st Fresnel Zone, some tolerance should be given for future obstructions.

This tolerance depends upon the K-Factor

- For K=4/3, full 1st Fresnel Zone+ 10m extra clearance
- For K=1, 2/3rd of 1st Fresnel Zone+ 10m extra clearance
- For K=2/3, grazing clearance of 2/3rd of 1st Fresnel Zone only



Fading

It is the change in signal strength at the receiver.

- Causes of Signal Loss can be classified into 2 categories
- 4. Atmospheric conditions related causes
- 5. Radio path related causes



<u>Atmospheric condition related causes</u>

- •Attenuation due to rain
 - -When wavelength is close to rain drop size
 - $-15\ G$ Hz and above , 1 to 10 db per km as per precipitation rate of rain fall
 - -Below 15 G Hz, attenuation is less than 1 db
- Attenuation due to cloud & fog
 - -Drop sizes are smaller than rain drop
 - –Attenuation is more for 15 G HZ and above
- Attenuation due to hail & snow
 - -Similar to the case of rain



<u>Radio path related causes</u>

Insufficient path clearances

-Rays getting obstructed by high-rise objects/ geographic features

Multi-path propagation

-Destructive interference of rays reaching on different paths through atmosphere

Fading due to ground reflection

-Ground reflected signal of significant strength causes fading due to interference with normal path signals



CLASSIFICATION OF FADING

- □ Rapid Fluctuation → Due to multipath interference. Occurs for a few seconds.
- ❑ Short Term Fluctuation Due to variation in characteristics of propagating medium. Occur for a few
- hours.
- Long Term Fluctuation Due to seasonal variations in propagating medium. Occur for a few days.

Fade out (Total Fading) occurs during sudden ionospheric disturbances, sun spot cycles, etc.



TYPES OF FADING

Frequency - Selective Fading: -

Alternate points of maximum (reinforcement) and minimum(cancellation) signal strength are encountered during space wave propagation from Tx to RX.

This phenomenon is called **selective fading**.

All terrestrial MW radio systems can suffer from multi-path propagation, where the Rx antenna receives not only the direct signal but also secondary signal which is slightly delayed relative to the direct beams, and bends due to the varying refractive index of the air.

The degree of multi-path fading is heavily dependent on the **Hop length**, weather condition and water path.



Flat fading

As its name implies is a non frequency dependent attenuation of the input signal at the receiver and typically occurs during periods of heavy rain particularly at higher MW frequency



Difficult to control short term and long term fluctuations.

But fading due to rapid fluctuations can be reduced by different Diversity Techniques.

- i. Frequency Diversity
- ii. Space Diversity
- iii. Polarity Diversity
- iv. Time Diversity







FREQUENCY DIVERSITY

ADVANTAGES

- 5. Reliability is more
- 6. Equivalent to 100% hot stand by, hence no need of providing stand by TX or RX.

DISADVANTAGES

10.Two frequencies are needed11.Improvement by diversity is not much, since 5% separation of frequency is rarely achieved.





SPACE DIVERSITY

ADVANTAGES

- 5. One frequency is used.
- 6. Propagation reliability is improved.
- 7. For more vertical separation of antennas, improvement factor can be more.

DISADVANTAGES

- The two antennas are kept on the same tower. The lower antenna should be in Line of Sight with the TX antenna. Hence length of tower may increase beyond 100m. SPACE DIVERSITY
- Costly
- Good tower foundation necessary, since wind pressure will be large.
 - Equipment reliability decreased, hence stand by required.



FREQUENCY ALLOCATIONS



Indian Railways have been allotted a frequency band of 7125 MHz to 7425 MHz (4.21 cms - 4.04 cms wavelengths) in the X_c band. (The band of frequency from 7250 - 7300 MHz is restricted in view of satellite to earth allotment).

The spot frequencies permitted in the band for operation of a transmitter (and Receiver) are governed by CCIR Recommendation 385 - 1 which inter - alia stipulates as follows:-

- f_{o} = Centre frequency = 7275 MHz
- $f_n =$ Channel frequency in MHz in lower half of the band
- f_n^1 = Channel frequency in MHz in Upper half of the band.



- then the frequencies (MHz) of the individual channels are expressed by the following relationships:-
- Lower half of band $f_n = f_o 154 + 7n$
- Upper half of band $f'_n = f_o + 7 + 7n$
- where n = 1, 2, 3, etc., 1upto 20.
- e.g., $f_1 = 7128$ MHz & $f'_1 = 7289$ MHz $f_2 = 7135$ MHz & $f'_2 = 7296$ MHz and so on.



2) In section over which the international conduction is arranged all the 'go' channels should be in one half of the band and all the 'return' channels in the other half of the band.

3) When systems with 300 telephone channels are operated in a radio frequency band, channel combination, which result in differences between channel frequencies of less than 14 MHz, should in general be avoided. If sufficient antenna discrimination is available, this precaution may be disregarded.



FREQUENCY PLAN


There are two distinct patterns of frequency plans employed on the Railways. They are the 'Four Frequency' and the 'Two Frequency' plans.

Allocation of frequencies in a four frequency plan is as shown in the figure.





ANTENNAS



ANTENNAS

An antenna is basically a transducer.

It converts RF electrical current into an EM Wave of the same frequency.

It forms a part of the transmitter as well as the receiver circuit.

It is also an impedance matching device. It matches/couples the transmitter and free space or free space and receiver.

The sample antenna is called a Half Wave Length Dipole.

The shortest length of dipole capable of resonance is an electrical half wave length.



- Center impedance of a simple dipole ~ 72 ohms (at resonant frequency)
- It increases as we go away from the center.
- The antenna impedance is required to be matched with the characteristic impedance of the feeder line so that maximum power transfer may take place.
- ***Isotropic antenna:** Radiates equal power in all directions.
- *Actual antenna: Does not radiates power equally in all directions.



Length of Antenna

Practical antennas have length 5% less than theoretical antennas.

This is because

1. Theoretical length is true when antennas are in free space.

2.For practical antennas, END EFFECT has to be considered, which is caused by

- a.Capacitance between pole and antenna
- b.Capacitance antenna and earth
- c.Inductive effect in the tightening material of antenna
- These effects cause the 5% reduction in length.

The practical length of a half wave dipole is

 $L_m = (142.5/F_{MHz})$ meters



©VHF

-For fixed stations : Dipoles for omni-bus

-For fixed stations : Yagi for directional

-For mobile sets : Whip antennas

⇔UHF

For fixed stations : Yagi, Grid

For mobile sets (Train radio) : Whip antennas

For GSM – BTS : Sectorized antenna

For GSM Mobile sets :

•MW

-Parabolic antenna (Dish antenna)

-Beam reflectors

-Passive reflectors



How to improve gain of dipole

Add parasitic elements (Director, Reflector)

Parasitic elements reduce impedance below 73 Ohms. Hence use either Shunt feed or Folded dipole



Shunt-fed Yagi antenna



Shunt-feed

Shunt-fed Yagi features
Length of dipole : 0.48 |
Length of director :0.46|
Length of reflector : 0.5 |
Separation between dipole & director : 0.1 |

Separation between dipole & reflector : 0.16 |

Gain : 6 db



Folded-dipole Yagi antenna



Yagi-feed

Folded dipole Yagi features

Length of dipole : 0.48

Length of 1st director :0.46

Subsequent directors' lengths taper-off for correct phasing of parasitic currents

Length of reflector : 0.5 |

Separation between rods : 0.15 to 0.25l

Gain : 10 db



Transmitting and receiving antennas for use in the UHF (.3 – 3GHz) and MW (1- 100GHz) regions tend to be directive. The dimensions of an antenna must generally be several wavelengths in order for it to have high gain. At the high frequencies , antennas need not be physically large to have multiple wavelength dimensions. For UHF and MW frequencies the following antennas are used: -

- 2. The Yagi-Udi Antennas.
- 3. Grid Pack or Grid Antennas.
- 4. Normal Parabolic antenna







The Yagi(Yagi-Uda) antenna is an array consisting of a driven element and one or more parasitic elements(Director ,Reflector). They are arranged collinearly and close together to increase directivity.





Grid Antenna: - A grid antenna employs welded tube which can be split into section for ease transportation and handling





GRIDPAK ANTENNA



Gain of Parabolic antenna (7 GHz band)

Antenna type	Gain of antenna
	6 (D/l) ²
Fiber antenna	17 db
	(Formula not applicable)
2.4 m dia metal antenna	43 db
3 m dia metal antenna	45 db
3.3 m dia metal antenna	46 db



Front to back ratio of a antenna: Ratio of the front Lobe power to back lobe power.

Half power beam width: It is the nominal total angular width of the main beam at the 3dB points. In the fig. the angle represents the beam- width.The beam width is given by $\Phi = 22/$ FB in degree; F = Frequency in GHz and B = Diameter of antenna in meters





PARABOLIC ANTENNA BEAMWIDTH

The 3dB bandwidth of main lob in the direction XY. In degree

- $\theta = 70\lambda/D = 70C/fD$
- θ = Bandwidth between half power point .
- λ = Wavelength.
- $C = 3x10^8$ Meter per second
- D = Antenna mouth diameter in meters.
- f = Frequency in Hertz.



PASSIVE REFLECTOR

The simplest and most common reflector system consists of a parabolic, antenna mounted at ground level and directed technically to illuminate a passive reflector at the top of a tower. This reflector, inclined at 45deg. redirects the beam horizontally to a distance site, where a similar Periscope system may be used to reflect the signal back to ground level.



PASSIVE REPEATERS

- Sometimes a tower cannot provide clearance over an obstruction . When the line of sight of MW is obstructed by mountains or any other substances the Passive repeaters may be used to merely change the path direction without amplification
- The Bill Board, a large, flat surface which is simply as a reflector is used as a repeater. Untypical a system, a bill board repeater might be located at a turn in a valley, effectively bending the beam to follow the valley



Ground plane Antenna(GP): -

GP antenna is used for HF and VHF communication. The basic design is quarter wavelength vertical antenna with four Radials Mounted at the antenna base. The radials may be made of tubes or wire. The Coaxial line from the transmitter of 50Ω characteristic impedance is connected to the GP antenna.





THANK YOU