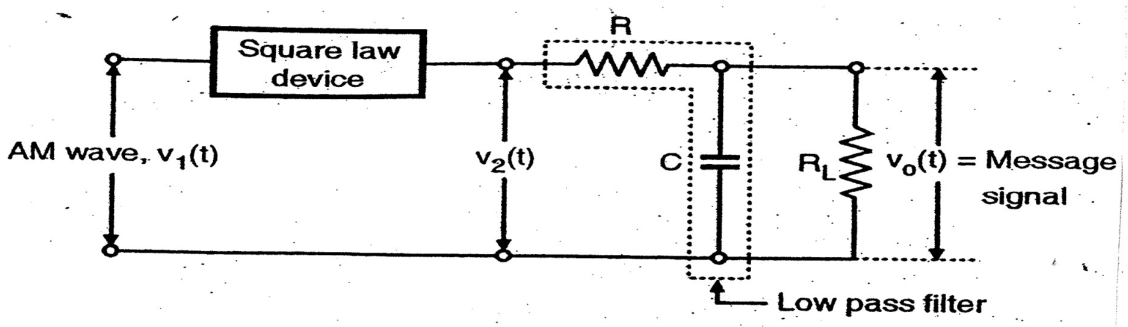
Lecture 05: Demodulation

The process of recovering the modulating message signal from the received modulated signal is known as Demodulation or detection (i.e. exactly the inverse operation of the modulation) and the circuit that performs this operation is known as demodulator or detector.

There are two types of standard AM detectors:

1. Square-law detector, and
2. Envelope detector.

1. Square-law detector:



A square law detector

A square-law detector utilizes a square-law modulator for the purpose of detection.

An AM signal can be demodulated by squaring it and then passing through a low-pass filter. So it consists i) Square-law non-linear device and ii) Low-pass filter.

From the transfer characteristic of Square-law device, its output is,

$$\mathbf{v_2(t) = a_1 v_1(t) + a_2 v_1^2(t) \rightarrow (1)}$$

Where, $v_1(t)$ is the input voltage to the square-law device, $v_2(t)$ is its output voltage, and a_1, a_2 are the device constants.

The input voltage $v_1(t)$ of AM wave is given by,

$$\mathbf{v_1(t) = A_C[1 + k_a m(t)] \cos(2\pi f_c t) \rightarrow (2)}$$

Substituting equation (2) in equation (1), we get

$$\mathbf{v_2(t) = a_1 A_C[1 + k_a m(t)] \cos(2\pi f_c t) + a_2[A_C[1 + k_a m(t)] \cos(2\pi f_c t)]^2}$$

$$\mathbf{\Rightarrow v_2(t) = a_1 A_C \cos(2\pi f_c t) + a_1 A_C k_a m(t) \cos(2\pi f_c t)}$$
$$\mathbf{+ a_2[A_C{}^2 \left(1 + k_a{}^2 m^2(t) + 2k_a m(t)\right)] \frac{[1 + \cos(4\pi f_c t)]}{2}}$$

$$\Rightarrow \mathbf{v_2(t) = a_1A_C\cos(2\pi f_c\, t) + a_1A_Ck_am(t)\cos(2\pi f_c\, t) + \frac{a_2{A_C}^2}{2} + \frac{a_2{A_C}^2{k_a}^2m^2(t)}{2}}$$

$$\mathbf{+\, a_2{A_C}^2k_am(t) + \frac{a_2{A_C}^2}{2}\left(1 + {k_a}^2m^2(t) + 2k_am(t)\right).\cos(4\pi f_c\, t)} \longrightarrow \mathbf{(3)}$$

In equation (3), the required term is $\mathbf{a_2{A_C}^2k_am(t)}$**,** which is due to the square term $\mathbf{a_2v_1^2(t)}$**.**Hence the name of this detector is Square-law detector.

The desired term is extracted by using a LPF. Thus the output of LPF is

$$\mathbf{v_o(t) = a_2{A_C}^2k_am(t)} \longrightarrow (4)$$

Thus the message signal $m(t)$ is recovered at the output of Square-law detector from AM wave.

Distortion in the output:

But there is another term which passes through the LPF to the load resistance R_L is as follows:

$$\mathbf{\frac{a_2{A_C}^2{k_a}^2m^2(t)}{2}}$$

This is an unwanted term and gives rise to a signal **distortion**.

The ratio of desired term to undesired term is given by,

$$D = \frac{\mathbf{a_2{A_C}^2k_am(t)}}{\frac{\mathbf{a_2{A_C}^2{k_a}^2m^2(t)}}{\mathbf{2}}} = \frac{2}{\mathbf{k_am(t)}}$$

We should maximize this ratio in order to minimize the distortion. To achieve this we should choose $\mathbf{|k_am(t)|}$ small as compared to unity for all values of t. But if $\mathbf{k_a}$is small then AM wave is weak.

2. Envelope detector:

Envelope detector is a simple and highly effective device used to demodulate AM wave. An envelope detector produces an output signal that follows the envelope of the input AM signal exactly. The envelope detector is used in all the commercial AM radio receivers.

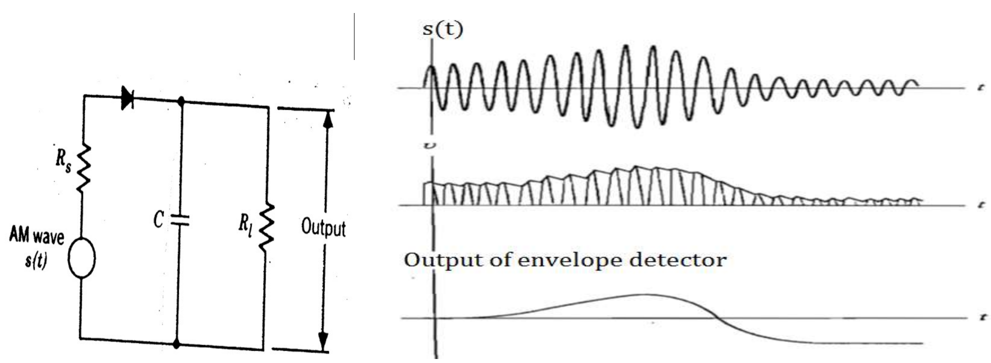


Fig.1. Envelope detector circuit diagram and its corresponding waveforms

The circuit diagram of envelope detector is shown in fig.1. And it consists of a diode and a resistor-capacitor (RC) low-pass filter.

Operation: The standard AM wave is applied at the input of envelope detector.

During positive half cycle of the input signal-

i) Detector diode is forward-biased
ii) The capacitor 'C' connected across load resistance R_l charges up to the peak-value of the input signal.
iii) As soon as capacitor charges to the peak-value, the diode stops conducting.
iv) The capacitor will discharge through R_l between positive peaks as shown in fig.1.
v) The discharging process continues until the next positive half cycle.
vi) When the input signal becomes greater than the voltage across the capacitor, the diode conducts again and the process is repeated.

During negative half cycle of the input signal-

i) The diode is reverse biased
ii) The capacitor will discharge through R_l.

It can be seen from the waveforms that the envelope of AM wave is being recovered successfully.

The selection of time-constant (Design Criteria):

The capacitor charges through 'D' & R_s when the diode is ON and it discharges through R_l when diode is OFF.

The charging time-constant R_sC should be short as compared to the carrier period $\frac{1}{f_c}$. So the capacitor 'C' charges rapidly, when

$$\boxed{R_sC \ll \frac{1}{f_c}}$$

On the other hand the discharging time constant R_lC should be long enough to ensure that the capacitor discharges slowly through the load resistance $'R_l'$ between positive peaks. This time-constant should not be too long which will not allow the capacitor voltage to discharge at the maximum rate of change of the envelope.

$$\therefore \boxed{\frac{1}{f_c} \ll R_lC \ll \frac{1}{W}}$$

Where W= maximum modulating frequency

Result is that the capacitor voltage or detector output is very nearly the same as the envelope of AM wave. The detector o/p usually has a small ripple at the carrier frequency, this ripple is easily removed by Low-pass filter.

NOTE: There are two types of distortions will occur in envelope detector, one will occur if discharging time constant is too long (called Diagonal clipping) and another will occur if there is over modulation in AM wave (called Negative clipping).

Advantages, Dis-advantages and Applications of AM Waves (DSBFC):

Advantages:

1. AM transmitters are less complex
2. AM receivers are simple and detection is easy
3. AM receivers are cost effective
4. AM waves can travel a long distance
5. Low bandwidth

Dis-advantages:

1. Power wastage takes place
2. It needs larger bandwidth
3. It gets affected due to noise

Applications:

1. Radio broadcasting
2. Picture transmission in a TV system

Explanation of Dis-advantages or limitations of AM Waves (DSBFC):

Amplitude modulation has several disadvantages:

1. Power is wasted in the transmission of AM wave:

Most of the transmitted power is in the carrier which does not carry any information. For 100% modulation 66.67% of the total power will be in the carrier, which does not contain any information.

The total power transmitted by an AM wave is given by $P_t = P_c + P_{USB} + P_{LSB}$

$$P_t = P_c + \frac{\mu^2}{4}P_c + \frac{\mu^2}{4}P_c$$

In this, the carrier component does not contain any information and one sideband is redundant.

So out of the total power, $P_t = P_c[1 + \frac{\mu^2}{2}]$ the wasted power is given by:

$$\text{Power wastage } = P_c + \frac{\mu^2}{4}P_c = P_c[1 + \frac{\mu^2}{4}]$$

2. <u>Bandwidth inefficient system:</u>

The transmitted signal requires twice the bandwidth of the message signal, $i.e. B_T = 2f_m$. This is due to the transmission of both the sidebands, out of which only one sideband is sufficient to convey all the information. Thus the bandwidth of DSBFC is double than actually required.

3. <u>AM wave gets affected due to noise:</u>

When the AM wave travels from the transmitter to receiver over a communication channel, noise gets added to it. The noise will change the amplitude of the envelope of AM in a random manner. As the information is contained in the amplitude variations of the AM wave, the noise will contaminate the information contents in the AM. Hence the performance of AM is very poor in the presence of noise.