Amplitude (Linear) Modulation

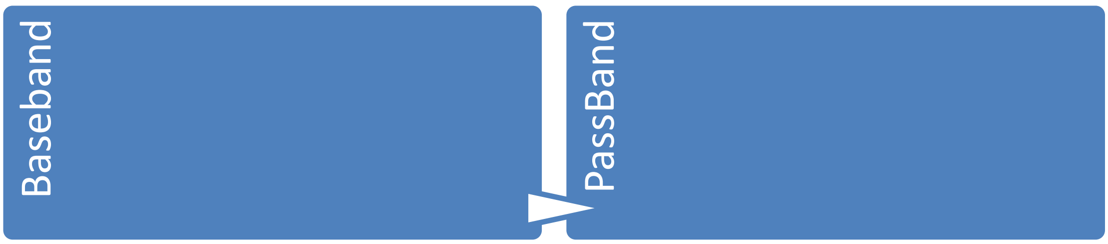
Contents

Introduction

Modulation: a process that causes a shift in the range of frequency in a signal.

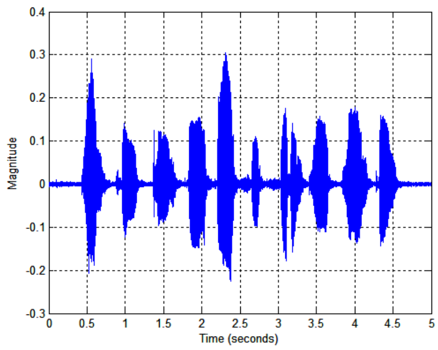
Types of Communications (baseband vs. Passband)

Communication systems can be classified into two groups depending on the range of frequencies they use to transmit information. These communication systems are classified into BASEBAND or PASSBAND system. Baseband transmission sends the information signal as it is without modulation (without frequency shifting) while passband transmission shifts the signal to be transmitted in frequency to a higher frequency and then transmits it, where at the receiver the signal is shifted back to its original frequency.

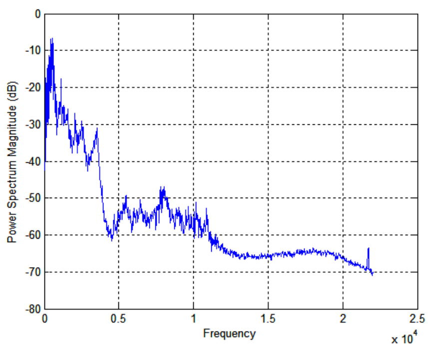


Baseband Communications: baseband is the band of frequencies of the signal delivered by the source or input transducer. Almost all sources of information generate baseband signals. Baseband signals are those that have frequencies relatively close to zero Examples (telephone voice 20-3.5 kHz, TV video 0-4.3 MHz, Digital data with rate R_b pulses per second, using Pulse Coded Modulation ,PCM, 0-R_b Hz).

A plot of an audio signal and its frequency spectrum are shown below, where it is seen that the most of the power of the audio signal is concentrated in the frequency range from (0 – 4 kHz). The telephone system used for homes and offices, for example, may transmit the baseband audio signal as it is when the call is local (from your home to your neighbor's home). However, when the telephone call is a long–distance call that is transmitted via microwave or satellite links, the baseband audio signal becomes unsuitable for transmission and the communication system becomes a passband system. Similarly, transmitting the video signal from your camera to your TV using a wire represents a baseband communication while transmitting that video signal via satellites passband transmission. Therefore, baseband transmission, which is easier than passband transmission, is usually used when communicating over wires, while over–the–air transmission requires passband transmission. Notice that even over wires, the transmission may be passband transmission in specific applications.



(a)



(b)

An audio signal in (a) time–domain, and (b) in frequency–domain.

Why to modulate? (Revisited Question)

1) For frequency division multiplexing (FDM).
2) To control the antenna size (wireless applications) antenna size is inversely proportional to frequency.
3) Propagation characteristics. Lower frequency signals penetrate more.
4) Exchange bandwidth with signal quality (SNR).

Types of carrier Modulations

In modulation, one characteristic or more of a signal (generally a sinusoidal wave) known as the carrier is changed based on the information signal that we wish to transmit. The characteristics of the carrier signal that can be changed are the amplitude, phase, or frequency, which result in Amplitude modulation (AM), Phase modulation (PM), or Frequency modulation (FM).

Note, the word modulation is also used for its English meaning without shifting frequencies, like in PAM, PWM,PPM, PCM, DM which are all baseband signals to be discussed later

Types of Amplitude Modulation (AM)

In AM the amplitude, A, of the carrier $c(t) = A\cos(\omega_c t + \theta_c)$ is varied in proportion with the baseband signal $m(t)$, the modulating signal , ω_c and θ_c are constants (we assume θ_c=0) without loss of generality. The carrier itself carries no information at all.

Assume that we have a message signal $m(t)$ with bandwidth (BW) $2\pi B$ rad/s (or B Hz) that has a FT

$$m(t) \Leftrightarrow M(\omega).$$

such that the frequency of the carrier ω_c is much larger than the highest frequency in the information signal (we set the amplitude of the carrier to be 1, but it can be any value).

AM is itself divided into different types:

1. **Double Sideband with carrier (we will call it AM)**: This is the most widely used type of AM modulation. In fact, all radio channels in the AM band use this type of modulation.

2. **Double Sideband Suppressed Carrier (DSBSC):** This is the same as the AM modulation above but without the carrier.

3. **Single Sideband (SSB):** In this modulation, only half of the signal of the DSBSC is used.

4. **Vestigial Sideband (VSB):** This is a modification of the SSB to ease the generation and reception of the signal.

Double Sideband Suppressed Carrier (DSBSC)

DSBSC Modulation

The DSBSC signal is simply obtained by multiplying the information signal with the carrier signal as shown in the modulator (or transmitter) block diagram shown below

$$g_{DSBSC}(t) = m(t)\cdot\cos(\omega_c t) \Leftrightarrow (1/2)\,[M(\omega - \omega_c) + M(\omega + \omega_c)].$$

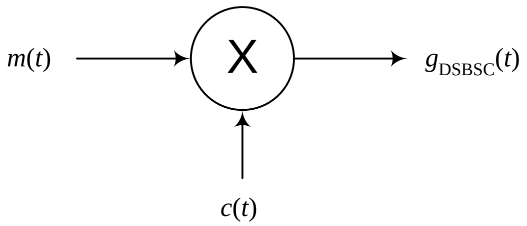
Bandwidth B Hz ➔ $2B$ Hz

On the frequency domain Figure below, explain:

USB: Upper Sideband (above ω_c)

LSB: Lower sideband (below ω_c)

No discrete component of ω_c ➔ **DSB-SC** (Double sideband suppressed carrier) Modulation



DSBSC Modulator (transmitter)

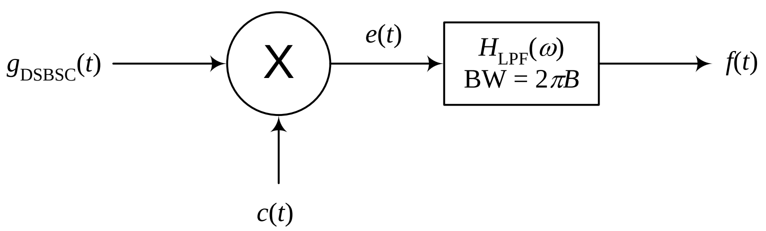
This signal $g_{DSBSC}(t)$ is a modulated signal that has its spectrum centered around ω_c and $-\omega_c$. Therefore, this signal becomes a passband signal with frequency that is much larger than the maximum frequency in $m(t)$.

To avoid overlap of the frequency spectrum, and $m(t)$ can be recovered,

$$\omega_c \geq 2\pi B$$

DSBSC Demodulation

The demodulation process of a DSBSC signal involves obtaining the original information signal or scaled version of it from the modulated signal. This can be done by multiplying the modulated signal with another carrier signal that has EXACTLY the same frequency and phase as the carrier signal in the modulator block as seen in the demodulator block diagram shown below. The amplitude of the two carrier signals in the modulator and demodulator are not important since they just affect the magnitude of the different intermediate signals and final output signal of the demodulator.



DSBSC Demodulator (receiver)

The signal labeled $e(t)$ in the demodulator becomes

$$e(t) = g_{DSBSC}(t)\cdot\cos(\omega_c t) = m(t)\cdot\cos^2(\omega_c t) = (1/2)\, m(t)\, [1 + \cos(2\omega_c t)]$$

$$= (1/2)\, m(t) + (1/2)\, m(t) \cos(2\omega_c t)$$

$$\Leftrightarrow (1/2)\, M(\omega) + (1/4)\, [M(\omega - 2\omega_c) + M(\omega + 2\omega_c)].$$

However, as seen in the FT of $e(t)$, the original message signal (scaled by 1/2) is present but also other components with frequencies centered around $2\omega_c$ and $-2\omega_c$. These components are undesired and must be removed to get the message signal. This can be done using a LPF (a filter centered around zero frequency that permits low frequencies to pass and rejects high frequencies). The BW of the filter must be $2\pi B$ rad/s (or B Hz) or possibly slightly higher (but not much higher that it will allow the high-frequency components around $2\omega_c$ and $-2\omega_c$ to partially or completely pass).

Therefore, the output signal $f(t)$ of the LPF will be

$$e(t) = (1/2)\, m(t) \quad \Leftrightarrow \quad (1/2)\, M(\omega).$$

This is simply a scaled version of the original transmitted signal that can be easily amplified to obtain the original signal exactly. We can get rid of the half by demodulating with $2\cos(\omega_c t)$.

Synchronous detection =**coherent** detection

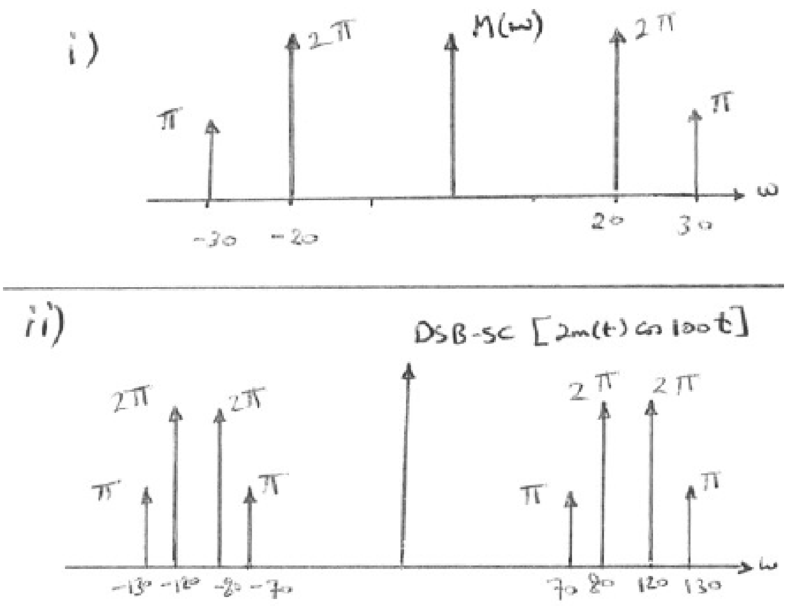
We need to generate a local signal with the same frequency and same phase as the carrier.

Modem=**Mod**ulate + **dem**odulate

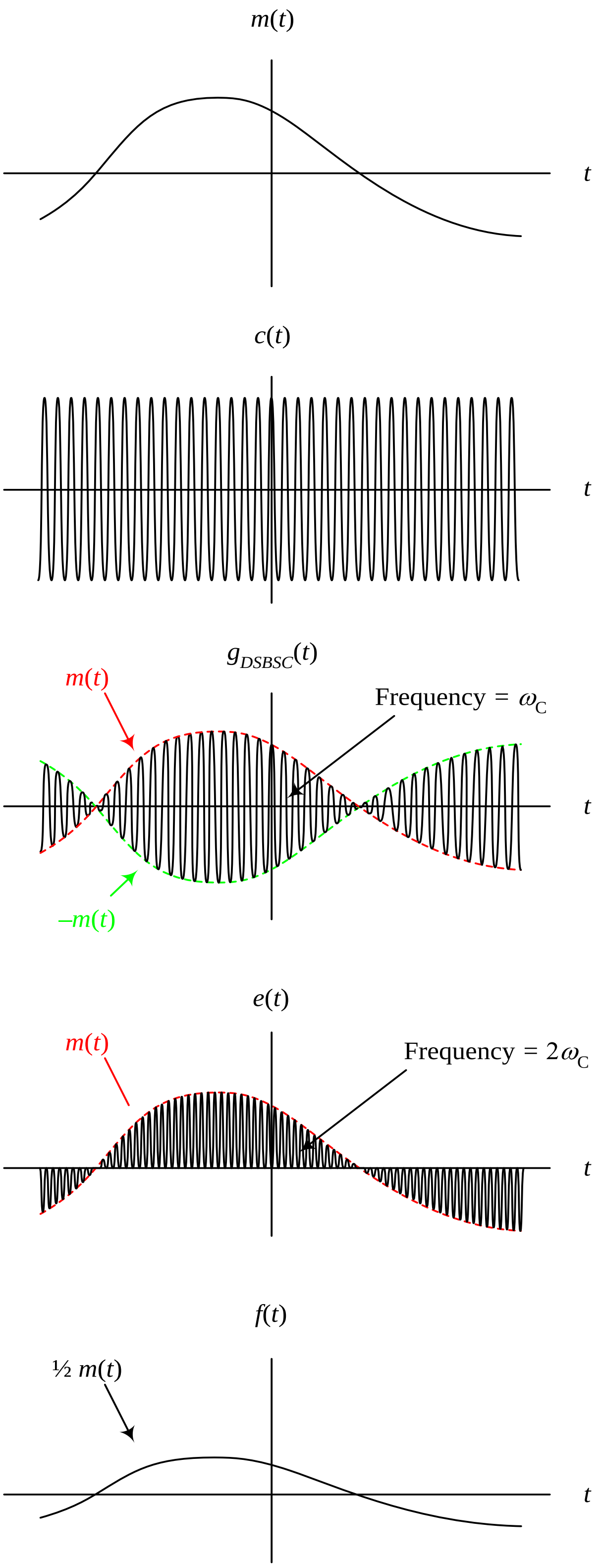
Example (Dual Tone Modulation)

A modulating signal *m(t)* is given by $m(t) = 2\cos 20t + \cos 30t$

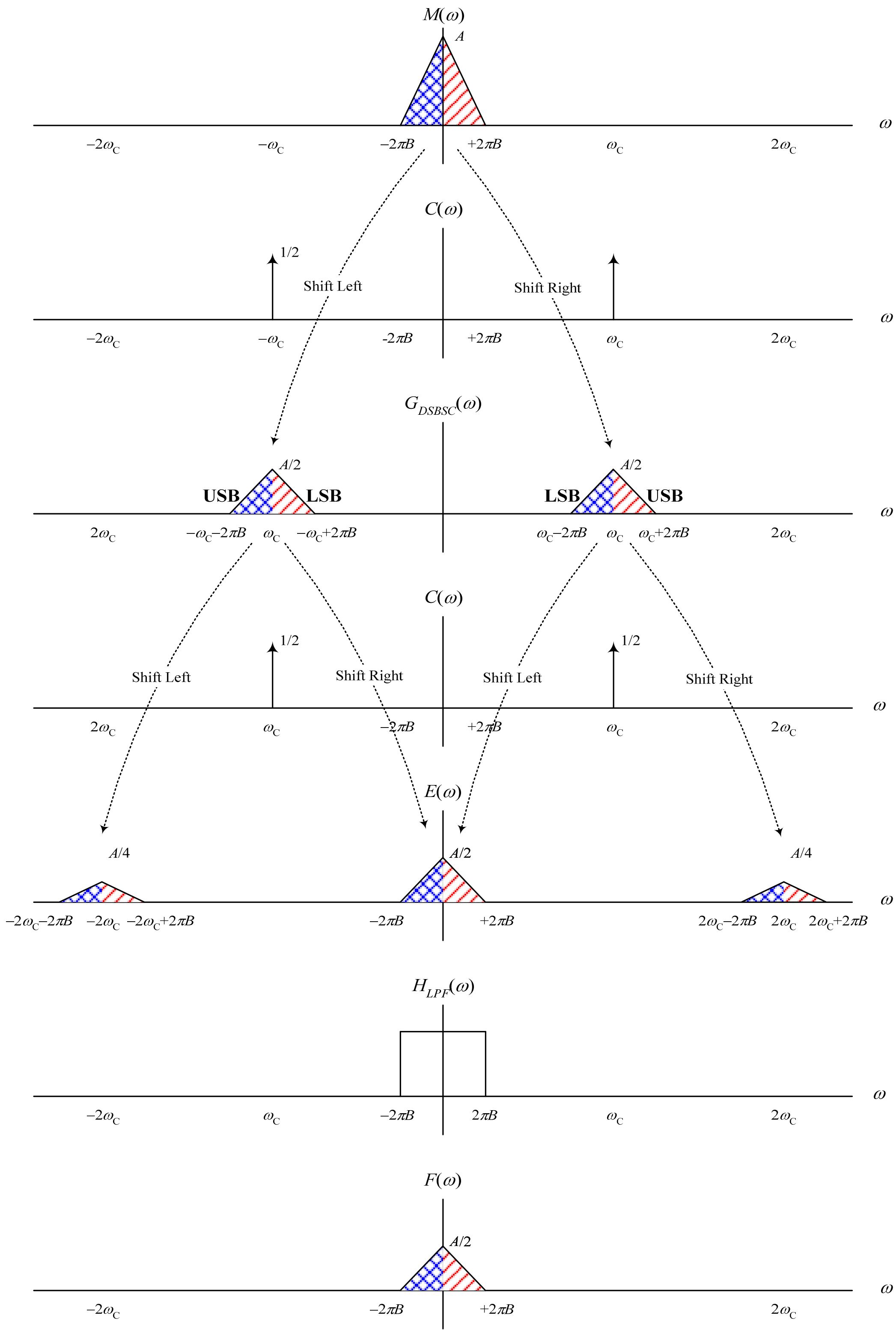
i. Sketch the spectrum of *m(t)*
ii. Sketch the spectrum of the DSB-SC signal $2m(t)\cos 100t$
Note the answer can be illustrated using PicoScope ® or Matlab®



$$\Phi_{DSB-SC}(\omega) = \frac{2}{2}\left[M(\omega+\omega_c) + M(\omega-\omega_c)\right]$$



Time–domain representation of the different signals obtained in the DSBSC modulation–demodulation process.



Frequency–domain representation of the different signals obtained in the DSBSC modulation–demodulation process.