

ECS332 2018/1

Part II.3

Dr.Prapun

#### 4.4 Classical DSB-SC Modulators

To produce the modulated signal  $A_c \cos(2\pi f_c t) m(t)$ , we may use the following methods which generate the modulated signal along with other signals which can be eliminated by a bandpass filter restricting frequency contents to around  $f_c$ .

**4.54. Multiplier Modulators** [6, p 184] or **Product Modulator** [3, p 180]: Here modulation is achieved directly by multiplying  $m(t)$  by  $\cos(2\pi f_c t)$  using an analog multiplier whose output is proportional to the product of two input signals.

- Such a multiplier may be obtained from
  - (a) a **variable-gain amplifier** in which the gain parameter (such as the  $\beta$  of a transistor) is controlled by one of the signals, say,  $m(t)$ . When the signal  $\cos(2\pi f_c t)$  is applied at the input of this amplifier, the output is then proportional to  $m(t) \cos(2\pi f_c t)$ .
  - (b) two logarithmic and an antilogarithmic amplifiers with outputs proportional to the log and antilog of their inputs, respectively.
    - Key equation:

$$A \times B = e^{(\ln A + \ln B)}.$$

**4.55.** When it is easier to build a squarer than a multiplier, we may use a **square modulator** shown in Figure 24.

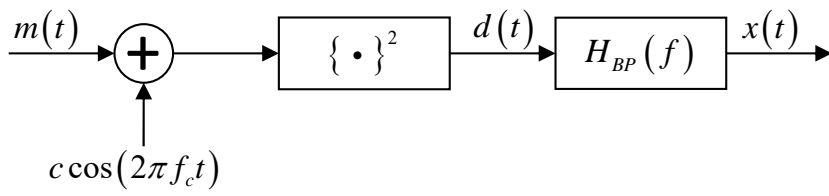
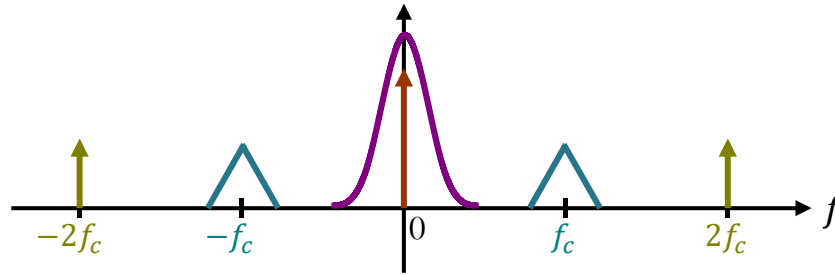


Figure 24: Block diagram of a square modulator

Note that

$$\begin{aligned}
 d(t) &= (m(t) + c \cos(2\pi f_c t))^2 \\
 &= m^2(t) + 2cm(t) \cos(2\pi f_c t) + c^2 \cos^2(2\pi f_c t) \\
 &= m^2(t) + 2cm(t) \cos(2\pi f_c t) + \frac{c^2}{2} + \frac{c^2}{2} \cos(2\pi(2f_c)t)
 \end{aligned}$$



Using a band-pass filter (BPF) whose frequency response is

$$H_{BP}(f) = \begin{cases} g, & |f - f_c| \leq B, \\ g, & |f - (-f_c)| \leq B, \\ 0, & \text{otherwise,} \end{cases} \quad (52)$$

we can produce  $2cgm(t) \cos(2\pi f_c t)$  at the output of the BPF. In particular, choosing the gain  $g$  to be  $(c\sqrt{2})^{-1}$ , we get  $m(t) \times \sqrt{2} \cos(2\pi f_c t)$ .

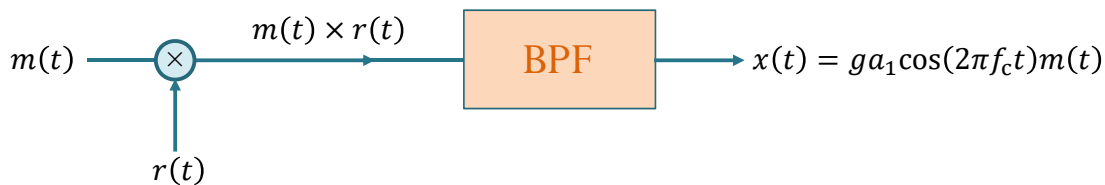
- Alternative, can use  $(m(t) + c \cos(\frac{\omega_c t}{2}))^3$ .

**4.56.** Another conceptually nice way to produce a signal of the form  $A_c m(t) \cos(2\pi f_c t)$  is to

(1) multiply  $m(t)$  by “any” **periodic and even** signal  $r(t)$  whose period is  $T_c = \frac{1}{f_c}$

and then

(2) pass the result through a BPF used in (52).

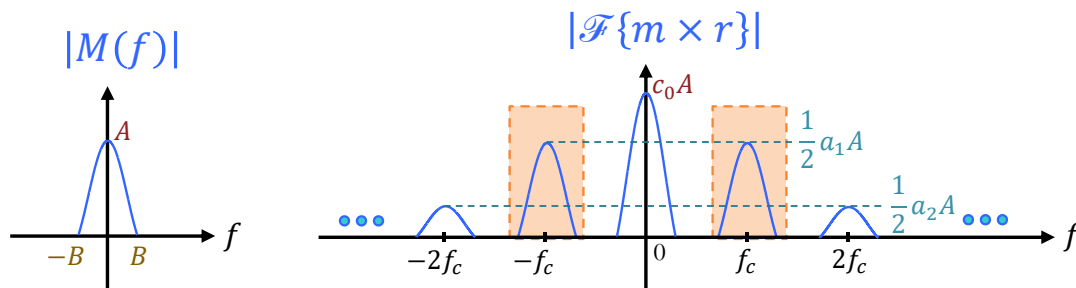


To see how this works, recall that because  $r(t)$  is an even function, we know that

$$r(t) = c_0 + \sum_{k=1}^{\infty} a_k \cos(2\pi(kf_c)t) \text{ for some } c_0, a_1, a_2, \dots$$

Therefore,

$$m(t)r(t) = c_0 m(t) + \sum_{k=1}^{\infty} a_k m(t) \cos(2\pi(kf_c)t).$$

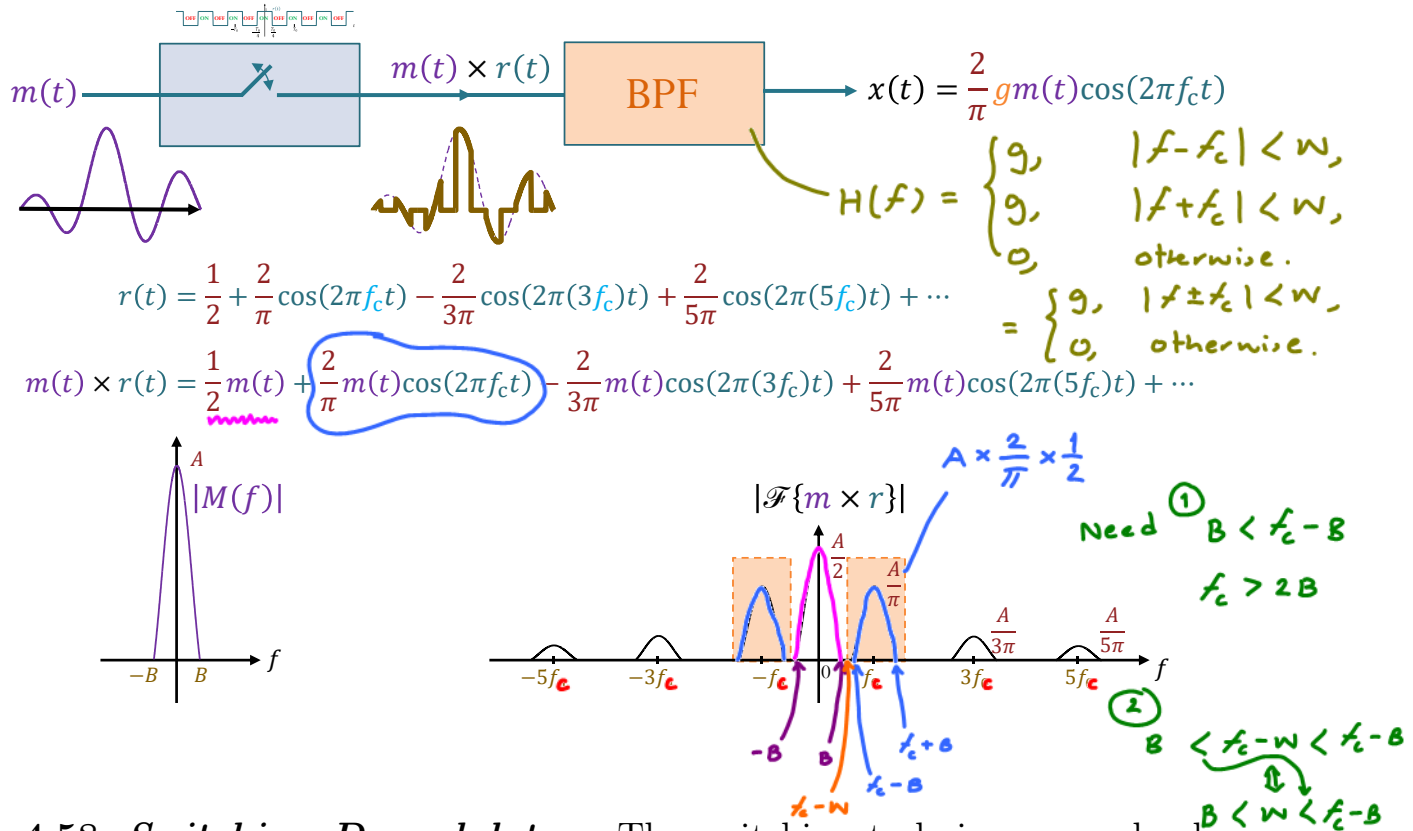


See also [5, p 157]. In general, for this scheme to work, we need

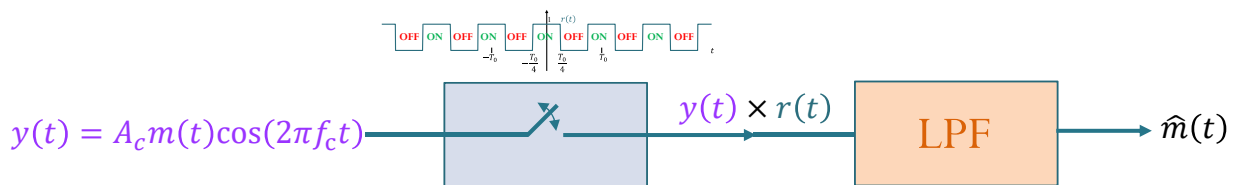
- $a_1 \neq 0$  period of  $r$ ;
- $f_c > 2B$  (to prevent overlapping).

Note that if  $r(t)$  is not even, then by (43c), the resulting modulated signal will have the form  $x(t) = a_1 m(t) \cos(2\pi f_c t + \phi_1)$ .

**4.57. Switching modulator:** An important example of a periodic and even function  $r(t)$  is the square pulse train considered in Example 4.47. Recall that multiplying this  $r(t)$  to a signal  $m(t)$  is equivalent to switching  $m(t)$  on and off periodically.



**4.58. Switching Demodulator:** The switching technique can also be used at the demodulator as well.



We have seen that, for DSB-SC modem, the key equation is given by (34). When switching demodulator is used, the key equation is

$$\text{LPF} \left\{ \frac{A_c}{\pi} m(t) \cos(2\pi f_c t) \times 1[\cos(2\pi f_c t) \geq 0] \right\} = \frac{A_c}{\pi} m(t) \quad (53)$$

$$H(f) = \begin{cases} 1, & |f| < B, \\ 0, & \text{otherwise.} \end{cases} \quad 68$$

[5, p 162].

$$\begin{aligned}
 r(t) &= \frac{1}{2} + \frac{2}{\pi} \cos(2\pi f_c t) - \frac{2}{3\pi} \cos(2\pi(3f_c)t) + \frac{2}{5\pi} \cos(2\pi(5f_c)t) + \dots \\
 y(t)r(t) &= \frac{1}{2} y(t) + \frac{2}{\pi} y(t) \cos(2\pi f_c t) - \frac{2}{3\pi} y(t) \cos(2\pi(3f_c)t) + \frac{2}{5\pi} y(t) \cos(2\pi(5f_c)t) + \dots \\
 &= \frac{1}{2} A_c m(t) \cos(2\pi f_c t) + \frac{2}{\pi} A_c m(t) \cos(2\pi f_c t) \cos(2\pi f_c t) - \frac{2}{3\pi} A_c m(t) \cos(2\pi f_c t) \cos(2\pi(3f_c)t) + \frac{2}{5\pi} A_c m(t) \cos(2\pi f_c t) \cos(2\pi(5f_c)t) + \dots \\
 &= \frac{1}{2} A_c m(t) \cos(2\pi f_c t) + \frac{1}{\pi} A_c m(t) (1 + \cos(2\pi(2f_c)t)) - \frac{1}{3\pi} A_c m(t) (\cos(2\pi(2f_c)t) + \cos(2\pi(4f_c)t)) + \frac{1}{5\pi} A_c m(t) (\cos(2\pi(4f_c)t) + \cos(2\pi(6f_c)t)) + \dots \\
 &\quad \xrightarrow{\cos(A)\cos(B) = \frac{1}{2} \cos(A+B) + \frac{1}{2} \cos(A-B)} \\
 &= \frac{1}{2} A_c m(t) \cos(2\pi f_c t) + \frac{1}{\pi} A_c m(t) + \frac{1}{\pi} A_c m(t) \cos(2\pi(2f_c)t) - \frac{1}{3\pi} A_c m(t) \cos(2\pi(2f_c)t) - \frac{1}{3\pi} A_c m(t) \cos(2\pi(4f_c)t) + \frac{1}{5\pi} A_c m(t) \cos(2\pi(4f_c)t) + \frac{1}{5\pi} A_c m(t) \cos(2\pi(6f_c)t) + \dots
 \end{aligned}$$

Note that this technique still requires the switching to be in sync with the incoming cosine as in the basic DSB-SC.