# Analog and Digital Communication


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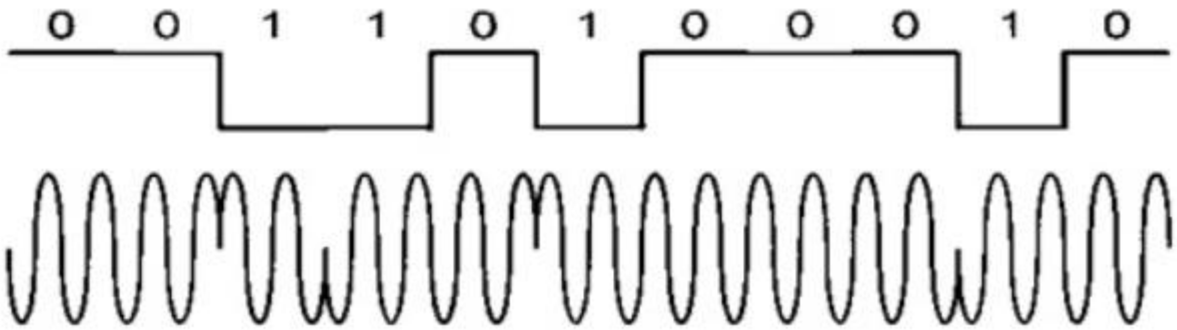
# Differential Phase Shift Keying(DPSK)

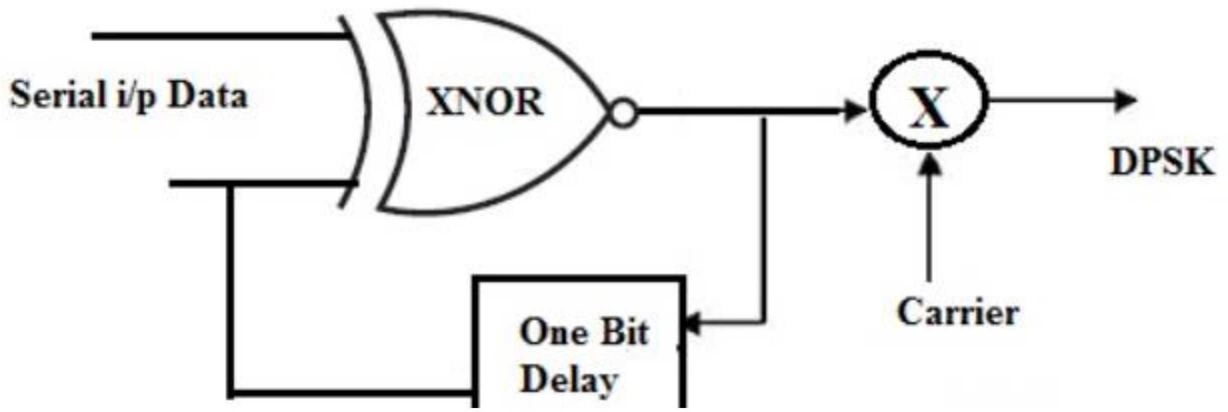
- It is one type of phase modulation used to transmit data by altering the carrier wave’s phase.
- In DPSK the phase of modulated signal is shifted relative to the previous signal element. The signal phase follows the high or low phase of the previous element.
- The binary bits input series can be changed so that the next bit depends upon the earlier bit. So, the earlier received bits in the receiver are utilized for detecting the current bit.




dpsk-waveforms

# DPSK Modulation

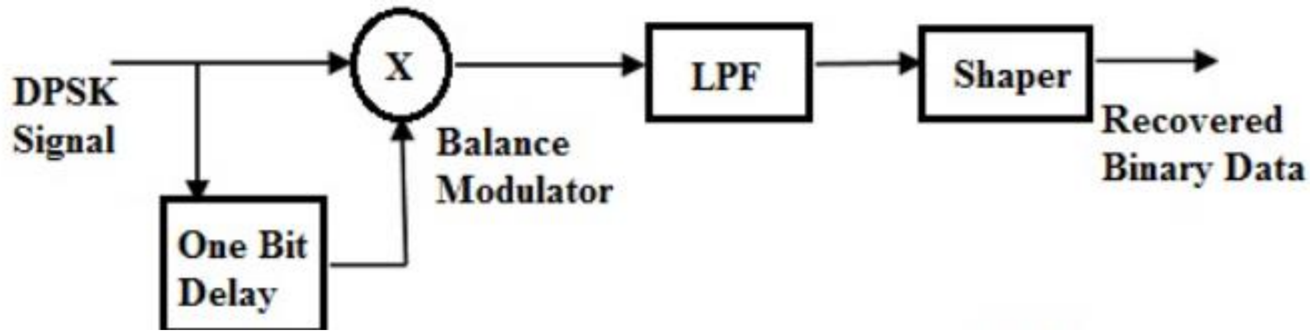
DPSK is a method of BPSK, where there is no reference phase signal. Here, the signal which is transmitted is used as a reference signal. The DPSK modulator diagram is shown below. This modulation encodes two separate signals namely the carrier signal as well as the modulating signal. The phase shift of each signal is 180°.




In the above figure, the serial input data can be applied to the XNOR gate & the o/p of the logic gate is fed back again to the input via 1-bit delay. Both the carrier signal as well as XNOR gate output is applied to the balanced modulator so that the modulated signal of DPSK can be generated.

## DPSK Demodulation

In this demodulator, both the previous bit and the reversed bit are compared with each other. The DPSK demodulator block diagram is shown below. From the above block diagram, it is clear that the DPSK signal is applied to a balanced modulator using a 1-bit delay input.




That signal is ready to release in the direction of lower frequencies using a low pass filter. After that, it is transmitted toward a shaper circuit for improving the unique binary data like the output. Here shaper circuit is a Schmitt trigger or comparator circuit.

# DPSK Advantages and Disadvantages

The advantages of DPSK include the following.

- This modulation doesn’t need the carrier signals at the end of the receiver circuit. Therefore compound circuits are not required.
- The BW of DPSK requirement is low evaluated to BPSK modulation.
- Non-consistent receivers are simple and inexpensive to construct, therefore extensively used in wireless communication.

The disadvantages of DPSK include the following.

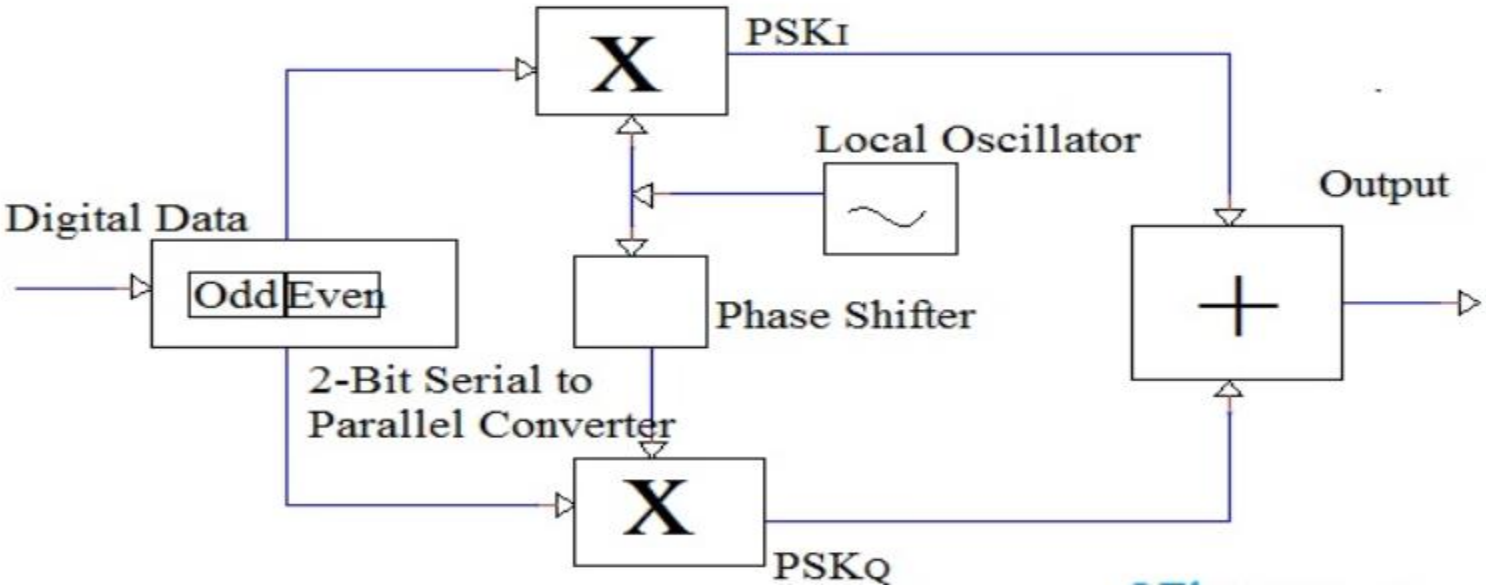
- The bit error rate or chance of error is high in DPSK contrast to BPSK.
- The interference of noise in DPSK is more.
- This modulation employs two consecutive bits intended for its response. Thus error in primary bit makes error within a subsequent bit as well as consecutively error spreads.

# Differential Phase Shift Keying Applications

The applications of differential phase-shift keying mainly include wireless communications like RFID, WLANs, and Bluetooth. The famous application among them is Bluetooth wherever alternatives of DPSK has been used like 8-DPSK, and π/4 – DQPSK modulation.

# Quadrature Phase Shift Keying (QPSK)

Quadrature Phase Shift Keying is a digital modulation method. In this method, the phase of the carrier waveform is changed according to the digital baseband signal. The phase of the carrier remains the same when the input logic is the 1 but goes a phase shift when the logic is 0. In Quadrature Phase Shift Keying, two information bits are modulated at once, unlike Binary Phase Shift Keying where only one bit is passed per symbol. Here, there are four carrier phase offsets with a phase difference of ±90° for four possible combinations of two bits( 00, 01, 10, 11).

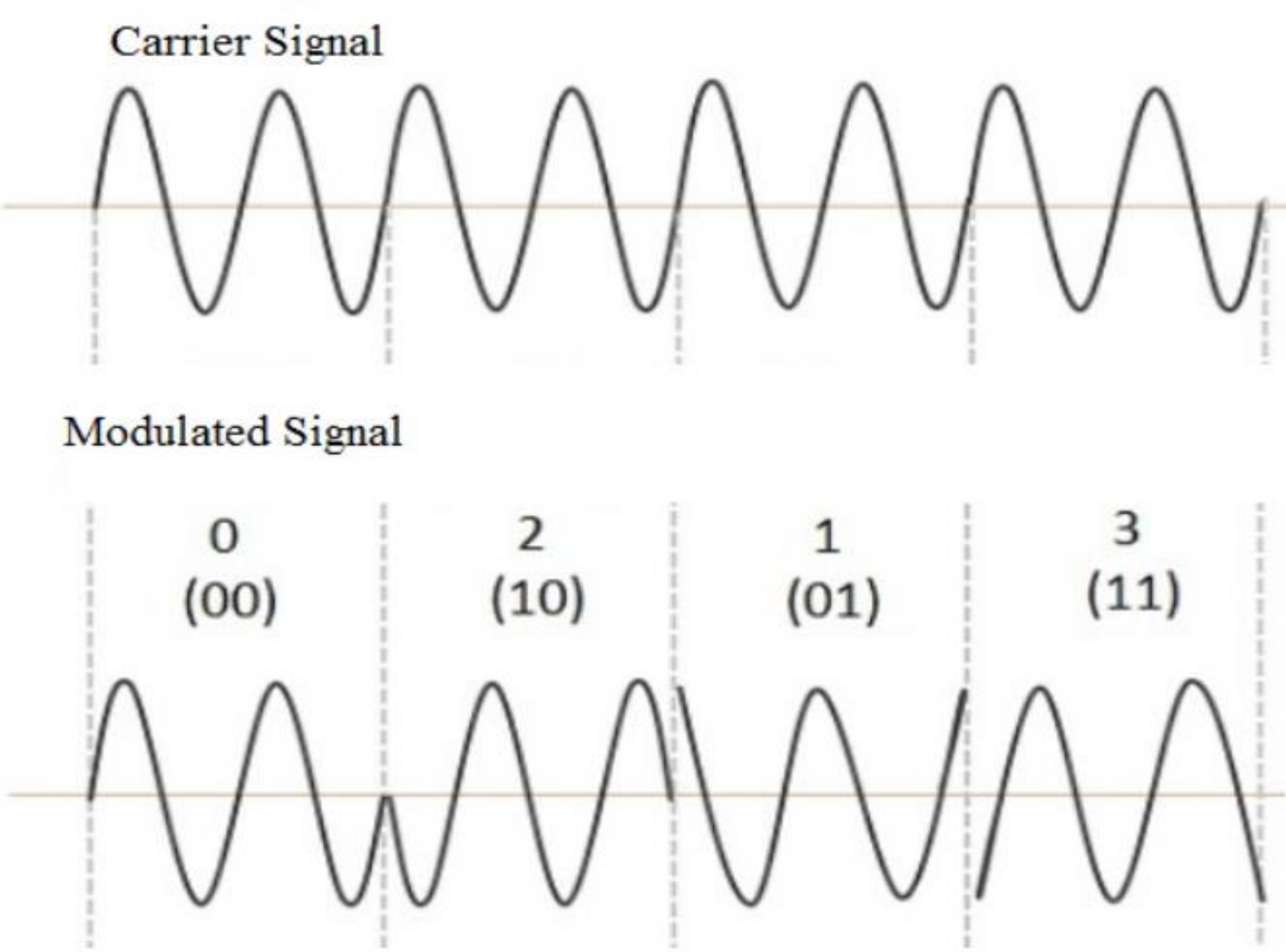


Instead of converting bits into a digital stream, QPSK converts it into bit pairs. This method is also known as the Double Side Band Suppressed Carrier modulation method.

At the transmitter input, the message signal bits are separated as even bits and odd bits using a bit splitter. These bits are then multiplied with the same carrier waveform to generate Even QPSK and Odd QPSK signals. The Even QPSK signal is phase shifter by 90°, using a phase shifter, before modulation. Here, the Local Oscillator is used for generating the carrier waveform. After separation of bits, a 2-bit serial to parallel converter is used. After multiplying with the carrier waveform, both Even QPSK and Odd QPSK are given to the summer when modulation output is obtained.

At the receiver end for demodulation, two product detectors are used. This product detectors convert the modulated QPSK signal into Even QPSK and Odd QPSK signals. Then the signals are passed through two bandpass filters and two integrators. After processing the signals are applied to the 2-bit parallel- to-series converter, whose output is the reconstructed signal.

# Waveform of Quadrature Phase Shift Keying




Quadrature-Phase-Shift-Keying-Waveform.

# Advantages and Disadvantages

- It provides good noise immunity.
- Compared to BPSK, bandwidth used by QPSK is reduced to half.
- The information transmission rate of Quadrature Phase Shift Keying is higher as it transmits two bits per carrier symbol.
- Carrier power remains constant as the variation in the QPSK amplitude is small.
- Effective utilization of available transmission bandwidth.
- Low error probability compared to other methods.
- The disadvantage of QPSK compared to BPSK is the circuit complexity.

# Binary Frequency Shift Keying (BFSK)

Binary Frequency Shift Keying (BFSK) is a type of digital modulation technique in which we are sending one bit per symbol i.e., ‘0’ or a ‘1’. Hence, the bit rate and symbol rate are the same. In BFSK, the information is encoded in the variation of the frequency of the carrier. We represent ‘0’ by carrier frequency ‘f1 ‘ and ‘1’ by carrier frequency ‘f2‘.

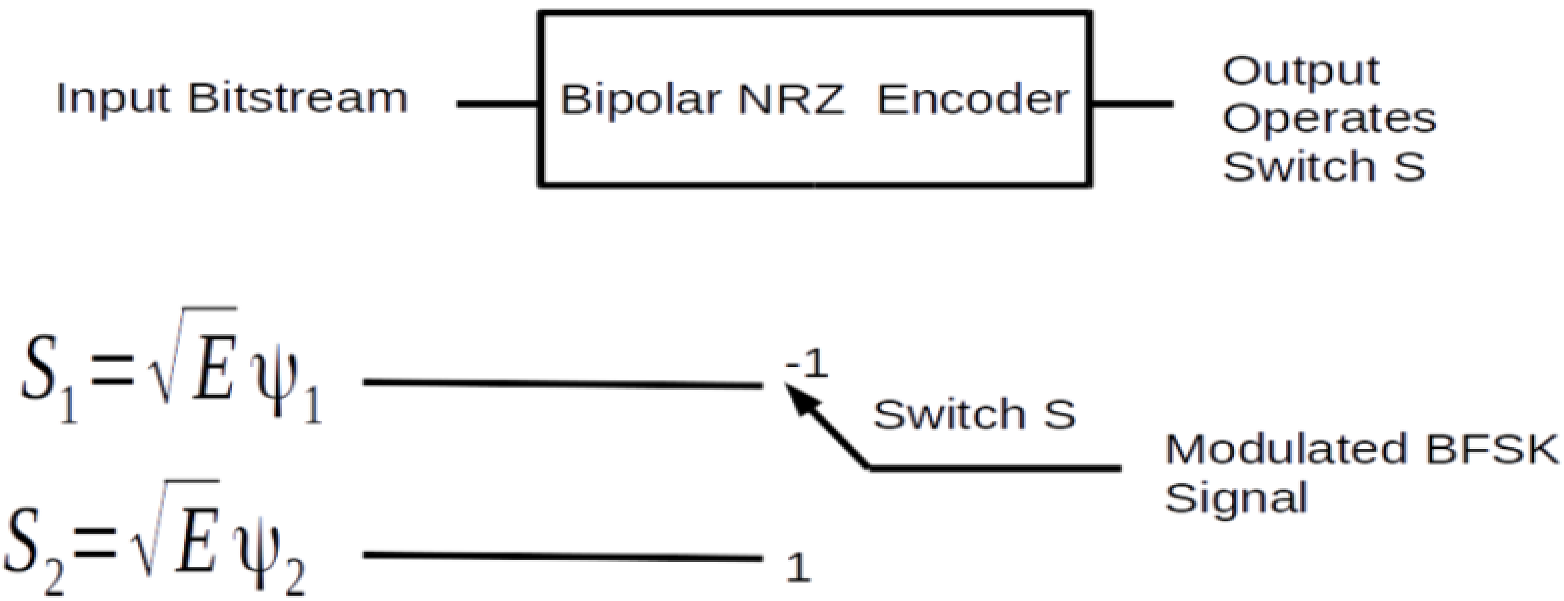
For example, we can have the following transmitted band-pass symbols:

$$S_1 = \sqrt{\frac{2E}{T}} \cos(2\pi f_1 t) \rightarrow represents\ '0'$$

$$S_2 = \sqrt{\frac{2E}{T}} \cos(2\pi f_2 t) \rightarrow represents\ '1'$$

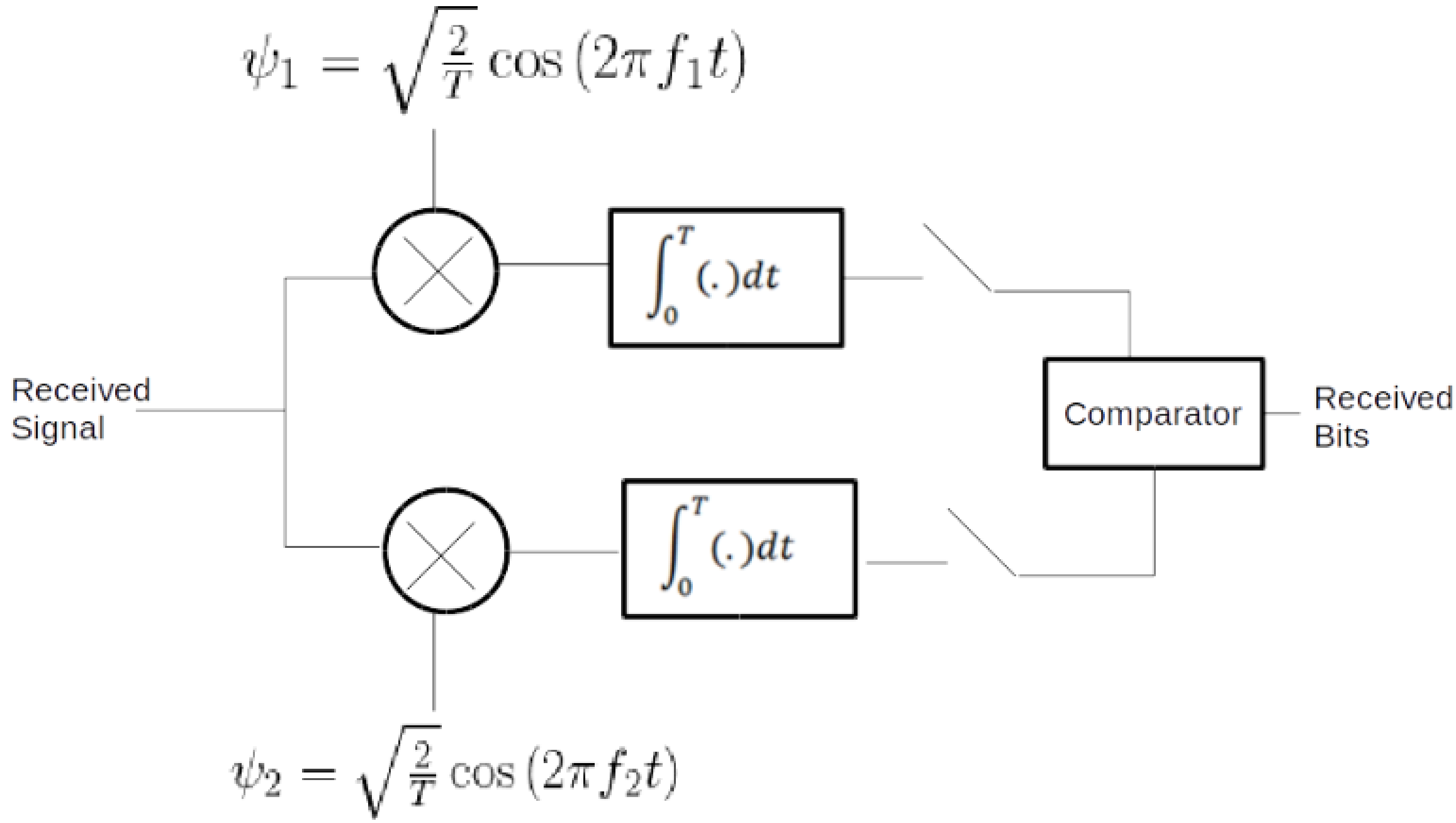
# BFSK Modulator

A simple BFSK modulator is shown in figure below. The incoming bit sequence is first encoded by a bipolar NRZ encoder. The NRZ encoder converts these digital bits into impulses to add a notion of time into them. Then NRZ waveform is generated by up-sampling these impulses. Afterwards, the output of NRZ encoder operates a switch. Based on whether the encoder’s output is +ve or -ve, the switch sends symbol S1 or symbol S2.



# BFSK Demodulator

Here, we do coherent demodulation of the BFSK signal at the receiver. Coherent demodulation requires the received signal to be multiplied with the carrier having the same frequency and phase as at the transmitter.

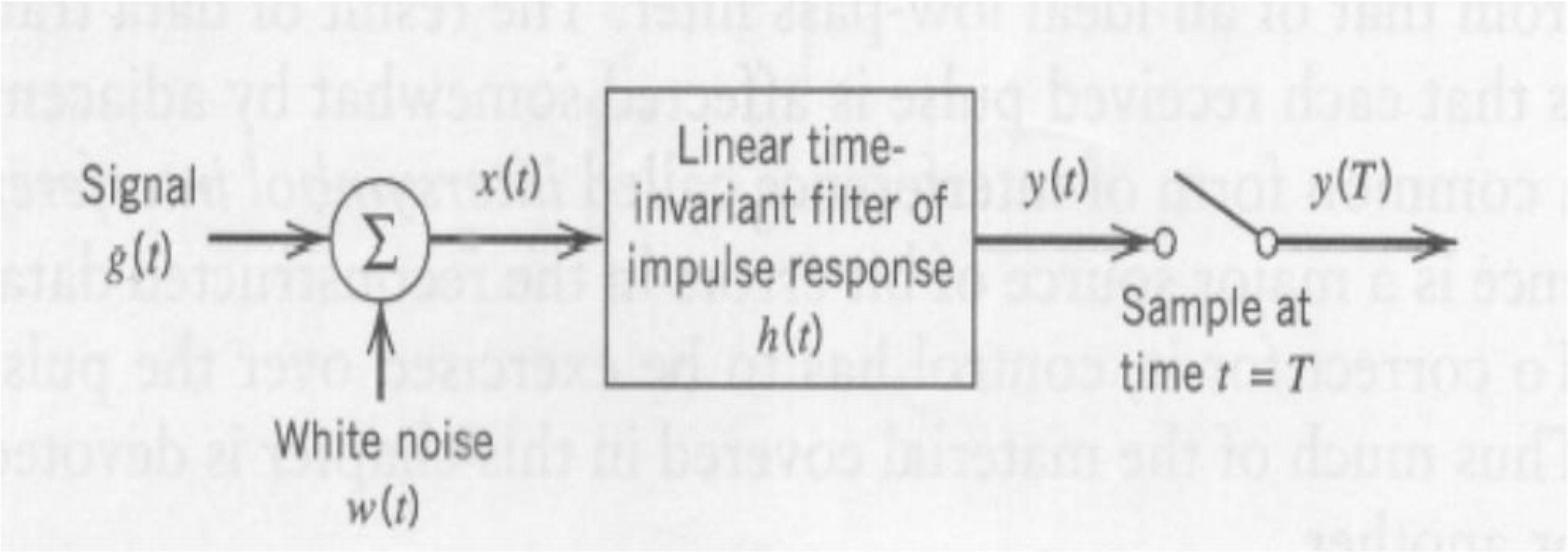


| Feature | DPSK (Differential Phase Shift Keying) | QPSK (Quadrature Phase Shift Keying) |
|---|---|---|
| Definition | DPSK is a digital modulation scheme that encodes data by varying the phase of the carrier wave in relation to the previous signal phase rather than an absolute reference. | QPSK is a digital modulation technique that changes the phase of the carrier signal to transmit data, using four distinct phase shifts (0°, 90°, 180°, and 270°) to represent two bits per symbol. |
| Phase Reference | Uses the phase of the previous symbol as a reference to determine the phase of the current symbol. | Uses a fixed reference phase to determine the phase of each symbol. |
| Bits per Symbol | Typically encodes one bit per symbol because it is primarily based on the phase change between consecutive symbols. | Encodes two bits per symbol due to its use of four distinct phases, making it more bandwidth-efficient. |
| Bandwidth Efficiency | Lower compared to QPSK because it transmits fewer bits per symbol. | Higher as it transmits more bits per symbol, thus making better use of the available bandwidth. |

| | | |
|---|---|---|
| **Complexity** | **Generally simpler in terms of receiver design because it does not require a coherent reference signal for demodulation. Phase changes are compared between successive symbols.** | **More complex as it requires a coherent demodulation scheme to precisely identify the four phase states, demanding more sophisticated synchronization mechanisms.** |
| Performance in Noise | Exhibits a higher bit error rate (BER) in noisy environments compared to QPSK, as noise can more easily affect the differential phase determination. | Offers better performance in noisy environments due to its phase states being farther apart, which makes it more resilient to noise and errors. |
| Application | Often used in environments where maintaining a phase reference might be difficult, making it suitable for non-coherent communication systems. | Widely used in applications requiring high data rates and efficient bandwidth usage, such as satellite communications and wireless networks. |
| Error Detection | Can inherently detect phase errors but at the expense of a higher BER. | Requires additional error detection and correction techniques to identify and correct errors due to its reliance on absolute phase measurements. |

# MATCHED FILTERS

- The matched filter is the optimal linear filter for maximizing the signal to noise ratio (SNR) in the presence of additive stochastic noise.
- Matched filters are commonly used in radar,in which a signal is sent out, and we measure the reflected signals, looking for something similar to what was sent out.
- Two-dimensional matched filters are commonly used in image processing, e.g., to improve SNR for X-ray pictures



- The filter input x(t) consists of a pulse signal g(t) corrupted by additive channel noise w(t), as shown by

$$x(t) = g(t) + w(t), \qquad 0 \leq t \leq T$$

- where T is an arbitrary observation interval. The pulse signal g(t) may represent a binary symbol I or 0 in a digital communication system.
- The w(t) is the sample function of a white noise process of zero mean and power spectral density No/2.
- The source of uncertainty lies in the noise w(t).
- The function of the receiver is to detect the pulse signal g(t) in an optimum manner, given the received signal x(t).
- To satisfy this requirement, we have to optimize the design of the filter so as to minimize the effects of noise at the filter output in some statistical sense, and thereby enhance the detection of the pulse signal g(t).
- Since the filter is linear, the resulting output y(t) may be expressed as

$$y(t) = g_o(t) + n(t)$$

- where $g_0(t)$ and $n(t)$ are produced by the signal and noise components of the input $x(t)$, respectively.
- A simple way of describing the requirement that the output signal component $g_0(t)$ be considerably greater than the output noise component $n(t)$ is to have the filter make the instantaneous power in the output signal $g_0(t)$, measured at time $t = T$, as large as possible compared with the average power of the output noise $n(t)$. This is equivalent to maximizing the peak pulse signal-to-noise ratio, defined as

$$\eta = \frac{|g_o(T)|^2}{E[n^2(t)]}$$

For the case of white noise, the description of the matched filter is simplified as follows: For white noise,= No / 2. Thus equation becomes,

$$H(f) = \frac{2K}{N_0} S^*(f) e^{-j\omega t_0}$$