Tishk International University
Science Faculty
IT Department

Wireless Networking

Lecture 3: Modulation and Multiple Access Techniques

4th Grade –Fall Semester

Instructor: Alaa Ghazi

Lecture 3
Modulation
and
Multiple Access Techniques

Agenda

1. Introduction
2. Digital Communications System
3. Goals in Communication Systems
4. Communication Channel Terms
5. Frequency Domain Concept
6. Modulation
7. Analogue Modulation
8. Digital Modulation
9. Multiple Access Techniques

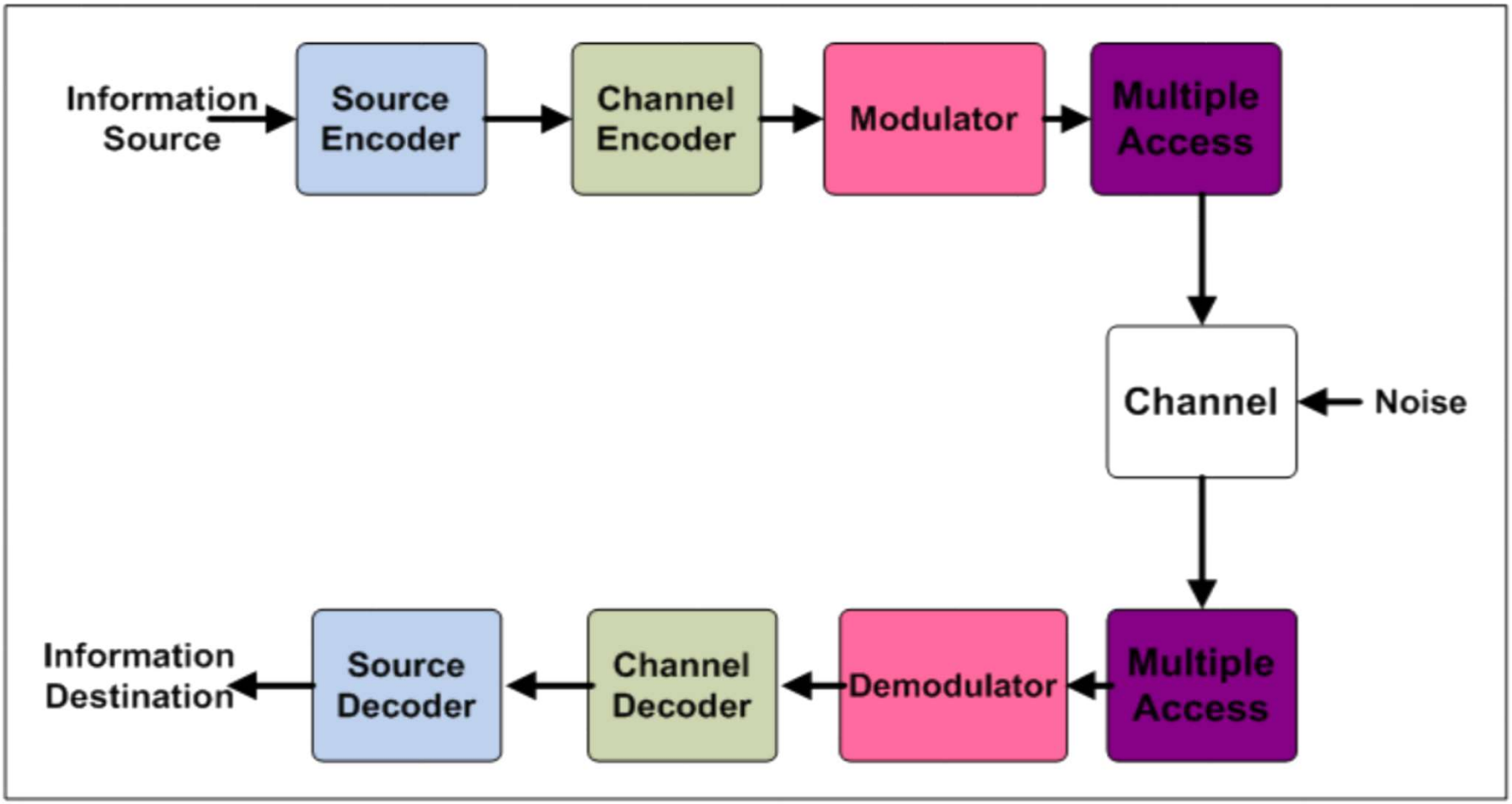
1. Introduction

Main purpose of communication is to transfer information from a source to a recipient via a channel or medium.

Communication systems are found whenever information is to be transmitted from one point to another.

Basic block diagram of a digital communication system is shown in the next slide

2. Digital Communications System



Source Encoder: Samples the analog signal, and converts the samples into a bit stream.

Channel Encoder: Accepts the digital signal and adds redundant data bits in the information sequence for the purpose of minimizing transmission errors.

Modulator: Converts the digital information into high frequency carrier waveforms that are compatible with the characteristics of the transmission channel.

Multiple Access Techniques: are ways to access a single channel by multiple users

The communication channel: is the physical medium that is used for transmitting signals from transmitter to receiver. In our course it is the Free Space.

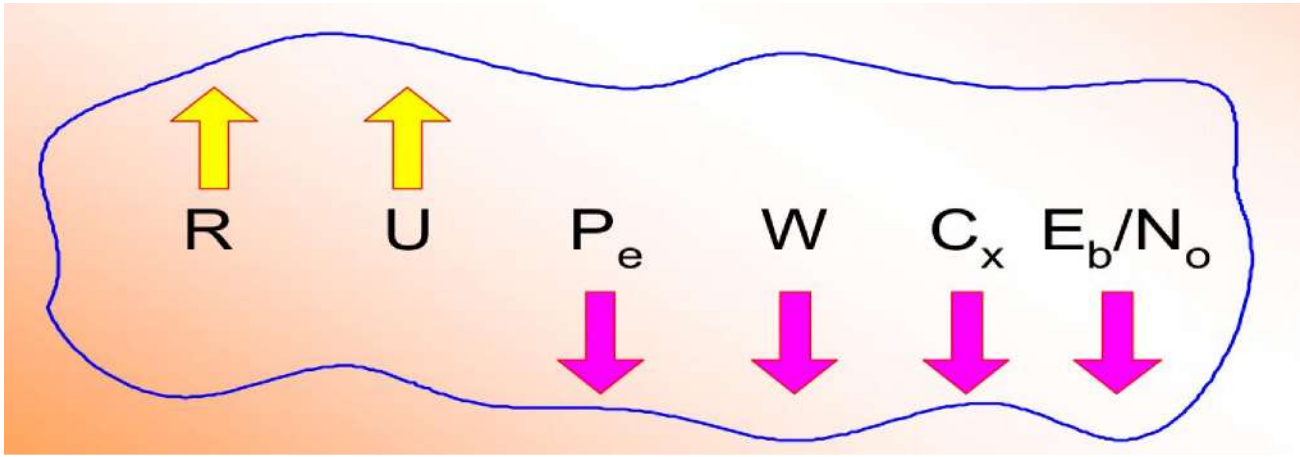
The demodulator converts the received waveform to the sequence of numbers that represents estimates of the transmitted data symbols.

Channel Decoder: attempts to reconstruct the original information using the redundancy contained in the received data.

Source Decoder: attempts to decode the sequence from the knowledge of the encoding algorithm, which results in the approximate replica of the original analogue input.

3. Goals in Communication Systems

- To maximize transmission rate, ***R***
- To maximize system utilization, ***U***
- To minimize bit error rate, $\boldsymbol{P_e}$
- To minimize required systems bandwidth, ***W***
- To minimize system complexity, $\boldsymbol{C_x}$
- To minimize required power, ***Eb/No***



4. Communication Channel Terms

Channel Capacity: the maximum rate at which data can be transmitted over a given communication channel, under given conditions

Data rate (bps) : the rate at which data can be communicated.

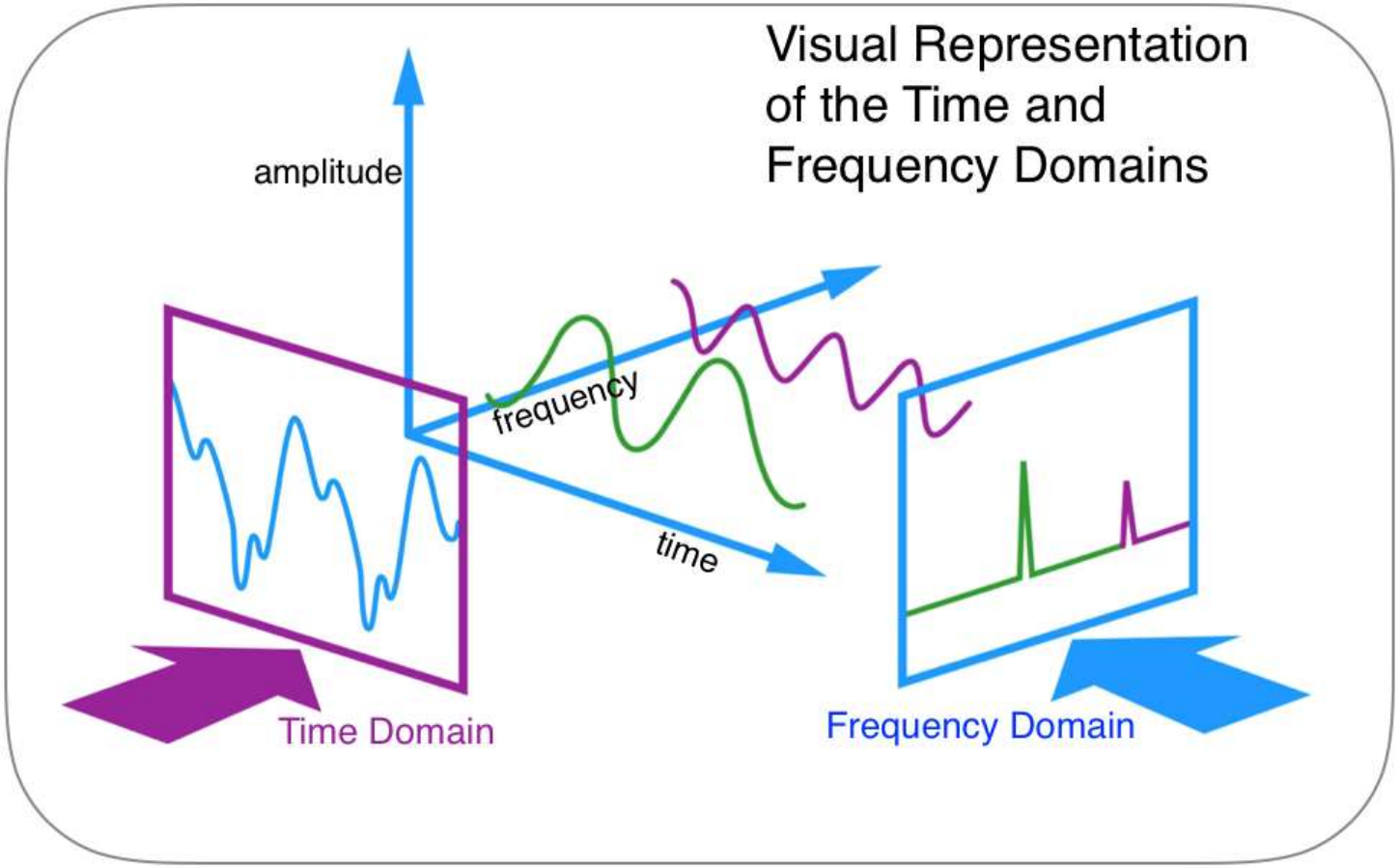
Bandwidth (Hz) : the bandwidth of the transmitted signal as limited by the transmitter and the nature of the transmission medium.

Noise : is unwanted electrical or electromagnetic energy that degrades the quality of signals and data.

Bit Error Rate : is the number of bit errors in the number of received bits of a data stream over a communication channel.

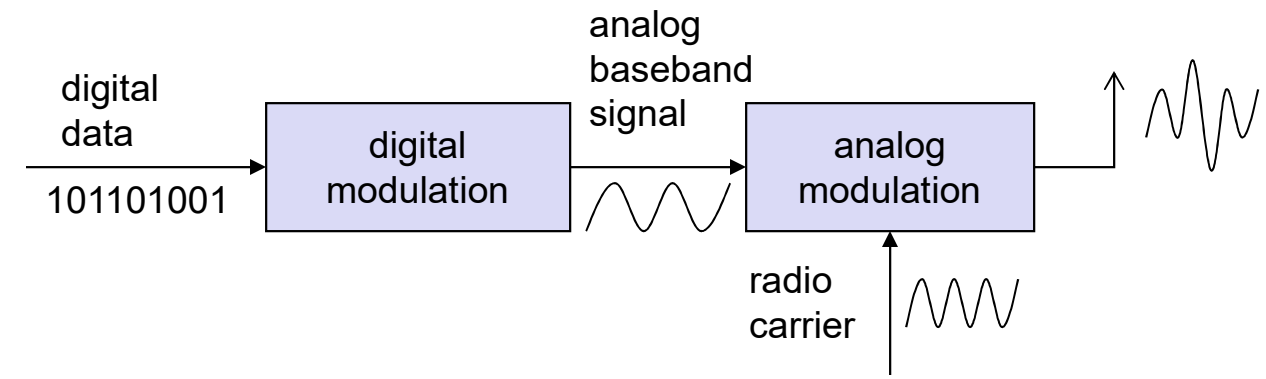
5. Frequency Domain Concept

Fourier transform of a **periodic signal** is a set of equally-spaced impulses (of different amplitudes) in the frequency domain.

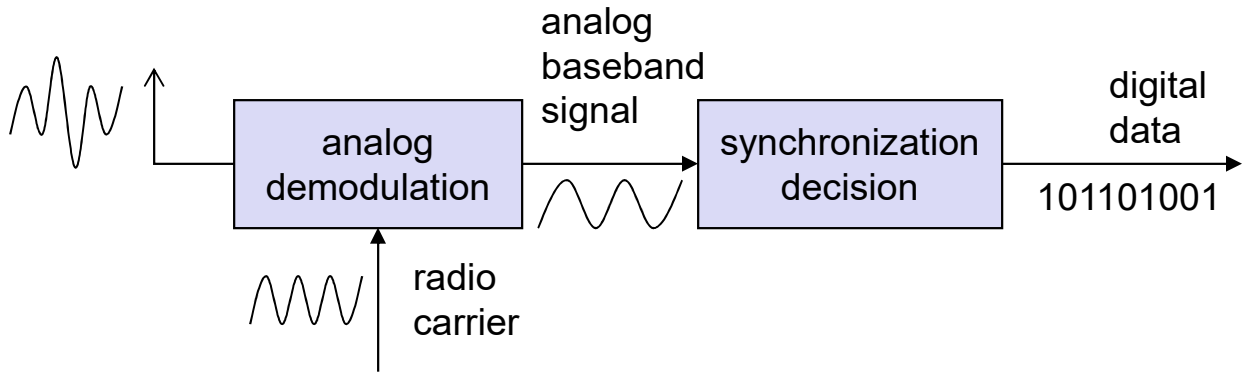


6. Modulation

Modulation of a radio wave can be performed by varying one or more of its signal components—amplitude, frequency, or phase—while keeping its other signal components constant.



radio transmitter



radio receiver

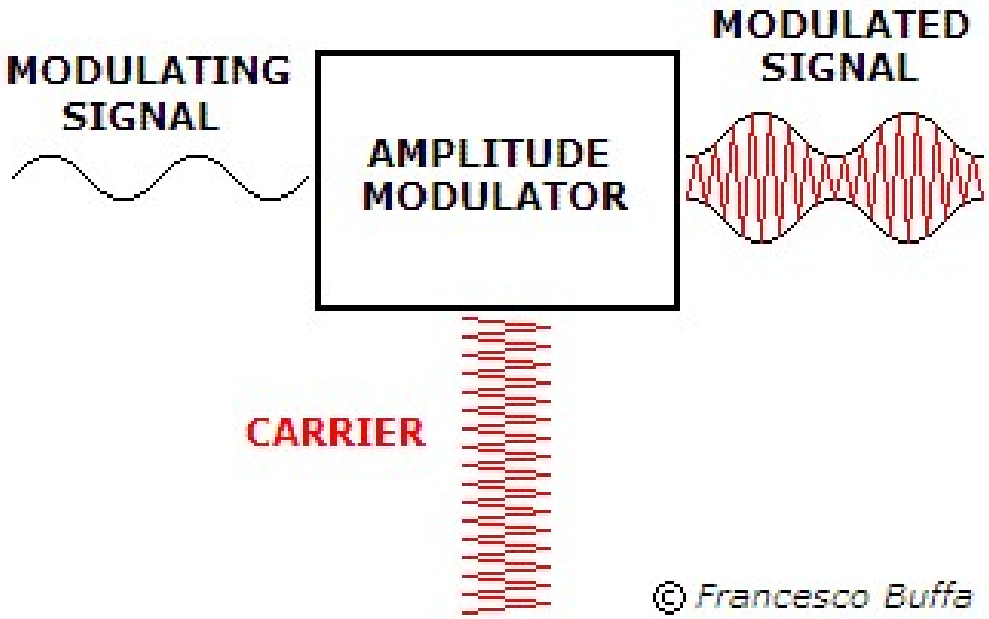
Types of Modulation

- Analog modulation
  - shifts center frequency of baseband signal up to the radio carrier, it has the following schemes:
  - ❖ Amplitude Modulation (AM)
  - ❖ Frequency Modulation (FM)
  - ❖ Phase Modulation (PM)
- Digital modulation
  - digital data is translated into an analog signal
  - The schemes are ASK, FSK, PSK, QPSK, QAM
  - differences in spectral efficiency, power efficiency, and robustness
- Motivation for Modulation use
  - smaller antennas
  - Frequency Division Multiplexing
  - medium characteristics

7. Analogue Modulation

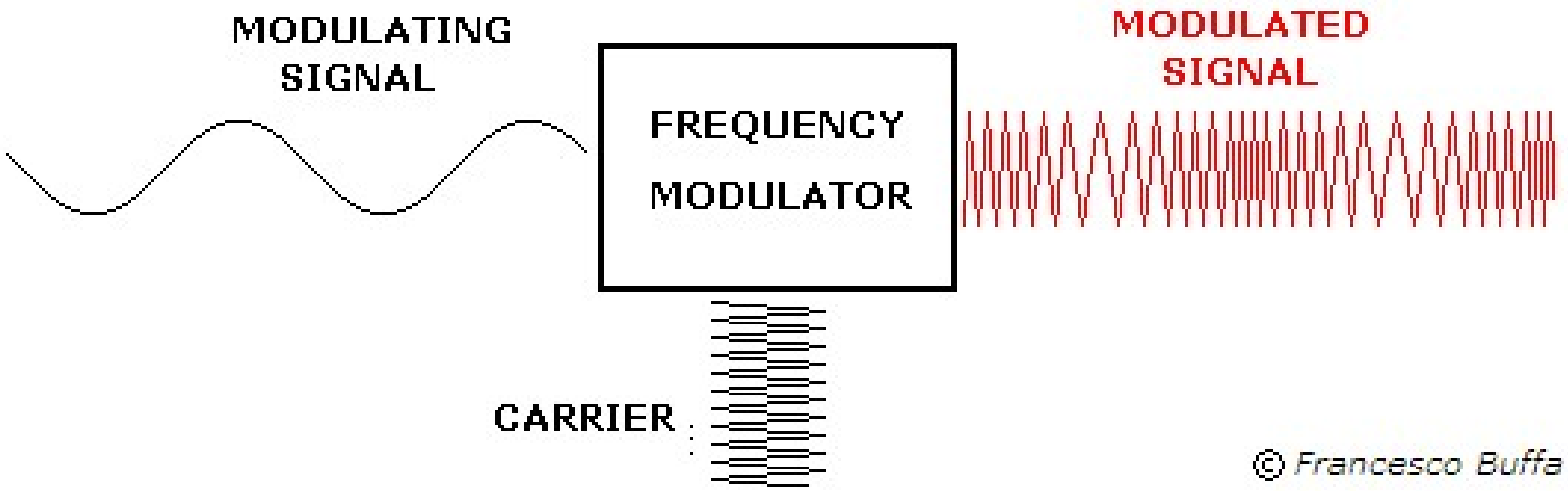
Amplitude Modulation (AM) is a technique where the amplitude of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.

Disadvantage: An amplitude modulation signal is prone to high levels of noise because most noise is amplitude based.



Frequency Modulation (FM) is a technique where the frequency of the carrier wave is varied, in accordance with the instantaneous value of the modulating signal.

Advantage: FM can give a better signal to noise ratio than AM when wide bandwidths are used.



8. Digital Modulation

Digital Modulation methods convert bit voltage level transitions and patterns into sine wave carrier variations. The most basic schemes of digital modulation are:

1. Amplitude Shift Keying (ASK),
2. Frequency Shift Keying (FSK), and
3. Phase Shift Keying (PSK).
4. Quadrature Phase Shift Keying (QPSK).
5. Quadrature amplitude modulation (QAM)

Advantages of Digital Modulation over Analogue Modulation ?

- ❖Compatibility with digital systems
- ❖Better security
- ❖Better quality
- ❖Greater capacity

Digital Modulation Schemes

Baseband digital message signal:

Analog sinusoidal carrier signal:

A. Carrier signal:

1 **ASK: Amplitude Shift Keying.**

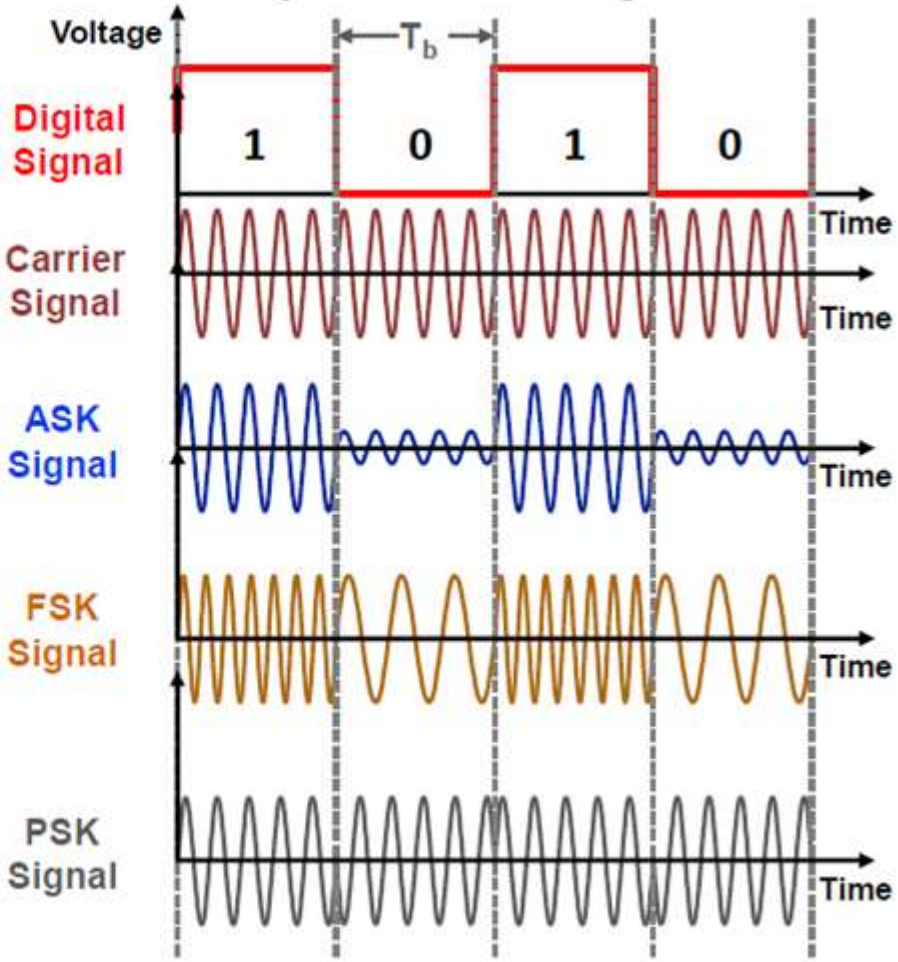
A. Message signal changes the carrier's **amplitude** :

2 **FSK: Frequency Shift Keying.**

A. Message signal changes the carrier's **frequency** :

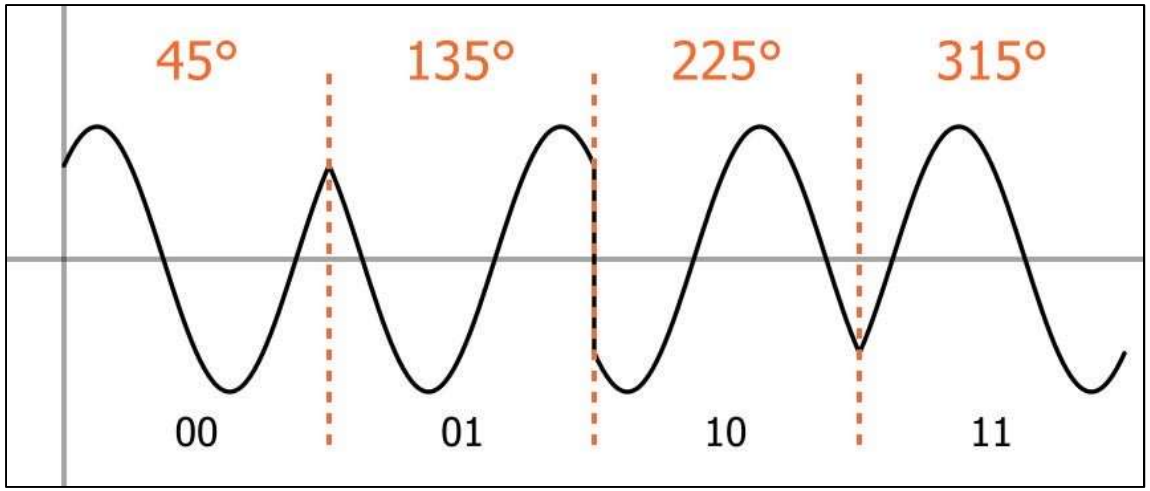
3 **PSK: Phase Shift Keying.**

A. Message signal changes the carrier's **phase** :



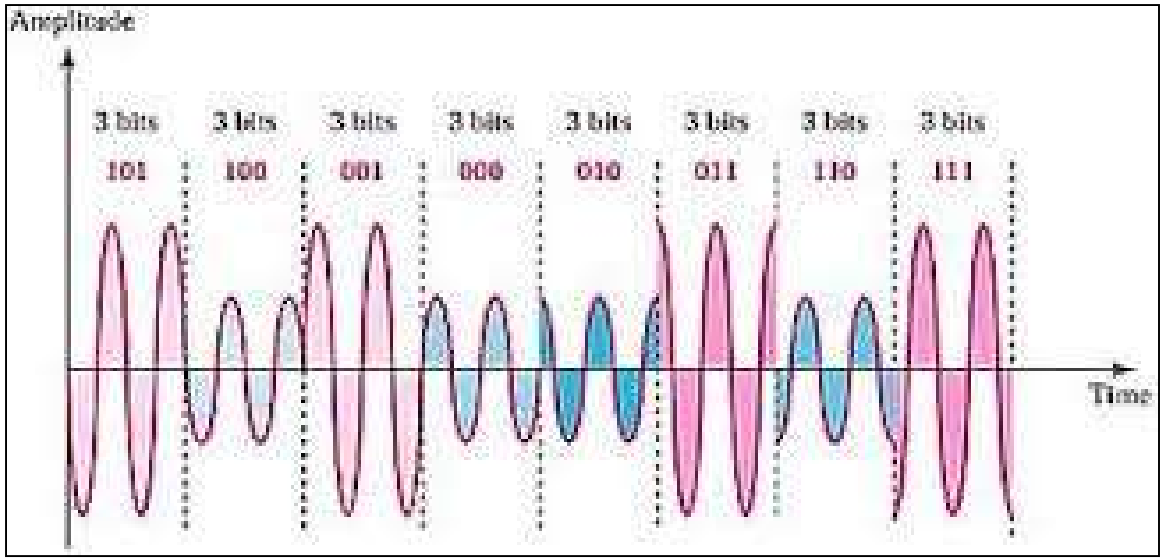
4. QPSK

- The only way to achieve high data rates with a narrowband channel is to increase the number of bits/symbol
- QPSK systems exhibits the same performance but twice the bandwidth efficiency of that of BPSK.
- In QPSK Carrier phase is changed by 45^0 ,135^0, 225^0, 315^0
- PSK is limited by the ability of the equipment to distinguish between small differences in phases which Limits the potential data rate.



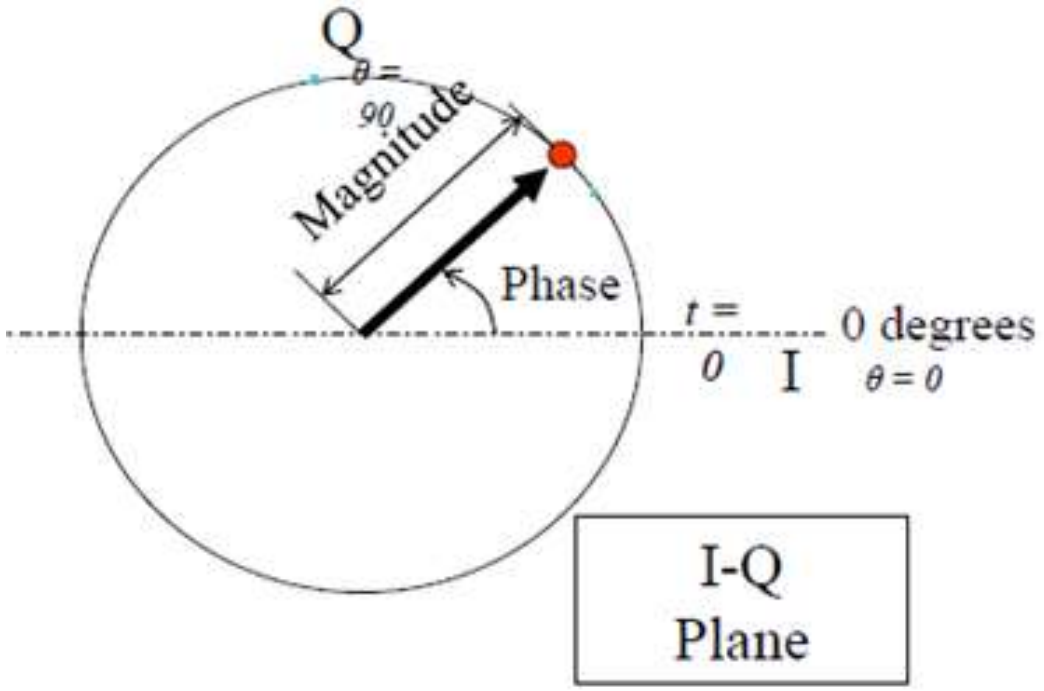
5. QAM

- Quadrature amplitude modulation is a combination of ASK and PSK so that a maximum contrast between each signal unit is achieved.
  - We can have x variations in phase and y variations of amplitude
  - x • y possible variation (greater data rates)
- Numerous variations. (4-QAM, 8-QAM, 16-QAM, 64-QAM and 256-QAM)

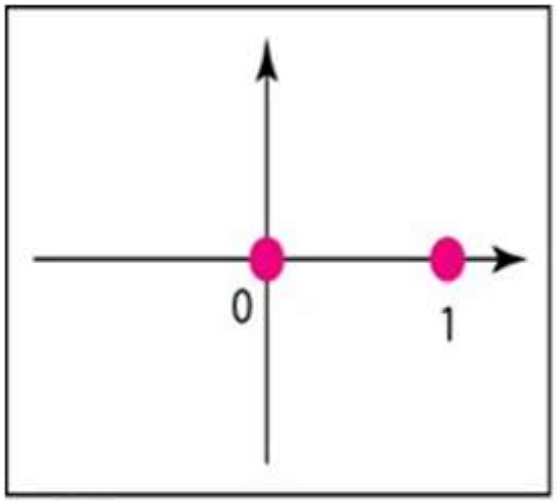


Constellation Diagrams

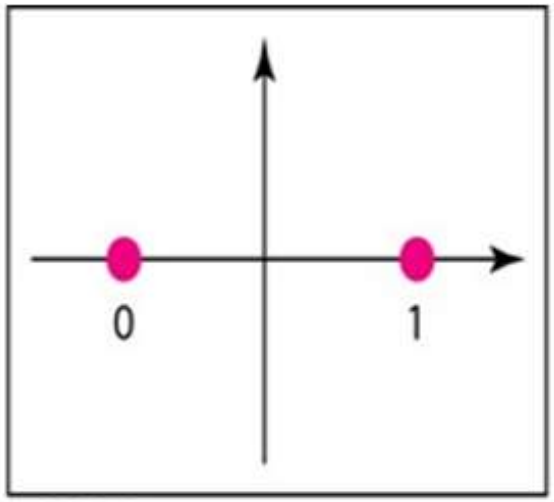
A constellation diagram is a representation of a signal modulated by a digital modulation as a two-dimensional scatter diagram in the complex plane.



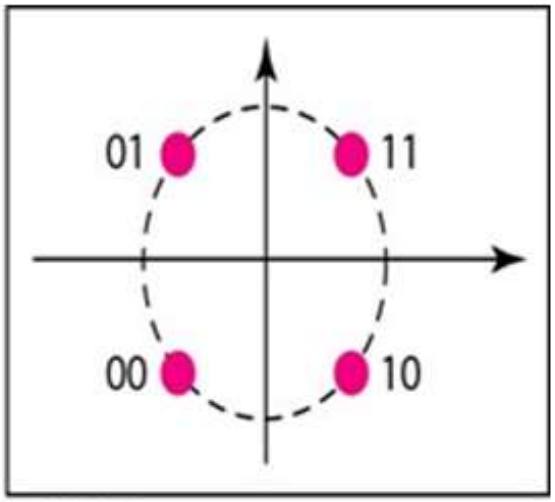
Constellation Diagrams Examples



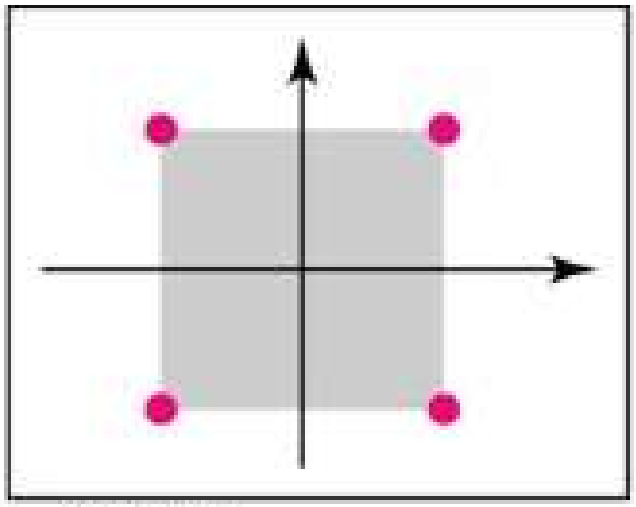
ASK



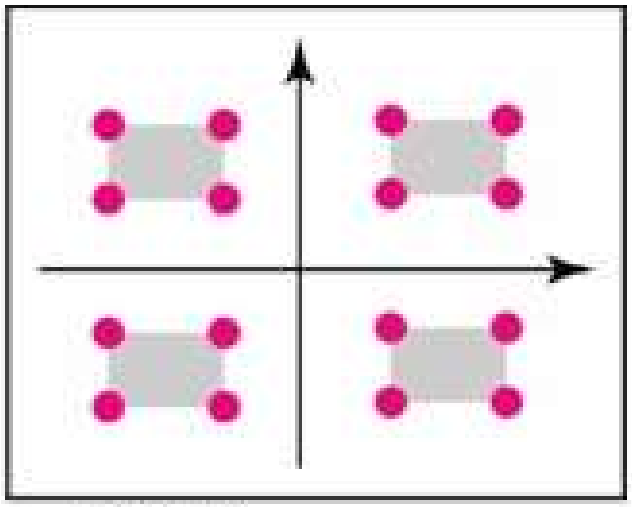
BPSK



QPSK



4-QAM



16-QAM

Bandwidth Efficiency Limits

Bandwidth Efficiency: Number of bits that can be transmitted for each Hz of channel bandwidth, expressed in bps/Hz.

Bandwidth Efficiency = $\log_2 M$

Where M is the number of discrete levels in the signal

Modulation format	Theoretical bandwidth efficiency limits
MSK	1 bit/second/Hz
BPSK	1 bit/second/Hz
QPSK	2 bits/second/Hz
8PSK	3 bits/second/Hz
16 QAM	4 bits/second/Hz
32 QAM	5 bits/second/Hz
64 QAM	6 bits/second/Hz
256 QAM	8 bits/second/Hz

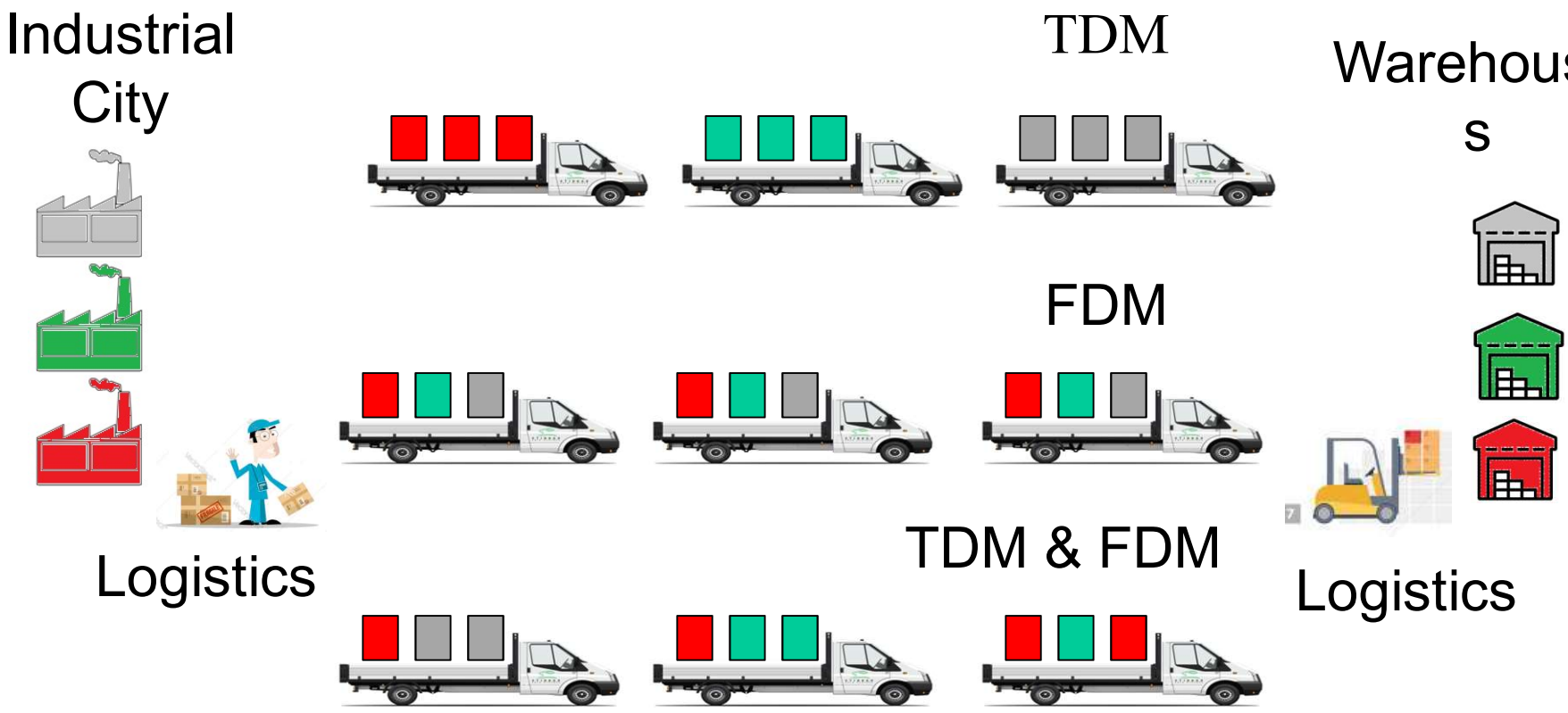
9. Multiple Access Techniques

The Goal of Multiple Access Techniques is to transfer signal from multiple users over a shared channel

The types of Multiple Access Techniques are:

- Frequency division multiple access (FDMA)
- Time division multiple access (TDMA)
- Time and Frequency Multiplex
- Code division multiple access (CDMA)
- Space division multiple access (SDMA)

Analogy of using shared road with shared communication Channel



TDMA

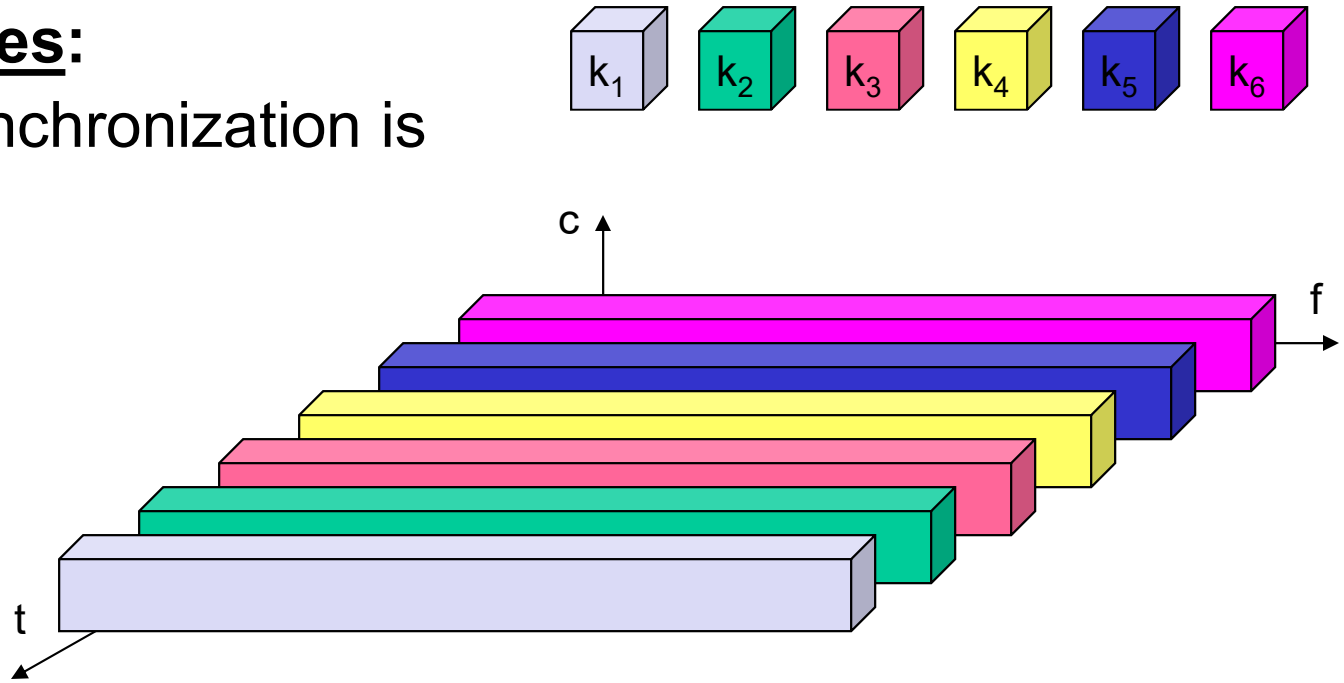
- A channel gets the whole spectrum for a certain amount of time

Advantages:

- only one carrier in the medium at any time
- throughput high even for many users

Disadvantages:

- Precise synchronization is necessary



FDMA

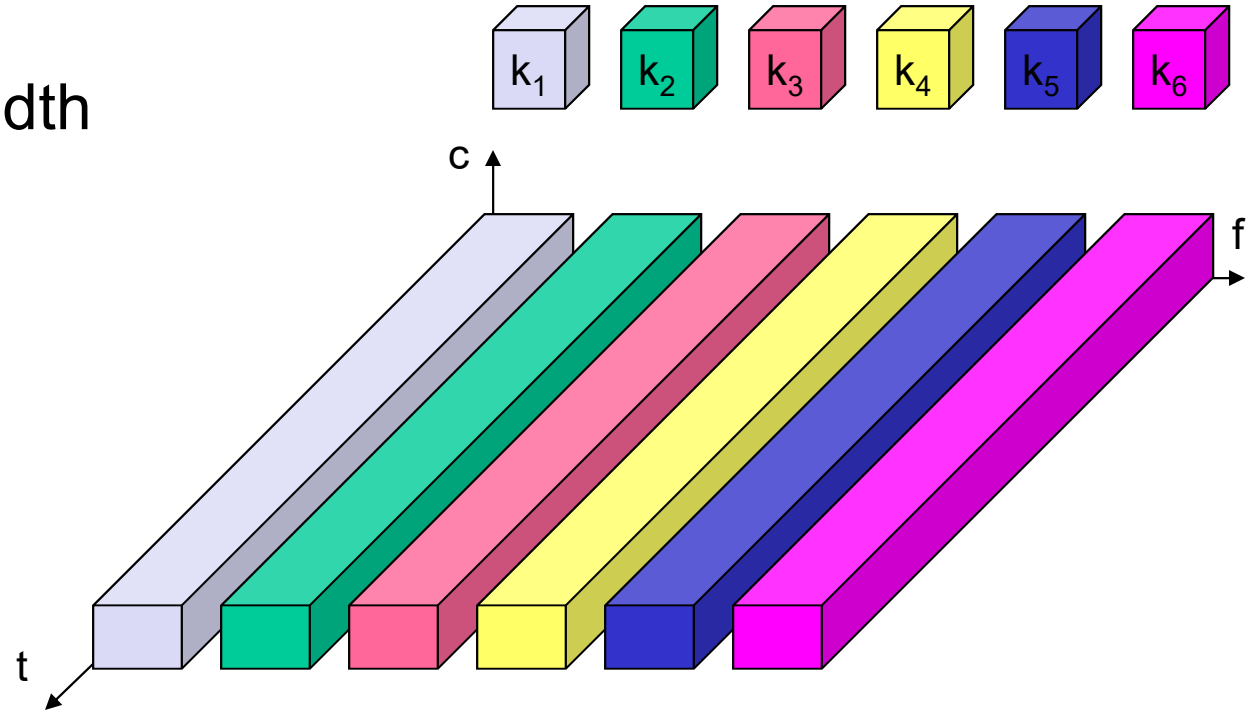
- Separation of the whole spectrum into smaller bands
- A channel gets a certain band for the whole time

Advantages:

- no dynamic coordination necessary
- works also for analog signals

Disadvantages:

- waste of bandwidth
- inflexible



Time and Frequency Multiplex

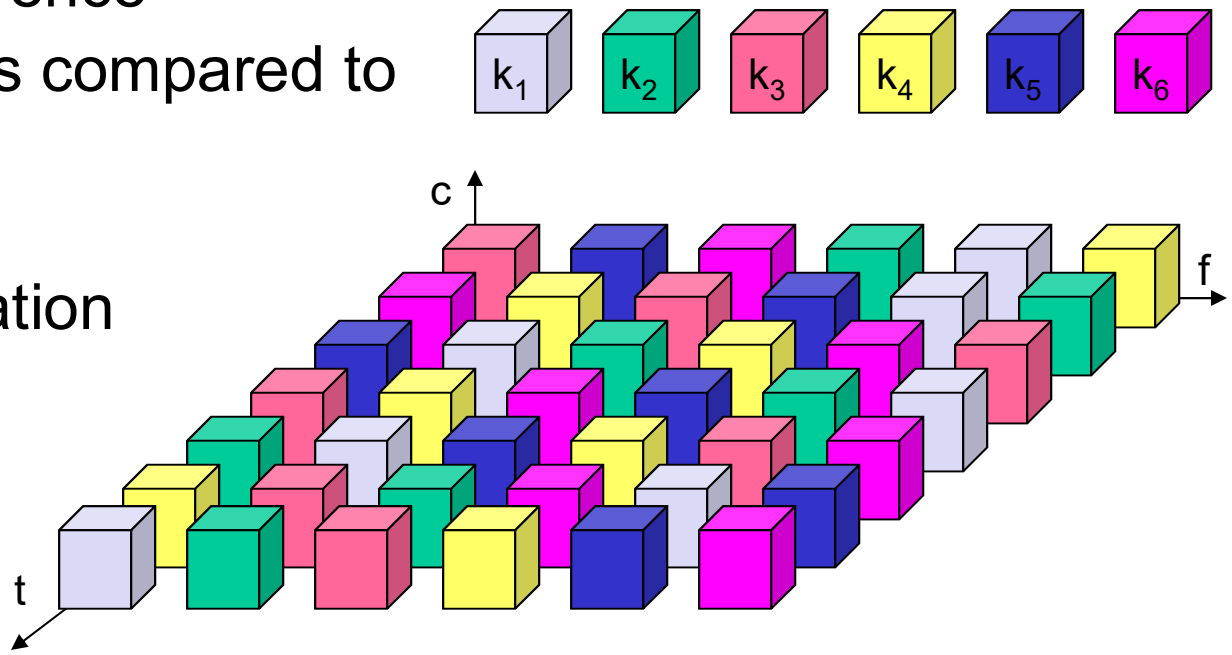
- Combination of both methods and used in GSM
- A channel gets a certain frequency band for a certain amount of time

Advantages:

- better protection against tapping
- protection against frequency selective interference
- higher data rates compared to code multiplex

Disadvantages:

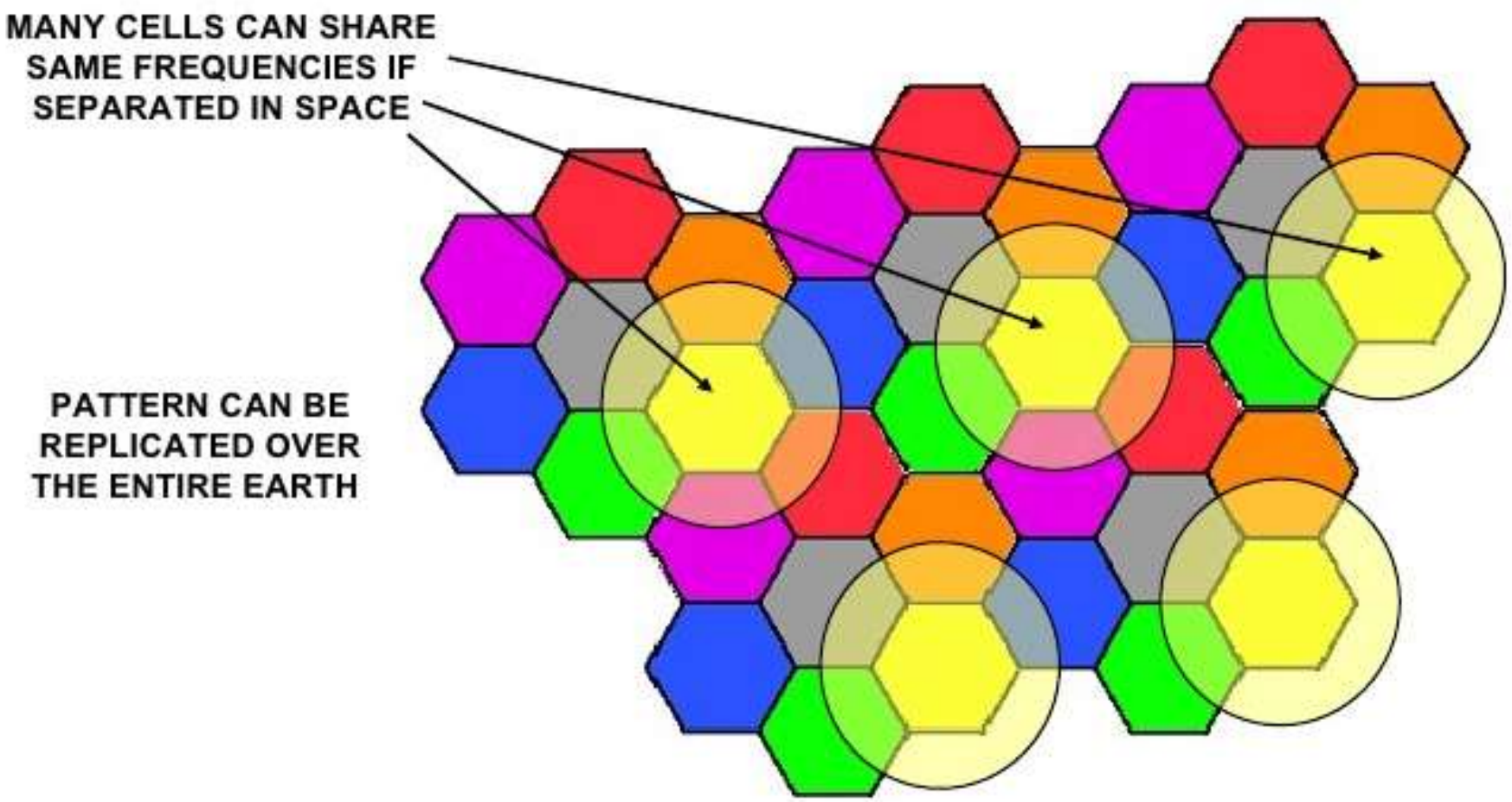
- precise coordination required



SDMA

- Space Division Multiple Access (SDMA) is dividing a particular coverage area into discrete sectors (or cells).
- In theory, the sectors are non-overlapping.
- Communications are centralized somehow inside each sector (central or base station: intra-cell management).
- Communications use different parameters in neighboring cells to ensure low or no interference (this requires coordination at a higher level: inter-cell management).
- Normally, this is ensured by using different frequency bands.

Space Division Multiple Access



CDMA

- Each channel has a unique code
- All channels use the same spectrum at the same time
- Implemented using spread spectrum technology (will be covered in next lectures)

Advantages:

- Bandwidth efficient
- No coordination is necessary
- good protection against interference and tapping

Disadvantages:

- Lower user data rates
- More complex system