PHY 359 2.0 / ASP 487 2.0
Telecommunication

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Digital Modulation

Modulation by Digital Signals

- For digital signals, there are several modulation techniques available. The three main digital modulation techniques are:

  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PSK)

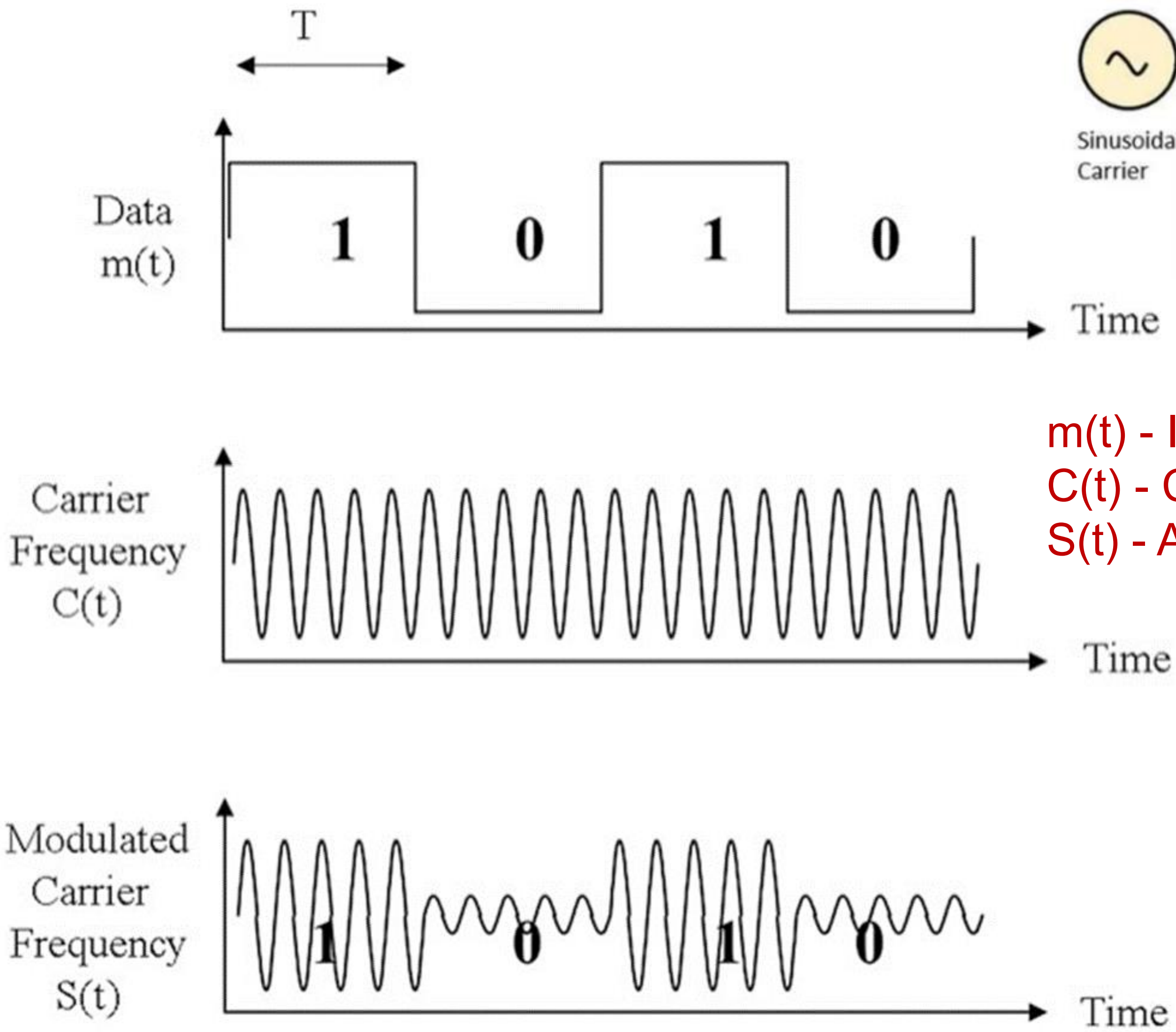
Amplitude shift keying (ASK)

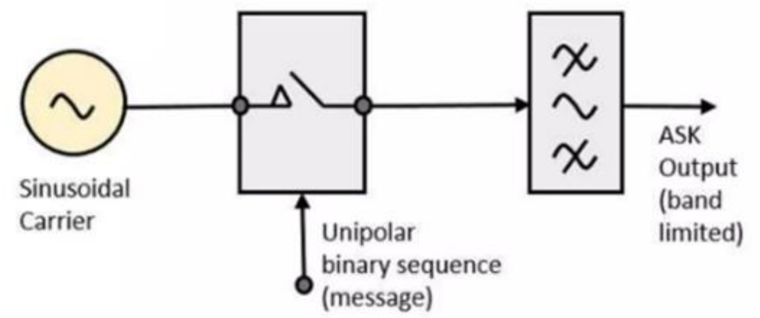
- known as On–Off Keying (OOK), is a method of digital modulation that utilizes amplitude shifting of the relative amplitude of the career frequency.
- The signal to be modulated and transmitted is binary; this is referred to as ASK, where the amplitude of the carrier changes in discrete levels,
- In accordance with the input signal

Binary 0 (bit 0): Amplitude of the carrier = Low
Binary 1 (bit 1): Amplitude of the carrier = High

- Output of the ASK-modulated carrier, For binary signal 1, the carrier is ON. For the binary signal 0, the carrier is OFF. However, a small residual signal may remain due to noise, interference, etc.

Amplitude shift keying (ASK)





m(t) - Input modulating digital signal
C(t) - Carrier signal
S(t) - ASK modulated signal

ASK – Modulation Technique

- This is an indispensable task in digital communications, where redundant bits are added to the raw data, enabling the receiver to detect and correct bit errors during transmission.
- Many error-coding schemes are available, and a simple coding technique, known as "Block Coding" illustrates the concept.
- Encoded ASK modulation scheme using (15, 8) block code where an 8-bit data block is formed as M-rows and N-columns (M = 4, N = 2).
- The product MN = k = 8 is the dimension of the information bits before coding.

Used Even parity

Data set – 8 bit

0	0	0	1	1	0	1	1

			P_H
	0	0	**0**
	0	1	**1**
	1	0	**1**
	1	1	**0**
P_V	**0**	**0**	**0**

P_H - Horizontal parity
P_V - Vertical parity

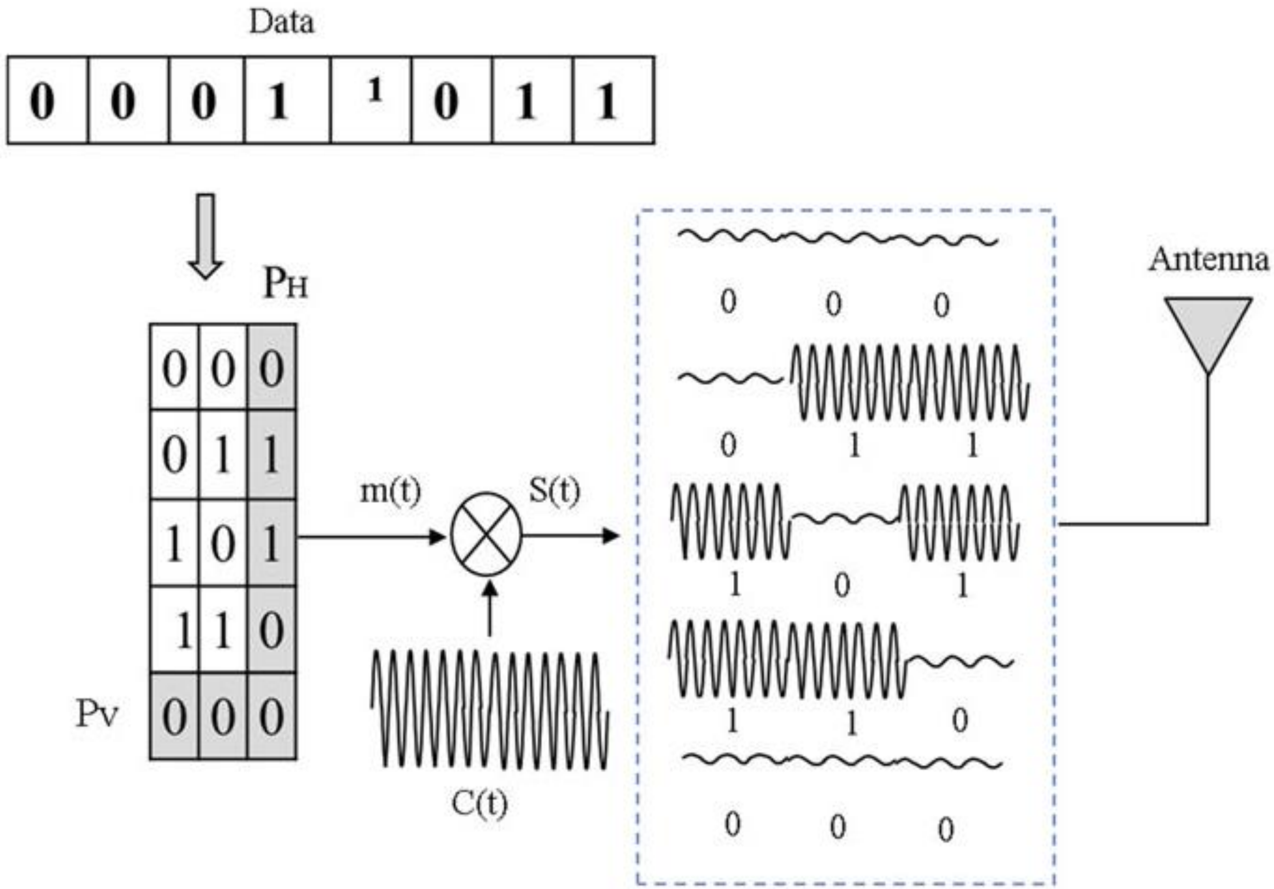
- ASK modulated and transmitted row by row.
- The resulting augmented dimension is given by the product (M + 1) (N + 1) = n = 15

ASK – Modulation Technique

- **Code Rate: r =** $\frac{MN}{(M+1)(N+1)} = \frac{4\times 2}{(4+1)(2+1)} = \frac{8}{15}$

- If the coded bit rate is $\mathbf{R_{bcoded}}$ and the Uncoded bit Rate is $\mathbf{R_{buncoded}}$

$$R_{bcoded} = \frac{Uncoded\ Bit\ Rate}{Code\ Rate} = \frac{R_{buncoded}}{r} = \frac{R_{buncoded}}{\frac{8}{15}} = \frac{R_{buncoded}\times 15}{8}$$



Parity Bit and Error Corrections

What Is the Parity Bit?

A parity bit is a simple method used to detect errors in digital communication and data storage, ensuring the accuracy of the data.

Even Parity And Odd Parity

Even Parity:

- The parity bit is set so that the total number of 1s in the code, including the parity bit, is even.
- If there are already an even number of 1s, the parity bit is 0. If there are an odd number of 1s, the parity bit is 1.

Odd Parity:

- The parity bit is adjusted to make the total number of 1s odd.
- If there are already an odd number of 1s, the parity bit is 0. If it's even, the parity bit is set to 1.
- Such error detection and correction circuit can be implemented by using combinational logic circuits.

Parity Bit and Error Corrections

Parity Generator Circuit Design

Ex: Even Parity Generator

3-bit message			Even parity bit generator (P)
A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

- **The standard type of parity generator/checker IC is 74180 IC**

Parity Bit and Error Corrections

Parity Checker Circuit Design

Ex: Even Parity Checker Truth Table

4-bit received message				Parity error check C_p
A	B	C	P	
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	0
0	1	1	0	0
0	1	1	1	1
1	0	0	0	1
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	0	1
1	1	1	1	0

ASK – Modulation Technique

- Input Data : $m(t) = 0 \text{ or } 1 \text{ (coded data)}$
- Carrier Frequency : $C(t) = A\cos(\omega t)$
- Modulated Carrier : $S(t) = m(t)C(t) = m(t)A\cos(\omega t)$

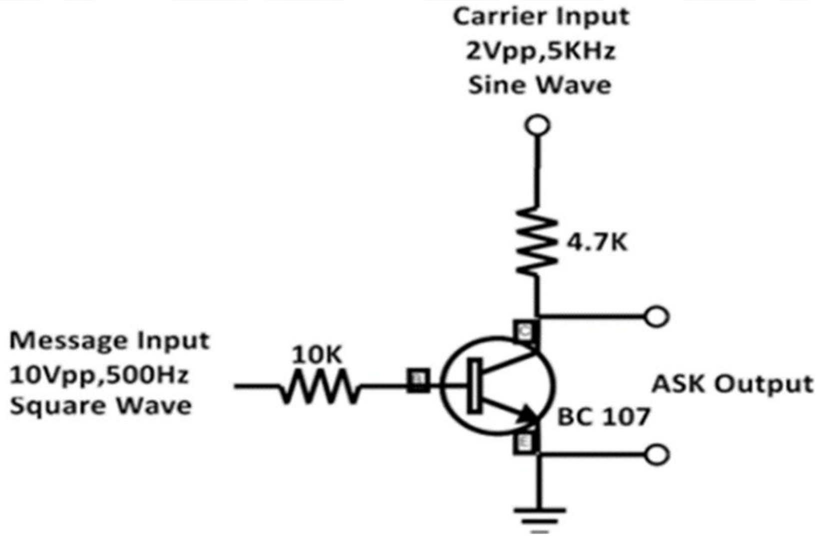
Therefore,

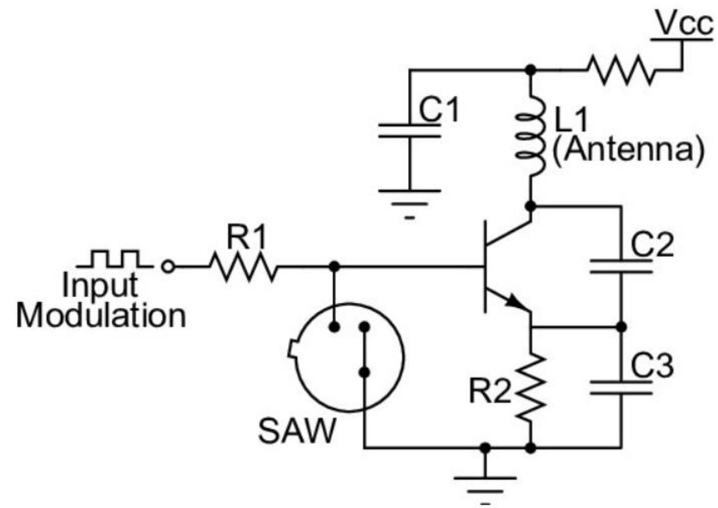
$$\text{For } m(t) = 1 : S(t) = A\cos(\omega t) \text{ i.e. the carrier is ON}$$

$$\text{For } m(t) = 1 : S(t) = 0, \text{ i.e. the carrier is OFF}$$

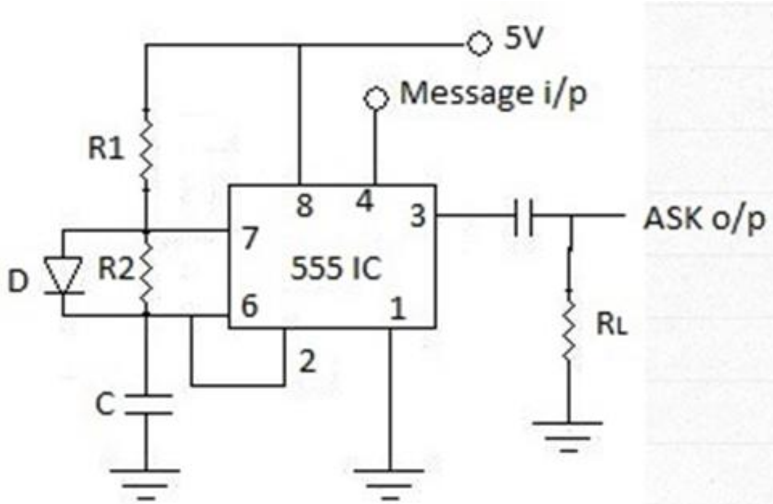
where A is the amplitude and ω is the frequency of the carrier.

Basic ASK – Modulator Circuit





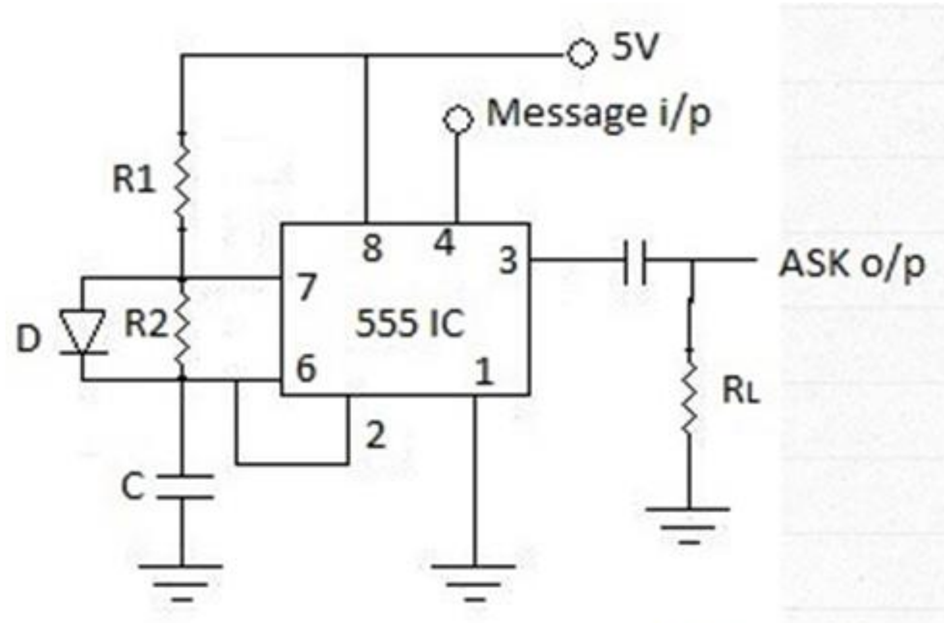
ASK – Modulator using Transistor



ASK – Modulator using 555 IC

Basic ASK – Modulator Circuit

ASK – Modulator using 555 IC

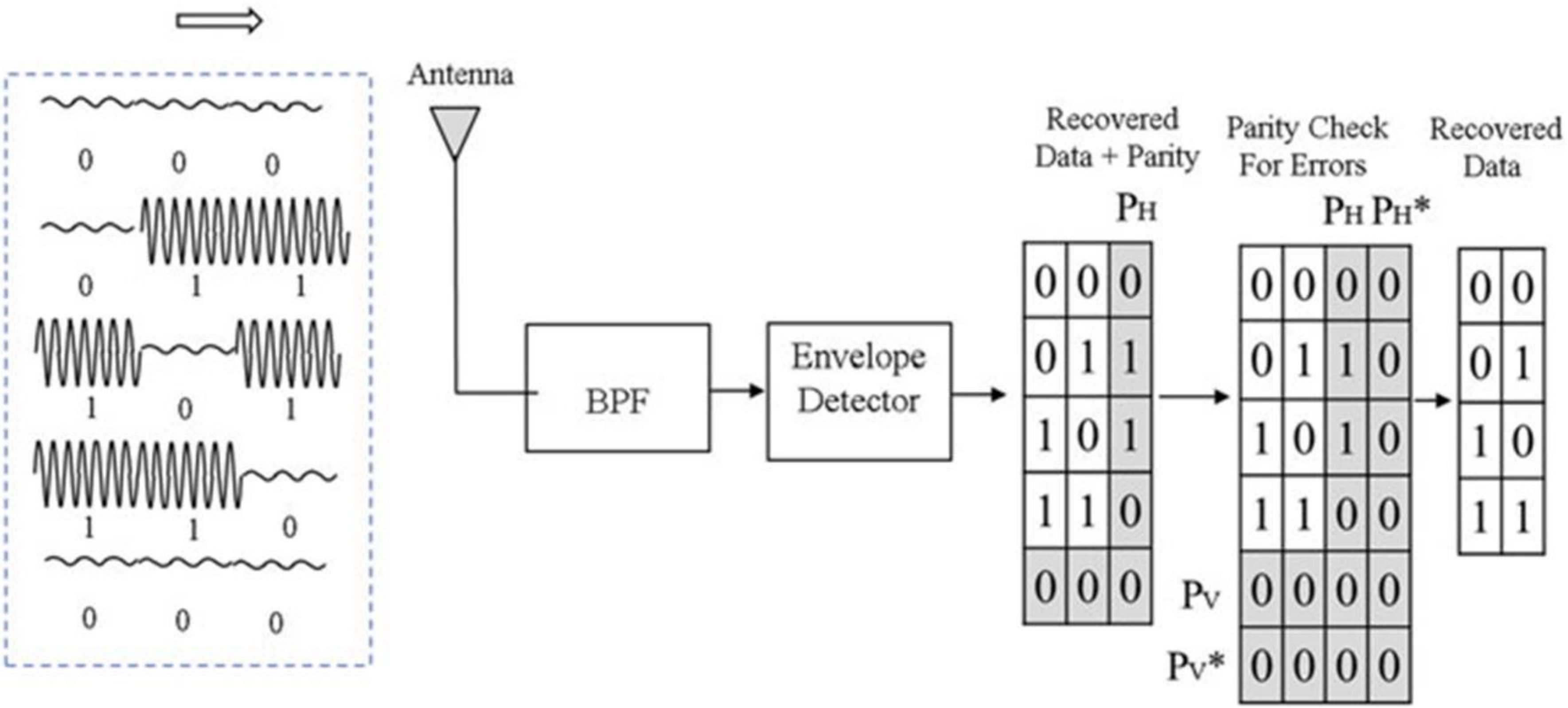


- The carrier signal can be varied by using the R1, R2, and C
- The carrier frequency (fc) = 0.69*C*(R1+R2)
- At pin no.4, apply the input binary signal or digital information, or data signal
- At pin 3, the circuit will generate the ASK-modulated wave
- It is suitable for low-frequency RF applications.

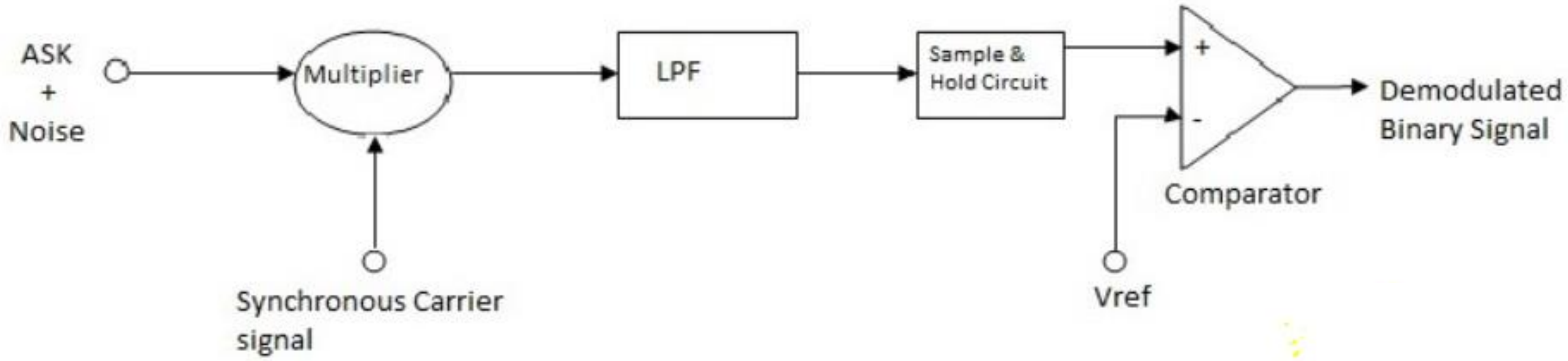
ASK Demodulation

- For ASK, the receiver uses a single band-pass filter tuned to the right carrier frequency.
- When the signal enters the receiver, it passes through a filter. Then, the receiver determines the value of each bit to recover the encoded data block, including horizontal and vertical parities.
- Then, the receiver appends horizontal and vertical parities (P_H* and P_V*) to check for errors and recover the data block.
- If there is an error, there will be a parity failure in P_H* and P_V* to pinpoint the error.

ASK Demodulation



ASK Demodulation



- The noise can be eliminated after the multiplier stage with the help of a low-pass filter
- Then it is forwarded from the sample and hold circuit for converting it into a discrete signal form.
- At each interval, the discrete signal voltage is compared with the reference voltage (Vref) using a comparator to reconstruct the original binary signal.

ASK Bandwidth

In digital communications, data is generally referred to as a non-periodic digital signal. It has two values:

- Binary-1 = High, Period = T
- Binary-0 = Low, Period = T

Also, data can be represented in two ways:

- Time domain representation and
- Frequency domain representation

The time domain representation, known as non-return-to-zero (NRZ), is given by:

$$
\begin{aligned}
V(t) &= V \qquad < 0 < t < T \\
&= 0 \qquad \text{elsewhere}
\end{aligned}
$$

ASK Bandwidth

The frequency domain representation is given by "Fourier transform"

$$V(\omega) = \int_0^T V \cdot e^{-j\omega t} dt$$

$$|V(\omega)| = VT\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]$$

P(ω) - Power spectral density

$$P(\omega) = \left(\frac{1}{T}\right)|V(\omega)|^2 = V^2 T\left[\frac{\sin(\omega T/2)}{\omega T/2}\right]^2$$

- The bandwidth of the power spectrum is proportional to the frequency.
- The one-sided bandwidth is given by the ratio $f/f_b = 1$. So, the one-sided bandwidth = $f = f_b$, where $f_b = R_b = 1/T$, T being the bit duration. The general equation for two-sided response is given by:

$$V(\omega) = \int_{-\infty}^{\infty} V(t) \cdot e^{-j\omega t} dt$$

ASK Bandwidth

- V(ω) - two-sided spectrum of V(t).
- This is due to both positive and negative frequencies used in the integral.
- The function can be a voltage or a current.

$$V(\omega) = \int_{-\infty}^{\infty} V(t) \cdot e^{-j\omega t} dt$$

Two-sided bandwidth (BW) = $2R_b$ (R_b - Bit rate before coding)

Example:

Consider the Bit rate before coding: R_{b1} = 10 kb/s and Code rate: r = 8/15 for the ASK modulation. Find:
(1) The bit rate after coding: R_{b2}
(2) Transmission bandwidth: BW

ASK Bandwidth

Fig (a): Discrete-time digital signal

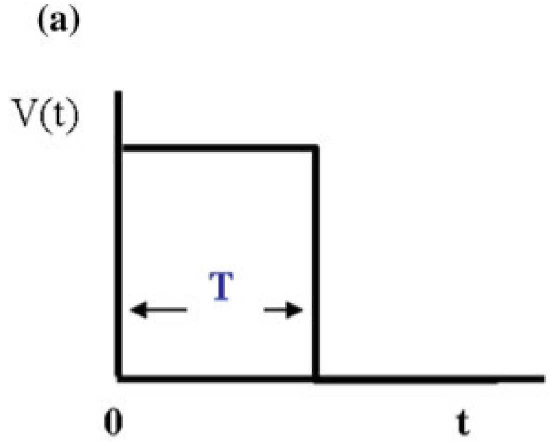


Fig (b): one-sided power spectral density

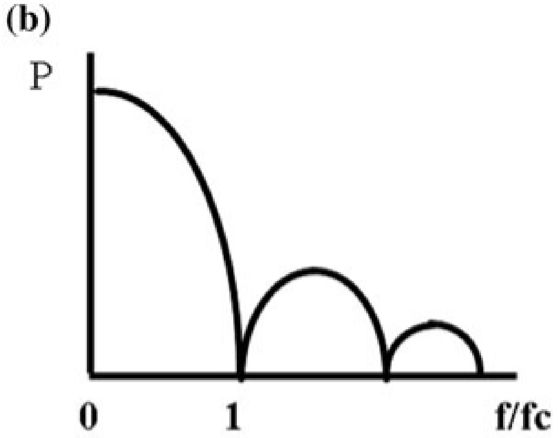
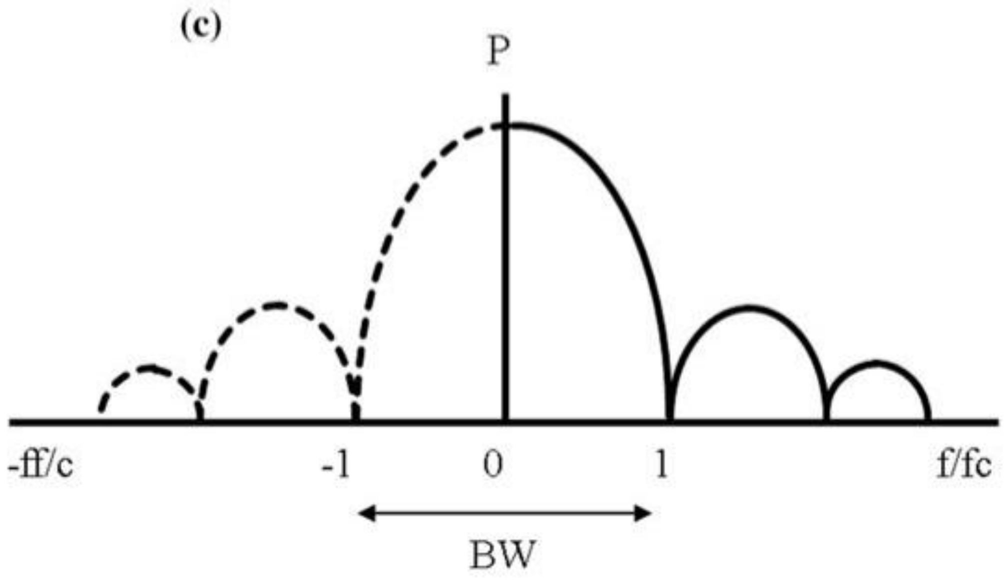


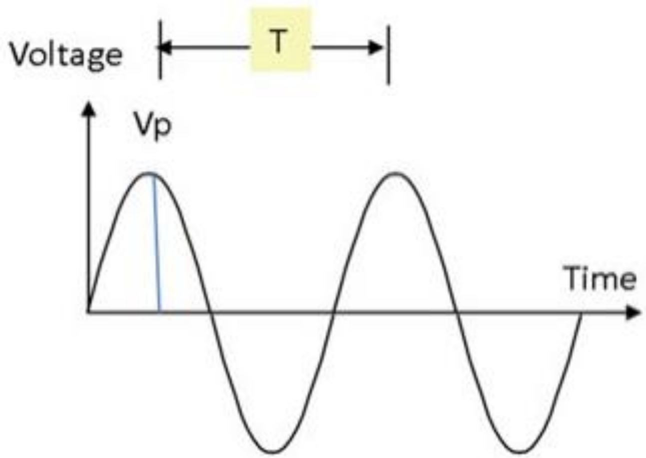
Fig (c): Two-sided power spectral density

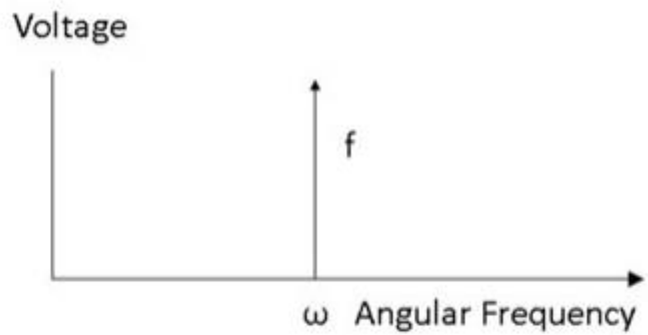


ASK Bandwidth

$V(t) = V_p \sin(\omega t_c)$ $\quad V_P = \text{Peak voltage}$

$\omega_c = 2\pi f_c$
f_c = Carrier frequency in Hz





Input Data : $m(t) = 0 \text{ or } 1$
Carrier Frequency : $C(t) = Ac\cos(\omega_c t)$
Modulated Carrier : $S(t) = m(t)C(t) = m(t)A_c\cos(\omega_c t)$

m(t) - Input digital signal and it contains an infinite number of harmonically related sinusoidal waveforms that we keep the fundamental and filter out the higher-order components, we write:

$$m(t) = A_m \sin(\omega_m t)$$

ASK Bandwidth

$m(t) = A_m \sin(\omega_m t)$ m(t) - Input digital signal

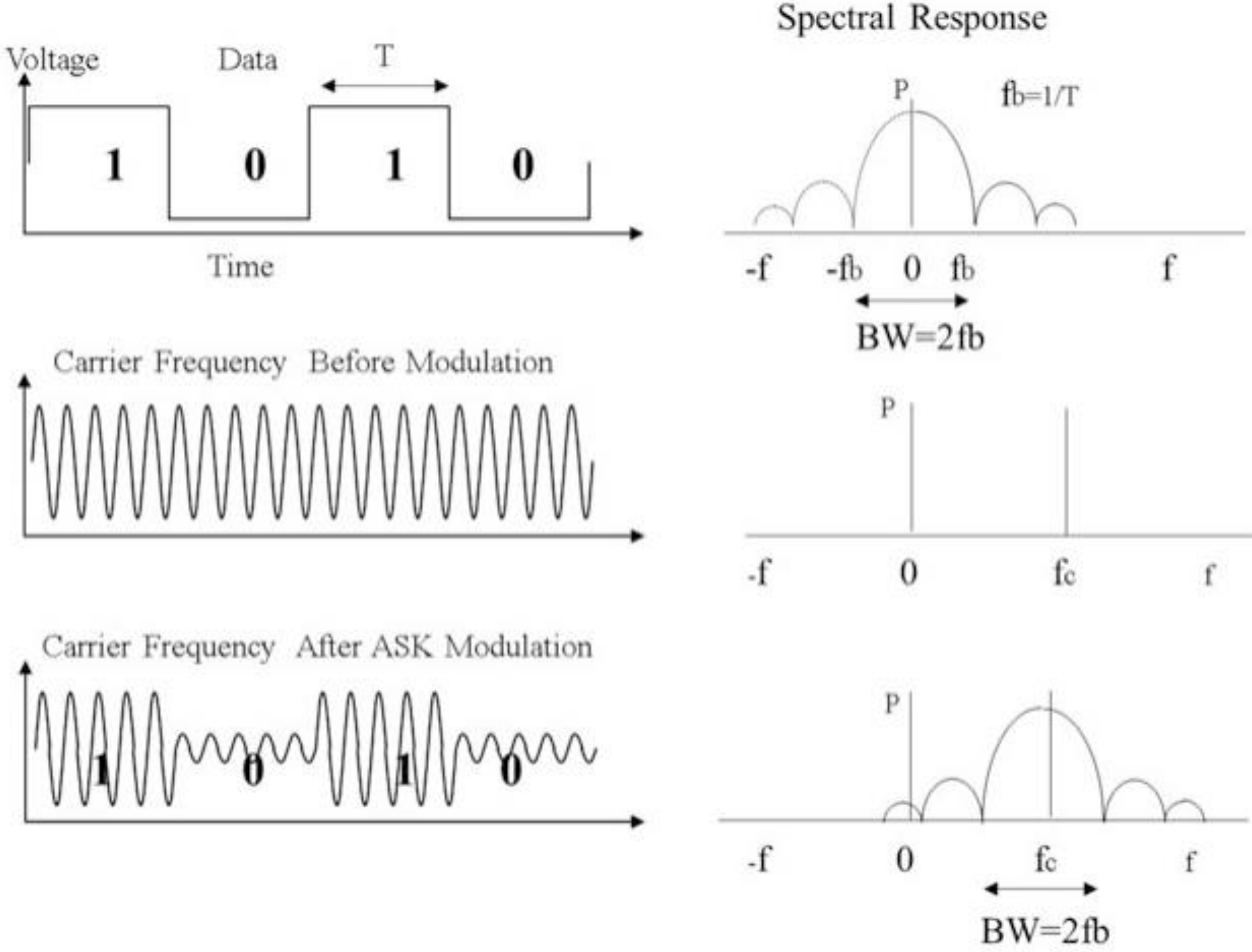
The ASK-modulated signal becomes:

$$S(t) = m(t)S(t) = A_m A_c \sin(\omega_m t)\cos(\omega_m t)$$
$$= 1/2\, A_m A_c \left[\sin(\omega_c - \omega_m)t + \sin(\omega_c + \omega_m)t\right]$$

- Bandwidth is given by: BW = 2 R_b (coded), R_b - the coded bit rate.

ASK Bandwidth

Figure shows: The spectral response of NRZ data before modulation, the Spectral response of the carrier before modulation, and the Spectral response of the carrier after modulation.



Advantages and Disadvantages

Advantages of amplitude shift Keying –

- It can be used to transmit digital data over optical fiber.
- The receiver and transmitter have a simple design which also makes it comparatively inexpensive.
- It uses lesser bandwidth as compared to FSK thus it offers high bandwidth efficiency.

Disadvantages of amplitude shift Keying –

- It is susceptible to noise interference and entire transmissions could be lost due to this.
- It has lower power efficiency.