Principles of Communications

ECS 332

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4.4 Switching MODEM

Office Hours:

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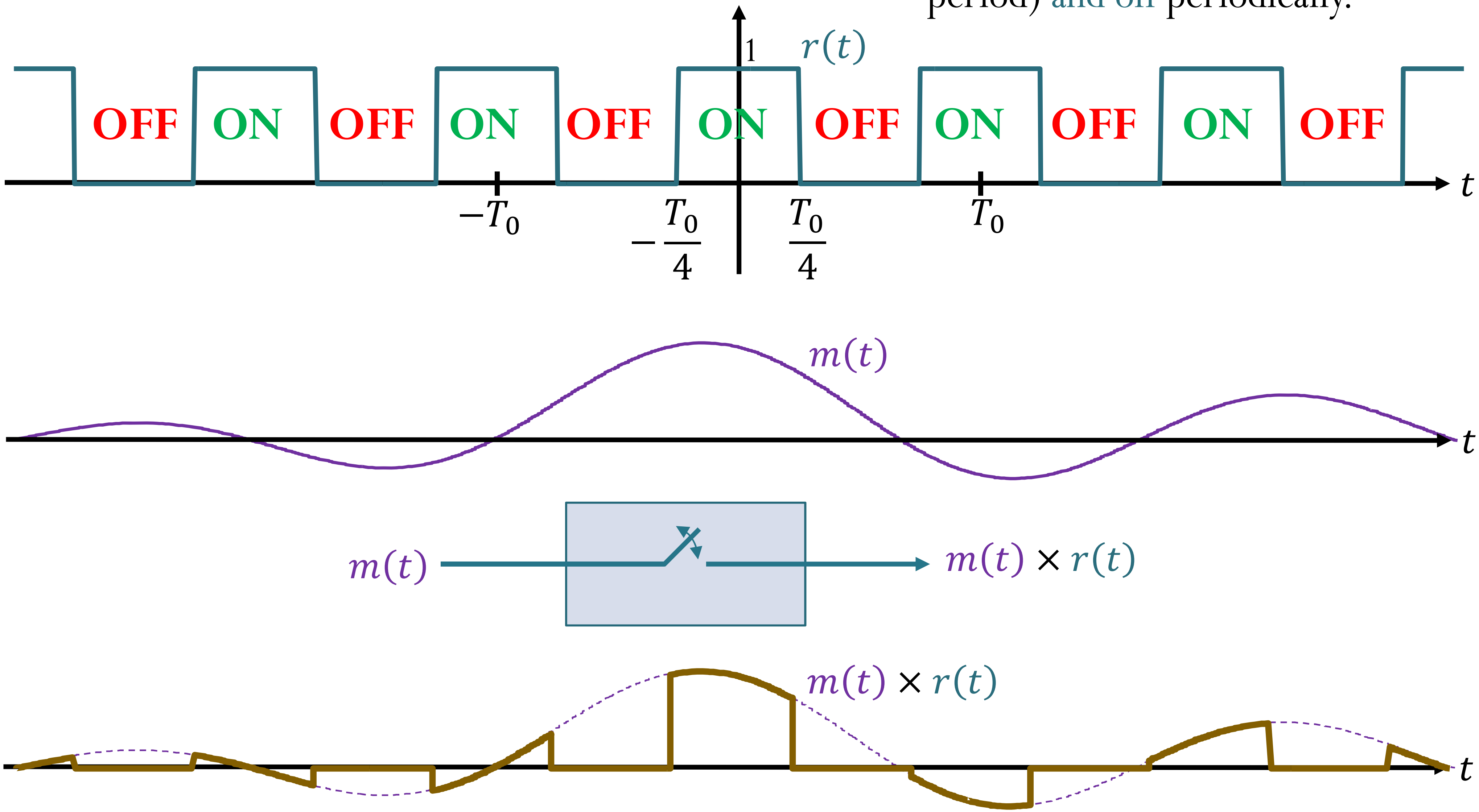
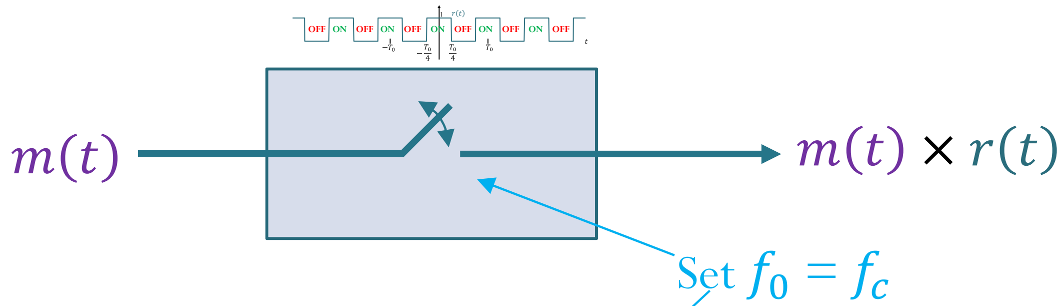
Wednesday	14:30-15:30
Friday	14:30-15:30

Switching Operation

Multiplying a signal $m(t)$ by the square-wave $r(t)$ is equivalent to switching $m(t)$ on (for half a period) and off periodically.

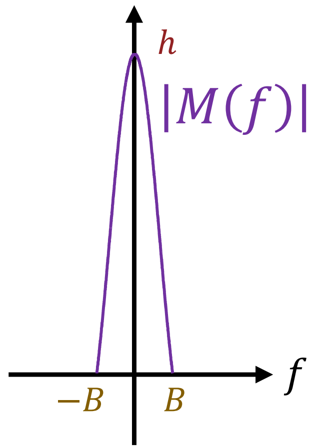


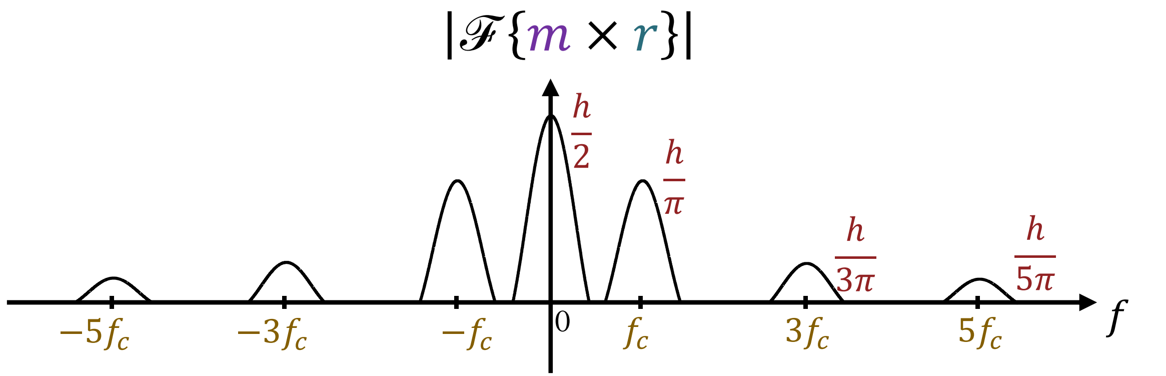
Switching Modulator



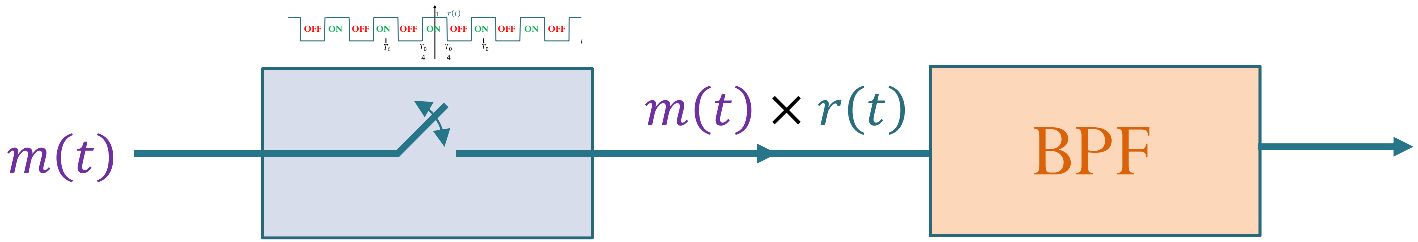
$$r(t) = \frac{1}{2} + \frac{2}{\pi}\cos(2\pi f_c t) - \frac{2}{3\pi}\cos(2\pi(3f_c)t) + \frac{2}{5\pi}\cos(2\pi(5f_c)t) + \cdots$$

$$m(t) \times r(t) = \frac{1}{2}m(t) + \frac{2}{\pi}m(t)\cos(2\pi f_c t) - \frac{2}{3\pi}m(t)\cos(2\pi(3f_c)t) + \frac{2}{5\pi}m(t)\cos(2\pi(5f_c)t) + \cdots$$





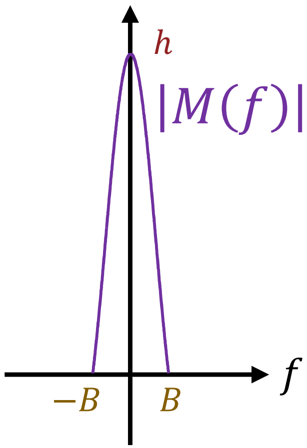
Switching Modulator

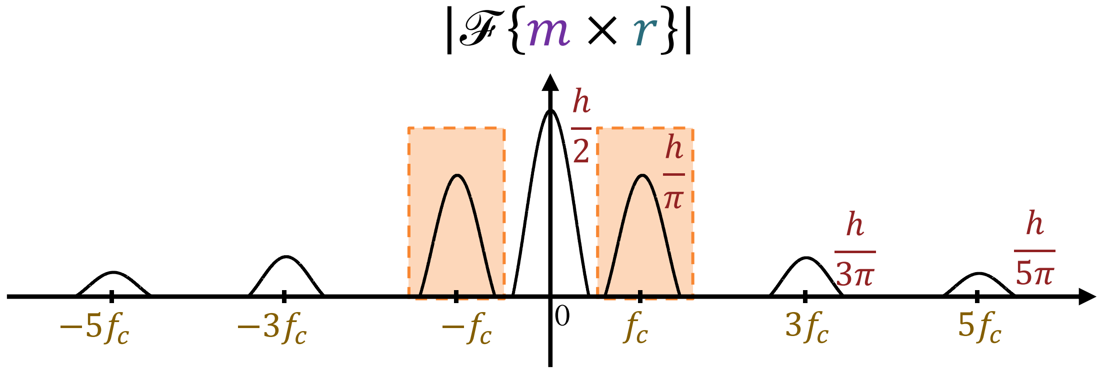


$$x(t) = \frac{2}{\pi} m(t)\cos(2\pi f_c t)$$

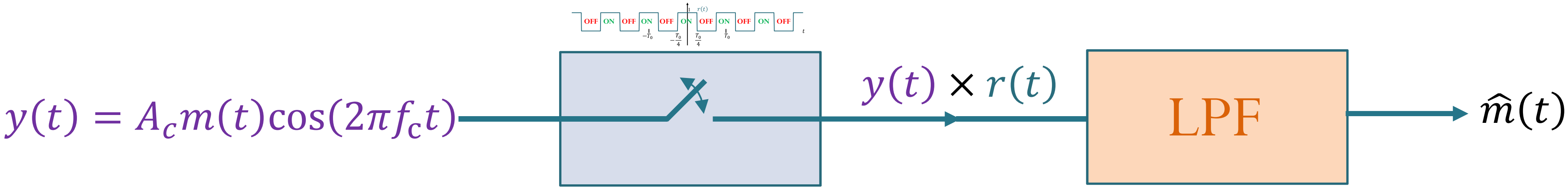
$$r(t) = \frac{1}{2} + \frac{2}{\pi}\cos(2\pi f_c t) - \frac{2}{3\pi}\cos(2\pi(3f_c)t) + \frac{2}{5\pi}\cos(2\pi(5f_c)t) + \cdots$$

$$m(t) \times r(t) = \frac{1}{2}m(t) + \frac{2}{\pi}m(t)\cos(2\pi f_c t) - \frac{2}{3\pi}m(t)\cos(2\pi(3f_c)t) + \frac{2}{5\pi}m(t)\cos(2\pi(5f_c)t) + \cdots$$





Switching Demodulator

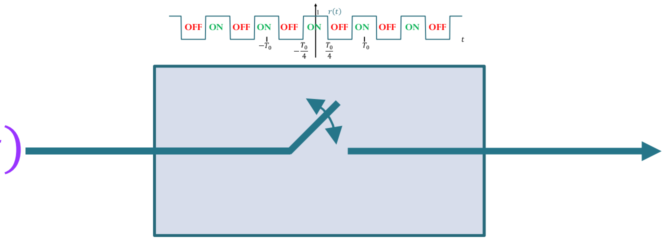


$$r(t) = \frac{1}{2} + \frac{2}{\pi}\cos(2\pi f_c t) - \frac{2}{3\pi}\cos(2\pi(3f_c)t) + \frac{2}{5\pi}\cos(2\pi(5f_c)t) + \cdots$$

$$y(t) \times r(t) = \frac{1}{2}y(t) + \frac{2}{\pi}y(t)\cos(2\pi f_c t) - \frac{2}{3\pi}y(t)\cos(2\pi(3f_c)t) + \frac{2}{5\pi}y(t)\cos(2\pi(5f_c)t) + \cdots$$

Switching Demodulator

$y(t) = A_c m(t)\cos(2\pi f_c t)$



$y(t) \times r(t)$

$$y(t)r(t) = \frac{1}{2}y(t) + \frac{2}{\pi}y(t)\cos(2\pi f_c t) - \frac{2}{3\pi}y(t)\cos\left(2\pi(3f_c)t\right) + \frac{2}{5\pi}y(t)\cos\left(2\pi(5f_c)t\right) + \cdots$$

$$= \frac{1}{2}A_c m(t)\cos(2\pi f_c t)$$

$$+ \frac{2}{\pi}A_c m(t)\cos(2\pi f_c t)\cos(2\pi f_c t)$$

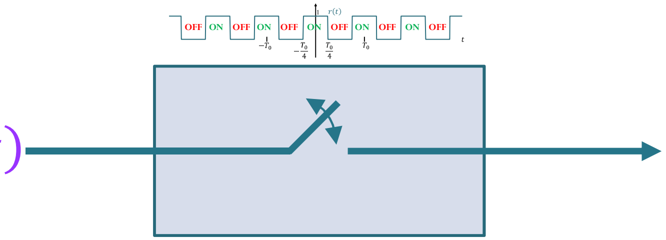
$$- \frac{2}{3\pi}A_c m(t)\cos(2\pi f_c t)\cos\left(2\pi(3f_c)t\right)$$

$$+ \frac{2}{5\pi}A_c m(t)\cos(2\pi f_c t)\cos\left(2\pi(5f_c)t\right) + \cdots$$

Now, recall that $\cos(A)\cos(B) = \frac{1}{2}\cos(A+B) + \frac{1}{2}\cos(A-B)$

Switching Demodulator

$y(t) = A_c m(t) \cos(2\pi f_c t)$

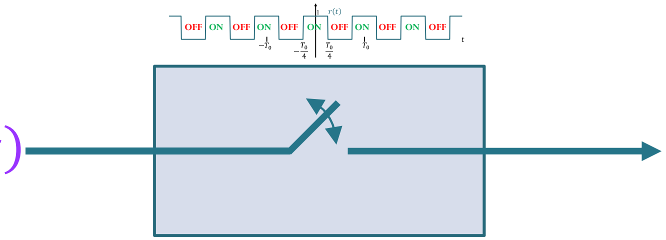


$y(t) \times r(t)$

$$y(t)r(t) = \frac{1}{2} A_c m(t) \cos(2\pi f_c t)$$
$$+ \frac{1}{\pi} A_c m(t)\left(1 + \cos\left(2\pi(2f_c)t\right)\right)$$
$$- \frac{1}{3\pi} A_c m(t)\left(\cos\left(2\pi(f_c)t\right) + \cos\left(2\pi(5f_c)t\right)\right)$$
$$+ \frac{1}{5\pi} A_c m(t)\left(\cos\left(2\pi(3f_c)t\right) + \cos\left(2\pi(7f_c)t\right)\right) + \cdots$$

Switching Demodulator

$y(t) = A_c m(t)\cos(2\pi f_c t)$

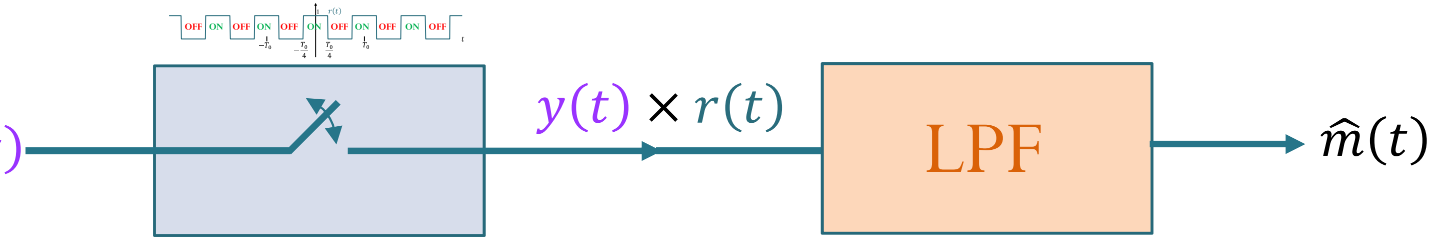


$y(t) \times r(t)$

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

Switching Demodulator

$y(t) = A_c m(t)\cos(2\pi f_c t)$



$$H_{\text{LPF}}(f) = \begin{cases} g, & |f| < B, \\ 0, & \text{otherwise.} \end{cases}$$

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

$$\hat{m}(t) = \frac{A_c g}{\pi} m(t)$$

$f_c > 2B$