Digital Carrier Modulation

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- In digital carrier modulation system, the modulating signal is digital which is the output of PCM or DM system and carrier signal is high frequency sinusoidal carrier.
- In digital carrier modulation system one of the properties of the carrier, namely amplitude, frequency or the phase is varied at a time with the binary modulating signal.
  1. **Amplitude shift keying:** The generation of ASK signal is simplest, is amplitude dependent, maximum noise is introduced and therefore ASK system has lowest signal to noise ratio.
     - ASK signal uses ON-OFF signaling.
     - In ASK probability of error (P_e) is high.
     - The ASK system is used for telegraphy.
  2. **Frequency shift keying:** The circuit configuration of FSK system is most complex, requires large bandwidth for its transmission but has relatively high S/N ratio.
     - FSK signal uses NRZ signaling.
     - In case of FSK, P_e is less.
     - Multiplexing is difficult.
     - Used in MODEM.
  3. **Phase shift keying:** The PSK system has relatively high SNR, relatively complex circuit, require lesser bandwidth as compare to FSK system.
     - PSK signal uses NRZ signaling.
     - This system has lowest probability of error
     - The PSK in its modified form is used for satellite communication or for the mobile communication.
- Comparison between ASK, PSK, FSK

Parameter	ASK	PSK	FSK
E	$\frac{1}{2}A^2T$	$\frac{1}{2}A^2T$	$E' = 2E$
P_s	$\frac{1}{2}\left(\frac{E}{T}\right)$	$\left(\frac{E}{T}\right)$	$\left(\frac{E}{T}\right)$
$P_{e(min)}$	$\text{erfc}\sqrt{\frac{P_sT}{\eta}}$	$\text{erfc}\sqrt{\frac{2P_sT}{\eta}}$	$\text{erfc}\sqrt{\frac{P_sT}{\eta}}$
BW	$\frac{2}{T_b}$	$\frac{2}{T_b}$	$(f_2 - f_1) + \frac{2}{T_b}$

Binary Phase Shift Keying (BPSK)

- Waveform b(t) is a NRZ (non-return-to-zero) binary waveform
- Transmitted Signal

$$V_{BPSK}(t) = b(t)\sqrt{2P_s}\cos\omega_0 t$$

where, P_s = Signal power

$b(t)$ = 1 V for Logic level 1

= −1 V for Logic level 0

- Received signal

$$V_{BPSK}(t) = b(t)\sqrt{2P_s}\cos(\omega_0 t + \theta)$$

where, θ = Phase shift corresponding to time delay θ/ω_0

Phase shift depends on the length of the path from transmitter to receiver

- Power spectral density of the BPSK signal

$$G_{BPSK}(f) = \frac{P_sT_b}{2}\left\{\left[\frac{\sin\pi(f - f_0)T_b}{\pi(f - f_0)T_b}\right]^2 + \left[\frac{\sin\pi(f + f_0)T_b}{\pi(f + f_0)T_b}\right]^2\right\}$$

where, T_b = Bit duration

- Energy contained in a bit duration

$$E_b = P_sT_b$$

- Bandwidth

$$BW = \frac{2}{nT_b}$$

where, n = Number of input

Remember:

- Differential phase-shift keying (DPSK) and differential encoded PSK (DEPSK) are modifications of BPSK.
- DPSK avoids the need to provide the synchronous carrier required at the demodulator for detecting a BPSK signal.

Quadrature Phase Shift Keying (QPSK)

- Four quadrature signals

$$V_m(t) = \sqrt{2P_s}\cos\left[\omega_0 t + (2m + 1)\frac{\pi}{4}\right] \quad .... \ m = 0, 1, 2, 3$$

- Bandwidth

$$BW = \frac{2}{2T_b} = R_b$$

M-ARY PSK

$$V_m(t) = \sqrt{2P_s}\cos(\omega_0 t + \phi_m) \quad \text{....m = 0, 1, 2, ...(M − 1)}$$

- Phase Angle

$$\phi_m = (2m + 1)\frac{\pi}{M}$$

Binary Frequency Shift Keying

$$V_{BFSK}(t) = \sqrt{2P_s}\cos[\omega_0 t + d(t)\Omega t]$$

where, $d(t)$ = 1 for logic levels 1 of data waveform
= −1 for logic levels 0 of data waveform
Ω = Constant offset from nominal carrier frequency

Note: ....

$$BW_{(BFSK)} = 2 \times BW_{(BPSK)}$$

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Minimum Shift Keying

- Transmitted signal

$$V_{MSK}(t) = \sqrt{2P_s}\left[\left\{b_e(t)\sin 2\pi\left(\frac{1}{4T_b}\right)\right\}\cos\omega_0 t + \left\{b_0(t)\cos 2\pi\left(\frac{1}{4T_b}\right)\right\}\sin\omega_0 t\right]$$

- Most important and useful feature of MSK is its phase continuity

$$\int_0^{T_b} \sin\omega_H t \cdot \sin\omega_L t \, dt = 0$$

- Probability of error in the detection of any signal.

$$P_{e(min)} = \text{erfc}\left(\frac{a}{\sqrt{\eta E/2}}\right)$$

where, erfc(u) = Complementary error function
a = Threshold level

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