Parul® University

Mobile Computing

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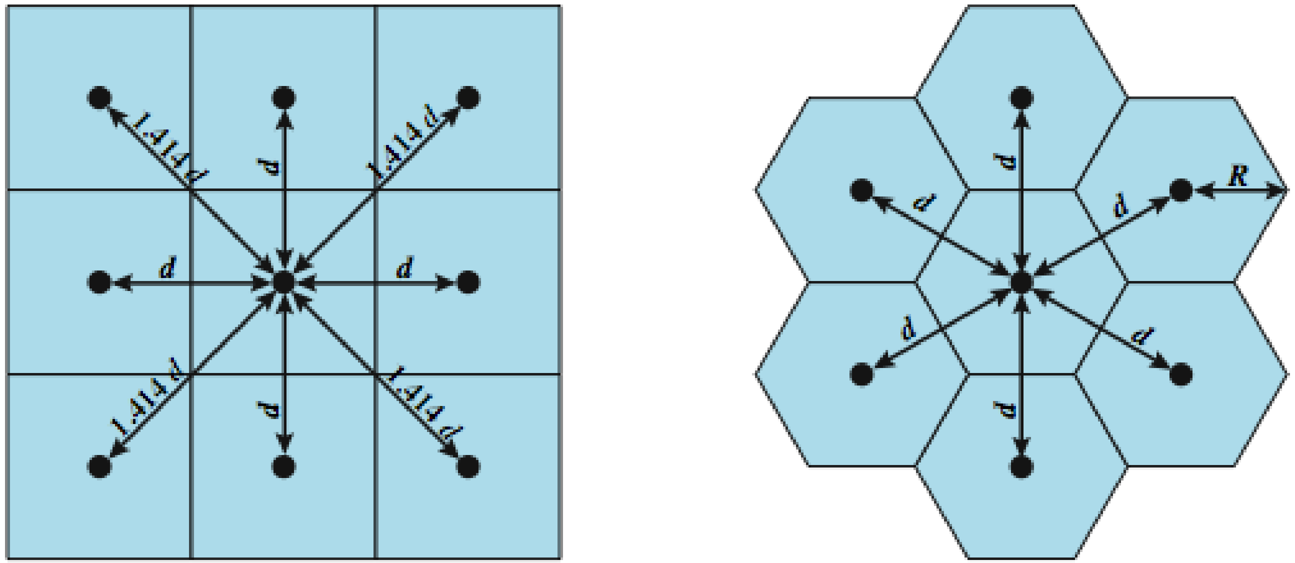
Chapter-2

Cellular Wireless-Networks

Cellular Wireless Networks

- key technology for mobiles, wireless nets etc.
- developed to increase mobile phone capacity.
- based on multiple low power transmitters.
- area divided into cells.
  - in a tiling pattern to provide full coverage.
  - each with own antenna.
  - each with own range of frequencies.
  - served by base station.
  - adjacent cells use different frequencies to avoid crosstalk.

Cellular Geometries



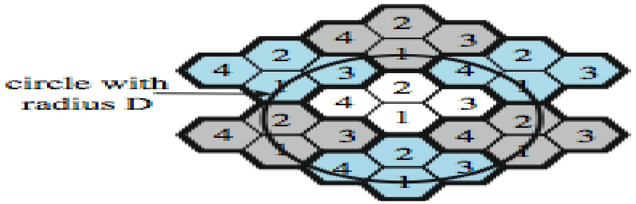
(a) Square pattern (b) Hexagonal pattern

Source: Wikipedia

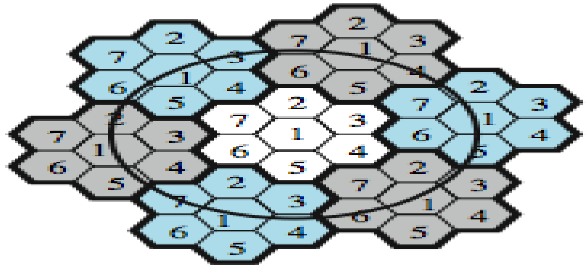
Frequency Reuse

- must manage reuse of frequencies.
- power of base transceiver controlled.
  - allow communications within cell on given frequency.
  - limit escaping power to adjacent cells.
  - allow re-use of frequencies in nearby cells.
  - typically 10 – 50 frequencies per cell.
  - example for Advanced Mobile Phone Service (AMPS)
    - N cells all using same number of frequencies.
    - K total number of frequencies used in systems.
    - each cell has K/N frequencies.
    - K=395, N=7 giving 57 frequencies per cell on average.

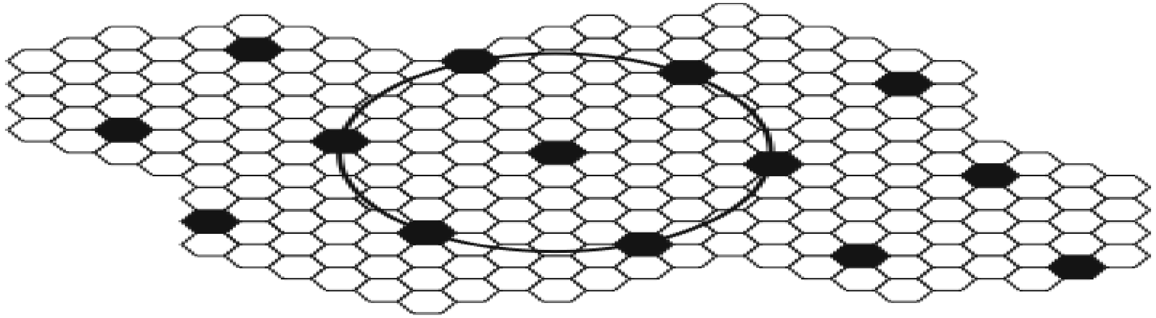
Frequency Reuse Patterns



(a) Frequency reuse pattern for $N = 4$



(b) Frequency reuse pattern for $N = 7$

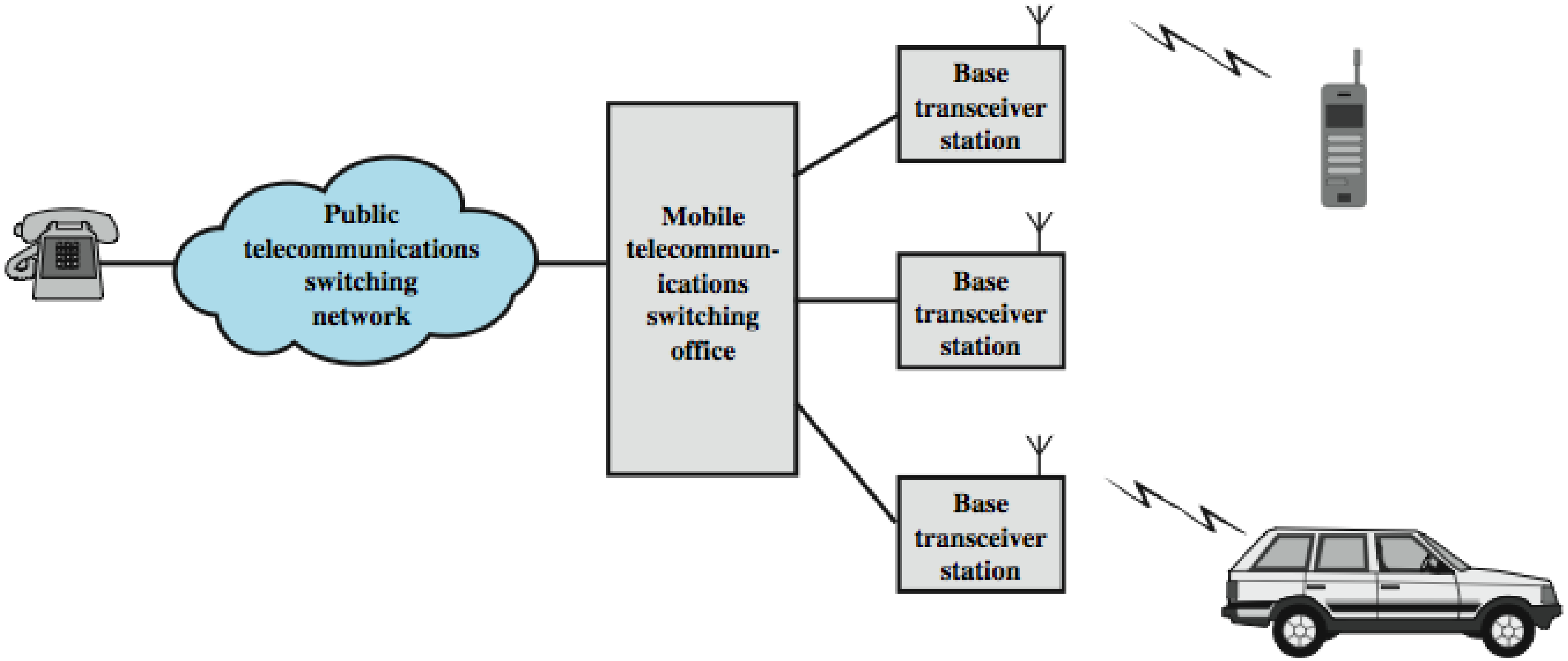


(c) Black cells indicate a frequency reuse for $N = 19$

Increasing Capacity

- **add new channels**
  - not all channels used to start with.
- **frequency borrowing**
  - taken from adjacent cells by congested cells, or assign frequencies dynamically.
- **cell splitting**
  - non-uniform topography and traffic distribution , use smaller cells in high use areas.
- **cell sectoring**
  - cell divided into wedge shaped sectors (3–6 per cell).
  - each with own channel set, directional antennas.
- **microcells**
  - move antennas from tops of hills and large buildings to tops of small buildings and sides of large buildings.
  - use reduced power to cover a much smaller area.
  - good for city streets, roads, inside large buildings.

Overview of Cellular System



Source: Wikipedia

First Generation Analog

- original cellular telephone networks.
- analog traffic channels.
- early 1980s in North America.
- Advanced Mobile Phone Service (AMPS).
- also common in South America, Australia, and China.
- replaced by later generation systems.

Operation

- AMPS-capable phone has numeric assignment module (NAM) in read-only memory
  - NAM contains number of phone.
  - serial number of phone.
  - when phone turned on, transmits serial number and phone number to MTSO.
  - MTSO has database of mobile units reported stolen.
  - MTSO uses phone number for billing.
  - if phone is used in remote city, service is still billed to user's local service provider.

AMPS Call Sequence

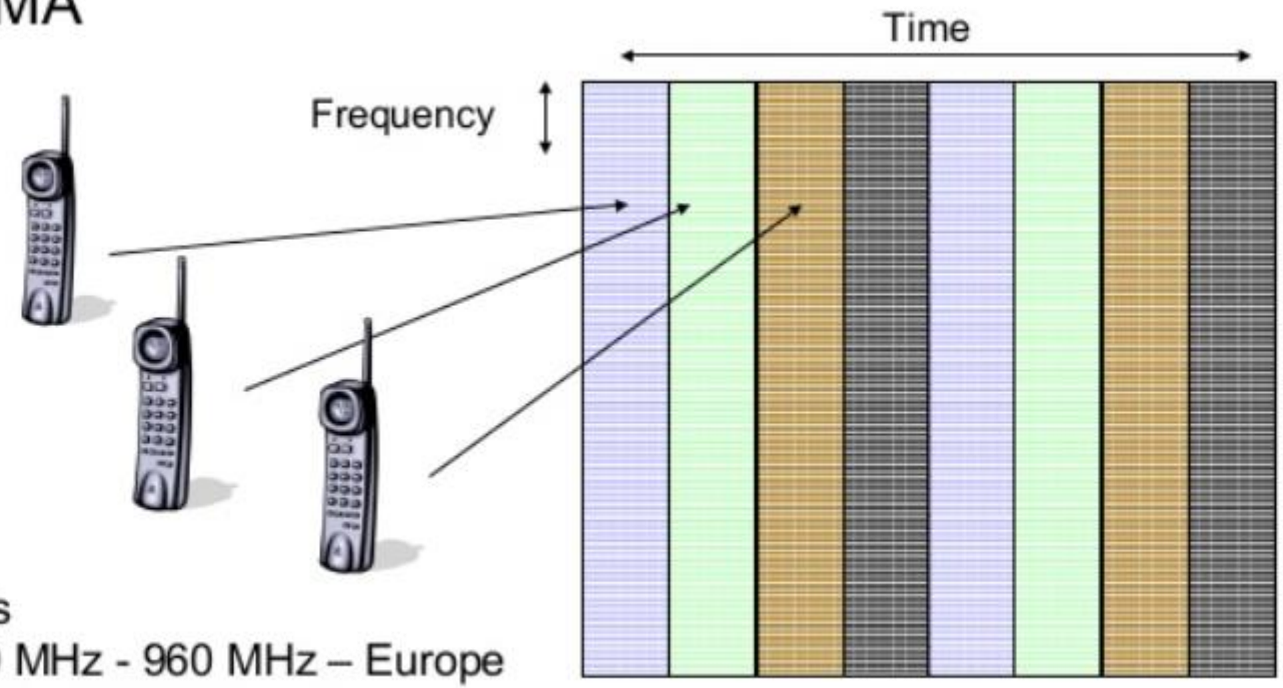
1. subscriber initiates call keying in number .
2. MTSO validates telephone number and checks user authorized to place call.
3. MTSO issues message to user's phone indicating traffic channels to use.
4. MTSO sends ringing signal to called party.
5. when called party answers, MTSO establishes circuit and initiates billing information.
6. when one party hangs up MTSO releases circuit, frees radio channels, and completes billing information.

Second Generation

- provide higher quality signals, higher data rates, support digital services, with overall greater capacity.
- key differences include
  - digital traffic channels
  - encryption
  - error detection and correction
  - channel access
    - time division multiple access (TDMA)
    - code division multiple access (CDMA)

Second-Generation TDMA

- TDMA



Frequencies

890 MHz - 960 MHz – Europe
1710 – 1880 MHz - Europe
1850 MHz – 1950 MHz - America

Source: Slideshare

Second-Generation CDMA

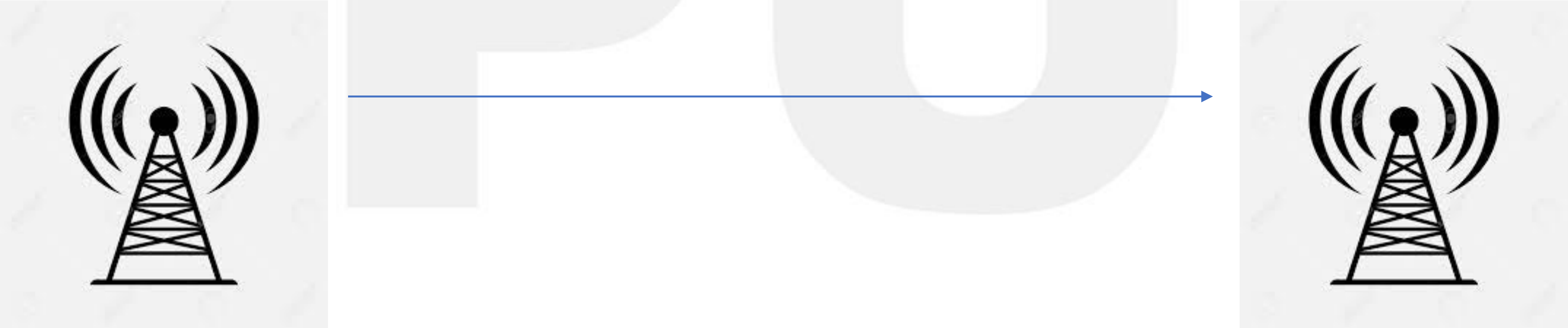
- provide higher quality signals, higher data rates, support digital services, with overall greater capacity.
- key differences include: digital traffic channels, encryption, error detection and correction.
  - channel access
    - time division multiple access (TDMA)
    - code division multiple access (CDMA)
- have a number of 2nd gen systems
  - for example IS-95 using CDMA.
- each cell allocated frequency bandwidth.
- is split in two
  - half for reverse, half for forward.
  - uses direct-sequence spread spectrum (DSSS).

Third-Generation Systems

- high-speed wireless communications to support multimedia, data, and video in addition to voice.
- 3G capabilities:
  - voice quality comparable to PSTN
  - 144 kbps available to users over large areas
  - 384 kbps available to pedestrians over small areas
  - support for 2.048 Mbps for office use
  - packet-switched and circuit-switched services
  - more efficient use of available spectrum
  - support for variety of mobile equipment

Antennas

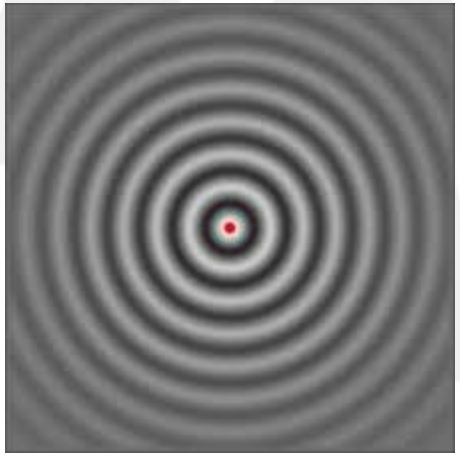
- It’s an electrical conductor or system of conductors used either for radiating electromagnetic energy or for collecting electromagnetic energy.



Source: Wikipedia

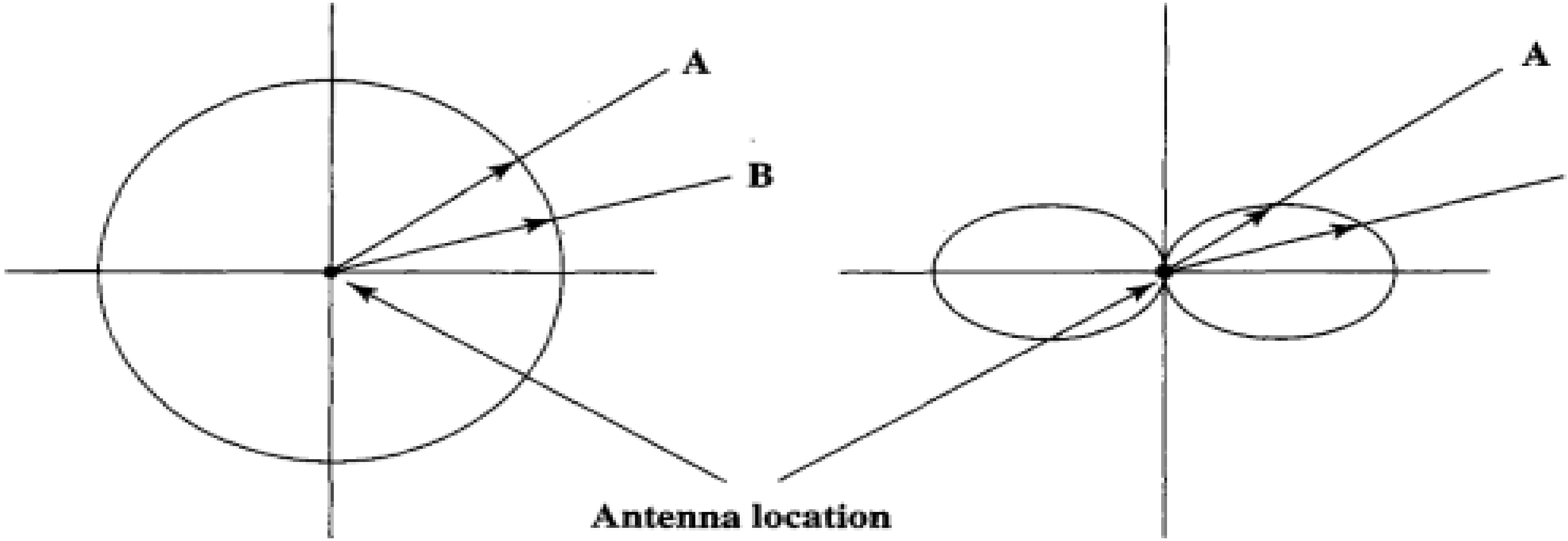
Radiation Patterns:

- Isotropic antenna: An isotropic antenna is a point in space that radiates power in all directions equally.



Source: Wikipedia

Idealized Radiation Patterns

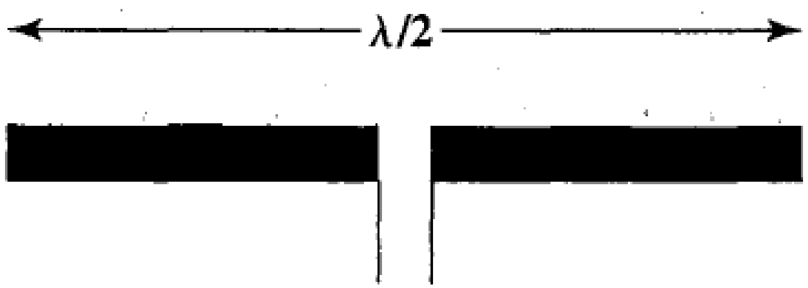


(a) Omnidirectional

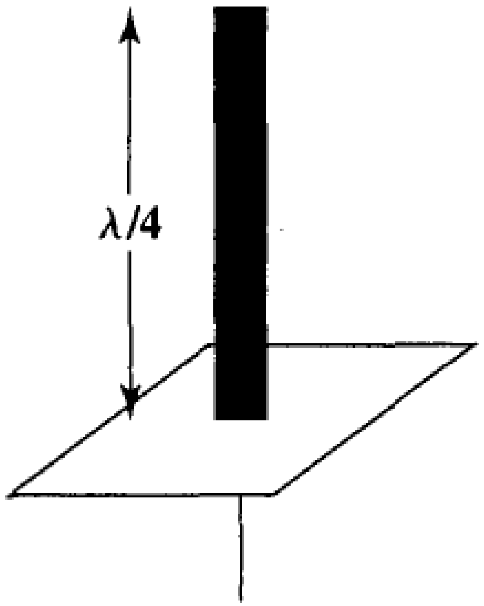
(b) Directional

Source: Wikipedia

Antenna Types



(a) Half-wave dipole



(b) Quarter-wave antenna

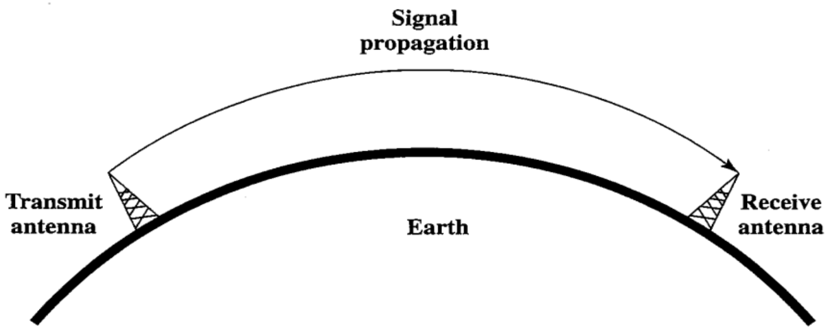
Antenna Gain

- Antenna gain is a measure of the directionality of an antenna. Antenna gain is defined as the power output, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna (isotropic antenna).
- A concept related to that of antenna gain is the effective area of an antenna. The effective area of an antenna is related to the physical size of the antenna and to its shape. The relationship where

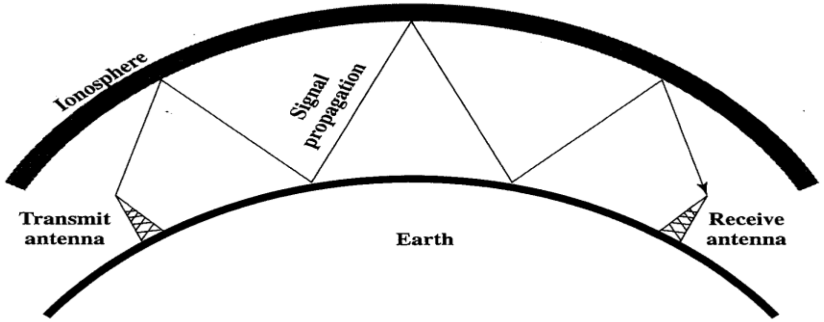
$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

G = antenna gain, Ae = effective area, f = carrier frequency, c = speed of light (~3 X 108 m/s) ,A = carrier wavelength,

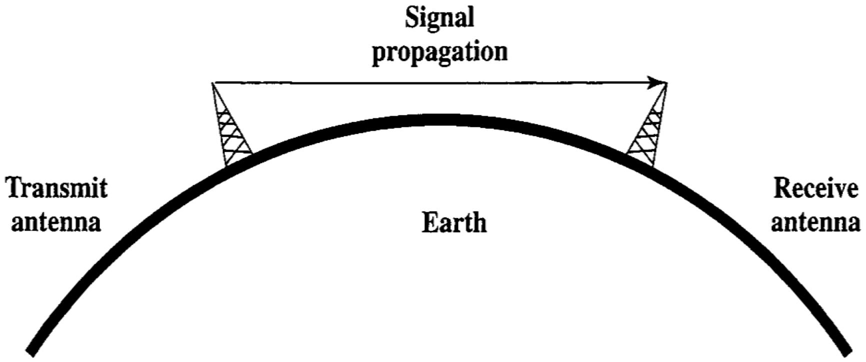
Propagation Modes



(a) Ground wave propagation (below 2 MHz)



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



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

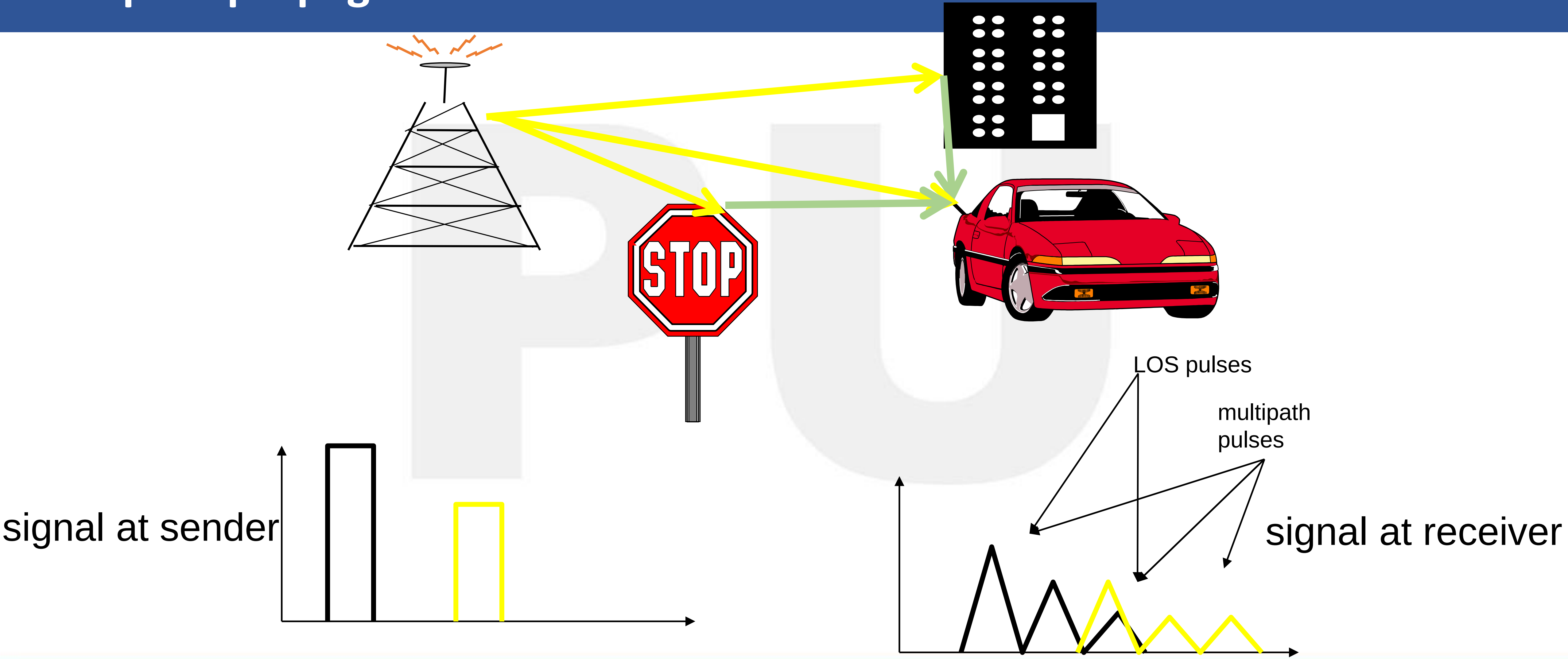
Line of Sight Transmission

- **Attenuation**
  - The strength of a signal falls off with distance over any transmission medium.
- **Free space loss**
  - loss of signal with distance.
- **Atmospheric Absorption**
  - from water vapour and oxygen absorption.
- **Noise**
  - unwanted signals that are inserted somewhere between transmission and reception.
- **Multipath**
  - multiple interfering signals from reflections.
- **Refraction**
  - bending signal away from receiver.

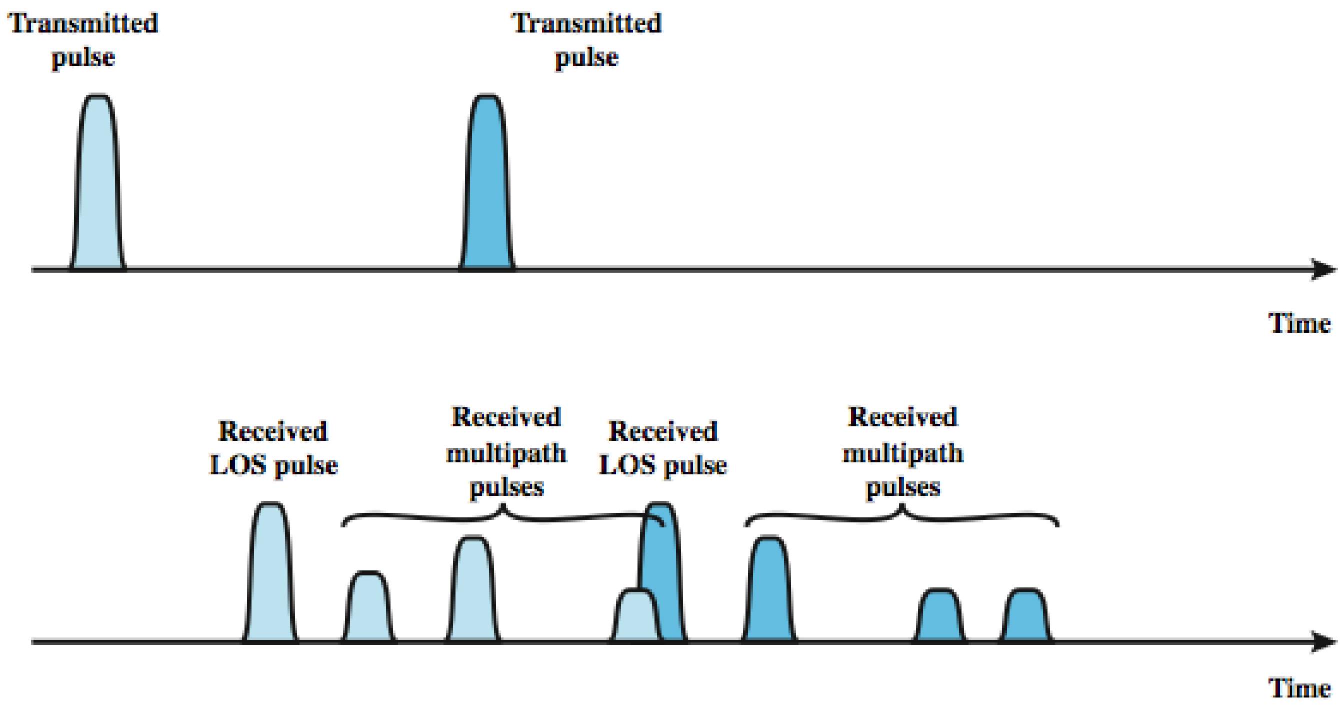
Fading in the Mobile Environment

- The term *fading* refers to the time variation of received signal power caused by changes in the transmission medium or path(s).
- In a fixed environment, fading is affected by changes in atmospheric conditions, such as rainfall.
- In mobile environment:
  - where one of the two antennas is moving relative to the other,
  - the relative location of various obstacles changes over time,
  - creating complex transmission effects.

Multipath propagation



Effects of Multipath Propagation

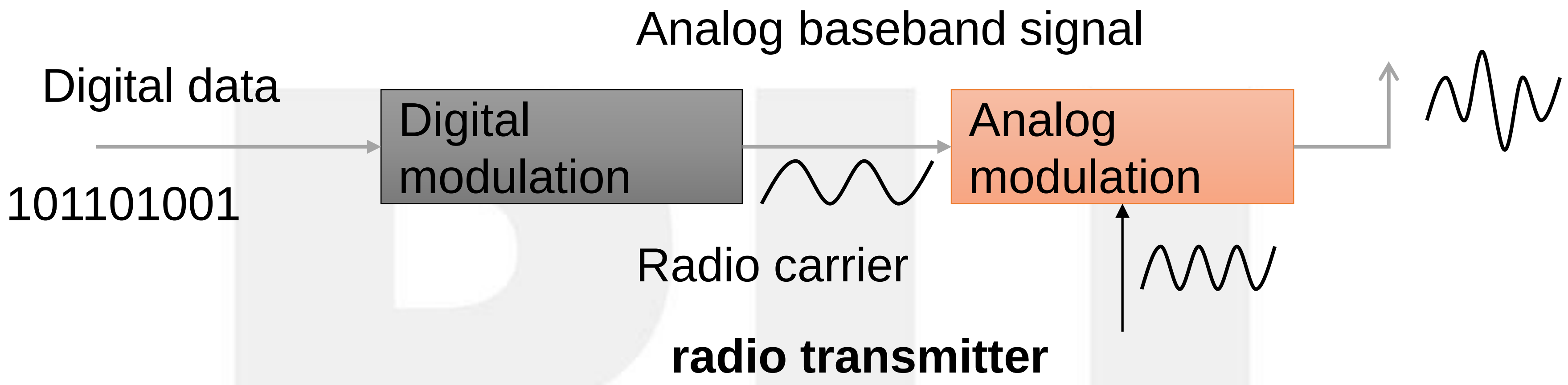


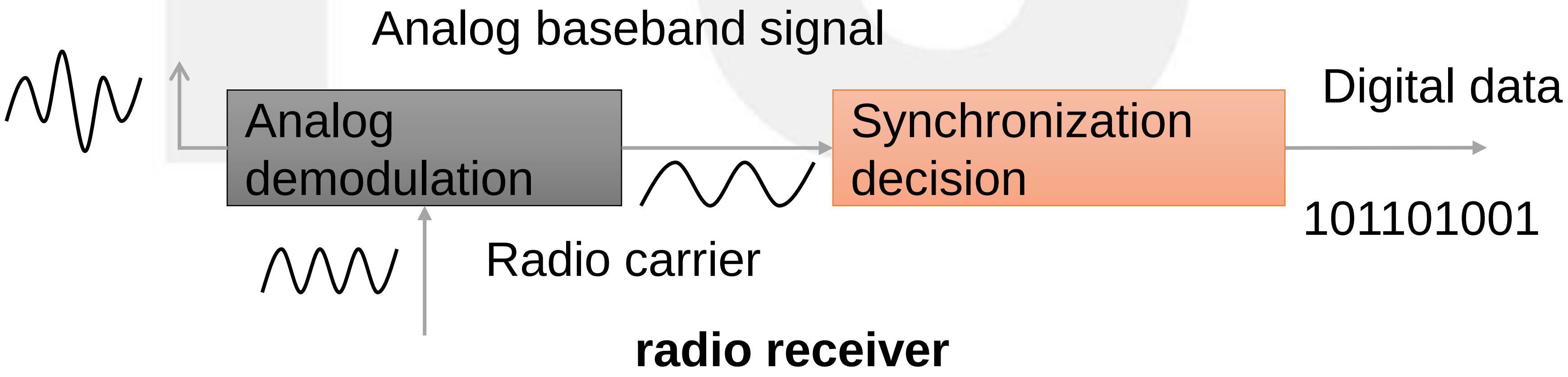
Source: Effects of Multipath Propagation[1]

Modulation

- The process of shifting the baseband signal to passband range is called *Modulation*.
- The process of shifting the passband signal to baseband frequency range is called *Demodulation*.
- Reasons for modulation:
  - Simultaneous transmission of several signals.
  - Practical Design of Antennas.
  - Exchange of power and bandwidth.

Modulation and demodulation



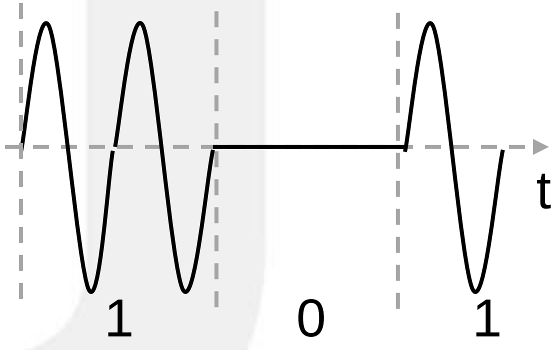


Signal Encoding Criteria

- Encoding technique is divided into:
  - Analog data to Analog signals
  - Analog data to Digital signals
  - Digital data to Analog signals
  - Digital data to Digital signals

Digital to Analog modulation

- **Amplitude Shift Keying (ASK):**
  - ❖The two binary values, 1 and 0, are represented by two different amplitudes.
  - ❖Low bandwidth requirements.
  - ❖Very susceptible to interference.
  - ❖Effects like multi-path propagation, noise, or path loss heavily influence the amplitude.
  - ❖Generally not used for wireless radio transmission but can be used in wired network(Optical Transmission).



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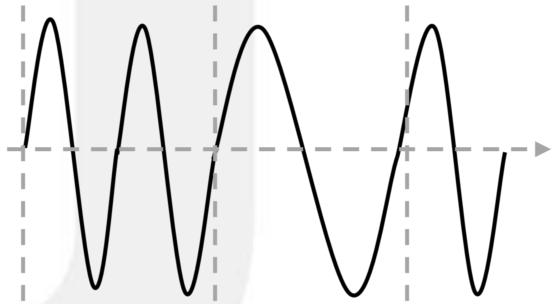
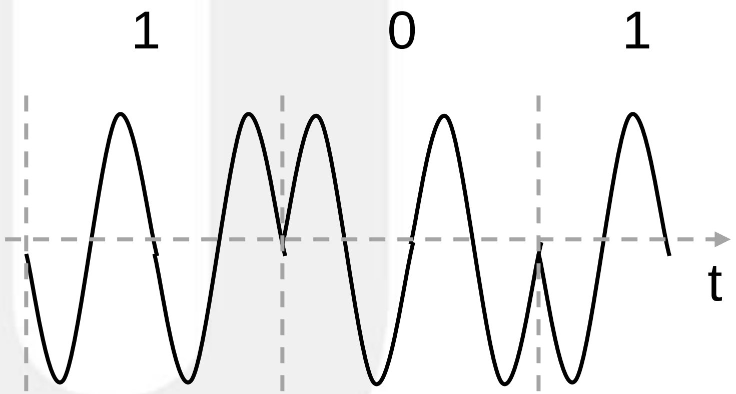
- **Frequency Shift Keying (FSK):**
  - ❖The simplest form of FSK, also called binary FSK (BFSK).
  - ❖It assigns one frequency f1 to the binary 1 and another frequency f2 to the binary 0.
  - ❖A very simple way to implement FSK is to switch between two oscillators, one with the frequency f1 and the other with f2, depending on the input.
  - ❖Needs larger bandwidth.
  - ❖A simple way to implement demodulation is by using two bandpass filters, one for f1 the other for f2.
  - ❖FSK needs a larger bandwidth compared to ASK but is much less susceptible to errors.



Digital to Analog modulation

- **Phase Shift Keying (PSK):**
  - ❖ More complex.
  - ❖ Uses shifts in the phase of a signal to represent data.
  - ❖ This simple scheme, shifting the phase by 180° each time the value of data changes
  - ❖ Robust against interference.
  - ❖ To receive the signal correctly, the receiver must synchronize in frequency and phase with the transmitter. This can be done using a phase lock loop (PLL).



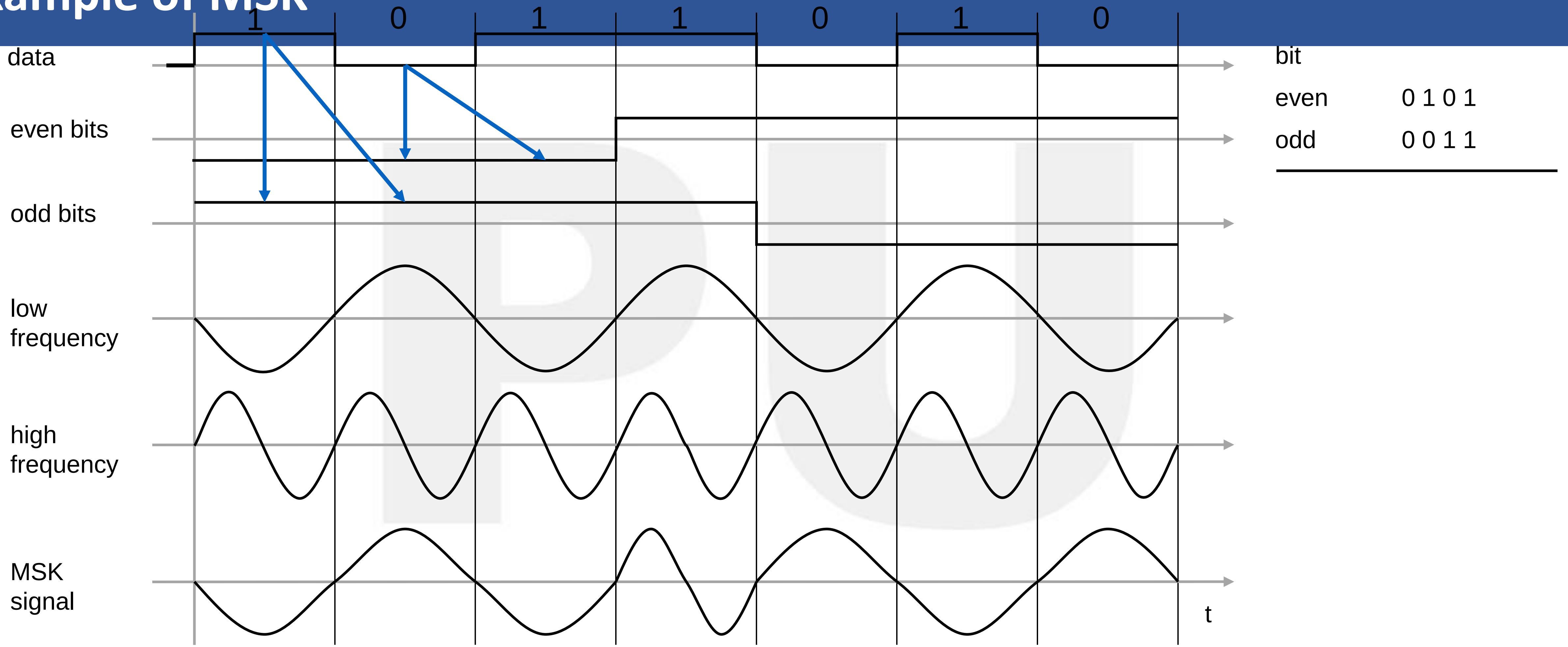
Digital modulation

Continued…

- Advanced Frequency Shift Keying:
- Special pre-computation avoids sudden phase shifts ➔ MSK (Minimum Shift Keying)
  - ❖Bit separated into even and odd bits, the duration of each bit is doubled.
  - ❖Depending on the bit values (even, odd) the higher or lower frequency, original or inverted is chosen.
  - ❖The frequency of one carrier is twice the frequency of the other.

  Even higher bandwidth efficiency using a Gaussian low-pass filter ➔ GMSK (Gaussian MSK), used in GSM.

Example of MSK

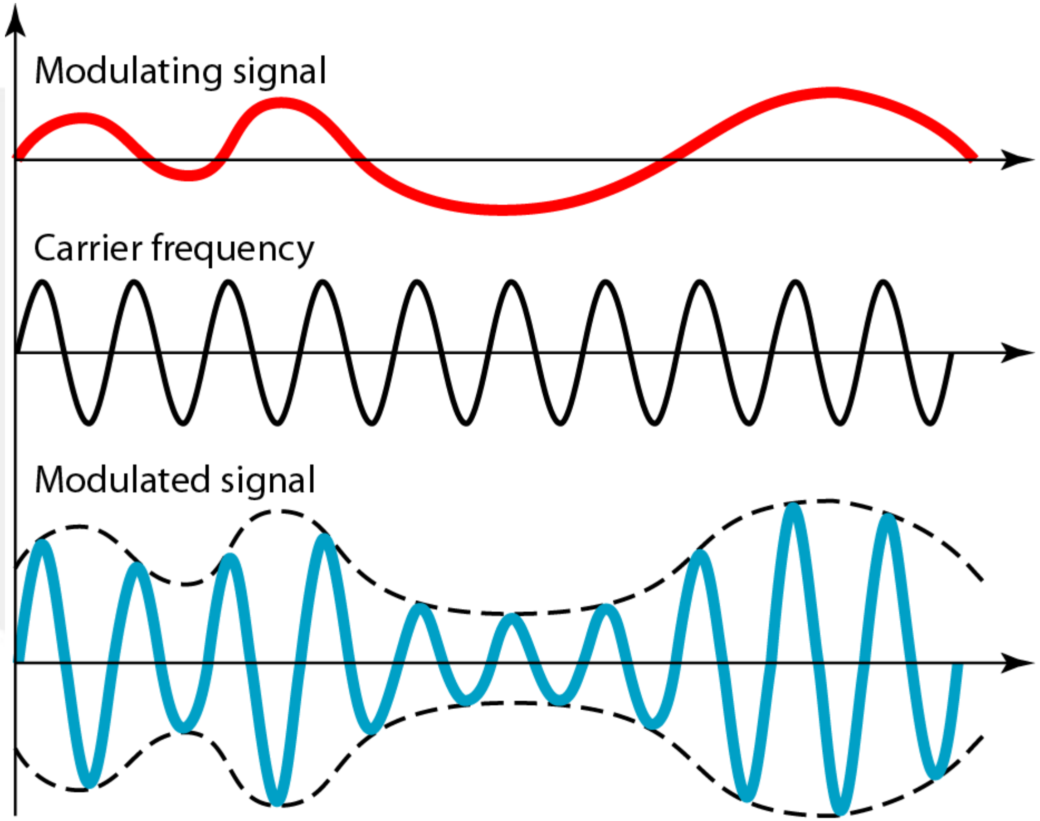


ANALOG TO ANALOG

- Analog-to-analog conversion is the representation of analog information by an analog signal. One may ask why we need to modulate an analog signal; it is already analog.
- Modulation is needed if the medium is bandpass in nature or if only a bandpass channel is available to us.
- Types of analog-to-analog modulation:
  - Amplitude modulation
  - Frequency modulation
  - Phase modulation

Amplitude Modulation

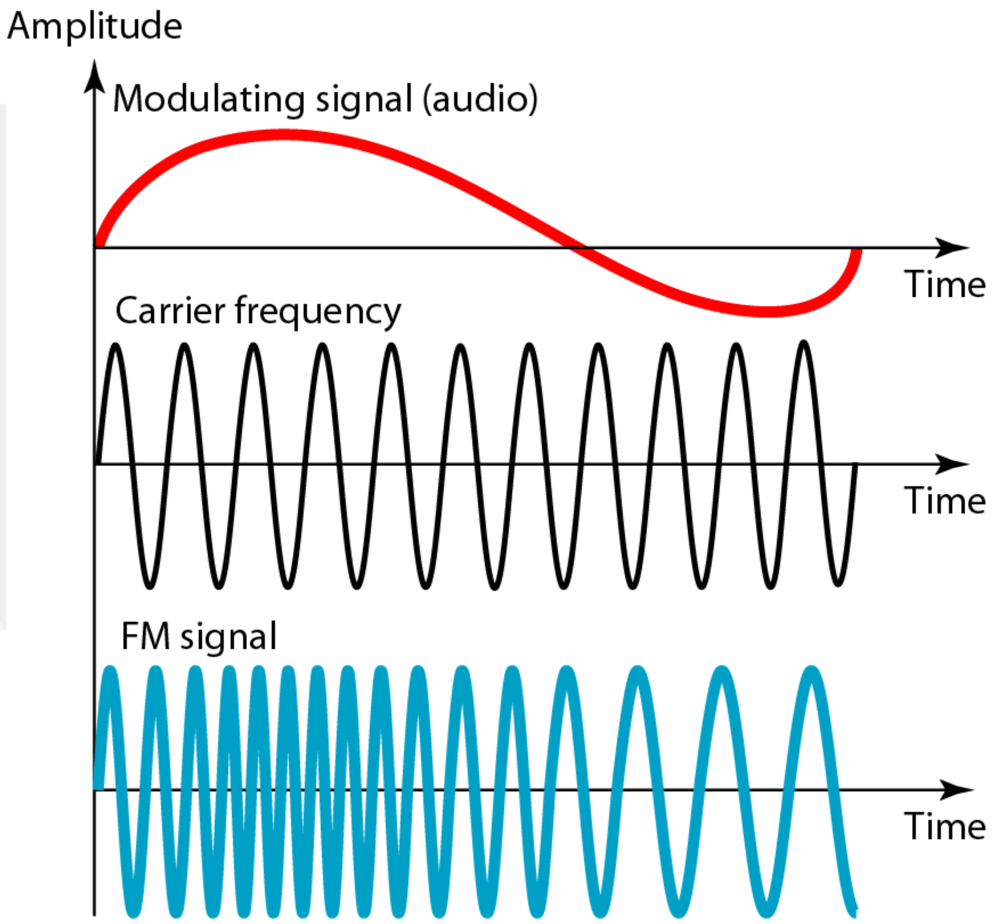
- A carrier signal is modulated only in amplitude value.
- The modulating signal is the envelope of the carrier.
- The required bandwidth is 2B, where B is the bandwidth of the modulating signal.
- Since on both sides of the carrier freq. f_c, the spectrum is identical, we can discard one half, thus requiring a smaller bandwidth for transmission.



Source: Wikipedia

Frequency Modulation

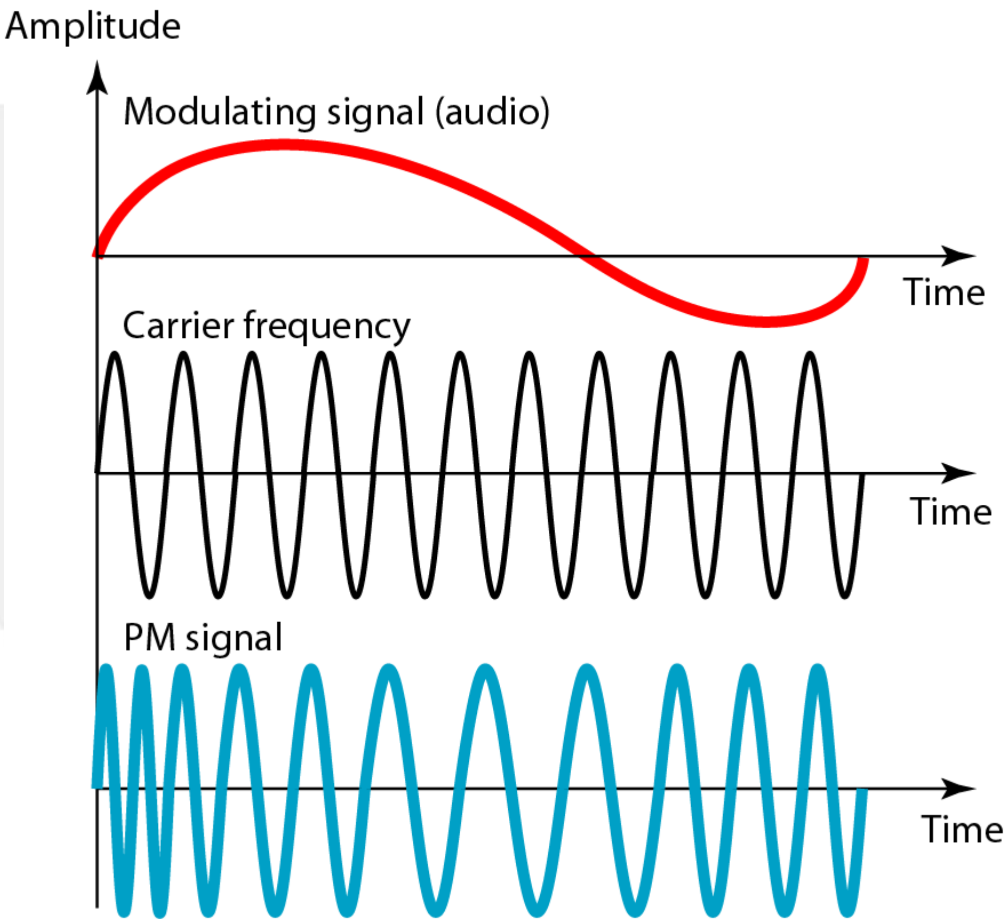
- The modulating signal changes the freq. f_c of the carrier signal.
- The bandwidth for FM is high.
- It is approx. 10x the signal frequency.



Source: Wikipedia

Phase Modulation (PM)

- The modulating signal only changes the phase of the carrier signal.
- The phase change manifests itself as a frequency change but the instantaneous frequency change is proportional to the derivative of the amplitude.
- The bandwidth is higher than for AM.



Source: Wikipedia

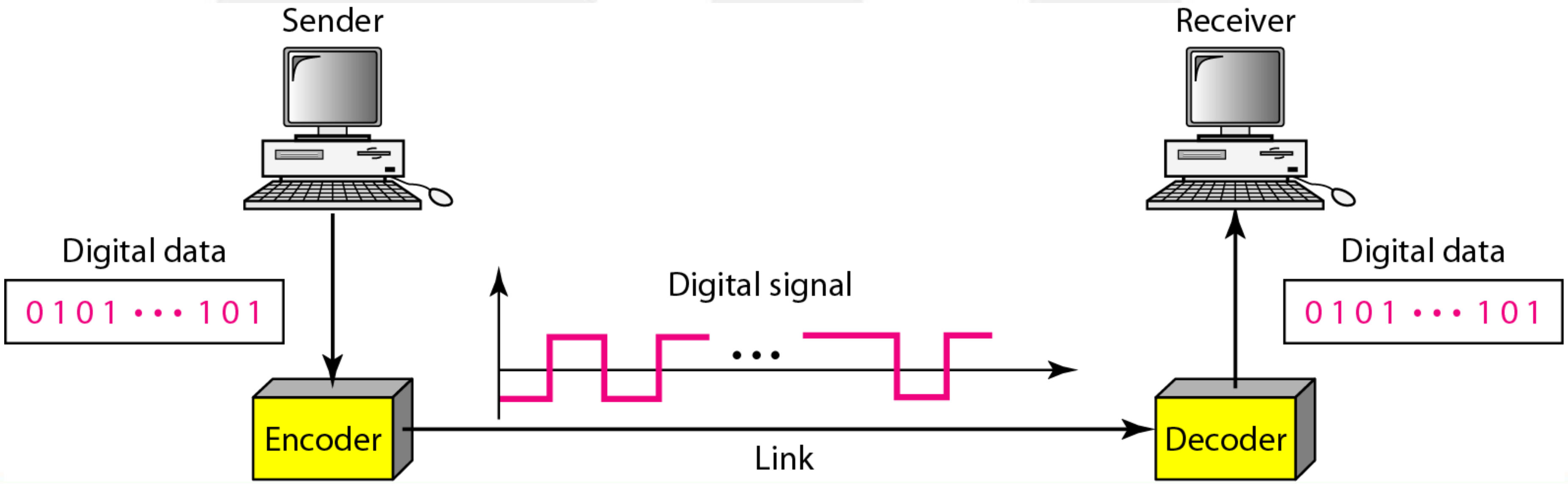
DIGITAL-TO-DIGITAL CONVERSION

- The conversion involves three techniques:
  - line coding,
  - block coding,
  - scrambling.

  Line coding is always needed; block coding and scrambling may or may not be needed.

Line Coding

- Converting a string of 1's and 0's (digital data) into a sequence of signals that denote the 1's and 0's.
- For example a high voltage level (+V) could represent a "1" and a low voltage level (0 or -V) could represent a "0".



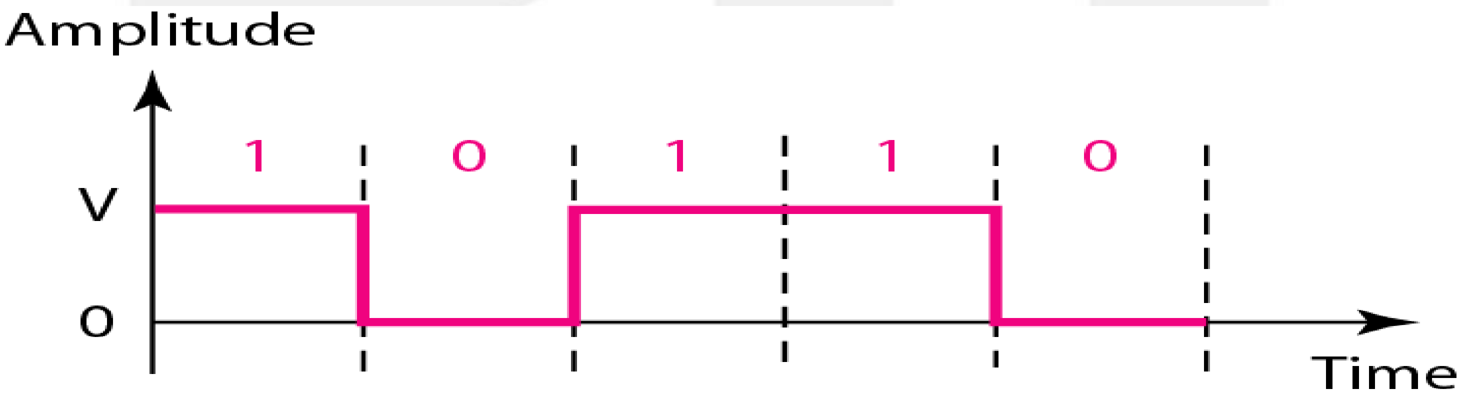
Source: Wikipedia

Mapping Data symbols onto Signal levels

- A data symbol (or element) can consist of a number of data bits:
  - 1 , 0 or
  - 11, 10, 01, ……
- A data symbol can be coded into a single signal element or multiple signal elements1
  - 1 -> +V, 0 -> -V
  - 1 -> +V and -V, 0 -> -V and +V
- The ratio ‘r’ is the number of data elements carried by a signal element.

Unipolar

- All signal levels are on one side of the time axis - either above or below.
- NRZ - Non Return to Zero scheme is an example of this code. The signal level does not return to zero during a symbol transmission.

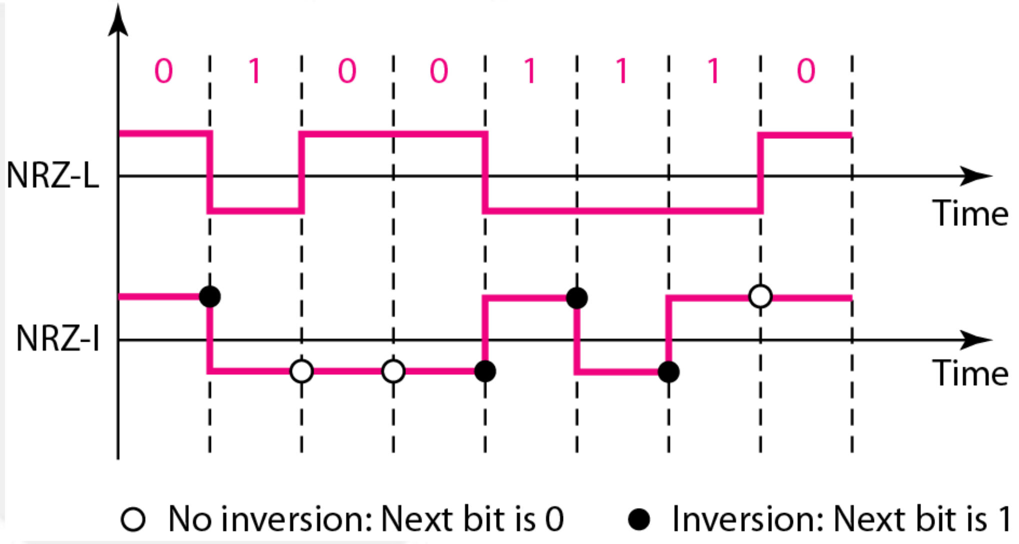


Unipolar NRZ scheme

Source: Wikipedia

Polar - NRZ

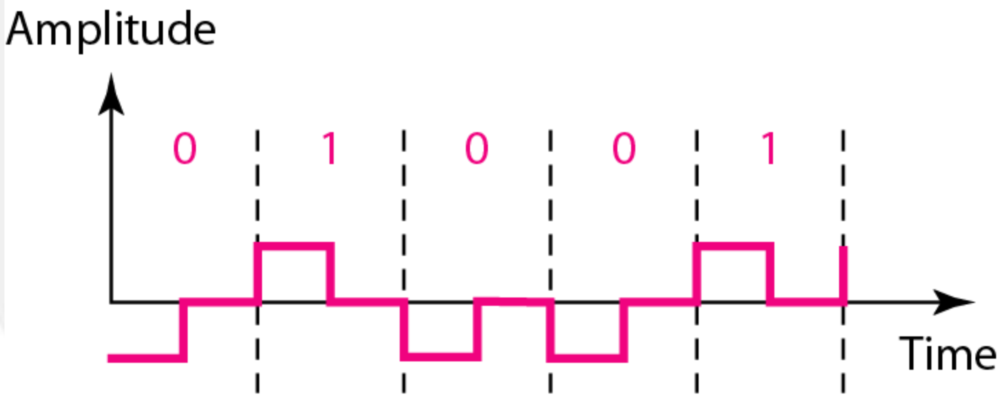
- The voltages are on both sides of the time axis.
- Polar NRZ scheme can be implemented with two voltages. E.g. +V for 1 and -V for 0.
- There are two versions:
  - NZR - Level (NRZ-L) - positive voltage for one symbol and negative for the other.
  - NRZ - Inversion (NRZ-I) - the change or lack of change in polarity determines the value of a symbol. E.g. a “1” symbol inverts the polarity a “0” does not.



Polar NRZ-L and NRZ-I schemes

Polar - RZ

- The Return to Zero (RZ) scheme uses three voltage values. +, 0, -.
- Each symbol has a transition in the middle. Either from high to zero or from low to zero.
- This scheme has more signal transitions (two per symbol) and therefore requires a wider bandwidth.
- Self synchronization - transition indicates symbol value.
- More complex as it uses three voltage level. It has no error detection capability.



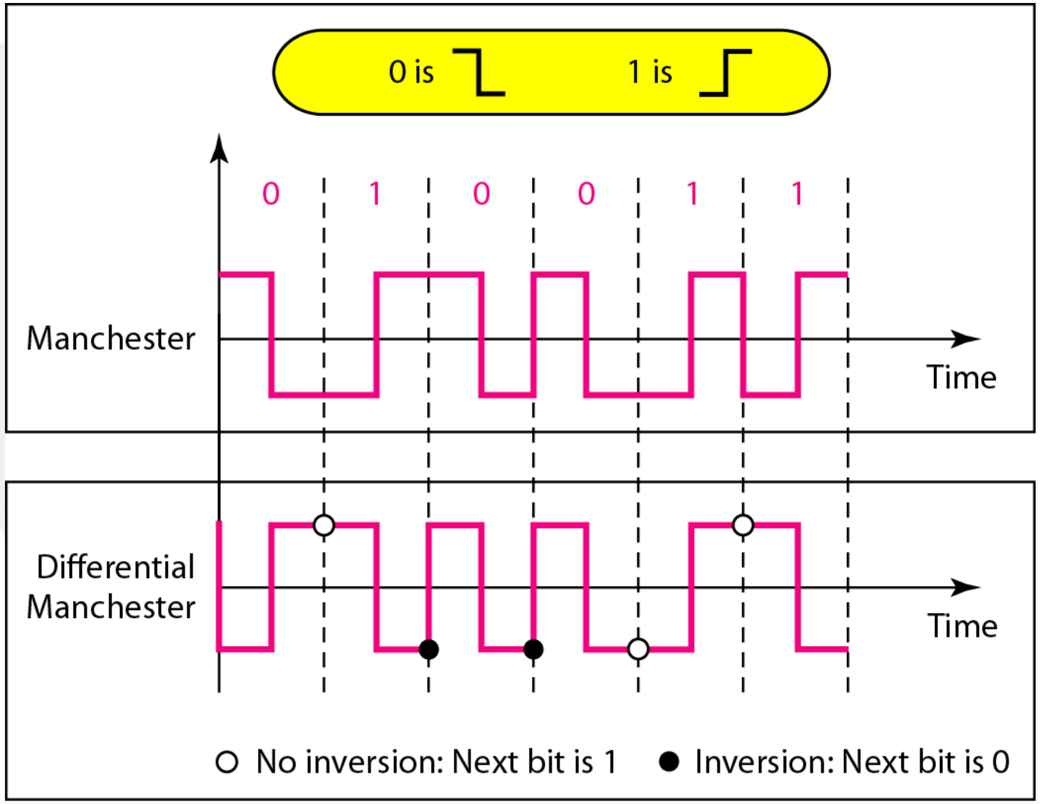
Polar RZ scheme

Source: Wikipedia

Polar - Biphase: Manchester and Differential Manchester

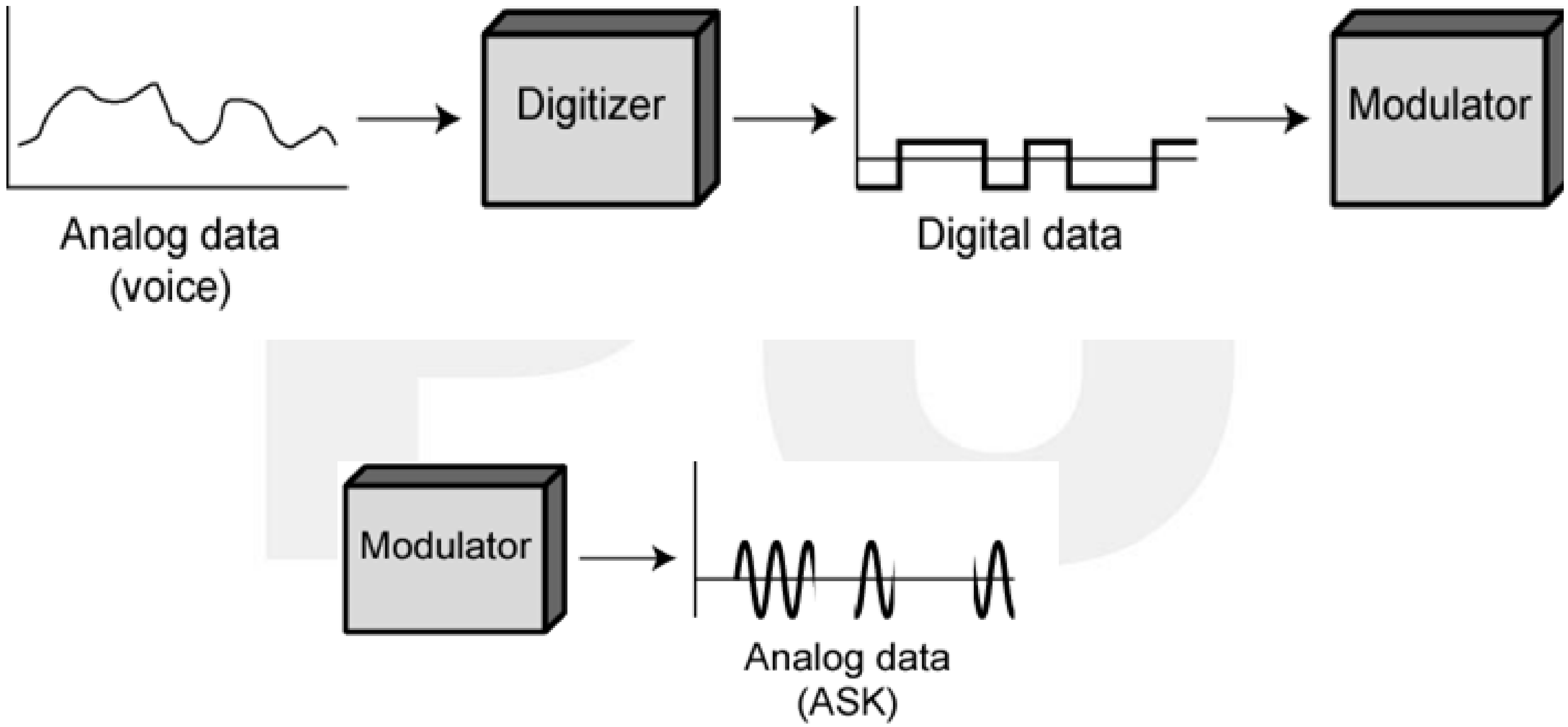
- Manchester coding consists of combining the NRZ-L and RZ schemes.
  - Every symbol has a level transition in the middle: from high to low or low to high. Uses only two voltage levels.

- Differential Manchester coding consists of combining the NRZ-I and RZ schemes.
  - Every symbol has a level transition in the middle. But the level at the beginning of the symbol is determined by the symbol value. One symbol causes a level change the other does not.



Polar biphase: Manchester and differential Manchester schemes

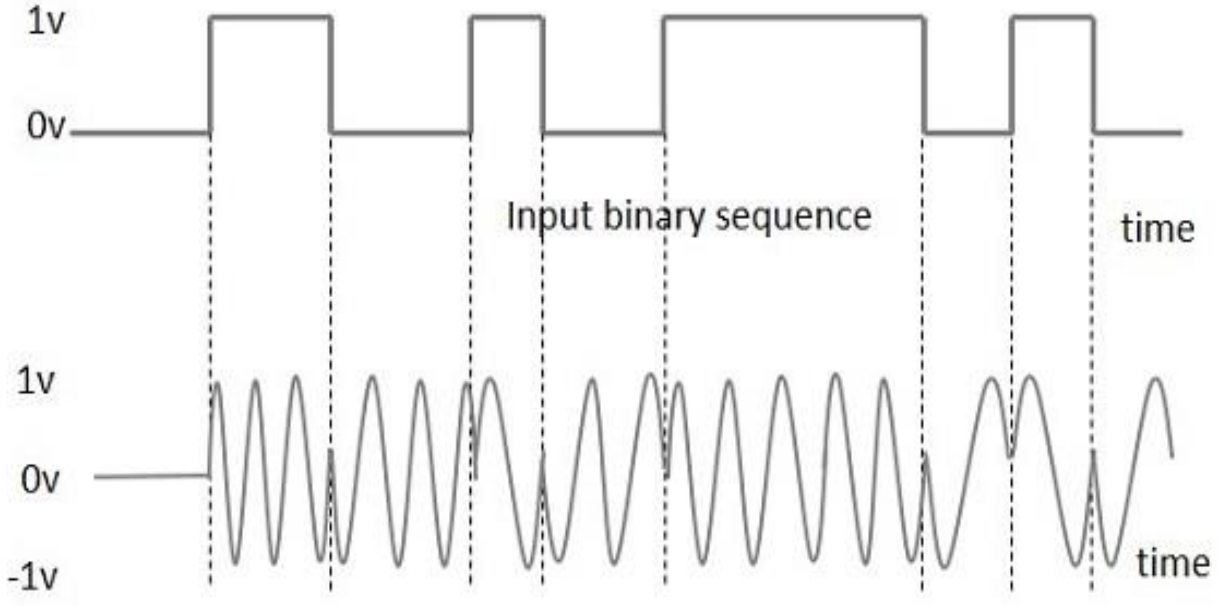
Analog to Digital Modulation



Source: Analog to Digital Modulation[1]

Advanced Phase Shift Keying

- BPSK (Binary Phase Shift Keying):
  - ❖bit value 0: sine wave
  - ❖bit value 1: inverted sine wave
  - ❖very simple PSK
  - ❖robust, used e.g. in satellite systems

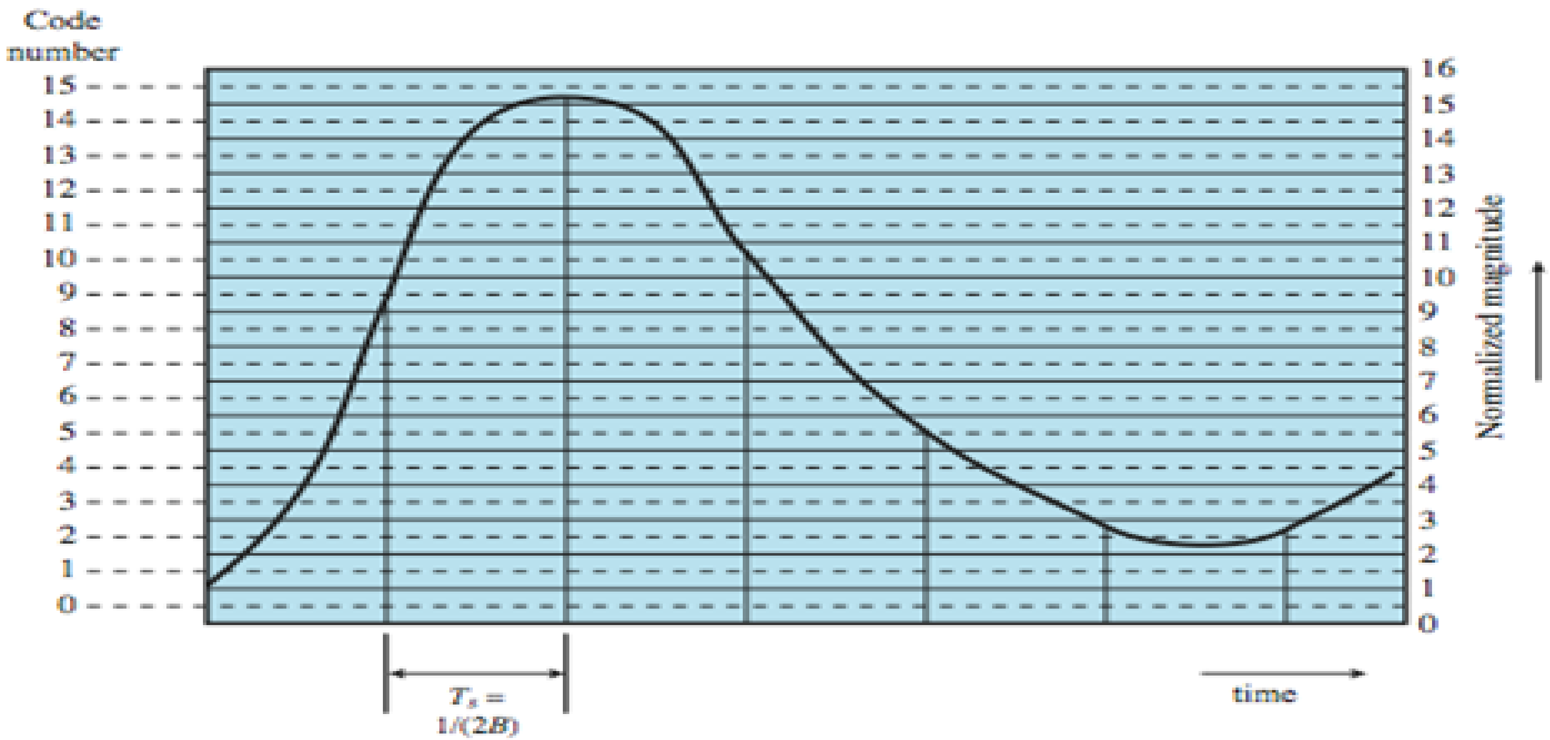


BPSK Modulated output wave

Pulse Code Modulation (PCM)

- sampling theorem: “If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal” .
  - strictly have analog samples
  - assign each a digital value

PCM Example



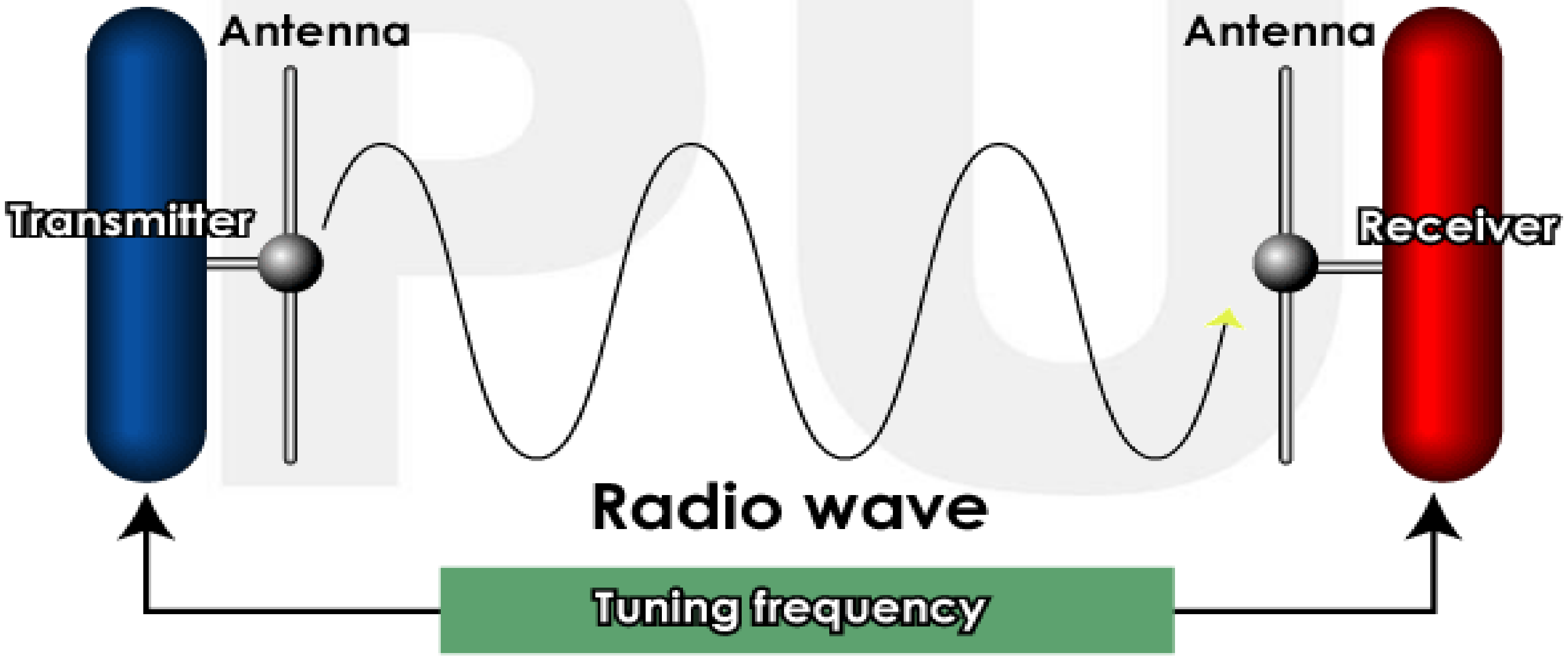
PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

Source: Wikipedia

Spread Spectrum

- Problem of radio transmission: frequency dependent fading can wipe out narrow band signals for duration of the interference.
- In a conventional wireless communication fixed frequency is used and this frequency does not change over time.
- For eg. When you listen to radio and tune it to 93.5 FM this frequency will be same always.

AM and FM radio



Source: Wikipedia

Problem with conventional wireless system

1) Interference:

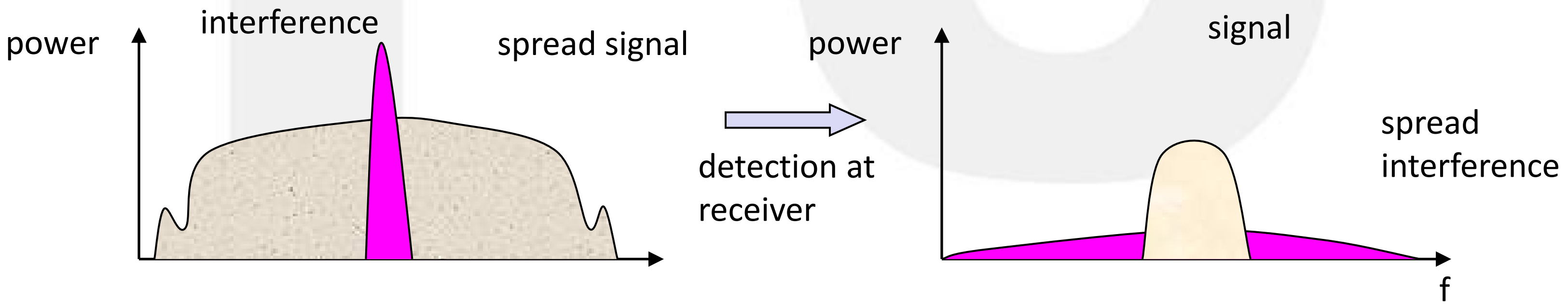
- When another signal transmitted on or very near the frequency of desired signal.

2) interception:

- Third party work as a listener so constant frequency signal not well suited to application in which information must kept confidential between the source and destination.

Solution(With Spread Spectrum technology)

- Solution: spread the narrow band signal into a broad band signal using a special code.
- Expansion of signals bandwidth.
- Spread data signal on a frequency spectrum.



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Types of Spread Spectrum

- Frequency Hopping Spread Spectrum (FHSS)

  Space application ,HF radio ,military ,WLAN.

- Direct Sequence Spread Spectrum

  WLAN,CDMA radio, Cordless phone,GPS , military.

Frequency Hopping Spread Spectrum

- Sender do not use a single frequency ,multiple frequency is used to transmit a data.
- Frequency of carrier is periodically modified following a specified sequence of frequency.
- This sequence is known as hopping sequences or spreading code.
- The amount of time spent on each frequency or hop is known as dwell time.

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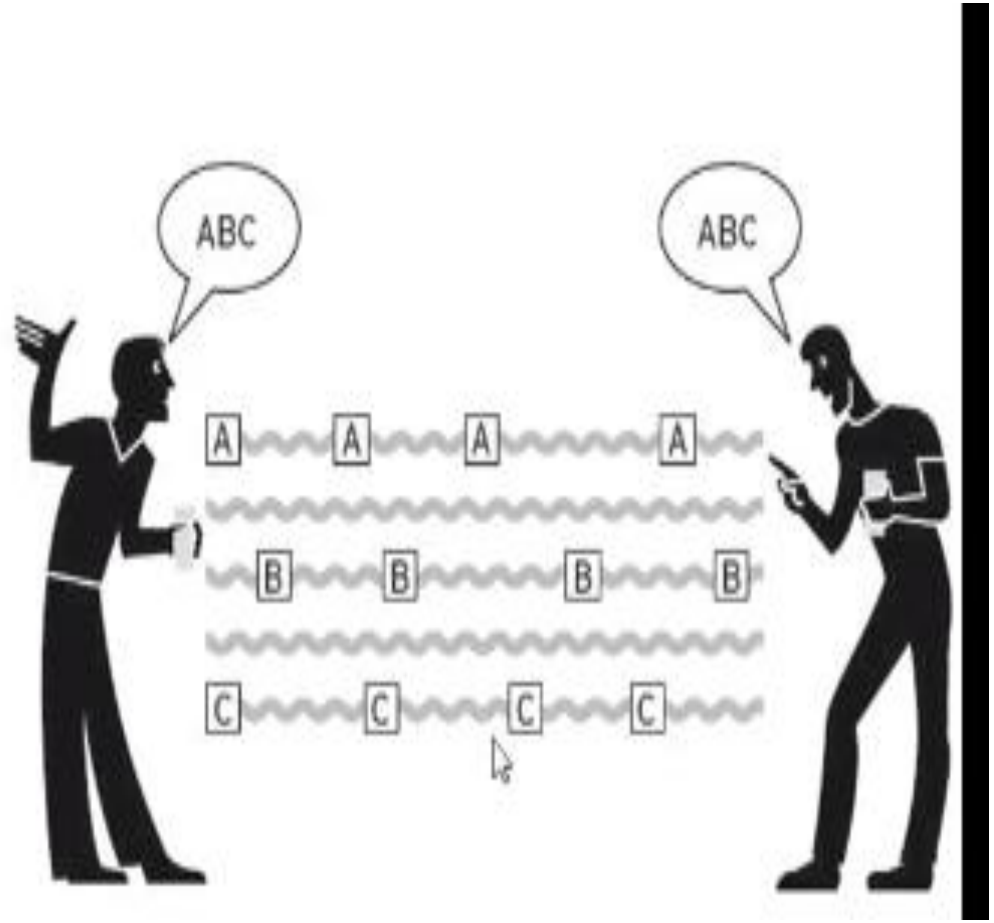
Signal is sent using many frequency.



Source: Wikipedia

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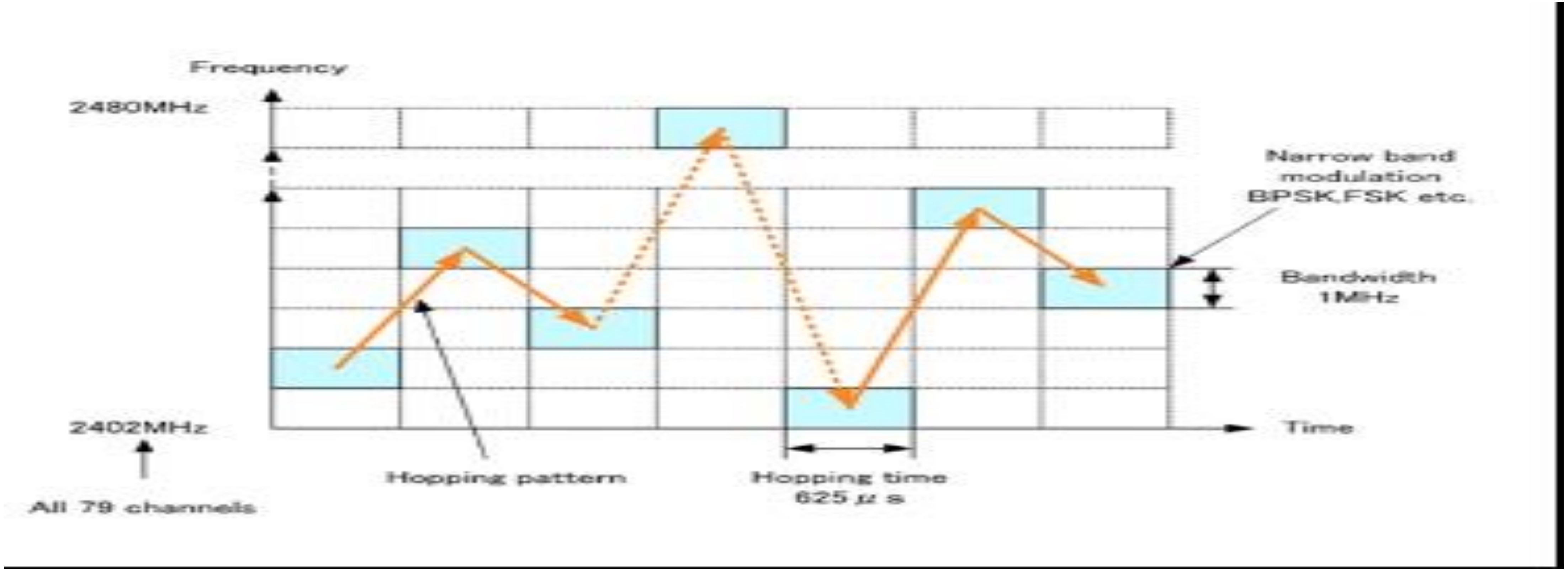
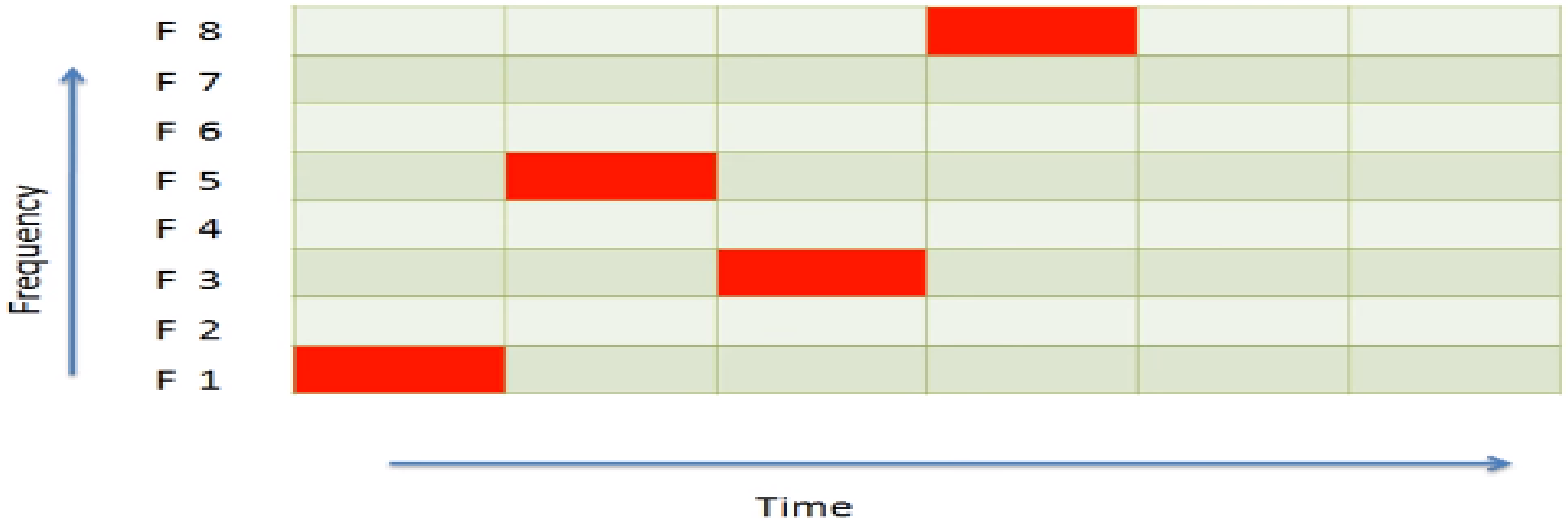


Source: Wikipedia

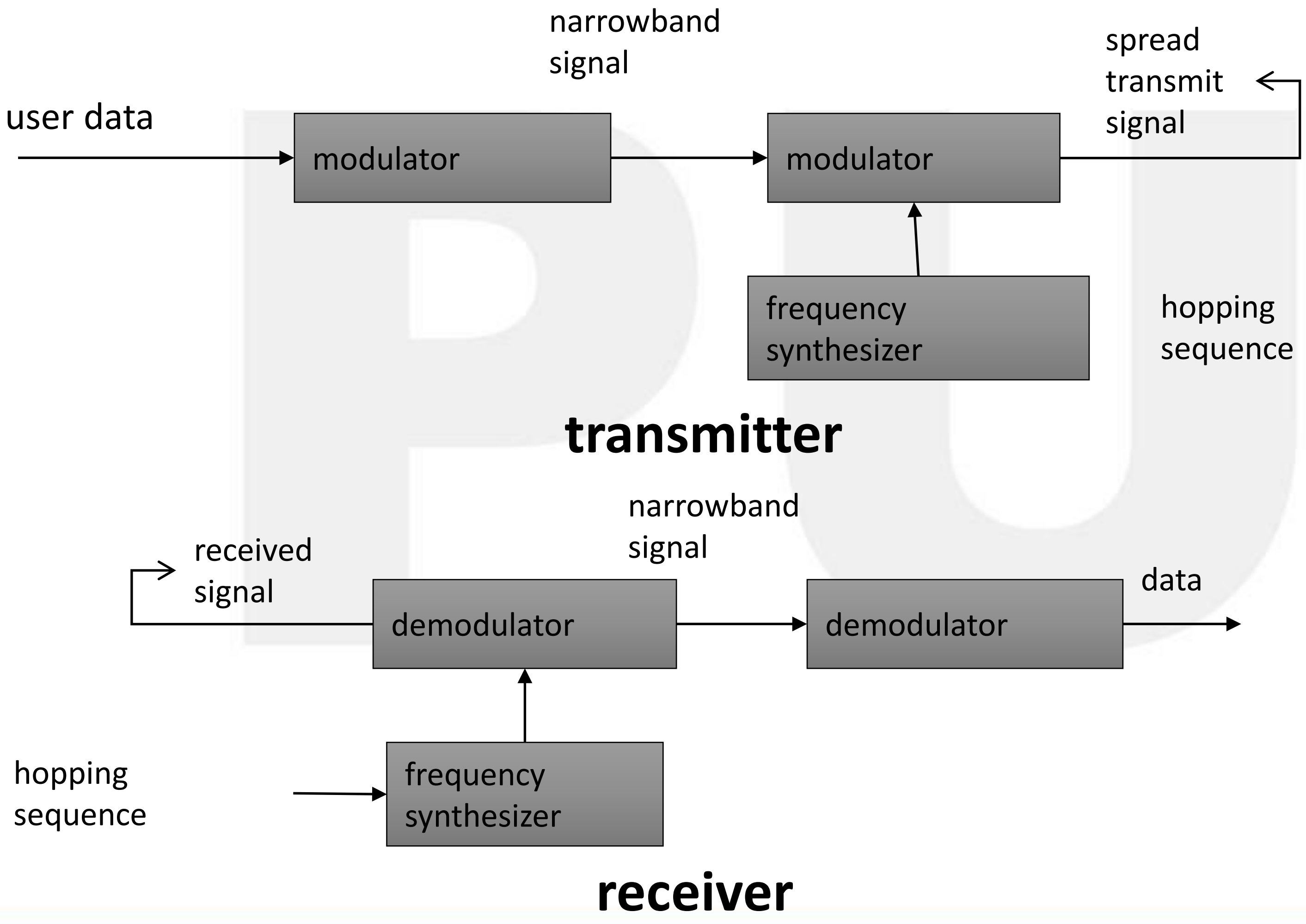
Continued...

Let's say sender A want to send some data. Hopping sequence for A is F1,F5,F3,F8



Source: Wikipedia

Frequency Hopping Spread Spectrum



FSHH Advantages and Disadvantages

Advantages:

- If multipath propagation is there then it is better method.
- Resistant from interference and interception.

Disadvantages:

- More difficult to synchronize
- High latency

Direct Sequence Spread Spectrum

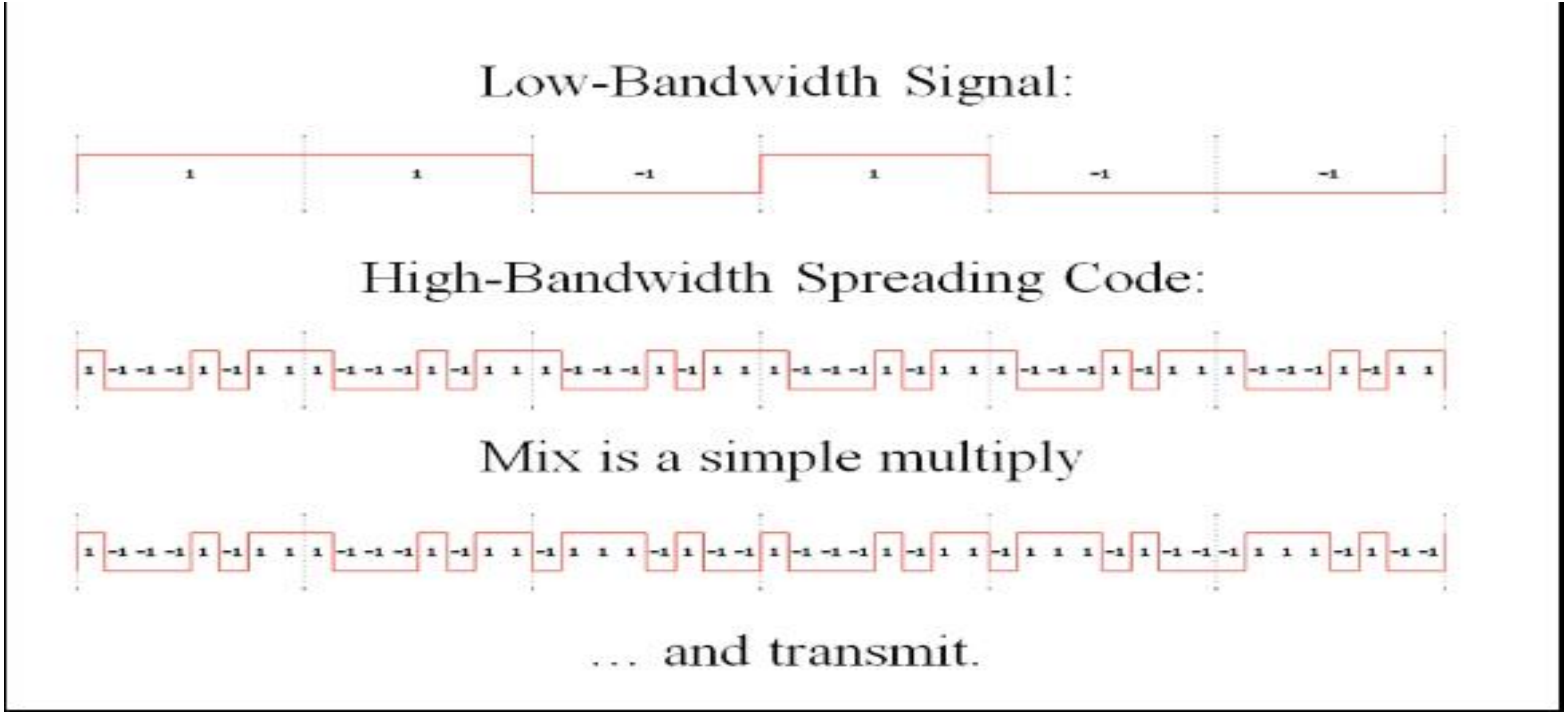
- Every user assigned a spreading code. This code is used to encode the signal.
- This code is multiplied with original message and resultant message is then transmitted.
- Receiver use same spreading code to decode the message to retrieve original message

Continued…

- For the duration of every message bit, the carrier is modulated following a specific sequence of bits (known as chips).This process is known as “chipping” and results in the substitution of every message bit by (same) sequence of chips.

- Spreading code example (100101)
- 0 is represented as -1.
- Spreading code is now (1,-1,-1,1,-1,1)

Continued…



Source: Wikipedia

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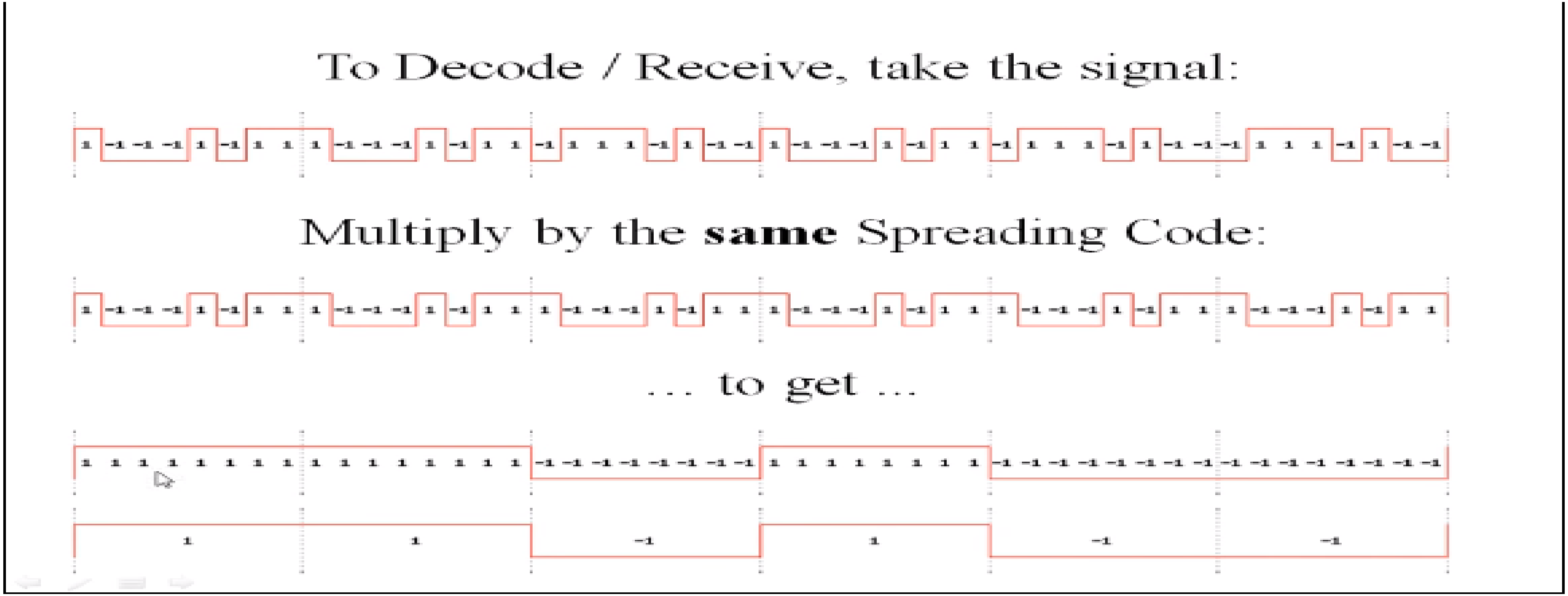

Source: Wikipedia

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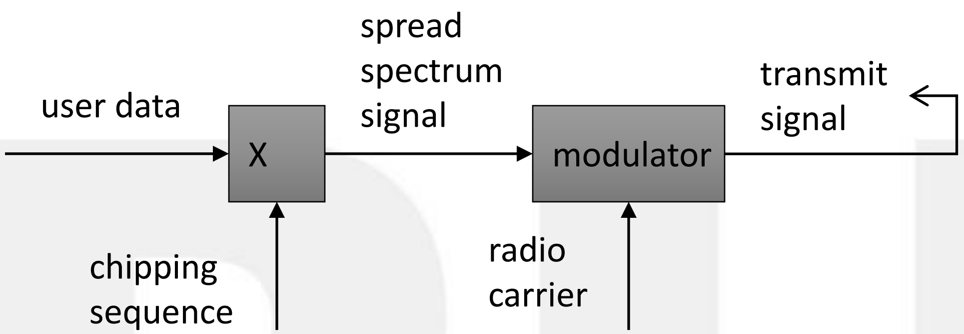
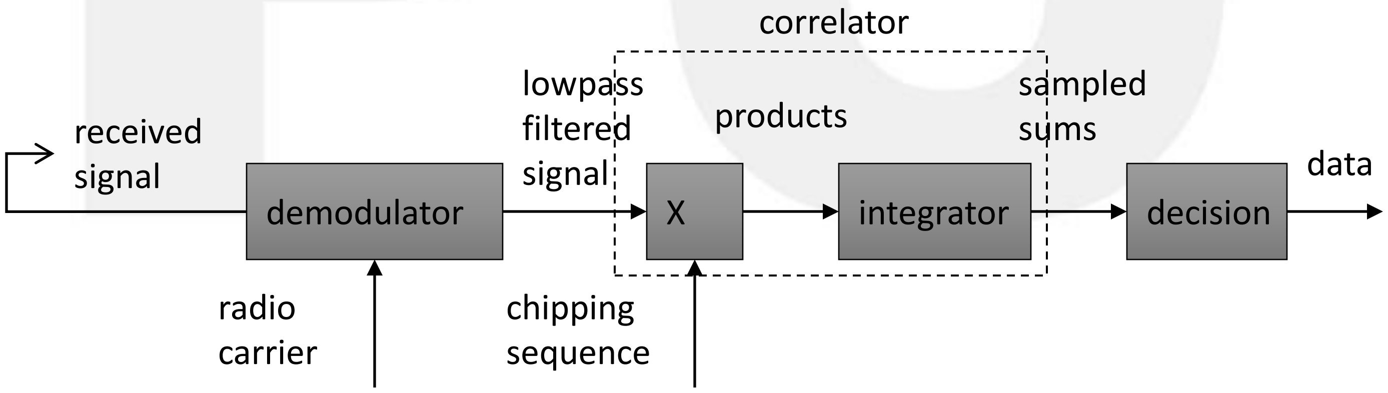


transmitter



receiver

DSSS Advantages and Disadvantages

Advantages:

- Resistant from interference and interception.
- More Reliable

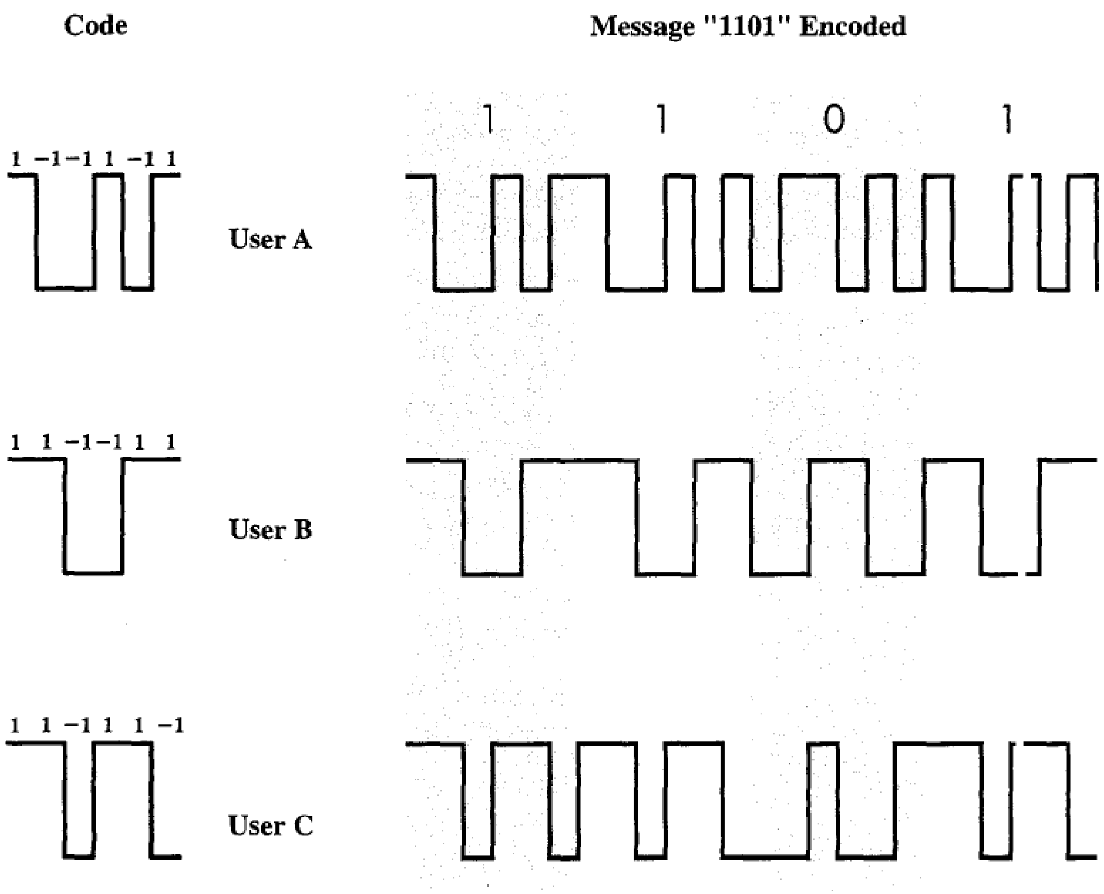
Disadvantages:

- Design of spreading code is tough task.

Code Division Multiple Access

- CDMA is a multiplexing technique used with spread spectrum. The scheme works in the following manner.
- We start with a data signal with rate D, Which we call the bit data rate. We break each bit into *k chips* according to a fixed pattern that is specific to each user, called the user's code. The new channel has a chip data l rate of *kD* chips per second.

Continued...



Source: CDMA Example[1]

References

1. William Stallings, Wireless Communications & Networks, 2nd edition.

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