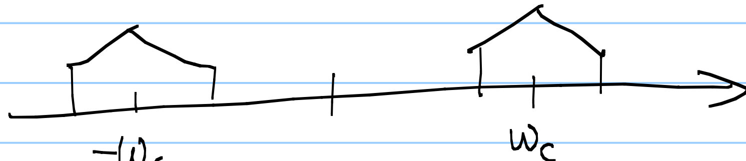
The 2nd drawback:
Require "synchronous carriers"

That is consider the case that we multiply $\sin(\omega_c t)$ in the Rx instead of $\cos(\omega_c t)$

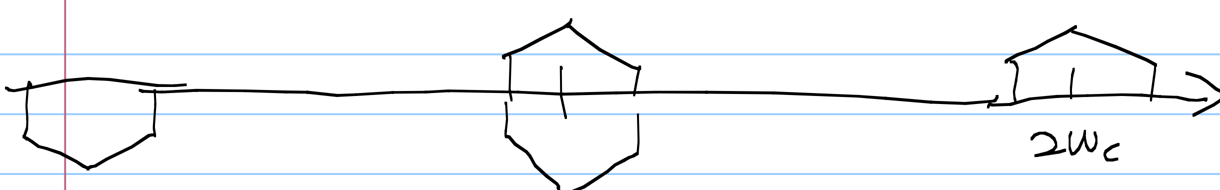
$$\hat{x}(t) = y(t)\sin(\omega_c t)$$

$$\because \sin(\omega_c t) = \frac{1}{2j}\left(\underbrace{e^{j\omega_c t}}_{\text{freq shift to the right}} - \underbrace{e^{-j\omega_c t}}_{\text{freq shift to the left.}}\right)$$

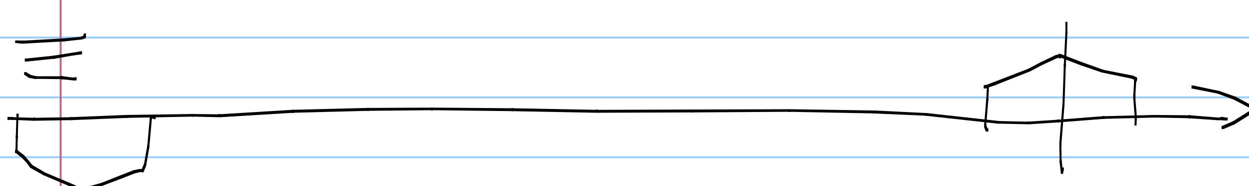
$Y(j\omega)$



$\hat{X}(j\omega)$

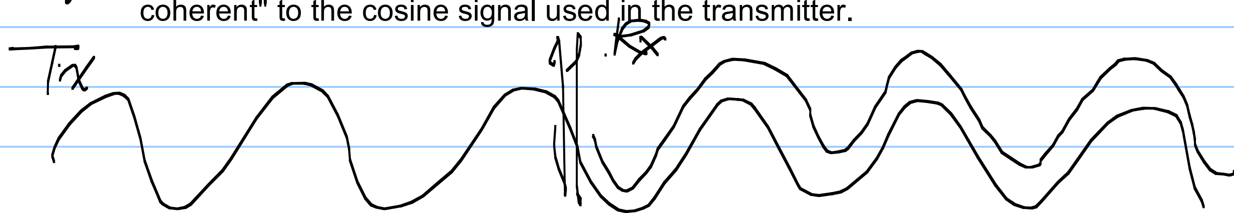


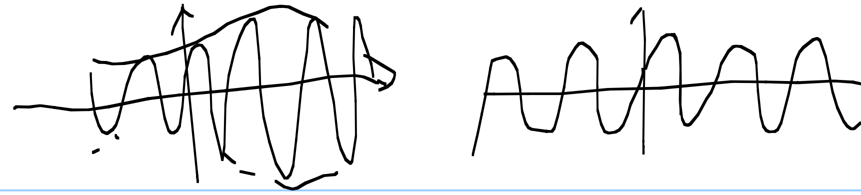
$\equiv$



So after the LPF, the receiver has "nothing"

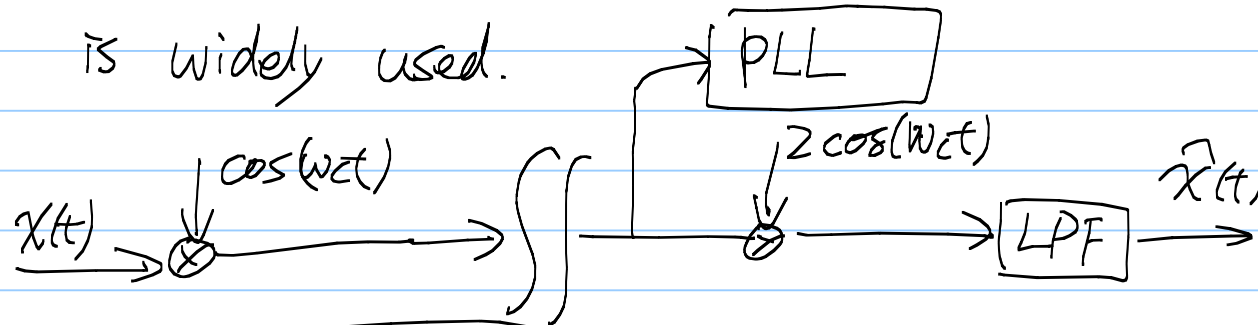
$\Rightarrow$ The receiver has to have a carrier signal that is "synchronous" (or equivalently "phase coherent" to the cosine signal used in the transmitter.





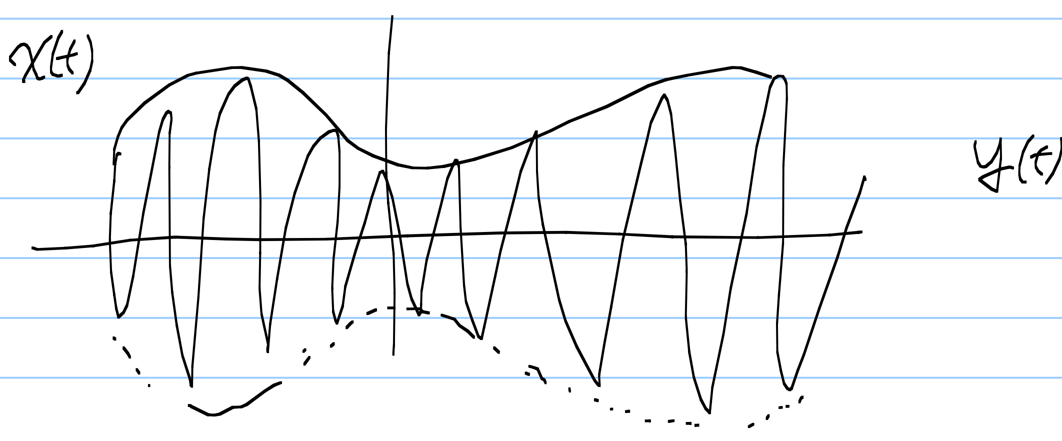
It is solvable by the "Phase Lock Loop", which generates coherent/synchronous signals.

⇒ The above "synchronous demodulation" is widely used.

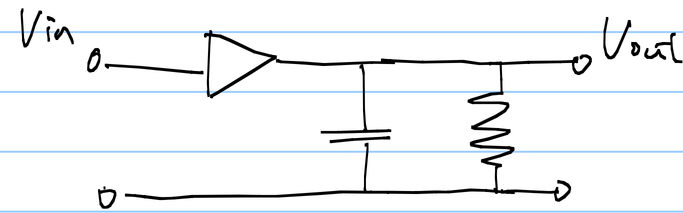


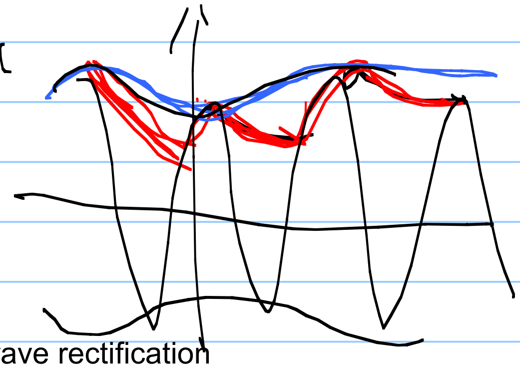
An alternative demodulation.
This method is less advanced but is extremely easy to implement.

* Asynchronous Demodulation of AM signals.
(Envelop detector)
Note that: The Tx side is implemented by the radio station. At the Rx end, different users can use different types of "demodulaters" that use different techniques.



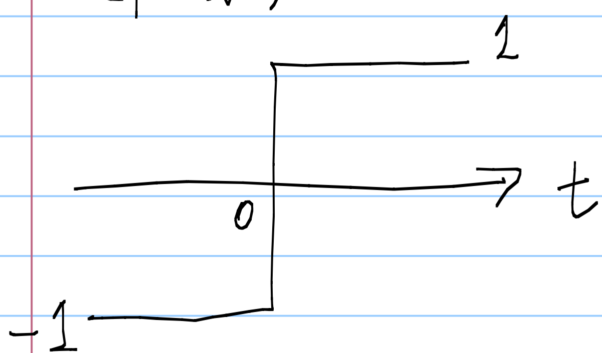
If the carrier signal oscillates much faster than x(t), then x(t) is the "envelope" of the wave form, which can be obtained by "half-wave rectification" (see p. 590-594).





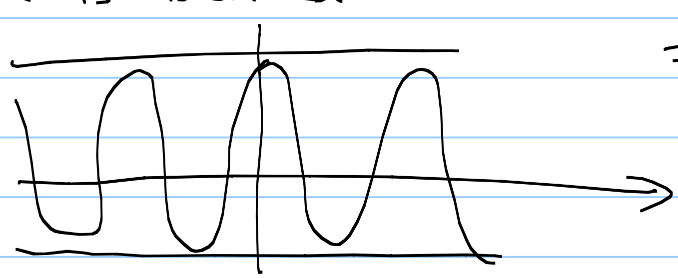
Drawback:: (1) Quality loss due to half-wave rectification
(2) Cannot take negative signals. Namely,

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



the jump here cannot be detected by an envelope detector

With asynchronous demod. (envelope detector), it is identical to

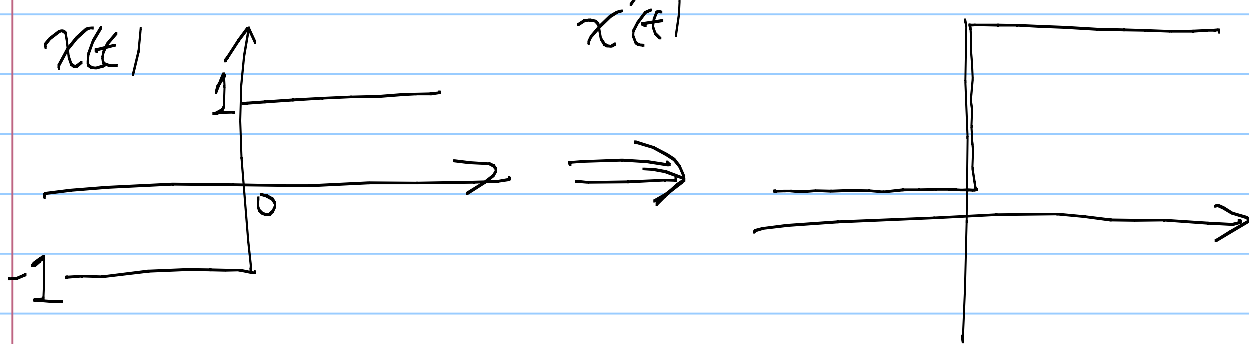


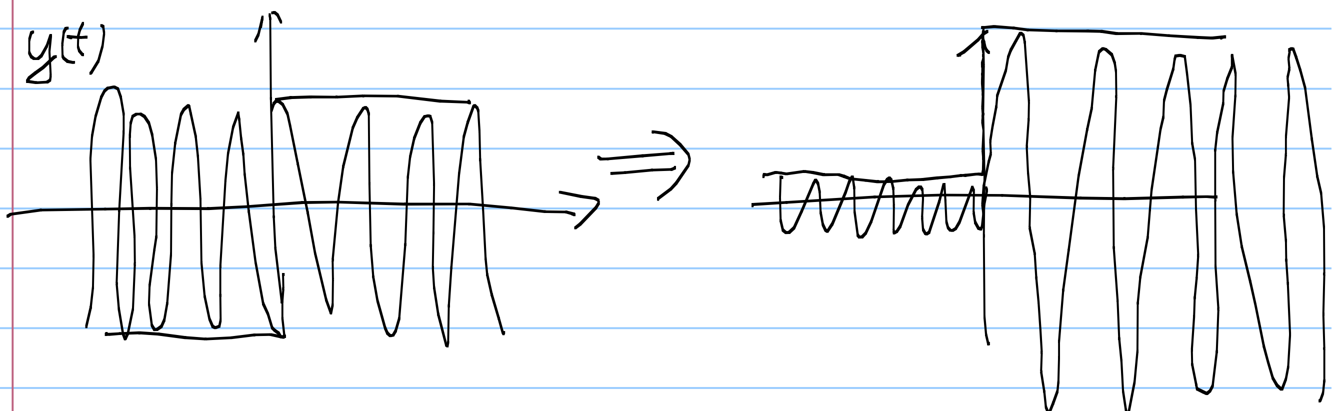
$\Rightarrow \tilde{x}(t)$ by Asynch Demod

However, since the "phase" at "t>0" changes, a shnchronous detector knows that the signal changes from x(t)= -1 for t<0 to x(t)=1 for t>0.

How to fix this problem?
Ans: Add some DC component to shift the original $x(t)$ to be above zero

$x'(t) = x(t) + K, \quad y(t) = x'(t)\cos(w_c t) = (x(t) + K)\cos(w_c t)$





What is the "price" of adding some DC component?
Ans: We need additional transmission power at the radio station.

Note: Nowadays, asynchronous demodulation is seldom used.

Section 8.3 Freq division multiplexing (FDM)

An even more practical scenario:

An antenna tower may like to broadcast several radio stations at the same time. How to achieve this goal?

Ans: Frequency-Division Multiplexing (FDM)

Multiplexing: Different users/signal sources would like to "share" the same media with minimal quality degradation.

FDM: A special type of multiplexiing such that mutlplexing is achieved by dividing the usage of the media by "frequencies."