Wireless characteristics :-

- Communication without wires
- Wires are replaced by electromagnetic waves.
- Electromagnetic waves carry a signal through atmospheric space.
- Use radio frequency RF waves, which ranges from 3KHZ to 300 GHZ.
- or ~~Infrar~~ Infrared IR, which ranges from 3THZ to 430THZ

Origin of wireless communication :- 1G, 2G, 3G, 4G, 5G [1G-AMPS - NMT → Nordic Mobile Telephony]

1864 - James Maxwell - Predicts the existence of Radio waves.

1886 - Rudolph Hertz - Demonstrate Radio waves.

1895 - J C Bose - Public demonstration of Radio waves.

1895 - 1901 - G. Macroni] 1G → Early wireless comm^n - Signal fires, morse code, Radio

HSCSD - High speed circuit switched data

GPRS - General Packet Radio Service

D-AMPS - Digital Advance Mobile phone System

CDMA one - Code division Multiple Access

HSCSD-GPRS - High Speed circuit switched data - General Packet Radio service.

D-AMPS-CDMA

Unit-4 → MT-2000 - Mobile Terminal

IMT-2000

W-CDMA

EDGE

WiMax

OFDM

MIMO

AUC — authenticate each SIM card that attempts to connect to GSM core n/w. once the authentication is successful, the HLR is allowed to manage the SIM services described above.

PSTN — Public Switch telephone n/w

ISDN — Integrated Service Digital n/w

[HLR
VLR] AUC

Unit - 1 [Transmission Fundamentals]

Cellphone Generations — 1G and 2G — 2.5G, 3G, 4G

Transmission Introduction :- 4G Transmission Fundamentals

Time domain concepts

Frequency Domain concepts

Radio Media — Analog Vs. Digital

Channel capacity

Transmission Media — signalling.

Wireless communication:- Transmitting / receiving voice and data using electromagnetic waves in space is called wireless communication.

Types of wireless communication — 1). Mobile 2). Portable 3). Fixed. The need of wireless communication is that it gives freedom from wires and less installation time and cost.

Need of wireless communication

1). Freedom from wires 2). Global coverage

3). Stay connected and Flexibility

There are certain challanges in wireless communication.

a). efficient hardware

b). efficient use of finite radio spectrum

c). Integrated services

d). n/w support for user mobility

e). connecting and coverage.

1G — First Generation Mobile Communication System

Not to

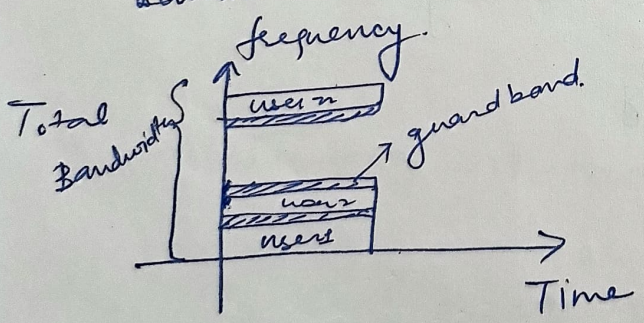
* The first generation mobile network was deployed in Japan by Nippon Telephone and Telegraph Company (NTT) in Tokyo in 1979.

* At the starting of 1980 it become popular in US, Finland UK and Europe.

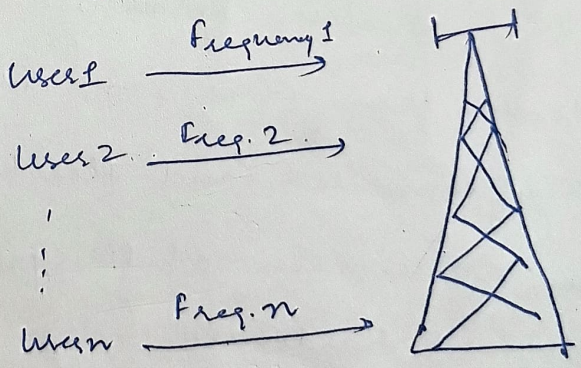
* The system is based on analog signals.

* Analog Modulation — mostly FM (Frequency modulation) is used in 1G system.

* FDMA (Frequency Division Multiple Access).
  - ↳ Multiple Access scheme are used to allow many mobile user to share a finite amount of radio spectrum.
  - ↳ The sharing of spectrum is required to achieve high capacity by simultaneously allocating the bandwidth.



Mobile station



Base station

* Mode of service — Voice only
* Analog signal only

{ inevitable handoff

↓ The complete region is cellular comm

Most Popular 1G system during the 1980's:-

* Advanced Mobile phone system (AMPS)
* Nordic mobile phone system (NMTS)
* Total Access communication system (TACS)

Freq. 800MHZ - 900MHZ
B/w = 10MHZ

Disadvantages of 1G system:-

* Poor voice quality due to interference.
* Poor battery life
* Large sized mobile phones
* less security
* limited number of users and cell coverage.
* Roaming was not possible.

AMPS	GSM
1). 1G	2G
2). Analog	digital
3). only HLR the contain user info	3). HLR as well as SIM info
4). less secure	4). more secure

2G – Second Generation Communication system

2G is introduced in late 1980's. Developed for voice communication. TDMA/FDD and CDMA/FDD multiple access techniques are used. It provides data rate up to 9.6 Kbps. GSM – Global System for Mobile communication

↳ CDMA – system developed by Qualcomm were also introduced and implemented in mid-1990s.

Key Features of 2G system:-

* The digital system
* SMS services are possible
* Roaming is possible
* First Internet at low data rate.

Limitation of Second Generation (2G):-

→ Developed for voice communication.

→ Not suitable for Internet (Packet Switched Services)

2.5G → In order to support higher data rate General Packet Radio Services (GPRS) was introduced and successfully deployed. GPRS was capable of data rate up to 171 Kbps (maximum). Packet Switching

Header	Payload	Trailer

EDGE — Enhanced data rate GSM evolution was also developed to improve data rate for GSM networks. EDGE was capable of ~~supporin~~ supporting data rate up to 473.6 Kbps EGPRS.

GSM/GPRS → GMSK (Gaussian minimum shift key) → 1 bit

EDGE → 8PSK → 3 bits at a time

3G — Third Generation

Third generation mobile communication started with the introduction of UMTS → Universal Mobile Terrestrial / Telecommunication System.

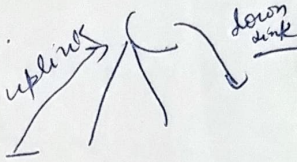
→ UMTS has data rate of 384 Kbps and it ~~sy~~ support video calling.

→ After the introduction of 3G mobile communication system smart phone become popular across the globe.

2G (GSM)	3G (GPRS)
2G	2.5G
Circuit Switching	Packet Switching
No direct connection to internet	Direct connection to internet
Low Data Rate	High Data rate

Key Feature of 3G:-

* Higher data rate * Video calling.
* Enhanced Security * Mobile app support * TV streaming.
* Better Web browsing. In order to enhance data rate in 3G network, two technology improvements are introduced to the network. HSDPA → High speed downlink packet Access and HSUPA → High speed uplink packet Access.



Disadvantages * expensive spectrum license
* costly Infrastructure, equipment

4G → Forth Generation Mobile System

↳ Forth Generation are enhanced Version of 3G network developed by IEEE, offer high data rate and capable of handling more advanced multimedia services. LTE and LTE advanced Wireless technology used in 4G system.

↳ simultaneous transmission of voice and data is possible with in LTE system, which significantly improves data rate.

↳ wireless transmission technology like WiMax are introduced in 4G system to enhance data rate and network performance.

Key Features of 4G System:-

* much higher data rate up to 1Gbps
* Enhanced security and mobility
* voice over LTE network VoLTE.

Drawback of 4G system:-

* Expensive hardware and infrastructure.
* costly spectrum

5G- Fifth Generation communication system:-

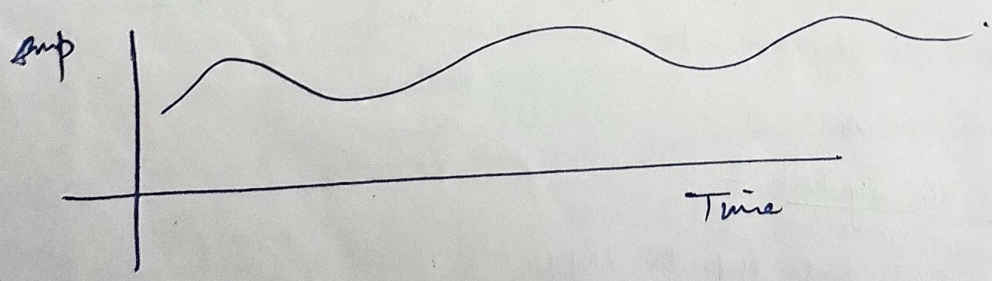
* 5G network is using advanced technologies to deliver ultrafast internet and multimedia for customers.

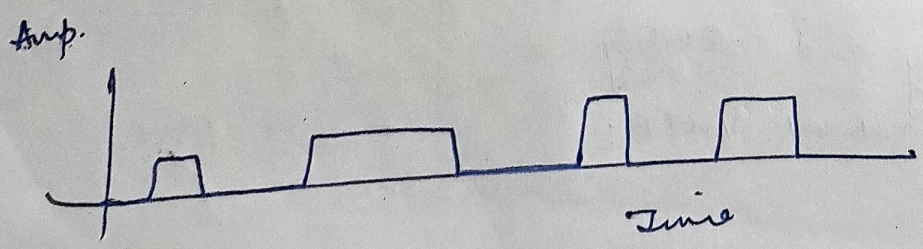
TIME DOMAIN CONCEPTS - FREQUENCY DOMAIN CONCEPTS

Viewed as functions of time, an electromagnetic signal can be either analog or digital.

An analog signal is one in which signal intensity varies in smooth fashion over time. In other words, there are no discontinuities in the signal.

A digital signal is one in which the signal intensity maintains a constant level for some period of time and then changes to another constant level.

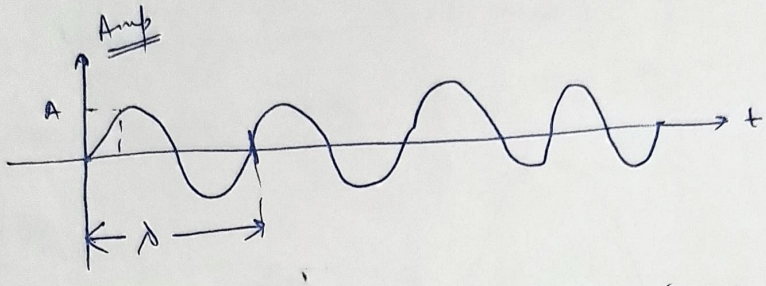




Periodic and A-periodic Signals :-

The signal in which the signal patterns repeat over time is periodic signal.

$$s(t+T) = s(t).$$



otherwise the signal is aperiodic signal.

$$\boxed{s(t) = A\sin(2\pi f t + \phi)}$$ — Representation of signal

freq.

phase

Peak Amp.

f is the frequency (rate) - cycles per second (HZ).

Phase :- Phase is a measure of relative position in time with in a single period of a signal.

The wavelength (λ) of a signal is the distance occupied by a single cycle.

$$\lambda = vT \Rightarrow \frac{\lambda}{T} = v \Rightarrow \lambda f = v$$

↳ c = velocity

↳ 3×10^8 m/s

$$\Rightarrow \lambda f = c$$

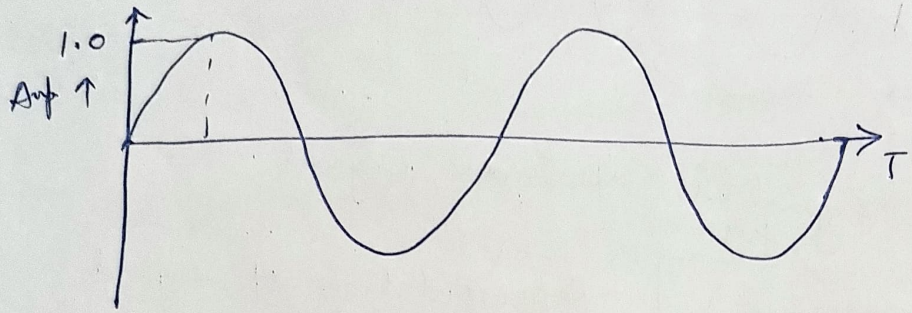
Frequency Domain concepts:-

An electromagnetic signal made up of many frequencies

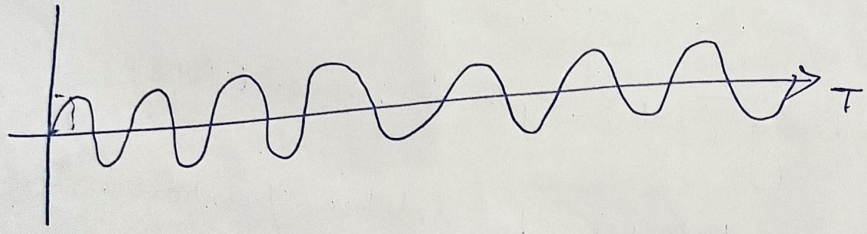
For example the signal:-

$$s(t) = (4/\pi) \times \left(\sin(2\pi f t) + 1/3 \sin(2\pi(3f)t) \right)$$

$3f \rightarrow$ second freq^n



$\sin(2\pi f t)$



$\cancel{1/3 \sin(3f}$

$1/3 \sin(2\pi(3f)t)$

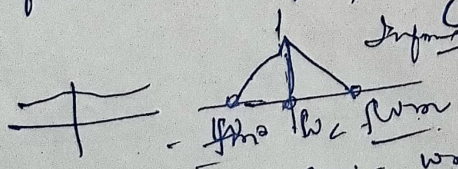
* The second frequency is an integral multiple of first frequency. When all of the ~~signals~~ frequency components of a signal are integer multiples of one frequency, the latter frequency is reffered to as fundamental frequency.

* The period of total signal is equal to the period of fundamental frequency.

Time domain signal $\xrightarrow{\text{Frequency domain}}$ Fourier Xform

Xform: Comm x a message

uses

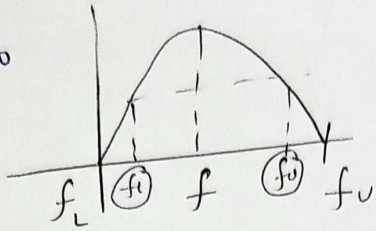


$BW = W_m - (-W_m)$

$= 2W_m$

Bandwidth :-

The difference b/w the upper and lower frequency band is called as bandwidth.



$$\boxed{B.W = f_U - f_L}$$

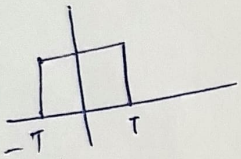
Relation between data rate and bandwidth :-

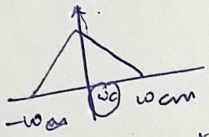
Band Limited Signal

And $B.W = \omega_m - (-\omega_m)$

$$\boxed{B.W = 2\omega_m}$$

Range of frequencies





sampling/quantization

Brief about sampling, quantization.

Signal

1. Analog / Digital
2. Periodic / aperiodic
3. Even/odd signal
4. Real/Imaginary
5. Deterministic / non deterministic signals
6. Energy/Power Signal

$x(t) = x(-t)$ = even

$x(t) = -x(-t)$ = odd

$$E = \int_{-\infty}^{\infty} x^2(t)\,dt$$

→ energy signal if it has finite energy

→ Power signal if it has finite power.

$$P = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x^2(t)\,dt$$

Power of energy signal = 0

energy of power signal = ∞

} Time domain signals are represented w.r.t time and.

they can be visualize on CRO (Cathode Ray Oscilloscope) while frequency domain signal can be visualized by using Spectrum Analyzer.

Analog and Digital Data Transmission:-

Analog → Continuous

Digital → discrete

Data — That convey meaning

Signal — Electric or Electromagnetic representation of data.

Transmission — Communication of data.

Channel Capacity:-

→ A variety of impairment can distort or cherpt a signal.

→ The maximum rate at which data can be transmitted is called the channel capacity.

Data rate (Baud Rate) — This is the rate in bits per second at which signal can be communicated.

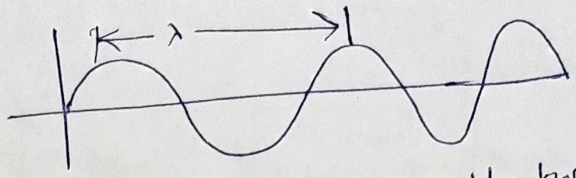
Bandwidth:-

Noise

Error Rate:- This is the rate at which error occurs.

Electromagnetic waves:-

- Electromagnetic waves can travel in space with velocity of light (3×10^8 m/s)
- In EM wave electric field and magnetic field are perpendicular to each other.

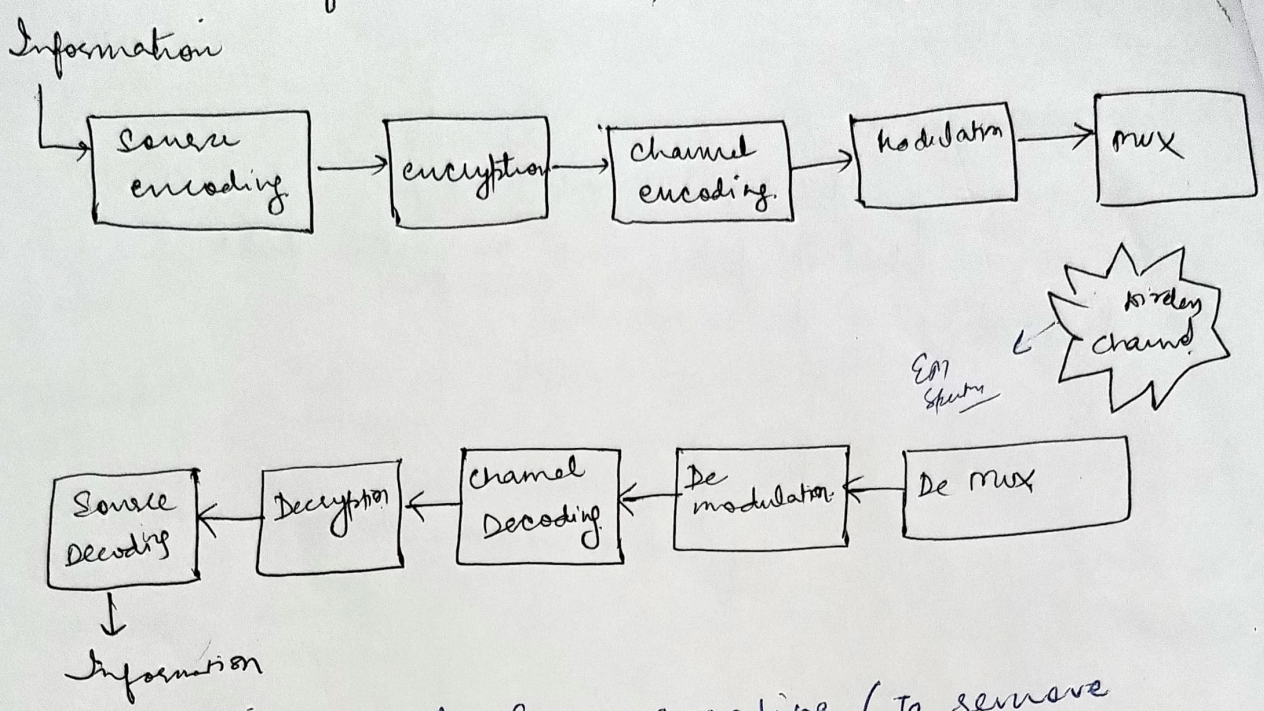


- wavelength λ is defined as distance b/w two crest or two troughs.
- $\lambda = c/f$
- First proposed by Maxwell.
- The higher the frequency the more energy the wave has
- These waves are also called as transverse waves.

Frequencies and Regulations:-

- The International Telecommunication Unit (ITU) located in Geneva is responsible for worldwide coordination of telecommunication facilities.
- ITU-R
  - → Region 1 (Europe, Middle east)
  - → Region 2 (Greenland, North and South America)
  - → Region 3 (Far East, Australia and New Zealand)

Elements of Wireless Communication System



Information — signal. Source encoding (To remove redundant information mixed with the information).

<u>Encryption</u>:- A way to render data unreadable to unauthorized party. It is used to secure wireless n/w with an authentication protocol.

<u>Channel coding</u> is used to encode the message to make it error free. (To increase the reliability of the system
- Parity bit is added

<u>Modulation</u> :- mixing the information signal with carrier is called modulation. Carrier is a high frequency signal

<u>AM</u> <u>FM</u> <u>PM</u>

<u>mux</u> — multiplexer.

EM Spectrum:-

Radio waves

↳ 3 KHZ – 300 GHZ

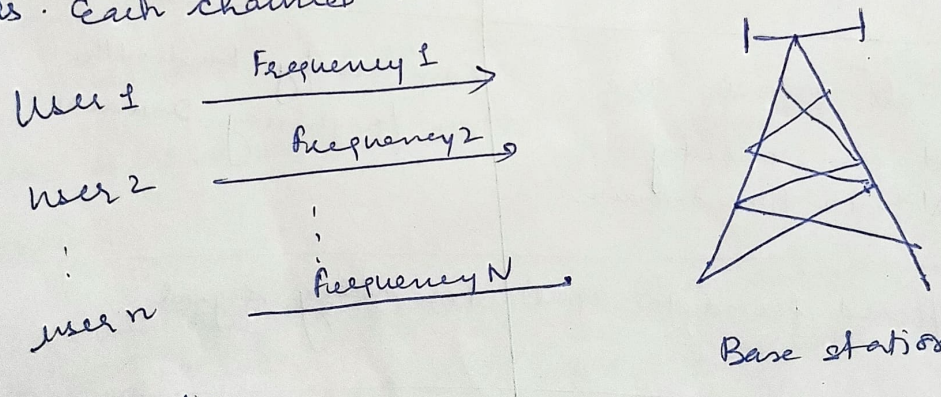
Multiple Access Technique:-

↳ Multiple Access technique allow many mobile user to share a finite amount of radio spectrum.

↳ The sharing of spectrum is required to achieve high capacity by simultaneously allocating the bandwidth.

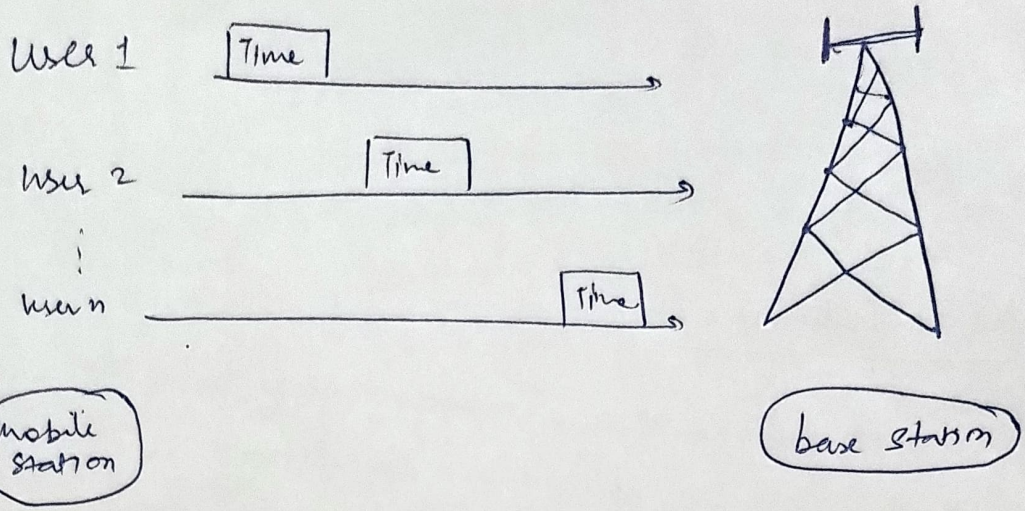
Frequency Division Multiplexing (FDM):-

It describes the schemes to subdivide the frequency dimension into several non overlapping frequency bands. Each channel is alloted its own frequency.



Time Division Multiplexing (TDM):-

It is a more flexible scheme where a channel is given the whole bandwidth for a certain amount of time i.e all user use same frequency but at different points in time.



CDMA

Separation is achieved by the code.

Q →

TDMA	FDMA
The signals which are multiplexed can occupy the bandwidth in time domain	Can occupy bandwidth in frequency domain.
It is preffered for digital signal	For analog signal
Synchronization is req.	Synch. is not required.
circuit not complex	Circuitary is complex
Problem of crosstalk is not there	Crosstalk

4G Transmission Fundamentals

1). 4G known as Forth generation for mobile Communication.

2). High speed data transmission suitable for HD video Calling.

3). 4G system adhere to the capabilities and feature specified by ITU (International Telecommunication Union) in IMT advance including transmission technology

4). 4G provide 100 Mbps speed to the user.

5). 4G streams high definition audio and videos.

LTE — Long Term Evolution — It is a high speed wireless communication used in communication.

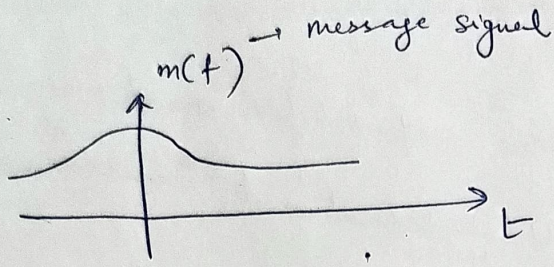
1). LTE data is transmitted with faster speed and lower latency.

2). 4G capabilities of transmitting and receiving signals are based on MIMO (multiple input and multiple output) and OFDM technologies. Due to this 4G offers high bandwidth and data rate.

CTS - Continous Time signal — Discrete time signal.

Sampling :- The process of converting continoustime signal into discrete time signals

Band limited signal.



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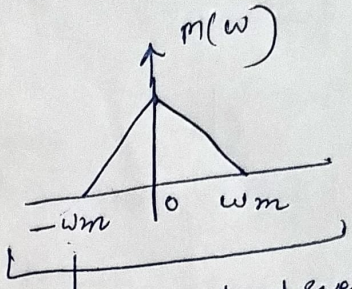
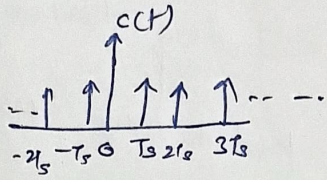


Base band signal

ω_m = maximum freqn. component of m(t).

↓

Sampler



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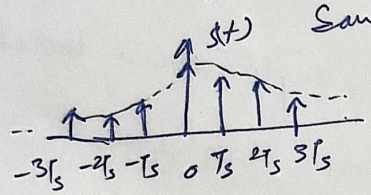


Sampled signal

s(t)

S(ω)

$$\omega_s = \frac{2\pi}{T_s}$$

$$\therefore \omega_s = 2\pi f_s \Rightarrow \omega_s = \frac{2\pi}{T_s}$$

$$s(t) = m(t) \cdot c(t)$$

$$\downarrow F.T$$

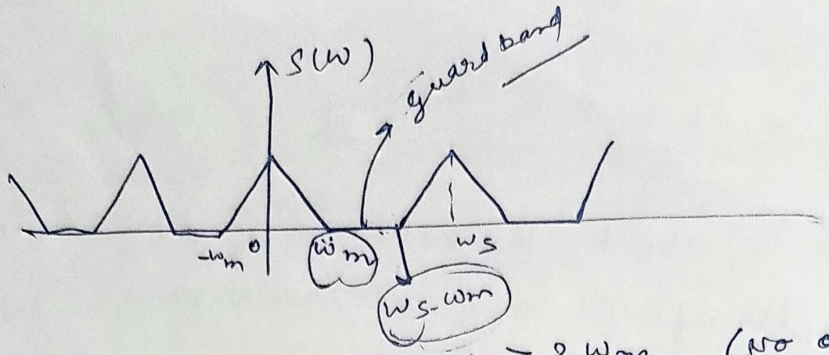
$$S(\omega) = \frac{1}{2\pi}\left[M(\omega) * C(\omega)\right]$$

$$C(\omega) = \omega_s \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_s)$$

$$S(\omega) = \frac{1}{2\pi}\left[M(\omega) * \omega_s \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_s)\right]$$

$$S(\omega) = \frac{\omega_s}{2\pi}\left[M(\omega) * \sum_{n=-\infty}^{\infty} \delta(\omega - n\omega_s)\right]$$

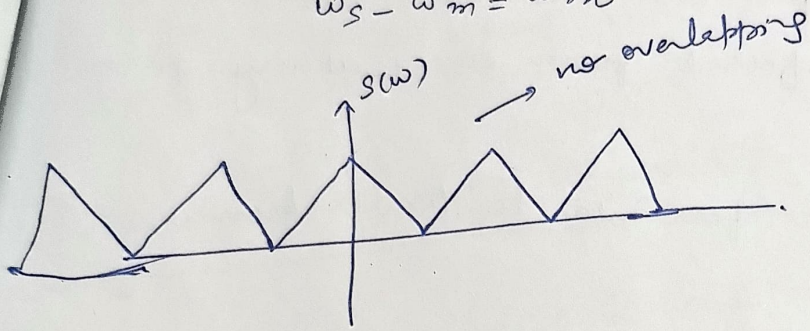
$$= \cancel{\frac{1}{T_s}\left[\sum_{n=-\infty}^{\infty} M(\omega)\right]} = \frac{1}{T_s}\left[\sum_{n=-\infty}^{\infty} M(\omega - n\omega_s)\right]$$



$\omega_s - \omega_m > \omega_m \Rightarrow \underline{\omega_s > 2\omega_m}$ (no overlapping)

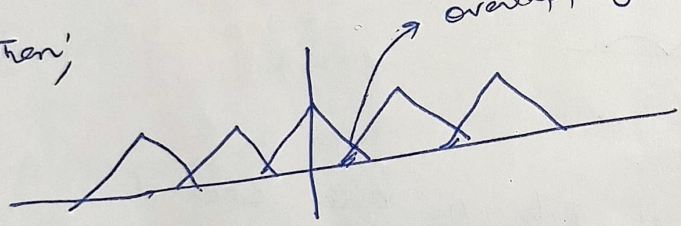
$\boxed{f_s \geq 2 f_m}$ → Nyquist theorem

$\omega_s - \omega_m = \omega_m$



But if $\omega_s - \omega_m < \omega_m$

Then;



<u>Sampling theorem</u>:- A signal can be recovered in it's sample and can be recovered back when sampling frequency is greater or equal to twice of the maximum freq. present in the signal.

$\boxed{\omega_s \geq 2\omega_m}$

↓

Nyquist theorem

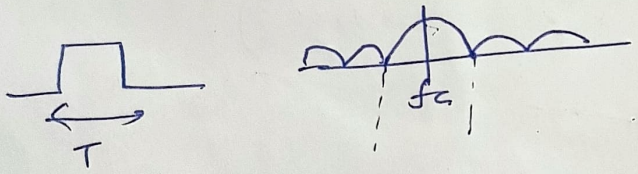
Bandwidth, Throughput and Latency

Bandwidth:- It is about the volume of the data that can be transferred over a network. The standard measurement for data transfer speed is Mbps. (10^6 bits per second)

Throughput:- Throughput indicates how much data was actually transferred from source at any given time.

Latency:- Time taken for data to travel from source to destination.

How are Data rate and bandwidth related



Data Rate → The no. of bits in one second is called data rate (mbps)

(**Band rate** — no. of signal changes per second is called band rate).

Analog and Digital Data Transmission:-

* The term analog and digital refers to continuous and discrete respectively.

* Data, signals, ~~Information~~ Transmission
  - Data → Information
  - Signals → Electromagnetic representation of data
  - Transmission → Communication of data by propagation

Analog and Digital Signalling:-

Analog signalling:- It is continuously varying EM wave

Channel Capacity:-

* A variety of impairment can distort or corrupt a signal
* The maximum rate at which data can be transmitted over given communication path or channel under given conditions refer to as channel capacity.

* Data rate:- This is data rate bits per second at which data can be communicated.

* Bandwidth:- It is the volume of data that can be transmitted over given comm. medium.

Cycles per second (bps)

Error Rate:- The rate at which error occur is called error rate.

Shannon Capacity Theorem:-

$$C = B \log_2 [1 + S/N]$$

C = channel capacity B = Bandwidth

S = Signal N = Noise power

Signal + Noise = Received. (At the receiver side)

It's mean square $= \sqrt{S+N}$

Noise power N then $\underbrace{MSV}_{\text{mean square value}}$ $= \sqrt{N}$

No of Levels separated without error

$$m = \frac{\sqrt{N+S}}{\sqrt{N}} = \sqrt{1 + \frac{S}{N}}$$

So Information

$$I = \log_2 m$$

$$= \log_2 \sqrt{1 + S/N}$$

$$= \frac{1}{2} \log_2 (1 + S/N)$$

If channel transmit K pulses per second then channel capacity $C = IK = \frac{K}{2} \log_2 (1 + S/N)$

Nyquist bandwidth $K = 2B$

$$\boxed{C = \frac{2B}{2} \log_2 (1 + S/N) = B \log_2 (1 + S/N)}$$

If bandwidth increases the capacity C will also increase so we cannot have infinite channel capacity.

For a typical telephone line with a signal to noise 30dB & audio bandwidth is 3KHZ. what is max. ~~be~~ data rate.

$SNR = 30dB$

$B = \cancel{30} \; 3KHZ$

dB	
10	10^1
20	10^2
30dB	$= 10^3$
40	10^4

$SNR = 10^3$

$$C = B \log_2 (1 + S/N)$$

$$= 3KHZ \log_2 (1 + 1000)$$

$$= 3 \times 10^3 \log_2 (1001)$$

$$\boxed{C = 3 \times 10^3 \frac{\log (1001)}{\log 2} = 3 \times 10^6}$$

$C = 3 \times 10^6$ bps $= 3$ Mbps.

$SNR = 20dB$ and video b/w $= 10MHZ$

$$C = 10 \times 10^6 \log_2 (1 + 10^2) = 10 \times 10^6 \log_2 (101)$$

$$= 10^7 \frac{\log (101)}{\log 2}$$

Q. Find out the capacity of the signal

Suppose that ~~channel capacity~~ spectrum of

Channel b/w 3 MHz and 4 MHz and SNR is 24dB

$B = 4 - 3 = 1$ MHz

$SNR = 24$ dB

$\downarrow$ SNR

$SNR = 24\,dB = 10 \log_{10} (S_1/S_2)$

$\Rightarrow 2.4 = \log_{10} SNR$

$SNR = \text{Antilog}(2.4)$

$\boxed{SNR = 251}$

$C = B \log_2 (1 + SNR)$

$C = 1 \times 10^6 \log_2 (252)$

$= 1 \times 10^6 \log_{10} (252) / \log 2$

$= ?$

Amps	GSM
1. 1G	1. 2G
2. Analog Technology	2. Digital Technology.
3. Poor performance for data Xfer.	3. Better ~~Xfer~~ performance for data xfer.
4. Only HLR contains the user information	4. Both HLR and SIM holds the users information.
5. Less secure than GSM.	5. more secure than AMPS.

Header	Payload	Trailer

GRRS Packet

Voice + data

Difference between GSM and GPRS:

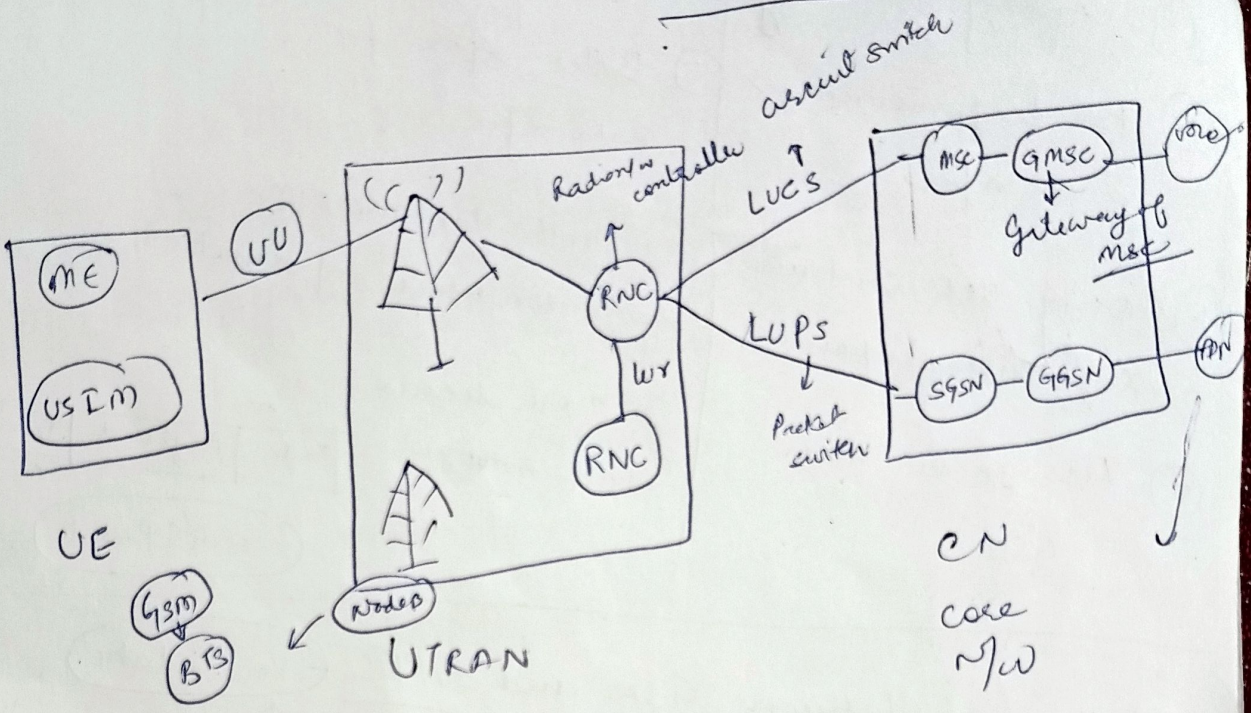
GPRS (General Packet Radio Service)

GSM	GPRS
1) 2G	1. 2.5G
2) Circuit Switching	2. Packet Switching
3). No direct connection to Internet.	3). Allow direct connection to Internet.
4). Data rate is low (~ 10 Kbps)	4). High Data rate (56 - 64 Kbps)

UMTS (Universal Mobile Telecommunication systems)

↓

3G Technology
- Circuit Switch — call
- Packet Switch — data



Support node

UMTS Terrestrial Radio Access n/w

PDN
↓
Packet data

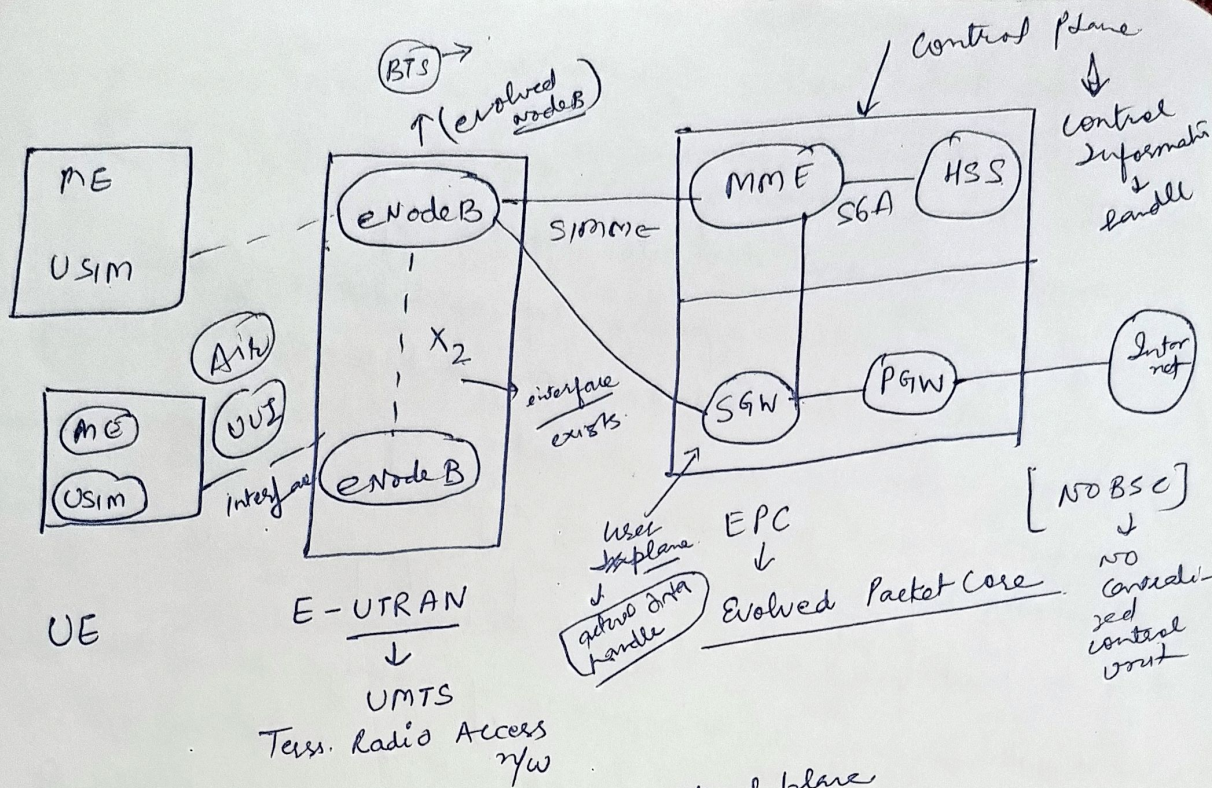
SGSN → Serving GPRS Support Node

GGSN → Gate GPRS Support Node.

4G Mobile Communication — LTE
↓
Long Term Evolution

VoLTE → voice over LTE

↓



Control plane — user information — control plane and user plane.

MME — ~~Mobility mgmt System~~ [

HSS — Home subscriber System

SGW — SGSN

Serving gateway (SGSN) same

(PGW → Packet data gateway n/w)

Wimax → (Worldwide Interoperability for Microwave Access)

↓

wireless Broadband instead of wi-Fi

Analog and digital signalling :-

1). The term analog and digital corresponds to continuous and discrete respectively.

* Signal is electromagnetic representation of data and data is the information that conveys something.
* Transmission is communication of data by propagation and processing of signals
* An analog signal is a continuously varying signals that may be propagated over different media.
* A digital signal is a sequence of voltage pulses that may be transmitted over a copper wire medium.
* A constant positive voltage level may represent binary 0 and constant -ve voltage level may represent binary 1.
* The principal advantage of digital signals is that they are less susceptible to noise and are cheaper.
* But the digital signals suffers to more attenuation.
* Digital transmission is concerned with the contents of the signals. A digital signal can be propagated thro' a limited distance before attenuation endangers the integrality of data. To achieve greater distance repeaters are used. Repeater receive the digital signal, recover the pattern of 1's and 0's and then retransmit it again. Thus the problem of attenuation overcomes using the
* Analog transmission is concerned with the analog transmission of data. ~~To~~ ~~If~~ In either case analog signals suffers from attenuation that limit the length of transmission line.

To achieve longer distance the analog signals includes amplifiers that boost the energy in the signal.

Transmission Media :-

Transmission media is the physical path b/w transmitter and receiver.

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Transmission Media

- Guided
  - 1). With guided media, the waves are guided along a solid medium such as copper or optical fibre cable.
    (Wired Transmission)
  - 2). For guided media, the medium itself is more important in determining the limitations of transmission.
- Unguided
  - The atmosphere and outer space are example of unguided media, which means of transmitting electromagnetic signals (wireless Transmission)
  - 2). For unguided media, the bandwidth of signal produced by transmitting antenna is more important than the medium.
    - * One key property of signals xmitted by antenna is the directionality.
    - * Lower frequency signals are omnidirectional (Propagate in all directions)
    - For unguided transmn and reception is by antennas.

* For high frequencies it is possible to focus the signal into directional beam.

Terrestrial Microwave

→ The most common type of microwave antenna is the parabolic 'dish'.

→ The typical size of parabolic dish is 3mm.

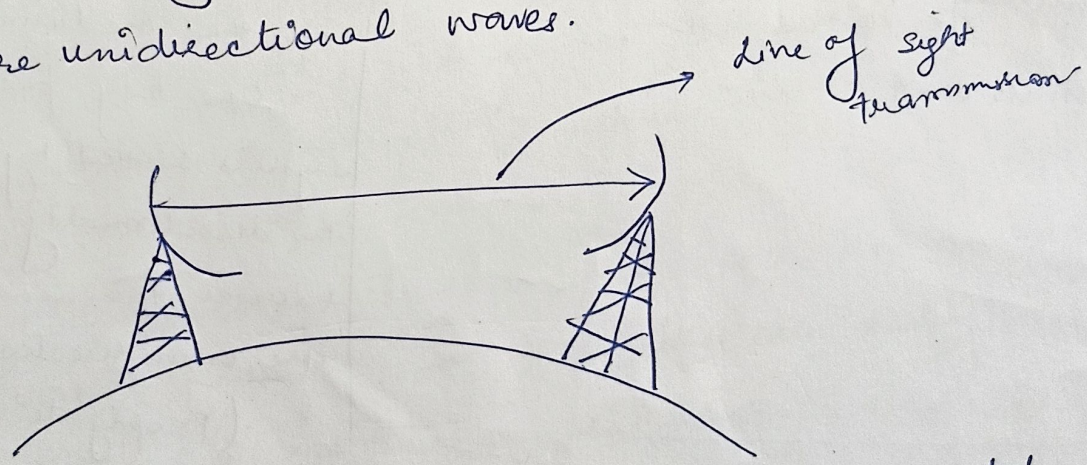
→ The ~~antenna~~ antenna is fixed rigidly and focus a narrow beam to achieve line of sight transmission for receiving antenna.

→ Microwave antennas are located at substantial height above the ground level to extend the range b/w the antennas.

→ It is a technology which transmit the focused beam of radio signals from one ground base microwave antenna to another antenna.

→ Microwaves are generally electromagnetic wave which has the frequency range from 1GHZ – 1000GHZ.

→ These are unidirectional waves.



Line of sight transmission means the antenna mounted on the towers are at direct sight of each other.

- Terrestrial microwave supports bandwidth up to 1 to 10 mbps.

- These waves are inexpensive and for short distance.

Applications of Terrestrial Microwave:-

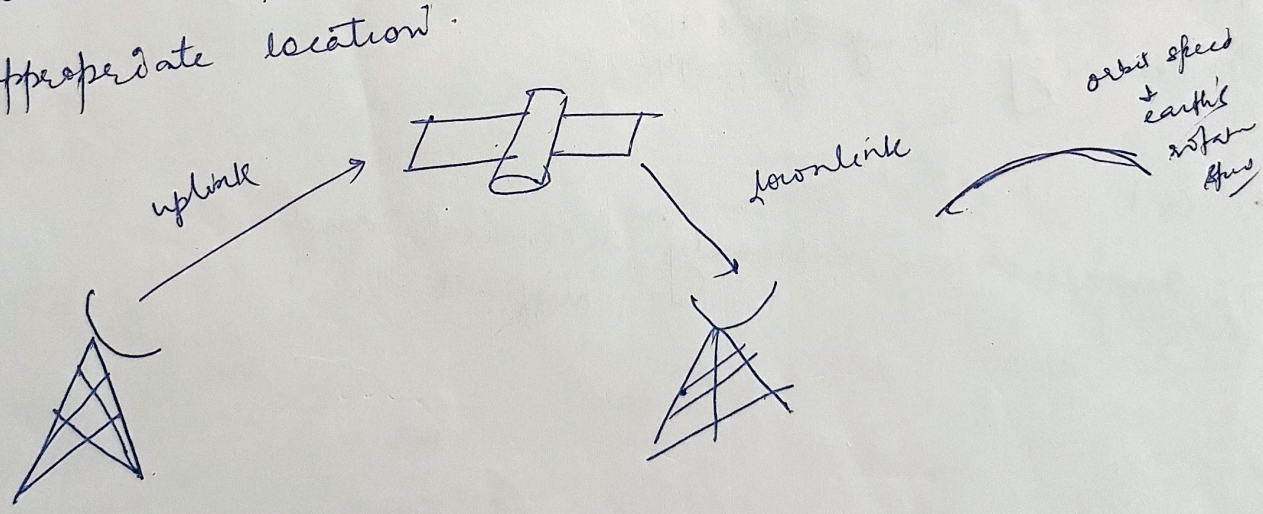
a). used for long distance telephone.

b). Parabolic dish transmitter mounted high.

c). used for voice and TV transmission.

Sattelite Microwave

It is used for broadcasting and receiving signals. These signals are transmitted to space where these sattelites are positioned and it retransmit the signal to appropriate location.



Guided Transmission Media.

Wires
- → Twisted Pair cables
- → coaxial cables
- → Optical fibre cables

Microwaves, IR, Radio-waves.

* A communication satellite is basically a microwave relay station placed precisely at 36,000 km above the equator where it's orbit speed exactly matches the earth's rotation speed.

* Since the satellite is positioned in geo-synchronous orbit then it appears stationary relative to earth

* The transponder used in satellite communication amplify the weak signals and send back it to the earth.

The satellites microwaves have the following characteristics

1). Frequency Range - a). 4-6 GHZ
b). 11-14 GHZ

2). Cost - high.

3). Installation - extremely technical and difficult.