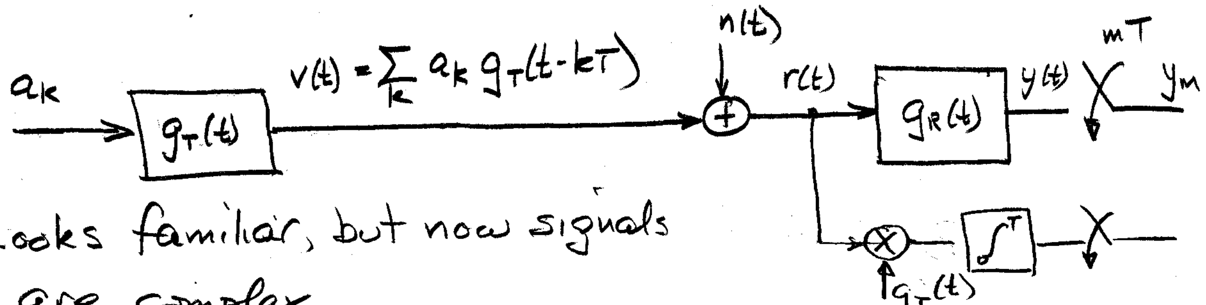
7.2 Digital Bandpass Signal Formats

- The signaling formats have not changed in principle from those in Section 5. However, the description has, along with the practical implications of cos & sin as dimensions.

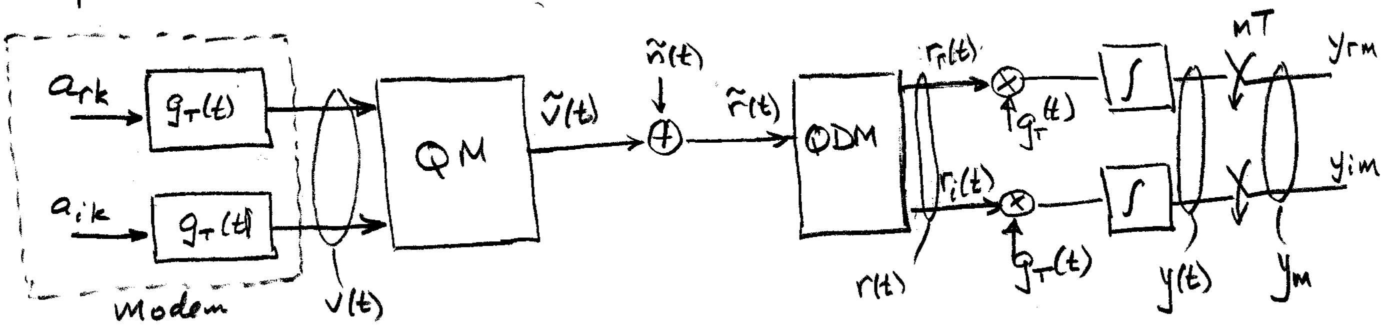
  We'll look at linear modulation and FSK.

- Linear modulation includes PAM, QAM, PSK etc



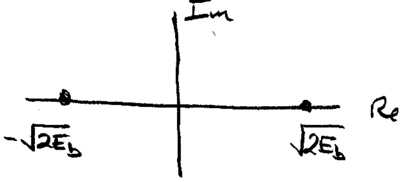
Looks familiar, but now signals are complex.

Expanded view

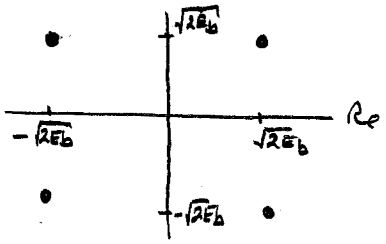


- Typical linear constellations

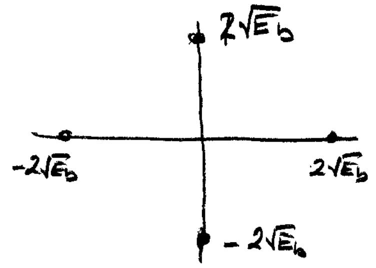
BPSK



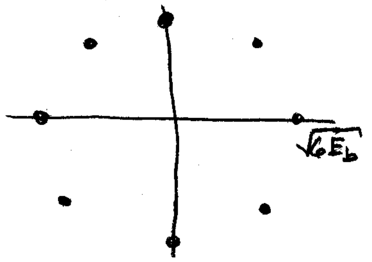
QAM



QPSK



8PSK



The scaling assumes that

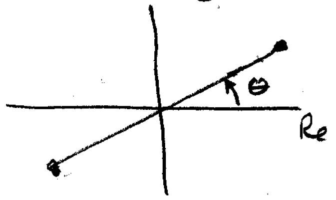
$$\int_{-\infty}^{\infty} g_T^2(t)\,dt = 1$$

The energy in one pulse of $\tilde{v}(t)$ is

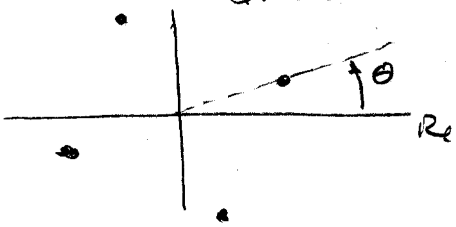
$$E_p = \frac{1}{2} E\left[\int_{-\infty}^{\infty} |a\, g_T(t)|^2 dt\right] = \frac{1}{2} E\left[|a|^2\right] \int_{-\infty}^{\infty} g_T^2(t)\,dt = E_b \log_2 M$$

when rotated by phase shift θ:

BPSK



QPSK

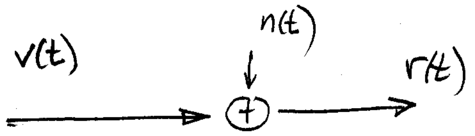


$|\theta| < \frac{\pi}{2}$ or errors even w/o noise

$|\theta| < \frac{\pi}{4}$ or errors w/o noise

Looks as though we should multiply by $e^{-j\theta}$

- 2FSK



$$v(t) = \begin{cases} e^{j2\pi \frac{\Delta f}{2} t} \\ e^{-j2\pi \frac{\Delta f}{2} t} \end{cases} \quad \text{in } 0 \le t \le T$$

or $v(t) = \exp\left(j\, 2\pi a_k \frac{\Delta f}{2} (t - kT)\right) e^{j\varphi_k}, \quad kT \le t < (k+1)T$

± 1

Δf is tone spacing

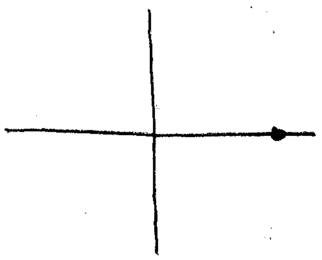
starts at $t = kT$

starting phase for sym k,

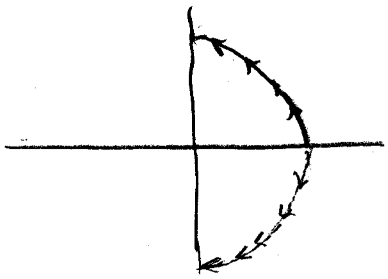
$$\varphi_k = 2\pi \Delta f T \sum_{i=0}^{k-1} a_i$$

$\Delta f T = h$

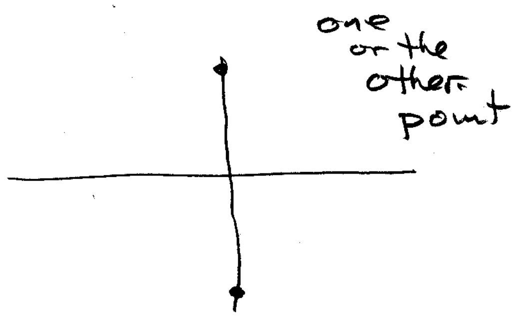
For MSK $(h = \frac{1}{2})$



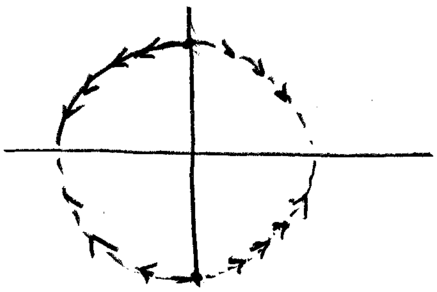
$t = 0$



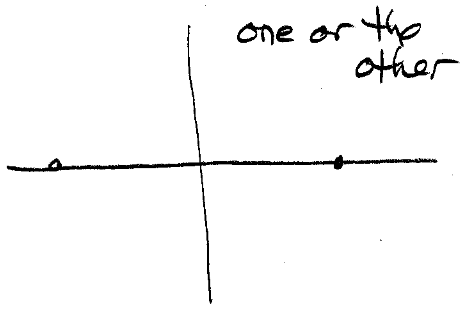
$0 \le t < T$



$t = T$

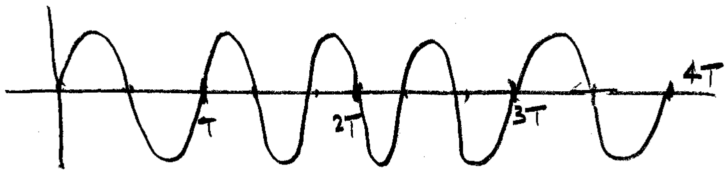


$T \le t < 2T$

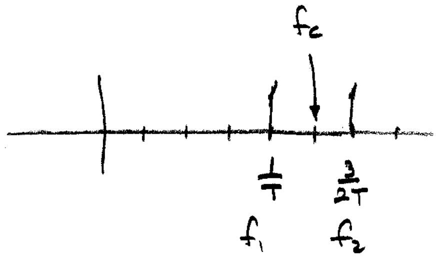


$t = 2T$

Relate it to



$f_1 = \frac{1}{T}$ $f_2 = \frac{3}{2T}$



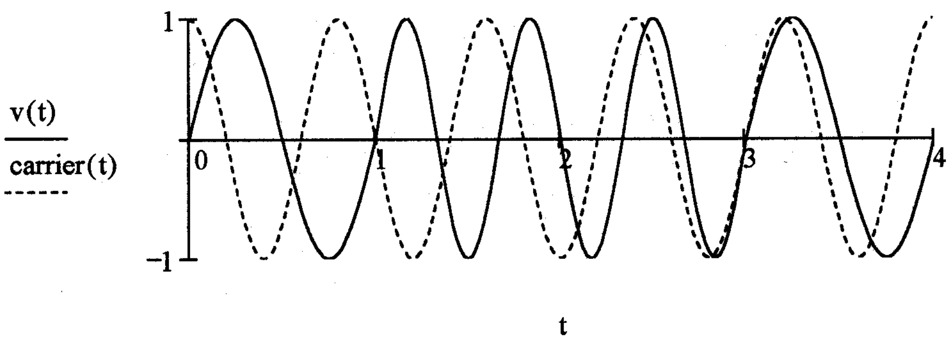
nominal $f_c = \frac{f_1+f_2}{2} = \frac{5}{4T}$ $\Delta f = \frac{3}{2T}$

$T := 1$ $f_1 := \frac{1}{T}$ $f_2 := \frac{3}{2 \cdot T}$ $f_c := \frac{5}{4 \cdot T}$

$v_1(t) := \sin(2 \cdot \pi \cdot f_1 \cdot t)$ $v_2(t) := \sin(2 \cdot \pi \cdot f_2 \cdot t)$

$$v(t) := \begin{cases} v_1(t) & \text{if } 0 \le t < T \\ v_2(t-T) & \text{if } T \le t < 2 \cdot T \\ -v_2(t - 2 \cdot T) & \text{if } 2 \cdot T \le t < 3 \cdot T \\ v_1(t - 3 \cdot T) & \text{if } 3 \cdot T \le t < 4 \cdot T \\ 0 & \text{otherwise} \end{cases}$$

$\text{carrier}(t) := \cos(2 \cdot \pi \cdot f_c \cdot t)$



At time 0, the signal lags the carrier by $\pi/2$; during pulse 1, it loses ground and, by T, it lags by π; during pulse 2, it is faster than the carrier, and is back to a lag of $\pi/2$; during pulse 3, it remains faster than the carrier, and its phase is 0 with respect to the carrier; during pulse 4, it is slower again, and falls back to a lag of $\pi/2$.