DIGITAL MODULATION TECHNIQUES WITH REAL-WORLD APPLICATIONS

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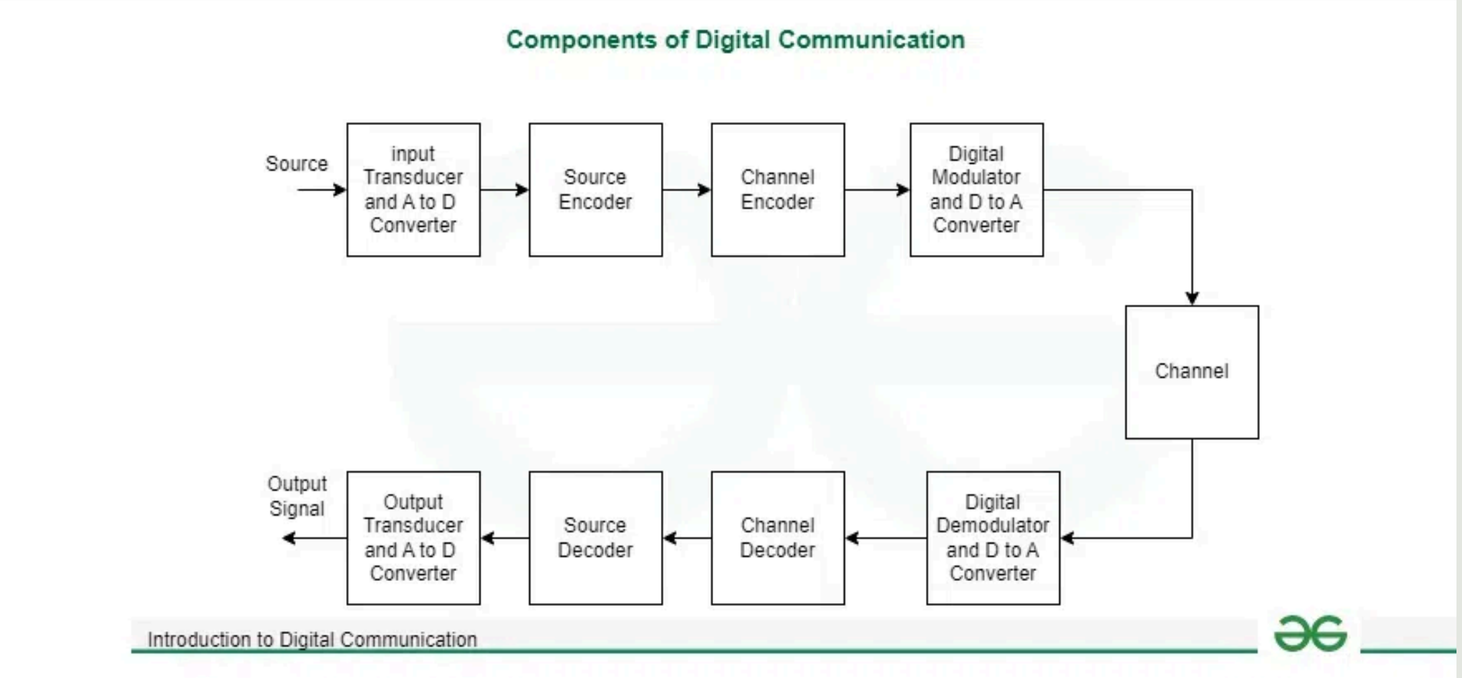
Introduction

- Digital modulation is the process of converting digital data (binary bits 0 and 1) into an analog waveform by varying one or more characteristics of a carrier signal — such as its amplitude, frequency, or phase — to enable transmission over communication channels.
- It allows efficient, noise-resistant wireless communication.
- Common digital modulation techniques include:
    - ASK (Amplitude Shift Keying)
    - FSK (Frequency Shift Keying)
    - PSK (Phase Shift Keying)



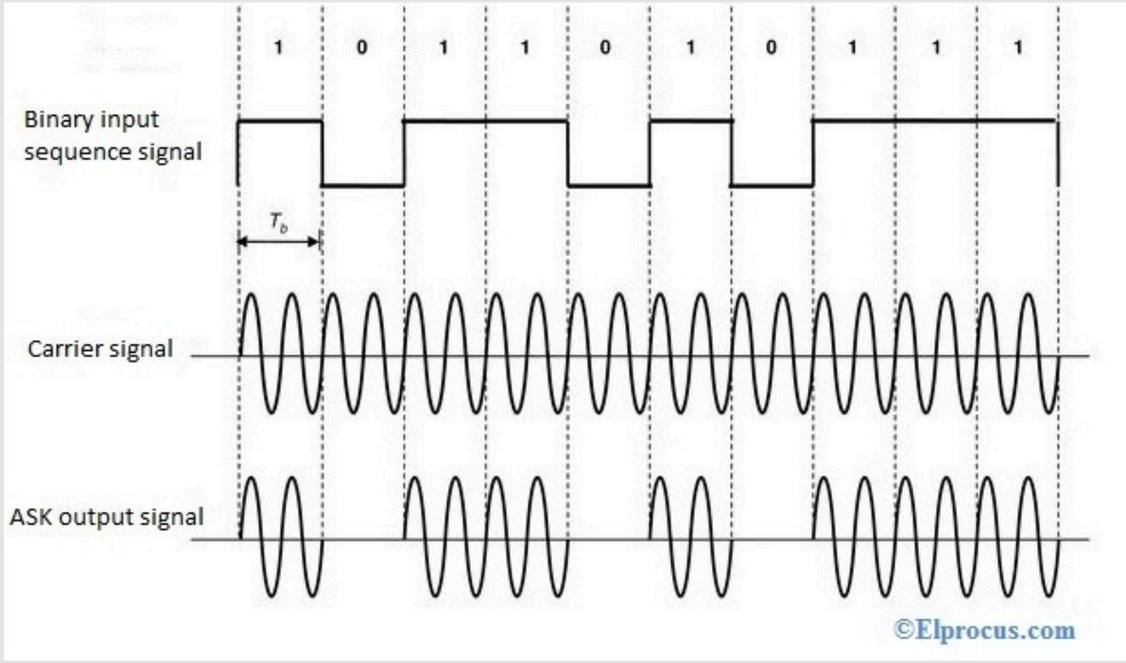
Amplitude Shift Keying (ASK)

- In ASK, the amplitude of the carrier wave changes according to digital data.
- A binary ‘1’ turns the carrier ON, and ‘0’ turns it OFF.
- It is simple and cost-effective but sensitive to noise.

Real-World Example:

RFID Tags use ASK to transmit stored ID data to RFID readers through electromagnetic coupling.

Formula: $s(t)=A\cos(2\pi f_c t)$



Frequency Shift Keying (FSK)

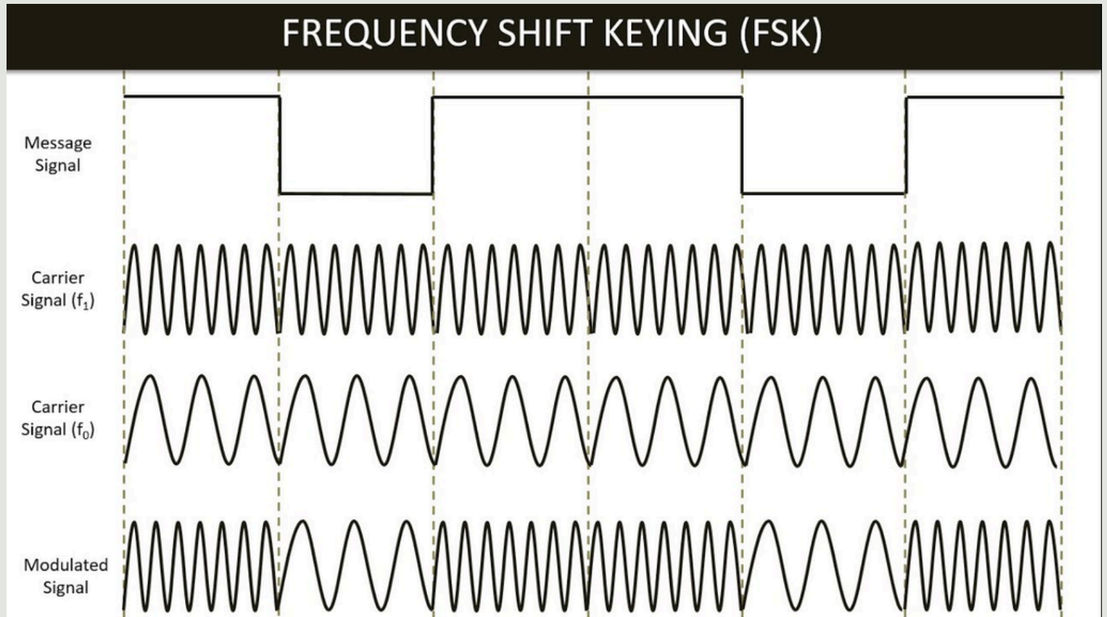
- FSK changes the frequency of the carrier depending on whether the input bit is 0 or 1.
- Two discrete frequencies represent logic levels:

  At **Bit 1** the frequency of output wave **increases**

  At **Bit 0** the frequency of output wave **decreases**
- It offers better noise immunity than ASK.

Real-World Example:

- Bluetooth uses Gaussian FSK (GFSK) to enable low-power, short-range wireless communication between devices.



Phase Shift Keying (PSK)

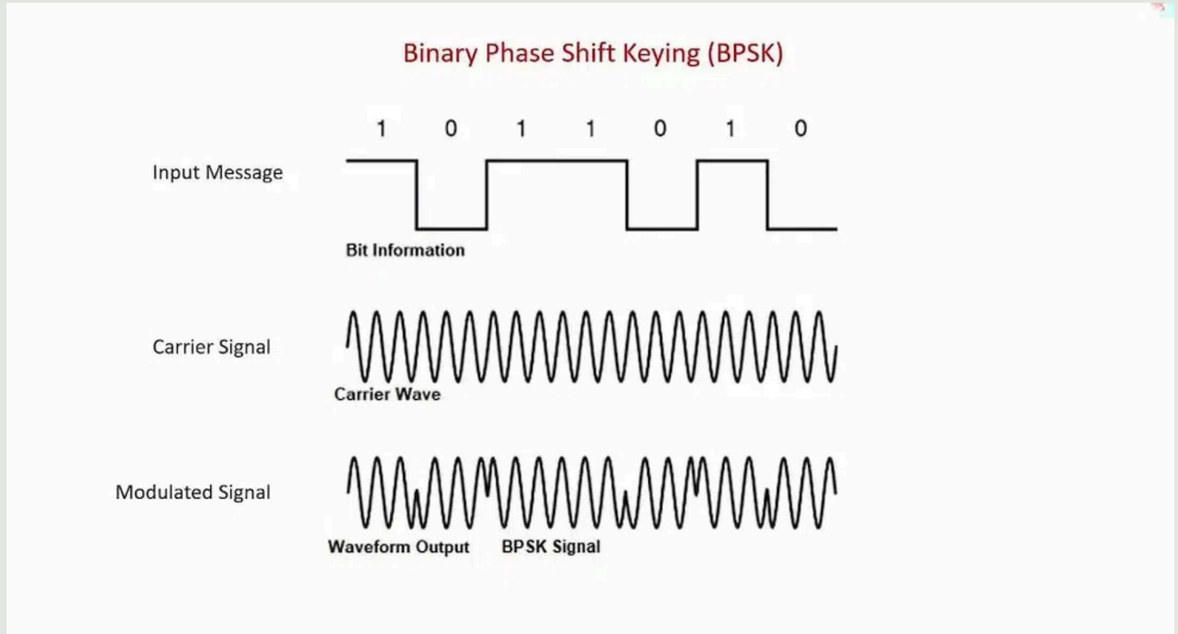
- Phase Shift Keying (PSK) is a digital modulation technique in which the phase of a constant-amplitude carrier is changed whenever the input bit changes. In Binary PSK (BPSK):
- Bit '0' → Phase = 0°
- Bit '1' → Phase = 180°
- Each bit transition causes a 180° phase shift, allowing reliable representation of digital data.

Real-World Example:

Wi-Fi uses PSK and higher-order variants (like QPSK, 16-QAM) for high-speed data transmission.

Formula:

$s(t) = A\cos(2\pi f_c t + \phi_i)$



Comparison and Conclusion

Technique	Parameter	Example	Key Feature	Limitation
ASK	Amplitude	RFID	Simple & low cost	Noise-sensitive
FSK	Frequency	Bluetooth	Better noise resistance	Requires more bandwidth
PSK	Phase	Wi-Fi	High efficiency & reliability	Complex demodulation

- Digital modulation enables efficient, reliable wireless data communication.
- ASK → RFID, FSK → Bluetooth, PSK → Wi-Fi demonstrate how modulation is chosen based on application needs for range, power, and speed.
- Python simulations help visualize signal behavior and improve understanding of digital communication systems.

References

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