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Switching Modulator for AM signal generation.

Lecture - 15 (EEL-306)

Feb - 19, 2014

- We would like to communicate the message signal $m(t)$ which is usually a band-limited baseband signal (e.g. voice signals).

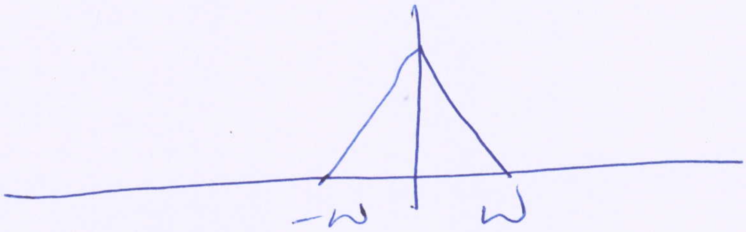
- Need for upconverting the signal to passband.
(e.g. in case of wireless channels, electromagnetic waves of lower frequency have a large wavelength which reduces the receive antenna gain of receive antennas whose dimension is only $1/100^{th}$ of the wavelength.
(The received power is proportional to the ratio of the area of the receiving antenna to ~~the~~ λ^2, where λ is the wavelength of the electromagnetic wave)

Since the performance at the receiver depends upon the signal to noise ratio. At ~~the~~ low frequencies the large wavelength of electromagnetic waves results in little received power at receivers whose area is much lesser than λ^2. The only possible way to communicate reliably is to then transmit ~~very~~ high power electromagnetic waves. Typical AM radio stations ~~transmit~~ radiate several 100 kW's of electromagnetic power.

- upconversion

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

$M(f)$.

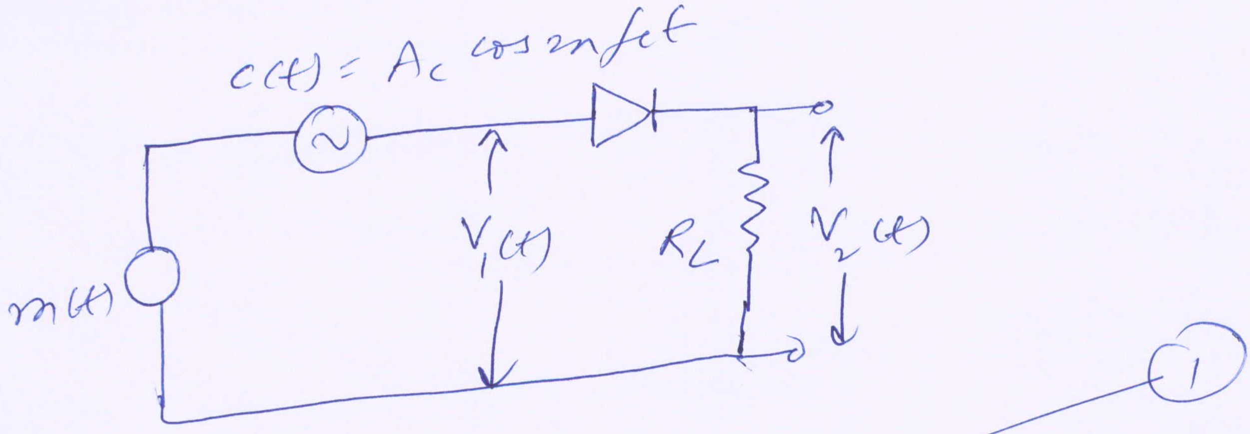


$$S(f) = \frac{M(f-f_c) + M(f+f_c)}{2}$$

s(t) is a band-limited passband signal, which makes it convenient for transmission.

- But how do we do this upconversion.

- We next discuss a simple electronic circuit which does this upconversion.



Assuming $|m(t)| \ll A_c$, the diode is forward biased when $c(t) > 0$ (assuming an ideal diode)

$$\therefore \quad V_2(t) \simeq \begin{cases} V_1(t), & \text{when } c(t) > 0 \\ 0, & \text{otherwise.} \end{cases} \quad \text{—— (2)}$$

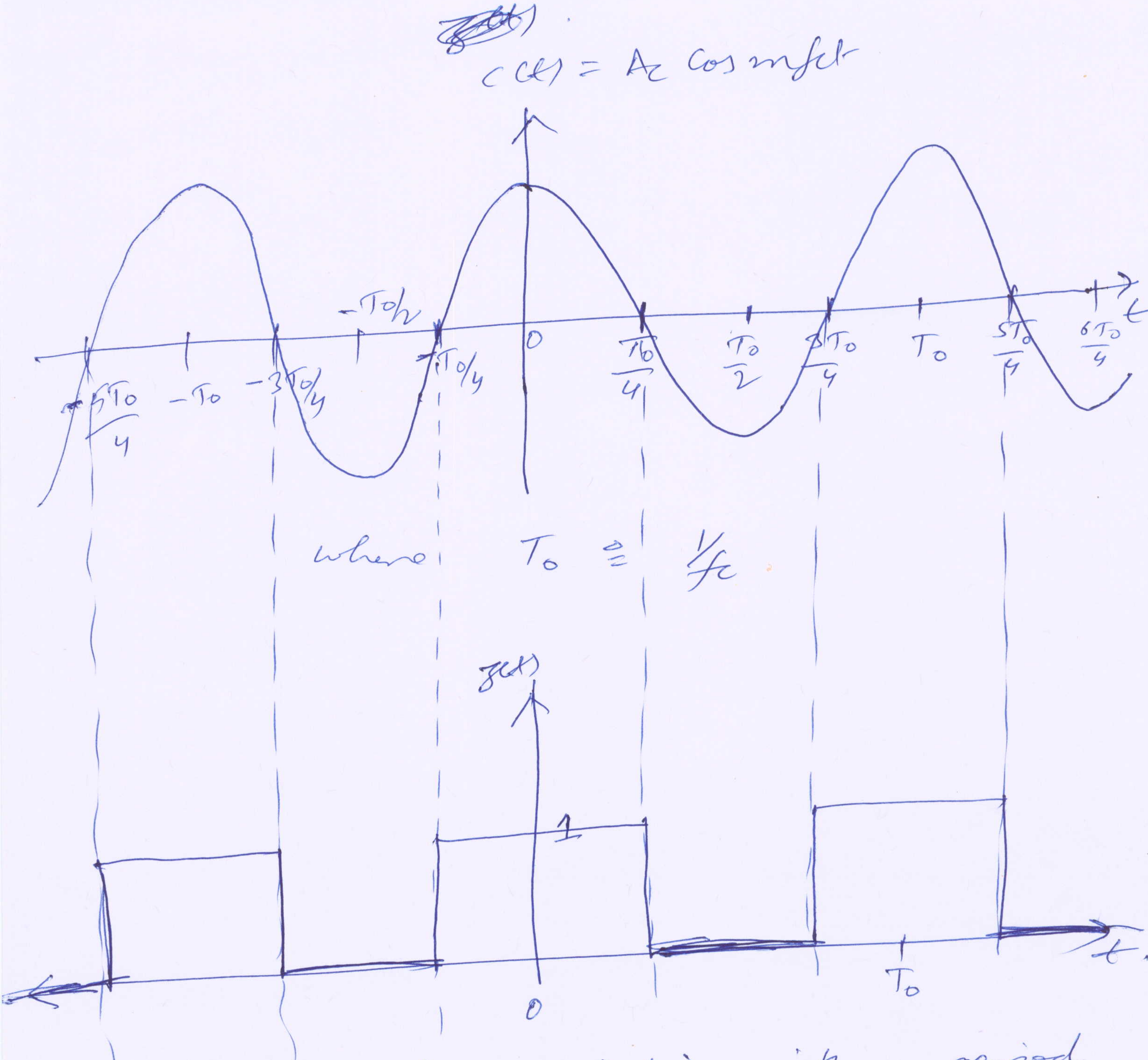
Let us define a signal

$$z(t) \triangleq \begin{cases} 1, & c(t) > 0 \\ 0, & \text{otherwise} \end{cases} \quad \text{—— (3)}$$

then from (2) it is clear that

$$V_2(t) = V_1(t)\, z(t)$$
$$= z(t)\,(m(t) + c(t)) \quad \text{—— (4)}$$

since $V_1(t) = m(t) + c(t)$.



where $T_0 \triangleq 1/f_c$

Note $z(t)$ is periodic with a period of $T_0 = 1/f_c$; i.e $z(t) = z(t+T_0)$. therefore have the Fourier series expansion for $z(t)$ given by

$$z(t) = \frac{1}{2} + \frac{2}{\pi} \sum_{n=1}^{\infty} \frac{(-1)^{n-1}}{2n-1} \cos[2\pi f_c t (2n-1)]$$

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We are now interested in finding the spectrum of $V_2(t)$ i.e., $V_2(f)$.

since $V_2(t) = z(t)\,(m(t) + c(t))$

$= z(t)\,m(t) + z(t)\,c(t)$

~~$V_2(f) = Z(f) \circledast M(f) + $~~

$$z(t)\,m(t) = \frac{m(t)}{2} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(2n-1)}\,m(t)\cos 2\pi f_c t(2n-1)$$

$$= \frac{m(t)}{2} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(2n-1)}\left[\frac{m(t)e^{j2\pi f_c t(2n-1)}}{2} + \frac{m(t)e^{-j2\pi f_c t(2n-1)}}{2}\right] \quad \text{--- (6)}$$

$\therefore$ ~~$\mathcal{F}(z(t))$~~

$\therefore \mathcal{F}(z(t)m(t))$

$$= \frac{M(f)}{2} + \frac{1}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(2n-1)}\,M(f - f_c(2n-1))$$

$$+ \frac{1}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\,M(f + f_c(2n-1))$$

similarly.

$$z(t)\,c(t) = \frac{A_c\cos 2\pi f_c t}{2} + \frac{A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\left\{2\cos 2\pi f_c t\,\cos 2\pi f_c t(2n-1)\right\}$$

$$= \frac{A_c\cos 2\pi f_c t}{2} + \frac{A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(2n-1)}\left\{\cos(2\pi f_c t\cdot 2n) + \cos 2\pi f_c t\,(2n-2)\right\}$$

$z(t)\,c(t)$

$$= \frac{A_c}{2}\cos 2\pi f_c t + \frac{A_c}{\pi} + \frac{A_c}{\pi}\sum_{n=1}^{\infty}\left\{\frac{(-1)^{n-1}\cos(2\pi f_c t\cdot 2n)}{(2n-1)} + \frac{(-1)^{n}\cos(2\pi f_c t\cdot 2n)}{(2n+1)}\right\}$$

$$= \frac{A_c}{\pi} + \frac{A_c}{2}\cos 2\pi f_c t + \frac{2A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(4n^2-1)}\cos(2\pi f_c t\cdot 2n) \quad \text{———} (7)$$

$\therefore (z(t)\,c(t))$

$$= \frac{A_c}{4}\left(e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right) + \frac{A_c}{\pi} + \frac{2A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(4n^2-1)}\left\{e^{j2\pi f_c t\cdot 2n} - e^{-j2\pi f_c t\cdot 2n}\right\}$$

$\therefore F(z(t)\,c(t))$

$$= \frac{A_c}{4}\left(\delta(f-f_c) + \delta(f+f_c)\right) + \frac{A_c}{\pi}\delta(f) + \frac{2A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{4n^2-1}\left\{\delta(f-2nf_c) + \delta(f+2nf_c)\right\}$$

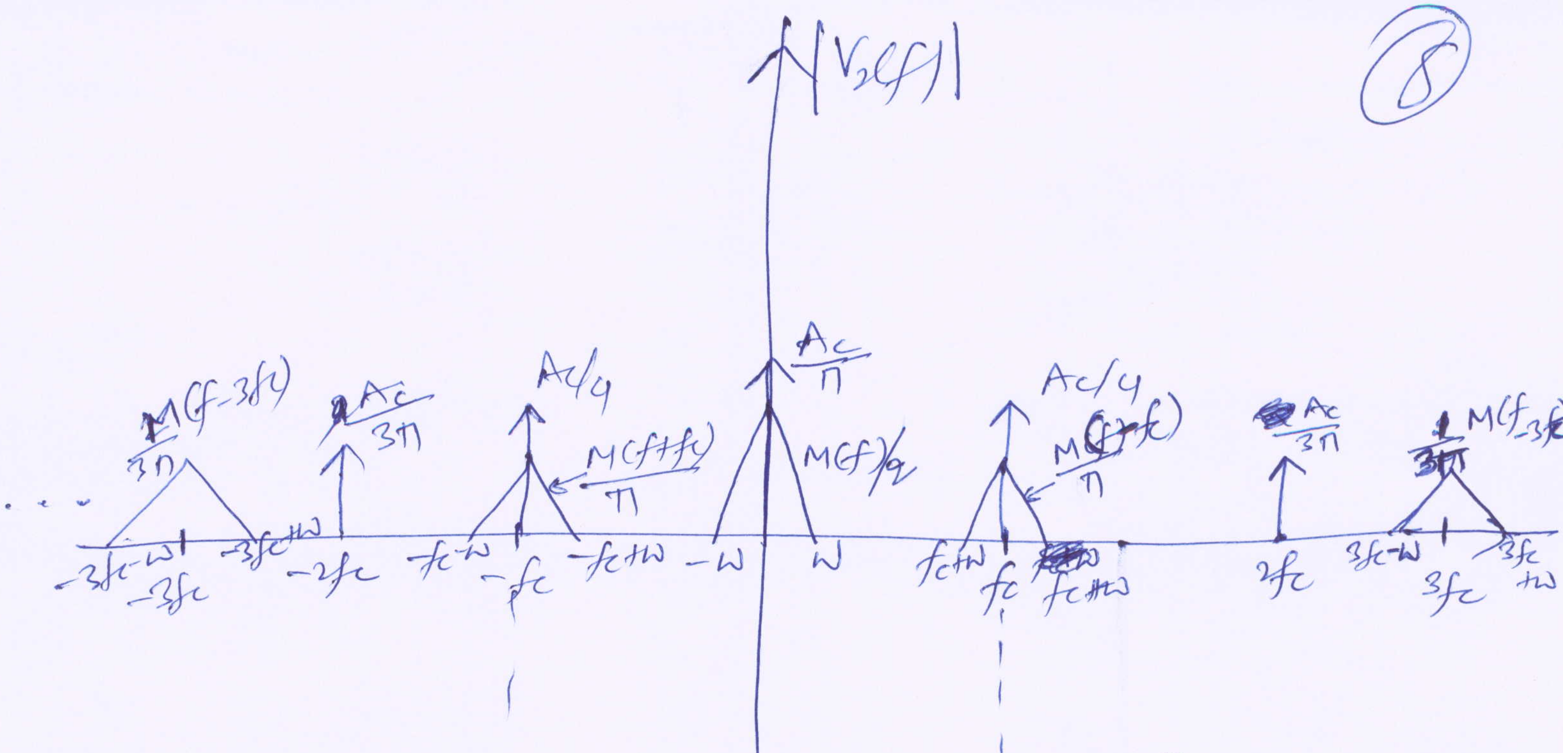
Combining (6) and (7) we get

$\therefore V_2(t) = z(t)m(t) + z(t)c(t)$

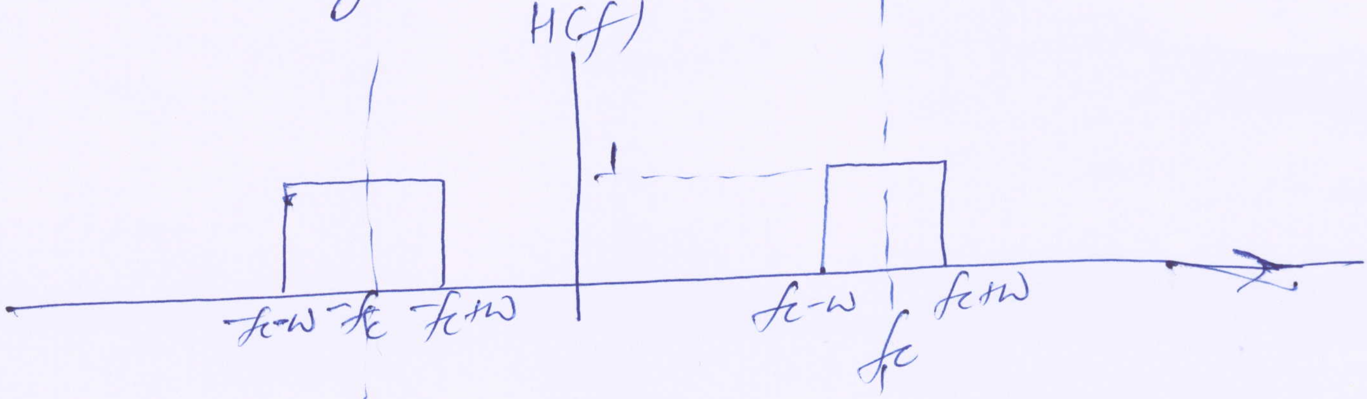
$$= \left(\frac{m(t)}{2} + \frac{A_c}{\pi}\right) + \frac{2}{\pi}m(t)\cos 2\pi f_c t + \frac{A_c}{2}\cos 2\pi f_c t + V_3(t),$$

where $V_3(t) = \frac{2A_c}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(4n^2-1)}\cos(2\pi f_c t\cdot 2n)$

$$+ \frac{2}{\pi}\sum_{n\geq 2}^{\infty}\frac{(-1)^{n-1}}{(2n-1)}m(t)\cos(2\pi f_c\cdot t(2n-1))$$

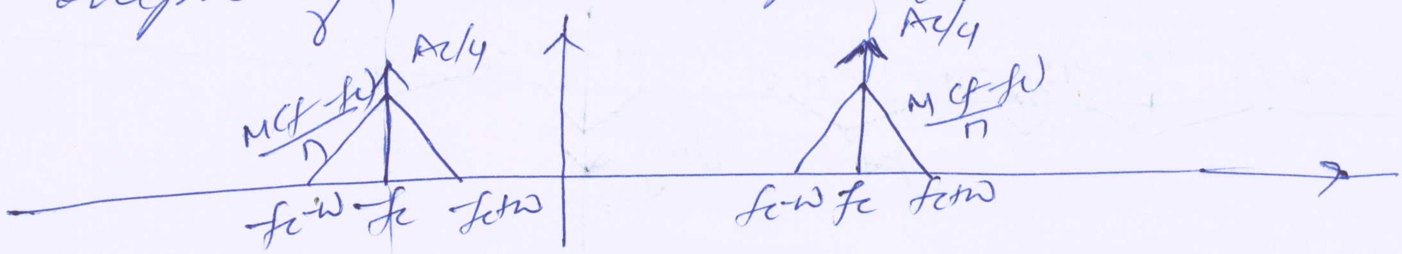


We now pass $v_2(t)$ through the following band pass filter



If $2f_c > f_c + W$ and $3f_c - W > f_c + W$

i.e., if $f_c > W$, then the output of the band pass filter is



In time domain, the output of the band pass filter is $s(t) = \frac{A_c}{2}\left(1 + \frac{4m(t)}{\pi A_c}\right)\cos 2\pi f_c t$

subject to the conditions

i) $|m(t)| \ll A_c$, and

ii) $f_c > W$.