DIGITAL MODULATION TECHNIQUES

EEEN 464 – DIGITAL COMMUNICATION

Tuesday, 03 June 2025

WHERE?
ELC 416 CURRICULUM

ECE 416 – DIGITAL COMMUNICATION SYSTEMS (3 Units)

Pre-requisites: ECE 328 - Principles of Communication Systems

Course Purpose:
To enable students understand the fundamental principles of digital transmission systems as used in fixed and mobile telephony, wired and wireless computer networks, data storage and digital broadcasting.

Expected Learning Outcomes:
At the end of the course, students will be able to:

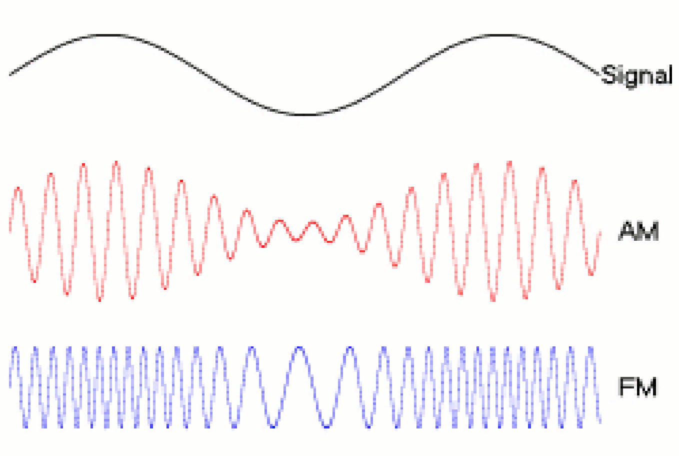
(i) describe binary and duo binary pulse Amplitude Modulation (PAM);
(ii) design digital coding schemes;
(iii) derive error performance equations for digital modulation schemes(ASK,FSK,PSK,DPSK);
(iv) state strengths and weaknesses of M-ary PSK with QAM signaling schemes;
(v) design a basic digital communication systems.

Course Content:
Signal digitization: Pulse Amplitude Modulation (PAM), sampling theorems and sampling circuits, Pulse code modulation (PCM). Quantization and signal conditioning: Uniform and non-uniform quantization; companding methods; vocoders; signal-to- quantization noise ratio. Waveform coding: Pulse transmission, PCM, Pulse-shaping; Delta modulation; adaptive delta modulation; Differential Pulse Code Modulation (DPCM), M-ary encoding. Digital Modulation: Amplitude shift keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM) and Differential Phase Shift Keying (DPSK). Signal recovery in ASK, FSK and PSK; Gaussian Minimum Shift Keying (GMSK); Performance comparison. Information theory: information sources, entropy, channel capacity; Source Coding; entropy coding. Error control: Error control coding techniques; Transmission errors; Error detection methods; intersymbol interference and the eye pattern; Linear block codes; Cyclic codes; convolution codes. Multiplexing: Frequency division multiplex (FDM), Time Division Multiplexing (TDM), plesiochronous digital hierarchy (PDH). Spread spectrum communication: Direct sequence and frequency hopping methods; synchronization, spreading codes and their generation. Data transmission: Local data transmission protocals (Ethernet, token ring); Modems; high Asymmetric Digital subscriber line (ADSL); Very–high Speed Digital subscriber line (VDSL), integrated services digital network (ISDN).

RECAP: WHAT IS MODULATION & WHY DO WE NEED IT?

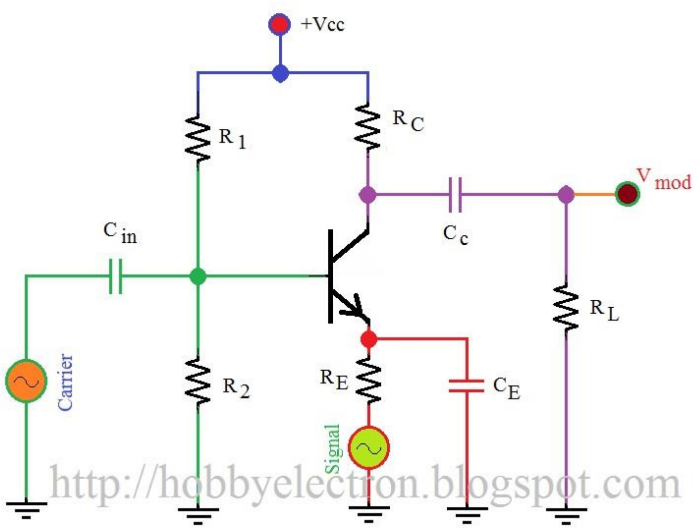
1. Modulation is a process by which a characteristic of a carrier is varied in accordance with a modulating signal.
2. Modulation is necessary because:
   a) It enables baseband signals to be transmitted over long distances and at higher frequencies on such radio bands as MF, SW, HF, VHF, UHF or microwave
   b) It allows the use of smaller/shorter antennas, i.e the higher the frequency, the shorter the antenna.
   c) It allows many baseband signals to share the same medium, e.g. many TV channels can be transmitted on a cable.
   d) It improves the quality of transmission, e.g. FM signals are not affected by additive noise.

RECAP: ANALOGUE MODULATION

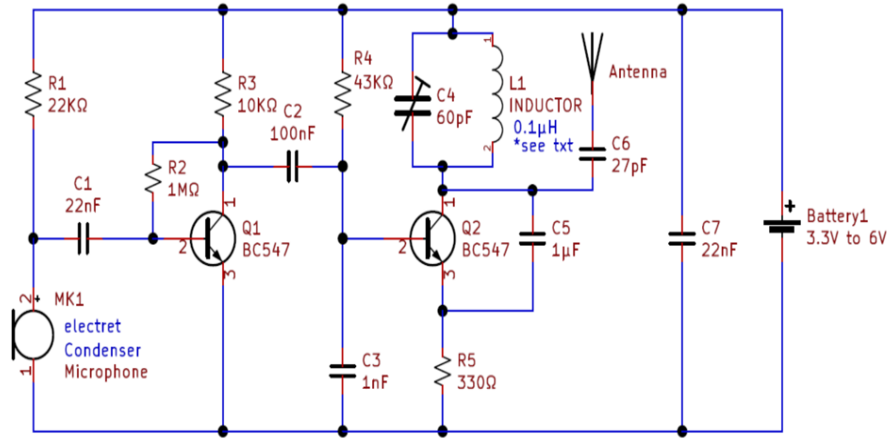


Amplitude is varied in accordance to the modulating signal

Frequency is varied in accordance to the modulating signal



(a) AM Modulator

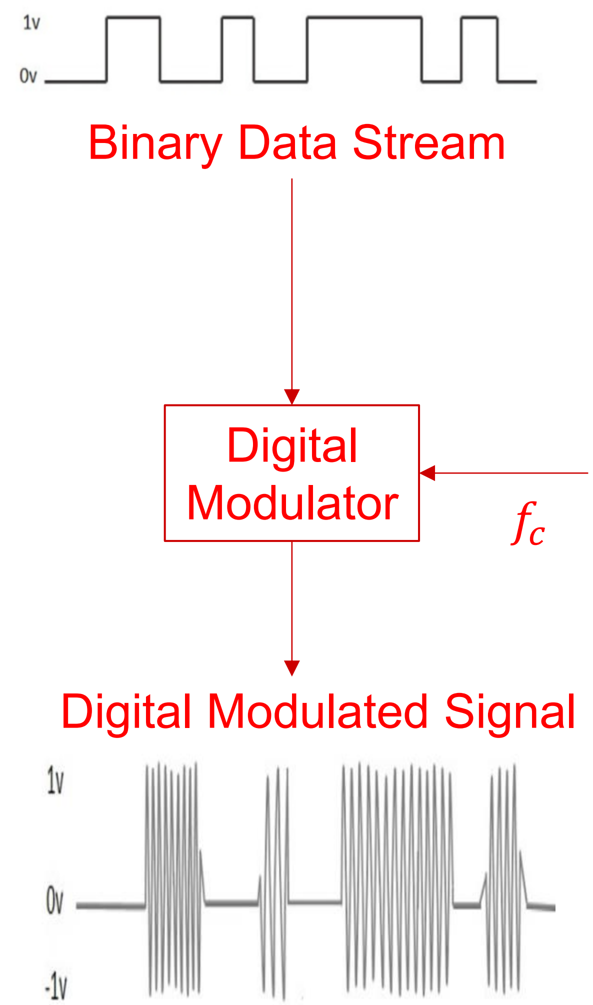


(b) FM Modulator

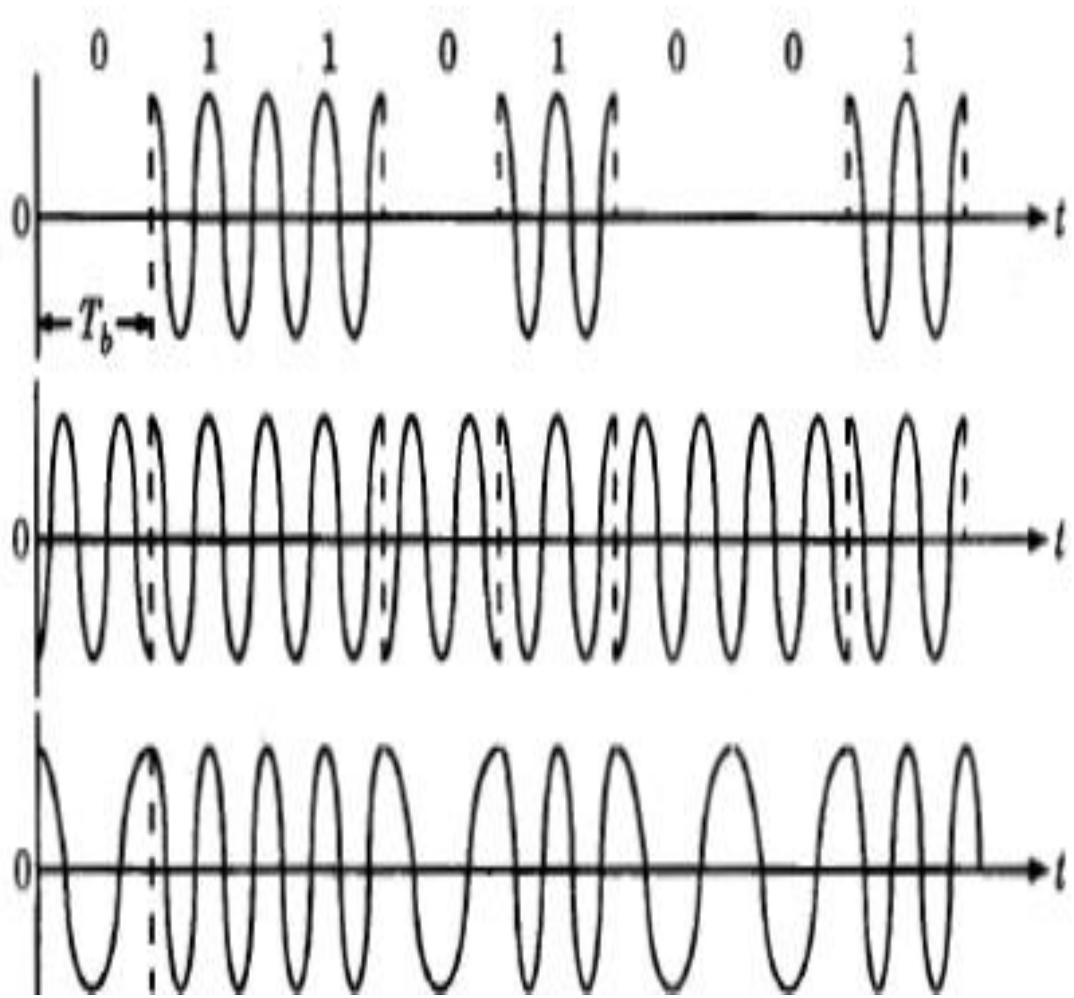
WHAT IS DIGITAL MODULATION & WHY DO WE NEED IT?

1. **Digital modulation** is the process of encoding a digital information signal onto the amplitude, phase, or frequency of a carrier at frequency f_c.

2. Digital communication provides
   a) **Higher transmission capacity** by using data compression techniques
   b) **High data security** by using encryption
   c) **Higher quality transmission** by using advanced coding techniques and error correction.



TYPES OF DIGITAL MODULATION SCHEMES



Amplitude Shift Keying (ASK)

Represents the binary data in the form of variations in the amplitude of a carrier signal.

Phase-shift Keying (PSK)

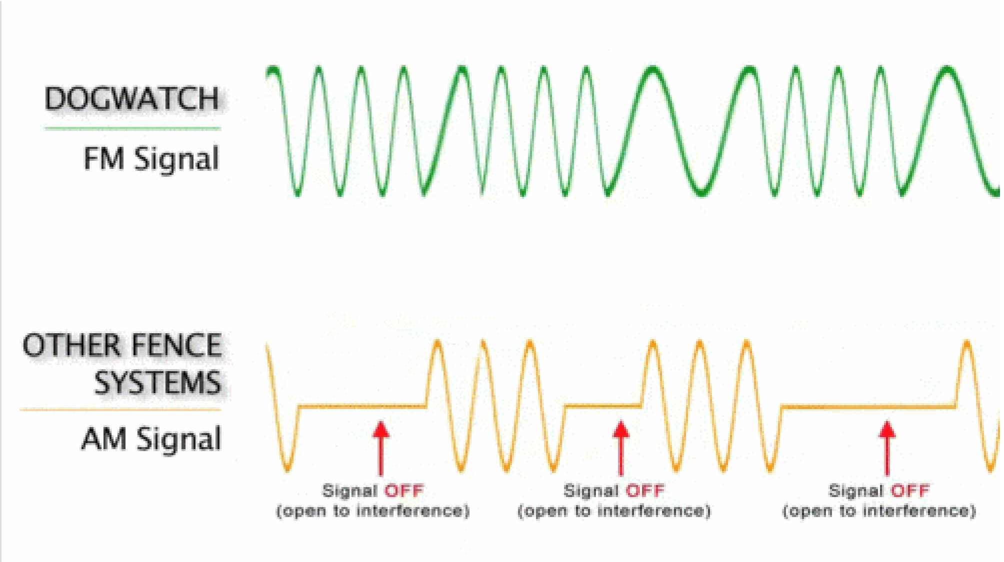
Represents the binary data in the form of variations in the phase of a carrier signal.

Frequency-shift keying (FSK)

Represents the binary data in the form of variations in the frequency of a carrier signal.

BANDWIDTH OF DIGITAL MODULATION CHANNEL

1. In order to transmit a digital signal over a long distance , we need a continuous-wave modulation process that converts the original baseband signal to pass-band frequency range.
2. As a result of digital modulation, there is some deviation in the carrier frequency. The maximum deviation is known as the **bandwidth of the Radio Frequency (RF) channel**.



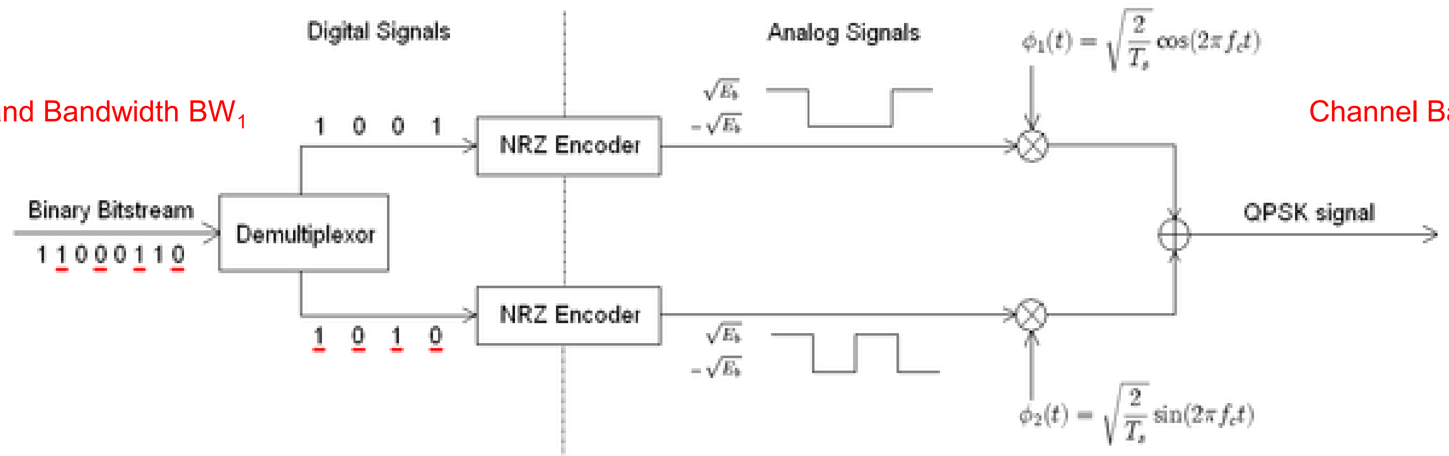
Output of FSK modulator

Output of ASK Modulator

M-ARY DIGITAL MODULATION

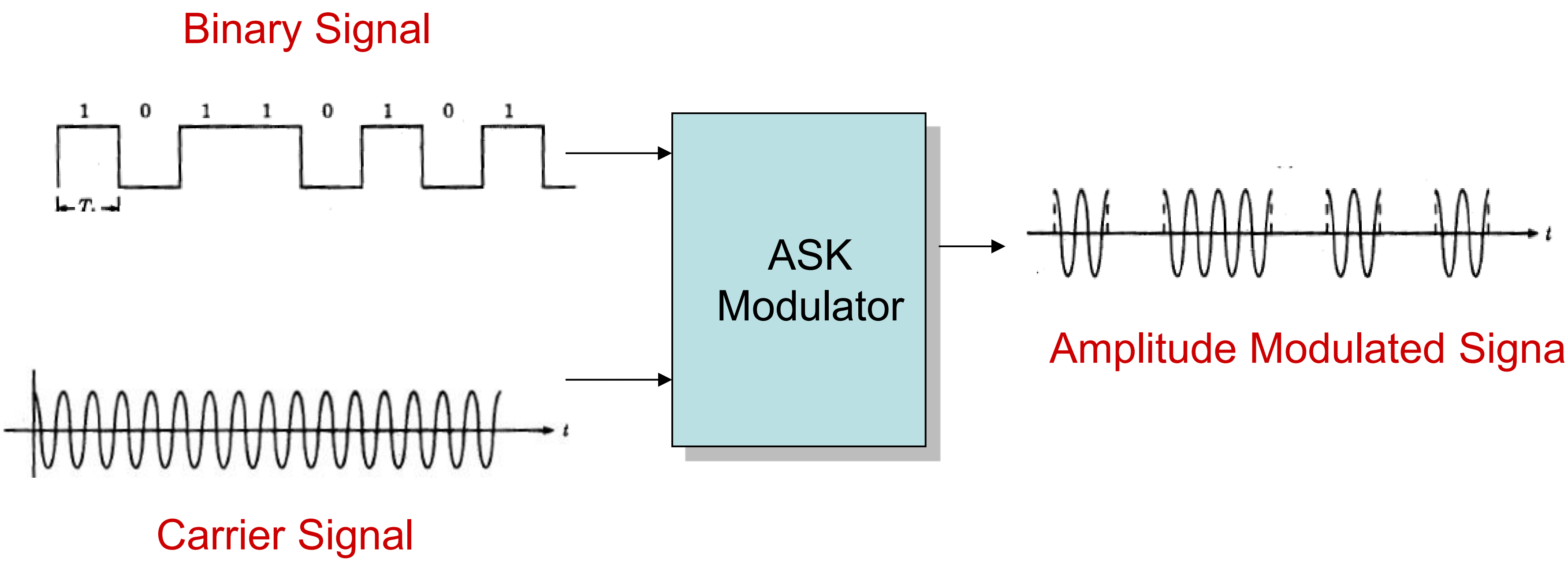
- **M-ary Modulation** creates one variation (symbol) for two or more bits simultaneously
- M-ary communication where M > 2 results in less channel bandwidth than binary (M = 2).

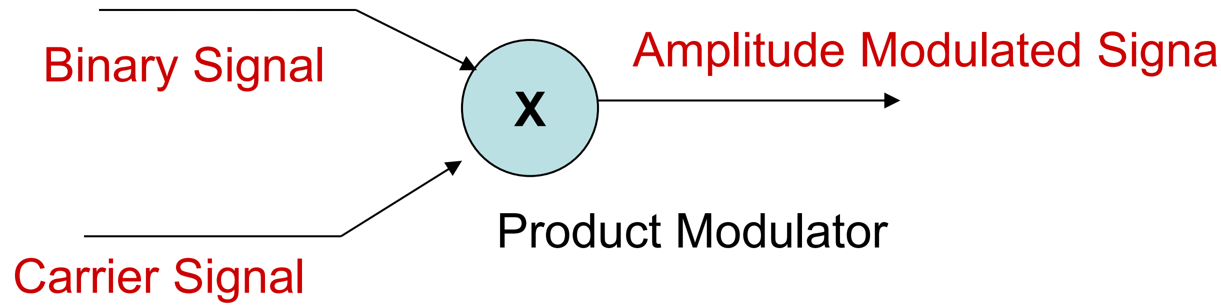
Baseband Bandwidth BW_1



Channel Bandwidth BW_2

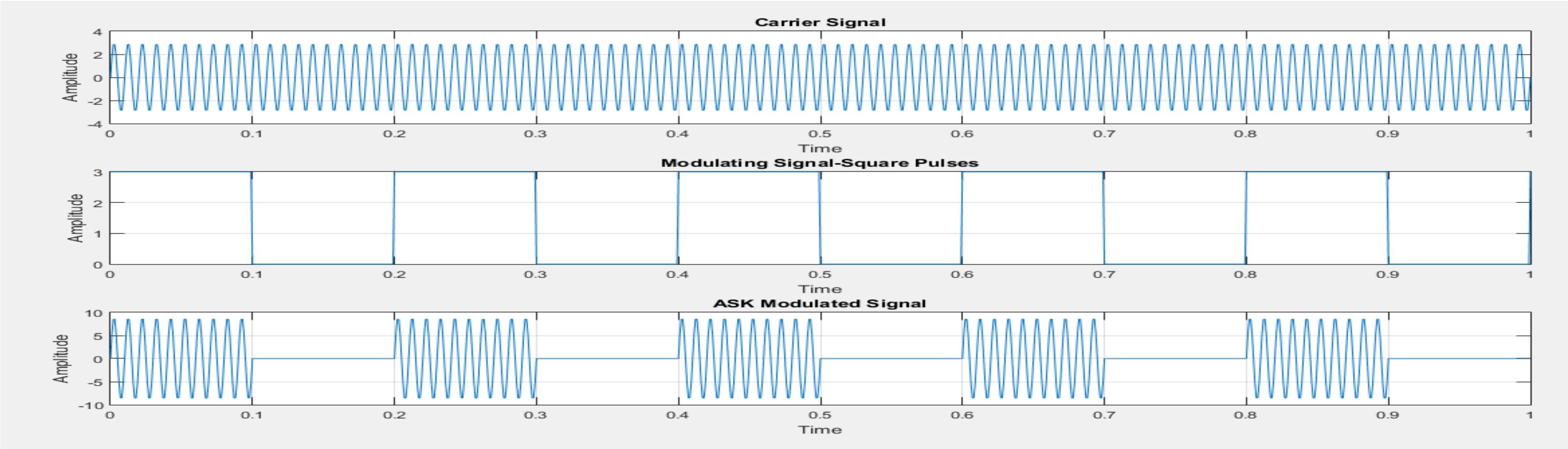
CREATING AMPLITUDE SHIFT KEYING (ASK) SIGNALS





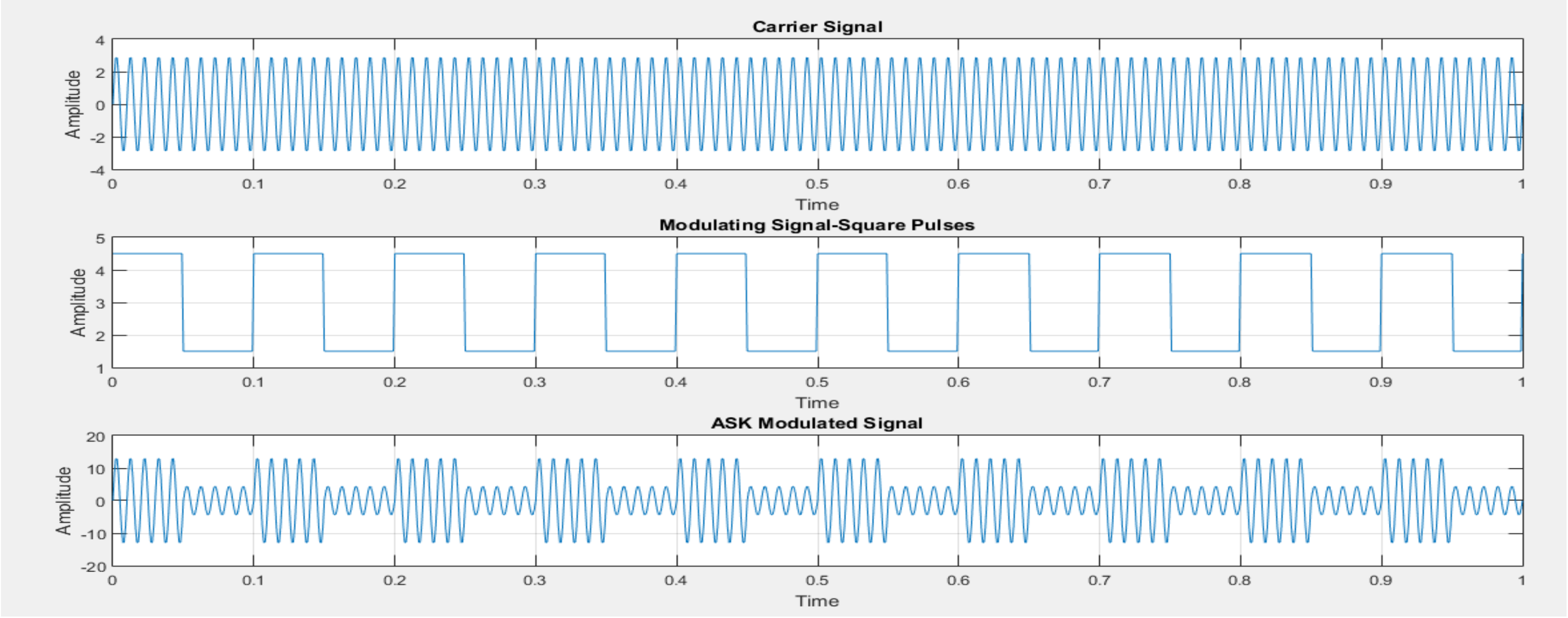
GENERATING ASK SIGNALS IN MATLAB / 01

```
F1 =  100;                          % Carrier frequency
F2  =   10;                         % Square wave pulse
A=3;                                %Amplitude
t=0:0.001:1;                        % Array  [0, 0.001,002 …….1.0]
x=A.*sin(2*pi*F1*t);                %Carrier Sine wave
u=A/2.*square(2*pi*F2*t)+(A/2);     %Square wave message
v=x.*u;                             %  Product Modulator
```

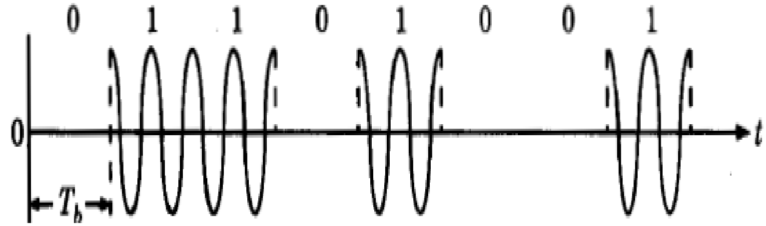


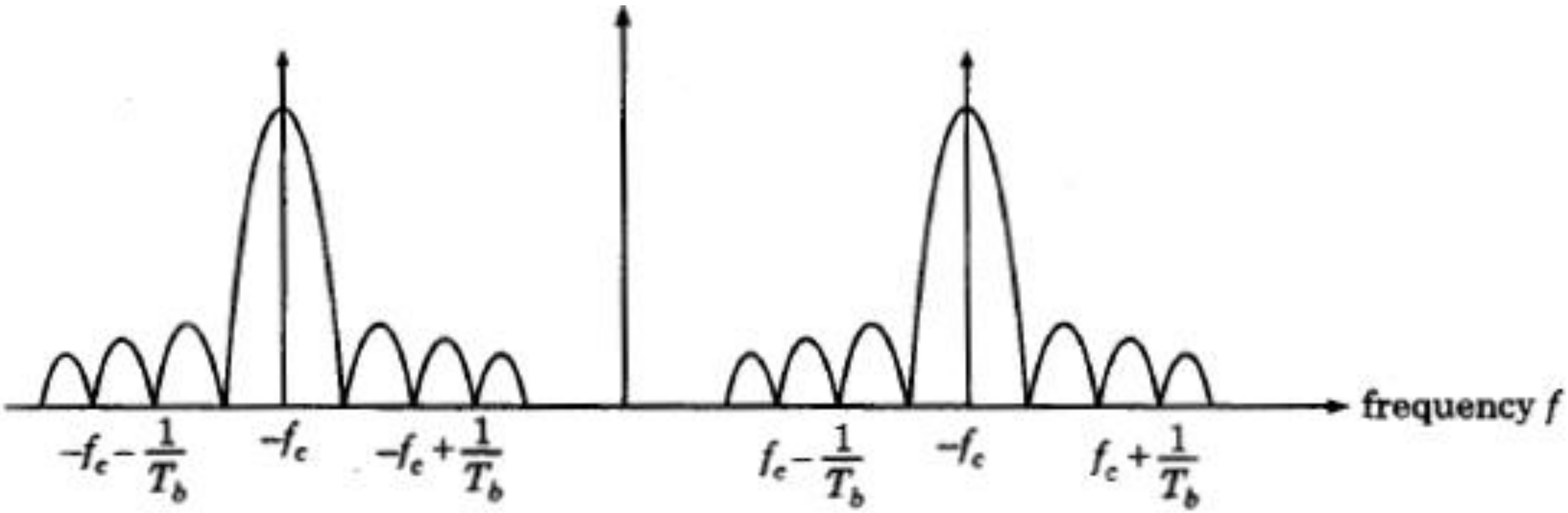
GENERATING ASK SIGNALS IN MATLAB /02

```
F1 =  100                          % Carrier frequency
F2  =   10                         % Square wave pulse
A=3;                               %Amplitude
t=0:0.001:1;                       % Array  [0, 0.001,002 …….1.0]
x=A.*sin(2*pi*F1*t);               %Carrier Sine wave
u=A/2.*square(2*pi*F2*t)+A;        %Square wave message
v=x.*u;                            %  Product Modulator
```



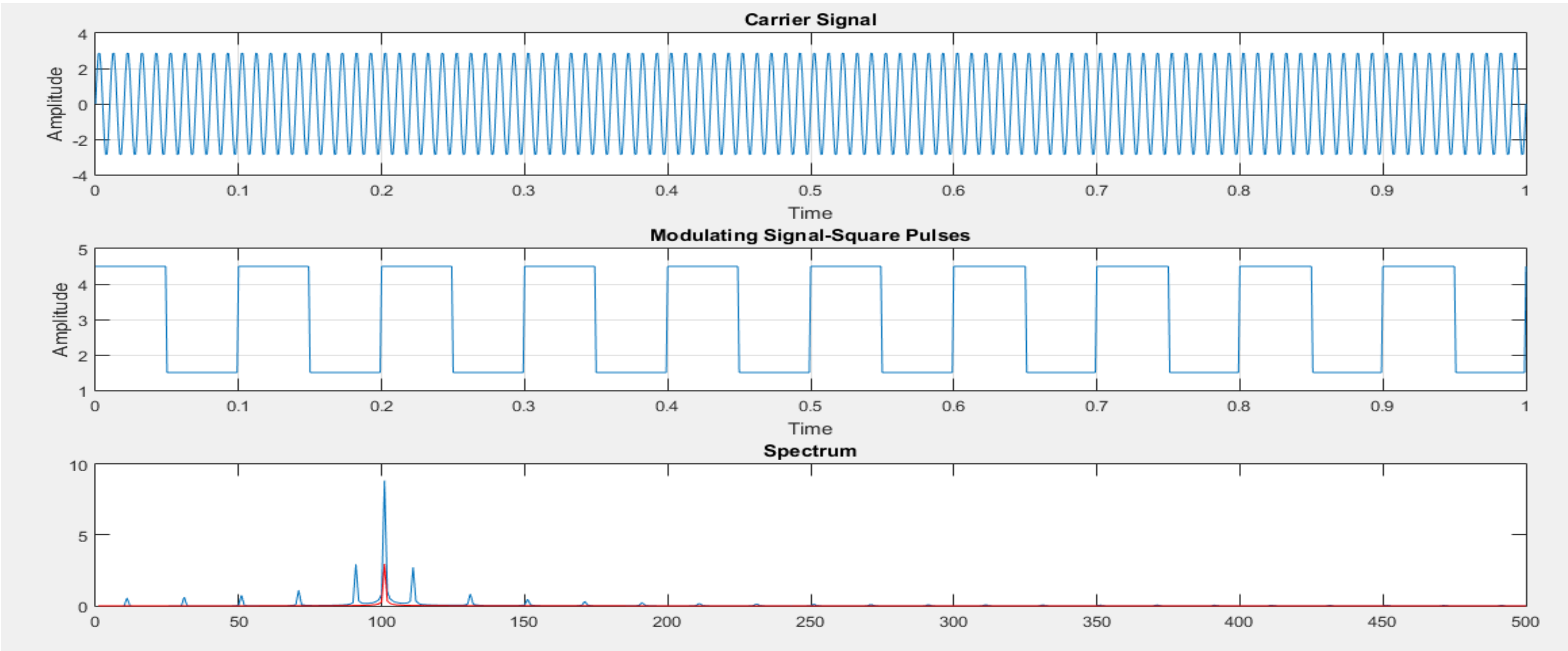
POWER SPECTRAL DENSITY OF ASK SIGNAL





COMPUTING THE POWER SPECTRUM IN MATLAB

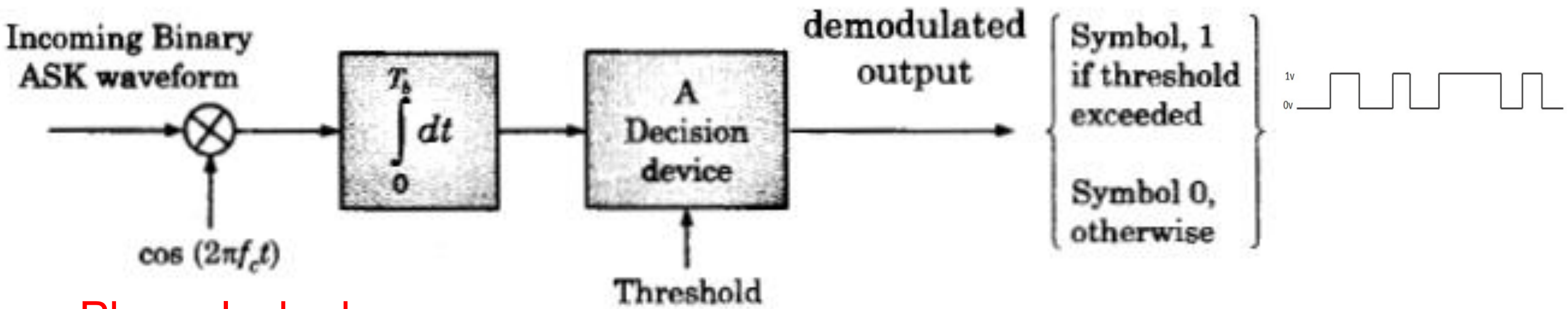
```
N=1000;                    % Sample size for FFT
k=1:N/2;                   % x-axis array used for plotting
F=fft(v);                  % Fast Fourier transform of carrier
M=fft(x);                  % Fast Fourier transform of ASK modulated signal
magF=abs([F(1)/N,F(2:N/2)/(N/2)]);
magM=abs([M(1)/N,M(2:N/2)/(N/2)]);
subplot(3,1,1);.
plot(t,x);
subplot(3,1,2);.
Plot(t,v);
subplot(3,1,3);.
plot(k,magF,k,magM,'r’);
title('Spectrum')
```



Carrier Signal
Amplitude
Time
Modulating Signal-Square Pulses
Amplitude
Time
Spectrum

DEMODULATION OF ASK SIGNALS

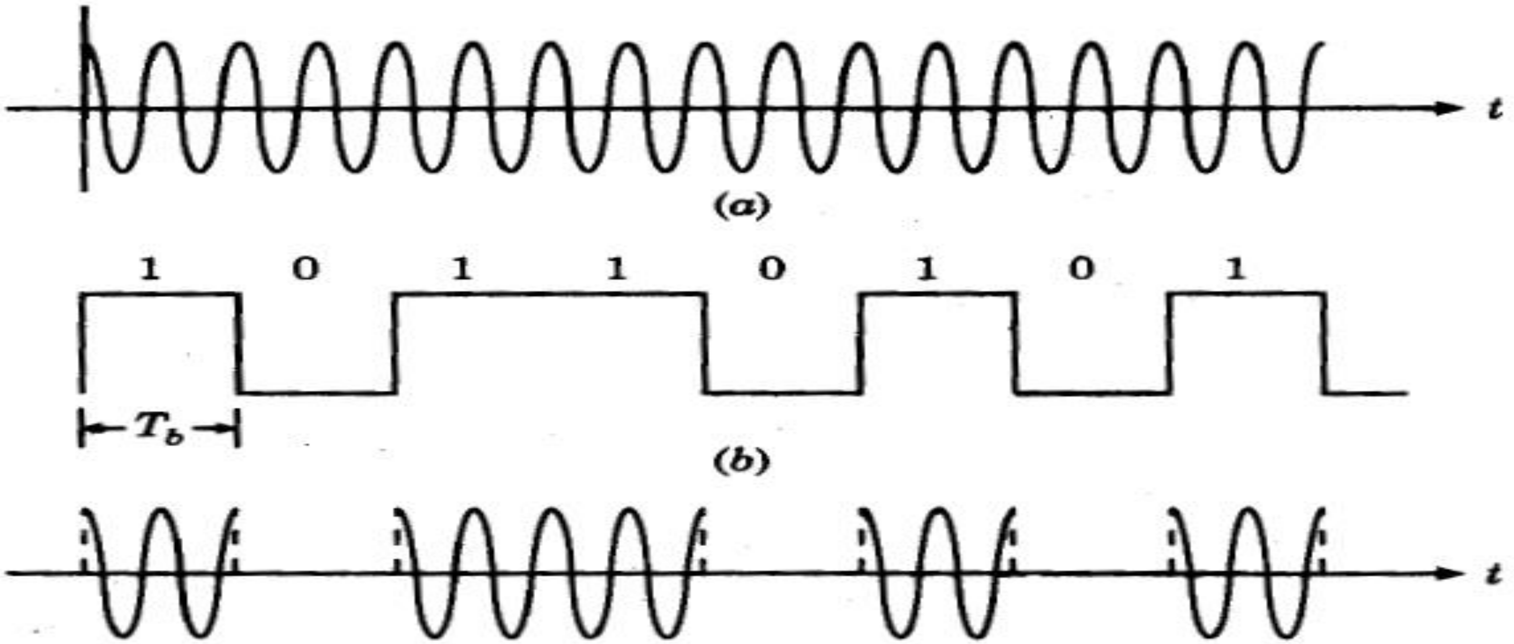
1. ASK generally requires that the receiver generates a carrier which is phase-locked with the signal carrier.
2. The process of correlating the received noisy signal with a local carrier generated at the receiver is called coherent detection or synchronous detection.



Phase-locked
carrier

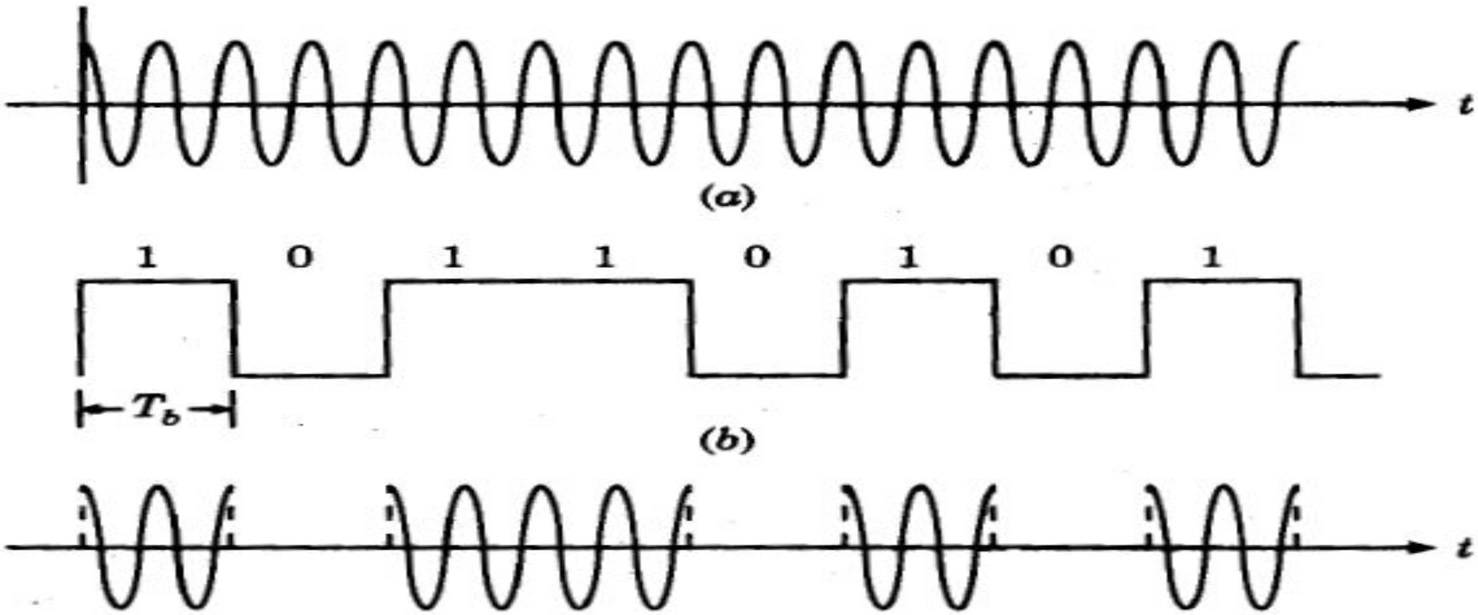
PHASE SYNCHRONIZATION

1. **Phase synchronization** ensures that the phase of the received signal is locked in phase with the transmitted signal.



TIMING SYNCHRONIZATION

2. **Timing synchronization** enables synchronization between the receiver and the transmitter with respect to switching (transition between 0 and 1) instants



ADVANTAGES & DISADVANTAGES OF ASK

ADVANTAGES

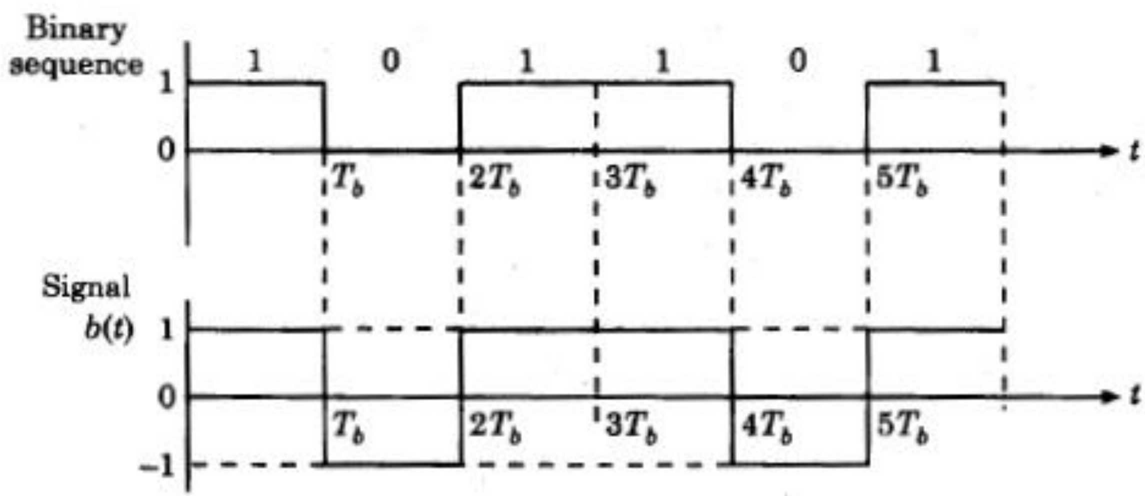
- Simplicity, i.e easy to generate and detect
- .

DISADVANTAGES

- More sensitive to noise
- Cannot be used at high data rates. Used at very low bit rates, i.e < 1000bps

GENERATION OF BINARY PHASE SHIFT KEY SIGNALS /01

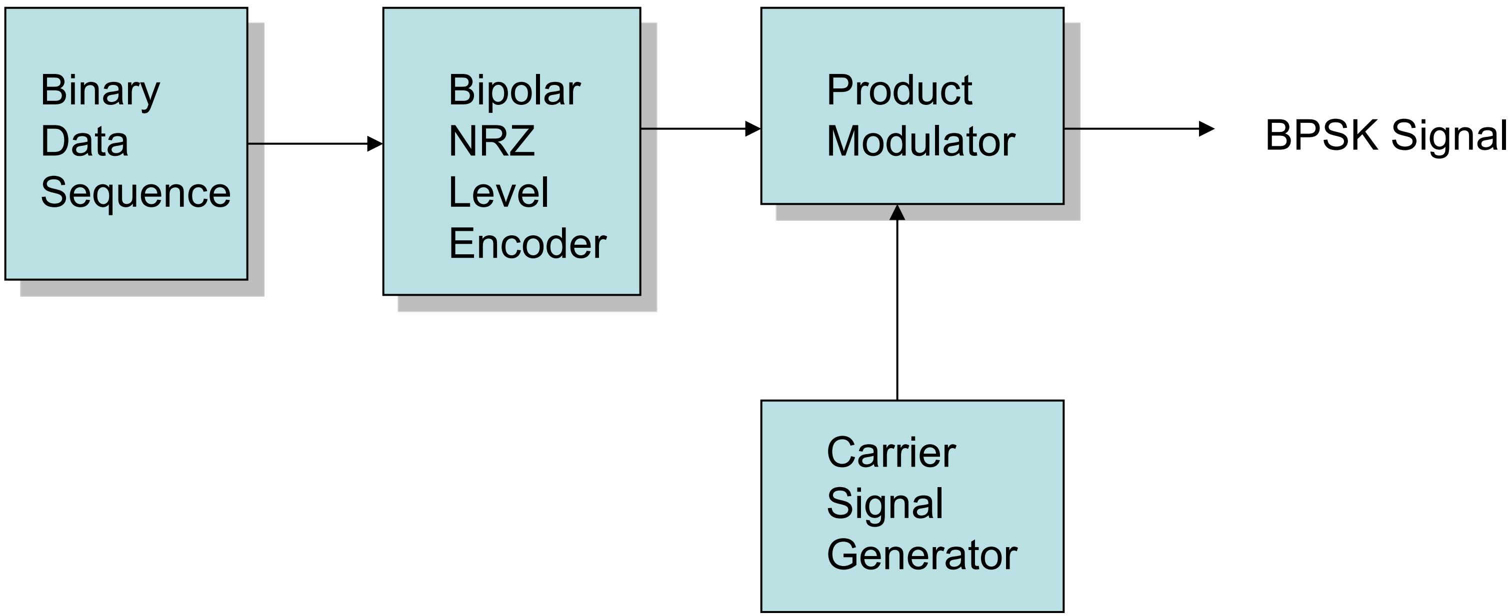
- The binary signal is first converted to an NRZ format using an NRZ encoder.
- The NRZ signal is then applied to a balanced modulator to generate a BPSK signal.



RZ

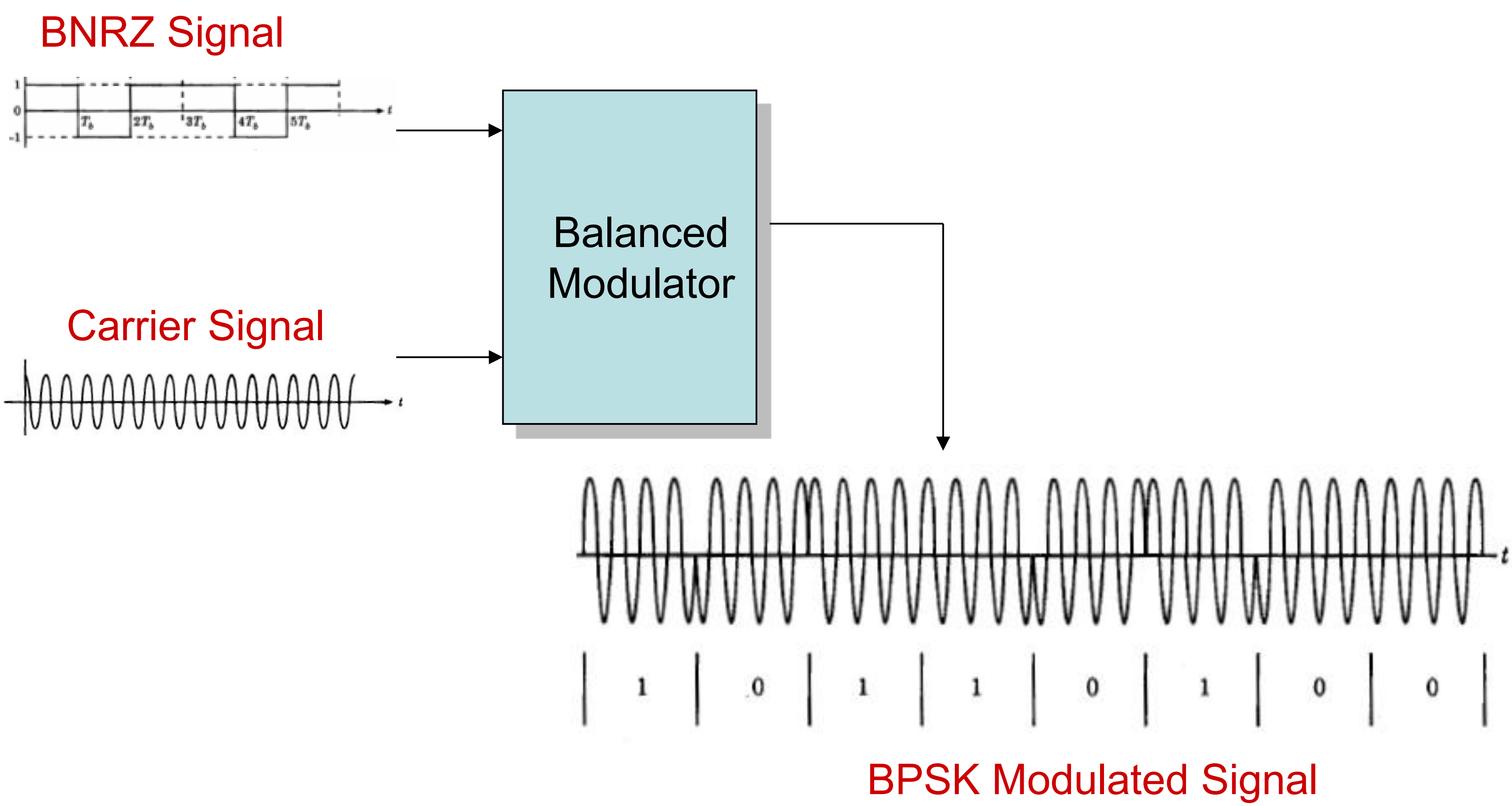
NRZ

GENERATION OF BINARY PHASE SHIFT KEY SIGNALS /02



BINARY INPUT	Bipolar NRZ	BPSK Output Signal
0	-1	$-A\cos\omega_c t$
1	+1	$+A\cos\omega_c t$

GENERATION OF BINARY PHASE SHIFT KEY SIGNALS /03



MATLAB ROUTINE FOR GENERATING & GRAPHING ASK, FSK & PSK

```
f=5;
f2=10;
x=[1 1 0 0 1 0 1 1];          % binary input signal
nx=size(x,2)
i=1;
while i < nx+1                % Loop for binary bits nx
     t = i:0.001:i+1;
    if x(i)==1                % If binary bit is 1
       ask=sin(2*pi*f*t);
       fsk=sin(2*pi*f*t);
       psk=sin(2*pi*f*t);
    else                      % if binary bit is 0
        ask=0;
        fsk=sin(2*pi*f2*t);
        psk=sin(2*pi*f*t+pi);
    end
```

```
subplot(3,1,1);                    % Plot graph number one of three-ASK
   plot(t,ask);
   hold on;
   grid on;
   axis([1 8 -1 1]);
 title('Amplitude Shift Keying')
   subplot(3,1,2);                 % Plot graph number two of three-FSK
   plot(t,fsk);
   hold on;
   grid on;
   axis([1 8 -1 1]);
title('Frequency Shift Keying’);
subplot(3,1,3);                    % Plot graph number three of three-PSK
   plot(t,psk);
   hold on;
   grid on;
   axis([1 8 -1 1]);
 title('Phase Shift Keying')
   i=i+1;
end
```

MATLAB GRAPH

1 1 0 0 1 0 1