Wireless Transmission contd.

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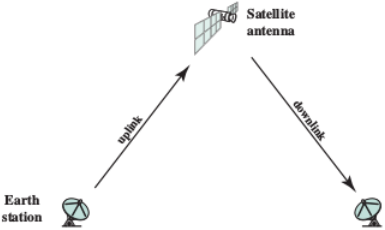
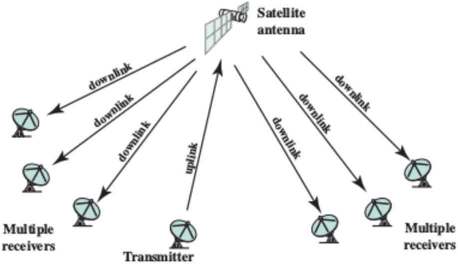
Satellite microwave

- A communication satellite is, in effect, a microwave relay station
- Used to link two or more ground-based microwave transmitter/receivers, known as earth stations, or ground stations.
- The satellite receives transmissions on one frequency band (uplink), amplifies or repeats the signal, and transmits it on another frequency (downlink).
- A single orbiting satellite will operate on a number of frequency bands, called transponder channels, or simply transponders

Satellite Communication Configurations



(a) Point-to-point link



(b) Broadcast link

Satellite transmission

- A satellite must remain stationary with respect to its position over the Earth
- Otherwise it would not be within line of sight of its base stations on earth
- To remain stationary, the satellite must have a period of rotation equal to the Earths period of rotation
- This match occurs at a height of 35,863 km at the equator
- Spacing: 3 degrees angular displacement with respect to earth in the 4/6 GHz band to avoid interference

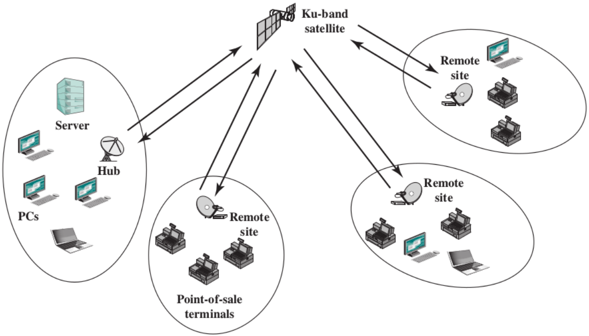
Satellite transmission

- Television distribution
- Long-distance telephone transmission
- Private business networks
- Global positioning

Television distribution

- Programs are transmitted to the satellite and then broadcast down to a number of stations, which then distribute the programs to individual viewers
- Cable television systems receive an ever-increasing proportion of their programming from satellites
- Direct broadcast satellite (DBS): satellite video signals are transmitted directly to the home user. This is called ______ by Indian service providers
- Point-to-point trunks between telephone exchange offices in public telephone networks (high usage international trunks)
- INSAT satellites by ISRO: Used by BSNL, GAIL, Oil and Natural Gas Corporation Ltd., Bombay Stock Exchange etc. and VSAT terminals for ATM/Bank connectivity (Source: https://www.isro.gov.in/applications/telecommunication)

Very Small Aperture Terminals (VSAT)



Transmission Characteristics

- Optimum frequency range: 1 to 10 GHz.
- Below 1 GHz, there is noise from natural sources
- Above 10GHz, attenuation due to atmospheric noise, precipitation
- 4/6 GHz band - Uplink: 5.925 to 6.425 GHz Downlink: 3.7 to 4.2 GHz
- 12/14-GHz band has been developed (uplink: 14 to 14.5 GHz; downlink: 11.7 to 12.2 GHz)
- –More attenuation but smaller receivers
- A propagation delay of about a quarter second from transmission from one earth station to reception by another earth station.

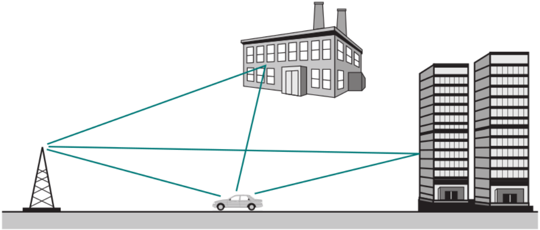
Broadcast Radio

- Microwave is directional while broadcast radio is omnidirectional
- Radio: 3 kHz to 300 GHz (FM radio, UHV and VHF television)
- Transmission is limited to line of sight
- There is no reflection from the atmospheric layers
- Less sensitive to attenuation from rainfall
- For microwave and radio frequencies

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

where d is the distance and λ the wavelength

Broadcast Radio



(b) Mobile radio

- Impairment: Reflection from land, water, natural or human-made objects can create multiple paths between antennas (multipath interference)
- –Depending on the differences in the path lengths of the direct and reflected waves, the composite signal can be either larger or smaller than the direct signal

Question

Radio waves suffer less attenuation compared to microwaves because

(A) they have longer wavelength

(B) they have shorter wavelength

(C) neither of the above

Question

Antennas for broadcast radio need not be precisely aligned because

(A) the antennas are omnidirectional

(B) the antennas are directional

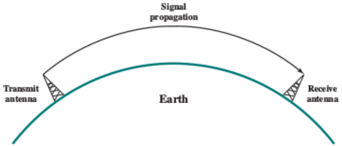
(C) neither of the above

Infrared transmission

- Achieved using transmitters/receivers (transceivers) that modulate noncoherent infrared light
- Transceivers must be within the line of sight of each other either directly or via reflection from a light-colored surface such as the ceiling of a room.
- Does not penetrate walls (does microwave penetrate walls?)
- Security and interference problems encountered in microwave systems are not present
- No frequency allocation issues

Wireless propagation

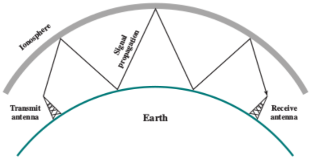
A signal radiated from an antenna travels along one of three routes: ground wave, sky wave, or line of sight (LOS)
Ground wave propagation:



(a) Ground wave propagation (below 2 MHz)

- more or less follows the contour of the Earth, well over the visual horizon
- up to 2 MHz
- scattered by the atmosphere in such a way that they do not penetrate the upper atmosphere
- spreads out from the transmitter along the surface of the earth
- follows the curvature of the earth
- Example: AM radio

Sky Wave Propagation



(b) Sky wave propagation (2 to 30 MHz)

- a signal from an earth-based antenna is reflected from the ionized layer of the upper atmosphere (ionosphere -50 to 1000 km) back down to Earth
- In reality caused by refraction : a continuous, gradual bending of a signal occurs if an electromagnetic wave is moving through a medium in which the index of refraction gradually changes
- the refractive index of the atmosphere decreases with height
- A signal can be picked up thousands of kilometers from the transmitter
- Examples: Amateur radio, international broadcasts (BBC, Voice of America)

Question

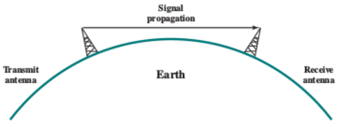
The refractive index of the atmosphere decreases with height. Therefore

(A) radio waves travel more slowly near the ground than at higher altitudes

(B) radio waves travel faster near the ground than at higher altitudes

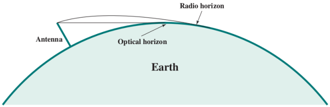
(C) radio waves travel at uniform speed regardless of the altitude

Line-of-Sight Propagation



(c) Line-of-sight (LOS) propagation (above 30 MHz)

- Above 30 MHz neither ground wave nor sky wave modes operate
- a signal can be transmitted between an earth station and a satellite overhead that is not beyond the horizon
- For ground-based communication, the transmitting and receiving antennas must be within an effective line of sight of each other
- Microwaves are bent or refracted by the atmosphere — will propagate farther than optical line of sight



Impairments specific to wireless line of sight

Free-space loss

- For any type of wireless communication the signal disperses with distance
- Transmitted signal attenuates over distance because the signal is being spread over a larger and larger area
- An antenna with a fixed area receives less signal power the farther it is from the transmitting antenna
- Primary mode of signal loss for satellite communications

Impairments specific to wireless line of sight

For the ideal isotropic antenna, free space loss is

$$\frac{P_t}{P_r} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi df}{c}\right)^2$$

where
P_t=signal power at the transmitting antenna
P_r=signal power at the receiving antenna
λ=carrier wavelength
d=propagation distance between antennas
c=speed of light ($3 * 10^8 m/s$)

$$L_{dB} = 10 \log \frac{P_t}{P_r}$$

Impairments specific to wireless line of sight

For other antennas, free space loss is

$$\frac{P_t}{P_r} = \frac{1}{G_r G_t}\left(\frac{4\pi d}{\lambda}\right)^2 = \frac{(\lambda d)^2}{A_t A_r} = \frac{(cd)^2}{f^2 A_r A_t}$$

where
G_t=Gain of the transmitting antenna=$\frac{4\pi A_t}{(\lambda)^2}$
G_r=Gain of the receiving antenna
A_t=effective area of the transmitting antenna
A_r=effective area of the receiving antenna

Observations

$$\frac{P_t}{P_r} = \frac{1}{G_r G_t}\left(\frac{4\pi d}{\lambda}\right)^2 = \frac{(\lambda d)^2}{A_t A_r} = \frac{(cd)^2}{f^2 A_r A_t}$$

It appears that as the frequency decreases, the free space loss increases, other factors remaining the same (keeping the antenna area and distance fixed)

We can easily compensate for this increased loss with antenna gains, by increasing the antenna area

Question

1) Determine the isotropic free space loss at 4 GHz for the shortest path to a synchronous satellite from Earth (35,863 km). 2) Suppose the satellite and ground based antennas have gains of 44dB and 48dB respectively, what is the free space loss? 3) Assume a transmit power of 250 W at the earth station. What is the power received at the satellite antenna?

Impairments specific to wireless line of sight

- Free space loss
- Atmospheric absorption: Water vapour and oxygen
- –Scattering :production of waves of changed direction or frequency when radio waves encounter matter (rain and fog).
- Multipath
- Refraction: Normally, the speed of the signal increases with altitude, causing radio waves to bend downward . Due to atmospheric variations, this may change