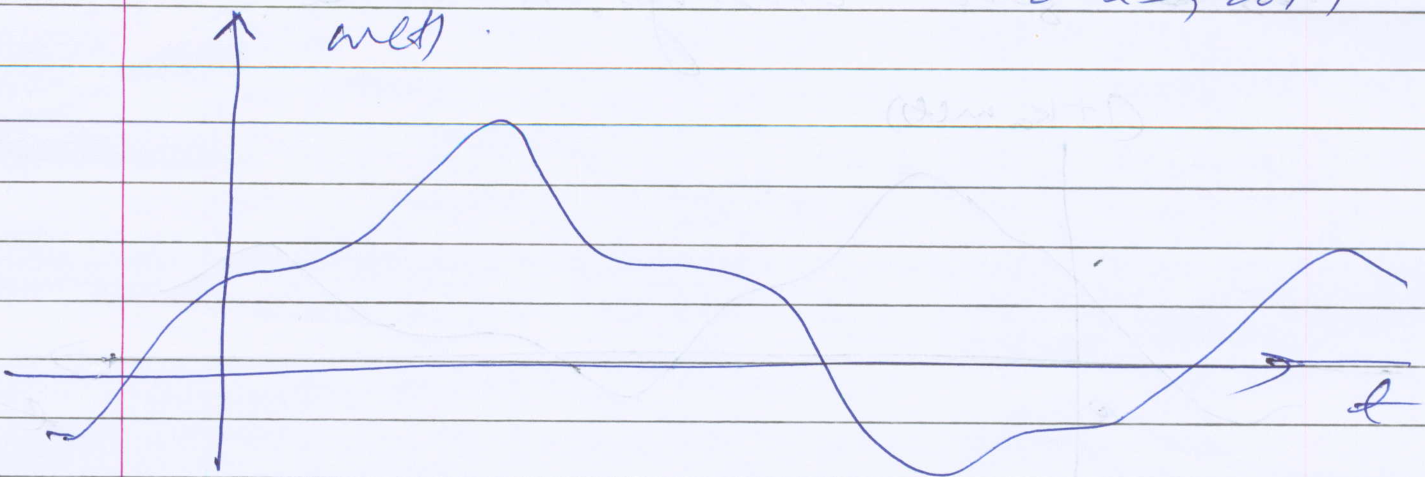
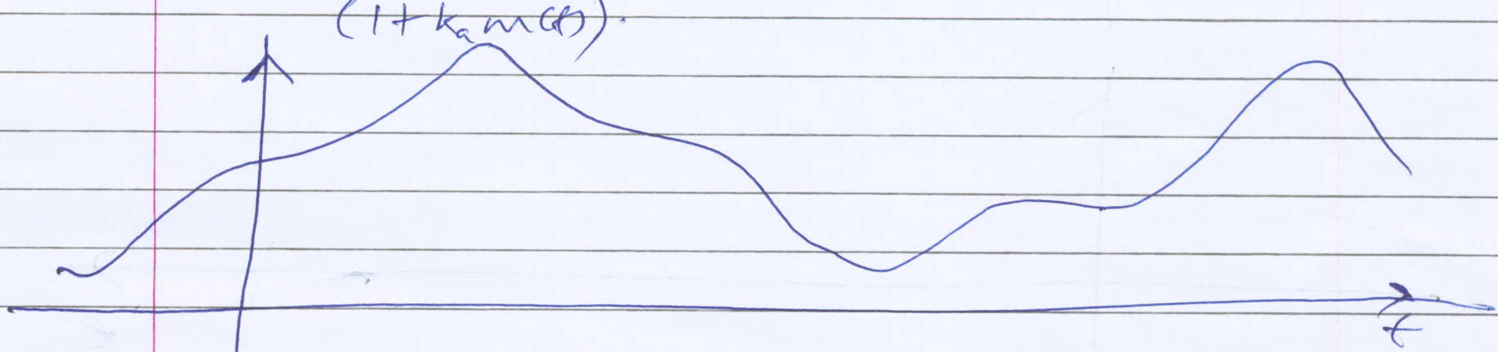
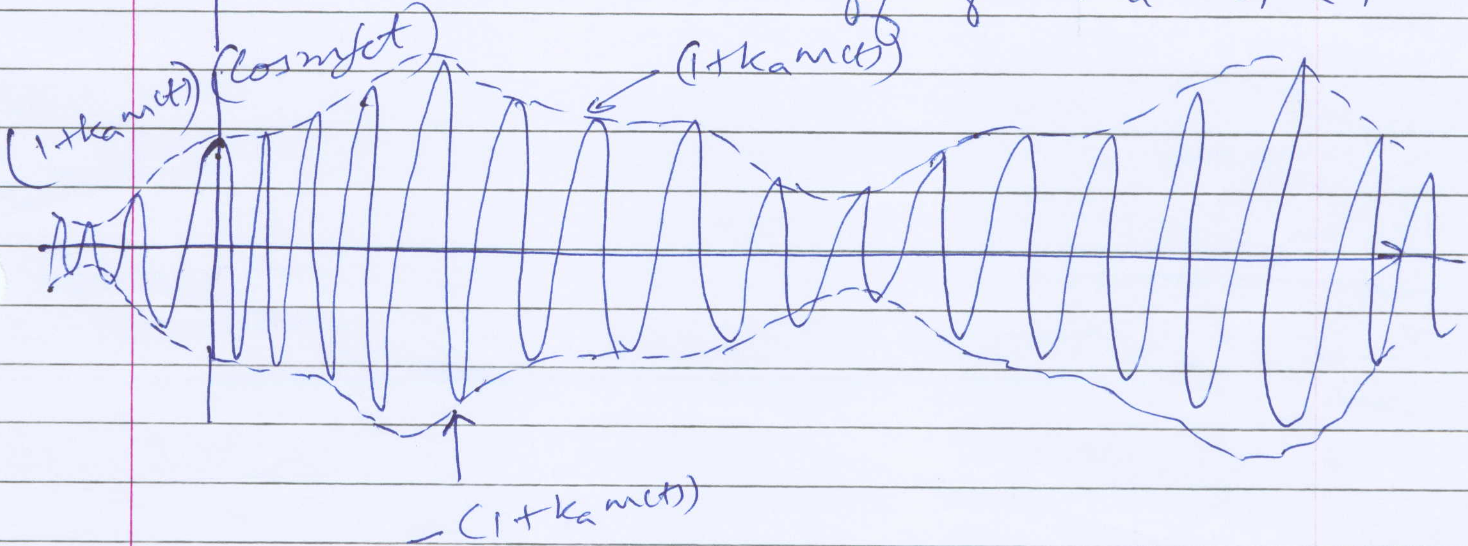
Envelope detector for AM signals. Lecture - 16

Feb 25, 2014



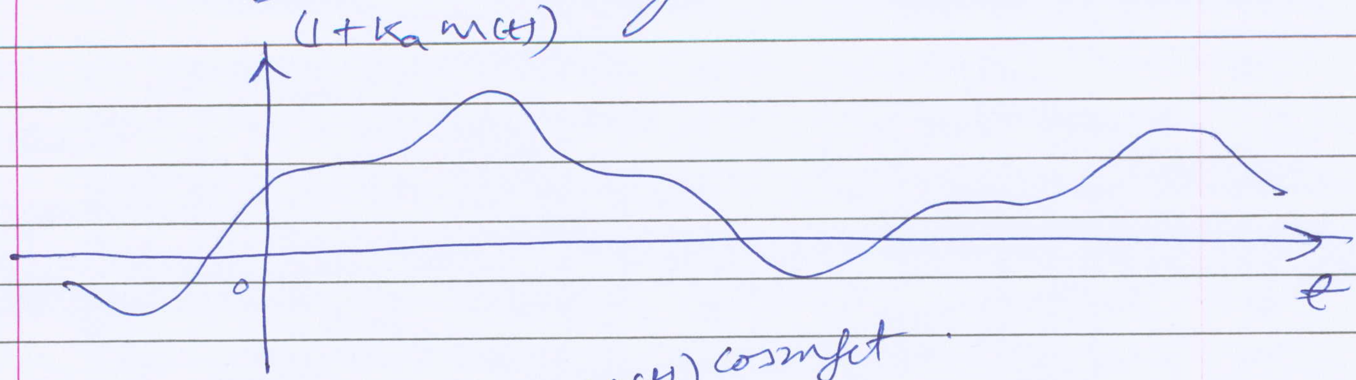


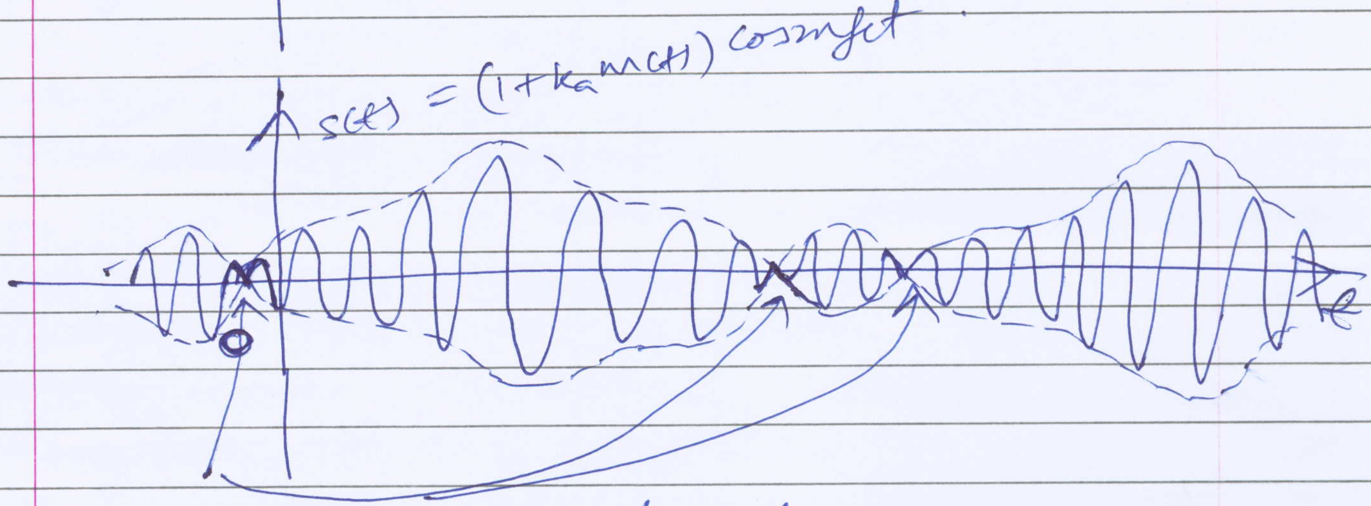
$1 + k_a m(t) > 0$ if $|k_a m(t)| < 1$



The envelope of $(1 + k_a m(t)) \cos 2\pi f_c t$ is the same as $m(t)$ if $f_c \gg W$ and $|k_a m(t)| \ll 1$.

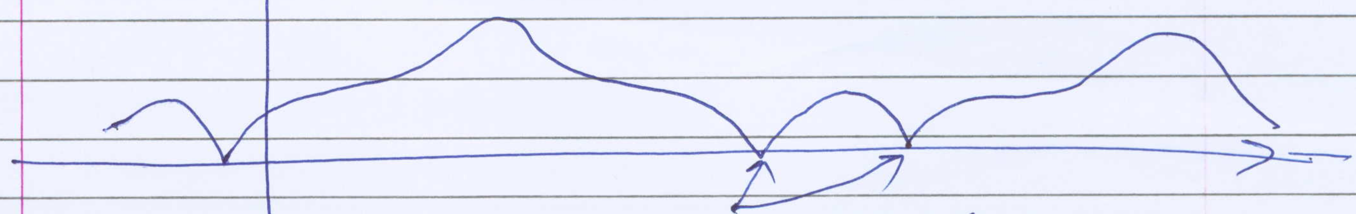
If $|k_a m(t)| < 1$, then $(1+k_a m(t))$ has zero crossings





phase reversals at zero crossings.

|envelope of $s(t)$| ~~[illegible]~~ $= |1+k_a m(t)|$.



reversal at zero crossings.

|envelope of $s(t)$| $= |1+k_a m(t)|$

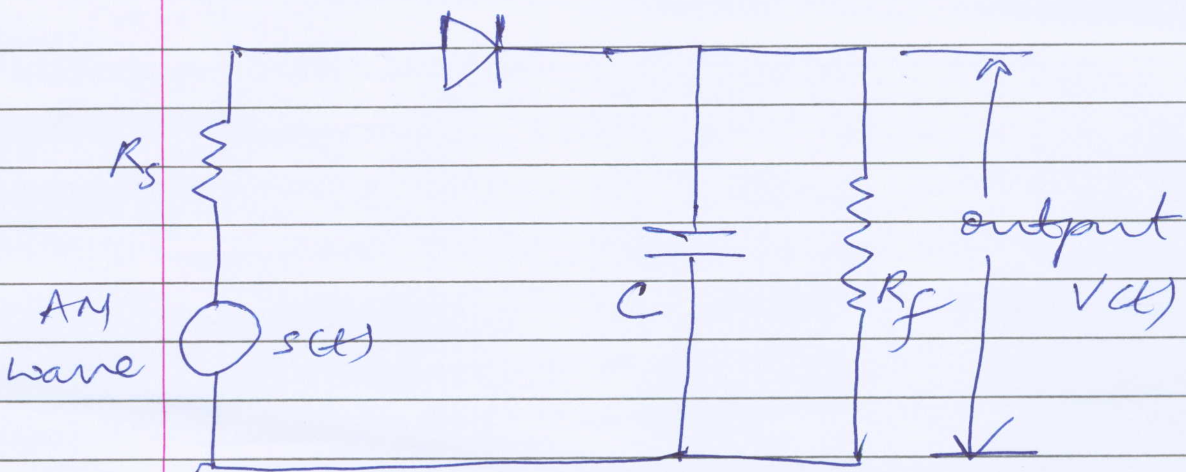
since
$$s(t) = \mathrm{Re}(\tilde{s}(t) e^{j2\pi f_c t})$$
$$= (1+k_a m(t)) \cos 2\pi f_c t$$
$$= \mathrm{Re}\{(1+k_a m(t)) e^{j2\pi f_c t}\}$$

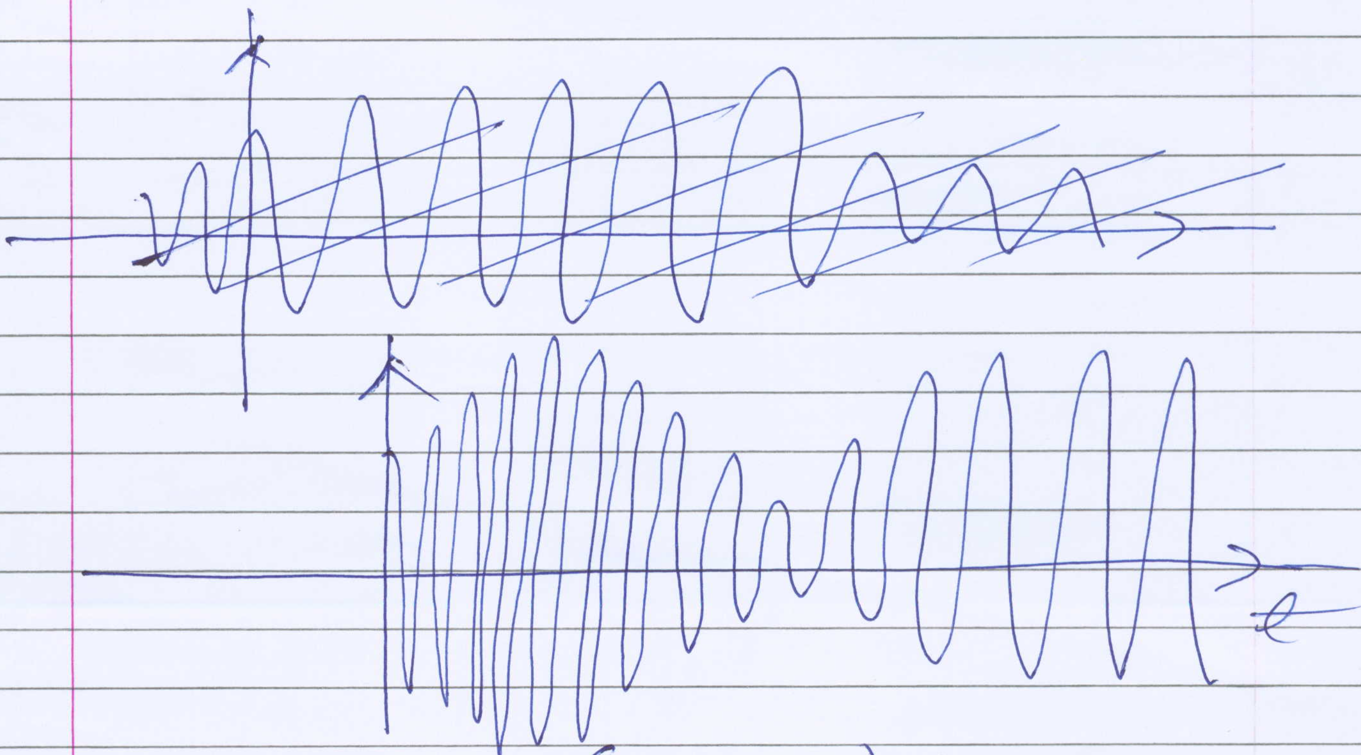
$\therefore$ $\tilde{s}(t) = (1+k_a m(t))$.

baseband envelope of $s(t)$

Similarly the absolute value of the envelope of $s(t)$ does not look like $(1+k_a m(t))$ ~~since~~ if $f_c < W$ (where we have assumed $m(t)$ to be band-limited to $[-W, W]$).

Envelope detector for detecting the envelope of $s(t)$.





$s(t) = (1+k_a m(t)) \cos 2\pi f_c t$.

In the positive part of the signal $s(t)$, the charging time constant of the capacitor is $\tau_{chg} = R_s C$.
For the output voltage $V(t)$ to follow the envelope the time constant should be less than the time period of the carrier i.e. $1/f_c$ so that the charging is fast.
~~In the negative~~
$$\therefore \quad \tau_{chg} = R_s C \ll 1/f_c$$
During the negative cycle the capacitor discharges, but if this discharging is fast the output voltage will simply track the carrier, and therefore $R_\ell C \gg 1/f_c$.
At the same time the discharging time constant cannot be very large compared to $1/W$ since otherwise the output will not change when the envelope is decreasing in magnitude. $\therefore \; R_\ell C \ll 1/W$.

So, for the envelope detector to work we must have

i) $|k_a m(t)| \ll 1$

ii) $R_s C \ll 1/f_c$

iii) $\frac{1}{f_c} \ll R_e C \ll 1/W$

Note that ~~ii) and~~ iii) implies that

$f_c \gg W$.

AM is simple to generate and detect. It is however wasteful of power and bandwidth.

Suppose $s(t) = (1 + k_a m(t)) \cos 2\pi f_c t$,

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

carrier power $= 1/2$

assuming $m(t)$ to be w.s.s. message power $= \frac{k_a^2}{2} E(m^2(t))$

since $|k_a m(t)| < 1$, $k_a m^2(t) \le 1$

$\therefore \frac{\text{message power}}{\text{carrier power}} = k_a^2 E(m^2(t)) \le 1$

So, $\frac{\text{total power}}{\text{message power}} = \frac{\text{message power} + \text{carrier power}}{\text{message power}} \geq 2$.

Therefore more than half of the total signal power is ~~utilized~~ used for transmission of the carrier signal.

The carrier signal was required to have a larger swing than the message signal ~~in order that the~~ so that the shape of the magnitude of the envelope of AM signal is the same as the message signal. This of course is required if we are restricted to the use of envelope detectors.

AM is wasteful of bandwidth.

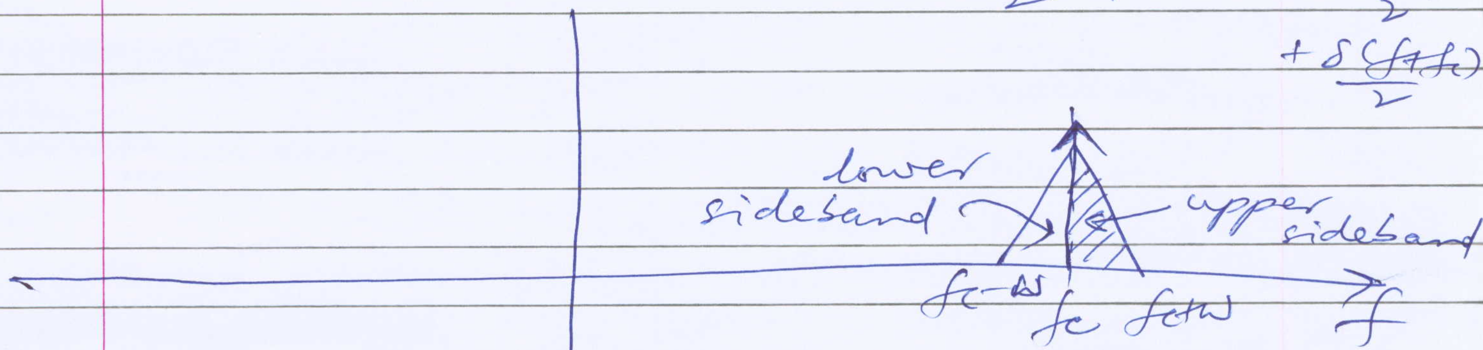
Since $m(t)$ is real valued

$M(f) = M^*(-f)$, and therefore

the positive frequency components of $m(t)$ contain the same information as the negative frequency components.

Due to this reason, after upconversion, $s(t) = (1+k_a m(t)) \cos 2\pi f_c t$.

$$S(f) = \frac{k_a M(f-f_c) + k_a M(f+f_c)}{2} + \frac{\delta(f-f_c)}{2} + \frac{\delta(f+f_c)}{2}$$



Since $M(f) = M^*(-f)$, the upper and lower sidebands of $S(f)$ contain the same information.

So, while the information in $m(t)$ is contained in a bandwidth of W Hz, the AM modulation discussed uses $2W$ Hz of bandwidth.

In the next class, we will therefore discuss two variants of the simple AM modulation

i) Double sideband – suppressed carrier (DSB-SC) where no carrier is transmitted (saves power wasting)

ii) Single sideband Modulation (SSB) where only one of the sidebands is transmitted. (saves bandwidth)