Phase Shift Keying (Modulation)

Prof. Hyunggon Park

Email: hyunggon.park@ewha.ac.kr
Homepage: http://mcnl.ewha.ac.kr

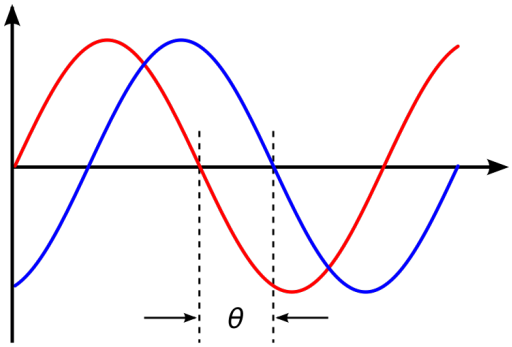
Multimedia Communications and Networking Lab.
Department of Electronic and Electrical Engineering
Ewha Womans University

Revisit: Phase

- Offset in the displacement from a specified reference point at time $t = 0$
- For a sinusoidal signal,

$$x(t) = A \cdot \sin(2\pi f t + \theta)$$

Amplitude — Carrier frequency — Phase



- Example:
  - $\cos(2\pi f t) = \sin(2\pi f t + \frac{\pi}{2})$: phase-shift between cosine and sine functions is $\pi/2$

Terms: in- and quadrature- phase

- You may encounter in-phase and quadrature-phase in studying communication theories.
- Consider two sinusoidal signals:

$$A(t)\sin(2\pi ft+\varphi(t)) = I(t)\sin(2\pi ft)+Q(t)\sin(2\pi ft+\frac{\pi}{2})$$
$$A(t)\cos(2\pi ft+\varphi(t)) = I(t)\cos(2\pi ft)+Q(t)\cos(2\pi ft+\frac{\pi}{2})$$

where

$$I(t)=A(t)\cos(\varphi(t)),\ \ Q(t)=A(t)\sin(\varphi(t)),$$

- Same phase with carrier: in-phase component $I(t)$
- $2\pi/4$ out of phase from carrier: quadrature-phase component $Q(t)$

PSK - Phase Shift Keying

- PSK sends digital data
  - Changing phase of a carrier frequency
  - Selecting a finite set of phases

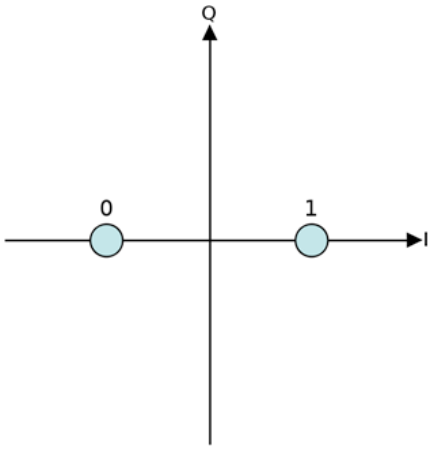
$$s_b(t) = A\cos(2\pi ft+\varphi(t))$$

$s_b(t)$: PSK Symbols

$\varphi(t)$: Set of distinct number of phases

BPSK - Binary PSK

- Use two phases
- Q: What would be the best phase selection?
- A: 0 and 180 degrees
- Q: Why?
- A: Can minimize the ambiguity between two phases
- Constellation:



BPSK

- Expression:

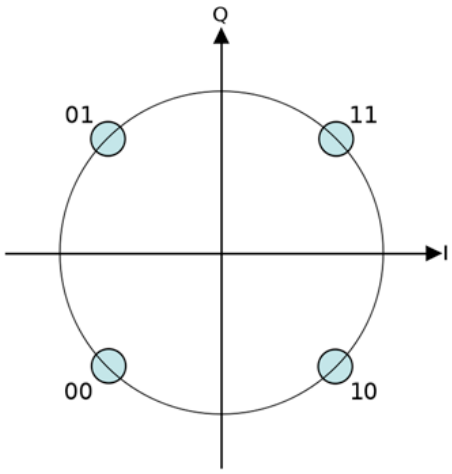
$$s_i(t) = A\cos(2\pi ft + \pi(1-i)),\ \ i = 0, 1$$
$$s_0(t) = A\cos(2\pi ft + \pi) = -A\cos(2\pi ft)$$
$$s_1(t) = A\cos(2\pi ft)$$

- Thus, basis function is $\phi(t) = A\cos(2\pi ft)$
  - i.e.,

$$s_0(t) = -\phi(t),\ \ s_1(t) = \phi(t)$$

QPSK - Quadrature PSK

- Use four phases
- Q: What would be the best phase selection?
- A: 45, 135, 225, and 315 degrees
- Q: Why?
- A: Can minimize the ambiguity among four phases
- Constellation:



QPSK

- Expression:

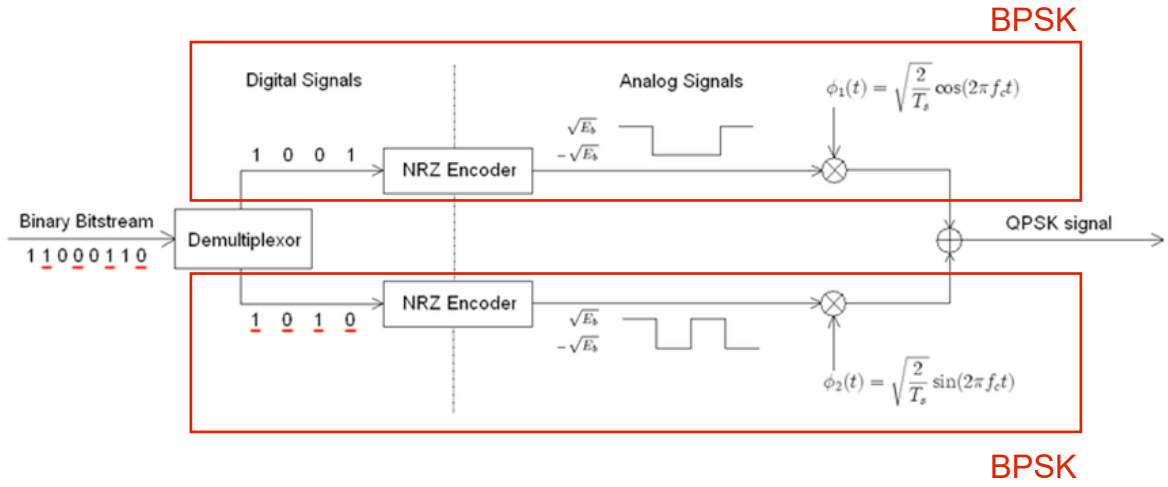
$$s_i(t) = A\cos(2\pi ft + \frac{\pi}{4}(2i-1)),\ \ i = 1,2,3,4$$

$$i = 1,2,3,4 \Rightarrow \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4}$$

- Basis functions are:

$$\phi_1(t) = A\cos(2\pi ft),\ \ \phi_2(t) = A\sin(2\pi ft)$$

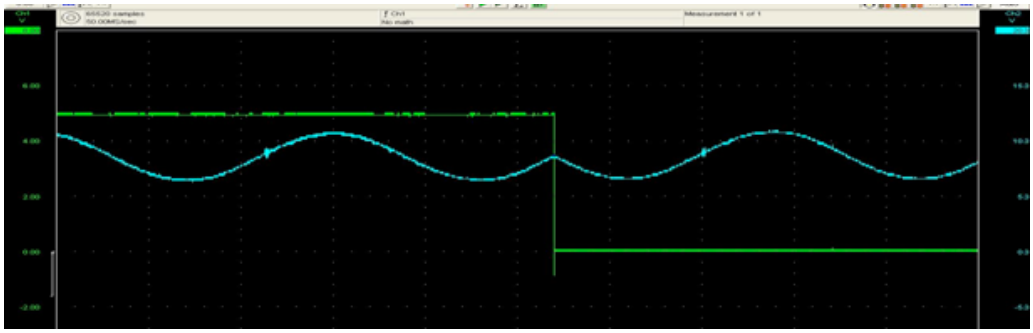
QPSK

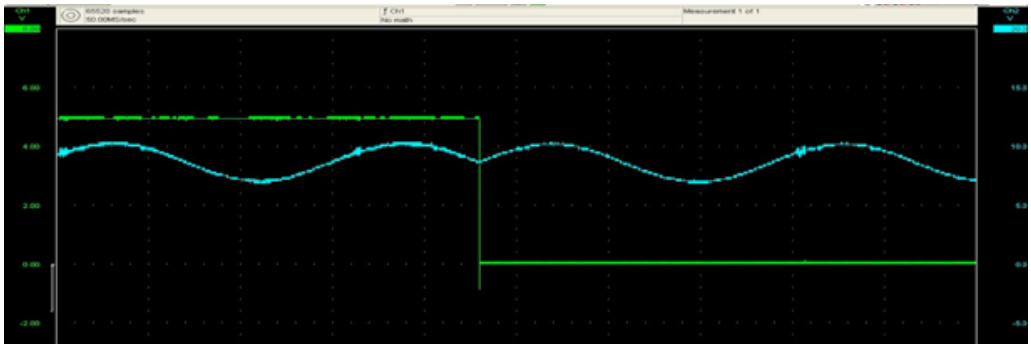


→ QPSK can be considered as two independent BPSKs!

Potential Results

- Try to observe phase changes when input signals are changing





Potential Results

- Based on different line encoding types: