Simulation and Analysis of Digital Modulation Techniques using MATLAB

Name : Aditi Vishwakarma (561)

Ved Yadav (562)

Shraddha Yedave (563)

Aim : ASK, PSK, FSK Simulation using Python/MATLAB and display waveforms- use for some application.

Software : MATLAB

Theory :

Amplitude Shift Keying (ASK)

- **Principle:** Amplitude Shift Keying (ASK) is the simplest form of digital modulation. It encodes digital data by varying the **amplitude** of the carrier wave while keeping its frequency and phase constant. The presence or absence (or changes in specific levels) of the carrier amplitude signifies the binary data.
- **Encoding Mechanism:**
    - In its most basic form, called **On-Off Keying (OOK)**, a binary '1' is represented by the transmission of the carrier wave at its full amplitude, and a binary '0' is represented by the absence of the carrier wave (zero amplitude).
    - More sophisticated ASK schemes can use multiple discrete amplitude levels to represent multiple bits per symbol (e.g., 4-ASK could use four amplitude levels to represent 00, 01, 10, 11).

- **Mathematical Representation (OOK):**
  $s_{ASK}(t) = A_{max} \cdot \cos(2\pi f_c t)$ for binary '1'
  $s_{ASK}(t) = 0$ for binary '0'

- **Characteristics:**
  - **Simplicity:** ASK modulators and demodulators are straightforward to design and implement, leading to low hardware cost.
  - **Bandwidth Efficiency:** Its bandwidth efficiency is relatively low, especially for basic OOK, as only one parameter (amplitude) is being varied.
  - **Noise Sensitivity:** ASK is highly susceptible to noise, interference, and channel fading. Any disturbance that alters the amplitude of the received signal can easily be misinterpreted as a change in data, leading to a higher bit error rate (BER). Therefore, it's generally unsuitable for long-distance or high-noise environments without significant error correction.

Frequency Shift Keying (FSK)

- **Principle:** Frequency Shift Keying (FSK) encodes digital data by varying the **frequency** of the carrier wave while keeping its amplitude and phase constant. Different frequencies are assigned to different binary digits.
- **Encoding Mechanism:**
  - In Binary FSK (BFSK), two distinct carrier frequencies are used: one frequency () represents a binary '1', and another frequency () represents a binary '0'.
  - The transition between these frequencies is typically smooth to avoid spectral splatter.
  - Like ASK, multi-level FSK (M-FSK) can use more than two frequencies to transmit multiple bits per symbol.

- **Mathematical Representation (BFSK):**
  $s_{FSK}(t) = A \cdot \cos(2\pi f_1 t + \phi)$ for binary '1'
  $s_{FSK}(t) = A \cdot \cos(2\pi f_2 t + \phi)$ for binary '0'

- **Characteristics:**
  - **Robustness against Amplitude Noise:** FSK is significantly more robust against noise and amplitude variations (like fading) compared to ASK. The receiver primarily detects frequency changes, which are less affected by amplitude distortion.
  - **Constant Envelope:** The modulated signal maintains a constant amplitude, simplifying the design of power amplifiers (which don't need to be perfectly linear) and improving power efficiency.
  - **Bandwidth Requirement:** FSK generally requires a larger bandwidth than ASK and PSK for a given data rate, especially if the frequency separation () is wide. This is because multiple distinct frequencies must be allocated.

Phase Shift Keying (PSK)

- **Principle:** Phase Shift Keying (PSK) modulates digital data by varying the **phase** of the carrier wave while keeping its amplitude and frequency constant. Changes in the phase of the carrier signal represent the different binary digits.
- **Encoding Mechanism:**
  - **Binary PSK (BPSK):** This is the simplest form. A binary '1' is typically represented by a carrier with a 0-degree phase shift (i.e., the original carrier). A binary '0' is represented by a carrier with a 180-degree phase shift (i.e., the inverted carrier). This effectively means a phase transition occurs whenever the data bit changes.
  - **Quadrature PSK (QPSK):** Encodes two bits per symbol by using four distinct phase shifts (e.g., 0°, 90°, 180°, 270°). This doubles the data rate for the same bandwidth compared to BPSK.
  - **M-ary PSK (M-PSK):** Generalizes QPSK by using M distinct phase angles (e.g., 8-PSK uses 8 phases to encode 3 bits per symbol).

- **Mathematical Representation (BPSK):**
  $s_{BPSK}(t) = A \cdot \cos(2\pi f_c t + 0)$ for binary '1'
  $s_{BPSK}(t) = A \cdot \cos(2\pi f_c t + \pi)$ for binary '0' (Note: $\cos(x + \pi) = -\cos(x)$)

- **Characteristics:**
  - **High Bandwidth Efficiency:** PSK, especially multi-level PSK, is highly bandwidth-efficient. By encoding multiple bits per symbol, it can achieve higher data rates within a given bandwidth compared to ASK or FSK.
  - **Good Noise Immunity:** PSK offers good immunity to noise and interference, particularly in terms of amplitude fluctuations, because the information is carried in the phase, not the amplitude. Its performance is generally superior to ASK and FSK.
  - **Constant Envelope:** Like FSK, PSK maintains a constant envelope, which is beneficial for power amplifier efficiency.
  - **Phase Ambiguity:** A common challenge in PSK demodulation is phase ambiguity, where the receiver might not know the absolute reference phase. This is often overcome by using Differential PSK (DPSK), which encodes information in the *change* of phase rather than the absolute phase.

Applications :

ASK (Amplitude Shift Keying)

- Infrared (IR) remote controls — like TV or AC remotes use ASK to send signals.
- Optical fiber communication — ASK is sometimes used for short-distance data transmission.
- Low-cost RF devices — garage door openers, wireless key fobs, RFID tags.

FSK (Frequency Shift Keying)

- Modems — early dial-up internet used FSK to send data over telephone lines.
- Walkie-talkies and pagers — use FSK for clear signal transmission.

- Bluetooth — uses a type of FSK called GFSK (Gaussian FSK).
- Radio control systems — remote car toys, wireless sensors.

PSK (Phase Shift Keying)

- Wi-Fi (802.11 standards) — uses BPSK, QPSK, or higher versions like 16-QAM (which combines PSK & ASK).
- Satellite communication — BPSK and QPSK for high-speed, long-distance data.
- Cellular networks (4G, 5G) — use QPSK and variants for efficient data transmission
- RFID & NFC systems — sometimes use PSK for secure and fast communication.

Conclusion

This micro-project successfully simulated and visualized ASK, FSK, and PSK digital modulation using MATLAB. The study clarified how binary data is encoded by varying a carrier's amplitude, frequency, or phase, respectively. We observed that ASK is simple but noise-prone, FSK offers better noise immunity through frequency changes, and PSK (BPSK) provides superior bandwidth efficiency and noise robustness via phase shifts. This project effectively illustrated the distinct characteristics and real-world applications of these fundamental modulation techniques.