UNIT-IV

DIGITAL MODULATION TECHNIQUES

There are basically two types of transmission of Digital Signals

Baseband data transmission : The digital data is transmitted over the channel directly. There is no carrier or any modulation. Suitable for transmission over short distances.

Pass band data transmission : The digital data modulates high frequency sinusoidal carrier. Suitable for transmission over longer distances.

Types of Pass band Modulation

The digital data can modulate phase, frequency or amplitude of carrier. This gives rise to three basic techniques:

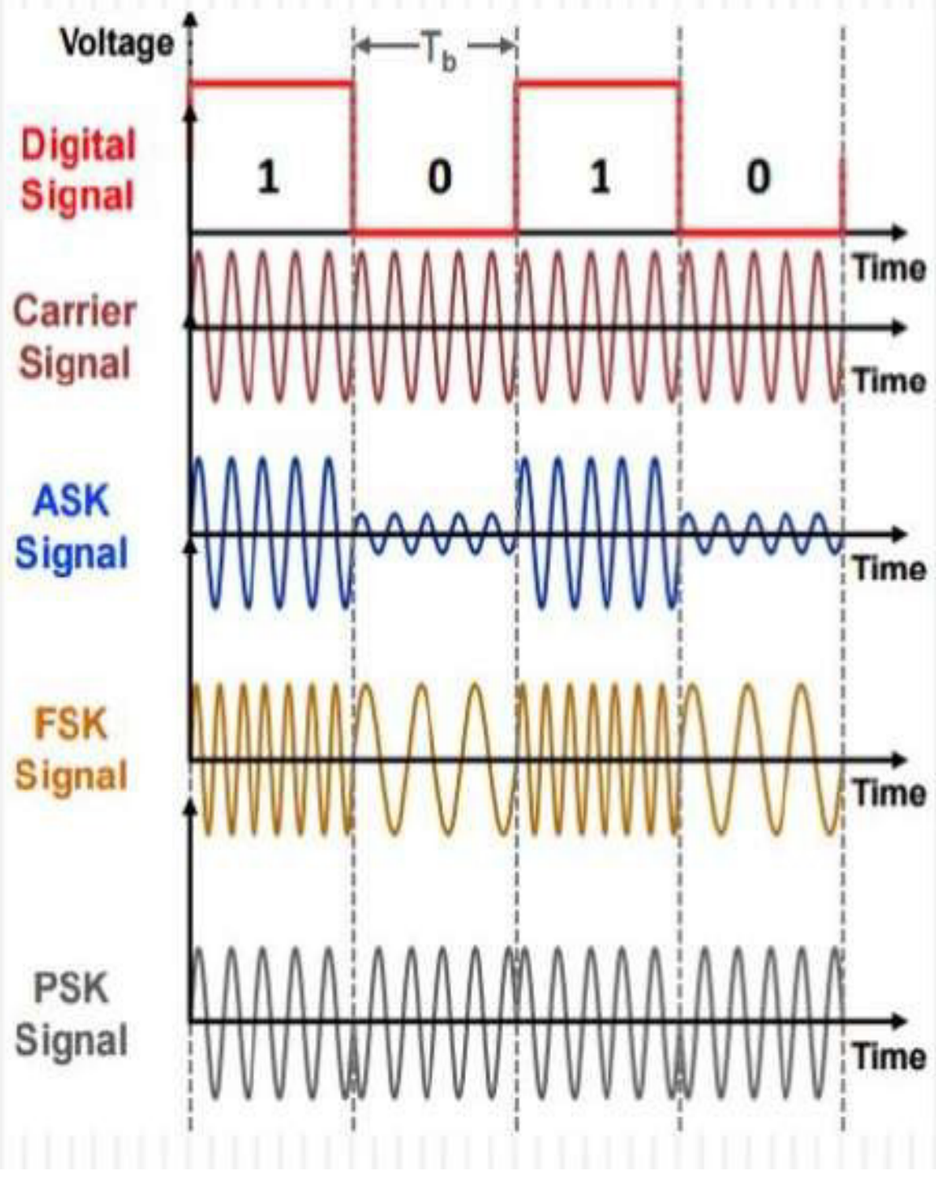
Phase Shift Keying (PSK): The digital data modulates the phase of the carrier.

Frequency Shift Keying(FSK): The digital data modulates the frequency of the carrier.

Amplitude Shift Keying (ASK): The digital modulates the amplitude of the carrier.

Digital Modulation Techniques

1. Baseband digital message signal: $m(t)$
2. Analog sinusoidal carrier signal:
   A. Carrier signal: $A_c \cos(2\pi f_c t + \phi_c)$
3. ASK: Amplitude Shift Keying.
   A. Message signal changes the carrier's amplitude : $A_i(t)$.
4. FSK: Frequency Shift Keying.
   A. Message signal changes the carrier's frequency : $f_i(t)$.
5. PSK: Phase Shift Keying.
   A. Message signal changes the carrier's phase : $\phi_i(t)$.



Types of Reception for Pass band Transmission

Two Types of methods for detection of pass band signals

Coherent (Synchronous) Detection: The local carrier generated at the receiver is phase locked with the carrier at the transmitter. Hence called Synchronous Detection.

Non Coherent (Envelope) Detection: The receiver carrier need not be phase locked with the transmitter carrier. It is called Envelope detection. It is simple but it has higher probability of error.

Requirements of Pass band Transmission Scheme

Maximum Data transmission rate

Minimum Probability of symbol error

Minimum Transmitted power

Minimum Channel Bandwidth

Maximum resistance to interfering signals

Minimum circuit complexity

Advantages of Pass band Transmission over Baseband transmission

Long Distance Transmission

Analog Channels, can be used for Transmission

Multiplexing techniques can be used for BW conservation.

Problems such as ISI and crosstalk are absent

Pass band transmission can take place over wireless channels also.

Introduction

In digital modulation, an analog carrier signal is modulated by a discrete signal.

Digital modulation can be considered as digital-to-analog and the corresponding demodulation is considered as analog-to-digital conversion.

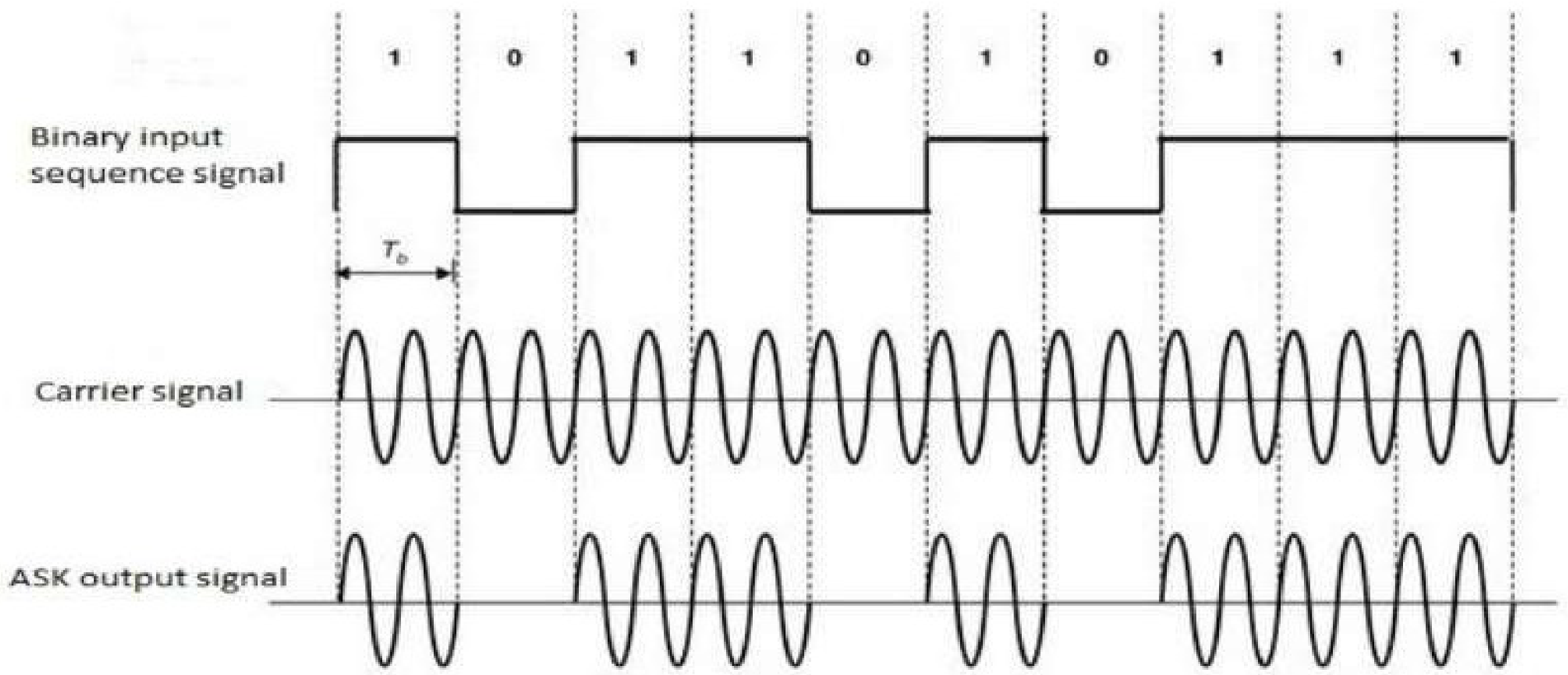
In Digital communications, the modulating wave consists of binary data and the carrier is sinusoidal wave.

Amplitude Shift Keying:

ASK is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal.

Any modulated signal has a high frequency carrier. The binary signal when ASK modulated, gives a **zero** value for **Low** input while it gives the **carrier output** for **High** input.

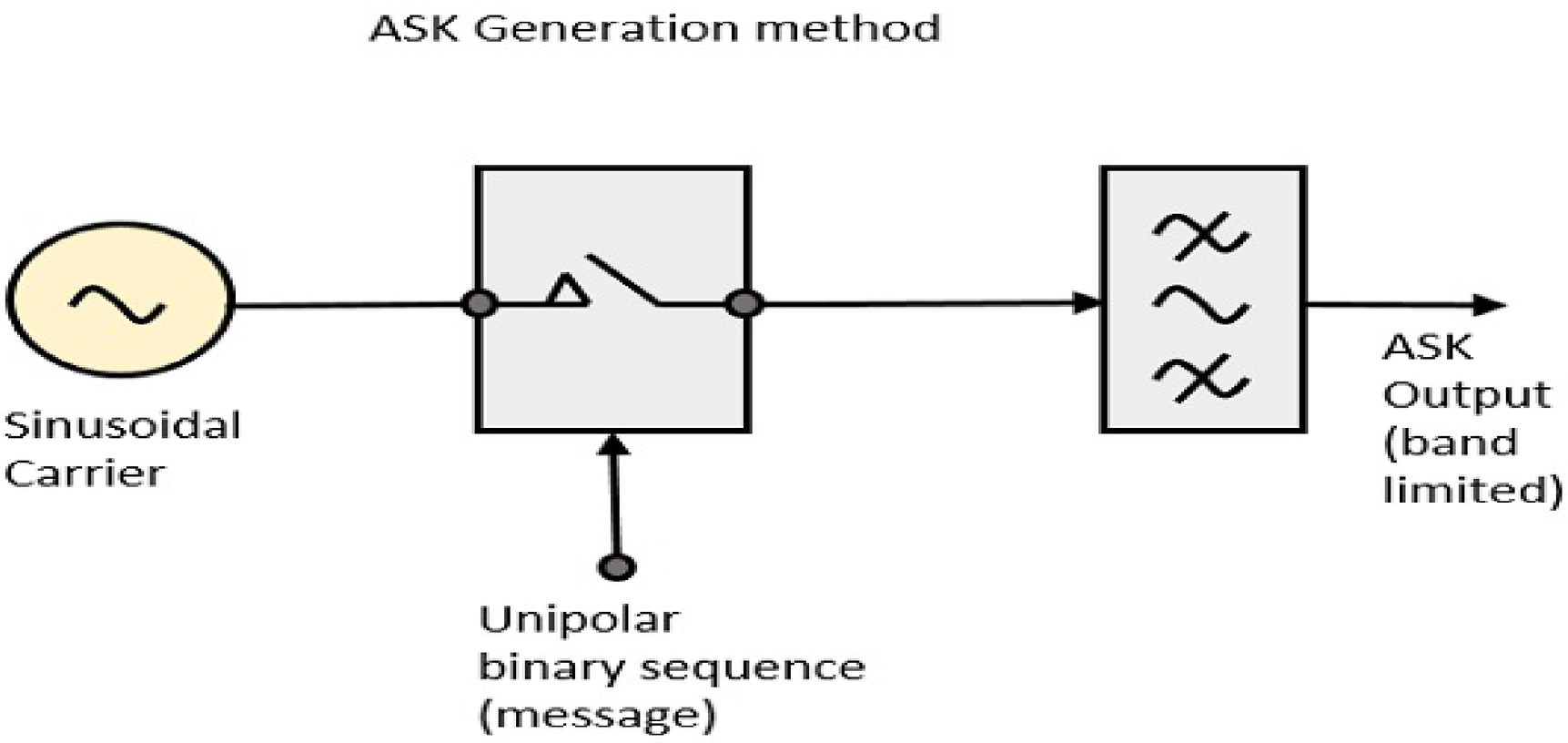
The following figure represents ASK modulated waveform along with its input.



To find the process of obtaining this ASK modulated wave, let us learn about the working of the ASK modulator.

ASK Modulator:

The ASK modulator block diagram comprises of the carrier signal generator, the binary sequence from the message signal and the band-limited filter. Following is the block diagram of the ASK Modulator.



The carrier generator, sends a continuous high-frequency carrier. The binary sequence from the message signal makes the unipolar input to be either High or Low. The high signal closes the switch, allowing a carrier wave. Hence, the output will be the carrier signal at high input. When there is low input, the switch opens, allowing no voltage to appear. Hence, the output will be low.

The band-limiting filter, shapes the pulse depending upon the amplitude and phase characteristics of the band-limiting filter or the pulse-shaping filter.

ASK Demodulator:

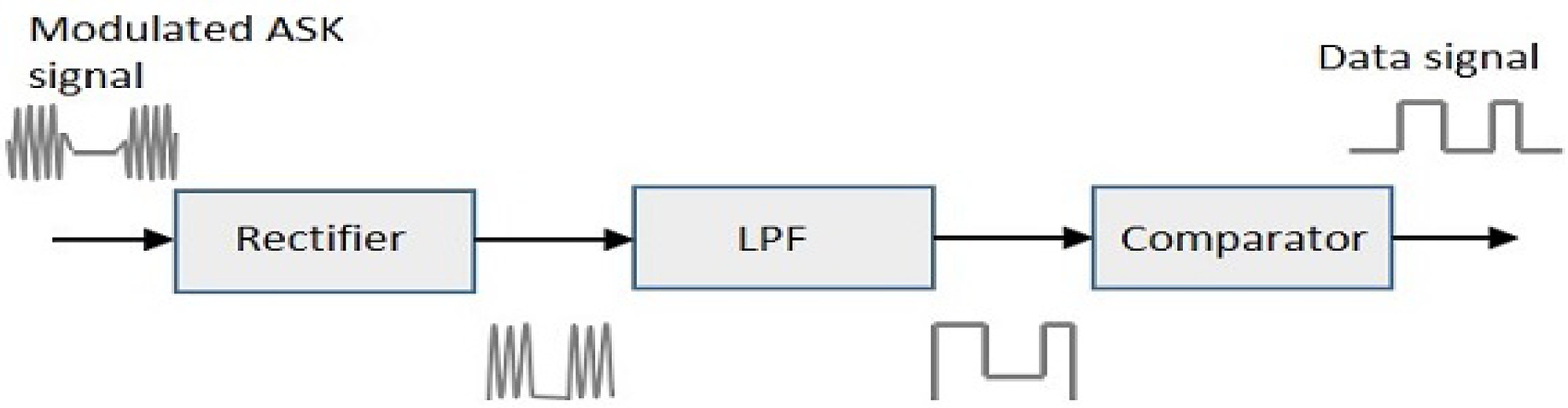
There are two types of ASK Demodulation techniques. They are −

- Asynchronous ASK Demodulation/detection
- Synchronous ASK Demodulation/detection

The clock frequency at the transmitter when matches with the clock frequency at the receiver, it is known as a **Synchronous method**, as the frequency gets synchronized. Otherwise, it is known as **Asynchronous**.

Asynchronous ASK Demodulator

The Asynchronous ASK detector consists of a half-wave rectifier, a low pass filter, and a comparator. Following is the block diagram for the same.

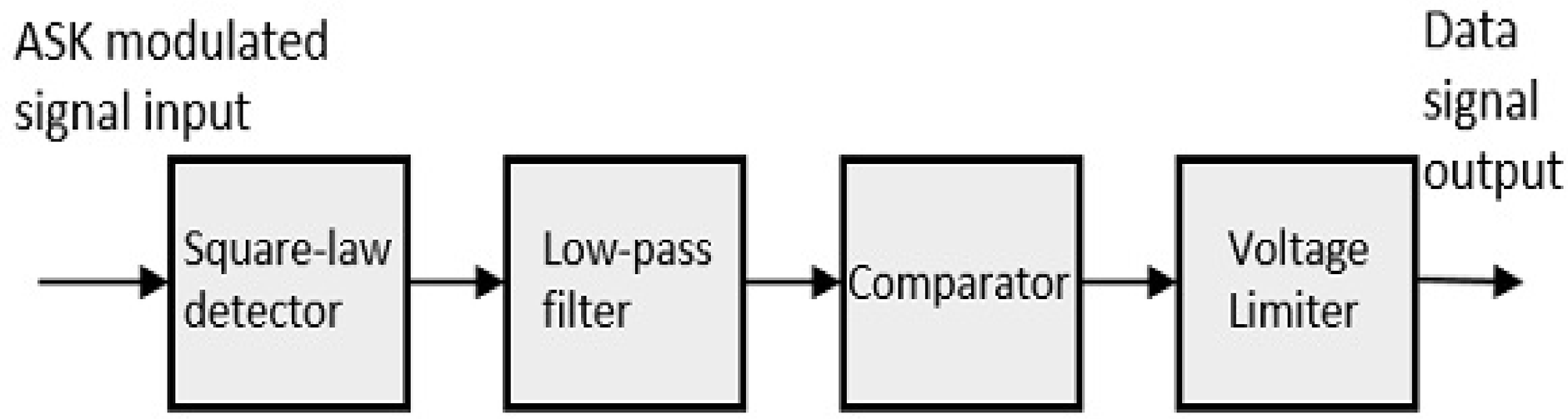


Asynchronous ASK detector

The modulated ASK signal is given to the half-wave rectifier, which delivers a positive half output. The low pass filter suppresses the higher frequencies and gives an envelope detected output from which the comparator delivers a digital output.

Synchronous ASK Demodulator

Synchronous ASK detector consists of a Square law detector, low pass filter, a comparator, and a voltage limiter. Following is the block diagram for the same.



Synchronous ASK detector

The ASK modulated input signal is given to the Square law detector. A square law detector is one whose output voltage is proportional to the square of the amplitude modulated input voltage. The low pass filter minimizes the higher frequencies. The comparator and the voltage limiter help to get a clean digital output.

Advantages and Disadvantages of ASK

Advantages

Simple to design, easy to generate and detect.

Requires low Bandwidth

Requires less energy to transmit the binary data.

Disadvantages

Susceptible to sudden amplitude variations due to noise and interference.

Applications of ASK

Mostly used for very low-speed data rate (upto 1200bps) requirements on voice grade lines in telemetry applications.

Used to transmit digital data over optical fibre for LED –based optical transmitters.

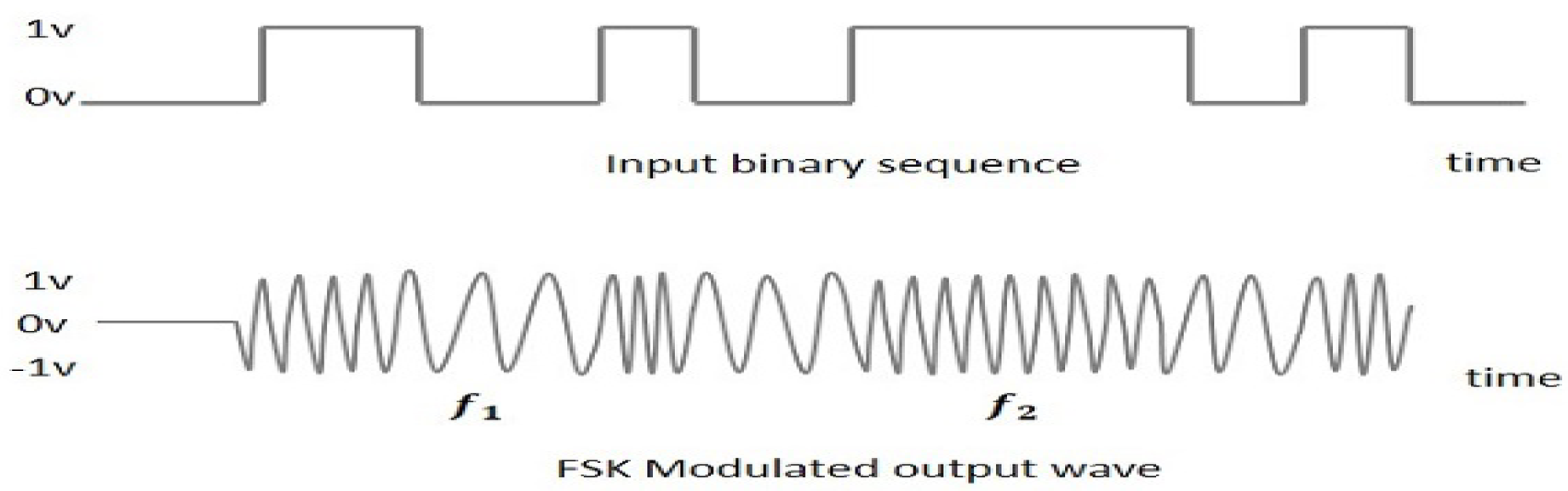
Wireless infrared transmissions using a directed beam or diffuse light in wireless LANs applications.

Frequency Shift Keying :

FSK is the digital modulation technique in which the frequency of the carrier signal varies according to the digital signal changes. FSK is a scheme of frequency modulation.

The output of a FSK modulated wave is high in frequency for a binary High input and is low in frequency for a binary Low input. The binary **1s** and **0s** are called Mark and Space frequencies.

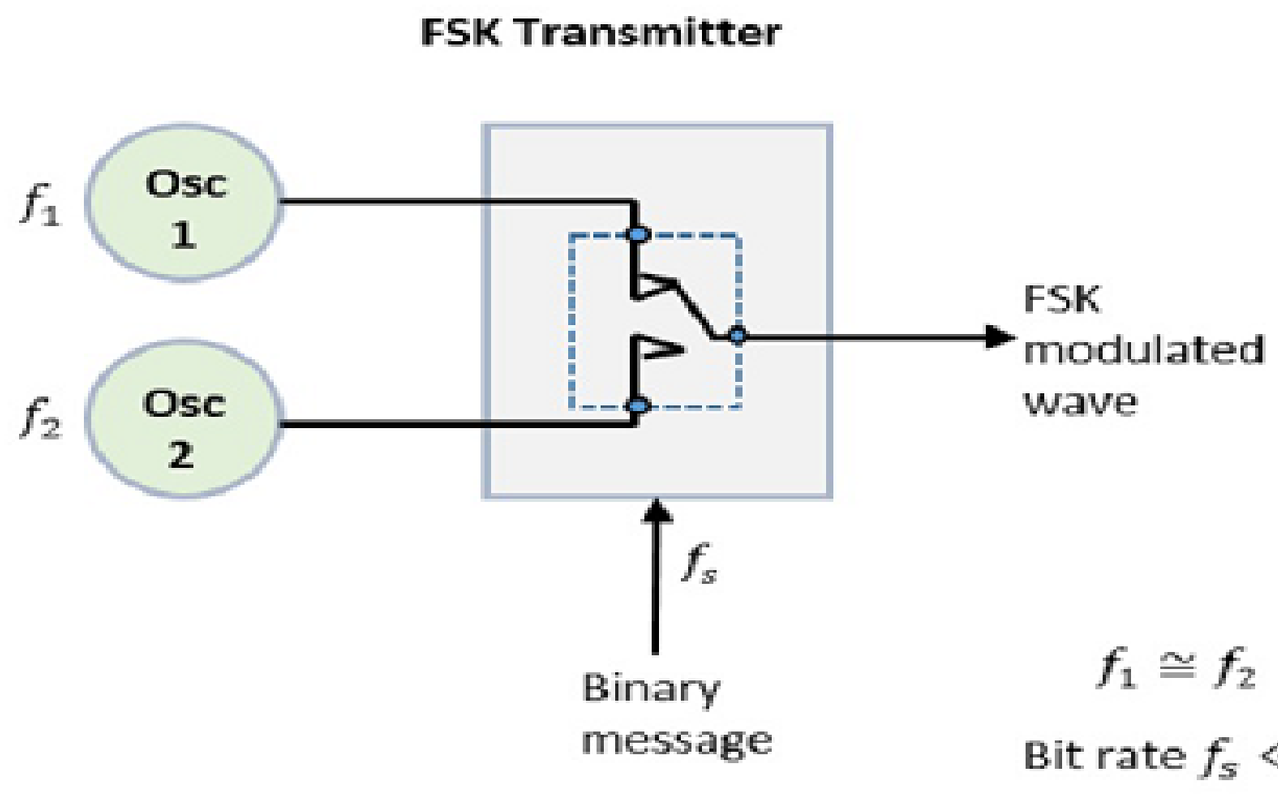
The following image is the diagrammatic representation of FSK modulated waveform along with its input.



To find the process of obtaining this FSK modulated wave, let us know about the working of a FSK modulator.

FSK Modulator

The FSK modulator block diagram comprises of two oscillators with a clock and the input binary sequence. Following is its block diagram.



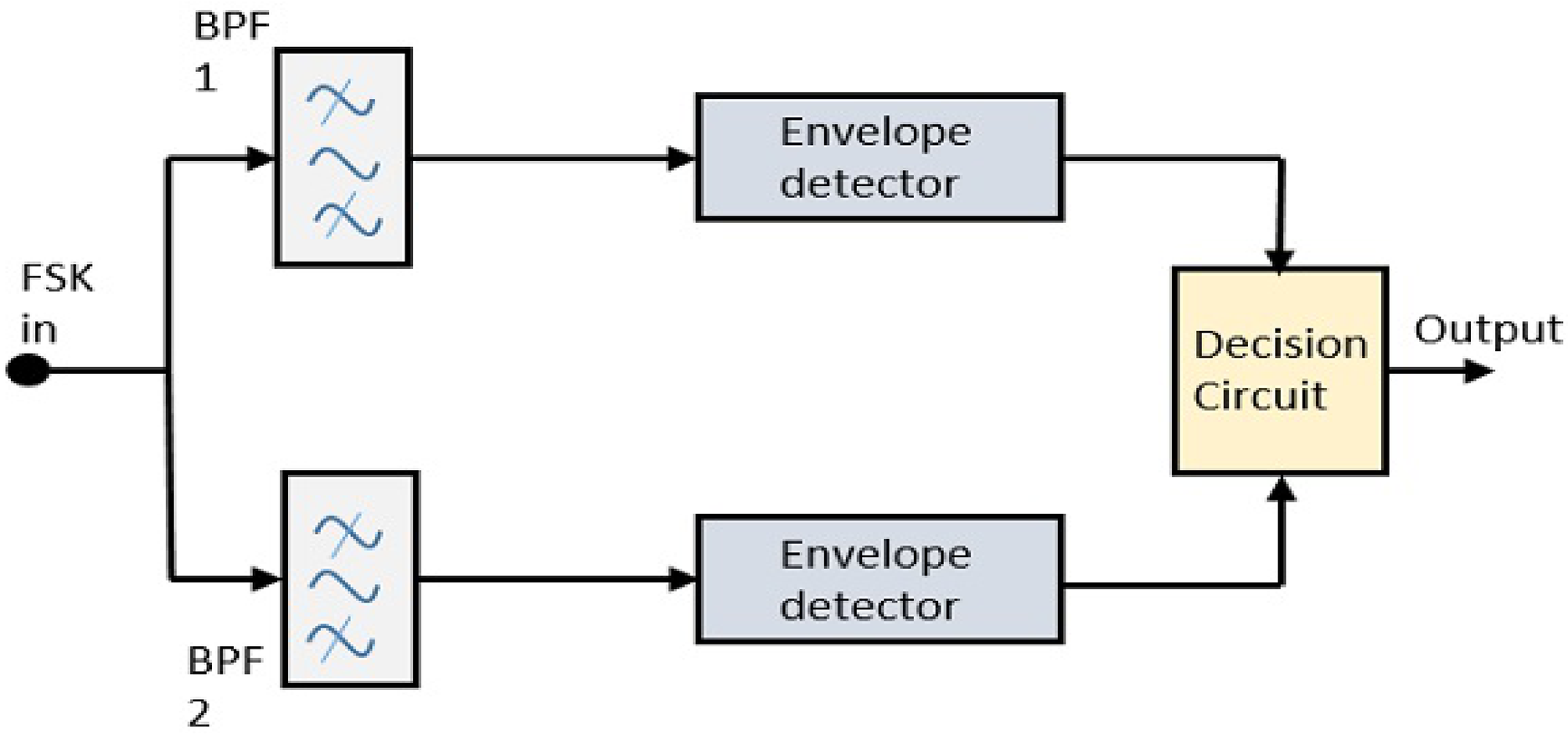
The two oscillators, producing a higher and a lower frequency signals, are connected to a switch along with an internal clock. To avoid the abrupt phase discontinuities of the output waveform during the transmission of the message, a clock is applied to both the oscillators, internally. The binary input sequence is applied to the transmitter so as to choose the frequencies according to the binary input.

FSK Demodulator

There are different methods for demodulating a FSK wave. The main methods of FSK detection are **asynchronous detector** and **synchronous detector**. The synchronous detector is a coherent one, while asynchronous detector is a non-coherent one.

Asynchronous FSK Detector

The block diagram of Asynchronous FSK detector consists of two band pass filters, two envelope detectors, and a decision circuit. Following is the diagrammatic representation.

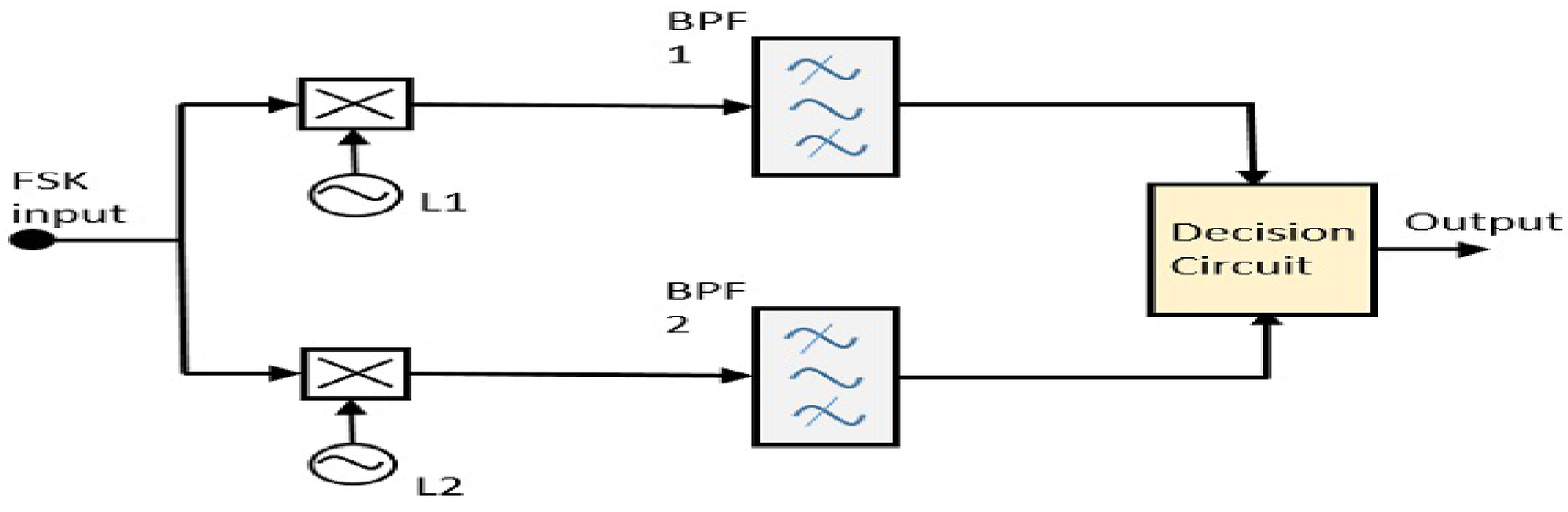


The FSK signal is passed through the two Band Pass filters BPFs ,tuned **Space** and **Mark** frequencies. The output from these two BPFs look like ASK signal, which is given to the envelope detector. The signal in each envelope detector is modulated asynchronously.

The decision circuit chooses which output is more likely and selects it from any one of the envelope detectors. It also re-shapes the waveform to a rectangular one.

Synchronous FSK Detector

The block diagram of Synchronous FSK detector consists of two mixers with local oscillator circuits, two band pass filters and a decision circuit. Following is the diagrammatic representation.



The FSK signal input is given to the two mixers with local oscillator circuits. These two are connected to two band pass filters. These combinations act as demodulators and the decision circuit chooses which output is more likely and selects it from any one of the detectors. The two signals have a minimum frequency separation.

For both of the demodulators, the bandwidth of each of them depends on their bit rate. This synchronous demodulator is a bit complex than asynchronous type demodulators.

Advantages and Disadvantages of FSK

Advantages

It is less susceptible to errors than ASK.

Better noise immunity than ASK.

Peak frequency offset is constant and always at its maximum.

The highest fundamental frequency is equal to half the information bit rate.

Relatively easy to implement.

Disadvantages

Not efficient in terms of transmission bandwidth requirement

It has poorer error performance than PSK or QAM.

Applications of FSK

Used in low-speed modems (up to 1200bps) over analog voice-band telephone lines.

Finds applications in pager systems, HF radio tele-type transmission systems, and LANs using coaxial cables.

Phase Shift Keying :

PSK is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications.

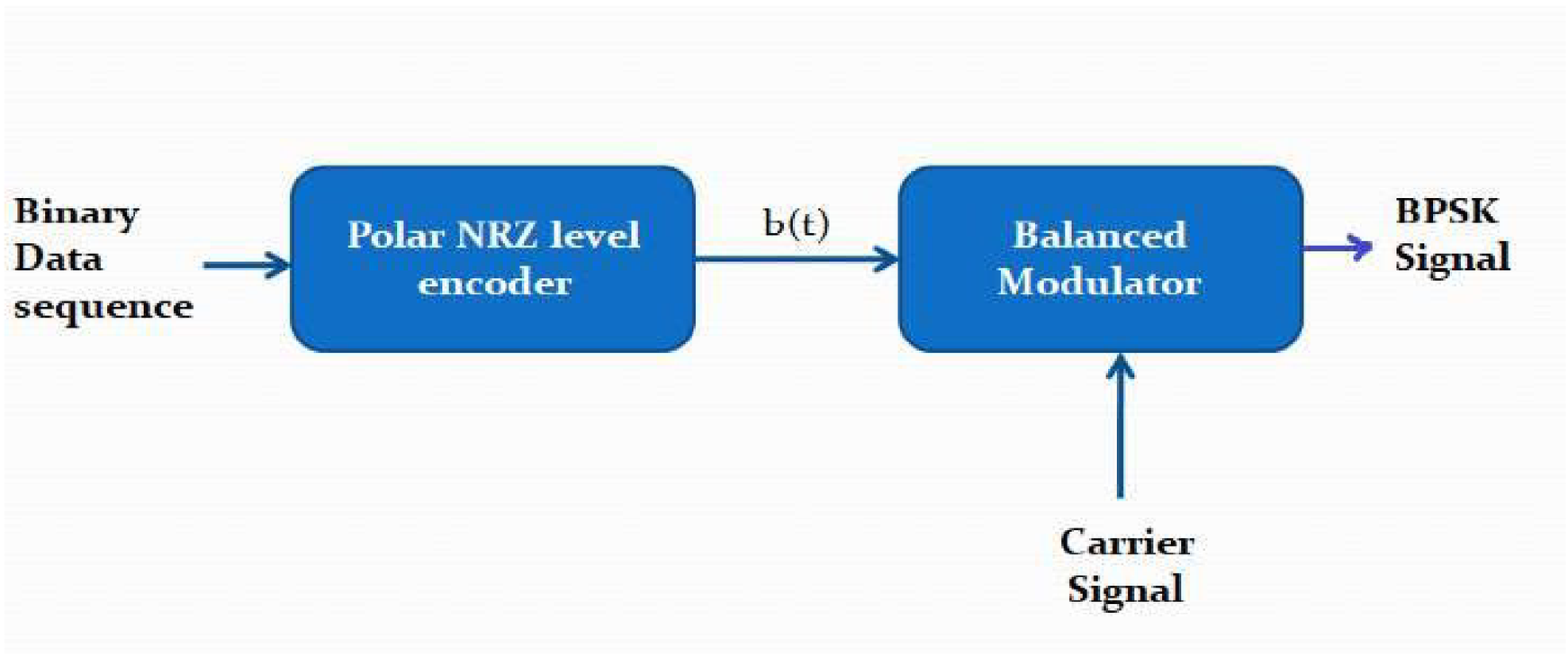
PSK is of two types, depending upon the phases the signal gets shifted. They are −

Binary Phase Shift Keying BPSK:

This is also called as 2-phase PSK or Phase Reversal Keying. In this technique, the sine wave carrier takes two phase reversals such as 0° and 180°.

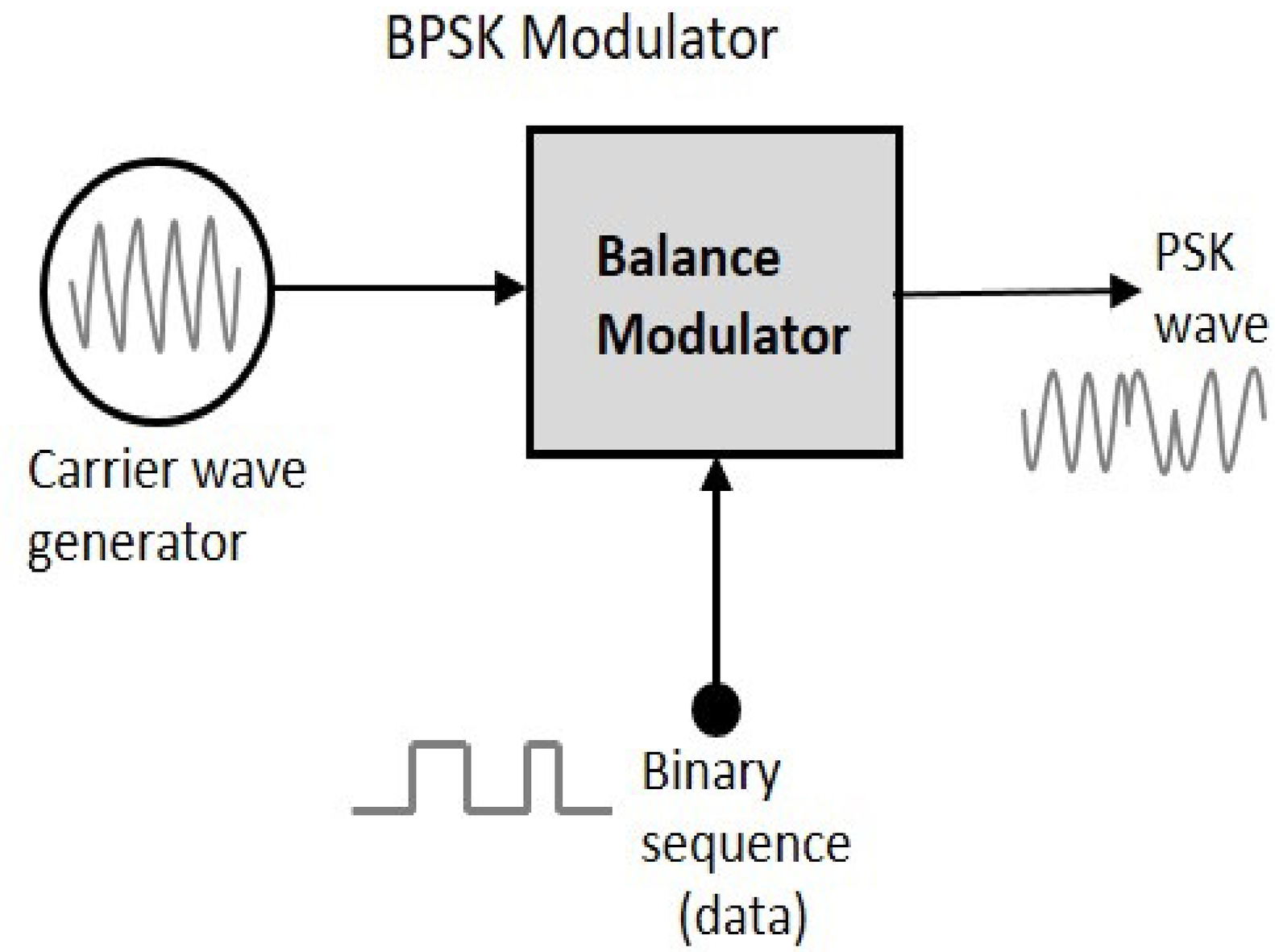
BPSK is basically a Double Side Band Suppressed Carrier DSBSC modulation scheme, for message being the digital information.

Generation of BPSK



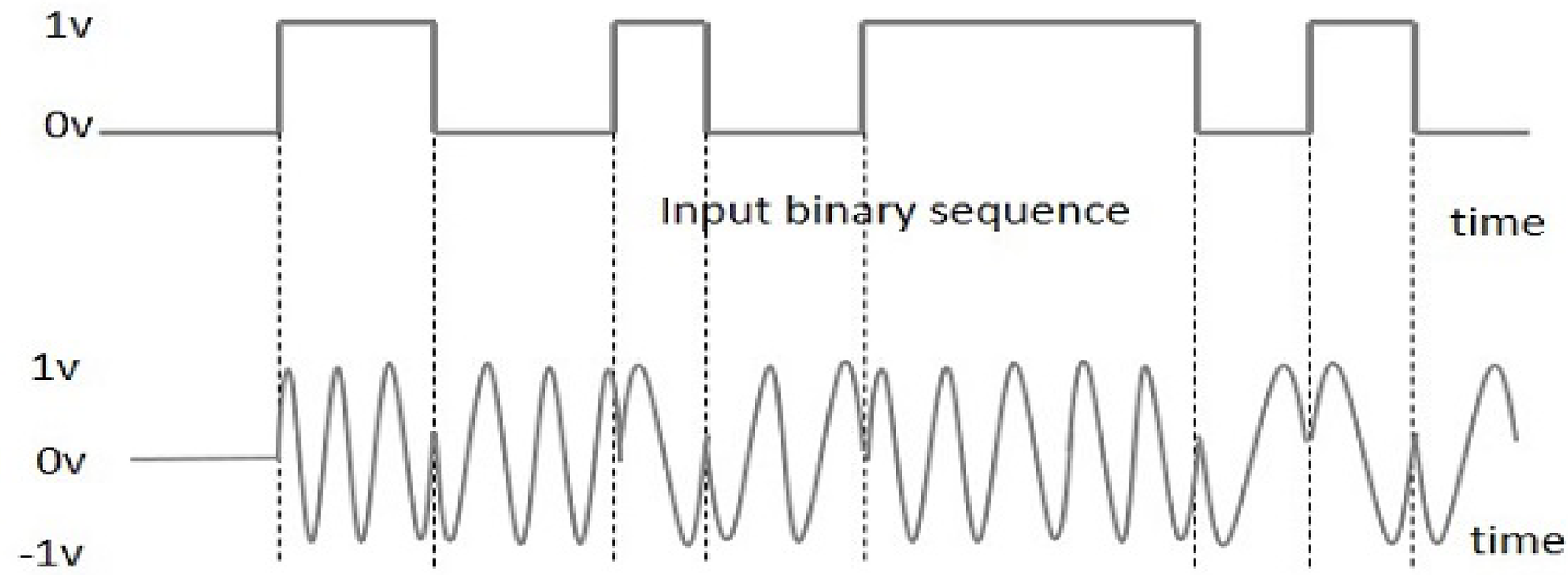
BPSK Modulator

The block diagram of Binary Phase Shift Keying consists of the balance modulator which has the carrier sine wave as one input and the binary sequence as the other input. Following is the diagrammatic representation.



The modulation of BPSK is done using a balance modulator, which multiplies the two signals applied at the input. For a zero binary input, the phase will be **0°** and for a high input, the phase reversal is of **180°**.

Following is the diagrammatic representation of BPSK Modulated output wave along with its given input.

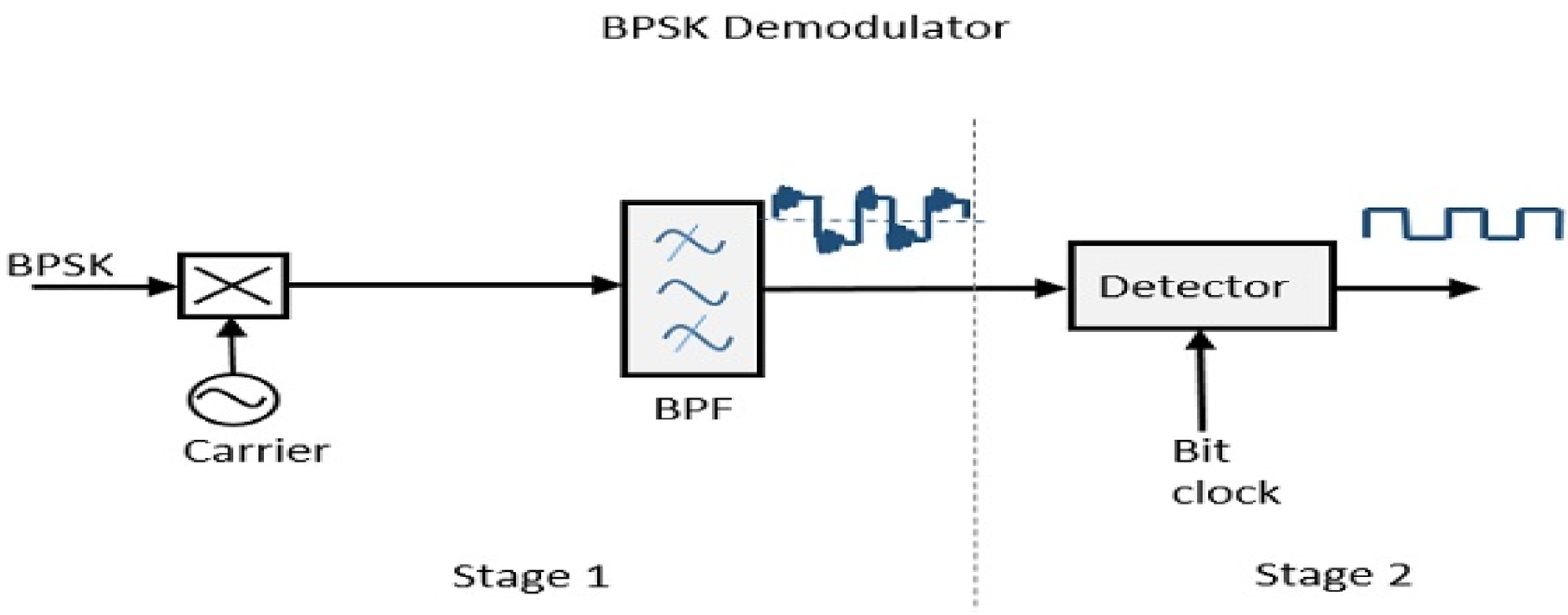


BPSK Modulated output wave

The output sine wave of the modulator will be the direct input carrier or the inverted 180°phase shifted input carrier, which is a function of the data signal.

BPSK Demodulator

The block diagram of BPSK demodulator consists of a mixer with local oscillator circuit, a bandpass filter, a two-input detector circuit. The diagram is as follows.



By recovering the band-limited message signal, with the help of the mixer circuit and the band pass filter, the first stage of demodulation gets completed. The base band signal which is band limited is obtained and this signal is used to regenerate the binary message bit stream.

In the next stage of demodulation, the bit clock rate is needed at the detector circuit to produce the original binary message signal. If the bit rate is a sub-multiple of the carrier frequency, then the bit clock regeneration is simplified. To make the circuit easily understandable, a decision-making circuit may also be inserted at the 2nd stage of detection.

Quadrature Phase Shift Keying QPSK

This is the phase shift keying technique, in which the sine wave carrier takes four phase reversals such as 0°, 90°, 180°, and 270°.

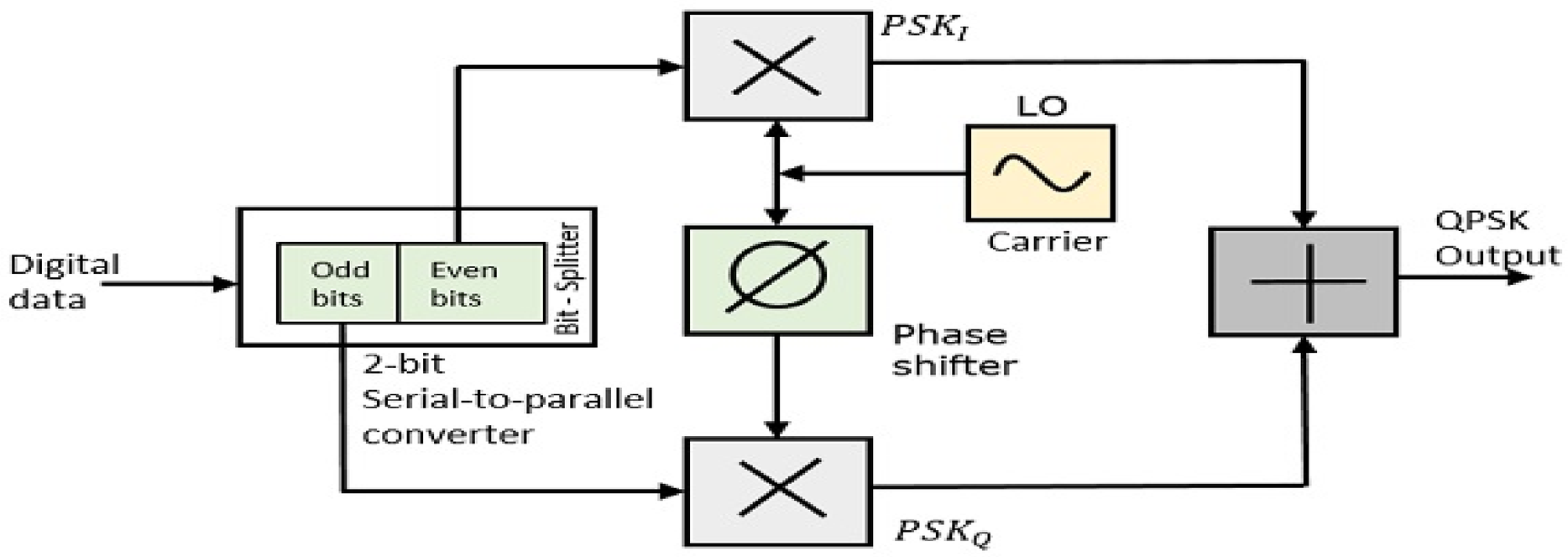
If this kind of techniques are further extended, PSK can be done by eight or sixteen values also, depending upon the requirement.

QPSK is a variation of BPSK, and it is also a Double Side Band Suppressed carrier DSBSC modulation scheme, which sends two bits of digital information at a time, called as **bigits**.

Instead of the conversion of digital bits into a series of digital stream, it converts them into bit pairs. This decreases the data bit rate to half, which allows space for the other users.

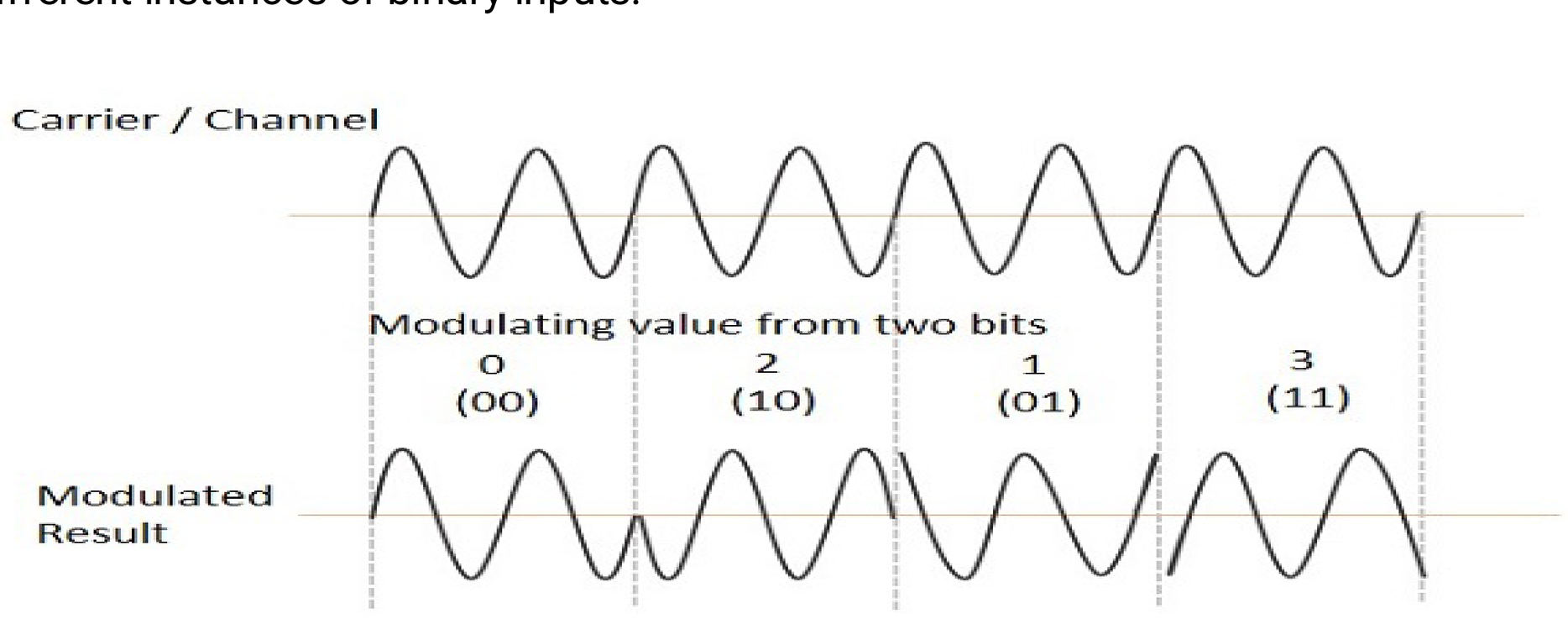
QPSK Modulator

The QPSK Modulator uses a bit-splitter, two multipliers with local oscillator, a 2-bit serial to parallel converter, and a summer circuit. Following is the block diagram for the same.



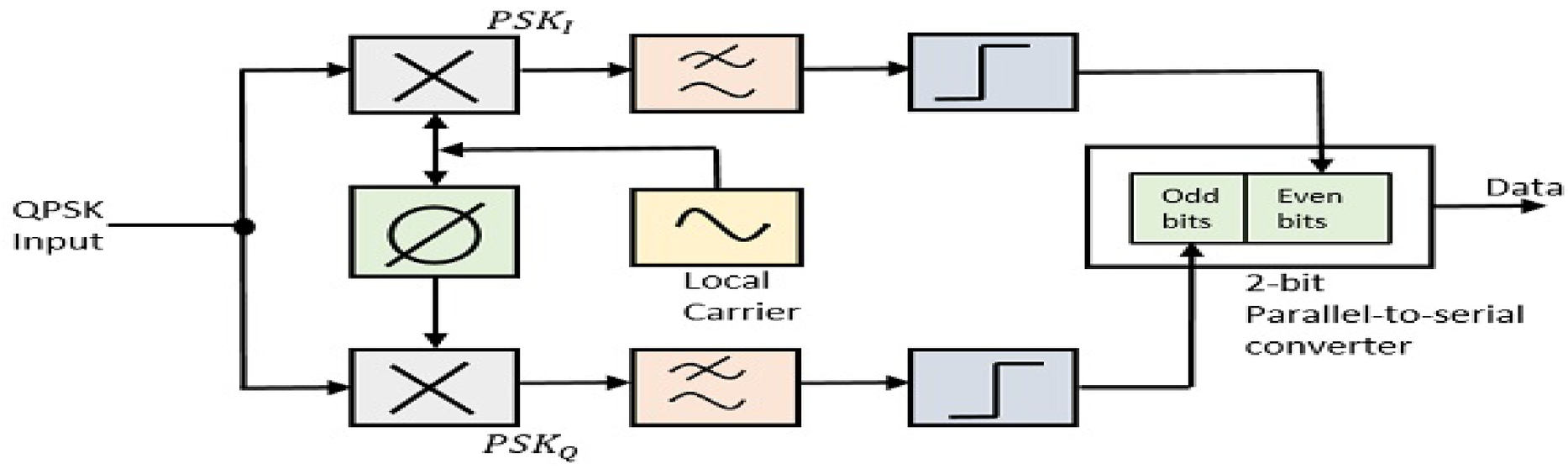
At the modulator's input, the message signal's even bits (i.e., 2nd bit, 4th bit, 6th bit, etc.) and odd bits (i.e., 1st bit, 3rd bit, 5th bit, etc.) are separated by the bits splitter and are multiplied with the same carrier to generate odd BPSK (called as **PSK_I**) and even BPSK (called as **PSK_Q**).
The **PSK_Q** signal is anyhow phase shifted by 90° before being modulated.

The QPSK waveform for two-bits input is as follows, which shows the modulated result for different instances of binary inputs.



QPSK Demodulator

The QPSK Demodulator uses two product demodulator circuits with local oscillator, two band pass filters, two integrator circuits, and a 2-bit parallel to serial converter. Following is the diagram for the same.



The two product detectors at the input of demodulator simultaneously demodulate the two BPSK signals. The pair of bits are recovered here from the original data. These signals after processing, are passed to the parallel to serial converter.

Advantages of PSK

Some of the major advantages of PSK are:

- It allows information to be transmitted in the radio communication in a way more efficiently as compared to that of FSK.
- It is quite less prone to error when we evaluate ASK modulation
- We can achieve a high rate of data transmission using this technique.
- It is also more power-efficient as compared to other techniques

Disadvantages of PSK

Some of the major disadvantages of PSK are:

- It has a very less bandwidth as compared to ASK
- It is a type of non-coherent reference signal
- Extremely difficult algorithms are used in decoding the binary information which is transmitted during PSK.
- They are at times are extremely sensitive to phase differences.
- It can sometimes generate the wrong modulation also.

Application of PSK

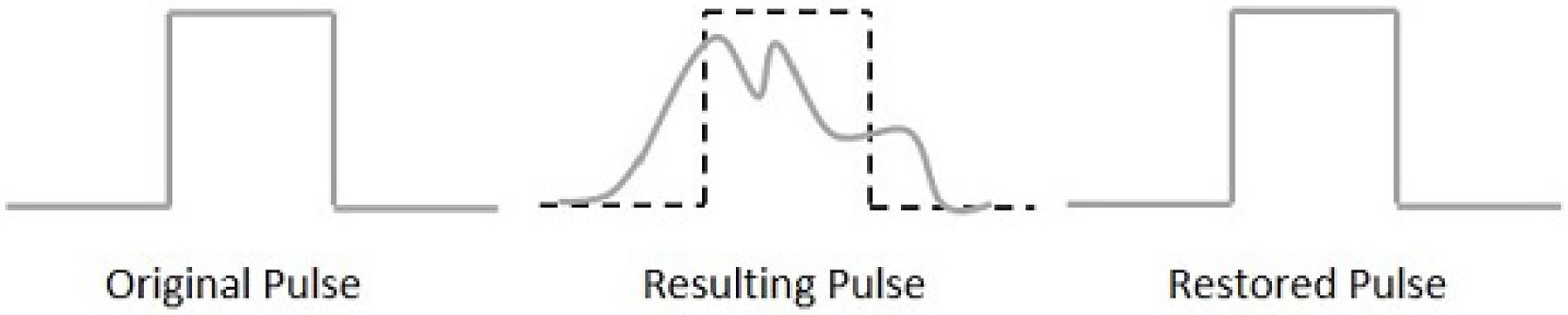
Some of the major **applications of Phase Shift Keying** are:

- Multi-channel WDM delay
- Delay and add a modulator
- Local oscillator
- Optical communication
- Nonlinear effect of WDM transmission
- Wireless LAN like Bluetooth and RFID.

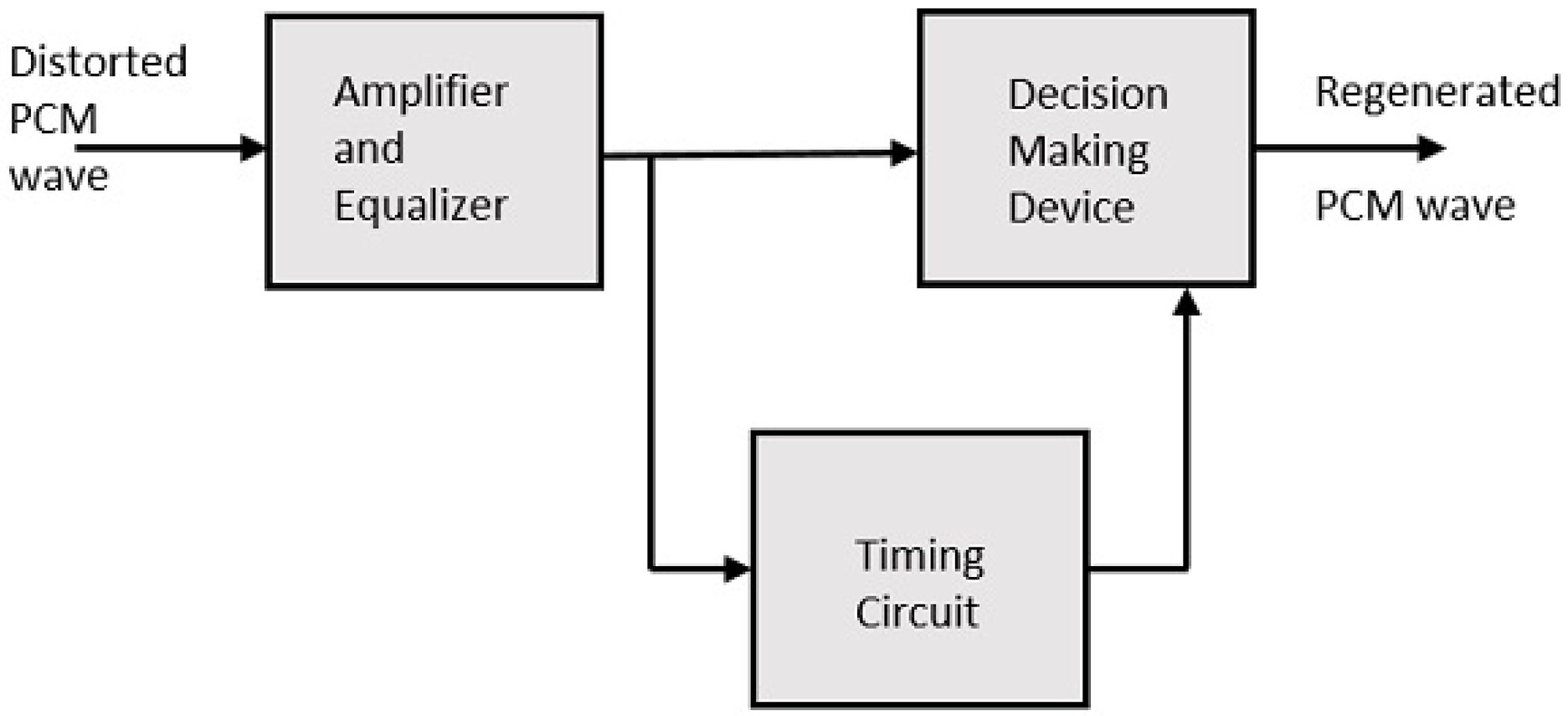
Regenerative Repeater:

For any communication system to be reliable, it should transmit and receive the signals effectively, without any loss. A PCM wave, after transmitting through a channel, gets distorted due to the noise introduced by the channel.

The regenerative pulse compared with the original and received pulse, will be as shown in the following figure.



For a better reproduction of the signal, a circuit called as **regenerative repeater** is employed in the path before the receiver. This helps in restoring the signals from the losses occurred. Following is the diagrammatical representation.



Block diagram of a regenerative repeater

This consists of an equalizer along with an amplifier, a timing circuit, and a decision making device. Their working of each of the components is detailed as follows.

Equalizer:

The channel produces amplitude and phase distortions to the signals. This is due to the transmission characteristics of the channel. The Equalizer circuit compensates these losses by shaping the received pulses.

Timing Circuit

To obtain a quality output, the sampling of the pulses should be done where the signal to noise ratio SNR is maximum. To achieve this perfect sampling, a periodic pulse train has to be derived from the received pulses, which is done by the timing circuit.

Hence, the timing circuit, allots the timing interval for sampling at high SNR, through the received pulses.

Decision Device

The timing circuit determines the sampling times. The decision device is enabled at these sampling times. The decision device decides its output based on whether the amplitude of the quantized pulse and the noise, exceeds a pre-determined value or not.

These are few of the techniques used in digital communications. There are other important techniques to be learned, called as data encoding techniques. Let us learn about them in the subsequent chapters, after taking a look at the line codes.