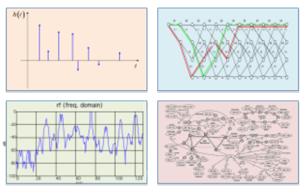


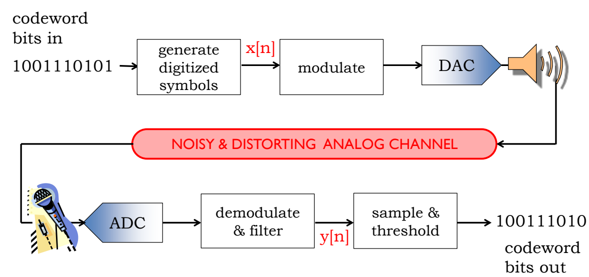
INTRODUCTION TO EECS II

DIGITAL COMMUNICATION SYSTEMS

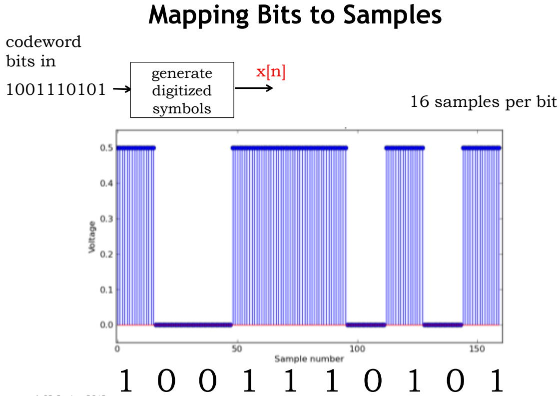
6.02 Spring 2012
Lecture #9

- Transmitting on a Physical Channel
- Bits to Samples
- Modulation and Demodulation
- Eye Diagrams

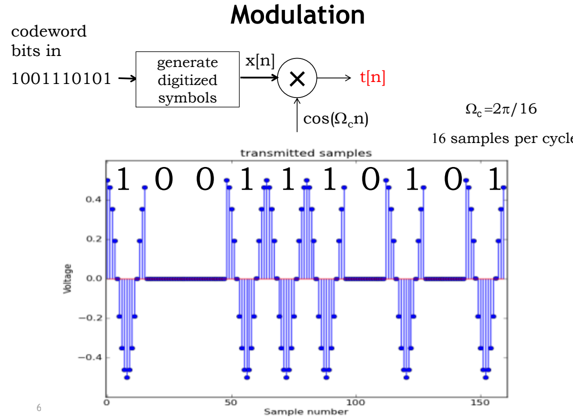
From Bits to Modulated Signal, and Back



Mapping Bits to Samples

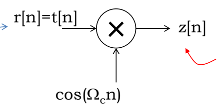


Modulation



Demodulation

Assuming no distortion or noise on channel, so what was transmitted is received



Hmm. So z[n] has what we want, but also has signal we don't want at $\pm 2\Omega_c$

$$z[n] = t[n]\cos(\Omega_c n)$$

$$z[n] = x[n]\cos(\Omega_c n)\cos(\Omega_c n)$$

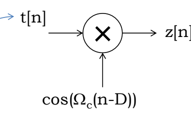
$$z[n] = 0.5x[n](1+\cos(2\Omega_c n))$$

$$z[n] = 0.5x[n] + 0.5x[n]\cos(2\Omega_c n)$$

What we want

Demodulation with phase offset

Assuming no distortion or noise on channel, so what was transmitted is received except delay



$$z[n] = t[n]\cos(\Omega_c(n-D))$$

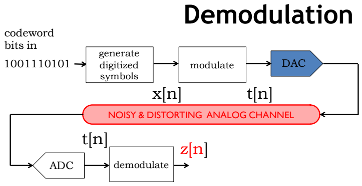
$$z[n] = x[n]\cos(\Omega_c n)\cos(\Omega_c(n-D))$$

$$z[n] = 0.5x[n]\cos(\Omega_c D) + 0.5x[n]\cos(2\Omega_c n - \Omega_c D)$$

What we want – except the $\cos(\Omega_c D)$ factor

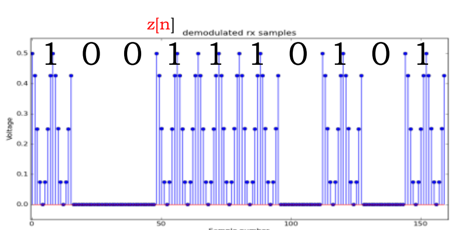
What happens when $\Omega_c D$ becomes $\pi/2$?

Demodulation

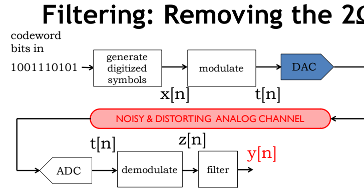


$\Omega_c = 2\pi/16$

16 samples per cycle

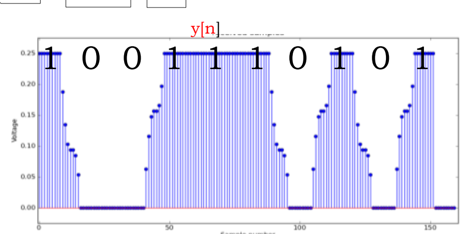


Filtering: Removing the $2\Omega_c$ component

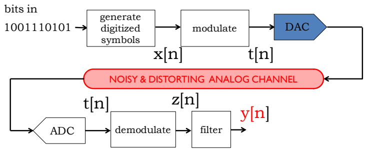


$\Omega_c = 2\pi/16$

16 samples per cycle



Averaging filter



$\Omega_c = 2\pi/16$

16 samples per cycle

y[n] = z[n]+…+z[n-L], L+1 length of the averaging filter

For L+1=8, $2\Omega_c$ component is at $2\pi/8$, which is 8 samples per cycle

So, the $\Sigma \cos(2\pi/8*(n-k)) = 0$ for k=0,…,L and the $2\Omega_c$ gets integrated out*

*Things get integrated out in regions where x[n] is constant for L+1 samples
At transitions, there is a bit of degradation, but we make decisions on the middle samples

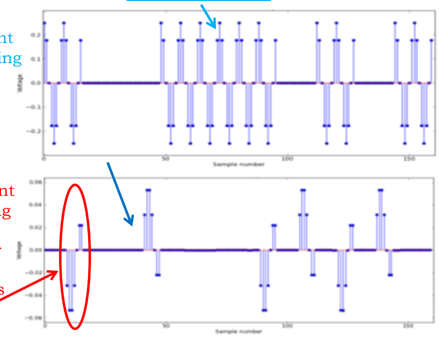
Averaging filter in action

$$z[n] = 0.5x[n] + \boxed{0.5x[n]\cos(2\Omega_c n)}$$

$2\Omega_c$ component before averaging

$2\Omega_c$ component after averaging

residual error only at bit to bit transitions



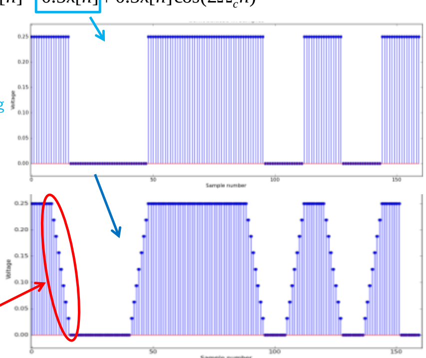
Averaging filter in action

$$z[n] = \boxed{0.5x[n]} + 0.5x[n]\cos(2\Omega_c n)$$

desired component before averaging

desired component after averaging

residual error only at bit to bit transitions



Averaging filter in action

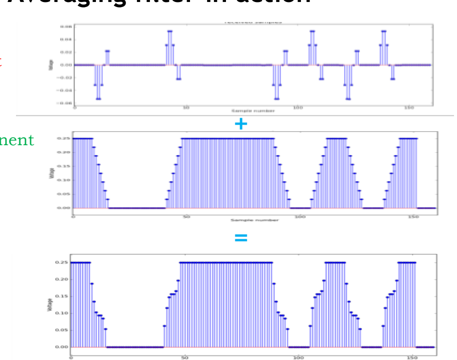
$2\Omega_c$ component after averaging

+

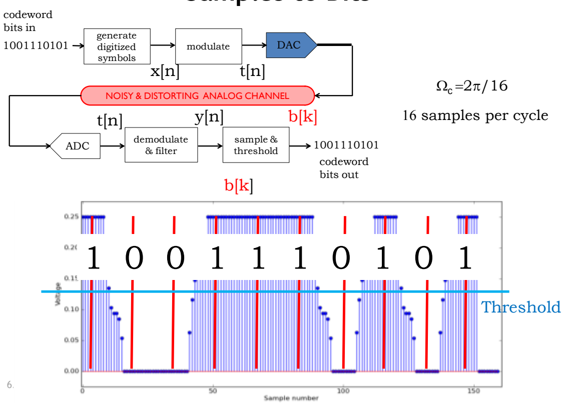
Desired component after averaging

=

Output of the averaging filter



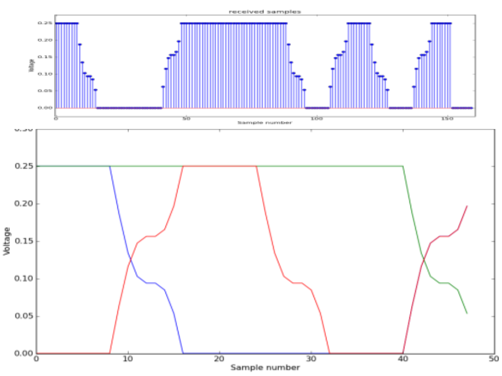
Samples to Bits



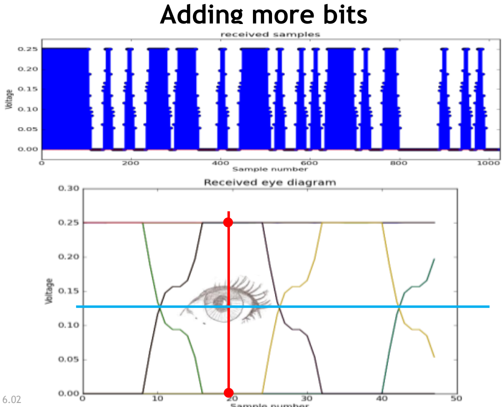
$\Omega_c = 2\pi/16$

16 samples per cycle

Eye Diagram



Adding more bits



Spot quiz

Horizontal grid is 1 μs

1. What is the **slowest** bit rate on this diagram?
   Longest Tb = 2 μs, hence slowest bit rate is 1/Tb = 1bit/2 μs = 500kb/s
2. If the sampling rate is 10 samples per bit, what is the sampling interval in μs?
   Ts = Tb/10 = 0.2 μs
3. What binary digits does this waveform represent at the slowest bit rate (assume on/off modulation)?
   1 0 0 1 1