Digital Modulation Forms

Within a limited environment, digital data can be transmitted directly as baseband pulses. However, for transmission at RF frequencies or as transmission over cables with transformer coupling, it is necessary to encode the signals in forms in which the spectra are shifted to higher frequencies. Some of the most basic methods for binary transmission will be studied in this module. This will include amplitude-shift keying (ASK), frequency-shift keying (FSK), and binary phase-shift keying (BPSK).

Amplitude Shift Keying (ASK)

(a) BASEBAND PCM SIGNAL

(b) AMPLITUDE-SHIFT KEYING (ASK) SIGNAL

ASK Generation

\[ A_1 \sin \omega_c t \]
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Noncoherent Detection of ASK Signal

\[ r(t) = A_0 \sin(\omega t) \]

\[ \text{FILTER} \]

\[ \text{BASEBAND PCM SIGNAL} \]

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Coherent Detection of ASK Signal

\[ r(t) = A_0 \sin(\omega t) \]

\[ \text{LOW-PASS FILTER} \]

\[ A_0 \sin(\omega t) \]

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ASK Bandwidth Estimation
ASSK Spectral Form

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**ASK Bandwidth Estimation Results**

- \( T_p \) = period = 2\( \tau \)
- \( f_p \) = fundamental frequency = \( \frac{1}{T_p} \) = 0.5 \( \frac{1}{\tau} \)
- \( R \) = data rate in bits/s = \( \frac{1}{T_p} \) = \( \frac{1}{2 \tau} \) = 2 \( f_p \)
- \( B_T = 2 f_p = R \)

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**Example 1.** A binary NRZ-L signal having a data rate of 200 kbits/s modulates an RF carrier in ASK. Determine the bandwidth.

\[ B_T = R = 200 \text{ kHz} \]
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**Frequency Shift Keying (FSK)**

(a) Baseband PCM signal

```
1 0 1 1 0 1 0 0
Time
```

(b) Frequency shift keying (FSK) signal

Time

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**FSK Generation**

```
BASEBAND PCM SIGNAL
VCO
RF FSK SIGNAL
```

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**Noncoherent Detection of FSK Signal**

```
FSK SIGNAL
BASEBAND FILTER 1
BASEBAND FILTER 2
ENVELOPE DETECTOR
TO BINARY RESTORATION CIRCUIT
```

Coherent Detection of FSK Signal

FSK Bandwidth Estimation Results

\[ B_T = 2(\Delta f + f_m) \]
\[ \Delta f = \frac{f_1 - f_0}{2} \]
\[ f_m = f_p = 0.5R \]
\[ B_T = f_1 - f_0 + R \]

Example 2. A binary NRZ-L signal having a data rate of 200 kbits/s modulates an RF carrier in FSK. The two RF frequencies are 150 kHz apart. Determine the bandwidth.

\[ B_T = f_1 - f_0 + R \]
\[ = 150 + 200 \]
\[ = 350 \text{ kHz} \]
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**Binary Phase Shift Keying (BPSK)**

(a) BASEBAND PCM SIGNAL

(b) BINARY PHASE-SHIFT KEYING (BPSK) SIGNAL

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**BPSK Generation**

BIPOLAR BASEBAND PCM SIGNAL → RF BPSK SIGNAL

\[ A_c \sin \omega_c t \]

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**BPSK Detection**

**Diagram of BPSK Detection**

- **Squaring Circuit**
- **Band-Pass Filter**
- **Frequency Divider**
- **Low-Pass Filter**

**BASEBAND PCM DATA SIGNAL**
Example 3. A binary NRZ-L signal having a data rate of 200 kbits/s modulates an RF carrier in BPSK. Determine the bandwidth.

\[ B_T = R = 200 \text{ kHz} \]
Summary

- Digital signals can be transmitted directly at baseband only under limited conditions.
- For either RF transmission or telephone line transmission, some form of modulation is required to shift the spectra.
- ASK involves turning a carrier on and off to represent the binary values.
- FSK involves switching between two frequencies that represent the binary values.
- PSK involves switching between two phases that represent the binary values.