VE216 Recitation Class 9

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VE216 SU20 TA Group

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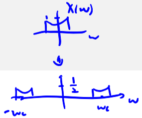
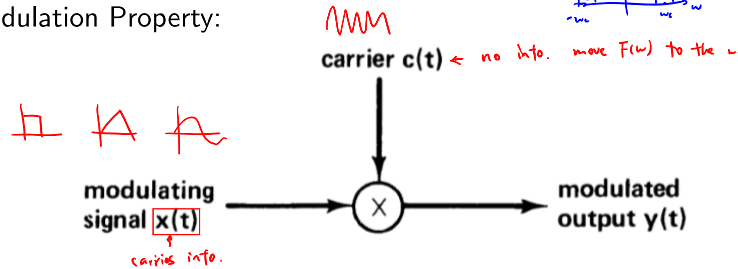
Overview

1. Chapter 8: Communications
   - Sinusoidal Amplitude Modulation (AM) - Synchronous
   - Sinusoidal Amplitude Modulation (AM) - Asynchronous
   - Frequency-division Multiplexing
2. Conclusion

Modulation



- Modulation Property:



$$x(t)\,\boxed{c(t)} \overset{\mathcal{F}}{\longleftrightarrow} \frac{1}{2\pi}\,[X(\omega) * C(\omega)]$$

- pulse carrier : - sampling
- sinusoidal carrier : 1st : consider $f(t)\cdot\cos(w_c t) \longleftrightarrow \frac{F(w-w_c)+F(w+w_c)}{2}$

$$c(t) = \cos(\omega_c t + \theta_c)$$

Method 1 : "split and shift"

Method 2 : by convolution with $\delta(w)$

Sinusoidal Amplitude Modulation

Transmit through air

- Block diagram of modulation system:
  $x(t)$ - information, $c(t)$ - carrier

$$
\begin{array}{c}
x(t) \rightarrow \bigotimes \rightarrow y(t) \rightarrow \text{ antenna} \\
\uparrow \\
\cos(\omega_c t + \theta_c)
\end{array}
$$

  Notice: here we multiply the carrier signal rather than do convolution

- Transmitted signal (i.e., modulated output $y(t)$):

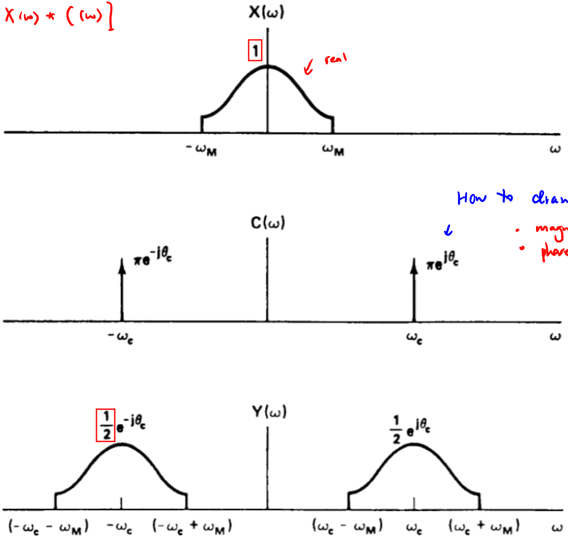
Here. consider strict case

$$
y(t) = x(t)c(t) = x(t)\cos(\omega_c t + \theta_c)
$$

$$
\stackrel{\mathcal{F}}{\longleftrightarrow} \quad Y(\omega) = \frac{1}{2}[e^{j\theta_c}X(\omega - \omega_c) + e^{-j\theta_c}X(\omega + \omega_c)]
$$

Sinusoidal Amplitude Modulation - Synchronous

$x(t) \cdot c(t) \leftrightarrow \frac{1}{2\pi}[X(\omega) * C(\omega)]$



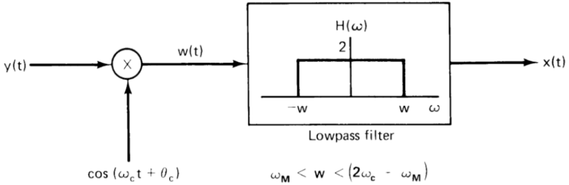
How to draw complex function?

- magnitude
- phase

> together to simplify

Synchronous Demodulation

- Block diagram of demodulation system:



- First multiply $y(t)$ by another $\boxed{cos(\omega_c t + \theta_c)}$ signal:

$$w(t) = y(t)\cos(\omega_c t + \theta_c)$$

$$W(\omega) = \frac{1}{2}[e^{j\theta_c}Y(\omega - \omega_c) + e^{-j\theta_c}Y(\omega + \omega_c)]$$

$$= \boxed{\frac{1}{4}e^{2j\theta_c}X(\omega - 2\omega_c) + \frac{1}{2}X(\omega) + \frac{1}{4}e^{-2j\theta_c}X(\omega + 2\omega_c)}$$

- Then followed by lowpass filtering to extract $X(\omega)$

Synchronous Demodulation

$f(t) \cdot \cos(w_c t + \theta_c) \leftrightarrow \frac{1}{2}[F(w-w_c) \cdot e^{j\theta_c} + F(w+w_c) \cdot e^{-j\theta_c}]$

Why make sense?

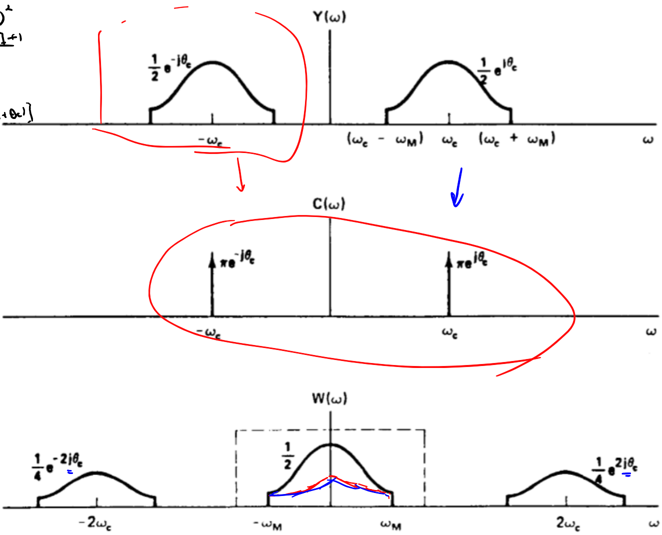
$x(t) \cdot \cos(w_c t + \theta_c)^2$

$= x(t) \cdot \frac{\cos[2(w_c t + \theta_c)] + 1}{2}$

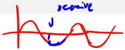
$= \boxed{\frac{1}{2} x(t)} +$

$\frac{1}{2} x(t) \cdot \cos[2(w_c t + \theta_c)]$

high freq.



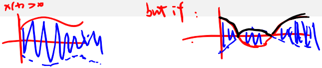
Asynchronous Demodulation: Motivation



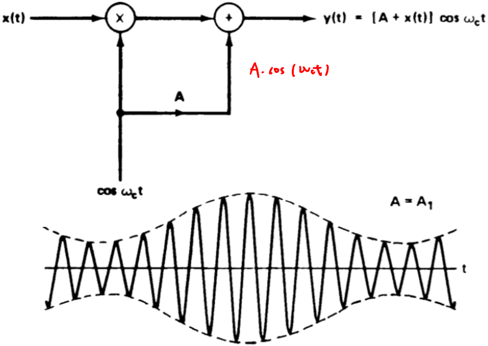
- It seems to be harmless to write the way synchronous Demodulation works on paper, but up to now we haven't considered how to implement it to hardware.
- The bad news is that in practice, it is possible that the phase θ_c and freq. ω_c is not available, therefore a sophisticated phase-tracking receiver is needed.
- But for commercial products like AM radio, one would expect the receivers to be simple and inexpensive.
- Therefore a different demodulation scheme is needed, which uses a more complicated and power inefficient transmitter, but a simple receiver.

Asynchronous Demodulation: Modulated signal

$x(t) > 0$ but if : . then $\hat{x}(t) \neq x(t)$



- Now the modulated signal is: $y(t) = (A + x(t))\cos(\omega_c t)$
- Often we choose A greater then the amplitude of $x(t)$ $A + x(t) > 0$
- The block diagram & how the output $y(t)$ looks like:

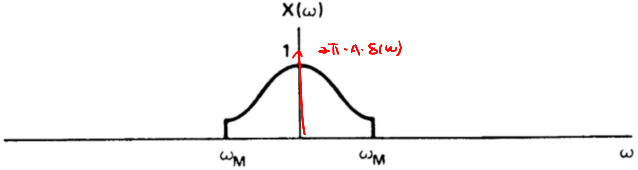


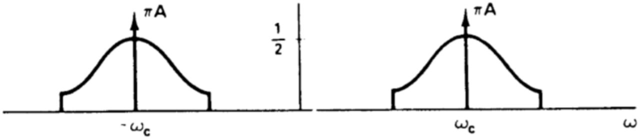
Asynchronous Demodulation: Frequency Domain

$$\begin{cases} x(t)\cdot c(t) \leftrightarrow \frac{1}{2}\left(F(\omega-\omega_c)+F(\omega+\omega_c)\right) \\ 1 \leftrightarrow 2\pi\cdot\delta(\omega) \end{cases}$$

- In frequency domain:

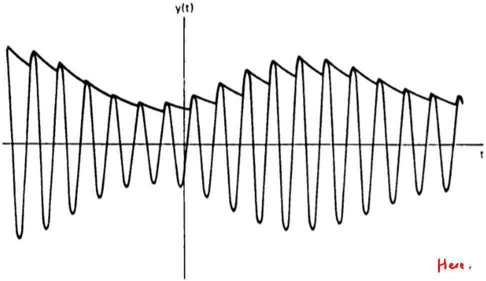
$$Y(\omega) = A\pi[\delta(\omega-\omega_c)+\delta(\omega+\omega_c)] + \frac{1}{2}[X(\omega-\omega_c)+X(\omega+\omega_c)]$$





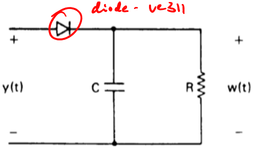
Asynchronous Demodulation

- Use a simple circuit to detect the envelop: $m(t) = A + \hat{x}(t)$
- It works because ω_c is much higher than frequency of $x(t)$



Here, do not analyze in freq. domain

diode - ve311



∵ diode is a special device

Asynchronous Demodulation

- The envolope detector gives us:

$$y(t) = (A + x(t))\cos(\omega_c t)$$

$$m(t) = A + \hat{x}(t)$$

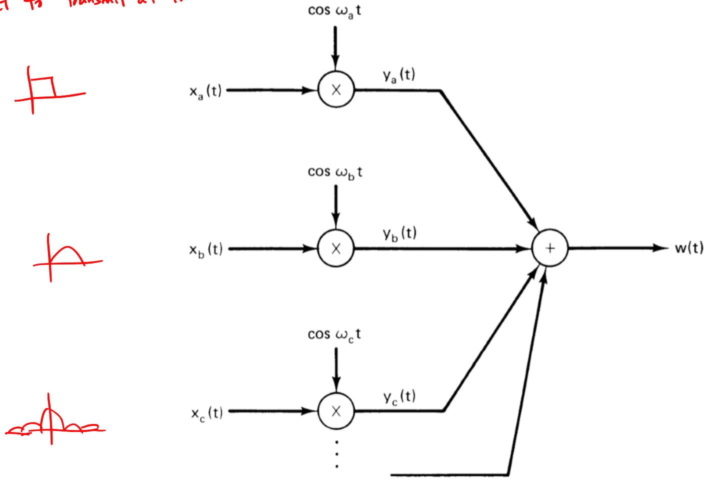
- Then eliminate the DC component (this is what we mean by "power inefficient") and you recover the orginal signal.
- The overall block diagram of demodulation:

$$y(t) \rightarrow \boxed{\text{Envelop detector}} \rightarrow m(t) \rightarrow \boxed{\text{DC blocking filter}} \rightarrow \hat{x}(t)$$

Frequency-division Multiplexing

In time domain:

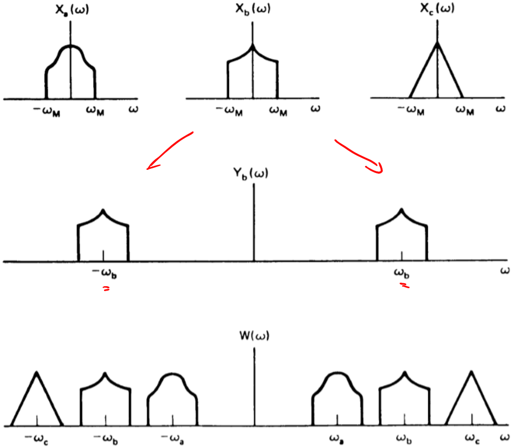
Want to transmit at the same time



Frequency-division Multiplexing

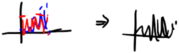
mixed together

In frequency domain:



separated:

Time domain:



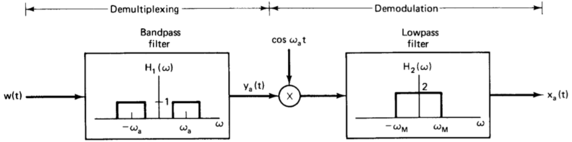
- time domain: a total mess
- freq. domain: gap large enough

⇓

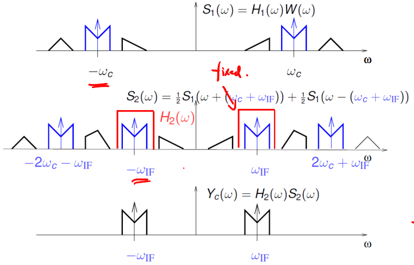
then will work

Demultiplexing and Demodulation

- synchronous demodulation



- asynchronous demodulation (using IF filter)



⇒ then envelop detector

Exercise : HW5 Q8.

Consider the amplitude modulation and demodulation systems with $\theta_c = 0$ and with a change in the frequency of the modulator carrier so that

$$w(t) = y(t)\cos\omega_d t$$

where

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

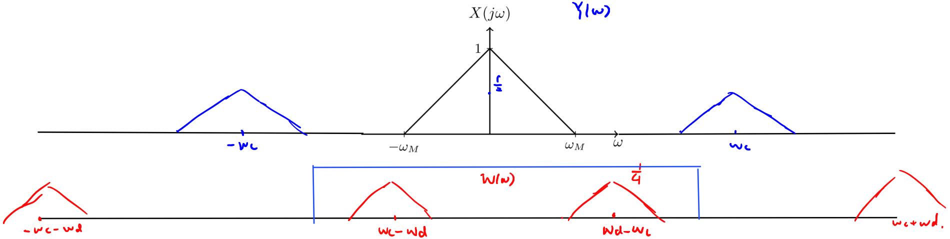
Assume >0.

Let us denote the difference in frequency between the modulator and demodulator as $\Delta\omega$ (i.e., $\omega_d - \omega_c = \Delta\omega$). Also assume that $x(t)$ is band limited with $X(j\omega) = 0$ for $|\omega| \geq \omega_M$, and assume that the cufoff frequency ω_{co} of the lowpass filter in the demodulator satisfies the inequality

$$\omega_M + \Delta\omega < \omega_{co} < 2\omega_c + \Delta\omega - \omega_M$$

(a) [5] Show that the output of the lowpass filter in the demodulator is proportional to $x(t)\cos(\Delta\omega t)$.

(b) [5] If the spectrum of $x(t)$ is that shown in figure below, sketch the spectrum of the output of the demodulator.



$\hat{x}(t) = \frac{1}{4}\cdot x(t)\cdot \cos[(w_d - w_c)t]$

Lab2

eg: DSB/WC-AM

- I am completely lost when I first learnt Chap.8 Communication System, it was only after completing Prelab2 that I finally understood.
- Please take a close look at Prelab2 Section 2.3 - 2.6

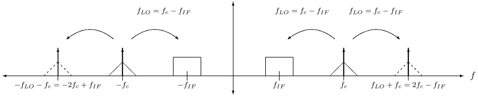


Figure 2.4.2: Using LO to Mix into IF Band when $f_{LO} = f_c - f_{IF}$

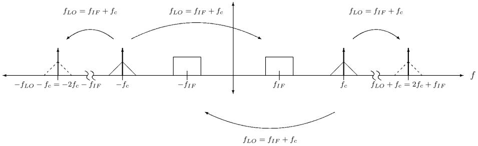


Figure 2.4.3: Using LO to Mix into IF Band when $f_{LO} = f_{IF} + f_c$

- Let's see a video on what really happens in real life - MIT Video Lecture 14 (30:10 – 33:00 min)

Conclusion

$x(t) \rightarrow \underset{c(t)}{\otimes} \rightarrow y(t)$

$\otimes \rightarrow \boxed{\text{lowpass}} \rightarrow \hat{x}(t)$

envelop $\rightarrow \hat{x}(t)$

may talk about it next week

- Have a close look at Prelab2 and Quiz7, then you'll be the expert to Chap. 8
- Get the big picture of mod. & demod.; solve problems graphically
- I guess at one time you may complain about why do we have to go through such a painful way just to get $x(t)$. ∵ transmit info. from one place to another
- But in fact the task is not at all easy, given the constrain of physical laws and hardware implementation.
- Using Asynchronous way (against syn.) is the first time in my collage life that I saw how the real life implementation affects our design
- Therefore, to me, the outcomes of these issues are amazing, because Electrical Engineers not only managed to develop a brand $\boxed{\text{new subject}}$ (comm.) based on the fairly $\boxed{\text{abstract mathematical property}}$ (associated with the Fourier transform), but also turn the theory into real life applications.

The End