Broadcasting Towers Operation

WEEK 4 – Review to Fundamentals of Telecommunication

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Objectives

At the end of the topic students will be able to:

1. Review of antenna and wave propagation.
2. Review of analogue and digital communication (ADC) systems.
3. Review of mobile communication.
4. Attenuation and signal control.

4.1.1 Antenna

- An antenna is a transducer that converts radio frequency (RF) fields into alternating current (AC) or vice versa.

Basic parameters

- **Radiation Pattern**: the graphical representation of the radiation properties of the antenna as a function of space coordinates.
- **Directivity**: the measure of how ‘directional’ an antenna’s radiation pattern is.
- **Gain**: the ratio of the power produced by the antenna to the power produced by a hypothetical isotropic antenna.
- **Bandwidth**: The range of frequencies over which the antenna operates effectively.
- **Polarization**: The orientation of the electric field of the radiated wave

4.1.1 Antenna cont'd

Types of antennas

- **Dipole** : simple antennas consisting of two conductive elements.
- **Monopole**: half of a dipole antenna, usually mounted above a ground plane.
- **Array**: multiple antennas working together to form a single antenna system.
- **Yagi-Uda**: directional antenna consisting of multiple parallel elements in a line.
- **Microstrip**: also known as patch antenna, commonly used in mobile and satellite communications.
- **Parabolic Reflector**: an antenna that uses a parabolic-shaped reflector to direct radio waves.

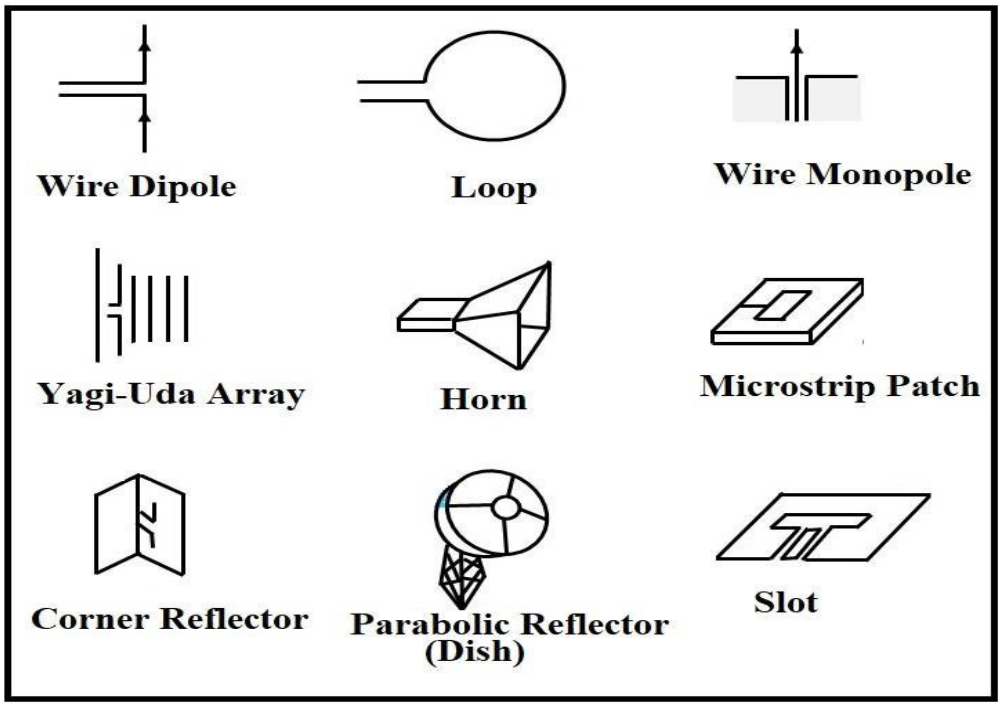
4.1.1 Antenna cont’d

Design and analysis

- Design involves selecting the appropriate type, size, and placement of the antenna to achieve desired performance.
- Simulation requires tools (software) like MATLAB and HFSS are used for designing and analysing antennas.
- Testing and measurement involves using equipment like network analysers and anechoic chambers to measure antenna parameters.

(“Antenna Theory: Analysis and Design” by Constantine A. Balanis, Wiley, 4th Edition, 2016, pp. 1-100.)

4.1.1 Antenna cont'd



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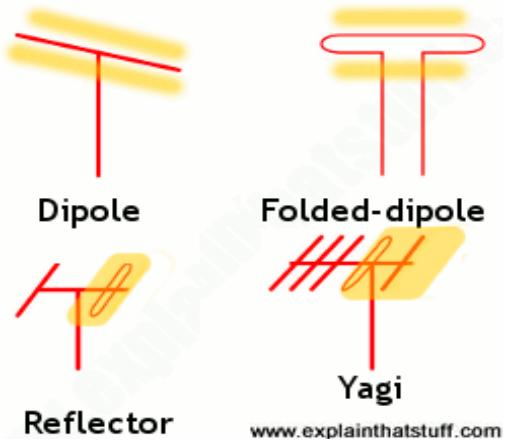


Link 2

1. (https://www.researchgate.net/figure/Several-types-of-Antennas-6_fig15_322509437)

2. (https://www.explainthatstuff.com/antennas.html)

4.1.2 Wave propagation

- It refers to the movement of electromagnetic waves through different media with influence of frequency, terrain, atmospheric conditions, and obstacles.

Modes of propagation

- **Ground wave**: radio waves that travel along the surface of the Earth.
- **Sky wave**: radio waves that are reflected to Earth from the ionosphere.
- **Line-of-Sight (LoS)**: radio waves that travel in a straight line from the transmitter to the receiver.

Propagation mechanisms ("Electromagnetic Waves and Radiating Systems", Edward C. Jordan and Keith G. Balmain, Prentice-Hall, 2nd Edition, 1968, pp. 200-300.)

- **Reflection**: bouncing of electromagnetic waves off surfaces.
- **Refraction**: bend of electromagnetic waves passing through different media.

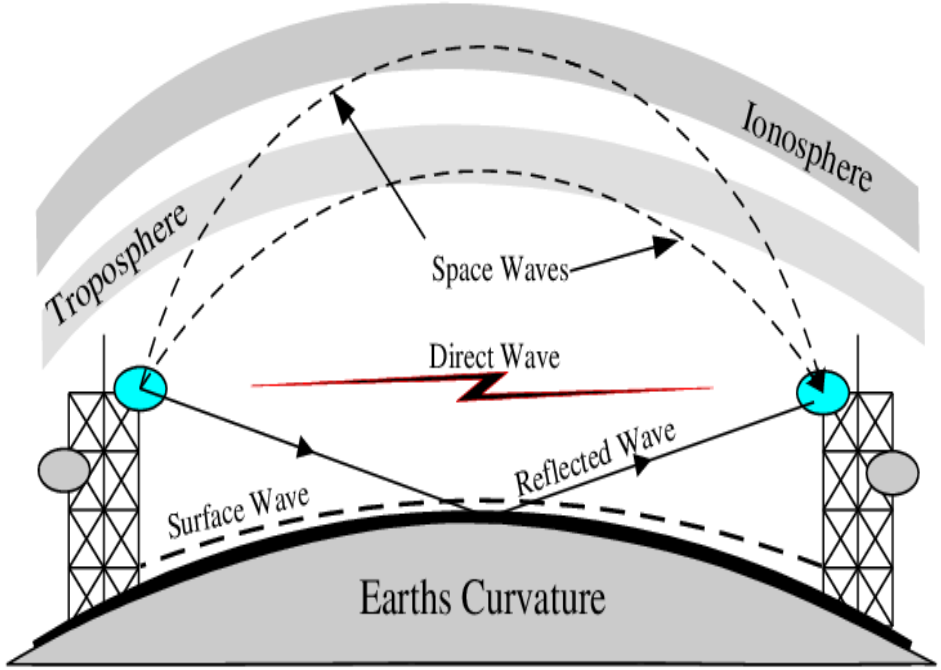
4.1.2 Wave propagation cont'd

- **Diffraction**: bending of electromagnetic waves around obstacles.
- **Scattering**: dispersion of electromagnetic waves when they encounter irregularities in the medium.

Factors affecting propagation

- Frequency: higher frequencies tend to have shorter ranges.
- Terrain: obstacles like mountains, buildings, etc can block or reflect radio waves.
- Atmospheric conditions: weather and atmospheric layers can affect signal strength and quality.
- Review these phenomena reminds the designs for efficient communication systems with proper signal coverage and quality. (Antennas and Wave Propagation, John D. Kraus and Ronald J. Marhefka, McGraw-Hill, 4th Edition, 2002, pp. 50-150.)

4.1.2 Wave propagation cont'd



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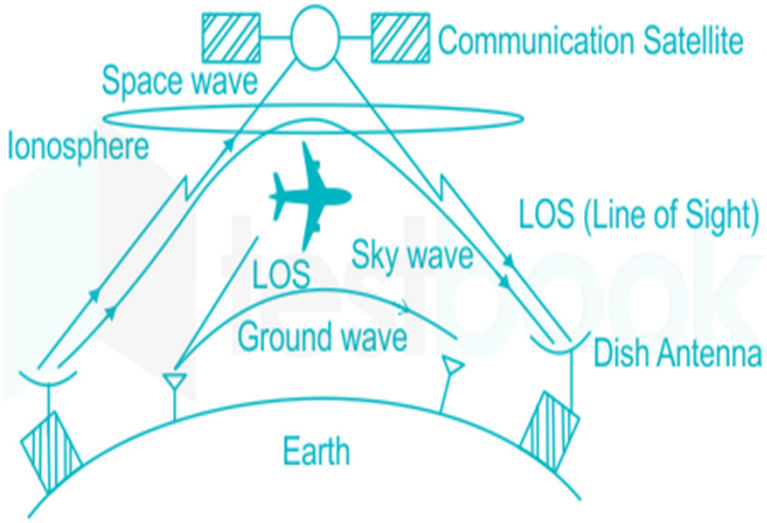
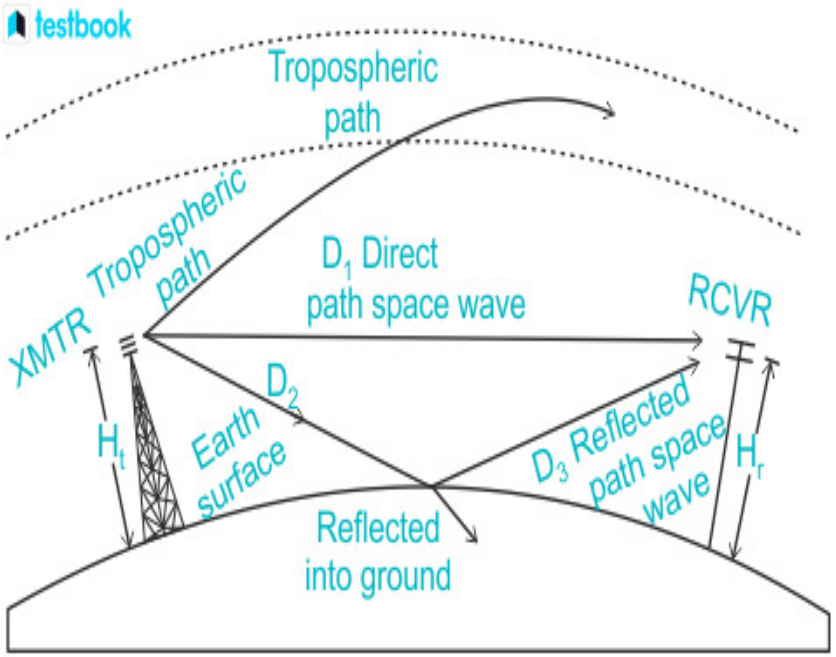


Link 2

1. (https://www.researchgate.net/figure/Common-types-of-radio-waves-in-wireless-communication-systems_fig1_228041875)

2. (https://testbook.com/question-answer/modes-of-space-communication-area-direct-wave--5ebc04aaf60d5d1c52b80c96)

4.1.2 Wave propagation cont'd



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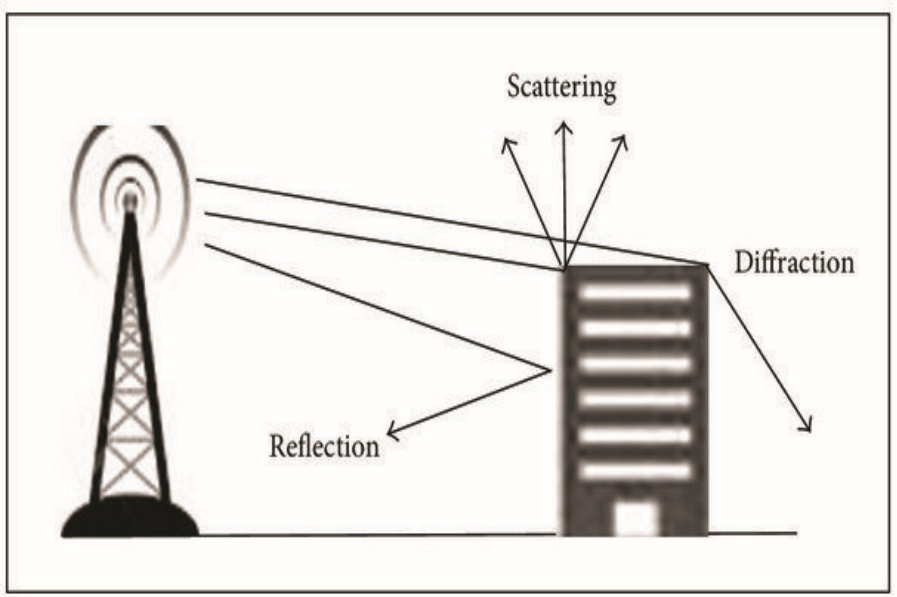


Link 2

(https://testbook.com/physics/sky-wave-propagation)

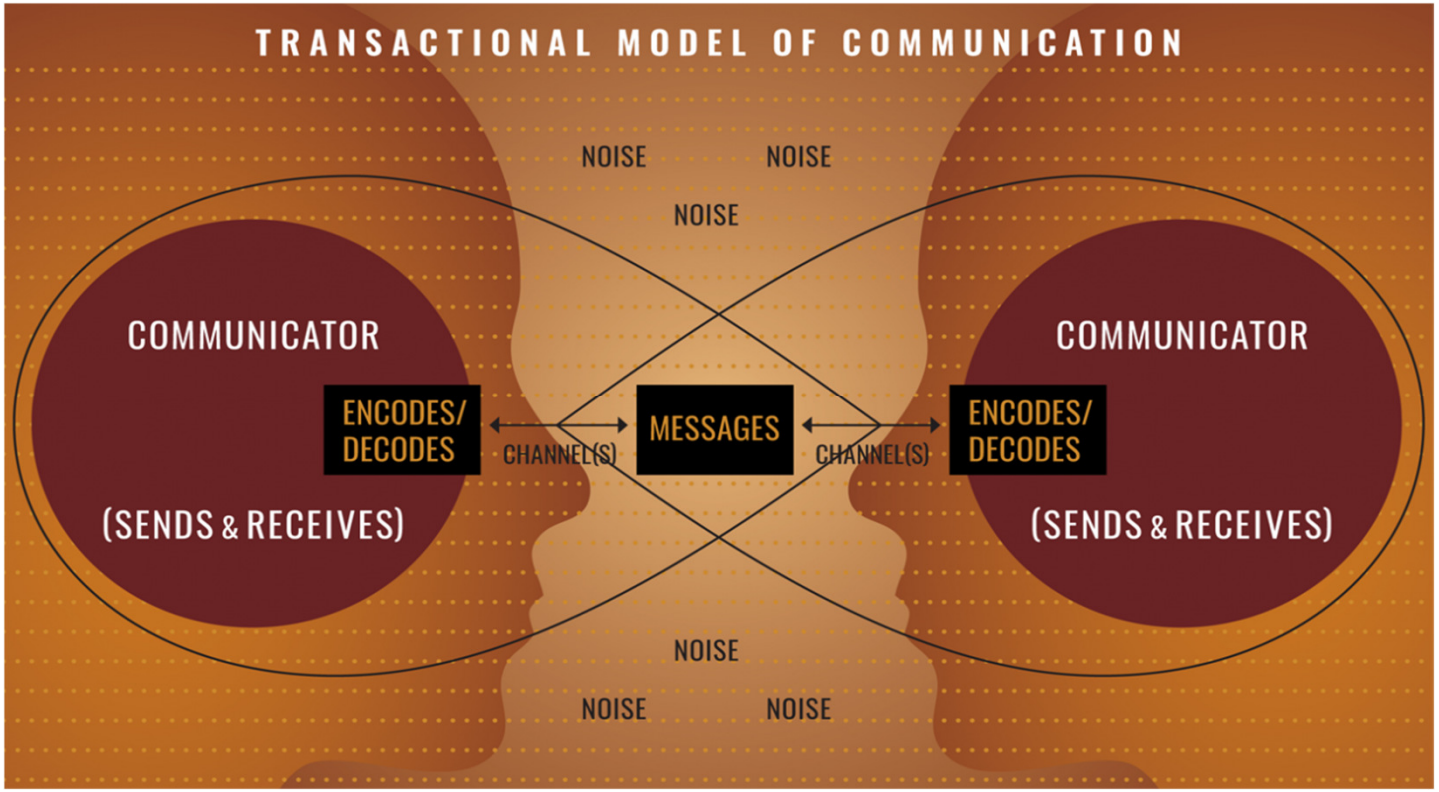
(https://www.researchgate.net/figure/Propagation-mechanisms-in-ray-tracing_fig2_320209043)

4.2 ADC

- The fundamental the art of communicating information by wires or wirelessly.
- Communication is used in various techniques like underwater acoustic, optical, radio, satellite, etc.
- Analogue was first introduced and included AM radio, FM radio, television, and first-generation cellular systems.
- It gradually outdated by the customer need and got replaced by digital with a fundamental difference being that digital has a capacity to transmit information while keeping a copy to use in case the communication is not successful.
- Every major wireless system being developed and deployed is built around digital communication including cellular communication, wireless local area networking, personal area networking, and high-definition television.

4.2 ADC cont'd

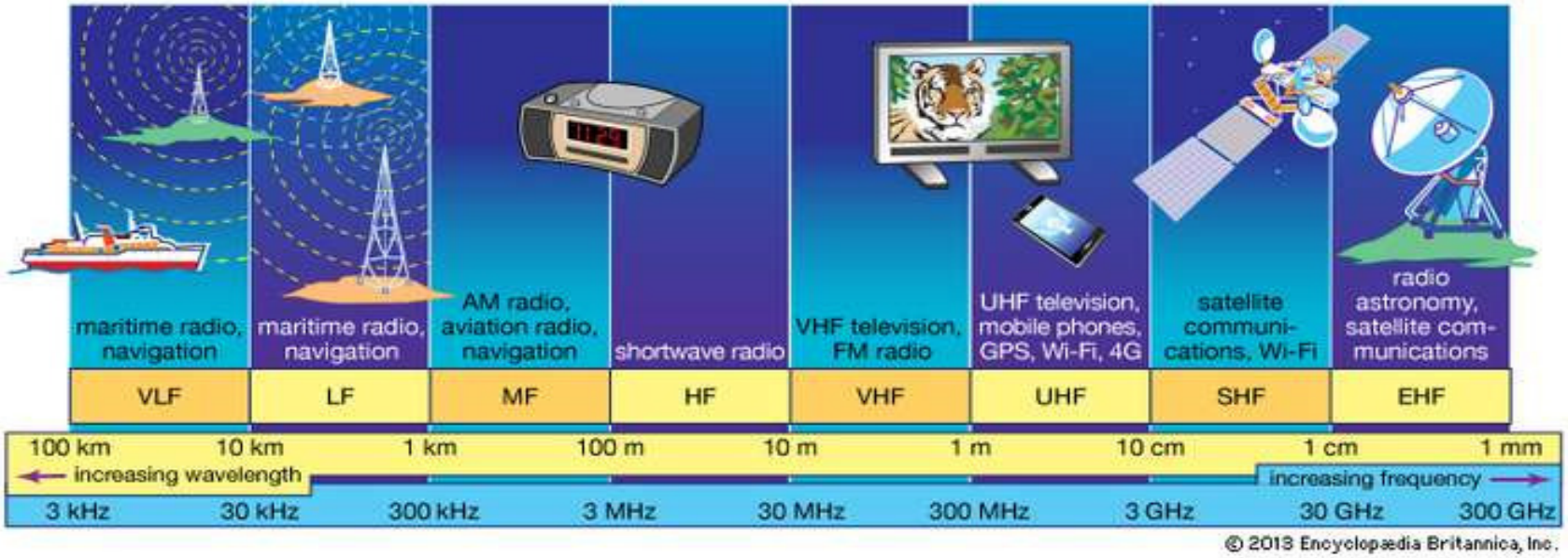
- The basic of communication is illustrated in the following figure.



(https://www.natcom.org/about-nca/what-communication)

4.2 ADC cont'd

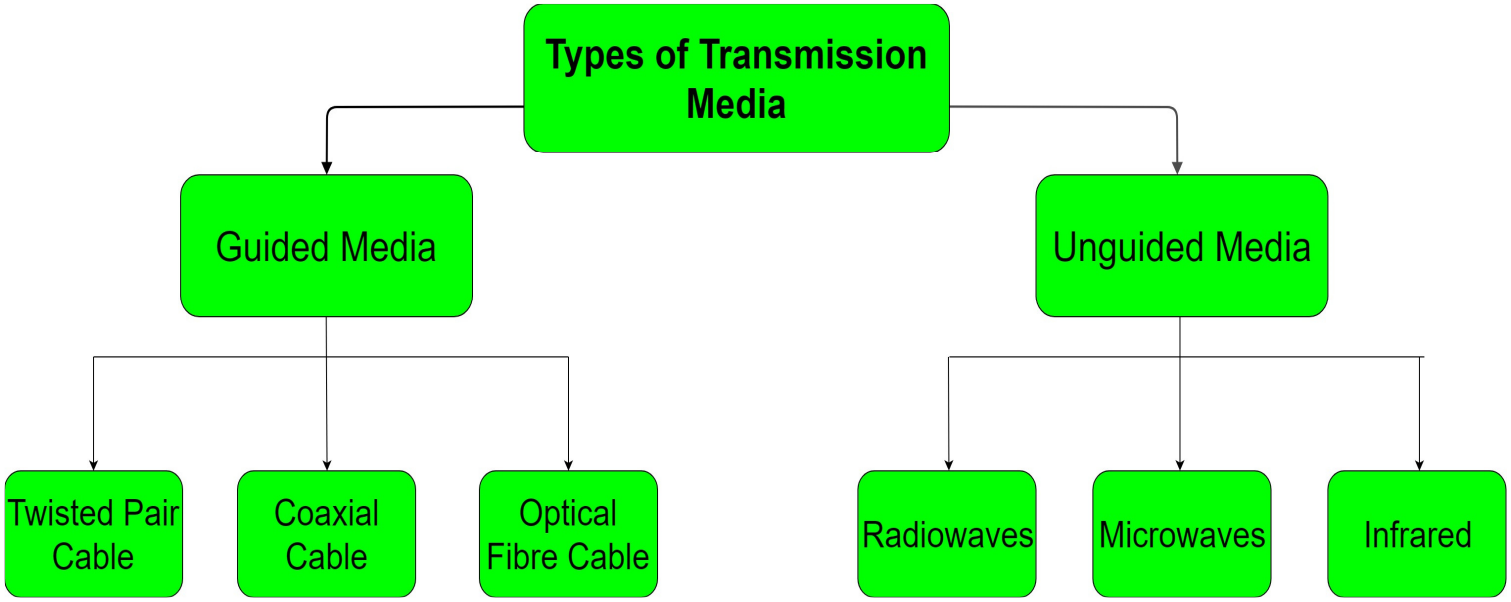
- The radio spectrum is the radio frequency (RF) portion of the electromagnetic spectrum.
- The frequency spectrum of an electrical signal is the distribution of the amplitudes and phases of each frequency component against frequency.



(https://www.britannica.com/science/radio-frequency-spectrum)

4.2 ADC cont'd

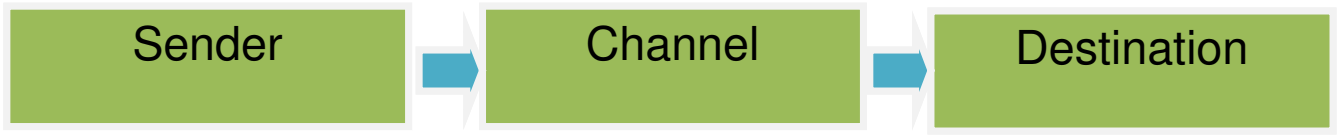
- A transmission medium is a physical path between the transmitter and the receiver i.e it is the channel through which data is sent from one place to another.



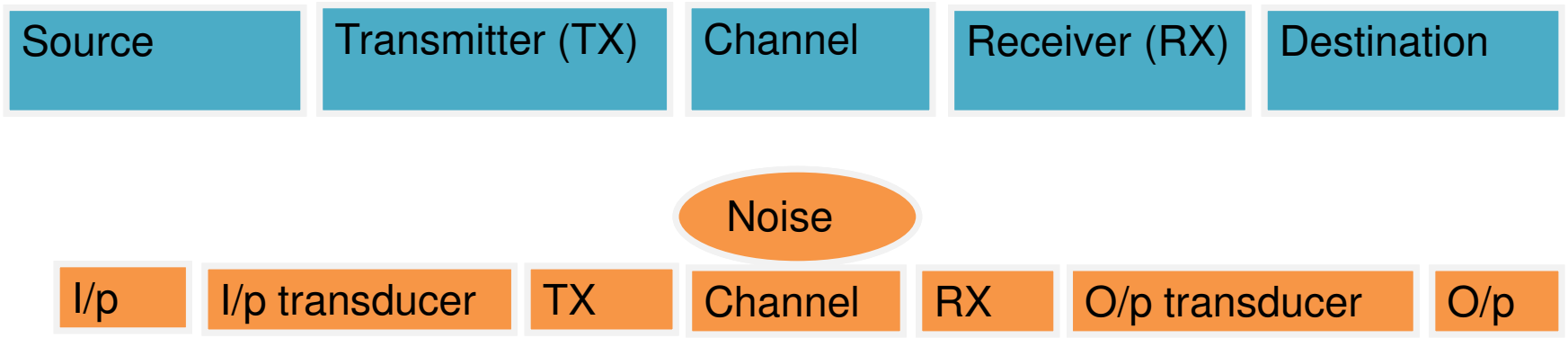
(https://winstartechnologies.com/transmission-media-in-computer-networks-and-its-types/)

4.2 ADC cont'd

- Parts of a communication system: Any system which provides communication consists of three main parts

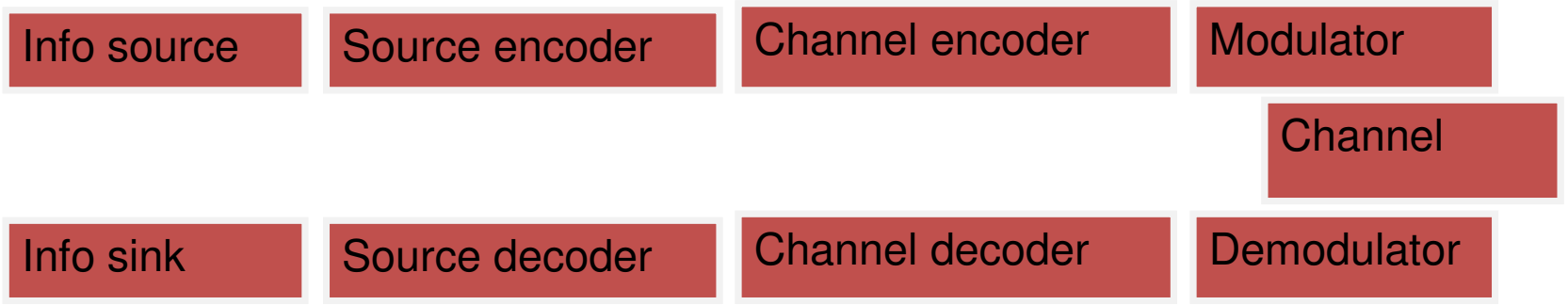


- The elaborated communication system is shown in the following figures.

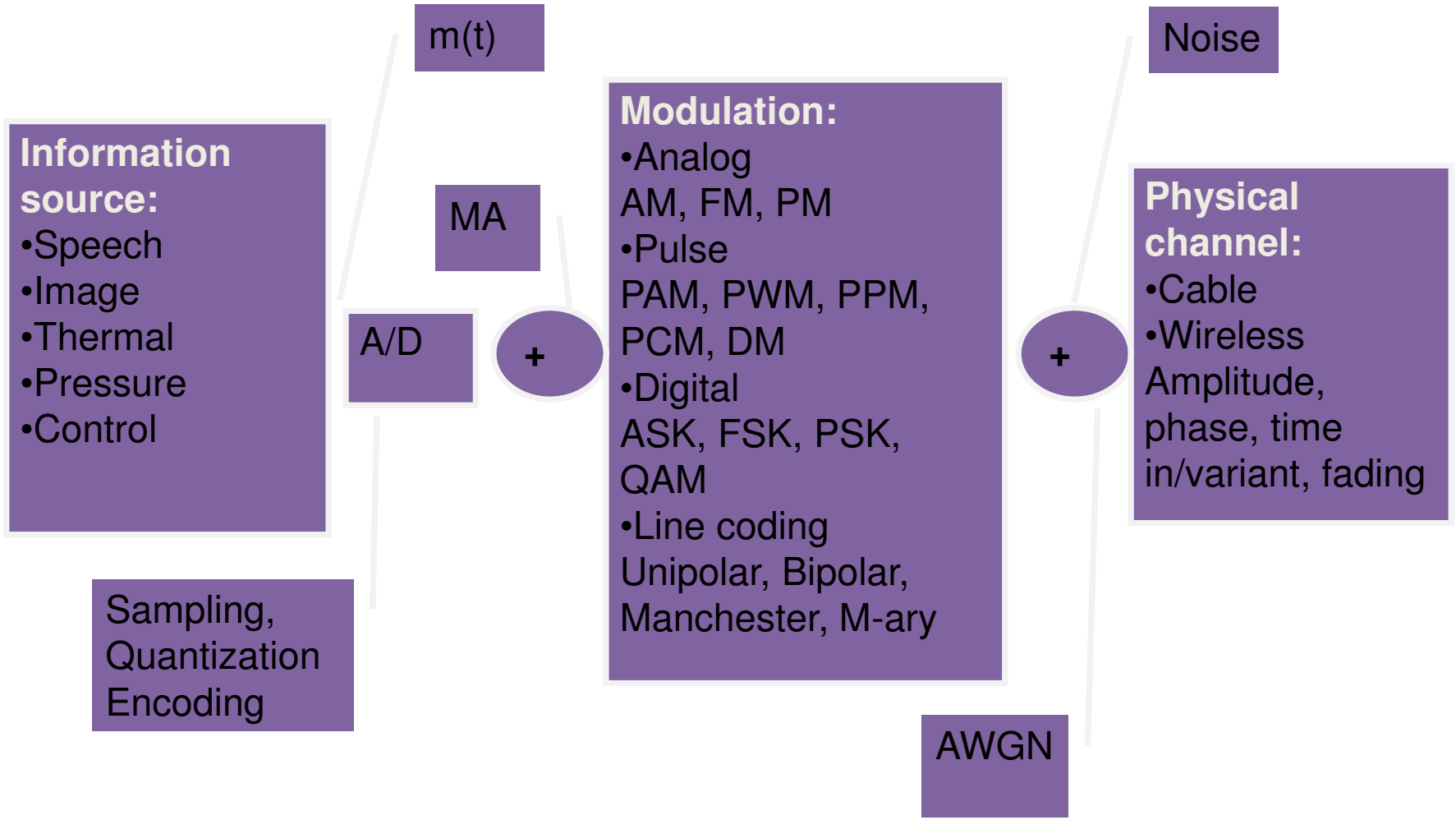


4.2 ADC cont'd

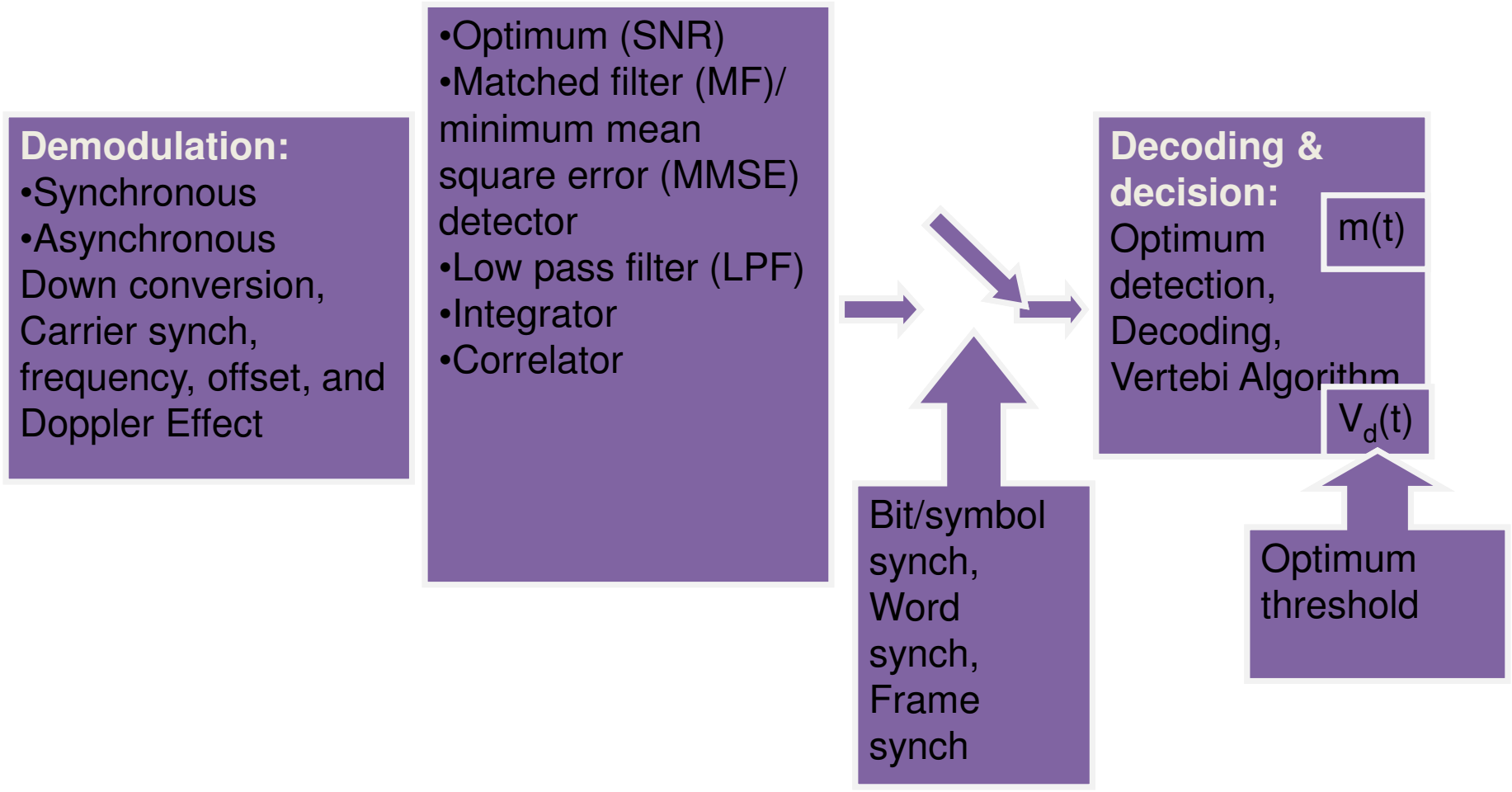
- A digital communication system adds improving block which provides its robustness to ensure efficient communication.
- A source encoder ensures the source is compressed and the channel encoder ensures the encryption that serves as error control in during transmission process.
- A digital system works on the source in digital form, if not; a process involving sampling, quantization and encoding through the Analogue to Digital Conversion (ADC) should be done for transmission by digital system.



4.2 ADC cont'd


m(t)
Noise
Information source:
•Speech
•Image
•Thermal
•Pressure
•Control
MA
A/D
+
Modulation:
•Analog
AM, FM, PM
•Pulse
PAM, PWM, PPM, PCM, DM
•Digital
ASK, FSK, PSK, QAM
•Line coding
Unipolar, Bipolar, Manchester, M-ary
+
Physical channel:
•Cable
•Wireless
Amplitude, phase, time in/variant, fading
Sampling, Quantization Encoding
AWGN

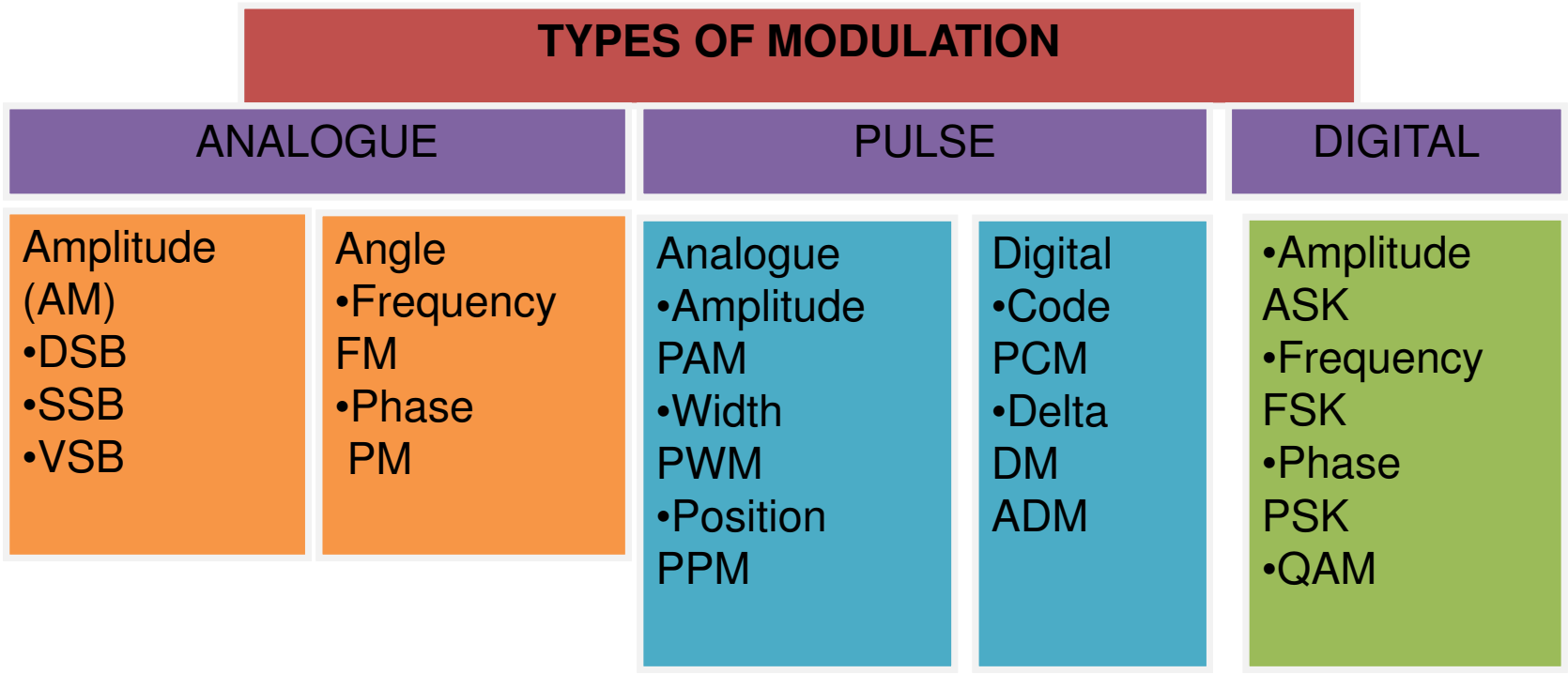
4.2 ADC cont'd


Demodulation:
•Synchronous
•Asynchronous
Down conversion, Carrier synch, frequency, offset, and Doppler Effect
•Optimum (SNR)
•Matched filter (MF)/ minimum mean square error (MMSE) detector
•Low pass filter (LPF)
•Integrator
•Correlator
Bit/symbol synch, Word synch, Frame synch
Decoding & decision:
Optimum detection, Decoding, Vertebi Algorithm
m(t)
$V_d(t)$
Optimum threshold

4.2 ADC cont'd

- For a signal to be transmitted to a distance, without the effect of any external interference or noise addition and without getting faded away, it must undergo a process called **Modulation**.
- It improves the strength of the signal without disturbing the parameters of the original signal. A **message carrying a signal** must get transmitted over a distance and for it to establish a reliable communication; it needs to take the help of a **high frequency signal** which should not affect the original characteristics of the message signal.
- The high frequency signal is called the carrier and modulation helps in changing the parameters of the carrier signal, in accordance with the instantaneous values of the modulating signal.

4.2. ADC cont'd

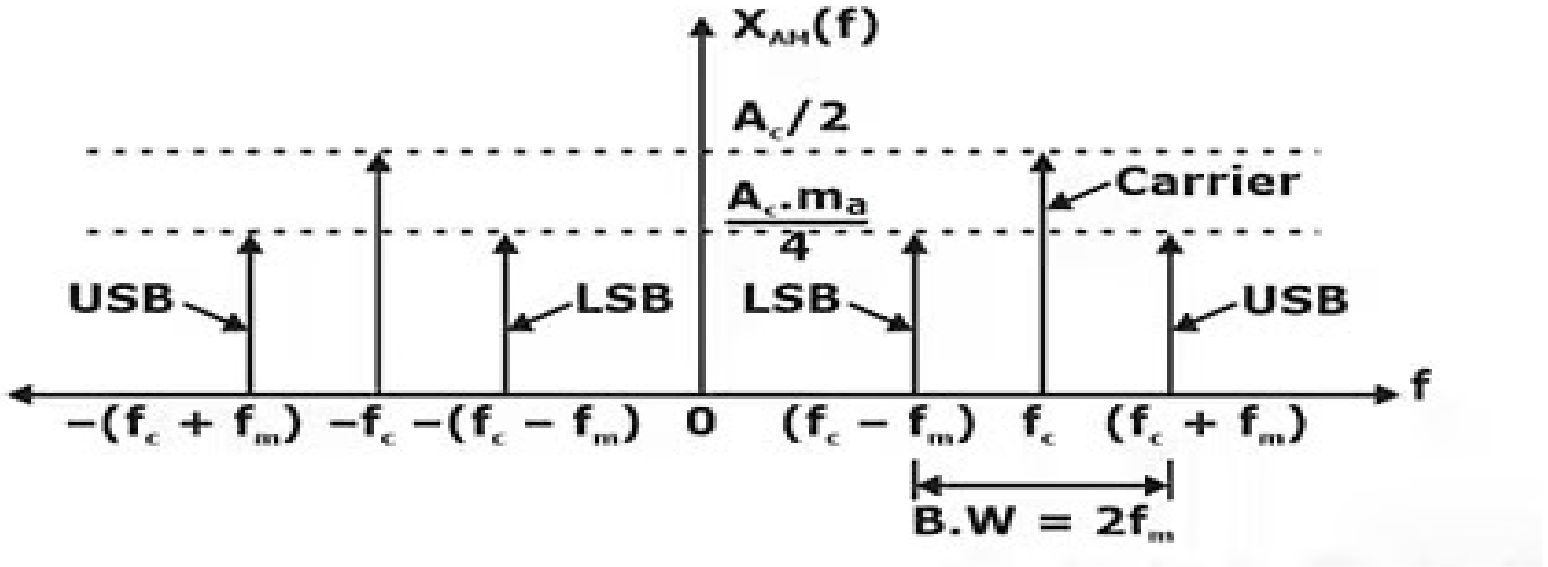

TYPES OF MODULATION
ANALOGUE
PULSE
DIGITAL
Amplitude (AM)
•DSB
•SSB
•VSB
Angle
•Frequency FM
•Phase PM
Analogue
•Amplitude PAM
•Width PWM
•Position PPM
Digital
•Code PCM
•Delta DM
ADM
•Amplitude ASK
•Frequency FSK
•Phase PSK
•QAM

4.2.1 Analogue communication

- The bandwidth and the power of an AM signal:

The spectrum shows that the bandwidth is twice the modulating frequency while the power is the combination of the carrier power and the side bands power.

- The spectrum for illustration is shown:



(https://edurev.in/t/186952/Communication--Amplitude-Modulation-Demodulation)

4.2.1 Analogue communication cont’d

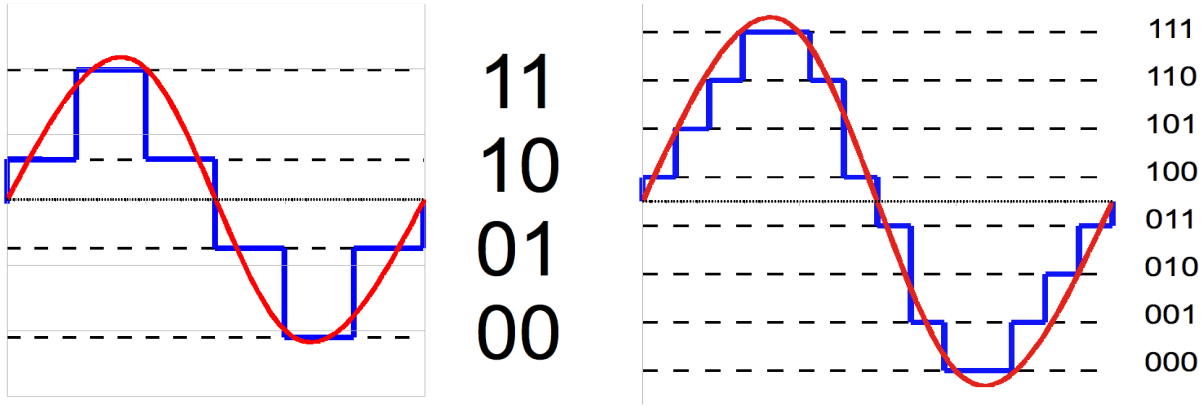
- The Frequency and phase modulation are an improved version of analogue modulation since, they overcome the waste of the power.
- Since in AM, the modulation occurs outside of the signal (amplitude), in FM/PM, it occurs inside the signal (angle or frequency and phase). Therefore, FM and PM are more power-efficient than AM because they use constant amplitude signals, which means less power is wasted.
- Therefore, the AM is a linear modulation while FM/PM is an exponential modulation.
- FM and PM have a more complex spectrum with multiple sidebands, while AM has two main sidebands (USB and LSB). FM and PM require a larger bandwidth up to 10 times than AM. FM and PM offer better noise immunity and higher fidelity, making them more suitable for high-quality audio transmissions.

4.2.2 Digital communication

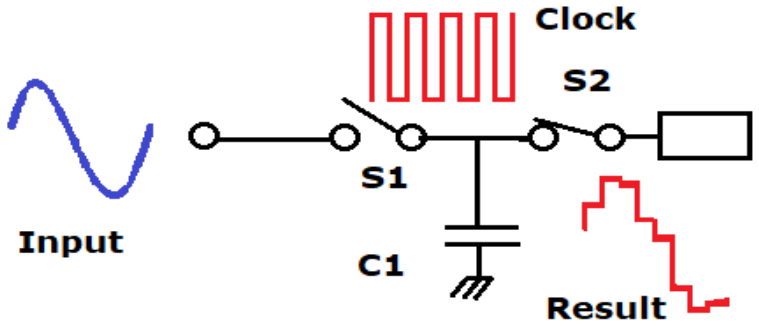
- In digital communication systems, the information propagates through the system in the form of symbols that are discrete or digital.
- Digital sequence is used as an interface between the source and the channel input as well as between the channel output and destination.
- The source encoder ensures data compression where fewer bits are transmitted to represent the message or information.
- To have the bits representing the message, a source should be digital, the analogue message requires to be digitized using ADC that involves sampling, quantization and encoding.
- This process helps to changes a continuous signal in both amplitude and time to a digital signal that is discrete in both amplitude and time.

4.2.2 Digital communication cont'd

- The sampling frequency and the resolution determines the smoothness of the signal converted.



(https://reparke.github.io/ITP348-Physical-Computing/lectures/week02/lecture_adc.html)



(https://www.circuitbasics.com/analog-to-digital-converters/)

4.2.2 Digital communication cont'd

- The generated codes (binary numbers) are processed to represent the message signal, the number of bits to be transmitted should be as minimum as possible with no effect on the original message (compression).
- This follows a logarithmic function with a consideration of the probability of occurrence of an event.
- Some important terms to consider are self-information, entropy of the source, the channel capacity and the bit rate.
- To ensure efficient communication optimal codes are generated from Huffman and Shannon Fano's optimal code.
- The channel capacity should be to the maximum rate for reliable data transfer.
- The result: **Redundancy Reduction →Data Compression**

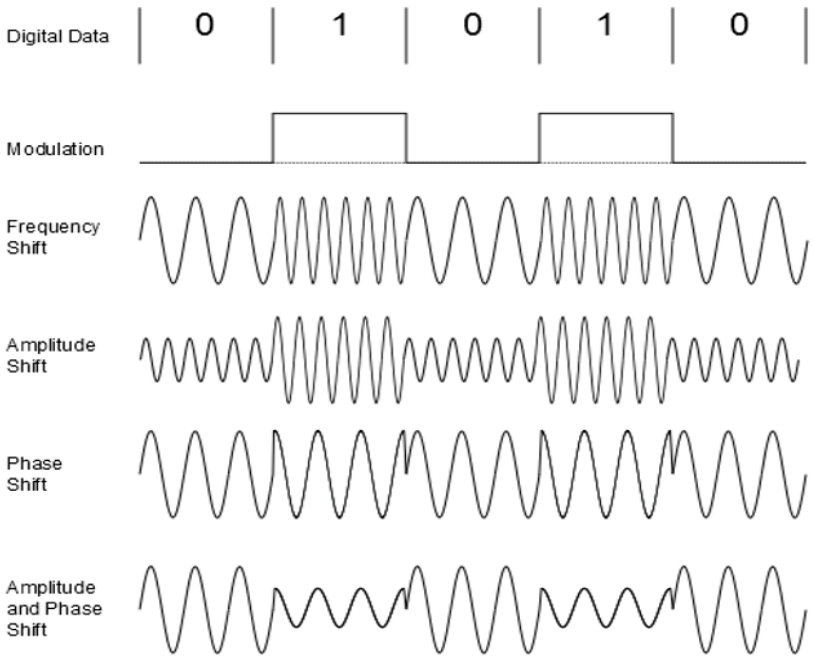
4.2.2 Digital communication cont'd

- The message prepared should pass through the channel and to ensure the error free transmission, the encryption of the message is done using error detection and correction.
- The **ARQ** and **FEC** are the methods used to accomplish that process.
- The coding techniques to highlight are Hamming codes, Cyclic redundancy codes, among others.
- The concept of error detection and correction is important as a additional bits are added to provide the security of the message before it is released in the channel for transmission purpose.
- The result: **Adding redundancy →Data encryption.**

4.2.2 Digital communication cont'd

- The digital modulation techniques involve representing the message signal in terms of zeros and ones, the carrier will behave as the modulating signal resulting in the absence and presence of the carrier (Amplitude Shift Keying or ON-OFF Keying), low and high frequency carrier (Frequency Shift Keying) as well as the in phase and out of phase carrier (Phase Shift Keying).
- For the system to be robust, M-ary signalling involving the amplitude and the phase, is used as strong modulation techniques which most used for current generation of mobile communication systems.
- The Pulse modulation techniques are semi-digital modulation which work through the analogue to digital conversion.

4.2.2 Digital communication cont'd



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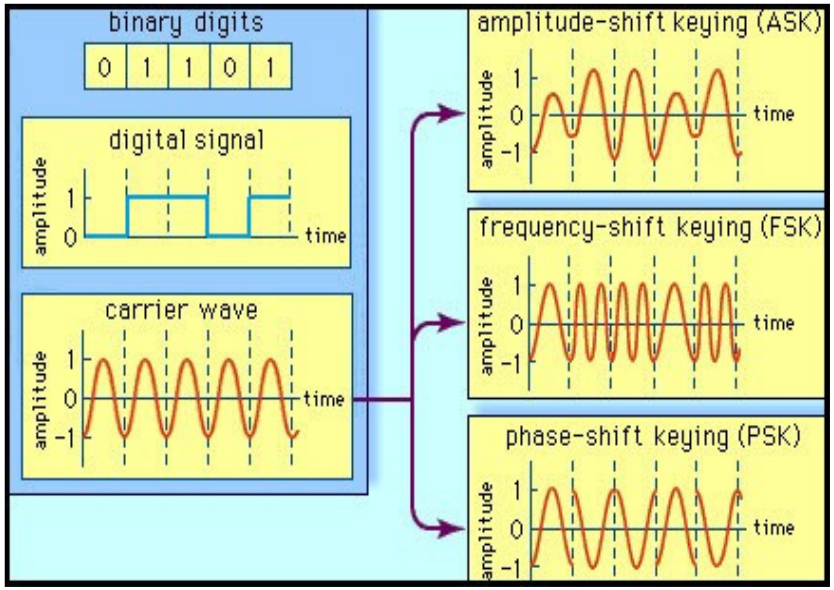
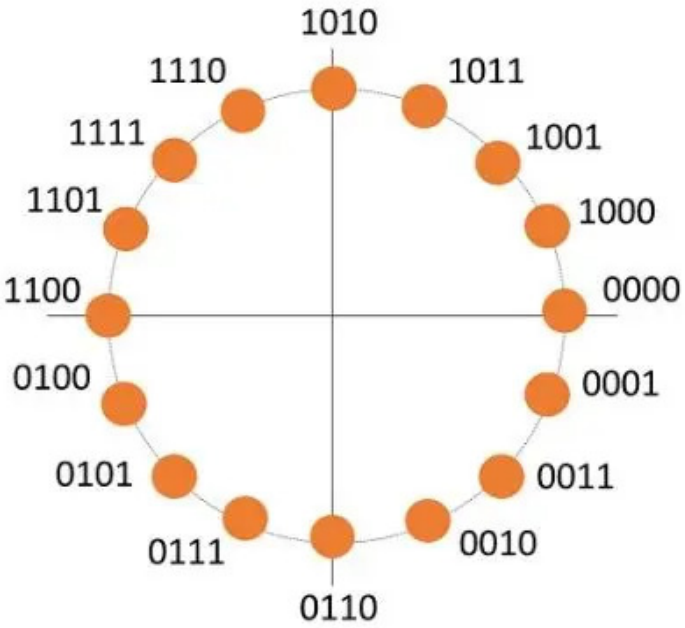


Link 2

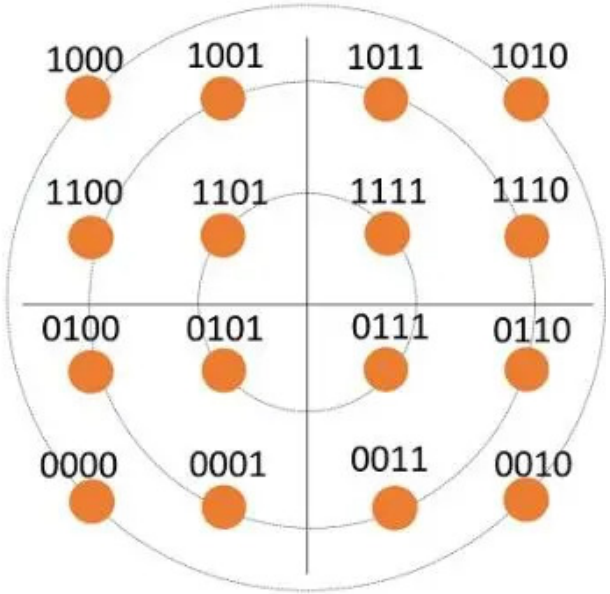
1. (https://www.5gtechnologyworld.com/digital-modulation-basics-part-1/)

2. (https://www.fmuser.net/content/?21047.html)

4.2.2 Digital communication cont'd



16PSK



16QAM

(https://www.keysight.com/blogs/en/tech/rfmw/2020/08/24/modulation-schemes-for-satellite-communications)

4.3 Mobile communication

- The cellular concept is a fundamental principle in mobile telecommunications, designed to increase the capacity and coverage of mobile networks. This involves dividing a geographic area into smaller regions called cells, each served by its own base station. This allows for efficient frequency reuse and better management of radio spectrum.
- Cells: entire service area is divided into hexagonal cells, each with its own base station. This structure helps manage the limited frequency spectrum by reusing frequencies in non-adjacent cells.
- Frequency reuse: frequencies are reused in different cells to maximize the use of available spectrum. The reuse pattern is carefully planned to minimize interference.

4.3 Mobile communication cont'd

- Base Stations (BS): each cell has a BS that communicates with mobile devices within its range. The base station consists of antennas, transceivers, and control equipment.
- Mobile Switching Centers (MSCs): they manage the routing of calls and data between base stations and the public switched telephone network (PSTN). They also handle handoffs between cells as users move.
- Handoff: when a mobile user moves from one cell to another, the call is seamlessly transferred to the new cell's BS. This process is managed by the MSC to ensure uninterrupted service.
- Co-channel interference occurs when the same frequency is used in nearby cells. Proper frequency planning and cell design help mitigate this.

4.3 Mobile communication cont'd

- Adjacent-channel interference: Caused by frequencies that are close to each other. This is minimized through careful frequency allocation and filtering.

Advantages

Increased capacity: by reusing frequencies, the cellular concept allows for a higher number of simultaneous users within a given area.

Scalability: the network can be expanded by adding more cells, making it adaptable to growing demand.

Improved coverage: smaller cells ensure better signal quality and coverage, especially in densely populated areas.

4.3 Mobile communication cont’d

Evolution from Analog to Digital Systems

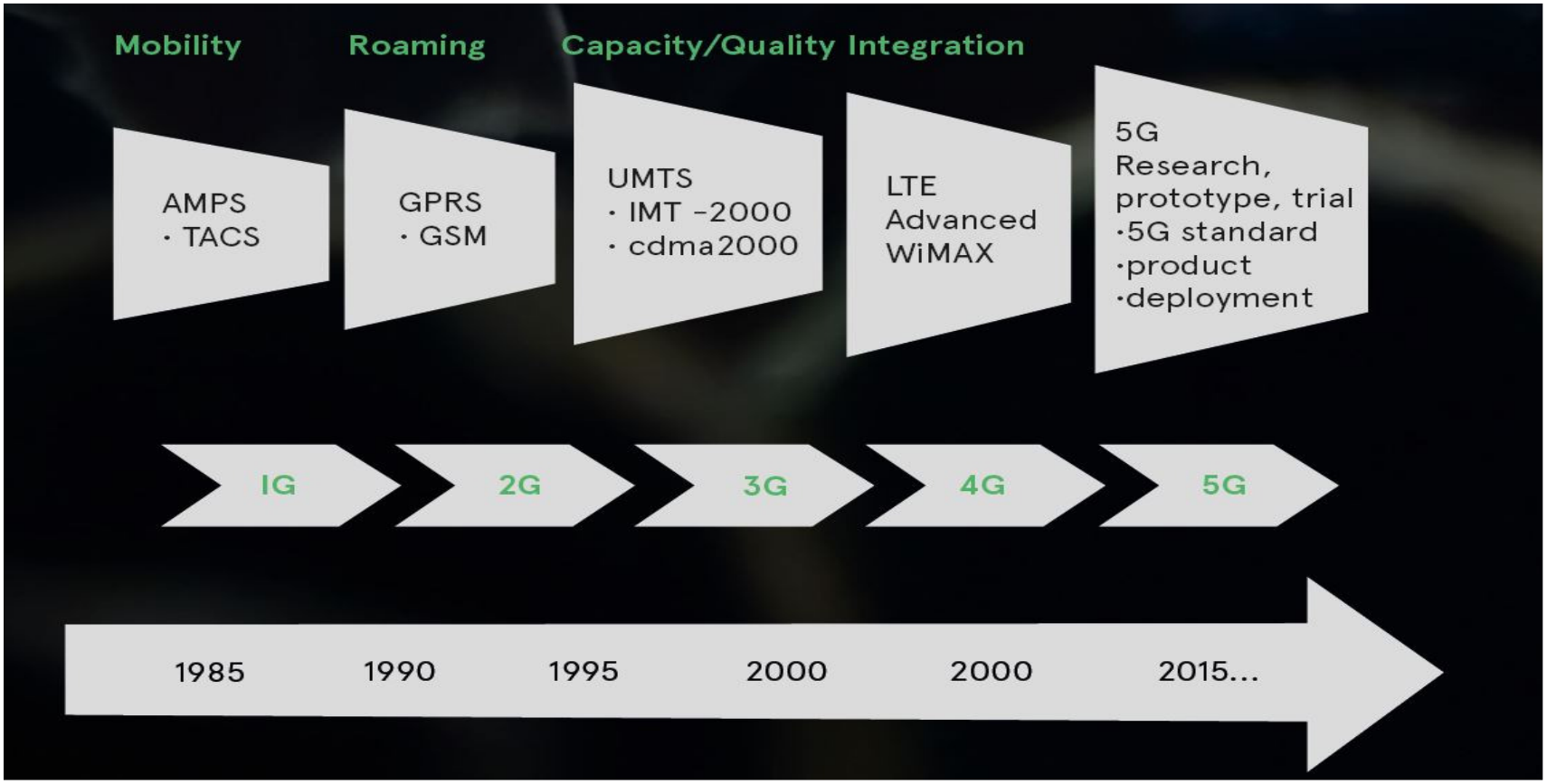
- **Analog systems**: early cellular systems used analogue technology, which had limitations in terms of capacity and signal quality. Examples include the Advanced Mobile Phone System (AMPS).
- **Digital systems**: modern cellular systems use digital technology, offering better capacity, security, and data services. Examples are Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA).

(Mobile Cellular Telecommunications: Analog and Digital Systems, William C. Y. Lee, McGraw-Hill,1995).

4.3 Mobile communication cont’d

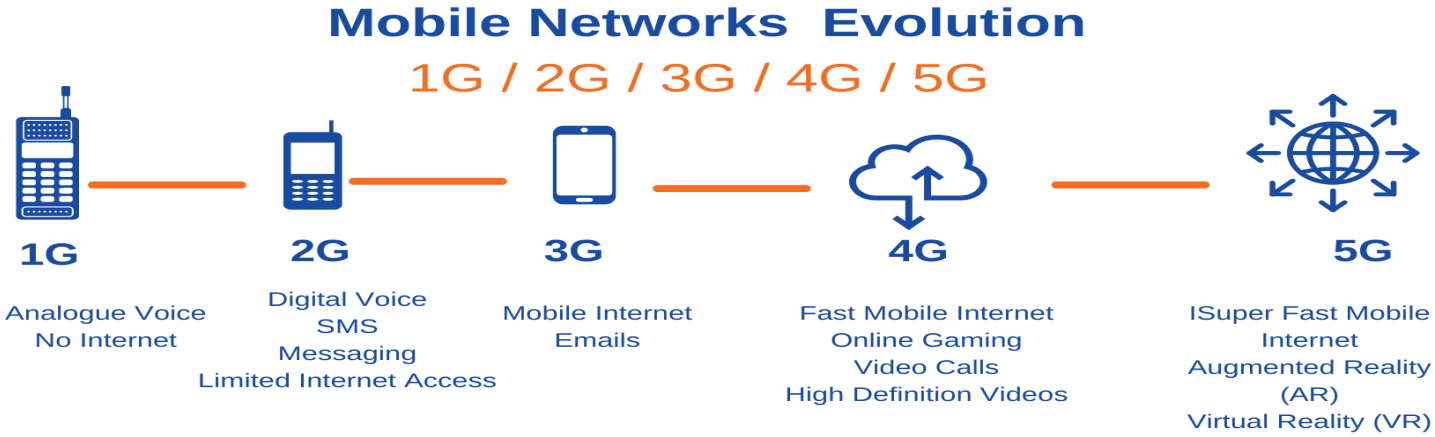
- **Frequency bands**: Different frequency bands are used for communication, such as 2G, 3G, 4G, and 5G, each offering varying speeds and capabilities.
- **GSM** was a standard developed to ensure compatibility between mobile networks while **CDMA** allows multiple users to share the same frequency band by assigning unique codes. Other technologies were developed.
- **LTE** (Long-Term Evolution): a standard for high-speed wireless communication, commonly referred to as 4G.
- **5G**: the latest generation, offering faster speeds, lower latency, and the ability to connect more devices simultaneously.

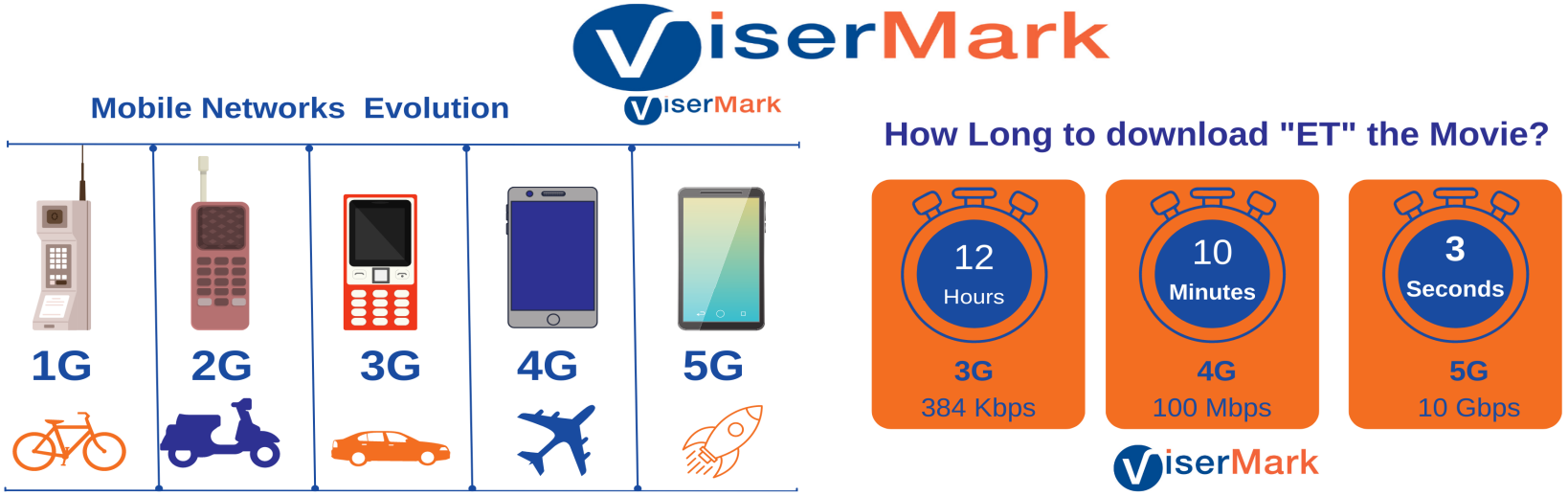
4.3 Mobile communication cont'd



(https://my.avnet.com/abacus/resources/article/the-evolution-of-cellular-networks/)

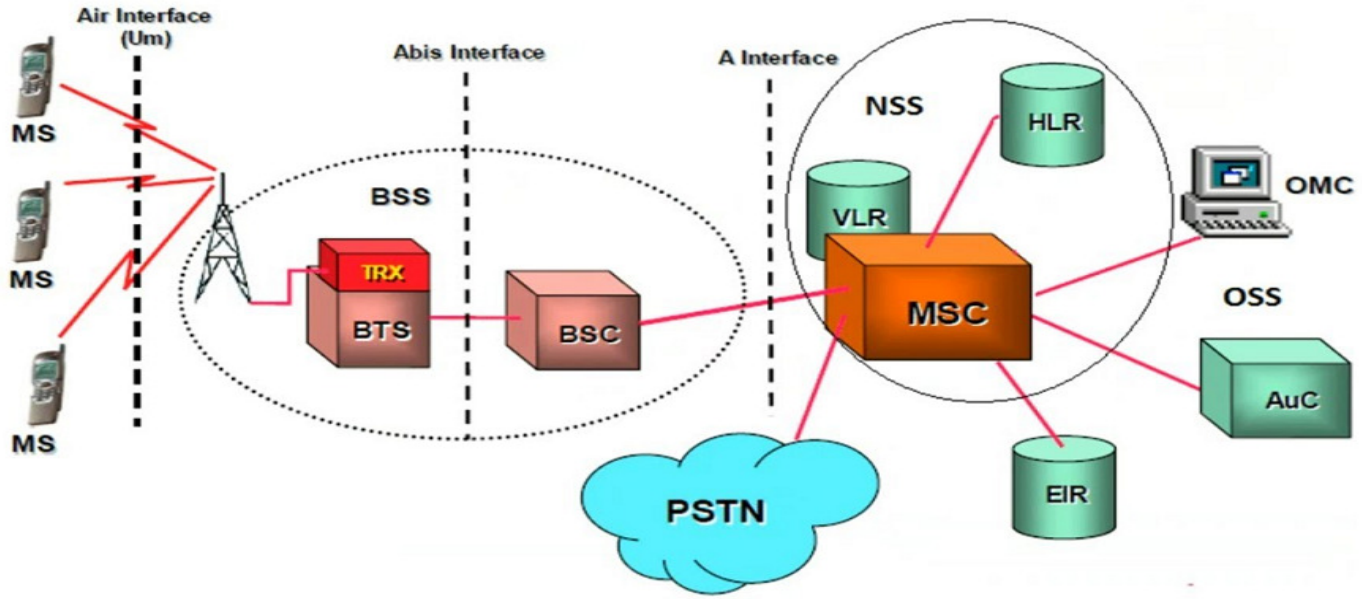
4.3 Mobile communication cont'd





(https://www.visermark.com/post/mobile-network-evolution-from-1g-to-5g)

4.3 Mobile communication cont'd



(https://microlek.com/courses/st101-introduction-to-the-gsm-network/)

4.4 Attenuation and Signal Control

- **Attenuation** refers to the reduction in signal strength as it propagates through space. For mobile broadcasting towers, attenuation is influenced by several factors as mentioned below.
- **Free space path loss** occurring in an unobstructed line-of-sight path.
- **Multipath propagation** usually in urban environments where signals can reflect off buildings and other structures, causing multiple paths to the receiver.
- **Obstructions** from like buildings, trees, and terrain can cause diffraction and scattering, leading to additional losses.
- **Atmospheric conditions** considering weather conditions such as rain, fog, and humidity can also contribute to signal attenuation. (Broadcast Engineer's Reference Book, EPJ Tozer, Routledge, 2004.)

4.4 Attenuation and Signal Control cont'd

- **Antennas** in different types (e.g., omnidirectional, directional) are used to optimize signal coverage and strength.
- **Power control** with adjustment in the transmitter helps in managing the coverage area and reduce interference with other signals.
- **Frequency management** utilizing different frequency bands to different cells helps to minimize interference and optimize the use of available spectrum.
- **Advanced technologies** by which modern mobile networks use like MIMO (Multiple Input Multiple Output) and beamforming help to enhance signal quality and capacity. (Broadcast Engineer's Reference Book, EPJ Tozer, Routledge, 2004.)

Thank you for your good attention

Q&A

References

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