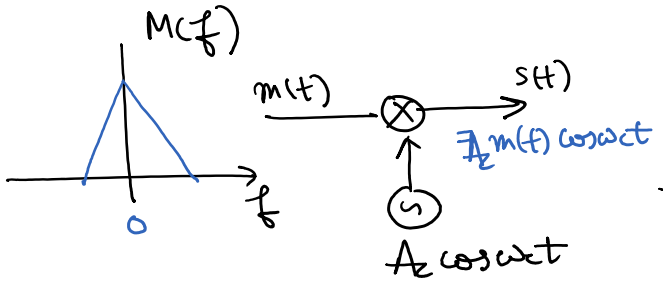
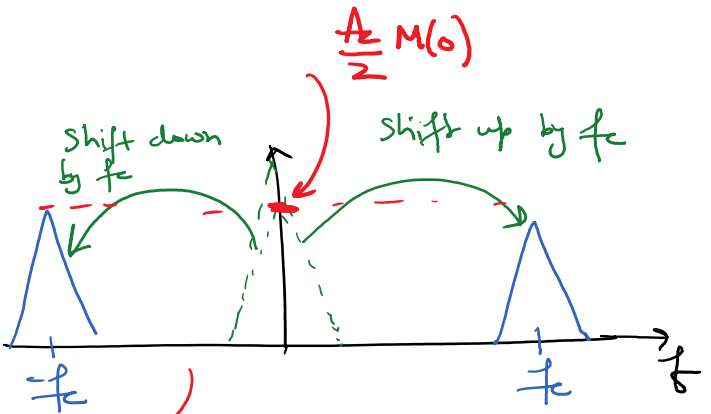
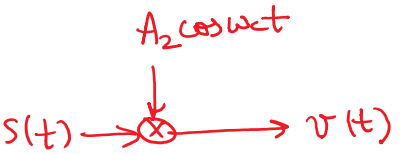
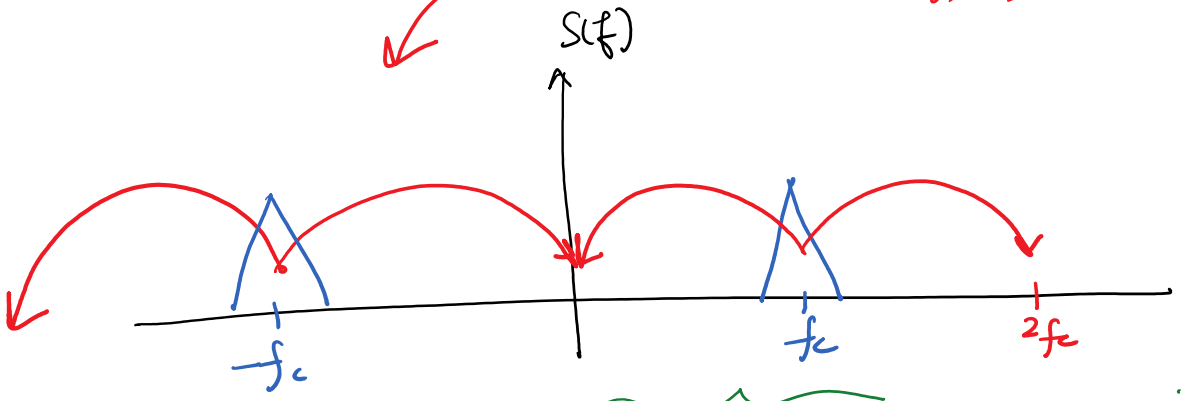
ECE 513- Lecture 3

Tuesday, August 28, 2018 9:26 AM



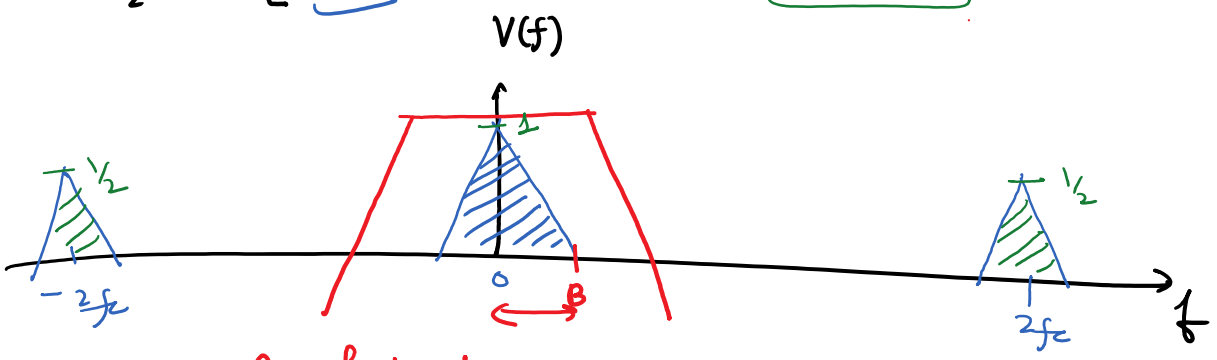






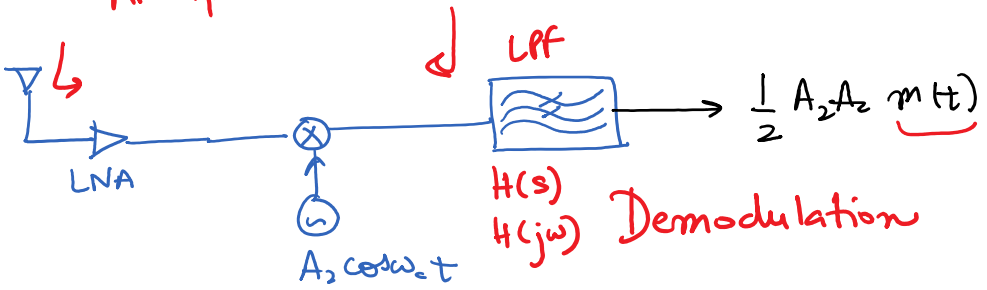
$$v(t) = \frac{1}{2}A_2A_2\left[m(t) + m(t)\cos(2\omega_c t)\right]$$

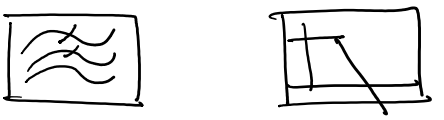
$$\frac{1}{2}\left[e^{j2\omega_c t} + e^{-j2\omega_c t}\right]$$



RF frontend

Rx





Lowpass filter

In general

$$m(t) = m_I(t) + j m_Q(t)$$ ← complex baseband signal

(in-phase, quadrature phase)

Let $A_c = 1$

transmitted signal

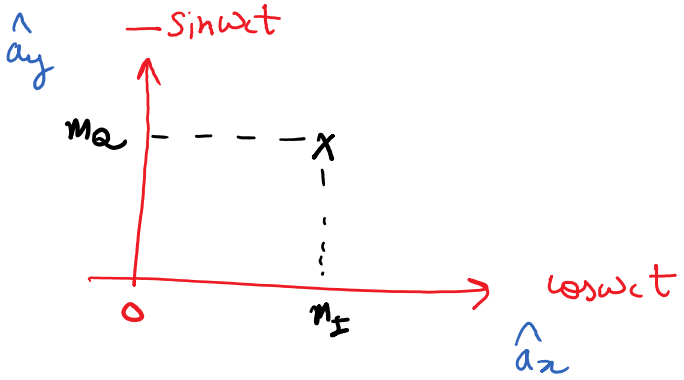
$$s(t) = \mathrm{Re}\{ m(t) e^{j\omega_c t} \}$$ ← complex modulation

complex carrier ⇒ $\cos\omega_c t + j \sin\omega_c t$

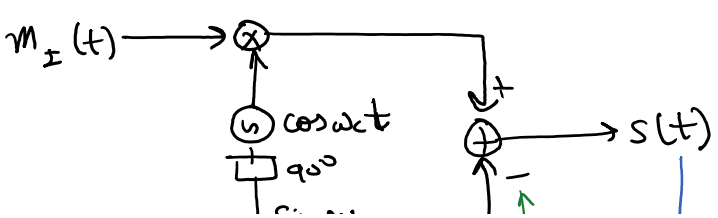
$$= \mathrm{Re}\{ [m_I(t) + j m_Q(t)][\cos\omega_c t + j \sin\omega_c t] \}$$

$$\boxed{s(t) = m_I(t)\cos\omega_c t - m_Q(t)\sin\omega_c t}$$

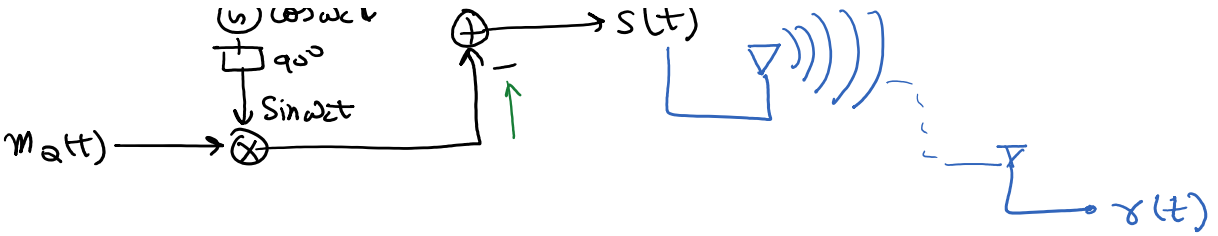
in phase, quadrature

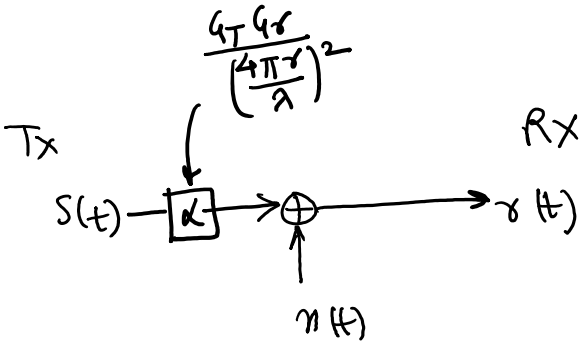


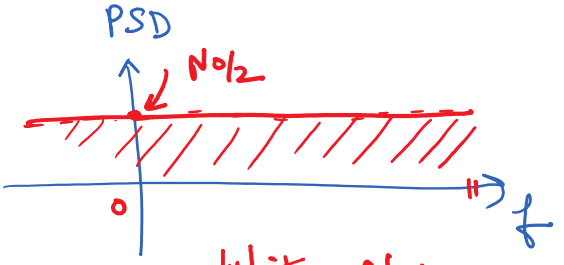
$$\hat{a}_x \cdot \hat{a}_y = \int_0^{T_b} \cos\omega_c t \sin\omega_c t \, dt = 0$$

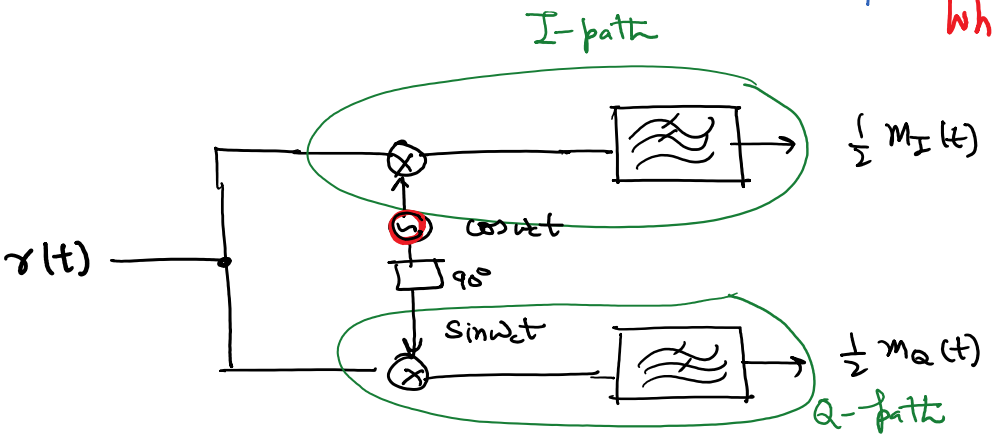


* $\cos\omega_c t$ & $\sin\omega_c t$ form a 2D vector space







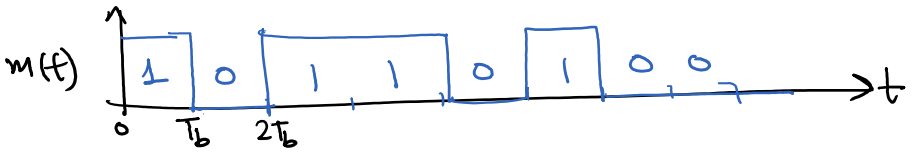


* Need the Rx oscillator to be synchronized with the Tx carrier.

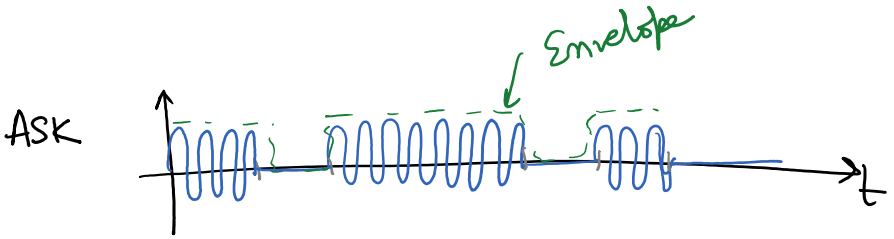
Digital Modulation :

* All modern communication systems employ digital modulation

$T \equiv T_b \Leftarrow$ bit period



Bit rate $R_b = \frac{1}{T_b}$

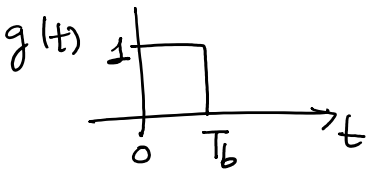


Amplitude shift keying

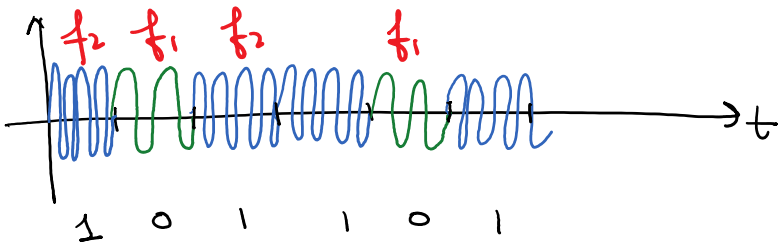
$$s(t) = A_c m(t) \cos \omega_c t$$

$$m(t) = \sum_{n=0}^{\infty} b_n g(t - nT_b)$$

$b_n \in \{0, 1\}$



FSK → frequency shift keying



$$s(t) = A \cos[\omega_2 t + m(t)\Delta\omega t]$$

$\Delta\omega = 2\pi \Delta f$, $\Delta f = f_1 - f_2$

$m(t)=0 \Rightarrow A_c \cos\omega_2 t$

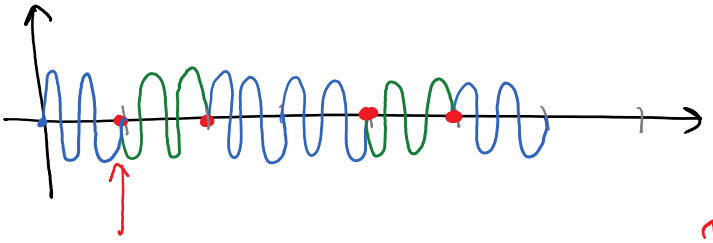
$m(t)=1 \Rightarrow A_c \cos\omega_1 t$

PSK → Phase shift keying

$s(t) = A_c \cos(\omega_c t + \phi_n)$

b_n	ϕ_n
0	π
1	0

1 0 1 1 0 1



phase jump of π

Binary PSK ⇒ BPSK

* Constant Envelope is preferred at times to minimize Power Amplifier distortion

PAPR ⇒ Peak to average power ratio of s(t)

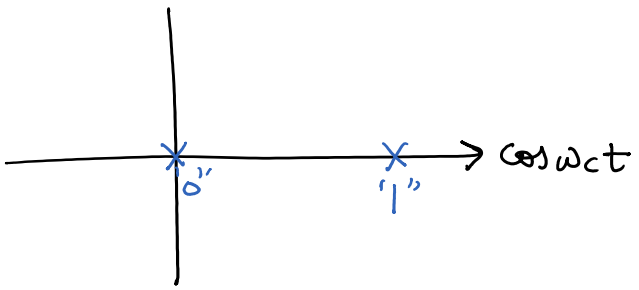
M-ary Digital Modulation Schemes.

* Binary modulation (Ask, Fsk, BPSK) have a spectral efficiency of 1 bps/Hz

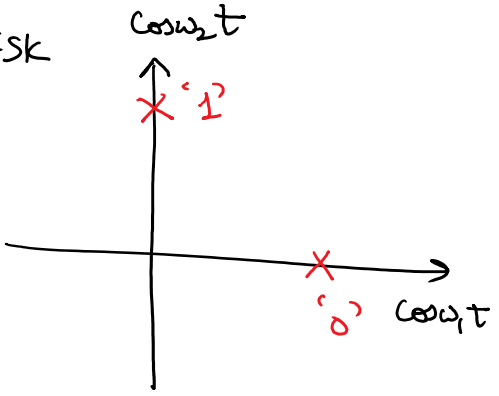
* M-ary modulation packs more bits in one time period (or more bits per symbol)
  ↳ higher data rates transmitted

Constellation Diagram

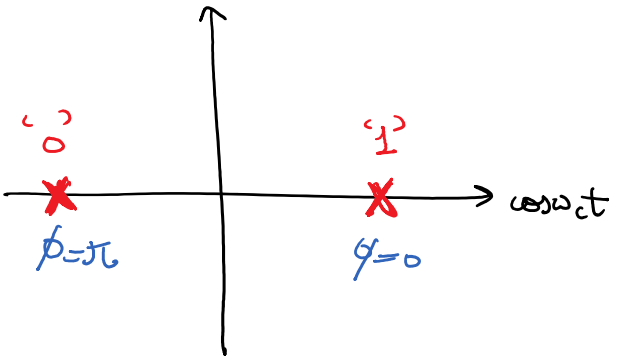
Ask

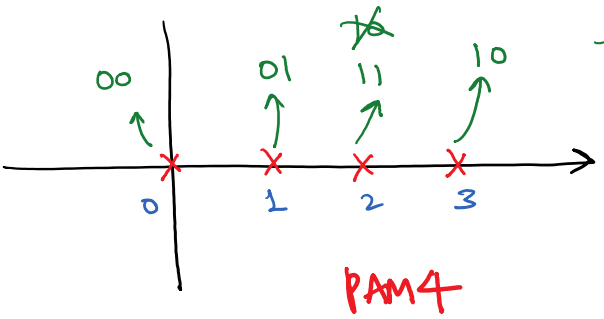


fsk



PSK





Gray encoding

Pulse amplitude modulation

PAM-M

PAM4

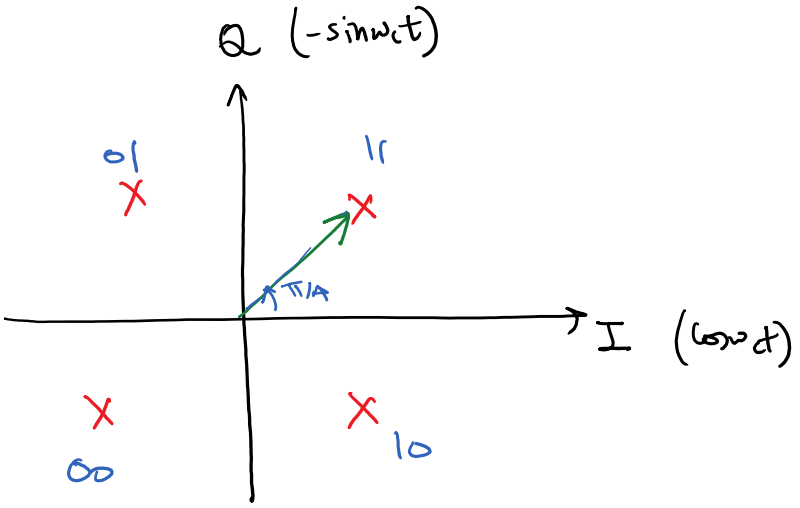
$$\text{bit rate} = \log_2 M \cdot R_b$$

$\log_2 M$ bits per symbol

$M = 4 \Rightarrow$ 2 bits/symbol

$M = 16 \Rightarrow$ 4 bits/symbol

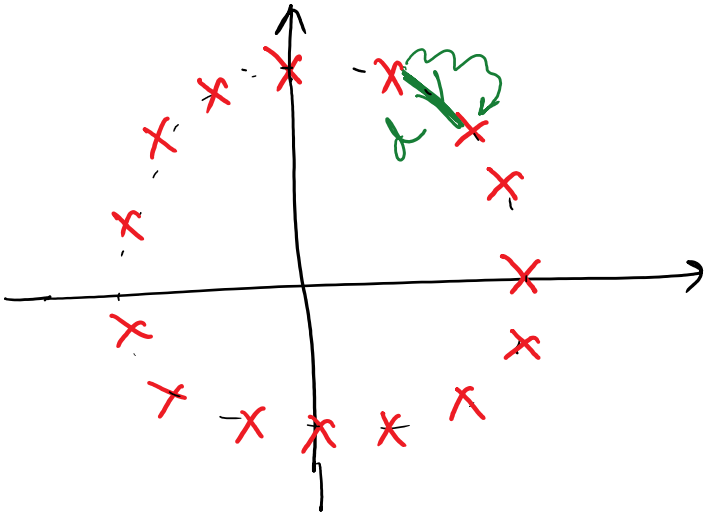
QPSK ⇒ Quadrature PSK



M = 4

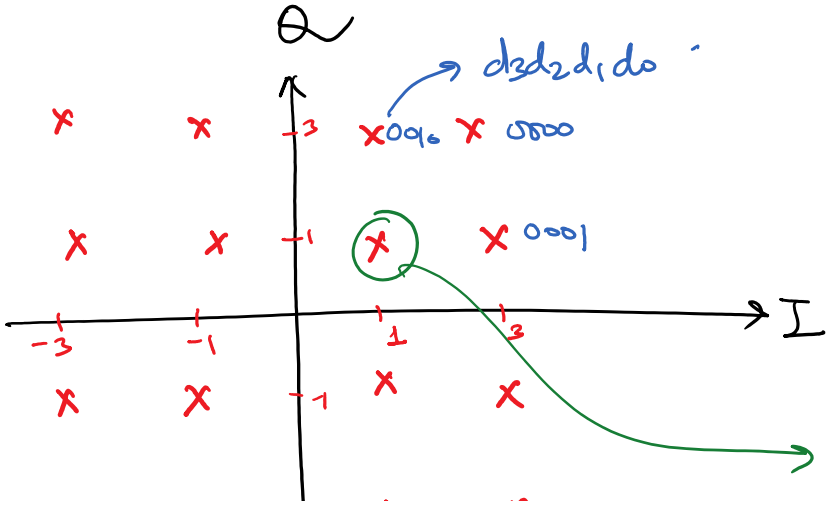
Constant Envelope

M- PSK



'd' to be maximized

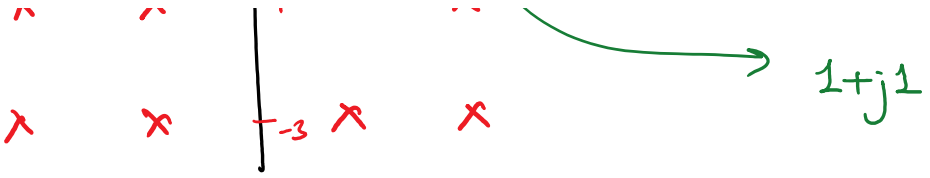
M- QAM → Quadrature Amplitude Modulation



16- QAM

4-bits Symbol

1+j1



$$s(t) = a_I \cos \omega_c t - b_Q \sin \omega_c t$$

$a_I \Rightarrow \pm 1, \pm 3, \ldots \pm (\log_2 M - 1)$

$b_Q \Rightarrow \pm 1, \pm 3, \ldots \pm (\log_2 M - 1)$

$$s(t) = \mathrm{Re}\{ m(t) e^{j\omega_c t} \}$$