

Wireless Embedded Systems

Department of Radio & Information Communications Engineering

CHUNGNAM NATIONAL UNIVERSITY

김병관

byungkwan.kim@cnu.ac.kr

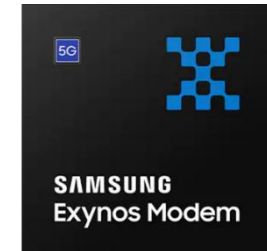
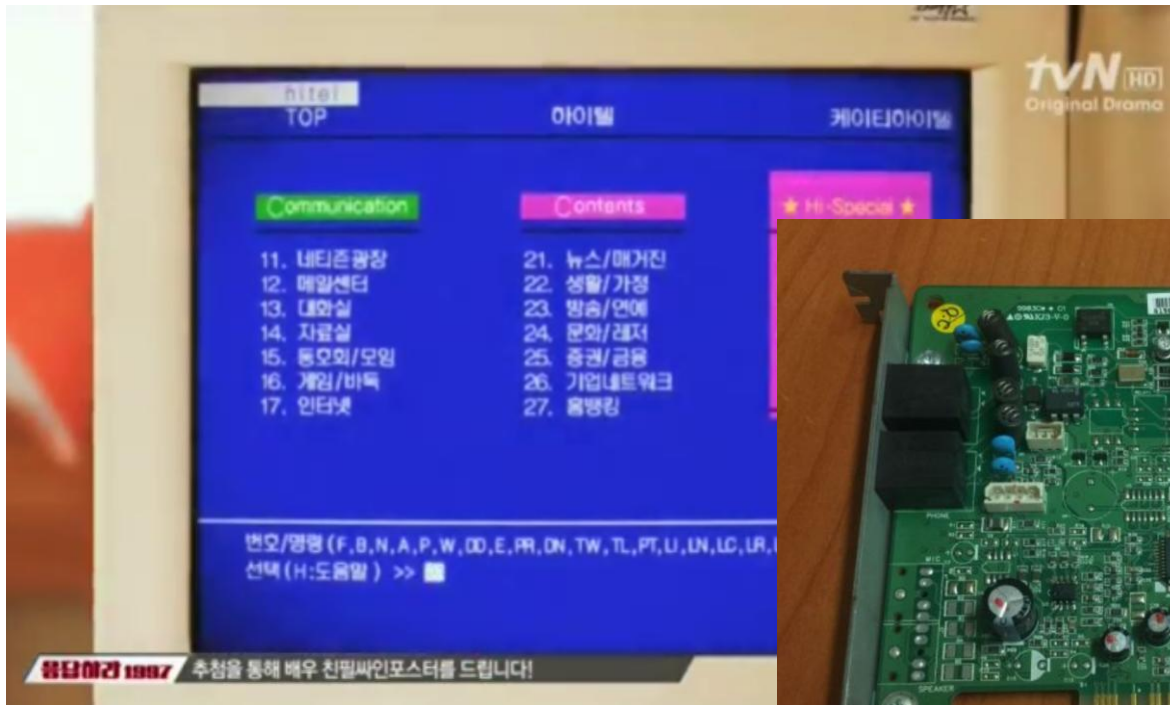
Course Overview

- Tentative Schedule

#	Topic	Lab/Assignment
1	Introduction	
2	Review: Python Basics, Signal & Systems	1. DFT vs FFT
3		
4		
5	Digital Signals and Sampling	2. Sampling & Windowing
6		
7	Analog & Digital Modulation	
8		
9	Midterm Exam	
10		
11	Software-Defined Radio	Env. Setup
12		
13		
14		
15	Wireless Communication Experiments (Spectrum Monitoring, Communication)	3. Time-Frequency Analysis
	Final Exam	

Analog & Digital Modulation

- What is modulation
 - Modem : Modulator & Demodulator



Analog & Digital Modulation

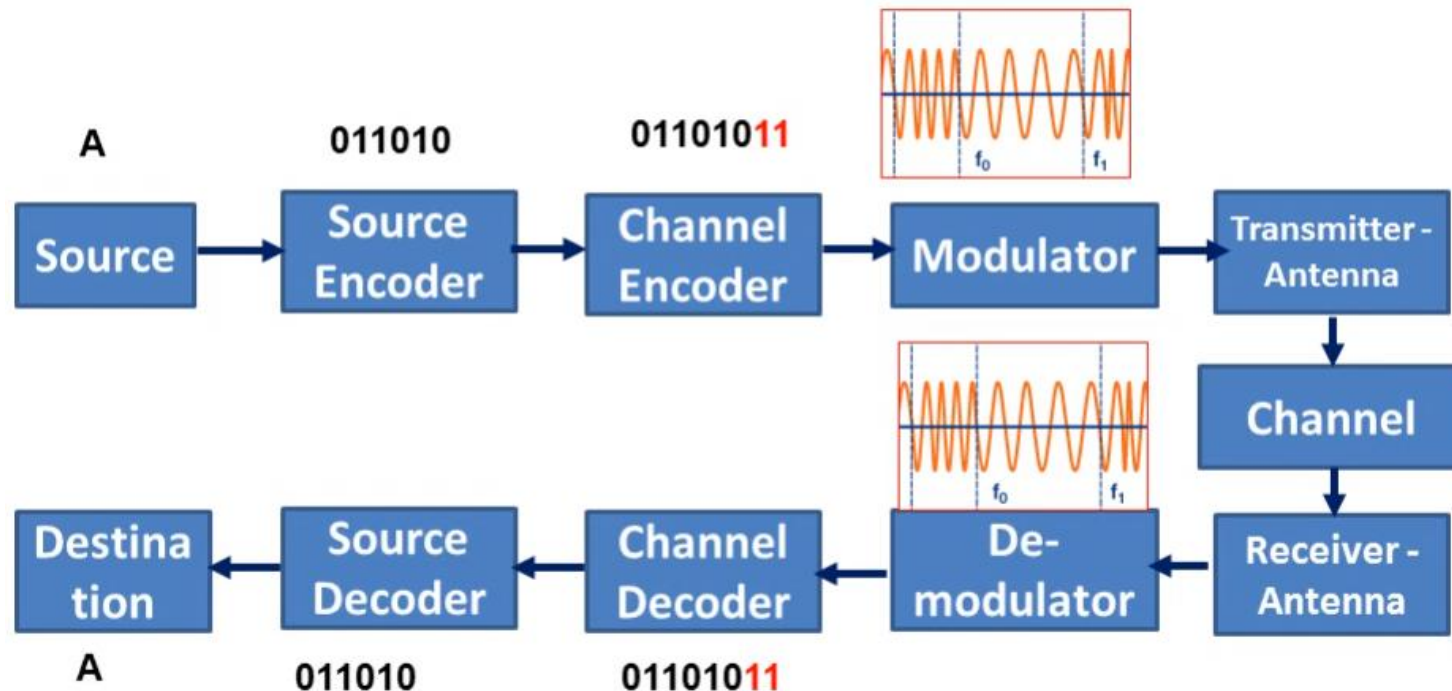
- What is modulation
 - is the process of **varying one or more properties** of a periodic waveform, called the carrier signal,
with a separate signal called the modulation signal that typically contains information to be transmitted.



수박
Watermelon
西瓜
pastèque
Citrullus lanatus

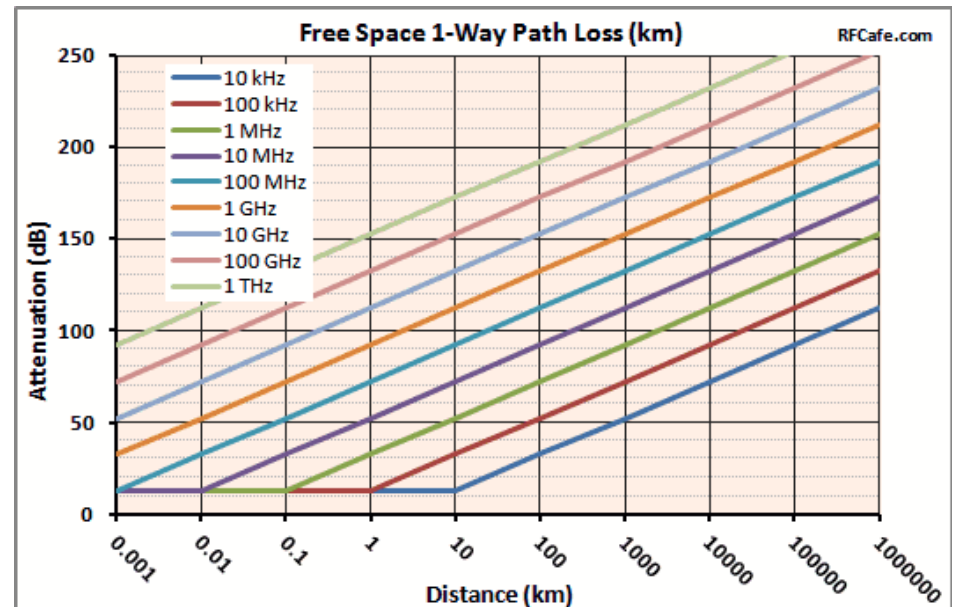
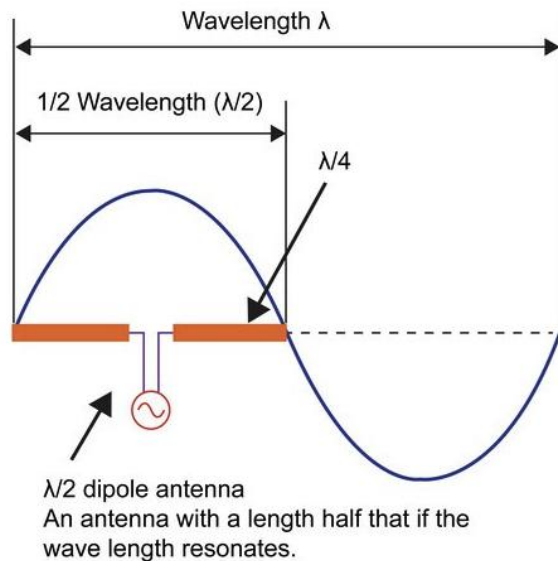
Analog & Digital Modulation

- A Digital Transceiver System
 - In each stage, signal is represented in a different format.



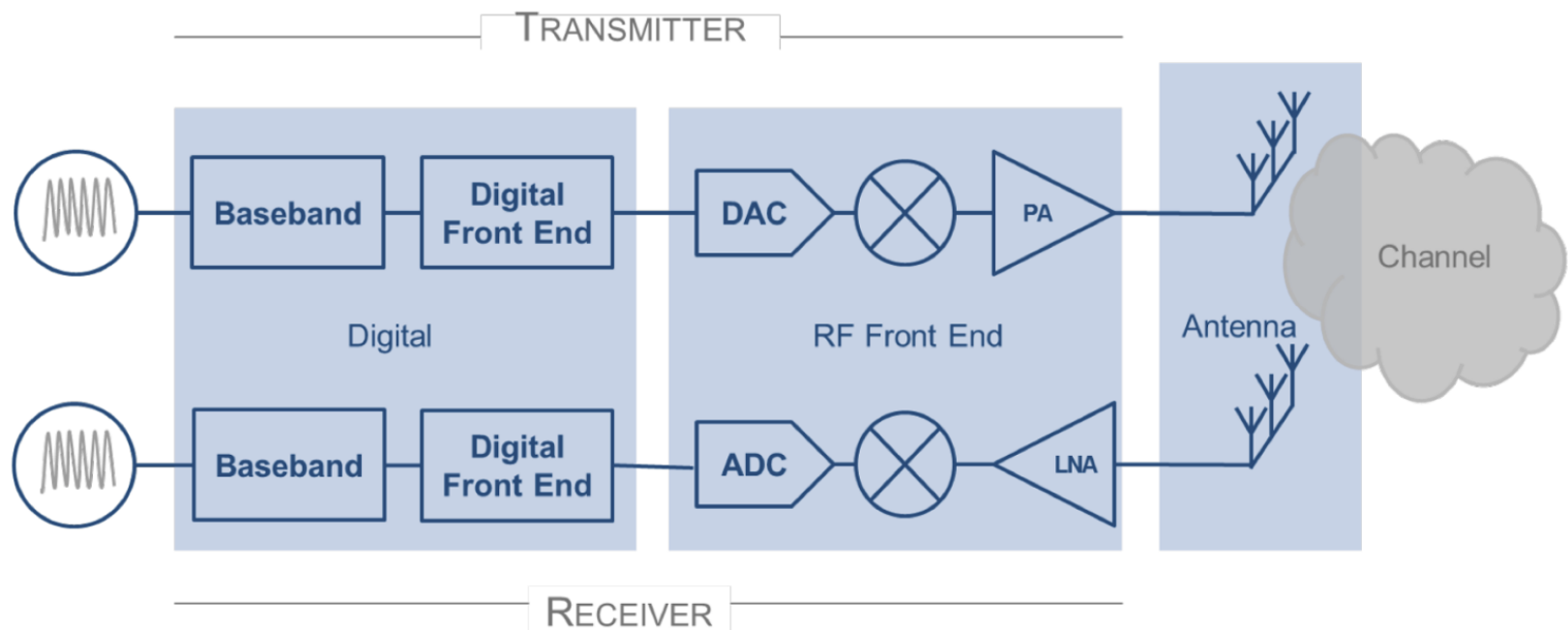
Analog & Digital Modulation

- Why do we use Radio Frequency (MHz to GHz)?
 - Bandwidth
 - Interference
 - Antenna Size
 - Propagation Characteristic (Coverage)



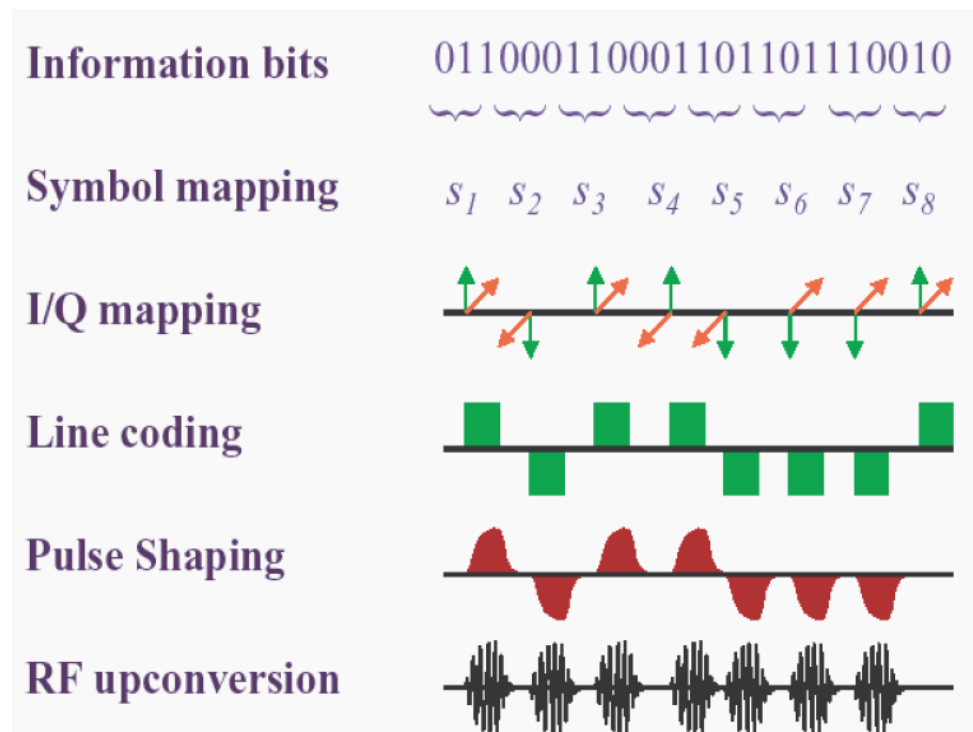
Analog & Digital Modulation

- A Wireless Transceiver System
 - Baseband / RF Frontend / Antenna
 - Up/down Frequency Conversion



Analog & Digital Modulation

- A Digital Transceiver System
 - In each stage, signal is represented in a different format.



Analog & Digital Modulation

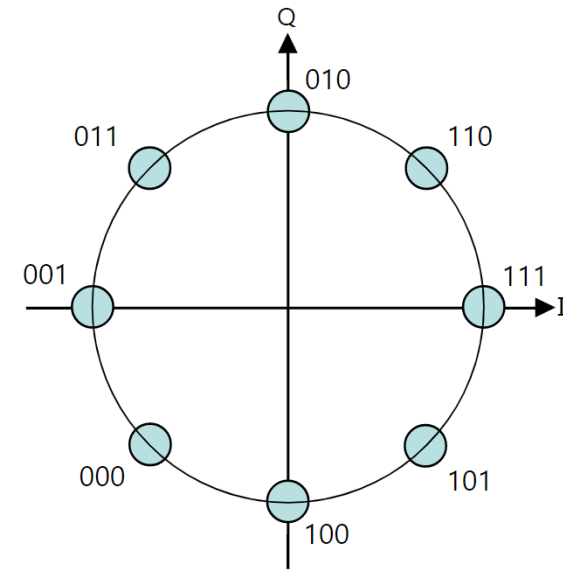
- Bit, Symbol, and Modulation
 - Symbol : a pulse unit, waveform for a fixed period time
 - In binary modulation : Each symbol represents one bit
 - In M-ary modulation : Each symbol represents k bits ($M = 2^k$)

bit	symbol
0	-1
1	1

K=1
M=2

bit	symbol
00	+3
01	+1
10	-1
11	-3

K=2
M=4



Analog & Digital Modulation

- Overview of Binary Digital Modulation Techniques

1. **Baseband digital message signal: $m(t)$**

2. **Analog sinusoidal carrier signal:**

A. Carrier signal: $A_c \cos(2\pi f_c t + \phi_c)$

3. **ASK: Amplitude Shift Keying.**

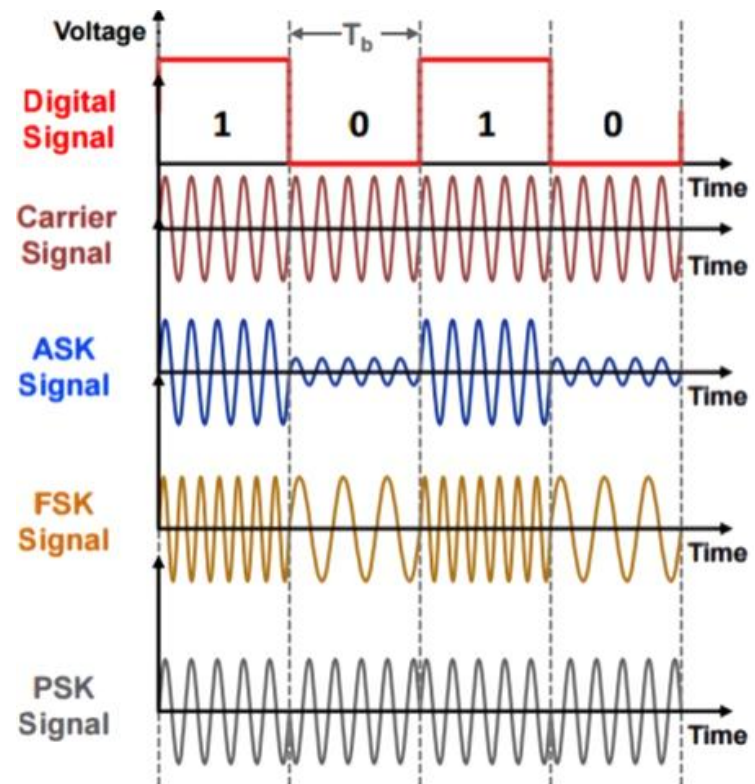
A. Message signal changes the carrier's **amplitude** : $A_i(t)$.

4. **FSK: Frequency Shift Keying.**

A. Message signal changes the carrier's **frequency** : $f_i(t)$.

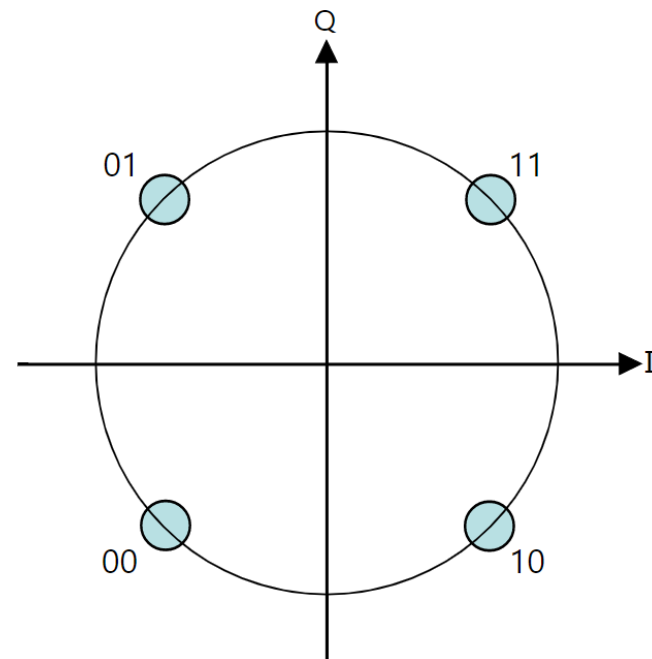
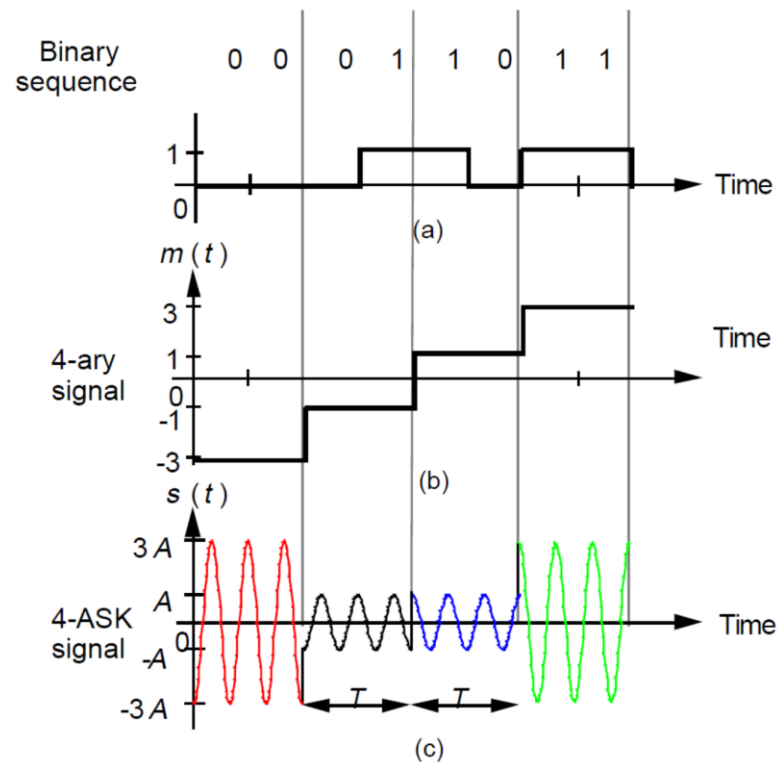
5. **PSK: Phase Shift Keying.**

A. Message signal changes the carrier's **phase** : $\phi_i(t)$.



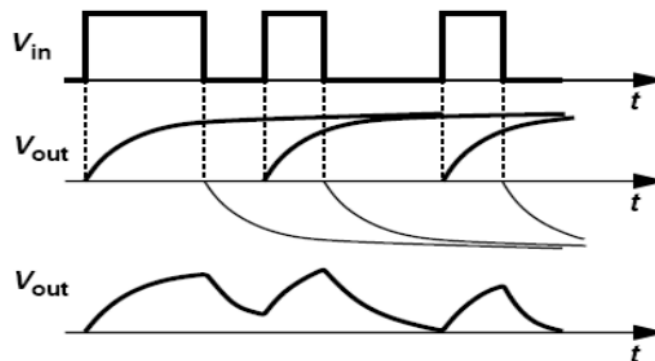
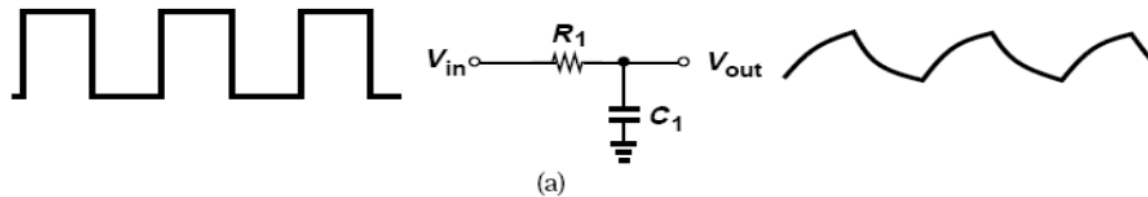
Analog & Digital Modulation

- Overview of M-ary Digital Modulation Techniques



Analog & Digital Modulation

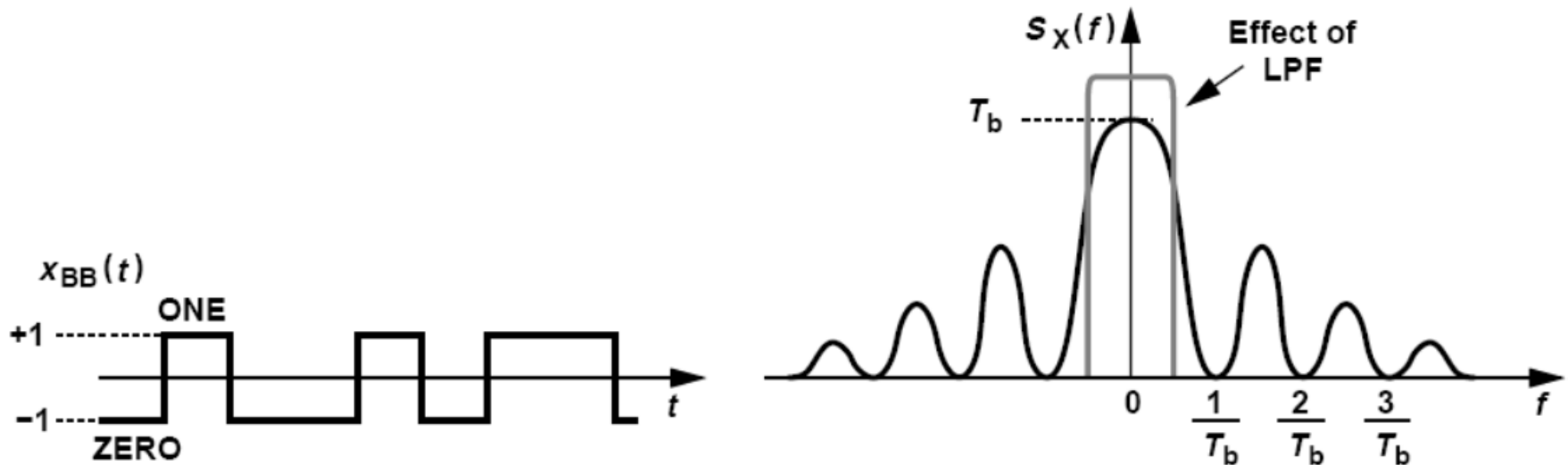
- Bandwidth
 - Linear time-invariant systems can distort a signal
 - if they don't provide sufficient **bandwidth**



Each pulse extends in time and spills to the time slot of other pulses. This is called Inter Symbol Interference (ISI).

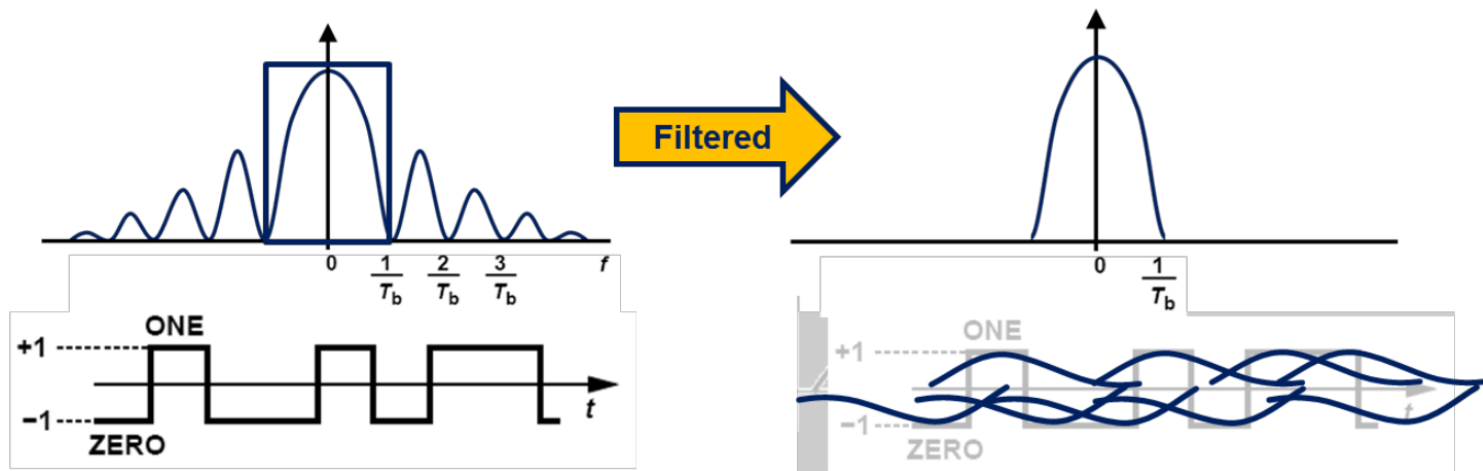
Analog & Digital Modulation

- Bandwidth
 - What is bandwidth of a random pulse stream?
 - In frequency domain, it is form of sinc^2 function
 - But the bandwidth is limited!



Analog & Digital Modulation

- Bandwidth
 - What happens if we just filter out except mainlobe?



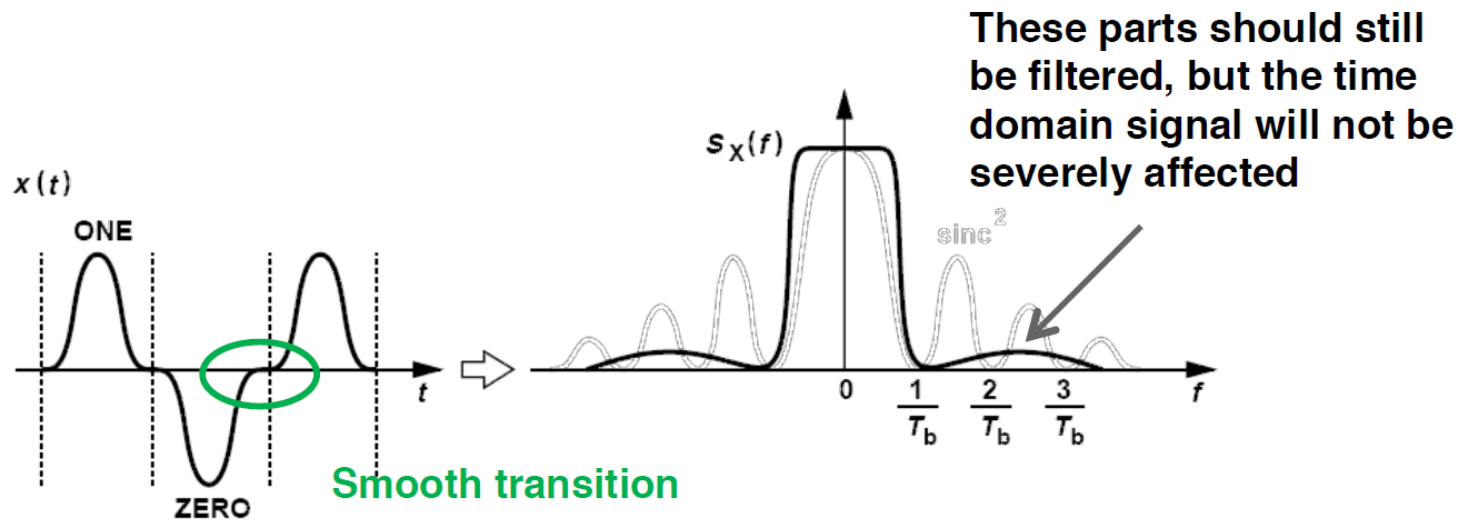
Each pulse extends in time and spills to the time slot of other pulses. This is called Inter Symbol Interference (ISI).

ISI results in distortion and error in detection

Analog & Digital Modulation

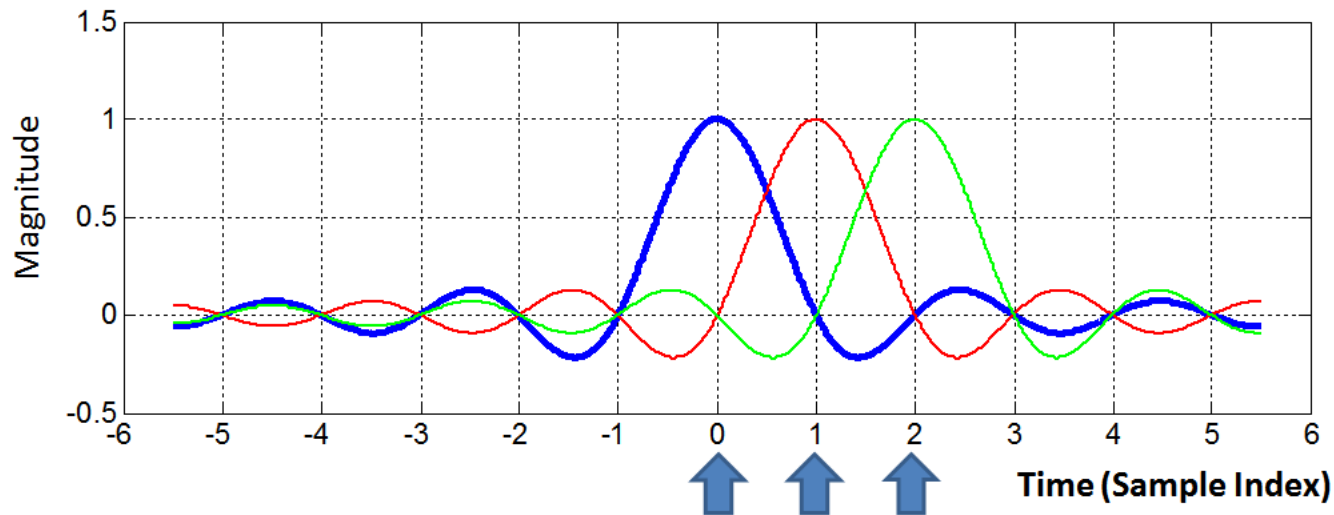
- Pulse Shaping

- What if we shape the pulses for less bandwidth?
- Smoother pulses take less bandwidth
- Problem solved?



Analog & Digital Modulation

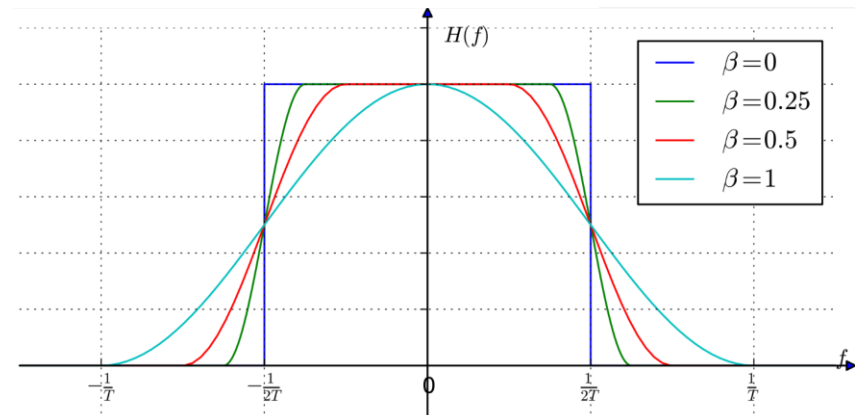
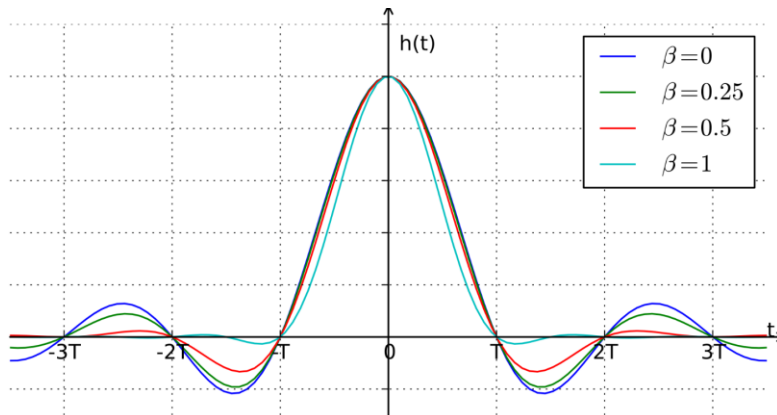
- Pulse Shaping – Nyquist Pulse
 - The value should be zero in the middle of other pulse.
 - Not only removes ISI, but also returns in minimum bandwidth
 - Theoretical minimum bandwidth : $R_b = 1/T_b$ Hz



Analog & Digital Modulation

- Pulse Shaping – Raised Cosine Pulse
 - Since Nyquist pulse is physically **unrealizable** (Ideal LPF)
 - We use odd-symmetrical pulse at cutoff frequency (in freq.)
 - Then, the impulse response will have zeros

$$H(f) = \begin{cases} 1, & |f| \leq \frac{1-\beta}{2T} \\ \frac{1}{2} \left[1 + \cos\left(\frac{\pi T}{\beta} \left[|f| - \frac{1-\beta}{2T} \right] \right) \right], & \frac{1-\beta}{2T} < |f| \leq \frac{1+\beta}{2T} \\ 0, & \text{otherwise} \end{cases}$$



Analog & Digital Modulation

- Pulse Shaping – Raised Cosine Pulse



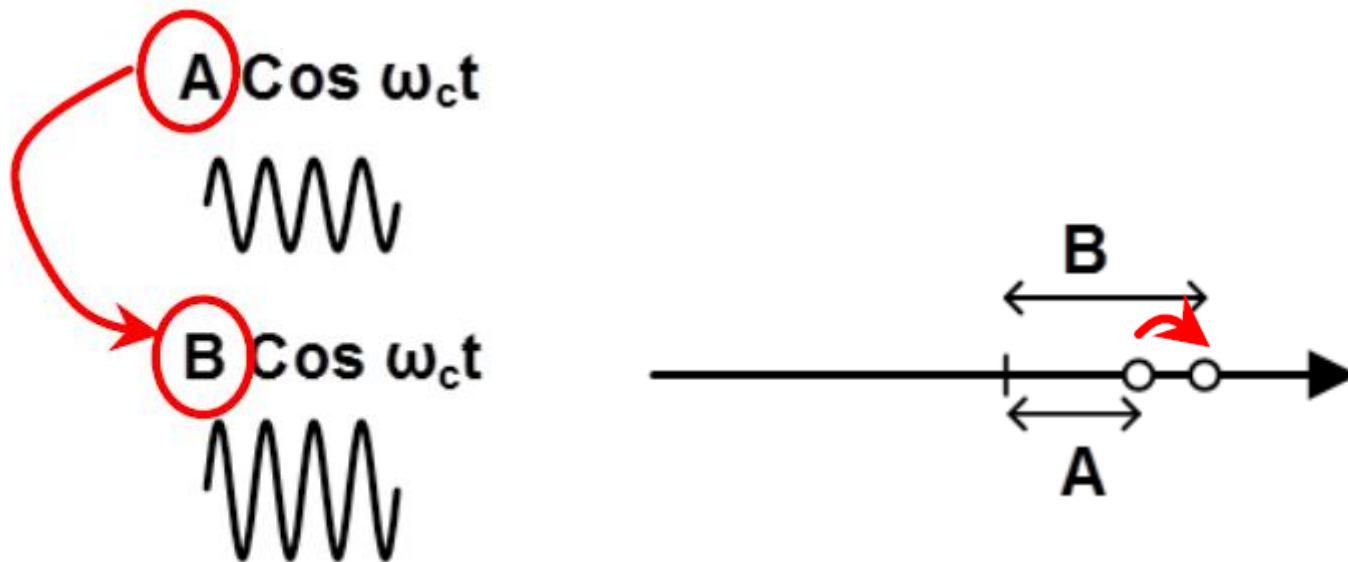
Facts about RRC



- RRC theoretically has infinite number of taps so it has infinite attenuation in the stop band. However, in implementation its length should be reduced to a finite value.
- Decreasing the number of samples (filter delay) reduces the stop band attenuation.
- The rolloff factor is a measure of the excess bandwidth of the filter, i.e., the bandwidth occupied beyond the Nyquist bandwidth of $1/2T$, where $1/T$ is symbol rate.
- As rolloff increases eye in the eye diagram opens up. This means that if there were no bandwidth restrictions it would be easier on the receiver if one used a large rolloff. (However, for bandwidth efficiency rolloff should be smaller.)
- Smaller rolloff gives narrower bandwidth. However, its side lobes increases so attenuation in stop band is reduced.
- RRC filters are implemented in the base band as a digital filter. Since implementing narrow (high Q) filters in the RF bands is difficult.

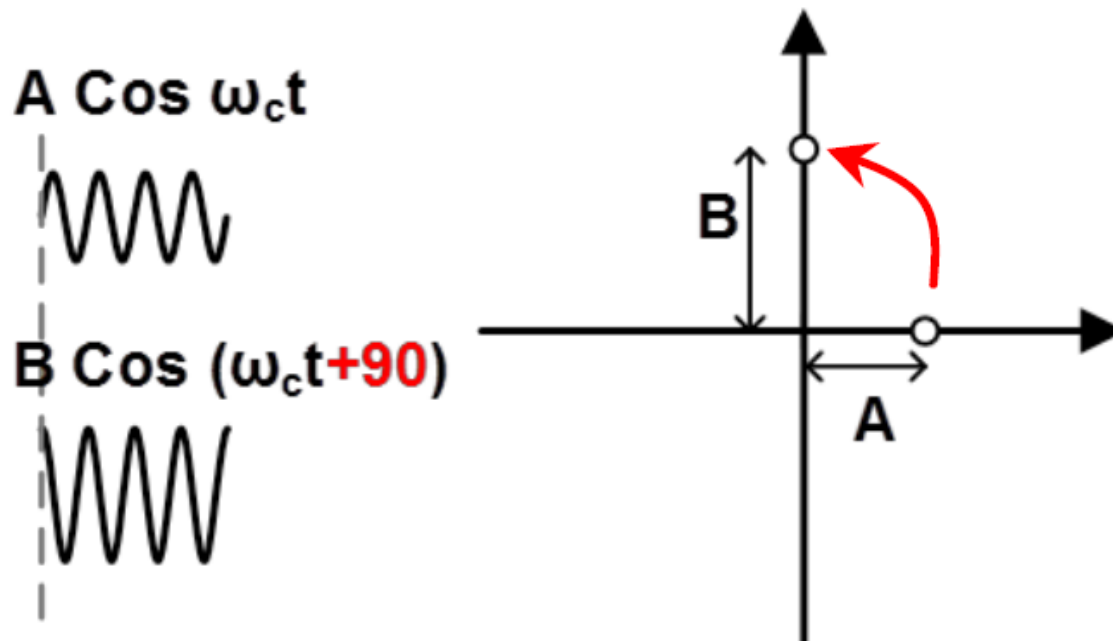
Analog & Digital Modulation

- Constellation Diagram
 - Useful representation of signals



Analog & Digital Modulation

- Constellation Diagram
 - Useful representation of signals



Analog & Digital Modulation

- Constellation Diagram Examples

- BPSK (Binary Phase Shift Keying)



Phases chosen to maximize distance

- QPSK (4-PSK, Quadrature Phase Shift Keying)

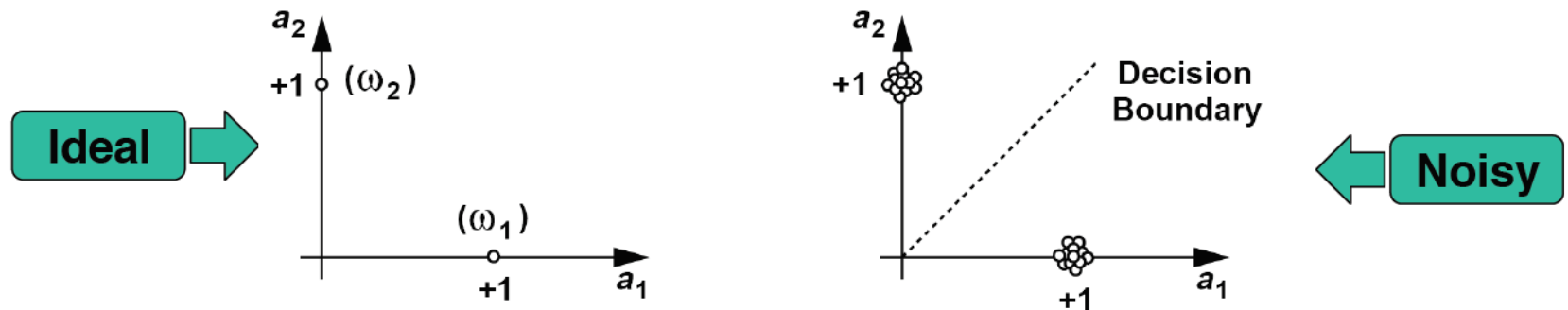


Analog & Digital Modulation

- Constellation Diagram Examples
 - FSK

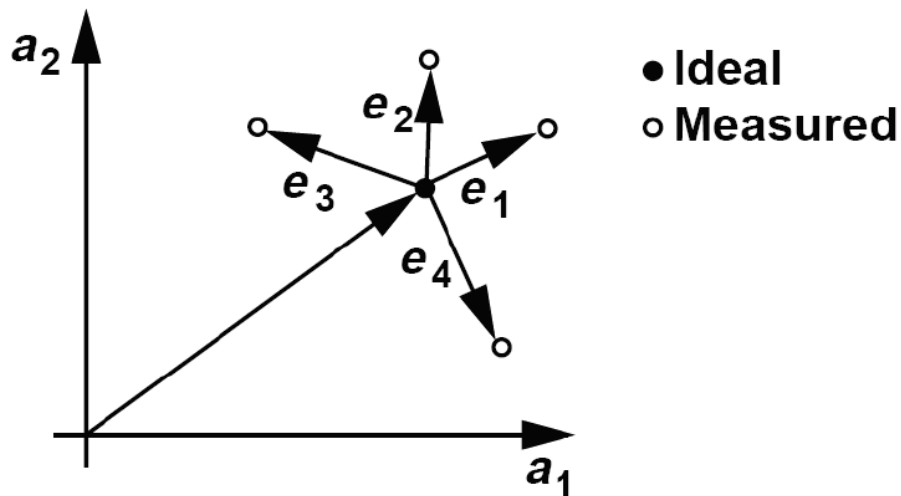
$$x_{FSK}(t) = a_1 \cos \omega_1 t + a_2 \cos \omega_2 t$$

$$a_1 a_2 = 10 \text{ or } 01 \text{ (bit)}$$



Analog & Digital Modulation

- Constellation Diagram Examples
 - EVM : Deviation of the constellation pts from ideal position.
 - Measured in % or dB



$$\text{EVM}_1 = \frac{1}{V_{rms}} \sqrt{\frac{1}{N} \sum_{j=1}^N e_j^2}$$

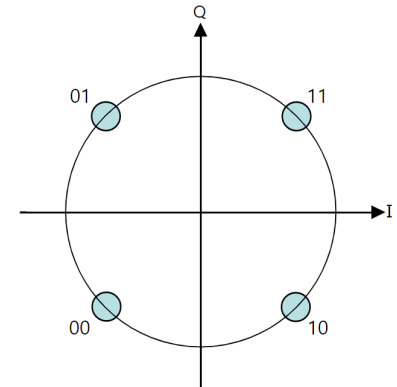
$$\text{EVM}_2 = \frac{1}{P_{avg}} \cdot \frac{1}{N} \sum_{j=1}^N e_j^2$$

Analog & Digital Modulation

- Quadrature Modulation

- Lets start with QPSK with $\phi_n = \left\{ \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4} \right\}$

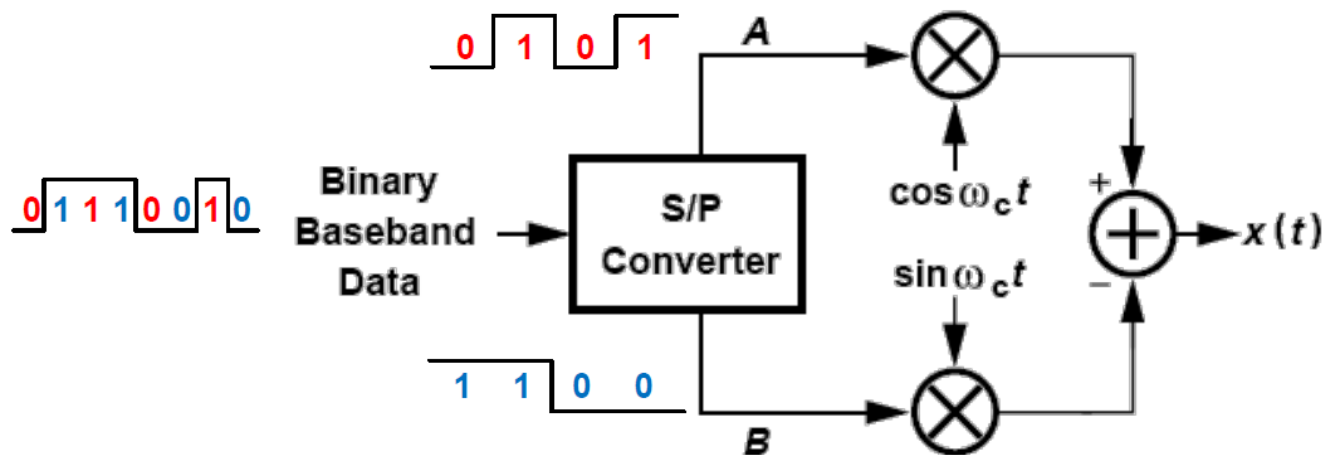
- $$\begin{aligned} QPSK &= \sum \cos(\omega_c t + \phi_n) \\ &= \sum (\cos \phi_n \cos \omega_c t - \sin \phi_n \sin \omega_c t) \\ &= \sum (\cos \phi_n \cos \omega_c t) - \sum (\sin \phi_n \sin \omega_c t) \\ &= \sum (A(t) \cos \omega_c t) - \sum (B(t) \sin \omega_c t) \end{aligned}$$



- Two signals: cos and sin $\rightarrow 90^\circ$ phase difference

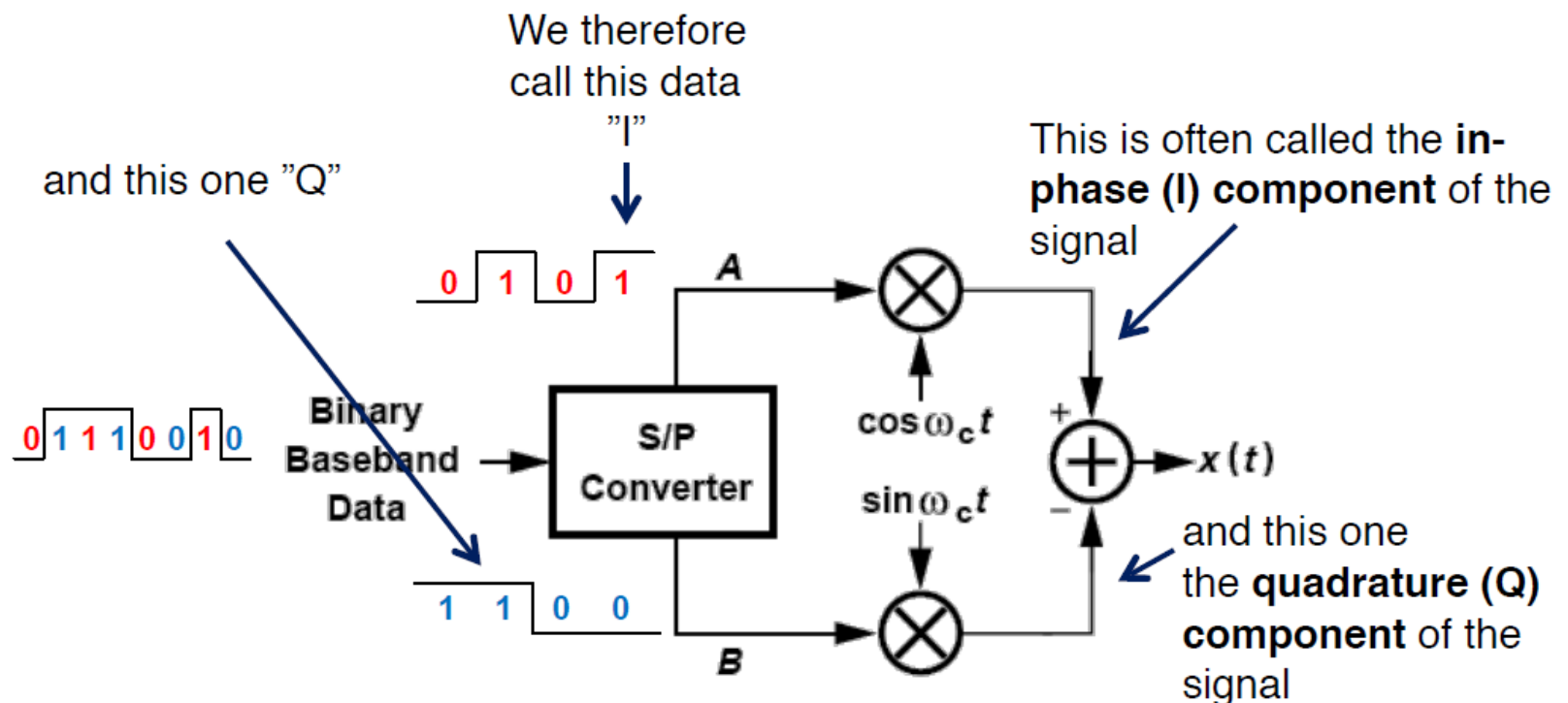
Analog & Digital Modulation

- Quadrature Modulation
 - QPSK $\cong$ two sum of two BPSK signals
 - Incoming data is first divided into two slower bit streams
 - Each are BPSK modulated with **cos** or **sin**
 - Outputs are added



Analog & Digital Modulation

- Quadrature Modulation



Thank you

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