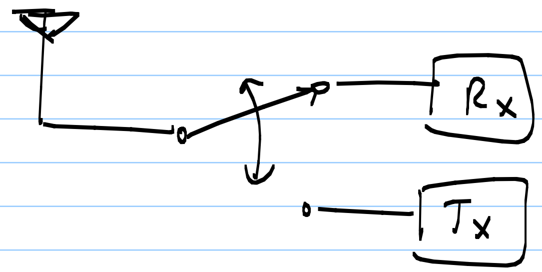
Lecture #2

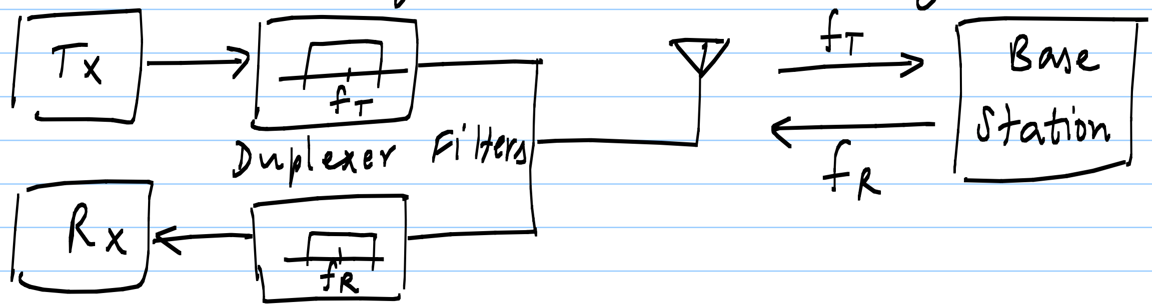
Multiple Access Techniques

1. TDD – time division duplexing



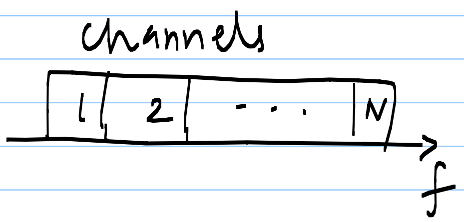
* Direct comm with peers
* Rx/Tx not on at same time
* RF switch loss is critical
* Nearby Tx can desensitise Rx

2. FDD – Frequency division multiplexing



* BPFs isolate Rx-Tx
* Tx/Rx duplex (ie on at same time)
* Basestation performs $f_T \leftrightarrow f_R$ conversion
* Loss of Duplexer/BPFs is critical (usually > RF switch loss)

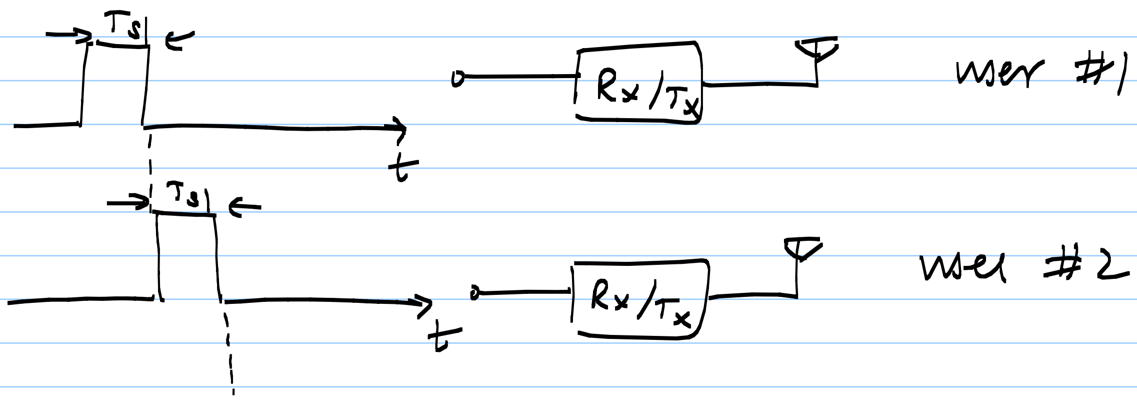
3. FDMA – Frequency Division Multiple Access



* Each user is assigned a channel (fixed till end of call)
* Separate channels for Rx & Tx
* Max # of simultaneous users = $\frac{\text{freq. Band width}}{\text{channel width}}$

⇒ insufficient capacity in crowded areas!

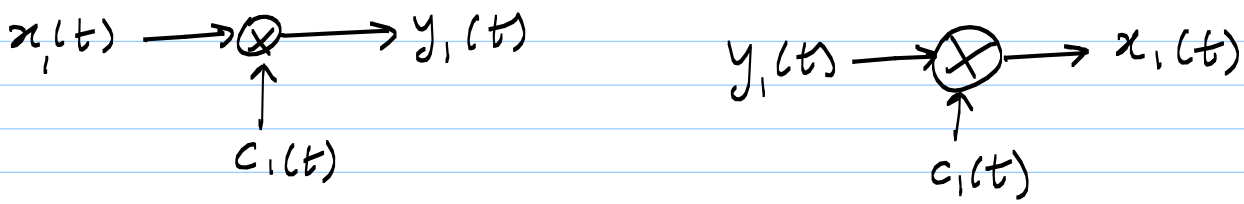
4. TDMA — Time division multiple Access



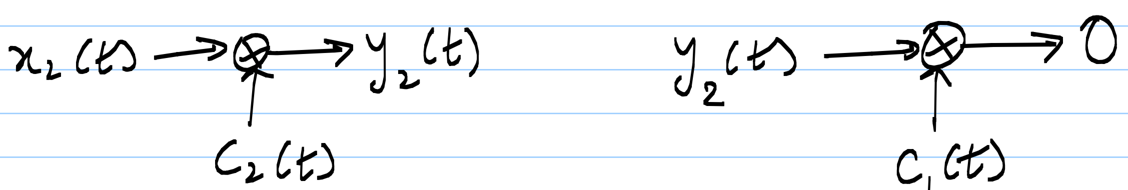
* Data transmitted/received as a "burst"
* Same freq. band shared in time
* Each Rx/Tx uses a time slot
* All slots put together ≡ a Frame
* PA can be turned on/off to save power
* More complex – time synchronisation

5. CDMA — Code Division Multiple Access

at Tx_1: at Rx_1:



at Tx_2: at Rx_1:



Basic idea: use orthogonal codes to separate users in signal space:

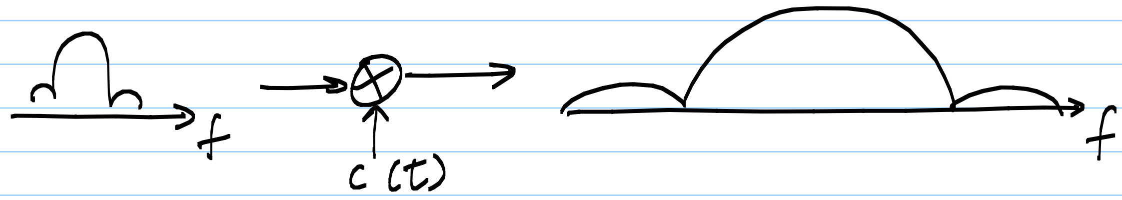
$$c_i \cdot c_j = [0] \quad \text{for } i \neq j$$
$$= [1] \quad \text{for } i = j$$

examples of orthogonal codes:

$c_1 = (1, 1, 1, 1)$; $c_2 = (1, -1, 1, -1)$;

$c_3 = (1, 1, -1, -1)$; $c_4 = (1, -1, -1, 1)$;

Codes can be used to spread the baseband signal (spread-spectrum comm.)



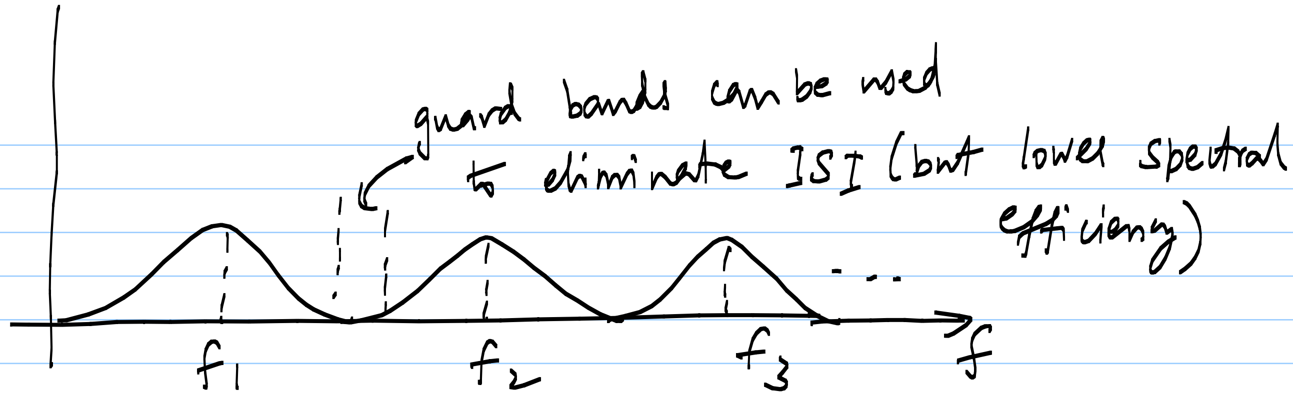
* BW usage (apparently) increases, but multiple users can occupy overlapping frequencies
* Other users' signals appear as random noise (ideally)

* CDMA has a soft capacity limit - increasing the number of users gradually raises the noise floor.
* Power control is critical - one single large Tx signal can raise the noise floor for all users.
* Note: TDMA - orthogonality in time

  FDMA - orthogonality in frequency

6) OFDM - Orthogonal Frequency division multiplexing

* Tx BW divided into many sub-channels
* Sub-channels orthogonal to each other

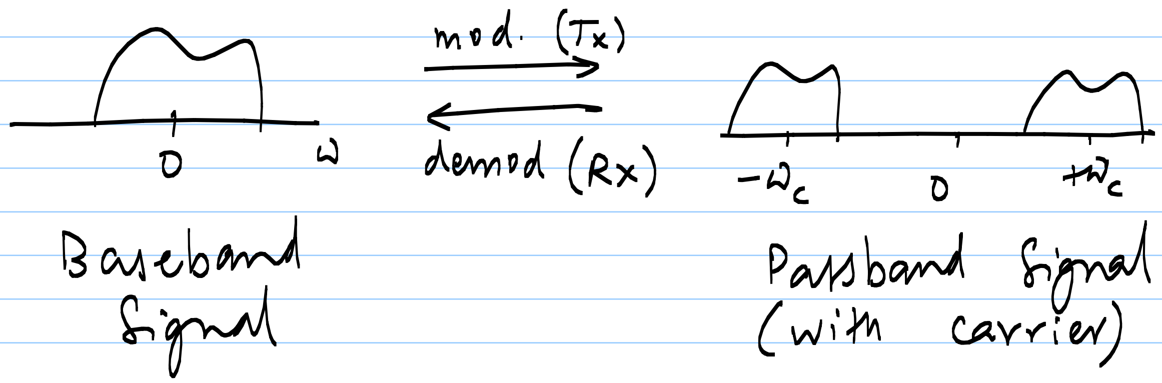


* Can be designed such that sinc response nulls occur at adjacent sub-carrier frequencies

Now, for some examples:

1) GSM – TDMA/FDMA and FDD
2) Qualcomm CDMA – CDMA and FDD
3) DECT (cordless telephone) – TDMA/FDMA and TDD
4) 802.11g (WiFi) – OFDM and TDD

Analog & Digital Comm.



Why modulation?

wired systems : shielding is better at high freq.

Wireless systems : a) antenna size can be smaller ($\propto \lambda$)

b) Share spectrum through regulation (to avoid overlap)

Passband signal

$$x(t) = a(t) \cdot \cos[\omega_c t + \theta(t)]$$

$a(t)$ ↑ amplitude; $\theta(t)$ ↑ phase

$$\text{frequency} = \omega_c + \frac{d\theta(t)}{dt}$$

Analog Modulation : AM, FM (PM)

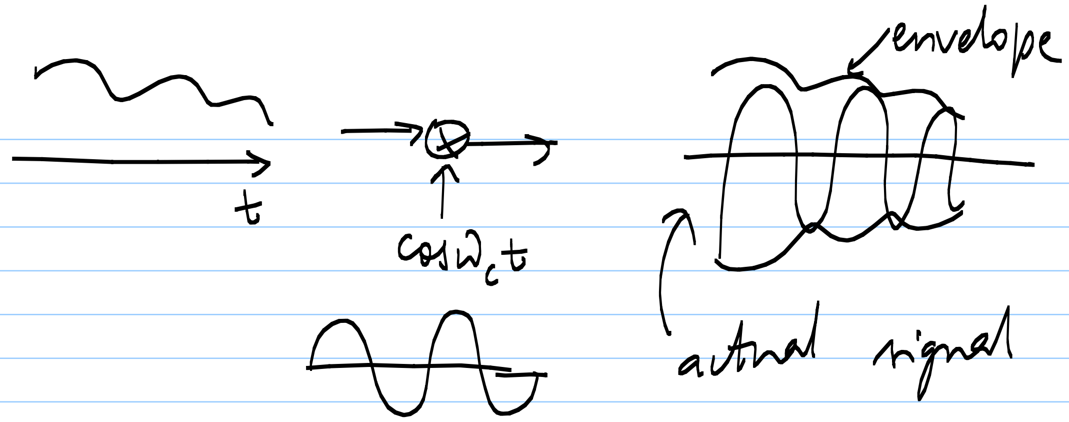
1. AM – amplitude modulation

$$x_{AM}(t) = A_c[1 + m \cdot x_{BB}(t)] \cos \omega_c t$$

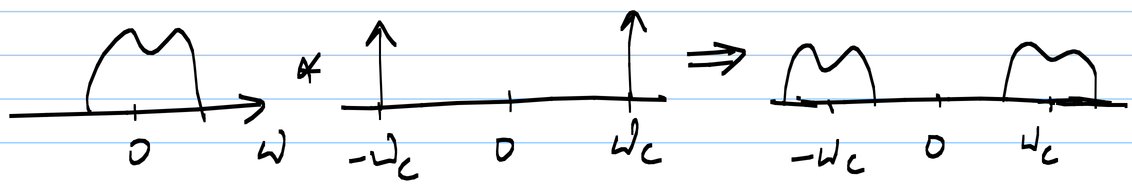
m ↑ modulation index

DSB-FC ⇒ Double-sideband full-carrier

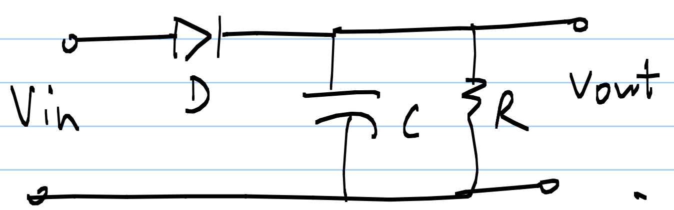
time domain :



freq. domain :



AM detector :



can be used as long as $1 + m x_{BB}(t) > 0$ for all t

Issues : 1) susceptible to noise 2) requires very linear PA

2. FM — frequency modulation

* mod. & demod. easier than PM

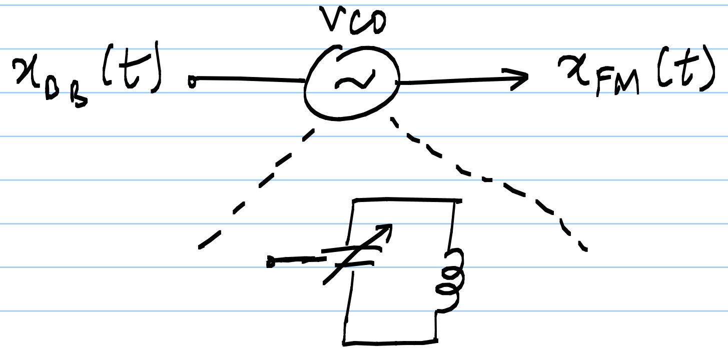
$$x_{FM}(t) = A_c \cos\left[\omega_c t + m\int_{-\infty}^{t} x_{BB}(t)\,dt\right]$$

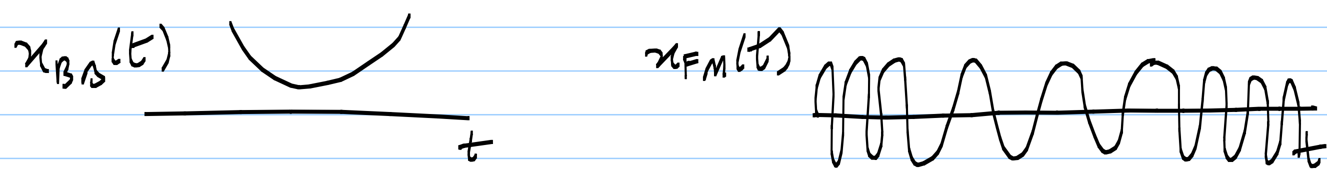
(m → FM index)

$$x_{PM}(t) = A_c \cos\left[\omega_c t + m\, x_{BB}(t)\right]$$

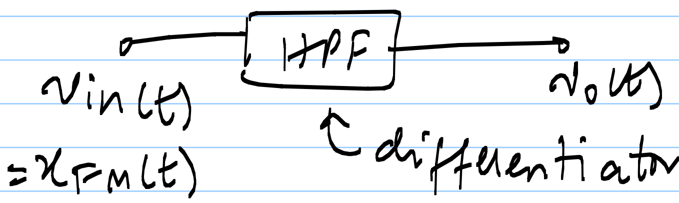
(m → PM index)

Simple FM modulator:

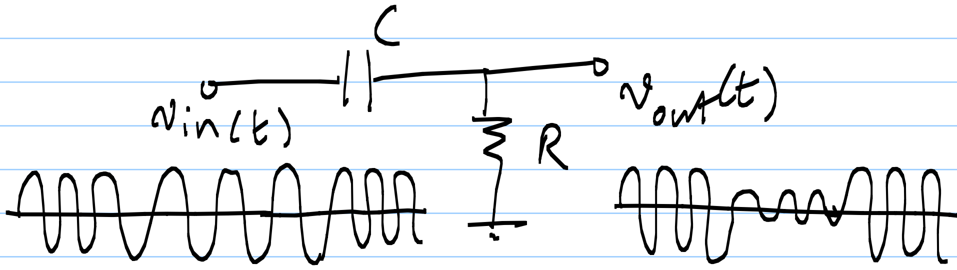




Simple FM demodulator:



$$v_o(t) = A_{out}\left[\omega_c + m\,x_{BB}(t)\right] \sin\left[\omega_c t + m\int_{-\infty}^{t} x_{BB}(t)\,dt\right]$$

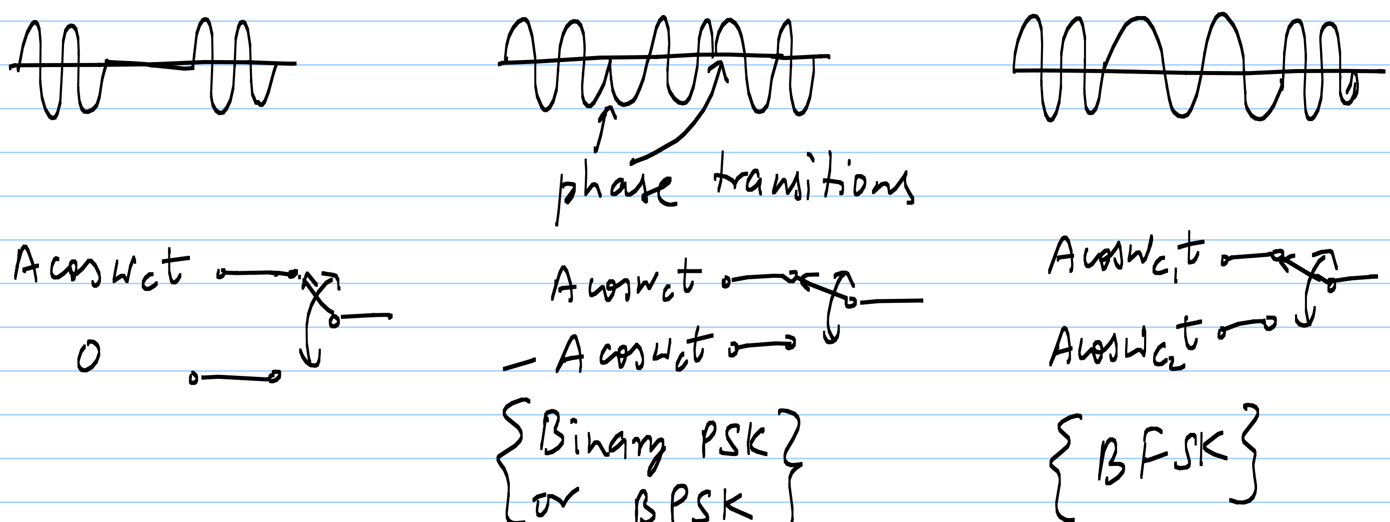


use envelope detector on this!

Digital Modulation: ASK, PSK, FSK etc.

(PSK, FSK: less sensitive to amplitude noise)

ASK | PSK | FSK



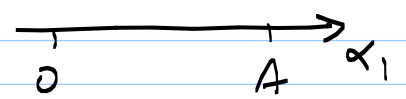
{Binary PSK or BPSK}

{BFSK}

Signal constellation Diagram:

Represents possible symbols in complex plane

ASK

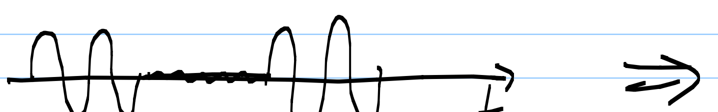


$\alpha_1 \leftrightarrow$ amplitude

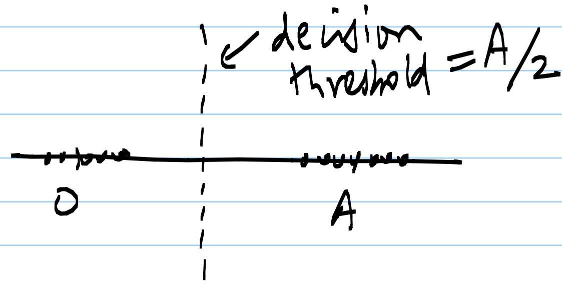
FSK

$\alpha_{1,2} \leftrightarrow$ frequency

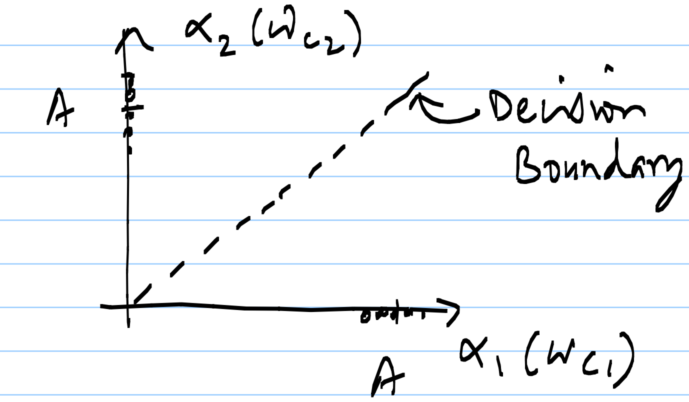
effect of noise in ASK:



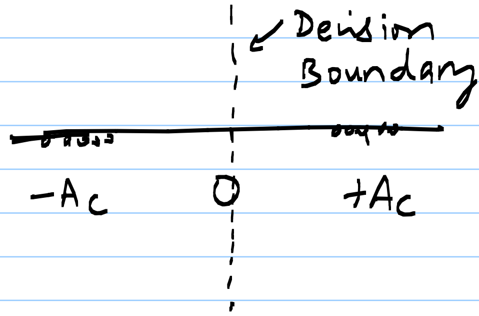
$\Rightarrow$



Noise with FSK:



BPSK

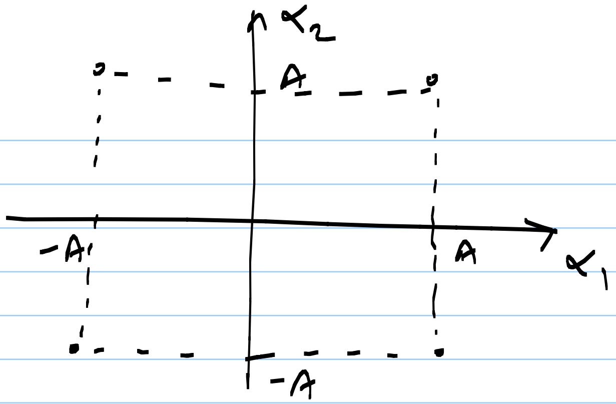


Quadrature Modulation:

$$x(t) = b_m A \cos\omega_c t - b_{m+1} A \sin\omega_c t$$

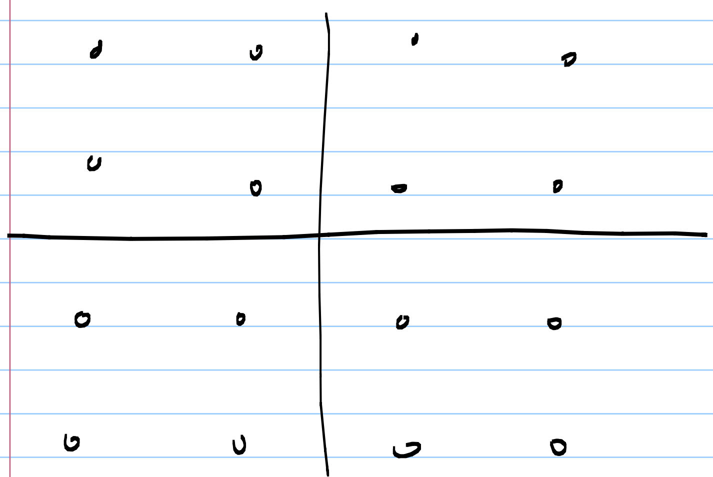
e.g. QPSK (WCDMA), MSK → GMSK (GSM), 8-PSK (EDGE)

QPSK:



In general, only certain transitions are allowed

QAM – Quadrature Amplitude Modulation



e.g. HSDPA uses 16-QAM