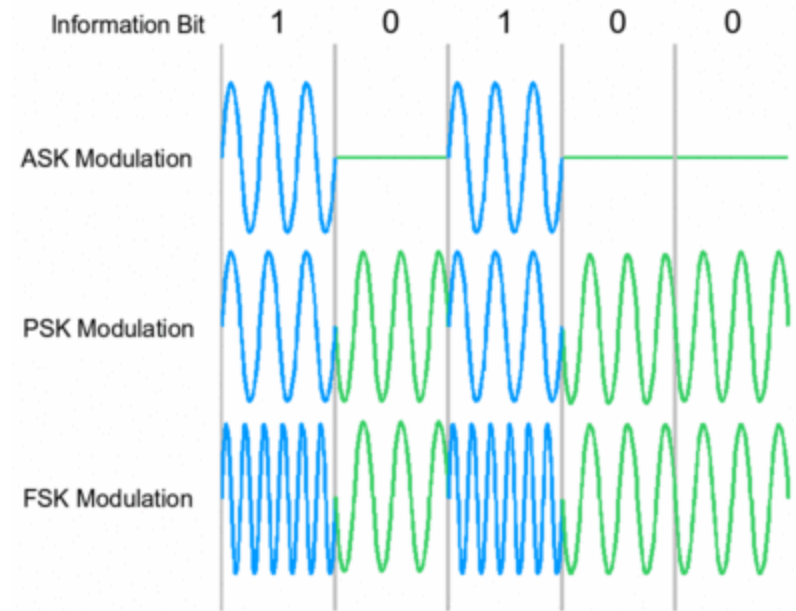


Modulation Techniques In Wired Networks

Cem Yusuf Aydoğdu

Common modulation techniques:

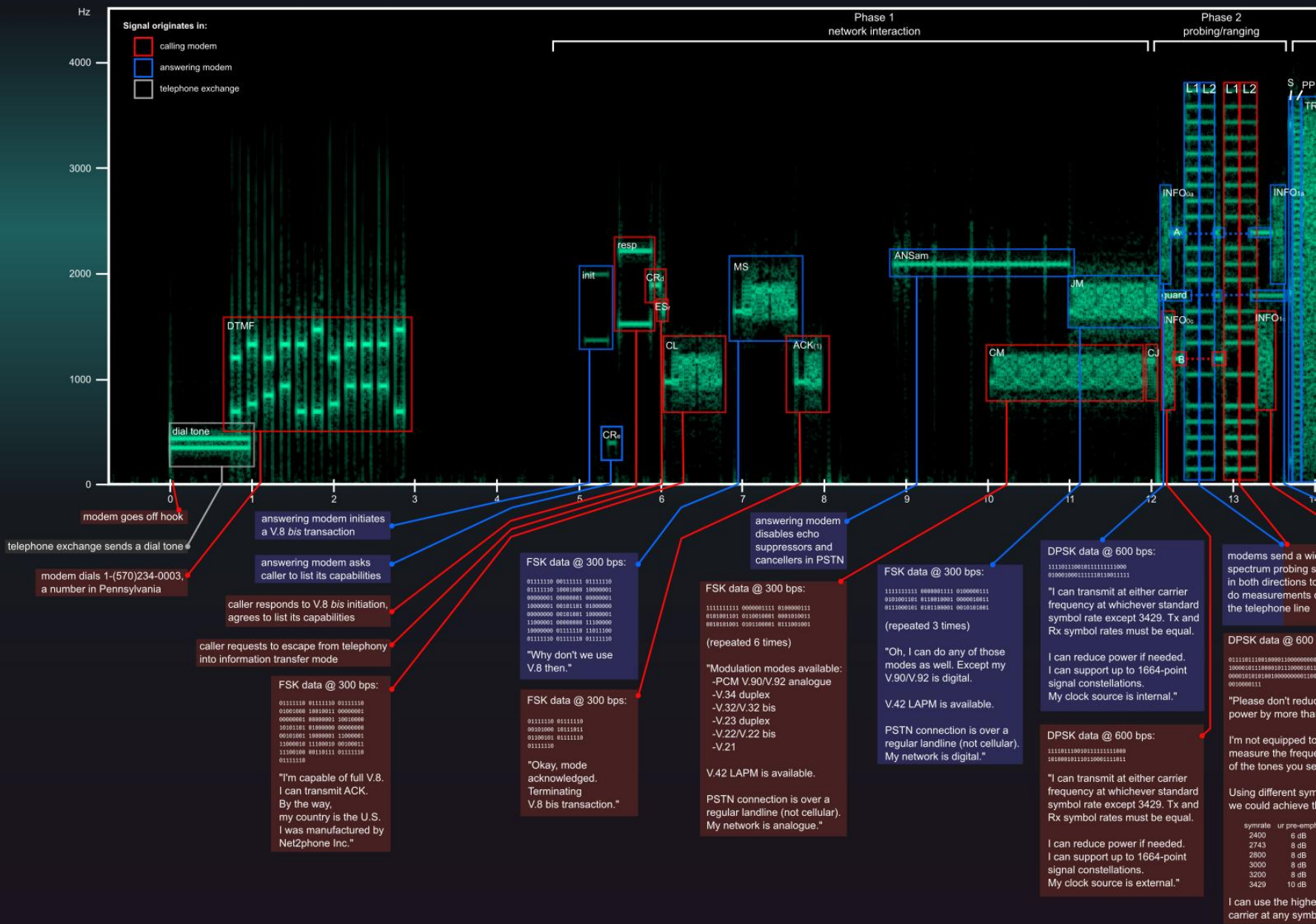
- ASK
- FSK
- PSK
- QAM

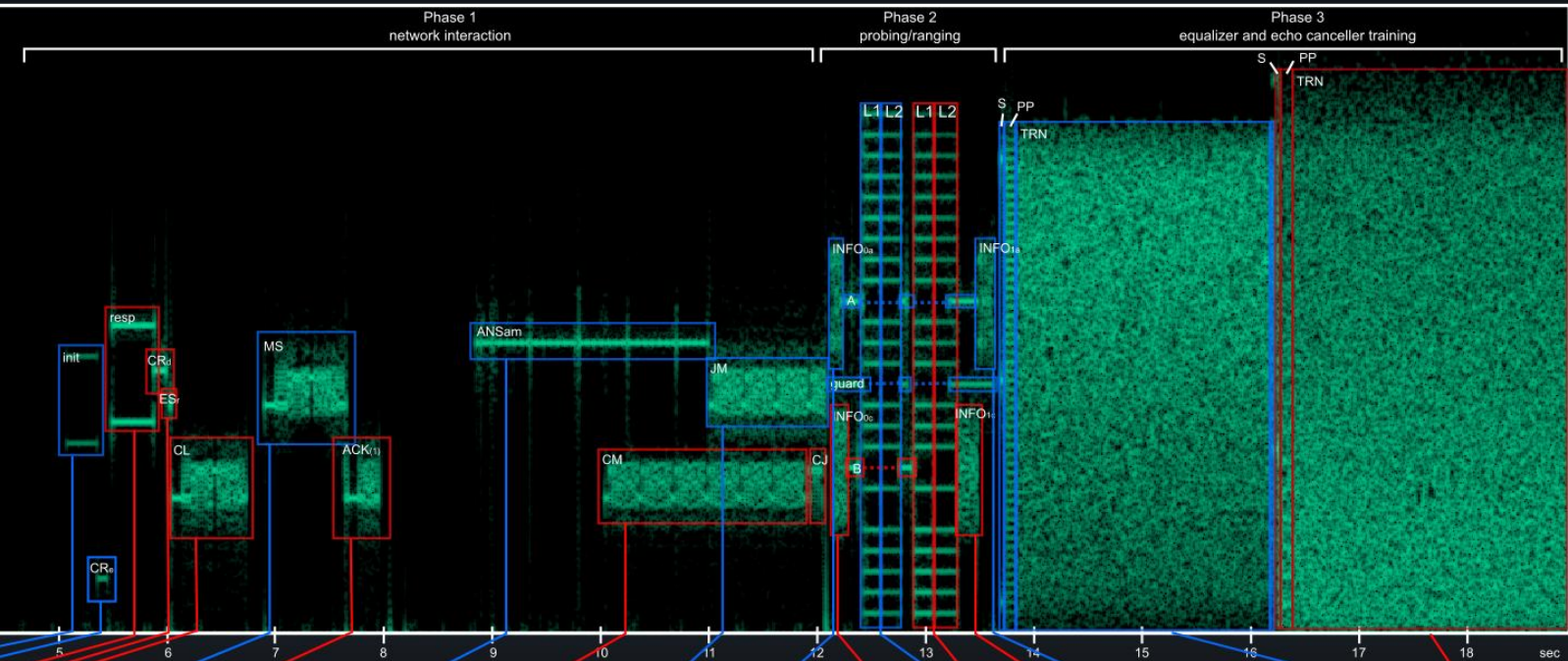


- ▶ Used in voice-band modems, DSL, coaxial cable modem applications

The Sound of the Dialup: an Example Handshake

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FSK data @ 300 bps:

```
111110 00111111 01111110
111110 10001000 10000001
000001 00000001 00000001
000001 00101101 01000000
000000 00101001 10000001
000001 00101001 10000001
000001 00000000 11000000
000000 01111110 11011100
111110 01111110 01111110
```

Why don't we use 8 then."

FSK data @ 300 bps:

```
111110 01111110
101000 10110011
100001 01111110
111110
```

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

FSK data @ 300 bps:

```
11111111 00000011 01000001 11
0101001101 01001000 00001001
0110000101 01010001 00000001
```

(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:

```
11111111 00000011 01000001 11
0101001101 01001000 00001001
0110000101 01010001 00000001
```

(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:

```
111101100010111111111000
010001000111111010011111
```

"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:

```
111101100010111111111000
101000101110100011110111
```

"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:

```
01111011100100011000000000110001
100001011000010110000101100001
000010101001000000000001100101010
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:

symbol rate	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:

```
1111011100100000000000000111001000
01010000000000000000000110111111
```

"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."

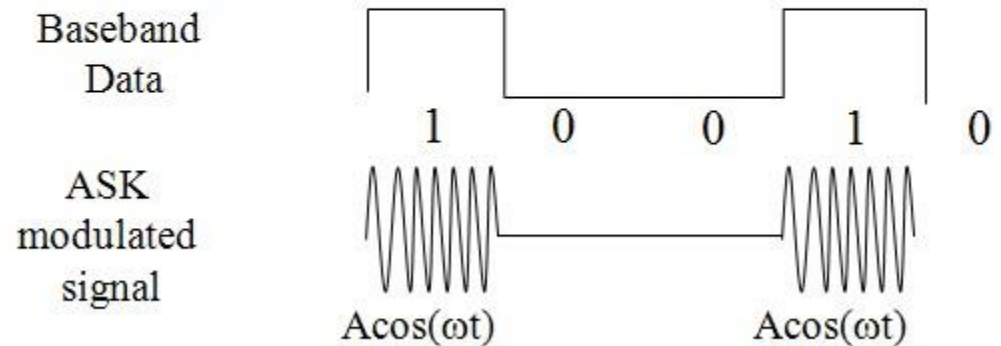
Modems go to scrambled data and learn how the other modem sounds over the channel. The final bitrate and signal constellation are also decided on.

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

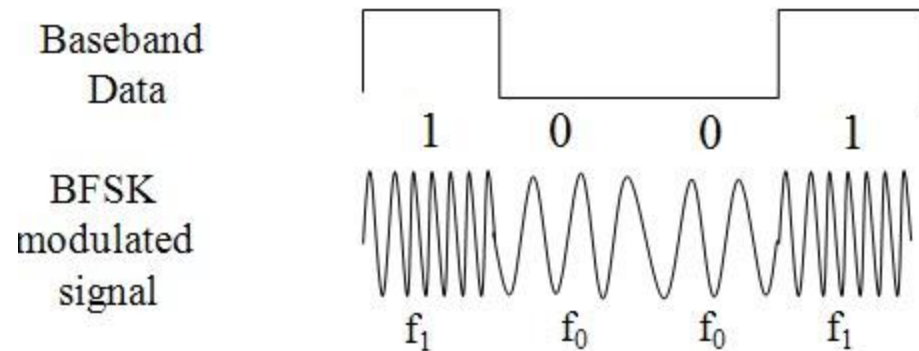
Amplitude Shift Keying (ASK)



FSK

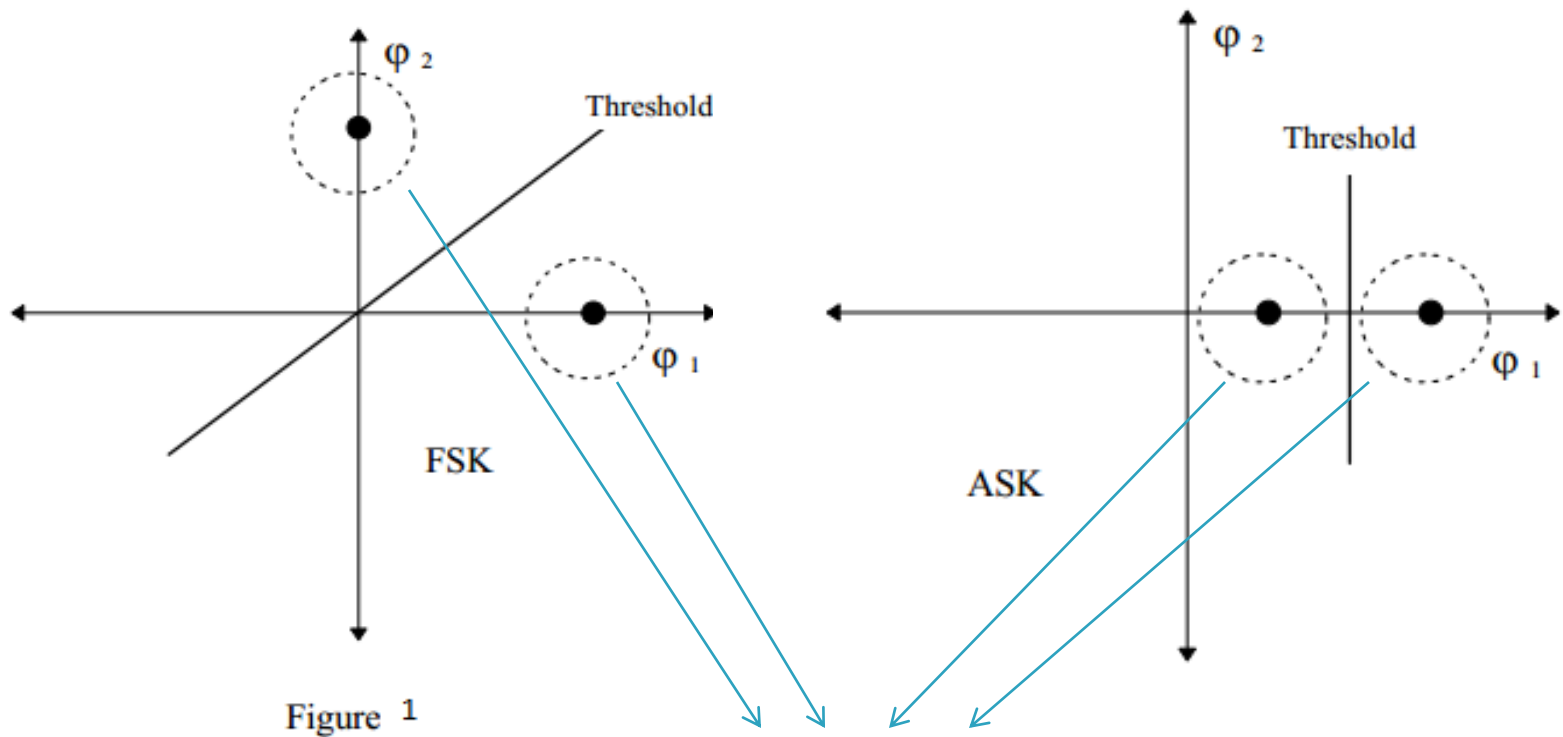
- ▶ Data bits are represented by frequency change
- ▶ Advantages:
 - Less susceptible to noise than ASK
- ▶ Disadvantages:
 - Higher cost than ASK
 - Need more spectrum compared to ASK
- ▶ Application:
 - Over voice lines

Frequency Shift Keying (FSK)



where $f_0 = A \cos(\omega_c - \Delta\omega)t$ and $f_1 = A \cos(\omega_c + \Delta\omega)t$

► Comparision of ASK and FSK in terms of error



Noise represented with dash

PSK

- ▶ Phase of carrier signal is changed to represent data

- ▶ Advantages:

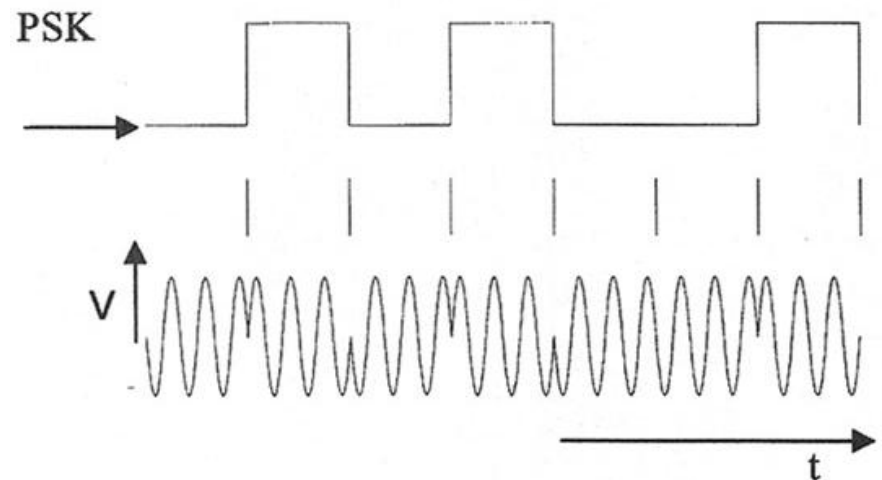
- Less susceptible to noise
- Requires less bandwidth than FSK

- ▶ Disadvantages:

- Higher cost than ASK
- More complex to detect signal

- ▶ Application:

- Fiber-optic and coaxial communications



QAM

- ▶ Combination of amplitude and phase modulation

- ▶ Advantages:

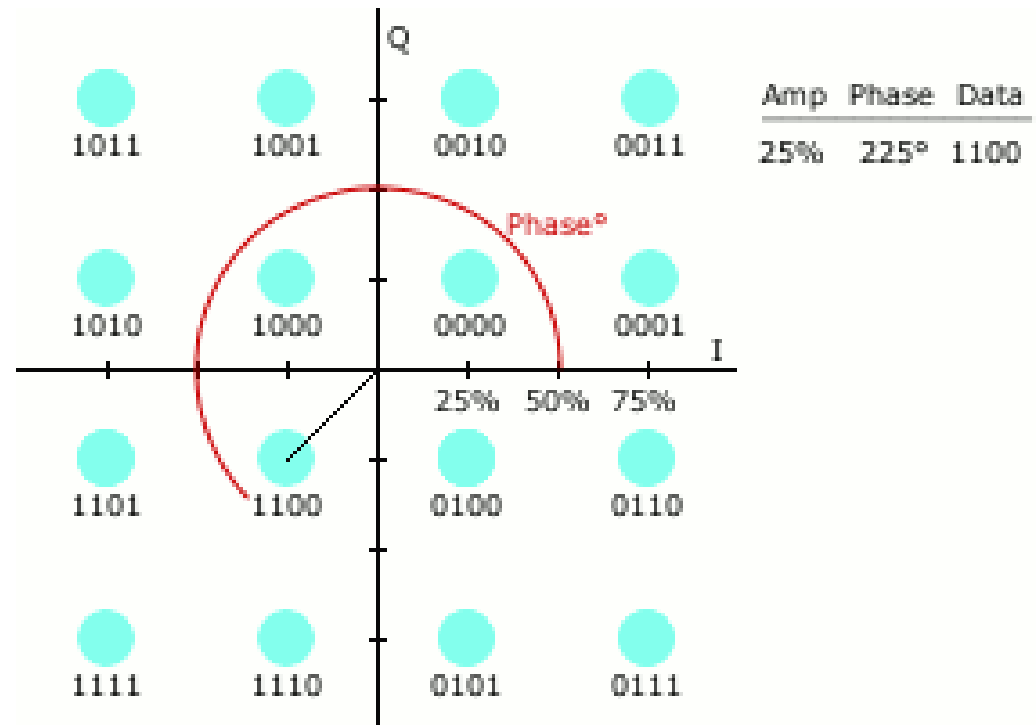
- Higher data rate

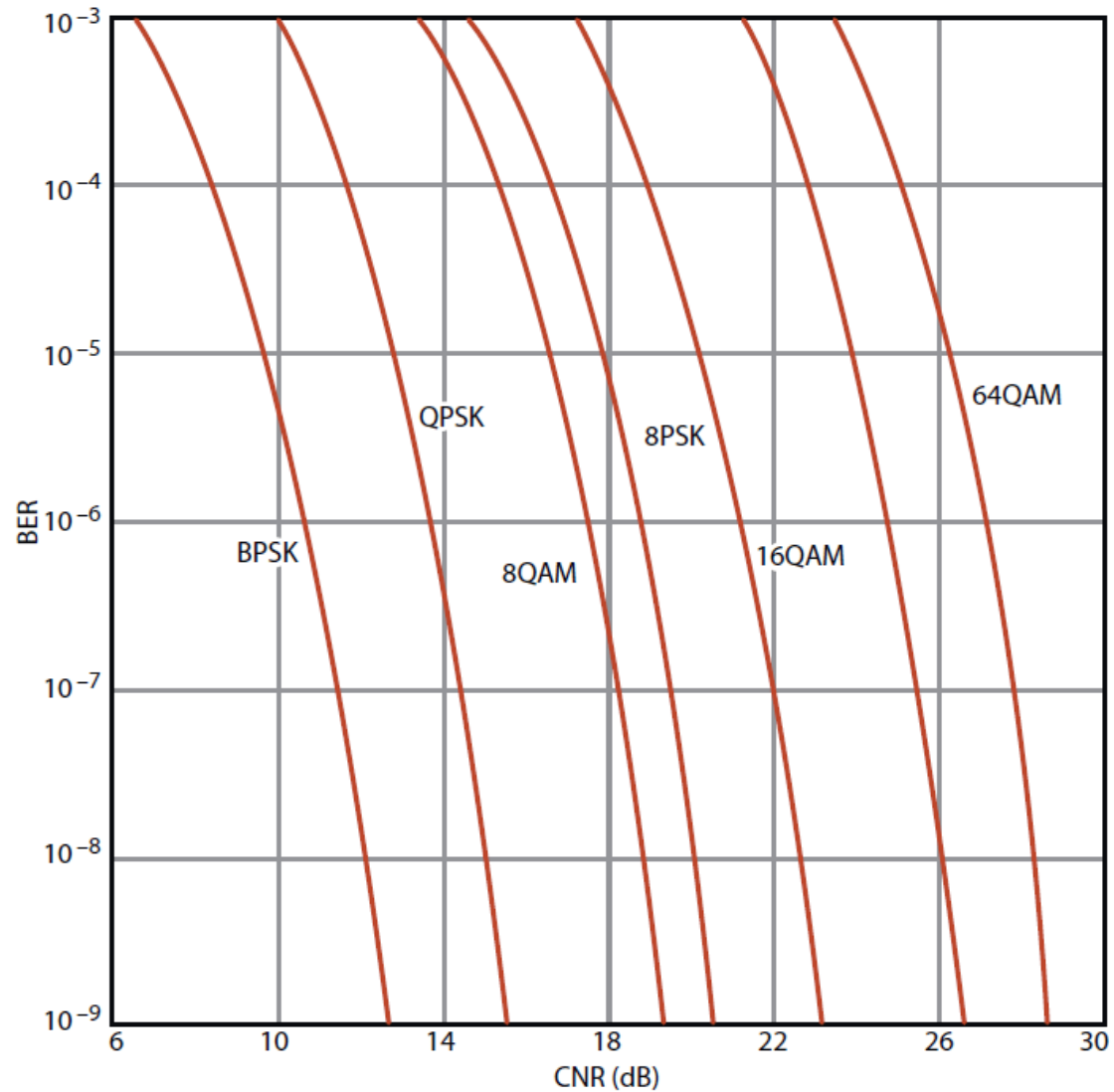
- ▶ Disadvantages:

- 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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- ▶ http://www.eecs.yorku.ca/course_archive/2010-11/F/3213/CSE3213_07_ShiftKeying_F2010.pdf
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