Veri Haberleşmesi ve Bilgisayar Ağları

“***Modulation - Line Coding***”

Dr. Cahit Karakuş, 2020

İçerik

- Modulation
- Dijital verilerin analog sinyalde taşınması
- Line Coding
- Multiplexing

Modulation - Coding

CODEC

- Daha hızlı veri transfer etmek
- Daha az veri depolama alanı kullanmak
- Codec, **Co**mpression (sıkıştırma) ve **dec**ompression (açma) kelimelerinin birleşiminden oluşur. Ayrıca codec, analog sinyali, veri ağı üzerinden taşınabilmesi için dijital hale dönüştürür.
- **Kanalın Performansını Artırma Yöntemleri:** Veri Sıkıştırma, İndirgeme, Kodlama, Modülasyon, Canstrator.
- Sıkıştırmadaki amaç: Daha az çoğullama devresi, daha az band genişliği, daha az iletişim ortamı.

Modem

- Sayısal verileri iletim hattından etkilenmeden iletilmesi için analog forma dönüştürür.
- **Modemler, verileri iletim hattına uyması için analog forma değiştirir.**
- Modem (modülatör-demodülatörden), dijital bilgileri kodlamak için bir analog taşıyıcı sinyali modüle eden ve ayrıca iletilen bilgilerin kodunu çözmek için böyle bir taşıyıcı sinyali demodüle eden bir cihazdır.
- Vericideki modemin işlevi - dijital verileri, iletim hattı özellikleriyle uyumlu analog sinyale dönüştürür.
- Modemlerin temel amacı gürültülü ortamdan sinyallerin bozulmadan iletilmesidir.

Modulation

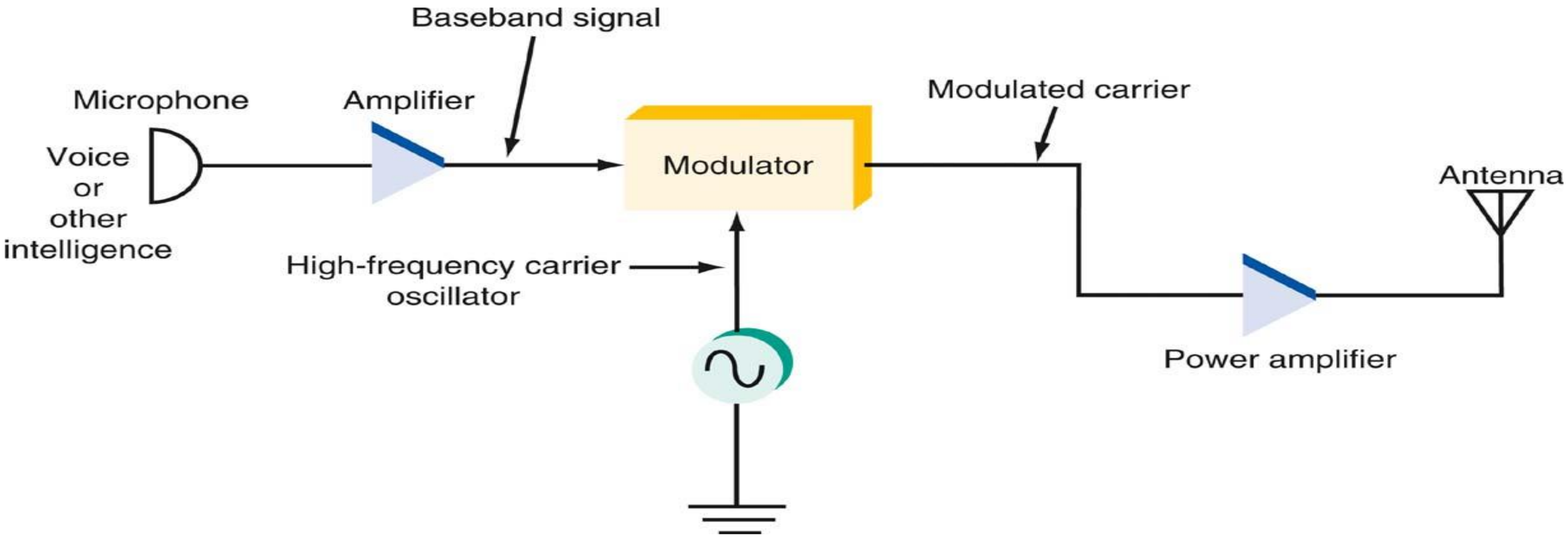
- **Modülasyon ve çoğullama, bilgiyi bir yerden diğerine verimli bir şekilde iletmek için kullanılan elektronik tekniklerdir. Modülasyon, bilgi sinyalini gürültüden ve bozucu etkilerden etkilenmemesi için ortamla daha uyumlu hale getirir. Çoğullama, birden fazla sinyalin aynı anda tek bir ortam üzerinden iletilmesine izin verir.**
- **Broadband Transmission Modulation:**
  - Ses, video veya veri ile modüle edilen yüksek frekanslı bir taşıyıcı sinyal kullanılır.
  - Bir radyo frekansı (RF) dalgası, uzayda uzun mesafeler kat edebilen elektromanyetik bir sinyaldir.
  - Geniş bant iletimi, bir taşıyıcı sinyal modüle edildiğinde, yükseltildiğinde ve iletim için antene gönderildiğinde gerçekleşir.
  - En yaygın iki modülasyon yöntemi şunlardır: Genlik Modülasyonu (AM)Frekans Modülasyonu (FM)
  - Başka bir yöntem, sinüs dalgasının faz açısının değiştirildiği faz modülasyonu (PM) olarak adlandırılır.

Modulation

Baseband Transmission

- Temel bant bilgisi, ortam üzerinden doğrudan ve değiştirilmeden gönderilebilir veya ortam üzerinden iletim için bir taşıyıcıyı modüle etmek için kullanılabilir.
  - Telefon veya interkom sistemlerinde ses tellere yerleştirilerek iletilir.
  - Bazı bilgisayar ağlarında, dijital sinyaller, iletim için doğrudan koaksiyel veya bükümlü çift kablolara uygulanır.

Modulation



Modulation at the transmitter.

Modulation

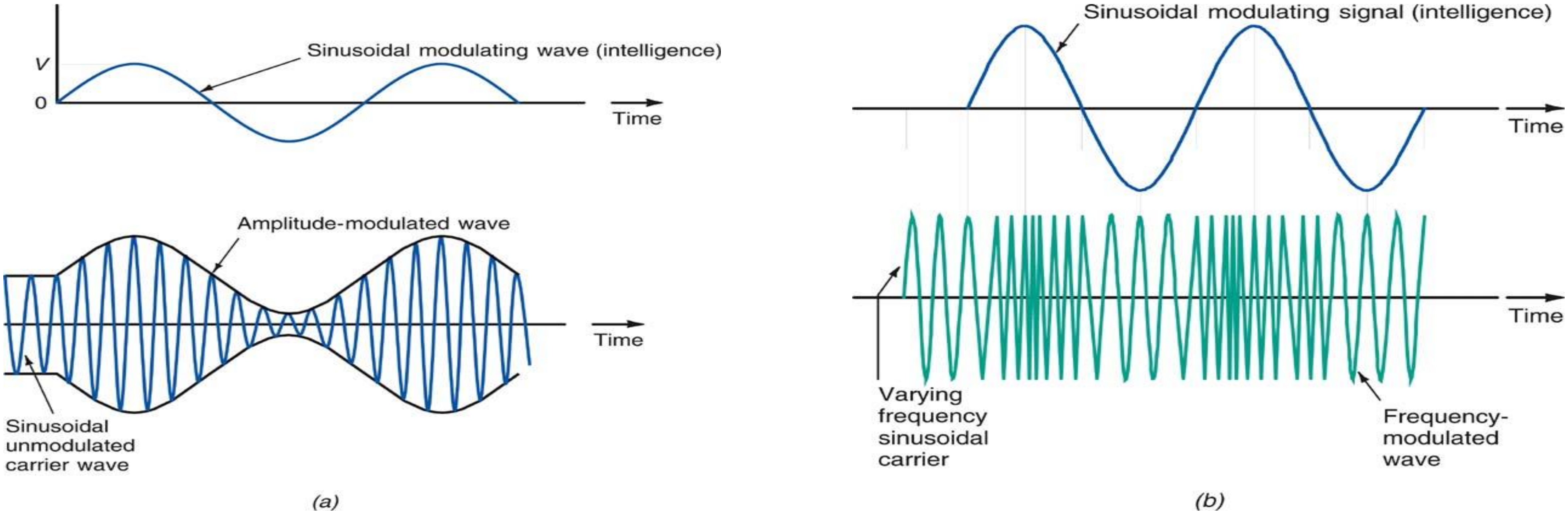


Figure 1-8: Types of modulation. (a) Amplitude modulation. (b) Frequency modulation.

Modulation

Broadband Transmission

- Frekans kaydırmalı anahtarlama (FSK), veriler frekans değişen tonlara dönüştürüldüğünde gerçekleşir.
- Modem adı verilen cihazlar (modülatör-demodülatör) verileri dijitalden analoğa ve tekrar geri çevirir.
- Orijinal temel bant (örneğin ses) sinyali çıkarıldığında alıcıda demodülasyon veya algılama gerçekleşir.

Modulation

- **Analog Modulation**
  - AM
  - FM
  - PM

Carrier:

$$c(t) = A\cos(2\pi f_c t + \theta)$$

Amplitude Frequency Pha

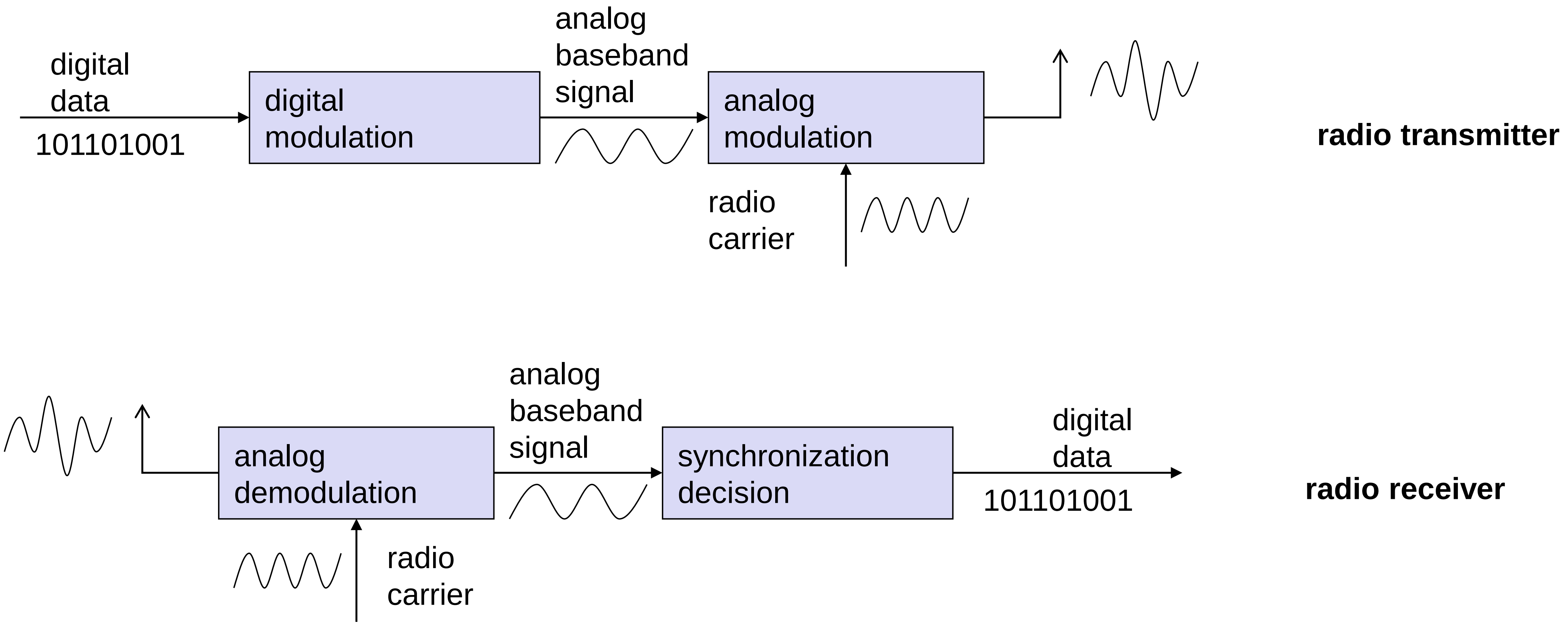
- **Pulse Modulation**
  - PAM / PPM / PCM / PWM

- **Digital Modulation**
  - ASK
  - FSK
  - PSK
  - QAM

Modulation

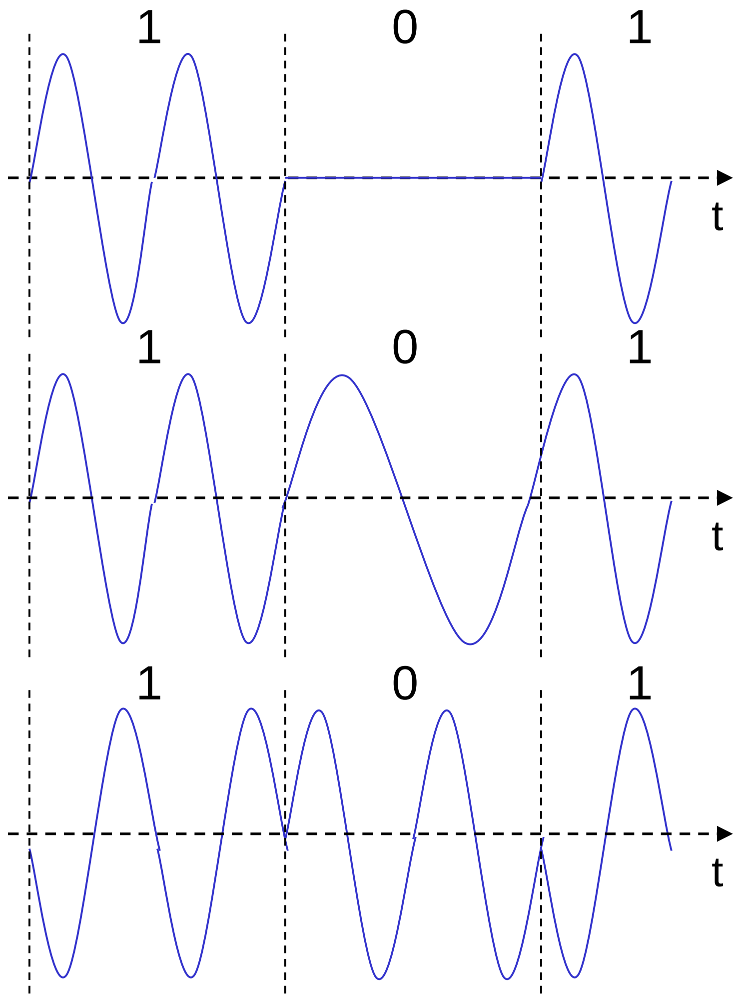
- Digital modulation
  - digital data is translated into an analog signal (baseband)
  - ASK, FSK, PSK - main focus in this chapter
  - differences in spectral efficiency, power efficiency, robustness
- Analog modulation
  - shifts center frequency of baseband signal up to the radio carrier
- Motivation
  - smaller antennas (e.g., $\lambda/4$)
  - Frequency Division Multiplexing
  - medium characteristics
- Basic schemes
  - Amplitude Modulation (AM)
  - Frequency Modulation (FM)
  - Phase Modulation (PM)

Modulation and demodulation

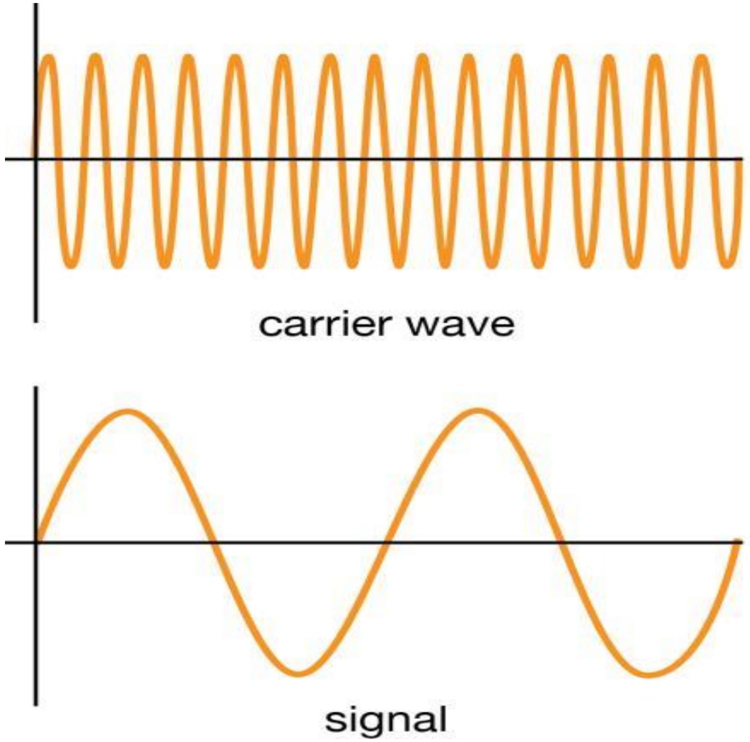


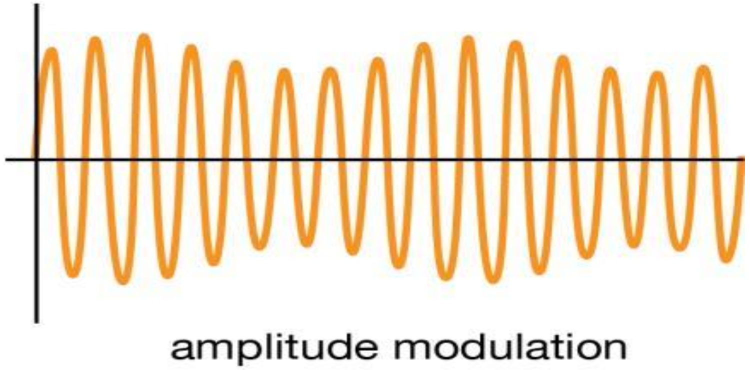
Digital modulation

- Modulation of digital signals known as Shift Keying
- Amplitude Shift Keying (ASK):
  - very simple
  - low bandwidth requirements
  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - needs larger bandwidth
- Phase Shift Keying (PSK):
  - more complex
  - robust against interference



Frequency modulation





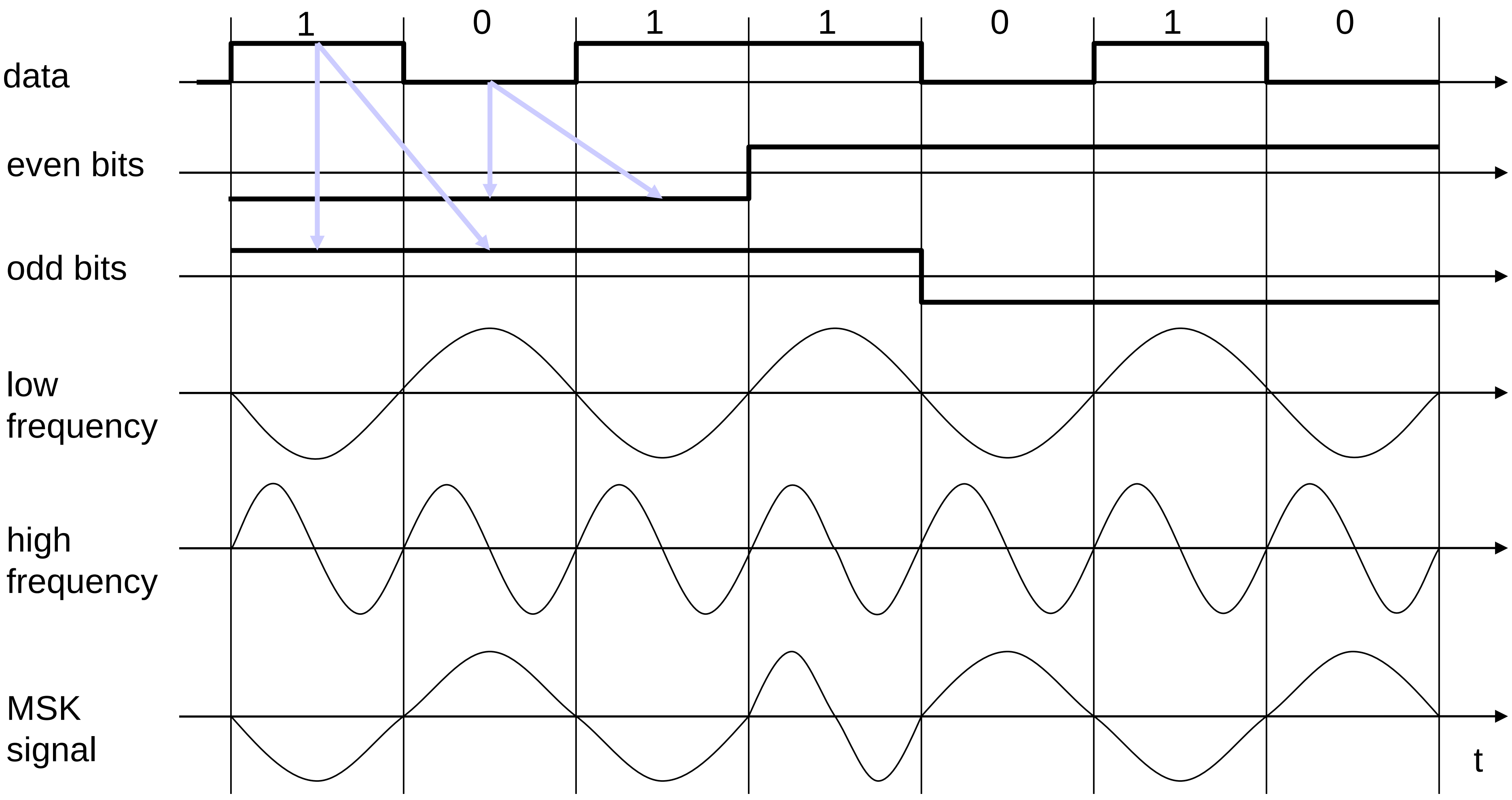
A radio frequency (r.f.) carrier wave of fixed amplitude is generated.
Its frequency varies once an a.f. signal is added.

Advanced Frequency Shift Keying

- bandwidth needed for FSK depends on the distance between the carrier frequencies
- 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
  - Equivalent to offset QPSK

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

Example of MSK



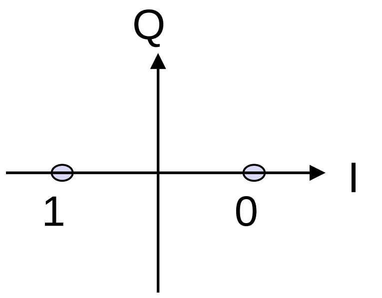
bit	
even	0 1 0 1
odd	0 0 1 1
signal	h n n h
value	- - + +

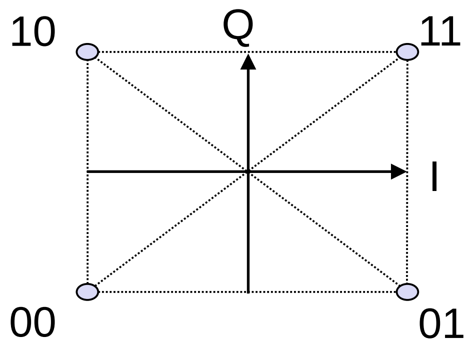
h: high frequency
n: low frequency
+: original signal
-: inverted signal

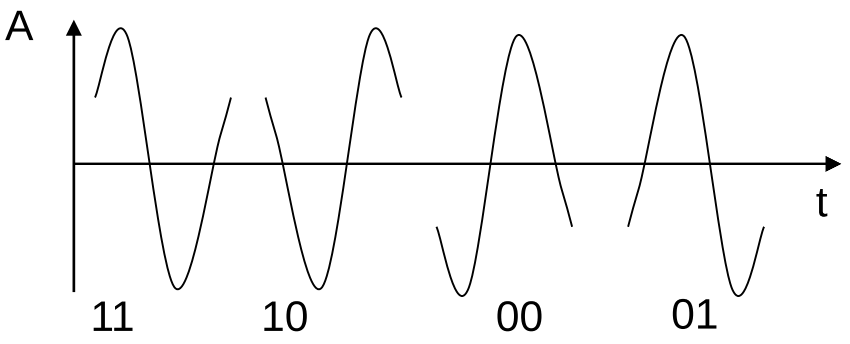
No phase shifts!

Advanced Phase Shift Keying

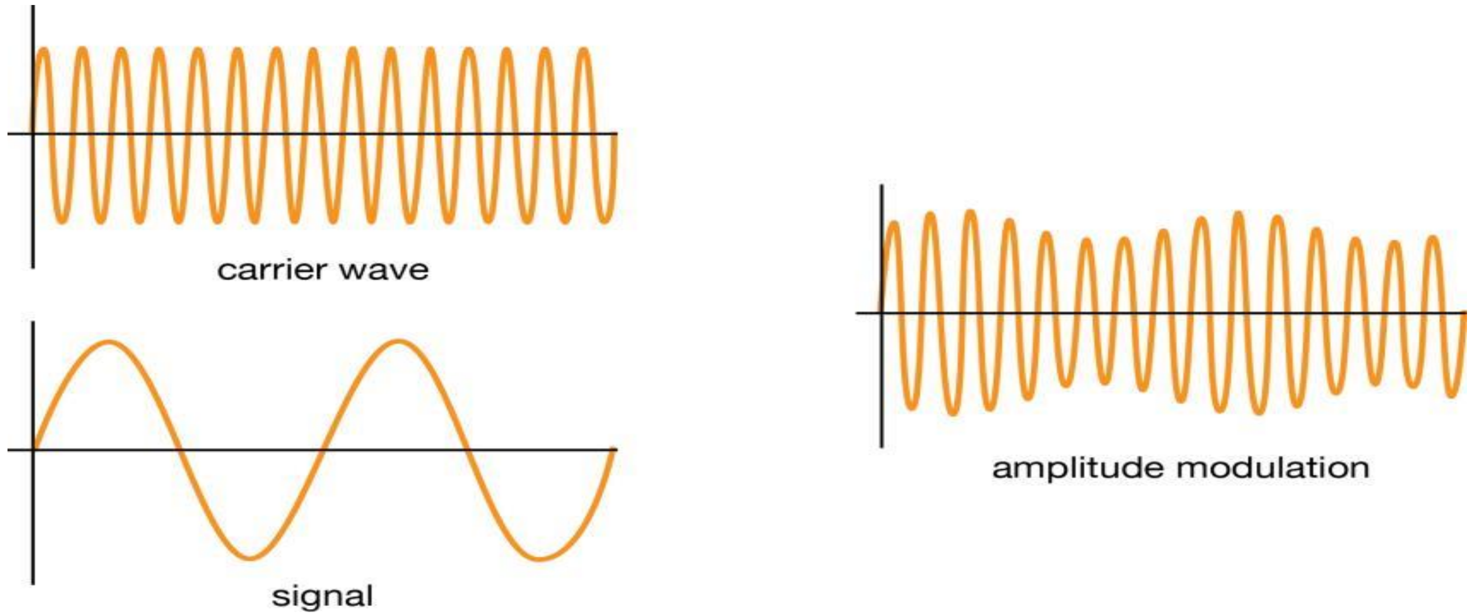
- BPSK (Binary Phase Shift Keying):
  - bit value 0: sine wave
  - bit value 1: inverted sine wave
  - very simple PSK
  - low spectral efficiency
  - robust, used e.g. in satellite systems
- QPSK (Quadrature Phase Shift Keying):
  - 2 bits coded as one symbol
  - symbol determines shift of sine wave
  - needs less bandwidth compared to BPSK
  - more complex
- Often also transmission of relative, not absolute phase shift: DQPSK - Differential QPSK (IS-136, PHS)







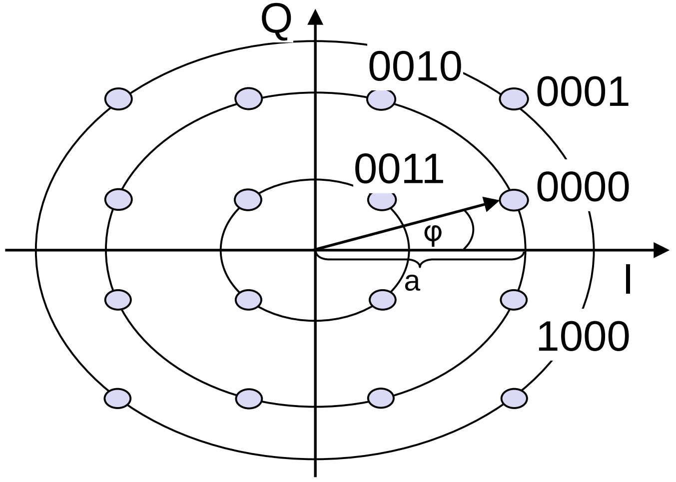
Amplitude modulation



A radio frequency (r.f.) carrier wave of fixed amplitude is generated. Its **amplitude** varies once an audio frequency (a.f.) signal is added.

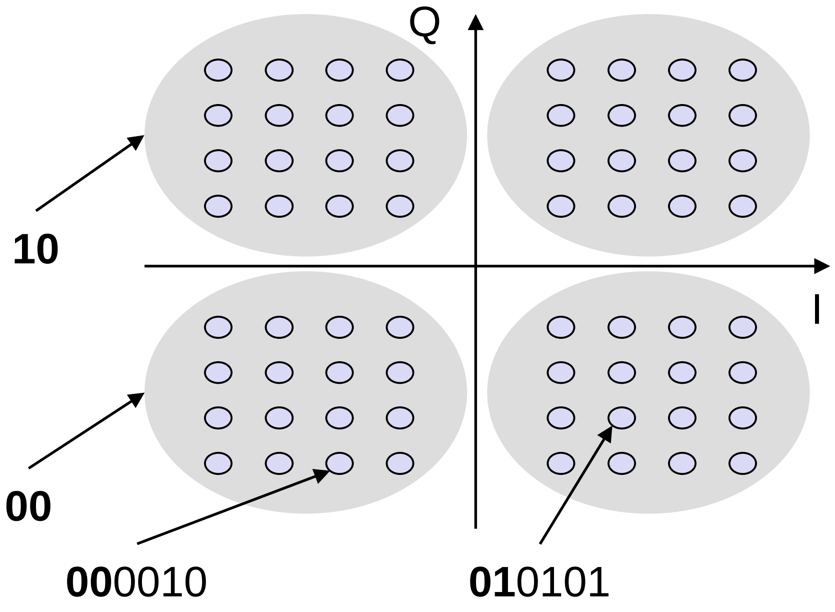
Quadrature Amplitude Modulation

- Quadrature Amplitude Modulation (QAM)
  - combines amplitude and phase modulation
  - it is possible to code n bits using one symbol
  - 2^n discrete levels, n=2 identical to QPSK
- Bit error rate increases with n, but less errors compared to comparable PSK schemes
  - Example: 16-QAM (4 bits = 1 symbol)
  - Symbols 0011 and 0001 have the same phase φ, but different amplitude a. 0000 and 1000 have different phase, but same amplitude.



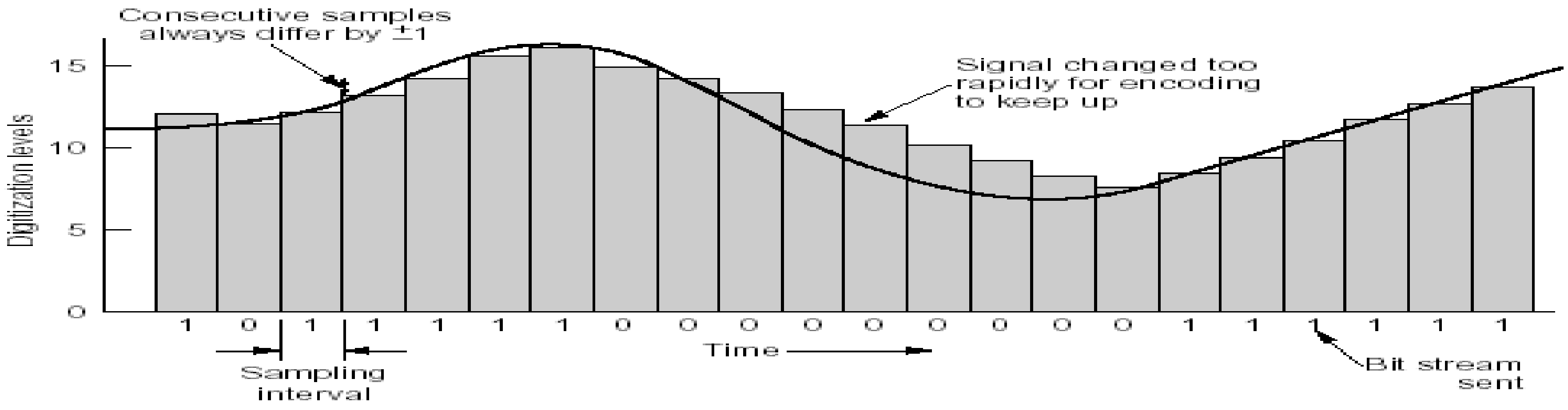
Hierarchical Modulation

- DVB-T modulates two separate data streams onto a single DVB-T stream
- High Priority (HP) embedded within a Low Priority (LP) stream
- Multi carrier system, about 2000 or 8000 carriers
- QPSK, 16 QAM, 64QAM
- Example: 64QAM
  - good reception: resolve the entire 64QAM constellation
  - poor reception, mobile reception: resolve only QPSK portion
  - 6 bit per QAM symbol, 2 most significant determine QPSK
  - HP service coded in QPSK (2 bit), LP uses remaining 4 bit



Compression

- differential modulation (send change to value, rather
- than value)
- delta modulation (shown) +1 or -1
- predictive encoding: extrapolate from earlier values and then send the change to this extrapolation



“Dijital verilerin analog sinyalde taşınması ”

DIGITAL-TO-ANALOG CONVERSION

Digital-to-analog conversion is the process of changing one of the characteristics of an analog signal based on the information in digital data.

- **Aspects of Digital-to-Analog Conversion**
- **Amplitude Shift Keying**
- **Frequency Shift Keying**
- **Phase Shift Keying**
- **Quadrature Amplitude Modulation**

Bit rate, N, is the number of bits per second (bps). Baud rate is the number of signal elements per second (bauds).
In the analog transmission of digital data, the signal or baud rate is less than
or equal to the bit rate.
S=Nx1/r bauds, Where r is the number of data bits per signal element.

Digital Modulation

- Modulation of digital signals known as Shift Keying
- Amplitude Shift Keying (ASK):
  - very simple
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  - very susceptible to interference
- Frequency Shift Keying (FSK):
  - needs larger bandwidth
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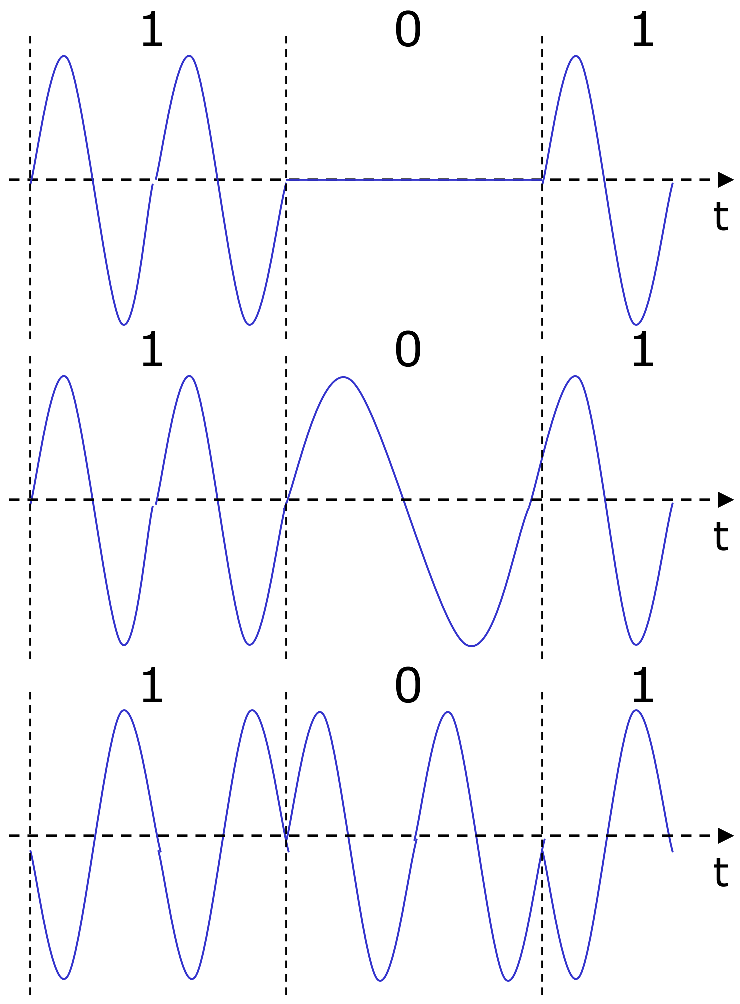
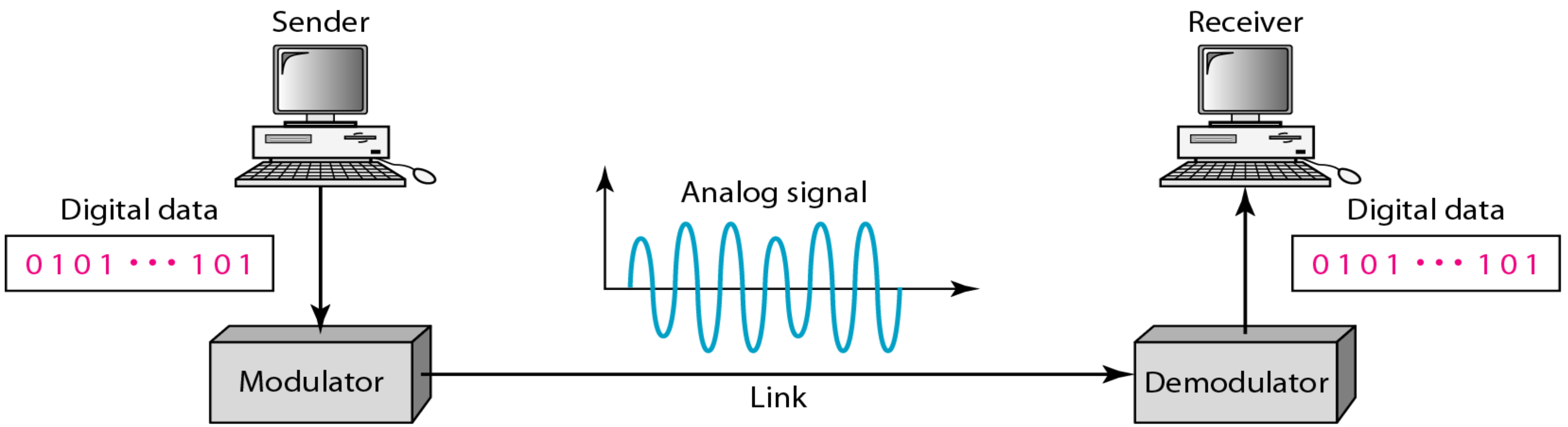
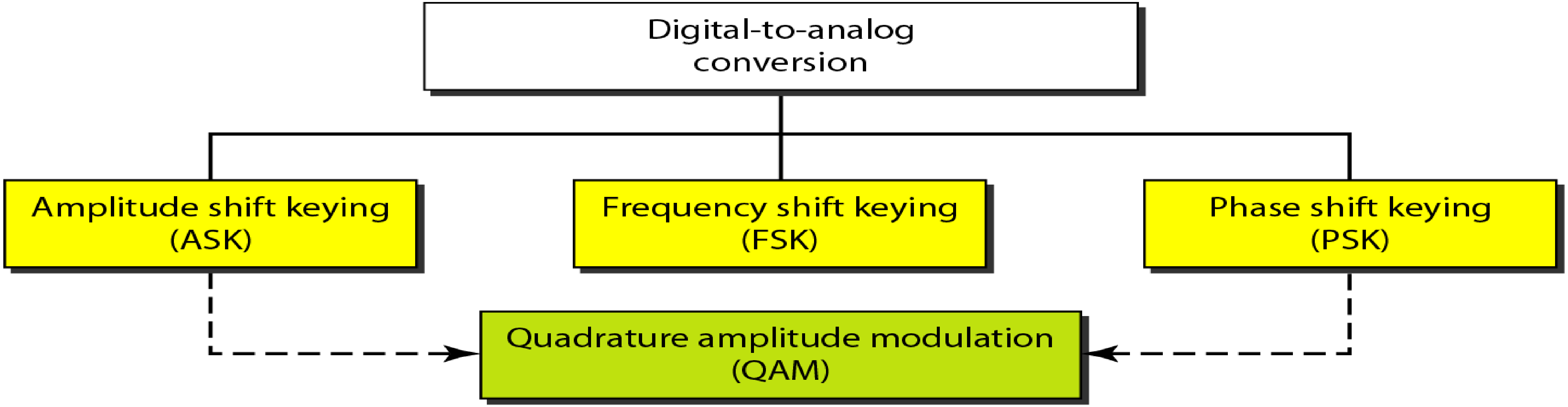


Digital to Analog Conversion

- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency f_c) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.



Types of digital-to-analog conversion



Example

An analog signal carries 4 bits per signal element. If 1000 signal elements are sent per second, find the bit rate.

Solution

In this case, r = 4, S = 1000, and N is unknown. We can find the value of N from

$$S = N \times \frac{1}{r} \qquad \text{or} \qquad N = S \times r = 1000 \times 4 = 4000 \text{ bps}$$

Example

An analog signal has a bit rate of 8000 bps and a baud rate of 1000 baud. How many data elements are carried by each signal element? How many signal elements do we need?

Solution

In this example, S = 1000, N = 8000, and r and L are unknown. We find first the value of r and then the value of L.

$$S = N \times \frac{1}{r} \rightarrow r = \frac{N}{S} = \frac{8000}{1000} = 8 \text{ bits/baud}$$

$$r = \log_2 L \rightarrow L = 2^r = 2^8 = 256$$

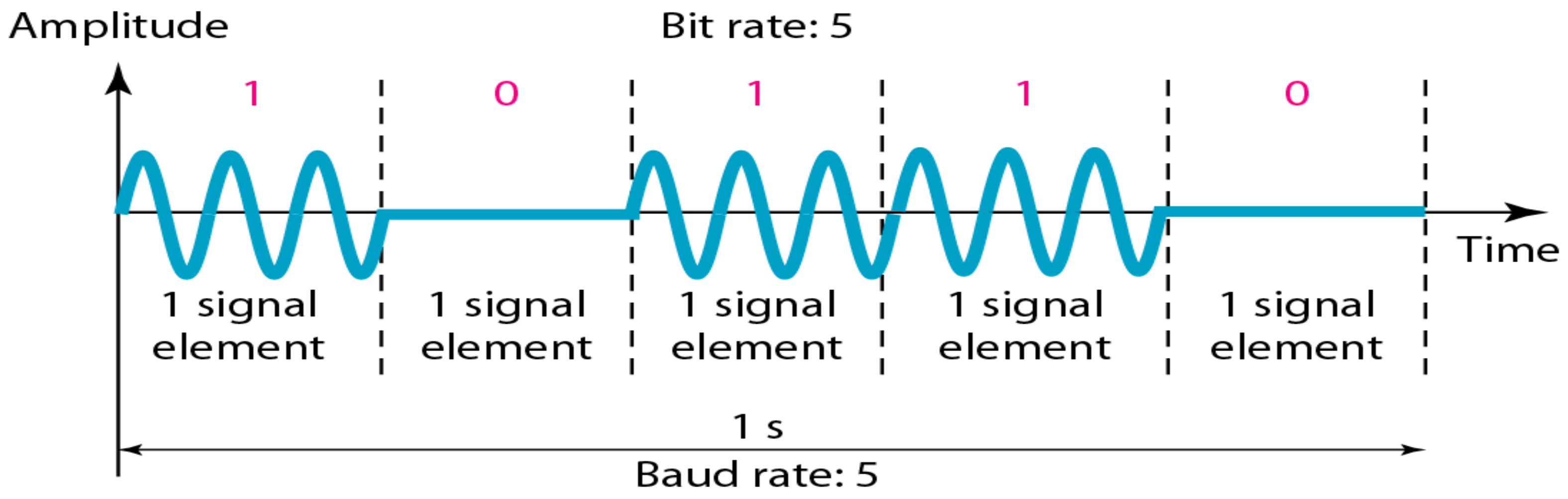
Amplitude Shift Keying (ASK)

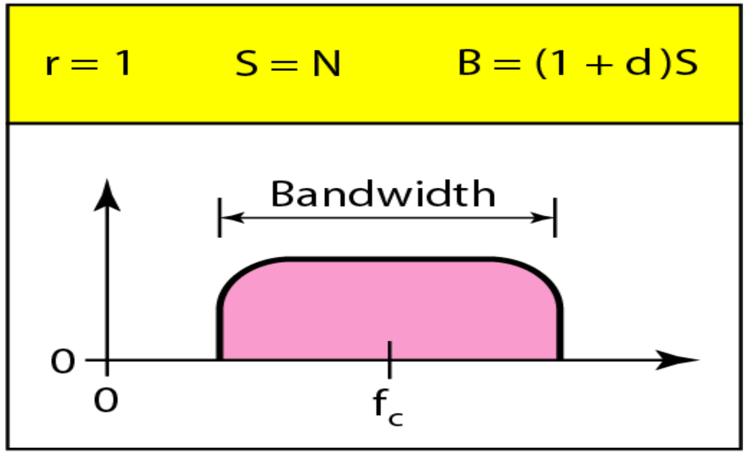
- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital “1” could not affect the signal, whereas a digital “0” would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.
- The bandwidth B of ASK is proportional to the signal rate S.

$$B = (1+d)S$$

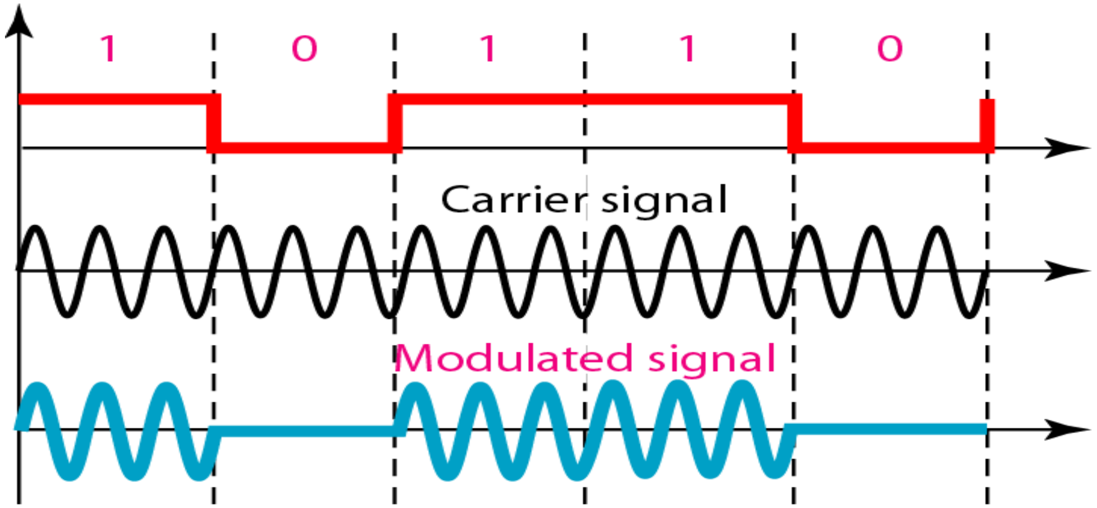
- “d” is due to modulation and filtering, lies between 0 and 1.

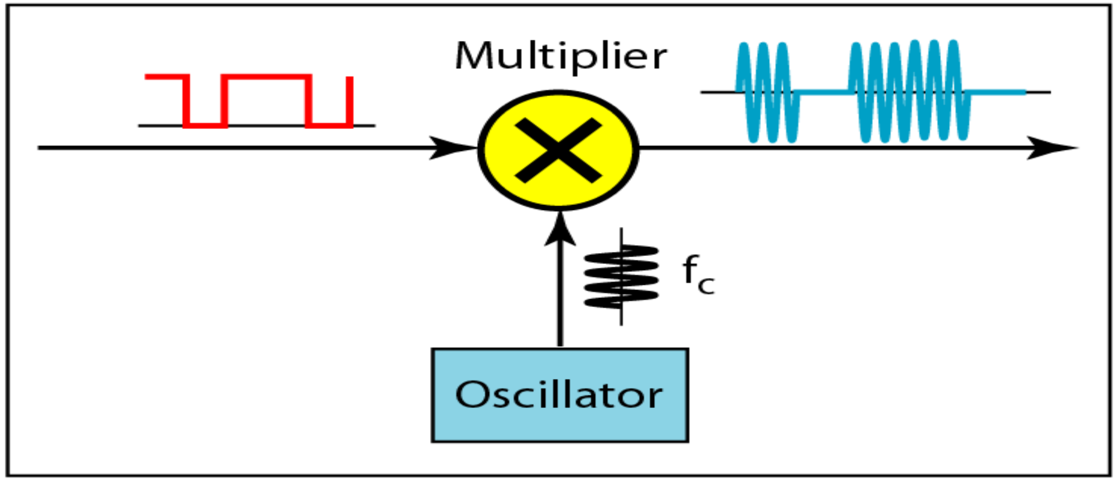
Binary amplitude shift keying





Implementation of binary ASK





Example

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What are the carrier frequency and the bit rate if we modulated our data by using ASK with d = 1?

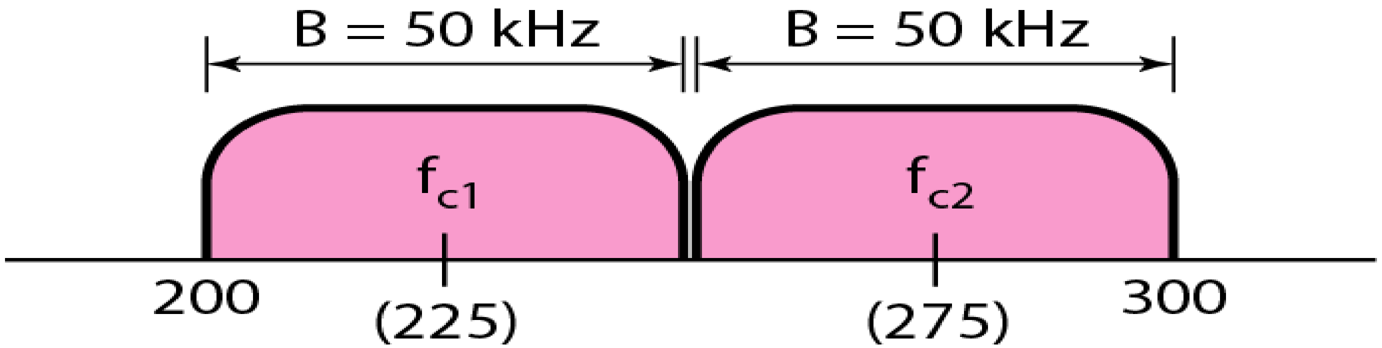
Solution

The middle of the bandwidth is located at 250 kHz. This means that our carrier frequency can be at f_c = 250 kHz. We can use the formula for bandwidth to find the bit rate (with d = 1 and r = 1).

$$B = (1 + d) \times S = 2 \times N \times \frac{1}{r} = 2 \times N = 100 \text{ kHz} \longrightarrow N = 50 \text{ kbps}$$

Example

In data communications, we normally use full-duplex links with communication in both directions. We need to divide the bandwidth into two with two carrier frequencies, as shown in Figure. The figure shows the positions of two carrier frequencies and the bandwidths. The available bandwidth for each direction is now 50 kHz, which leaves us with a data rate of 25 kbps in each direction.

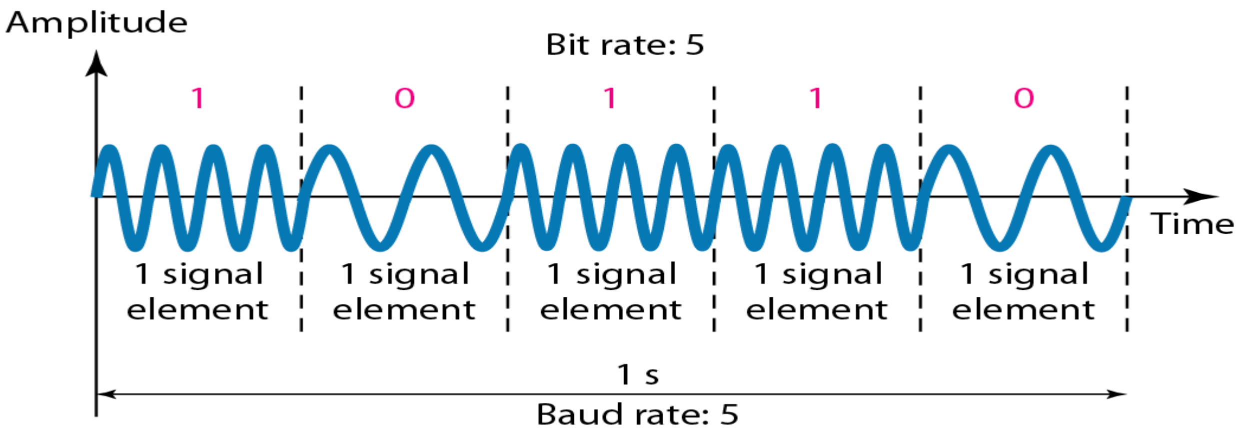


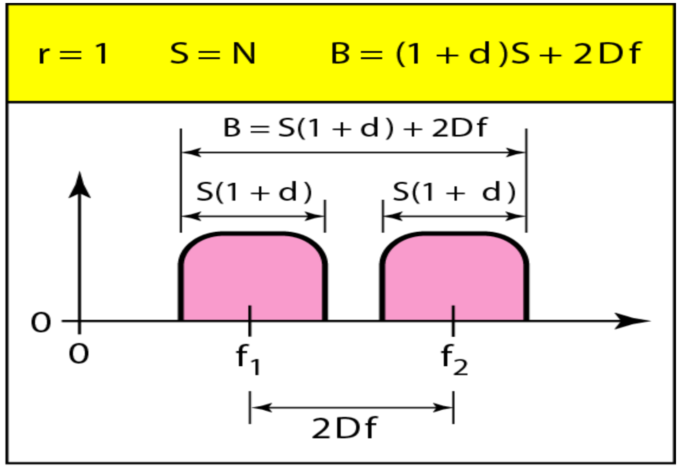
Bandwidth of full-duplex ASK used in Example 5.4

Frequency Shift Keying

- The digital data stream changes the frequency of the carrier signal, f_c.
- For example, a "1" could be represented by $f_1=f_c+\Delta f$, and a "0" could be represented by $f_2=f_c-\Delta f$.
- If the difference between the two frequencies (f_1 and f_2) is $2\Delta f$, then the required BW B will be:

$$B = (1+d)xS + 2\Delta f$$





Binary frequency shift keying

Example

We have an available bandwidth of 100 kHz which spans from 200 to 300 kHz. What should be the carrier frequency and the bit rate if we modulated our data by using FSK with d = 1?

Solution

This problem is similar to Example 5.3, but we are modulating by using FSK. The midpoint of the band is at 250 kHz. We choose 2Δf to be 50 kHz; this means

$$B = (1 + d) \times S + 2\Delta f = 100 \;\longrightarrow\; 2S = 50 \text{ kHz} \quad S = 25 \text{ kbaud} \quad N = 25 \text{ kbps}$$

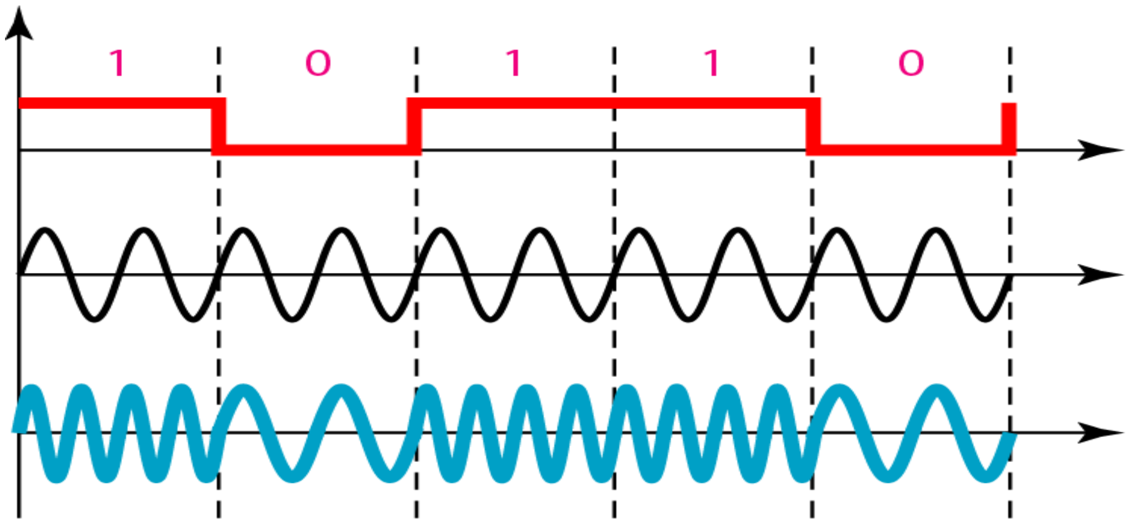
Coherent and Non Coherent

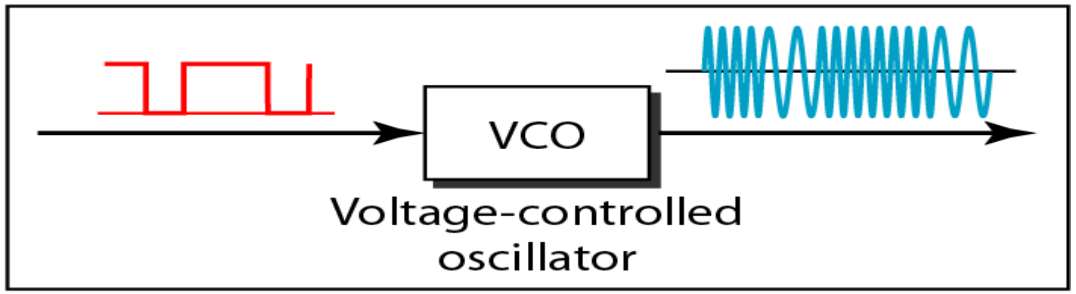
- In a non-coherent FSK scheme, when we change from one frequency to the other, we do not adhere to the current phase of the signal.
- In coherent FSK, the switch from one frequency signal to the other only occurs at the same phase in the signal.

Multi level FSK

- Similarly to ASK, FSK can use multiple bits per signal element.
- That means we need to provision for multiple frequencies, each one to represent a group of data bits.
- The bandwidth for FSK can be higher

$$B = (1+d)xS + (L-1)/2\Delta f = LxS$$





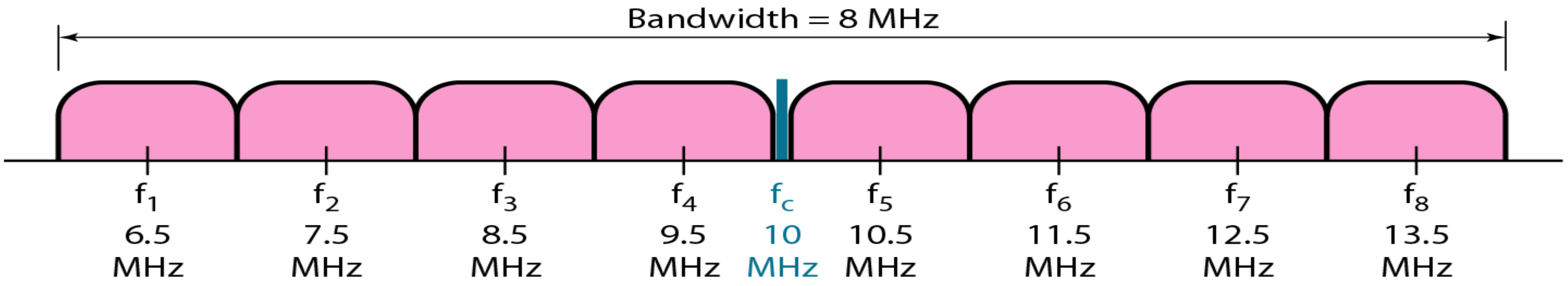
Bandwidth of MFSK

Example

We need to send data 3 bits at a time at a bit rate of 3 Mbps. The carrier frequency is 10 MHz. Calculate the number of levels (different frequencies), the baud rate, and the bandwidth.

Solution

We can have $L = 2^3 = 8$. The baud rate is $S = 3$ Mbps/3 = 1 Mbaud. This means that the carrier frequencies must be 1 MHz apart ($2\Delta f = 1$ MHz). The bandwidth is $B = 8 \times 1M = 8M$. Figure 5.8 shows the allocation of frequencies and bandwidth.



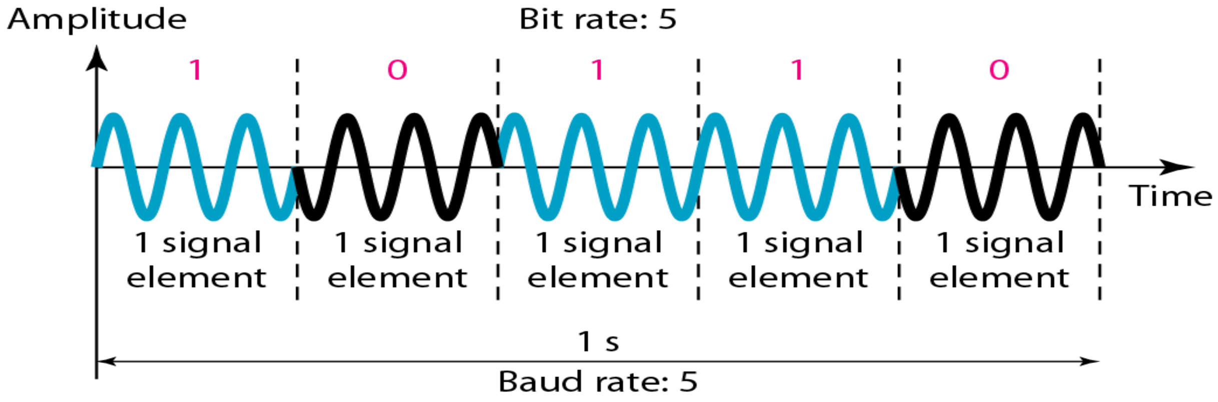
Bandwidth of MFSK

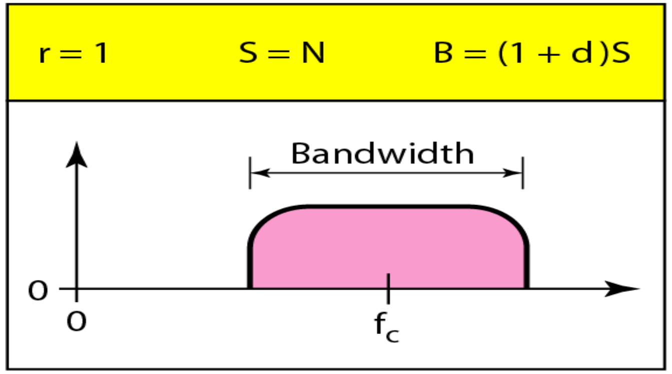
Phase Shift Keying

- We vary the phase shift of the carrier signal to represent digital data.
- The bandwidth requirement, B is:

$$B = (1+d)xS$$

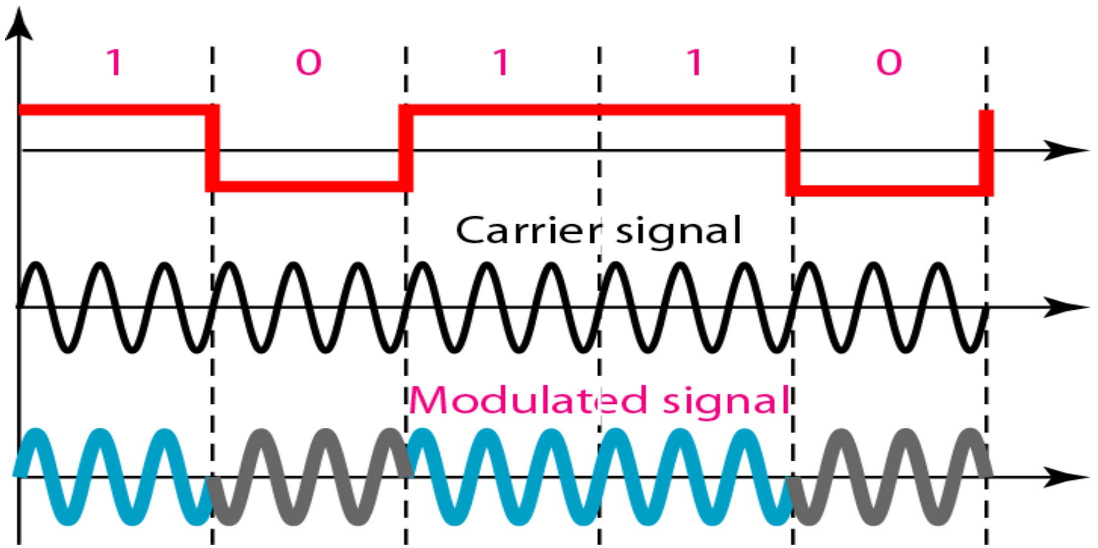
- PSK is much more robust than ASK as it is not that vulnerable to noise, which changes amplitude of the signal.

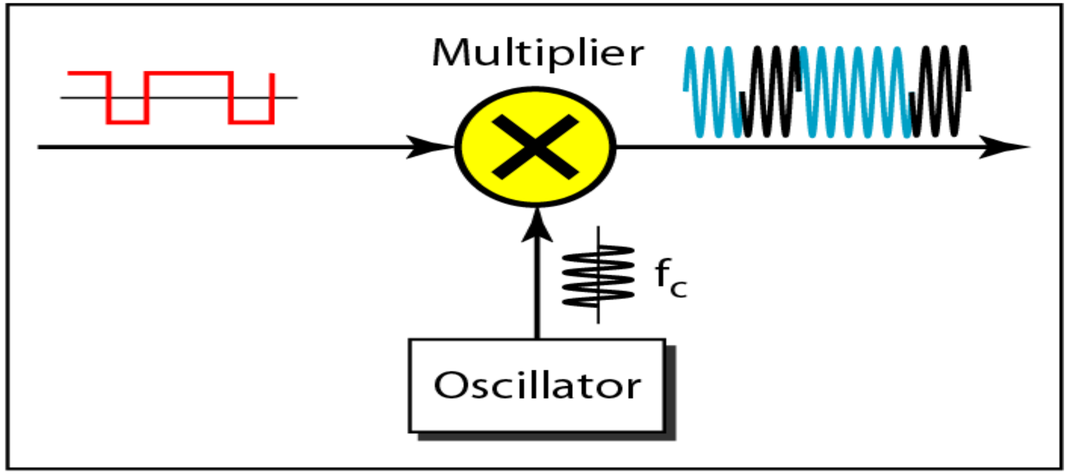




Binary phase shift keying

Implementation of BASK

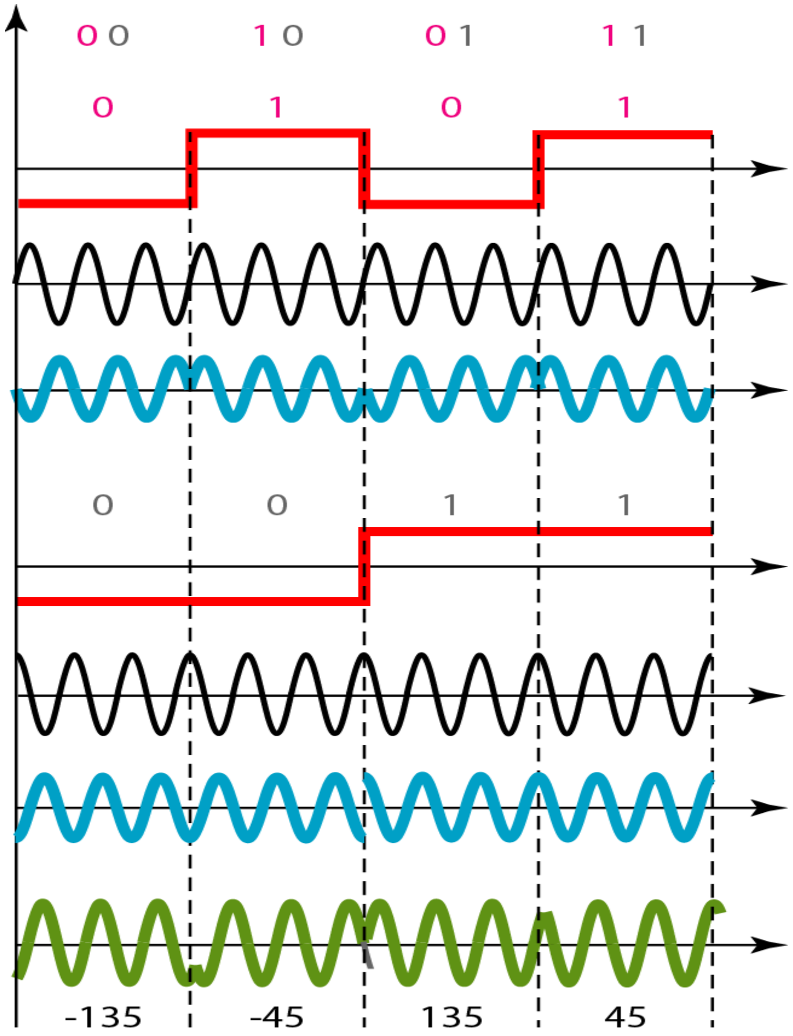


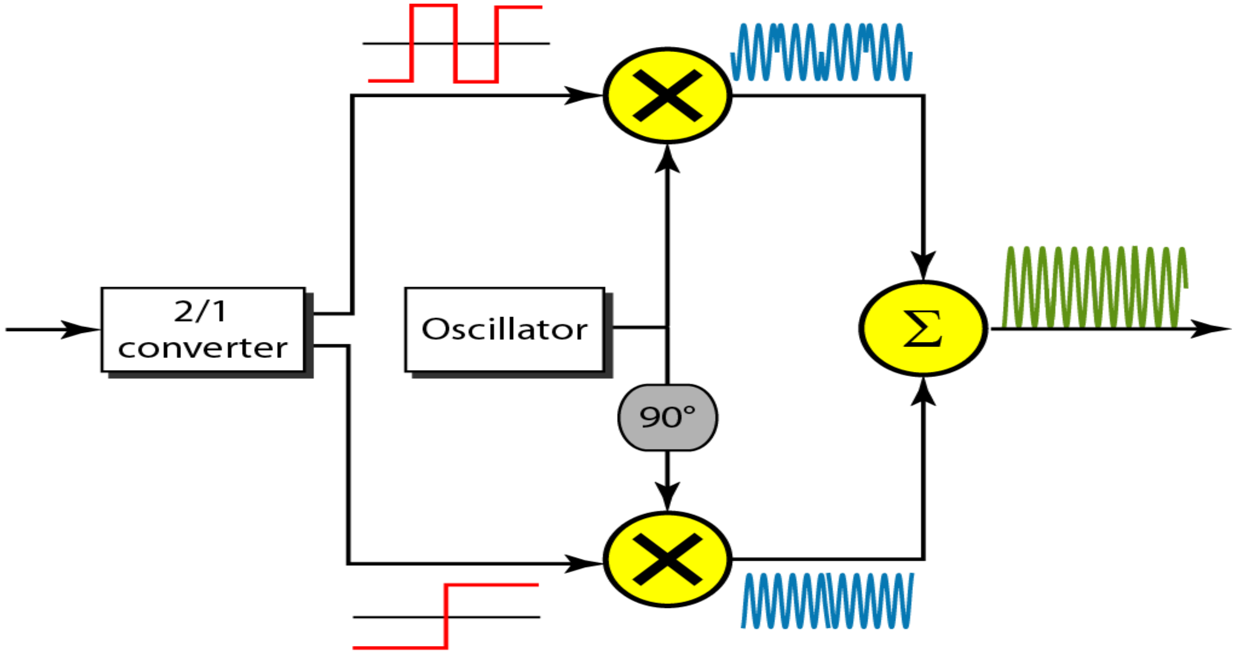


Quadrature PSK

- To increase the bit rate, we can code 2 or more bits onto one signal element.
- In QPSK, we parallelize the bit stream so that every two incoming bits are split up and PSK a carrier frequency. One carrier frequency is phase shifted 90^o from the other - in quadrature.
- The two PSKed signals are then added to produce one of 4 signal elements. L = 4 here.

QPSK and its implementation





Example

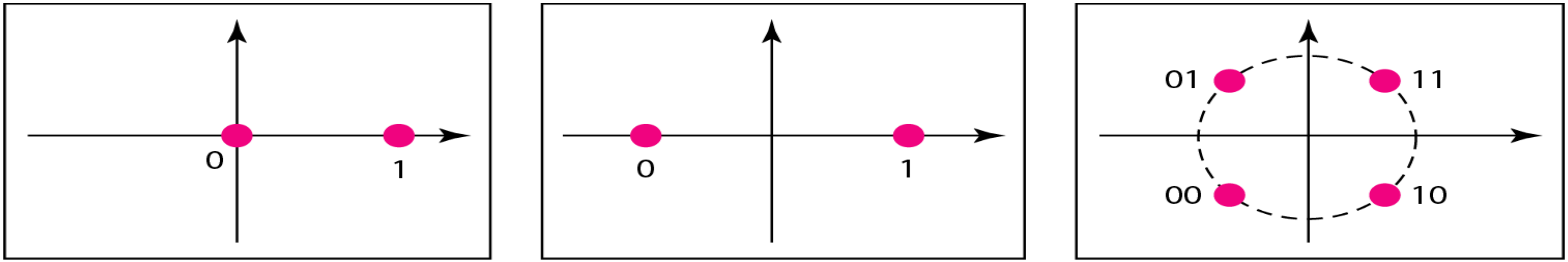
Find the bandwidth for a signal transmitting at 12 Mbps for QPSK. The value of d = 0.

Solution

For QPSK, 2 bits is carried by one signal element. This means that $r = 2$. So the signal rate (baud rate) is $S = N \times (1/r) = 6$ Mbaud. With a value of $d = 0$, we have $B = S = 6$ MHz.

Example

Show the constellation diagrams for an ASK (OOK), BPSK, and QPSK signals.

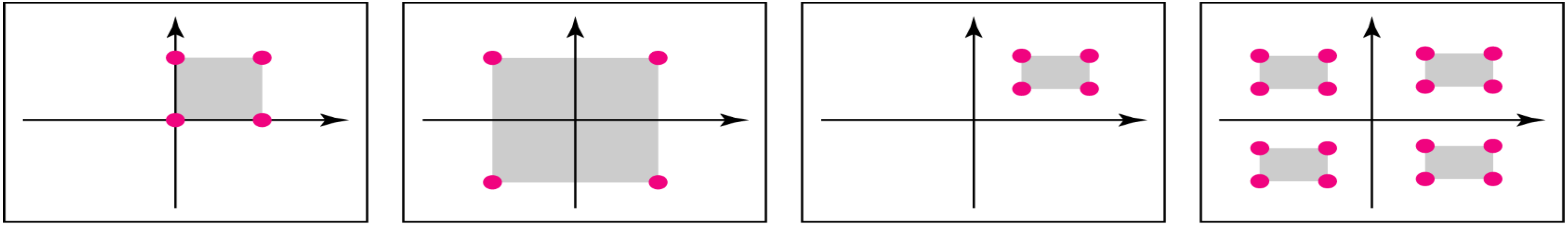


a. ASK (OOK) b. BPSK c. QPSK

Figure shows the three constellation diagrams.

Constellation diagrams for some QAMs

Quadrature amplitude modulation is a combination of ASK and PSK.



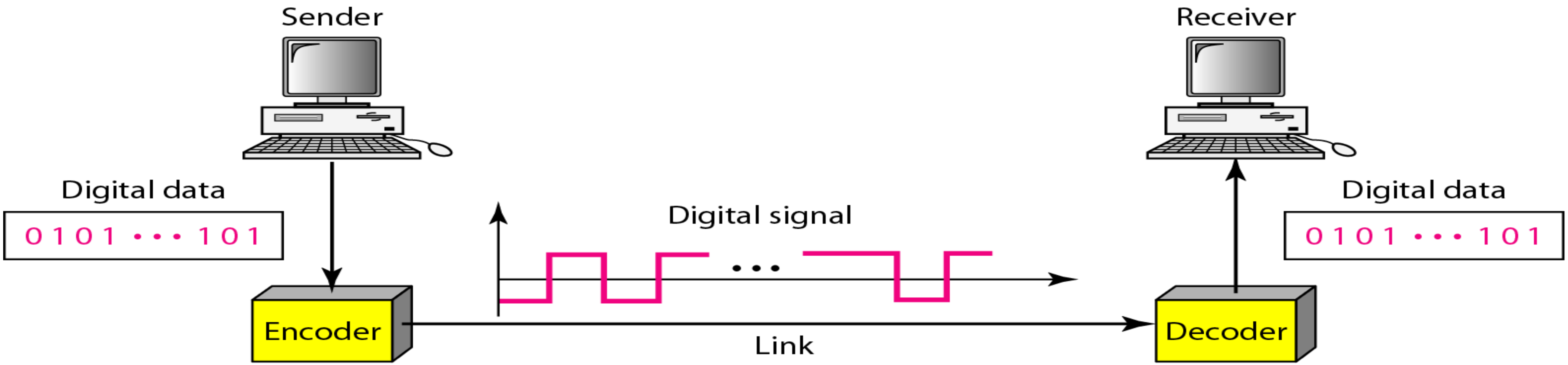
a. 4-QAM b. 4-QAM c. 4-QAM d. 16-QAM

“Line *Coding*”

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".

Line coding and decoding



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 elements
  - 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.

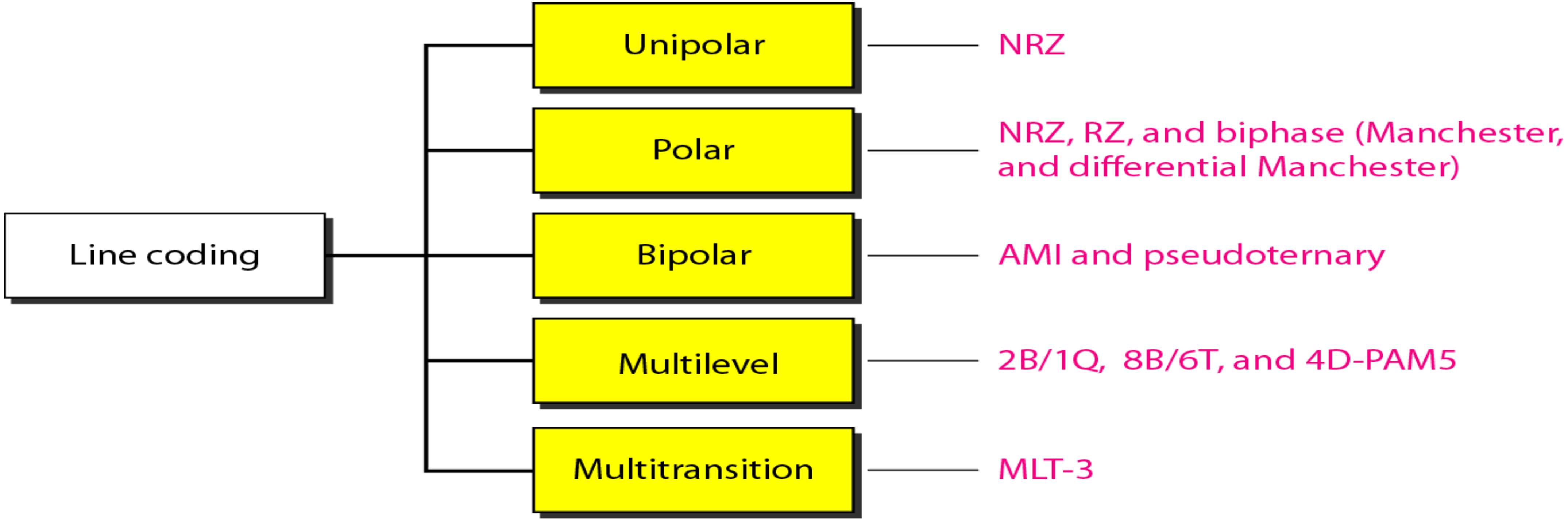
Relationship between data rate and signal rate

- The data rate defines the number of bits sent per sec - bps. It is often referred to the bit rate.
- The signal rate is the number of signal elements sent in a second and is measured in bauds. It is also referred to as the modulation rate.
- Goal is to increase the data rate whilst reducing the baud rate.

Encoding Techniques

- Digital data, digital signal
- Analog data, digital signal
- Digital data, analog signal
- Analog data, analog signal

Line coding schemes



Digital Data, Digital Signal

- Digital signal
  - Discrete, discontinuous voltage pulses
  - Each pulse is a signal element
  - Binary data encoded into signal elements

Terms

- Unipolar: All signal elements have same sign
- Polar: One logic state represented by positive voltage the other by negative voltage
- Data rate: Rate of data transmission in bits per second
- Duration or length of a bit: Time taken for transmitter to emit the bit
- Modulation rate: Rate at which the signal level changes. Measured in baud = signal elements per second.
- Mark and Space: Binary 1 and Binary 0 respectively

Interpreting Signals

- Need to know
  - Timing of bits - when they start and end
  - Signal levels
- Factors affecting successful interpreting of signals
  - Signal to noise ratio
  - Data rate
  - Bandwidth

Comparison of Encoding Schemes (1)

- Signal Spectrum
  - Lack of high frequencies reduces required bandwidth
  - Lack of dc component allows ac coupling via transformer, providing isolation
  - Concentrate power in the middle of the bandwidth
- Clocking
  - Synchronizing transmitter and receiver
  - External clock
  - Sync mechanism based on signal

Comparison of Encoding Schemes (2)

- Error detection
  - Can be built in to signal encoding
- Signal interference and noise immunity
  - Some codes are better than others
- Cost and complexity
  - Higher signal rate (& thus data rate) lead to higher costs
  - Some codes require signal rate greater than data rate

Encoding Schemes

- Nonreturn to Zero-Level (NRZ-L)
- Nonreturn to Zero Inverted (NRZI)
- Bipolar -AMI
- Pseudoternary
- Manchester
- Differential Manchester
- B8ZS
- HDB3

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.
- Scheme is prone to baseline wandering and DC components. It has no synchronization or any error detection. It is simple but costly in power consumption.

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.

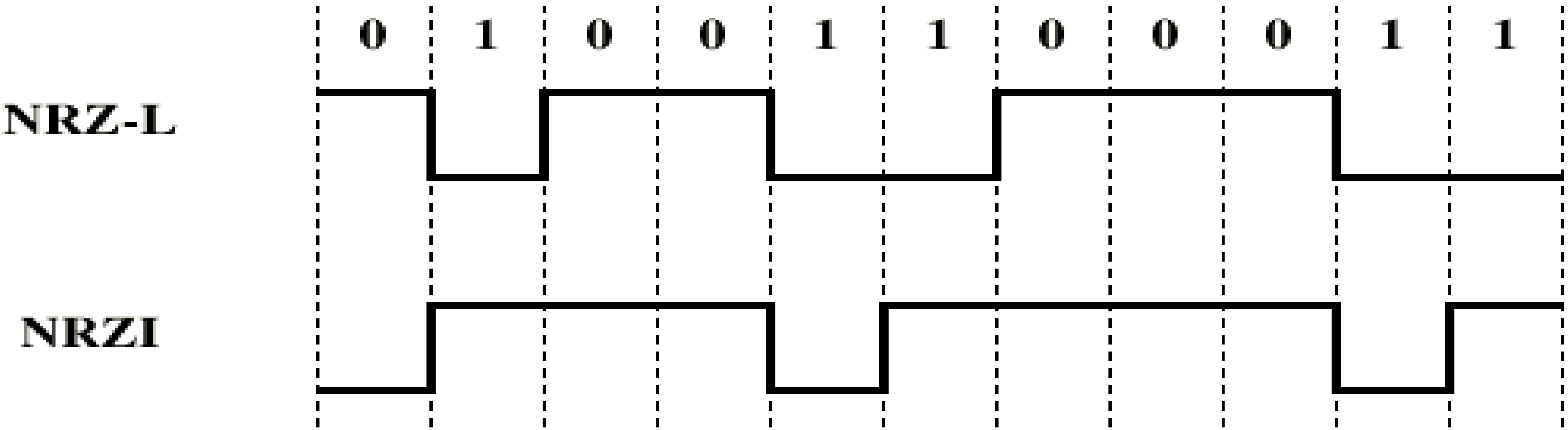
Nonreturn to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - no transition I.e. no return to zero voltage
- e.g. Absence of voltage for zero, constant positive voltage for one
- More often, negative voltage for one value and positive for the other
- This is NRZ-L

Nonreturn to Zero Inverted

- Nonreturn to zero inverted on ones
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
- Transition (low to high or high to low) denotes a binary 1
- No transition denotes binary 0
- An example of differential encoding

NRZ



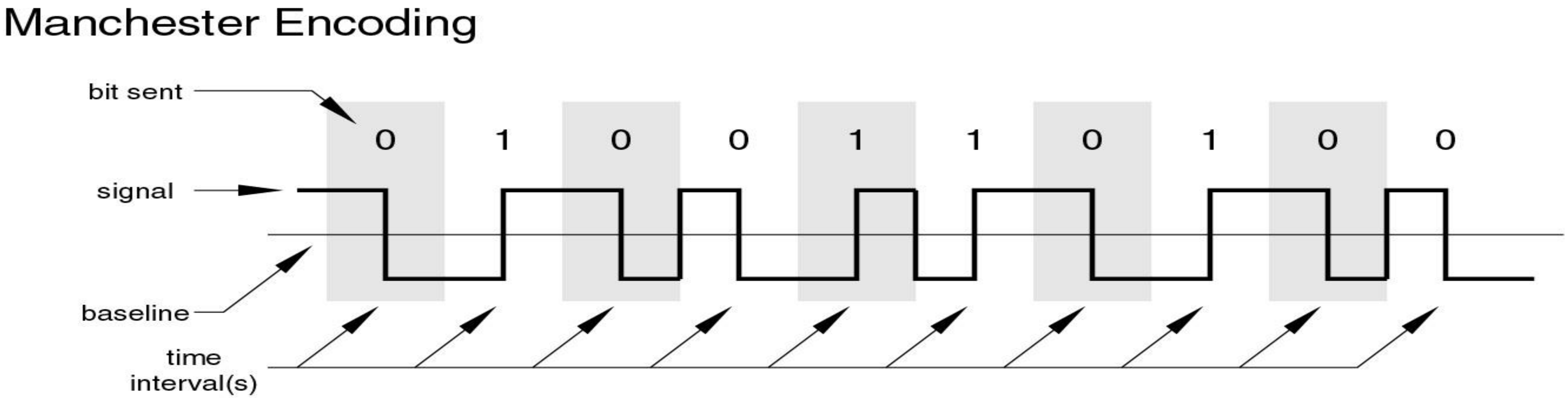
Biphase

- Manchester
  - Transition in middle of each bit period
  - Transition serves as clock and data
  - Low to high represents one
  - High to low represents zero
  - Used by IEEE 802.3
- Differential Manchester
  - Midbit transition is clocking only
  - Transition at start of a bit period represents zero
  - No transition at start of a bit period represents one
  - Note: this is a differential encoding scheme
  - Used by IEEE 802.5

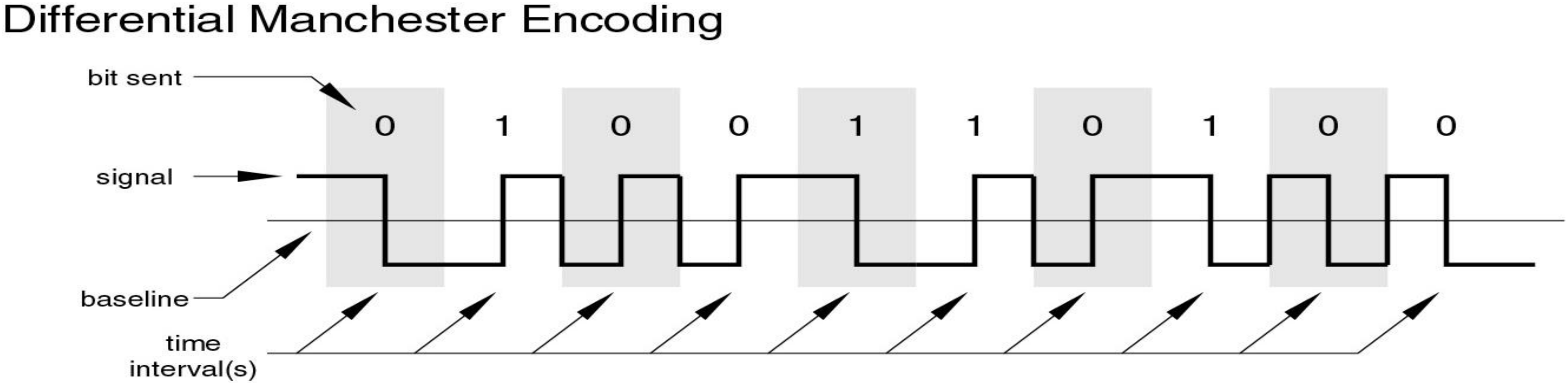
Polar - Biphase: Manchester and Differential Manchester

- 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.

Manchester Encoding



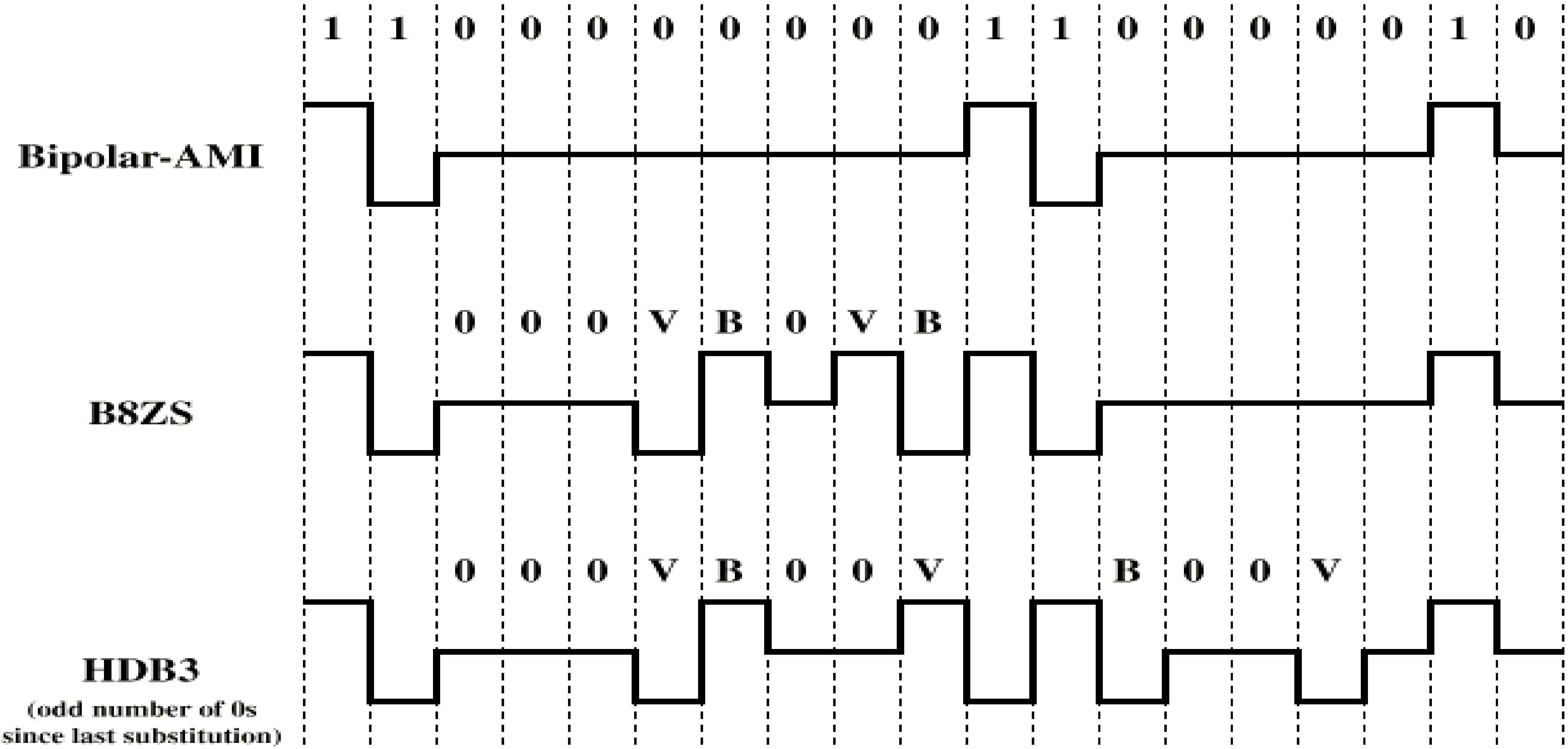
Differential Manchester Encoding



B8ZS

- Bipolar With 8 Zeros Substitution
- Based on bipolar-AMI
- If octet of all zeros and last voltage pulse preceding was positive encode as 000+-0-+
- If octet of all zeros and last voltage pulse preceding was negative encode as 000-+0+-
- Causes two violations of AMI code
- Unlikely to occur as a result of noise
- Receiver detects and interprets as octet of all zeros

B8ZS and HDB3



B = Valid bipolar signal
V = Bipolar violation

HDB3

- High Density Bipolar 3 Zeros
- Based on bipolar-AMI
- String of four 0s replaced with one or two pulses

Table 5.4 HDB3 Substitution Rules

	Number of Bipolar Pulses (ones) since Last Substitution	
Polarity of Preceding Pulse	**Odd**	**Even**
−	000−	+00+
+	000+	−00−

High Density Bipolar 3 (HDB3)

- Same goal as B8ZS
- Based on AMI
- Replaces every four consecutive 0s based on
  - Number of pulses since last substitution
  - Polarity of last logical 1

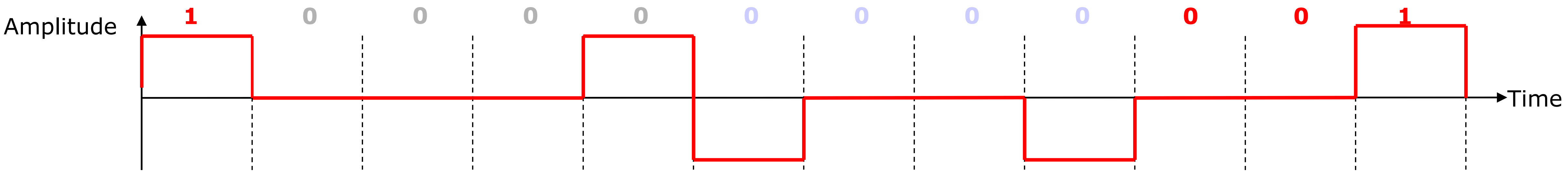
Last 1 polarity / # of 1s	+	-
ODD(revised 2011)	0000→000+	0000→000-
Even(revised 2011)	0000→-00-	0000→+00+

High Density Bipolar 3 (HDB3)

- Goal like B8ZS to improve Sync of AMI
- Just like AMI except 4 0’s are replaced by code
- For 0000 use 000V or B00V
  - Where B and V are + or –
  - And V is AMI violation, B is Balance Bit
- Use 000V if ODD number of + and – pulses so far
- Use B00V if EVEN, and B is opposite last pulse

High Density Bipolar 3 (HDB3)

- Example: (revised 1-6-11)
  - Number of 1s since last substitution is even, last 1 negative (before this string)
  - Encode 10000000000001



Nonreturn to Zero-Level (NRZ-L)
0 = high level
1 = low level

Nonreturn to Zero Inverted (NRZI)
0 = no transition at beginning of interval (one bit time)
1 = transition at beginning of interval

Bipolar-AMI
0 = no line signal
1 = positive or negative level, alternating for successive ones

Pseudoternary
0 = positive or negative level, alternating for successive zeros
1 = no line signal

Manchester
0 = transition from high to low in middle of interval
1 = transition from low to high in middle of interval

Differential Manchester
Always a transition in middle of interval
0 = transition at beginning of interval
1 = no transition at beginning of interval

B8ZS
Same as bipolar AMI, except that any string of eight zeros is replaced by a string with two code violations

HDB3
Same as bipolar AMI, except that any string of four zeros is replaced by a string with one code violation

Kaynaklar

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Sincerely,

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thank you