Mobile Wireless Communication Systems

Part 1- Introduction & Principles

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Reading List

- Wireless Communication: Theory and Applications, by Arumita Biswas and Mainak Chowdhury, Pub: Cambridge 2017
- 5G Mobile and Wireless Communications Technology, Edt. By: A Osseiran, et al, Pub: Cambridge Univ. Press, 2016
- Communication Technology Update and Fundamentals, 14th edition (Grant AE, Meadows JH, editors, in association with Technology Futures, Inc.). Focal Press, New York and London. 2014
- - Mobile and Data Communications Systems, D Wong, D Britland, Pub: Artech House
- - Mobile Communications, A Jagoda, M DeVillepin, Pub: J. Wiley
- Mobile Information Systems, Editor: J. Walker, Pub: Artech House
- Introduction to Digital Mobile Communications, Y Akaiwa, Pub: J. Wiley
- Mobile Communications, 2nd Ed, J Schiller, ISBN 0-321-12381-6
- Wireless Communications & Networks – Stallings
- Mobile Communications – Dr. J. Schiller
- -3G Wireless Demystified - Harte
- Introduction to Telecommunications - Anu Gokhale
- Mobile Communication Systems, Parsons J D and Gardiner J G, Blackie USA Halsted Press
- Mobile Communications Engineering, Lee, William C. Y., McGraw-Hill, Inc.
- Digital Communications over Fading Channels, S Alouini, J Wiley, 2005
- Optical Wireless Communicatios, Z Ghassemlooy, et al, CRC Press 2012

Websites:

- IEC Online Education
- How Stuff works
- Teracom Training Institute
- Telecom Writing

Contents

- Introduction
- Principles
- Frequency Band
- History
- Transmission Properties
- Cellular Concept
- Traffic Engineering
- Propagation, Fading, etc.
- Modulation
- Performance

Wireless Communications

- Introduced in the 19th century and developed over the subsequent years.
- One of the most important mediums of transmission of information between devices.
- The information is transmitted through the air using electromagnetic waves with no cables or wires or other electronic conductors.
- Refers to a range of wireless communication devices and technologies ranging from
  - smart phones
  - computers
  - laptops
  - Bluetooth technology
  - WiFi
  - WiMAX
  - Etc.

https://www.elprocus.com/types-of-wireless-communication-applications/

Mobile Communications - Definition

- Operate over a very **large area** with a **limited bandwidth**
- Cellular mobile system - uses a large number of **low-power transmitters** (100 W or less)

- Offers **larger capacity** through **cell splitting**
- Variable power levels allow **cells to be sized** according to **subscriber density& demand** in a particular region

- Mobility - Mobile users travelling from cell to cell with conversations handed over between cells
- Channels (frequencies) used in one cell can be **reused** in another cell some distance away

Mobile Communications - Principles

- Wave propagation - is closely affected by the **wavelengths** of the propagating signal
- Uses a separate radio channel to talk to the cell site
- Cell site talks to many mobiles at once, using one channel per mobile

- Channels use a pair of frequencies for:
  - forward link for transmitting from the cell site
  - reverse link for the cell site to receive calls from the users
- Radio energy dissipates over distance - so mobiles must stay near the base station to maintain communications
- Basic structure of mobile networks includes telephone systems and radio services

Wireless Communications

Advantages

- Data or information can be transmitted without using any physical connections at a fast speed
- Low maintenance and installation cost of the networks for the service providers
- Flexibility, convenience, and accessibility - Access to the internet from anywhere.

Disadvantages

- Low level of security at the physical level
- Low data rates since two many people are using the network.

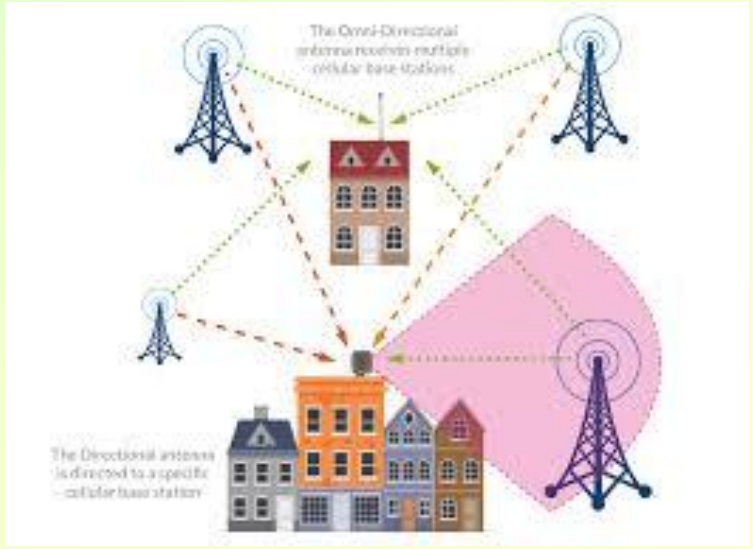
Early Mobile Systems

- A single base station - similar to TV broadcasting

One very powerful transmitter located at the highest spot would cover an area with a radius of up to 50 km

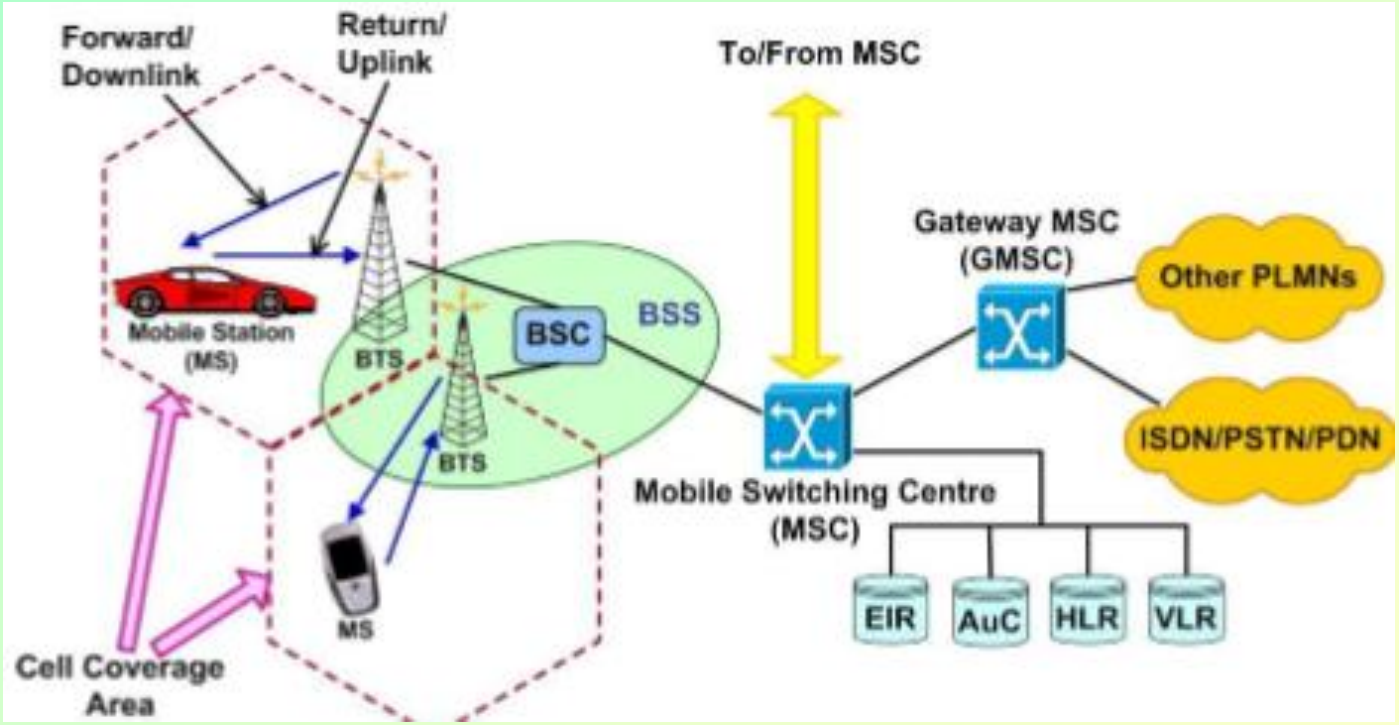
- Use of multiple base station with low power transmitters to cover a large area

E.g. dividing a metropolitan region into 100 different cells 12 channels each



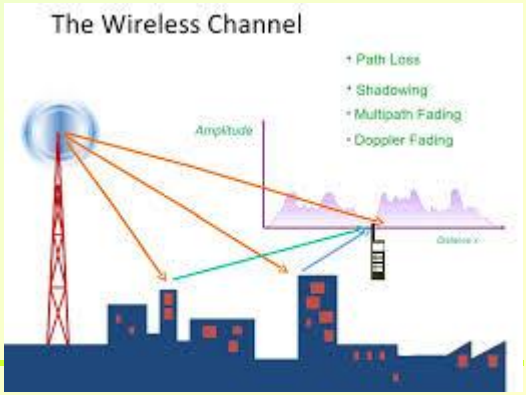
Mobile Communications - System

- Mobile Unit
- Mobile Base Station (BS)
- Mobile Switching Centre (BSC)



Mobile Comms. – Sub-sections

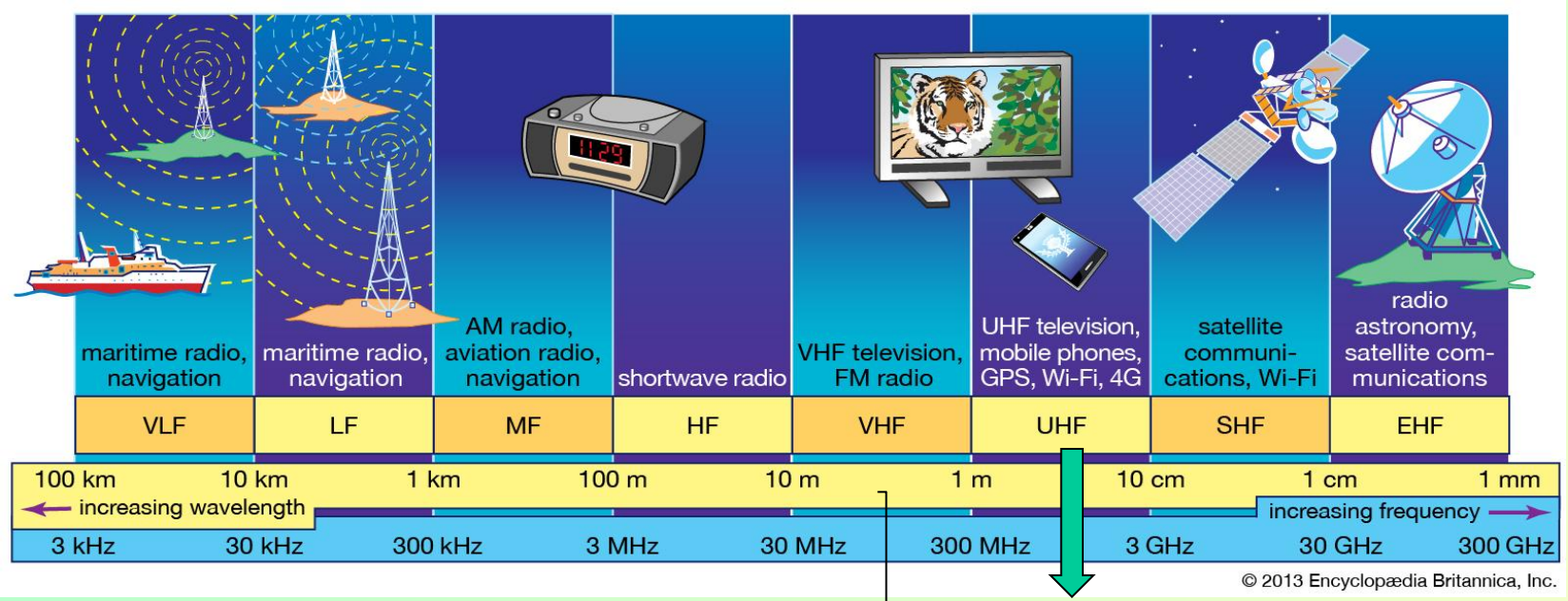
- Mobile Base Station (MBS): – includes
  - an antenna
  - a controller
  - a number of receivers
- Mobile telecommunications switching office (MTSO)
  - Mobile Switching Center (MSC)
    - Connects calls between mobile units
    - Call blocking
    - Call termination
    - Call dropping
    - Handover
    - Calls to/from fixed and remote mobile subscriber
- Transmission channels between mobile unit and MBS



Mobile System Characteristics

- Frequency sharing
- Loss and Interference
- Line-of sight and non-line of sight coverage
- Base station antenna (30 m)
- Mobile antenna (1.5 – 3 m)
- Beyond line-of-sight
- Long distance

Frequency Bands



VHF Mid Band (70 - 87.5 MHz)
VHF High Band (148 - 174 MHz)

Generally speaking, lower frequencies
- Propagate longer distances
- Penetrate objects better

* Most widely used

- Band (403 - 420 MHz)
- Band (450 - 520 MHz)
- Band 900 MHz (820 - 960 MHz)
  - 840-935 MHz* – GSM - Base station to mobile
  - 896-901 MHz* – GSM - Mobile to base station
- Band 1.9 GHz (1880 - 1900 MHz)
  - 1850-1900 MHz* – GSM (USA)
  - 1885-2200 MHz – UMTS
- 2.4-2.48 GHz - WiFi
- 5.3-5.8 GHz - WiMAX

Mobile Communications – Analogue

1934- USA — 1st Generation Analogue Cellular Systems
- Amplitue Modulation:
- For public safety
- 5000 mobiles
- Vehicle ignition noise is a major problem

1935 USA Europe Asia — Frequency Modulation
- 800 - 900 MHz and 400 - 500 MHz
- 120 kHz RF bandwidth, channel spacing of 30 kHz
- Data rate 5 - 10 kbps
- No of channels 400 – 1000, half-duplex

1946- USA — First Generation Public Mobile Telephone Service:
- Coverage distance: 50 km, 60 kHz bandwidth
- Single powerful transmitter

Mobile Communications – Analogue

1960 Cellular Radio, developed by Bell Labs.

1970 Cellular Mobile System (USA)

1980 Advanced Mobile Telephone Systems (AMPS)

- Frequency bands: 800 - 900 MHz and 400 - 500 MHz
- Channel spacing 30 kHz and no of channels 400 – 1000
- Data rate 5 - 10 kbps
- FM for speech, FSK for signaling, FDM

Digital Cellular- Digital

What does it offer?

- Best quality compared with analogue system

- Improved bandwidth efficiency
  - Reduced from 30 kHz to 10 kHz, and then to 5 kHz.
    This is achieved via 3-time-slot Time Division Multiple Access (TDMA) (i.e. three pairs of people using a 30 kHz radio channel simultaneously)

- Use of micro-cellular technology to accommodate smaller and smaller cells particularly around the new frequency band of 2 GHz

- Improved frequency reuse

History - 2nd Generation (2G) Systems (1991-4)

Digital voice services with some moderate rate data service

- Technology: TDMA, TDMA hybrid FDMA
- Characteristics:
  - Digital voice and low speed data
  - Frequency band @ 900 MHz, RF channel spacing 200 kHz
  - Modulation: GMSK, DPSK, Fixed frequency assignment
  - Speech rate 13 kbps, Speech coding, TDMA
  - High security and higher capacity,
  - Improved speech Quality of service (QoS)

1. NEC Cellstar 500 series (1992)
2. Nokia 2110 series (1994)
3. Nokia 5120 (1998)
4. Kyocera 2135 (2002)
5. Audiovox CDM8300 (2002)
6. Samsung SCH-A650 (2004)

- Group Special Mobile (GSM): 1.8 GHz, and 1.9 GHz – Circuit switching
- USDC 1.9 GHz
- Digital Cordless Systems (DCS) 1.8 GHz

Current - 3rd Generation (3G) Systems (1995 -)

- Support Multimedia Packet-based Services
  - Internet Service:
    - 144kb/s (Outdoor and higher velocity)
    - 384kb/s(from outdoor to indoor) and 2Mb/s (indoor)
  - Speech of QoS and other services

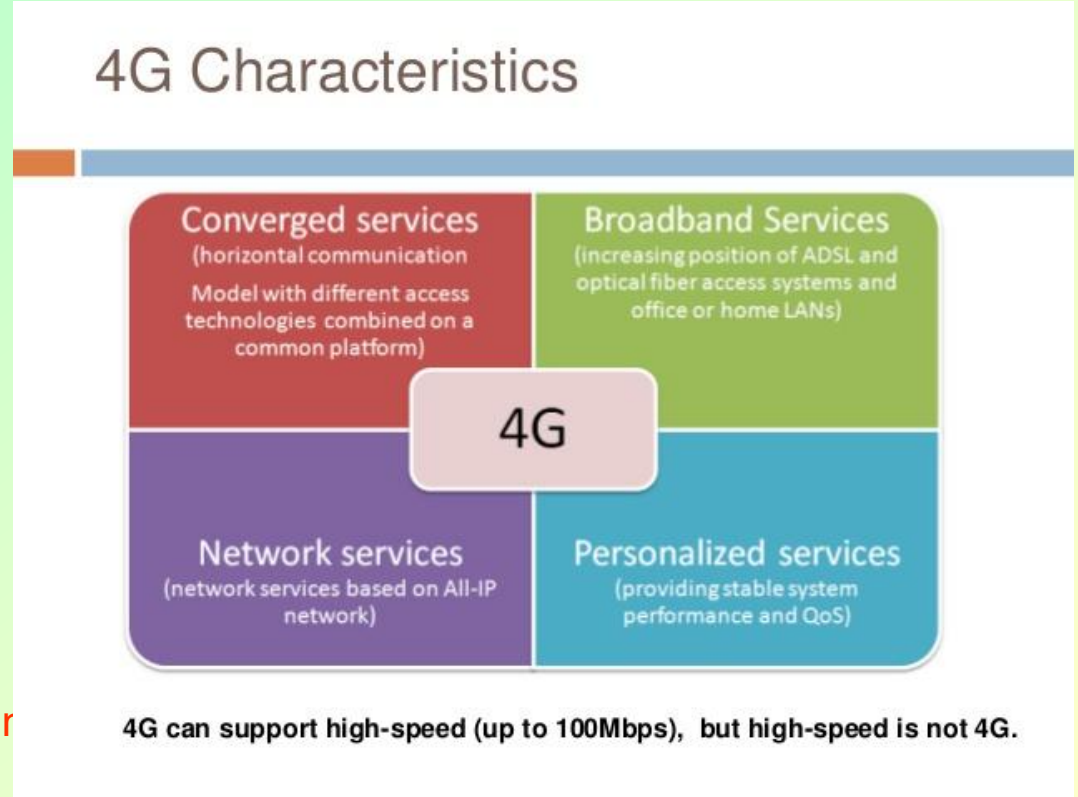
- First Transitional System: 2 GHz
- 2000 - 2nd Transitional Systems: 2.5 GHz
- 2001 - 1st CDMA Network @ 144 k bps
- 2002- Handover between GSM and WCDMA by Nokia and Vodafone
- 2003 World's 1st IPv6 over 3G UMTS/**WCDMA** network, Ericsson
- 2003 World's 1st CDMA2000 high-speed packet data phone call (3.09 Mbps), Nokia
- 2004, World's 1st Enhanced Datarate for Global Evolution
- EDGE-WCDMA 3G packet data handover, Nokia and TeliaSonera
- 2005, 9 Mbps with WCDMA, HSDPA phase 2, Ericsson
- 2005, 1.5 Mbps enhanced uplink WCDMA system, Ericsson

3G - Drawbacks

- CDMA – Offering higher data rates
- 3G phones are costly
- Spectrum limitation and it's allocation
- People using 3G mobiles can only enjoy its features with 3G subscribers only
- Multiple standards
  - IMT-2000 – Require operators to obtain a new spectrum
  - IMT-DS (W-CDMA) with a wide channel spacin of 5 MHz
  - IMT-TC (TD-SCDMA/UTRA TDD)
  - IMT-FT (DECT)
- Require wider bandwidth

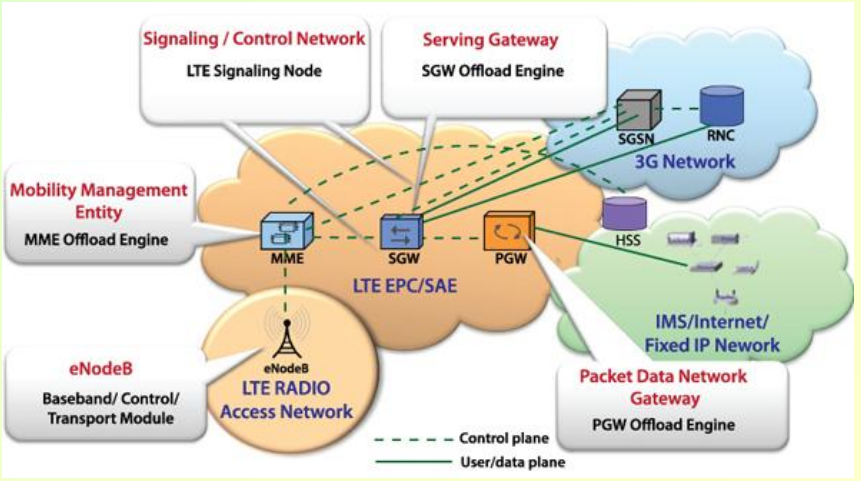
Current - 4G Systems

- Convergence of cellular mobile networks and WLANs
  - Higher spectral efficiency
  - 100 Mbps for high mobility users
  - 1 Gbps for low mobility access
  - Long Term Evolution (LTE) and LTE-Advanced
  - Low cost of networks
  - Users access to broadband multimedia services
- Convergence of mobile communications and broadcasting
  - Cellular operators offering customers a range of broadband multimedia services in vehicular environments
  - Users access to broadband multimedia multi-media services



Current - 4G System

- Not a significant market share in 2010 from a global perspective.
- Mobile Internet and massive video
- LTE (Long Term Evolution) is known as a new 4G mobile phone standard devised by the International Telegraph Union Radiocommunication regulator:
  - 700 MHz; 850 MHz; 1700/2100 MHz; 1900 MHz; 2300 MHz
  - Higher data speed (100 Mbps – 1 Gbps) – OFDM
    - Download: 150 Mbps (practical: 20 Mbps) and Upload: 50Mbps (practical: 10 Mbps) Note: These numbers will be different depending on location, deployment and the number of users
  - Shorter latency
  - Better energy efficiency
  - Packet transmission
  - Improved security
  - Low cost per bits
  - Removal of IP address limitation
  - Smooth handover
  - Global roaming
  - Bringing IP to the base stations



https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.rcrwireless.com%2F20140509%2Fevolved-packet-core-epc%2Flte-network-diagram&psig=AOvVaw3S98hL6CCeO2_9s-Gob32Q&ust=1600171383370000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCMDrw9vM6OsCFQAAAAAdAAAAABAO

4G - Features

- Hardware
  - Ultra wide band networks
    - Uses any part of the frequency spectrum
    - Lower power (transmitting pulses)
  - Smart antenna
- Sofware
  - Software defined radio
    - Can be configured to any radio or frequency standard
    - Phone should automatically switch from CDMA to TDMA when needed
    - Users can download the interface when in a new country, thus easy roaming
  - Packet layers
  - Packet

- Costly
- Battery use are higher
- Complex implementation

xG - Comparison

1G

- Analogue
- Poor voice quality
- Poor battery life
- Big phone size
- No security
- Frequent call drop
- Limited capacity and range
- Poor hand-over
- Different systems
- Deployed in 1980s

2G

- First used in Europe in 1990s
- Digital narrowband technology – More spectrally efficient
- Two standards: GSM, TDMA and CDMA
- Improved battery life
- Smaller phone size
- Improved security
- Improved data rate: Up to 9.6 kbps-270 kbps
- Improved hand-over
- Low transmission quality
- Spotty coverage
- Not supporting video
- Abrupt drop calls

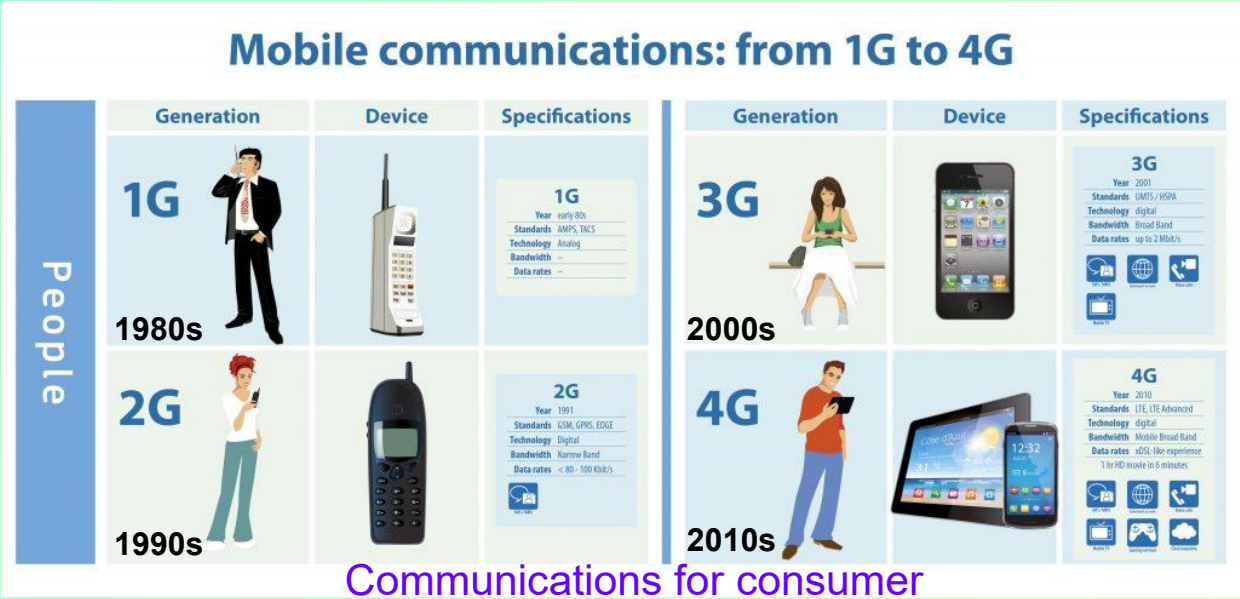
3G

- Support both voice and video
- Broadband capacity
- Uses W-CDMA and EVDO, EDGE (i-phone used it)
- Reduced complexity
- Higher data rates: 384 kbps – 3 Mbps
- Improved spectral efficiency: 5 MHz
- Higher bandwidth is still required
- High cost of spectrum
- Huge capacity

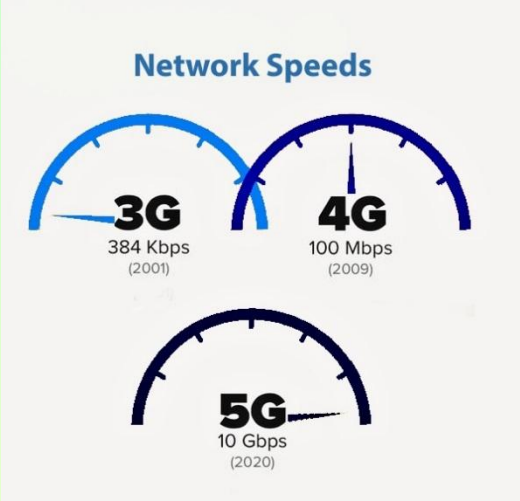
4G

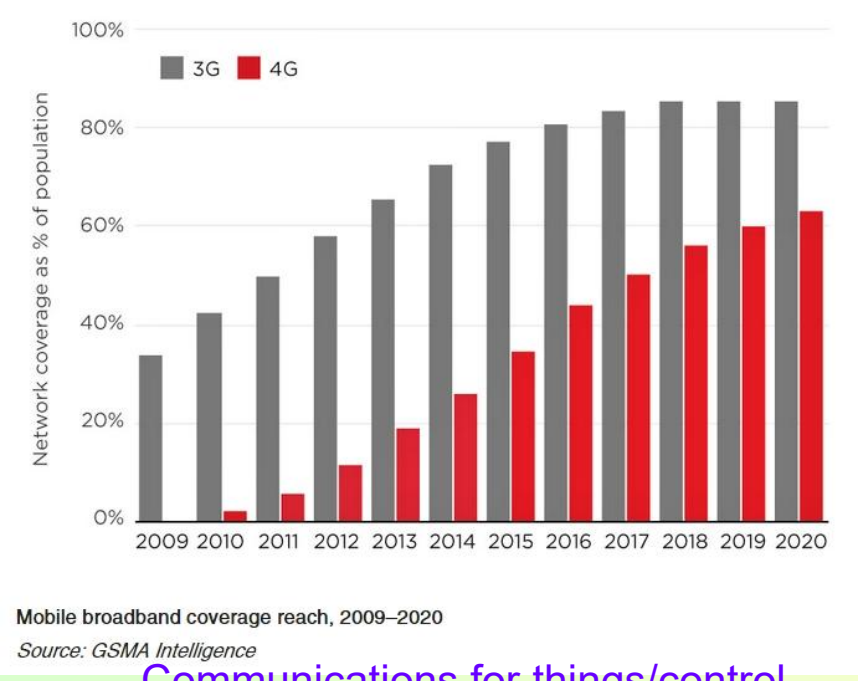
- Support both voice and high quality video
- Packet transmission
- All IP - IPv6 (128 bits)
- High throughput (3-5 Mbps for moving devices)
- IEEE 802.16m
- LTE, WiMAX, WiFi
- Reduced complexity
- Higher data rates: 20 – 300 Mbps WiFi
- Reduced cost
- Faster and more reliable
- Higher bandwidth is still required

xG - Comparison



Communications for consumer





Communications for things/control

2020s

5G –

- The technological infrastructure can further enhance data throughput of existing networks to support the growing number of users and services accessible from mobile network.
- A theoretical maximum speed of 20 Gbps, up to 20 times faster than the maximum speed theorized for 4G (1 Gbps).
- Currently being developed and trialled ready for commercial launch from 2020. Widespread availability of 5G services is expected by 2025.

http://www.sicomtesting.com/blog/en/dal-1g-al-5g-il-passato-e-il-futuro-degli-standard-gsm-umts-hspa-ed-lte/

Future Wireless - 5G System

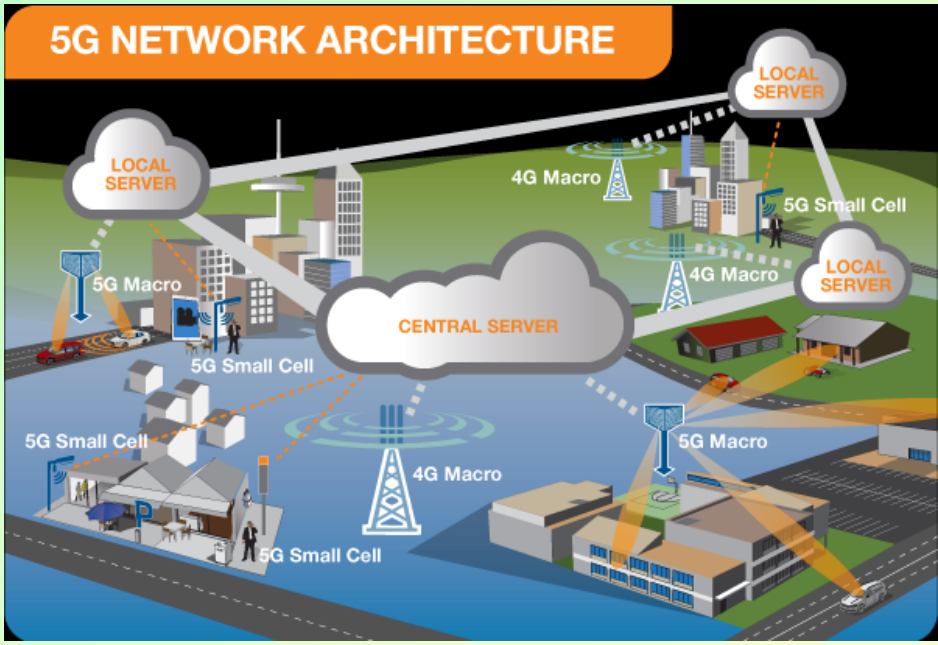
WHAT IS 5G? CONTRIBUTION OF EU RESEARCH

European Commission

What 5G will bring to you?	What's new with 5G?	EU projects	5G applications	Why not today?
amazing volume amazingly fast	spectrum extension; millimetre waves; cell densification; increase spectrum efficiency; advanced antennas; 3D beam-forming techniques; new electronic components; backhaul optimization; D2D; moving networks (vehicle based cells)	METIS, SEMAFOUR, 5GNOW, HARP, duplo, MOWEBA, MiWaveS, E²NETWORK	 hologram TV, immersive presence, augmented reality, ultra large volume transfers	spectrum saturation; limited spectrum aggregation; current hardware not able to function at high frequencies; expensive deployment & maintenance of small cells
always best connected	combination of 4G, 3G, Wi-Fi, & new radio access to create an integrated & dynamic radio access network; connectivity management mechanisms	METIS, SEMAFOUR, MCN, Tropic, CROWD	 staying connected everywhere including high-speed trains, planes, crowds	seamless handover (e.g. cellular to Wi-Fi) not supported
no perceived delay (Latency: A few ms)	ultra-low latency; software-defined networks; decoupling functional architecture from the underlying physical infrastructure; network intelligence closer to users; MEC (mobile edge computing), D2D	METIS, MCN, iJOIN	 tactile internet; reactive interfaces; electricity grid control, vehicle to vehicle, robot control; connected cars, remote surgery	4G latency ≥ 10ms
massive amount of connected things & people	new waveform; cell densification; much less signalling traffic & no synchronisation; RAN architecture	METIS, 5GNOW, iJOIN	 internet of things, smart cities, connected cars, e-health	current OFDM waveform limitations; interference prevents scaling up; 4G chipsets cost; energy consumption
energy efficiency	millimetre waves for front-haul & backhaul; new operation mechanisms for dense networks; pooling of base station processing; on-demand consumption; massive machine communications; power amplifiers; DSP (digital signal processing) – enabled optical transceivers; harvesting ambient energy; optimization of sleep mode switching	MCN, iJOIN, CROWD	 80% energy saving; deployment in developing countries	Base stations idle time not optimised; unused functions activated; air interface/hardware not energy optimized
flexible programmable networks	software-defined networks; network function virtualisation; decoupling functional architecture from the underlying physical infrastructure; APIs	unify, TNOVA	 new business models for innovative SMEs providing network functions; emergence of super MVNOs; pan European operators, faster innovation in network services	many various network management software; not interoperable; bundling of network functions in hardware boxes
secure networks	physical channel authentication; virtualised authentication	MYLAWS	 networks for police & security professionals; privacy	Security as add-on not by design; fragmented approach

5G System - Network Architecture

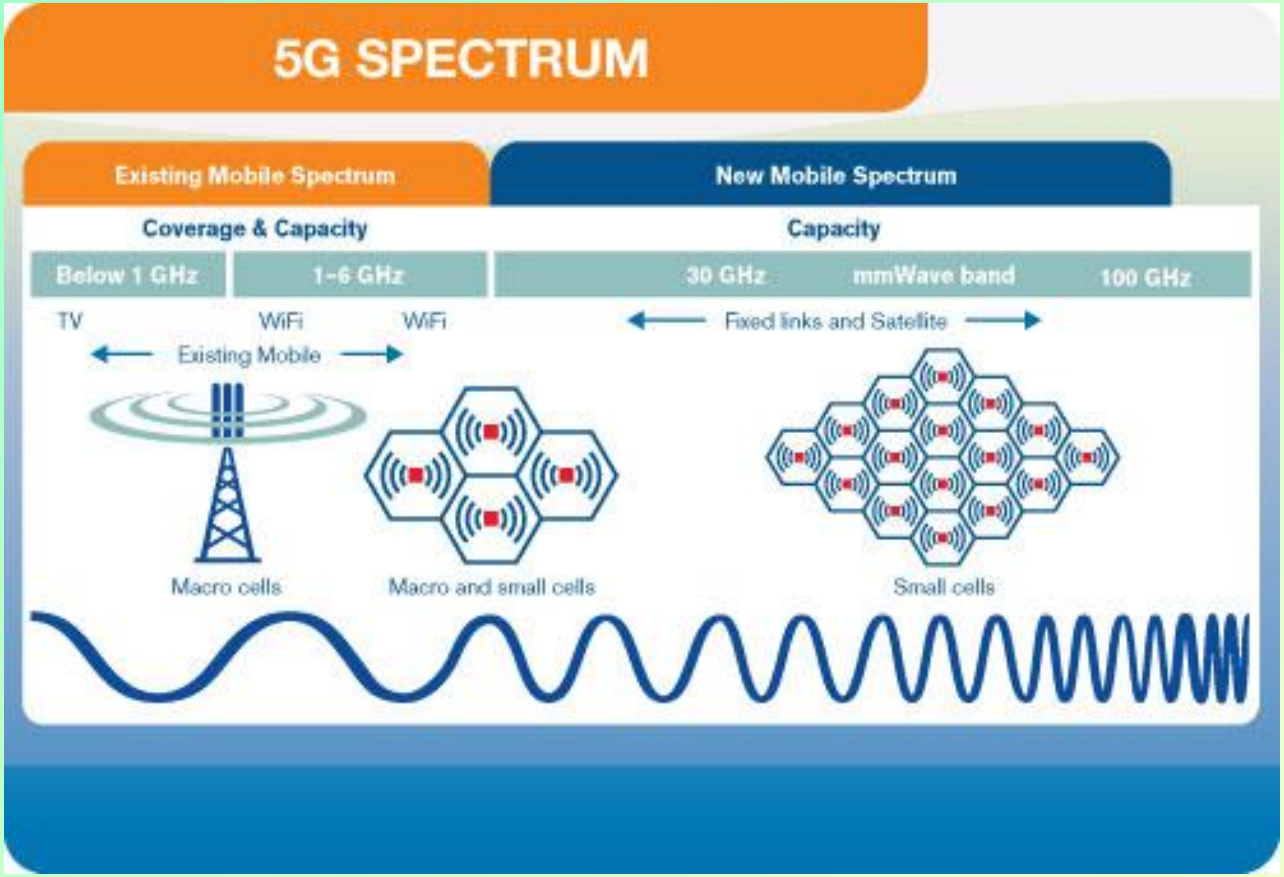
- Most operators initially integrate 5G with 4G networks to provide a continuous connection
- The Radio Access Network - including **small cells**, towers, masts, and dedicated in-building and home systems that connect mobile users and wireless devices to the main core network.
  - Continuous connection - using small cells distributed in clusters depending on where users require connection, which will complement the macro network that provides wide-area coverage.
- The Core Network - mobile exchange and data network that manages mobile voice, data, and internet connections.
  - Being redesigned to better integrate with the internet and cloud based services and also includes distributed servers across the network improving response times (reducing latency).
- Network Slicing – a smart way to segment the network for a particular industry, business or application.



- **Network Function Virtualization (NVF)** - to instantiate network functions in real time at any desired location within the operator's cloud platform.
  - NFs that used to run on dedicated hardware for example a firewall and encryption at business premises can now operate on software on a virtual machine.

http://www.emfexplained.info/?ID=25916

5G System – Frequency Bands



https://gceurope.org/everything-youve-ever-wanted-to-know-about-5g-but-were-too-afraid-to-ask-episode-1/

Initial frequency bands:

- 600-700 MHz
- 3-4 GHz
- 26-28 GHz
- 38-42 GHz

It is also expected that there will be future reuse of existing low band spectrum for 5G as legacy networks decline in usage and to support future use cases.

New spectrum at millimetre wave bands

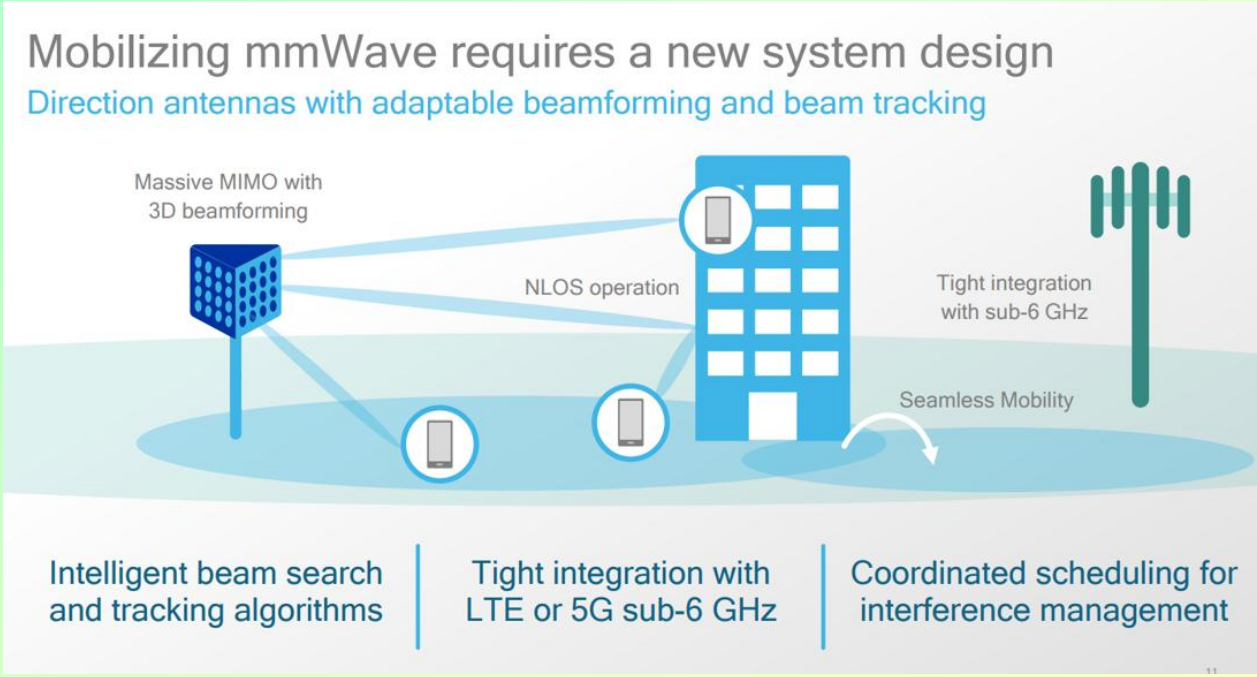
- above 30 GHz up to 86 GHz
  - Short range
  - For localised coverage

Modulation: OFDMA

5G System – Massive MIMO

- Massive' MIMO (multiple input, multiple output) antennas
  - To send and receive more data simultaneously.
  - More people can simultaneously connect to the network
  - High throughput.

- The overall physical size similar to 4G
  - However, the individual antenna element size is smaller allowing more elements (in excess of 100) in the same physical case, because of a higher frequency.



https://www.forbes.com/sites/tiriasresearch/2018/07/24/qualcomm-makes-millimeter-wave-a-reality-for-first-gen-5g-phones/

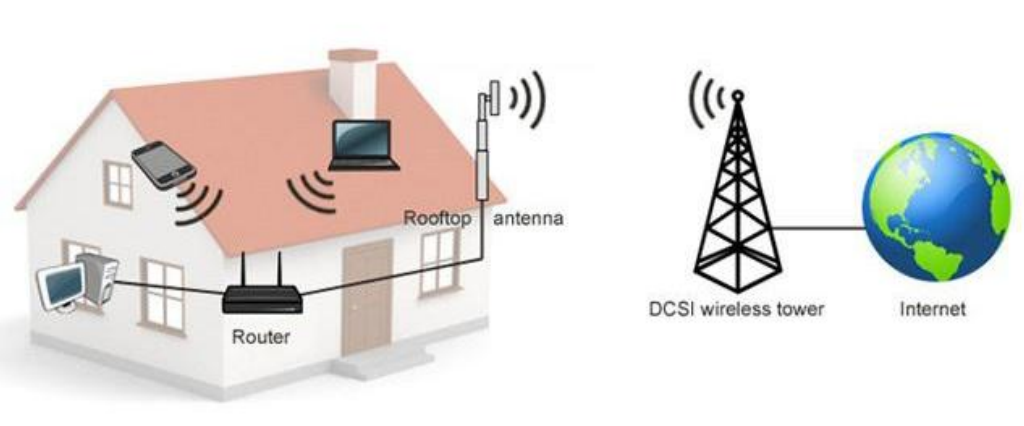
- User equipment including mobile phones and devices will also have MIMO antenna technology built into the device @ millimetre frequencies.
- Beam steering
  - Base station antennas to direct the RF to the users and devices rather than in all directions.
  - Uses advanced signal processing algorithms to determine the best path for the radio signal to reach the user.

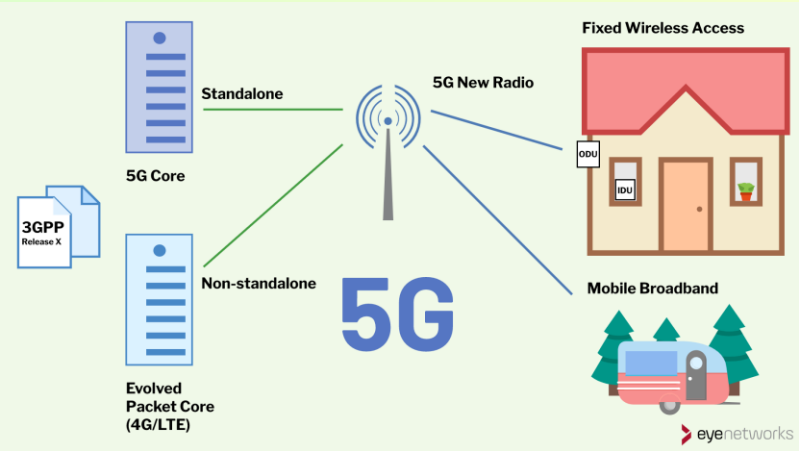
4G vs. 5G vs. 6G

Parameter	4G	5G	6G
Lattency	100 ms	10 ms	< 1ms
Peak data rate	1Gbps	10 Gbps	1 Tbps
Max. spectral efficiency	15 bps/Hz	30 bps/Hz	100 bps/Hz
Mobility	Up to 350 km/h	Up to 500 km/h	Up to 1000 km/h
Satellite integration	No	No	Fully
Max. frequency	6 GHz	90 GHz	10 THz
Connection density	100k connection/km^2	1M connection/km^2	> 1M connection/km^2
Artificial intelligent	No	Partial	Fully
Architecture	MIMO	Massive MIMO	Intelligent sutface

Fixed Wireless Access

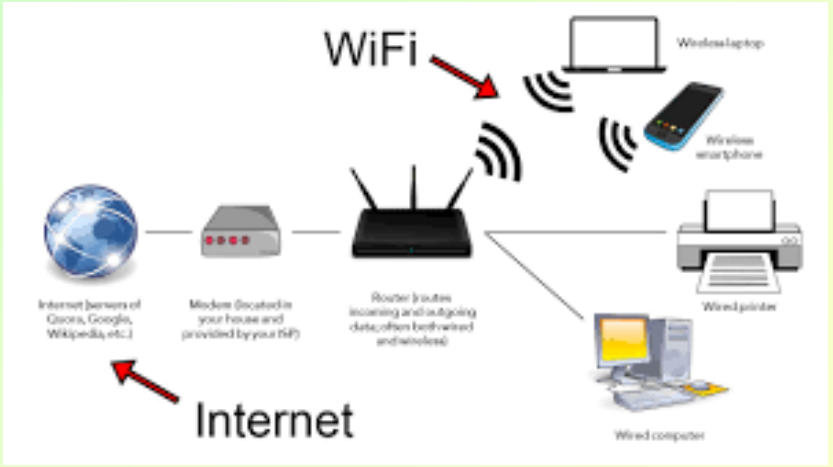
- Are ubiquitous and a part of most telecommunication deployment strategies
- Specific frequencies of the radio spectrum
- Low power wireless communications - used by various electronic devices like smart phones, laptops, etc.
- Offer very limited coverage
- A router works as a communication hub wirelessly
- These networks allow users to connect only within close proximity to a router
- Offers portability wirelessly
- Networks are protected with passwords for security





Fixed Wireless Access – WiFi

- IEEE 802.11 - Used in home networks, indoor business environments and Hotspots.
- Wi-Fi 802.11a (up to 2 Mbps) - **2.4 GHz** or **5 GHz**
- Wi-Fi 802.11b (up to 11 Mbps) - 2.4 GHz
- Wi-Fi 802.11g (up to 54 Mbps) - 2.4 GHz
- Wi-Fi 802.11n (up to 600 Mbps) - 2.4 GHz or 5 GHz
- Wi-Fi 802.11ac (up to 1700 Mbps) – 5 GHz
- Wi-Fi 802.11ac-2013 (up to 7 Gbps) – 5 GHz
- Wi-Fi 802.11ad (up to 7 Gbps) – 60 GHz (short range)



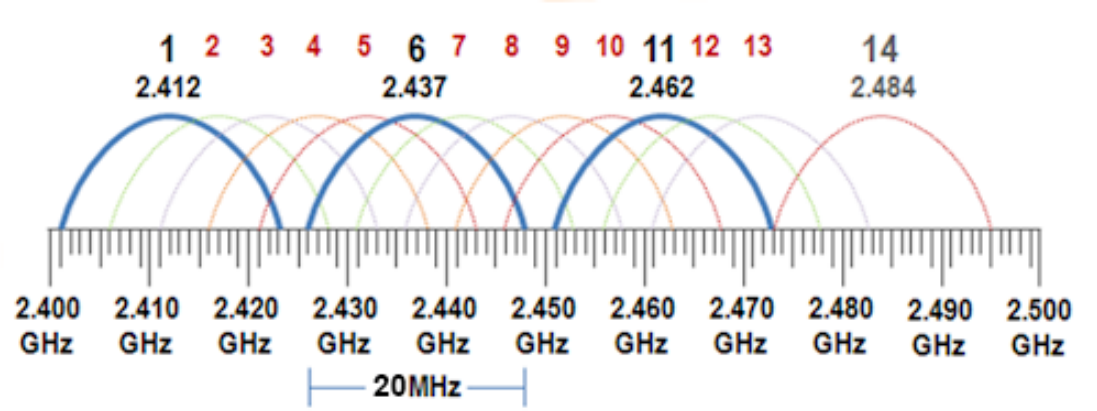
Fixed Wireless Access – WiFi

Frequench (GHz)	Advantage	Disadvantage
2.4	Larger coverage area – Good for high mobility	Lower data rate
	Better penetration through solid objects	More susceptible to interference
	Universally compatible	Other devices (microwave, baby monitors, security cameras) useg this frequency → interference
5	Higher data rate – Good for gaming or video conference High density use	Shorter range (except 802.11 ac)
	Lower interference	Poor penetration through solid objects
	Fewer devices use this band	

2.4GHz range – Used in 802.11 b standard
5GHz range - Used by the 802.11a standard (data 6 - 54 Mbps) and the new 802.11n draft standard

https://www.centurylink.com/home/help/internet/wireless/which-frequency-should-you-use.html

Fixed Wireless Access – WiFi



2.4GHz Channel	Frequency (MHz)	2.4GHz Channel	Frequency (MHz)
1	2412	8	2447
2	2417	9	2452
3	2422	10	2457
4	2427	11	2462
5	2432	12	2467
6	2437	13	2472
7	2442	14	2484

TABLE 1: COMPARING WI-FI-5 AND WI-FI 6 STANDARDS

Parameter	Wi-Fi 5 (802.11ac)	Wi-Fi 6 (802.11ax)
Frequency	5 GHz	2.4 and 5.0 GHz
Bandwidths (channels)	20, 40, 80+80, 160 MHz	20, 40, 80+80, 160 MHz
Access	OFDM	OFDMA
Antennas	MU-MIMO (4 × 4)	MU-MIMO (8 × 8)
Modulation	256QAM	1024QAM
Maximum data rate	3.5 Gb/s	9.6 Gb/s
Maximum users/AP	4	8

https://chetnet.ltd.uk/wireless/2-4ghz-v-5ghz/

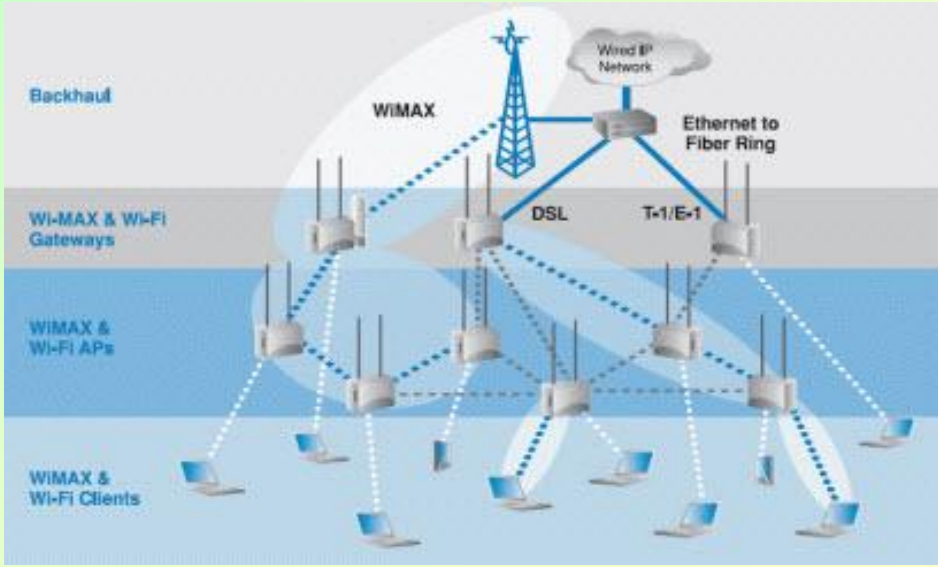
2.4 GHz: Range is used in 802.11 b standard

5 GHz:

- Range is adopted in the 802.11a standard (data 6 - 54 Mbps) and the new 802.11n draft standard

Fixed Wireless Access – WiMax

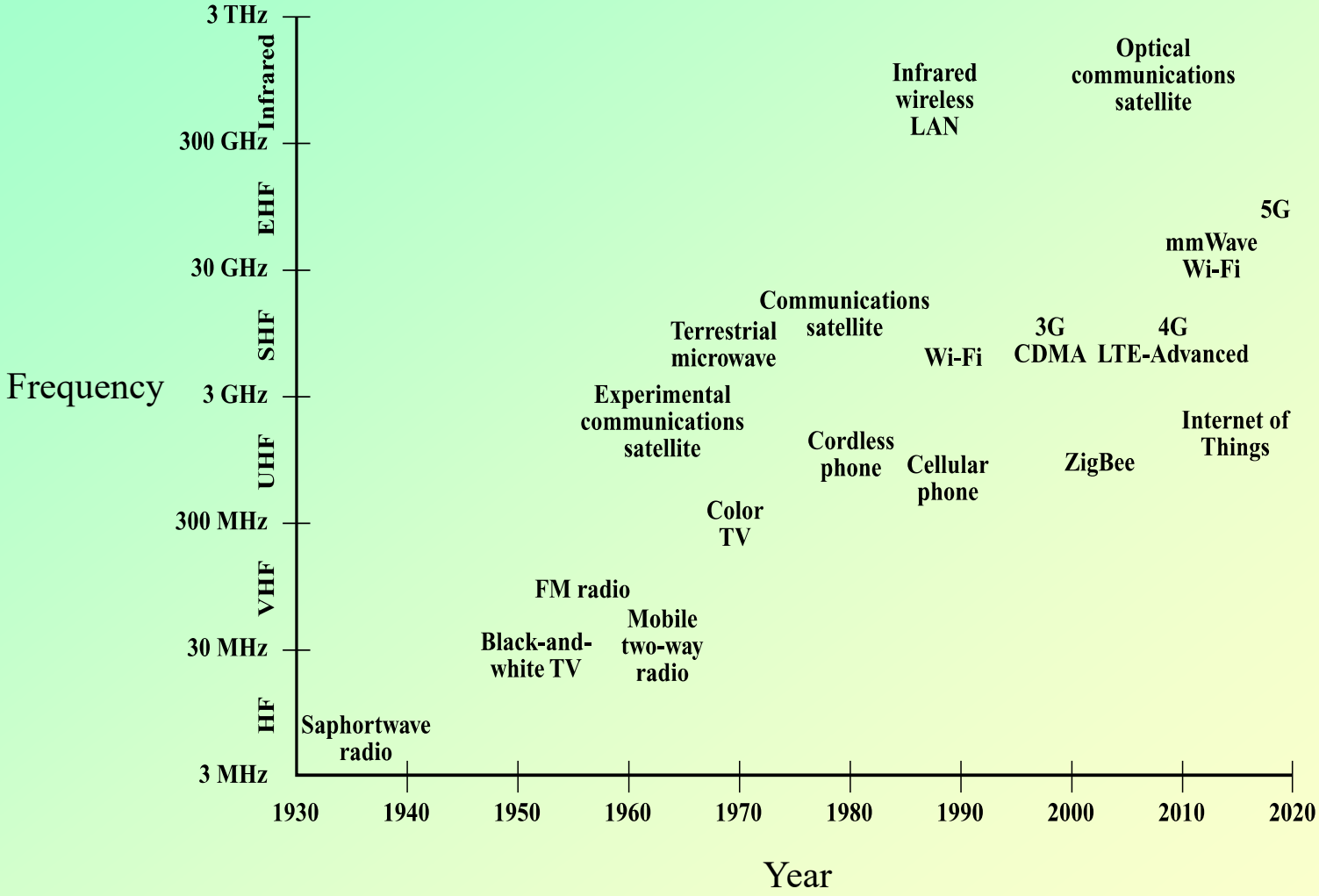
- IEEE 802.16 - Specifically designed for wider area high-speed networking, can even extend to Mobile Broadband operators (802.16e)
- Wi-Fi 802.11ad (up to 7 Gbps) – 60 GHz (short range)
- WiMAX 802.16/d (up to 1 Gbps+) - 2.3 GHz, 2.5 GHz, 2.6 GHz, 3.5 GHz
- 4G TD LTE (up to 1 Gbps+) - 3.5 GHz, 3.6 GHz



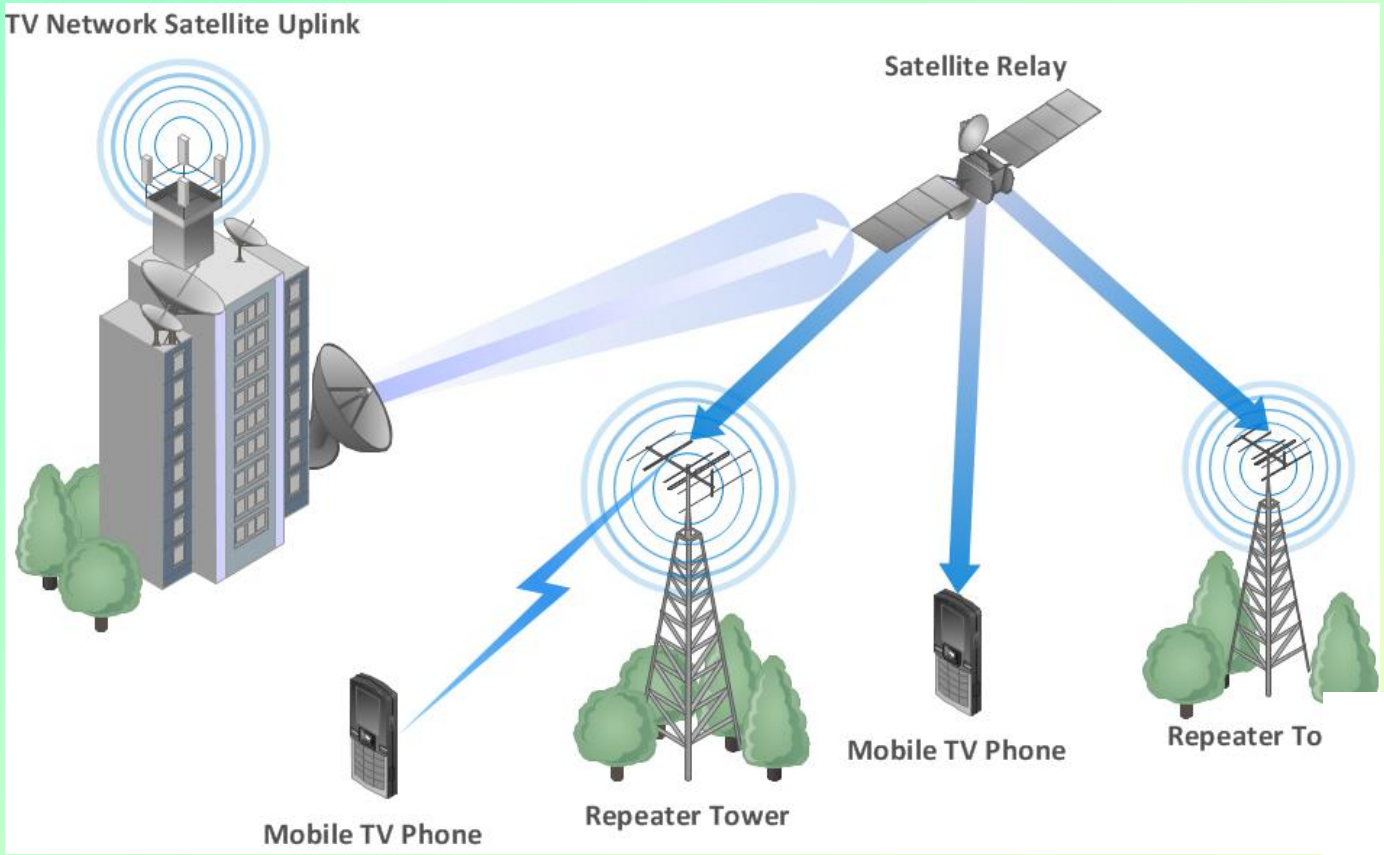
Bluetooth Technology

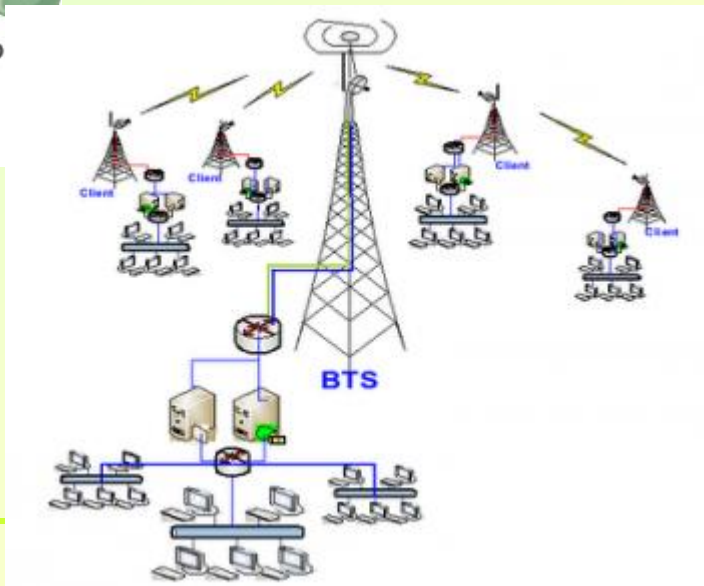
- The main function is to allow the users to connect a range electronic devices wirelessly to a system for the data transfer.
- Cell phones are connected to hands free earphones, mouse, wireless keyboard.
- It has many functions and it is used commonly in the wireless communication market.

Some Milestones in Wireless Communications



Typical Wide-Area System





Most Common Types of Communications Technologies

- Global Systems for Mobile (GSM) Communications
- Code Division Multiple Access (CDMA)
- Universal Mobile Telecommunication System (UMTS)
- **Long Term Evolution (LTE)** using the **Orthogonal Frequency Division Multiplexing (OFDM)method**
- Adaptive communications

Most Common Types of Communications Technologies

GSM

- First to use the cellular protocol to replaced 1G standard:
  - Developed by European Communications Standards Institute in 1982 for 2G digital cellular communication.
  - Defined as digital, was based on optimal switching of a communication network to full duplex speaking telephony, which included data packet transfer communication.
  - 1989 - GSM become an international standard covering up to 90% of the activity of 2G in 219 countries.

CDMA

- Developed in USA with a high security level.
- Separates different conversations by coding or by frequency sharing (FDMA).
  - It enables conducting a large number of conversations simultaneously over the same range of frequencies, with no interference between them.
- "Qualcomm", applied it to cellular communications, which ensures the communications continuity during movement from one cell to another.

Most Common Types of Communications Technologies

UMTS

- For 3G and is based on Wideband Code Division Multiple Access (W-CDMA)
- Designed by the 3rd Generation Partnership Project (3GPP)
  - A collaboration between groups of telecommunications associations to create a globally applicable 3G mobile phone system, and represents the European-Japanese counterpart to the International Mobile Telecommunications for the year 2000 (IMT-2000) International Telecommunications Union specifications for cellular communication systems.
- Marketed under the label GSM3 - To differentiate between UMTS and other communication network technologies, it is sometimes marketed under the label GSM3
- Replaced the GSM in 2G.

LTE

- A revolutionary move from 3G to LTE
- Data at a rate - Hundreds of Mbps up to a Gbps at low cost.
- Uses **OFDM** - the main feature of 4G:
  - Unlike time division multiplexing (TDM) in 2G and code division multiplexing (CDM) in 3G GSM, OFDM offers optimal solutions for the common problems encountered in wireless communication arising from multiple reflections and dispersions of radio waves, and movement of the transmitter or receiver.

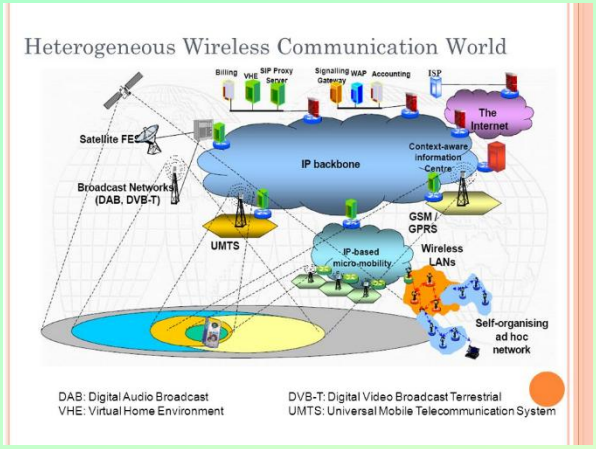
Most Common Types of Communications Technologies

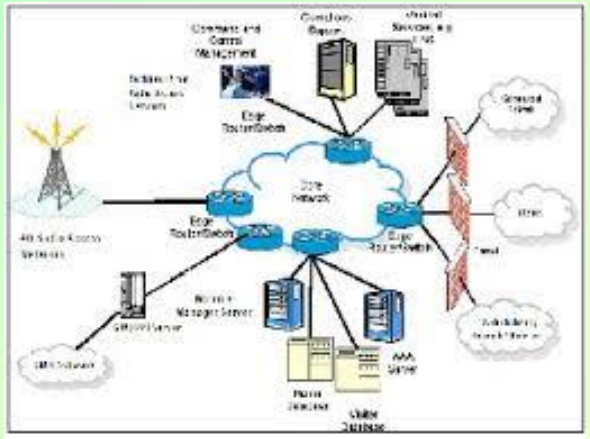
Adaptive communication

- In new communication technologies there is the need for monitoring the power level, thus adaptive communications.
- This feature facilitate dynamic allocations and variation of power at any given time depending on the conditions of reception and the quality of communications.
  - Transmission distance
  - The angle of direction or presence or absence of obstructions,

thus enabling efficient communication while restricting the power optimally and decreasing the level of radiation exposure.

Mobile Technology- Applications



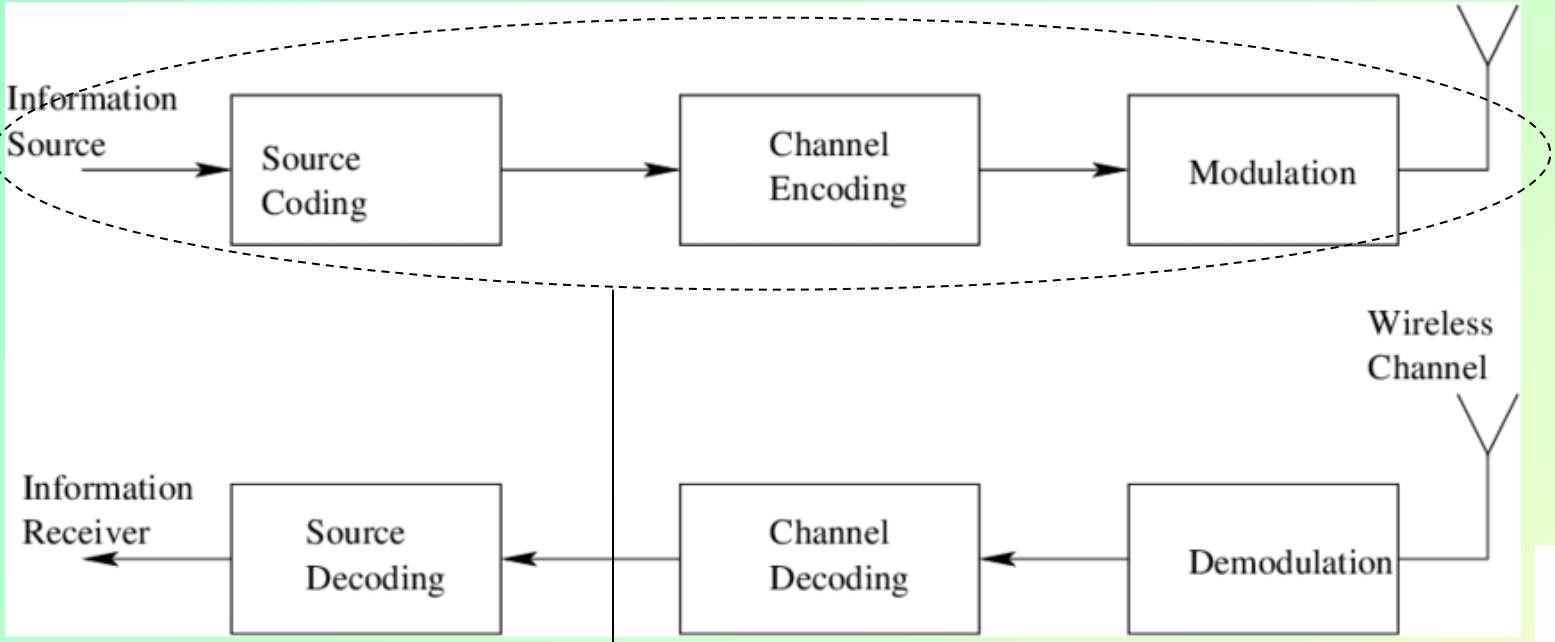


Everywhere

Wireless Communications - Issues

- Convenient and less expensive, but not perfect
- Health and environmental issue
- Wireless channel
  - Line-of-sight – Desirable but not essential
  - Signals can still be received via:
    - Transmission through objects
    - Reflections
    - Scattering
    - Diffraction
- Noise
- Interference from other users
- Doppler spread caused by movement

Wireless Communications – System Block Diagram

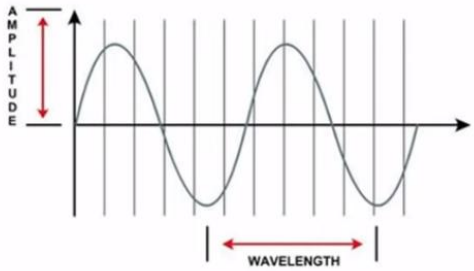


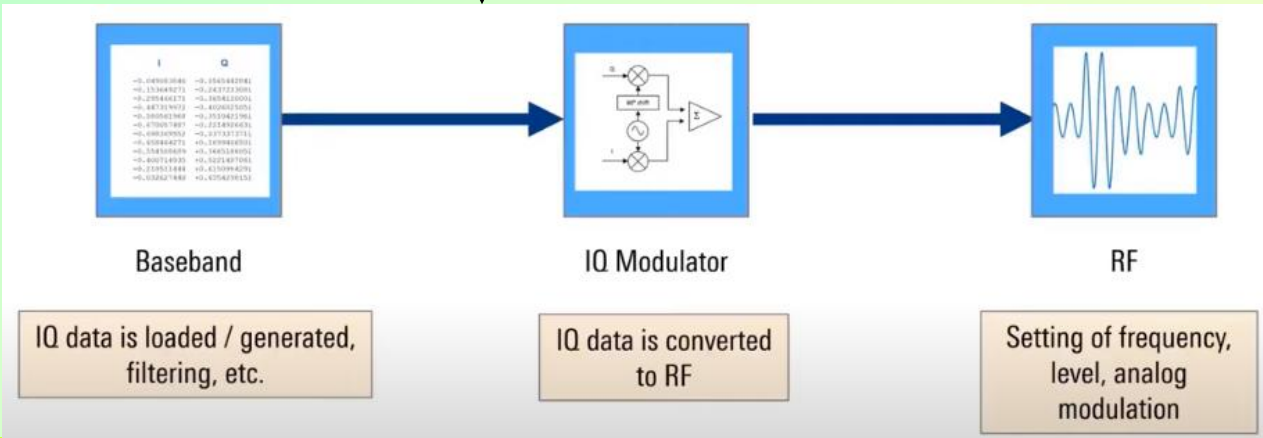
Wavelength: 360º movement of an RF wave, called a Hertz (Hz)

Amplitude: Power level of an RF wave. In Wi-Fi, typically measured in milliwatts (mW) or decibels relative to 1 mW (0 dBm)

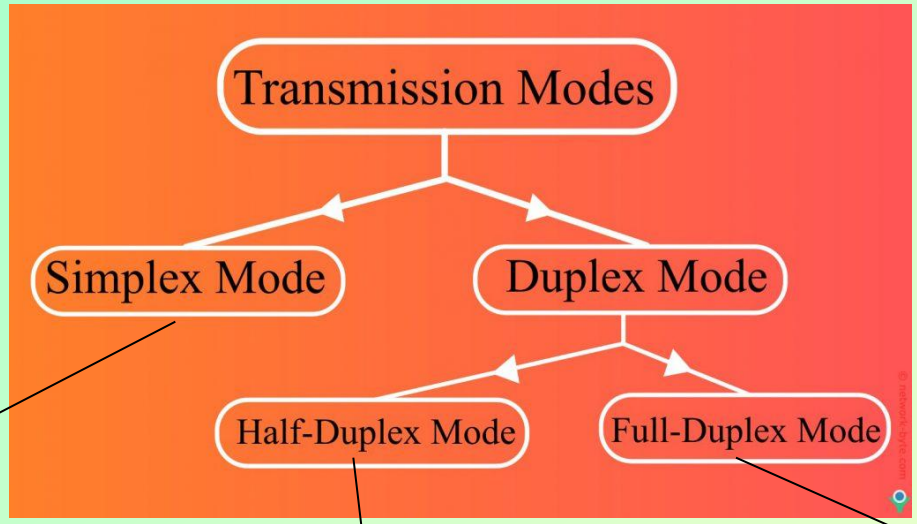
Period: The distance between two identical points on an RF wave

Phase: the relationship between ***two*** signals based on ***when*** their alternative current levels are rising and falling





Transmission Types

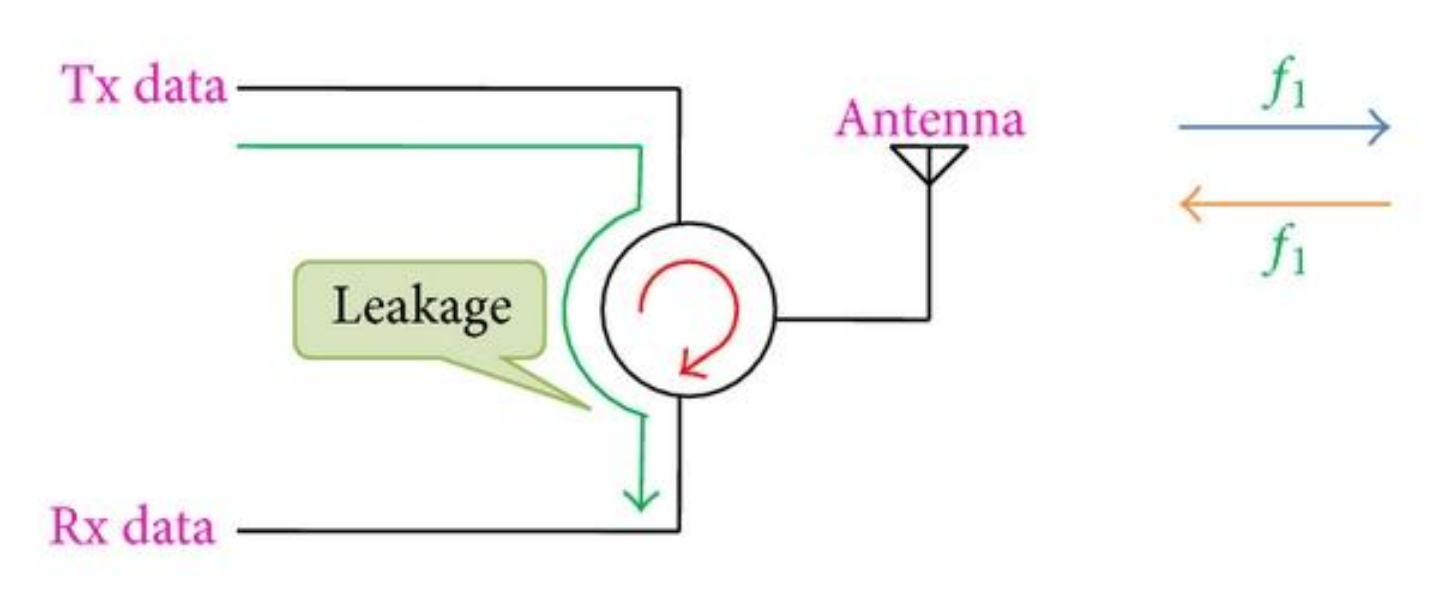


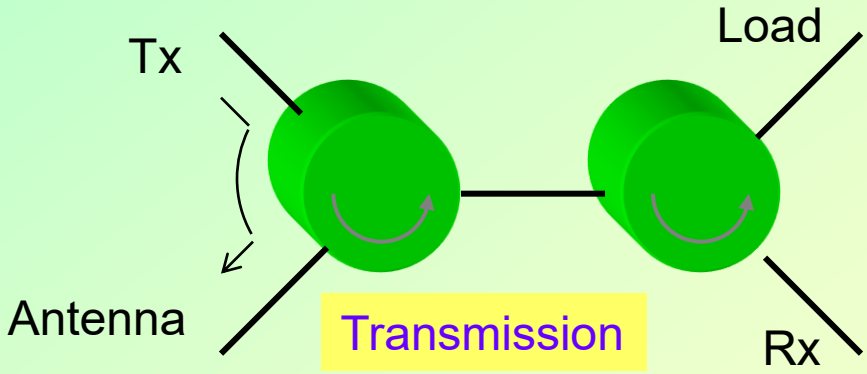
- Can send the signals only in one direction.
- Thus, entire bandwidth of the channel can be used during the transmission.
- E.g.,: **Radio station** and TV

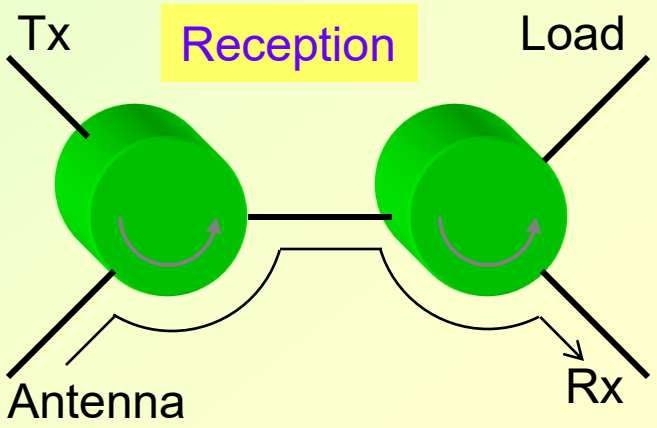
- Can send signals in both the directions but in only one direction at a time.
- It may be considered as a simplex communication channel whose transmission direction can be switched.
- E.g.,: Walkie-Talkie

- Can send signals in both the directions at the same time.
- Full duplex communication channels greatly increases the efficiency of communication.
- E.g.,: Telephone

Transmission - Duplex Operation

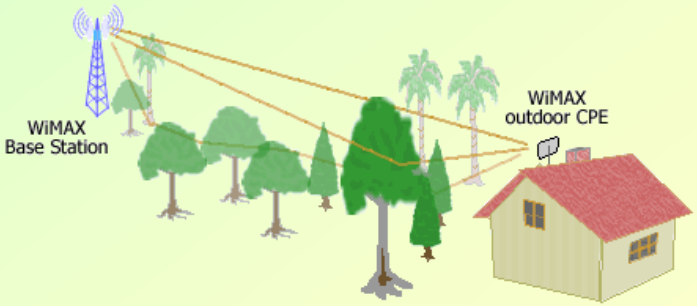






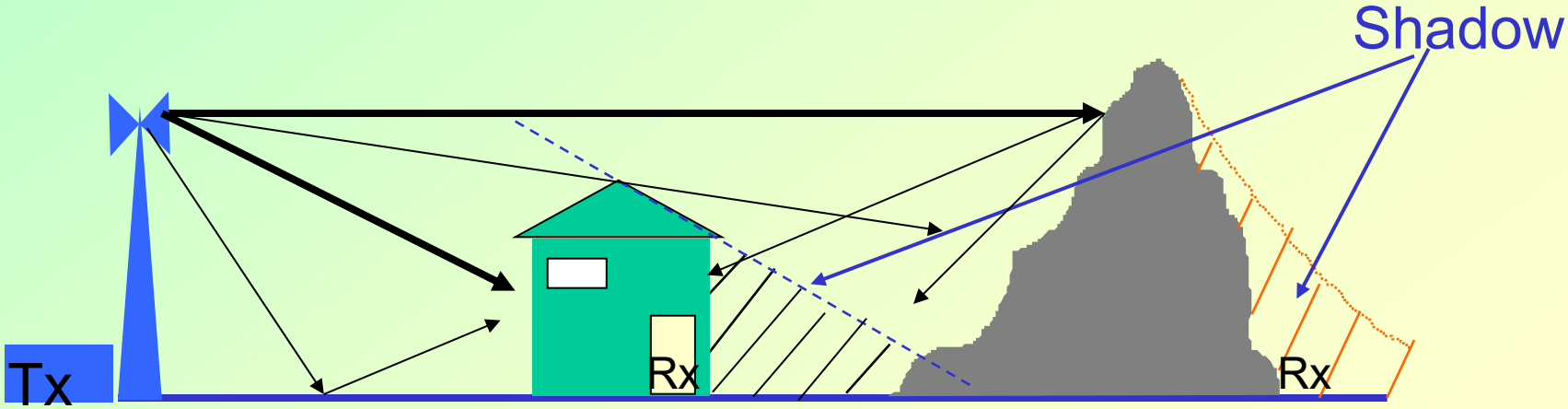
Mobile Transmission Environment

- Deep Radio Shadow + Radio Horizon
- Reflection, Refraction and Scattering
- Fading
  - Frequency-Selective
  - Multipath
- Propagation Path Loss (Attenuation)
- Doppler Shift
- Delay Distortion
- Noise and Interference
- Urban, Suburban, and Rural Environments



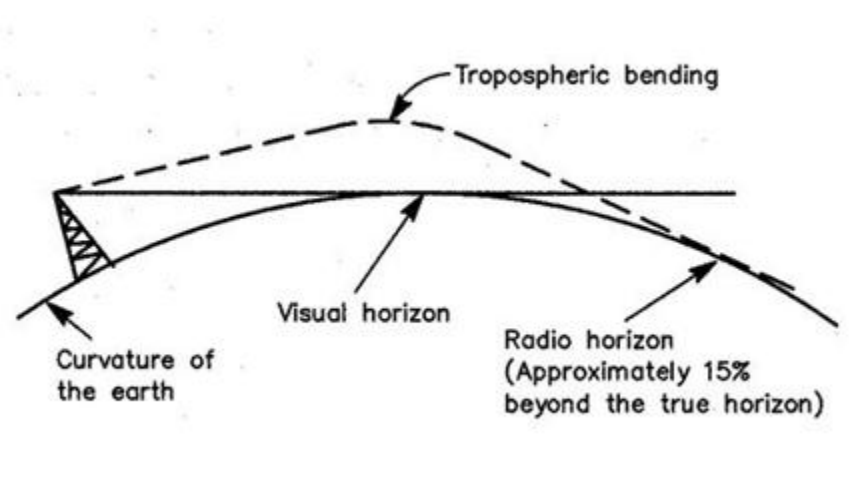
Transm. Pro. - Deep Radio Shadow

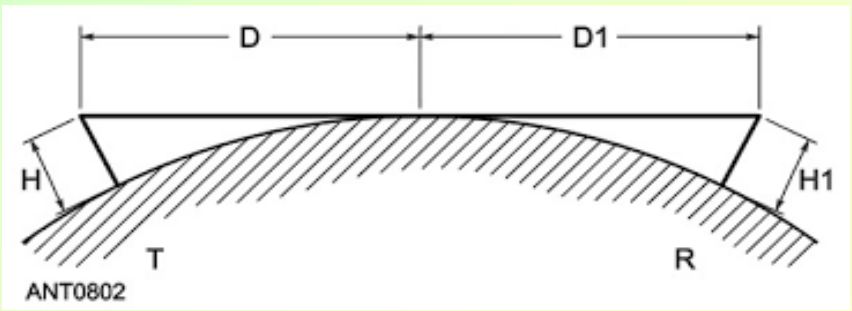
- Radio waves at low frequencies can diffract (bend) around object
- At high-frequencies, wave diffraction does not take place well, therefore a ***deep radio shadow*** occurs on the un-illuminated side of the obstruction (e.g., building, hill, truck, or even human being)
  - It results in deviation of the power of the received electromagnetic signal from the average value.



Transm. Env. - Radio Horizon

- Is 30% farther from the transmitting antenna than the equivalent visible horizon due to the reduction of the refraction in the upper atmosphere compared to that at ground level.
  Beyond radio horizon, the signal strength falls very rapidly → in areas well beyond the horizon the same frequency can be reused without .

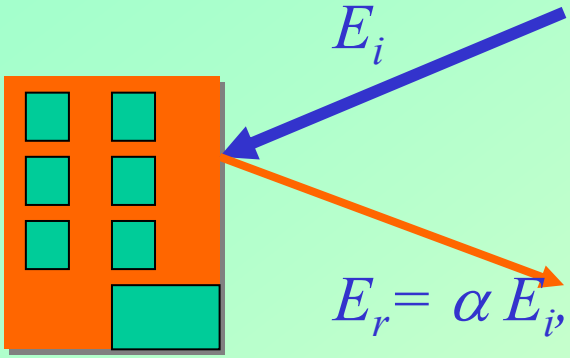




- The higher the transmitter antenna, the further away is its radio horizon.
- The coverage area (not the radius) is **approximately proportional** to the antenna heights of both transmitter and receiver.
- Between the transmitter and horizon, in open, flat country, ***the received power reduces approximately as the inverse fourth power of distance*** from the transmitter (as we see later on).

Transmission Env. – *contd.*

Free space line of sight



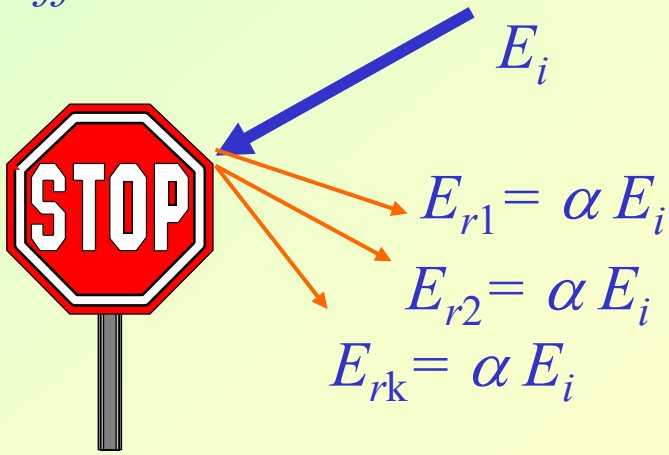
Reflection at large obstacles √

- Object size >> λ

$E_r = \alpha E_i$, *where* α *is the absorption coefficient* < 1

Scattering at small obstacles

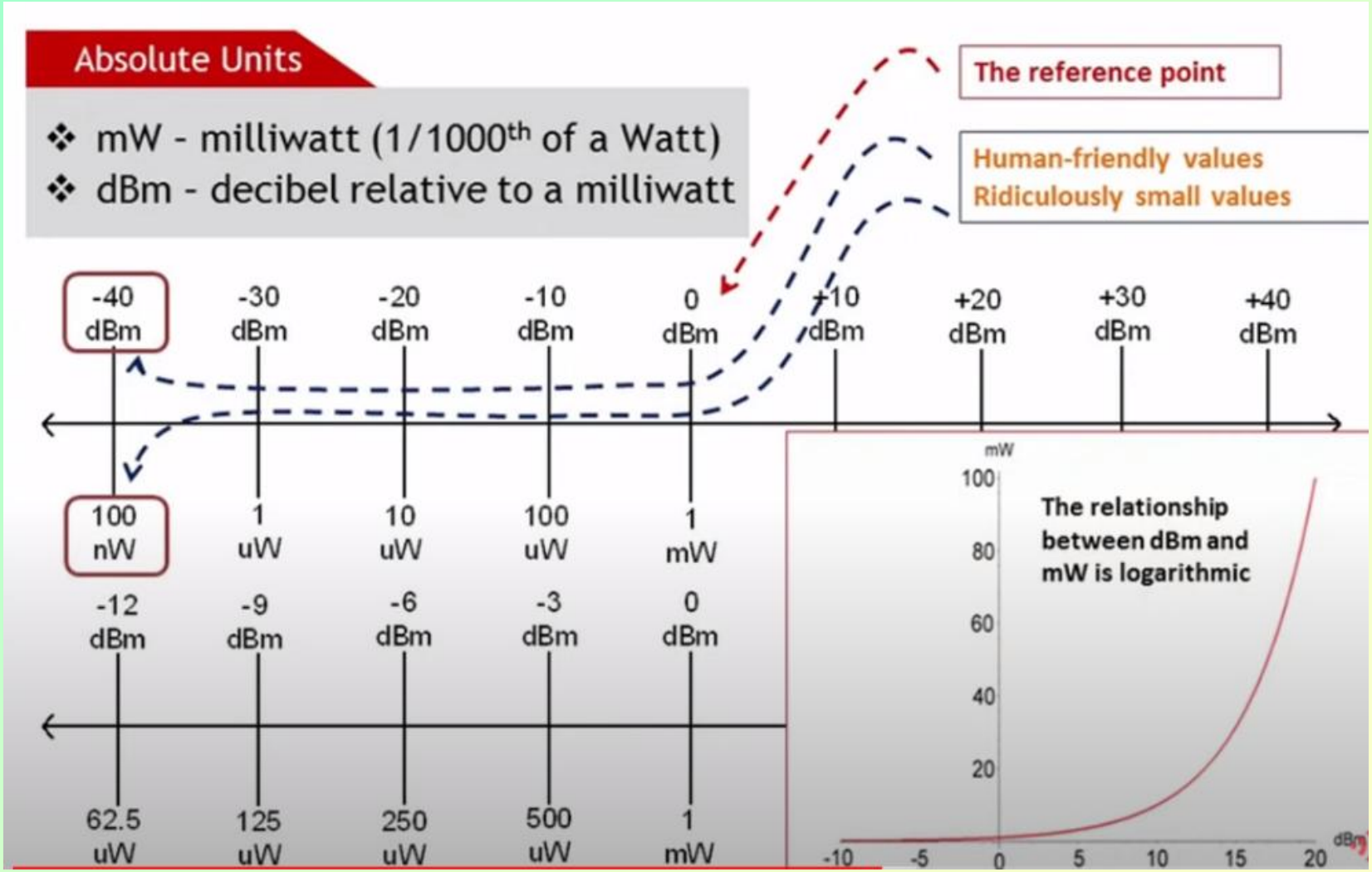
- Object size >> λ



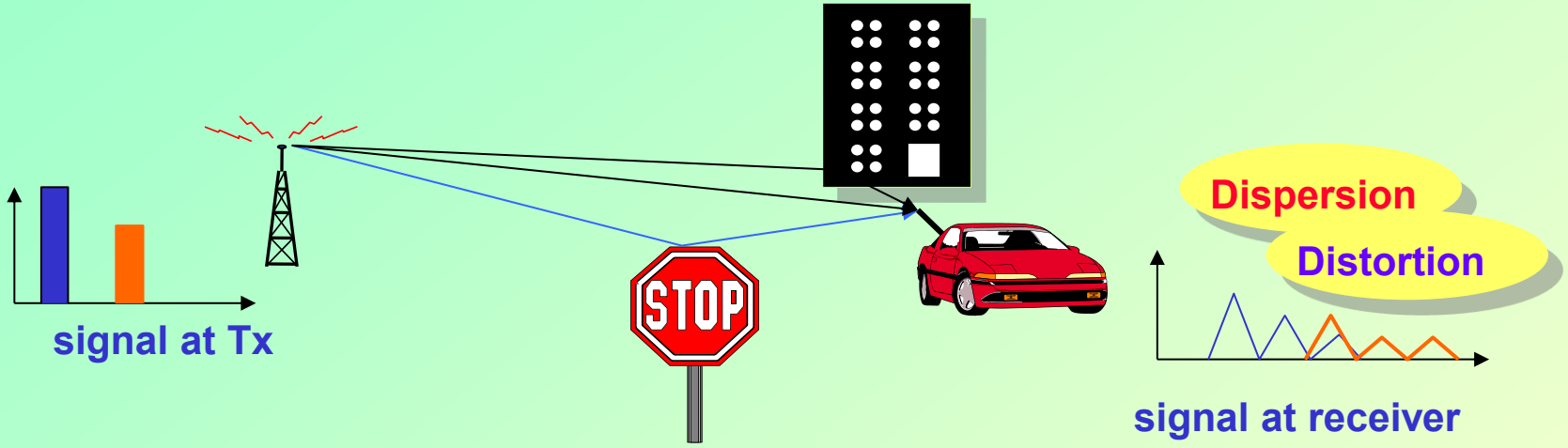
Diffraction at edges

- Makes possible to go round corners

Transmission Env. – Power



Transm. Env. – Loss/Dispersion, Etc.,



- **Attenuation:** Typical mean **building penetration losses** are 10 to 20 dB, but penetration losses as high as 40 dB have been encountered. which is due to absorption of energy and Scattering of energy
- **Dispersion:** signal is dispersed over time, thus interfering with "neighbor" symbols --> ***Inter Symbol Interference***
- **Distortion:** signal reaches a receiver directly and phase shifted:- distorted signal depending on the phases of the different parts
- Multipath **fading**
- **Delay distortion:** Digital signals, where different frequency components of the same signal travel at slightly different speeds.

Transm. Env. - Bandwidth

- All real channels have a limited bandwidth.

- Not all the frequency components of transmitted signal will pass through the channel.

- At the receiver, exact regeneration of the original signal becomes quite difficult.

- **Resulting in the received signal distortion**

Transm. Pro. – Limited Energy

Mobile unit (MU)

Powered by one way or by rechargeable batteries

↓

Thus, low energy consumption

↓

1- Transmitter power amplifier – High efficiency amplifiers (Class C and F) (> 50%)

↓

Leads to nonlinearity → Harmonic distortions

↓

Use of modulation schemes that are insensitive to nonlinearity (e.g., constant envelope)

Transmit power should be adoptable, - Depending on the position of MU from the base station.

Transm. Pro. – Limited Energy

Mobile unit (MU)

Powered by one way or rechargeable batteries

Thus, low energy consumption

2- Signal processing – energy efficient

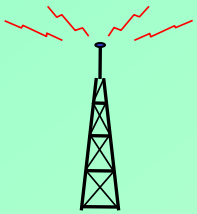
CMOS technology – Is power efficient

3- High sensitivity and low noise receiver – E.g., as low as -100 dBm for GSM → Low noise amplifier; signal processing, network planning

If it is -80 dBm:

- **then transmit power is higher by a factor of 100 to achieve the same coverage**
- **the battery would need to be 100 times larger**

Transm. Pro. – Noise & Interference

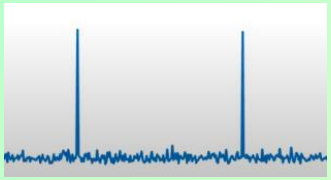


RF signal

. Thermal noise
. Amplifier noise

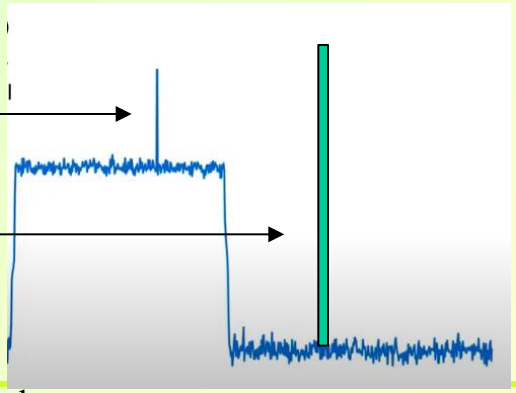
Receiver → **RF** + Noise

Implies noise



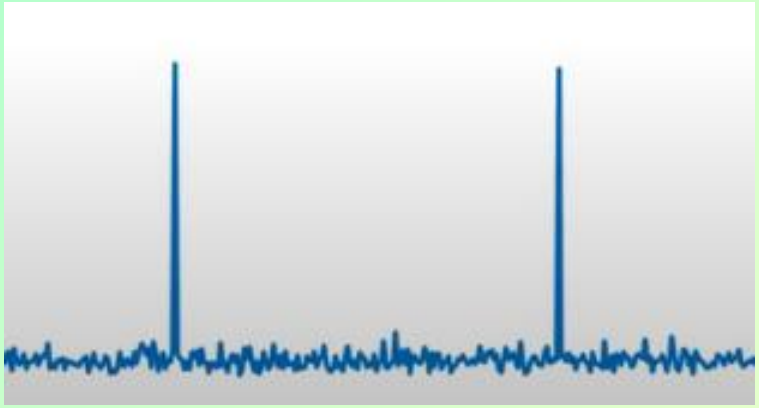
Phase noise ⇨ Rotation of constellation diagram ⇨ Higher errors

CW interference → In-band
CW interference → Out-band



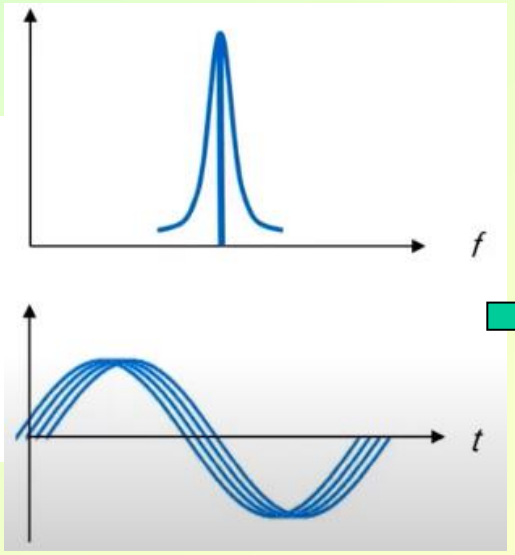
Transm. Pro. – Noise & Interference

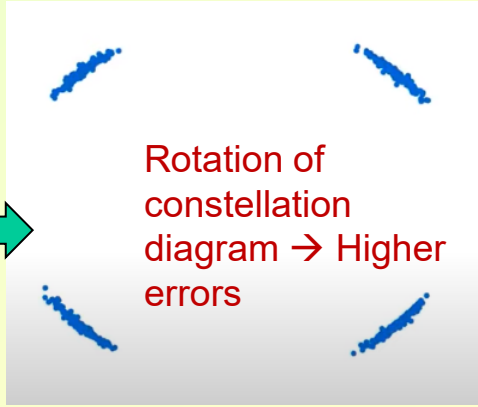
Impulse noise



Phase noise

- Phase noise is short term variations in the frequency of a signal
- Excessive phase noise can cause many types of problems
  - High EVM in communications systems
  - Errors in radar systems (masks slow-moving targets)





How to Combat Issues?

- Modulation – use a signal format to send as many bits as possible
- Error control coding – add extra bits so errors are detected/corrected.
- Adaptive modulation and coding – dynamically adjust modulation and coding to current channel conditions.
- Equalization – counteract the multipath effects of the channel.
- Multiple-input multiple-output systems – use multiple antennas
  - Point signals strongly in certain directions
  - Send parallel streams of data.
- Direct sequence spread spectrum – expand the signal bandwidth
- Orthogonal frequency division multiplexing – break a signal into many lower rate bit streams
  - Each is less susceptible to multipath problems.

Mobile Phones Technology - Disadvantages

- Symptoms caused by the radiation of mobile phones are:
  - headache, earaches, blurring of vision and even causing cancer

    Though, these problems are still under research. Mobile phone users are advice to reduce the usage on mobile phones if it is possible.
- Mobile phone addiction.
  - Mobile phone addiction is becoming one of the biggest non-drug addictions in the 21st century in particular among the teenagers.
  - New models of mobile phones are released almost everyday. In order to get up-to-date, people tend to change their mobile phones once in a while. These became habits among the mobile phone users causing them to spend unnecessary cost on mobile bills and

Summary

- History
- Mobile technologies
- Principle
- Characteristics
- Transmission properties

Next Lecture

Cellular Concept