Lecture-6

Analog Communications

Abstract:

Pre-envelope

For the real valued signal $g(t)$, the pre-envelope is defined as

$$g_p(t) = g(t) + j\hat{g}(t) \tag{1}$$

We know that

$$FT\{\hat{g}(t)\} = -j\ sign(f)G(f) \tag{2}$$

The amplitude modulation of the information bearing baseband signal $m(t)$ is performed as follows.

Using $m(t)$ we obtain a complex envelope signal as

$$s_c(t) = A_c[1 + k_a m(t)]$$

which is a low-pass signal. Using the baseband signal $s_c(t)$ we obtain a pass-band signal as

$$s(t) = Re\left\{s_c(t)e^{j2\pi f_c t}\right\}$$

which can be derived as

$$s(t) = A_c[1 + k_a m(t)]\cos 2\pi f_c t$$

which is the amplitude modulated signal. Note that $m(t)$ is read as the modulating wave or modulating signal and f_c is called carrier frequency.

If $|k_a m(t)| > 1$ then, phase reversals occur whenever $1 + k_a m(t)$ crosses the horizontal axis.

The term

$$|k_a m(t)| \times 100$$

is called percentage modulation.

Example: When $|k_a m(t)| = 1/2$ we have 50% modulation.

Fourier Transform of the Amplitude Modulated Signal

Assume that the Fourier transform of the baseband signal $m(t)$ is as shown in Figure-1.

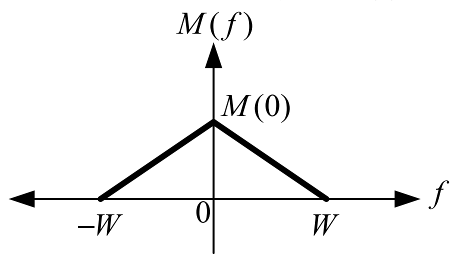

Figure-1

The **amplitude modulated signal**

$$s(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t$$

can be written as

$$s(t) = A_c[1 + k_a m(t)] \cos 2\pi f_c t \rightarrow s(t) = A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t$$

where taking the Fourier transform of both sides, we obtain

$$S(f) = A_c FT\{\cos 2\pi f_c t\} + A_c k_a FT\{m(t) \cos 2\pi f_c t\}$$

leading to

$$S(f) = A_c FT\{\cos 2\pi f_c t\} + A_c k_a [FT\{m(t)\} * FT\{\cos 2\pi f_c t\}]$$

in which substituting

$$FT\{\cos 2\pi f_c t\} = \frac{1}{2}\big(\delta(f - f_c) + \delta(f + f_c)\big)$$

we get

$$S(f) = \frac{A_c}{2}\left(\delta(f - f_c) + \delta(f + f_c)\right) + \frac{A_c k_a}{2}\left[M(f) * \left(\delta(f - f_c) + \delta(f + f_c)\right)\right]$$

leading to

$$S(f) = \frac{A_c}{2}\left(\delta(f - f_c) + \delta(f + f_c)\right) + \frac{A_c k_a}{2}[M(f - f_c) + M(f + f_c)] \tag{3}$$

The graph of (3) can be drawn as in Figure-2.

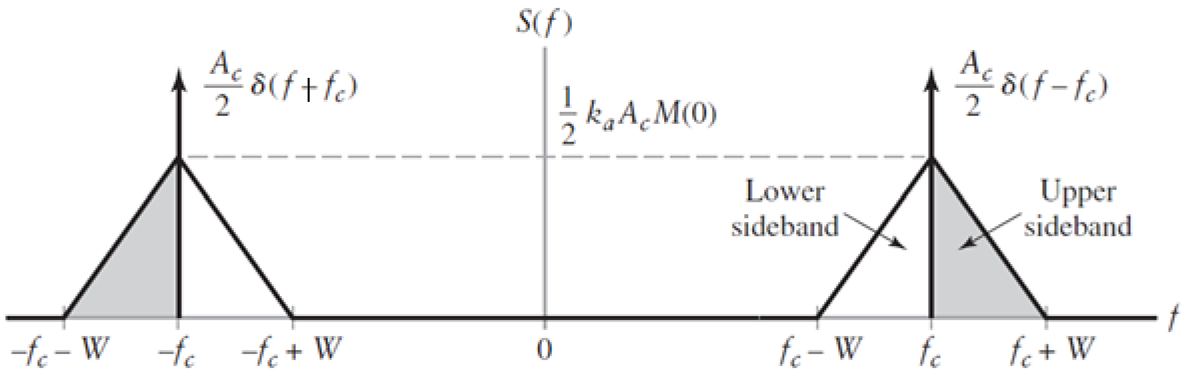

Figure-2

The bandwidth of the baseband signal $m(t)$ is

$$W.$$

On the other hand, the bandwidth if the amplitude modulated signal, i.e., AM signal, is

$$2W.$$

In positive frequency region, the portion of the spectrum lying above the carrier frequency f_c is called upper sideband.

Whereas the portion of the spectrum lying below the carrier frequency f_c is called lower sideband.

Due to its symmetric spectrum the signal

$$s_c(t) = A_c[1 + k_a m(t)]$$

is also called **double sideband amplitude modulated** signal. That DSB-AM signal.

Demodulation of AM

Extracting the message signal from the modulated signal is called demodulation.

Demodulation can be considered as the reverse process of the modulation.

For the demodulation of the DSM-AM signal, we use the envelope detector circuit which is shown in Figure-3.

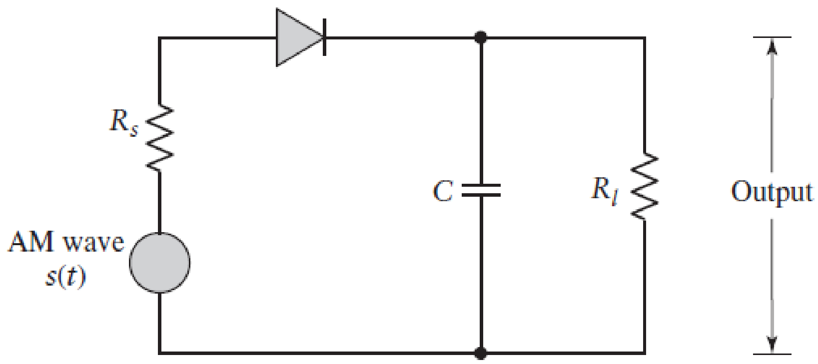

Figure-3

The operation of this envelope detector is as follows.

On a positive half-cycle of the input signal, the diode is forward-biased and the capacitor C charges up rapidly to the peak value of the input signal.

When the input signal falls below this value, the diode becomes reverse-biased and the capacitor C discharges slowly through the load resistor.

The discharging process continues until the next positive half-cycle.

When the input signal becomes greater than the voltage across the capacitor, the diode conducts again and the process is repeated

We should have

$$(R_s + r_f)C \ll \frac{1}{f_c} \ll R_l C \ll \frac{1}{W}$$

where

$(R_s + r_f)C$: Charging Time Constant, r_f is the diode resistance
$1/f_c$: *Carrier period*
$R_l C$: *Discharging Time Constant*

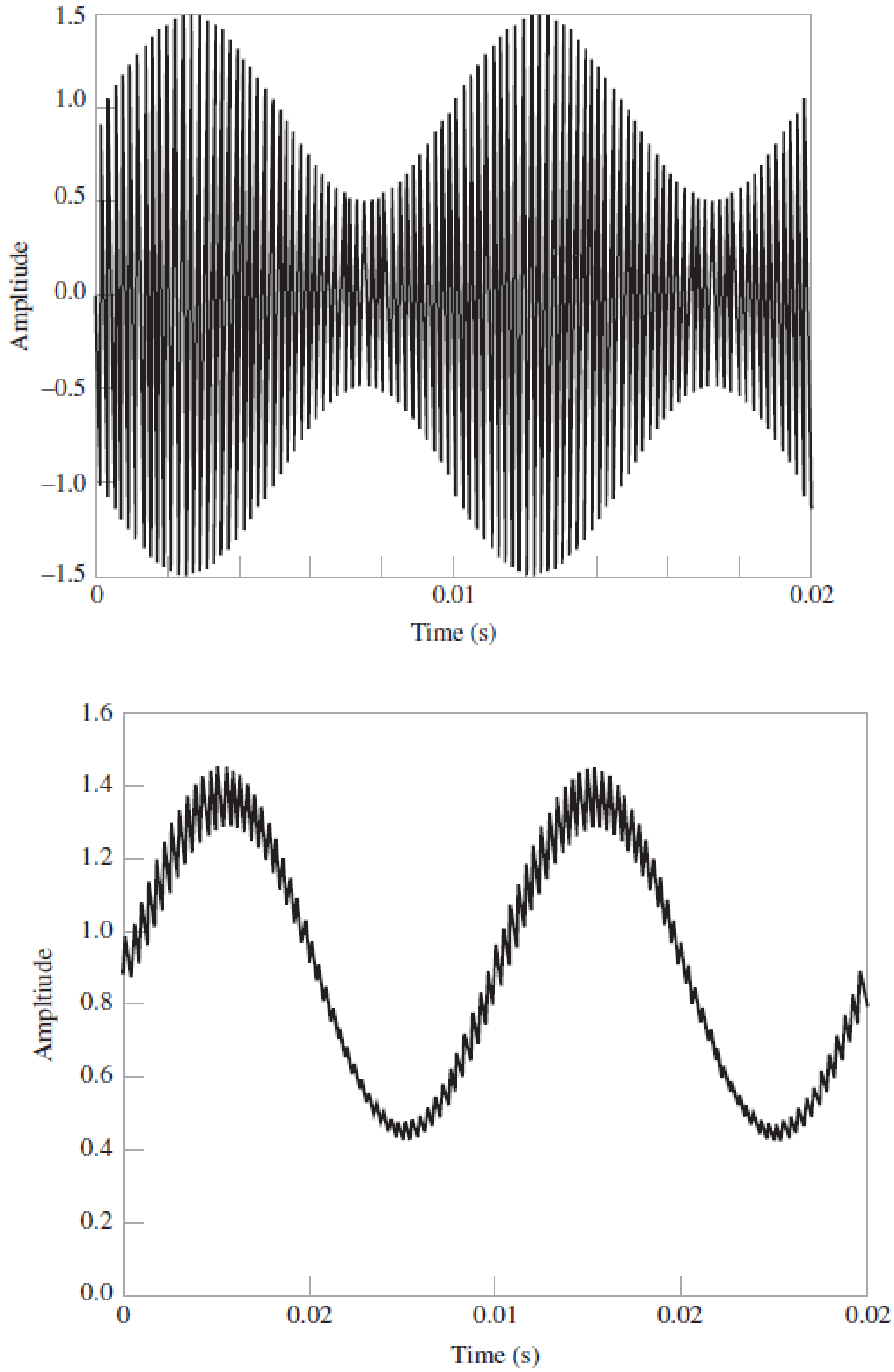

Figure-4

Note that for and RC circuit the capacitor charging and discharging formulas are given as

$$V_C(t) = V_s\left(1 - e^{-\frac{t}{\tau}}\right) \quad \tau = RC$$

$$V_C(t) = V_s e^{-\frac{t}{\tau}} \quad \tau = RC$$

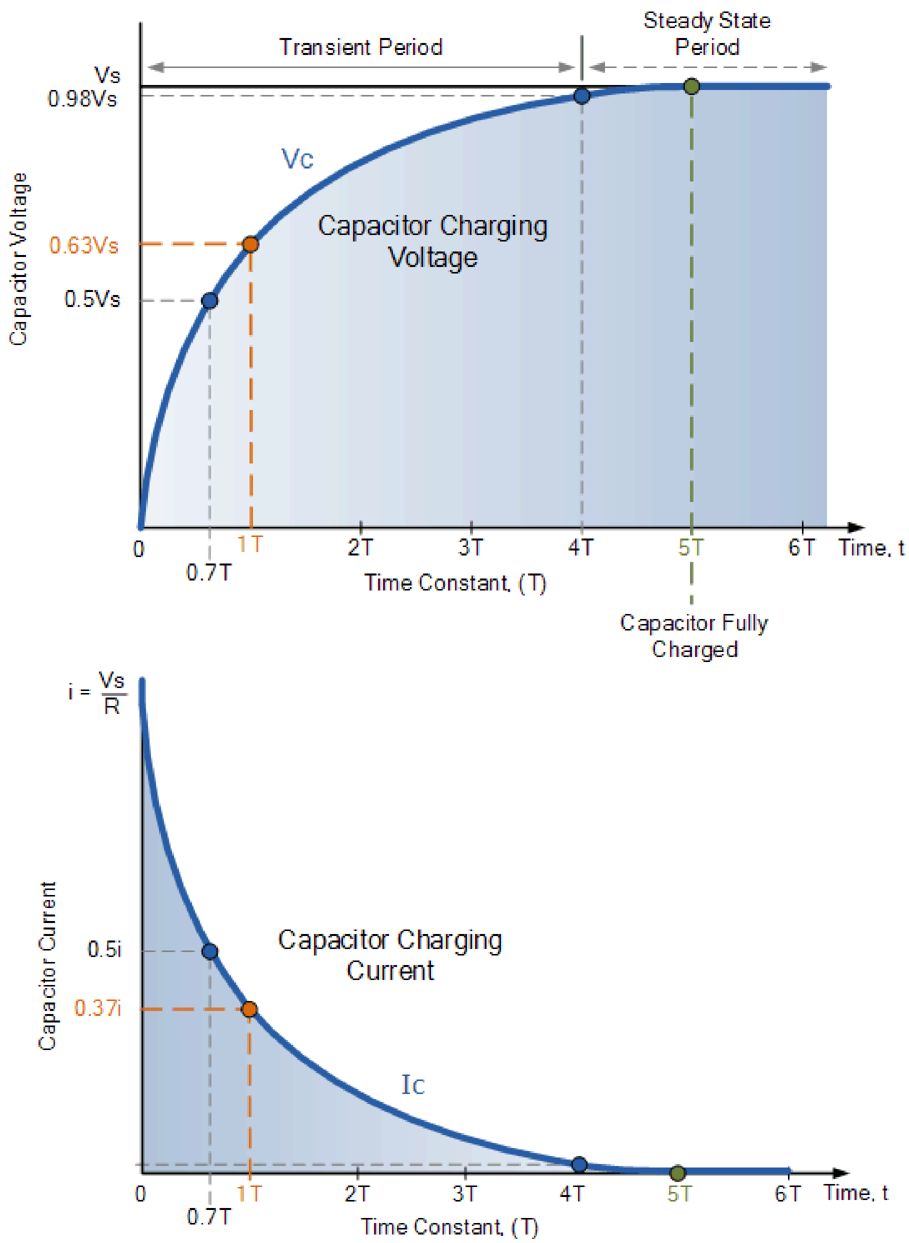

Figure-5

Example: The components of the envelope detector circuit for $f_c = 20kHz$ and message signal bandwidth W = 1kHz can be selected as

$$R_s = 75\Omega \quad r_f = 25\Omega \quad R_l = 25\Omega \quad \mathrm{C} = 0.01\mu\mathrm{F}$$

Drawbacks of DSB-AM

The drawbacks of the amplitude modulated signal

$$s(t) = A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t$$

can be outlined as

a) DSB amplitude modulation is a power in efficient modulation type. The transmission of carrier signal wastes the power unnecessarily.

b) For the baseband signal $m(t)$ of bandwidth W, the amplitude modulated signal requires a bandwidth of $2W$, and this is a waste of the bandwidth.

To reduce the high power and high bandwidth of the DSM-AM process better AM modulation techniques are suggested. However, although better AM modulation techniques reduce the power and bandwidth requirement, they increase the hardware complexity for the modulation and demodulation circuits.

Modified Forms of Amplitude Modulation

a) Double sideband suppressed carrier (DSB-SC).

In this AM modulation technique, the carrier signal is suppressed, i.e., it is not transmitted in the AM signal.

The DSB-SC signal has the form

$$s(t) = A_c k_a m(t) \cos 2\pi f_c t.$$

In this wave power saving is achieved. However, the bandwidth use is the same as that of the DSB-AM method.

b) Vestigial sideband modulation (VSB Modulation)

In this modulation method, only one sideband and a vestige of the other sideband is used for the transmission. This form of modulation is used for the transmission of wideband signals such as television signals. A variable size of carrier signal is also transmitted.

c) Single sideband modulation (SSB Modulation)

In this modulation method, only the upper sideband or the lower side band is used for the transmission. SSB modulation is used for the transmission of voice signals.

SSB modulation requires minimum power and bandwidth. For this reason, it is an optimum modulation method. However, increased cost and increased hardware complexity are the main disadvantages of this method.