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DIGITAL COMMUNICATION

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- ASK (Amplitude Shift Keying Modulation)
- FSK (Frequency Shift Keying Modulation)
- PSK (Phase Shift Keying Modulation)

Digital Modulation – ASK, FSK, PSK

Digital Modulation provides more information capacity, high data security, quicker system availability with great quality communication. Hence, digital modulation techniques have a greater demand, for their capacity to convey larger amounts of data than analog ones.

There are many types of digital modulation techniques and we can even use a combination of these techniques as well. In this chapter, we will be discussing the most prominent digital modulation techniques.

- ASK (Amplitude Shift Keying Modulation)
- FSK (Frequency Shift Keying Modulation)
- PSK (Phase Shift Keying Modulation)

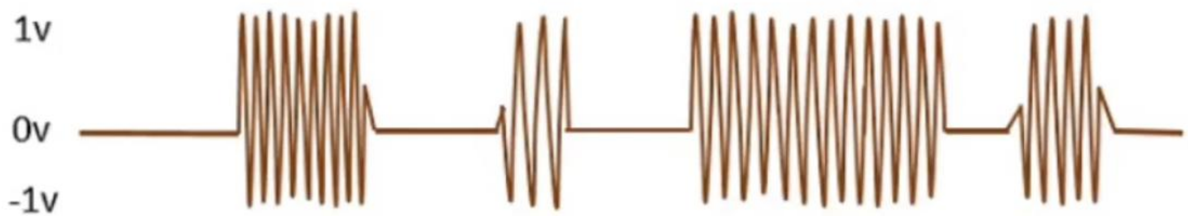
Amplitude Shift Keying

The amplitude of the resultant output depends upon the input data whether it should be a zero level or a variation of positive and negative, depending upon the carrier frequency.

Amplitude Shift Keying (ASK) is a type of Amplitude Modulation which represents the binary data in the form of variations in the amplitude of a signal.

Following is the diagram for ASK modulated waveform along with its input.

Input binary sequence



ASK Modulated output wave

Any modulated signal has a high frequency carrier. The binary signal when ASK is modulated, gives a zero value for LOW input and gives the carrier output for HIGH input.

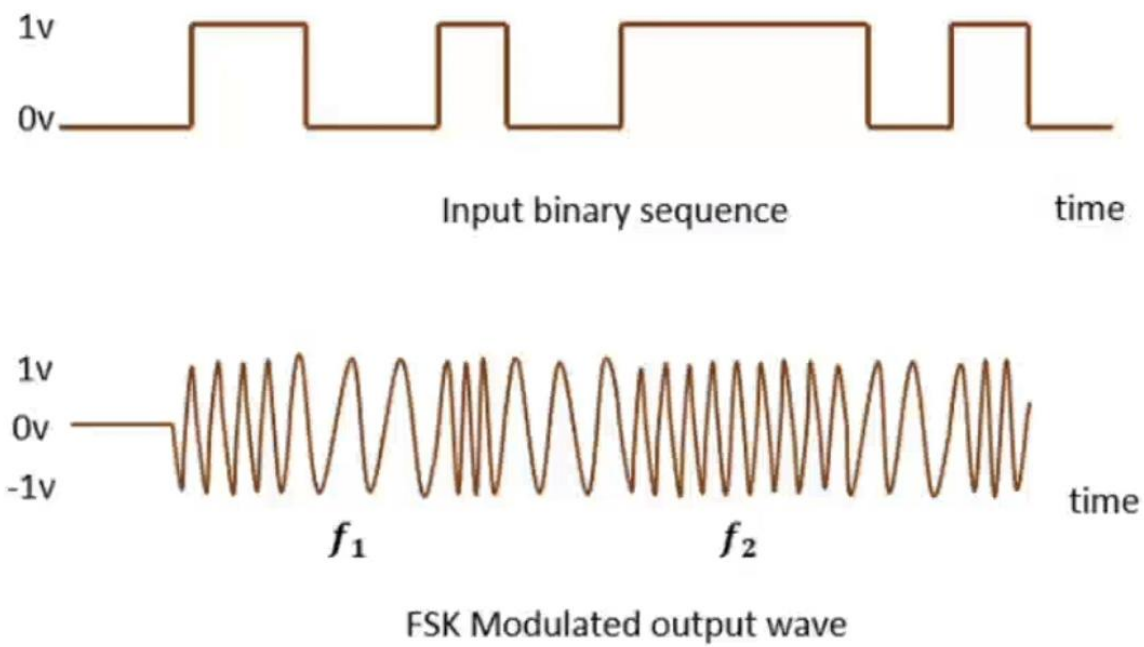
FSK (Frequency Shift Keying Modulation)

Frequency Shift Keying

The frequency of the output signal will be either high or low, depending upon the input data applied.

Frequency Shift Keying (FSK) is the digital modulation technique in which the frequency of the carrier signal varies according to the discrete digital changes. FSK is a scheme of frequency modulation.

Following is the diagram for FSK modulated waveform along with its input.



The output of a FSK modulated wave is high in frequency for a binary HIGH input and is low in frequency for a binary LOW input. The binary 1s and 0s are called **Mark** and **Space frequencies**.

Phase Shift Keying (PSK) is the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time. PSK technique is widely used for wireless LANs, bio-metric, contactless operations, along with RFID and Bluetooth communications.

The phase of the output signal gets shifted depending upon the input. These are mainly of two types, namely BPSK and QPSK, according to the number of phase shifts. The other one is DPSK which changes the phase according to the previous value.

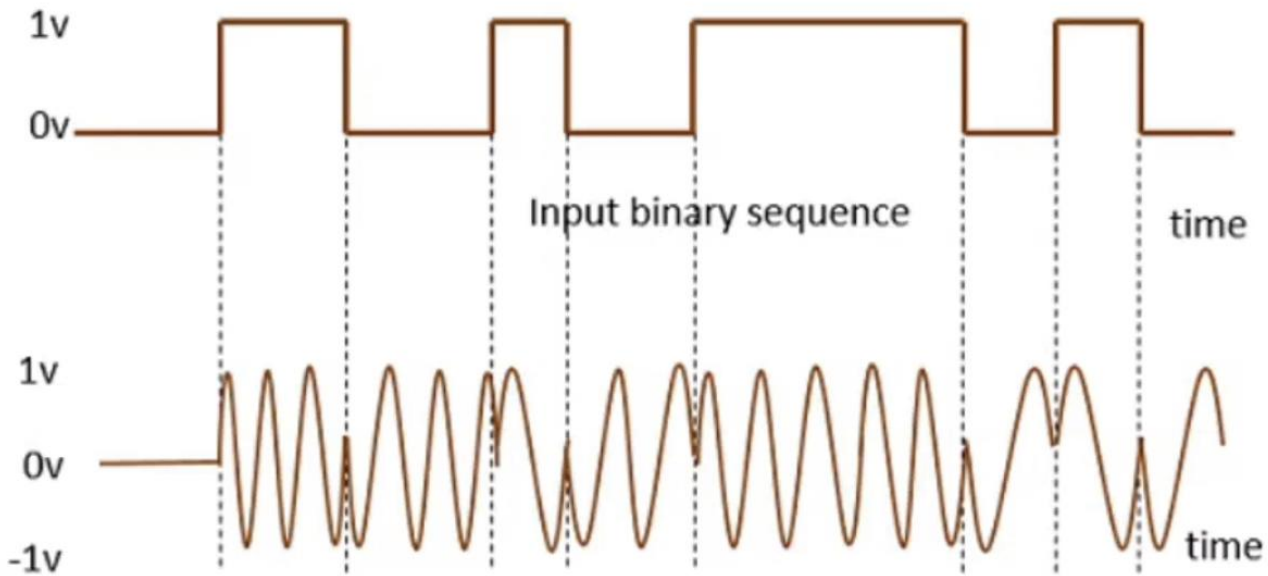
PSK is of two types, depending upon the phases the signal gets shifted. They are −

Binary Phase Shift Keying (BPSK)

This is also called as **2-phase PSK** (or) **Phase Reversal Keying**. In this technique, the sine wave carrier takes two phase reversals such as 0° and 180°.

BPSK is basically a DSB-SC (Double Sideband Suppressed Carrier) modulation scheme, for message being the digital information.

Following is the image of BPSK Modulated output wave along with its input.



BPSK Modulated output wave

ASK (Amplitude Shift Keying Modulation)

ASK is a digital modulation technique defined as the process of shifting the amplitude of the carrier signal between two levels, depending on whether 1 or 0 is to be transmitted.

Let the message be binary sequence of 1's and 0's. It can be represented as a function of time as follows:

$$v_m = V_m \qquad \text{when symbol is 1}$$
$$= 0 \qquad \text{when symbol is 0}$$

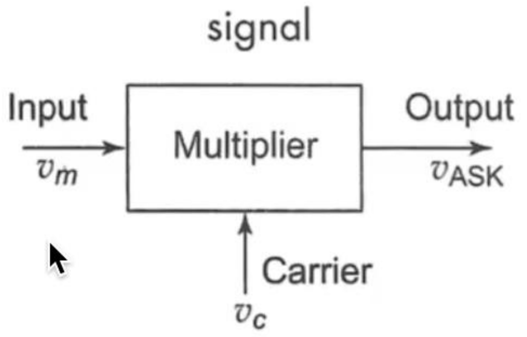
Let the carrier be defined as

$$v_c = V_c \cos\omega_c t$$

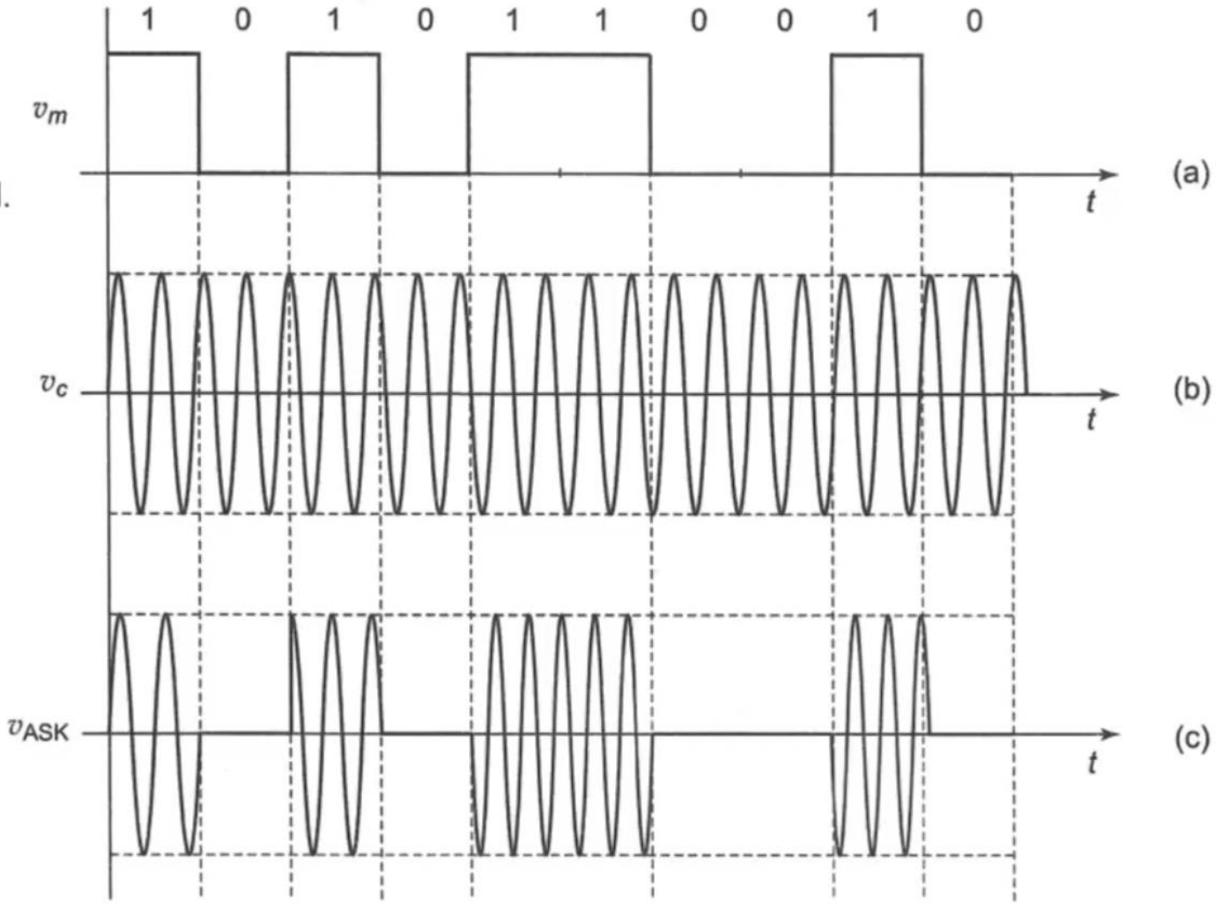
The corresponding ASK signal is given by the product of v_m and v_c as

$$v_{ASK} = V_m V_c \cos\omega_c t \qquad \text{when symbol is 1}$$
$$= 0 \qquad \text{when symbol is 0}$$

ASK Signals

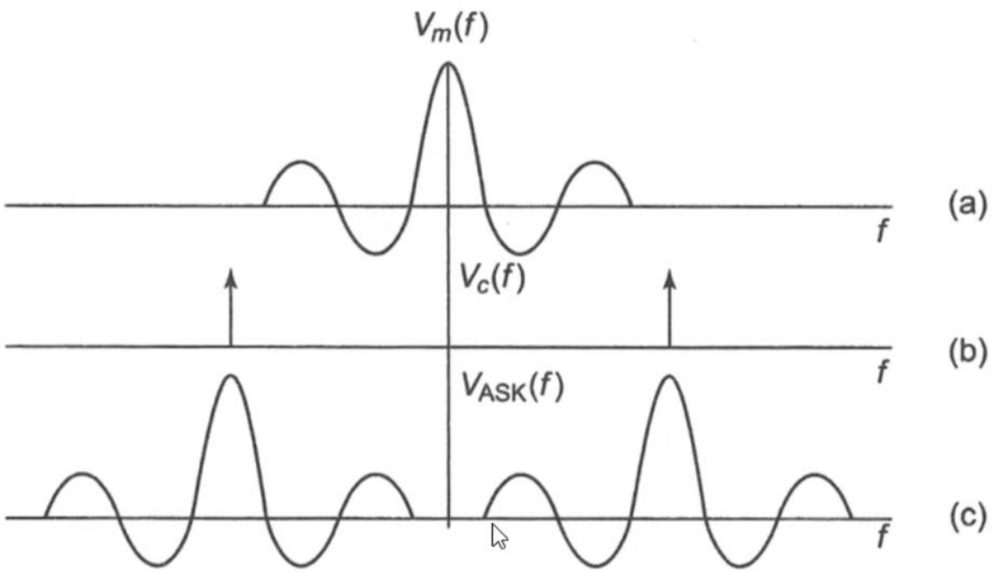


Block diagram of generation of ASK signal.



Time domain representation of generation of ASK signal: (a) mesage, (b) carrier, and (c) ASK

ASK Spectrum



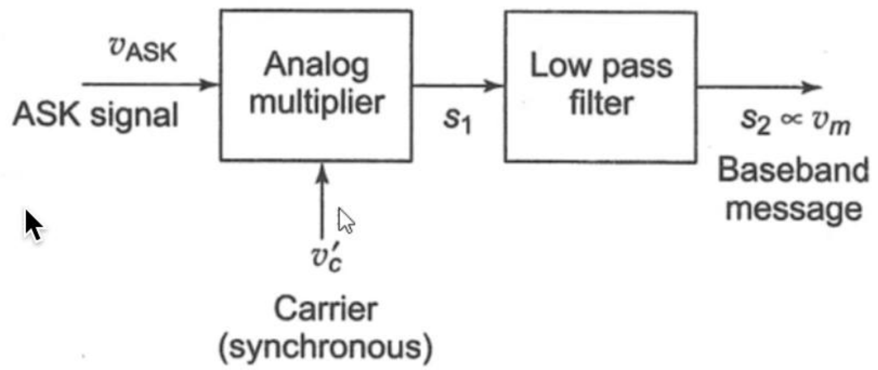
Spectra during generation of ASK signal. Spectrum of (a) message, (b) carrier, and (c) ASK signal.

ASK Demodulation

Demodulation of ASK Signal The demodulation is also termed as detection. There are two ways in which the message can be demodulated, namely, coherent and non-coherent detection. Due to the requirement of carrier in the receiver which is in sychronism with that of the transmitter, the coherent detection circuit is more complex compared to non-coherent detector. However, the coherent detector provides better performance under noisy condition.

1. Coherent ASK Detector
2. Non-Coherent ASK Detector

Coherent ASK Detector



Block diagram of coherent ASK detector.

In coherent detection, a copy of carrier used for modulation is assumed to be available at the receiver. The incoming ASK signal is multiplied with the carrier signal. The output of the multiplier will be a low frequency component representing amplitude scaled version of baseband message and ASK signal at twice the carrier frequency. The baseband message is retreived by passing this signal through a low pass filter.

Let the synchronous carrier at the receiver be given by

$$v_c' = V_c' \cos\omega_c t.$$

The output of the multiplier is given by

$$s_1 = v_{ASK} v'_c = \frac{V_m V_c V'_c}{2}(1 + \cos 2\omega_c t) \quad \text{when symbol is 1}$$

$$= 0 \quad \text{when sumbol is 0}$$

The output of the low pass filter is given by

$$s_2 = V_m (V_c V'_c) \quad \text{when symbol is 1}$$

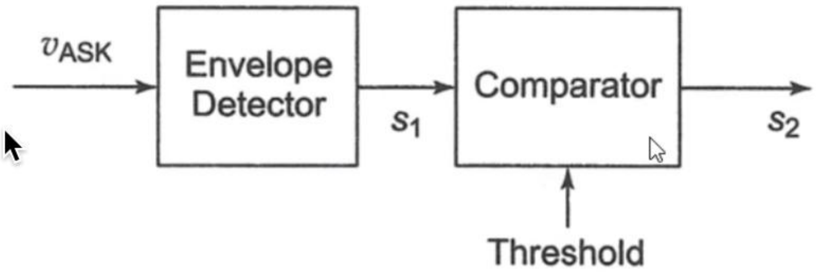
$$= 0 \quad \text{when symbol is 0}$$

Thus the filter output is

$$s_2 \propto v_m$$

Hence, the recovery of baseband message is carried out.

Non-Coherent ASK Detector



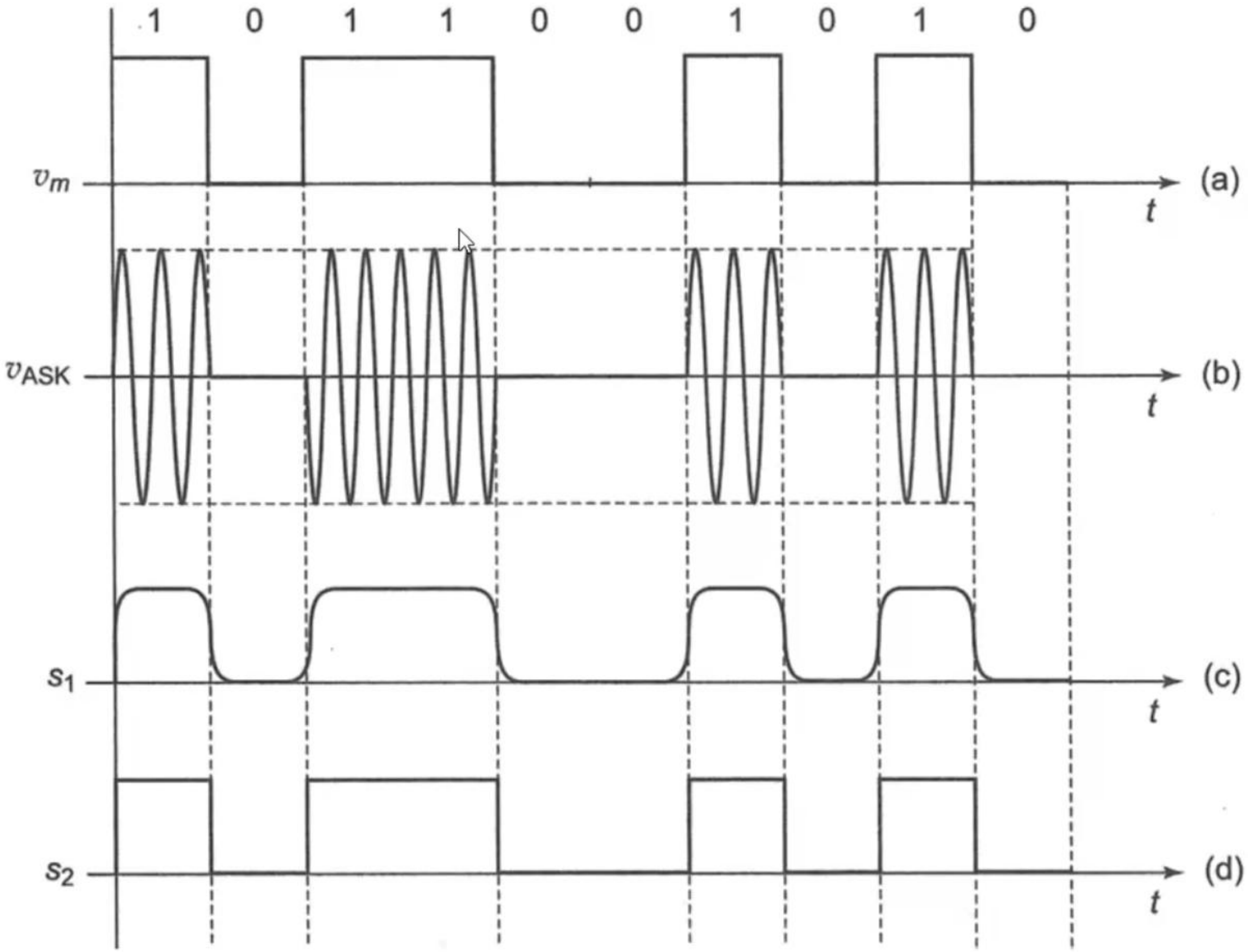
Block diagram of non-coherent ASK detector.

In non-coherent detection, there is no reference carrier made available at the receiver. Hence we have to follow other approach. In case of ASK, simple envelope detector will suffice. The incoming ASK signal is passed through an envelope detector which tracks the envelope of the ASK signal which is nothing but the baseband message.

The output of the

diode will be an unipolar signal containing the envelope information. The high frequency variations are further removed by passing it through a low pass filter. The output of the low pass filter may be further refined by passing it through a comparator which compares the output of the envelope detector to a preset threshold and sets all values greater than or equal to the threshold to high level and rest to the low level. The waveforms at various stages of the non-coherent ASK detector are shown in Fig.

Non Coherent ASK Signals



Time domain representation of signals at various stages of non-coherent ASK detector.
(a) message, (b) ASK signal, (c) output of envelope detector and (d) output of comparator.

Determine the minimum bandwidth required to transmit 10 kbits/sec of binary signal by using ASK modulation scheme. ○○●

Solution:

Ask modulation scheme uses two amplitude levels, either 0 or 1. Thus, the number of bits require to represent each level η is given by

$$\eta = \log_2 2 = 1 \text{ bit/sample}$$

If the bit rate R_b = 10 kbits/sec, then the minimum bandwidth required for transmission is

$$BW = \frac{R_b}{\eta} = \frac{10 \text{ kbits/sec}}{1} = 10 \text{ kHz}$$

FSK (Frequency Shift Keying Modulation)

FSK is a digital modulation technique defined as the process of shifting the frequency of the carrier signal between two levels, depending on whether 1 or 0 is to be transmitted.

Let the two carriers be defined as

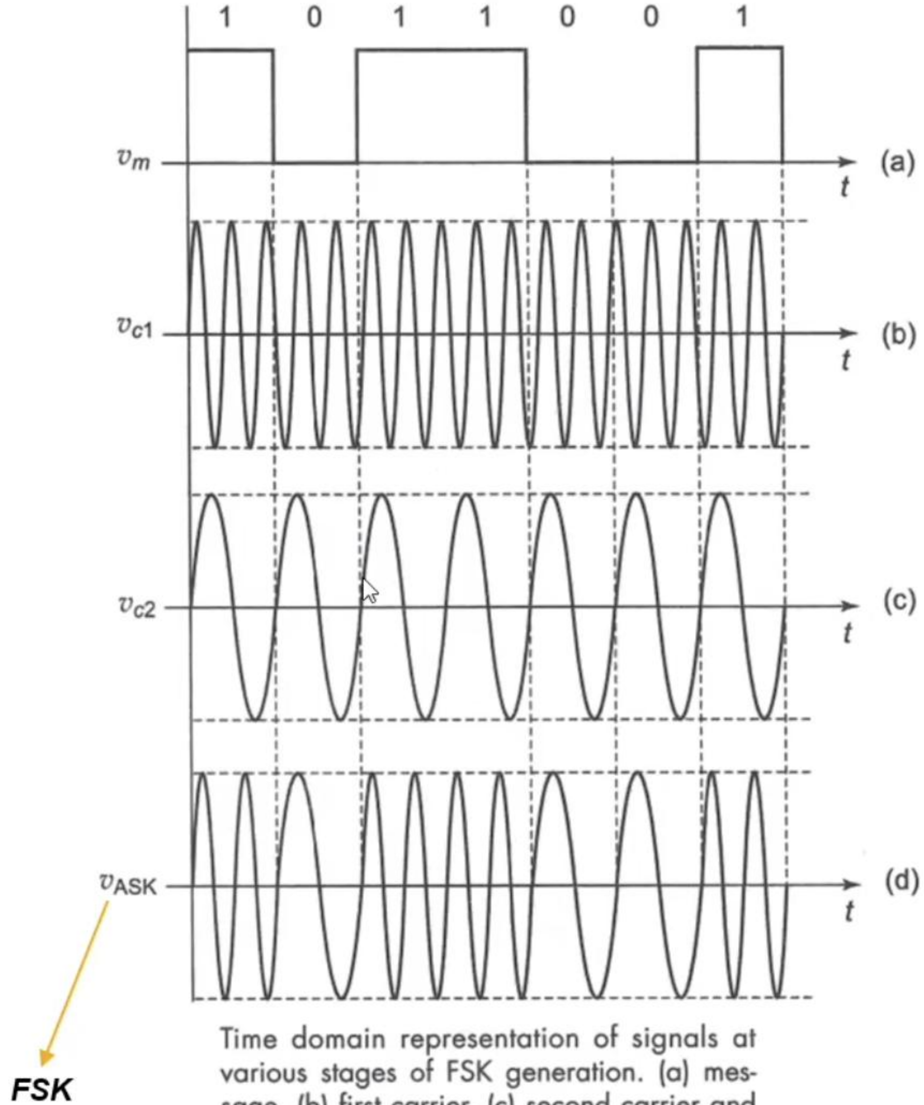
$$v_{c1} = V_c \cos\omega_{c1} t$$
$$v_{c2} = V_c \cos\omega_{c2} t$$

The corresponding FSK signal is defined as

$$\begin{aligned} v_{ASK} &= V_m V_c \cos\omega_{c1} t \quad \text{when symbol is 1} \\ &= V_m V_c \cos\omega_{c2} t \quad \text{when symbol is 0} \end{aligned}$$

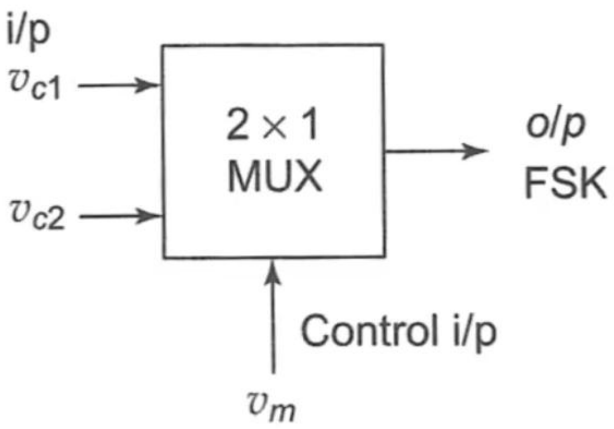
FSK

FSK Signals



Time domain representation of signals at various stages of FSK generation. (a) message, (b) first carrier, (c) second carrier and (d) FSK signal.

FSK Generator

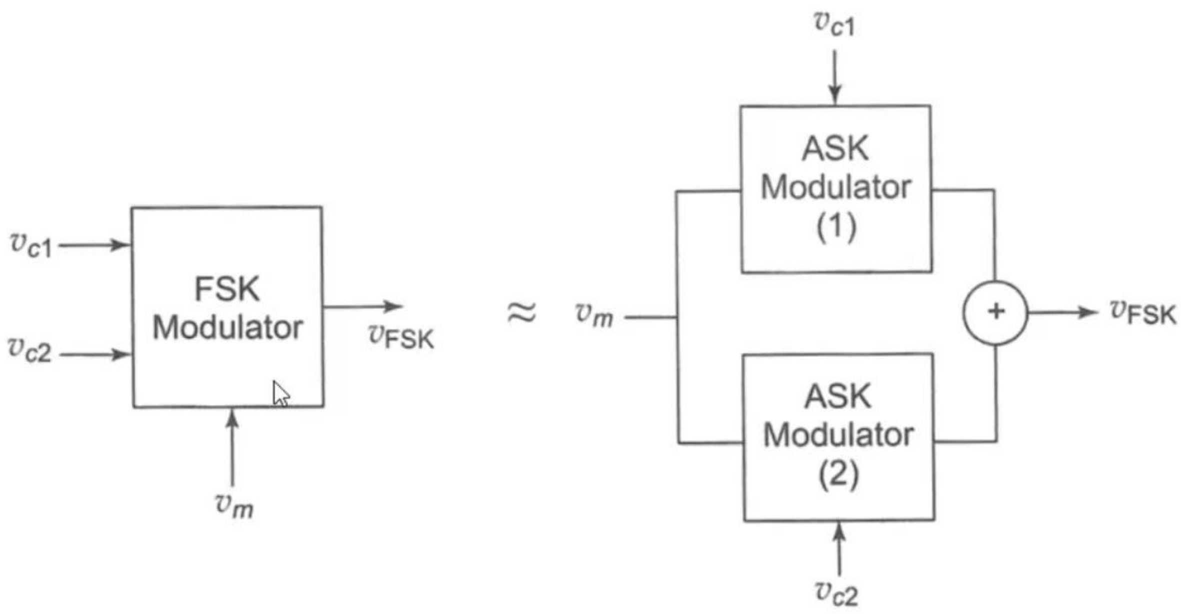


Block diagram of FSK generator.

The question is whether such a process results in the shift of spectrum of baseband message to the passband ?

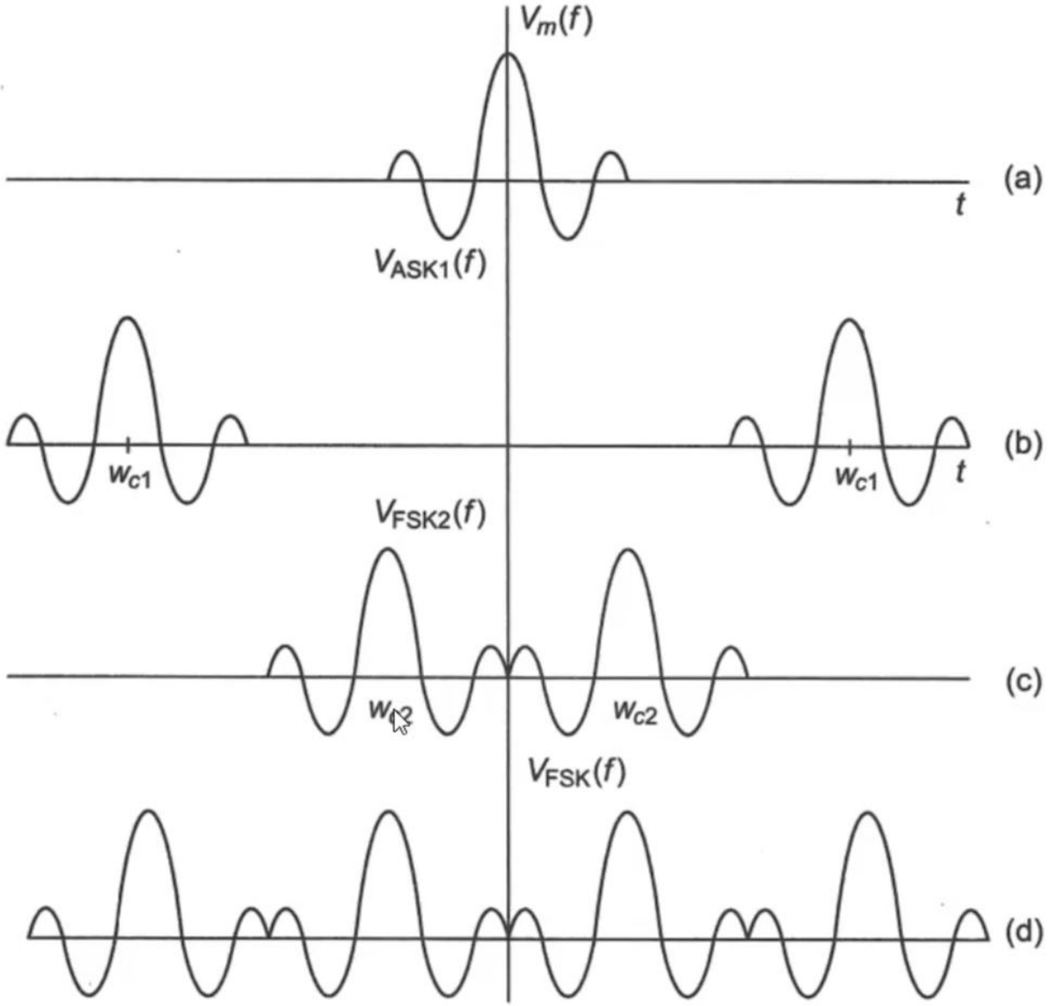
The answer is Yes.

To appreciate this, we can treat the FSK modulation process conceptually as two ASK processes, one using carrier signal with frequency $\omega c1$ and other using $\omega c2$.



Equivalent representation of FSK modulator in terms of two ASK modulators.

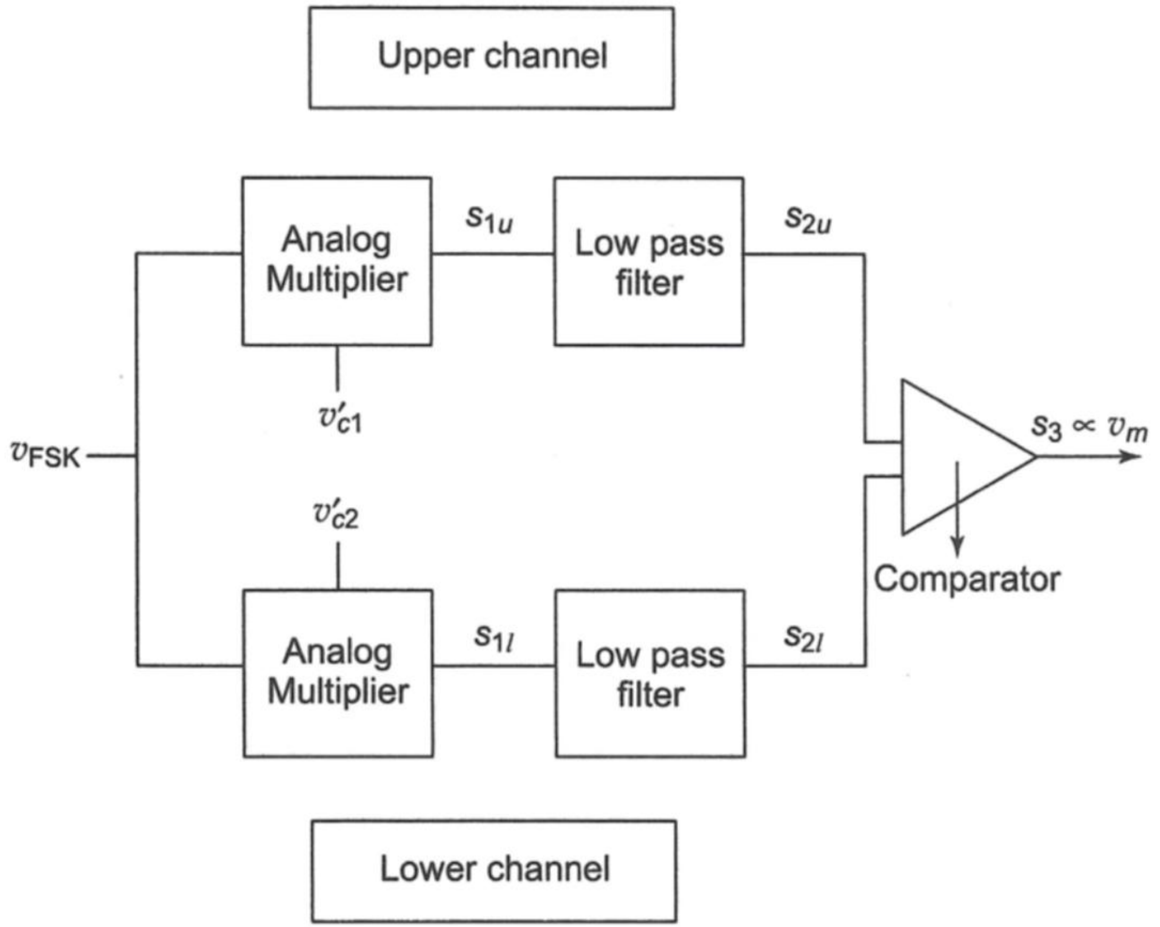
FSK Spectrum



Spectra of various signals involved FSK generation. Spectrum (a) message, (b) first ASK modulator, (c) second ASK modulator and (d) FSK modulator.

Demodulation of FSK Signal In this case also, the message can be demodulated either by coherent or non-coherent detection. Both demodulation processes can be understood easily by considering the ASK view of FSK as illustrated in Fig.

FSK Coherent Detector



Block diagram of coherent detector of FSK.

The block diagram for the coherent detection of FSK is drawn as given in Fig. The incoming FSK signal is multiplied by the carrier signal with frequency ω_{c1} in the upper channel and carrier signal with frequency ω_{c2} in the lower channel. The output of the multiplier in the upper channel will be low frequency message and ASK signal at twice ω_{c1} during the intervals when the FSK is due to the carrier of frequency ω_{c1} and will be ASK signals at $(\omega_{c1} \pm \omega_{c2})$ during intervals when the FSK is due to the carrier of frequency ω_{c2}. Thus the output of the low pass filter in the upper channel will contain baseband message during intervals belonging to the carrier frequency ω_{c1} and zero during the intervals belonging to ω_{c2}. Exactly opposite happens in the lower channel. The outputs of the two channels are further passed onto a comparator. The ouput of the comparator will be high when upper channel output is greater than the lower channel and low when lower channel output is greater than the upper channel. In this way the baseband message is retreived from the FSK signal

Let the synchronous carriers at the receiver be given by

$$v'_{c1} = V'_c \cos\omega_{c1} t$$

$$v'_{c2} = V'_c \cos\omega_{c2} t$$

The output of the multiplier in the upper channel during the interval having frequency ω_{c1} is given by

$$s_{1u} = v_{FSK} v'_{c1} = \frac{V_m V_c V'_c}{2}(1 + \cos 2\omega_{c1} t)$$

The output of the multiplier in the upper channel during the interval having frequency ω_{c2} is given by

$$s_{1u} = \frac{V_m V_c V'_c}{2}(\cos(\omega_{c1} - \omega_{c2})t + \cos(\omega_{c1} + \omega_{c2})t)$$

The output of the low pass filter in the upper channel during the interval having frequency ω_{c1} is given by

$$s_{2u} = \frac{V_m V_c V'_c}{2}$$

The output of the low pass filter in the upper channel during the interval having frequency ω_{c2} is given by

$$s_{2u} = 0$$

Thus, the filter output in the upper channel is

$$s_{2u} \propto v_m$$

during the interval having frequency ω_{c1} and

$$s_{2u} \propto 0$$

during the interval having frequency ω_{c2}.

The output of the multiplier in the lower channel during the interval having frequency ω_{c1} is given by

$$s_{1l} = \frac{V_m V_c V'_c}{2}(\cos(\omega_{c1} - \omega_{c2})t + \cos(\omega_{c1} + \omega_{c2})t)$$

The output of the multiplier in the lower channel during the interval having frequency ω_{c2} is given by

$$s_{1l} = v_{FSK}\, v'_{c1} = \frac{V_m V_c V'_c}{2}(1 + \cos 2\omega_{c1} t)$$

The output of the low pass filter in the lower channel during the interval having frequency ω_{c1} is given by

$$s_{2l} = 0$$

The output of the low pass filter in the lower channel during the interval having frequency ω_{c2} is given by

$$s_{2l} = \frac{V_m V_c V'_c}{2}$$

Thus, the filter output in the lower channel is

$$s_{2l} \propto 0$$

during the interval having frequency ω_{c1} and

$$s_{2l} \propto v_m$$

during the interval having frequency ω_{c2}.

Therefore, the output of the compartor is given by

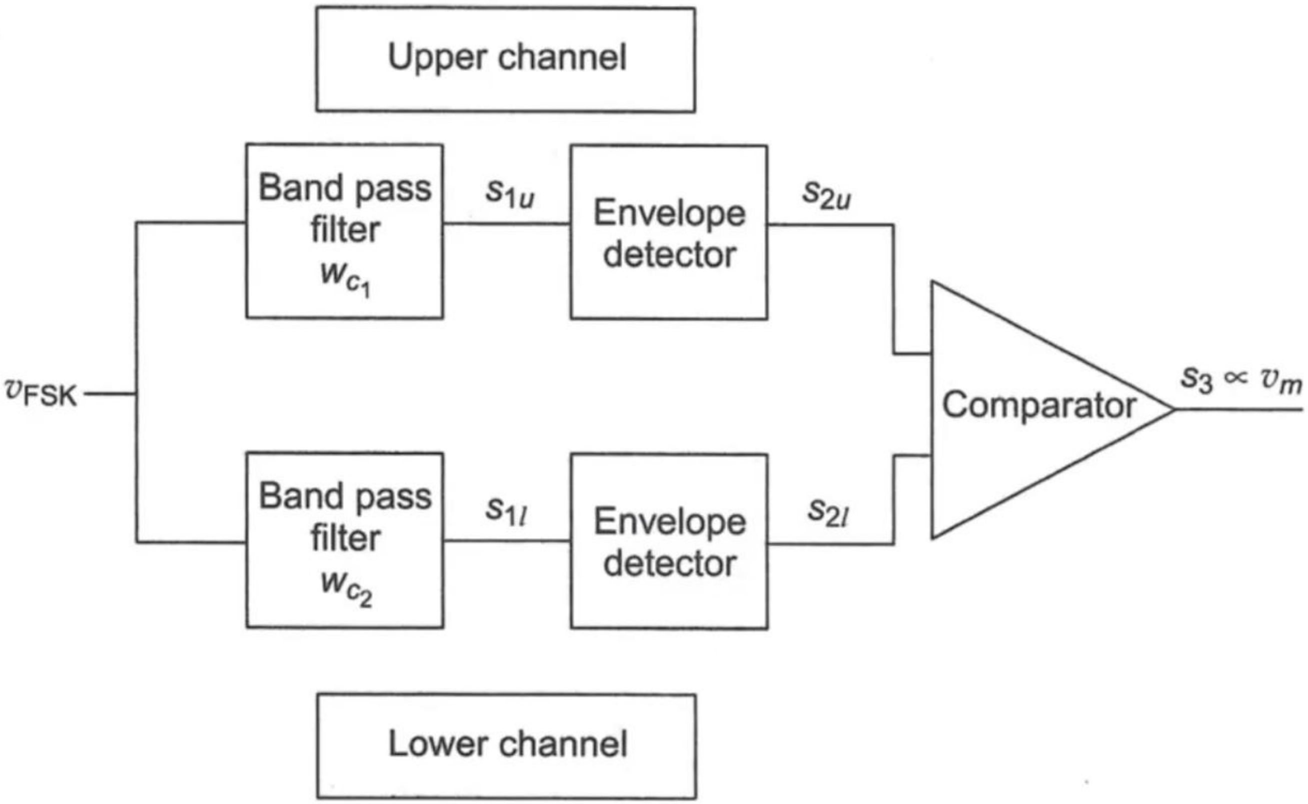
$$s_3 \propto v_m$$

Hence, the recovery of baseband message is carried out.

FSK Non-Coherent Detector

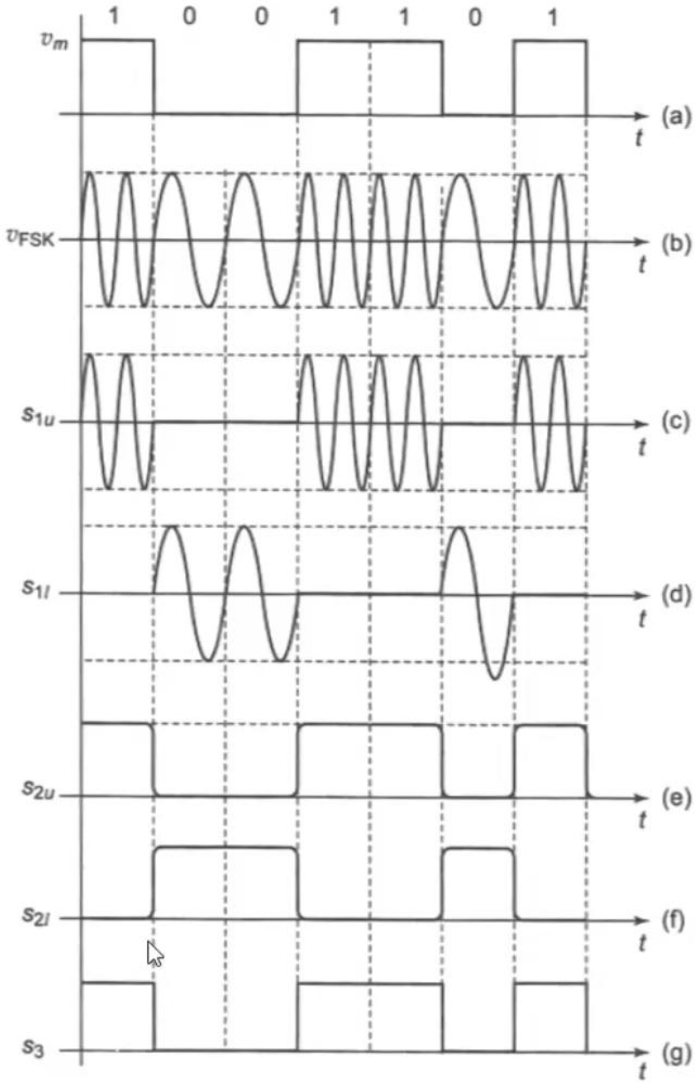
In case of non-coherent detection, envelope detectors can be used as shown in the arrangement given in Fig. The incoming FSK signal is passed through a filter tuned to ω_{c1} and then an envelope detector in the upper channel. Similarly, the same FSK signal is passed throug a filter tuned to ω_{c2} and then an envelope detector in the lower channel. Thus the distinction between the upper and lower channels is due to the two filters. During the interval represented by the carrier signal with frequency ω_{c1}, the output the upper channel will be high whereas that of the lower channel is low. Exactly opposite happens during the inerval represented by the carrier signal with frequency ω_{c2}. The outputs of the upper and lower channels envelope detectors are applied to a comparator which produces the output proportional to the message. The waveforms at various stages of the non-coherent FSK detector are shown in Fig.

FSK Non-Coherent Detector



Block diagram of non-coherent detector of FSK.

FSK Non-Coherent Detector Signals



Signals at varioys stages in the non-coherent detection of FSK. (a) message, (b) FSK signal Output of envelope detector in (c) upper channel and (d) lower channel. Output of low pass filter in (e) upper channel and (f) lower channel, (g) comparator output.