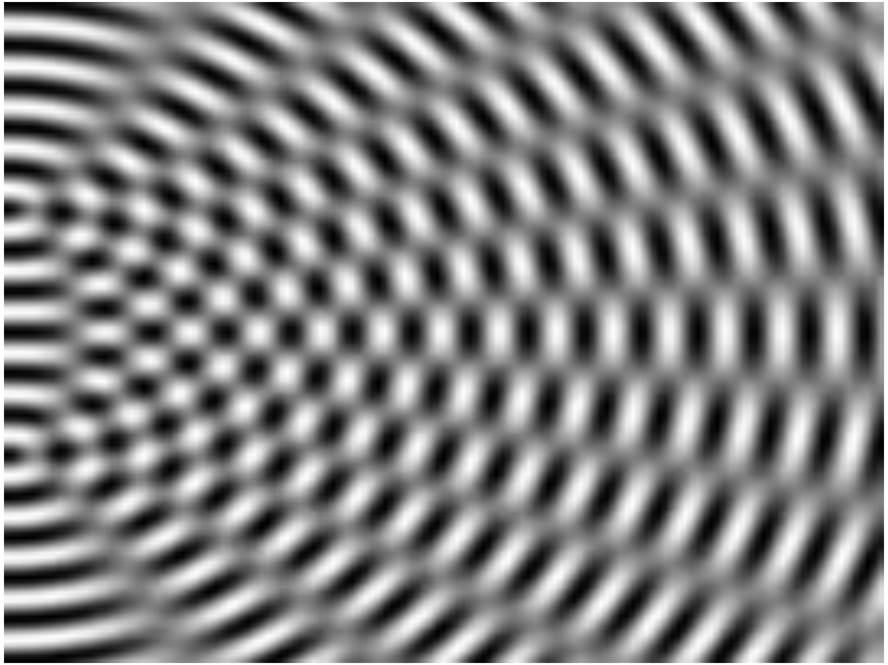
Veri Haberleşmesi ve Bilgisayar Ağları

Wireless and Satellite Communication”

Dr. Cahit Karakuş, 2020

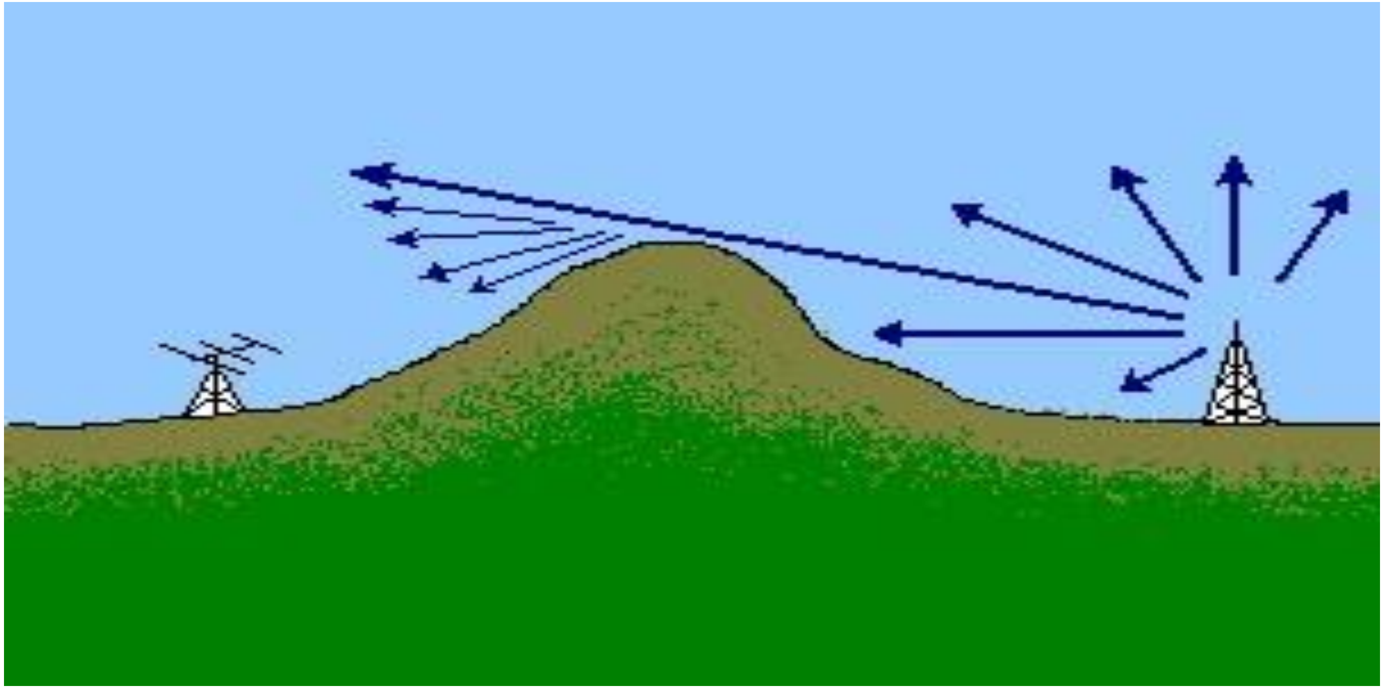
Interference and Diffraction

Two Waves Interfering



Diffraction

Wave bends as it passes an obstacle.



Kablosuz Erişim

Short Range Wireless Communications

- Range: up to about 10 metres
- Examples: Bluetooth, IrDA (infrared), ZigBee and IEEE 802.15.4, Ultra Wide Band (UWB)
- Applications: connect electronic devices together
  - Wireless desktop: keyboard, mouse, PC, monitor connected *without* cables
  - Personal or Body Area Networks: devices carried with you (mobile phone, PDA, camera, watch, headset) connected
  - Automation: control and monitoring of devices (lights, machinery, A/C, entertainment) in homes, offices, factories, hospitals, …

Technology	*Frequency*	*Data Rate*	*Power*	*Range*
Bluetooth	2.4GHz	<3Mb/s	1-3mW	1-10m
ZigBee	915MHz/ 2.4GHz	<250kb/s	1mW	10's m
UWB	3-10GHz	>100Mb/s	~1mW	<10 m
IrDA	350THz	115kb/s to < 4Mb/s	~1mW	<1 m

Wireless LANs

- Range: metres to 100’s of metres
- Examples: IEEE 802.11 series (11b, 11a, 11g, 11n)
- Applications: home/office LAN connectivity; city/public hot spots; …
- Topology: point-to-multipoint (shared medium)

Technology	*Frequency*	*Data Rate*	*Range*
11b	2.4GHz	11Mb/s	20-300m
11a	5GHz	54Mb/s	15-30m
11g	2.4GHz	54Mb/s	25-75m
11n	5GHz	300Mb/s	20-60m

Point-to-Point Fixed Wireless

- Range: up to 10's of kms
- Examples: proprietary microwave products, IEEE 802.16 (WiMax), IEEE 802.11
- Applications: replacement for point-to-point WAN (core) links (e.g. alternative for PDH, SDH)
- Typically fixed devices (e.g. antennas on towers), using highly directional antennas
- WiMax (802.16) theoretically provides speeds up to 70Mb/s (or a range of 50km)
  - Symmetrical speeds, licensed spectrum

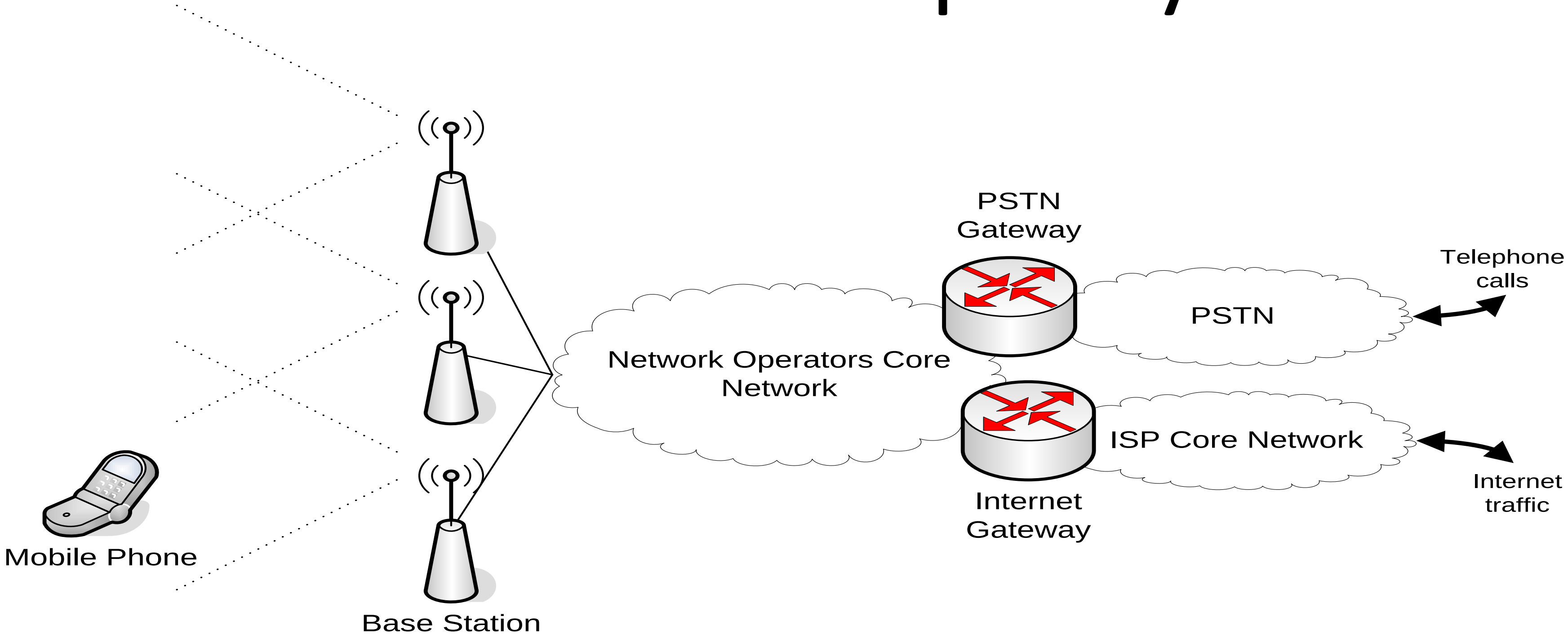
Technology	*Frequency*	*Data Rate*	*Range*	*Direction*
802.11b	2.4GHz	11Mb/s	10-20km	LOS
802.16	~11GHz	10-20Mb/s	10-20km	LOS
802.16	2.3/2.5/ 3.5GHz	2Mb/s	10km	NLOS

Mobile Telephony

- Range: km's
- Examples:
  - GSM derived: CSD, GPRS, EDGE, UMTS, HSPA, LTE
  - CDMAone derived: 1xRTT, EV-DO, UMB
- Applications: mobile Internet access; voice/video over IP; data collection and monitoring

- Mobile phone networks have progressively been updated to support both voice calls and data

Mobile Telephony



GSM Derived Data Technologies

- Circuit Switched Data (CSD) 14 kb/s
  - Create a circuit-switched connection over original GSM voice call connection
- General Packet Radio Service (GPRS) 60/40 kb/s
- Enhanced Data Rates for GSM Evolution (EDGE) 240/120 kb/s
  - GPRS and EDGE are extensions to GSM; most networks support them with minor upgrades
- Universal Mobile Telecommunication System (UMTS) 384 kb/s
  - A new system compared to GSM; most widely used 3G system
- High Speed Packet Access
  - Extensions of UMTS to increase data rates
  - HSDPA (D = downlink) 14.4Mb/s
  - HSUPA (U = uplink) 5.7Mb/s
  - HSPA+ 42/22 Mb/s
- Long Term Evolution (LTE) 326/86 Mb/s
  - A new system compared to UMTS

Wireless Networks

- Wireless technologies can be used for both access and core networks
  - Access: WLAN, Bluetooth, Mobile Telephony, WiMax, Satellite
    - Mainly provide mobility to users or access in remote areas
  - Core: WiMax, Satellite, WLAN
    - Act as cable replacement where hard to deploy cables; typically fixed devices

- Wireless technologies are typically lower data rates than similar cost wired technologies
  - WLAN (54Mb/s) vs Ethernet (100/1000Mb/s)
  - EDGE (240kb/s) vs ADSL (1.5Mb/s)
  - HSPA (~10Mb/s) vs Optical (100Mb/s)
  - WiMax (35Mb/s) vs Optical (1000Mb/s)

Frequencies and regulations

- ITU-R holds auctions for new frequencies, manages frequency bands worldwide (WRC, World Radio Conferences)

Examples	Europe	USA	Japan
Cellular phones	**GSM** 880-915, 925-960, 1710-1785, 1805-1880 **UMTS** 1920-1980, 2110-2170	**AMPS, TDMA, CDMA, GSM** 824-849, 869-894 **TDMA, CDMA, GSM, UMTS** 1850-1910, 1930-1990	**PDC, FOMA** 810-888, 893-958 **PDC** 1429-1453, 1477-1501 **FOMA** 1920-1980, 2110-2170
Cordless phones	**CT1+** 885-887, 930-932 **CT2** 864-868 **DECT** 1880-1900	**PACS** 1850-1910, 1930-1990 **PACS-UB** 1910-1930	**PHS** 1895-1918 **JCT** 245-380
Wireless LANs	**802.11b/g** 2412-2472	**802.11b/g** 2412-2462	**802.11b** 2412-2484 **802.11g** 2412-2472
Other RF systems	27, 128, 418, 433, 868	315, 915	426, 868

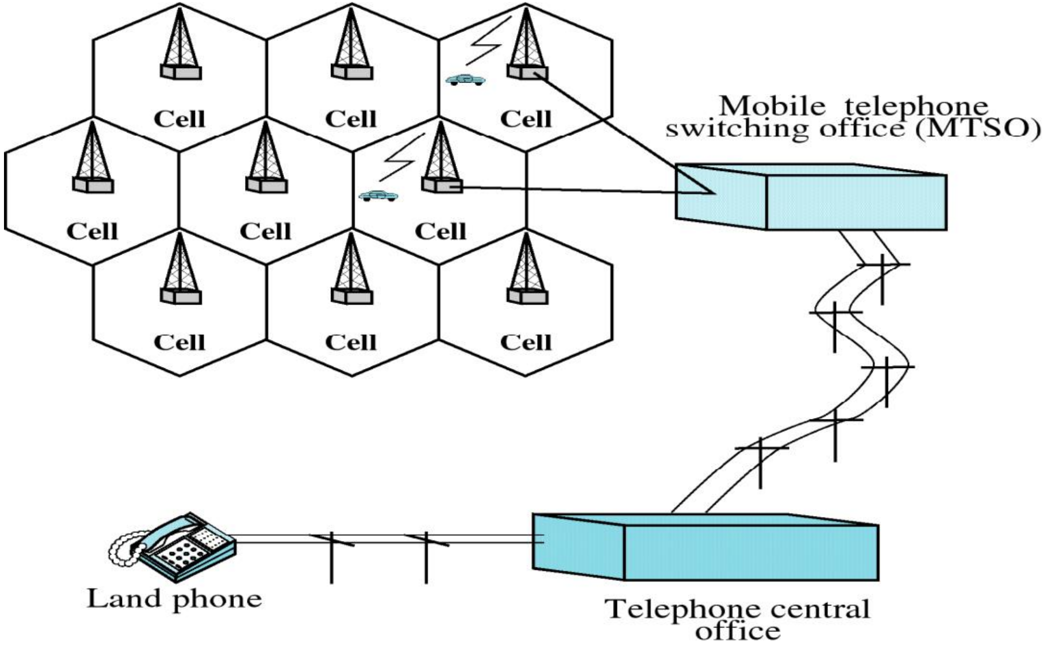
Cellular Network Examples

- 0G
  - Single, powerful base station covering a wide area, and each telephone would effectively monopolize a channel over that whole area while in use (developed in 40's)
  - No frequency use or handoff (basis of modern cell phone technology)
- 1G
  - Fully automatic cellular networks
  - introduced in the early to mid 1980s
- 2G
  - Introduced in 1991 in Finland on the GSM standard
  - Offered the first data service with person-to-person SMS text messaging

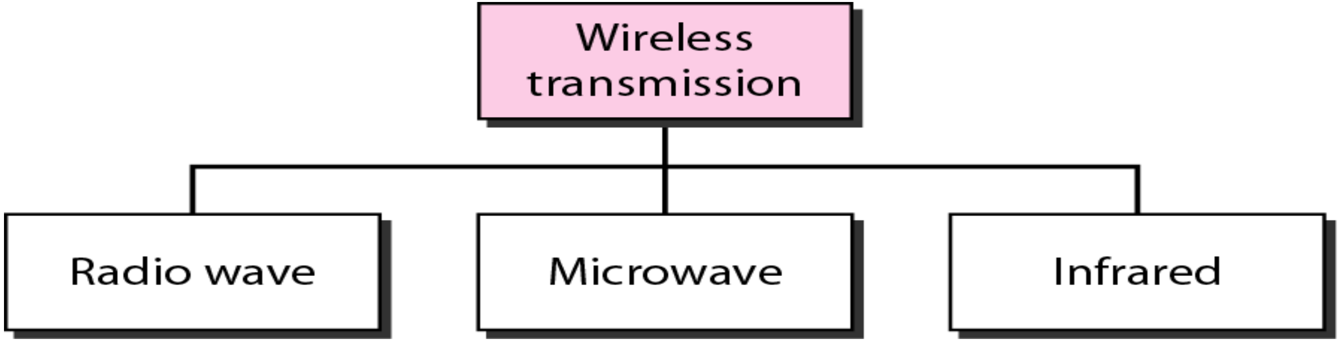
Cellular Network Examples

- 3G:
  - Faster than PCS; Used for multimedia and graphics
  - Compared to 2G and 2.5G services, 3G allows simultaneous use of speech and data services and higher data rates (up to 14.4 Mbit/s on the downlink and 5.8 Mbit/s.
- 4G:
  - Fourth generation of cellular wireless;
  - providing a comprehensive and secure IP based service to users "Anytime, Anywhere" at high data rates

Cellular System



Wireless transmission waves



- Radio waves are used for multicast communications, such as radio and television, and paging systems. They can penetrate through walls. Highly regulated. Use omnidirectional antennas.
- Microwaves are used for unicast communication such as cellular telephones, satellite networks, and wireless LANs. Higher frequency ranges cannot penetrate walls. Use directional antennas - point to point line of sight communications.
- Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Wireless Channels

- Are subject to a lot more errors than guided media channels.
- Interference is one cause for errors, can be circumvented with high SNR.
- The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
- Channel also subject to fading and no coverage holes.

Promising Technology Solutions to the Rural Challenge

- Wi-Fi: Rural Citywill be home to the world's largest Wi-Fi hotspot. The Networks announced plans to sell Wi-Fi chips with data rates up to 240 Mbps, the speed of current Wi-Fi chips at 54 Mpbs.
- WiMAX: With a range of up to 40 miles, WiMAX may be a promising solution for delivering broadband to rural areas. Although WiMAX is still under development, the FCC and FEMA authorized deployment of a WiMAX network (15 mile range with 45 Mbps bandwidth
- BPL: Broadband-over-power-line (BPL) system and is available to about 10,000 of the city's 12,500 homes.
- WISPs: Wireless Internet service providers, traditionally provide broadband connectivity in areas not reached by cable or DSL. Now WISPs are expanding into urban areas.

Promising Technology Solutions to the Rural Challenge (cont'd)

▪ Unlicensed Mesh Networking: By linking nodes on an ad hoc basis, mesh technology promises to deliver high bandwidth at an order of magnitude lower cost than existing licensed wireless technologies. Mesh architecture permits the extension of wireless coverage to areas that do not have wire infrastructure, and can link diverse devices or networks. Community Wireless Network has offered free 1.5 Mbps Internet access on a mesh network. The network can support 50-100 simultaneous users with three high-capacity E-1 wires that connect to the Internet..

▪Satellite: Satellites have long held potential for communications coverage of large, sparsely populated areas.

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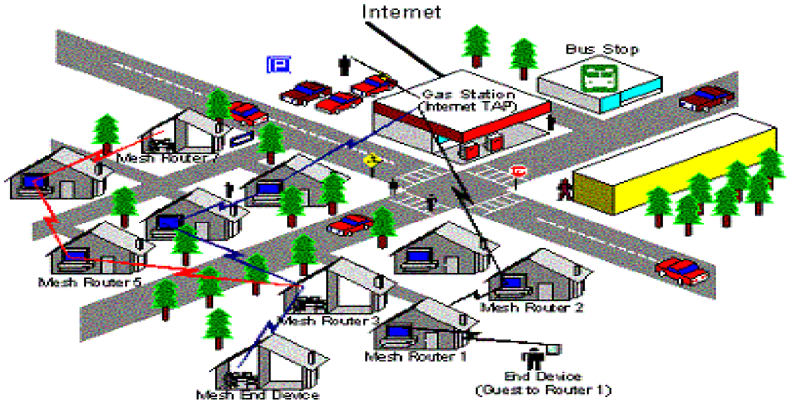
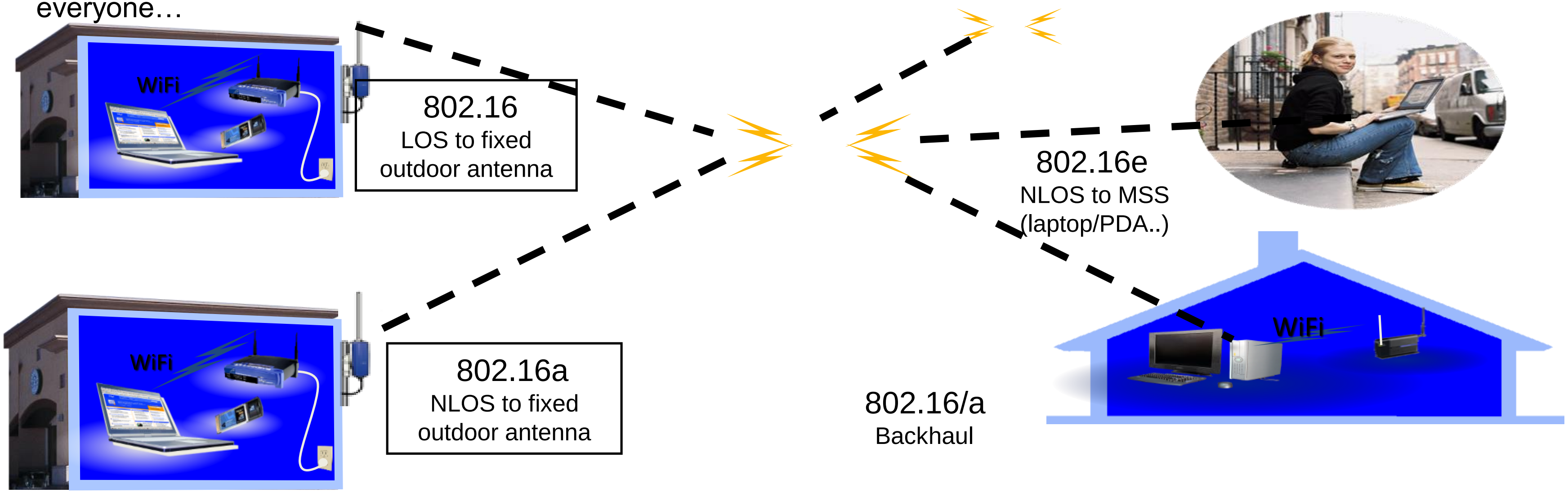


Self-Organizing Neighborhood Wireless Mesh Networks

Wireless Broadband

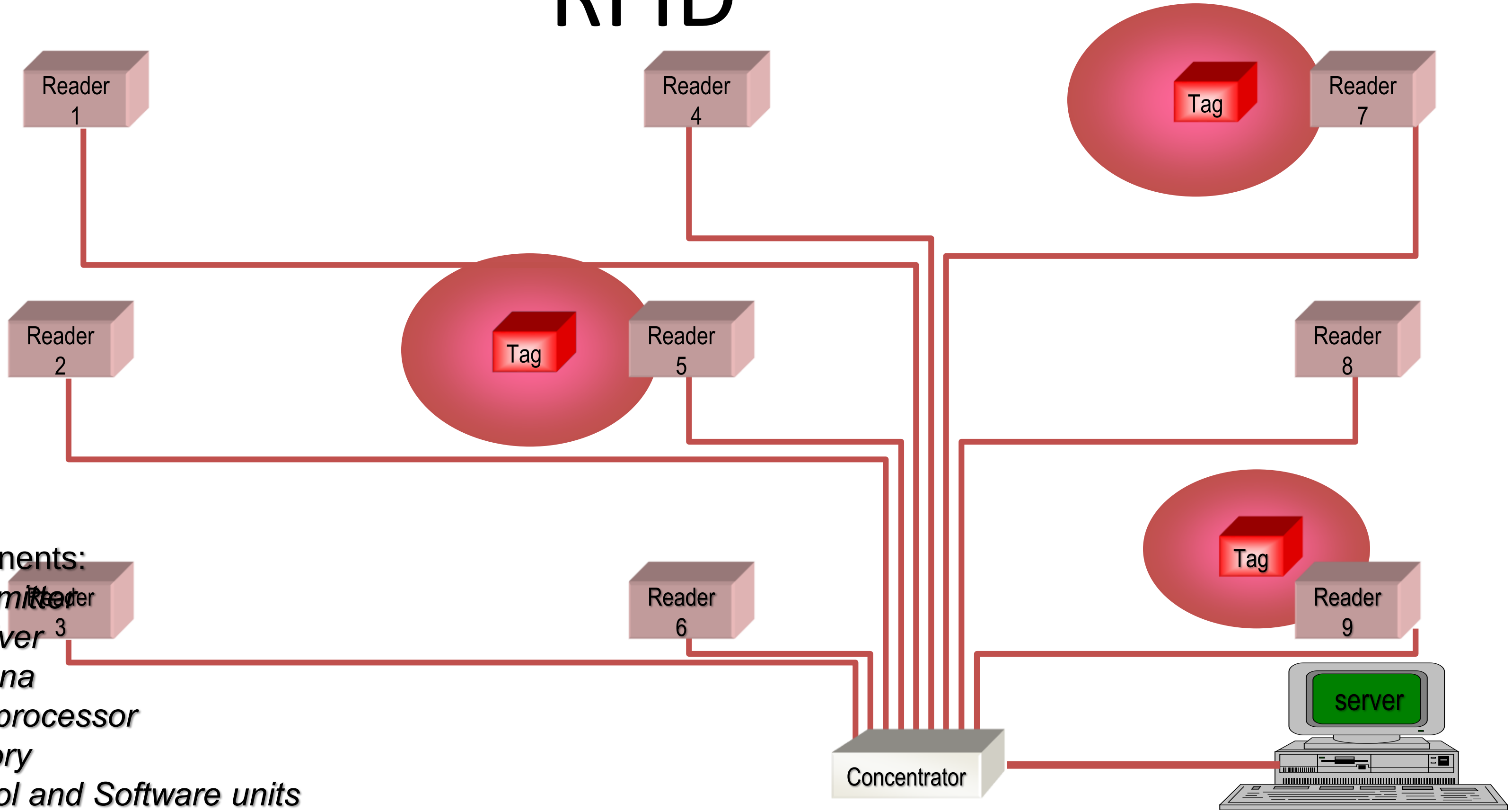
The growing demand for broadband services on a global scale is clear and uncontestable Businesses, public institutions and private users regard it as an enabling technology and it has become a given requirement for delivering communications services in the Information Age. In last mile markets where traditional cable or copper infrastructures are either saturated, outdated or simply out of reach, Broadband Wireless Access (BWA) technology fills the void admirably, providing highly efficient and cost effective access services for millions of subscribers who would otherwise be left out of the loop.

The introduction of the Wireless MAN standards (802.16 and HiperMAN) and the guidelines set forth by the WiMAX Forum to ensure its success, will do much to encourage the growth of broadband wireless markets everywhere, benefiting everyone…



MSS: Mobile Subscriber Station; LOS: Line of Sight; NLOS: Non Line of Sight

RFID



- The components:
  - *Transmitter*
  - *Receiver*
  - *Antenna*
  - *Microprocessor*
  - *Memory*
  - *Control and Software units*
  - *Communication channels*
  - *Energy*
  - *Protocols*

- Active or passive RFID
- At the Passive RFID, The TAGs take the energy from READER as magnetic power

TRACKING AND NAVIGATION

- ***GPS*** ***Global Positioning System***
- ***DGPS*** ***Differential GPS***
- ***MPS*** ***Mobile Positioning System***
- ***WPS*** ***Wireless Positioning System***
- ***DPS*** ***Digital Positioning System***

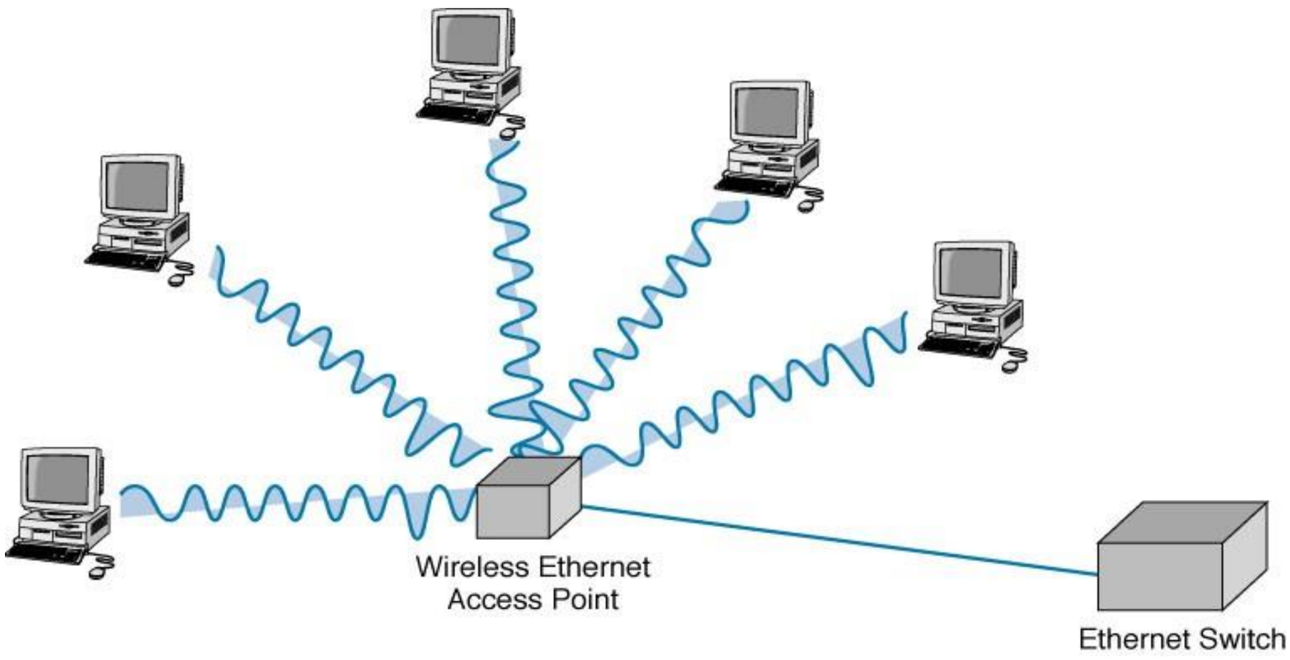
- Navigation (with velocity)
- Tracking (with velocity)
- Mapping (with attributes)
- Guidance Systems
- Surveying (Feasibilty vs. Legality).
- Real-time vehicle location, mapping and reporting
- Connection to sensors and controls
- Event monitoring and history analysis
- Fully mobile Control Centers
- Multiple Control Centers capability
- Compatibility to various GIS formats

Wireless Ethernet (IEEE 802.11)

- Wireless LANs dispense with cables and use radio or infrared frequencies to transmit signals through the air.
- WLANs are growing in popularity because they eliminate cabling and facilitate network access from a variety of locations and for mobile workers (as in a hospital).
- The most common wireless networking standard is IEEE 802.11, often called Wireless Ethernet or Wireless LAN.

Wireless LAN Topology

- WLAN topologies are the same as on Ethernet: physical star, logical bus
- Wireless LAN devices use the same radio frequencies, so they must take turns using the network.
- Instead of hubs, WLANs use devices called **access points** (AP). Maximum transmission range is about 100-500 feet. Usually a set of APs are installed making wireless access possible in several areas in a building or corporate campus.
- Each WLAN computer uses an NIC that transmits radio signals to the AP.
- Because of the ease of access, security is a potential problem, so IEEE 802.11 uses 40-bit data encryption to prevent eavesdropping.



A wireless Ethernet access point connected into an Ethernet Switch.

WLAN Media Access Control

- Wireless LANs use **CSMA/CA** where CA = collision avoidance (CA). With CA, a station waits until another station is finished transmitting plus an additional random period of time before sending anything.
- Two different WLAN MAC techniques are now in use: the **Physical Carrier Sense Method** and the **Virtual Carrier Sense Method**.

Physical Carrier Sense Method

- In the **physical carrier sense method**, a node that wants to send first listens to make sure that the transmitting node has finished, then waits a period of time longer.
- Each frame is sent using the Stop and Wait ARQ, so by waiting, the listening node can detect that the sending node has finished and can then begin sending its transmission.
- With Wireless LANs, ACK/NAK signals are sent a short time after a frame is received, while stations wishing to send a frame wait a somewhat longer time, ensuring that no collision will occur.

Virtual Carrier Sense Method

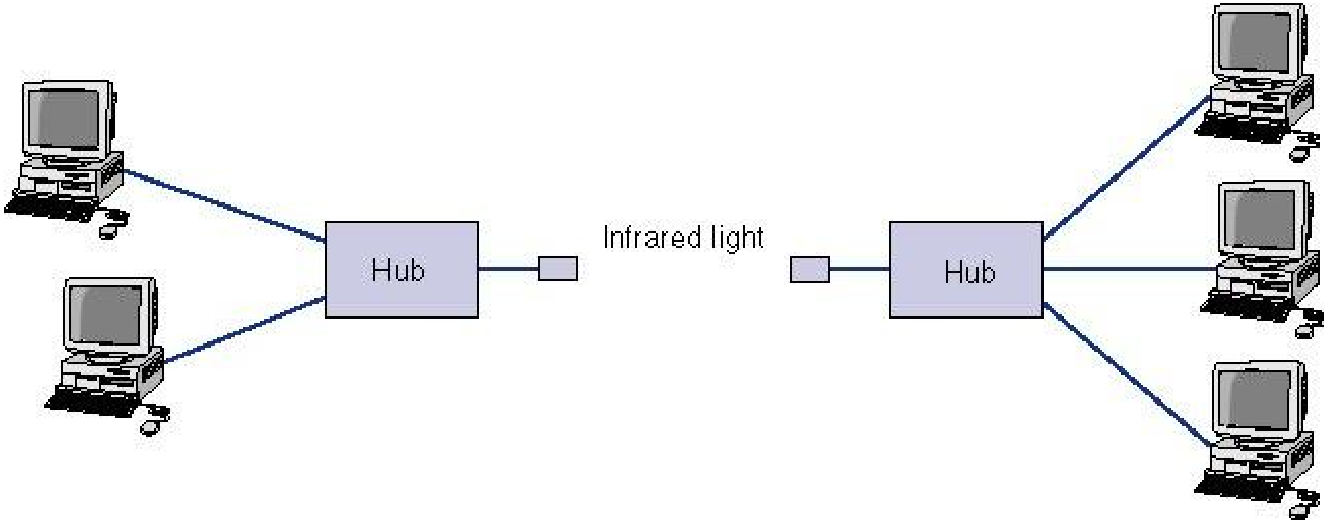
- When a computer on a Wireless LAN is near the transmission limits of the AP at one end and another computer is near the transmission limits at the other end of the AP's range, both computers may be able to transmit to the AP, but can not detect each other's signals.
- This is known as the **hidden node problem**. When it occurs, the physical carrier sense method will not work.
- The **virtual carrier sense method** solves this problem by having a transmitting station first send a request to send (RTS) signal to the AP. If the AP responds with a clear to send (CTS) signal, the computer wishing to send a frame can then begin transmitting.

Types of Wireless Ethernet

- Two forms of the IEEE 802.11b standard currently exist, utilizing the 2.5 GHz band:
  - **Direct Sequence Spread Spectrum** (DSSS) uses the entire frequency band to transmit information. DSSS is capable of data rates of up to 11 Mbps with fallback rates of 5.5, 2 and 1 Mbps. Lower rates are used when interference or congestion occurs.
  - **Frequency Hopping Spread Spectrum** (FHSS) divides the frequency band into a series of channels and then changes its frequency channel about every half a second, using a pseudorandom sequence. FHSS is more secure, but is only capable of data rates of 1 or 2 Mbps.
- **IEEE 802.11a** uses Orthogonal Frequency Division Multiplexing (OFDM), operates in the 5 GHz band with data rates of up to 54 Mbps.
- **IEEE 802.11g** uses OFDM in the 2.5 GHz band, operates at up to 54 Mbps, and is compatible with 802.11b

Infrared Wireless LANs

- **Infrared WLANs** are less flexible than IEEE 802.11 WLANs because, as with TV remote controls that are also infrared based, they require line of sight to work.
- Infrared Hubs and NICs are usually mounted in fixed positions to ensure they will hit their targets.
- The main advantage of infrared WLANs is reduced wiring.
- A new version, called **diffuse infrared**, operates without a direct line of sight by bouncing the infrared signal off of walls, but is only able to operate within a single room and at distances of only about 50-75 feet.



Infrared Wireless LAN

Bluetooth

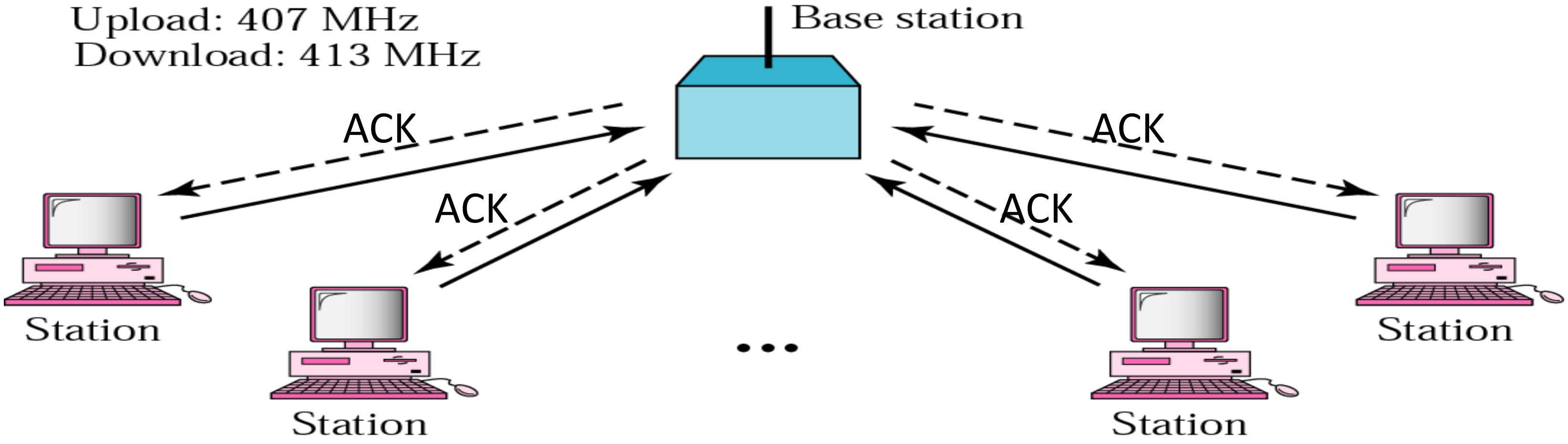
- Bluetooth is a 1 Mbps wireless standard developed for **piconets**, small personal or home networks.
- It may soon be standardized as IEEE 802.15.
- Although Bluetooth uses the same 2.4 GHz band as Wireless LANs it is not compatible with the IEEE 802.11 standard and so can not be used in locations that use the Wireless LANs.
- Bluetooth's controlled MAC technique uses a master device that polls up to 8 "slave" devices.
- Examples of Bluetooth applications include; linking a wireless mouse, a telephone headset, or a Palm handheld computer to a home network.

Contention Protocols

- **ALOHA**
  - Developed in the 1970s for a packet radio network by Hawaii University.
  - Whenever a station has a data, it transmits. Sender finds out whether transmission was successful or experienced a collision by listening to the broadcast from the destination station. Sender retransmits after some random time if there is a collision.
- **Slotted ALOHA**
  - Improvement: Time is slotted and a packet can only be transmitted at the beginning of one slot. Thus, it can reduce the collision duration.

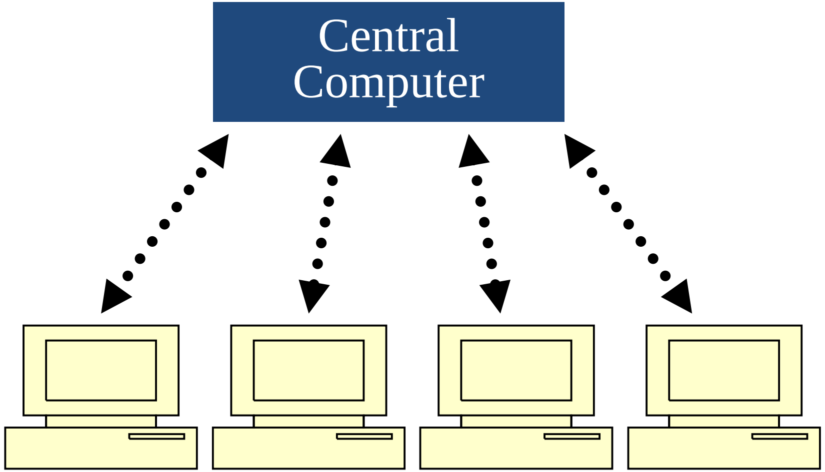
ALOHA Network

- Developed by Norm Abramson at the Univ. of Hawaii
  - the guy had interest in surfing and packet switching
  - mountainous islands → land-based network difficult to install
  - fully decentralized protocol



Aloha

- Nodes sends the message when it has data to send.
- If it receives an ack, it considers the transmission completed, otherwise it retransmits after a random delay.
- Simple, distributed protocol, but not very efficient
  - 18% maximum utilization
- Slotted Aloha: more efficient.
  - Reduces chances of collision
  - 37% maximum utilization

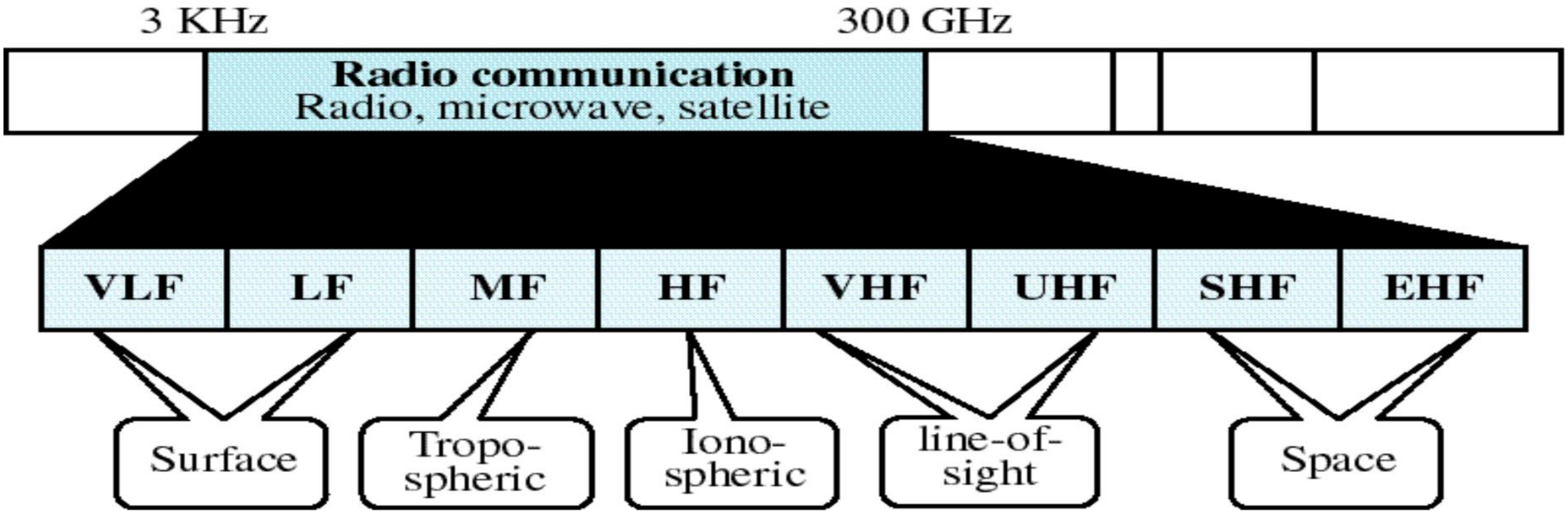


Mobile Communications
Wireless Transmission

- Frequencies
- Signals, antennas, signal propagation
- Multiplexing
- Spread spectrum, modulation
- Cellular systems

Radio Communication Band

VLF	Very low frequency	VHF	Very high frequency
LF	Low frequency	UHF	Ultra high frequency
MF	Middle frequency	SHF	Super high frequency
HF	High frequency	EHF	Extremely high frequency

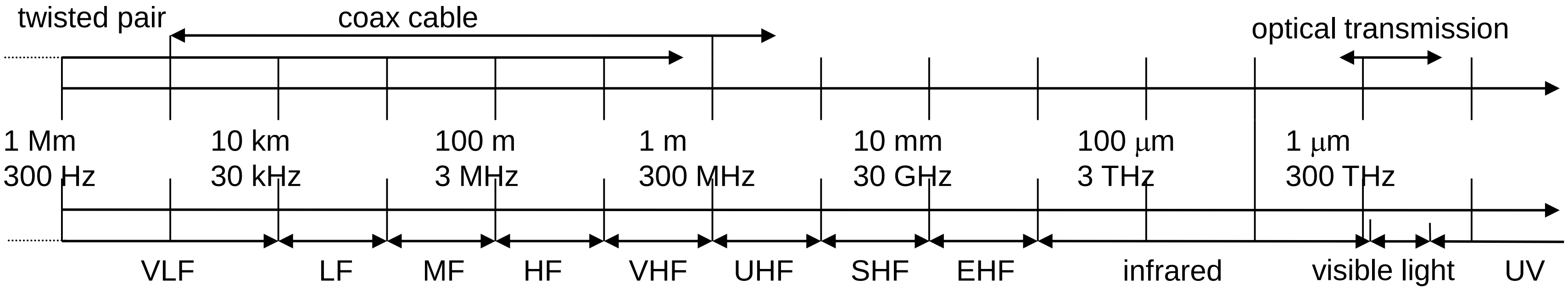


Frequencies for communication

- VLF = Very Low Frequency
- LF = Low Frequency
- MF = Medium Frequency
- HF = High Frequency
- VHF = Very High Frequency

UHF = Ultra High Frequency
SHF = Super High Frequency
EHF = Extra High Frequency
UV = Ultraviolet Light

- Frequency and wave length
  - $\lambda = c/f$
  - wave length λ, speed of light $c \cong 3x10^8 m/s$, frequency f

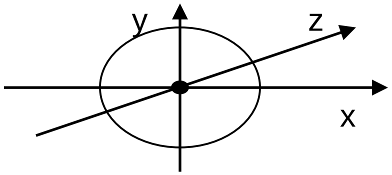


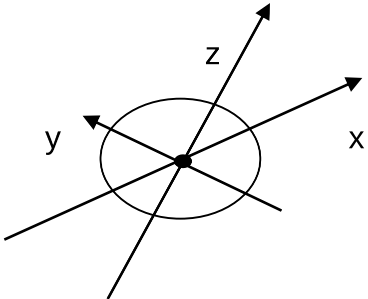
Frequencies for mobile communication

- VHF-/UHF-ranges for mobile radio
  - simple, small antenna for cars
  - deterministic propagation characteristics, reliable connections
- SHF and higher for directed radio links, satellite communication
  - small antenna, beam forming
  - large bandwidth available
- Wireless LANs use frequencies in UHF to SHF range
  - some systems planned up to EHF
  - limitations due to absorption by water and oxygen molecules (resonance frequencies)
    - weather dependent fading, signal loss caused by heavy rainfall etc.

Antennas: isotropic radiator

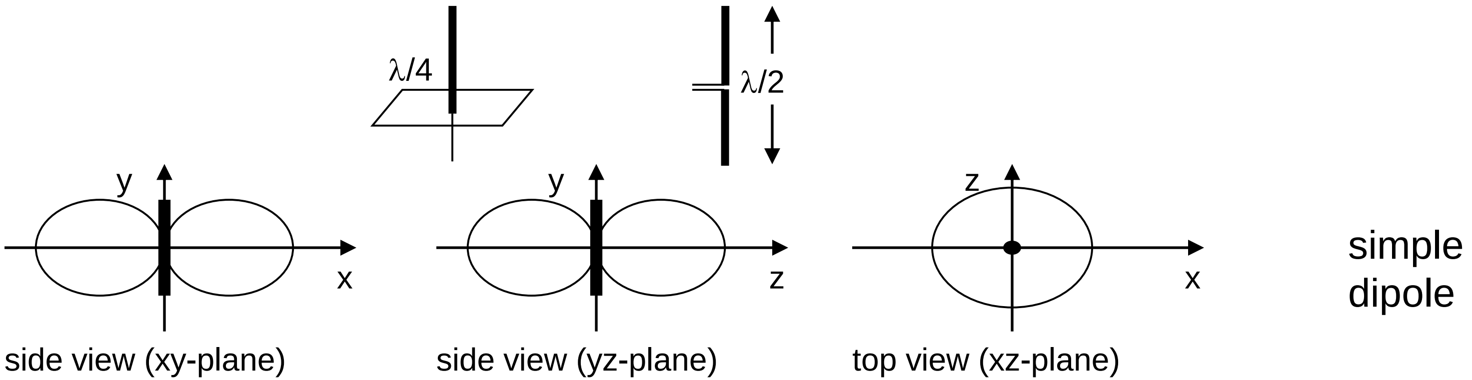
- Radiation and reception of electromagnetic waves, coupling of wires to space for radio transmission
- Isotropic radiator: equal radiation in all directions (three dimensional) - only a theoretical reference antenna
- Real antennas always have directive effects (vertically and/or horizontally)
- Radiation pattern: measurement of radiation around an antenna





ideal
isotropic
radiator

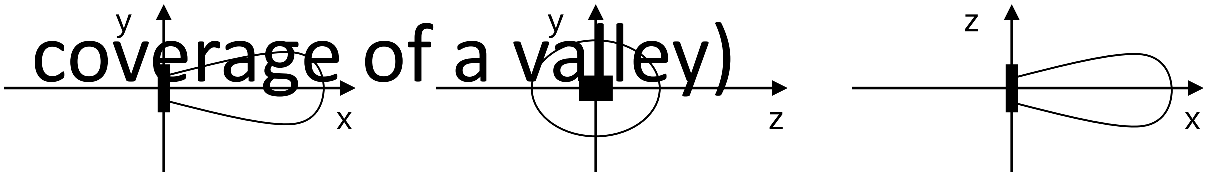
Antennas: simple dipoles



- Real antennas are not isotropic radiators but, e.g., dipoles with lengths $\lambda/4$ on car roofs or $\lambda/2$ as Hertzian dipole ➔ shape of antenna proportional to wavelength
- Example: Radiation pattern of a simple Hertzian dipole
- Gain: maximum power in the direction of the main lobe compared to the power of an isotropic radiator (with the same average power)

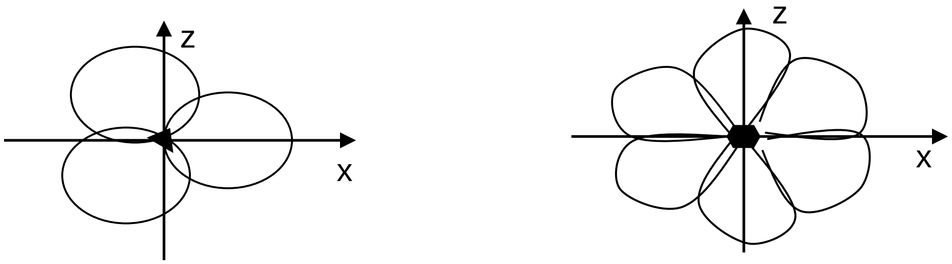
Antennas: directed and sectorized

- Often used for microwave connections or base stations for mobile phones (e.g., radio coverage of a valley)



side view (xy-plane) side view (yz-plane) top view (xz-plane)

directed antenna

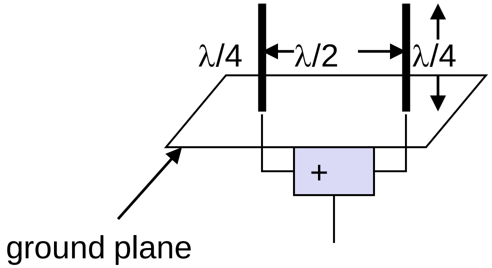


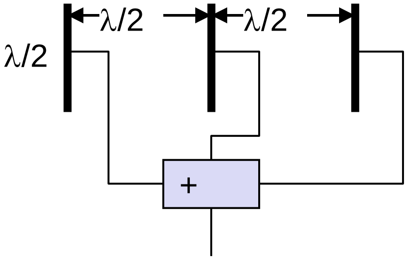
top view, 3 sector top view, 6 sector

sectorized antenna

Antennas: diversity

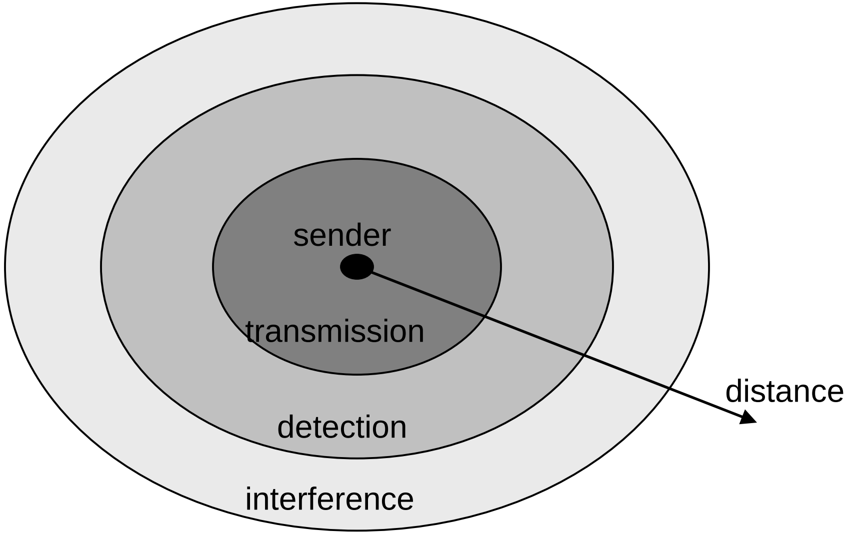
- Grouping of 2 or more antennas
  - multi-element antenna arrays
- Antenna diversity
  - switched diversity, selection diversity
    - receiver chooses antenna with largest output
  - diversity combining
    - combine output power to produce gain
    - cophasing needed to avoid cancellation





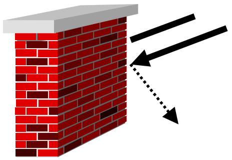
Signal propagation ranges

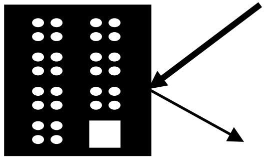
- Transmission range
  - communication possible
  - low error rate
- Detection range
  - detection of the signal possible
  - no communication possible
- Interference range
  - signal may not be detected
  - signal adds to the background noise

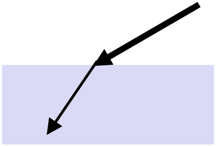


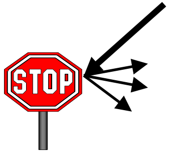
Signal propagation

- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$ in vacuum – much more in real environments (d = distance between sender and receiver)
- Receiving power additionally influenced by
- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- refraction depending on the density of a medium
- scattering at small obstacles
- diffraction at edges


shadowing


reflection


refraction



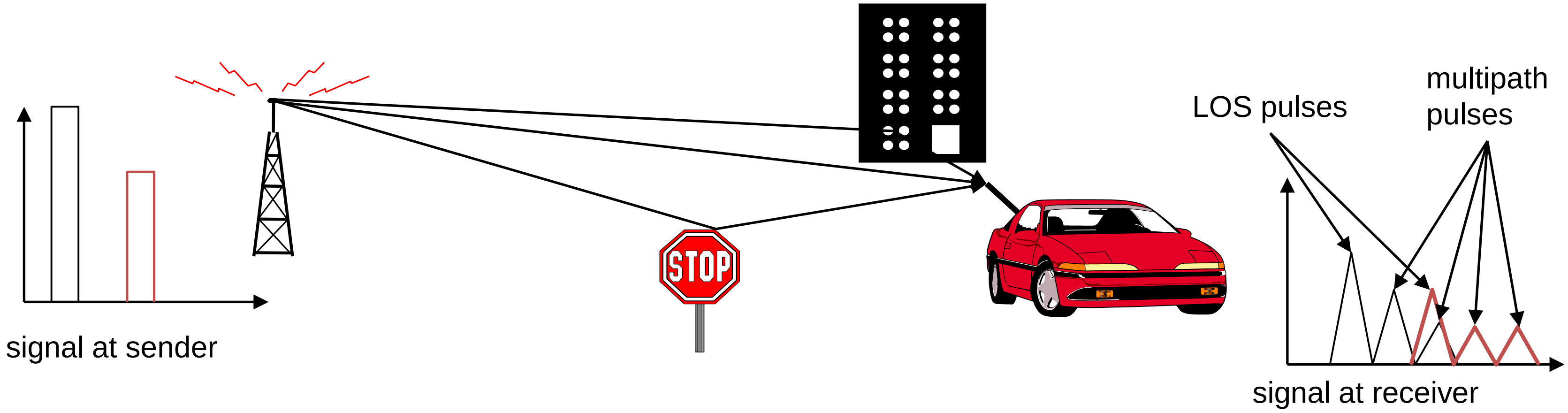
scattering


diffraction

Multipath propagation

- Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction
- Time dispersion: signal is dispersed over time
  - interference with “neighbor” symbols, Inter Symbol Interference (ISI)
- The signal reaches a receiver directly and phase shifted
  - distorted signal depending on the phases of the different parts

Multipath propagation



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- ITU-R holds auctions for new frequencies, manages frequency bands worldwide (WRC, World Radio Conferences)

Examples	Europe	USA	Japan
Cellular phones	**GSM** 880-915, 925-960, 1710-1785, 1805-1880 **UMTS** 1920-1980, 2110-2170	**AMPS, TDMA, CDMA, GSM** 824-849, 869-894 **TDMA, CDMA, GSM, UMTS** 1850-1910, 1930-1990	**PDC, FOMA** 810-888, 893-958 **PDC** 1429-1453, 1477-1501 **FOMA** 1920-1980, 2110-2170
Cordless phones	**CT1+** 885-887, 930-932 **CT2** 864-868 **DECT** 1880-1900	**PACS** 1850-1910, 1930-1990 **PACS-UB** 1910-1930	**PHS** 1895-1918 **JCT** 245-380
Wireless LANs	**802.11b/g** 2412-2472	**802.11b/g** 2412-2462	**802.11b** 2412-2484 **802.11g** 2412-2472
Other RF systems	27, 128, 418, 433, 868	315, 915	426, 868

Cellular Network Examples

- 0G
  - Single, powerful base station covering a wide area, and each telephone would effectively monopolize a channel over that whole area while in use (developed in 40's)
  - No frequency use or handoff (basis of modern cell phone technology)
- 1G
  - Fully automatic cellular networks
  - introduced in the early to mid 1980s
- 2G
  - Introduced in 1991 in Finland on the GSM standard
  - Offered the first data service with person-to-person SMS text messaging

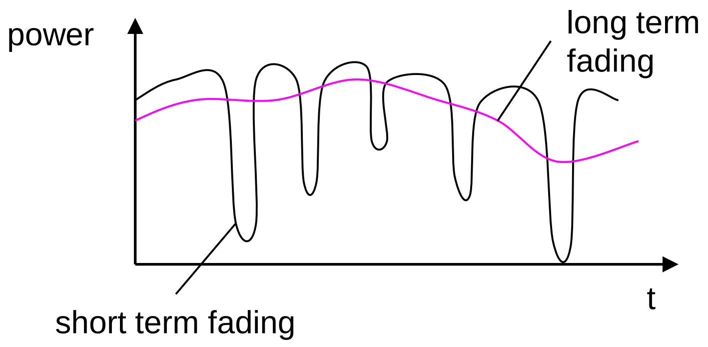
Cellular Network Examples

- 3G:
  - Faster than PCS; Used for multimedia and graphics
  - Compared to 2G and 2.5G services, 3G allows simultaneous use of speech and data services and higher data rates (up to 14.4 Mbit/s on the downlink and 5.8 Mbit/s.
- 4G:
  - Fourth generation of cellular wireless;
  - providing a comprehensive and secure IP based service to users "Anytime, Anywhere" at high data rates

Effects of mobility

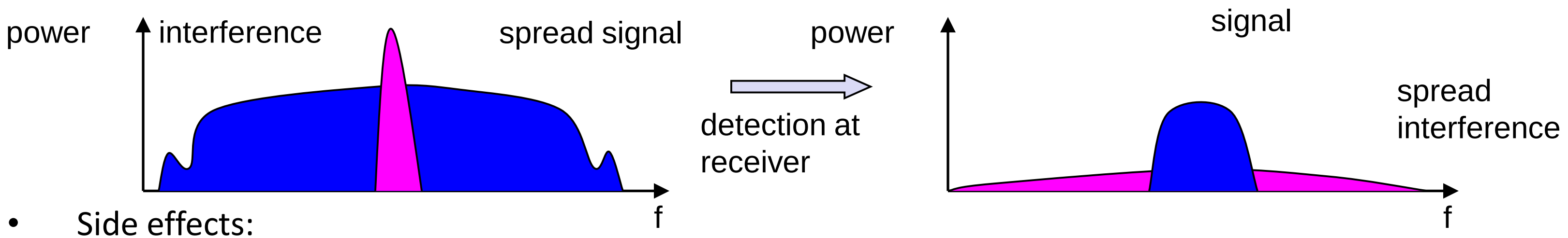
- Channel characteristics change over time and location
  - signal paths change
  - different delay variations of different signal parts
  - different phases of signal parts
  - ➔ quick changes in the power received (short term fading)

- Additional changes in
  - distance to sender
  - obstacles further away
  - ➔ slow changes in the average power received (long term fading)



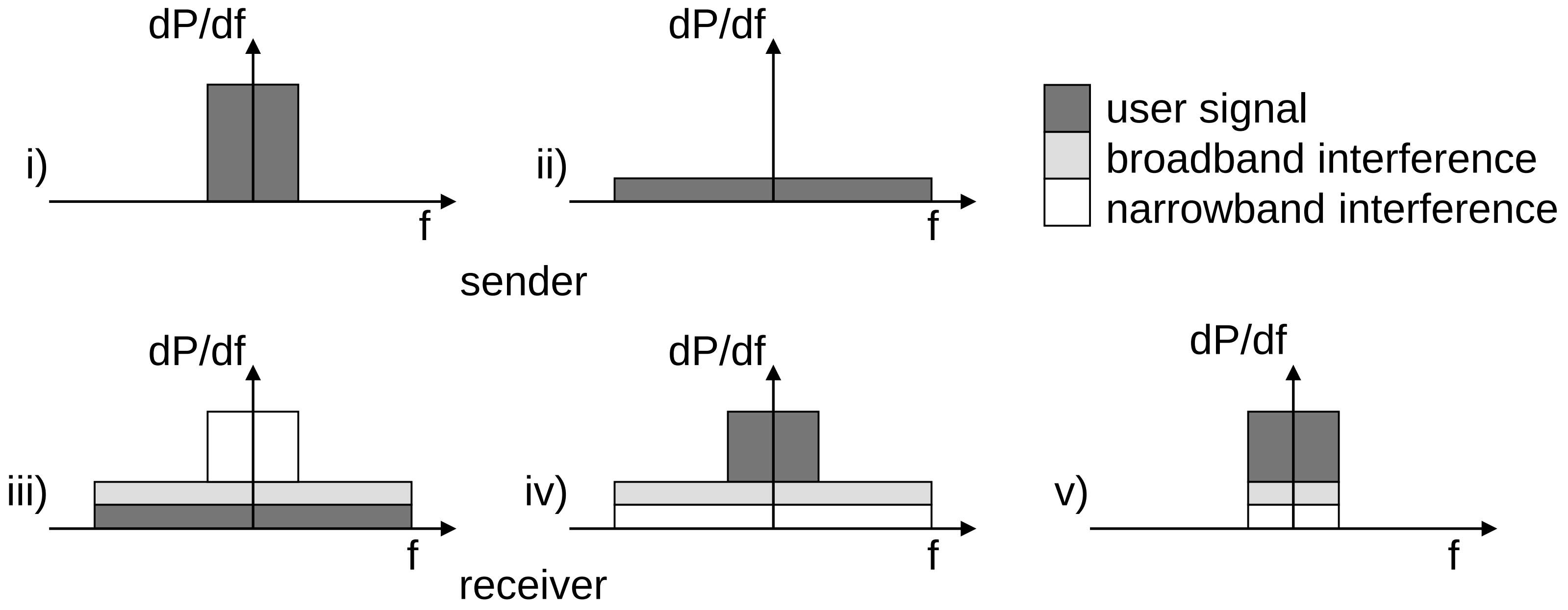
Spread spectrum technology

- Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference
- Solution: spread the narrow band signal into a broad band signal using a special code
  - protection against narrow band interference

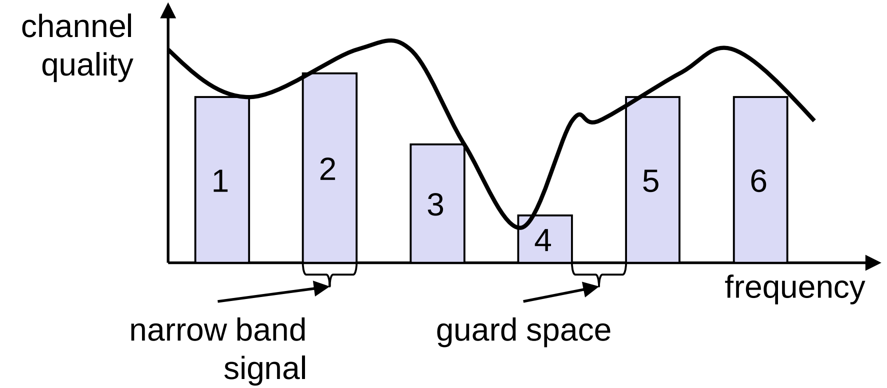


- Side effects:
  - coexistence of several signals without dynamic coordination
  - tap-proof
- Alternatives: Direct Sequence, Frequency Hopping

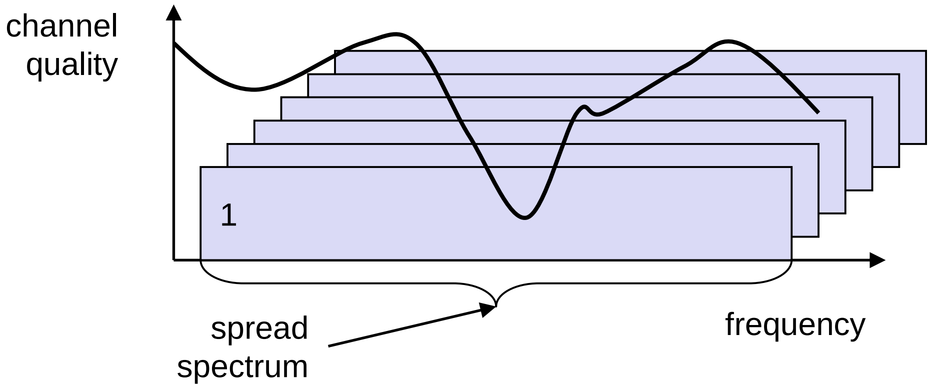
Effects of spreading and interference



Spreading and frequency selective fading



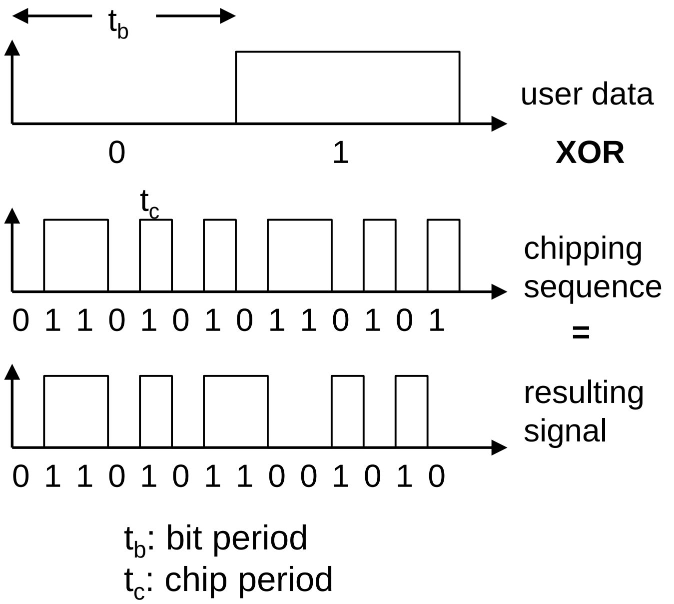
narrowband channels



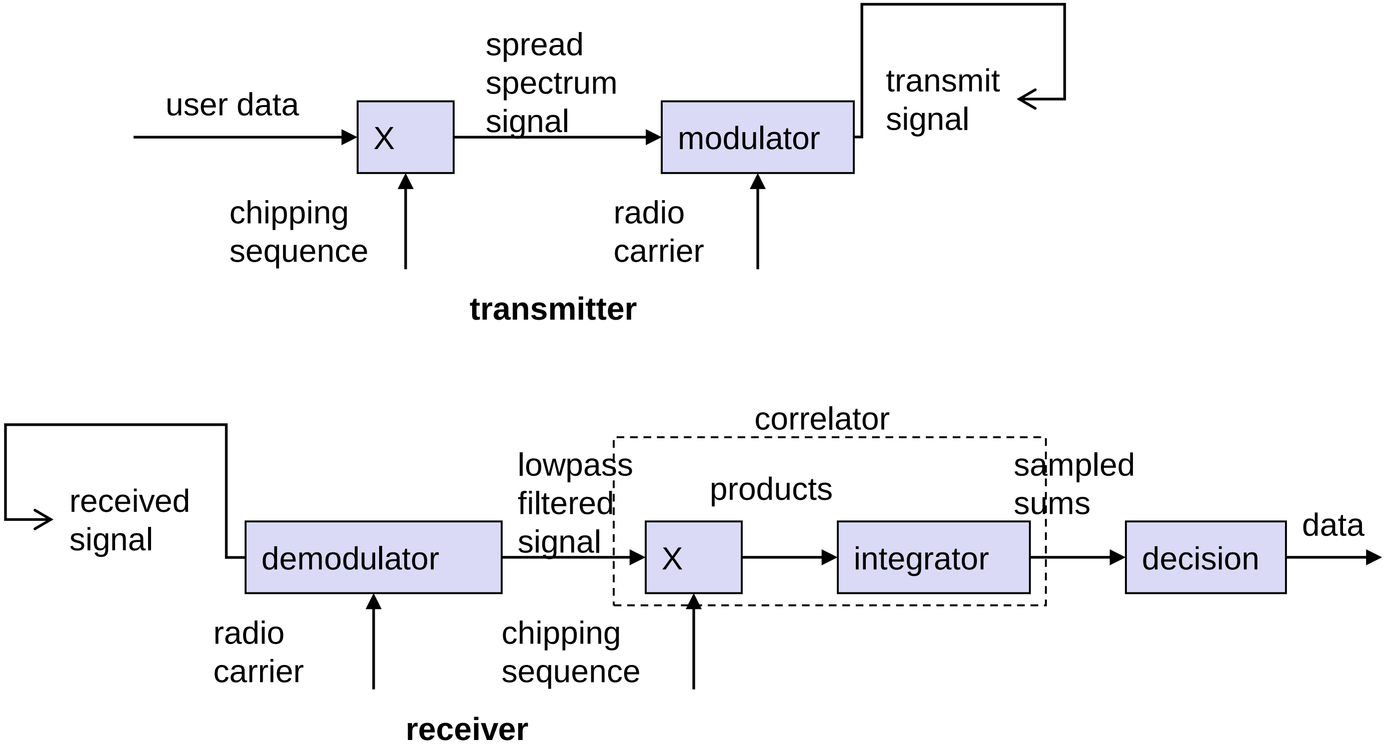
spread spectrum channels

DSSS (Direct Sequence Spread Spectrum) I

- XOR of the signal with pseudo-random number (chipping sequence)
  - many chips per bit (e.g., 128) result in higher bandwidth of the signal
- Advantages
  - reduces frequency selective fading
  - in cellular networks
    - base stations can use the same frequency range
    - several base stations can detect and recover the signal
    - soft handover
- Disadvantages
  - precise power control necessary



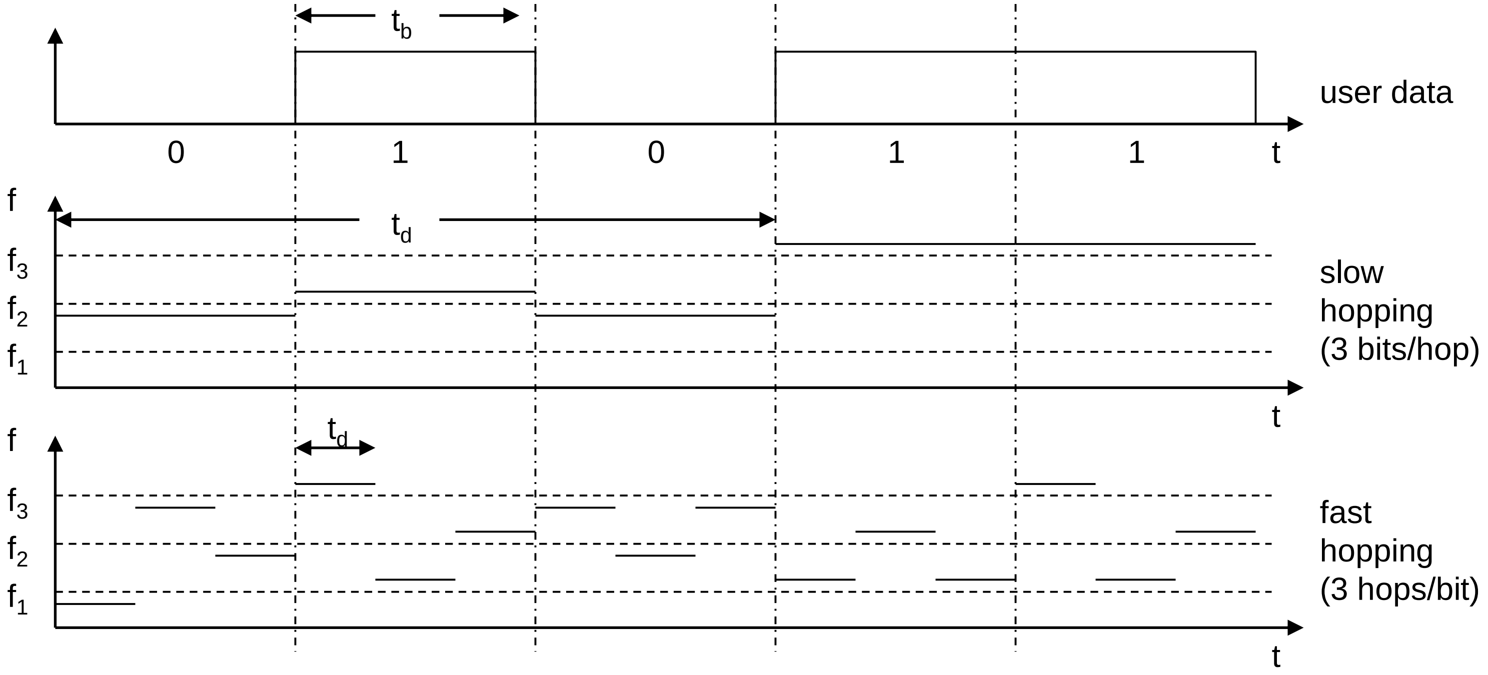
DSSS (Direct Sequence Spread Spectrum) II



FHSS (Frequency Hopping Spread Spectrum) I

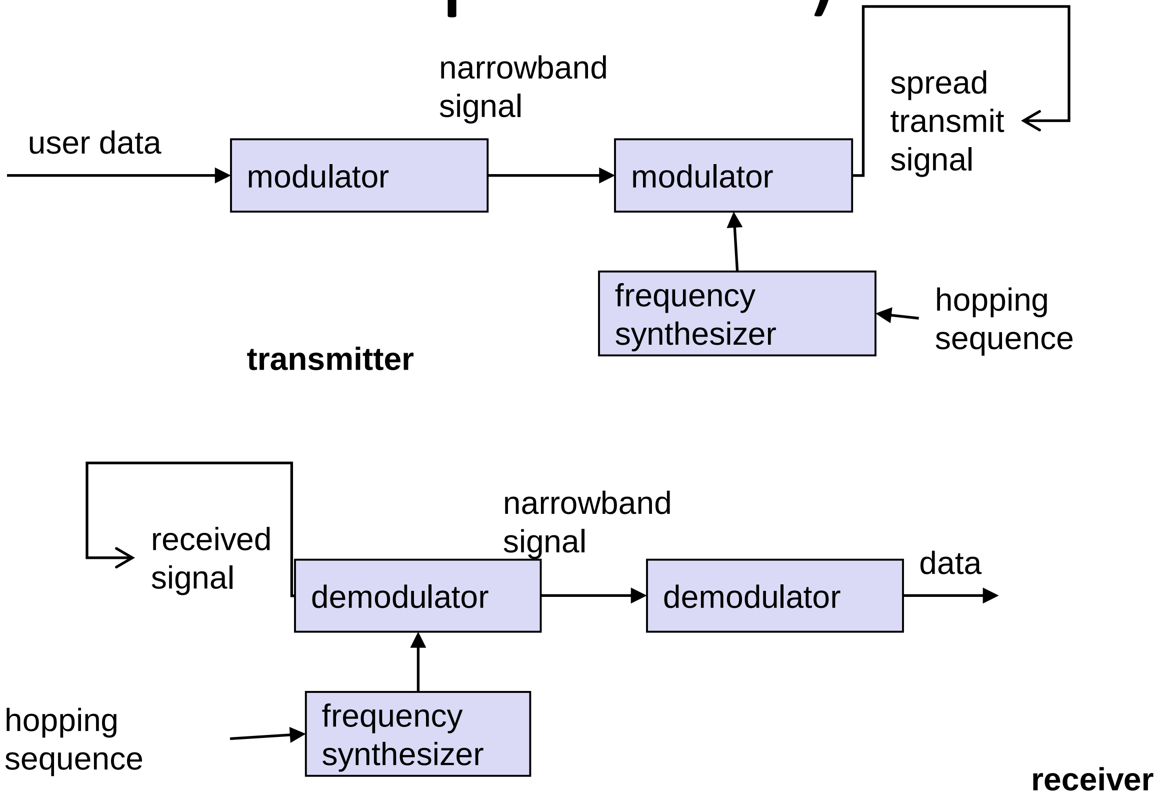
- Discrete changes of carrier frequency
  - sequence of frequency changes determined via pseudo random number sequence
- Two versions
  - Fast Hopping:
    several frequencies per user bit
  - Slow Hopping:
    several user bits per frequency
- Advantages
  - frequency selective fading and interference limited to short period
  - simple implementation
  - uses only small portion of spectrum at any time
- Disadvantages
  - not as robust as DSSS
  - simpler to detect

FHSS (Frequency Hopping Spread Spectrum) II

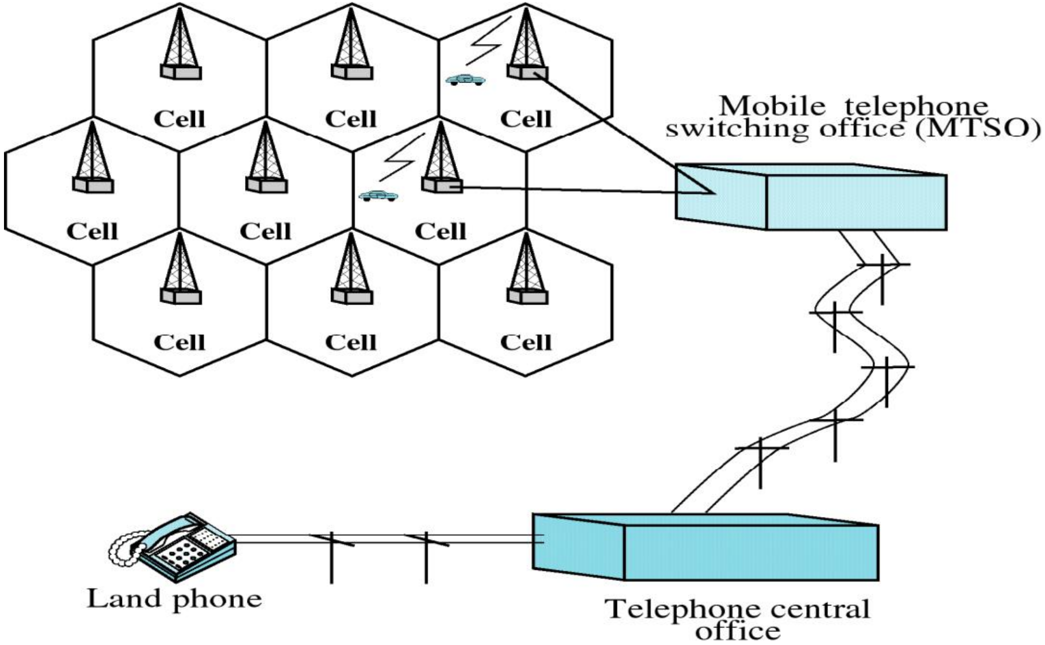


t_b: bit period t_d: dwell time

FHSS (Frequency Hopping Spread Spectrum) III



Cellular System



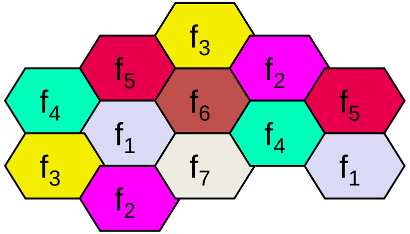
Cell structure

- Implements space division multiplex
  - base station covers a certain transmission area (cell)
- Mobile stations communicate only via the base station

- Advantages of cell structures
  - higher capacity, higher number of users
  - less transmission power needed
  - more robust, decentralized
  - base station deals with interference, transmission area etc. locally
- Problems
  - fixed network needed for the base stations
  - handover (changing from one cell to another) necessary
  - interference with other cells
- Cell sizes from some 100 m in cities to, e.g., 35 km on the country side (GSM) - even less for higher frequencies

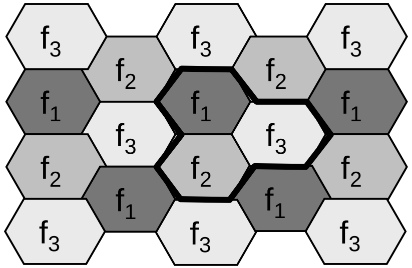
Frequency planning I

- Frequency reuse only with a certain distance between the base stations
- Standard model using 7 frequencies:

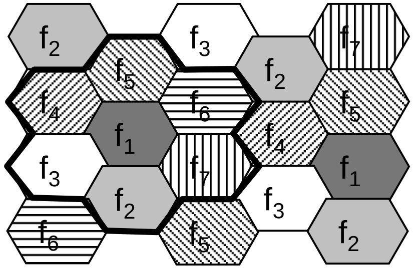


- Fixed frequency assignment:
  - certain frequencies are assigned to a certain cell
  - problem: different traffic load in different cells
- Dynamic frequency assignment:
  - base station chooses frequencies depending on the frequencies already used in neighbor cells
  - more capacity in cells with more traffic
  - assignment can also be based on interference measurements

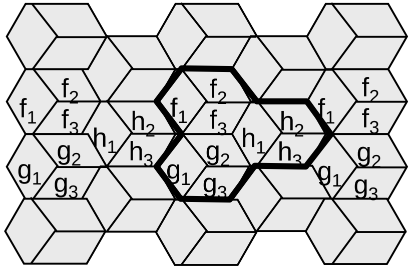
Frequency planning II



3 cell cluster



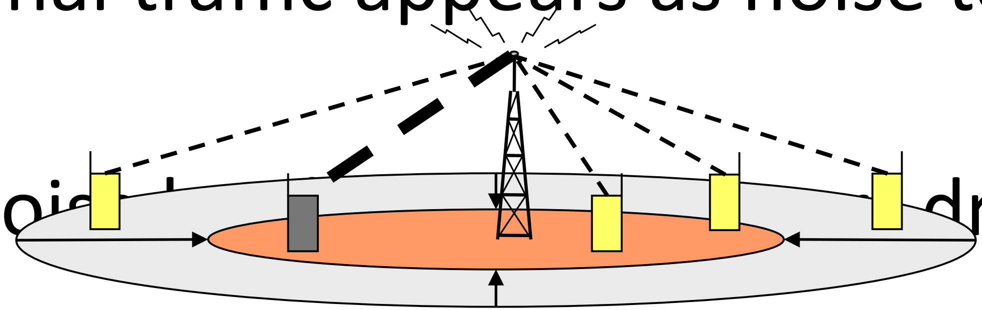
7 cell cluster



3 cell cluster
with 3 sector antennas

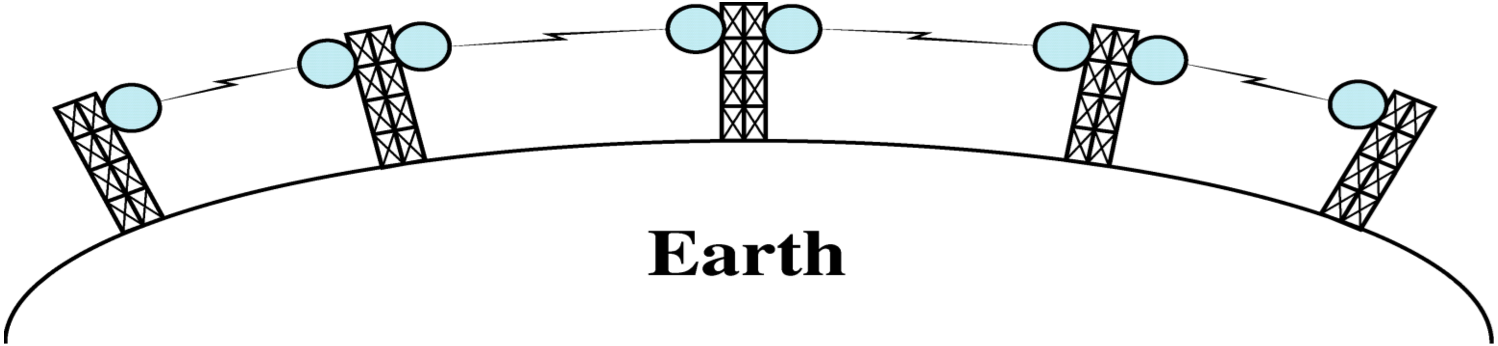
Cell breathing

- CDM systems: cell size depends on current load
- Additional traffic appears as noise to other users
- If the noi … drop out of cells

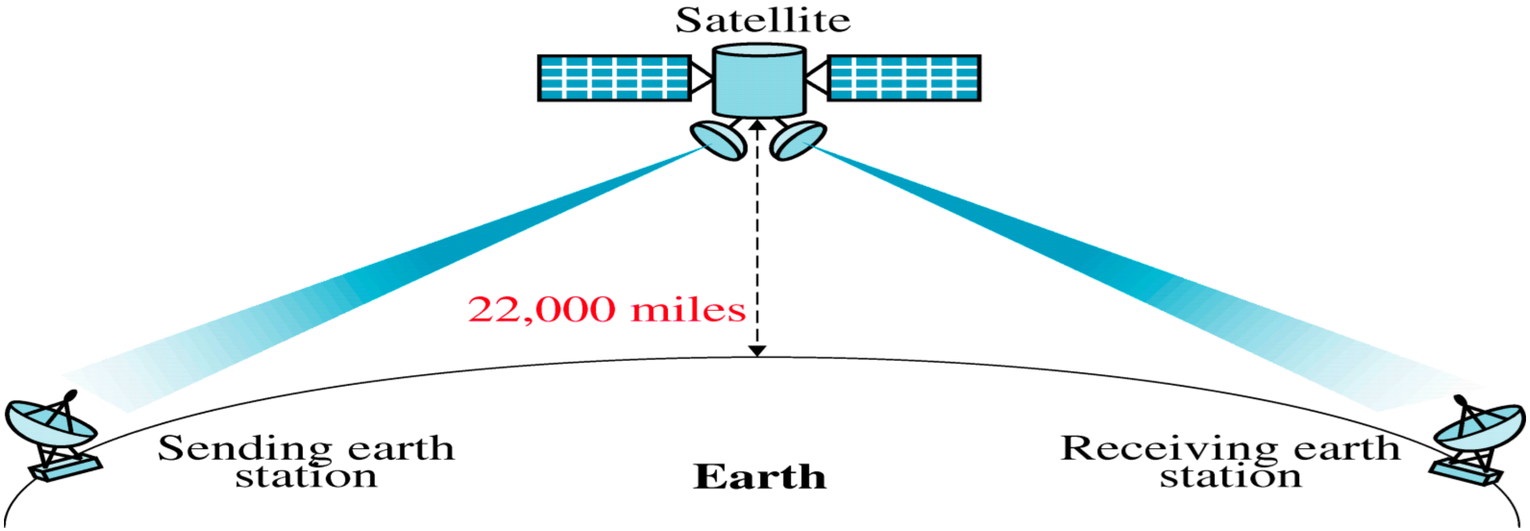


Satellite Communication

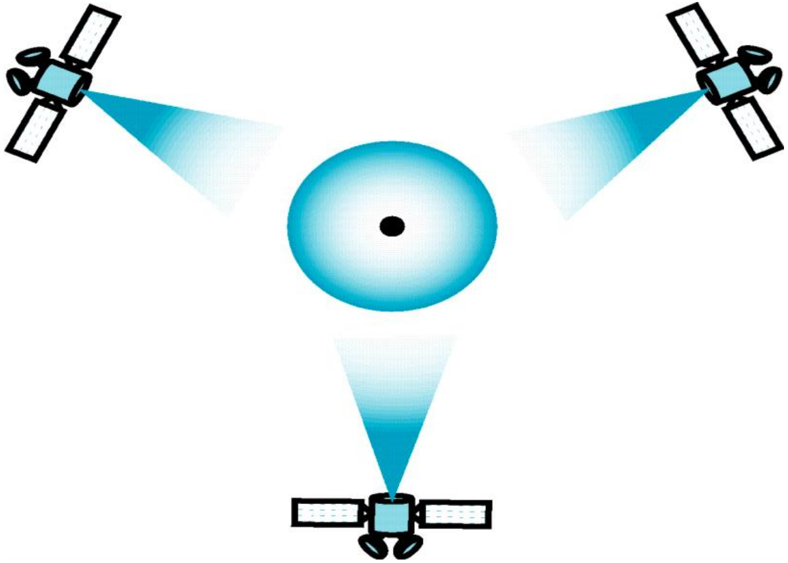
Terrestrial Microwave



Satellite Communication



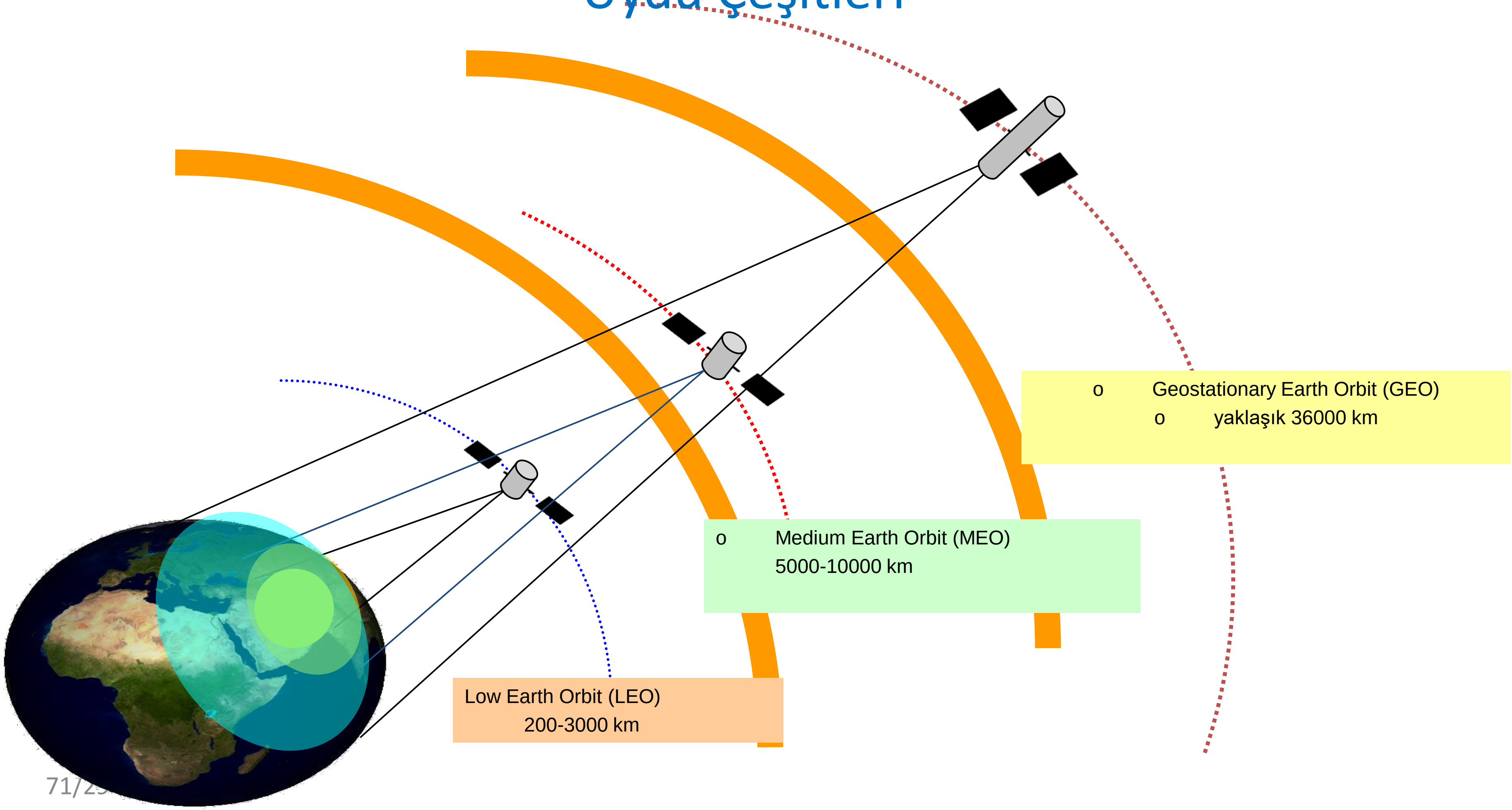
Geosynchronous Orbit



Uydu
Gözetleme ve Haberleşme Sistemleri

Dr. Cahit Karakuş

Uydu Çeşitleri



LEO

- Circular Low Earth Orbit (LEO)
- The altitude of the satellite is constant and equals to several hundreds of kilometres.
- The period is of the order of one and half hours.
- The orbit is nearly 90^{o} inclination, which guarantees that the satellite will pass over every region of the Earth.
- Used for observation and mobile satellites

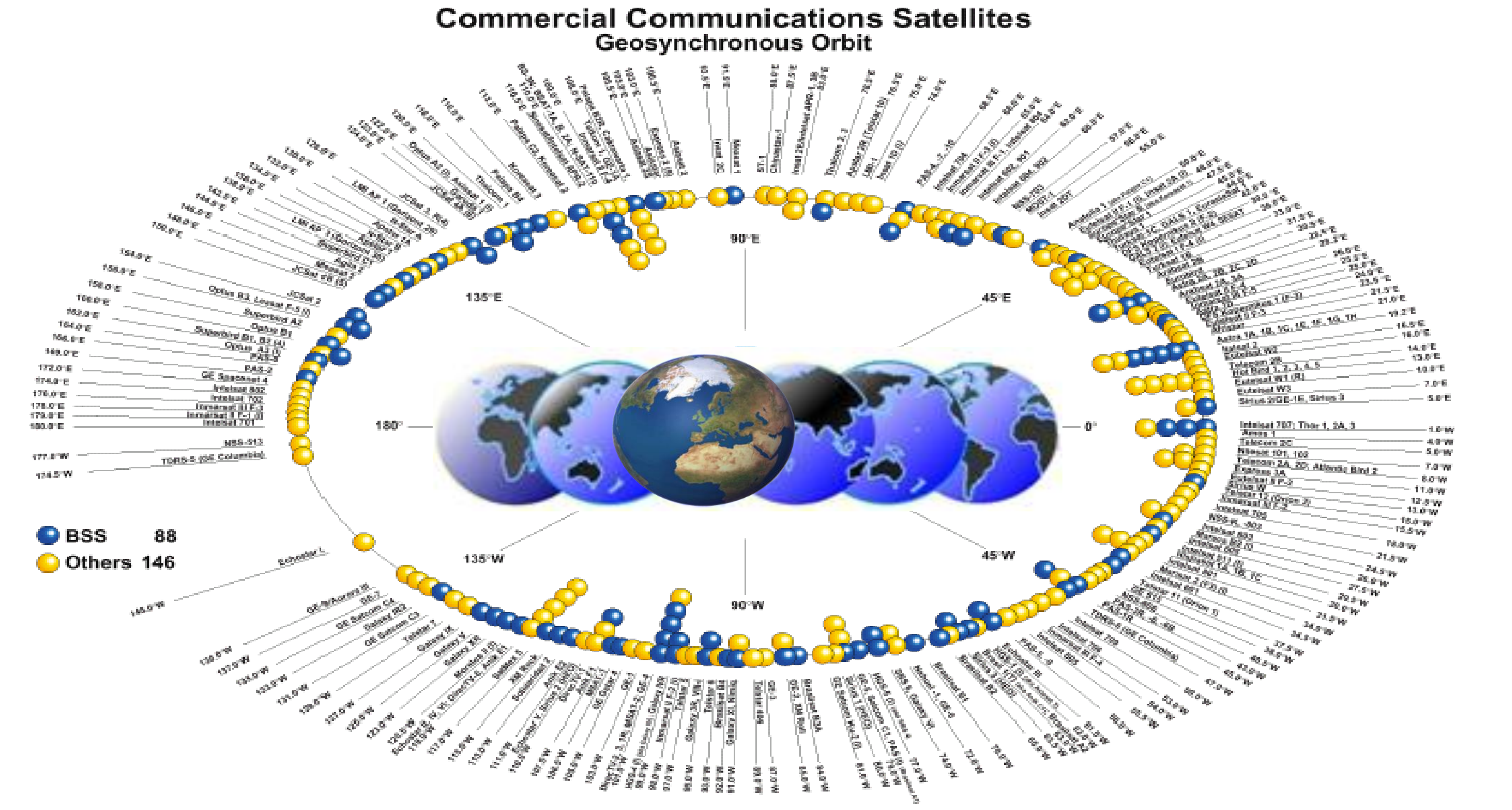
MEO

- Circular Medium Earth Orbits (MEO), also named Intermediate Circular Orbits (ICO)
- The altitude is about 10,000 km and an inclination of about 50^{o} and period of 6 hours.
- With constellations of about 10 to 15 satellites, a continuous coverage of the World is guaranteed

Geostationary

- Circular orbit with zero inclination (equatorial)
- The satellite orbits around the Earth at altitude of 36.000km and in the same direction as the Earth.
- The period is equal to that of the rotation of the Earth and in the same direction.
- The satellite thus appears as a fixed point in the sky and ensures continuous operation as a radio relay in real time for the area of visibility of the satellite
- One satellite covers 43% of the Earth's surface.

Figure 3: Geostationary Satellites by Orbital Location



Turksat Uyduları ve Kapsama Alanları

- Turksat 1A was the first attempt of the project and launched by Ariane 4 from Centre Spatial Guyanais in Kourou, French Guiana on January 24, 1994. Due to the failure of the launcher, the satellite exploded in the air before reaching its orbit.

- Turksat 1B: After the loss of Turksat 1A, Turksat 1B was successfully located at 42°E orbit on August 11, 1994. After the orbital tests Turksat 1B was put into service on October 10, 1994. Turksat 1B has three different coverage areas, Turkey, Central Europe and Central Asia. The satellite carries 16 transponders, 10 of 36 MHz, 6 of 72 MHz operating in Ku band (11–14 GHz). There are 4 transponder switching capability between Turkey and Central Europe, and 3 between Turkey and Central Asia. Turksat 1B provides TV and radio broadcasting, data and telephone transmissions.

- Turksat 1C: After the Turksat 1A launch failure, Aérospatiale Company started building a new satellite under the insurance terms of the turnkey system contract. Modifying the contract with Aérospatiale, Turksat 1C coverage area was enlarged by two big zones different from Turksat 1B coverage areas. Turksat 1C was designed for covering Turkey on west spot and Europe on east spot so as to serve simultaneously between Turkey and Europe with Turkey and Central Asia and to provide direct connection between Europe and Central Asia.

  Turksat 1C was successfully launched at 31.3°E position on July 10, 1996.

  Completing the orbital tests, this satellite shifted from longitude 31.3°E to 42°E.

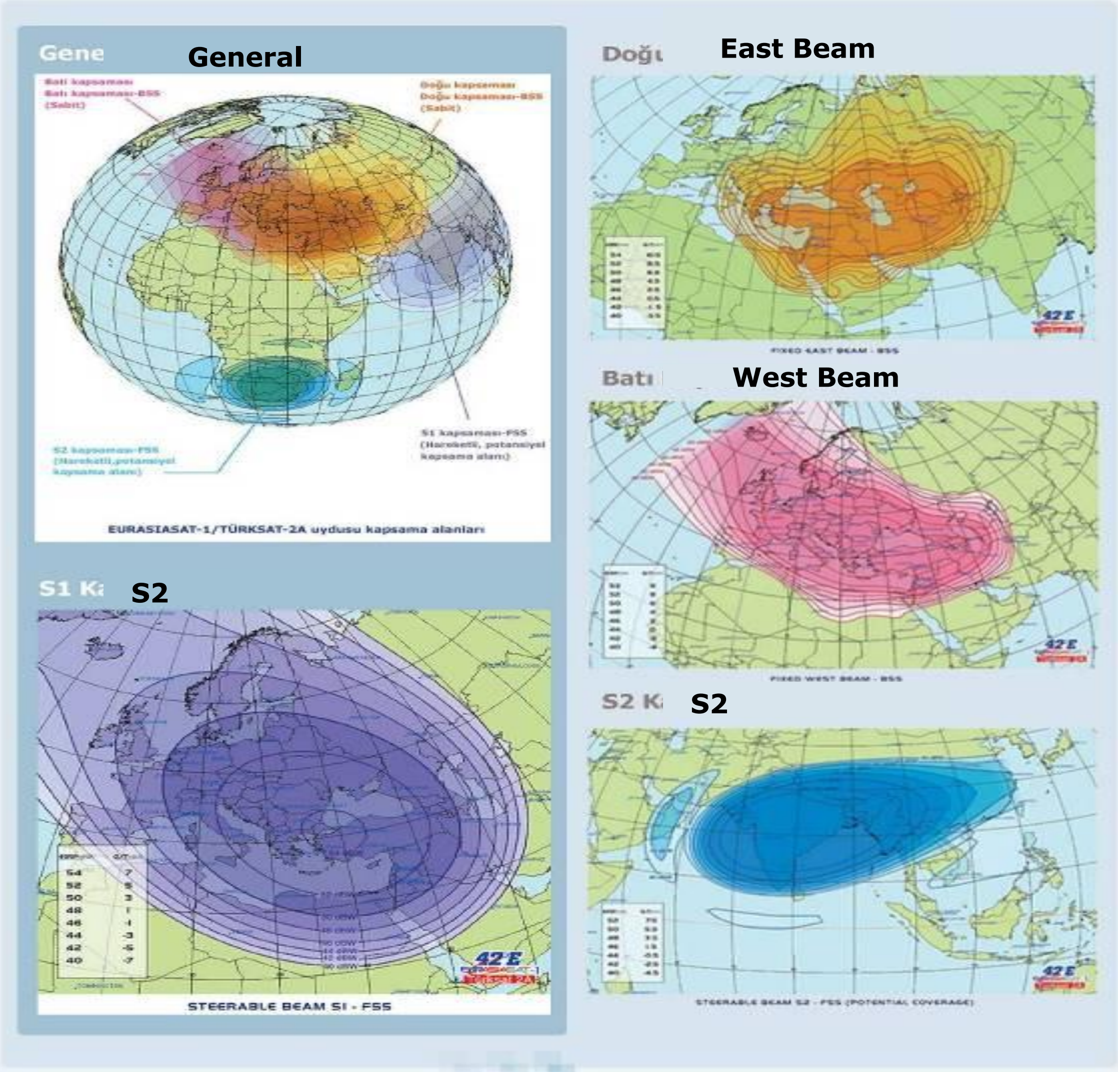
  After this process which took 17 days, the broadcast traffic of the Turksat 1B was transferred to Turksat 1C. Finally when these processes finished Turksat 1B was shifted with similar orbital manoeuvres to 31.3°E position.

  On July 16 2008, all traffic on Turksat 1C was transferred to Turksat 3A. After this date Turksat 1C was shifted at 31.3°E. It is being used in inclined orbit. In October 27 2008, it got deactivated.

Turksat 2A

- Türk Telekom set up a joint venture company with Aérospatiale (merged by Alcatel Space, then Thales Alenia Space), called EurasiaSat, which would be in charge of purchasing a new generation satellite named Turksat 2A (also known as Eurasiasat 1). Turksat 2A started commercial service on February 1, 2001 with the same 42°E location of Turksat 1C.
- Turksat 2A satellite carries a 34 high powered transponders payload consisting of 22 of 33 MHz fixed beam transponders and 12 of 36 MHz transponders with 2 steerable beams.
- Turksat 2A BSS Band fixed beam transponders have two coverage zones like Turksat 1C:
- West Zone covers the British Isles in the west, Scandinavian countries in the north, North Africa in the south, Caspian Sea in the east.
- East Zone covers the Balkan Peninsula in the west, Russian Federation in the north, Pakistan in the south, China national boundary in the east.
- Inside of the footprint such as south Asia and Republic of South Africa can be accessed over the Turksat 2A FSS Band steerable beam transponders.

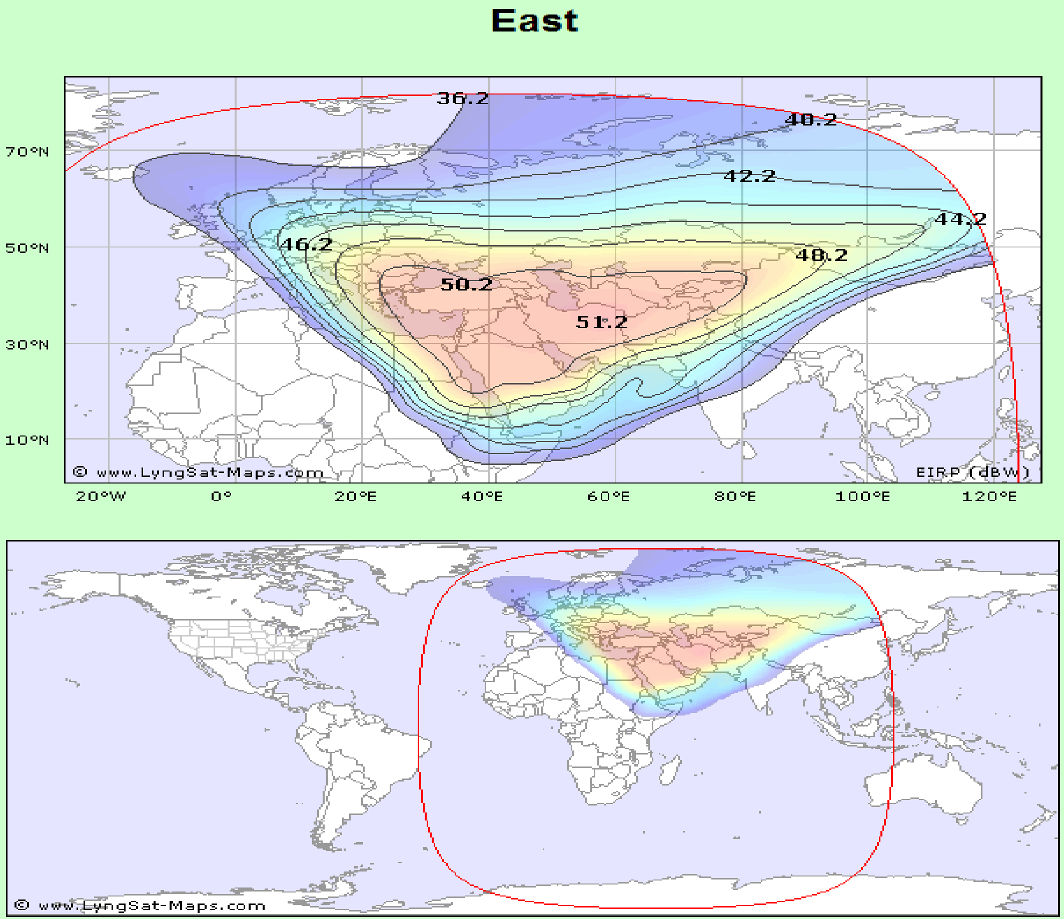
Eurasiasat-1



Turksat 3A

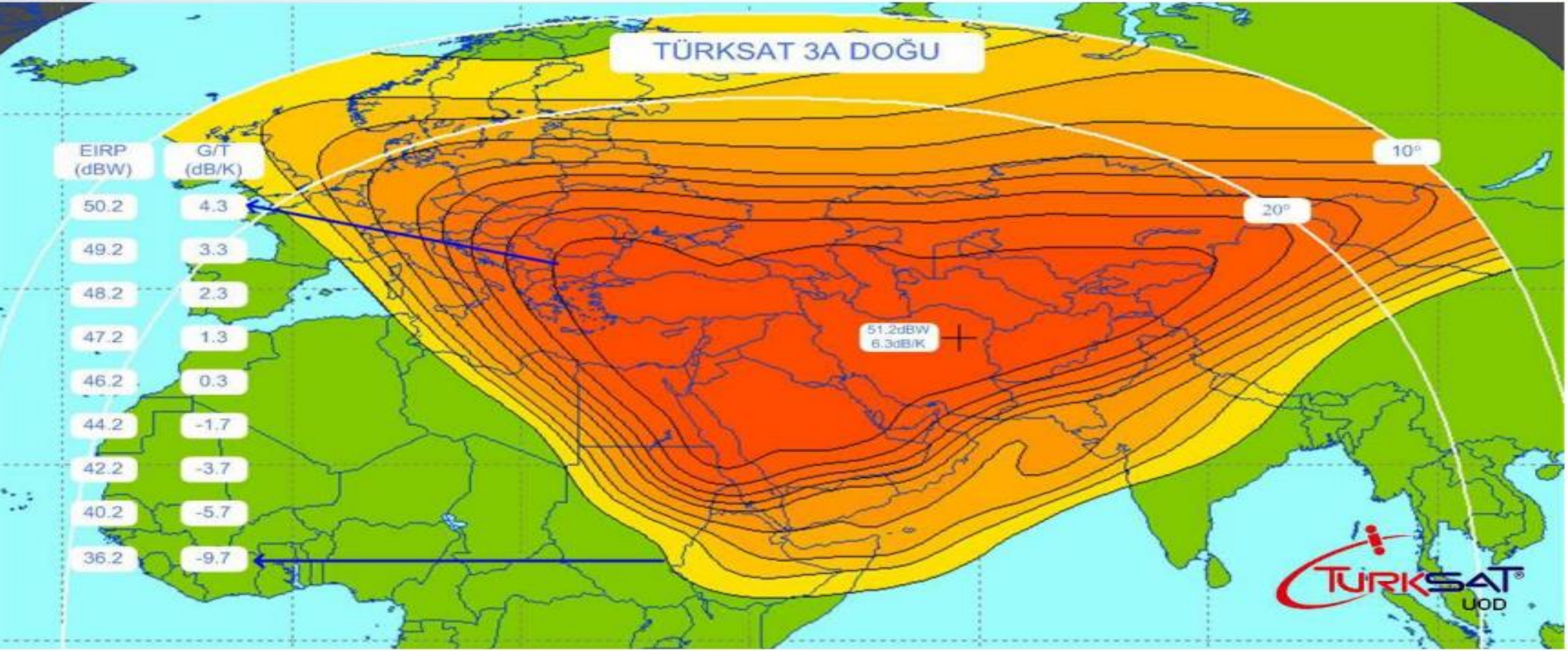
- Turksat 3A satellite will enable Turksat to offer telecommunication services as well as direct TV broadcasting services though a broader area than its existing satellites covering Turkey, Europe, Middle East, North Africa and Central Asia. With the help of its switchable transponders, Turksat 3A will act as a bridge between Europe and Asia. Turksat 3A's Turkey coverage has been specially designed to provide very efficient gain for broadband applications like VSAT services giving customers low-cost, up-link systems.
- Based on Thales Alenia Space Spacebus 4000B2, Turksat 3A is fitted with 24 Ku-band transponders and offers beginning of life power of about 8 kW. Positioned at 42°E, Turksat 3A will weight 3060 kg at launch and will replace Turksat 1C satellite.[3]
- Turksat 3A was launched by Arianespace atop an Ariane 5ECA carrier rocket, along with the British Skynet 5C satellite, in a dual-payload launch on 12 June 2008 at 22:05:02 GMT, from ELA-3 at the Guiana Space Centre.

Turksat 3A

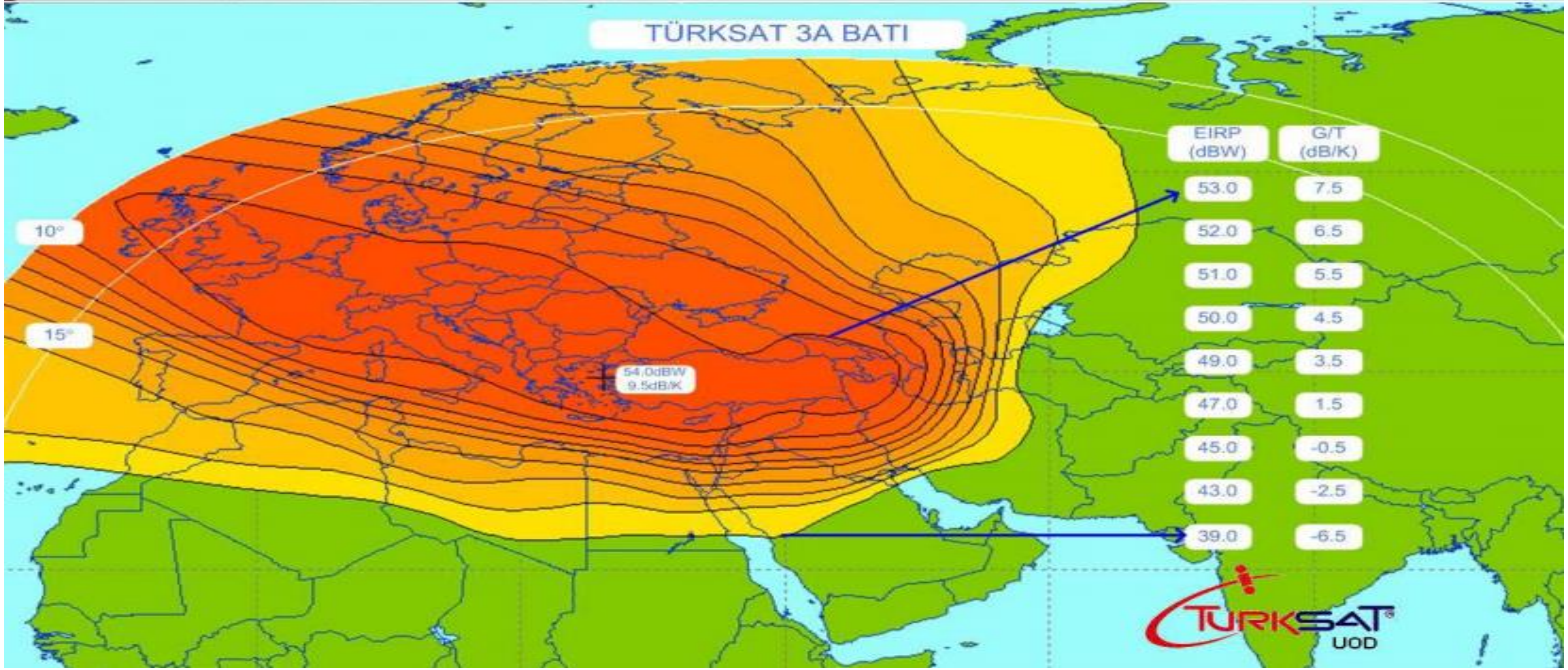


Ku band	
EIRP (dBW)	Size (cm)
>50	50
50	50-60
49	55-65
48	60-75
47	65-85
46	75-95
45	85-105
44	95-120
43	105-135
42	120-150
41	135-170
40	150-190
39	170-215
38	190-240
37	215-270
36	240-300
35	270-335
34	300-380
33	335-425
32	380-475
31	425-535
30	475-600
<30	>535

Turksat 3A East Beam

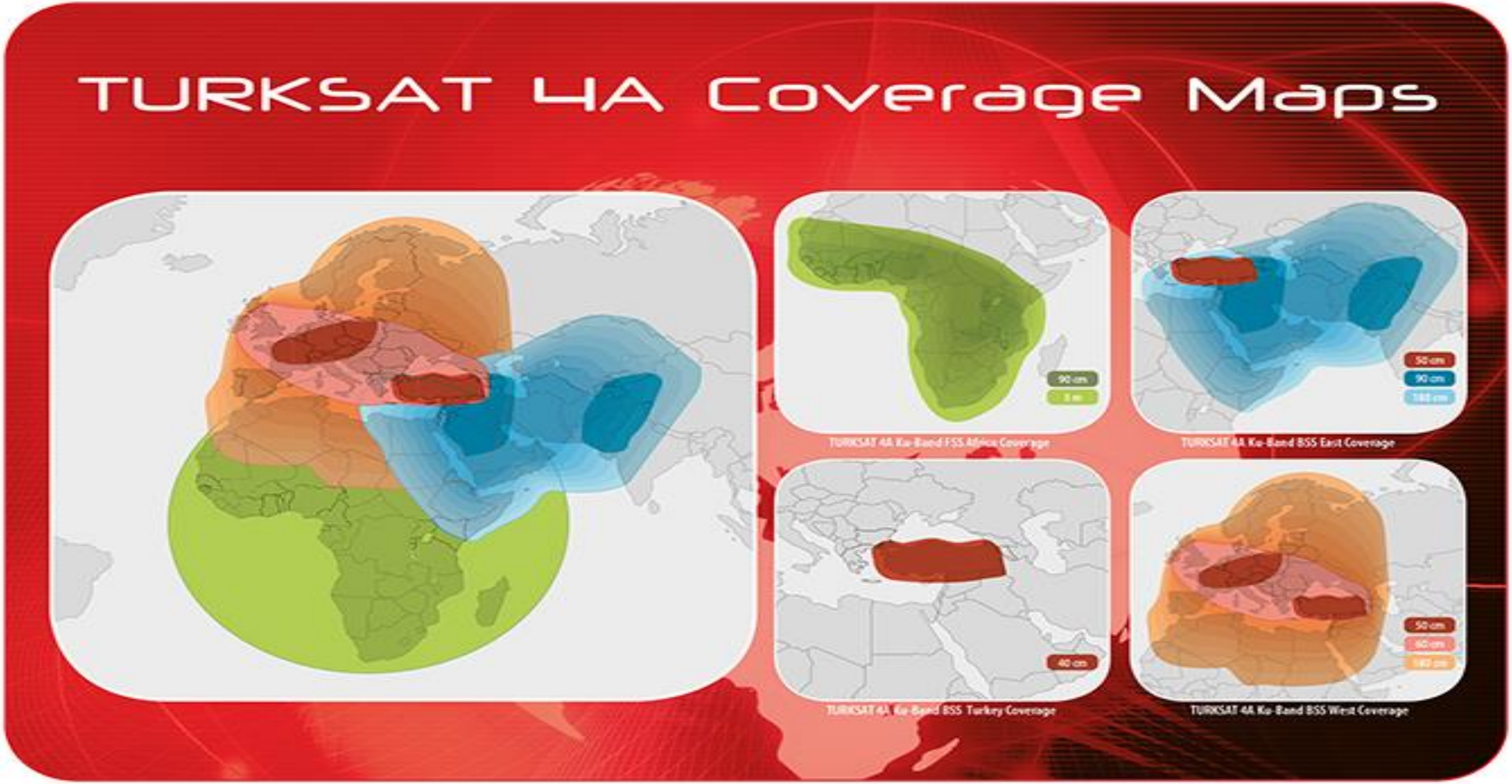


Turksat 3A West Beam



Turksat 4A

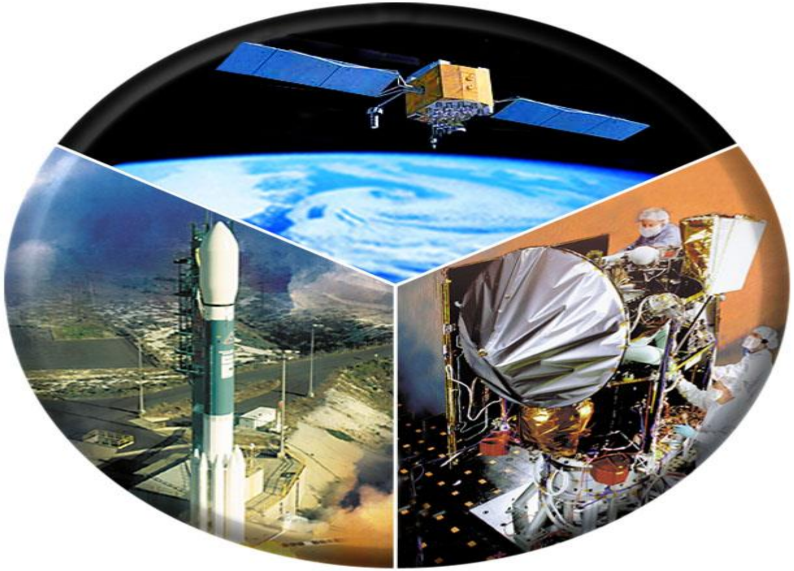
- Turksat 4A was successfully launched from the Baikonur Cosmodrome temporarily at 50°E position on 14 February 2014 at 23:09 GMT. It will remain at this position around three months. During this period, orbital and subsystem tests will be conducted. Thenafter, the satellite will be transferred to 42°E
- Turksat 4A will enable Turksat AS to offer telecommunication and direct TV broadcasting services throughout Turkey, as well as in Europe, Central Asia, the Middle East and Africa. Turksat 4A will provide Ku-band high-power direct TV broadcasting channels and both C- and Ka-band communications channels.


TURKSAT 4A Coverage Maps
90 cm
TURKSAT 4A Ku-Band FSS Africa Coverage
50 cm
90 cm
TURKSAT 4A Ku-Band BSS East Coverage
40 cm
TURKSAT 4A Ku-Band BSS Turkey Coverage
50 cm
TURKSAT 4A Ku-Band BSS West Coverage

Uydu Haberleşmesi Kullanım Alanları

<u>Communications</u>
- Wireless Networks
- Messaging
- Telephony
- Mobile Satellite phones
- Internet Backbone
- VSAT's
- Credit Card Validation

<u>Remote Sensing</u>
- Oil pipeline monitoring
- Rail Management
- Infrastructure Planning
- Forest Fire Prevention
- Urban Planning
- Flood and Storm watches
- Air Pollution management



<u>GPS/Navigation</u>
- Position location
- Timing
- Land/Sea Rescue
- Mapping

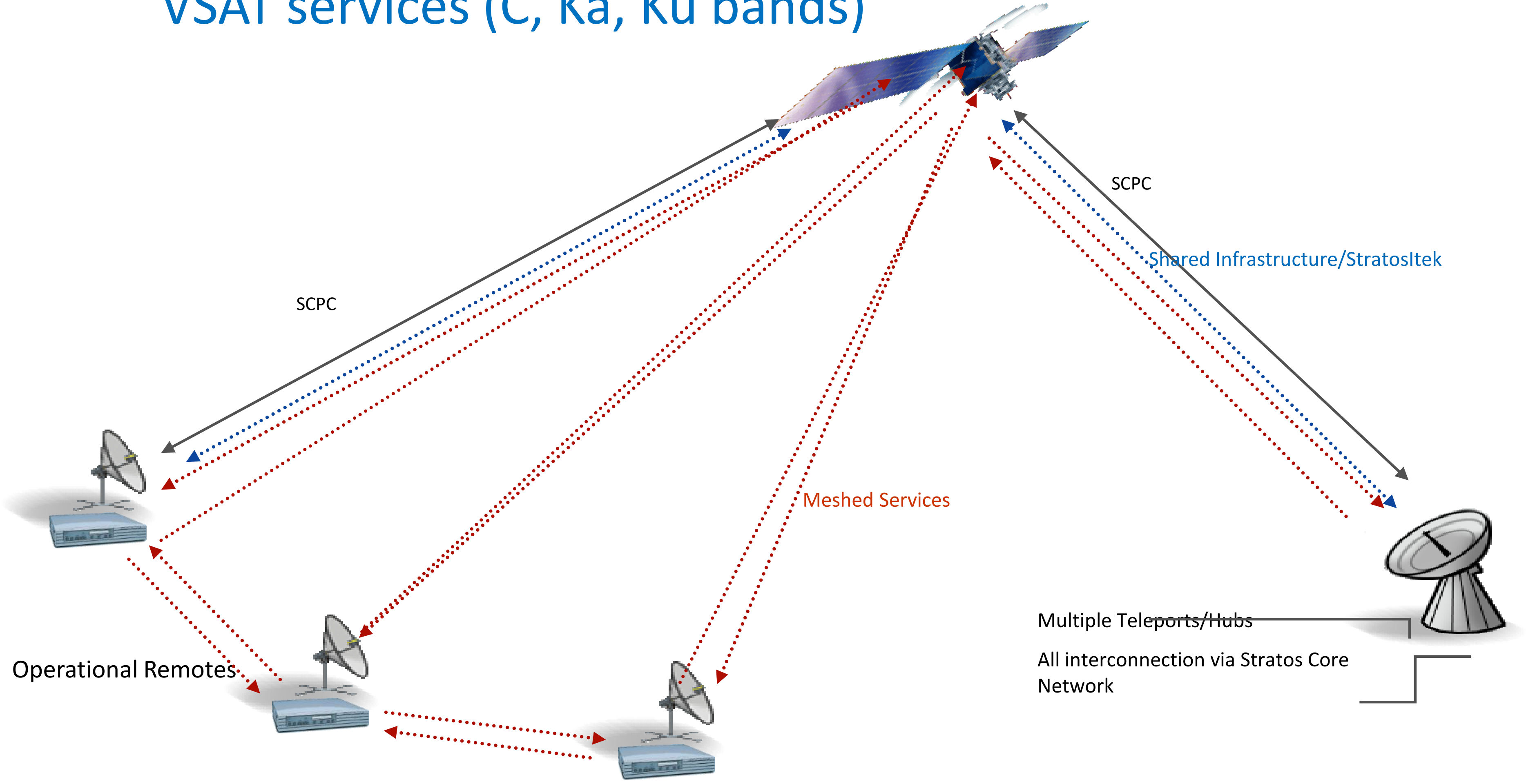
<u>Broadband</u>
- Tele-Medicine
- Tele-Education
- Videoconferencing

<u>Entertainment</u>
- Direct to Consumer TV
- Broadcast and Cable Relay
- DARS

<u>Support Services</u>

Launch Vehicles	Ground Equipment	Insurance	Manufacturing

VSAT services (C, Ka, Ku bands)

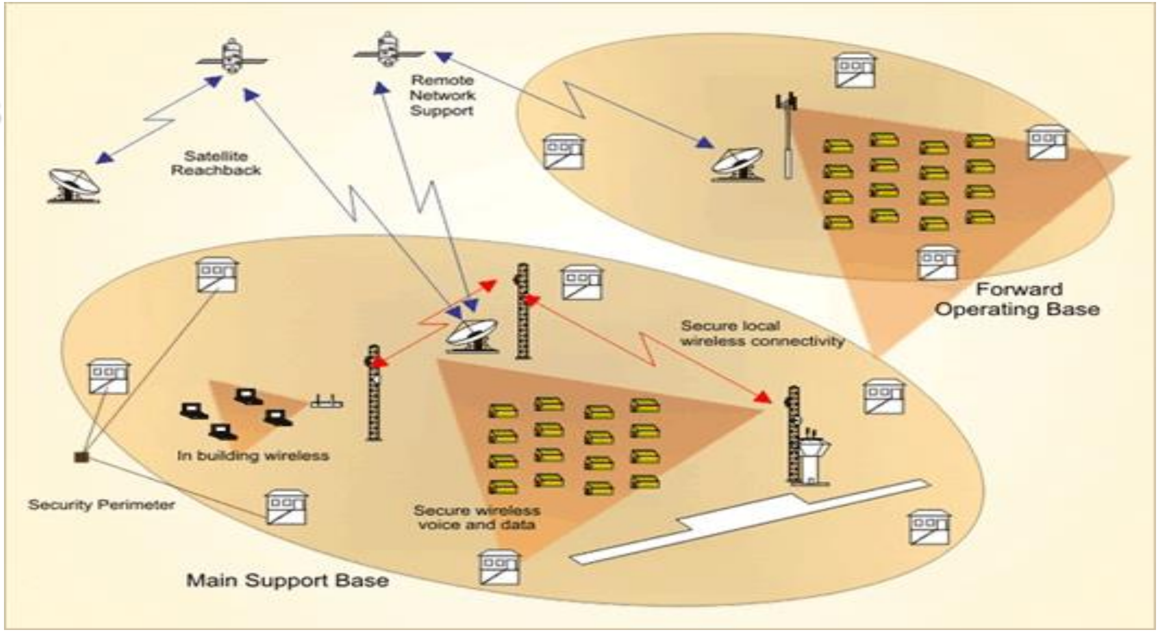


USA – Bosnia, Kosovo, Iraq, Afghanistan

SCPC – Wireless GSM Networking

SCPC satellite link and double hop to connect regional GSM networks in Bosnia, Kosovo, Iraq and Afghanistan.

Network utilizes microwave and local wireless technologies for local service extensions.



Spacelink INTERNATIONAL

Uzaktan Algılama

- Provides scientific, industrial, civil, military and individual users with high-resolution images for:
  - natural resource monitoring
  - urban and utility/telecom planning
  - agricultural assessments
  - insurance and risk management
  - oil and gas exploration
  - mapping
  - natural disaster/emergency response
  - national/regional security

- Sub Meter commercial imagery

Link Parameters

- A link consist of four parts.

1. Transmitter (Tx)
2. Receiver (Rx)
3. Media
4. Noise

A link equation is waritten as

Pr=Pt+Gt+Gr- Sum of all losses

- Antenna Gain
- Radiation Pattern
- Beamwidth
- Polarisation
- XPD (Cross Polarisation Discrimination)
- EIRP (Equivalent Isotropically Radiated Power)
- RPE (Radiation Pattern Envelop)
- Received Signal Power

Friis Equation

$$A_{eff} = \frac{\lambda^2 G_R}{4\pi}$$

where G_R is the gain of the receiving antenna and λ is the wavelength. Now we can write the expression for computing the received power as

$$P_{received} = \psi A_{eff} = = \frac{G_{ES} P_{ES}}{4\pi r^2} \frac{\lambda^2 G_R}{4\pi}$$

We can rewrite the above in dB as

$$P_{received} = EIRP_{ES} + G_R - 10 \text{ Log} \left(\frac{4\pi r}{\lambda} \right)^2$$

Flux Density

Flux Density is a measure of energy that is available for gathering from a particular source. It is called the *Radio Power of a Source* in Astronomy. The Sun, Moon, and stars all emit Radio Power (Flux Density). The Sun bathes us with Flux density at the rate of 10^{-19} Watts per square ft per unit bandwidth. (ITU however defines this unit bandwidth to be equal to 4 MHz.)

The Flux Density is defined by

$$\psi = \frac{G P}{4\pi r^2}$$

Computing Free Space Loss

For a signal going from ground to the satellite, the free space loss is largest of all other types of losses. It can be simplified and written as

$$FSL = \left(\frac{4 \pi r}{\lambda} \right)^2$$

Simplifying, we can write this in dB form as

Free Space Loss (FSL) = 32.4 + 20 Log (r) + 20 Log (f)

where *r* is the distance and *f* the frequency.

The Earth Station has an EIRP of 60 dB and the satellite antenna has a gain of 52 dB at 12 GHz. What is the received power at the satellite?

$P_{received} = EIRP_{ES} + G_R - FSL$

$P_{received} = 60\ dBW + 52 - FSL$

$FSL = -92.4 + 20 \text{ Log } (22000) + 20 \text{ Log } (12 \times 10^9) = 196\ dB$

$P_{received} = 60\ dBW + 52 - FSL = -80\ dBW$

Noise Figure

An antenna has a noise temperature of 70^0K. What is the noise power density? (b) What is the noise power if we assume that the bandwidth is 24 MHz.

(a) $N_0 = k\,T_N = 1.38 \times 10^{-23} \times 70 = 9.66 \times 10^{-22}$ Joules

(b) $P_N = N_0\,B_N = 9.66 \times 10^{-22} \times 24 \times 10^6 = 2.3 \times 10^{-14}$ Watts

In doing link budgets, calculating the G/T or the Noise Figure of a receiver

A satellite receiver has a gain of 30 dB and its antenna temperature is 700K. What is its G/T?

G/T = 30 dB - 10 log 700 = 1.5 dB

the link power and noise

Now let's write the link equation in terms of C/N

$$C = EIRP + G - Losses$$

In above, first write out the carrier power, which is just the sum of the EIRP of the transmitter, the gain of the receiver and any associated implementation losses. So thats all the power that is available to the signal.

Remember we said that

$$N = k\ T\ B_{N},$$

Now divide the above expression for C, with expression for N and write it out in dB form

$$C/N = EIRP + G/T - Losses - k - B_n$$

Now let's convert C/N to C/N_0, we do that by dividing the above by Noise Bandwidth B_n.

$$C/N_0 = C/N \times B_n$$

$$C/N_0 = EIRP_{ES} + G/T_s - Losses - k - B_n + B_n$$

The bandwidth has dropped out as we said earlier, all terms containing the N_0 term are independent of signal bandwidth. C/N_0 is then a figure that is independent of signal bandwidth.

However, you will hear much more often about C/N (also referred to as SNR) that C/N_0. What is nice about C/N as opposed to C/N_0 is that we can say things like, "I want my CNR to be 15 dB for the uplink and 10 dB for the downlink." Since has a range that applies universally, it makes it easy to compare links.

The figure C/N allows us to compare systems and determine if we have met certain specs and as such is a much more important number than C/N_0.

the complete set of link equations.

The uplink

$$\frac{C}{N_0} = EIRP_{ES} + \frac{G}{T}_{Satelliterceiver} - FreeSpaceLos - k - Losses_{rain,misalign} - IBO$$

The downlink

$$\frac{C}{N_0} = EIRP_{Satellit} + \frac{G}{T}_{Ground\,Receiver} - FreeSpaceLos - k - Losses_{rain,misalign} - OBO$$

Conversion to E_b/N_0

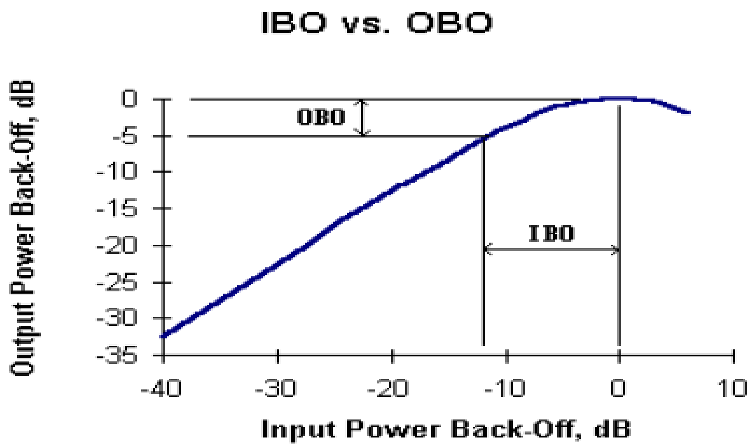
$$\frac{E_b}{N_0} = \frac{C}{N_0} - R_b$$

Link Margin

$$Margin = \left(\frac{E_b}{N_0}\right)_{available} - \left(\frac{E_b}{N_0}\right)_{requred}$$

Output and Input Backoff

The Uplink Transmitter has a rated EIRP of a certain level, but if the uplink transmitter transmits instead at a lower power level, then this reduction in power is called the input backoff for the satellite. But if the input power is backed off then obviously the output power would also be backed off, and the maximum EIRP can not be delivered. The reduction in the output power due to the reduction in the input power or input-backoff is called the Output Backoff. The relationship between Input Backoff (IBO) and Outback off (OBO) is not linear and generally looks like the curve of Figure 11.

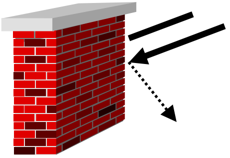


Operating the transmitter at less than max power on earth or on satellite requires adjustment to the EIRP, called OBO

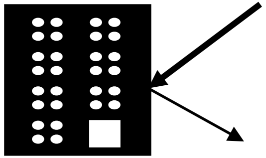
Signal propagation

- Propagation in free space always like light (straight line)
- Receiving power proportional to $1/d^2$
  (d = distance between sender and receiver)
- Receiving power additionally influenced by
  - fading (frequency dependent)
  - shadowing
  - reflection at large obstacles
  - refraction depending on the density of a medium
  - scattering at small obstacles
  - diffraction at edges

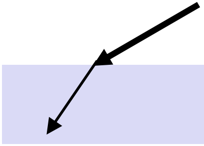
- Equipment, antenna, and waveguide failures
- Fading and distortion from multipath reflections
- Absorption from rain, fog, and other atmospheric conditions
- Interference from other frequencies



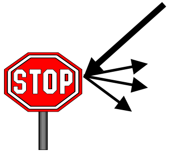
shadowing



reflection



refraction



scattering

diffraction

Yayınım gücünü olumsuz etkileyen faktörler

- Fading
- Bulut hareketi
- İklimsel değişimler, Yağmur, Kar, Tipi
- Gaz
- Yer hareketleri

Rain

Signal attenuation due to rain is the second most significant after free space loss. It is particularly significant for frequencies in the Ku and Ka bands. We have to deal with rain losses for both uplinks and downlinks.

It also varies a great deal from location to location since it is a function of the rain rate. The attenuation can vary from .1 dB — 12 dB

Accommodations are instead made by providing ground diversity, which just means that there are two receivers instead of one which may or may not be geographically separated. Ground Diversity such as having another ground station located a few miles away in a rainy region can improve the rain attenuation by more than half. Other ways to accommodate for location-specific rain attenuation is to allow higher power for the transmitters and variable error correcting codes and variable data rates.

There many popular rain models that help us compute the rain loss. Some of these are

1. NASA Rain Attenuation Model
2. Crane Rain Attenuation Model
3. CCIR Rain Attenuation Model

Gaseous Absorption

The attenuation caused by clouds and fog due to the phenomena of gaseous absorption and has to be considered particularly for frequencies above 10 GHz. These effects are primarily due to amplitude reduction which reduces signal power, but water can also affect the phase of dual-polarized signals.

For Ku-band and below, these losses are small and can be ignored.

Sensitivity

- Minimum detectable input signal level for a given output SNR (also called *noise floor*)
- Not necessarily related to required output SNR

Antenna Gain

The gain of an antenna is the ratio of the power radiated (or received) per unit solid angle by the antenna in a given direction to the power radiated (or received) per unit solid angle by an isotropic antenna fed with the same power.

$$G_{max} = (4\pi / \lambda^2)\, A_{eff}$$

The gain is maximum in the direction of maximum radiation

Antenna Effective Area

The antenna effective area (A_{eff}) is the equivalent electromagnetic surface area of the antenna.

$$A_{eff} = \eta A$$

$$A = \frac{\pi D^2}{4}$$

$$G_{max} = \eta (\pi D / \lambda)^2$$

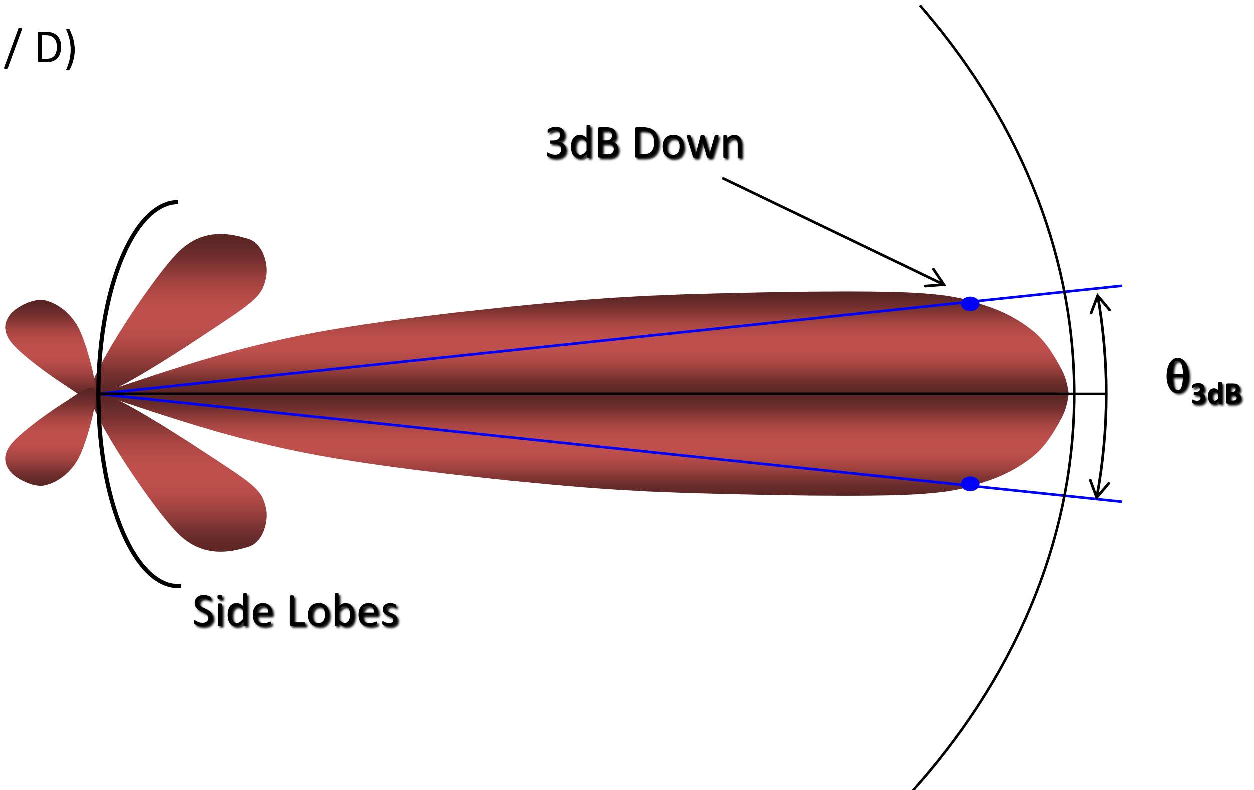
or

$$G_{max} = \eta (\pi D f / c)^2$$

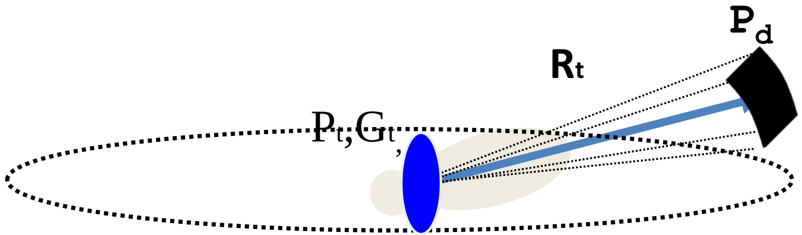
The efficiency factor η is typically 0.55 - 0.6

Antenna Radiation Pattern
(Polar Representation)

$\theta_{3dB} = 70 (\lambda / D)$

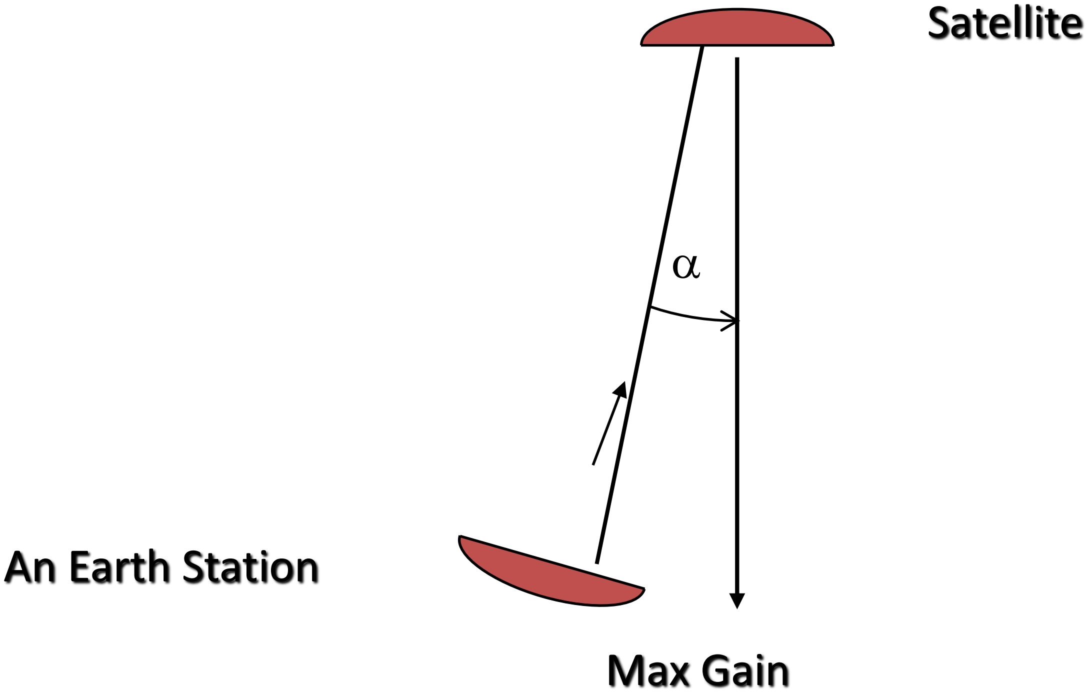


The power density at the target

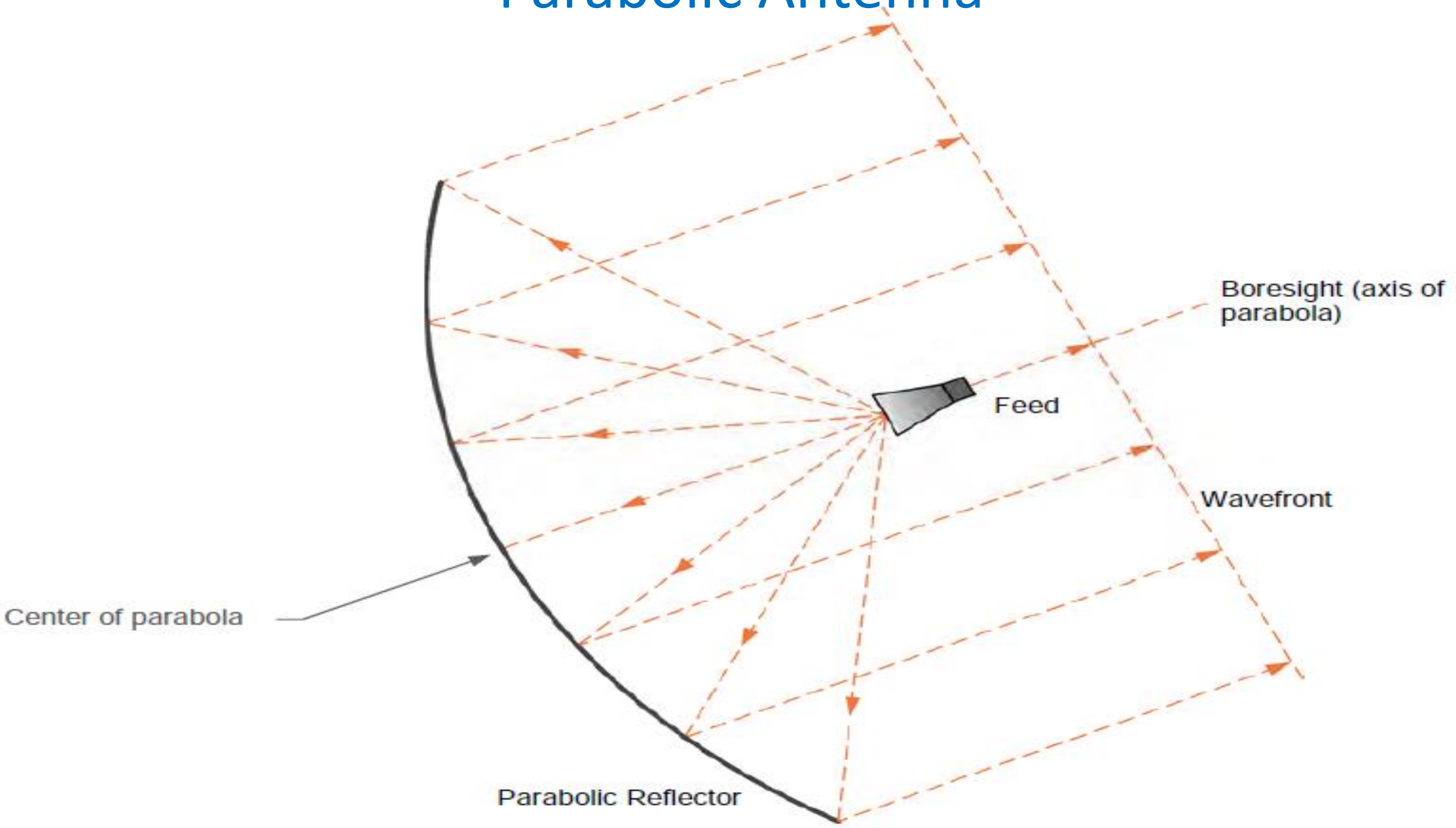


$$P_d = \frac{P_t G_t}{4\pi R_t^2} \quad , W/m^2$$

Antenna Pointing Error

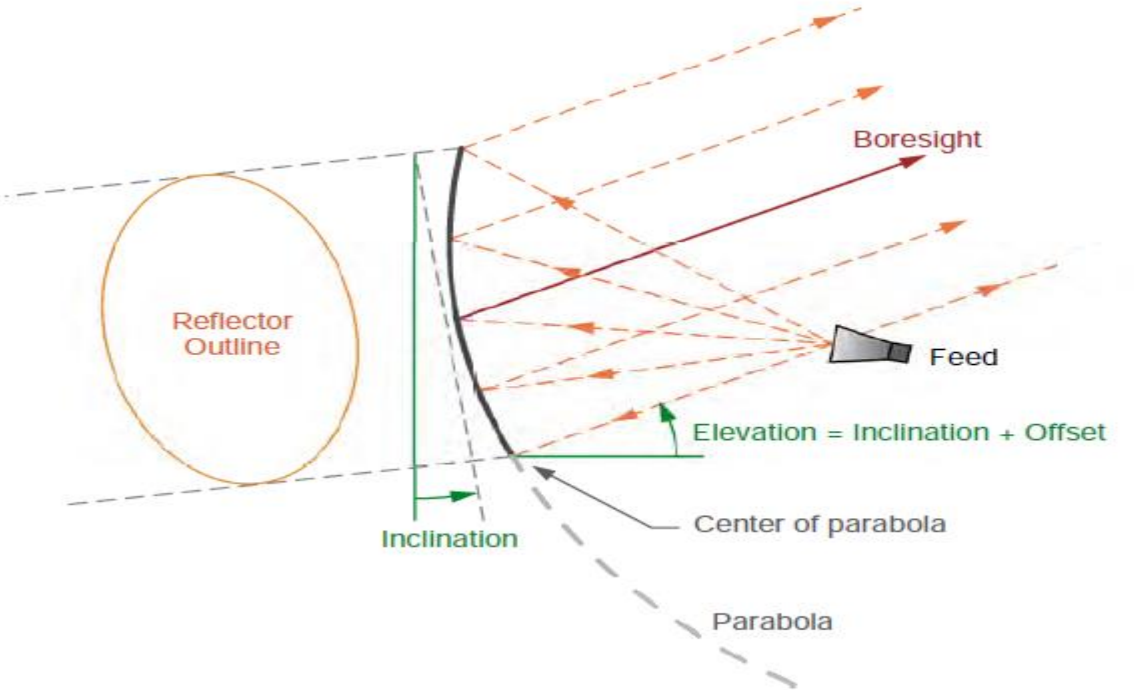


Parabolic Antenna



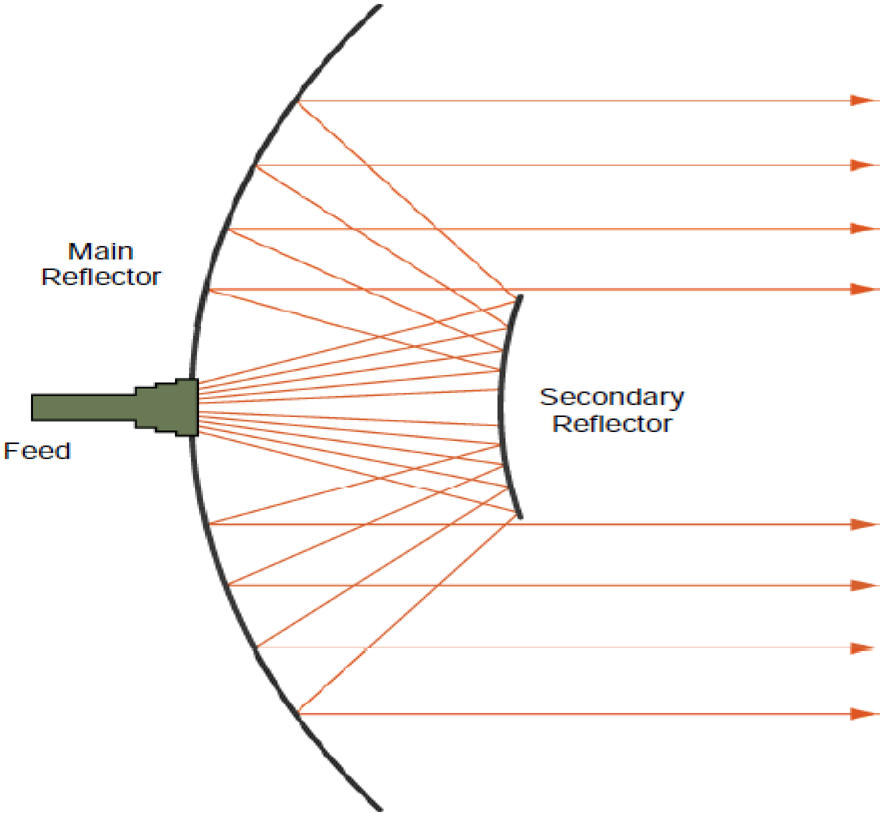
Parabolic antenna.

Offset- Feed Parabolic Antenna



Offset-feed parabolic antenna.

Cassegrain Antenna



Cassegrain antenna.

Earth Station Antenna Dish Sizes

- Earth Station Category Diameter
- Very large dish 15 to 30 m diameter
- Large dish 7 to 15 m diameter
- Medium dish 3 to 7 m diameter
- Small dish 0.5 m to 3 m diameter

The dish size is directly related to the gain of the antenna, which is a measure of how much the antenna focuses the RF signal.

Earth station dish sizes

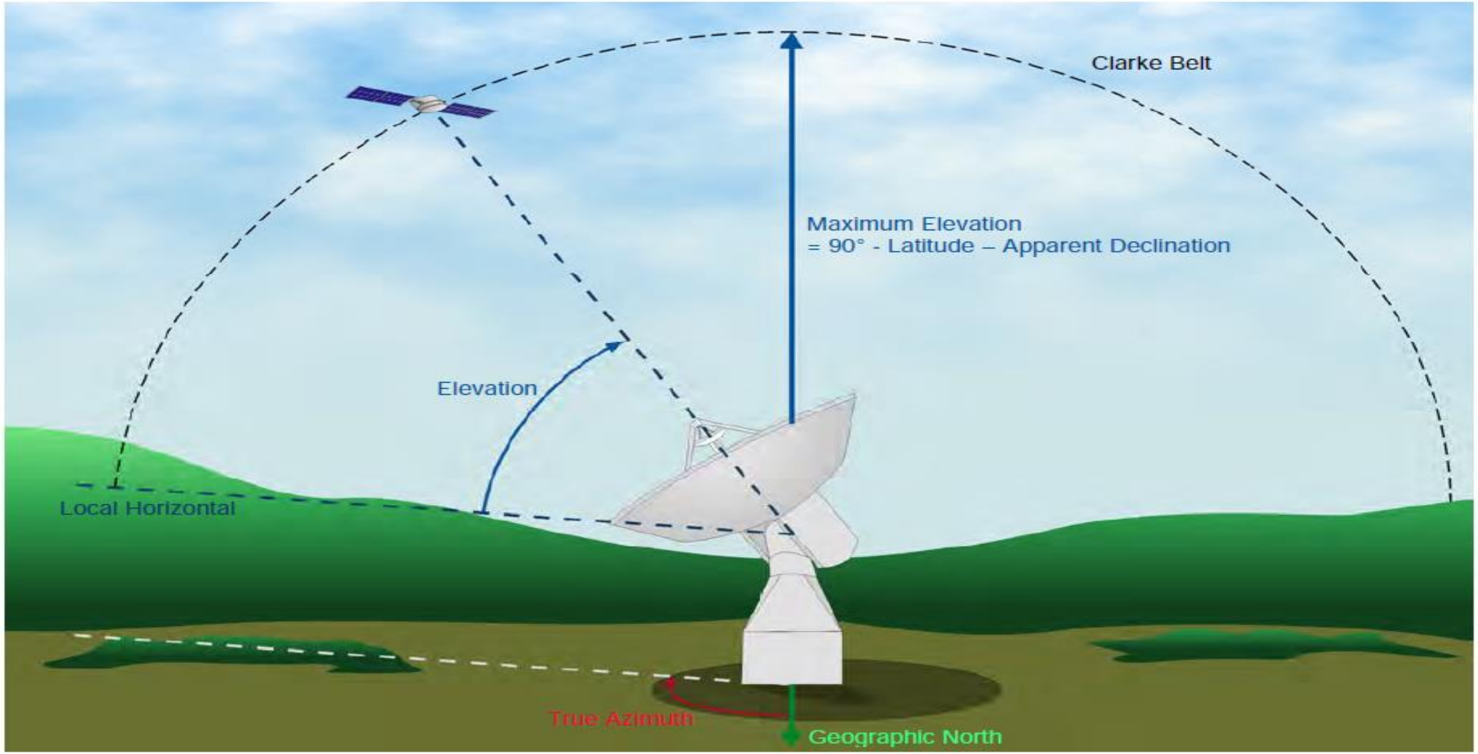
Antenna look-angle adjustments.

offset-feed parabolic Dish Antenna.

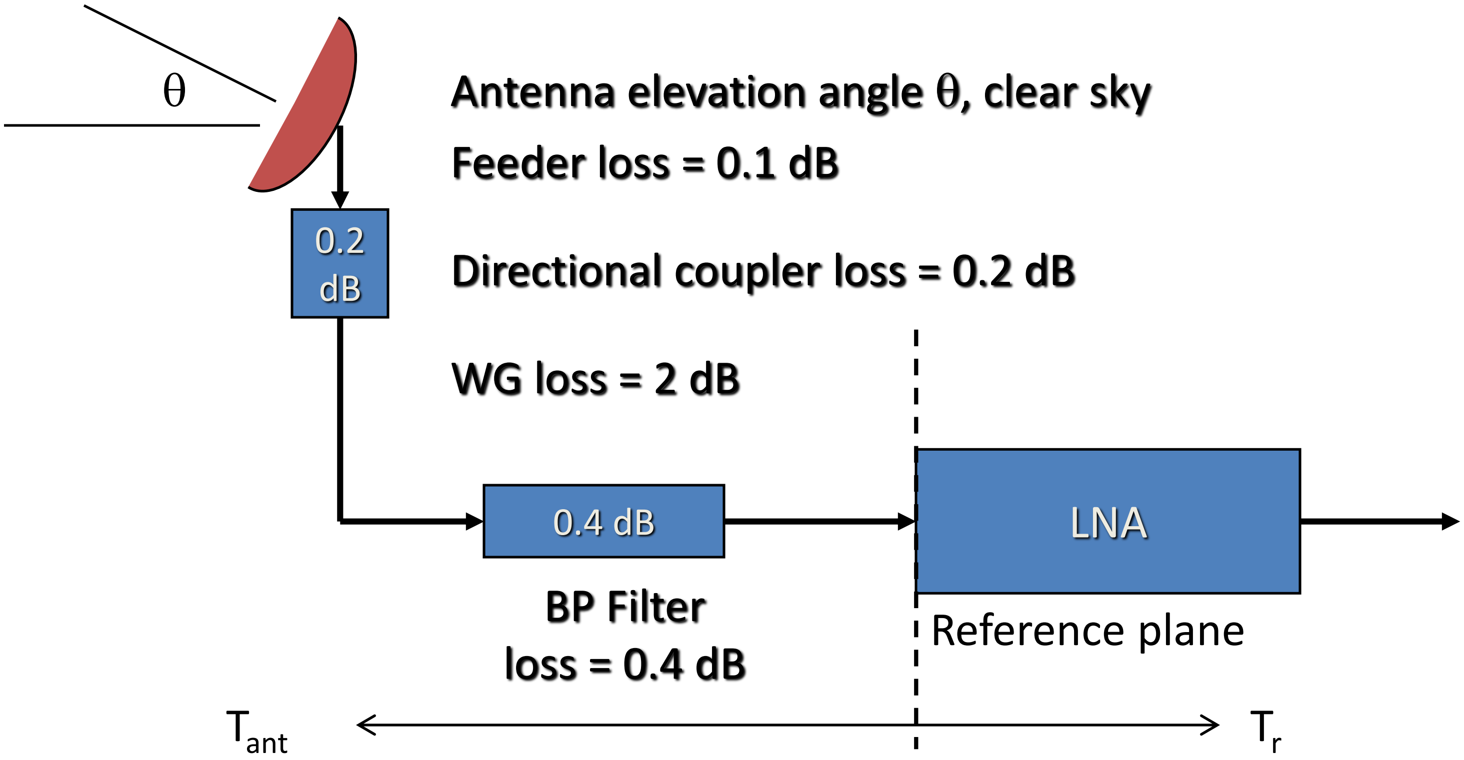
Polarization

- An electromagnetic wave is a combination of an electric and a magnetic field. The two fields always appear simultaneously. The plane of the electric field is orthogonal to the plane of the magnetic field and both planes are perpendicular to the direction of propagation. By convention, the polarization of an electromagnetic wave is defined as the orientation of the plane of the electric field.
- Polarization can be linear, where the electric field is always oriented at the same angle with respect to a reference plane. For antennas on a satellite, the reference plane is usually the equatorial plane. In most cases, linear-polarization is either horizontal, where the electric field is parallel to the plane of the equator, or vertical. For earth-station antennas, however, the reference plane is the local horizontal plane. Because of the curvature of the earth, these two reference planes are not parallel, unless the earth station and the satellite have the same longitude. The angle between these reference planes is called the polarization angle, or skew. It is the difference between the polarization of the signal transmitted by the satellite and the apparent polarization of the received signal. An adjustment for the polarization angle must be made when aligning a linearly polarized earth-station antenna, in order to maximize the signal.

Earth station-satellite geometry



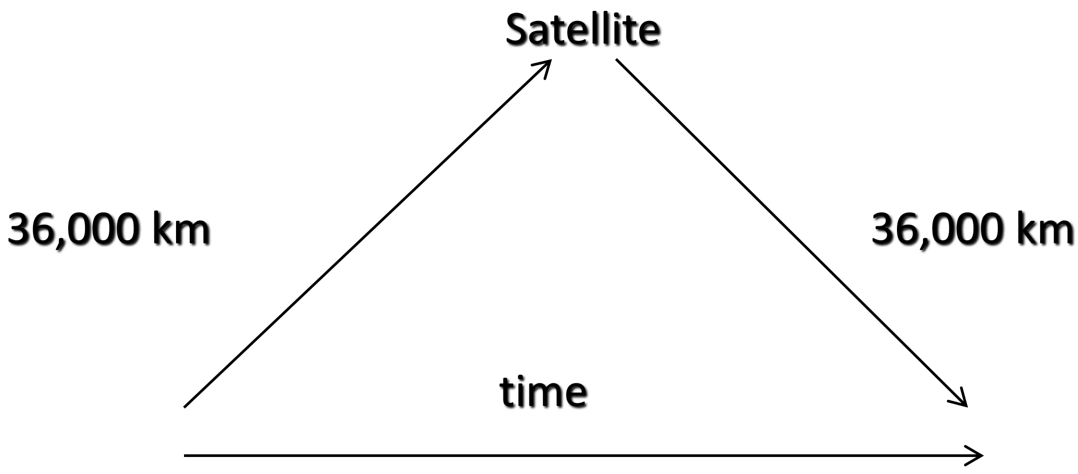
Earth Station Receiving System



Low-noise amplifier (LNA, LNB, LNC, LNBF)

- The first active component in a satellite receiver is a special type of amplifier called a low-noise amplifier (LNA) which is used to amplify the weak signal captured by the antenna to a usable level while introducing as little noise as possible. This is always followed by a down converter to translate the RF signal to the first IF frequency range.
- Some receivers use a variation of the LNA called a low-noise converter (LNC), which combines a low-noise amplifier and a down converter. Both the LNA and the LNC have a relatively narrow bandwidth, corresponding to the bandwidth of a single transponder (channel) of the satellite. A type of low-noise converter called the low-noise block (LNB) handles a large bandwidth spanning several or all transponders of the satellite. A low-noise block combined with a down converter is sometimes called a low-noise block converter or low-noise block down converter, although the term low-noise block is often used instead. An LNB combined with a feedhorn is called an LNB feedhorn (LNBF).

Propagation Delay



$$\frac{2 \times 36 \times 10^6}{300 \times 10^6} = 0.24 \text{ sec}$$

Kaynaklar

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Sincerely,

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thank you