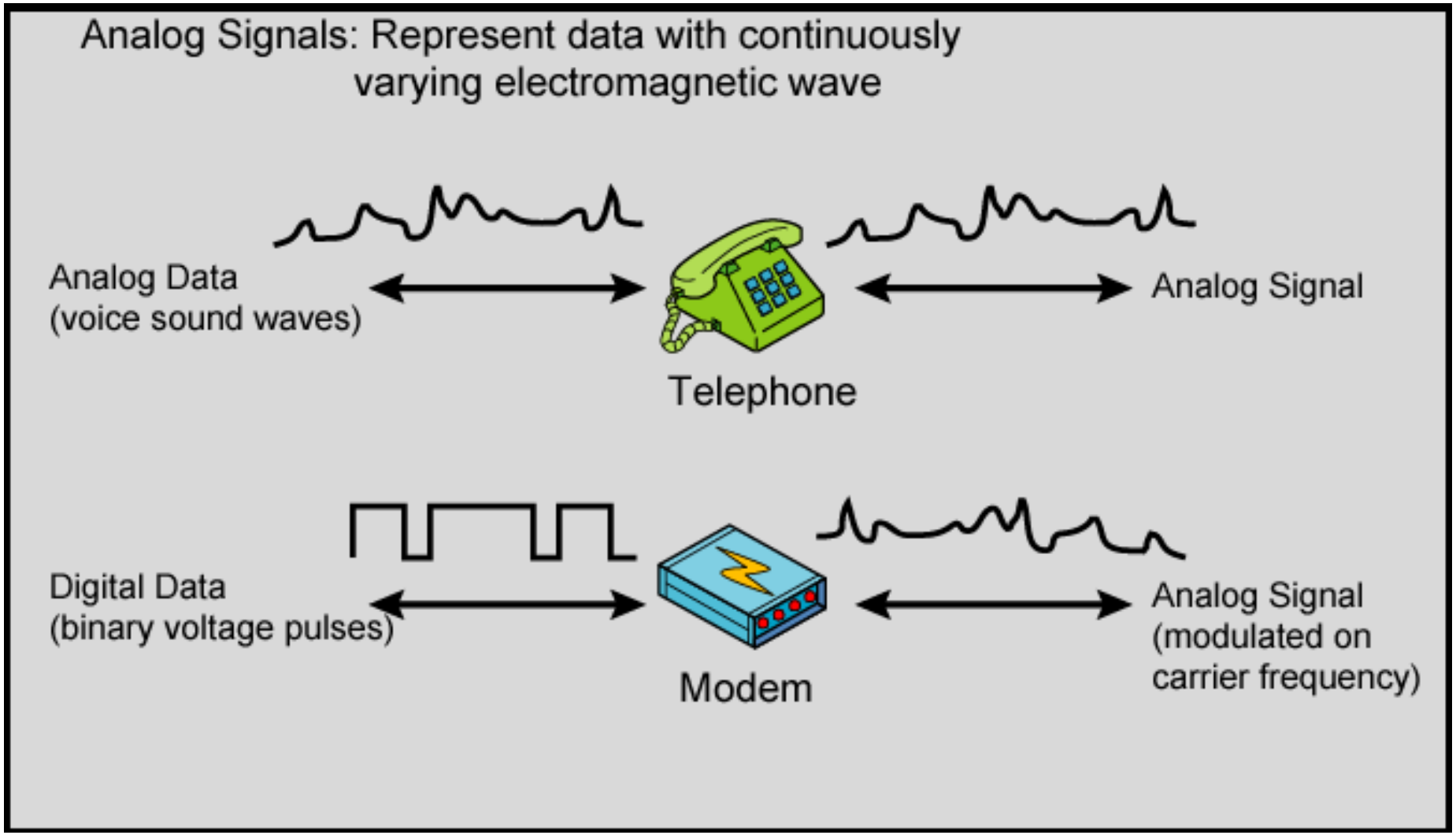
Analog Transmission

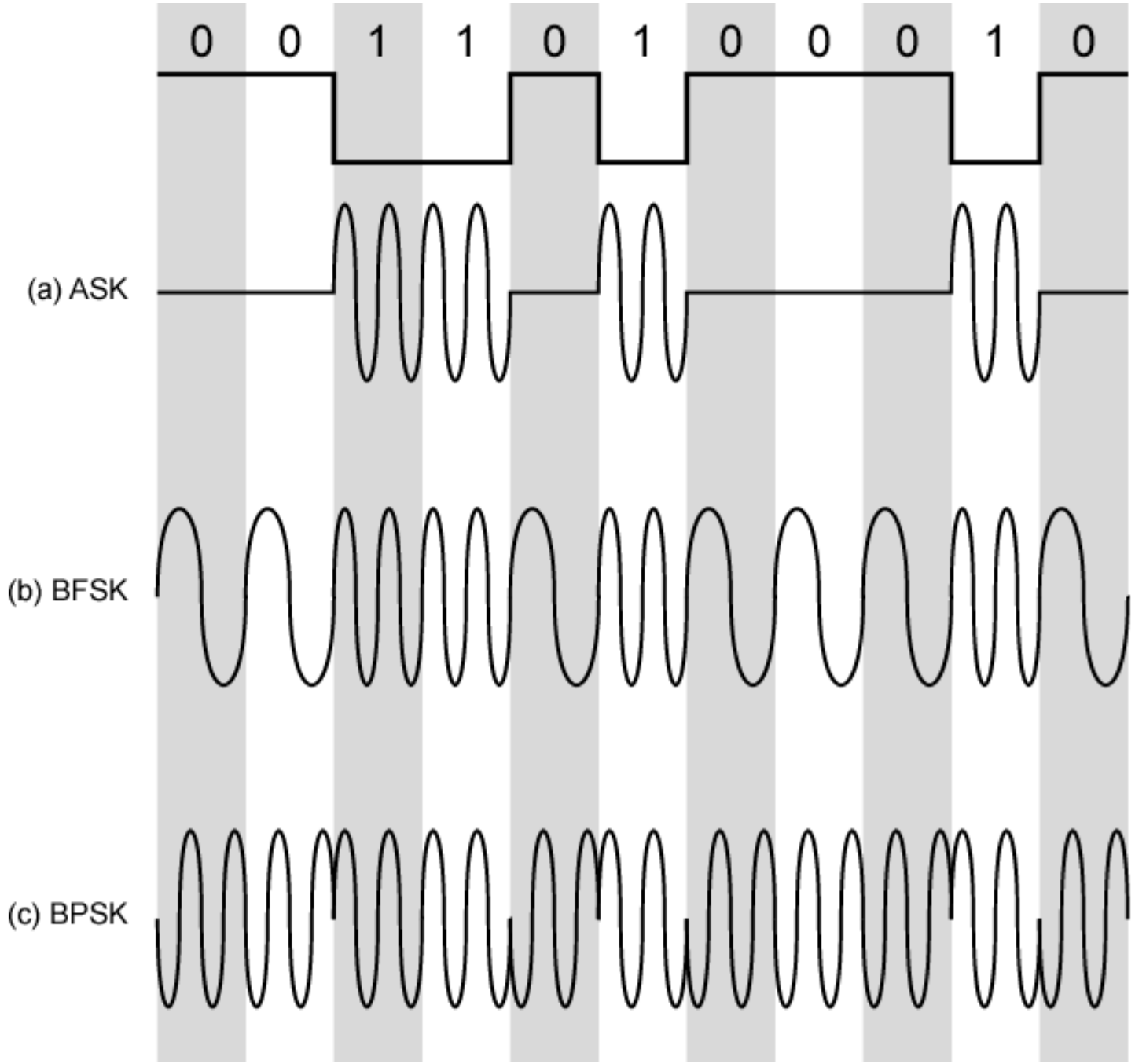
Analog Signals



Modulation of Carrier Amp., Freq., or Phase

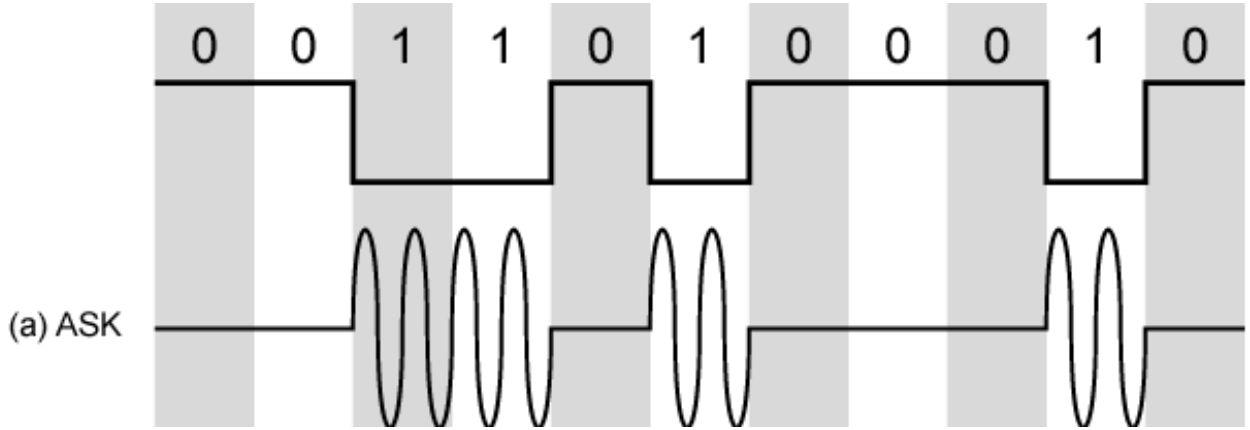
Modulation with digital signal

Modulation Techniques

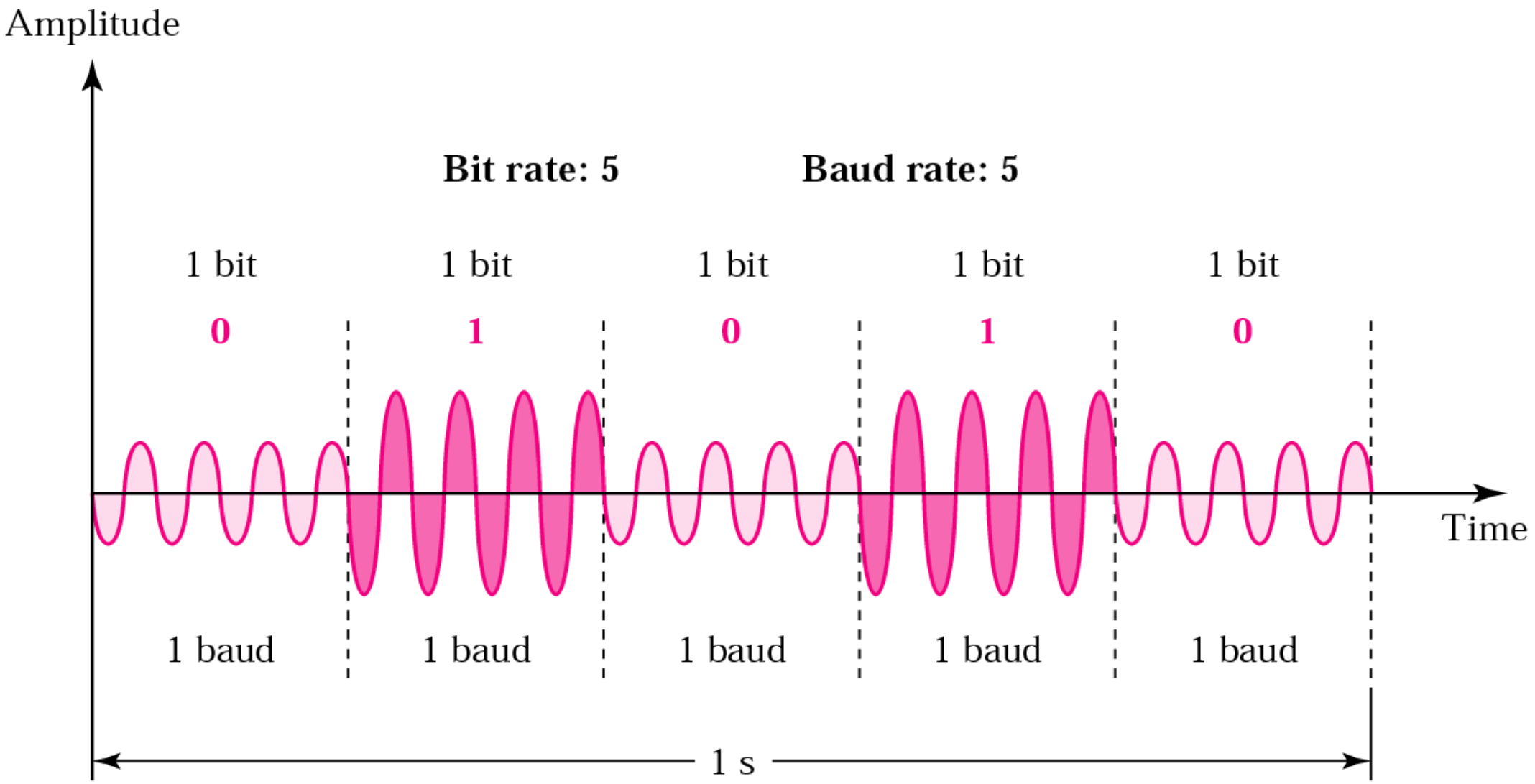


Amplitude Shift Keying

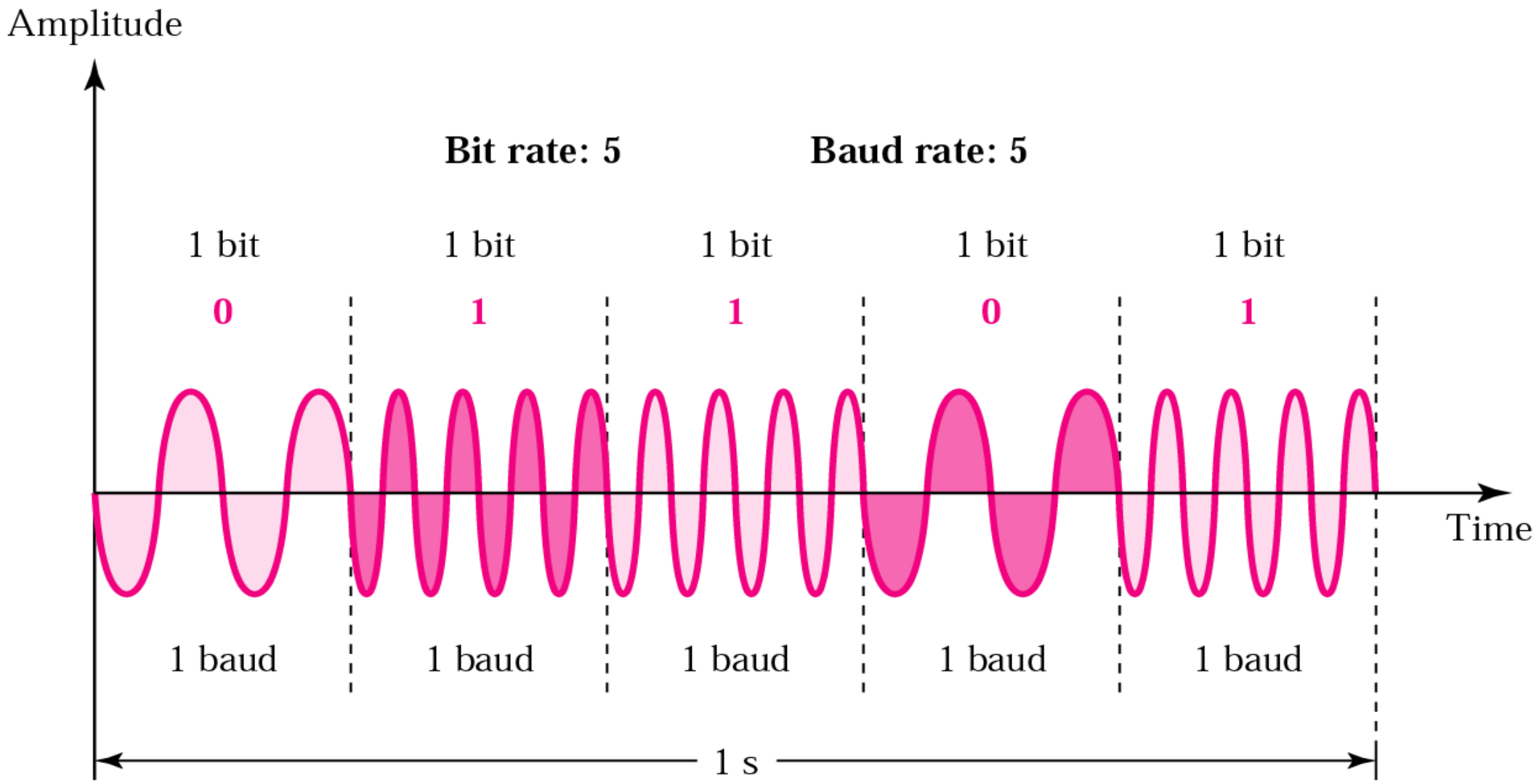
- encode 0/1 by different carrier amplitudes
  - usually have one amplitude zero
- susceptible to sudden gain changes
- inefficient
- used for
  - up to 1200bps on voice grade lines
  - very high speeds over optical fiber



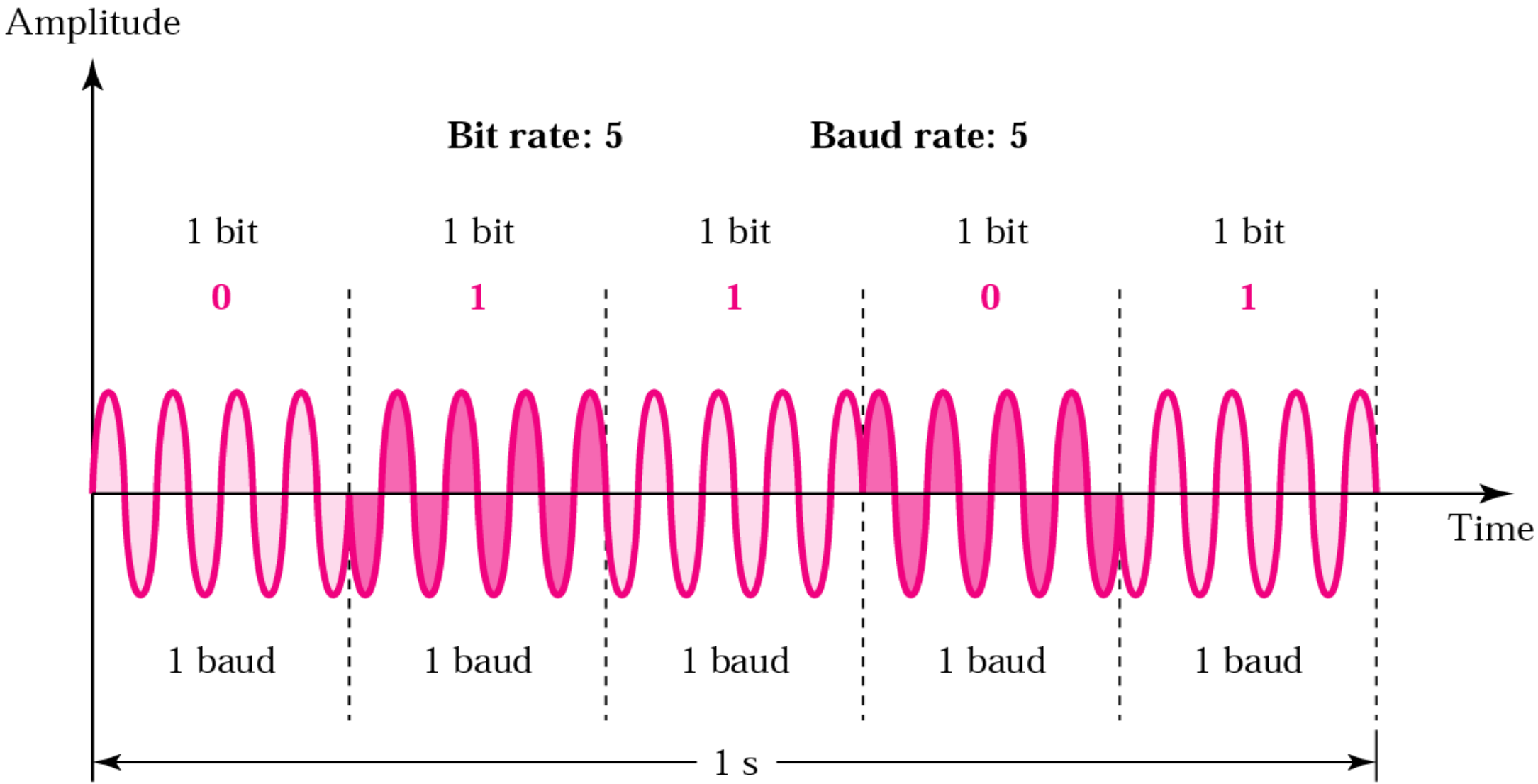
Amplitude Shift Keying



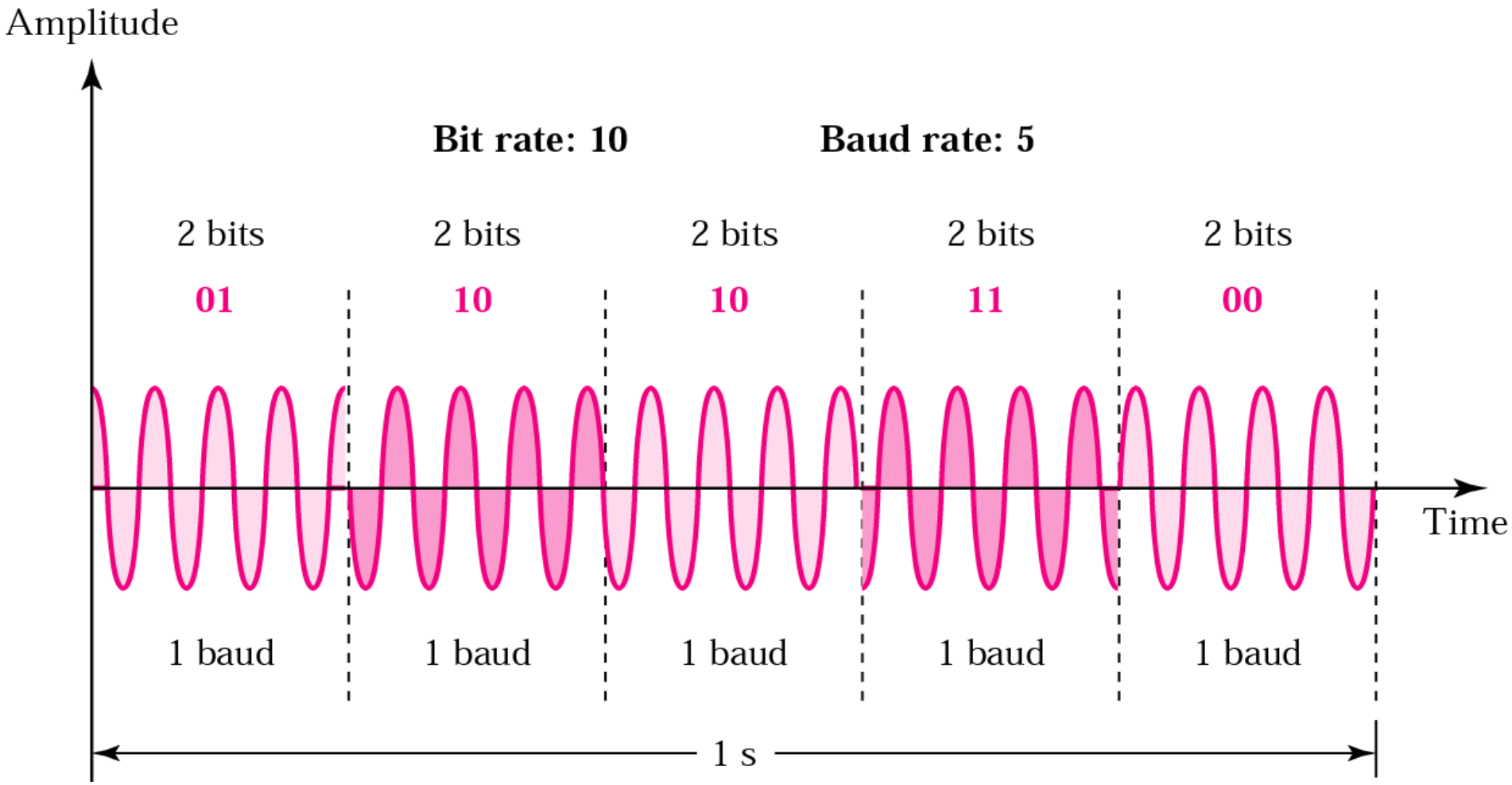
Frequency Shift Keying



Phase Shift Keying

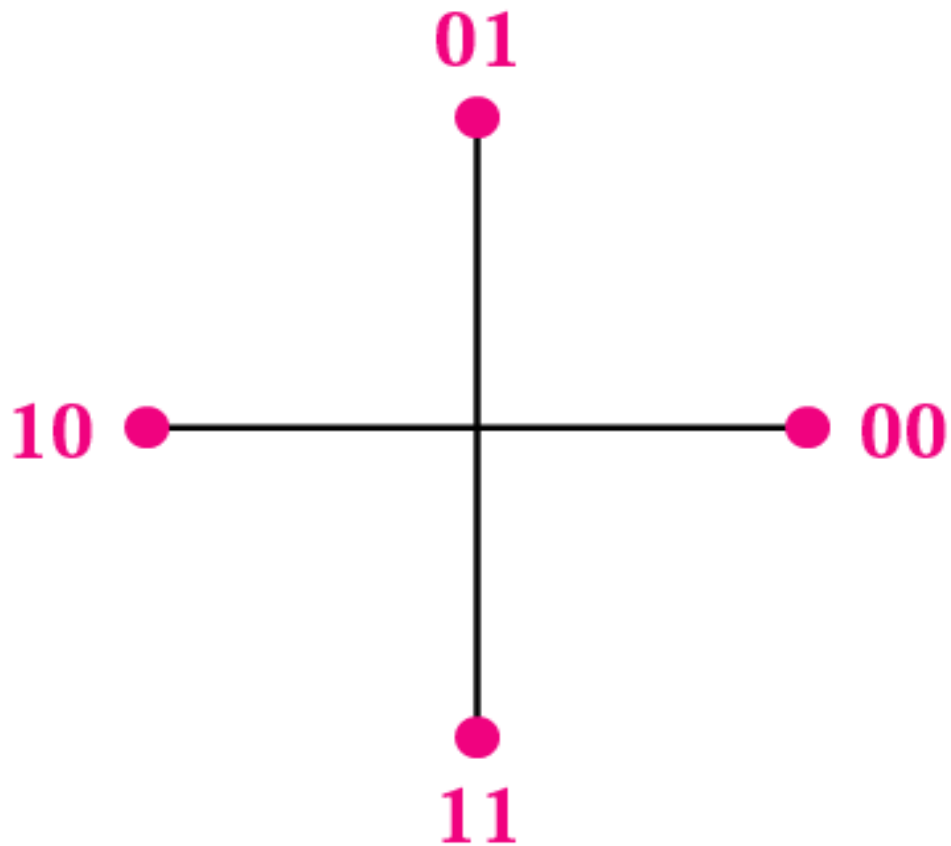


Quadrature Phase Shift Keying



Dibit	Phase
00	0
01	90
10	180
11	270

Dibit
(2 bits)

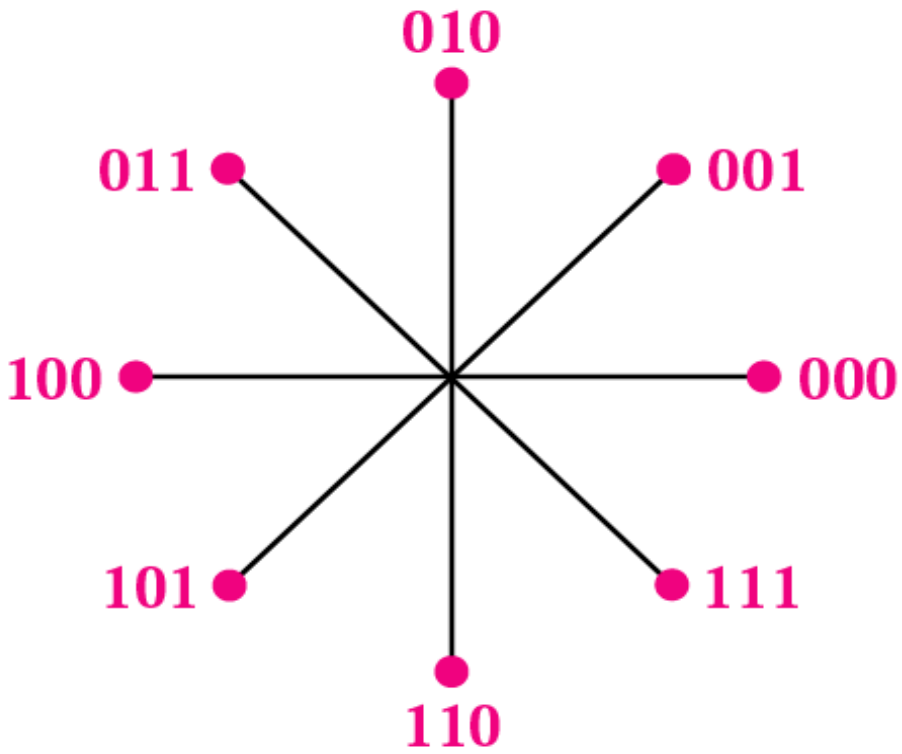


Constellation diagram

8-level Phase Shift Keying

Tribit	Phase
000	0
001	45
010	90
011	135
100	180
101	225
110	270
111	315

Tribits
(3 bits)



Constellation diagram

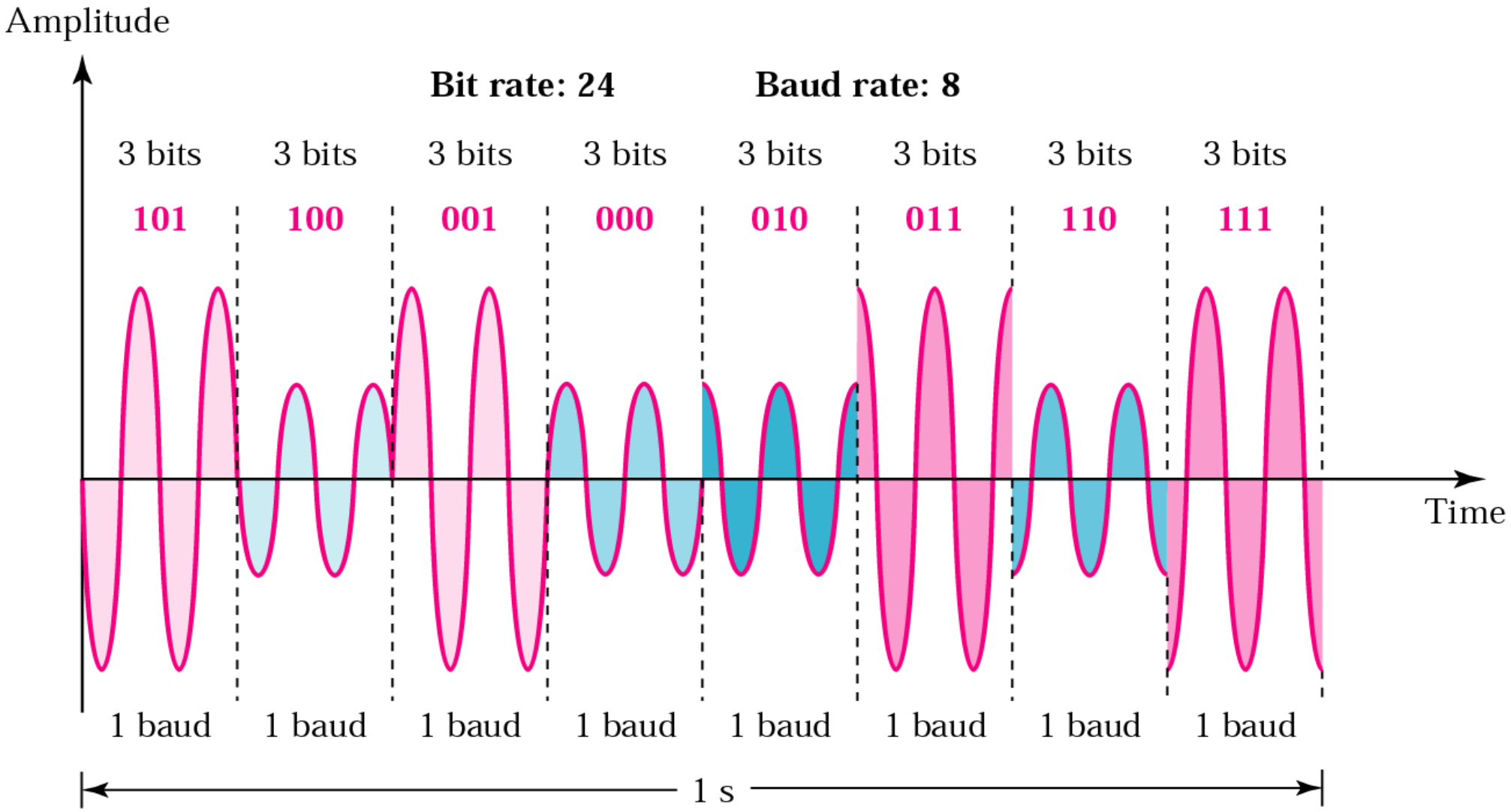
Performance of Digital to Analog Modulation Schemes

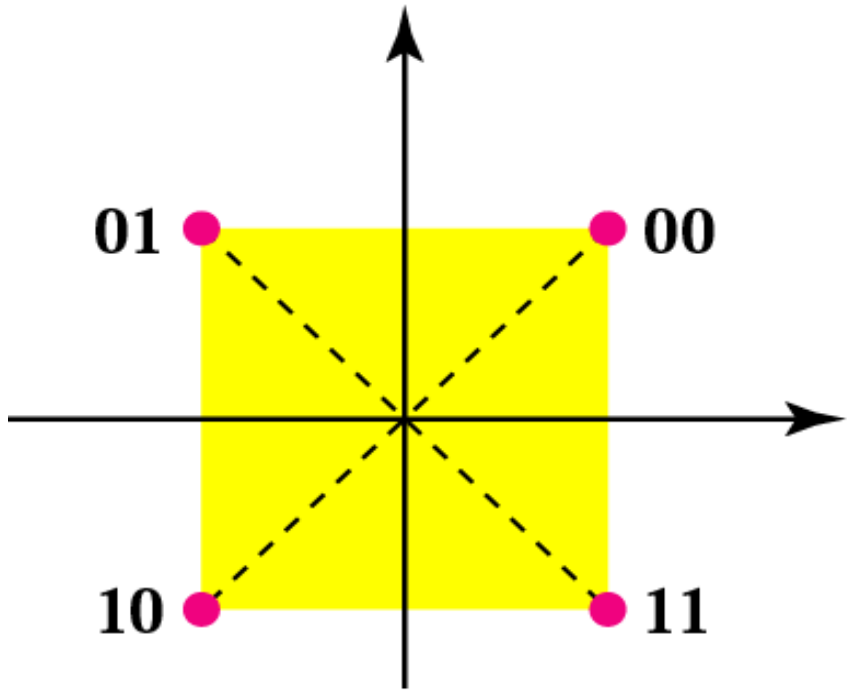
- bandwidth
  - ASK/PSK bandwidth directly relates to bit rate
  - multilevel PSK gives significant improvements
- in presence of noise:
  - bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK
  - for MFSK & MPSK have tradeoff between bandwidth efficiency and error performance

Quadrature Amplitude Modulation

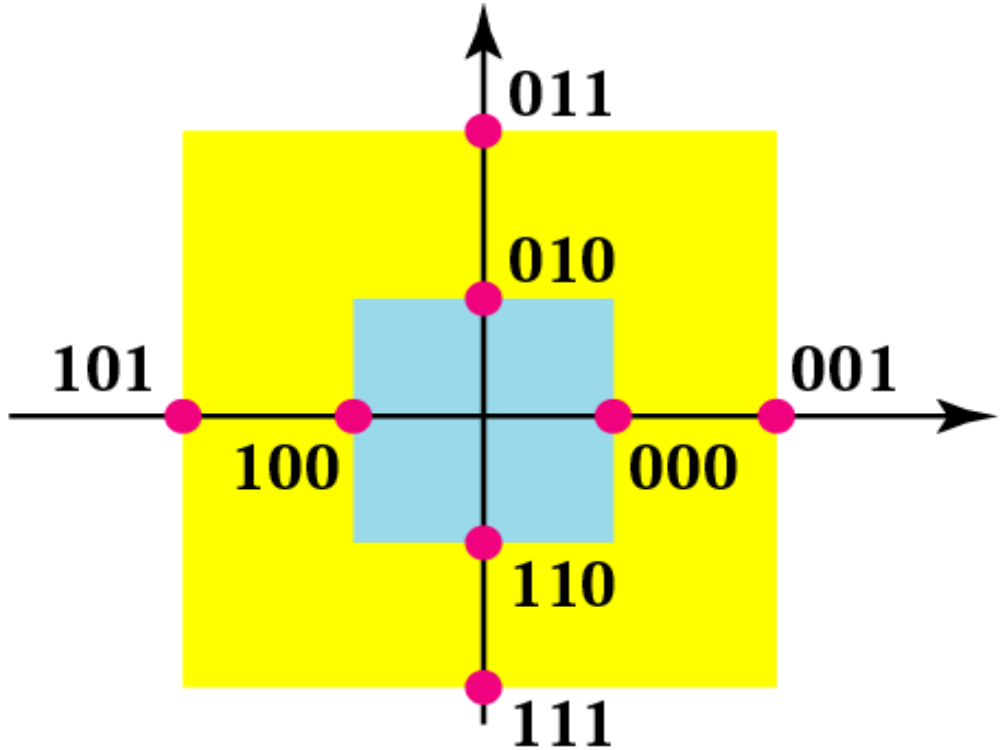
- QAM used on asymmetric digital subscriber line (ADSL) and some wireless
- combination of ASK and PSK
- logical extension of QPSK
- send two different signals simultaneously on same carrier frequency
  - use two copies of carrier, one shifted 90°
  - each carrier is ASK modulated
  - two independent signals over same medium
  - demodulate and combine for original binary output

8-QAM


Amplitude
Bit rate: 24
Baud rate: 8
3 bits
3 bits
3 bits
3 bits
3 bits
3 bits
3 bits
3 bits
101
100
001
000
010
011
110
111
Time
1 baud
1 baud
1 baud
1 baud
1 baud
1 baud
1 baud
1 baud
1 s



4-QAM
1 amplitude, 4 phases

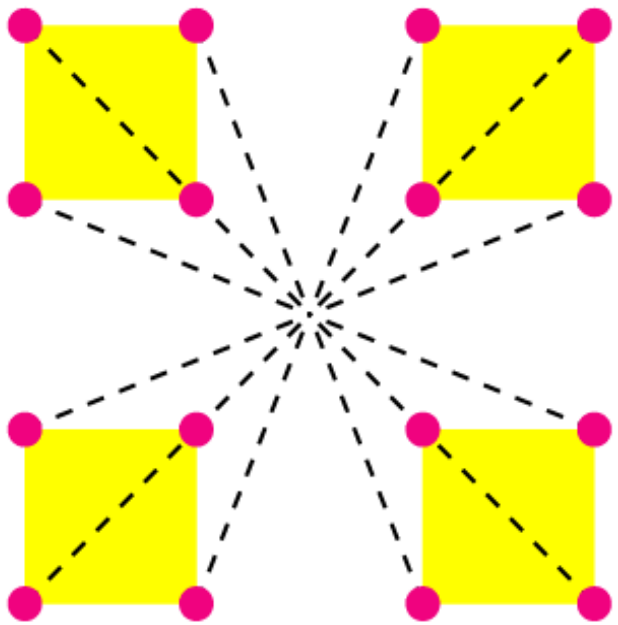


8-QAM
2 amplitudes, 4 phases

QAM Variants

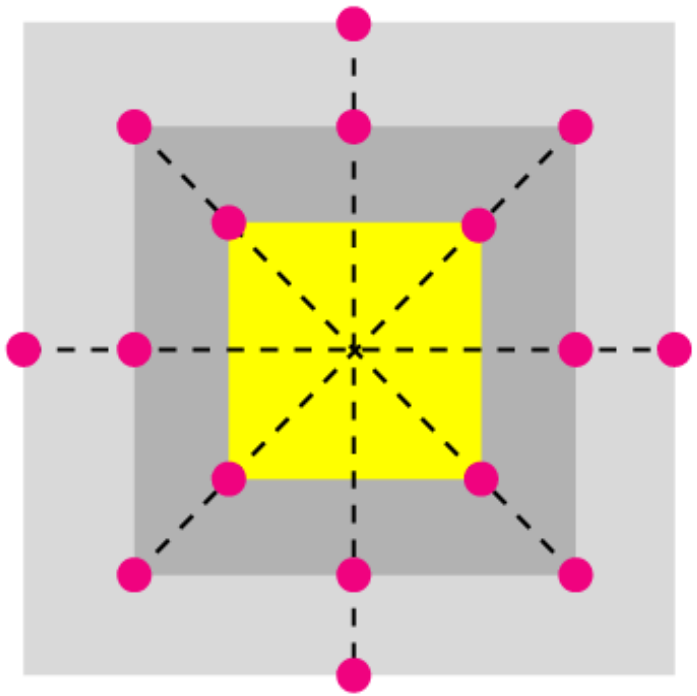
- two level ASK
  - each of two streams in one of two states
  - four state system
  - essentially QPSK
- four level ASK
  - combined stream in one of 16 states
- have 64 and 256 state systems
- improved data rate for given bandwidth
  - but increased potential error rate

3 amplitudes, 12 phases



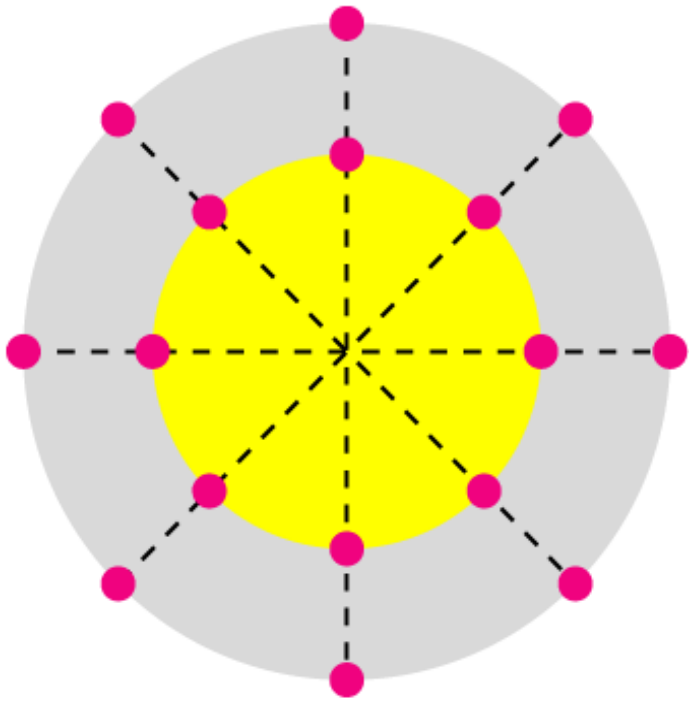
16-QAM

4 amplitudes, 8 phases



16-QAM

2 amplitudes, 8 phases



16-QAM

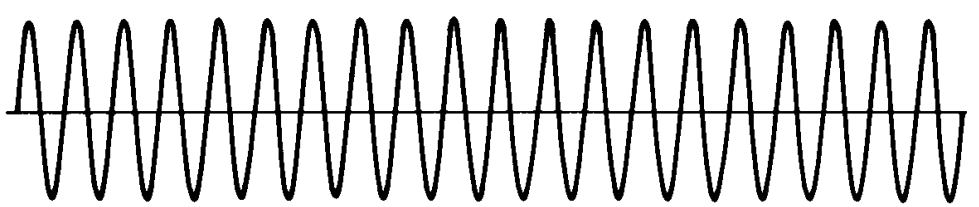
Modulation	Units	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK	Bit	1	N	N
4-PSK, 4-QAM	Dibit	2	N	2N
8-PSK, 8-QAM	Tribit	3	N	3N
16-QAM	Quadbit	4	N	4N
32-QAM	Pentabit	5	N	5N
64-QAM	Hexabit	6	N	6N
128-QAM	Septabit	7	N	7N
256-QAM	Octabit	8	N	8N

Analog Data, Analog Signals

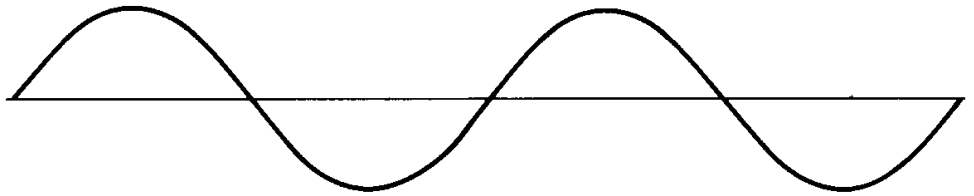
- modulate carrier frequency with analog data
- why modulate analog signals?
  - higher frequency can give more efficient transmission
  - permits frequency division multiplexing (chapter 8)
- types of modulation
  - Amplitude
  - Frequency
  - Phase

Analog Modulation Techniques

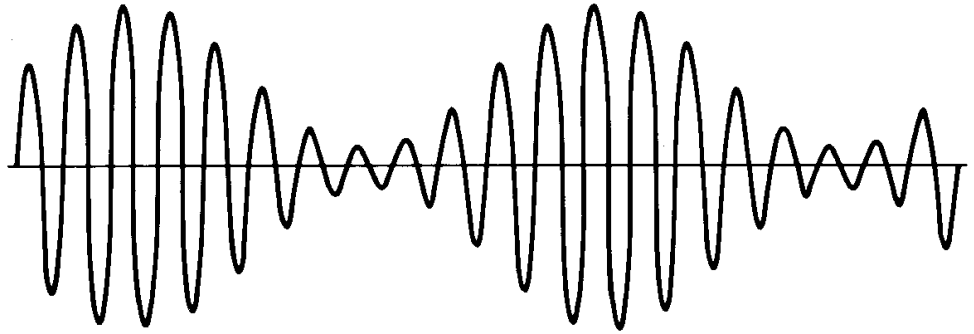
- Amplitude Modulation
- Frequency Modulation
- Phase Modulation



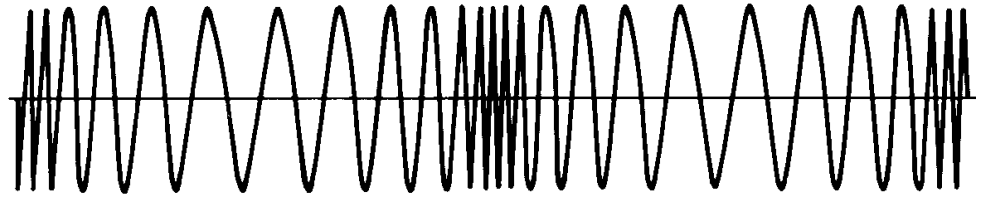
Carrier



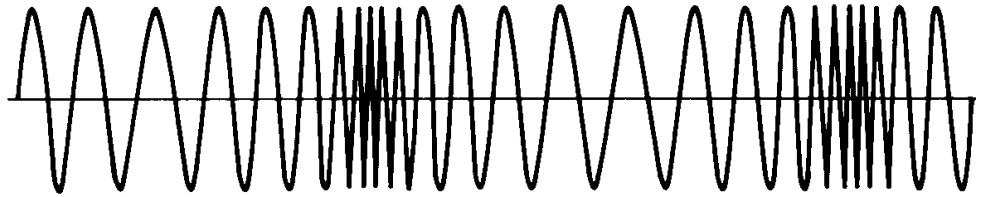
Modulating sine-wave signal



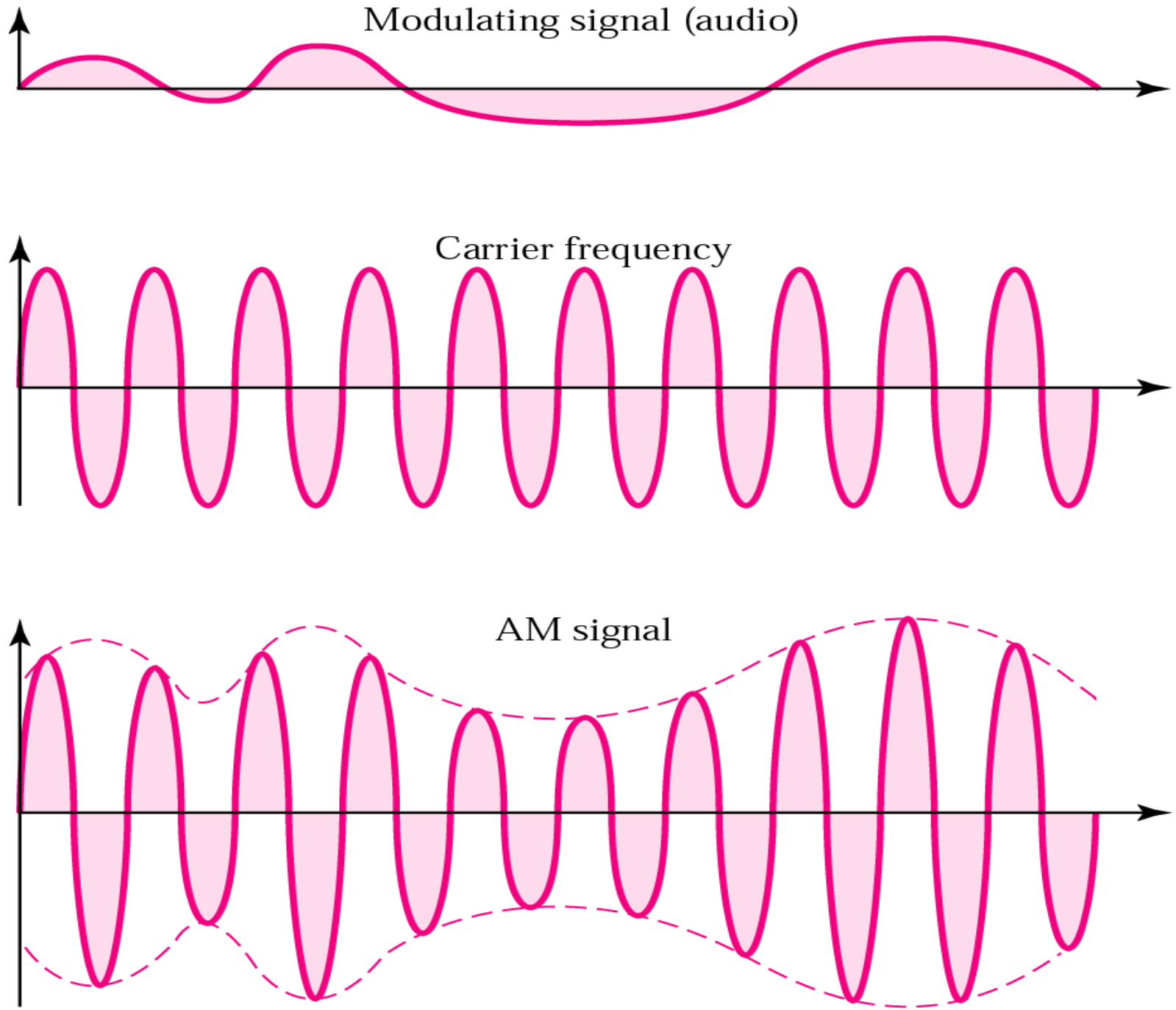
Amplitude-modulated (DSBTC) wave



Phase-modulated wave



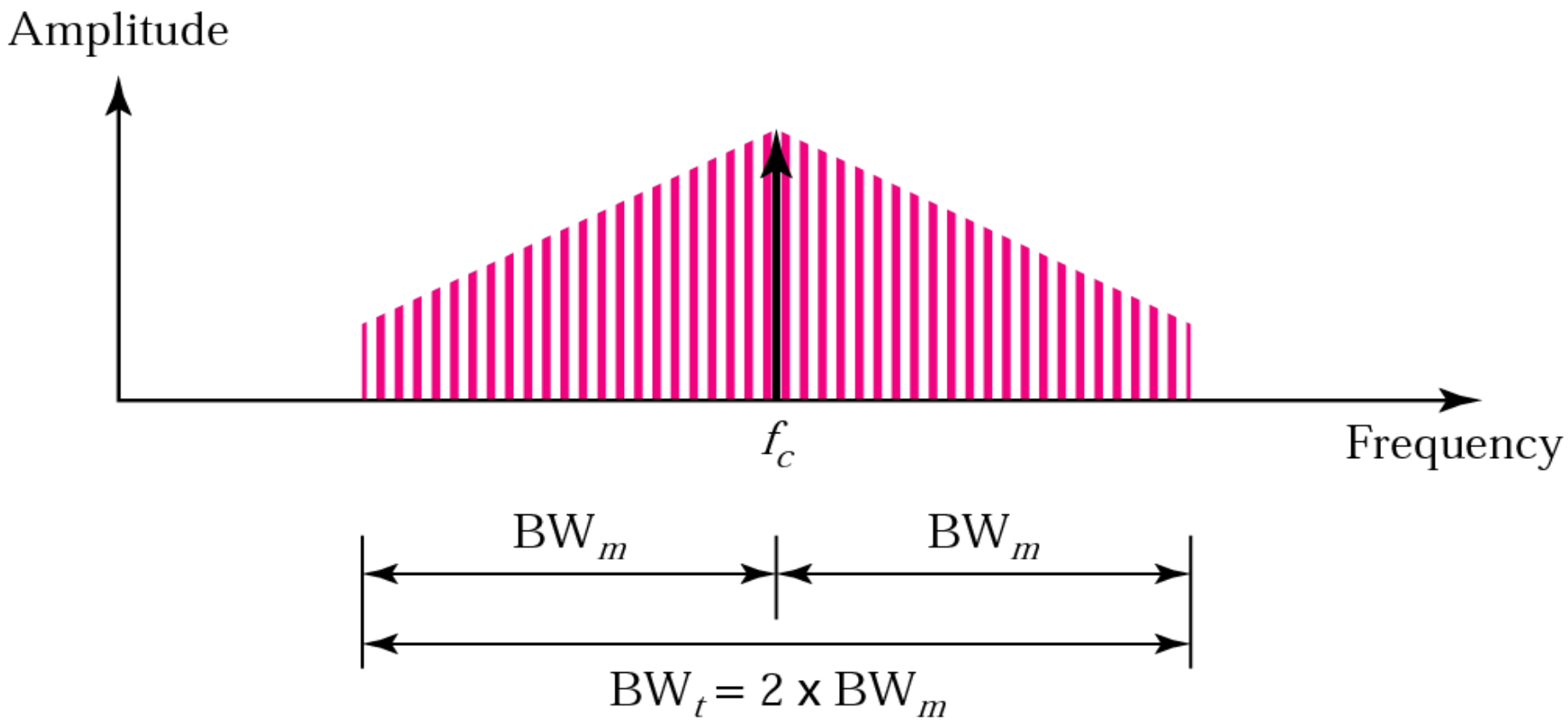
Frequency-modulated wave

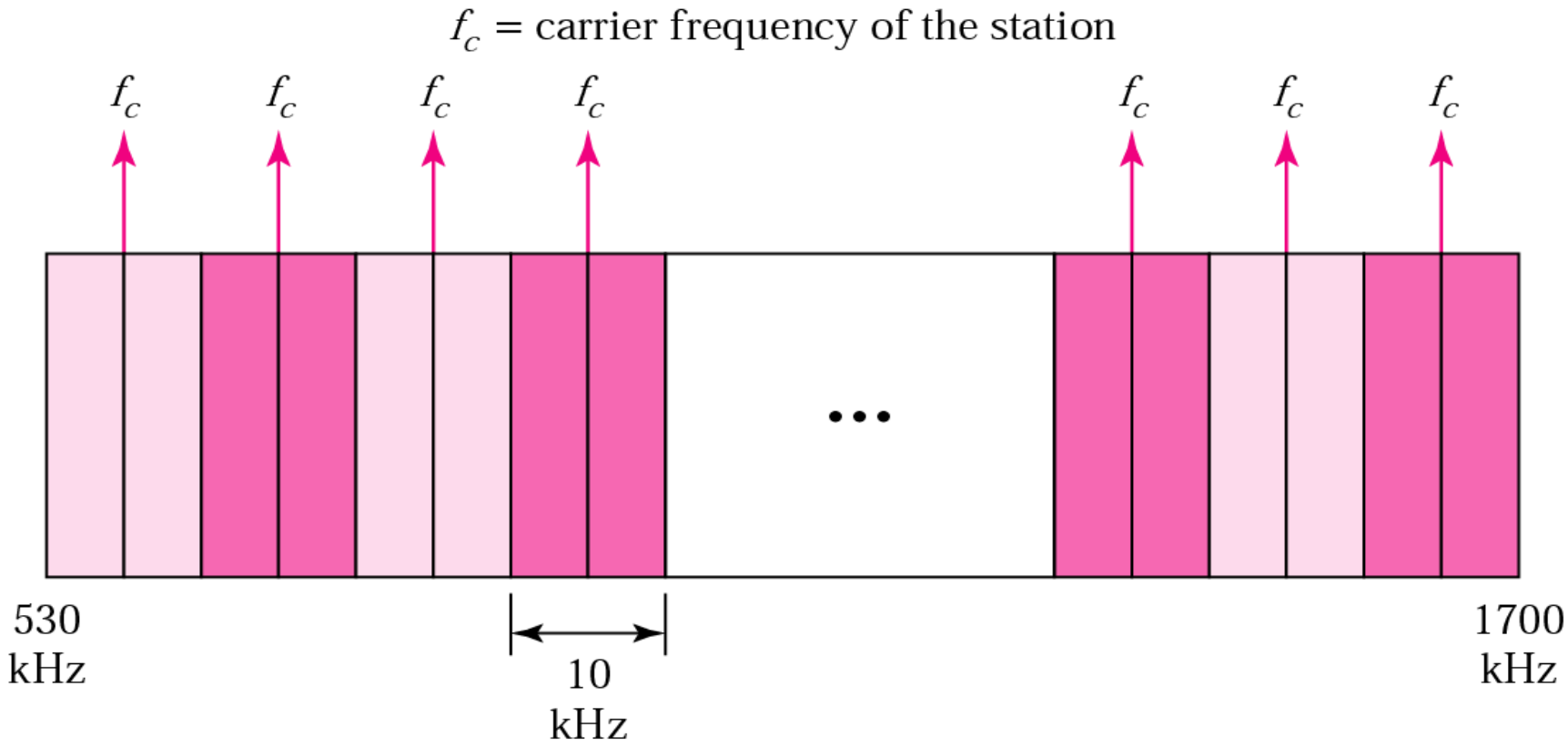

Modulating signal (audio)
Carrier frequency
AM signal

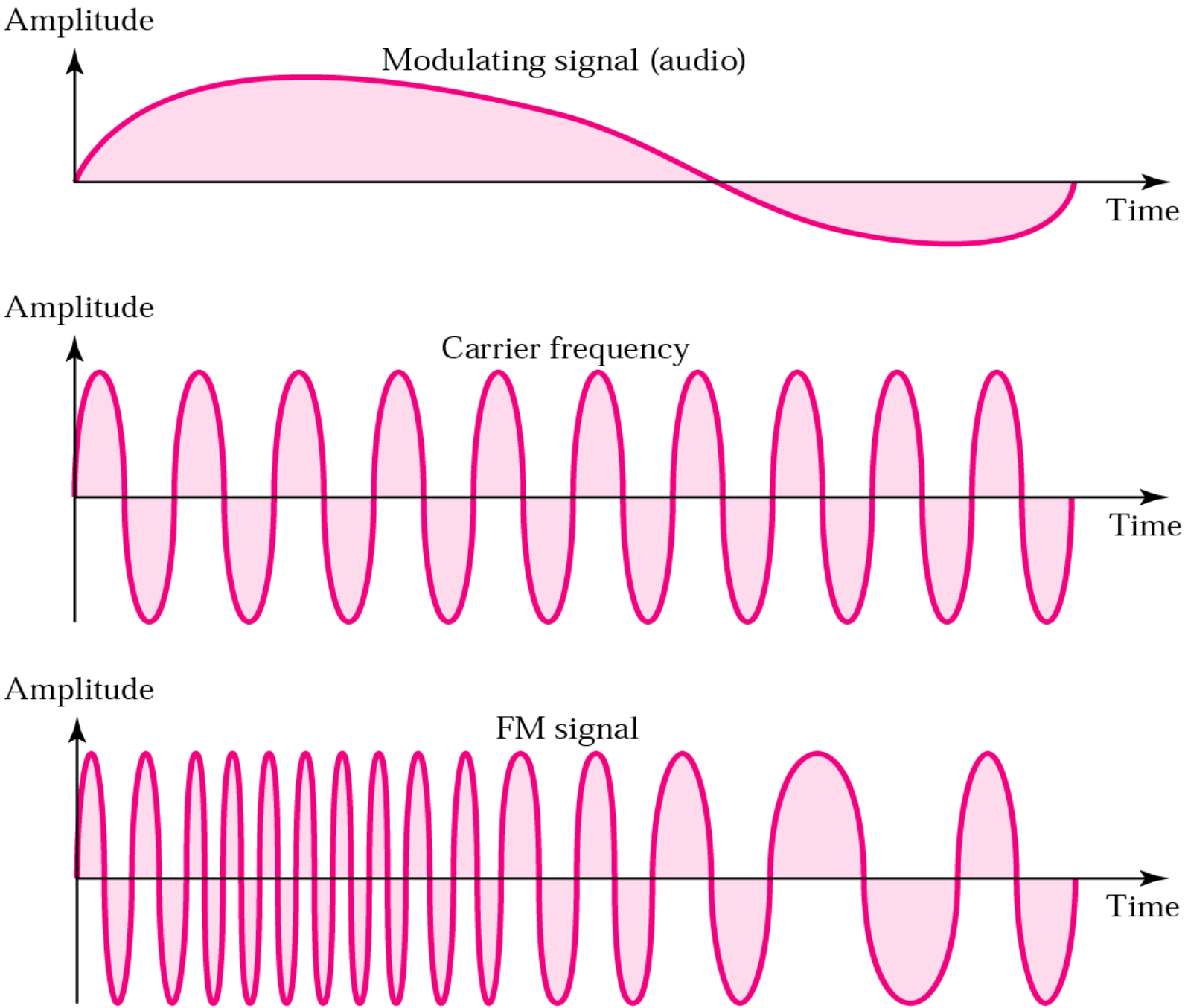
BW_m = bandwidth of the modulating signal (audio)

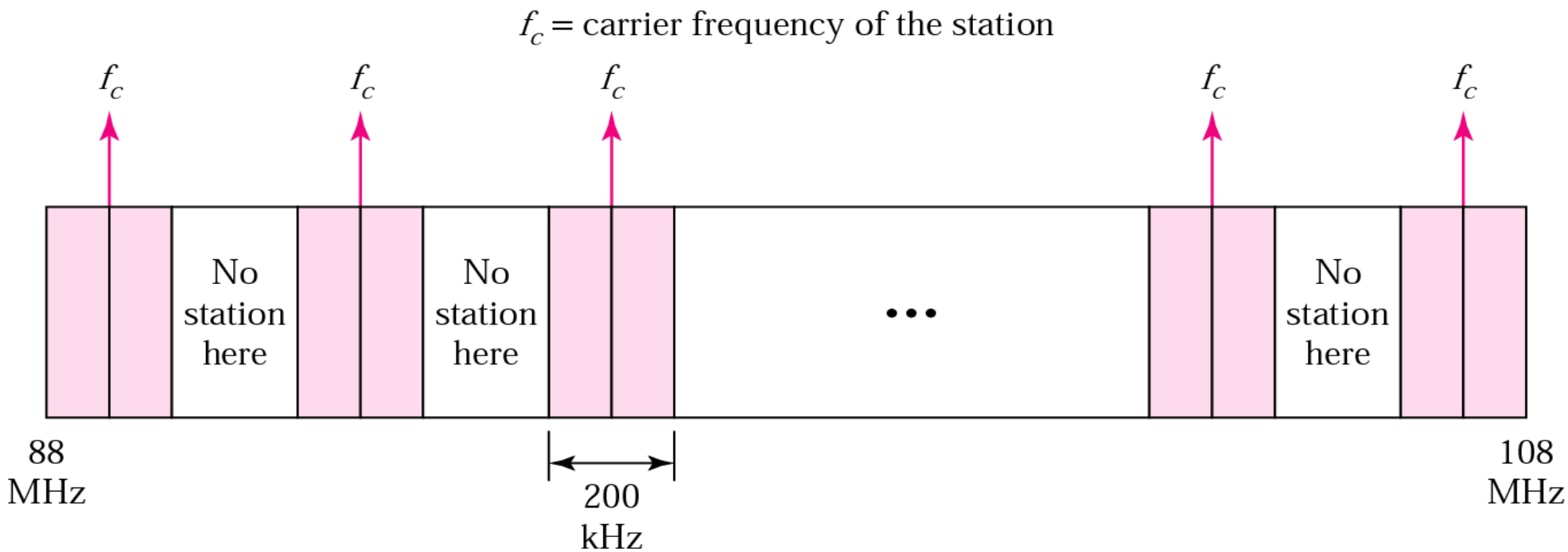
BW_t = total bandwidth (radio)

f_c = frequency of the carrier




f_c = carrier frequency of the station
f_c
f_c
f_c
f_c
f_c
f_c
f_c
530 kHz
10 kHz
1700 kHz


Amplitude
Modulating signal (audio)
Time
Amplitude
Carrier frequency
Time
Amplitude
FM signal
Time


f_c = carrier frequency of the station
f_c
f_c
f_c
f_c
f_c
No station here
No station here
No station here
88 MHz
200 kHz
108 MHz