Evolution of Modulation Techniques in Wireless and Wired Network

Part 1- About Modulation and Its Techniques

Hasan Hüseyin Çağlar 150110042

*Understanding What Modulation is

- -In General
- -ın Network Technology

*Basic Modulation Concepts

- -Analog Modulation Techniques
- ---Amplitude Modulation (AM)
- ---Frequency Modulation (FM)
- ---Phase Modulation (PM)
- ---Quadrature amplitude modulation (QAM)

- -Digital Modulation Techniques
- ---PSK (phase-shift keying)
- ---FSK (frequency-shift keying)
- ---ASK (amplitude-shift keying)
- ---QAM (quadrature amplitude modulation)

- -Other Modulation Techniques
- ---Line Coding
- ---Pulse Modulation Methods

- *Historical view on Importance of Modulation and Its Techniques
- -Past
- -Present
- -Future

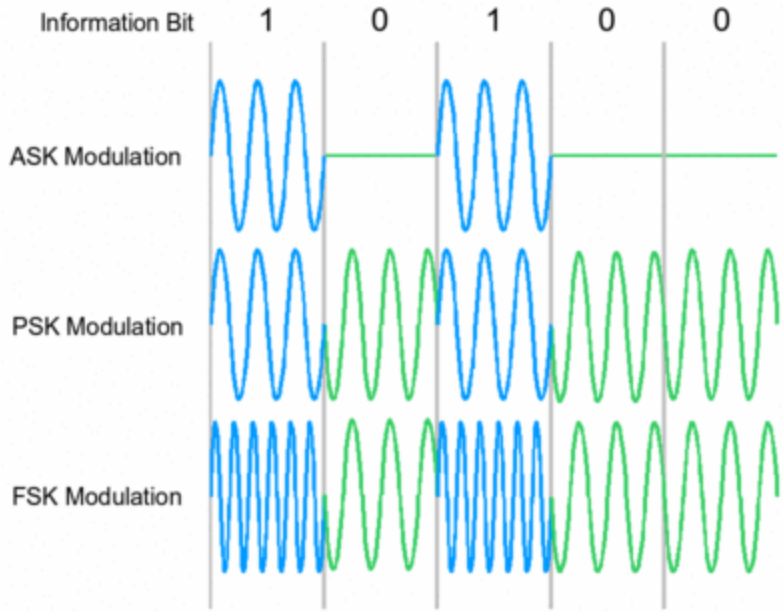
- (*outline may change until presentation time)

Modulation Techniques In Wired Networks

Cem Yusuf Aydoğdu

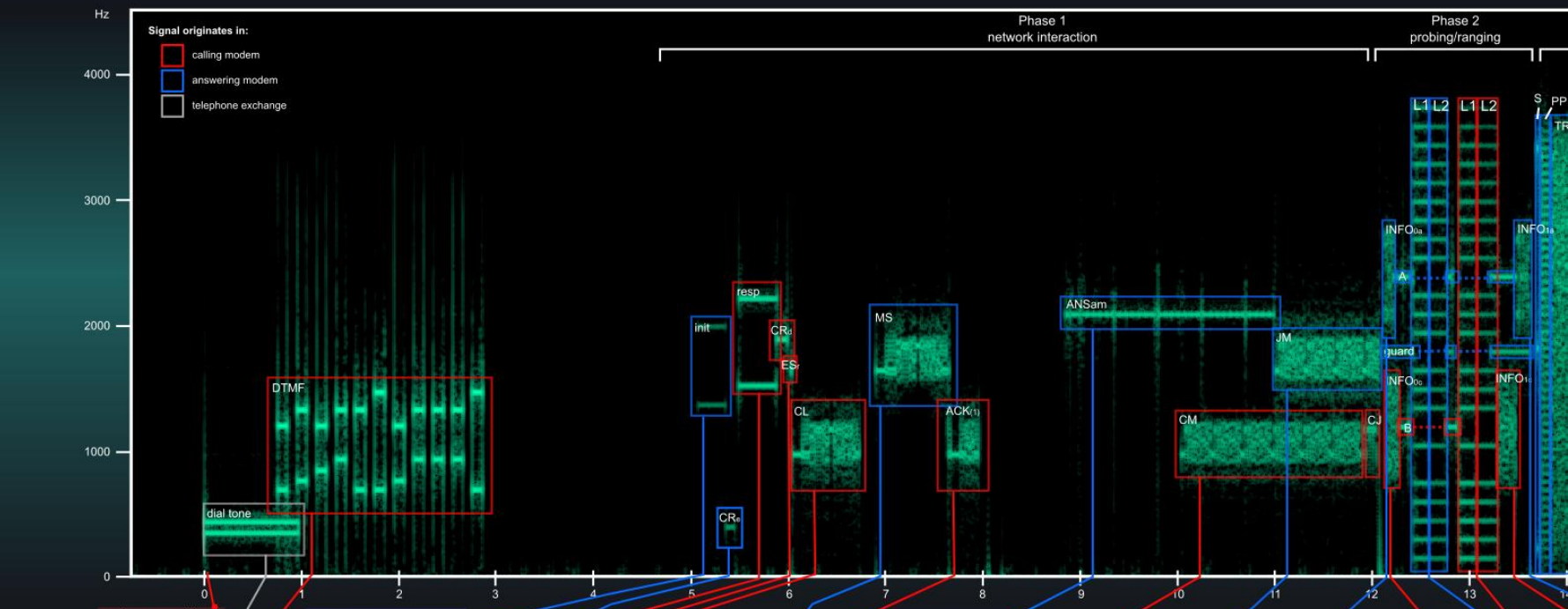
Common modulation techniques:

- ASK
- FSK
- PSK
- QAM



- Used in voice-band modems, DSL, coaxiacal cable modem applications

The Sound of the Dialup: an Example Handshake



modem goes off hook

telephone exchange sends a dial tone

modem dials 1-(570)234-0003, a number in Pennsylvania

answering modem initiates a V.8 *bis* transaction

answering modem asks caller to list its capabilities

caller responds to V.8 *bis* initiation, agrees to list its capabilities

caller requests to escape from telephony into information transfer mode

FSK data @ 300 bps:

```
01111110 01111110 01111110
01001000 10010011 00000001
00000001 00000001 00000001
10000001 00101101 01000000
00000000 00101001 10000001
11000001 00000000 11100000
10000000 01111110 11011100
01111110 01111110 01111110
```

"Why don't we use V.8 then."

FSK data @ 300 bps:

```
01111110 01111110
00101000 10111011
01100101 01111110
01111110
```

"Okay, mode acknowledged.
Terminating V.8 bis transaction."

answering modem disables echo suppressors and cancellers in PSTN

FSK data @ 300 bps:

```
1111111111 0000001111 0100000111
0101001101 0110010001 0001010011
0010101001 0101100001 0111001001
```

(repeated 6 times)

"Modulation modes available:
-PCM V.90/V.92 analogue
-V.34 duplex
-V.32/V.32 bis
-V.23 duplex
-V.22/V.22 bis
-V.21

V.42 LAPM is available.

PSTN connection is over a regular landline (not cellular).
My network is analogue."

FSK data @ 300 bps:

```
1111111111 0000001111 0100000111
0101001101 0110010001 0001010011
0011000101 0101100001 0010101001
```

(repeated 3 times)

"Oh, I can do any of those modes as well. Except my V.90/V.92 is digital.

V.42 LAPM is available.

PSTN connection is over a regular landline (not cellular).
My network is digital."

DPSK data @ 600 bps:

```
1111011100101111111111000
0100010001111100110011111
```

"I can transmit at either carrier frequency at whichever standard symbol rate except 3429. Tx and Rx symbol rates must be equal.

I can reduce power if needed.
I can support up to 1664-point signal constellations.
My clock source is internal."

DPSK data @ 600 bps:

```
1111011100101111111111000
1010001011101100011111011
```

"I can transmit at either carrier frequency at whichever standard symbol rate except 3429. Tx and Rx symbol rates must be equal.

I can reduce power if needed.
I can support up to 1664-point signal constellations.
My clock source is external."

modems send a wi
spectrum probing s
in both directions to
do measurements
the telephone line

DPSK data @ 600

```
0111101110010011000000000
1000010111000010111000010111
0000101010100100000000011000
0010000111
```

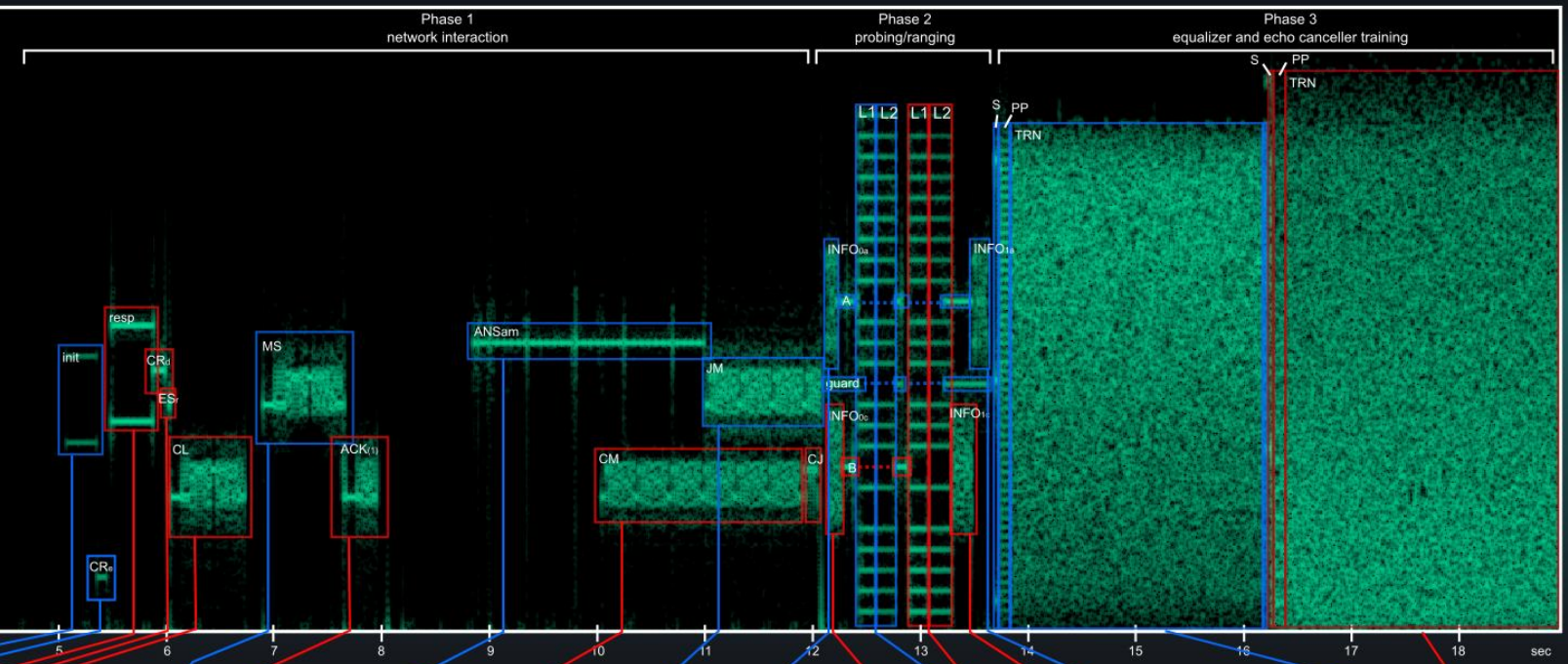
"Please don't reduc
power by more tha

I'm not equipped to
measure the freque
of the tones you se

Using different sym
we could achieve t

symrate	ur pre-emph
2400	6 dB
2743	8 dB
2800	8 dB
3000	8 dB
3200	8 dB
3429	10 dB

I can use the highe
carrier at any symb



SK data @ 300 bps:

```
111110 00111111 01111110
111110 10001000 10000001
000001 00000001 00000001
000001 00101101 01000000
000000 00101001 10000001
000001 00000000 11100000
000000 01111110 11011000
111110 01111110 01111110
```

Why don't we use
.8 then."

SK data @ 300 bps:

```
111110 01111110
101000 10111011
100101 01111110
111110
```

Okay, mode
cknowledged.
erminating
.8 bis transaction."

answering modem disables echo suppressors and cancellers in PSTN

FSK data @ 300 bps:

```
1111111111 0000001111 0100000111
0101001101 0110010001 0001010011
0010101001 0101100001 0111001001
```

(repeated 6 times)

"Modulation modes available:
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-V.23 duplex
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FSK data @ 300 bps:

```
1111111111 0000001111 0100000111
0101001101 0110010001 0001010011
0111000101 0101100001 0010101001
```

(repeated 3 times)

"Oh, I can do any of those modes as well. Except my V.90/V.92 is digital.

V.42 LAPM is available.

PSTN connection is over a regular landline (not cellular). My network is digital."

DPSK data @ 600 bps:

```
1111011100101111111111000
0100010001111110110011111
```

"I can transmit at either carrier frequency at whichever standard symbol rate except 3429. Tx and Rx symbol rates must be equal.

I can reduce power if needed.
I can support up to 1664-point signal constellations.
My clock source is internal."

DPSK data @ 600 bps:

```
1111011100101111111111000
1010010111001110001111011
```

"I can transmit at either carrier frequency at whichever standard symbol rate except 3429. Tx and Rx symbol rates must be equal.

I can reduce power if needed.
I can support up to 1664-point signal constellations.
My clock source is external."

modems send a wide-spectrum probing signal in both directions to do measurements of the telephone line

DPSK data @ 600 bps:

```
0111101111001000011000000000110001
1000010111000010111000010111000001
0000101010100100000000011001010010
0010000111
```

"Please don't reduce your power by more than 6 dB.

I'm not equipped to accurately measure the frequency offset of the tones you sent.

Using different symbol rates, we could achieve the following:

symrate	ur pre-emph α	bps
2400	6 dB	14400
2743	8 dB	16800
2800	8 dB	16800
3000	8 dB	16800
3200	8 dB	19200
3429	10 dB	21600

I can use the higher frequency carrier at any symbol rate."

DPSK data @ 600 bps:

```
1111011100101000000000000111001000
0101100000000001100110110001011111
```

"Please don't reduce power any further.

Your tones were offset by 0 Hz.

Let's use a symbol rate of 3200. We can achieve a maximum of 4800 bps. For your pre-emphasis filter, select the parameters β = 1.0 dB and γ = 2.0 dB.

Please use carrier at 1920 Hz for transmission, I'll use 1829."

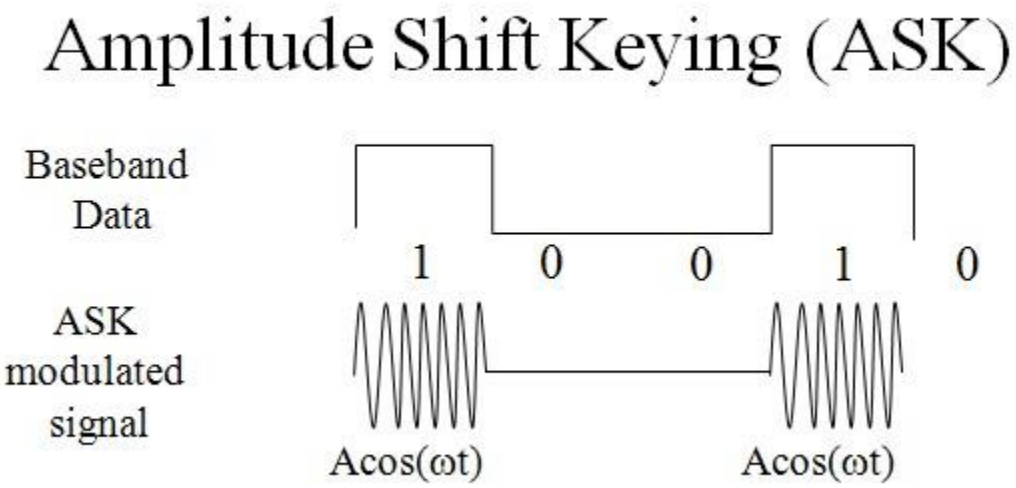
Modems go to scrambled data and learn how the other modem sounds over the channel. The final bitrate and signal constellation are also decided on.

A final training phase called Phase 4 will follow, after which the modem speaker goes mute and data can be put through the connection.

ASK

- Binary representation of data with amplitudes

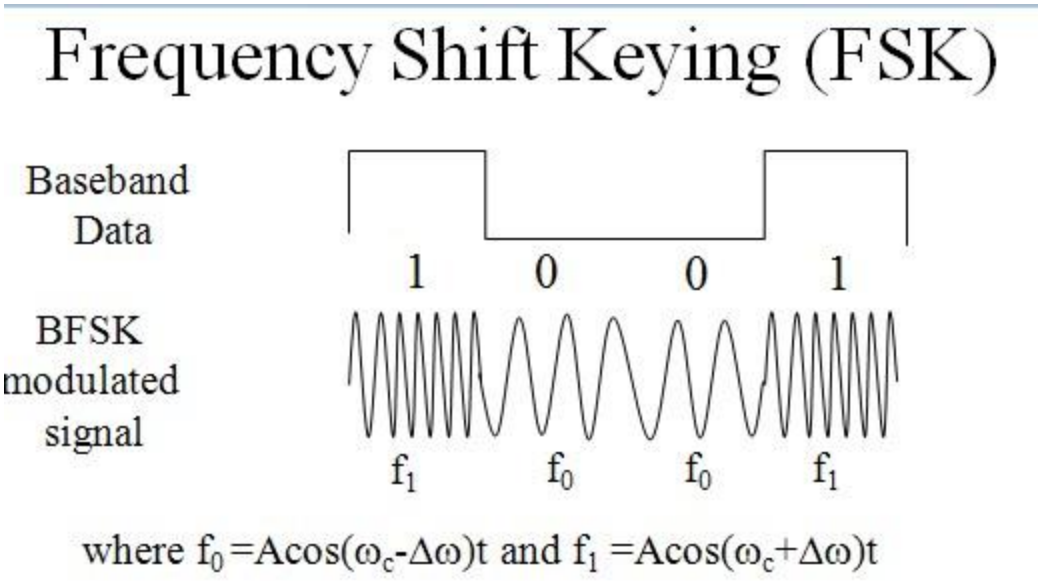
- Advantages:
  - Simple, cheap
- Disadvantages:
  - Susceptible to noise
  - Less efficient
- Application:
  - Fiber optic cables



FSK

- Data bits are represented by frequency change

- Advantages:
  - Less susceptible to noise than ASK
- Disadvantages:
  - Higher cost than ASK
  - Need more spectrum compared to ASK
- Application:
  - Over voice lines



- Comparision of ASK and FSK in terms of error

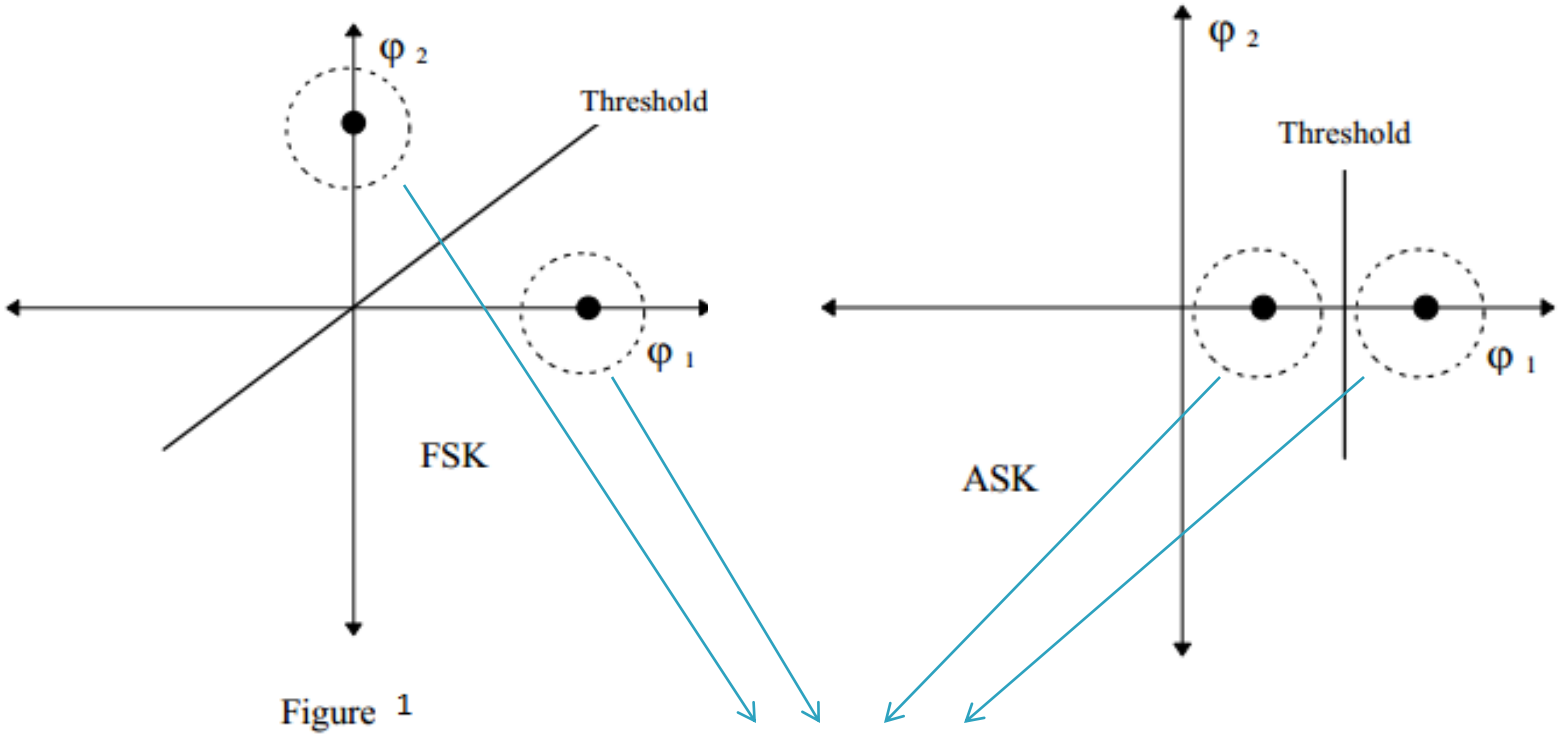
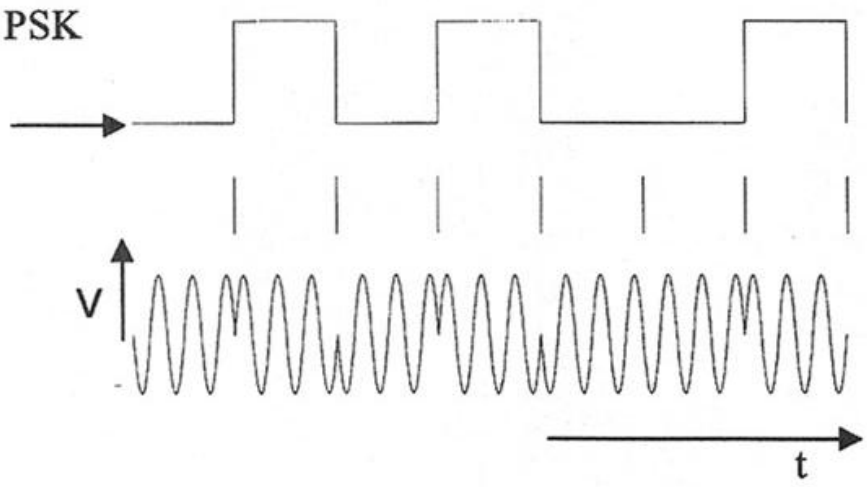


Figure 1

Noise represented with dash

PSK

- Phase of carrier signal is changed to represent data

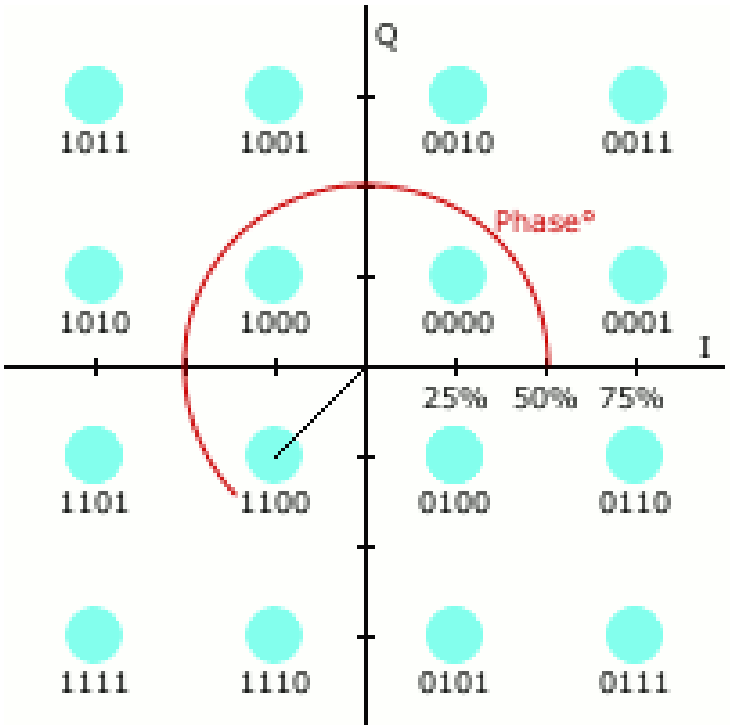


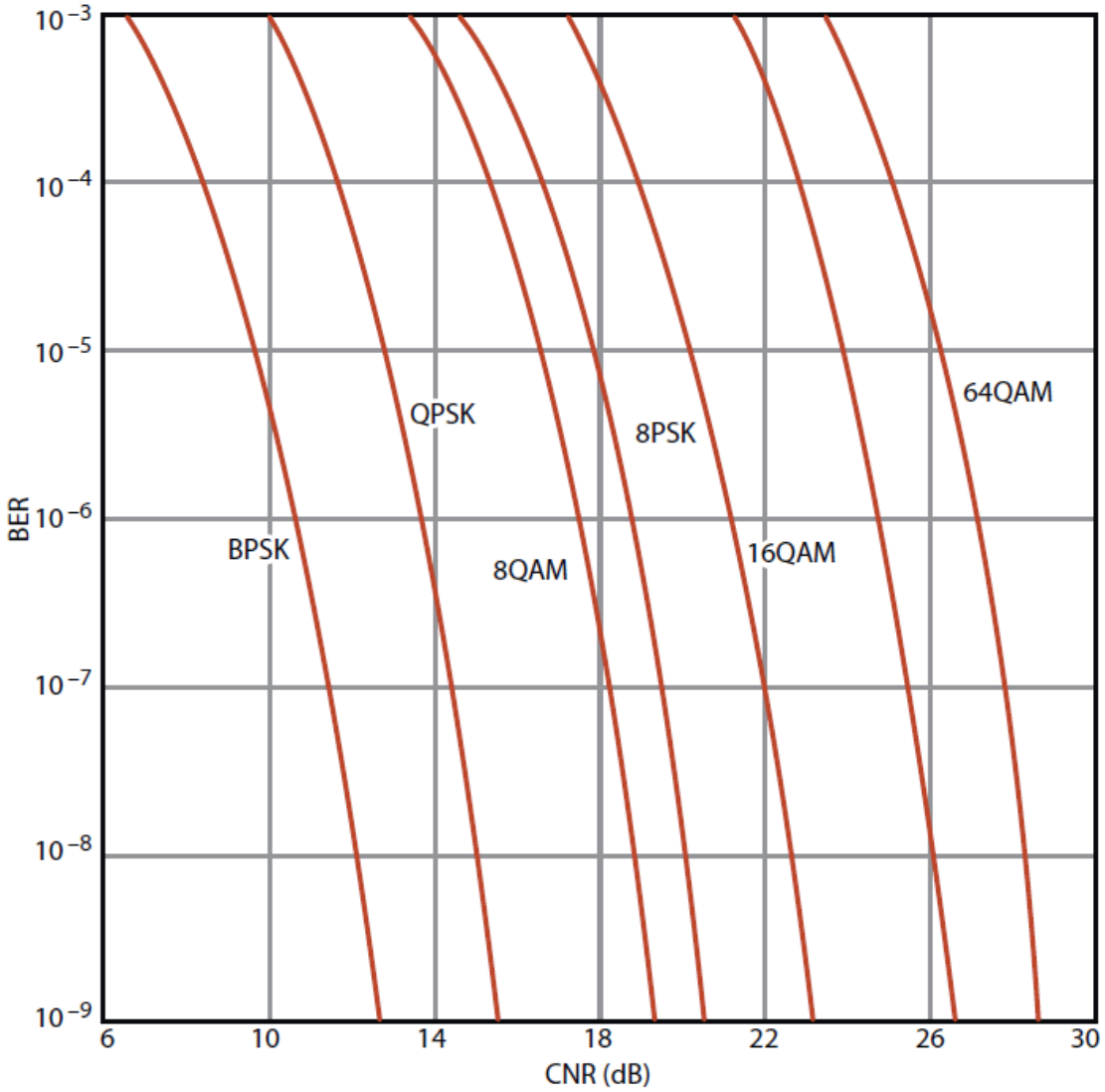
- Advantages:
  - Less susceptible to noise
  - Requires less bandwidth than FSK
- Disadvantages:
  - Higher cost than ASK
  - More complex to detect signal
- Application:
  - Fiber-optic and coaxial communications

QAM

- Combination of amplitude and phase modulation

- Advantages:
  - Higher data rate
- Disadvantages:
  - High complexity
- Application:
  - Digital cable TV
  - Cable modem





7. This is a comparison of several popular modulation methods and their spectral efficiency expressed in terms of BER versus CNR. Note that for a given BER, a greater CNR is needed for the higher QAM levels.

References

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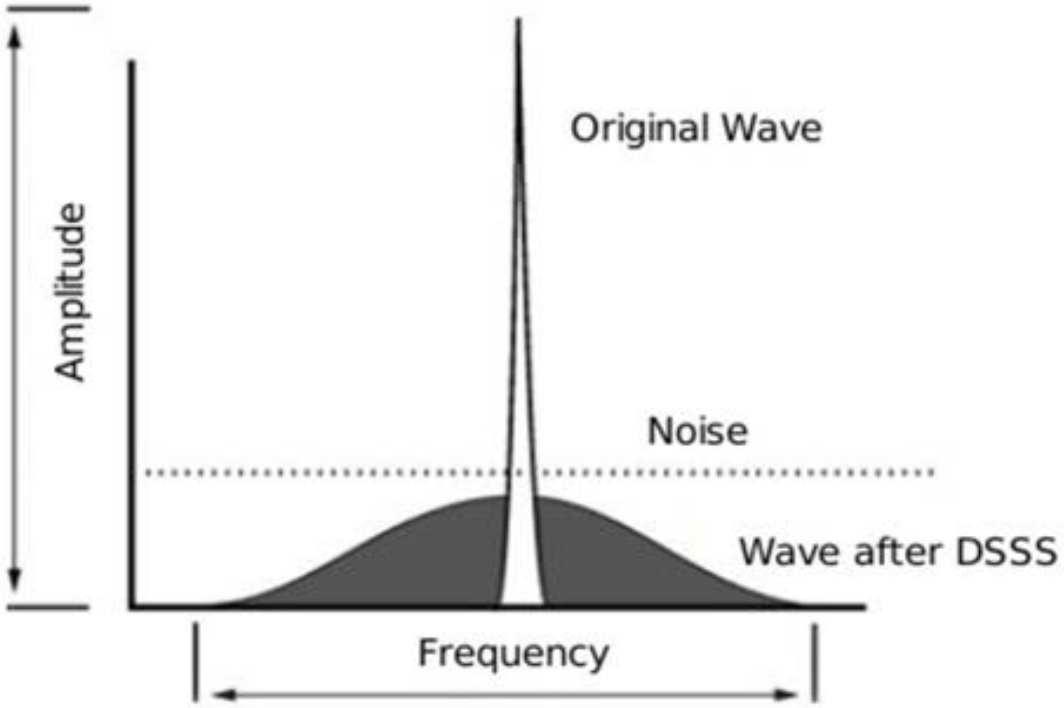
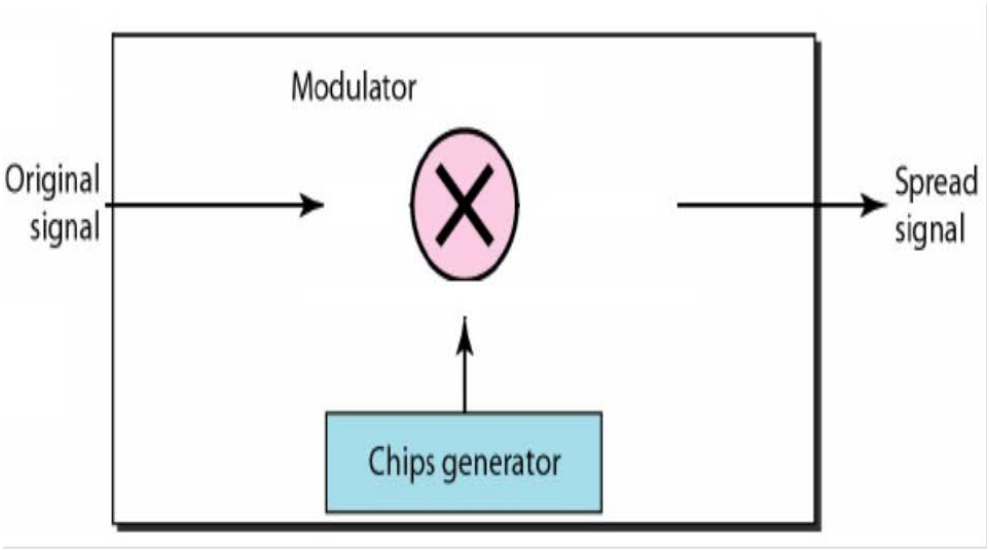
DSSS (Direct-Sequence Spread Spectrum)



- Meaning of Spread Spectrum
  - signal is spread across the entire frequency spectrum that is being used.
  - Each bit in the original signal is represented by multiple bits after signal is transmitted into channel.

How DSSS modulation works?

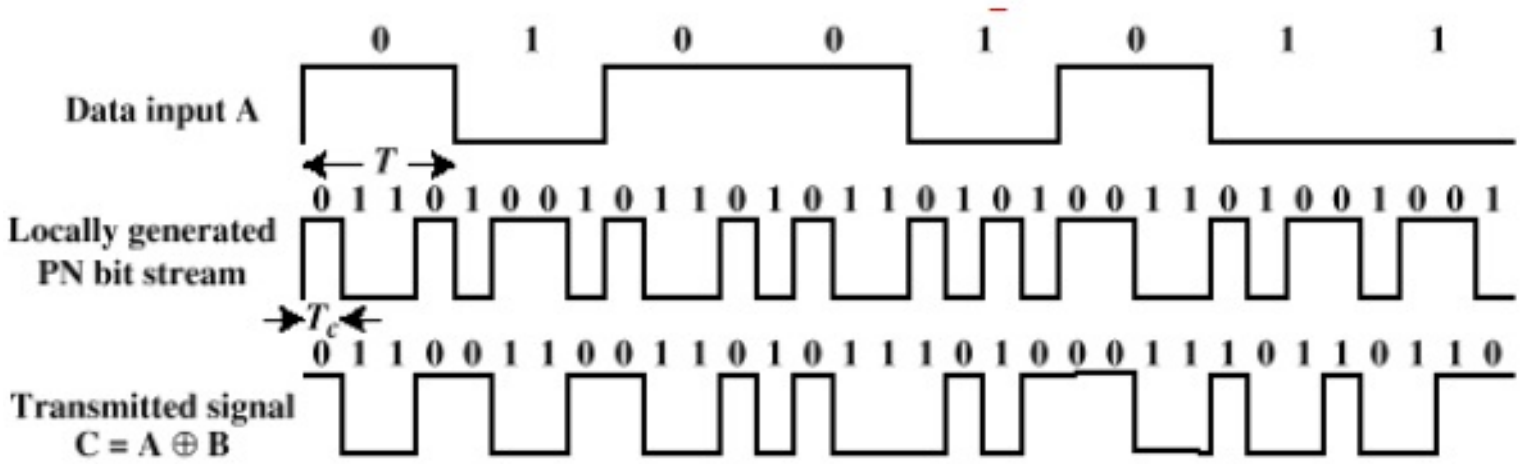


Chipping sequence

Long chipping sequences result in higher bandwidth

– XOR

the signal and chipping Sequence

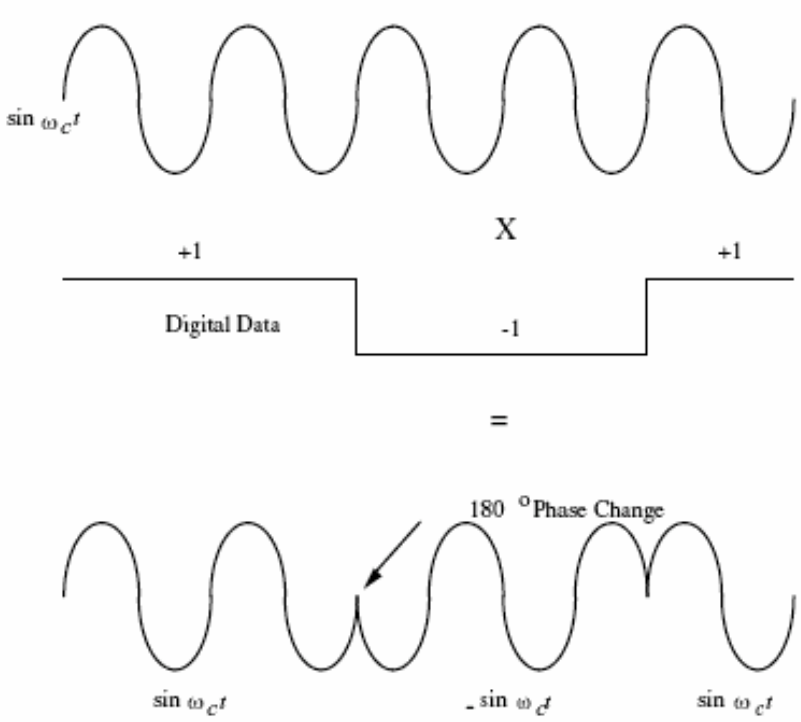


BPSK (Binary Phase-Shift Keying)

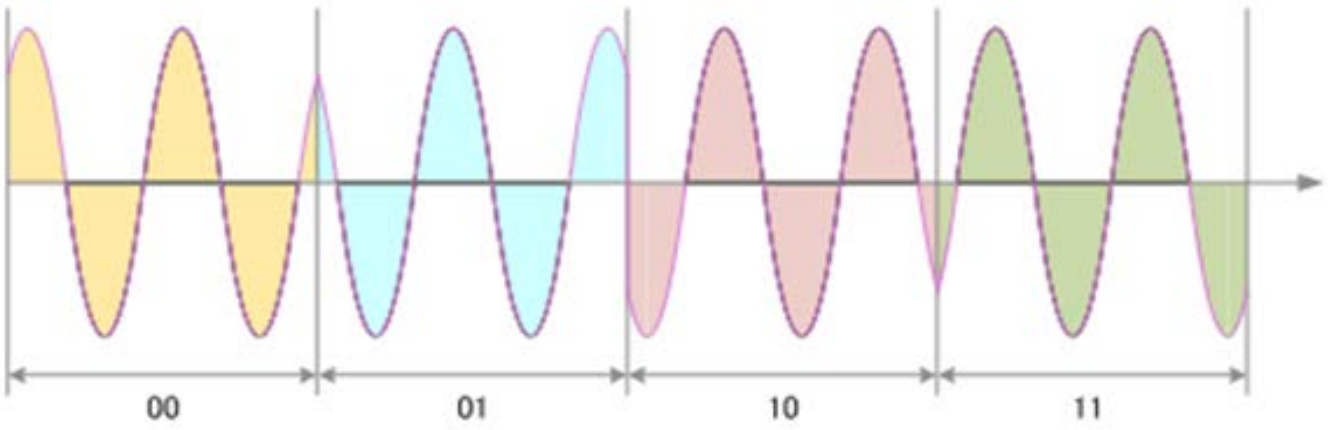
- Two binary values represented by two different frequencies (f1 and f2)

$$s(t) = \begin{cases} A\cos(2\pi f_1 t), & binary\ 1 \\ A\cos(2\pi f_2 t), & binary\ 0 \end{cases}$$

- These frequences are separated by 180°



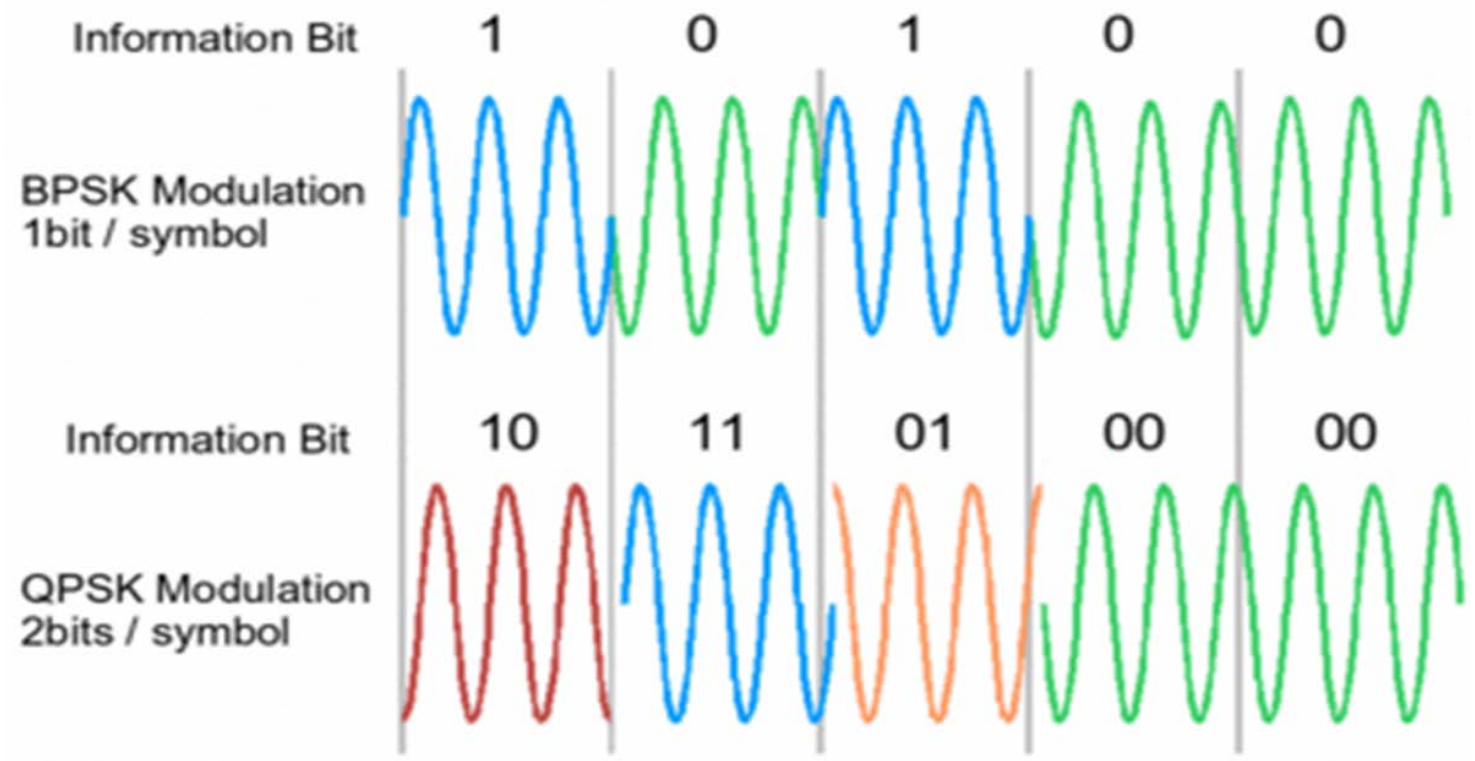
QPSK (Quadrature Phase Shift Keying)



$$s(t) = \begin{cases} A\cos(2\pi f_c t + \frac{\pi}{4}) & \leftrightarrow \quad 11 \\ A\cos(2\pi f_c t + \frac{3\pi}{4}) & \leftrightarrow \quad 01 \\ A\cos(2\pi f_c t + \frac{3\pi}{4}) & \leftrightarrow \quad 00 \\ A\cos(2\pi f_c t - \frac{\pi}{4}) & \leftrightarrow \quad 10 \end{cases}$$

The main idea of QPSK is that there is only one frequency but combinations of each 2 bits is differing in phase by 90 degrees

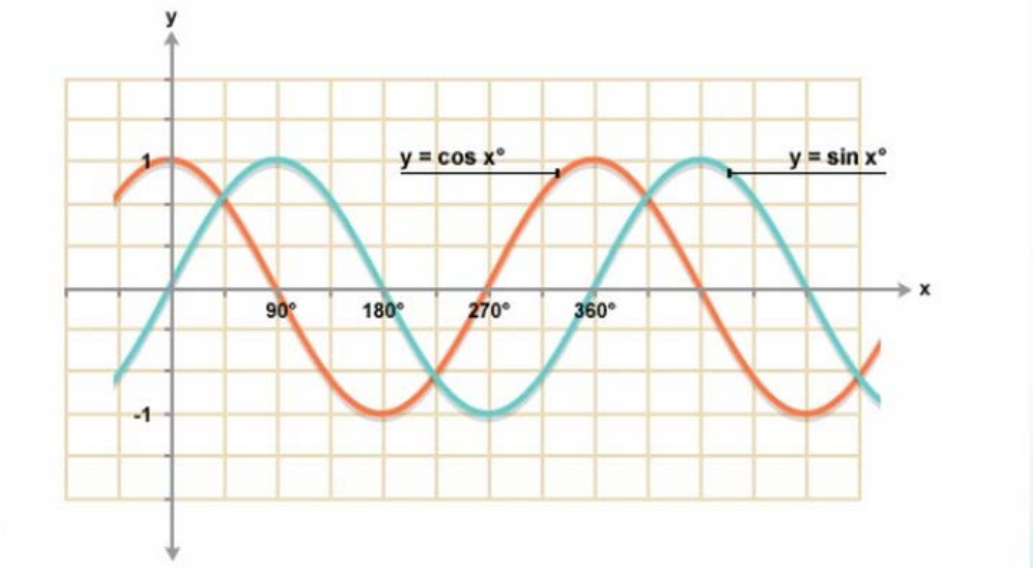
BPSK and QPSK

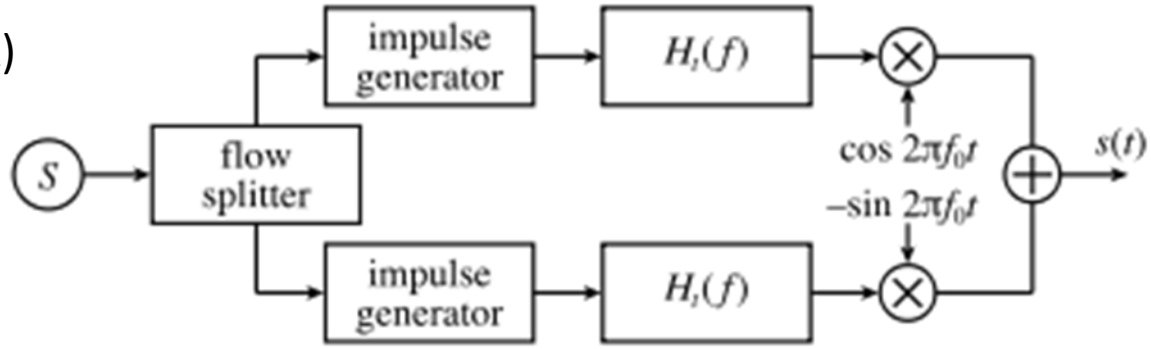


- BPSK, 1 bit per symbol is encoded on the other hand QPSK has the capability to encode 2 bits per symbol. This feature doubles the data rates while staying within the same bandwidth.

QAM

- For higher data rate QAM is developed and replace the BPSK and QPSK schemes.
- Two carriers,which are using the same frequency but differing in phase by 90 degrees
- The modulated waves(two carriers) are summed, and the final waveform is a combination of both phase-shift keying (PSK) or phase modulation (PM) and amplitude-shift keying (ASK) or amplitude modulation (AM) .



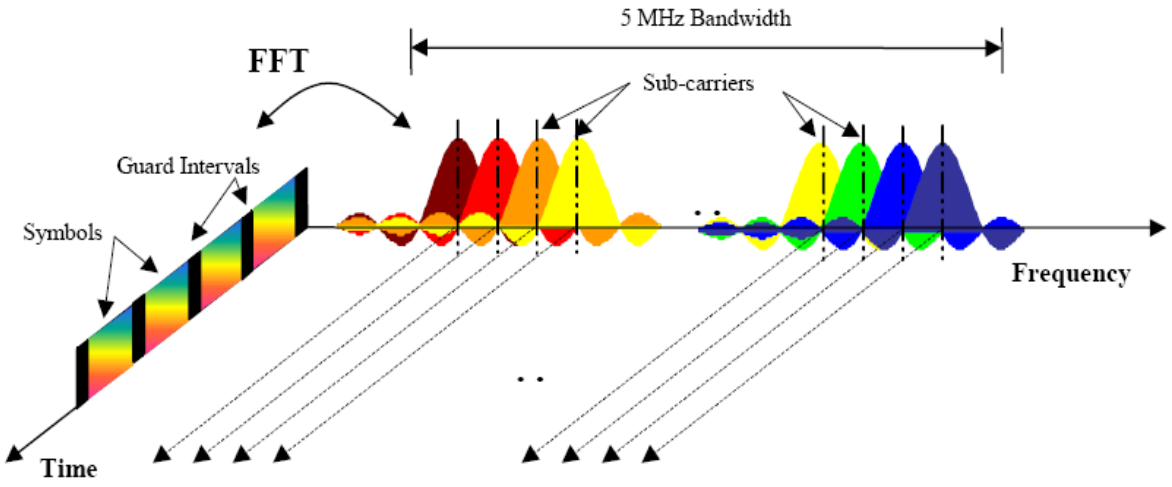


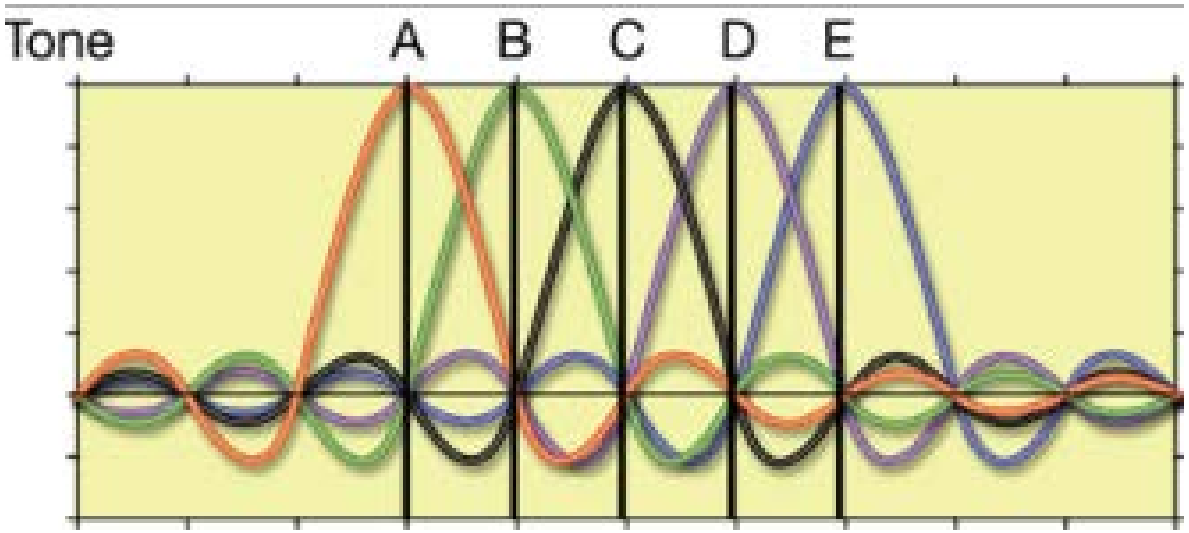
BPSK QPSK and QAM

MODULATION	BITS PER SYMBOL	SYMBOL RATE
BPSK	1	1 x bit rate
QPSK	2	1/2 bit rate
8PSK	3	1/3 bit rate
16QAM	4	1/4 bit rate
32QAM	5	1/5 bit rate
64QAM	6	1/6 bit rate

- The advantage of using QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol.
- By selecting a higher order format of QAM, the data rate of a link can be increased.

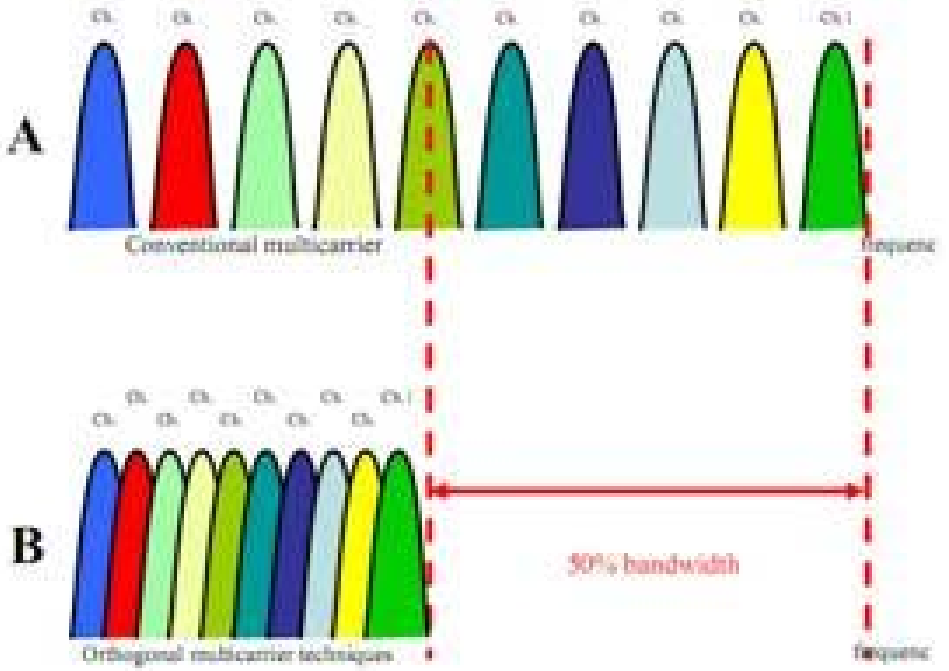
OFDM(Orthogonal frequency-division multiplexing)



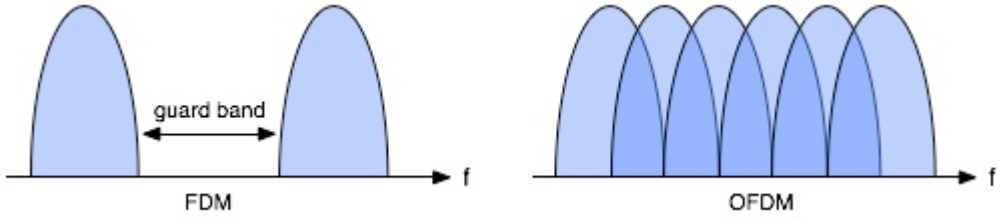


- OFDM is combination of modulation and multiplexing
- Ortogonality means one signal will not overlap with the other.(HOW?)

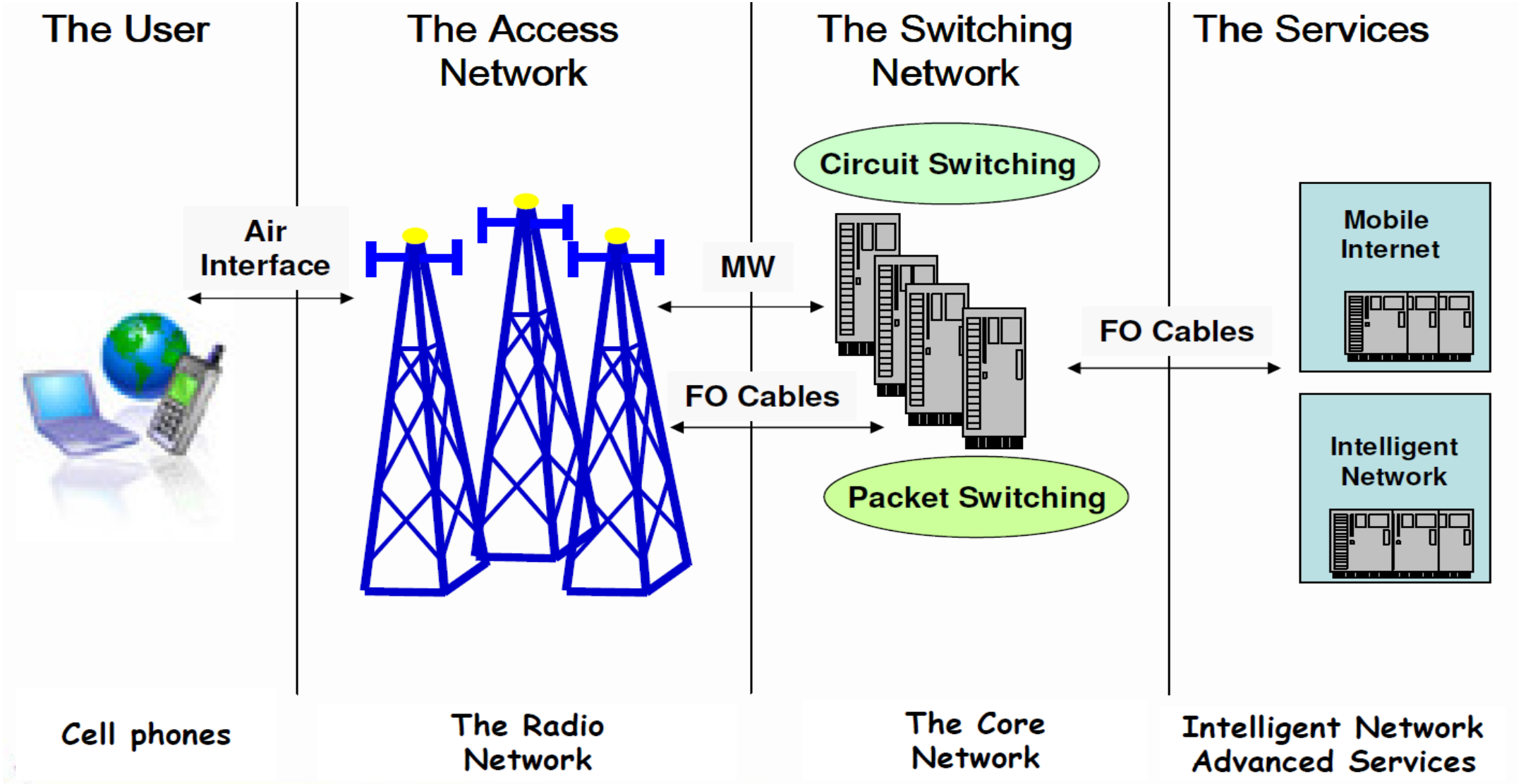
OFDM vs FDM



- Bandwidth Efficiency
- Multipath response



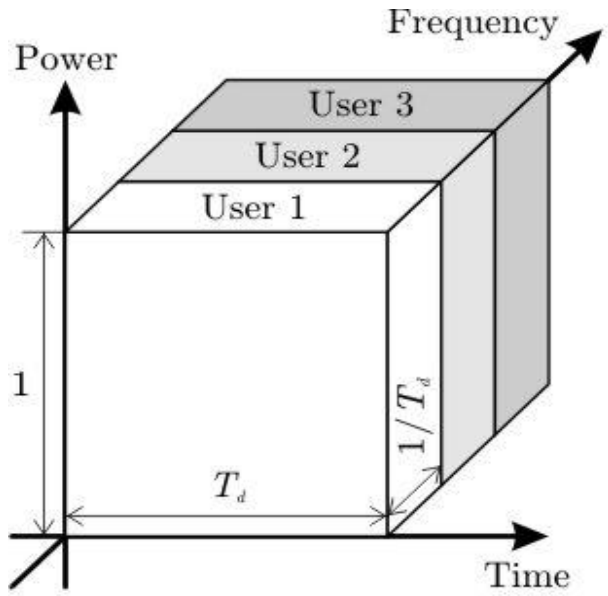
CELLULAR NETWORK STRUCTURE



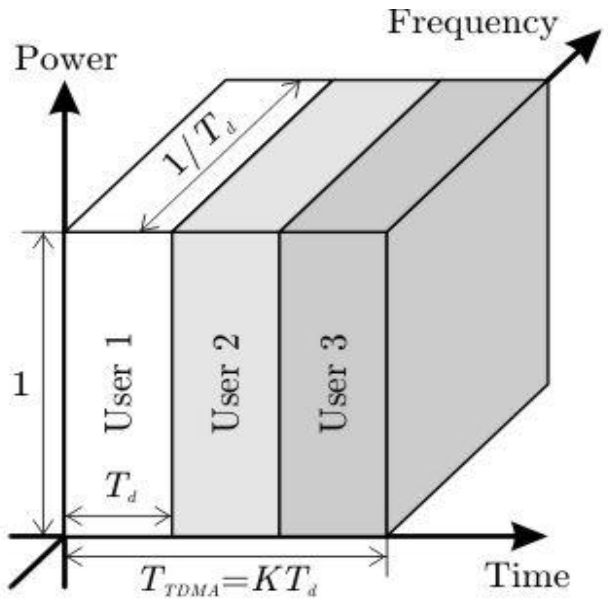
Let's go deeper!

Major air-interface access methods in cellular networks:

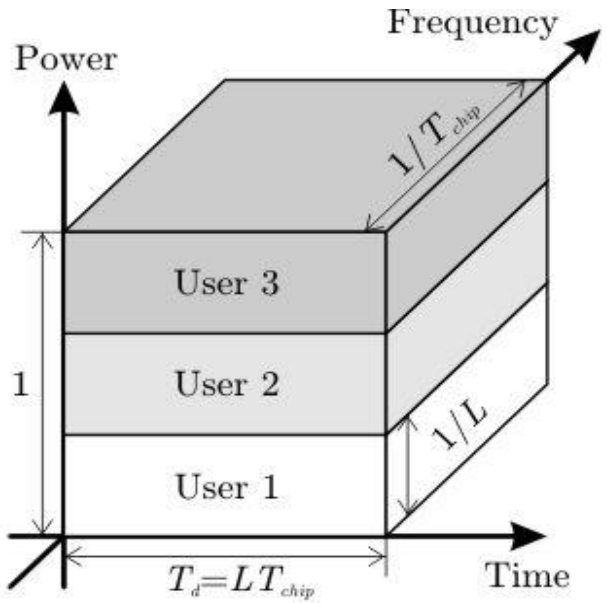
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access
- Code Division Multiple Access



FDMA

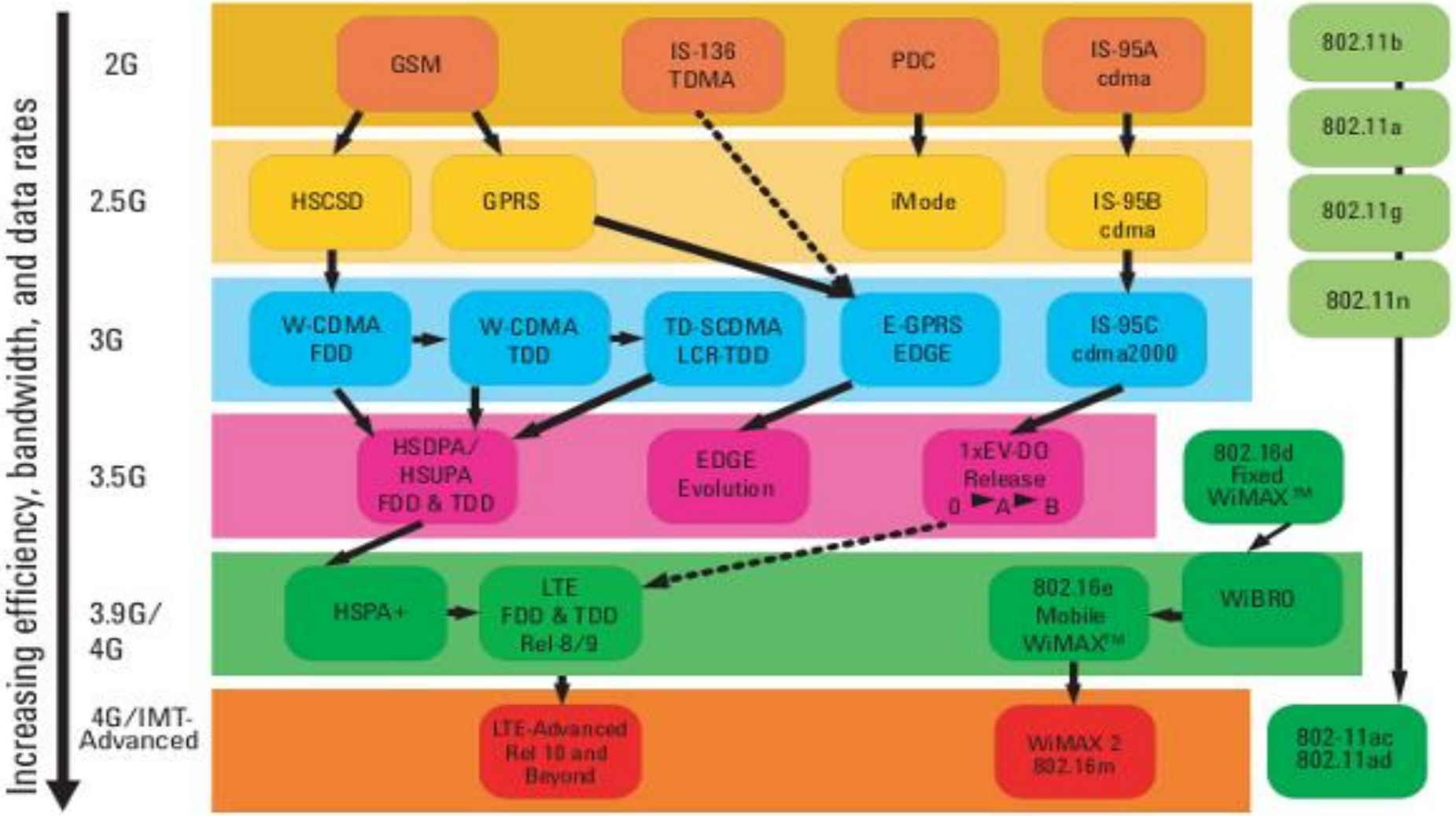


TDMA



CDMA

CELLULAR NETWORK EVOLUTION DIAGRAM



GENERATIONS	STANDARDS	TECHNOLOGIES
1G	AMPS	AMPS, TACS,
	OTHER	NMT, Hicap
2G	GSM/3GPP	GSM, CSD
	CDMA / 3GPP2	CDMAOne
2.5G	GSM / 3GPP	HSCSD, GPRS, EDGE/EGPRS
	CDMA / 3GPP2	CDMA2000
3G	3GPP	UMTS(UTRAN), WCDMA-FDD, WCDMA-TDD, UTRA-TDD
	3GPP2	CDMA2000
3G+	GSM / 3GPP	HSDPA, HSUPA, LTE
	CDMA / 3GPP2	EV-DO Rev
4G	GSM / 3GPP	LTE ADVANCED
	CDMA / 3GPP2	LTE ADVANCED
	OTHER	IEEE 802.16m (WiMAX)
5G	GSM/3GPP, 4G + WWWW	IEEE 802.16ac

First Generation Cellular Network

- Only voice calls
- Analog signal is used

☹ Critical Drawbacks

Capacity is limited

Poor handoff reliability

No security and poor voice transmission

The most important aim is to increase the capacity! So, the solution…

Second Generation Cellular Network

Some new Technologies has been developed such as GSM.

Addition to 1G specifications,

- TDMA
- GSM
- CDMA

These were the problem solvers at that time…

- Digital signals were used. So power consumption decreased.
- New services enabled such as sms, e mail
- Privacy protection increased

But later on, some additional necessities has come out.

2.5 Generation Cellular Network

GPRS

- Better use of radio and network resources.
- Completely transparent IP support

EDGE

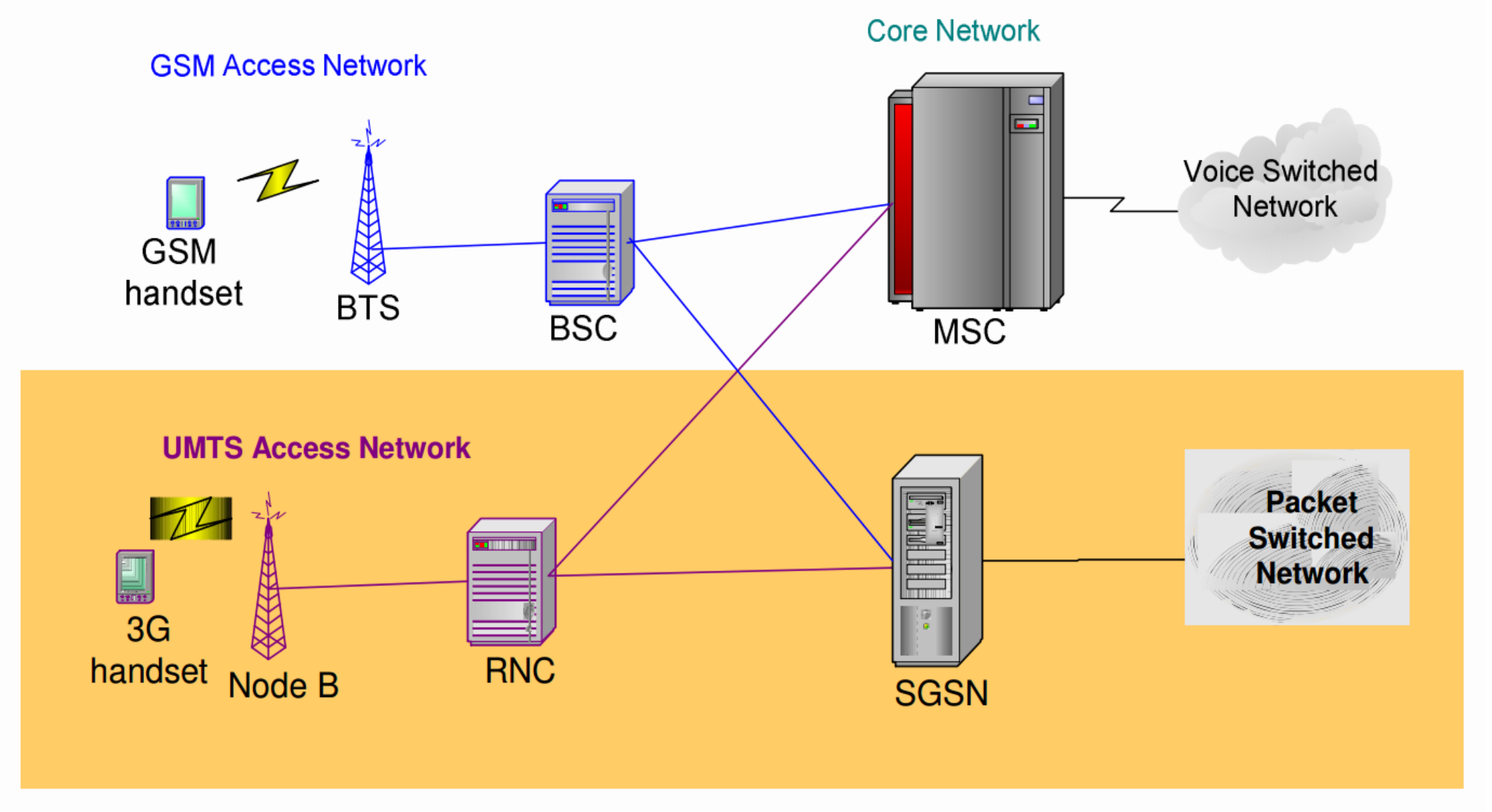
- Has better modulation techniques that improves data-rate

TOWARDS 3G…

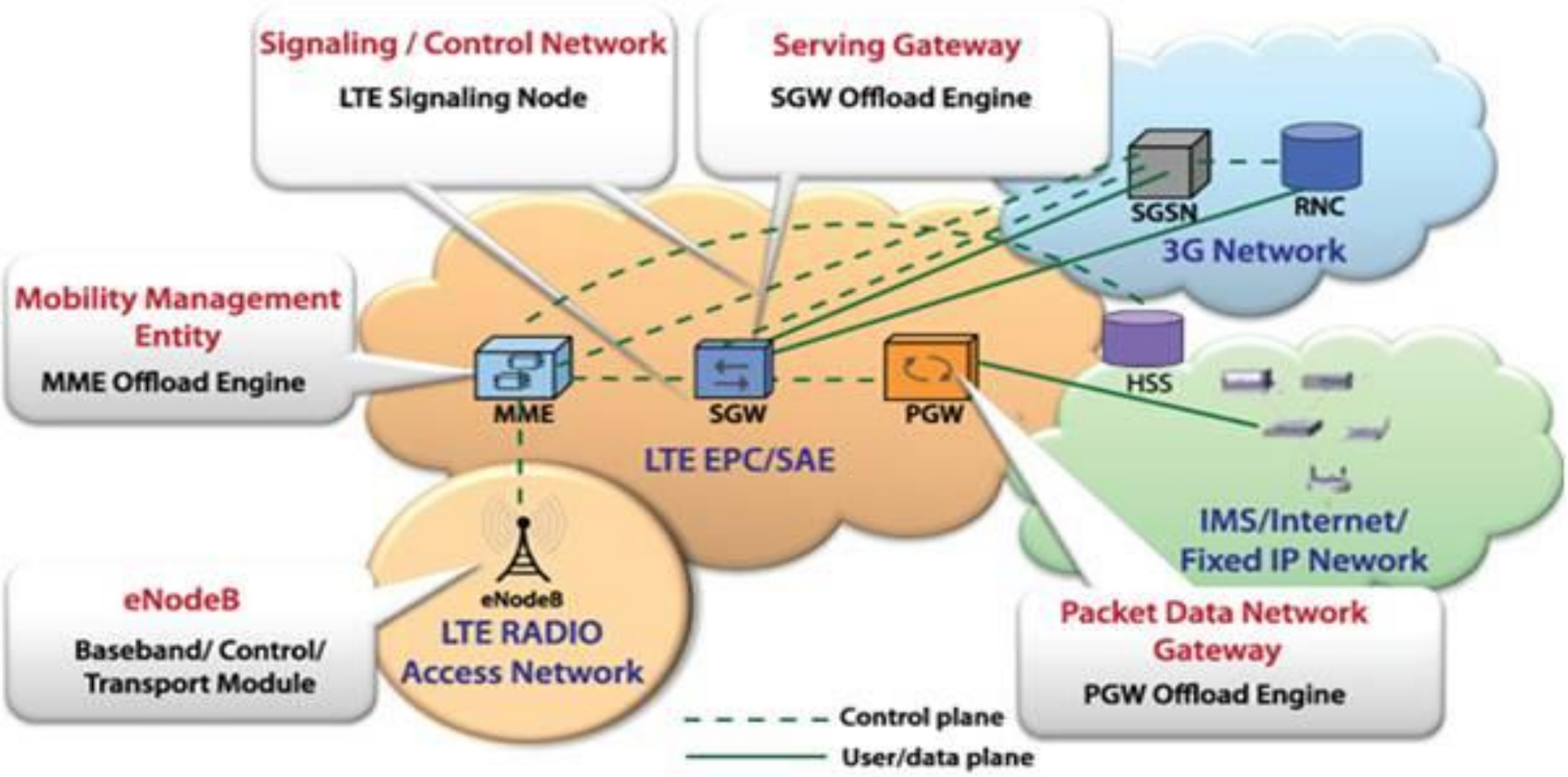
- Support both packet-switched and circuit switched data transmission
- Provides high data rate.
- Now, it can be used worlwide.

So, what has been changed?

2G vs. 3G


Core Network
GSM Access Network
GSM handset
BTS
BSC
MSC
Voice Switched Network
UMTS Access Network
3G handset
Node B
RNC
SGSN
Packet Switched Network

4G


Signaling / Control Network
LTE Signaling Node
Serving Gateway
SGW Offload Engine
SGSN
RNC
3G Network
Mobility Management Entity
MME Offload Engine
MME
SGW
PGW
HSS
LTE EPC/SAE
IMS/Internet/
Fixed IP Nework
eNodeB
Baseband/ Control/
Transport Module
eNodeB
LTE RADIO
Access Network
Packet Data Network Gateway
PGW Offload Engine
Control plane
User/data plane

What LTE brings new?

- **Simplified architecture**
- **Support for both FDD and TDDcommunication systems as well as half-duplex FDD with the same radio access technology**
- **Support for inter-operation and co-existence with legacy standards (e.g., GSM/EDGE,UMTS and CDMA2000)**
- **OFDMA for the downlink, SC-FDMA for the uplink to conserve power**
- **E-UTRA – the radio access network used in LTE**

Table 1: COMPARISON OF ALL GENERATIONS OF MOBILE TECHNOLOGIES

Technology ⇨ / Feature ⇩	1G	2G	3G	4G	5G
Start/ Deployment	1970 – 1980	1990 – 2004	2004-2010	Now	Soon (probably 2020)
Data Bandwidth	2kbps	64kbps	2Mbps	1 Gbps	Higher than 1Gbps
Technology	Analog Cellular Technology	Digital Cellular Technology	CDMA 2000 (1xRTT, EVDO) UMTS, EDGE	Wi-Max LTE Wi-Fi	WWWW(coming soon)
Service	Mobile Telephony (Voice)	Digital voice, SMS, Higher capacity packetized data	Integrated high quality audio, video and data	Dynamic Information access, Wearable devices	Dynamic Information access, Wearable devices with AI Capabilities
Multiplexing	FDMA	TDMA, CDMA	CDMA	CDMA	CDMA
Switching	Circuit	Circuit, Packet	Packet	All Packet	All Packet
Core Network	PSTN	PSTN	Packet N/W	Internet	Internet

REFERENCES

Sharma P. Evolution of Mobile Wireless Communication Networks-1G to 5G as well as Future Prospective of Next Generation Communication Network from International Journal of Computer Science and Mobile Computing

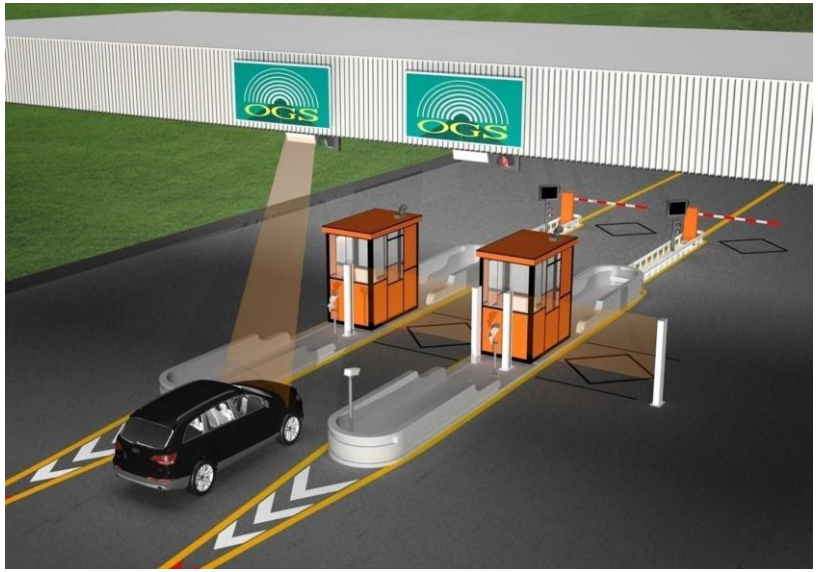
Orzach Y. Introduction to Cellular Networks from NDI Communications

Korhonen J, 2nd Edt. Introduction to 3G Mobile Communications.

General information and Modulation of wireless RFID technologies

Berkay KÖKSAL ~ 150120025

Radio-frequency identification (**RFID**) is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects.



- Access management
- Tracking of goods
- Tracking of persons and animals
- Airport baggage tracking logistics
- Timing sporting events

Advantages of RFID usage

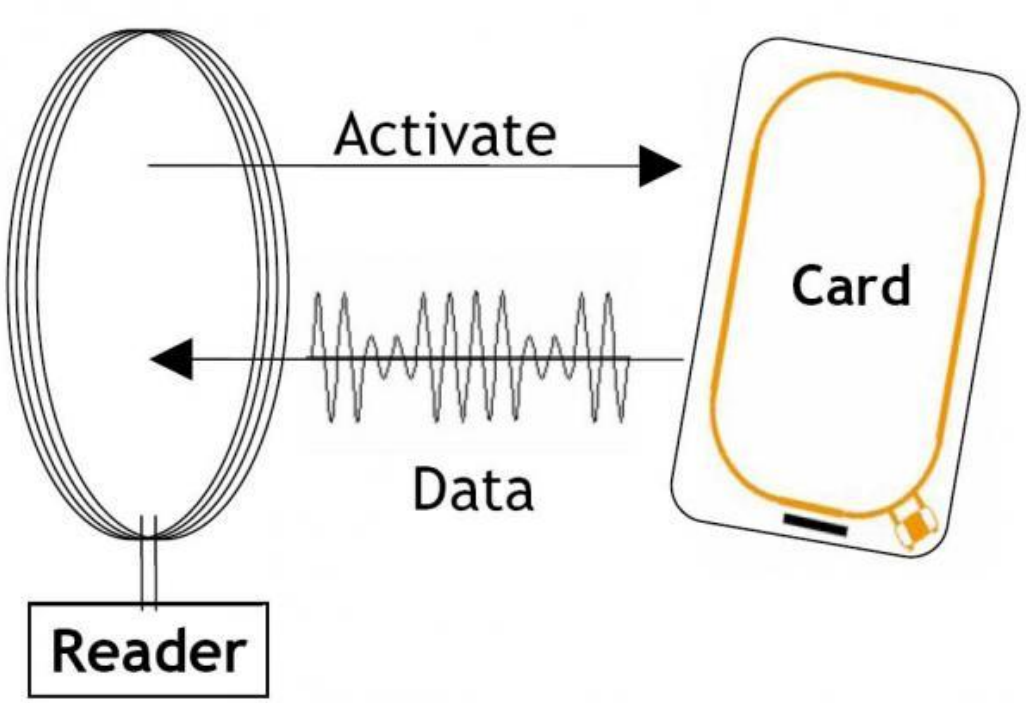
Scanning Range

RFID Capabilities

RFID systems can scan multiple items simultaneous.

RFID tags can contain more information

RFID allow you to add or change data

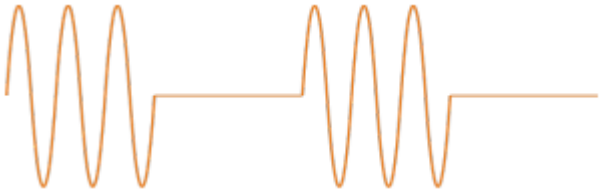


Speed and Convenience

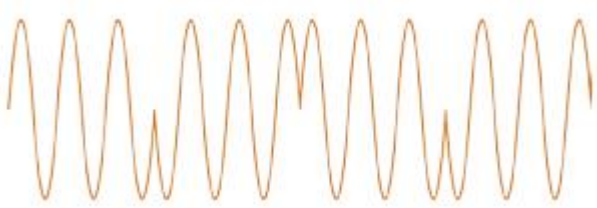
Tag does not necessarily need to be within line of sight of the reader

Cost Reduction

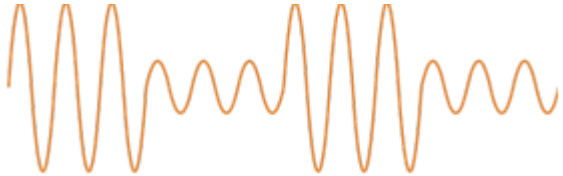
MUST PROVIDE POWER TO PASSIVE RF TAGS!



On-off keying (OOK)



Phase-shift keying(PSK)



Amplitude-shift keying(ASK)

Modulation Techniques that being used in RFID <u>Readers</u>

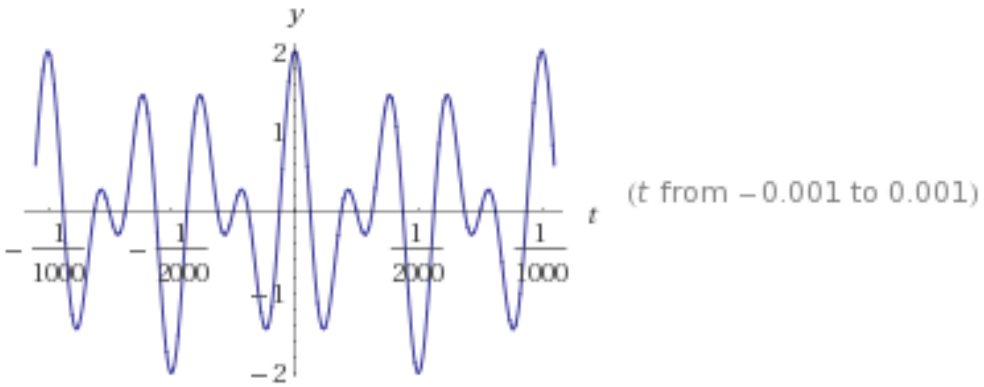
- Double-sideband amplitude shift keying (DSB-ASK)
- Single-sideband ASK (SSB-ASK)
- Phase-reversal ASK (PR-ASK)

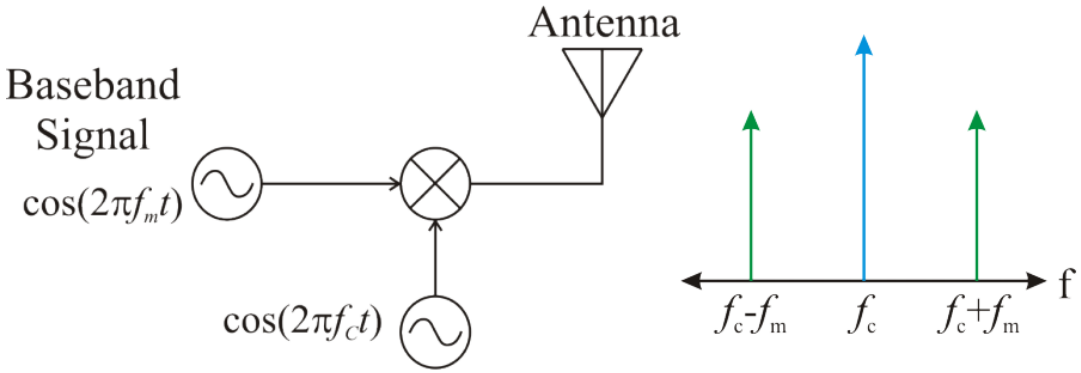
– Double-sideband amplitude shift keying (DSB-ASK)
– Single-sideband ASK (SSB-ASK)
– Phase-reversal ASK (PR-ASK)

DSB-ASK

Simple but not that efficient

$$\cos(2\pi \times 3000\, t) + \cos(2\pi \times 5000\, t)$$





– Double-sideband amplitude shift keying (DSB-ASK)

– Single-sideband ASK (SSB-ASK)

– Phase-reversal ASK (PR-ASK)

SSB-ASK

Requires an I/Q modulator

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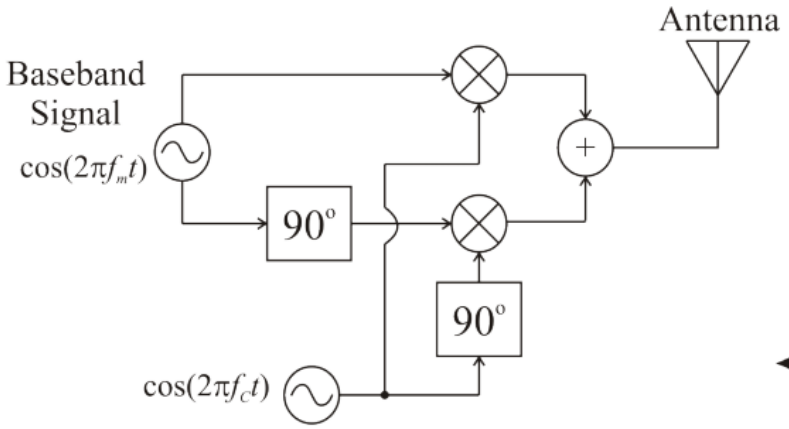
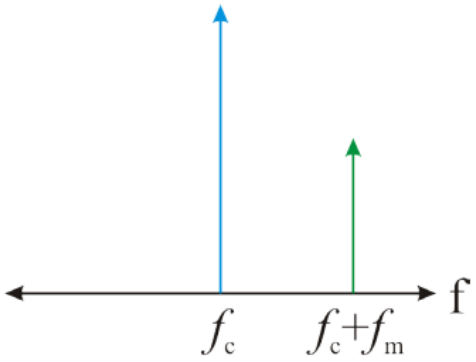
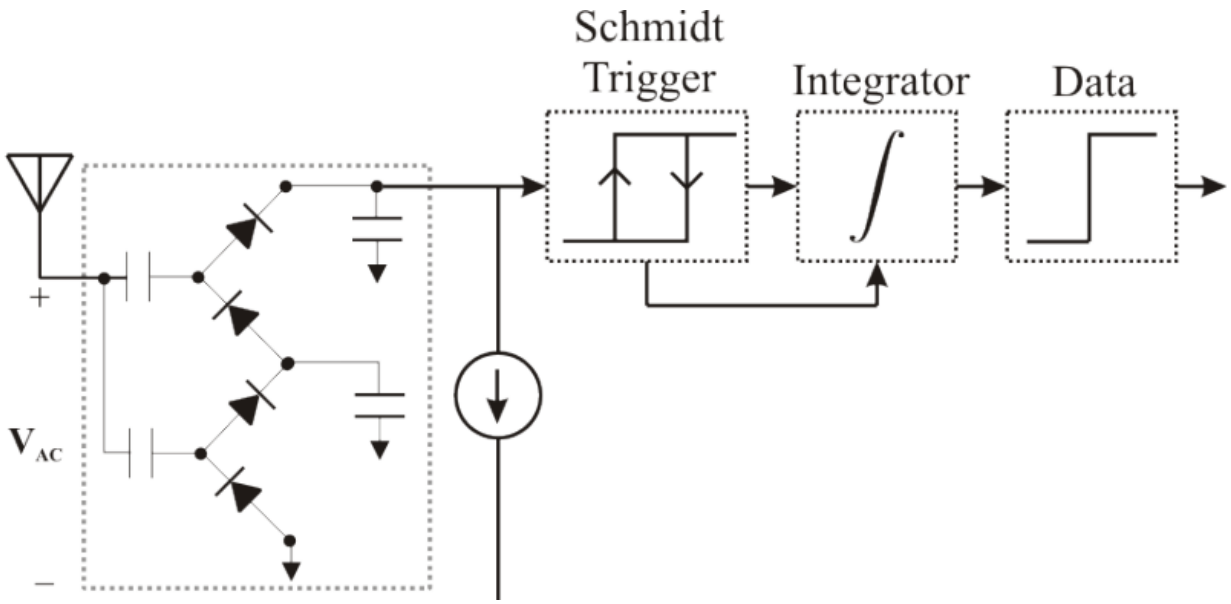
- low bandwidth requirement
- power saving
- less effected by noise

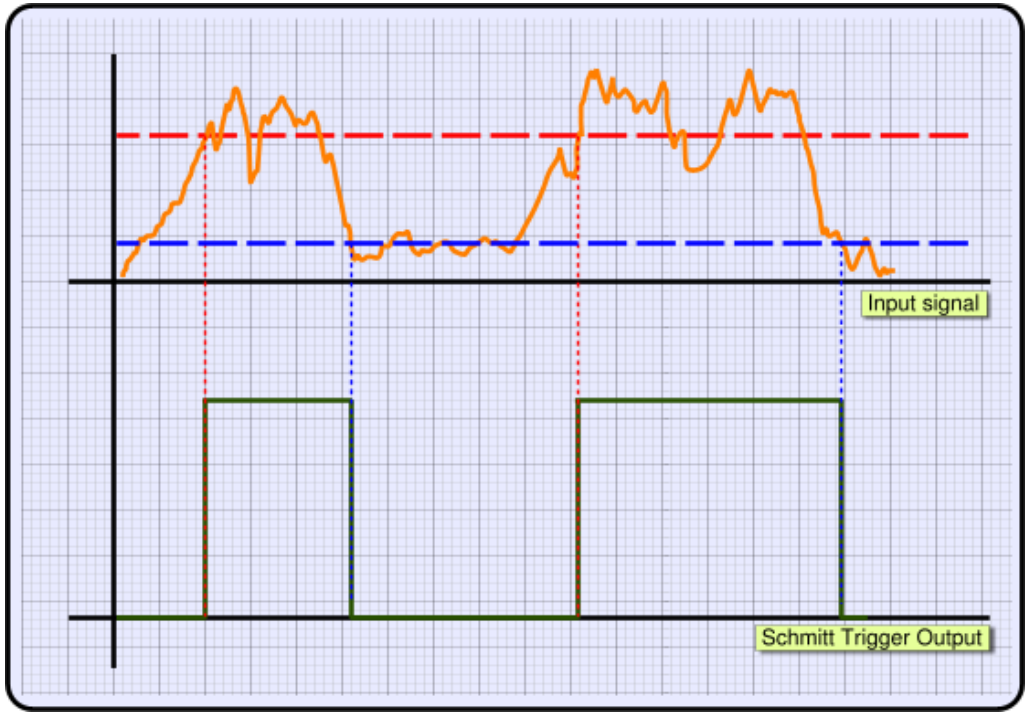
- Complex modulation and demodulation circuitry
- Expansive in comparison to DSB

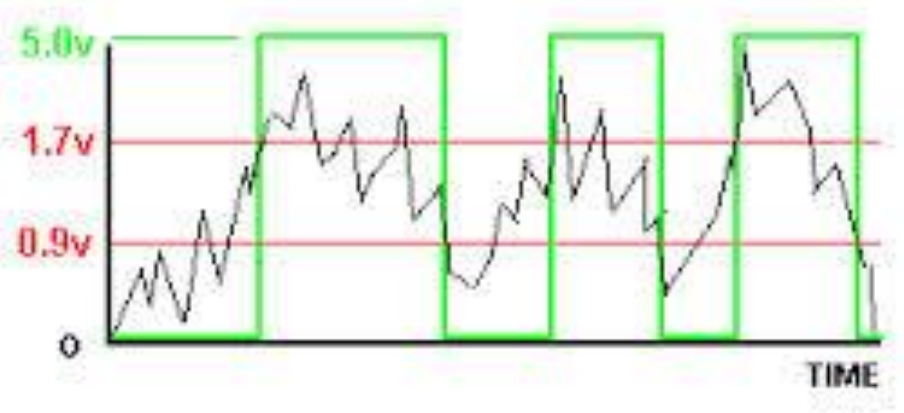




DE-Modulation Techniques that being used in RFID Readers



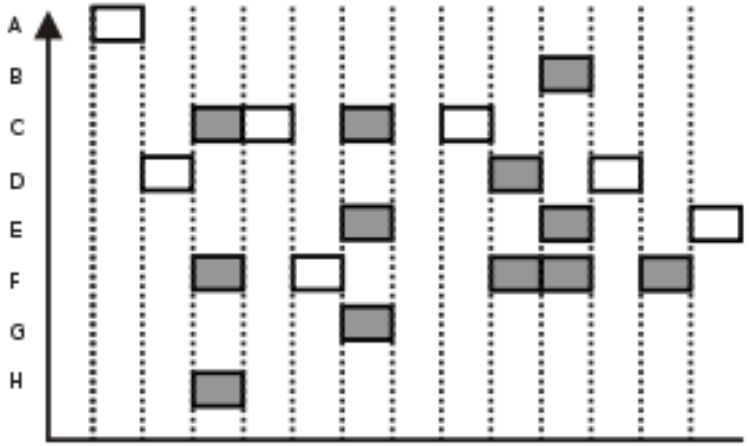




RFID Communication Protocols

EPCglobal Generation 1 Class 0
EPCglobal Generation 1 Class 1

1. Reader talk first
2. Tags can be read,written and killed in the process
3. Uses a Slotted-Aloha algorithm to avoid collisions



Slotted ALOHA protocol (shaded slots indicate collision)