Lecture content

- Modulation
  - Double sideband-suppressed carrier (DSB-SC)
  - Double sideband (DSB)

Why modulation?

To shift spectral to a pre-selected operating frequency band in a given communication channel.

Use of frequency modulation improves the noise immunity.

Use of frequency division multiplexing increases the capacity of a communication channel.

Use of amplitude modulation is simple cheap, although not power efficient.

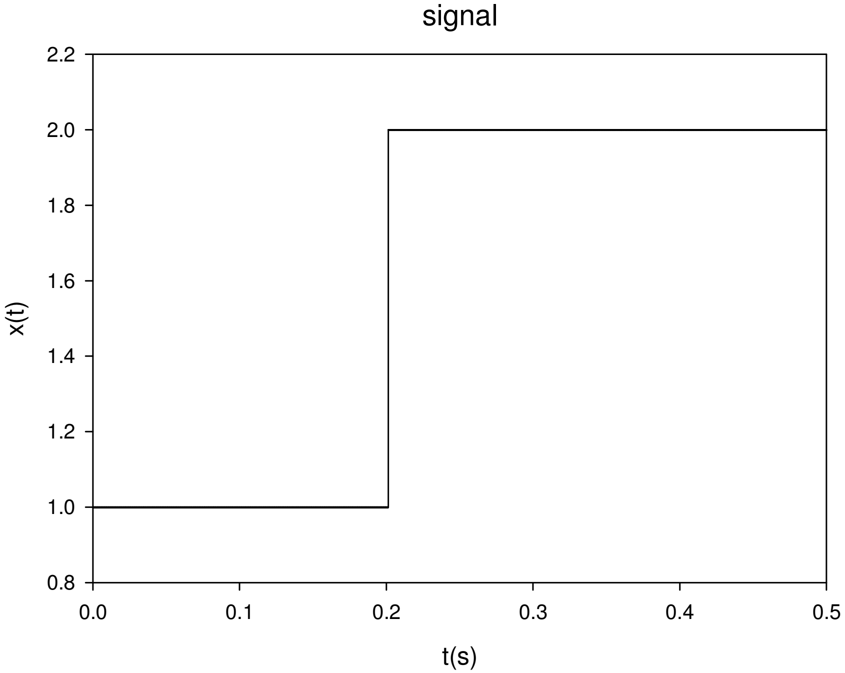
Provide possibility of suitable physical dimension of transmitting and receiving antennas.

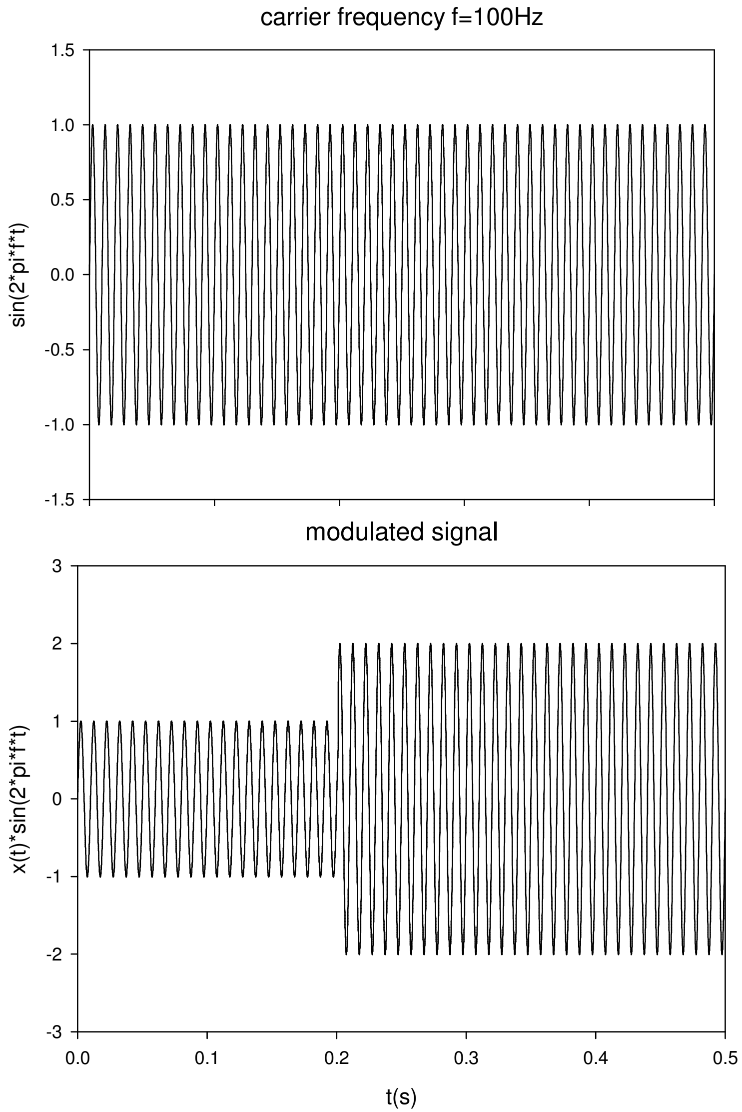
Modulation

MODULATION

Modulation is important in communication to shift the spectrum of a signal $x(t)$ to a higher frequency range so that it is possible to achieve good transmission. For instance an antenna with dimension of at least 1.5×10^5m is required to transmit a frequency of 200Hz (human voice lies in the frequency range 200Hz to 4kHz). There are many modulation techniques but we will only discuss the amplitude modulation.

Signal modulation





http://www.ocf.berkeley.edu/~arosko/waveapplet.html

http://www.youtube.com/watch?v=3ZMPcPR7W3Q

Modulation

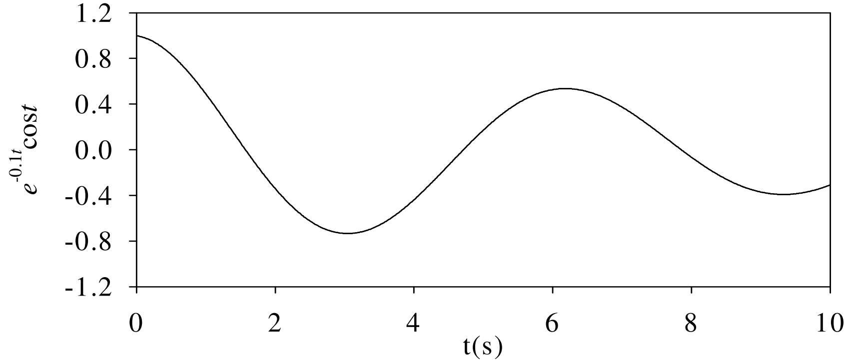
Consider a signal $x(t)$ with a spectrum $X(\omega)$ band limited to W, i.e $X(\omega) = 0$ for $|\omega| > W$. In amplitude modulation (AM), the amplitude of a carrier signal $x_c(t) = \cos\omega_c t$ is modulated by the signal $x(t)$ where ω_c is assumed to be greater than W. The modulated signal is obtained by multiplying $x(t)$ by $x_c(t)$ to give

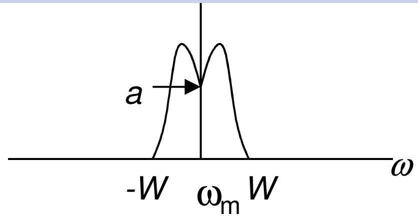
$$x_m(t) = x(t)\cos\omega_c t.$$

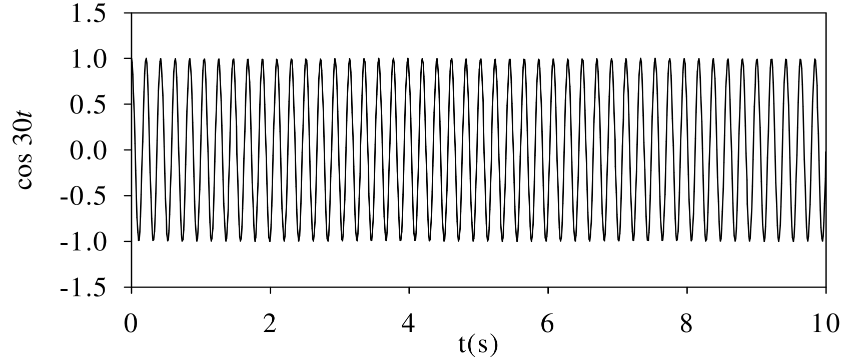
$$X_m(\omega) = \frac{1}{2}\left[X(\omega+\omega_c) + X(\omega-\omega_c)\right]$$ Frequency Shift

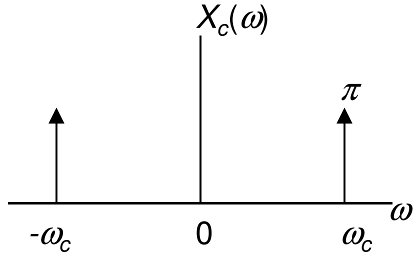
Modulation

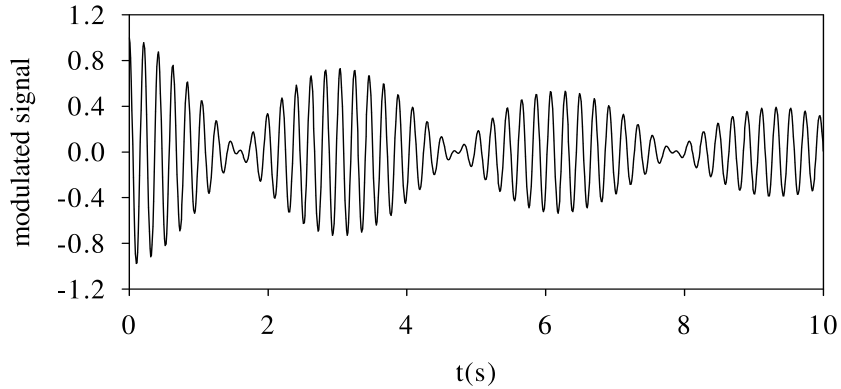
For illustration only: Spectrum is not real

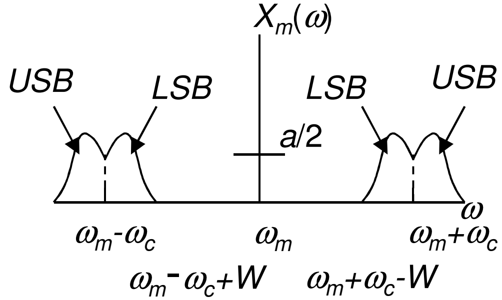












The spectrum of the modulated signal is

$$X_m(\omega) = \frac{1}{2}\left[X(\omega + \omega_c) + X(\omega - \omega_c)\right]$$

The spectrum within $[\omega_c, \omega_c + W]$ is called the upper side band (USB) while the spectrum within $[\omega_c - W, \omega_c]$ is called the lower side band (LSB).

The two impulses due to the carrier signal do not appear in $Xm(\omega)$. The modulation scheme in figure 2 is therefore called double sideband-suppressed carrier (DSB-SC). This modulation scheme does not require the carrier signal to be transmitted leading to low power consumption. However it requires synchronisation between the transmitter and receiver for demodulation of the DSB-SC signals.

Modulation

To recover the signal $x(t)$ from $x_m(t)$ we can use a synchronous demodulator which multiplies $x_c(t)$ by $\cos\omega_c t$. The output of the demodulator is

$$y(t) = x_m(t)\cos\omega_c t$$

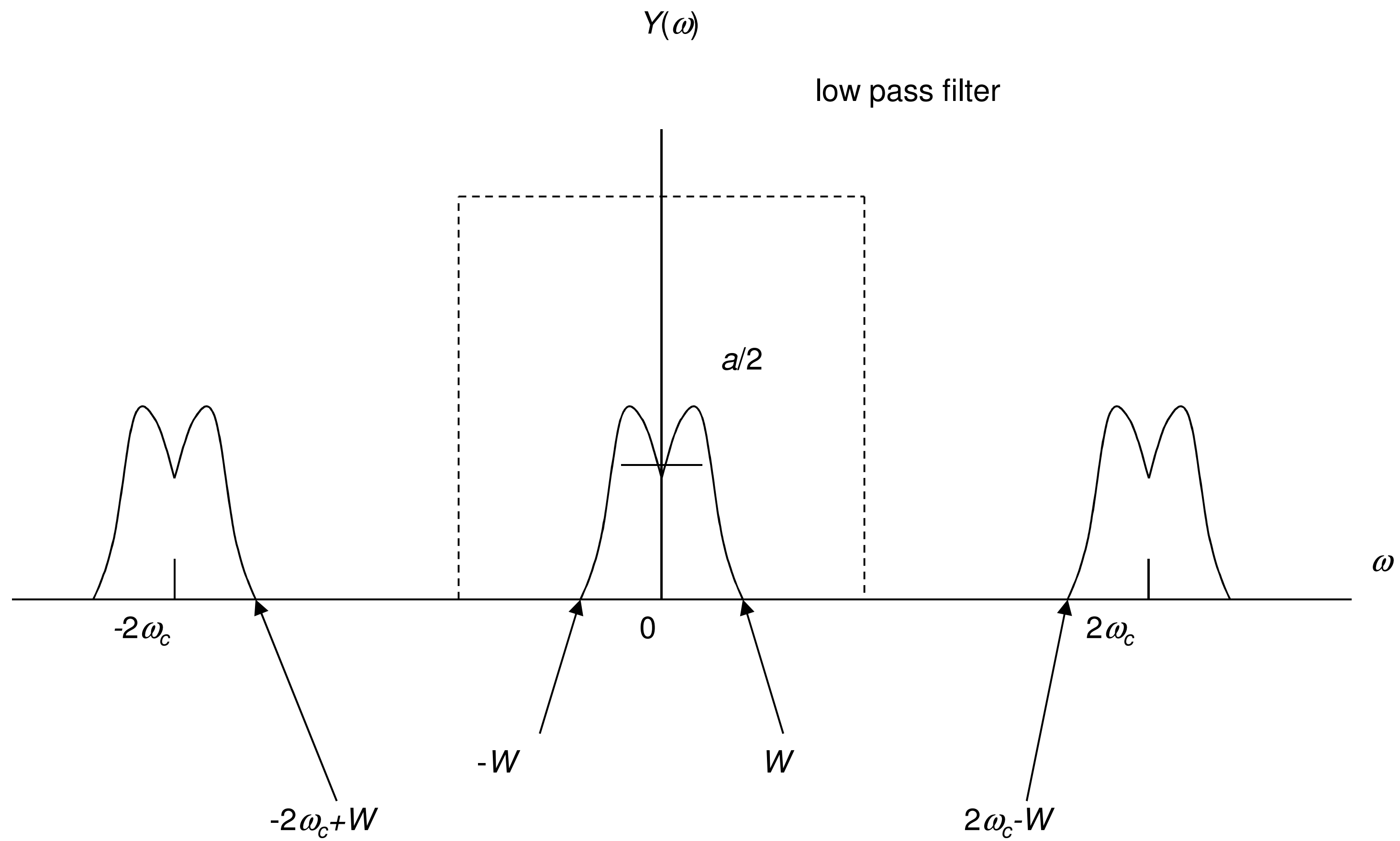
and the Fourier Transform of y(t) is

$$Y(\omega)=\frac{1}{2}\left[X_m(\omega+\omega_c)+X_m(\omega-\omega_c)\right]=\frac{1}{2}\left[\frac{1}{2}\left(X(\omega+2\omega_c)+X(\omega)\right)+\frac{1}{2}\left(X(\omega)+X(\omega-2\omega_c)\right)\right]$$

$$Y(\omega)=\frac{1}{2}X(\omega)+\frac{1}{4}X(\omega+2\omega_c)+\frac{1}{4}X(\omega-2\omega_c)$$

Next we use a low pass filter with a gain of 2 and a cutoff frequency greater than W but less than $2\omega_c$-W, to recover $x(t)$.

Modulation



$Y(\omega)$
low pass filter
$a/2$
ω
$-2\omega_c$
0
$2\omega_c$
$-W$
W
$-2\omega_c+W$
$2\omega_c-W$

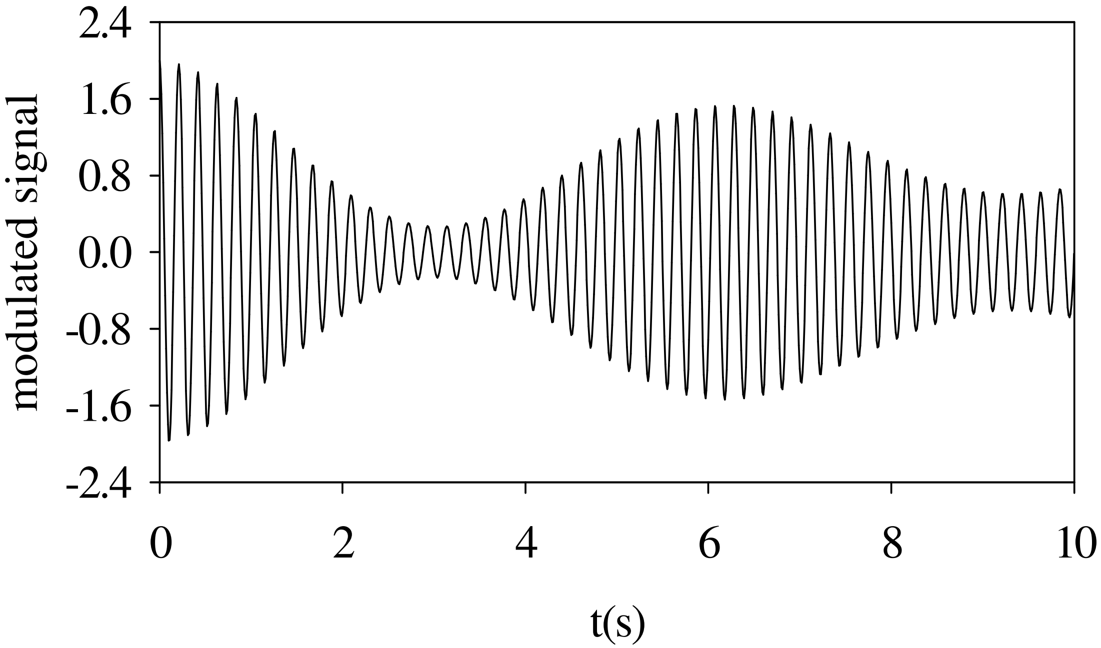
Modulation

In another form of AM scheme, the modulated signal is given by

$$x(t) = A_m \cos \omega_m t$$

$$x_m'(t) = [A + x(t)]\cos \omega_c t = A\cos \omega_c t + A_m \cos \omega_m t \cos \omega_c t$$

where *A* is selected so that *A* + *x*(*t*) > 0. The modulated signal is shown in figure 4 for *A* = 1.



It is also possible to add a modulation index term, μ

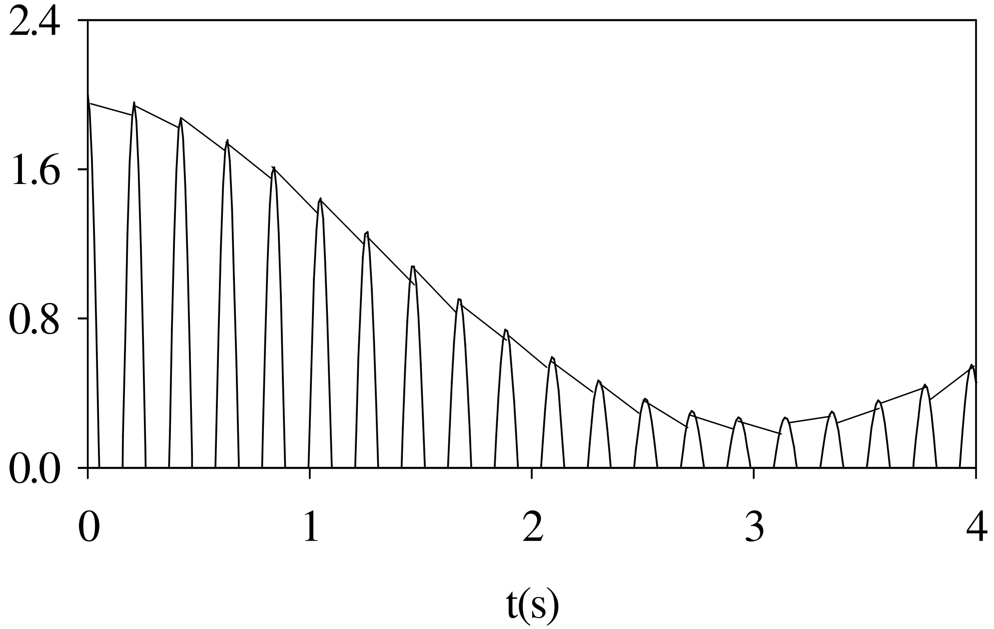
$$x_m'(t) = [A + A\mu x(t)]\cos \omega_c t$$

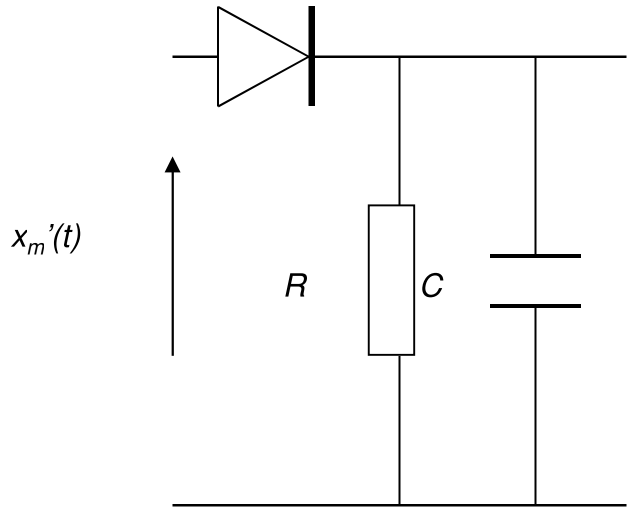
The frequency spectrum of $x_m'(t)$ is

$X_m'(\omega) = A\pi[\delta(\omega+\omega_c) + \delta(\omega-\omega_c)] + 0.5[X(\omega+\omega_c) + X(\omega-\omega_c)]$.

This modulation scheme is referred to as double sideband (DSB) AM. The transmitted signal $x_m'(t)$ contains the carrier signal and both the USB and the LSB. In this scheme $x(t)$ can be reconstructed using an envelope detector which consists of a diode, a resistor and a capacitor, as shown in figure 5. If the values of R and C are properly selected the output of the demodulator will be close to the upper envelope of $x_m'(t)$.

Modulation





Modulation

In communication several signals can be transmitted simultaneously by using frequency division multiplexing in which each signal occupies a different portion of the radio spectrum. For instance the frequency band 540-1600kHz for AM radio and 87.5-108MHz for FM radio.