Lecture 08: DSB-SC Detection

Detection of DSB-SC

1. Coherent Detection of DSB-SC Modulated Waves

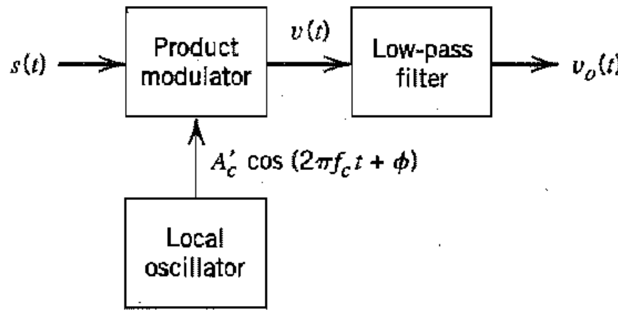

Figure: Coherent detector for demodulating DSB-SC modulated wave

The modulating signal $m(t)$ is recovered from a DSB-SC wave $s(t)$ by first multiplying $s(t)$ with a locally generated carrier wave and then low pass filtering the product as shown in fig.1. For faithful recovery of modulating signal $m(t)$, local oscillator o/p should be exactly coherent or synchronized in both frequency and phase with the carrier wave used in the product modulator to generate DSB-SC wave $s(t)$.This method of demodulation is known as ***coherent detection or synchronous demodulation***.

The output of the product modulator is applied to the low-pass filter which eliminates all the unwanted frequency components and produces the required message signal.

Analysis of coherent detection:

Let the output of local oscillator as $\mathbf{c'(t) = A_c' \cos(2\pi f_c t + \phi) \rightarrow (1)}$

Here the phase difference has been measured w.r.t. the original carrier signal used at the DSB-SC modulator.

The output of the product modulator is $\mathbf{v(t) = s(t).\, c'(t) \rightarrow (2)}$

Here $\mathbf{s(t) = DSB - SC\ input = m(t).\, c(t) = A_c m(t) \cos(2\pi f_c t) \rightarrow (3)}$

Thus, $\mathbf{v(t) = s(t).\, c'(t) = A_c m(t) \cos(2\pi f_c t)\, A_c' \cos(2\pi f_c t + \phi)}$

$$\Rightarrow \mathbf{v(t) = \frac{A_c A_c'}{2} m(t)[\cos(4\pi f_c t + \phi) + \cos(\phi)]}$$

$$\Rightarrow \mathbf{v(t) = \frac{A_c A_c'}{2} m(t) \cos(\phi) + \frac{A_c A_c'}{2} m(t) \cos(4\pi f_c t + \phi) \rightarrow (4)}$$

So, the output of the product modulator consists two terms and the first term is the wanted term whereas the second term is unwanted one.

This signal $v(t)$ is now passed through the LPF which allows only the first term and rejects the second term. Hence the filter output is

$$\mathbf{v_0(t) = \frac{A_c A'_c}{2} m(t)\cos(\phi)} \ \rightarrow (\mathbf{5})$$

Thus the output of the coherent detector is proportional to the message signal $m(t)$ if the phase error term $\mathbf{cos(\phi)}$ is constant.

Effect of the phase error on the demodulated output:

The output of the coherent detector is $\mathbf{v_0(t) = \frac{A_c A'_c}{2} m(t)\cos(\phi)}$

Here the phase error $\boldsymbol{\phi}$ varies randomly with time in practice due to the random nature of the communication channel. So the term $\mathbf{cos(\phi)}$ will also vary randomly with the time and hence the output of the demodulator will also vary w.r.t. the time because its amplitude is $\mathbf{\frac{A_c A'_c}{2}\cos(\phi)}$.

If $\boldsymbol{\phi}=0^0$, $v_0(t) = \frac{A_c A'_c}{2} m(t)$ and

If $\boldsymbol{\phi}=90^0$, $v_0(t) = 0$.

Hence, the amplitude of demodulator output is maximum i.e. $\frac{A_c A'_c}{2}$ when the phase error is zero and the amplitude is zero when the phase error is 90^0 or $\frac{\pi}{2}$ radians. This effect is known as ***quadrature null effect*** of the coherent detector.

So the random nature of the phase error attenuates the demodulated output, and it is undesirable.

Hence the circuitry must be provided in the detector to keep locally generated carrier $c'(t)$ in perfect synchronism, in both the frequency and phase w.r.t. the original carrier $c(t)$.

2. COSTAS loop demodulation of DSB-SC waves:

One method of obtaining a practical synchronous receiver system, suitable for demodulating DSB-SC waves, is to use the COSTAS receiver shown in fig.1.

The receiver consists of two coherent detectors supplied with the same DSB-SC input signal $\mathbf{A_c m(t)\cos(2\pi f_c t)}$, but with individual local oscillator signals that are in-phase quadrature with respect to each other (i.e., the local oscillator signal supplied to the product modulators are $90^{\ 0}$ out of phase).

The frequency of the local oscillator is adjusted to be the same as the carrier frequency $'\mathbf{f_c}'$. The detector in the upper path is referred to as the In-phase coherent detector or **I-Channel** and that in the lower path is referred to as the Quadrature-phase coherent detector or **Q-Channel**. These two detectors are coupled together to form a negative feedback system designed in such a way as to maintain the local oscillator synchronous with the carrier wave.

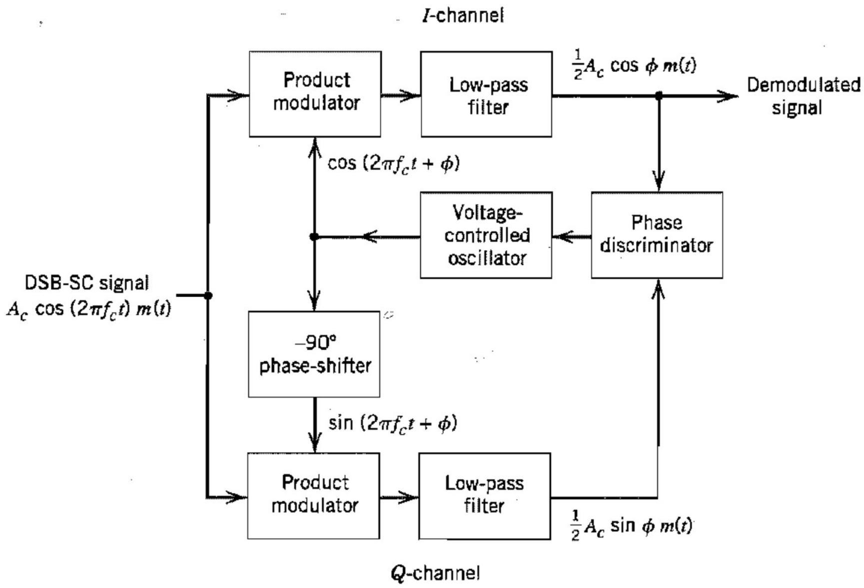

Fig.1. COSTAS loop detector

Operation:

i) When the local oscillator is of the same phase as the carrier wave $\mathbf{A_c \cos(2\pi f_c t)}$ used to generate the incoming DSB-SC wave, the I-channel output contains the desired demodulated signal $m(t)$, whereas Q-channel output is zero.

$$\mathbf{V_{OI} = \frac{1}{2}\, A_C m(t) \cos\emptyset}$$

i.e., whenever the carrier is synchronized , $\emptyset = \mathbf{0\ and\ \cos\emptyset = \cos 0^0 = 1}$

$$\boxed{\mathbf{V_{OI} = \frac{1}{2}\, A_C m(t)}}$$

And since $\mathbf{\sin\emptyset = \sin 0^0 = 0}$, $\boxed{\mathbf{V_{OQ} = 0}}$

ii) When the local oscillator phase changes by a small angle $'\emptyset'$ radians, the I-channel output will remain unchanged, but Q-channel produces some output which is proportional to $\sin\emptyset \cong \emptyset$ for small $\emptyset$. This Q-channel output will have the same polarity as the I-channel output for one direction of local oscillator phase drift and opposite polarity for the opposite direction of local oscillator phase drift.

Thus, by combining I- and Q-channel outputs in phase discriminator (which consists of a multiplier followed by a LPF), a DC control signal is obtained that automatically corrects for local phase errors in the voltage controlled oscillator (VCO).

Advantages of DSB-SC:

1. Low power consumption or power saving,
2. The modulation system is simple,
3. Efficiency is more than AM,
4. Carrier wave is suppressed,
5. Linear modulation type is required.

Disadvantages of DSB-SC:

1. Design of receiver is complex,
2. Bandwidth required is same as that of AM.

Applications of DSB-SC:

1. Analogue TV systems to transmit colour information,
2. Used for Point-to-point communication.