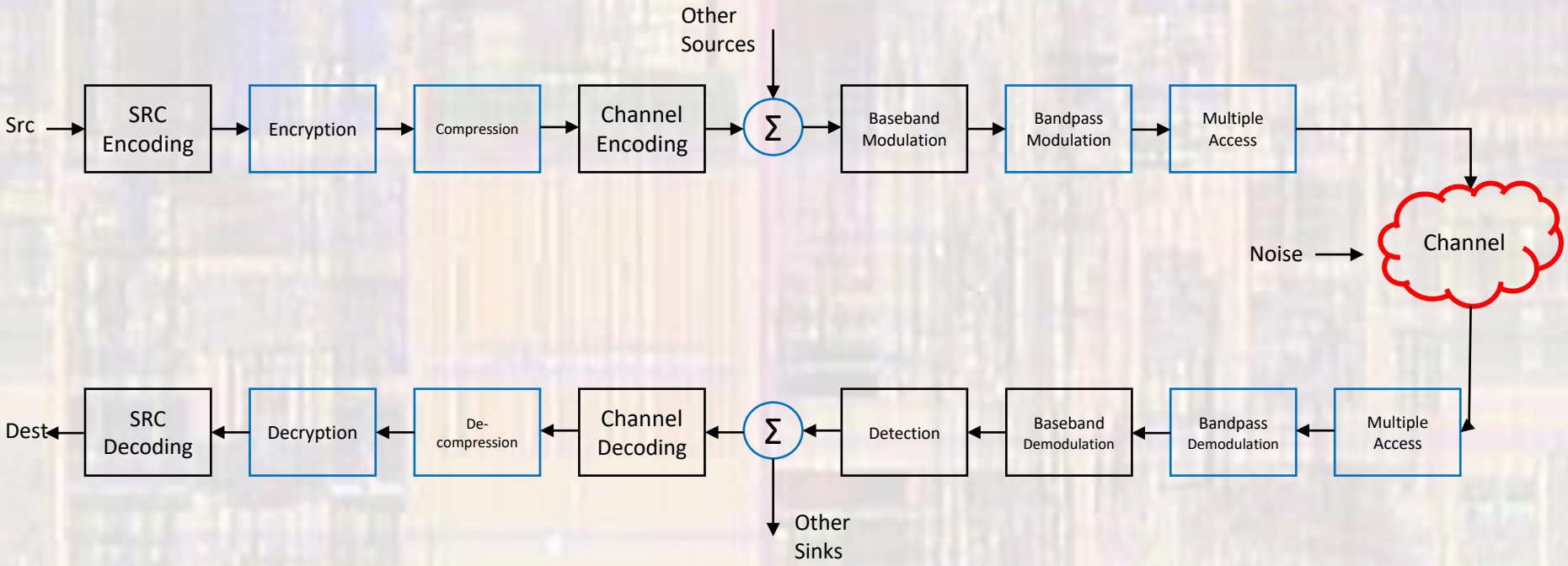
Data Communications

Last updated 4/15/24

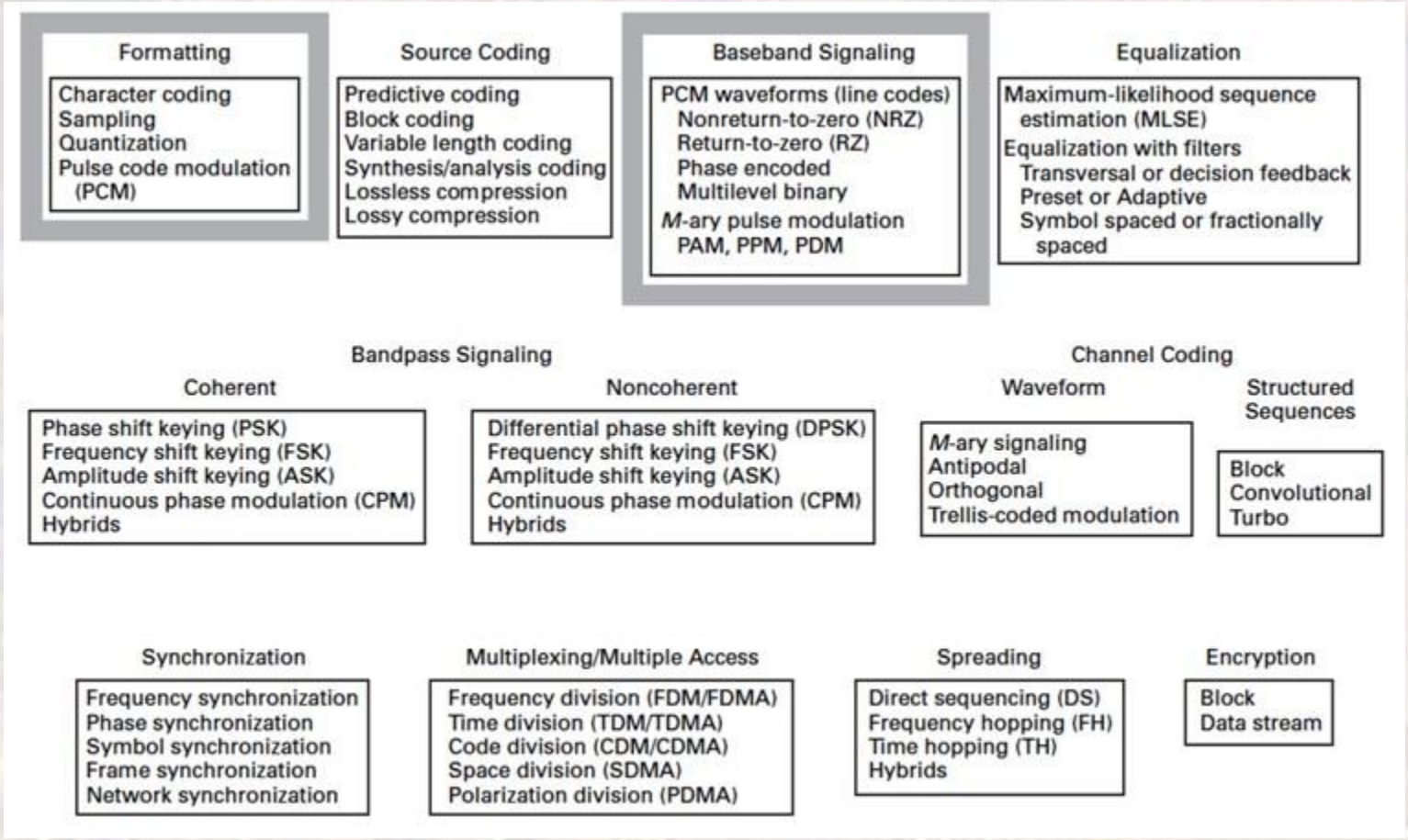
Data Communications

- Generalized Digital Communications System



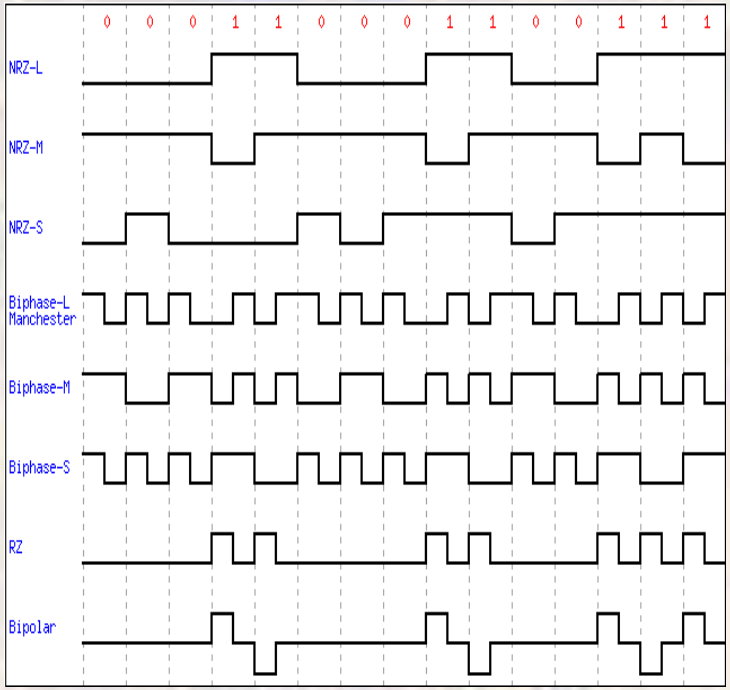
Data Communications

- Generalized Digital Communications System



Data Communications

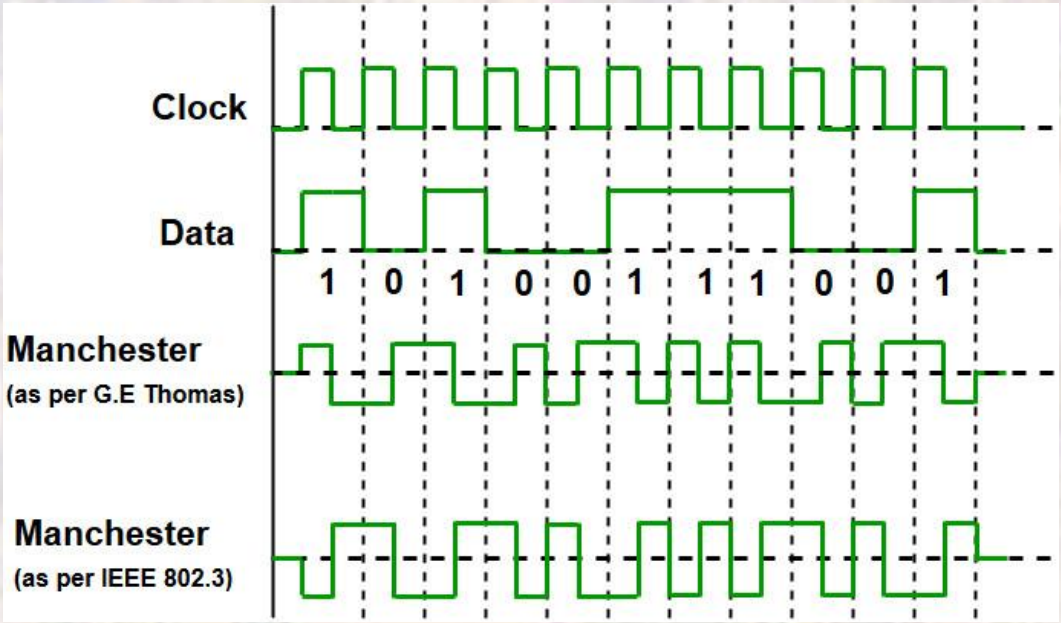
- Baseband Modulation
  - Basic



NRZ-L	**Non Return-to-Zero (Level)** At the start of each bit time, the signal level goes high if the bit is 1, or low if it is 0.
NRZ-M NRZI	**Non Return-to-Zero (Mark)***or* **Non Return-to-Zero Inverted** At the start of each bit time, the signal level changes if the bit is 1
NRZ-S	**Non Return-to-Zero (Space)** At the start of each bit time, the signal level changes if the bit is 0
Biphase-L Manchester	**Biphase (Level) or "Manchester"** The signal level changes in the middle of every bit time, with a rising edge if the bit is 1 or a falling edge if the bit is 0.
Biphase-M	**Biphase (Mark)** The signal level changes at the start of every bit time. The signal level changes in the middle of a bit time if the bit is 1
Biphase-S	**Biphase (Space)** The signal level changes at the start of every bit time. The signal level changes in the middle of a bit time if the bit is 0
RZ	**Return-to-Zero** The signal level is normally low. At the start of each bit time, the signal level goes high if the bit is 1, then returns to normal in the middle of the bit time.
Bipolar-RZ	**Bipolar Return-to-Zero** The signal level is normally low. At the start of each bit time, the signal level goes high if the bit is 1, then returns to normal in the middle of the bit time. On alternate pulses, the signal level goes negative if the bit is 1, then returns to normal in the middle of the bit time.

Data Communications

- Baseband Modulation
  - Manchester



Data Communications

- Baseband Modulation
  - 4b/5b

Data Sequence	*Encoded Sequence*	*Control Sequence*	*Encoded Sequence*
0000	11110	Q (Quiet)	00000
0001	01001	I (Idle)	11111
0010	10100	H (Halt)	00100
0011	10101	J (Start delimiter)	11000
0100	01010	K (Start delimiter)	10001
0101	01011	T (End delimiter)	01101
0110	01110	S (Set)	11001
0111	01111	R (Reset)	00111
1000	10010		
1001	10011		
1010	10110		
1011	10111		
1100	11010		
1101	11011		
1110	11100		
1111	11101		

Data Communications

- Baseband Modulation
  - 8b/10b

Rules for Running Disparity

Previous RD	Disparity of code word	Disparity chosen	Next RD
−1	0	0	−1
−1	±2	+2	+1
+1	0	0	+1
+1	±2	−2	−1

3b/4b code

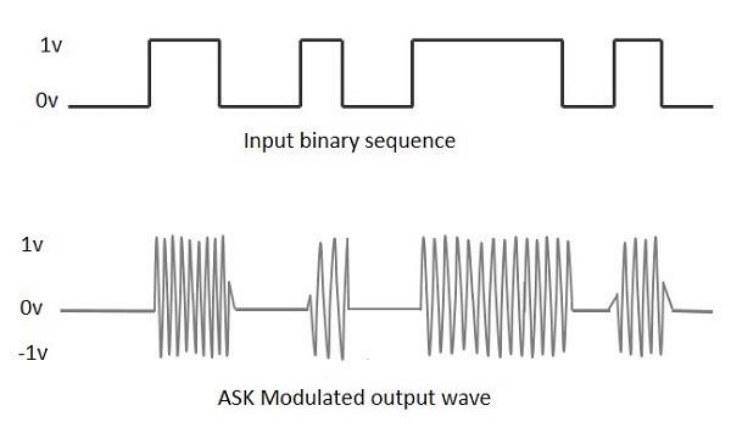
input		RD = −1	RD = +1	input		RD = −1	RD = +1
	HGF	fghj			HGF	fghj	
D.x.0	000	1011	0100	K.x.0	000	1011	0100
D.x.1	001	1001		K.x.1 ‡	001	0110	1001
D.x.2	010	0101		K.x.2 ‡	001	1010	0101
D.x.3	011	1100	0011	K.x.3	011	1100	0011
D.x.4	100	1101	0010	K.x.4	100	1101	0010
D.x.5	101	1010		K.x.5 ‡	001	0101	1010
D.x.6	110	0110		K.x.6 ‡	001	1001	0110
D.x.P7 †	111	1110	0001				
D.x.A7 †	111	0111	1000	K.x.7 † ‡	111	0111	1000

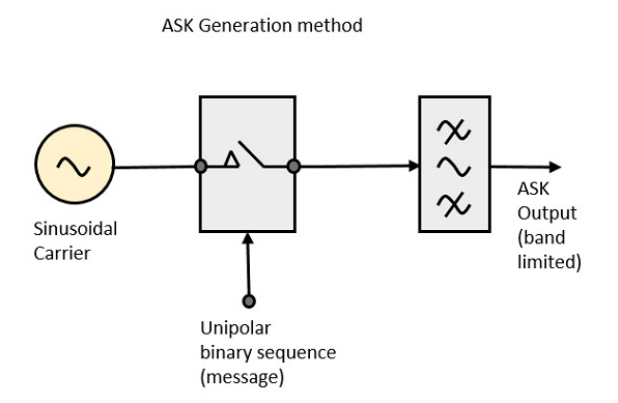
5B/6B code

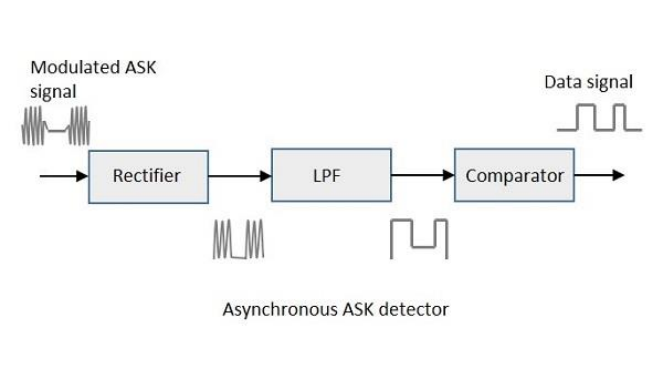
input		RD = −1	RD = +1	input		RD = −1	RD = +1
	EDCBA	abcdei			EDCBA	abcdei	
D.00	00000	100111	011000	D.16	10000	011011	100100
D.01	00001	011101	100010	D.17	10001	100011	
D.02	00010	101101	010010	D.18	10010	010011	
D.03	00011	110001		D.19	10011	110010	
D.04	00100	110101	001010	D.20	10100	001011	
D.05	00101	101001		D.21	10101	101010	
D.06	00110	011001		D.22	10110	011010	
D.07	00111	111000	000111	D.23 †	10111	111010	000101
D.08	01000	111001	000110	D.24	11000	110011	001100
D.09	01001	100101		D.25	11001	100110	
D.10	01010	010101		D.26	11010	010110	
D.11	01011	110100		D.27 †	11011	110110	001001
D.12	01100	001101		D.28	11100	001110	
D.13	01101	101100		D.29 †	11101	101110	010001
D.14	01110	011100		D.30 †	11110	011110	100001
D.15	01111	010111	101000	D.31	11111	101011	010100
				K.28	11100	001111	110000

Data Communications

- Bandpass Modulation
  - ASK

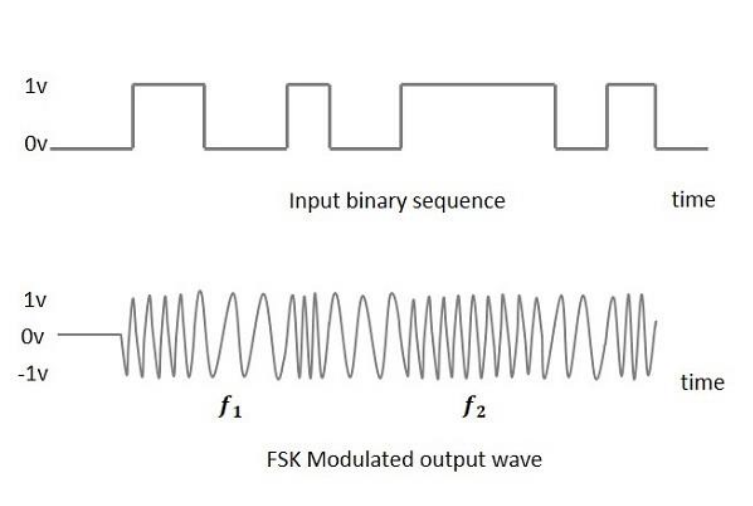


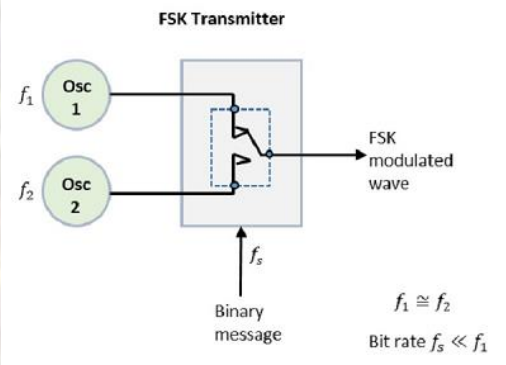


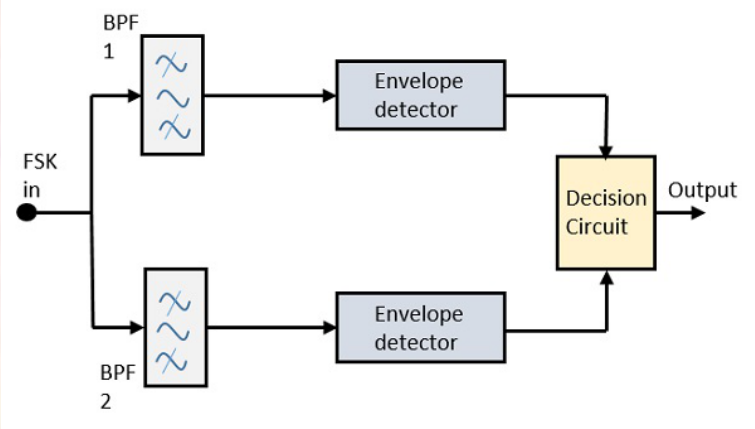


Data Communications

- Bandpass Modulation
  - FSK

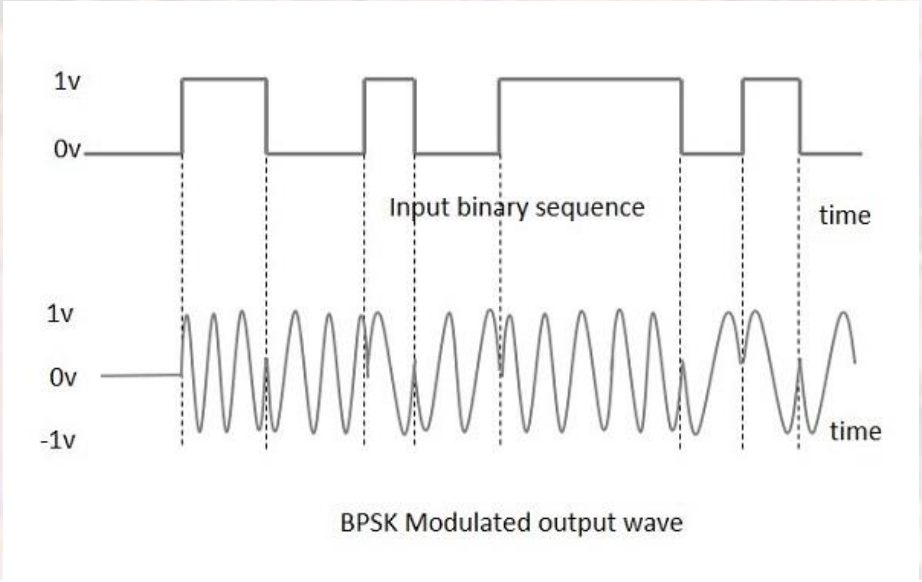


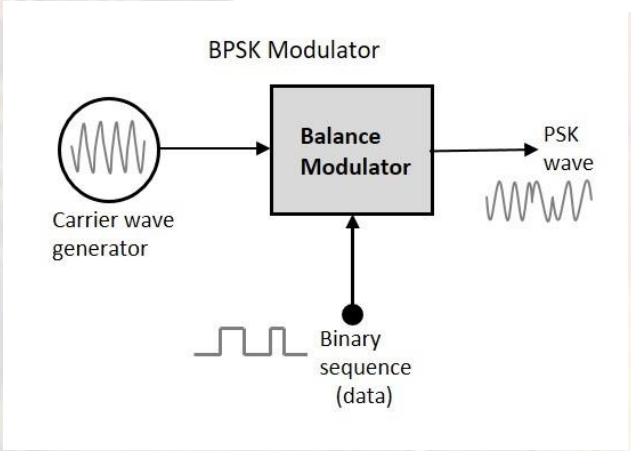


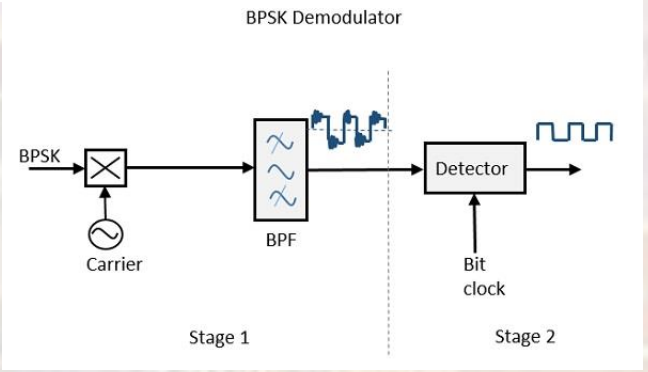


Data Communications

- Bandpass Modulation
  - BPSK

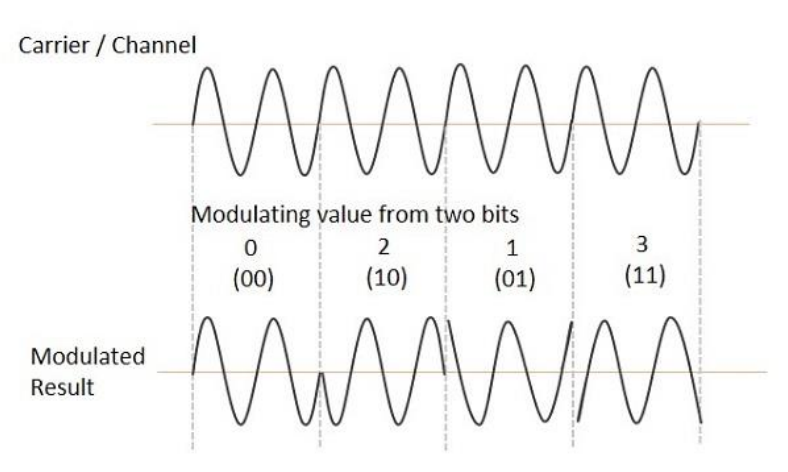


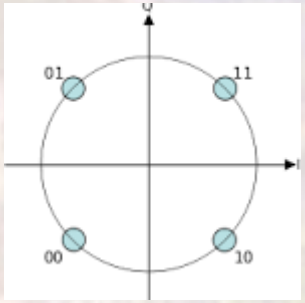


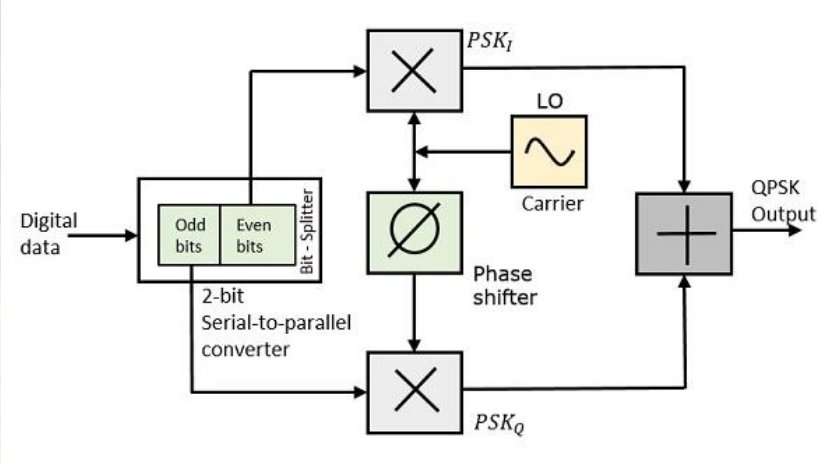


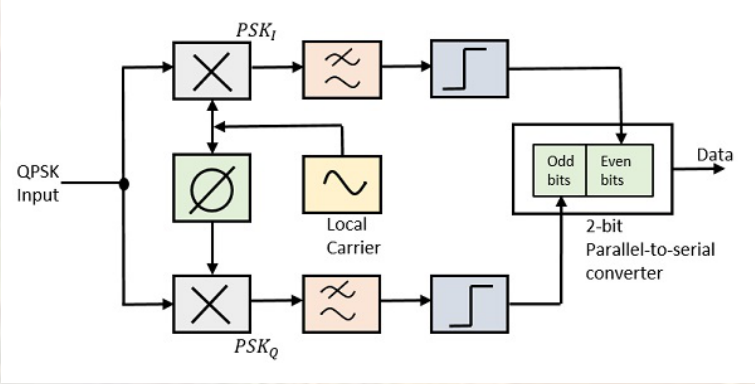
Data Communications

- Bandpass Modulation
  - QPSK



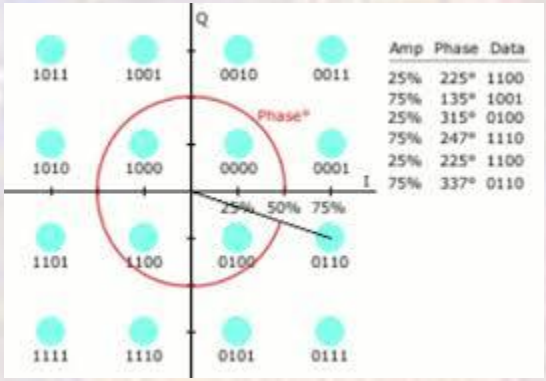


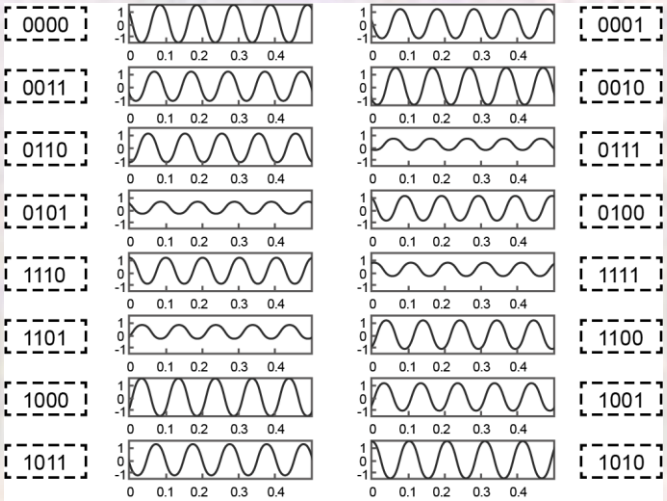




Data Communications

- Bandpass Modulation
  - QAM (16)





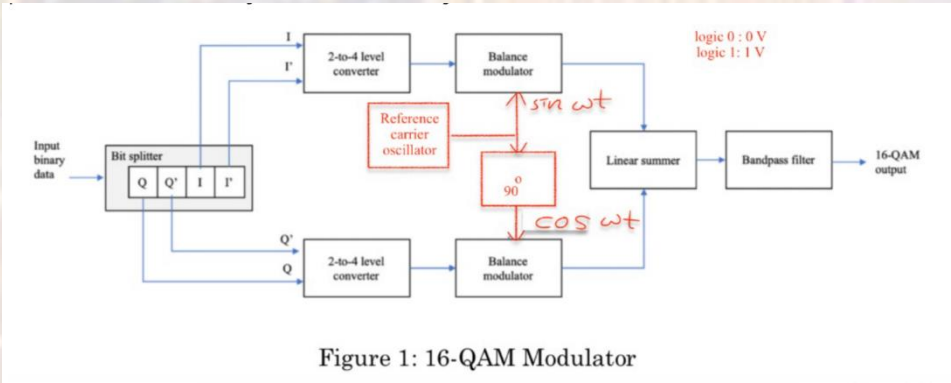
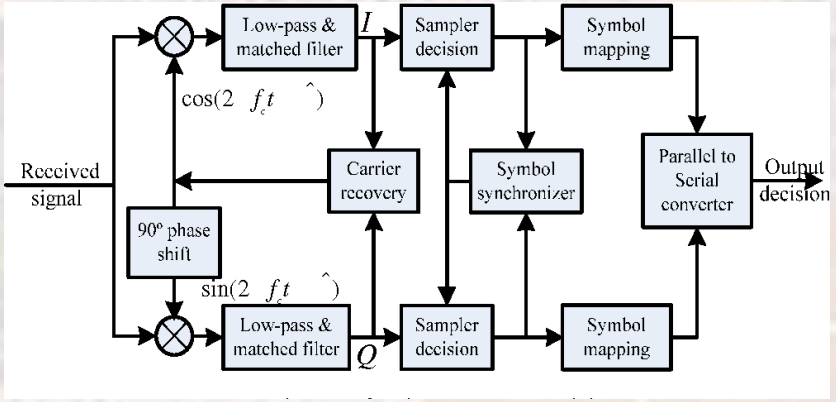


Figure 1: 16-QAM Modulator

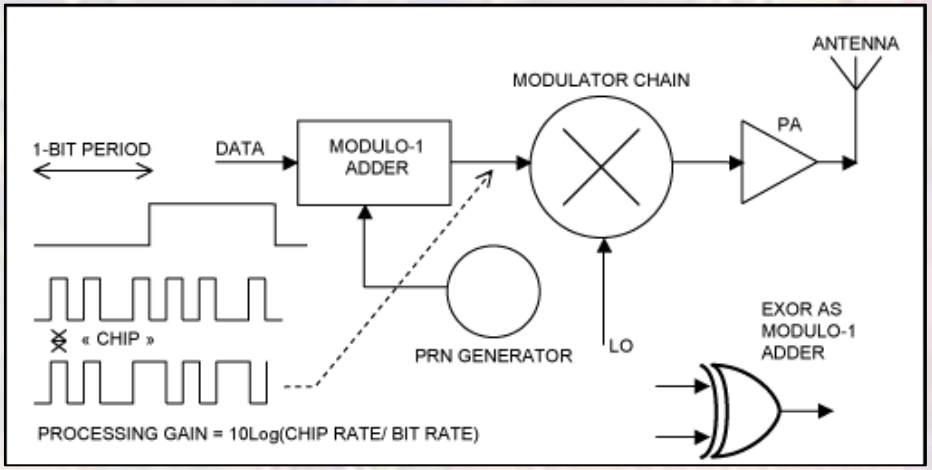


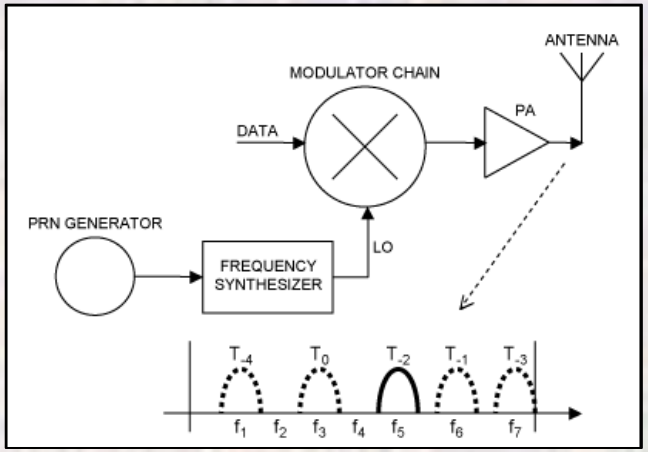
Data Communications

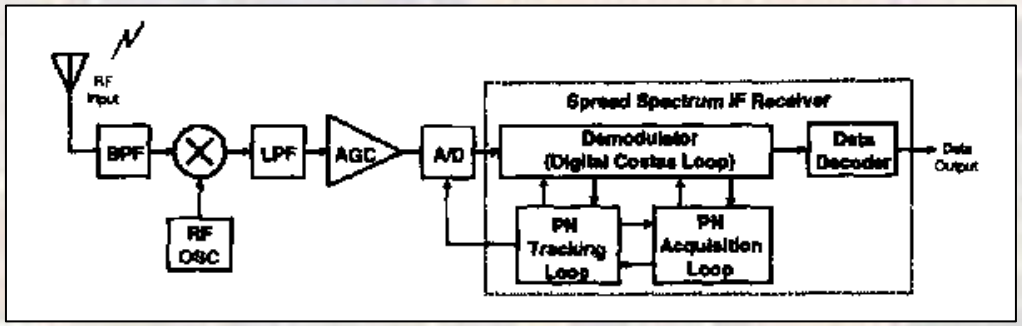
- Bandpass Modulation
  - Spread Spectrum
    - Large codes are used to modulate the signal
    - Direct Sequence
      - 1 bit → 4096 bits
    - Frequency hopping
      - Codes used to select frequencies
    - Spreads the spectrum
      - With same energy and wider bandwidth – signal level drops
        - Looks like noise
    - Due to unique codes multiple users can occupy the same band
    - Hard to jam
    - Hard to eavesdrop

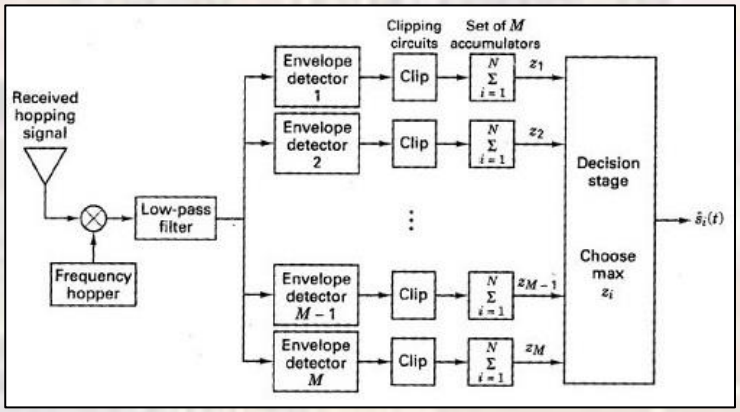
Data Communications

- Bandpass Modulation
  - Spread Spectrum









Data Communications

- Multiple Access
  - TDMA
    - Common frequency, Time driven slots
  - FDMA
    - Separate carrier frequencies (Channels)
  - CDMA
    - Unique code used to create unique spread spectrum signals
  - SDMA
    - Space division – using directional anntenas