COMMUNICATION SYSTEMS

1. BASICS OF COMMUNICATION
2. AMPLITUDE MODULATION

BASICS OF COMMUNICATION

1. Communication: Processing, sending and receiving of information

2. Information: Intelligence, signal, data or any measurable physical quantity

3. Basic Communication System:

Source of information → Transmitter → Link → Receiver → Destination

Source of information:

i) Speech
ii) Pictures
iii) Words
iv) Codes
v) Symbols
vi) Commands
vii) Data

Transmitter:

i) Oscillators ii) Amplifiers
iii) Filters iv) Antenna

Link:

i) Wire Links
ii) Wireless
iii) Optic Fibres

Receiver

Destination:

i) Radio ii) TV iii) Computer iv) Telephone
v) Teleprinter vi) Telegraph vii) Fax viii) Internet

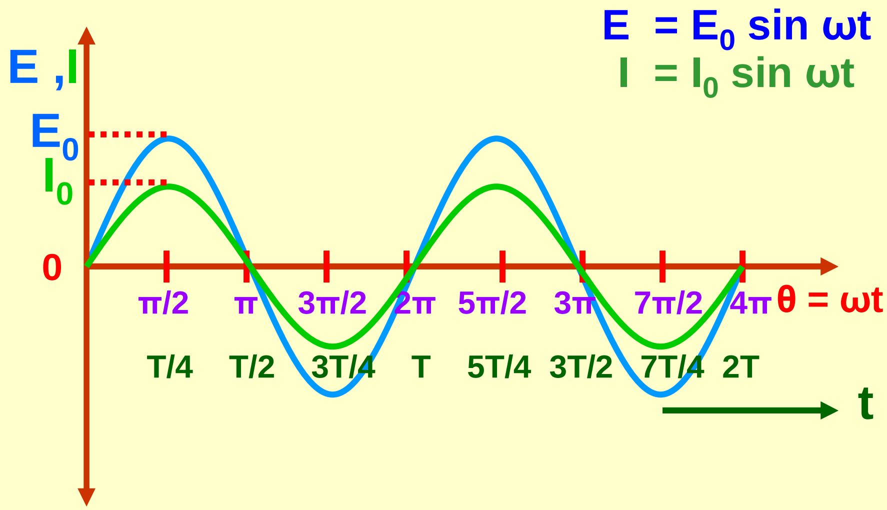
Forms of Communication:

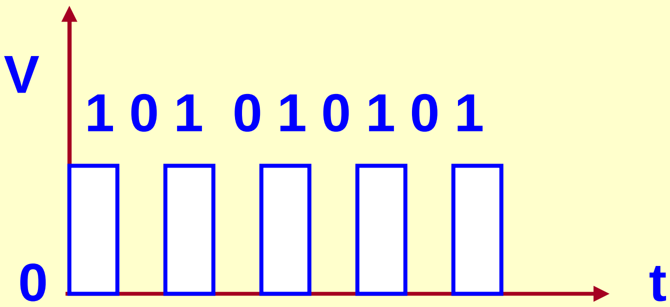
1. Radio Broadcast
2. Television Broadcast
3. Telephony
4. Telegraphy
5. Radar
6. Sonar
7. Fax (Facsimile Telegraphy)
8. E-mail
9. Teleprinting
10. Telemetering
11. Mobile Phones
12. Internet

Types of communication:

1. Cable communication
2. Ground wave communication
3. Sky wave communication
4. Satellite communication
5. Optic fibre communication

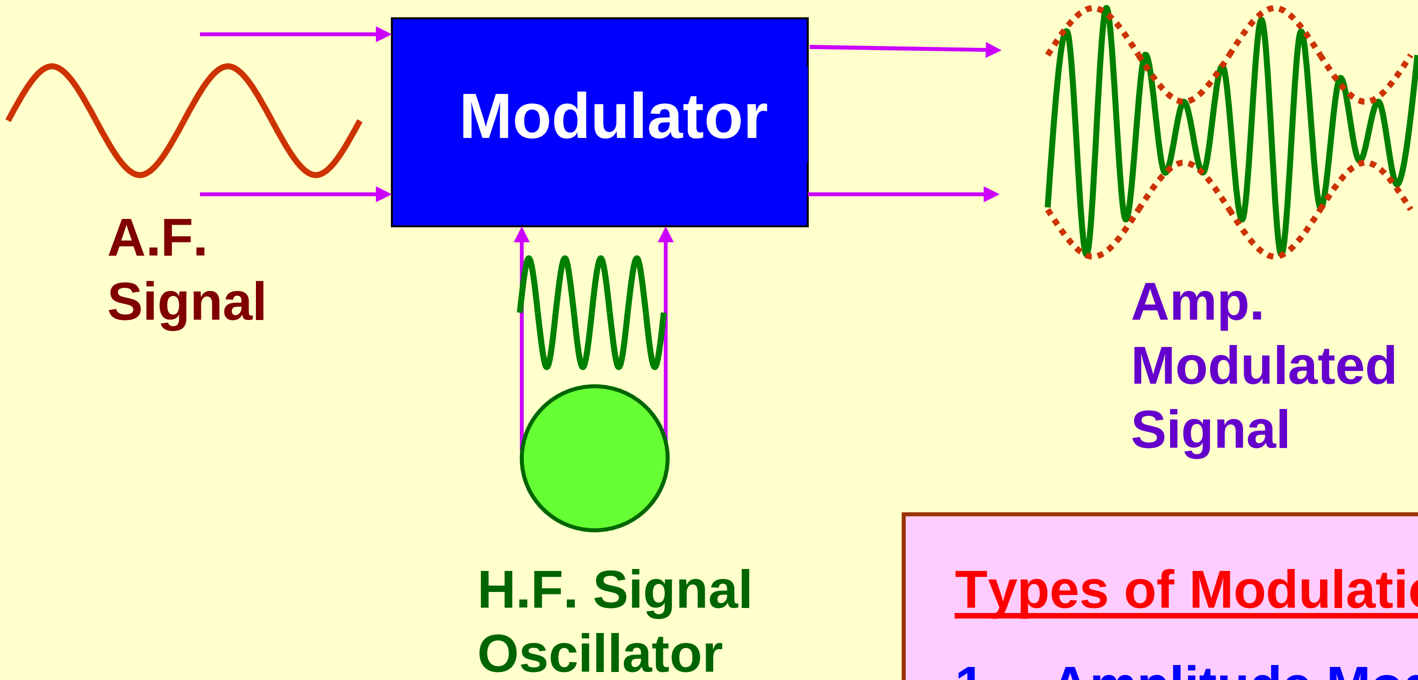
Analogue signal	Digital signal
A continuous signal value which at any instant lies within the range of a maximum and a minimum value.	A discontinuous signal value which appears in steps in pre-determined levels rather than having the continuous change.





MODULATION:

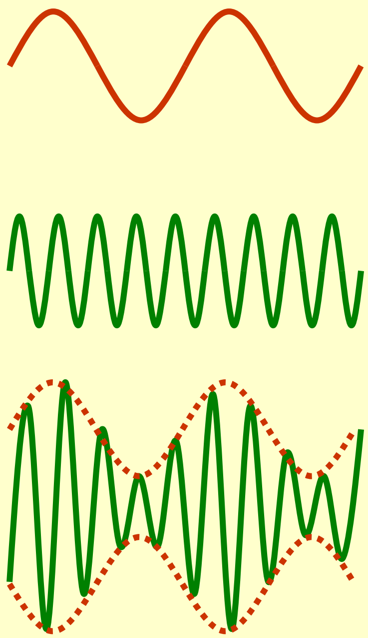
Modulation is the process of variation of some characteristic of a high frequency wave (carrier wave) in accordance with the instantaneous value of a modulating signal.



Types of Modulation:

1. **Amplitude Modulation**
2. **Frequency Modulation**
3. **Pulse Modulation**
4. **Phase Modulation**

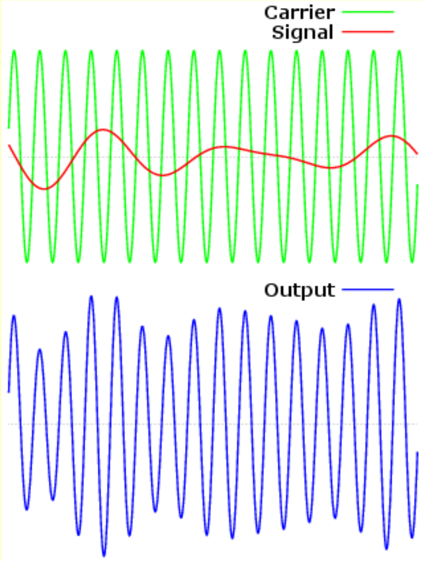
AMPLITUDE MODULATION (AM):



$e_m = E_m \sin \omega_m t$

$e_c = E_c \sin \omega_c t$

$e = (E_c + E_m \sin \omega_m t) \sin \omega_c t$



(Courtesy: Internet)

$e = E_c \sin \omega_c t + (m_a E_c/2) \cos (\omega_c - \omega_m)t - (m_a E_c/2) \cos (\omega_c + \omega_m)t$

Modulation Index $(m_a) = k_a E_m/E_c$

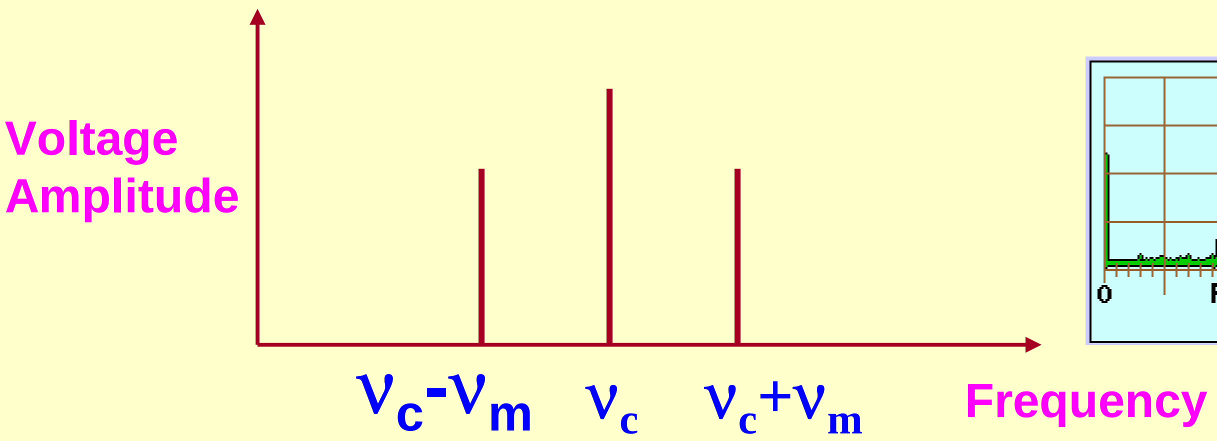
If $k_a = 1$, then $m_a = E_m/E_c$

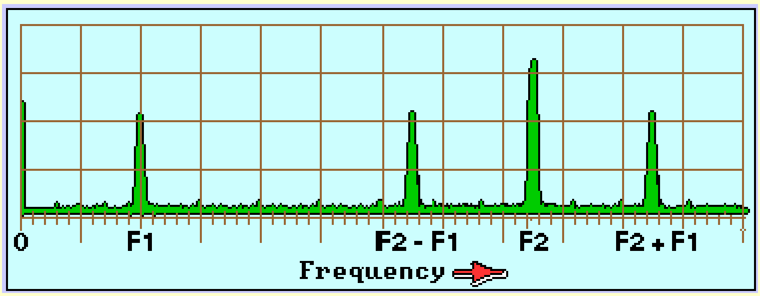
Inferences from equation for e:

1. The Amplitude Modulated wave is the summation of three sinusoidal waves with the frequencies ν_c, $\nu_c-\nu_m$ and $\nu_c+\nu_m$ namely Original frequency, Lower Side Band frequency and Upper Side Band frequency respectively.

2. The Bandwidth required for AM, BW = 2 ν_m

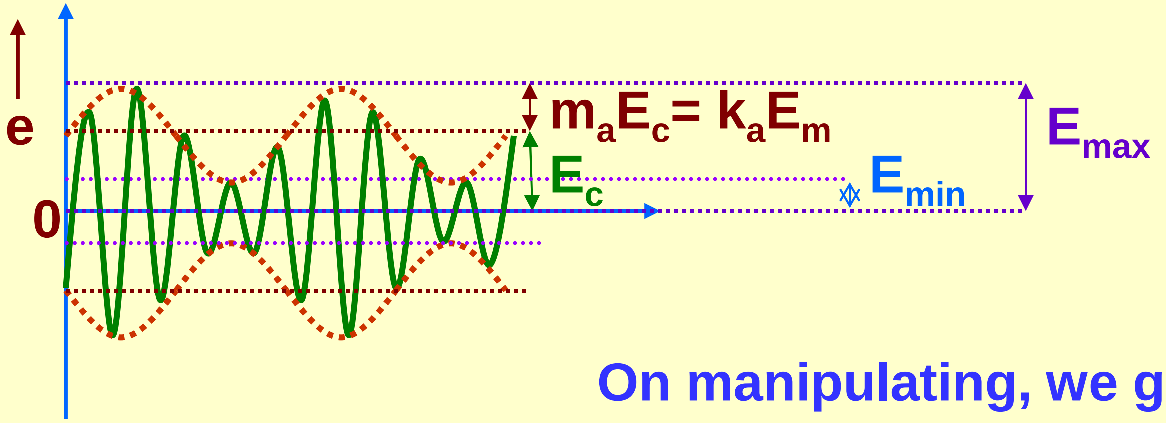
3. The amplitude E_c of the unmodulated carrier wave is made proportional to the instantaneous voltage ($e_m = E_m \sin \omega_m t$) of the modulating wave.





(Courtesy: Internet)

Significance of Modulation Index:

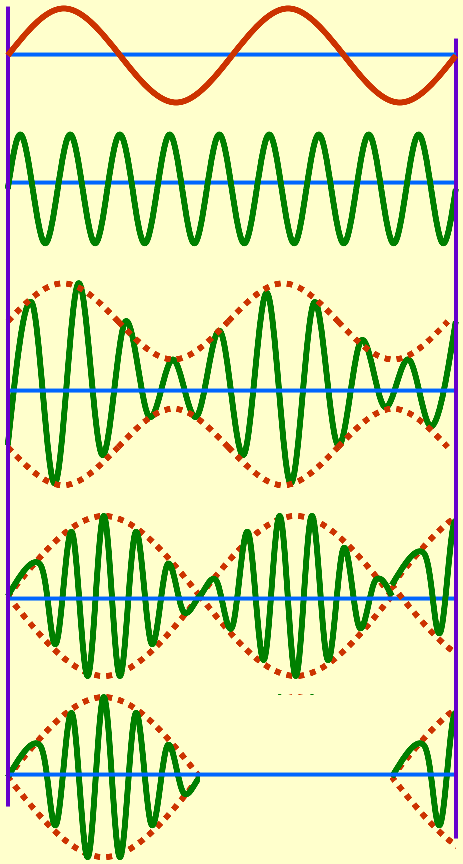


$E_{max} = E_c + m_aE_c$

$E_{min} = E_c - m_aE_c$

On manipulating, we get

$$m_a = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$



AF signal

$m_a = 0$ (No modulation)

$m_a = 0.5$ or 50%

$m_a = 1$ or 100%

$m_a > 1$ or 100%

Generally,

$0 < m_a < 1$

Power Relation in the AM wave:

If the modulated wave is applied to a resistor of resistance R (say antenna circuit), then the r.m.s. power dissipated in the form of heat is,

$$P_{r.m.s} = (1/R)[\{E_c/2\sqrt{2}\}^2 + \{m_a E_c/2\sqrt{2}\}^2 + \{m_a E_c/2\sqrt{2}\}^2]$$

$$P_{rms} = (E_c^{\,2}/2R)\,[1 + (m_a^{\,2}/2)] = P_c[1 + (m_a^{\,2}/2)]$$

(where P_c is power dissipated by unmodulated carrier wave)

If $m_a = 1$, then $P_{rms} \rightarrow P_{max}$ and $P_{max} = 3\,P_c/2$

Similarly, Power carried by both side bands $P_{SB} = P_{rms}/3$ which is wasted.

Advantages:

1. AM is an easier method of transmitting and receiving speech signals.
2. It requires simple and inexpensive receivers.
3. It is a fairly efficient system of modulation.

Drawbacks:

1. AM is more likely to suffer from noise.
2. Appreciable energy is contained by three components of AM wave. Sufficient energy can be saved by suppressing carrier wave and one of the side bands. This process makes the equipment complex.
3. Cost of such transmitters and receivers becomes practically more.

Space Communication

This Chapter includes:

1. Space Communication
2. Power Density, Attenuation
3. Range of Electromagnetic Waves
4. Ground Wave Propagation
5. Sky Wave Propagation
6. Space Wave Propagation
7. TV Transmission and Height of TV Antenna
8. Satellite Communication
9. Remote Sensing Satellites

Space Communication:

Space Communication means free space communication.

A free space does not have solid particles or ionised particles and it has no gravitational or other fields of its own. When the frequency of transmitted wave is very high the actual space is considered nearly a free space.

Power Density:

Power density is radiated power per unit area and is inversely proportional to the square of distance from the source.

Antenna:

Antenna is a device which acts as an emitter of electromagnetic waves and it also acts as a first receiver of energy.

Attenuation:

Attenuation is the loss of power of radiation due to absorption of energy in space and power density goes on decreasing as the electromagnetic waves go away from their source.

It is proportional to the square of the distance travelled and is generally measured in decibel (dB).

Range of Electromagnetic Waves:

S. No.	Name of the frequency range (Band)	Short Form	Frequency Range
1	Very Low Frequency	VLF	3 kHz to 30 kHz
2	Low Frequency	LF	30 kHz to 300 kHz
3	Medium Frequency or Medium Wave	MF or MW	300 kHz to 3 MHz
4	High Frequency or Short Wave	HF or SW	3 MHz to 30 MHz
5	Very High Frequency	VHF	30 MHz to 300 MHz
6	Ultra High Frequency	UHF	300 MHz to 3,000 MHz
7	Super High Frequency or Micro Waves	SHF	3,000 MHz to 30,000 MHz (3 GHz to 30 GHz)
8	Extremely High Frequency	EHF	30 GHz to 300 GHz

Propagation of Electromagnetic Waves:

Depending on the frequency, radio waves and micro waves travel in space in different ways depending on the behaviour of these waves w.r.t. the earth and the atmosphere. They are:

1. Ground wave propagation
2. Sky (or ionospheric) wave propagation
3. Space (or tropospheric) wave propagation

1. Ground wave propagation: (AM Radio waves)

In ground wave propagation, the radio waves (AM) travel along the surface of the earth. These waves are called ground waves or surface waves.

In fact, these waves are not confined to surface of the earth but are guided along the earth's surface and they follow the curvature of the earth.

The energy of the radio waves decreases as they travel over the surface of the earth due to the conductivity and permittivity of the earth's surface.

Attenuation increases with the increase in frequency.

Therefore, the ground waves are limited to frequency of 1.5 MHz (1500 kHZ) or wavelength of 200 m.

Ground waves progress along the surface of the earth and must be vertically polarised to prevent from short-circuiting the electric component.

A wave induces currents in the earth over which it passes and thus loses some energy by absorption. This is made up by energy diffracted downward from the upper portions of the wavefront.

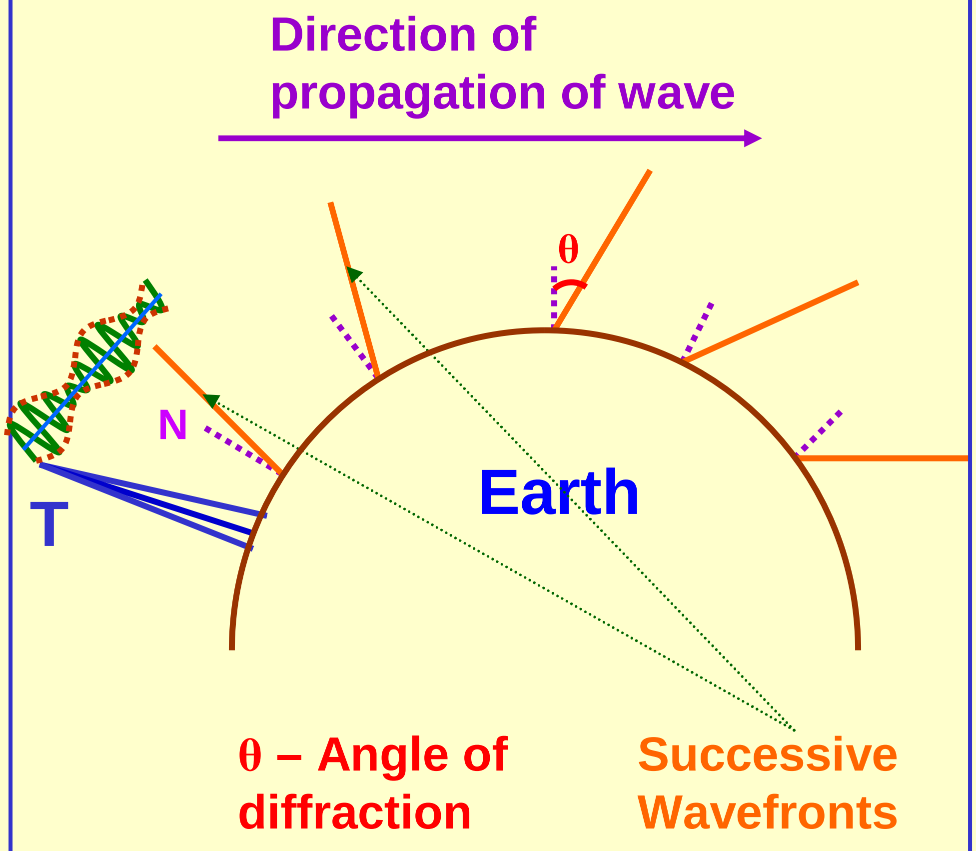
Another way of attenuation is due to diffraction and gradual tilting of the wavefront.

The increasing tilt of the wavefront causes greater short-circuiting of electric field components of the wave.

Eventually, at some distance from the antenna, the wave "lies down and dies".

The maximum range of a transmitter depends on its frequency as well as its power.

In MF band, the range can not be increased only by increasing its power because propagation is definitely limited by its tilt.



2. Sky wave propagation or Ionospheric wave propagation: (AM Radio waves)

Sky waves are the AM radio waves which are received after being reflected from ionosphere. The propagation of radio wave signals from one point to another via reflection from ionosphere is known as sky wave propagation.

The sky wave propagation is a consequence of the total internal reflection of radiowaves. Higher we go in the ionosphere, free electron density increases and refractive index decreases.

The UV and high energy radiations from the Sun are absorbed by the air molecules and they get ionised to form the ionised layer or electrons and ions. Ionosphere extends from 80 km to 300 km in the atmosphere above the earth's surface.

The oscillating electric field of electromagnetic wave (frequency ω) does not affect the velocity of the ions (negligible change because the em wave field is weak) in the ionosphere but changes the velocity of the electrons.

This changes the effective dielectric constant ε' and hence the refractive index n' as compared to the free space values ε_0 and n_0.

ε' and n' are related to ε_0 and n_0 as

$$n' = \sqrt{(\varepsilon' n_0)} \quad \text{or} \quad n' = n_0 \left[1 - (Ne^2 / \varepsilon_0 m\omega^2)\right]^{1/2}$$

where e is the electronic charge, m is the mass of the electron and N is the electron density in the ionosphere.

It is clear that the refractive index of ionosphere n' is less than its free space value n_0. So, it acts as rarer medium. Therefore, for the angle of incidence above the critical angle, the electromagnetic waves undergo total internal reflection and reach the earth back.

Since n' depends on ω and N, the waves of different frequencies will be reflected back from the different depths of ionosphere depending on electron density N in that region.

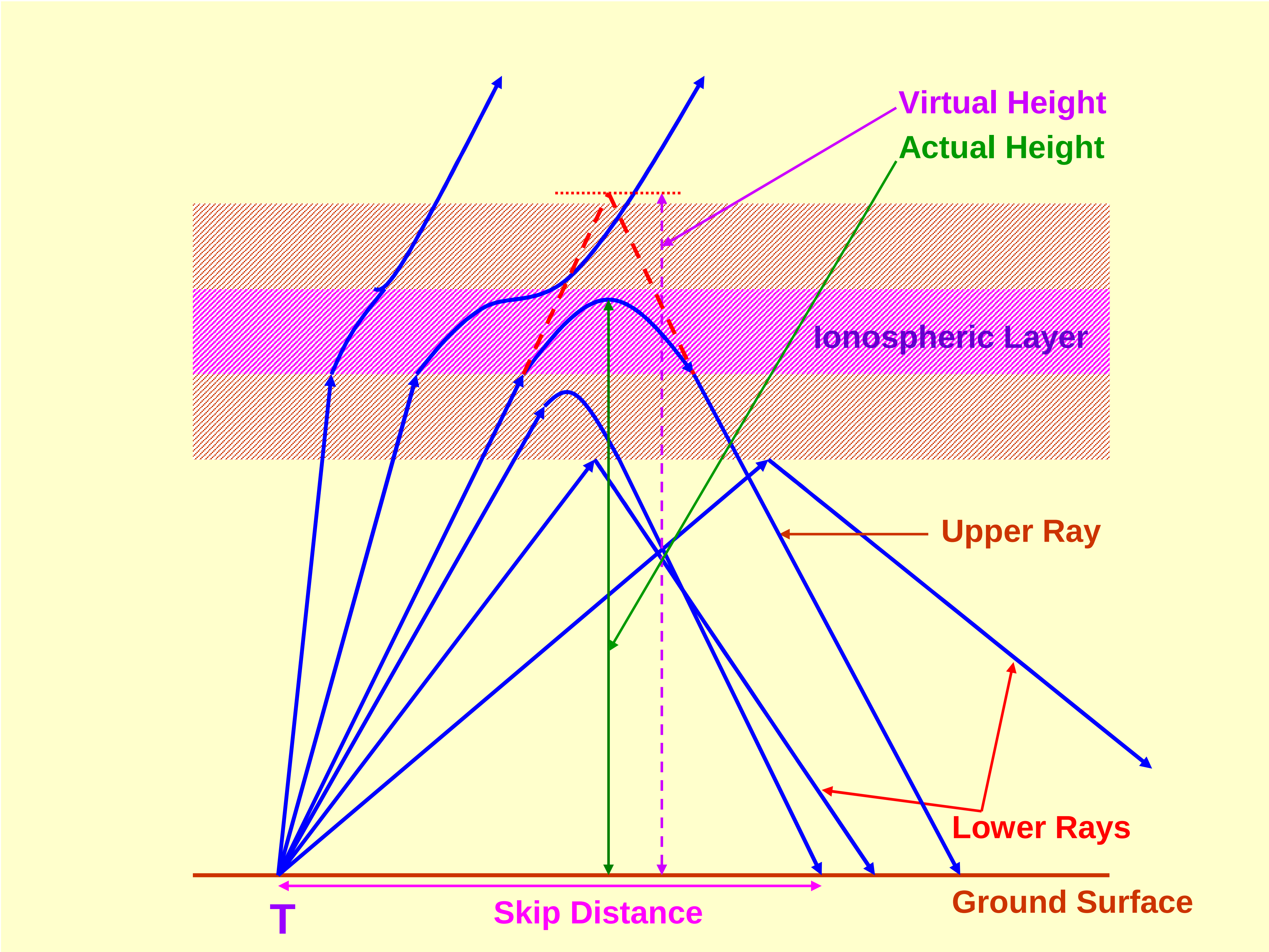
If the frequency ω is too high, then the electron density N may never be so high as to produce total internal reflection. This frequency is called 'critical frequency' (f_c). If the maximum electron density of the ionosphere is N_{max} per m^3, then the critical frequency is given by:

$$f_c \approx 9(N_{max})^{1/2}$$

The critical frequency ranges approximately from 5 to 10 MHz.
The frequencies higher than this cross the ionosphere and do not return back to the earth.

The sky wave propagation is limited to the range of 2 MHz to 30 MHz. This region is called 'short wave band'.

The communication in AM band below 200 m wavelength is via the sky wave only.


Virtual Height
Actual Height
Ionospheric Layer
Upper Ray
Lower Rays
Ground Surface
T
Skip Distance

Important Terms used in Sky wave propagation:

Critical Frequency (f_c):

It is the highest frequency for a given ionospheric layer that can be returned down to the earth by that layer after having been beamed straight up at it.

$$f_c \approx 9(N_{max})^{1/2}$$

Maximum Usable Frequency (MUF):

It is the limiting frequency but for some specific angle of incidence other than the normal.

$$\text{MUF} = \frac{\text{Critical Frequency}}{\cos\theta} = f_c \sec\theta$$

This is called 'secant law' and is very useful in making preliminary calculations for a specific MUF. Strictly speaking, it applies only to the flat earth and the flat reflecting layer.

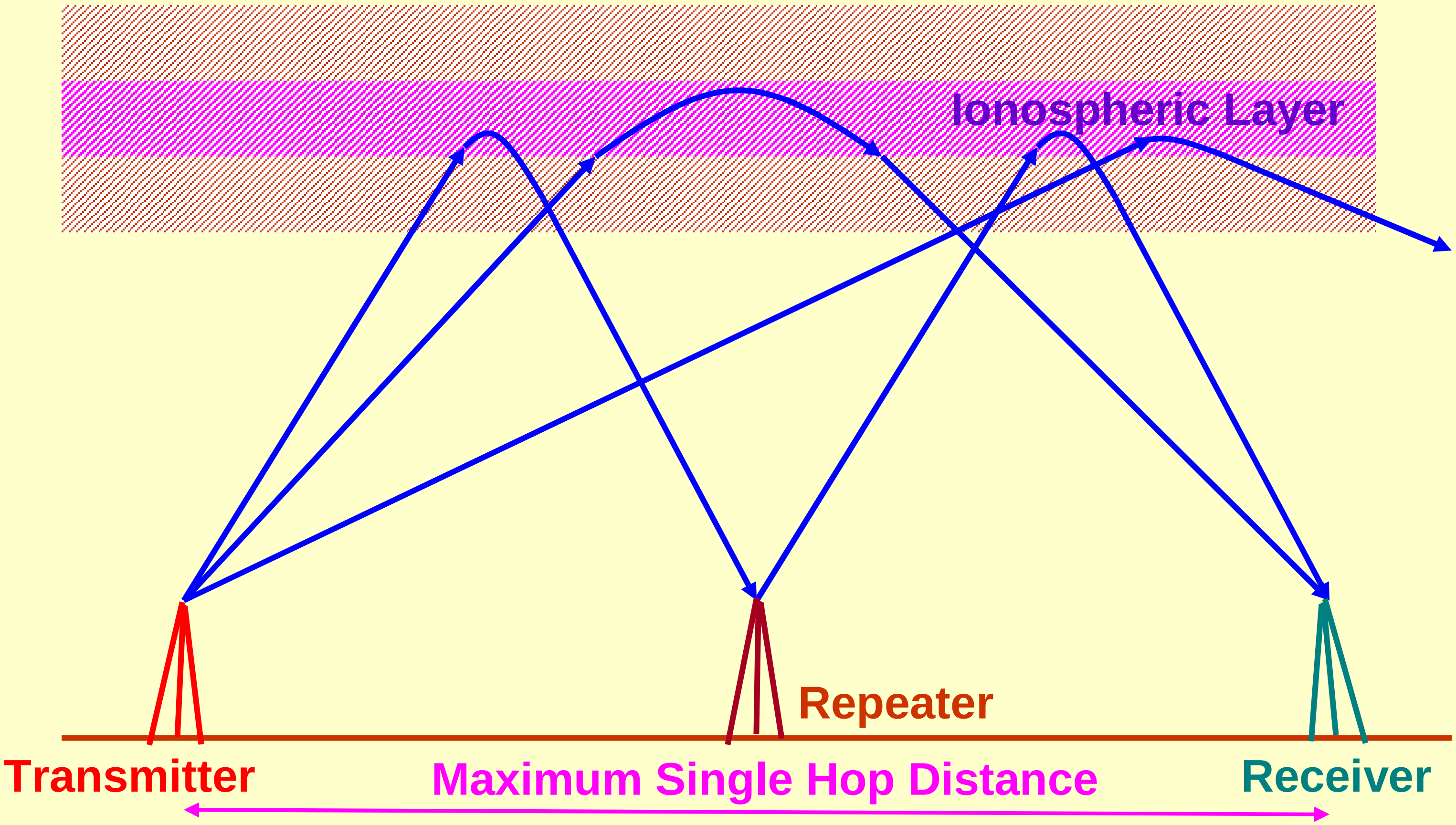
Skip Distance:

It is the shortest distance from a transmitter, measured along the surface of the earth, at which a sky wave of fixed frequency (more than f_c) will be returned to earth, but nevertheless a definite minimum also exists for any fixed transmitting frequency.

At the skip distance, only the normal or lower ray can reach the destination, whereas at greater distances, the upper ray can be received as well, causing interference. This is a reason why frequencies not much below the MUF are used for transmission.

Another reason is the lack of directionality of high-frequency antennas.

If the frequency used is low enough, it is possible to receive lower rays by two different paths after either one or two hops. But this will result in interference again.



3. Space wave propagation or Tropospheric wave propagation: (AM Radio waves)

Space waves travel in (more or less) straight lines. But they depend on line-of-sight conditions. So, they are limited in their propagation by the curvature of the earth.

They propagate very much like electromagnetic waves in free space.

This mode is forced on the waves because their wavelengths are too short for reflection from the ionosphere, and because the ground wave disappears very close to the transmitter, owing to tilt.

Radio Horizon:

The radio horizon for space waves is about four-thirds as far as the optical horizon. This beneficial effect is caused by the varying density of the atmosphere, and because of diffraction around the curvature of the earth.

It is given with good approximation, by the empirical formula

$$d_t = 4\sqrt{h_t}$$

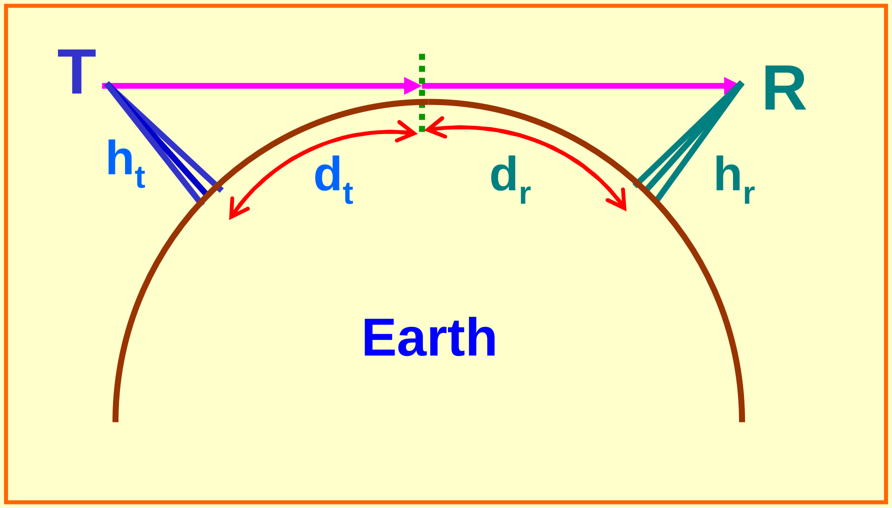
where d_t = distance (in km) from the transmitting antenna,

h_t = height (in m) of transmitting antenna above the ground

The same formula applies to the receiving antenna.

The distance between the Transmitter and the Receiver is

$$d = d_t + d_r = 4\sqrt{h_t} + 4\sqrt{h_r}$$



If the transmitting and receiving antennas are 225 m and 16 m above the ground, then the distance between them can be 76 km (= 60 + 16).

Commercially, links more than 100 km are hardly used.

Frequency Modulated Communication (TV Signals):

The TV signals are frequency – modulated. They employ frequency greater than 80 MHz.

They can not be propagated by ground wave because the signals get absorbed by ground due to their high frequency.

The propagation by sky wave is also not possible because the ionosphere can not reflect the frequencies higher than 40 MHz.

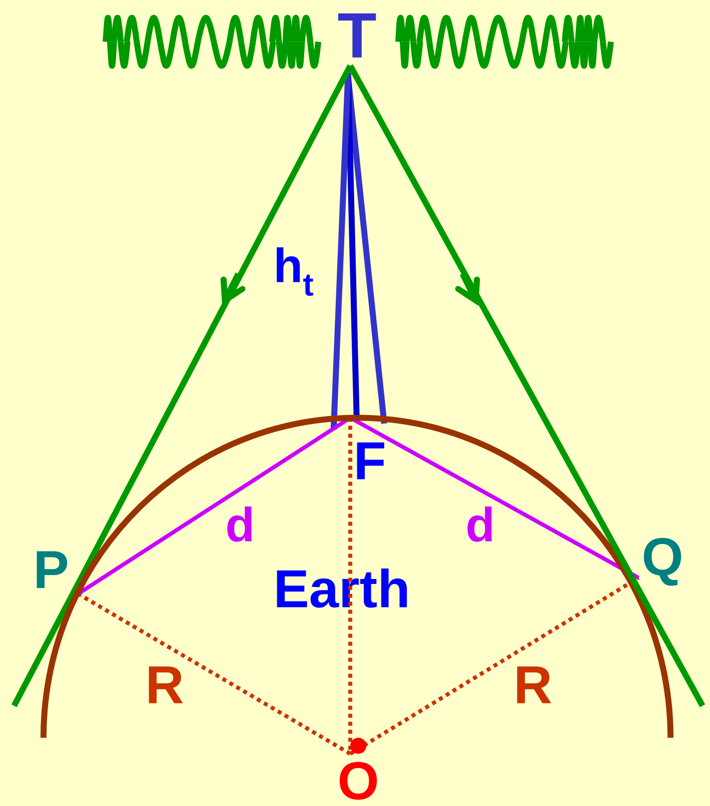
The only way for the transmission of TV signals is that the receiving antenna should directly intercept the signal from the transmitting antenna. (Space-wave or line of sight propagation)

Height of TV Transmitting Antenna:

The TV signals (frequency modulated electromagnetic waves) travelling in a straight line directly reach the receiver end and are then picked up by the receiving antenna.

Due to the finite curvature of the earth, the waves cannot be seen beyond the tangent points P and Q.

The effective range of reception of the broadcast is essentially the region from P to Q which is covered by the line of sight.



Let h be the height of the transmitting antenna, d be the distance (radius) of coverage from the foot of the tower and R be the radius of the earth.

$$OT^2 = OQ^2 + QT^2$$

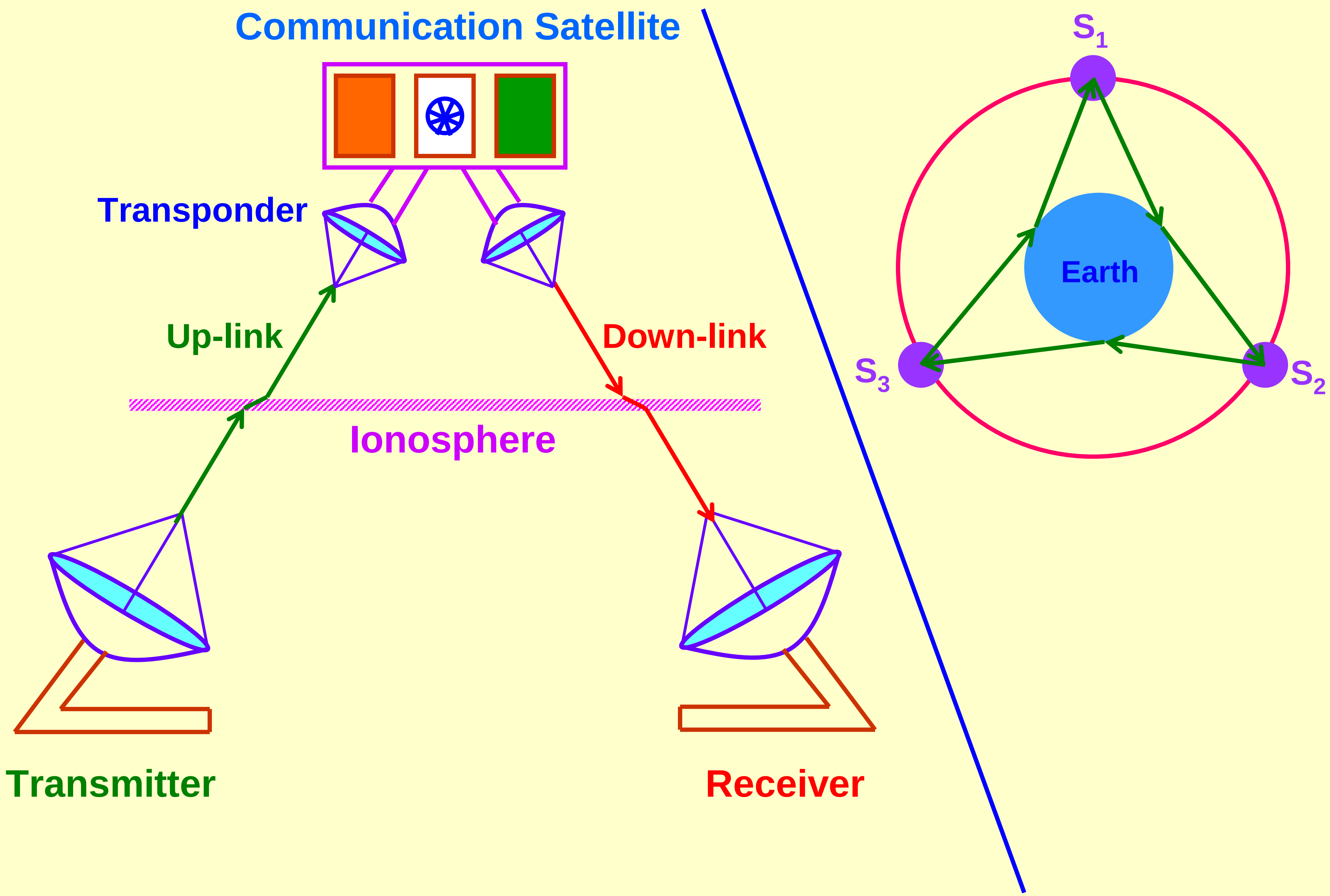
$$(R + h)^2 = R^2 + d^2 \qquad \text{(Note: } QT \approx FQ = d\text{)}$$

or $$d^2 = h^2 + 2hR$$

$$d = \sqrt{(h^2 + 2hR)} \qquad \text{or} \qquad \boxed{d \approx \sqrt{(2hR)}}$$

The antenna of height 80 m can transmit the signal with coverage radius of 32 km and area of 3217 sq. km.

Satellite Communication:



Satellite communication uses UHF / Microwave regions. Microwaves carrying audio, video, telephone, telex, FAX signals, etc. are transmitted from the earth to the satellites orbiting in the space and retransmitted from the satellites to different parts of the earth (world).

The special devices used for this purpose in satellites are called 'transponders'.

Satellite communication is mainly done through 'geostationary satellites'. Three geostationary satellites placed in equatorial orbits at 120° from one another can cover practically the whole populated land area of the world.

Frequency modulation is used for both 'up channel' and 'down channel' transmission. Though FM needs a larger bandwidth, it offers good immunity from interference and requires less power in the satellite transmitter.

Orbit of Communication Satellite:

For global communication, a satellite should move uniformly round a circular orbit with a period of $84.4[r / R]^{3/2}$ minutes, where r is the radius of the orbit of the satellite and R is the radius of the earth.

The circular orbit of the communication satellite is specified in terms of:

(i) The orbit radius (ii) The angle of inclination of the orbit's plane to the Earth's equatorial plane (iii) The position of the ascending mode
(iv) The phase angle of the satellite.

Height of Communication Satellite:

The area of the earth from which a satellite is visible increases with the altitude.

At altitudes below 10,000 km, the number of satellites required for global coverage would be excessive.

At altitudes above 20,000 km, the time taken by signals may be large enough to cause confusion in telephonic conversation.

If time-delay difficulties are ignored, then a synchronous satellite at 36,000 km height can be advantageously used.

Earth-Track Integral System for Communication Satellites:

If several satellites are spaced around the same orbit in space, the tracks of the satellites will be different due to Earth's rotation about its own axis.

If four satellites are placed into different orbits with their ascending modes displaced successively by 30° intervals to the east direction, the difference, in effects of Earth's rotation, can be counteracted and the paths of all the satellites relative to the Earth will be the same.

Such Earth-Track integral systems can be arranged to have the satellite period an integral factor of the sidereal day in order to have the same track repeated day after day.

Remote Sensing Satellites:

'Remote Sensing' is obtaining information about an object by observing it from a distance and without coming into actual contact with it.

The orbit of a remote sensing satellite is such that the satellite passes over a particular latitude at approximately the same local time. i.e. the position of the Sun with respect to a point on the Earth remains approximately the same as the satellite passes over it. Such orbits are called Sun-synchronous orbits.

A remote sensing satellite takes photographs of a particular region with nearly the same illumination every time it passes through that region.

Applications:

1. In Geology
2. In Agriculture
3. In Forestry
4. In Land Mapping
5. In Ocean and Coastal Data
6. In Monitoring Environmental Conditions
7. In Biodiversity
8. In Ground Water Management
9. In Flood Damage Assessment
10. In the Field of Defence
11. In Mapping Wastelands
12. In Early Warning Systems (Natural Calamities)
13. In Management of Water Resources
14. In Fisheries Sectors
15. In Tourism Industry
16. In Planning Pipeline Routs, Ring Roads and Urban Settlements