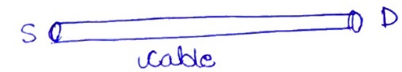
S. No.	Date	Title	Page No.	Teacher's Sign / Remarks

03/01/17

Satellite Communication

Voice signal - 20 Hz to 20 KHz

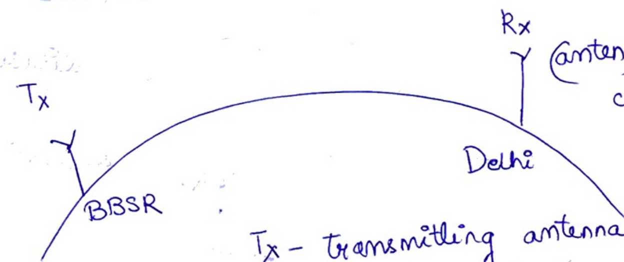


S - Source
D - Destination

(less resistance) and is more costly

(source signal)

(distortion in received signal)



(antenna) since using cable is not effective

Tx - transmitting antenna
Rx - receiving antenna

BBSR → [I + carrier] → Delhi

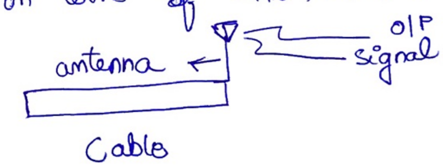
I ↓ voice signal or any signal

The carrier frequency is very high in terms of KHz, MHz, GHz.

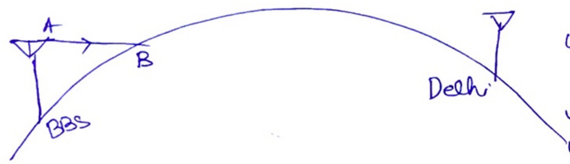
Ex:

Source signal

∗ [carrier] (cos $\omega_c t$ cos $2\pi f_c t$)



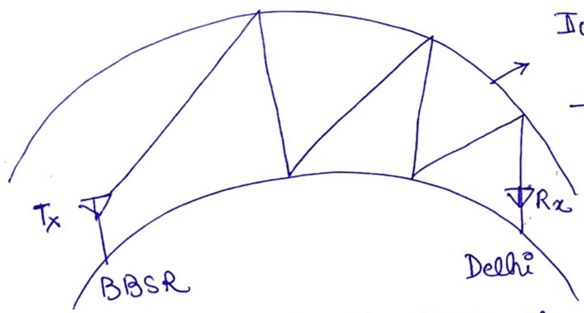
In KHz range, amplitude modulation exists (550 – 1605 KHz)



If signal transmits in AB then it will not reach Delhi and intersect with horizon so we use ionosphere propagation.

ionosphere propagation:

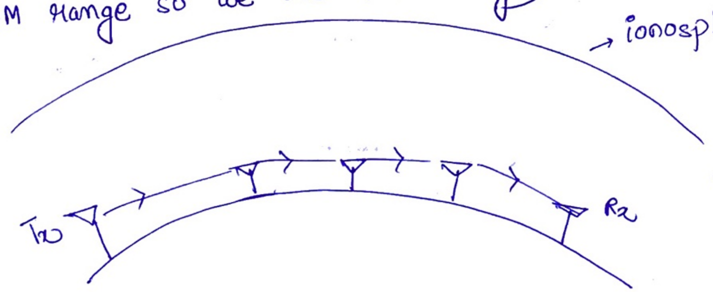
Signal is - uly charged and electrons also -uly charged so they will repel. Range: 550 to 1605 KHz (AM)



→ So disadvantage is delay and distortion.

But this will take long time - if we say 'hello' then it will be heard after 5 mins.

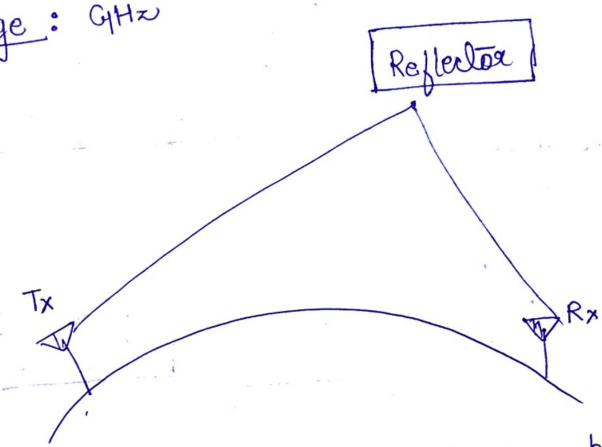
Range: (FM) 80 – 108 MHz (as we have distortion in AM range so we use FM range) → Point to Point communication



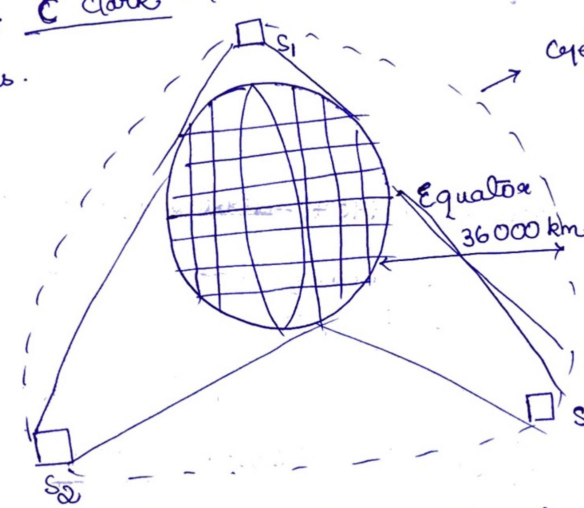
here, distortion is less but cost is more. If we want to communicate to USA then it is not feasible to use so many antenna. So we use GHz range.

If the size of the antenna is more then it is a disadvantage because there may be breakdown during wind.

Range: GHz



1945 → C clark → Total earth can be covered by 3 Satellites.

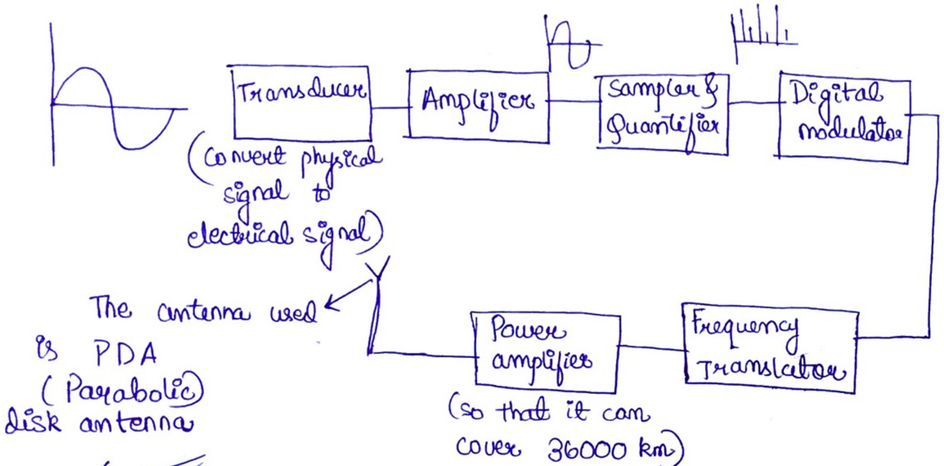


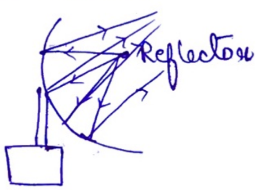
S_1, S_2 and S_3 are the satellites.

Each satellite will cover 42% area of earth and are placed at angle of 120°

We need to place the satellites in the geostationary orbit present at a distance of 36000 km above the earth.

So the satellites are called Geo-stationary satellites.





First satellite - launched in 1957 - first artificial satellite (sputnik)

1958 - SCORE → Christmas greeting from president Eisenhower

1960 - Reflecting satellite (ECHO)

1960 - Store and forward transmission by COURIER

1962 - power relay satellite "Telestar & Relay"

1963 - first geostationary satellite (SYNCON)

1965 - first commercial geostationary satellite (INTELSAT - I) (Early Bird)

06/01/17

Frequency allocation :

Radio Communication Services	Frequency bands uplink / downlink	Usual terminology
1. fixed satellite service	6/4 GHz	C band
	8/7 GHz	X band
	14/12.11 GHz	Ku band
	30/20 GHz	Ka band
	50/40 GHz	V band
2. Mobile Satellite Service (MSS)	1.6/1.5 GHz	L band
	30/20 GHz	Ka band
3. Broadcasting satellite service (BSS)	2.6/2.5 GHz	S band

(uplink - from all stations to satellite)
(downlink - from satellite to stations)
(uplink always greater than downlink)

Frequency band	Range	Application
L	1-2 GHz	Mobile, audio broadcasting
S	2-4 GHz	Mobile Navigation
C	4-8 GHz	Fixed
X	8-12 GHz	Military
Ku	12-18 GHz	Video broadcasting
K	18-24 GHz	Fixed (not used for any purpose)
Ka	24-40 GHz	Video broadcasting inter satellite

(space has infinite bandwidth so we can transmit any frequency)

let carrier frequency used is 971 kHz → this frequency is used only in cuttack station, so we cannot use it elsewhere.

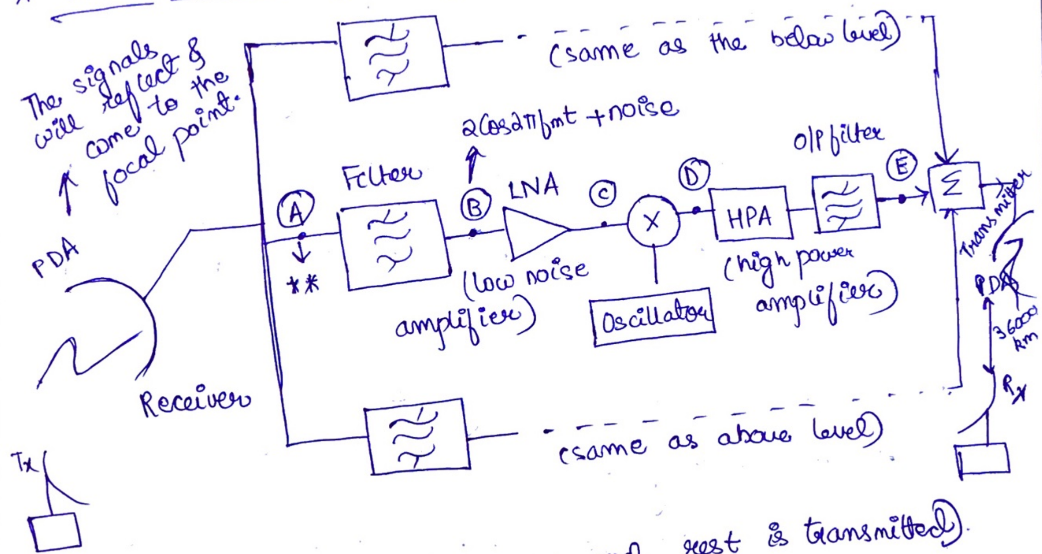
AM range = 550-1605 KHz (long distance communication)
FM range = 88-108 MHz (less noise)
(if we use this, it cannot be used to communicate with hyderabad, Ranchi etc)

hence we normally use GHz range.

Normally human voice is 20 Hz - 20 kHz - so if one sings a song at cuttack, it cannot be heard at bbsr. So to make it possible they use a carrier frequency of 971 kHz which is very large.

* baseband → original or signal
carrier → passed with the original signal.

* Basic block diagram of Satellite :



Filter: (filtering some frequency and rest is transmitted)

let in Tx, there are many channels such as ZTV, NDTV, AjTak → so all these channels will be send using one carrier.

let channel be $\cos 2\pi f_m t$ (let $f_m = 10$ kHz)

carrier frequency $= \cos 2\pi f_c t$ (let $f_c = 6$ GHz)

$$\therefore \underbrace{\cos 2\pi f_m t \times \cos 2\pi f_c t}_{(\cos a \times \cos b)}$$

$$\Rightarrow \cos 2\pi (f_m + f_c)t + \cos 2\pi (f_c - f_m)t$$

** at point A, the amount of signal will be $\cos 2\pi (f_m + f_c)t + \cos 2\pi (f_c - f_m)t$

at filter, the signal at point A is multiplied by $\cos 2\pi f_c t$

i.e $[\cos 2\pi(f_m+f_c)t + \cos 2\pi(f_c-f_m)t] \times \cos 2\pi f_c t$

$$\Rightarrow \underbrace{\cos 2\pi(f_m+2f_c)t}_{\text{high frequency}} + \underbrace{\cos 2\pi f_m t}_{\text{low frequency}}$$

so the low pass filter will pass the low frequency only

$\therefore$ o/p at the filter will be : $2\cos 2\pi f_m t$ + some noise (at point B)

This noise will be removed by LNA.

o/p at LNA = $K\cos 2\pi f_m t$ (o/p at point C)

K ↓ constant, which amplifies the signal.

Oscillator will generate higher frequency. let it be :

$\cos 2\pi f_{c_2} t$ (let f_{c_2} = 40 GHz)

o/p at point D will be: (o/p after multiplication)

$$K_1 \cos 2\pi(f_m+f_{c_2})t + K\cos 2\pi(f_{c_2}-f_m)t$$

The o/p filter will remove noise : so o/p will be at point E.

$$K_2 \cos 2\pi(f_{c_2}+f_m)t + K_2\cos(2\pi(f_{c_2}-f_m))t$$

$\boxed{K_2 >> K_1}$

Note :

(i) A communication satellite may be considered as a distant microwave repeater that receives uplink transmissions, and provides filtering, amplification, processing and frequency translation to the downlink band for re-transmission.

(ii) The uplink and downlink bands are seperated in frequency to prevent interference as well as to prevent oscillation within the satellite amplifier, while permitting simaultaneous transmission and reception within the satellite amplifier.

(iii) While permitting simaultaneous transmission & reception at different frequencies through a device is called the multiplexer

(iv) Moreover, lower frequency band is normally used on the downlink to exploit the lower atmospheric process (also or path loss power plus) thereby minimizing satellite amplifier requirements.

(v) The first stage in the modern transponder amplifier change are provided by solid state FET amplifier. This devices require careful design to minimize noise & intermodulation effects.

(vi) channel filters must also be employed carefully designed to minimize interference from adjacent channels. The final stage of amplification in the transponder are typically provided by travelling wave tube amplifier

$R = S \cdot \frac{l}{A}$

$R \cdot j\omega L \,,\ \frac{1}{j\omega C}$

wire rotating is native.

Resistance term (used in DC)
Impedance " (" " AC)

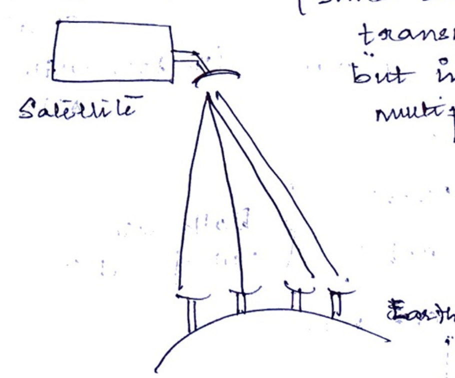
10/1/17

ORBITAL MECHANICS

Advantages of Satellite Communication

(i) It is capable of transmitting signal long dist. without using relay with high capacity

(ii) It is a point-to-multipoint transmission. (since satellite has one transmitting antenna, but in earth we have multiple antenna).



(iii) Satellite costs are independent of distance.

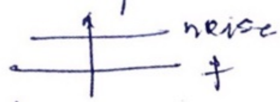
(iv) It provides fixed free space loss in AWGN (Additive white Gaussian noise) channel.

white → as it is constant

spectrum is const. w.r.t. frequency

Gaussian nature – standard nature

(noise spectrum is constant with freq. hence white)



noise is added to the signal, hence additive

(v) the entire globe can be covered with only 3 satellites.

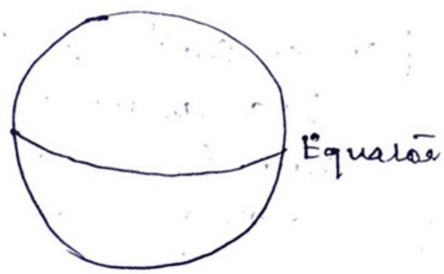
(vi) It offers very high bandwidth in order of 700 MHz or more than this.

Orbital mechanics

Satellites are placed in:

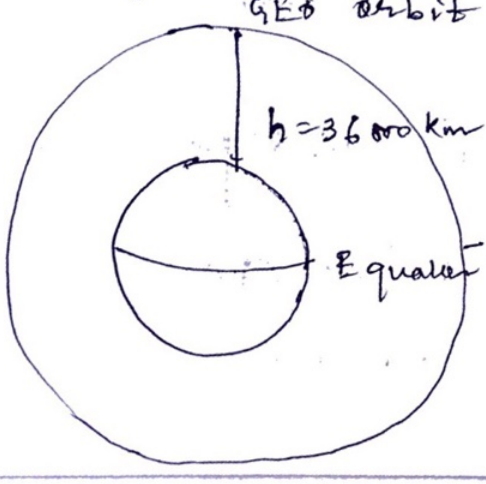
(i) Medium earth orbit [MEO)

(ii) Low earth orbit [LEO)



Geosynchronous orbit } Both are
Geostationary orbit } called GEO.

GEO orbit.



Geosynchronous orbit

23 hrs 56 min 4 sec — 1 sederal day.

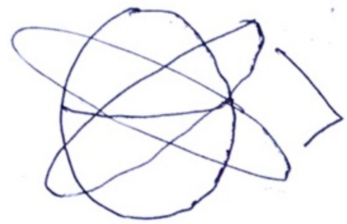
→ It is an orbit about the earth of a satellite with an orbital period that matches the rotation of the ~~Earth~~ ~~of~~ on its axis (1 sederal day) of approximately 23 hrs 56 min 4 sec. The synchronization of rotation and orbital period means that for an observer on surface of earth, an object in geosynchronous orbit returns to exactly the same position in the sky after a period of 1 sederal day.

→ A specific case of geosynchronous orbit is the geostationary orbit (i.e. directly above the equator). A satellite in the geostationary orbit appears stationary always at the same point in the sky to ground observers.

Running notes:

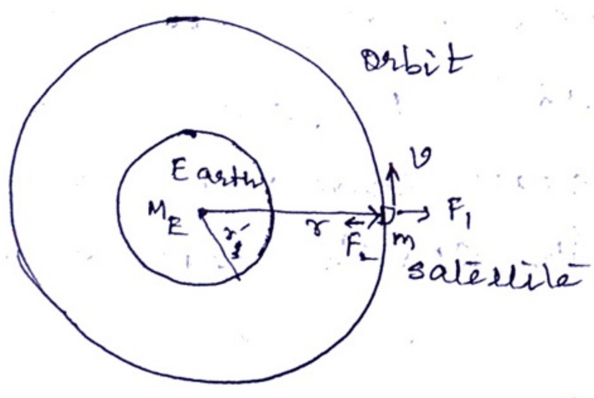
Earth is moving and satellite we are also moving at same speed, and they are rotating just above the equator. So, any observer will think that the satellite is stationary - Geo-stationary.

we can place the satellite on equator [as in geo-stationary) but we can place the satellites in any other angle as shown:



the satellites can be placed in any one of thes angle).

So, at 23hr 56min 4sec → we will find the satellite is over our head. When we view from head. So, every day after this time we see the satellite in same position — Geosynchronous, whereas in geo stationary at all the ~~ite~~ times the satellite appears to remain in the same position.



→ Assume the orbit of satellite is circular in nature.

→ Let the satellite rotating at a distance 'r' from the centre of Earth and r' is the distance from centre to surface of Earth.

M_E : Mass of Earth.

m : mass of satellite

When satellite moving in the orbit, then 2 forces act : centripetal & centrifugal.

→ when $F_1 = F_2$

satellite will be in stable position on the orbit.

→ F_1 = centrifugal force (because of the vel of the satellite)

F_2 = centripetal force. (because of gravitational force of earth)

$$\boxed{F_1 = \frac{mv^2}{r}}$$

$$\boxed{F_2 = ma}$$

$a = 9.8$

→ As we are moving away from the earth, gravitational const increases.

$$F_2 = ma = \frac{mGM_E}{r^2} = \frac{m\mu}{r^2}$$

μ = kepler's constant.

$F_1 = \frac{mv^2}{r}$

and $F_2 = m \cdot a$
acceleration of mass m because of earth.

$F_2 = \frac{m G M_E}{r^2} = \frac{m\mu}{r^2}$ (G = gravitational force)

where μ = kipler's constant

mass of earth (M_E) = 5.974×10^{24} kg

universal gravitational constant = $6.672 \times 10^{-11} \frac{N\text{-}m^2}{kg^2}$

and $r' = 6378.137$ km

$F_1 = F_2$

$\Rightarrow \frac{\cancel{m}\mu}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{r}$

$\Rightarrow \boxed{V = \sqrt{\frac{\mu}{r}}}$ where $\mu = G M_E$

Time of revolulation of a satellite:

$time = \frac{distance}{velocity}$

$\boxed{time = \frac{2\pi r}{V}}$

satellite	Orbital height (km) (from surface of earth)	Orbital velocity ($\frac{km}{sec}$)	Orbital period Hr	Min	Sec
INTELSAT (GEO)	35786.03	3.6747	23	56	4.1
NEW ICO (MEO)	10,255	4.8954	5	55	48
Sky-bridge (LEO)	1,469	7.1272	1	55	17.5
Iridium (LEO)	780	7.4624	1	40	27

LEO - low earth orbit
MEO - medium earth orbit
GEO - geo earth orbit

Q. what should be the orbital velocity of the geo satellite of height = 35786.03 and orbital period = 23 Hr 56 min 4.1 sec.

Ans: Time = $23 \times 60 \times 60 + 56 \times 60 + 4.1$
= ________ sec

height = 35786.03

We know, velocity = $\sqrt{\frac{\mu}{r}} = \sqrt{\frac{G M_E}{r}}$

$r = 35786.03 + 6378.137$

=

substitute the values & find the value of v.

$$\mu = GM_E$$
$$= 6.672 \times 10^{-11} \times 5.974 \times 10^{24}$$
$$= 3.986004418 \times 10^{5} \frac{km^3}{sec^2}$$

$$V = \sqrt{\frac{\mu}{r}} = \_\_\_\_\_\_$$ (ans)

* Notes :

(i) The fundamental properties of orbits are summarized in kepler's 3 laws of planetary motion:

Law 1 : The orbit of each planet (satellite) is an ellipse with the sun (earth) at one focus.

Law 2 : The line joining the sun (earth) to a planet (satellite) sweeps out equal areas in equal times.

Law 3 : The square of the period of revolution is propotional to the cube of the semi-major axis.

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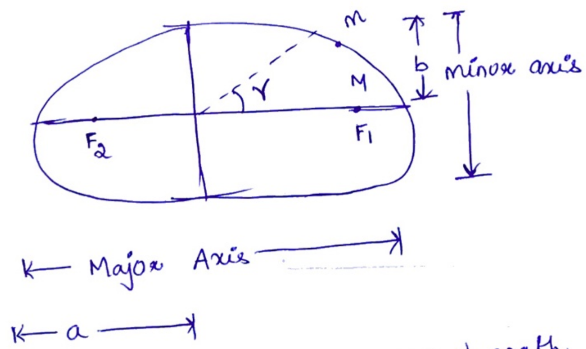
Kepler's Planetary motion laws :

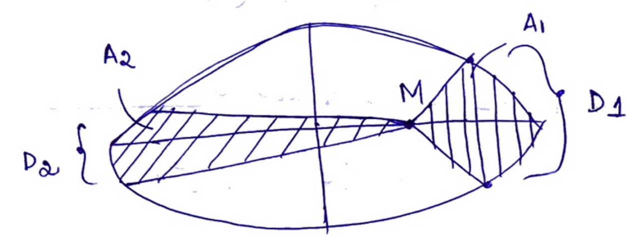
(1) 1st law :



a = semi major axis
b = semi minor axis

M = mass of earth
m = mass of satellite

(2) Law 2 :



(area D_1 = area D_2)

(3) Law 3 : $\boxed{T^2 \propto a^3}$

* eccentricity of ellipse (e) : $\sqrt{\frac{a^2-b^2}{a^2}}$

$$\Rightarrow e = \sqrt{1-(b/a)^2} \quad --- (1)$$

if $e < 1 \rightarrow$ ellipse

$e > 1 \rightarrow$ hyperbola

$e = 1 \rightarrow$ parabola

$e = 0 \rightarrow$ circle

from eq^n (1):

$$\boxed{b = a\sqrt{1-e^2}}$$ (where b = semi-minor axis)

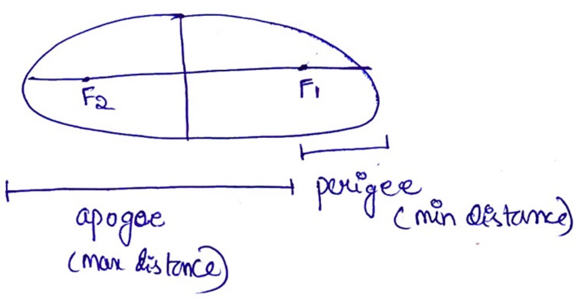
and radius $$\boxed{r = \frac{a(1-e^2)}{1+e\cos v}}$$

when $\cos v = 1$ then r will be minimum

$r_{min} = a(1-e)$ (perigee)

and when $\cos v = -1$ then r will be maximum

$r_{max} = a(1+e)$ (apogee)



* Advantage & disadvantage of geo-synchronous satellite:

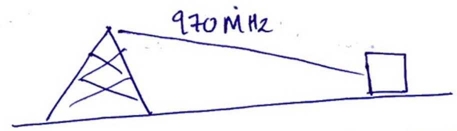
Advantage:

(i) Geo-synchronous satellite remains almost stationary in respect to a Earth station (ES). Consequently, expensive tracking equipment is not required at earth station

(ii) Geo synchronous satellites are available to all earth station within their shadow 100% of the time. The shadow of the satellite includes all the earth station that have a line of sight path to it & lie within the radiation pattern of the satellite's antennas.

(iii) There is no need to switch from one geo synchronous satellite to another as they orbit overhead. Consequently, there is no transmission breaks during switching times.

(iv) The effect of dupler's shift is negligible.



when we are moving towards base station so we may get 965 MHz but if we go away from base station, the frequency may be 975 MHz but not exact 970 MHz → this is dupler's shift

$\boxed{f \pm \Delta f}$ → dupler's shift

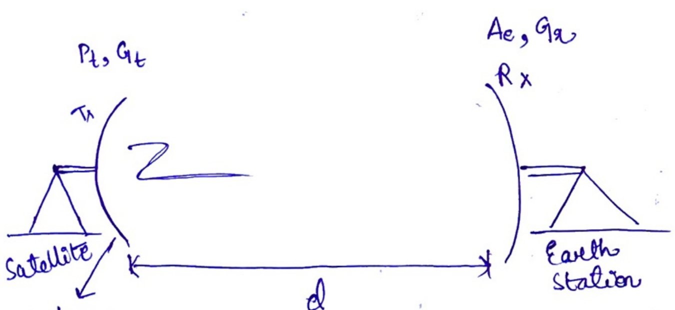
* Disadvantage:

(i) Geo synchronous satellite requires sophiscated and heavy propulsion devices on hard board to keep them on a fixed orbit.

(ii) High altitude geo-synchronous satellites introduce much longer propagation delay. The round trip propagation delay is b/w the Earth station & the geo stationary satellite is b/w 500 ms to 600 ms.

(iii) ~~High~~ precision ~~spectrumship is~~ req' Geo ~~stationary~~ synchronous satellite require high transmit power & more sensitive receiver because of longer distance and greater path loss.

BASIC TRANSMISSION THEORY



antenna which transmits power P_t and gain of antenna is G_t.

d = distance from satellite to surface of earth.

P_t = transmitted power

G_t = gain of transmitter antenna

A_e = effective area of receiver

G_r = gain of receiving antenna

$$\text{gain} = \frac{\text{output power}}{\text{input power}}$$

(or)

$$\text{gain} = \frac{\text{output voltage}}{\text{input voltage}}$$

gain may be +ve or −ve. (output power higher than input higher then +ve → this acts as amplifier, but if output power less than input power then gain is −ve → this acts as attenuator)

gain is measured in dB.

$$\boxed{0\ dB = 1}$$

when gain = 1, the device is said as buffer and also in common-collector configuration voltage gain = 1.

we need to measure the ~~power~~ flux density (power per unit area) at a distance d from the antenna.

$$\underbrace{P}_{\text{flux density}} = \frac{P_t G_t}{4\pi d^2} \left(\frac{W}{m^2}\right)$$

→ unit. → watt/m^2

Power received (P_r) by the Earth station receiving antenna having effective area A_e is: $\boxed{P \times A_e}$ watt

P → flux density.

$$P_r = \frac{P_t G_t}{4\pi d^2} \times A_e \quad \text{---(1)}$$

$$\text{and} \quad \boxed{G_r = \frac{4\pi A_e}{\lambda^2}} \text{---(2)} = \frac{4\pi A_e f^2}{c^2} = \frac{4\pi}{\lambda^2} \times \frac{\pi D^2}{4}\eta$$

where λ = wavelength of the frequency.

D = diameter of antenna.

$\underbrace{\eta}_{\text{efficiency}}$ = range varies from 50% to 75%.

$$\therefore \boxed{A_e = \frac{\pi D^2}{4}\eta}$$

putting the value of Ae from eq^n (2) into 1 we get:

$$P_r = \frac{P_t G_t}{4\pi d^2} \times \frac{G_r \lambda^2}{4\pi}$$

$$\Rightarrow \boxed{P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}}$$

In units of dB:

$$10 \log P_r = 10 \log\left[\frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}\right]$$

$$= 10 \log P_t G_t + 10 \log G_r - 10 \log\left(\frac{4\pi d}{\lambda}\right)^2$$

$$= 10 \log(EIRP) + \underbrace{10 \log G_r - 10 \log\left(\frac{4\pi d}{\lambda}\right)^2}$$

during subtraction there is a path loss.

EIRP = $P_t G_t$ (effective isotropic radiated power)

EIRP is +ve since P_t & G_t should be positive as we don't need any attenuation. (G_t -ve means attenuation)

& if distance & frequency increases then received power P_r decreases.

if frequency increases $10 \log\left(\frac{4\pi d}{\lambda}\right)^2$ increases then max value will be subtracted so P_r will be very less, so path loss increases. and also if distance 'd' increases then path loss increases.

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

∴ path loss $L_p = \left(\frac{4\pi d}{\lambda}\right)^2$

$$\therefore \boxed{P_r(dB) = EIRP(dB) + G_r(dB) - L_p(dB)}$$ → eq^n of received power.

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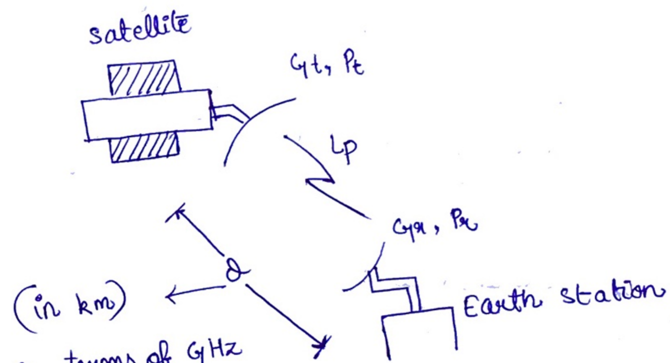
Basic Transmission Theory of satellite



f in terms of GHz

$$P_r = \frac{P_t G_t G_r}{\left(\frac{4\pi d}{\lambda}\right)^2} = \underset{(W)}{EIRP} \times G_r \times \frac{1}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$10 \log P_r = 10 \log(EIRP) + 10 \log G_r - 10 \log_{10}\left(\frac{4\pi d}{\lambda}\right)^2$$

$$\Rightarrow \boxed{P_r(dBW) = EIRP(dBW) + G_r(dB) - L_p(dB)}$$

Converting km into m.

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi d f}{c}\right)^2 = \left(\frac{4\pi \times 10^3 d(km) \times 10^9 f(GHz)}{3 \times 10^8\ m/sec}\right)^2$$

by taking 10log on both sides we get:

$$\Rightarrow 10\log L_p = 20\log\left(\frac{4\pi\times10^4}{3}\right) + 20\log d(km) + 20\log f(GHz)$$

$$\Rightarrow \boxed{10\log L_p = 92.5dB + 20\log d(km) + 20\log f(GHz)}$$

Qn: A geosynchronous satellite at a distance of 36000 km from the surface of earth & Radiated a power of 10 watt in the desired direction through an antenna having a gain of 20 dB. What should be the power density at the receiving side on the surface of earth and also the power received by an antenna having an effective aprature of 10 m². Assume frequency = 4GHz.

Ans: Power density at ~~dis~~ distance d
Power received at distance d
} To find

Given:

$d = 36000$ km.

$P_t = 10$ watt

$G_t = 20dB$

$A = 10m^2$

$$\therefore G_r = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi A_e}{(c/f)^2} = \frac{4\pi A_e\times f^2}{c^2} = \frac{4\times\pi\times10\times(4\times10^9)^2}{(3\times10^8)^2}$$

$$=$$

$$P_r = \frac{P_t\cdot G_t\cdot G_r}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$\therefore P_r(dBW) = EIRP(dBW) + G_r(dB) - L_p(dB)$$

and,
$$10\log L_p = 92.5dB + 20\log d(km) + 20\log f(GHz)$$

$$\Rightarrow 10\log L_p = 92.5dB + 20\log 36000 + 20\log 4$$

$$\Rightarrow 10\log L_p =$$

Now, $EIRP = P_t\cdot G_t$ → we cannot directly multiply since one is in dB & other is in watt.

$\cancel{10\log_{10} EIRP} = \cancel{10\log_{10} P_t} + \cancel{10\log_{10} G_t}$

$\cancel{10\log_{10} EIRP} = \cancel{10\log_{10} 10} + \cancel{10\log_{10}}$

$20dB = 10\log_{10} x$

so x is 100.

$$\therefore EIRP = 100\times10$$

$$\boxed{EIRP = 1000 \text{ watt}}$$

$$10\log P_r = 10\log(EIRP) + 10\log G_r - 10\log\left(\frac{4\pi d}{\lambda}\right)^2.$$

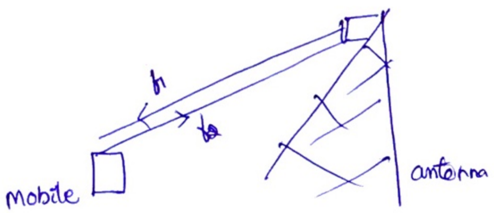
$$P_r(dBW) = EIRP(dBW) + G_r(dB) - L_p(dB)$$

$$\Rightarrow P_r(dBW) =$$

Qn: why uplink frequency choosen higher than downlink frequency.

Ans: (i) Interference is avoided by choosing differente frequency for uplink & downlink since the same antenna is used for both transmission and reception in satellite.

Explanation: (Mobile Communication)



(f_1 and f_2 are always different else the receiver can't understand what the speaker is talking and vice versa).

The same antenna is used for both transmission & reception → similarly the same antenna is used for transmission & reception in satellite.

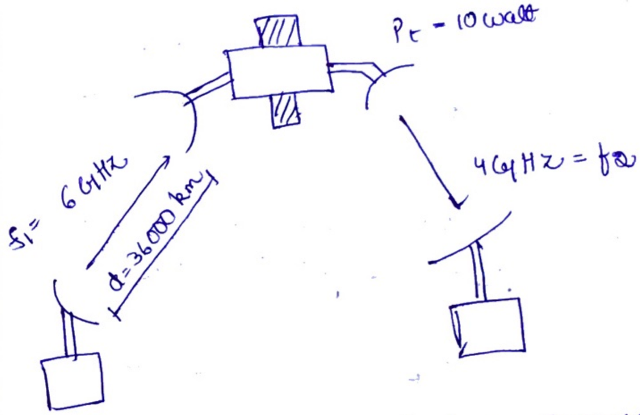
uplink / downlink
6GHz / 4GHz

These values are always different else we can't understand what the satellite transmits and the satellite cannot understand what we transmit.

(ii) Free space loss is more if the frequency is more. If the downlink frequency is choosen high then more path loss will occur. But that loss cannot be compensated by the satellite since the power is limited at the satellite. On the other hand by

choosing higher uplink frequency the corresponding path loss can be compensated by pumping more power from the earth base transmitter.

Explanation:
(Path loss is also known as free space loss – L_p)



f increases then L_p increases.
f decreases then L_p decreases.

Let f_1 = 4GHz and f_2 = 6GHz
So the satellite need to transmit power P_t = 20 watt instead of P_t = 10 watt for frequency of 6GHz. But to increase the power P_t we need to use amplifier so the weight of the satellite will increase → To maintain ~~keep~~ the satellite's (above the earth surface at 36000 km) longetivity, the weight of satellite should be less hence P_t cannot be increased to 20 watt so in turn f_2 cannot be 6GHz and will be reduced to 4GHz so $f_1 = f_2$ which is not possible as per explanation 1, hence f_1 = 6GHz and f_2 = 4GHz.

(iii) The beamwidth of the antenna is given by:

$$\theta_{3dB} = \frac{70\lambda}{D} = \frac{70\,c}{D\,f}$$

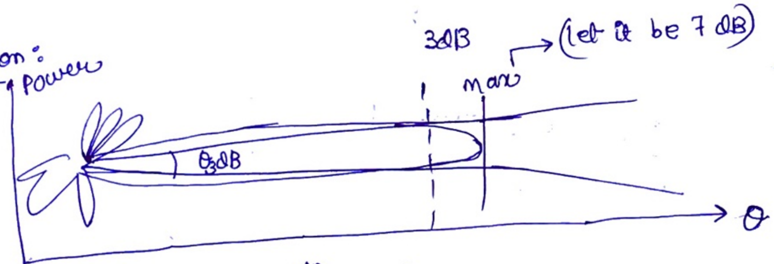
$$\theta_{3dB} \propto \frac{1}{f}$$

If the frequency is higher then the 3dB beamwidth from antenna will be narrow, so that a fine pencil beam with concentrating power can be aimed at the satellite which is located at a fixed point in the space.

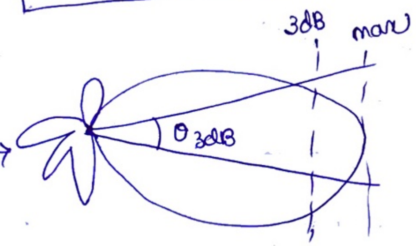
On the other hand, the downlink frequency is less so that broader the beam width, that coverage is more.

Explanation:

When 3dB is less →



when 3dB angle is more →



for covering max area, the beamwidth should be maximum.

so that the receiving signal from satellite is transmitted to maximum area of the earth.

20/1/17

Satellite Link Design

we know,

$$P_r = \frac{P_t \cdot G_t \cdot G_r}{\left(\frac{4\pi d}{\lambda}\right)^2} = \frac{P_t \cdot G_t \cdot G_r\, \lambda^2}{(4\pi d)^2} = \frac{P_t G_t G_r}{(4\pi)^2} \times \left(\frac{\lambda}{d}\right)^2$$

$$= \frac{P_t \cdot G_t \cdot G_r}{(4\pi)^2} \cdot \left(\frac{c}{fd}\right)^2 \quad \text{--- (1)}$$

also,

$$P_r = EIRP \times G_r \times \frac{1}{\left(\frac{4\pi d}{\lambda}\right)^2}$$

$$= EIRP \times G_r \times \frac{1}{L_p}$$

Link Design equation.

and,

$$\boxed{P_r(dB) = EIRP(dBW) + G_r(dB) - L_p(dB) - L_{ta}(dB) - L_{ra}(dB) - L_a(dB)}$$

where L_{ta} = loss because of transmitting antenna

L_{ra} = loss because of receiving antenna

L_a = atmospheric loss

L_p = loss because of propagation

Eqn (1) can also be written as:

$$\frac{P_t \cdot G_t \cdot G_r}{(4\pi)^2} \cdot \left(\frac{c}{fd}\right)^2 = \frac{P_t G_t \cdot G_r}{(4\pi)^2}\left(\frac{3\times10^8}{10^9 f(GHz) \times 10^3 d(km)}\right)^2$$

let, $f = 6\,GHz$

$d = 36000$ km

$$L_p = \left(\frac{4\pi d}{\lambda}\right)^2 = \frac{4\pi \times 10^3 d(km)}{3\times10^8\ m/sec} \times 10^9 f(GHz)$$

$$\boxed{10\log L_{p\,(dB)} = 92.5\,(dB) + 20\log d\,(km) + 20\log f\,(GHz)}$$

$$\frac{\text{carrier power}}{\text{noise power}} = \frac{\text{received power}}{\text{Noise power }(N_0)} = \frac{P_r}{N_0} = \frac{C}{N}$$

$$\frac{C}{N} = \frac{P_r}{N_0} = \frac{(EIRP)\, G_r \cdot \left(\frac{1}{L_p}\right)}{K T_s B}$$

where K = Boltzman's constant $= 1.39 \times 10^{-23}\ J/°K$

T_s = system noise temperature $(°K)$ (kelvin)

B = Bandwidth

in terms of dB :

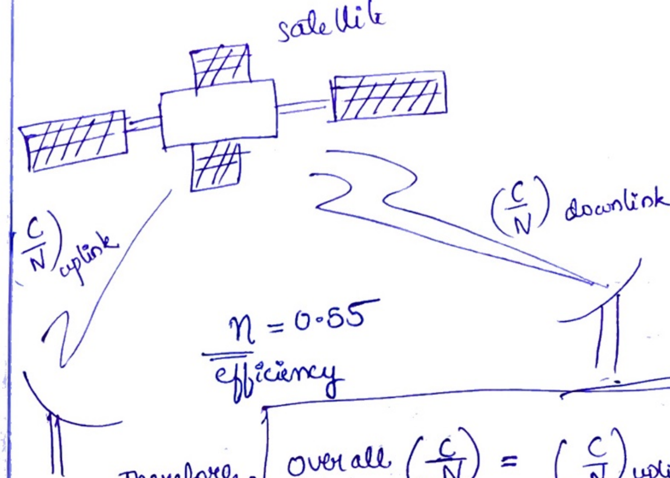
$$\left(\frac{C}{N}\right)_{dB} = 10\log\left(EIRP \times \frac{G_r}{T_s} \times \frac{1}{L_p} \times \frac{1}{K} \times \frac{1}{B}\right)$$

$$= 10\log(EIRP) + 10\log\frac{G_r}{T_s} - 10\log L_p - 10\log K - 10\log B$$

$$\boxed{\left(\frac{C}{N}\right)_{dB} = EIRP\,(dBW) + \frac{G_r}{T_s}(dB/K) - L_p\,(dB) + 228.6\,(dBJ/°K) - B\,(dB\,Hz)}$$

(∵ $EIRP = P_t \cdot G_t$

P_t is in terms of watt & G_t is unitless so we write dBW)



$\eta = 0.55$
efficiency

Therefore,

$$\boxed{\text{overall}\left(\frac{C}{N}\right) = \frac{\left(\frac{C}{N}\right)_{uplink} \times \left(\frac{C}{N}\right)_{downlink}}{\left(\frac{C}{N}\right)_{uplink} + \left(\frac{C}{N}\right)_{downlink}}}$$

Example :

uplink parameters :

(i) uplink frequency = 14.25 GHz
(ii) transmitter power = 174 watt (P_t)
(iii) antenna diameter = 7 m
(iv) tracing loss = 1.2 dB
(v) distance b/w earth station & satellite = 37506 km
(vi) Satellite receiver antenna gain to system noise temp is 1.6 dB/°K
(vii) Bit rate = 60 mbps (mega bit)
(viii) modulation = QPSK

Downlink parameters :

(i) " frequency : 11.95 GHz

(ii) EIRP = 44 dBW

(iii) Satellite transmitter antenna diameter = 0.372 m

(iv) Earth station noise temp = 160°K

(v) Tracing loss = 0.9 dB

(vi) Bit rate = 60 mbps

(vii) Modulation = QPSK

Find the overall $\left(\frac{C}{N}\right)$ and bit ~~beam~~ ~~heat~~ energy $\left(\frac{E_b}{N_0}\right)$ overall.

Ans:

(i) To find EIRP :

$$EIRP = P_t \cdot G_t$$

$$= 174(W) \times \left(\frac{4\pi A_e}{\lambda^2}\right)$$

$$= 174 \times \left(\underbrace{\frac{4\pi}{\lambda^2} \times \frac{\pi d^2}{4} \times n}_{\text{formula for } G_t}\right)$$

→ efficiency

formula for G_t. (the same formula is for G_r)

$$= 174 \times \left(\frac{4\pi f^2}{c^2} \times \frac{\pi d^2}{4} \times 0.55\right)$$

$$= 174 \times \frac{\pi^2 \times f^2}{c^2} \times n \times d^2$$

→ diameter

$$= 174 \times \pi^2 \times \frac{(10^9 f(GHz))^2}{(3\times10^8 m/sec)^2} \times 0.55 \times (7m)^2$$

$$EIRP = 174(W) \times 57.78 dB.$$

$$\Rightarrow EIRP(dB) = 10\log 174 (dBW) \times 57.78 dB.$$

$$\Rightarrow EIRP(dB) = 22.4 (dBW) \times 57.78 dB$$

$$\Rightarrow \boxed{EIRP(dB) = 80.185 dBW}$$

(ii) To find $\frac{G_r}{T_s}$

it is given as : $\frac{G_r}{T_s} = 1.6 dB/°K$ (given in question)

(iii) $L_p (dB) = 92.5 + 20\log d(km) + 20\log f(GHz)$

$$\Rightarrow L_p(dB) = 92.5 + 20\log 37506 + 20\log 14.25$$

$$\Rightarrow \boxed{L_p(dB) = 207.05 dB}$$

(iv) Tracing loss = 1.2 dB (given in question)

$$\therefore \left(\frac{C}{N}\right) = EIRP(dBW) + \frac{G_r}{T_s}(dB/°K) - L_p(dB) + 228.6 dB/K - B(dBHz)$$

(we did not consider bandwidth because it is not given in ques")

$$= 80.185 dBW + 1.6 dB/°K - 207.05 dB + 228.6 dB/K - 1.2 dB$$

this is the tracing loss which is given in ques", if any other loss is provided in ques, we have to subtract it for finding the value of (C/N)

$$\boxed{\left(\frac{C}{N}\right)_{uplink} = 102.335 dB}$$

Similarly, $\left(\frac{C}{N}\right)_{downlink} = 100.383$

These are not in dB → so we need to convert our calculated values from dB to normal scale.

Therefore:

$$\left(\frac{C}{N}\right)_{overall} = \frac{\left(\frac{C}{N}\right)_{downlink} \times \left(\frac{C}{N}\right)_{uplink}}{\left(\frac{C}{N}\right)_{uplink} + \left(\frac{C}{N}\right)_{downlink}}$$

=

(Refer pg-37)

Overall ~~beam~~ bit energy by noise ratio: $\left(\frac{E_b}{N_0}\right)$

$$\boxed{\left(\frac{E_b}{N_0}\right)_{uplink} = \frac{\text{bit energy}}{\text{noise power}}}$$

Received power (C) = $\frac{\text{bit energy } (E_b)}{T_b}$

$\Rightarrow C = \frac{E_b}{T_b}$

now, $\frac{E_b}{N_0} = \frac{C}{N_0} \times T_b$

~~where Bit energy = $\frac{C}{T_b} = \frac{C}{\text{time period of bit}}$~~

given,

uplink speed = 60 Mbps

i.e 60×10^6 bits → 1 sec

$\Rightarrow$ 1 bit $= \frac{1}{60 \times 10^6}$ sec

(ex: 10 bps – 10 bits are transmitted in 1 sec
10 bit – 1 sec
1 bit – 1/10 sec
so each bit duration i.e T_b is 1/10 sec)

$\Rightarrow T_b = \frac{1}{60 \times 10^6}$ sec

∴ ~~Bit energy = $\frac{C}{T_b}$ = $3 \times 10^8 \times 60 \times 10^6$~~

$$\left(\frac{E_b}{N_0}\right)_{uplink} = \frac{C/T_b}{N_0} = \left(\frac{C}{N_0}\right)_{uplink} \times \left(\frac{1}{T_b}\right)_{uplink}$$

$= 272.27$ dB

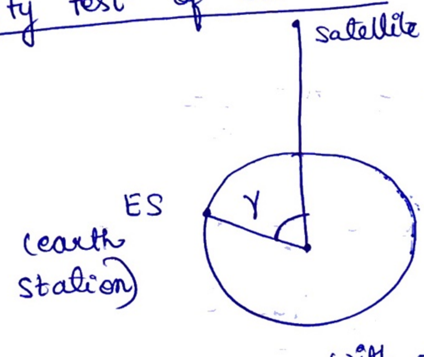
Similarly find $\left(\frac{E_b}{N_0}\right)_{downlink} = 182.095$ dB.

Then,

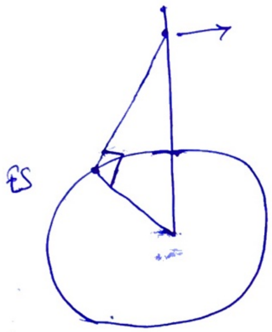
$$\boxed{\text{overall}\left(\frac{E_b}{N_0}\right) = \frac{\left(\frac{E_b}{N_0}\right)_{uplink} \times \left(\frac{E_b}{N_0}\right)_{downlink}}{\left(\frac{E_b}{N_0}\right)_{uplink} + \left(\frac{E_b}{N_0}\right)_{downlink}}}$$

* Visibility test of Satellite:

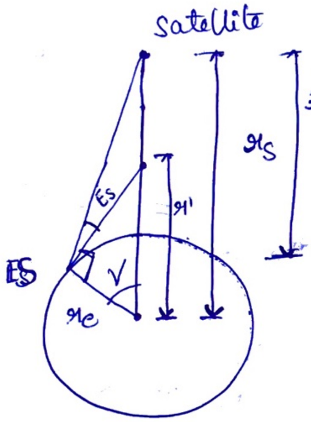
Example:



Qn: what should be the max angle γ so that if we stand at the given point ES so that we can see the satellite / communicate with the satellite.



from ES we can see upto this point but if satellite is below this point, we cannot see the satellite but above that point we can see the satellite.



36000 km (distance from surface to satellite)

r_e = radius of earth

r_S = distance of satellite

$r_S = 36000 + r_e$

$r_e = 6378.137$

$\Rightarrow \boxed{r_S = 42378}$

Condition for visibility:

$\boxed{r_S > r'}$ else we cannot see the satellite

$\cos\gamma = \dfrac{r_e}{r'} \quad \Rightarrow \quad r' = \dfrac{r_e}{\cos\gamma}$

Now, $\dfrac{r_e}{\cos\gamma} < r_S$, for visibility

$\Rightarrow \dfrac{6378.137}{\cos\gamma} < 42378$

$\Rightarrow \dfrac{6378.137}{42378} < \cos\gamma$

$\therefore$ $\boxed{\text{Max value of } \gamma = 81.3^\circ}$ (so above 81.3° we cannot see the satellite)

23/1/17

Equivalent System Noise Temperature of cascade stages

(from page 34)

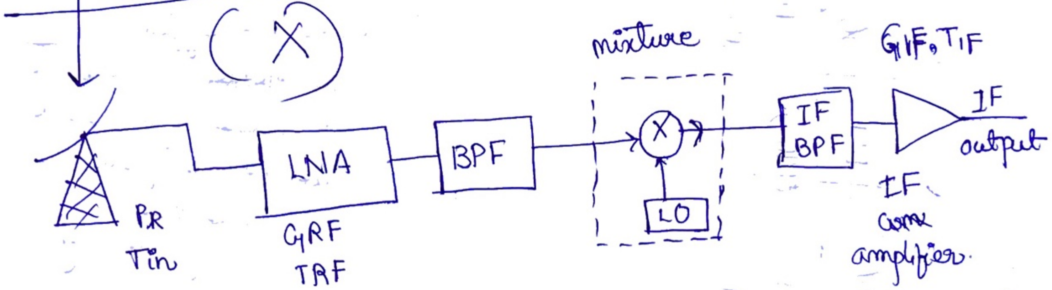
Received power $(C) = \dfrac{E_b}{T_b}$

$\Rightarrow \dfrac{E_b}{N_0} = \dfrac{C}{N_0} \times T_b$

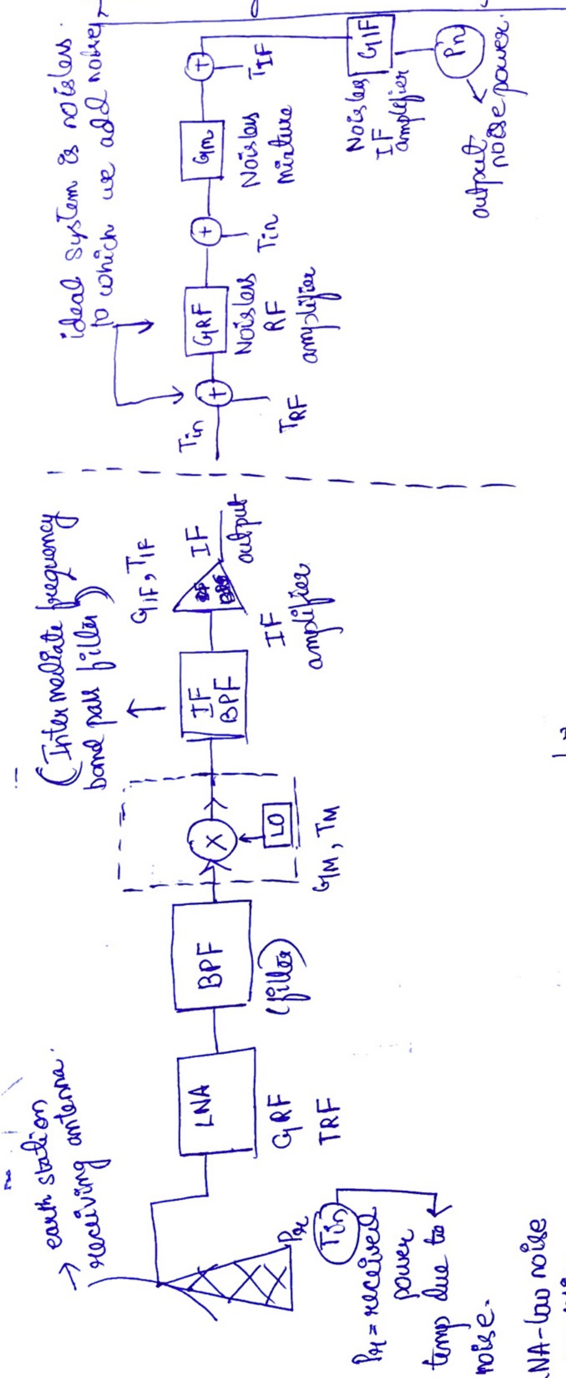
$\Rightarrow \dfrac{E_b}{N_0} = \left(\dfrac{C}{N_0}\right) \times \left(\dfrac{1}{R_b}\right)$ where $R_b = \dfrac{1}{T_b}$

Bit energy (E_b)

$$\boxed{10\log\left(\frac{E_b}{N_0}\right) = 10\log\left(\frac{C}{N_0}\right) - 10\log R_b}$$



Equivalent System Noise Temperature of Cascade Stages



(1) Consider a cascaded arrangement of 3 stages with respective individual gains as:

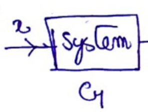
G_{RF}, G_M and G_{IF}

and input noise temperature parameters as:

T_{RF}, T_M and T_{IF}

we know, $P_n = KTB$

This temp is created due to thermal noise.



where G = gain of system

To make the system noiseless:

we seperate noise & the noiseless system so the noiseless system the noise is added gradually.

we know, $P_n = G_{IF} K T_{IF} B_n$ where K = boltzman constant, B_n = bandwidth

The total noise power will be:

$$P_n = G_{IF} K T_{IF} B_n + G_m G_{IF} K T_m B_n + G_{RF} G_m G_{IF} K (T_{in} + T_{RF}) B_n$$

This is the individual noise power which is added to the 3 noisless systems as shown in fig i.e G_{RF}, G_m, G_{IF}.

$$\Rightarrow P_n = G_{RF} G_M G_{IF} K B_n \left[T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_M \cdot G_{RF}} \right]$$

$$\Rightarrow \boxed{P_n = G_{RF} G_M G_{IF} K B_n T_s}$$

where $\boxed{T_s = T_{in} + T_{RF} + \frac{T_m}{G_{RF}} + \frac{T_{IF}}{G_M G_{RF}}}$

(if T_{in} is not given in ques then don't consider it.)

Suppose there are 3 gains G_1, G_2, G_3 and the corresponding temp are T_1, T_2, T_3

∴ System noise temp (T_s) will be:

$$\boxed{T_s = T_1 + \frac{T_2}{G_1} + \frac{T_3}{G_2 G_1}}$$

Question: (40)

A 4GHz receiver has the following parameters:

$T_{in} = 25K$, $T_{RF} = 50K$, and $T_m = 500K$, $T_{IF} = 1000K$

$G_{RF} = 23°$, $G_{IF} = 30°$,

Case 1: Find out the system noise temp for $G_m = 0°$.

Case 2: " " " " " " T_s " $G_m = 10dB$ loss.

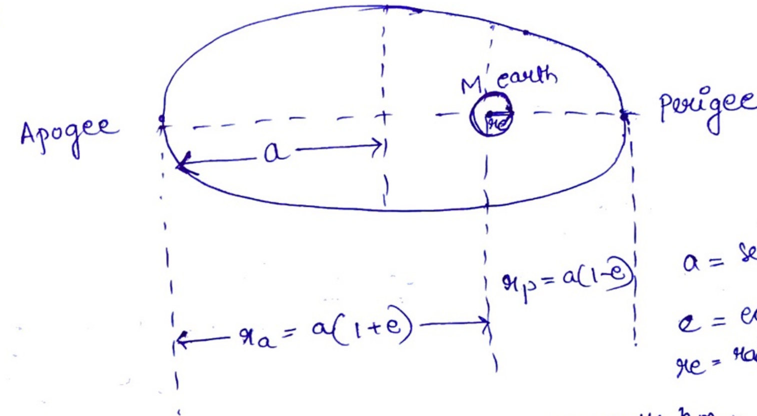
Ans: **Case 2:**

$G_m = 10dB$ loss.

(No value should be in dB so convert to normal form while calculating)

Question: (Kepler's 3rd law) (41)

A satellite is an elliptical orbit with a perigee of 1000 km and an apogee of 4000 km from the surface of the earth.



a = semi major axis
e = eccentricity
re = radius of earth.

Using the mean earth radius of 6378.14 km, find the period of the orbit in hrs, mins and secs & find the eccentricity of the orbit.

Ans: Formula for period:

$$T^2 = \frac{4\pi^2}{\mu} a^3$$

for elliptical orbit, eccentricity $(e) < 1$

$\mu = 3.986004418 \times 10^5 \ km^3/sec^2$

given, $r_a = a(1+e)$ and $r_p = a(1-e)$

dividing both we get:

$$\frac{r_a}{r_p} = \frac{1+e}{1-e}$$

$$\Rightarrow \frac{4000}{1000} = \frac{1+e}{1-e}$$

$\Rightarrow 4(1-e) = (1+e)$

$\Rightarrow 4-4e = 1+e$

$\Rightarrow 3 = 5e$

$\Rightarrow e = 3/5 = \boxed{0.6}$

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now, $r_p = a(1-e)$

$\Rightarrow 1000 = a(1-0.6)$

$\Rightarrow a = \dfrac{1000}{0.4}$

$\Rightarrow \boxed{a = 2500}$

alternate method to find a:

$2a = 4000 + \underline{2\times 6378.14} + 1000$

↳ since the distance of r_p & r_e is from surface of earth so total distance will be $r_p + r_e$ + diameter of earth.

$\Rightarrow \boxed{a = 8878.14 \text{ km}}$

and $1000 + r_e = a(1-e)$

$\Rightarrow \boxed{e = 0.169} < 1.$

then find the period T.

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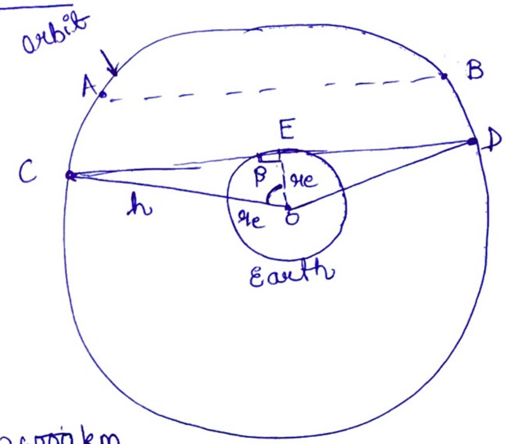
* Maximum line of sight distance between Geostationary Satellite:



If one satellite is at A & other at B then is the line AB the max line of sight? or the line CD is the max line of sight.

$h = 36000$ km

$r_e = 6378.14$ km

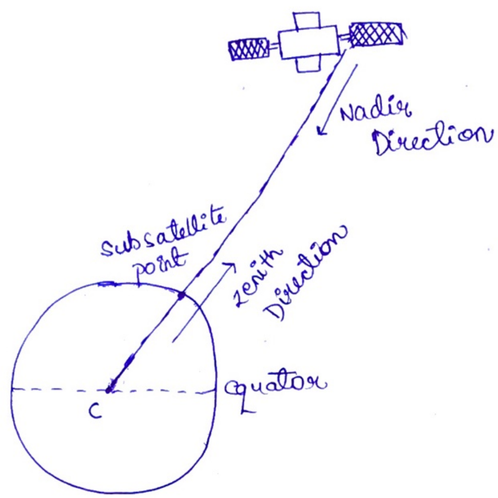
ΔCOE is a right angle triangle.

~~tan β = CE/h~~

24/1/17

Look Angle Determination of Satellite

$\boxed{\text{Elevation Angle, Azimuth Angle}}$



Notes :

(i) Subsatellite Point :

(a) The sub satellite point is a place where the line drawn from the centre of earth to the satellite passes through the earth surface.

(b) This point will be an equator for an ideal geostationary satellite

(c) The satellite point is the nadir pointing direction from the satellite

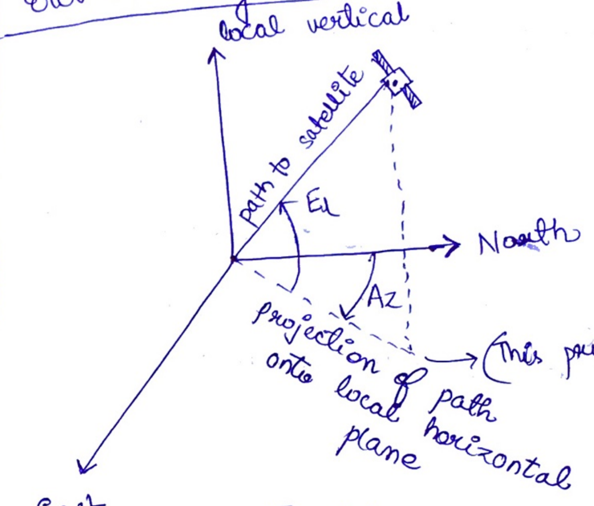
(d) For a satellite, in an equitarial orbit, it will always be located on the equator.

(e) Since the geostationary satellite are in equitarial orbits and are designed to stay stationary over the earth, it is usual to give their orbital location in terms of their sub satellite point.

(f) To an observer of a satellite standing at a sub satellite point, the satellite will appear directly over head in the zenith direction from the observing location.

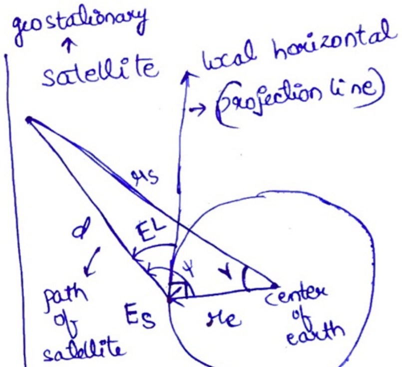
(g) so the zenith and Nadir paths are therefore opposite direction along the same path.

Elevation Angle :



→ (This projection line is always tangent to the surface of earth)

Fig I :



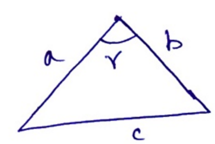
$r_e = 3678.13$ km

$d = 36000$ km

$r_s =$

Fig II

law of cosine :



$$\boxed{c^2 = a^2 + b^2 - 2ab\cos\gamma}$$

law of sine :

$$\boxed{\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}}$$

* Elevation Angle:

(i) The coordinates to which an earth station antenna must be pointed to communicate with a satellite is called the Look Angles.

(ii) These are most commonly expressed as Azimuth (A_z) and Elevation (E_l) angle.

(iii) Azimuth is measured eastwards (clockwise) from the geographical north point to the projection of the satellite path on a horizontal plane at earth station.

(iv) Elevation is the angle measured upward from the local horizontal plane at the earth station to the satellite path.

Finding E_l from Fig b:

$$E_l = \psi - 90^\circ$$

taking cos both sides we get:

$$\cos E_l = \cos(\psi - 90^\circ)$$

$$\Rightarrow \boxed{\cos E_l = \sin\psi} \quad \text{---(1)}$$

given, r_s, d, r_e and γ. we need to find E_l.

Using the sine law:

$$\frac{r_s}{\sin\psi} = \frac{d}{\sin\gamma}$$

$$\Rightarrow \frac{r_s}{\cos E_l} = \frac{d}{\sin\gamma} \quad (\because \text{from eq}^n\ 1)$$

$$\Rightarrow \frac{r_s \sin\gamma}{d} = \cos E_l$$

$$\Rightarrow \boxed{E_l = \cos^{-1}\frac{r_s \sin\gamma}{d}} \quad \text{----(2)}$$

Using the cosine law: (we find the value of d)

$$d^2 = r_s^2 + r_e^2 - 2 r_e r_s \cos\gamma$$

$$\Rightarrow d^2 = r_s^2\left[1 + \left(\frac{r_e}{r_s}\right)^2 - \frac{2 r_e}{r_s}\cos\gamma\right]$$

$$\Rightarrow \boxed{d = r_s\left[1 + \left(\frac{r_e}{r_s}\right)^2 - \frac{2 r_e}{r_s}\cos\gamma\right]^{1/2}} \quad \text{--- (3)}$$

Now put the value of 'd' from eq (3) to eq^n (2) to get the value of E_l.

Finding γ:

$$\boxed{\cos\gamma = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s)}$$

Where $\boxed{L_e}$ = no of degree in latitude that the earth station is north from the equator.

$\boxed{l_e}$ = west from longitude (no of degrees in longitude that the earth station is west from Greenwich meridian.

$\boxed{L_s}$ = The subsatellite point at north latitude ~~latitude~~ ~~longitude~~.

$\boxed{l_s}$ = The subsatellite point at west ~~latitude~~ longitude

* ~~Note: For geostationary satellite,~~

$\boxed{\cancel{le = 0}}$

Question:

An earth station situated in the dockland of London, England, needs to calculate the look angle to the geostationary satellite (i.e. $\cancel{le = 0}$) in the Indian Ocean operated by INTEL-SAT. The detail of earth station & the satellites are given below:

(i) Earth station longitude & latitude are 52° North & 0°.

(ii) satellite longitude (subsatellite point) is 66° east

(Find γ and E_l).

Ans:

$$\cos\gamma = \cos(\cancel{Le})\cos(Ls)\cos(ls - \cancel{le}) + \cancel{\sin(Le)}\sin(Ls)$$

~~putting~~ $Le = 0$ we get:

$$\cancel{\cos\gamma} = \cos(Ls)\cos(\cancel{ls - le}) + 0$$

$$\Rightarrow \cancel{\cos\gamma} = \cancel{\cos(Ls)\cos(ls - le)}$$

$$\Rightarrow \cos\gamma = \cos(52°)\cos(66°)$$

Azimuth angle $= 180° - \alpha$

$= 180° - \alpha$

$= 180° - 70.667$

$= \boxed{109.33}$

(clockwise from north)

and $\alpha = \tan^{-1}\left[\dfrac{\tan|ls - le|}{\sin(Le)}\right]$

$= \tan^{-1}\left[\dfrac{\tan|66 - 0|}{\sin(52)}\right]$

$\therefore \alpha = 70.667$

(Ans)

* For most geostationary satellite, the subsatellite point is on the equator at a ~~longitude~~ latitude ls ~~and the~~ longitude (ls) and latitude ($L_s = 0$).

Ans:

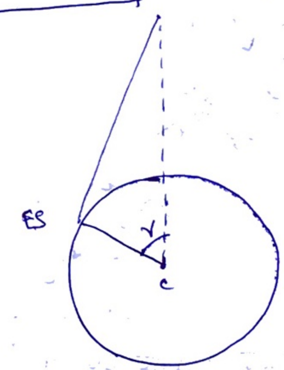
$$\cos\gamma = \cos(Le)\cos(Ls)\cos(ls - le) + \sin(Le)\sin(Ls)$$

$\Rightarrow ls = 0$

$\Rightarrow \cos\gamma = \cos(Le)\cos(ls - le)$

$\Rightarrow \cos\gamma = \cos(52°)\cos(66°)$

$\Rightarrow \boxed{\gamma = 75.49°}$



$\boxed{\gamma < 81.3}$ hence the visibility test is clear so we can communicate.

Finding E_l:

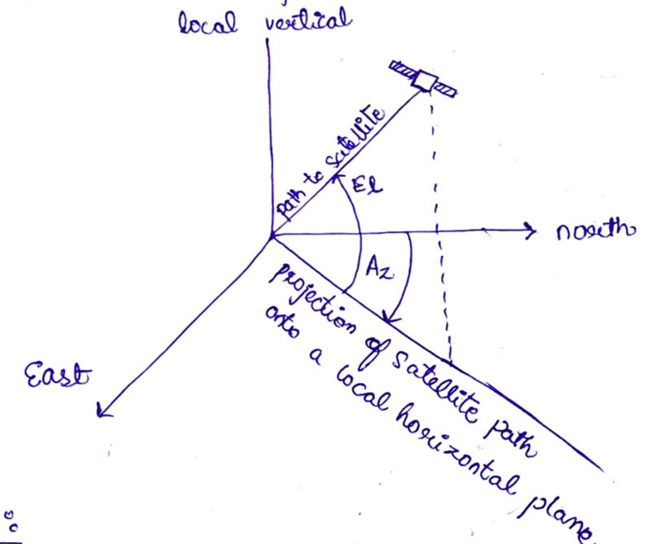
30/1/17 ## Azimuth Angle Calculation

L_e = Earth station north latitude

l_e = Earth station west longitude

L_s = Subsatellite point at North latitude

l_s = subsatellite point at west longitude

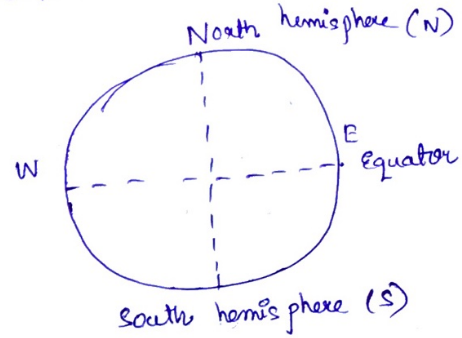


Notes :

(i) Because the earth station, the centre of the earth, the satellite, and the sub-satellite point all lie in the same plane, the azimuth angle (A_z) from the earth station to the satellite is the same as the Azimuth from the earth station to the subsatellite point.

(ii) This is more difficult to compute than the elevation angle because of the exact geometry involved depends on whether the sub-satellite point is east or west of the earth station, and in which of the hemisphere the earth station and the sub satellite point are located.

(iii) The problem simplifies somewhat for ~~geosynchronous~~ geostationary satellite, which ~~will be~~



Case 1 : (Earth station in northern hemisphere)

(a) Satellites to the south east (SE) of the earth station, then the azimuth angle is equal to $(180° - \alpha)$

(b) Satellite to the south west (SW) of the earth station, then the azimuth angle is equal to $(180° + \alpha)$.

Case 2 : (Earth station in the southern hemisphere with)

(a) Satellites to the north east of the earth station, then the azimuth angle is equal to $A_z = \alpha$.

(b) Satellite to the north west (NW) of the earth station, then the azimuth angle is equal to $A_z = 360° - \alpha$.

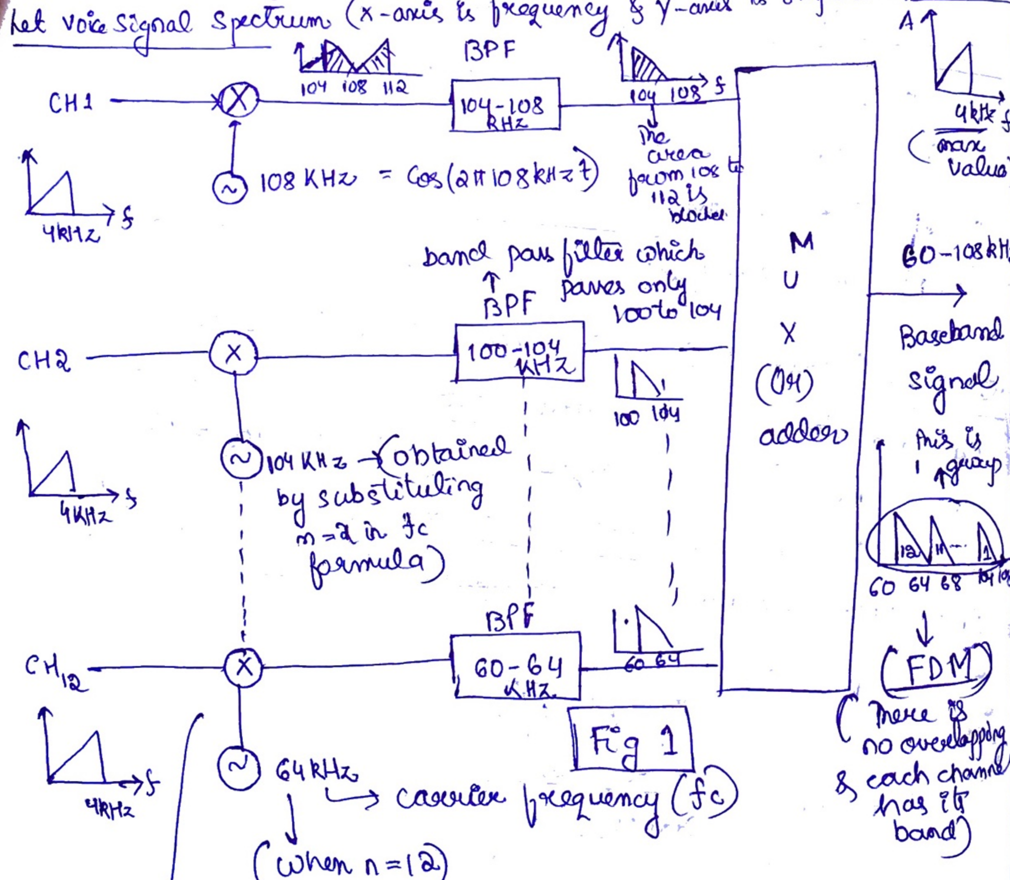
Formula for finding α :

$$\alpha = \tan^{-1}\left[\frac{|(l_s - l_e)|}{\sin(L_e)}\right]$$

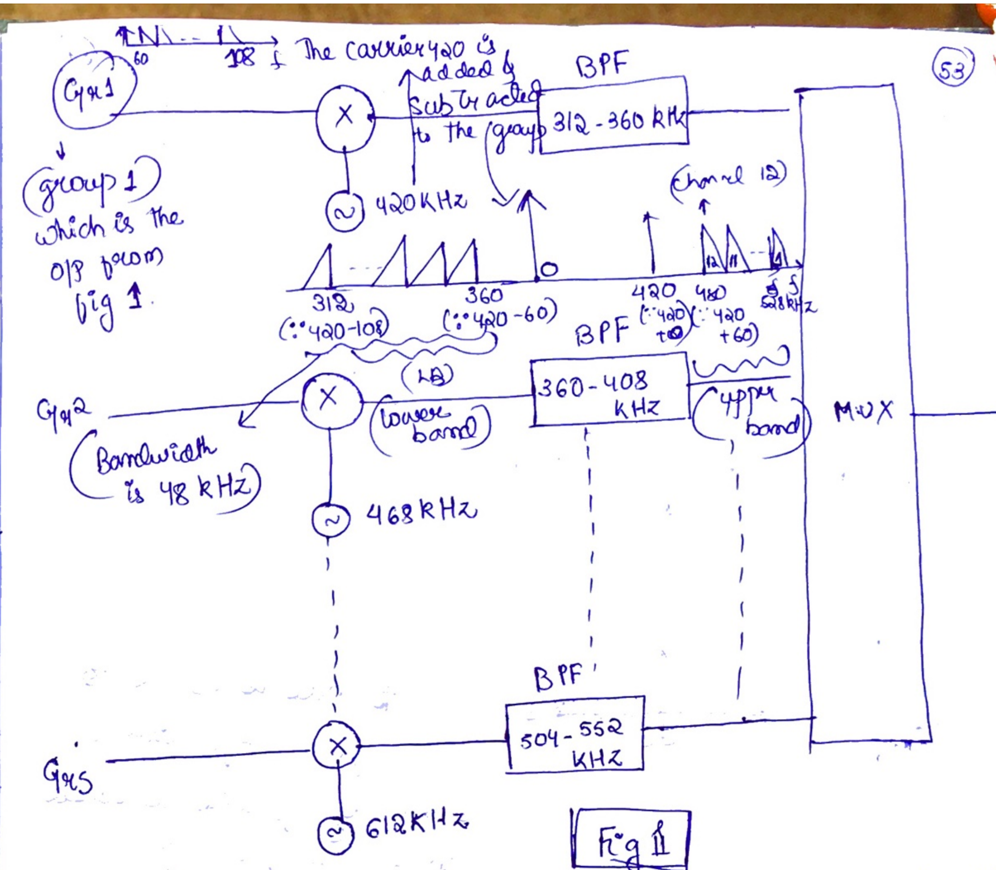
Qn: The latitude and longitude of an earth station are 20° 17 min 7 sec (20° 17' 7'' N) (north) and ~~xxx~~ degrees 85 50' 55'' E respectively. The longitude of the geostationary satellite is 55° east. Calculate the elevation angle & azimuth angle. Also calculate the distance of the station w.r.t the satellite.

Analog Telephone Transmission

Let voice signal spectrum (x-axis is frequency & y-axis is amplitude) will be:



The original signal is transferred to long distance using carrier of different carrier frequency.



Notes:

(i) In analog telephone transmission system, for satellite links 12 voice channels are multiplexed using FDM (frequency division multiplexing) to make a group.

(ii) 5 such groups are further multiplexed using FDM to make a super group.

(iii) In this case, double sided band suppressed carrier (DSB-SC) and LSB (lower side band) is transmitted.

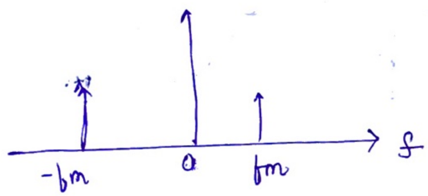
(iv) Carrier frequency $(f_c) = (112 - 4n)$ kHz, where $n = 1, 2, \ldots 12$

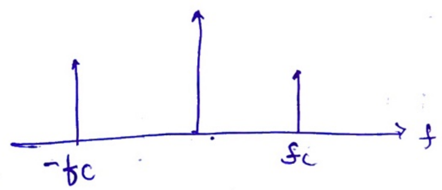
Let $n=1$ then $f_c = 108$, when $n=2$ $f_c = 104$ and so on when $n=12$ $f_c = 64$.

Explanation for Fig $\hat{1}$:

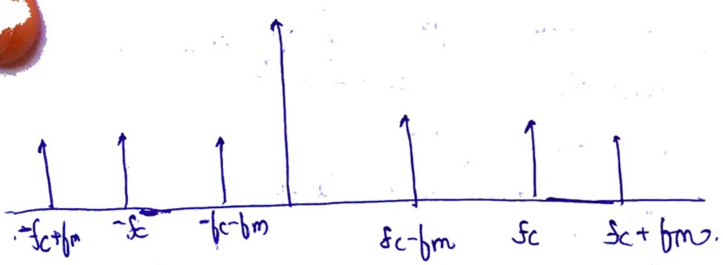
$\cos 2\pi f_m t \times \cos 2\pi f_c t$ → (Carrier is multiplied by original signal)

$= \cos 2\pi(f_c + f_m)t$
$+ \cos 2\pi(f_c - f_m)t$





(fc will be added to +fm and -fm and 0. similarly -fc will be added to +fm, -fm and 0)



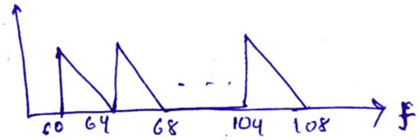
From fig 1 & $\hat{1}$:

Since from fig 1 we will get 12 groups

Total no of voice signals $= 12 \times 5$ → This is from fig $\hat{1}$ since we have 5 groups

= 60 voice channels will be transmitted.

In the o/p signal:



the gap b/w 2 bands is 4 kHz and so is the gap b/w carrier frequency i.e 4kHz (108 - 104) = 4 kHz and similarly gap b/w all carrier frequency is 4kHz

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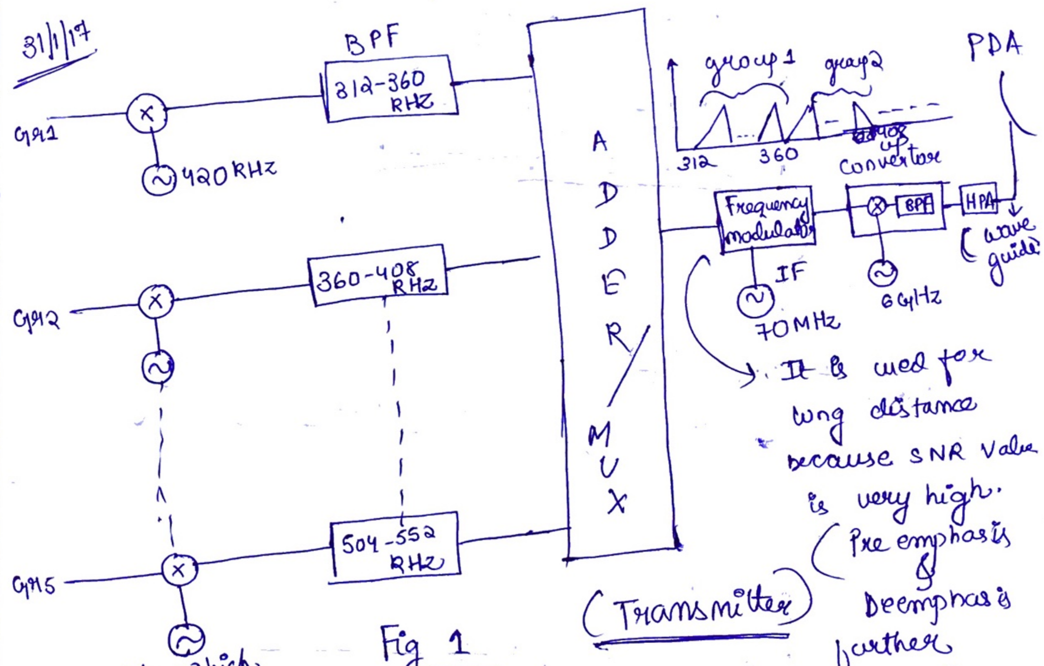


It is used for long distance because SNR value is very high. (Pre emphasis & Deemphasis further improve the SNR value)

(Transmitter)

Fig 1

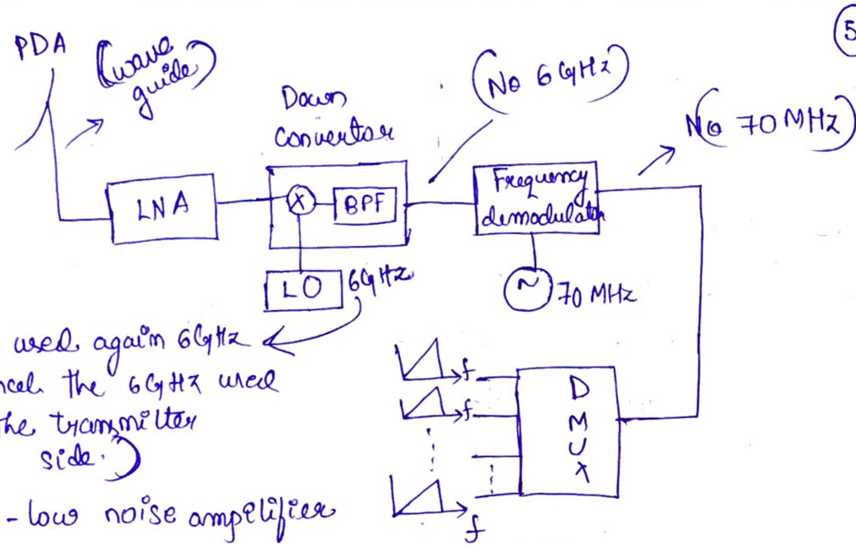
wave guide: cable which handles high frequency

IF: intermediate frequency

Carrier frequency (f_c) - 70MHz.

up converter → Converts the carrier frequency of 70MHz to 6 GHz.

HPA → high power amplifier (we use high power so that it travels 36000 km) (here klystron is used)



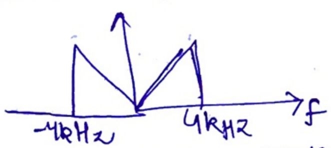
(we used again 6GHz to cancel the 6GHz used in the transmitter side.)

LNA - low noise amplifier

Fig II (Receiver)

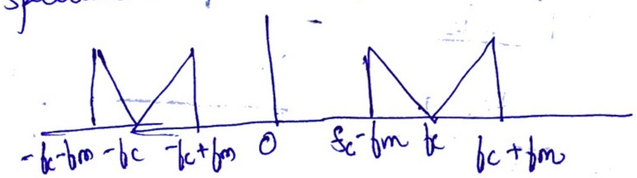
Explanation for receiver side :

let voice signal be :

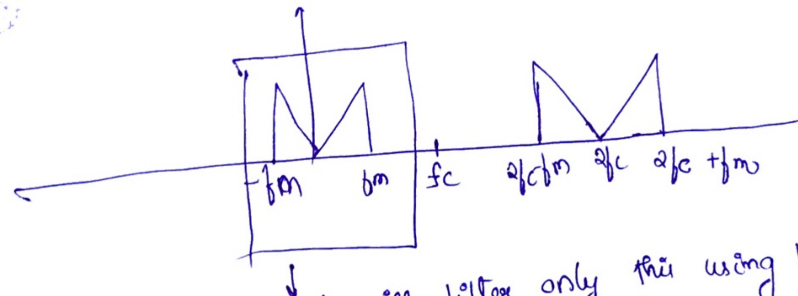


This signal is multiplied by carrier $\cos 2\pi f_c t$ for long distance communication.

so spectrum will be :



If we again multiply carrier $\cos 2\pi f_c t$ by the spectrum we get : (i.e after transmitting the signal using carrier frequency, to again recover the signal we use the same carrier frequency).

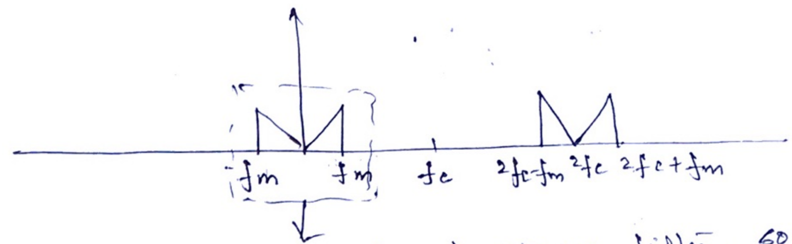


we will filter only this using low pass filter → So this is same as the original voice signal.

Therefore,

(In receiver side, we use the same carrier frequency as in transmitter side)

Add all the values then subtract all the values



we use low pass filter, so this portion is filtered out as a result

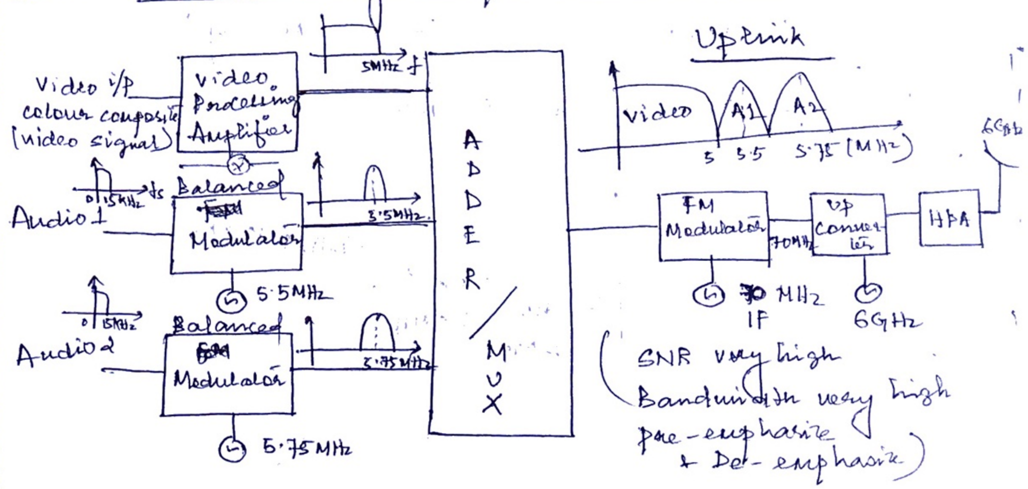
→ So this is same as the original voice signal.

Therefore,

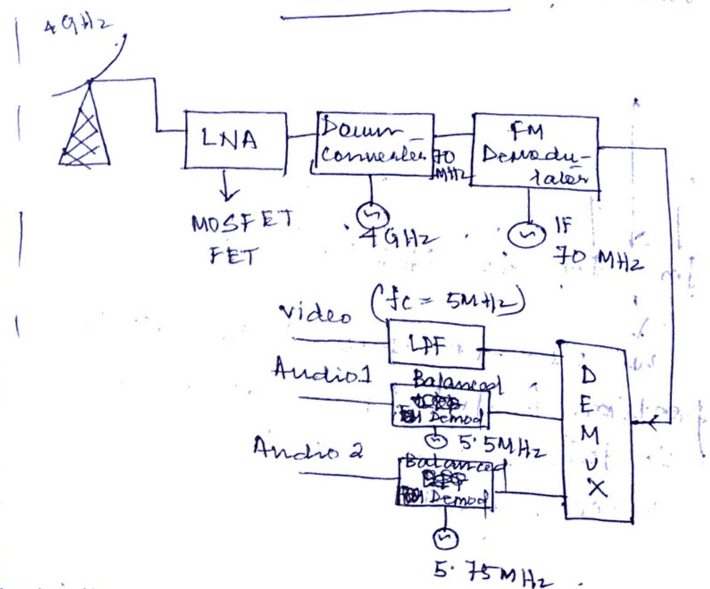
In receiver side, we use the same carrier freq. as in transmitter side.

(* recover the signal we use the same carrier freq.)

6/2/17 Satellite Analog ~~Telephone~~ TV Transmission



Downlink

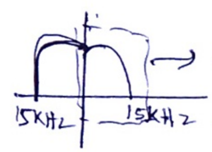


fc = cut-off freq.

Uplink

video's bandwidth always higher.

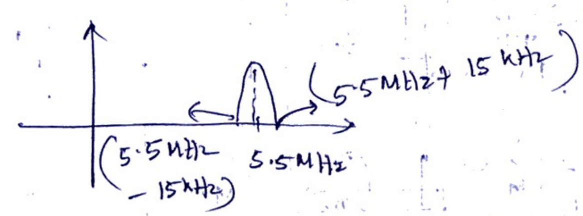
Video, audio to be transmitted at the same time.



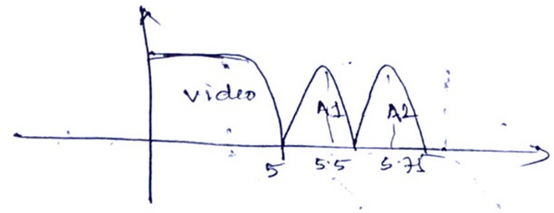
→ replica of the negative part as well.

Balanced modulator : a simple multiplier.

Spectrum shifted to 5.5MHz.



After passing through ADDER, the spectrum is



For long dist. transmission, we need High Power Amplifier (wave guide)

Downlink

To remove the carrier, multiply with the carrier itself.

$$x(t) \cos 2\pi f_c t \times \cos 2\pi f_c t$$

$$x(t) \cos^2 2\pi f_c t$$

$$x(t) \left(\frac{1+\cos 2\pi f_c t}{2}\right)$$

$$\frac{x(t)}{2} + \overset{4}{x}(t) \ldots$$

we have to obtain $x(t)$.

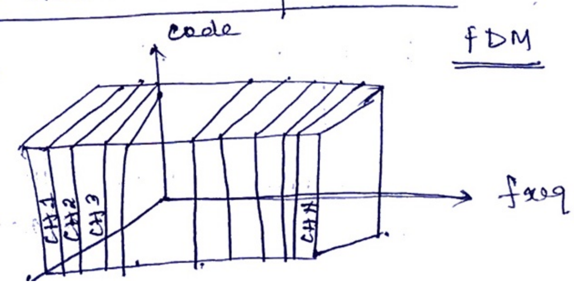
Imp.

(In analog Telephone Transmission, also Down Converter should be 4 GHz) [Tally with the dig.]

Multiple Access Technique

FDM

Fig (i)



TDMA

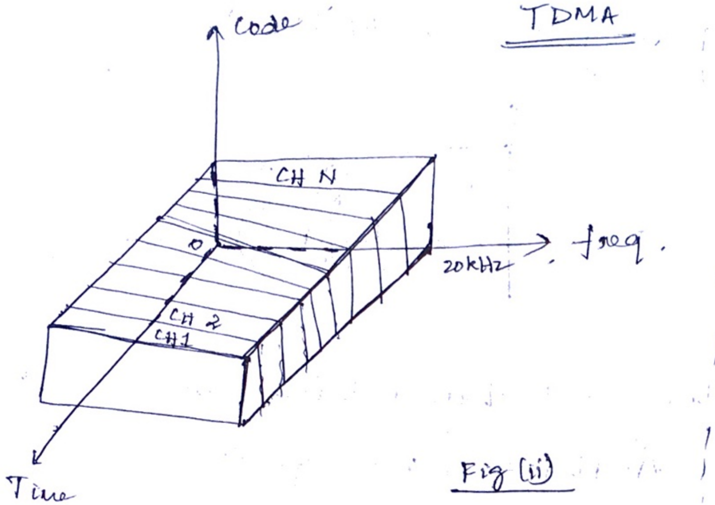


Fig (ii)

CDMA

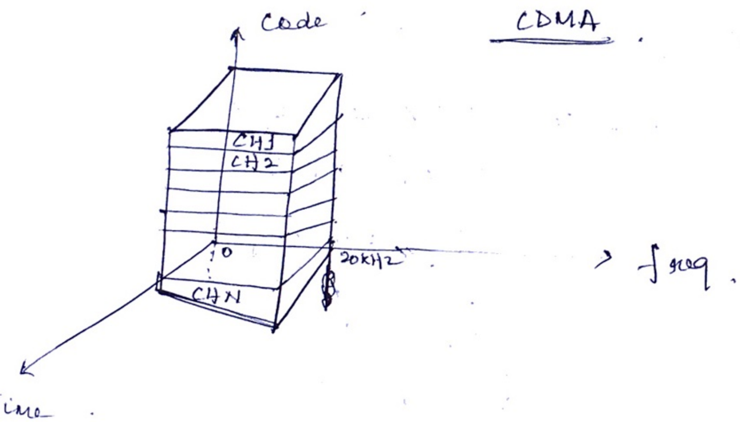


Fig (iii)

Eg:-

Suppose 50 students, want to make comm channel, everybody needs a specific spectrum.

Each and every channel have their own freq,

fig (i) :→ Freq. Division Multiplexing

(Dividing freq. equally, all channels will come together - multiplexing)

→ There's wastage of Bandwidth efficiency. Suppose using channel 1 [always fixed for one student], hence, efficiency is not good.

fig (ii) : Time Division Multiple Access (TDMA) (GSM technology)

→ Suppose giving 20kHz Bandwidth to all the students, dividing the time. (Eg:- GSM technology)

Same bandwidth provided to all students

Problem

→ channel being multipath, there may be channel delay.

fig(iii) Code Division Multiple Access (CDMA).

20 KHz given to all the students, time slots also remain the same, hence the code is different for ch1, ch2 --- and so on.

Eg:- Suppose the code generated by mobile is 1001 is transmitted → (1001) × fc would be transmitted to there

Suppose 4 users are

- a
- b
- c
- d

The code generated by mobile 'a' is 1001 (correlation is good)

If 'b' 1100 (correlation is bad)
(matching)

c : 1101

d : 1011.

In this case, 'a's clarity is more.

Disadvantage: Bandwidth is very high.

Part of CDMA:

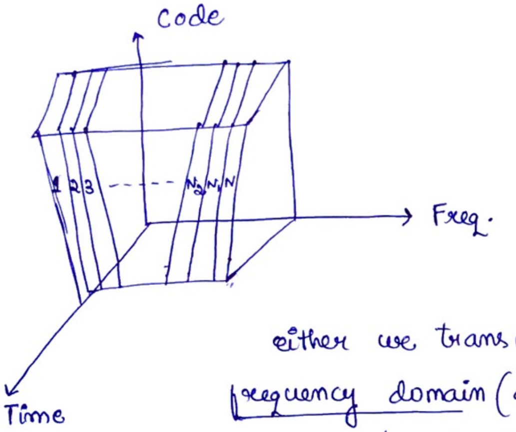
(i) PN Sequence.
(ii) FH SS.
(iii) Direct Sequence Spread Spectrum.

07/2/17

Multiple Access Technique

(60)

Frequency Division Multiple Access (FDMA) : (1st generation of Mobile Communication)



either we transmit through frequency domain (difficult because frequency / bandwidth is limited) or time domain (not very secure) or Code domain (secure and latest domain being used)

Notes :

(i) FDMA channel carries only 1 phone circuit at a time.

(ii) If an FDMA channel is not in use then it sits ideal and cannot be used by other users to increase or share capacity, it is essentially a wastage of resources.

(iii) After the assignment of a voice channel, the base station (earth station) and the mobile station transmits simultaneously & continuously.

(iv) FDMA is usally implemented in narrow band.

(v) The symbol time of a narrow band signal is large as compared to the average delay spread. This implies that the amount of ISI (inter symbol interference) is low and thus no equalization is required.

(61)

* Advantages of FDMA :

(i) The complexity of FDMA mobile system is lower as compared to the TDMA system.

(ii) Since FDMA is a continuous transmission scheme, fewer bits needed for synchronization and as compared to the TDMA.

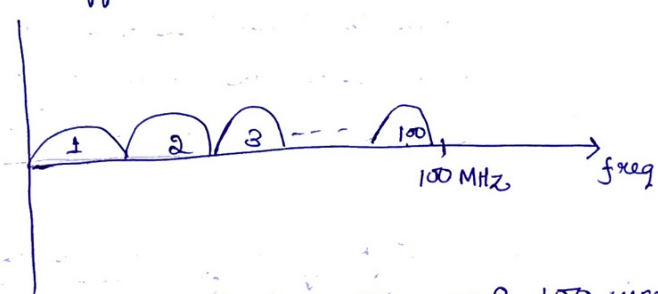
(iii) Capacity can be increased by reducing the information bit rate and using an efficient digital speech coding scheme.

* Disadvantages of FDMA :

(i) The FDMA mobile unit uses duplexer since the transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber unit and base stations.

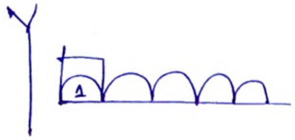
(ii) FDMA systems have higher cost as compared to TDMA system because it needs costly bandpass filter to eliminate spurious radiation at the base station.

(iii) Cross Talk arising from the adjacent channel is produced by the non-linear effects.



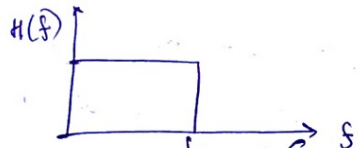
Let govt. gives a bandwidth of 100 MHz and 100 users are using it, but if there are 200 students → the rest will not get resource → hence disadvantage.

* The above signals will be received a receiver



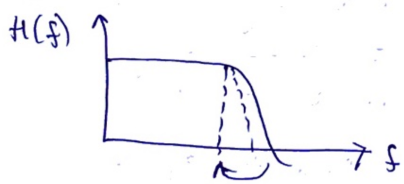
So if someone wants to receive only signal sent by 1 then they use a band pass filter which only extracts band 1 signal.

The output of filter should be as follows:



fc → (Sharp cut off frequency)

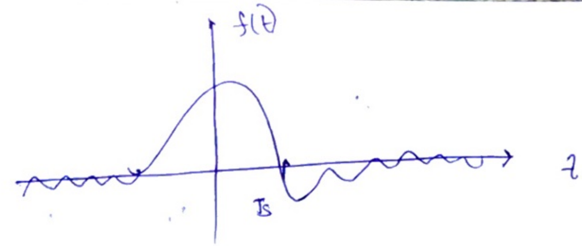
but actually the o/p being produced is with more slope as follows:



So we need to make the slope change so that it comes to ideal case → so to make band pass filter with ideal case, extra components are required and thus more cost is incurred → disadvantage

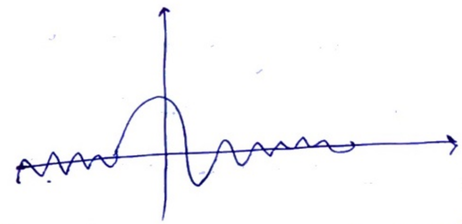
* Advantages & disadvantages of using narrow band

*

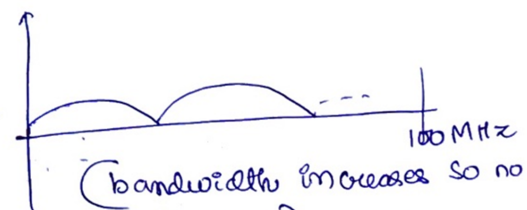


Cross Talk arises if there are more users & bandwidth is less.

To reduce cross talk, the value of Ts has to be reduced



This will result in increase in bandwidth but then less no of users decreases

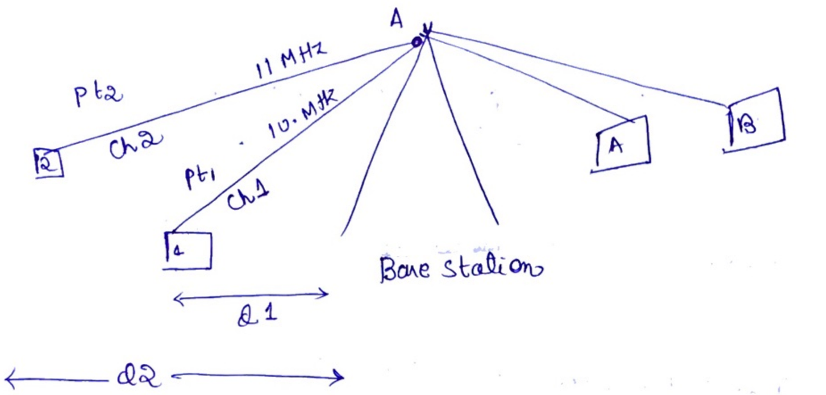


(bandwidth increases so no of users decreases)

Hence there is a trade off b/w Cross Talk & bandwidth.

* As distance increases, power decreases.

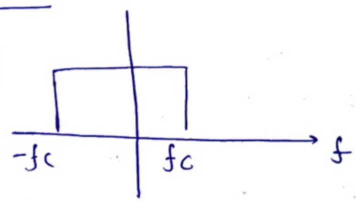
*



when 1 and 2 transmit signal to A & B respectively then at point A there will be ~~ap~~ cross talk because the power of ch 1 will dominate the power of ch 2. (The power of ch 1 is more than channel 2 since as distance increases power decreases)

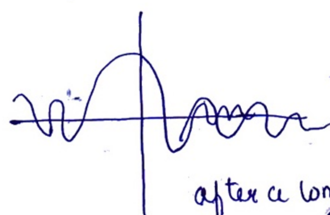
*Filter :

(i)



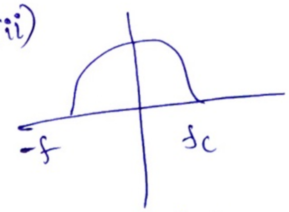
but in real life sharp cut off frequency is not possible, there is always slope.

$\xrightarrow[\text{inverse}]{\text{fourier}}$



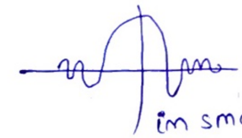
after a long distance it will come to zero value

(ii)



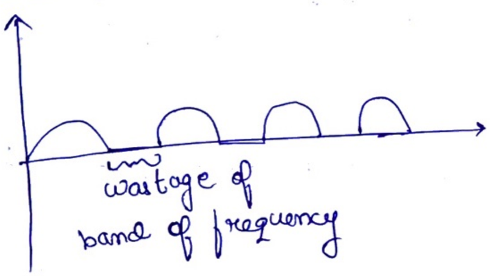
Raised Cosine filter

$\xrightarrow[\text{inverse}]{\text{fourier}}$



in small terms distance it will come to zero value so there will be no cross talk.

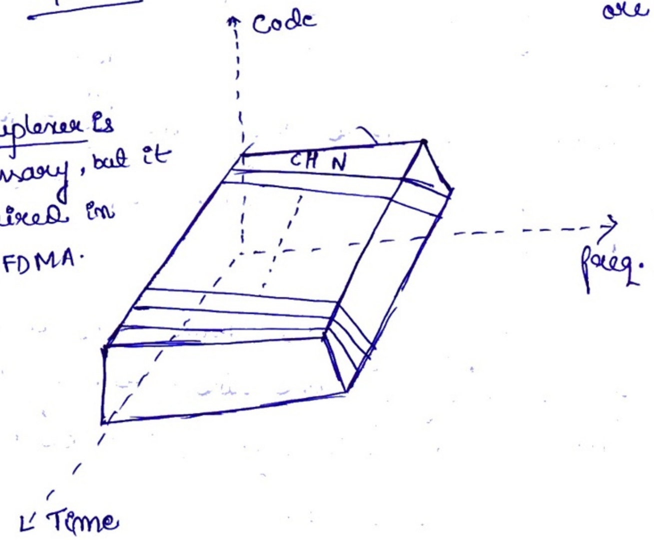
To design raised cosine filter :

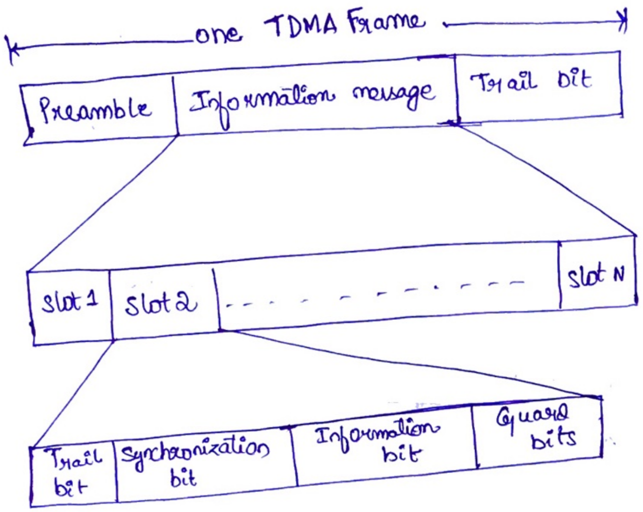


wastage of band of frequency

14/2/17 TDMA (Time Division Multiple Access) (Time is divided, code & frequency are same)

here duplexer is not necessary, but it was required in case of FDMA.





2nd Generation Mobile Communication GSM (In GSM = 8 time slots)

Note:

(i) TDMA system divide the radio spectrum into time slots and in each slot only one user is allowed to either transmit or receive.

(ii) TDMA system transmit data in a buffer and burst method (at a time transmit a signal), thus transmission for any user is non-continuous, but it is continuous in FDMA.

(iii) TDMA share single carrier frequency with several users, where each user makes use of non-overlapping time slots. The no of time slots per frame depends upon modulation technique & available bandwidth.

(iv) Data transmission for user of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption since

the subscriber, transmitter can be turned off when not in use.

(v) TDMA uses different time slots for transmission & reception. Thus duplexer is not required.

(vi) Adaptive equalization is usually necessary in TDMA system, since the transmission rate is high as compared to FDMA system.

(vii) TDMA transmit each signal with sufficient guard time between time slots to accomodate time inaccuracies because of clock instability, delay spread, transmission delay because of propagation distance. ~~and the traits~~

*Disadvantages of TDMA:

(i) TDMA requires synchronization

(ii) TDMA require a substantial amount of signal processing for matched filtering and correlation detection for synchronizing with the time slot.

Qn: In a GSM, time slot consist of 6 trailing bits, 8.25 guard bits, 26 training bits & 2 traffic bursts of 58 bits of data. Find the framing efficiency.

Ans:

$$\text{Efficiency } (\eta) = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100$$

Where b_{OH} = overhead bits

b_T = total no of bits in a frame.

$b_T = 8 \times \left(6 + 26 + (2 \times 58) + 8.25\right)$

$=$

b_{OH} = overhead bits

$= \underline{8}\left(6 + 26 + 8.25\right)$

Since we have 8 slots

The overhead bits are those of trail bit, synchronization bit, guard bits

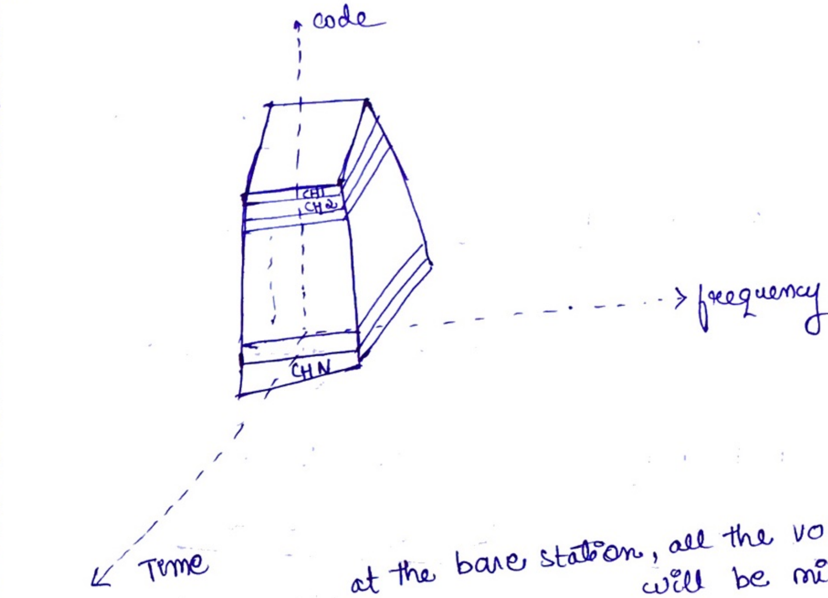
Trail bit	Synchronization bit	Information bit	Guard bit
6	26	2 × 58	8.25

Since there are 2 traffic bursts.

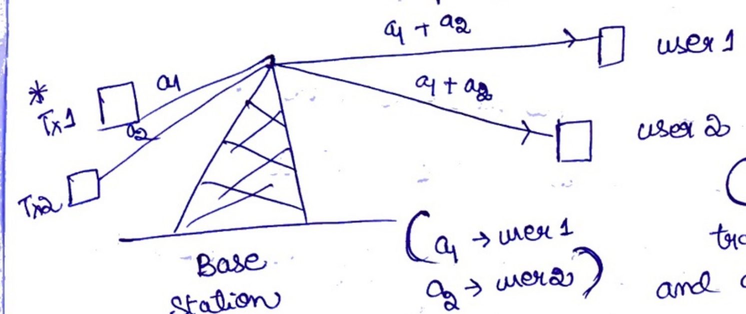
$\therefore \quad \eta = \left(1 - \frac{b_{OH}}{b_T}\right) \times 100$

CDMA

*



at the base station, all the voice signals will be mixed up.



(a_1 is the data to be transmitted to user 1 and a_2 is the data to be transmitted to user 2)

* How will user 1 receive only a_1 data & reject a_2 data
& " " user 2 " " a_2 " " " a_1 data.

Ans: let user 1 has a code (1 1 1 1)
& user 2 has a code (1 -1 -1 1)

Tx1 talks with user 1 & Tx2 talks with user 2.

Tx1 code – (1 1 1 1)   Tx2 code (1 -1 -1 1) initially, a_1 is multiplied by code [1 1 1 1]

$$a_1[1\ 1\ 1\ 1] = a_1\ \ a_1\ \ a_1\ \ a_1$$

and Tx2 will multiply its data by its code [1 -1 -1 1]

$$a_2[1\ -1\ -1\ 1] = a_2\ \ -a_2\ \ -a_2\ \ a_2$$

when they reach voice station, all voice signals will be mixed up.

$$a_1[1\ 1\ 1\ 1] = a_1\ \ a_1\ \ a_1\ \ a_1$$

$$a_2[1\ -1\ -1\ 1] = a_2\ \ -a_2\ \ -a_2\ \ a_2$$

Sum: $a_1+a_2\ \ \ a_1-a_2\ \ \ a_1-a_2\ \ \ a_1+a_2$

Now user 1 will receive the above sum i.e:

$$a_1+a_2\ \ \ a_1-a_2\ \ \ a_1-a_2\ \ \ a_1+a_2$$

now user 1 has code [1 1 1 1] so we multiply the code with received signal & add the entire thing.

$$\begin{array}{cccc} a_1+a_2 & a_1-a_2 & a_1-a_2 & a_1+a_2 \\ * & * & * & * \\ 1 & 1 & 1 & 1 \end{array} \longleftarrow \text{(multiplication)}$$

$$(a_1+a_2) + (a_1-a_2) + (a_1-a_2) + (a_1+a_2)$$

$$= \boxed{4a_1}$$ (so user 1 receives only a1 data)

similarly user 2 multiplies the received signal by code [1 -1 -1 1] and adds the entire signal.

$$\begin{array}{cccc} a_1+a_2 & a_1-a_2 & a_1-a_2 & a_1+a_2 \\ 1 & -1 & -1 & 1 \end{array}$$

$$a_1+a_2 + (-a_1+a_2) + (-a_1+a_2) + a_1+a_2$$

$$= \boxed{4a_2}$$ (so user 2 only receives a_2 data)

* The dot product of codes of the users are orthogonal. (multiply the codes & add them so we get 0)

user 1: 1 1 1 1

user 2: 1 -1 -1 1

$$1+(-1)+(-1)+(1) = 0$$

hence the dot product of the codes are orthogonal.

* If user 2 code is (1 1 -1 1) instead of (1 -1 -1 1) Then we get intersymbol interference. So the code sent i.e Tx2 should be same as the code received by user i.e user 2. and codes of user 1 & user 2 should be orthogonal.

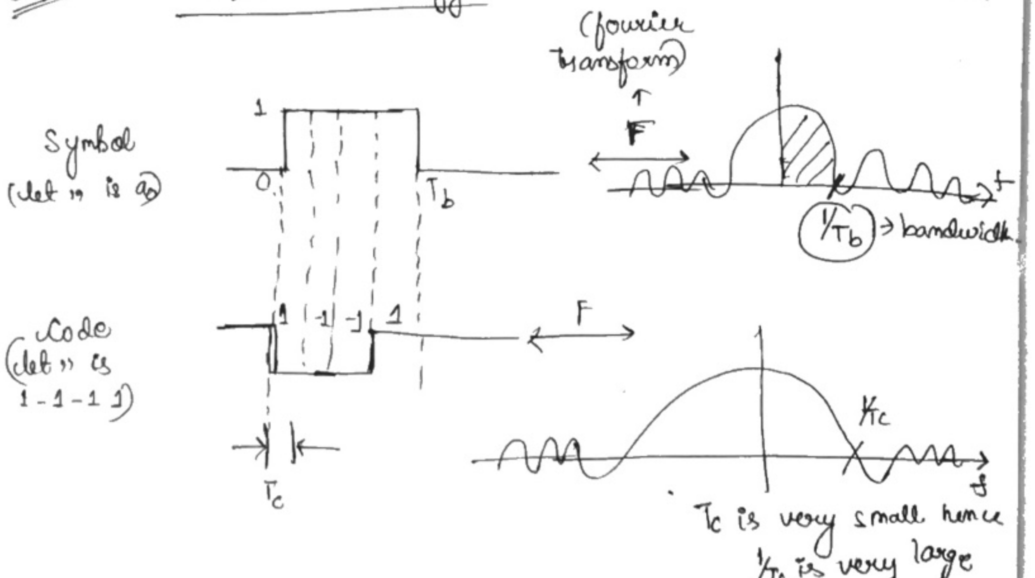
$$\begin{array}{cccc} a_1+a_2 & a_1-a_2 & a_1-a_2 & a_1+a_2 \\ 1 & 1 & -1 & 1 \end{array}$$

$$a_1+\cancel{a_2}+\cancel{a_1}-\cancel{a_2}-\cancel{a_1}+a_2+a_1+a_2$$

So this results in intersymbol interference. $\longleftarrow \boxed{2a_1+2a_2}$

20/2/17

CDMA Technology



T_b = bit Duration $\quad$ T_c = chip period

We multiply code by symbol & transmit it

If we take fourier transform the symbol which is a gate func^n so we get a sinc function

We have to arrange the code in such a way that it fits between the period 0 to T_b.

If code has 100 bits and then $T_c = \frac{T_b}{100}$

here there are 4 bits.

We are intentionally spreading the bandwidth of the signal hence known as spread spectrum. So disadvantage in CDMA technology is bandwidth very high & hence less customers can be addressed. The advantage is: signal to noise ratio is very realiable and it is very secure.

Ex: Let are data rate transmission is 1 kbps i.e 1000 bits are transmitted in 1 sec.

$\therefore$ 1 bit is transmitted in $\frac{1}{1000}$ sec i.e 1 msec

$\therefore \boxed{T_b = 1\text{msec}}$ hence bandwidth $= 1/T_b = 1/1\text{msec} = \boxed{1\text{kHz}}$

Let code = 4bits. So $T_c = \frac{1\text{msec}}{4}$

here bandwidth $= 1/T_c = \boxed{4\text{kHz}}$.

So if we have 10 customers, in 1st case we can handle all 10 customers whereas in 2nd case we can deal with only 2 customers

Note: (Spread Spectrum multiple Access (SSMA)):

(i) SSMA uses signals which have transmission bandwidth i.e several orders of magnitude greater than RF (radio frequency) bandwidth.

(ii) A pseudo noise (PN) sequence converts a narrow band signal to a wide band noise like signal before transmission.

Advantage:

(i) Immunity to multi path interference

(ii) Robust multiple access capability

Disadvantage:

(i) Bandwidth is very high

(ii) Near-far problem → It is a condition in which a receiver captures a strong signal & thereby makes it impossible for the receiver to detect a weak signal.

There are 2 types of spread spectrum :

(i) Frequency Hopped spread spectrum (FH-SS)

(ii) Direct sequence spread spectrum (DS-SS)

(i) In CDMA systems, the narrow band signal is multiplied by a very large bandwidth signal called the spreading signal.

(ii) All users in CDMA system use same carrier frequency & may transmit simaultaneously.

(iii) Each user has its own pseudo-random codeword which is approximately orthogonal to each other.

(iv) The receiver performs a time correlation operation to detect only the specific desired codeword.

(v) Each user operates independently with no knowledge of the other users.

* Features of CDMA technology :

(i) Many users of a CDMA system share the same frequency.

(ii) Unlike the TDMA or FDMA, CDMA has capacity limits.

(iii) CDMA data rate is high in comparision to FDMA & TDMA.

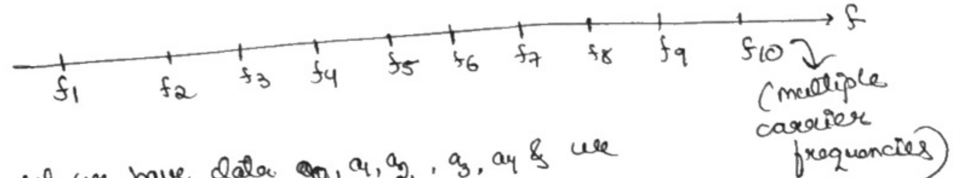
(iv) Multi path fading may be substantially reduced because signal is spread over large spectrum.

* Frequency Hopped Spread Spectrum :

Frequency → jumping of frequency
Spread → the signal is spreaded
Spectrum → implies frequency

Spread spectrum → represents CDMA (so code is necessary & code should be orthogonal for each user else we cannot spread)

Frequency jumping of each user → Frequency hopped



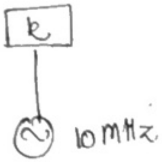
let we have data a_0, a_1, a_2, a_3, a_4 & we transmit a_0 by carrier f_1, a_1 by f_2, a_2 by f_3 and a_3 by f_4 and a_4 by f_5.

let $f_1 = 10\,MHz$, $f_2 = 20\,MHz$, $f_3 = 30\,MHz$ and so on

If we set frequency range sequentially then enemy can hack the data.

So we transmit a_0 by f_1, a_2 by f_9, a_3 by f_{10}, a_4 by f_7, a_5 by f_2 → this is known as frequency hopping. hence tracking of data becomes difficult by hacker.

How to generate frequency hopping : We will use an oscillator & multiply the frequency value by k (which is an analog value)

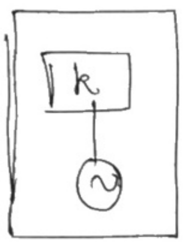


k value should be random in nature so that enemy cannot hack.

let code = $\underline{1\ 1\ 1\ 1}$ so 10 MHz will be multiplied by 15.
(binary value of 15)

(So the code should be in such a way that we get random values → hence frequency hopped code spectrum)

PN sequence :



→ frequency synthesizer

Q. how to generate PN sequence with digital circuit ?

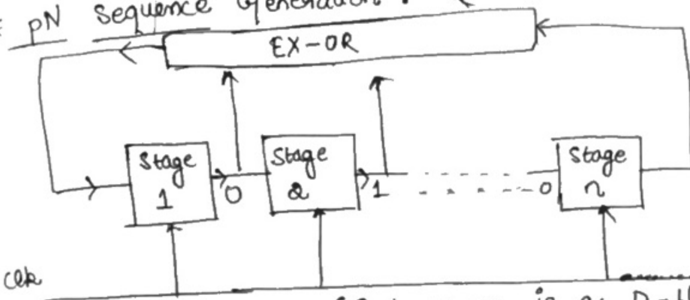
Ans :

03/03/17

Direct Sequence Spread Spectrum (DS-SS)

(related to CDMA)

* PN Sequence Generation : → (To generate the code which are orthogonal to each other.)

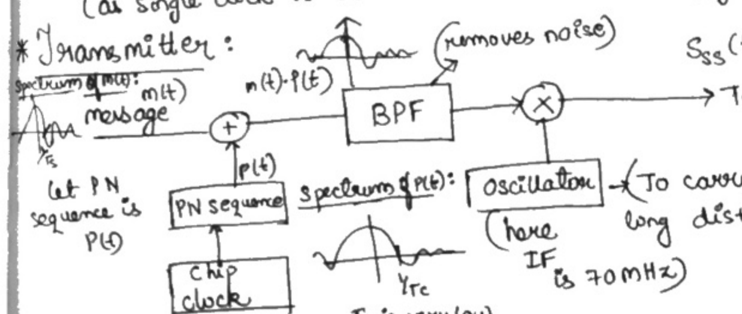


(O/P is orthogonal and random)

(Each stage is a D-flip flop) (as single clock is used hence circuit is synchronous)

(initially the sequence should not be all zero's, we should keep at-least one 1.)

* Transmitter :



(removes noise)

let PN sequence is p(t)

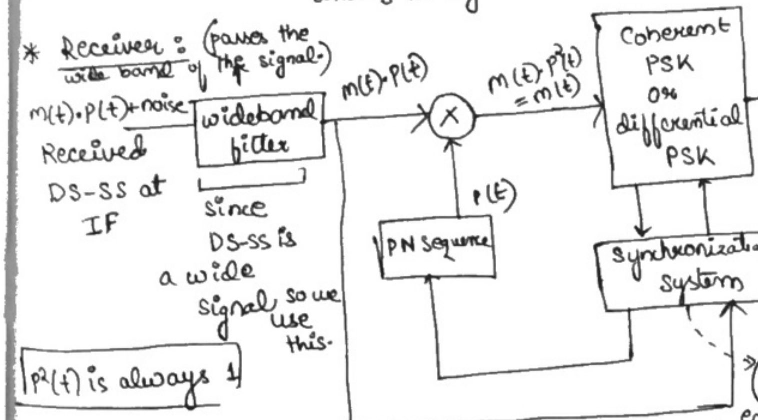
(To carry the signal to a long distance)

(here IF is 70 MHz)

T_c is very low and T_s is high

(PSK-phase shift keying - this is a modulator)

* Receiver : (passes the wide band of the signal.)



Received DS-SS at IF

Since DS-SS is a wide signal so we use this.

$\boxed{p^2(t) \text{ is always } 1}$

(since there will be some distortation so exact m(t) will not be received)

(helps to identify the exact p(t) which is transmitted by the transmitter system.)

(The clk period in PN sequence generation is very narrow as compared to message signal).

* Notes : (DS-SS)

(i) Spread spectrum is a special modulation technique that spreads the transmitted signal over a frequency range much wider than the min bandwidth required to send the signal.

(ii) Widening the signal bandwidth in this fashion, increases the probability that the received information will closely match with the transmitted information.

Types of spread spectrum :

(i) Direct sequence
(ii) Frequency Hopped

Direct Sequence Spread Spectrum :

(i) The received spread spectrum signal for a single user can be represented as :

$$\boxed{S_{ss}(t) = \sqrt{\frac{2E_s}{T_s}}\; m(t)\; P(t)\; \cos(2\pi f_c t + \theta)}$$

where $\sqrt{\frac{2E_s}{T_s}}$ = Normalizing factor

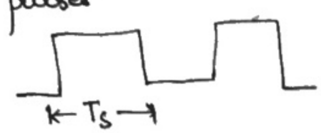
$m(t)$ = message signal

$P(t)$ = PN sequence

$\cos(2\pi f_c t + \theta)$ - carrier with frequency f_c

(ii) $m(t)$ is the data wave form in the time sequence of non-overlapping rectangular pulses.

$m(t)$ =

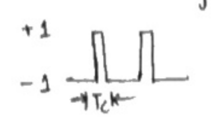


Its amplitude is equal to +1 and -1. Time duration is T_s.

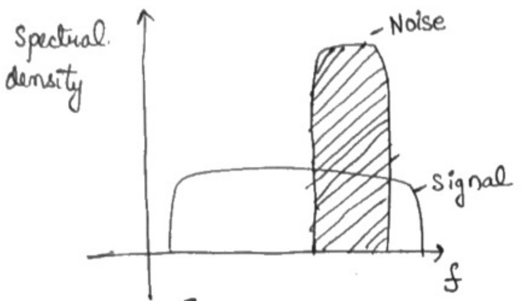
(iii) $p(t)$ represents a chip. (80)

(iv) The data waveform is a time sequence of non-overlapping rectangular pulses. Its amplitude is +1 and −1. Time duration is T_c.

$p(t)$:

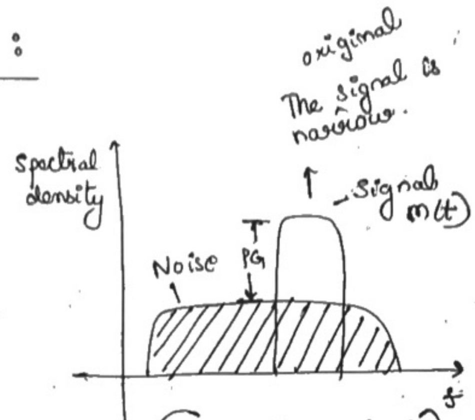


* Frequency Spectrum Analysis :



(Received signal before wideband filter) fig I

(The wide band is $m(t) \cdot p(t)$ with some added noise as shown in shaded region) → (refer receiver diagram of PN sequence)



(Correlator output)

Fig II

where PG = processing gain

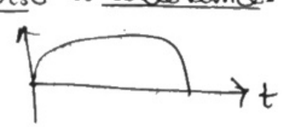
and $\boxed{PG = \frac{T_s}{T_c}}$

In receiver side, we multiply : $(m(t)p(t) + n(t))\, p(t)$

(refer receiver diagram of PN sequence)

$= m(t) + n(t)p(t)$

In frequency domain, noise is narrow as shown in fig 1, but in time domain, noise is wide band.



(time domain)

$n(t) \cdot p(t)$ → both $n(t)$ and $p(t)$ are very narrow, (81) so in frequency domain, it will be very wide (since in ~~frequency~~ time domain they are very narrow). This wide band of $n(t) \cdot p(t)$ is shown in fig II.

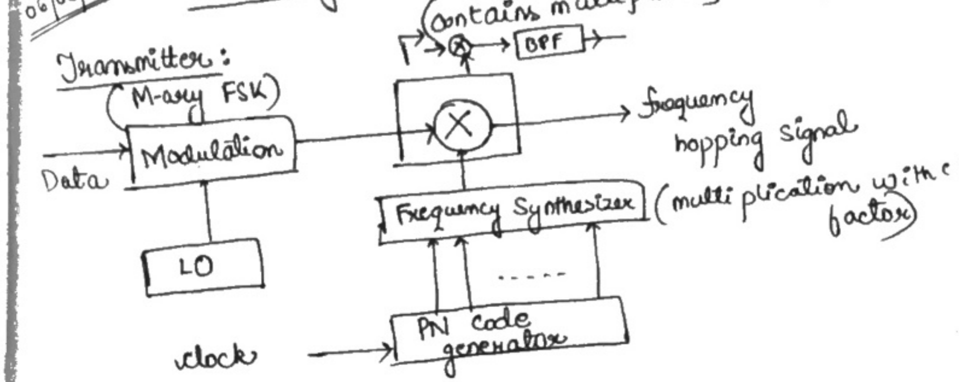
*Advantage of spread spectrum :-

(i) In the received signal, the amplitude of received noise will be very less.

06/03/17

Frequency Hopped Spread Spectrum (FH-SS)

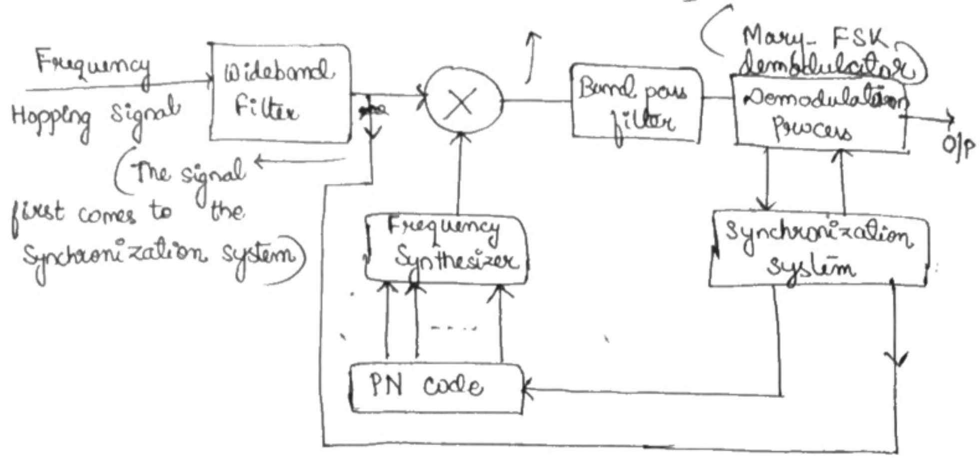
Transmitter :



LO : local Oscillator

Receiver:

(here the data is equal to received data)



Two types of frequency hopping:

- sending data in continuous way
- sending data in random way (Very Secure)

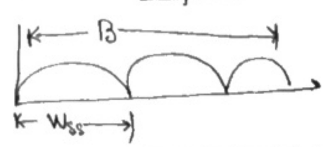
(The random carriers are the PN sequence which are converted to analog format and then multiplied with the carrier).

Notes:

(i) The set of possible carrier frequencies is called the hop set.

(ii) Hopping occurs over a frequency band that includes a no of channels.

(iii) The bandwidth of a channel used in the Hop set is called instantaneous bandwidth (W_{SS}).



(iv) The bandwidth of the spectrum over which the hopping occurs is called total hopping bandwidth (B).

(v) If only a single carrier frequency (single channel) is used in each Hop, digital data modulation is called single channel modulation.

(vi) The time duration between the Hop is called the Hop duration or Hopping period (T_H).

(vii) The processing gain $= \frac{W_{SS}}{B}$

Process of operation: (Transmitter)

(i) Incoming binary data are applied to a M array-FSK.

(ii) The resulting modulated wave and the o/p from a digital frequency synthesizer are applied to a mixture that consist of a multiplier followed by a band pass filter.

(iii) The filter is designed to select some frequency component resulting from the multiplication process as the transmitted signal.

(iv) In practice, successful K bit of a PN sequence Device which enables the carrier frequency to Hop over 2^K distinct values.

Receiver:

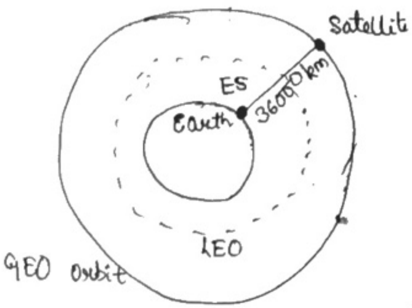
(i) In the receiver, the frequency hopping is first removed by mixing (down converting) the received signal with the o/p of a local frequency synthesizer that is synchronously controlled in the same manner as that in the transmitter

(ii) The resulting o/p passes through a band pass filter and subsequently processed by a non-coherent M-array FSK detector.

07/03/17

Orbital Effects on Communication of Satellite system Performance

(1) Doppler's shift
(2) Effect due to variation of the orbital distance
(3) Effect of solar eclipse
(4) Sun's transit outrage



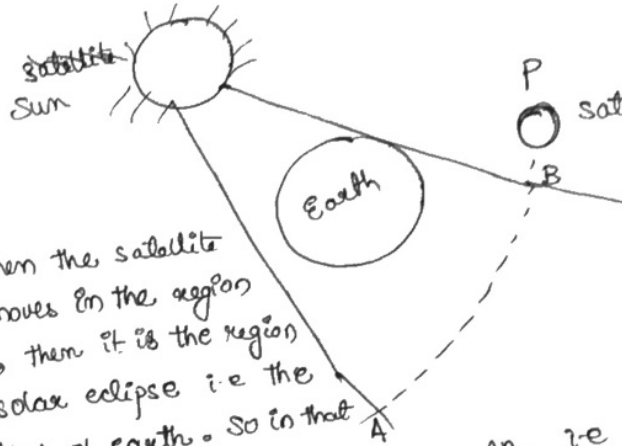
The satellites in LEO move very fast as compared to GEO satellites.

f_T = frequency of transmission = 1000 MHz
but we cannot receive 1000 MHz, we may receive more or less → this is known as Doppler's shift

There is no doppler shift in GEO orbit because the satellite remains stationary w.r.t the earth station.

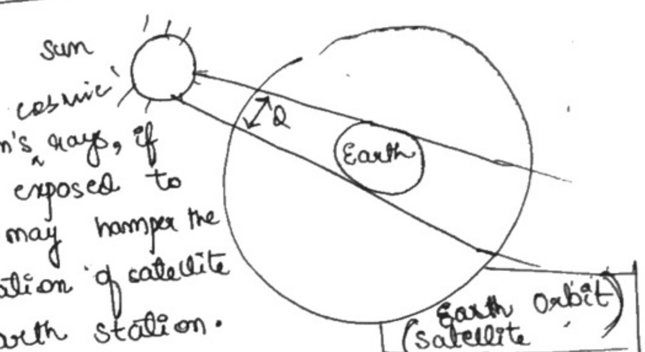
Doppler shift occurs when there is movement of satellite/object w.r.t the viewer. In this case we don't receive the exact frequency, it may be more or less.

* Effect of Solar Eclipse :



When the satellite moves in the region AB, then it is the region of solar eclipse i.e the shadow of earth. So in that case before entering the region AB, i.e at point P the satellite has to be fully charge, to cover the entire area AB. If the satellite is not fully charged, then it may not be able to cover the entire distance AB and hence the communication b/w the earth station & satellite will be hampered.

* Sun's transit Outrage :



The sun's cosmic rays, if directly exposed to satellite may hamper the communication of satellite with earth station.

So when the satellite is moving very near to the earth, the distance 'd' should be covered very quickly else the communication will be hampered because of the direct impact of harmful sun's rays.

Notes:

Doppler's shift:

(i) The geostationary satellites appear stationary w.r.t an earth station terminal, whereas in case of LEO satellite, the satellite is in relative motion w.r.t the earth station terminal.

(ii) If the transmitted frequency is f_T, the received frequency f_R is higher than f_T when the transmitter is moving towards the receiver.

(iii) The received frequency f_R is lower than the f_T when the transmitter is moving away from the receiver.

(iv) Mathematically, the relationship b/w transmitted & received frequency are:

$$\frac{f_R - f_T}{f_T} = \frac{\Delta f}{f_T} = \frac{V_T}{V_P} \quad \text{---- (1)}$$

$$\Rightarrow \Delta f = \frac{V_T}{V_P} \times f_T$$

$$\Rightarrow \boxed{\Delta f = \frac{V_T}{\lambda}} \quad \text{------ (2)}$$

where, V_T is the component of the transmitted velocity directed towards the receiver.

and, $\boxed{V_P = c}$ i.e speed of light or phase velocity of light i.e 3×10^8 m/sec.

and, λ is the wavelength of the transmitted signal.

If the transmitter is moving away from the receiver then V_T is -ve. This change in frequency is called doppler shift, the doppler effect.

Qn: A LEO satellite is in a circular polar orbit with an altitude h = 1000 km (i.e from surface of earth to satellite). A transmitter on the satellite has a frequency of 2.65 GHz.

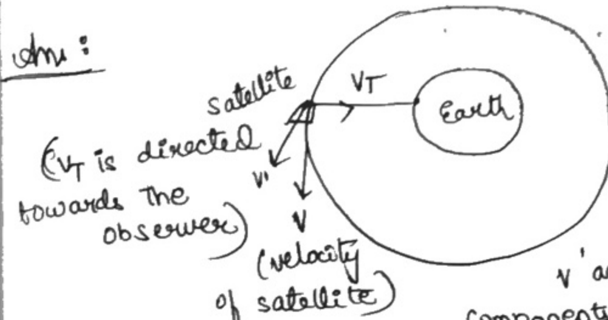
Find:

(i) Velocity of the satellite in orbit.

(ii) The component of the velocity towards an observer at earth station as the satellite appear over the horizon, for an observer who is in the plane of satellite orbit.

(iii) Find the doppler shift of the received signal at the earth station. Use the mean earth radius as 6378 km.

Ans:



V' and V_T are the two components of the velocity V.

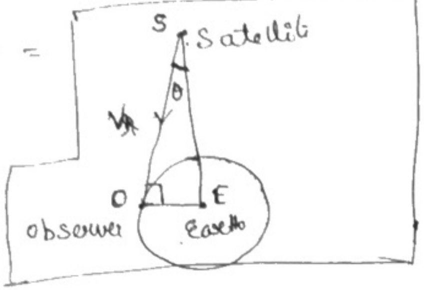
(i) Velocity of satellite:

(ii) The component of velocity towards an observer in the plane of orbit as the satellite appear over the horizon is given by:

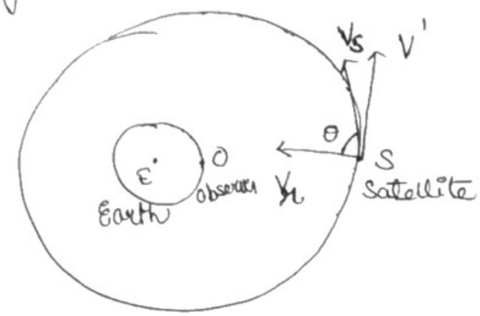
$$\boxed{V_R = V_S \cos\theta}$$

where θ = angle b/w satellite velocity vector and the direction of the observer of the satellite.

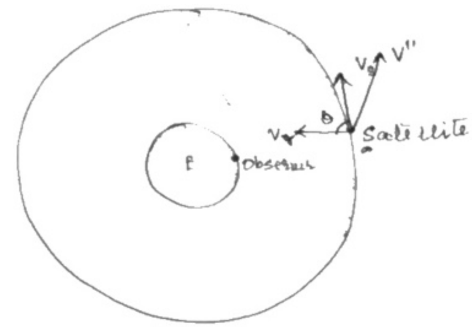
and $\cos\theta$ =



V_r = velocity towards the observer

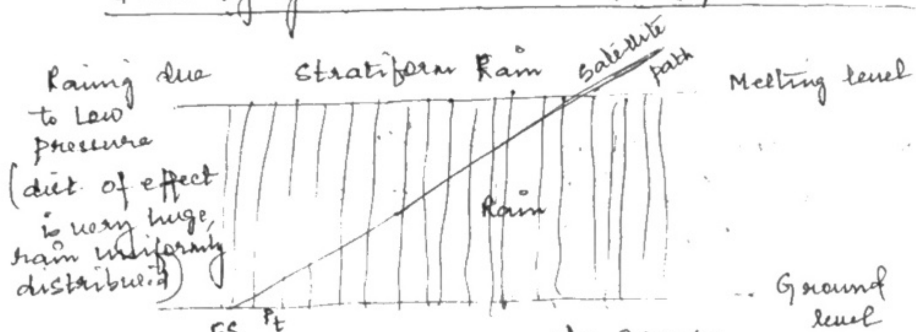


$\cos\theta$ =



17/3/17

Quantifying Attenuation and Depolarization



uplink (6 GHz / downlink 4 GHz)

Fig (i)

$d = 36000$ km

$$P_r = \frac{P_t G_t \cdot G_r}{(4\pi d/\lambda)^2}$$

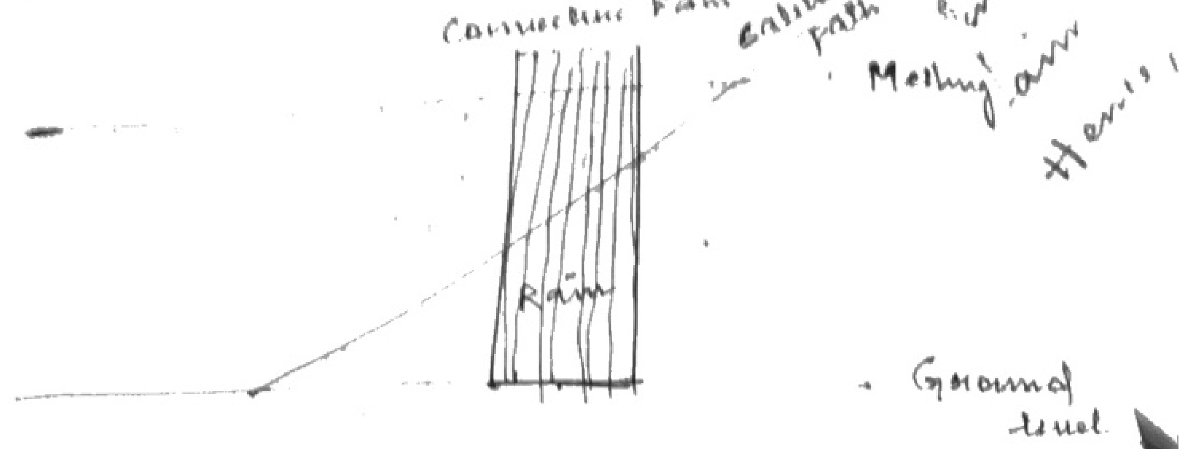
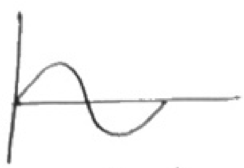
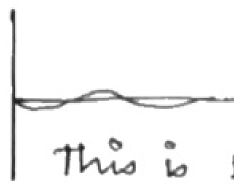


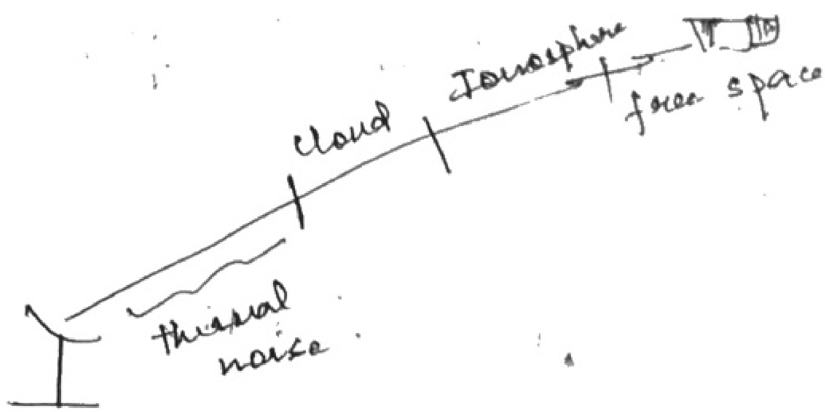
Fig (ii)



original signal



This is path loss due to long distance



→ Because of cloud rain is there and due to rain signals are distorted or attenuated

Quantifying attenuation is of 2 types-

(i) Hydrometric Effect
(Hydrogen)

(ii) Non-Hydrometric Effect

Melting line

Rains occurring only in summer season ie
Rain "occurring in specific regions only
Hence, path covered is less. [Refer fig (ii)]

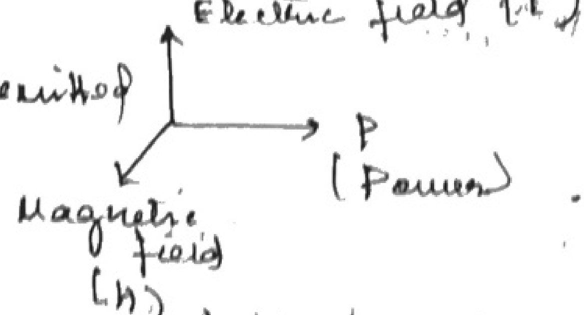
Hydrometric effect 2 types;

Rain → Convective
→ Stratiform Rain

Polarization : Suppose transmitting a signal,
~~the~~ In space magnetic field exists.


→ EMF (electromagnetic field)

Signals transmitted will have

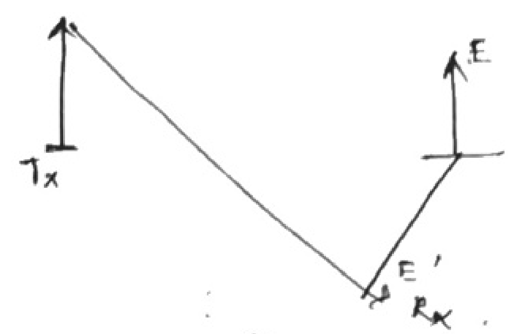


$$\boxed{P = E \times H}$$

→ The signal orientation in terms of waves field whether horizontally or vertically polarization.

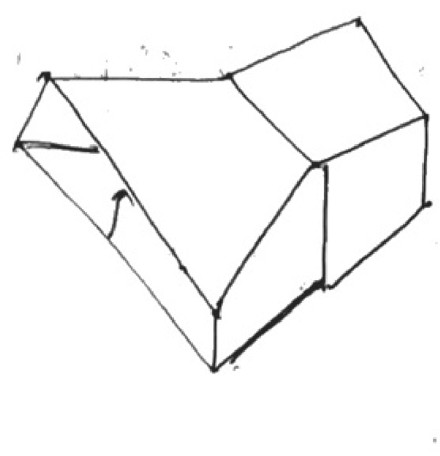
→ Polarization : Orientation of Electric field

→ De-polarization : In case of ~~cloudy area~~ rainy season,
(not obeying ~~the~~ polarization).



The vertical electric field will come down (E') at receiver side. This situation arises due to rain.

→ Antenna used for polarization is Horn Antenna.



(i) Attenuation 'A' = decibel diff. bet the power received P_r at a given time 't' and power received under ideal propagation condition (clear sky).

$$\boxed{\begin{array}{l} P_{r_1} \text{ (without rain)} \\ P_{r_2} \text{ (with rain)} \end{array} \Bigg\} \therefore \text{ attenuation } = P_{r_1} - P_{r_2}}$$

So for all values, In dB units we can write:

$$\boxed{A(t) = P_r \text{ clear sky} - P_r(t)}$$

$A(t)$ → Attenuation at time 't'.

(ii) Attenuation $A(t)$ on satellite communication leads operating at C, Ku, Ka bands is caused by absorption of the signal in rain.

(iii) To calculate attenuation, 3 steps are to be followed:

(a) Determine the rainfall rate for the time percentage of interest

(b) Calculate the specific attenuation of the signal at this rainfall rate in dB/km.

(c) Find the effective length of the path over which this specific attenuation applies.

(d) the difficult part to cal. to pt. (c) because rain falls in 2 broad categories :-

→ Stratiform rain
→ Convective rain.

these 2 diff. atmospheric mechanisms have diff. effects on satellite paths :-

[Refer fig(i)]
1. Stratiform rain : (i) It is generated in cloud layers containing ice, and results in widespread rain at the rate of less than 10 mm/hr.

(ii) It consists of a constant rainfall rate over a very large area.

2. Convective rain : (i) It is generated by the
[Refer fig(ii)] vertical air currents that can be very powerful, leading to thunderstorms and high rainfall rate.

(ii) It is very imp. for satellite comm. sys. as it is major cause of the link outage. | link will be

(i) It is confined to a narrow but tall column rain

Stratiform rain situations .

(i) In this case widespread sys. of stratiform rain, ie. rain appears to stratified horizontally, completely cover the path to the satellite from the ground upto the point where the rain temperature is 0°C.

(ii) This level is called melting level because above this level precipitation is frozen and consists of snow and ice crystal particles.

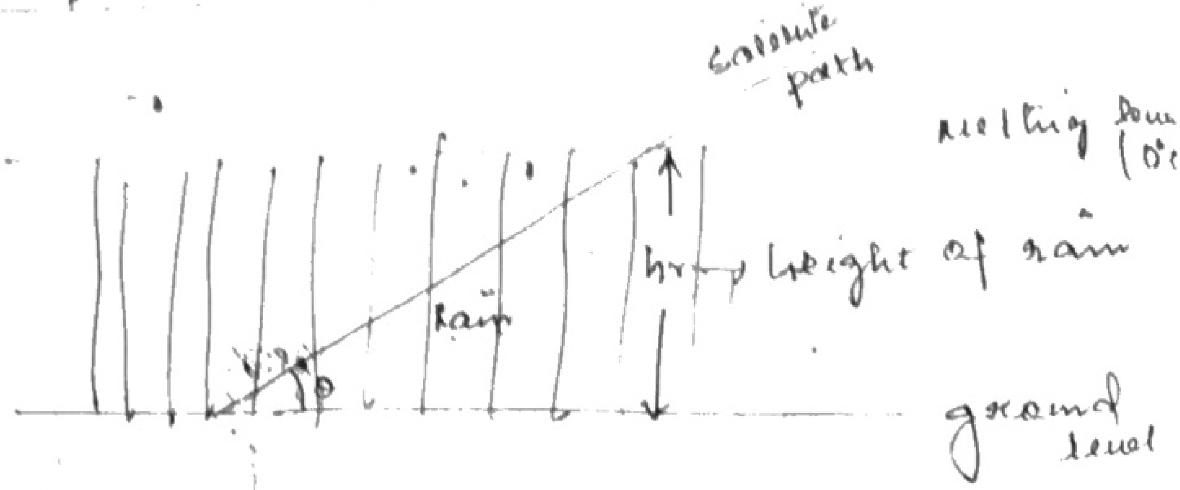
Convective rain situation :

(i) In this case, a tall col. of convective rain enters the satellite to ground path or satellite path.

(ii) Convective storms normally occur in summer. Thus the melting level is much higher than the winter.

(iii) In many cases the melting level is not well defined as the Strong convective activity inside the storm will push the liq. rain well above the melting level height

Stratiform rain attenuation calculation

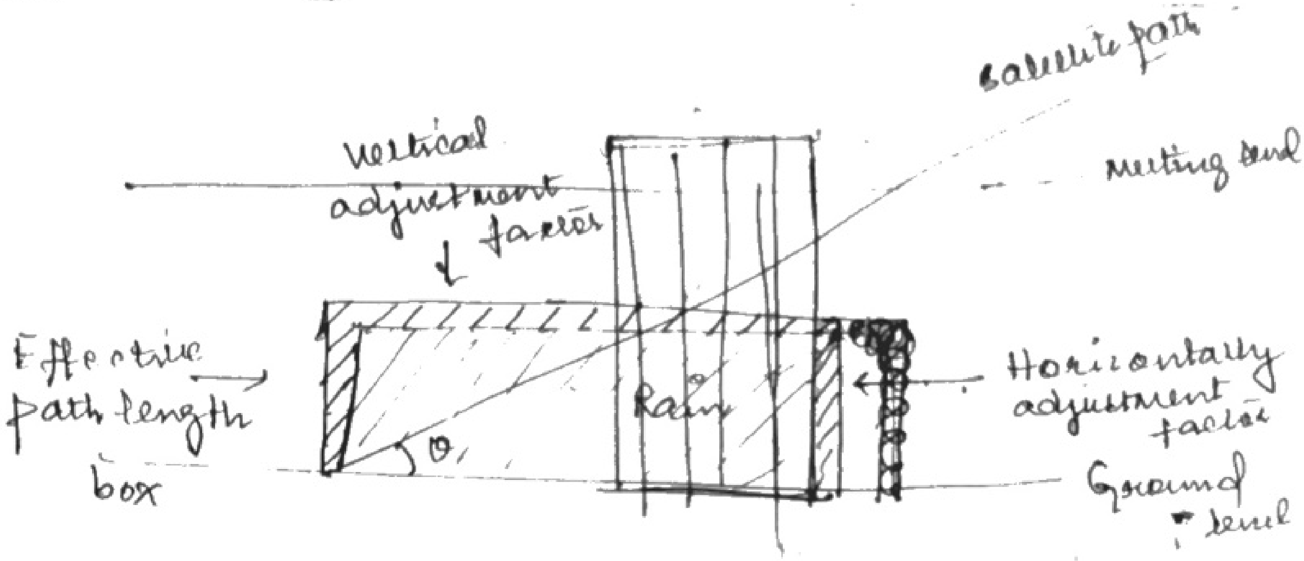


→ In this case the rainfall rate along the path can be considered to be uniform and the path completely immersed in rain.

→ The effective path through rain is the path over which the rain may be considered to be uniform. Also it can be considered as the same path as the physical path length in stratiform rain.

→ The path attenuation A = Specific attenuation (dB/km) × Effective path length of rain $\left(\frac{h_r}{\sin\theta}\right)$.

Convective rain attenuation calculation



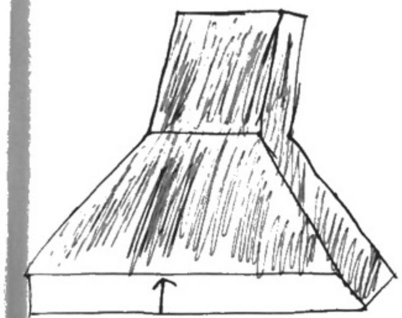
→ In case of convective rain, the melting level and the elevation angle are used to develop 2 adjustment factors — (i) vertical/height adjustment factor
(ii) Horizontal adjustment factor

→ Once this adjustment have been used, a smaller box is created inside which it may be assumed that the rainfall rate is uniform.

→ the length of the path exists inside the box is the effective path length and it is multiplied with the specific attenuation to get path attenuation

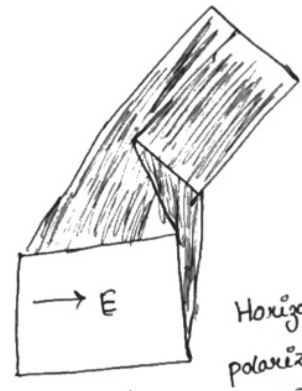
20/03/17

Depolarization



vertically polarized Horn antenna

Fig 1



Horizontally polarized horn antenna

Fig II

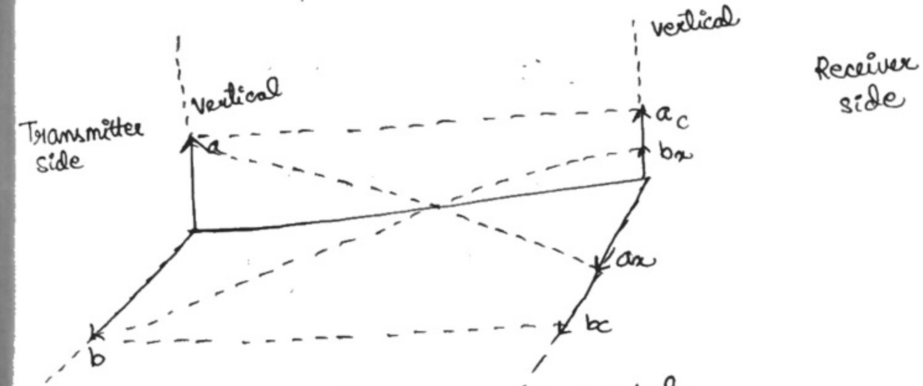


Fig III

polarization : orientation of electric field

a_c : co-polarized vertical component

b_c : co-polarized amplitude in horizontal component.

a_x : cross polarized component of 'a' in ,, direction in receiver side.

In vertical direction, we receive $a_c + b_x$ (here b_x is unwanted)

In horizontal direction, we receive $b_c + a_x$ (here b_c is original one, a_x is unwanted signal) This is called cross talk effect.

* Cross Polarization : X

Polarization : P

Cross polarization interference in horizontal : I_H

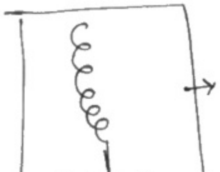
" " " " vertical : I_V

$$\boxed{\begin{aligned} XPI_H &= \frac{b_c}{a_x} \\ XPI_V &= \frac{a_c}{b_x} \end{aligned}} \quad (dB)$$

(This is always represented in dB format)

* Cross-polarization is also named as depolarization.

* If heavy rain, a_x value will be more, if low rain, a_x value will be less.



Helical antenna

→ purpose: to receive cross polarized signal.

* Notes :

(i) All the signals have a polarization orientation that is defined by electric field.

(ii) Depolarization occurs because of rain and ice crystals.

(iii) " is more difficult to quantify the attenuation

(iv) Let us elaborate the process by which depolarization is measured :

(a) Imagine a dual polarized antenna transmitting orthogonal polarized signal.

(b) We will call these two polarizations V (for vertical) and H (for horizontal) for conviniencе.

(c) let the complex phasor amplitudes of the transmitted electric field vectors with polarization V and H be : a and b respectively, as shown in Fig iii.

(d) The transmitting antenna is excited so that a and b are equal.

(e) If the transmission medium b/w transmitting & receiving antenna were clear air, phasor 'a' would give rise to a V polarization wave of amplitude a_c, at the receiving antenna and phasor 'b' would cause an H polarization wave of amplitude b_c. The subscript 'c' stands for co-polarized.

(v) If asymetrical rain or ice crystal particles exist in transmission medium some of energy in 'a' will couple into a small (cross polarized) H polarized field component whose amplitude at the receiving antenna is a_x and 'b' will give rise to a small 'V' polarized component b_x.

(vi) For an ideal receiving system, we have V channel O/P = $a_c + b_x$ and H channel O/P = $b_c + a_x$ as shown in fig iii.

(vii) The unwanted b_x terms represent interference with the wanted signal a_c and the unwanted a_x term is in interference with the wanted signal b_c.

(viii) This interference will cause cross talk, and increases the bit error rate (BER) on digital communication link.

(ix) This generation of unwanted cross polarization is called De-polarization.

(x) The measure of de-polarization that is most useful for analyzing communication systems is the Cross polarization isolation XPI.

$$\boxed{\begin{aligned} XPI_H &= \frac{b_c}{a_x} \\ XPI_V &= \frac{a_c}{b_x} \end{aligned}} \quad dB$$

(xi) Physically, XPI is the decibel ratio of wanted power to unwanted power in the same channel. The larger the XPI value, the less interference and better the communication channel will perform.

The larger the XPI value the less interference and better the comm. channel will perform.

21/3/17

Propagation Effects that are not associated with Hydrometeors (Non Hydrometric Effect)

Atmospheric Absorption

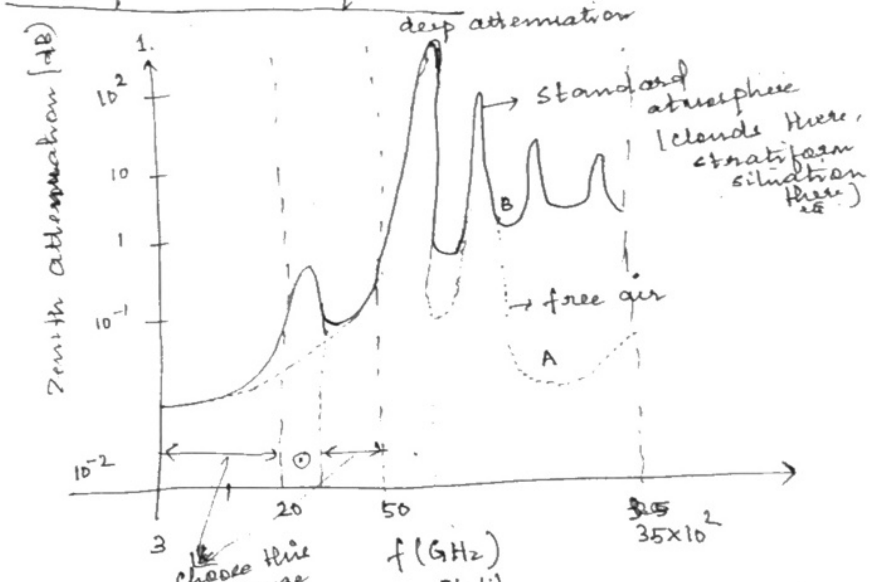


Fig (i)

→ Here, range from 3 to 350, as microwave range > 3 GHz.

⊙ avoid this range for effective communication

* 1 Atmospheric absorption (because of
2. cloud attenuation (because of cloud
3. troposphere scintillation & (" " Iono
and low angle fading { (" " connective effect on air near to ground)
4. Faraday rotation in atmosphere (because of Ionosphere).

Notes :

Atmospheric absorption :

Propagation effects that are not associated with raindrops or ice crystals are * 1, 2, 3 and 4.

Scintillation

(i) Atmospheric effects with influence of astronomical observations [fluctuation of radio waves by solar winds).

(ii) At microwave freq. and above electromagnetic waves interact with molecules in the atmosphere to cause signal attenuation.

(iii) The 2 curves in fig (i) represents the gaseous attenuation that would be observed looking straight up from the sea level (on a zenith path); curve A is for dry atmosphere (no water vapour present) ~~and~~ while curve B is for standard atm.

Curve A shows only the region at absorption peaks of the O_2 molecules

Curve B includes region at absorption peaks due to water vapour molecule.

Cloud attenuation

(i) Clouds have become an important factor for Ka band paths and all V-band (50 - 60 GHz) systems.

(ii) The difficulty with modelling cloud attenuation is that clouds are of many types and can exist at many levels, each type having a diff. probability of occurrence.

(iii) The water droplet concentration in each cloud will also vary and clouds made up of ice crystals cause little attenuation.

(iv) Typical values of cloud attenuation i.e. thin mixed water-filled clouds are bet. 1-2° ~~and~~ freq. around 30 GHz.

Tropospheric Scintillation and Low angle fading

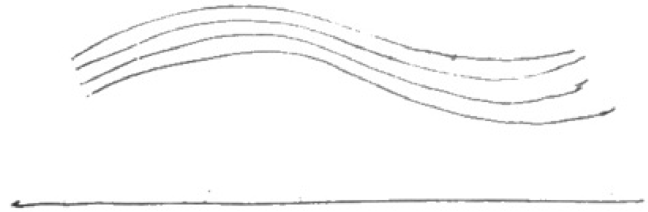


Fig (a) Stratified Layers (calm conditions)

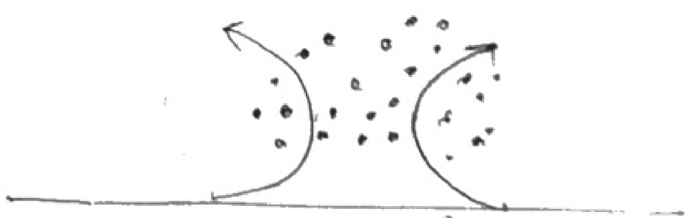


Fig (b) Turbulent Mixing (convective conditions)

(i) the atm. close to the ground sometimes called the boundary layer, is rarely steel in nature.

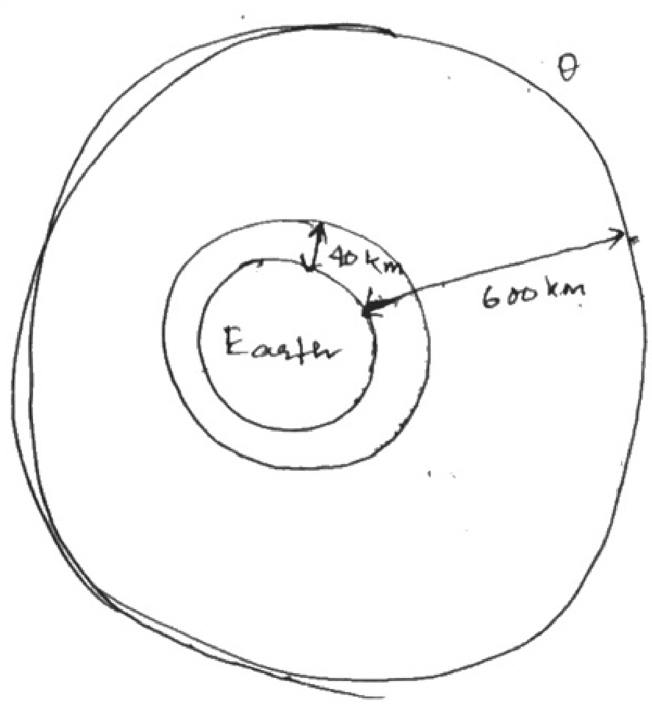
(ii) Energy from sun warms the earth's surface and the resultant convective activity agitates the boundary layer.

this agitation results ~~a~~ in turbulent mixing of diff. parts of boundary layer, causing small scale variation in refractive index.

(iv) In fig(a), air is calm and lower atm. next to earth's surface ~~forms~~ (boundary layer) has slightly diff. refractive index.

(v) In fig(b), earth's surface is heated by energy from sun and convective activity arises which lead to diff. refractive indices.

Faraday Rotation in atmosphere



(i) Ionosphere exists near to 40 - 600 km. It is that portion of earth's atmosphere consists of large no of e^- and ions.

(ii) At its lowest, reaches down close to 40 km above the earth, there is no distinct upper boundary but it exists above 600 km from the earth.

(iii) Electrically, the ionosphere is inhomogeneous and anisotropic plasma

(iv) For a given freq. and direction of propagation w.r.t. the earth's magnetic field, there exists 2 characteristic polarizations.

(v) Waves with these polarization called characteristic waves.

(vi) Any wave entering the ionosphere can be resolved into 2 components with the characteristic polarization.

(vii) The phase shift and attenuation experienced by the characteristic waves can be calculated at any pt along the propagation path.

the total electric field can be computed as the vector sum of fields of characteristic waves.

(IX) this total field can be interpreted as an attenuated and depolarized version of the wave that enter the ionosphere.

(X) thus when a linearly polarized satellite path signal reaches the atmosphere, it divides the wave with 2 characteristic polarization.

(XI) The wave that leaves the ionosphere has diff polarization ~~that~~ than linearly polarized wave that was transmitted. this called the faraday rotation.

$$\phi = \int \frac{2.36 \times 10^4}{f^2} \cdot N_2 B_0 \cos\theta \, dz \text{ (rad)}$$

(e^-/m^3)

For a path length through ionosphere of rotation angle ϕ is given above

where, $\theta \rightarrow$ angle bet. geometric field and direction of propagation.

$E \rightarrow$ Electron density (ie e^- per cubic m).

$B_0 \rightarrow$ Geometric flux density (Tesla unit).

24/3/17

Antenna

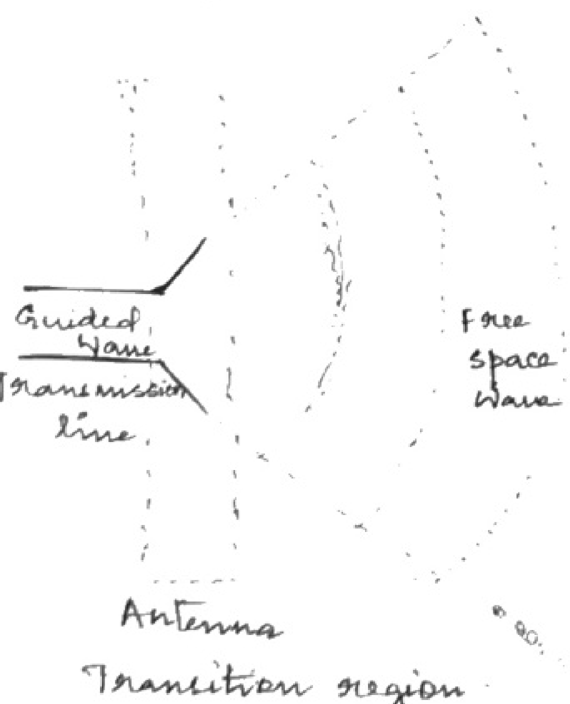
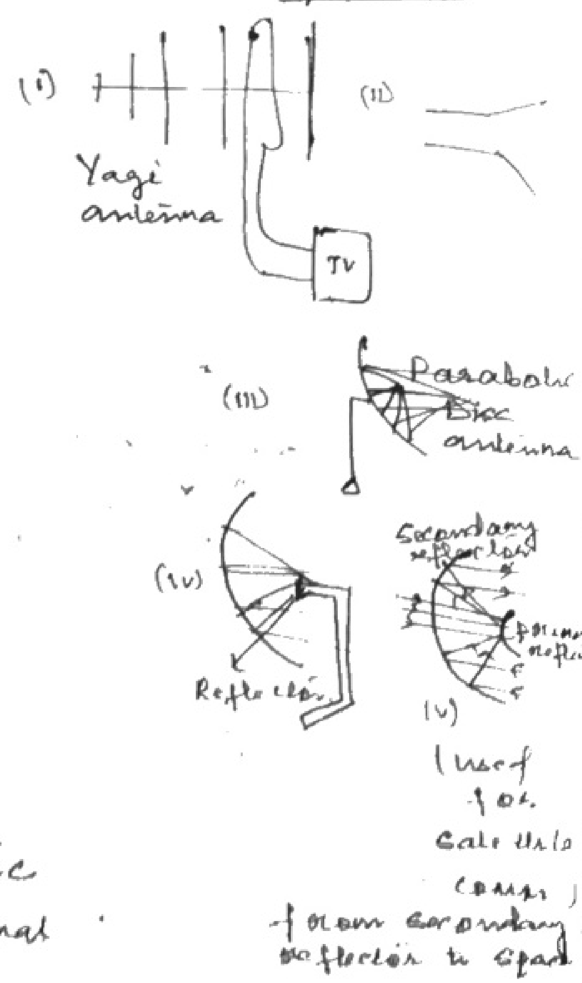


Fig (1)

Diff kinds of antenna possible



Antenna is a transition device which converts electric signal to electromagnetic signal.

Antenna

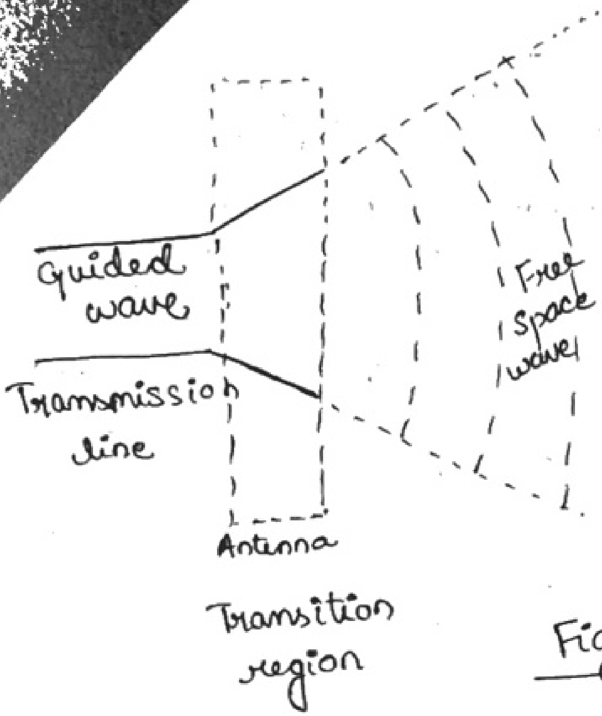


Fig 1

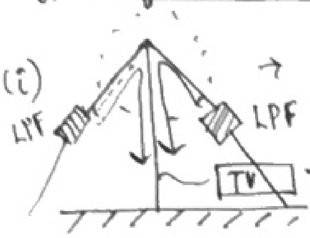
→ Antenna is a transition device which converts electric signal to electromagnetic signal.

* Types of antenna :

-[VT.]

Comb
capacito
indu

(i)

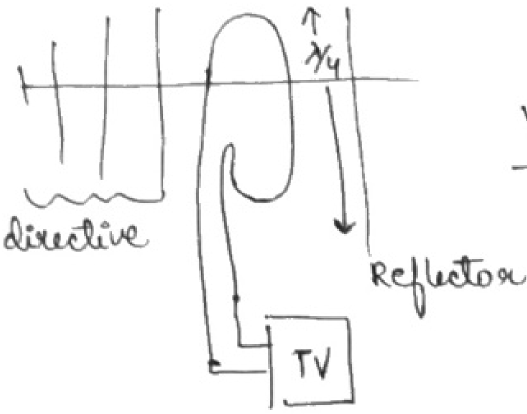


→ radiates power in all directions

→ (it is any TV or system Connected to the antenna)

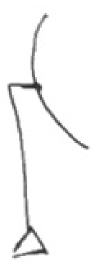
If high frequency Then will not pass through LPFs return back and through the antenna reaches our TV or any System

(ii)



Yagi antenna (we choose the length to be $\lambda/4$, else it is not possible to construct an antenna of Such long height)

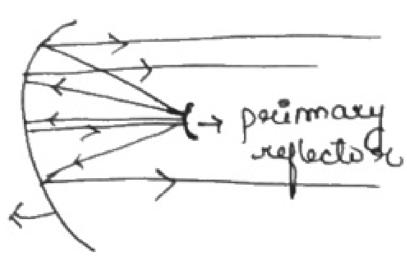
(iii)



Parabolic Disk antenna (This is total directive in nature, all signals come to the focal point) → This is the advantage as compared to Yagi antenna.

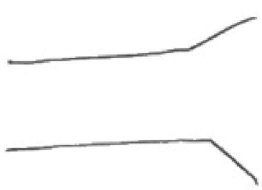
(iv)

here we have a wave guide



(used for satellite & radar Communication)

(v)



(vi)

(it) o/p if transmission length is $\lambda/4$ then max power can be transmitted through a cable

i.e if input power transmitted is P_t then max power can be received at the o/p which is P_r.

Hence in Yagi antenna we choose the length to be $\lambda/4$ so as to Transmit max power

* Notes : (Antenna)

(i) To radiate or receive electromagnetic waves, an antenna is required.

(ii) A radio antenna is defined as the structure associated with the region of transition b/w a guided wave and a free space wave or between a free space wave & a guided wave as shown in Fig 1.

* Design of Small Earth Station Antenna :

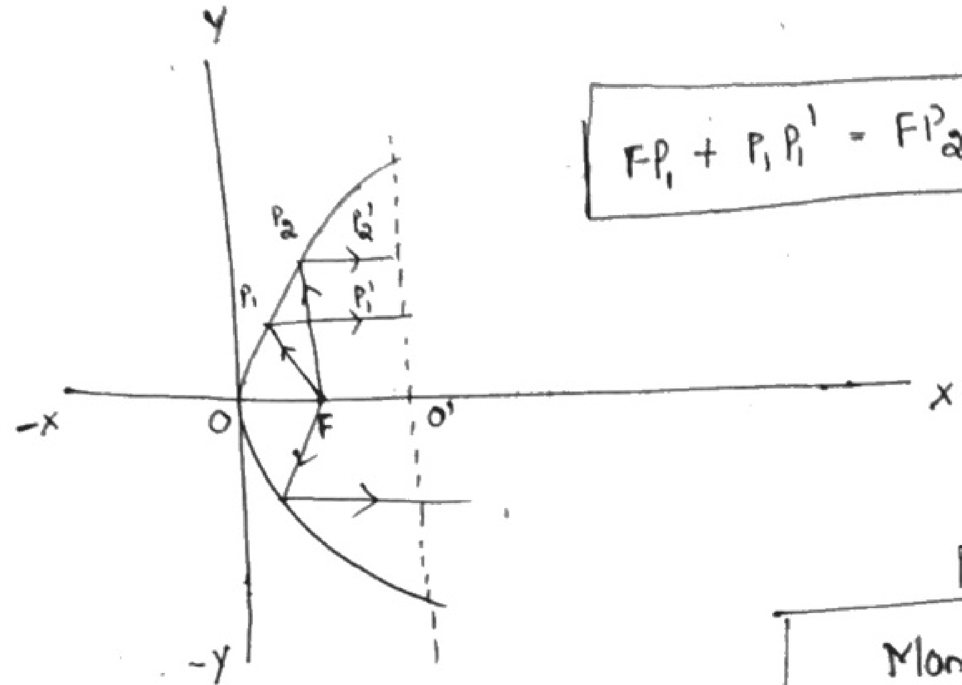
(i) The antenna considered belong to various classes :

(a) Horn antenna

(b) The phased array antenna

(c) Parabolic antenna

* Front Fed Paraboloid Reflector Antenna :



$$\boxed{FP_1 + P_1P_1' = FP_2 + P_2P_2' = \cdots\cdots}$$

Pg 59

Monday Presentation

Telemetry, tracking Command & monitoring

O → vertex

OO' → axis of paraboloid

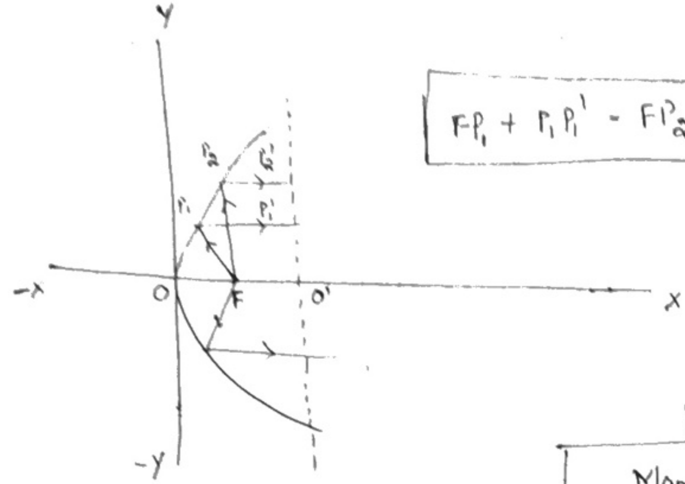
OF → focal length

Notes :

(i) A ~~paraboloid~~ parabola may be defined as the locus of a point which moves in such a way that its distance from a fixed point (called focus) plus its distance from a straight line (called directrix) is constant.

(ii) The entire parabolic reflector antenna consist of 2 basic components i.e the reflector and a source of primary radiation at the focus.

(iii) The sources is called the primary radiation or feed radiator or simply feed with the reflector.



$$FP_1 + P_1P_1' = FP_2 + P_2P_2' = \dots$$

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Pg 59

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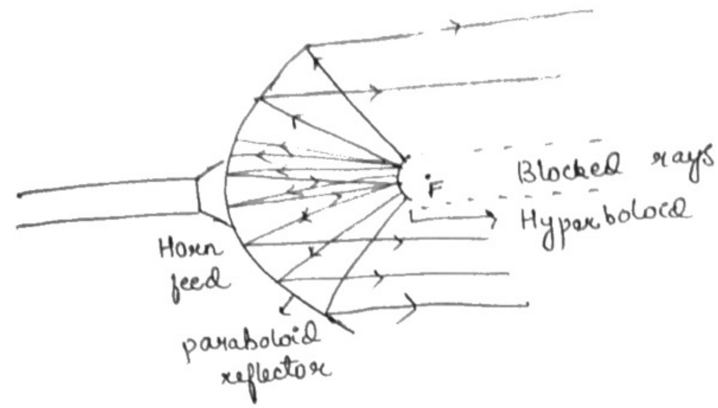
2/11/17 - Cassegrain feed Antenna



Notes :

(i) As shown in the above figure in which primary field feed radiator is positioned around an opening near the vertex of the paraboloid instead of at focus.

(ii) Cassegrain feed system employs a hyperboloid secondary reflector whose one of the foci ~~p~~ coincides with the focus of paraboloid.

(iii) The feed radiator is aimed at the secondary hyperboloid reflector or sub-reflector.

(iv) The radiations emitted from the feed radiator are reflected from cassegrain secondary reflector which illuminates the main paraboloid reflector as if they had originated from the focus.

Disadvantage :

(i) Some of the radiations from the paraboloid reflector is obstructed. This is tolerable in greater dimension paraboloid but becomes problem with small dimension paraboloid. This aperture blocking defect can be avoided by using an offset reflector. Ans

Advantage:

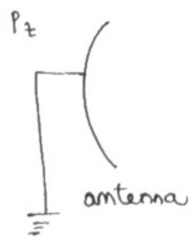
(i) Reduction in spill over and minor lobe radiation.

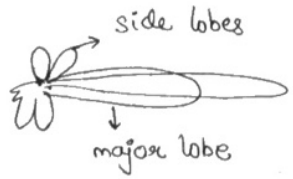
(ii) Availability to get an equivalent focal length much greater than the physical length.

(iii) ~~Avai~~ Ability to place the feed in convinient location

Minor lobe: θ vs P → (Polar plot)

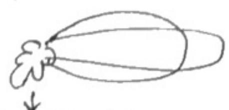
where P = Power





(When we on a torch, the rays will come straight and some may radiate in some side directions resulting in side lobes)

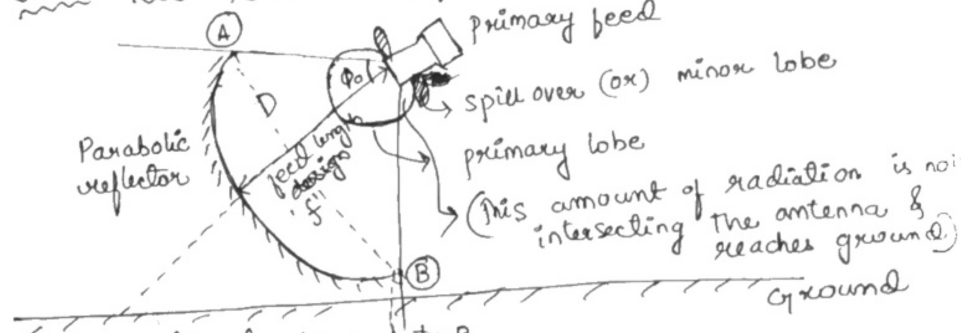
according to cassegran feed antenna, power radiated from side lobes is very less.



(So side lobes are very small)

(Spade
Single carrier
per-channel pulse
code modulated
Access Demand
Assignment Equipment)

* Front Feed Paraboloid Reflector Antenna



D = diameter from A to B

$$\boxed{\tan\left(\frac{\phi_0}{2}\right) = \frac{D}{4f}}$$ where f = focal length

Note:

(i) Above figure illustrates the mounting of an antenna with a parabolic reflector which has symmetry of rotation w.r.t the principle axis on which the primary feed is placed at the focus.

(ii) The main weakness of this mounting is that the feed supports and the feed itself have a masking effect on the radiating apparture.

(iii) This blocking leads to a reduction of antenna efficiency and an increase in the level of the side lobes due to diffraction by the obstacles.

(iv) Furthermore, the primary feed focus the earth & the part of the radiation pattern of the primary feed does not intersect the reflector easily captures the radiation emitted by a ground and it makes a large contribution to the antenna noise temp.

(v) To obtain the lower noise temp, a directional primary feed and a long focal length is necessary.

Telemetry, Tracking, Command & Monitoring : (TTC&M)

(i) To support the primary mission of communication satellite, the sub systems of the satellite are of primary importance.

(ii) TTC&M is one of the sub system of satellite. The other subsystems are as follows :

(a) Attitude and Orbit Control System (AOCS) .

(b) Power System

(c) Communication Subsystems

(d) Thermal control system .

(iii) The TTC&M is a part of the satellite management task, which also involves an earth station and a group of personnel.

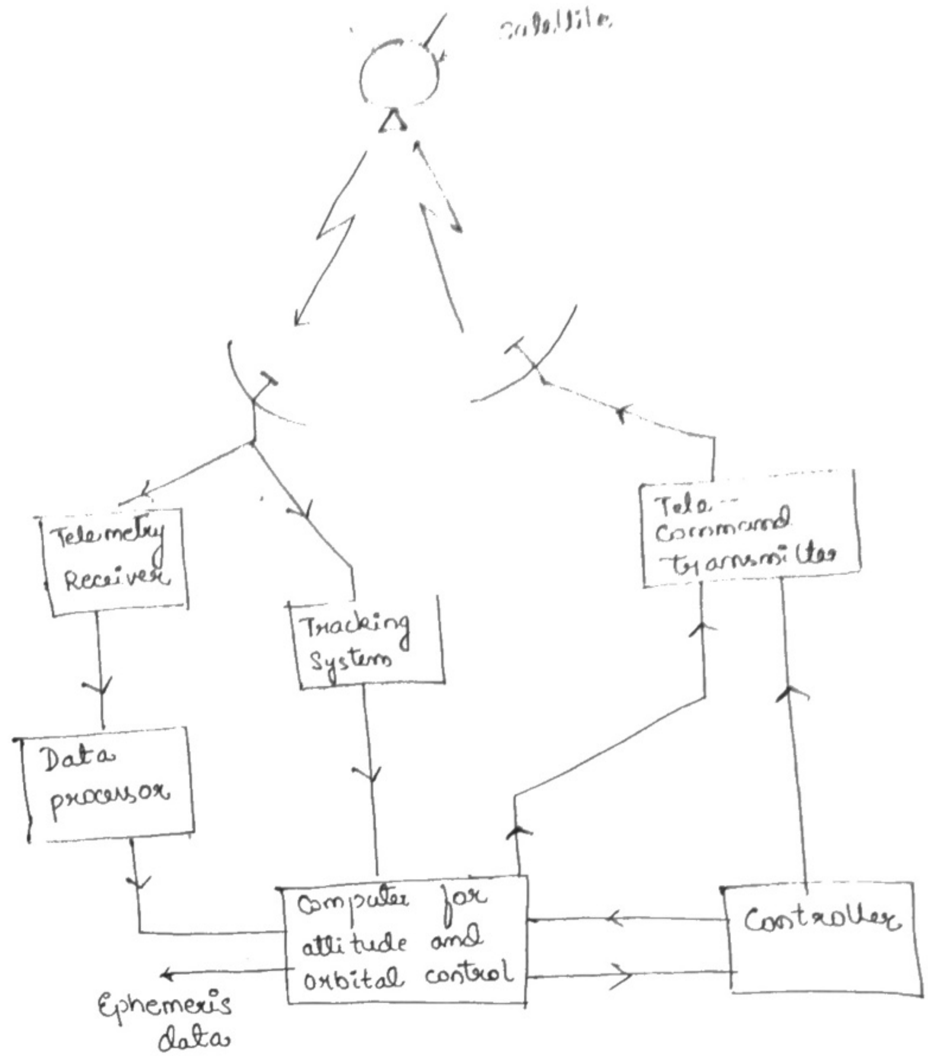
(iv) The main functions of the satellite management are :

(a) to control the attitude & orbit of the satellite

(b) monitor the status of all sensors and subsystems on the Satellite .

(c) switch on or off sections of the communication system .

(v) The block diagram of TTC&M system is as follows :



TTC&M System

Telemetry & Monitoring System :

(i) The telemetry data sends data derived from many sensors on the satellite, which monitor the satellite's health via a telemetry link to the controlling earth station.

(ii) There are several sensors located on the satellite for different purpose such as :

(a) to monitor pressure in fuel tanks.
(b) voltage & current in power conditioning unit.
(c) current ~~drawn~~ drawn by each sub system.
(d) Temp of different sub systems.

(iii) Telemetry data are usually digitized and transmitted as phase shift keying (PSK) of a low-power telemetry carrier using time division techniques.

(iv) At the controlling earth station, a computer can be used to monitor, store & decode the telemetry data so that the status of any system or sensor on the satellite can be determined immediately by the controller on the earth.

Tracking :

(i) It is performed primarily by the earth station.

(ii) The orbital data is obtained from the tracking system i.e the system provides information on the range, the elevation angle & the azimuth angle.

(iii) Active determination of range can be achieved by transmitting a pulse or sequence of pulses to the satellite & observing the time delay before the pulse is received again. (Satellite ranging is a technique by which horizontal positions are calculated as a function of distances from known locations.)

Command :

(i) The command system is used to make changes in attitude & corrections to the orbit and to control the communication system.

(ii) It is also used to control the antenna pointing and communication system configuration to suit current traffic requirements, and to operate switches on the satellite.

(iii) The control code (generated at the control terminal of the computer) is converted into a command word, which is sent in a TDM frame to the satellite.

(iv) After checking for validity in the satellite, the word is sent back to the control station via the telemetry link where it is checked again in the computer.

(v) If it is found to have been received correctly, an execute instruction will be sent to the satellite so that the command is executed.

(vi) The entire process may take 5 or 10 s, but minimizes the risk of erroneous commands causing a satellite malfunction.

(vii) The command and telemetry link are usually seperate from the communication system, although they may operate in the same frequency band (6 & 4 GHz).

SPADE System :

(i) SPADE is an acronym for Single-channel-per carrier (SCPC), Pulse Code modulation, multiple Access, Demand Assignment Equipment.

(ii) It is the first ~~communication~~ digital communications Satellite which was brought into service by INTELSAT in 1971.

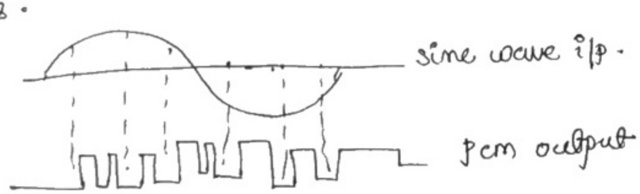
(iii) The term SCPC in the acronym of SPADE ~~means~~ refers to (a) using a single signal at a given frequency or bandwidth i.e it uses separate carrier for each of its channels.

(b) This is in contrast to frequency or time division multiplexing which combines many channels on a single carrier.

(c) It is a "dedicated bandwidth" technology, hence donot allow to share the bandwidth available on the satellite among several earth station.

(iv) Pulse Code modulation :

(a) It is a technique in which the amplitude of an analog signal is converted to a binary value represented as a series of pulses.

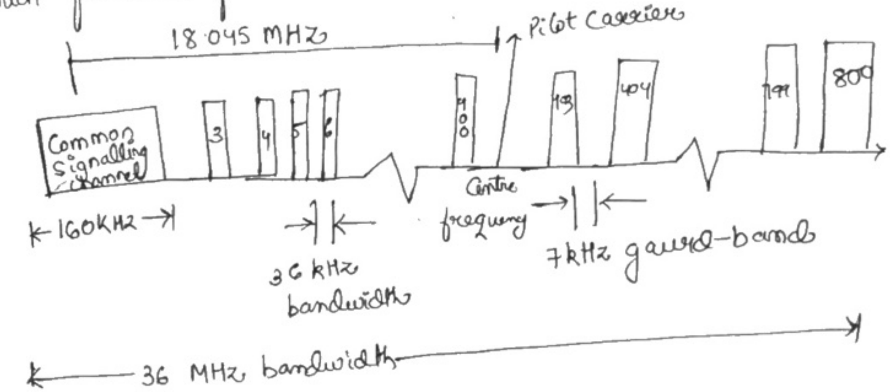


(v) multiple Access :

(a) These are the techniques to access a single channel by multiple users.

(b) It can also be defined as a scheme that allows several earth stations to transmit in the same time span.

(vi) SPADE is a distributed form of SCPC without the need for a central control station. In addition to approximately 800 frequency slots, it includes a Common Signalling channel (CSC) which ~~facilitates~~ facilitates the demand assignment.



channel allocation in SPADE system.

Common Signalling channel (CSC) :

(i) When an call request arises, an earth station chooses a pair of frequency slots for the duration of calls.

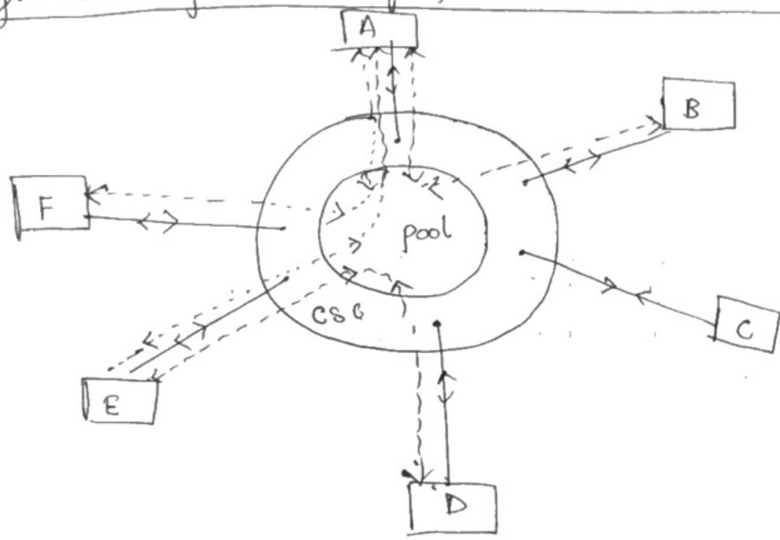
(ii) Information about the slots chosen in exchanged ~~by~~ on the CSC, which has a bandwidth of 160 KHz.

(iii) A seperate multiple access scheme is required for the CSC itself.

(iv) Each station maintains a list of available frequency slots, & chooses a pair at random.

(v) After the termination of the call, the slots are returned to a common pool.

Diagrammetric representation of spade Communications System



(vi) To prevent interference with CSC, voice channels 1 & 2 are left vaccant and correspondingly channels 400, 401, 402 and 800 are also left vaccant.

(vii) Thus 6 channels are removed from total 800, leaving a total of 794 one way or 397 full duplex voice circuits.

Topics for friday: (1) TDMA; FDMA spread spectrum
(2) Hydrometric effect & non-hydrometric effect.
(3) TTC&m

Demand Assignment:

(i) In systems where a fixed no of satellite channels are pre-assigned to each earth station there are, times when channels at some stations remain unused while other stations have to refuse traffic because they have insufficient channel.

(ii) In demand-assignment system, each earth station requests satellite capacity to satisfy the allocation of just sufficient satellite capacity is its intermediate needs; so as soon as any of this capacity is no longer required the station returns it to a pool where it becomes available to any other station which needs it.

(iii) Hence DA makes efficient use of satellite capacity.

(iv) SPADE terminals compose of common equipment and a no of channel units. The common equipment includes a signalling & switching processor & timing circuits.

(v) Each channel unit includes a voice detector, a PCM codec, a QPSK modem & a channel frequency synthesizer.

Disadvantage of SPADE:

(i) The terminals are very expensive and difficult to maintain.

Book:
Satellite Comm. System
Engineer → W L Pritchard
Page no 238 (TTC&M, Attitude Control)

FDMA, TDMA, CDMA

Multiple access :

(i) The ability of the satellite to carry many signals at the same time is known as multiple access.

(ii) Multiple access allows the communication capacity of the satellite to be shared among a large no of earth stations & to accomodate the different mixes of communication traffic that are transmitted by the earth station.

Multiplexing :

(i) Process of combining a no of signals into a single signal so that it can be processed by a single amplifier or transmitted over a single radio channel.

Differences b/w multiple access & multiplexing :

(i) multiplexing applies to signals that are generated at one location, whereas multiple access refers to signals from a no of different geographical locations.

Types of multiple access :

(i) fixed access (FA) or preassigned access (PA)
(ii) Demand access (DA)

Fixed access : if the proportion allocated to each earth station is fixed in advance, the system is called FA.

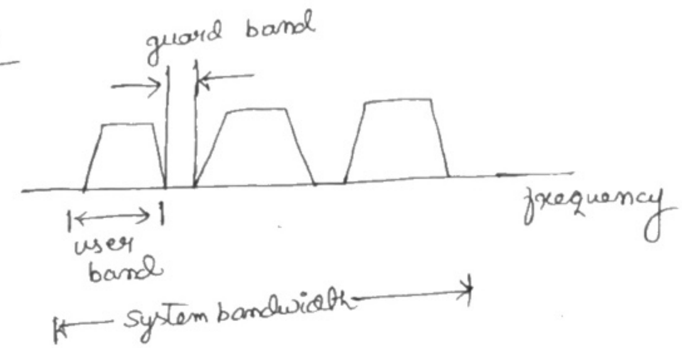
Demand access : If the resource is allocated as needed depending on changing traffic conditions, the system is called DA.

The various multiple access techniques are :

(i) FDMA
(ii) TDMA
(iii) CDMA

In all the three techniques some resource is shared.

FDMA :



(i) Here, all users share the satellite at the same time, but each user transmits at a unique allocated frequency.
(ii) It can be used with analog as well as digital signals.
(iii) In a fixed assignment system, each transmitting earth station was allocated a frequency & bandwidth for each group of signals it wished to send.
(iv) when an earth station sends one signal on a carrier, the FDMA access technique is called single channel per carrier (SCPC).

Disadvantages of FDMA :

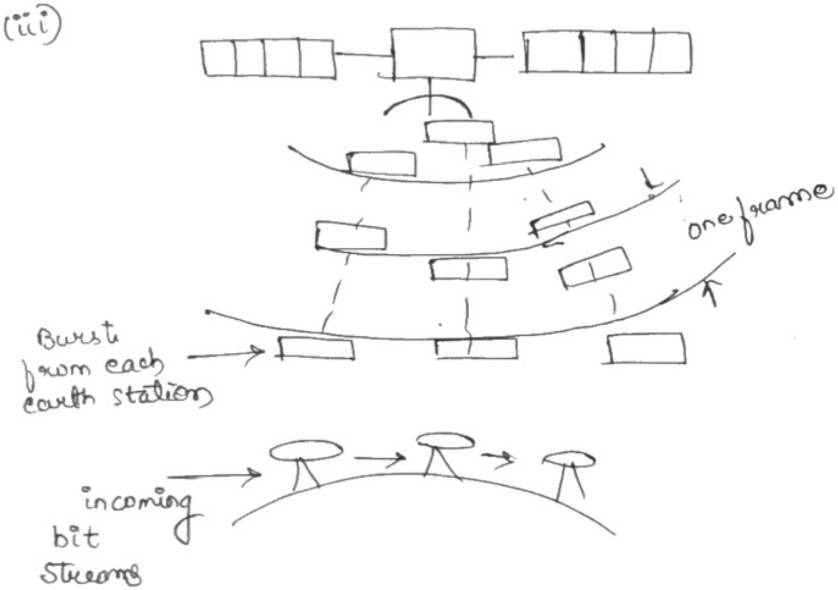
(i) Guard bands leads to a waste of capacity.
(ii) The max flow rate per channel is fixed & small.

TDMA :

(i) A no of earth stations take turns transmitting bursts of RF signals through a transponder.

(ii) It is not well suited for narrow band signals whereas FDMA is usally implemented in narrow band.

(iii)



(iv) TDMA is an RF multiple access technique that allows a single transponder to be shared in time b/w RF carriers from different earth station.

(v) A time overlap of two RF signals is called a collision and results in data in both signals being lost. Collisions must not be allowed to occur in a TDMA system

TDMA frame structure :

(i) A TDMA frame contains the signal transmitted by all of the earth station in a TDMA n/w.

(ii) It has a fixed length & is built up from the burst transmission of each earth station, with guard times b/w each burst.

(iii) Each station transmits a preamble that contains synchronization & other data essential to the operation of the n/w before sending data.

(iv) In some system, a seperate reference burst may be transmitted by one of the stations, designated as master station

(v) A reference burst is a preamble followed by no traffic bits.

CDMA :

(i) In CDMA, all users transmit to the satellite on the same frequency & at the same time.

(ii) The earth stations transmit orthogonally coded spread spectrum signals that can be seperated at the receiving earth station by correlation with the transmitted code.

(iii) It is a digital technique.

(iv) The bits of a CDMA code are called chips & chip rate is always much greater than the data rate.

(c) CDMA is also known as spread spectrum because it takes the digitized version of an analog signal and spreads it out over a wider bandwidth at a lower power level.

Spread spectrum :

(i) " " is a form of wireless communication in which the frequency of the transmitted signal is deliberately varied resulting

(ii) Spread spectrum uses wideband, noise-like signals that are hard to detect, intercept or demodulate.

(iii) Spread spectrum signals are harder to jam (interfere with) than narrow band signals

(iv) These low probability of intercept and anti-jam features are why the military has used the spread spectrum.

(v) These signals are intentionally made to be a much wider band than the information they are carrying to make them more noise-like.

(vi) Because spread spectrum signals are so wide they transmit at a much lower spectral power density.

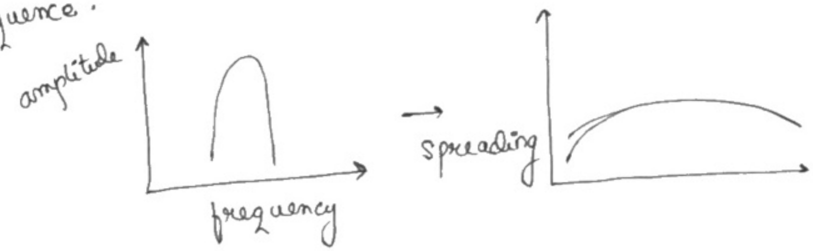
(vii) Two types of spread spectrum techniques:

(i) Direct sequence

(ii) Frequency hopped.

Direct sequence spread spectrum :

(i) In this process, the narrow band information is spread out in a much larger bandwidth by using a pseudo-random chip sequence.



(ii) Both the narrow band signal of the spread-spectrum signal both use the same amount of transmit power & carry the same information.

(iii) At the receiving end, the spread spectrum signal is de-spread to generate the original narrowband signal.

Frequency hopped spread spectrum :

(i) It uses different carrier frequency at different times but whereas DS-SS uses a fixed frequency

(ii) In these architectures, the receiver & the transmitter must be synchronized in time & frequency in order to ensure proper transmission & reception of signals. Whereas in DS-SS only the chips need to be synchronized.

Advantages of spread spectrum :

(i) Reduced crosstalk interference

(ii) Inherent security

(iii) Better voice quality

(iv) hard to detect, intercept & demodulate

(v) Harder to jam.

Hydrometric & Non-hydrometric effects :

(i) There are many phenomena that lead to signal loss on transmission through the earth's atmosphere.

(ii) These phenomena can be classified into 2 categories :

(a) Hydrometric : (These are associated with rain drops or ice crystals & include :

(i) Rain attenuation

(ii) Rain & ice crystal depolarization

(b) Non-hydrometric :

(i) Atmospheric absorption

(ii) cloud attenuation

(iii) refractive effects

(iv) Faraday rotation

(v) Ionospheric scintillation

Hydrometric effects :

Rain affects the transmission of an electromagnetic signal in three ways :

(i) It attenuates the signal

(ii) It increases the system noise temp

(iii) It changes the polarization.

All these three mechanisms cause a degradation in the received Signal quality & become increasingly significant as the carrier frequency increases.

attenuation : (Rain attenuation)

(i) The attenuation is caused by the scattering & absorption of electromagnetic waves by drops of liquid water.

(ii) Absorption increases the molecular energy, corresponding to a slight increase in temp & results in an equivalent loss of signal energy.

(iii) The standard method of representing rain attenuation is through an equation of the form :

$$L_r = \alpha R^\beta L = \gamma L$$

where L_r is the rain attenuation in decibels (dB)

R is the rain rate in millimeters per hour

L is an equivalent path length (km) which depends on angle of elevation to the satellite, the height of the rain layer & the latitude of the earth station

α & β are the coefficients that depend on frequency and to some extent on the polarization.

γ = specific rain attenuation & is measured in dB/km.

Depolarization :

The change in polarization has 2 effects :

(i) loss in signal strength : because of misalignment of the antenna relative to the clear sky orientation given by :

$$\boxed{L = 20 \log (\cos \tau)}$$

where τ is the tilt angle relative to the polarization direction induced by the rain.

(ii) additional interference noise due to the admission of a portion of the signal in the opposite polarization.

(iii) Normally, a horizontally polarized ~~satellite~~ signal is parallel to the equitorial plane & a vertically polarized signal is ⊥lar to the equitorial plane.

(iv) when de-polarization occurs it can cause co-channel interference & crosstalk b/w dual-polarized satellite links.

Non-hydrometric effects:

Atmospheric absorption:

(i) At microwave frequencies & above, (frequencies b/w 300 MHz & 300 GHz), electromagnetic waves interact with molecules in the atmosphere to cause signal attenuation

(ii) At certain frequencies, resonant absorption occurs & severe attenuation can result.