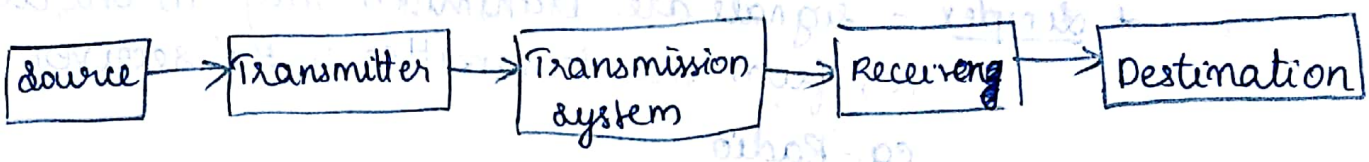
4/8/17
Friday

MODULE - I

Data Communication Model



Source - Generates the data to be transmitted
eg:- telephone, personal computer

Transmitter - The transmitter transforms and encodes information in electromagnetic waves or pulses which can be transmitted across a transmission system. eg:- modem.

Transmission System - A single line or complex network connecting source and destination.

Receiver :- Accepts the electromagnetic signal from the transmission system and converts into a form which can be handled by the destination.
eg:-

Destination - Takes the incoming data from the receiver.

* The communication system exchange data between two parties
* Transmission medium could be a
  → guided medium :. eg:- twisted wire, coaxial cable or optical fibre

→ unguided medium (wireless) - through electromagnetic waves through vaccum, air or water.

⇒ the communication could be

* Simplex - signals are transmitted only in one direction i.e, from the transmitter to the receiver.
  eg:- Radio

* Half Duplex - Both stations can transmit and receive but only one at a time.
  eg:- walkie talkie

* Full Duplex :- Both stations can transmit and receive simultaneously
  eg:- telephone

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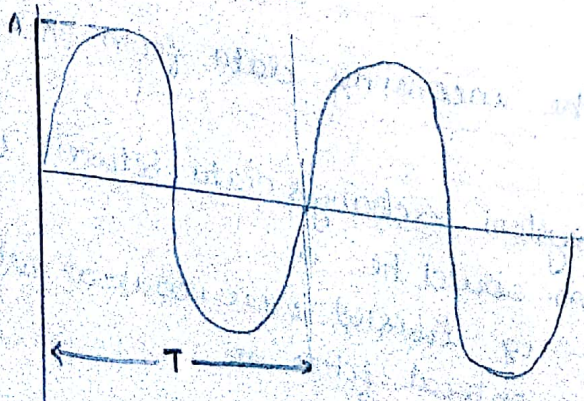
Aperiodic Analog signal

- An analog signal is one in which the signal intensity varies in a smooth way in time or has no breaks or discontinuation in the signal
- $s(t)$ is continous if $\lim_{t \to a} s(t) = a$

Analog Time Domain



⇒ The simplest form of a signal is a periodic signal, in which the signal pattern repeats over time.

- mathematically, it can be stated as: $s(t)$ is periodic if $s(t+T) = s(t)$ over $-\infty < t < \infty$ $\quad T = \frac{1}{f}$

eg:- A sine wave

* A sine wave is represented by three parameters
  - A (peak amplitude)
  - f (frequency)
  - p (phase)

i.e., $s(t) = A(\sin(2\pi f t + \phi))$

* A or the peak amplitude is the maximum value of the signal. (strength of the signal over time)
* f - frequency - the rate at which the signal repeats
* Amount of time for one wave - T (period)
* ϕ - phase - measure of a relative position in time within a single period of a signal
* λ - wavelength - the distance occupied by the cycle. -distance between any two points of corresponding phase of two consecutive cycles.

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

Frequency Domain

→ There will be set of frequencies which are integral multiples of fundamental frequencies.

→ The period of total signal is always equal to the period of a fundamental frequency.

Analog & Digital signal

* Analog signals are contenous in nature and most of the data collected by the sensors (like Audio signal, video, etc) are analog in nature.
* Digital signals are discrete in nature.
* signals are electric or electronic representation of data.
* Physical propagation of signal through a suitable medium or substance is called signaling and the communication of data by propagation and processing of signal is called transmission.
* In any communication system, point to point communication of signals are electromagnetic in nature. It could be through a guided or wired medium eg:- coaxial, twisted wire, fibre optics.
* If $s(t+T) \neq s(t)$ it is called aperiodic
* Digital signals are cheaper than analog signals. They are less susceptible to interference but digital signals suffes more from attenuation.

Analog Transmission

- is a means of transmitting analog signals without regard to their content (it may contain digital or analog data).
- It needs amplifiers to boost the signal for long run communication.
- Noise also gets amplified and cascading makes it more distorted but analog communication can tolerate more distortion and ~~the~~ at the receiver the data will be still intelligible.

Digital Transmission

* digital transmission is concerned with the content of the signal but it can be transmitted only over a ~~can~~ limited distance before attenuation makes it less intelligible (un-intelligible)
* Noise and other impairments endanger the integrity of data
* To achieve greater distance, repeaters have to be used.

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⇒ The repeaters recover the digital data from the analog signal and generates a new clean analog signal. The noise or distortion does not get cumulative.

⇒ The VLSI technology have made the digital signalling much cheaper.

⇒ Data integrity is better
⇒ Better capacity utilisation
⇒ Better encryption technologies available makes it more secure. Similar signals can integrated and makes overall communication cheaper.

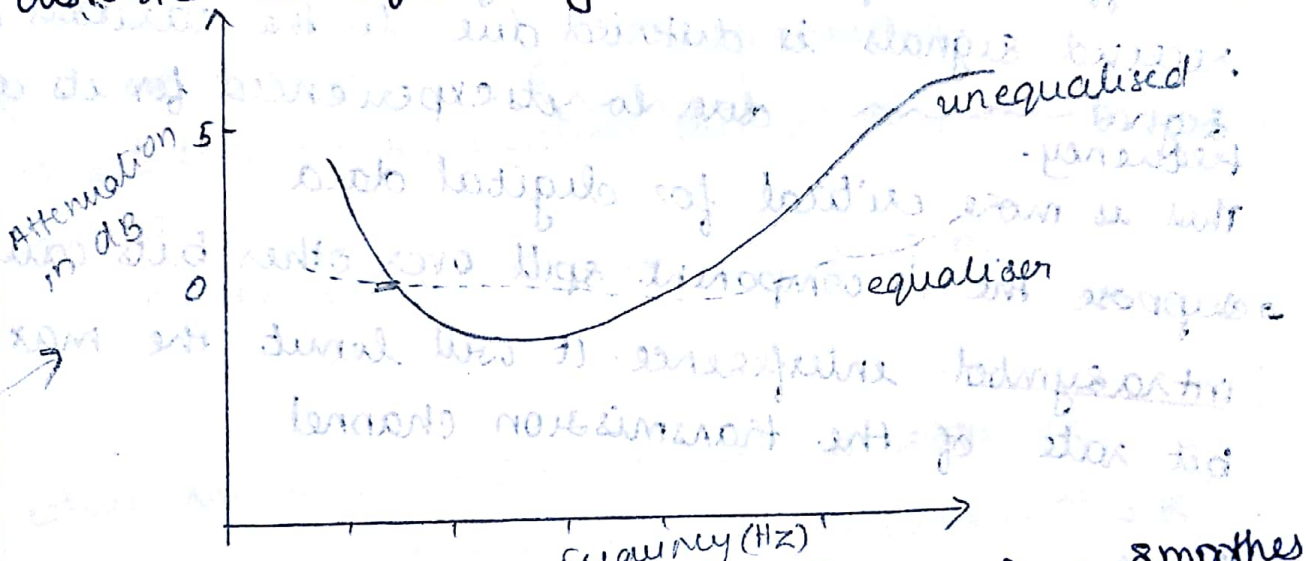
Transmission Impairments

I Attenuation

* Strength of signal falls off with distance for any transmission medium.
* For guided medium, exponential increase in attenuation is experienced. Hence a constant number of dBs per unit distance is introduced.
* For unguided medium, it is a more complex function of ~~attenuation~~ atmospheric condition and parameters
* the main concerns of attenuation are:
  1) The received signal should have sufficient strength to be detected as signal.
  2) It should have sufficient level of power as compared to the noise to be received without error.
  3) Attenuation very often is an increasing function of frequency. Hence, for higher frequency attenuation will be more.
  4) Amplifiers and repeaters are used to alenate the strength fading and distinction of signal from the noise to a good distance extend.

⇒ If transmitter power is high, noise also gets high. so raising the transmitter power to boost the signal has its limitation

⇒ Attenuation varies as a function of frequency especially for an analog signal. so received signal gets distorted. so equalising techniques are used.



⇒ Especially for voice grade telephones which smoothes out the attenuation effects.

⇒ Another way is to amplify higher frequencies more as compared to lower frequencies.

⇒ The upper end of voice band are attenuated more than the lower frequencies. this suddenly causes this suddenly causes distortion of peak signal. The flatening of curve improves the quality of sound. For digital signal, attenuation causes less problem.

II ⇒ The delay distortion occurs, because velocity of signal is varied with frequency

For a band limited signal, velocity tends to be highest near the centre and falls off near the edges

[Delay distortion is relevant only in guided media]

Hence varies frequency components arrive at the receiver at different time resulting in phase difference

The effect is referred as delay distortion since received signals is distorted due to the various delays ~~signal~~ due to its experienced for its component frequency.

This is more critical for digital data.

→ suppose the i's component spill over other bits causing intrasymbol interference. It will limit the max bit rate of the transmission channel

III Noise

In any data transmissions, the signal consists of

* the transmitter signal
* distortion of transmitted signal
* additional unwanted signal inserted between transmission and reception

→ All undesired signals are referred as noise.

→ The types of noises are:

- Thermal noise
- Intermodulation noise
- Cross Talk
- Impulsive noise

Thermal Noise

- occurs due to the agitation of electrons. It is present in all transmission mediums and is a function of temp. Thermal noise is uniformly distributed across all bandwidths used in communication system. and hence is refered as white noise.
This cannot be avoided hence it gives an upperbound for communication system performance.
→ For satellite communication this is particularly relevant.
→ The amount of thermal noise is given by

$$N_0 = KT$$

where N_0 is noise power density in watts/Hz

$K \rightarrow$ boltzmann constant, $K = 1.38 \times 10^{-23}\ J\,K^{-1}$

$T \rightarrow$ temperature in kelvin

Intermodulation Noise

⇒ When different frequencies share the same transmission medium, it results in intermodulation noise.
⇒ It produces a frequency which is the sum or difference of two orginal signals or multiples of those frequencies.
⇒ This is due to the non-linearity of the transmitter, receiver or transmission medium intervention.
→ Excessive non-linearity is caused by component malfunction or overloading of excessive signal strength

Crosstalk

⇒ occurs due to electrical coupling between nearby twisted pair or rarely in case of co-axiall cables carrying multiple signals.

⇒ It can also occur when microwave antennas pick up unwanted signals even if antennas are highly directional. this is caused by spreading of signals during propagation

⇒ crosstalk is of same order of magnitude as the thermal noise.

Impulsive Noise

⇒ impulsive noise is non-continous. It consists of irregular pulses or noise spikes. It is highly unpredictable and is of very short duration, generally having relatively high amplitudes.

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⇒ The source of an impulsive noise could be electromagnetic disturbance such as lightening or faults and flaws in communication system. It is generally a minor annoyance for analog data such as a short clicks and crackles but no loss of intelligibility for data. But this is a primary source of data for digital data communication.

Channel capacity

- The maximum range at which data can be communicated over a communication path under given conditions.

- Data Rate

Can be expressed as bits per second at which data can be communication

Bandwidth

constrained by the transmitted signal, transmitter and the transmission medium.
expressed as cycles/second or Hertz.

Nyquist bandwidth

In a noiseless channel, the only limitation of data rate is by the bandwidth of the signal.
Nyquist states that the rate of data is 2P, signals with frequences not > B. is sufficient for the signal rate. the converse is also true, given the bandwidth B, the highest data rate carried by the channel is 2B

$$\text{channel capacity} = 2B \log_2 L$$

Shanon's Capacity theorem

In a noisy channel, one has to consider the relationship between data rate, noise and error rate.

At a given noise level, higher the data rate, higher will be the error rate.

Signal to noise ratio (SNR) is the ratio of the power of signal to the power of noise, measured as

$$SNR = 10 \log_{10} \frac{\text{signal power}}{\text{noise power}}.$$

This gives the possibility of making a ~~ext~~ code ~~for~~ at this rate in a noisy channel without error

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

Transmission Medium

-To transmit any signal from the transmitter to the receiver, a transmission medium is required.

Any transmission medium will have transmission impairements such as noise, cross talk, intermodulation, intermodulation frequencies and attenuation.

⇒ They are two types of transmission mediums
- → Guided
- → Unguided

Be it any medium, the factors we are interested in are:
- data rate
- bandwidth
- error rate etc.

Usually if bandwith is greater we will have highes data rate.

Transmission impairments → highest for twisted wire
→ lowest for optical cables
→ co-axial cables stand in between

Twisted Pair Cable

they are seperately insulated & twisted together to to lessen the interference

they are bundled into cables they are usually installed in home wiring

Transmission characteristics

twisted cable can be used for both analog & digital signals.

Analog signal need amplifiers every 5-6 kms and digital signal needs amplifier every 2-3 km

→ Twisted wire cable has limitations in distance, bandwidth data rate

→ Used in home connection.

→ more susceptible to interference and noise due to electrical coupling

→ Application: home connection from DPs to end offices in subscriber loops.

→ Usually twisted pair cable is less expensive than other wire

→ Two types.
- Unshielded twisted pair
- shield twisted pair (has less of interference problem

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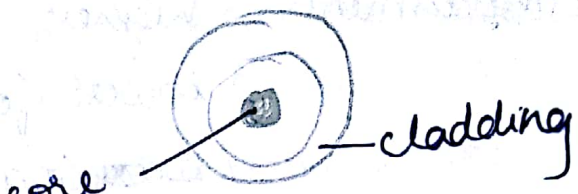
Coaxial Cables



The outer conductor is a braided sheath. The inner conductor is made of solid metal. They are seperated by an insulation material and its all covered by a padding. The material and the thickness of the padding depends on which the coaxial

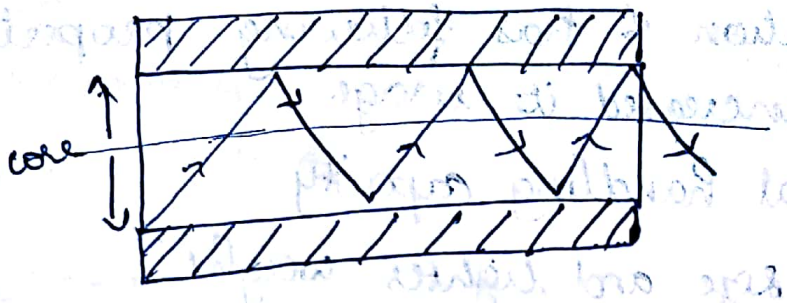
* coaxial cables can be used to operate over a wide range of frequencies.
* The typical applications are:
  - ~~telephone dis~~ television distribution
  - long distance telephone transmission
  - short run computer systems link
  - LAN
* transmission characteristics

are generally in between twisted wire cables and fibre optic cables. For long haul analog transmission, amplifiers are needed every few kilometers. the spacing gets closer as frequencies gets higher.

The highest bandwidth usually used for analog transmission is 500 MHz.

- The principle constraints on performance are attenuation, thermal noise & intermodulation noise.

Optical Fibre



Physical discription

An optical fibre is a thin flexible medium capable of guiding an optical ray which has 2-125 μm diameter. various types of glass, plastics and silica.

An optical fibre cable has a cylindrical shape and consists of 3 concentric sections- A core, cladding & a jacket

core- innermost section & consists of 1 or more very thin strands or fibres made of glass or plastic and has a diameter in the range of ~~100μm~~ 8-100 μm.

Each fibre is surrounded by its own cladding which again is made of glass or plastic but has of optical properties different from that of core. so that the light would always be confined within it by the property of total internal reflection.

The outermost layer is called a jacket which is composed of plastic or other materials to protect against moisture, abrasion, crushing & other environmental dangers.

⇒ Fibre optics can be used for long distance communication military operation & has following properties which has increased its usage

* greater signal handling capacity
* its smaller size and lighter weight
* comparitively low attenuation
* electromagnetic isolation
* Greater repeater spacing

Typical application

Long haul trunks
metropolitan trunks
rural exchange trunks
subscriber loops
LAN

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Wireless Transmission

⇒ 1GHz - 14GHz range is used as microwave frequencies for wireless transmission.

⇒ Antennas are must for wireless transmission

→ the antenna ~~height~~ is size, shape, height and so also is the antenna gain which gives a parameter for the efficiency of antenna.

→ microwave frequencies are suitable for point to point communication for terrestial transmission

and 30 MHz - 1 GHz are suitable for omnidirectional applications. This range is known as radio range.
- Effective area of the antenna is always relative to its physical size & shape.

Terrestial microware

Dish antennas, usually parabolic antennas are used for this purpose with a typical size of 3m in diameter. They are fixed rigidly at considerable height for line of sight transmission for receiving antennas.

Long distance transmission is achieved by a series of relay towers if it is out of distance for point to point transmission

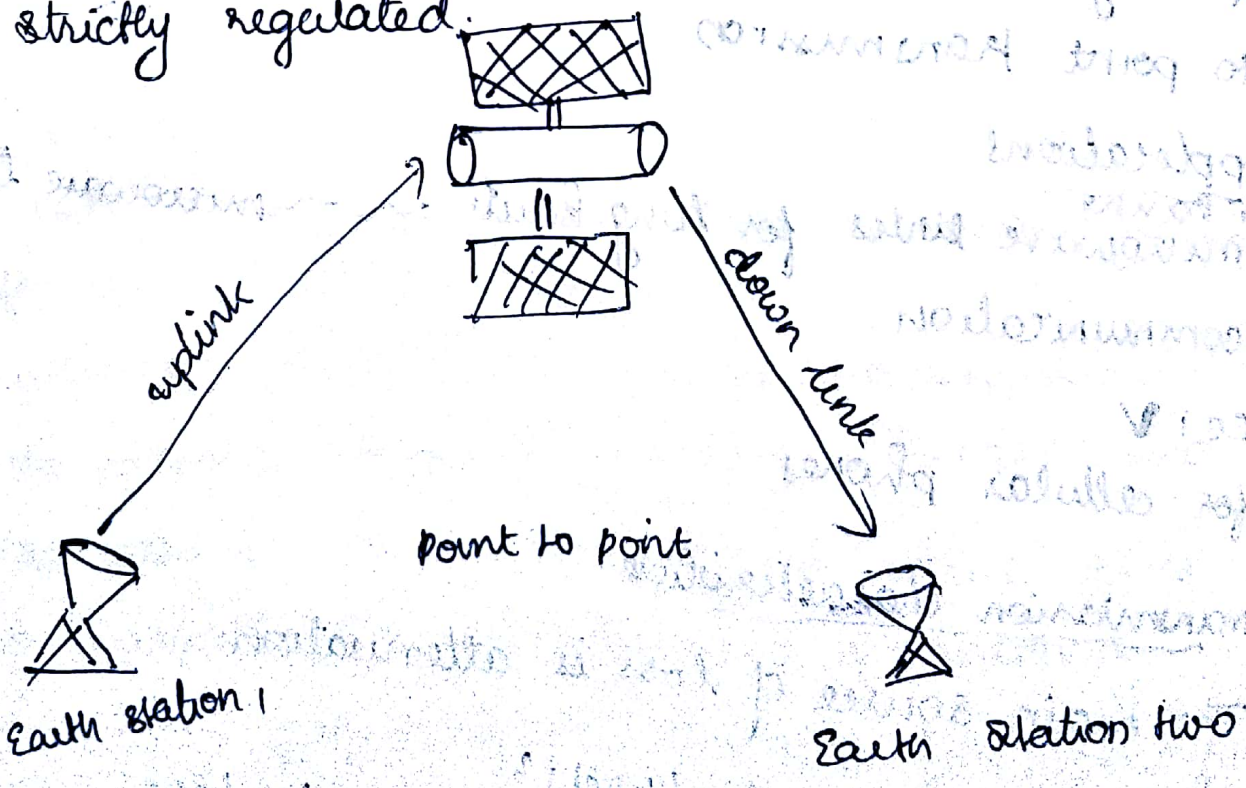
Applications
- microware links for long haul ~~microware telephon~~ communication
- CCTV
- for cellular phones

transmission characteristics
- The main source of loss is attenuation

where $L = 10 \log \left(\frac{4\pi d}{\lambda}\right)^2$

L - loss
d - distance of antenna
λ - wavelength

- Usually 1-4 GHz are used for this purpose.
- for long haul communi 4-6 GHz are used and 12 GHz are typical for cable TV antenna.
- For very short point to point commi 22 GHz is used
- It is to be noted that for higher frequencies antennas are cheaper and smaller repeaters are used with 10-100 km
- The attenuation of radiation increases with rainfall. ~~Not~~ 10 GHz frequencies, which is more noticable.
- with growing popularity of microwaves, interference also is a problem. Hence frequency bands are strictly regulated.



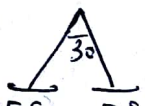
Satellite Microwave

In this the communicatn satellite act as microwave relay station. It can link two transmitter-receiver as in the point to point communication.

A single satellite can operate on a number of frequency bands called transponders channel. An uplink (earth station to satellite) with a diff. frequency of atleast 2 GHz is used with a downlink (from satellite to earth station) is used for this purpose.

Either 4-6 GHz or 12-14 GHz are typical for this purpose.

An earth angle or an angle spacing of 4° is required for 12-14 GHz and 3° for 4-6 GHz.



The satellite should be geo synchronous for communicatn purpose using microwave links

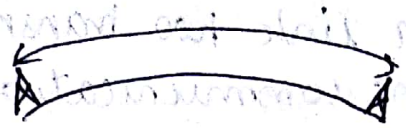
Applicatn

- For TV distribution
- for long distance telephone communicatn
- For private business networks.

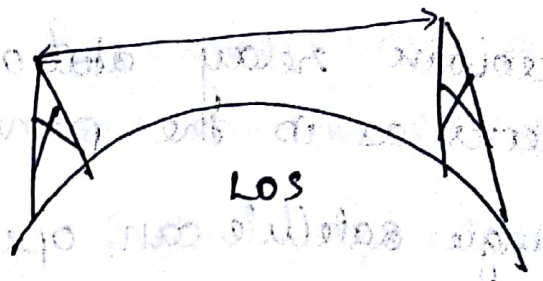
⇒ Some properties of the satellite communtn are

* for long haul communication, a delay is felt in vocal conversation it also introduces problems in areas of error control and flow control

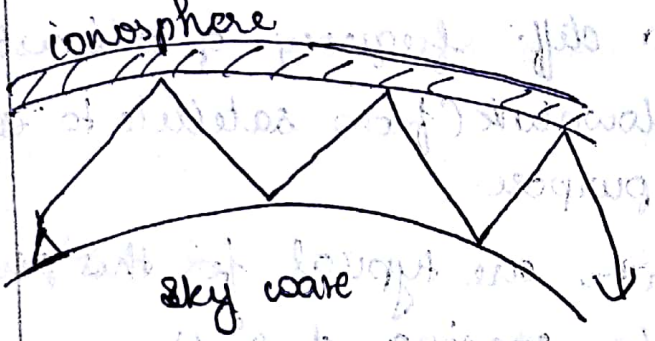
Wireless propagation



Ground wave



LOS



1. Ground wave propagation

Frequencies of 2 MHz is used for this. Groundwave propagation follows contour of the earth and can propagate considerable distances well over the visual horizon - this is beeg of the electromagnetic wave tendency to follow the curvature as a result of magnetic attraction and slowing the wave front near this is typically used for A.M radio applications for medium band waves.

Sky-wave propagation

- This is used for hamradio radio, c v radio and international network like BBC, voice of America.
- In the sky wave prop. the signal from ... is reflected from the ionosphere back to earth. do after multiple reflections the sky-wave signal can travel a number
- This can be quicker 1000's of km for the transmitter

LOC propagation

- only freq. above 30 MHz are used for this.
- main problems faced - refraction ~~the optical~~
- the optical line of sight can be given by

$$d = 357\sqrt{h}$$

d - distance travelled by electromagnetic wave
h - tower height

- ~~Adjustment~~ Adjustment factor called k is used to account for refraction.

- If two antennas are used for transmitter and receiver $3.57(\sqrt{kh_1} + \sqrt{kh_2})$ will be the max distance achieved where h_1 and h_2 are heights of transmitting and receiving antenna $k = 4/3$