Principles of Communications
ECS 332

Dr. Prapun Suksompong

prapun@siit.tu.ac.th

9.1 Analog Pulse Modulation

Office Hours:
BKD 3601-7
Monday 14:40-16:00
Friday 14:00-16:00

Naturally digital information

- Text is commonly encoded using ASCII, and MATLAB automatically represents any string file as a list of ASCII numbers.

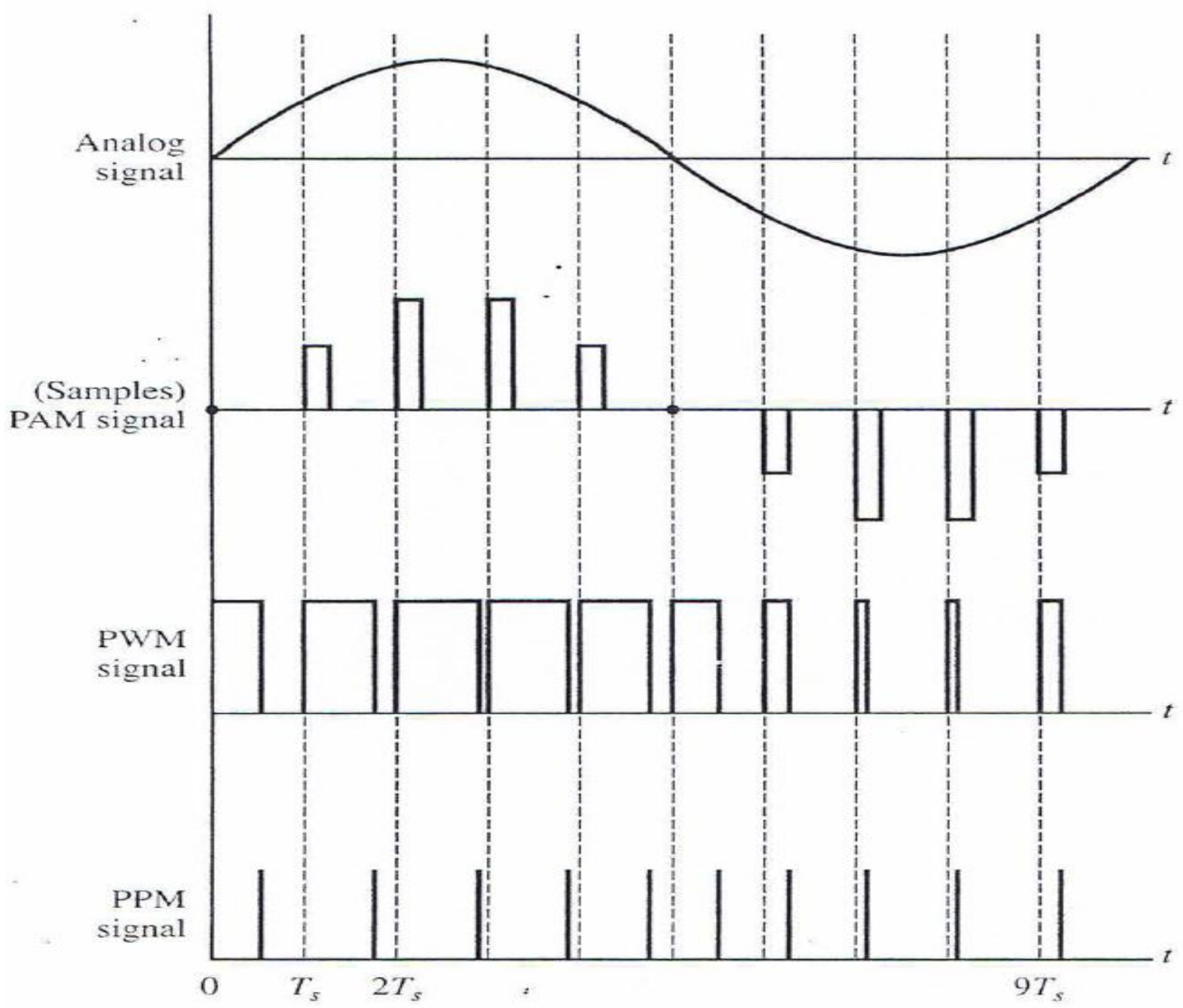
```
>> str='I love ECS332';
>> real(str)

ans =

    73    32   108   111   118   101    32    69    67    83    51    51    50

>> dec2base(str,2)

ans =

1001001
0100000
1101100
1101111
1110110
1100101
0100000
1000101
1000011
1010011
0110011
0110011
0110010
```

text string

(decimal) ASCII representation of the text string

binary (base 2) representation of the decimal numbers

Illustration of PAM, PWM, and PPM



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9.2 Nyquist Pulse Shaping

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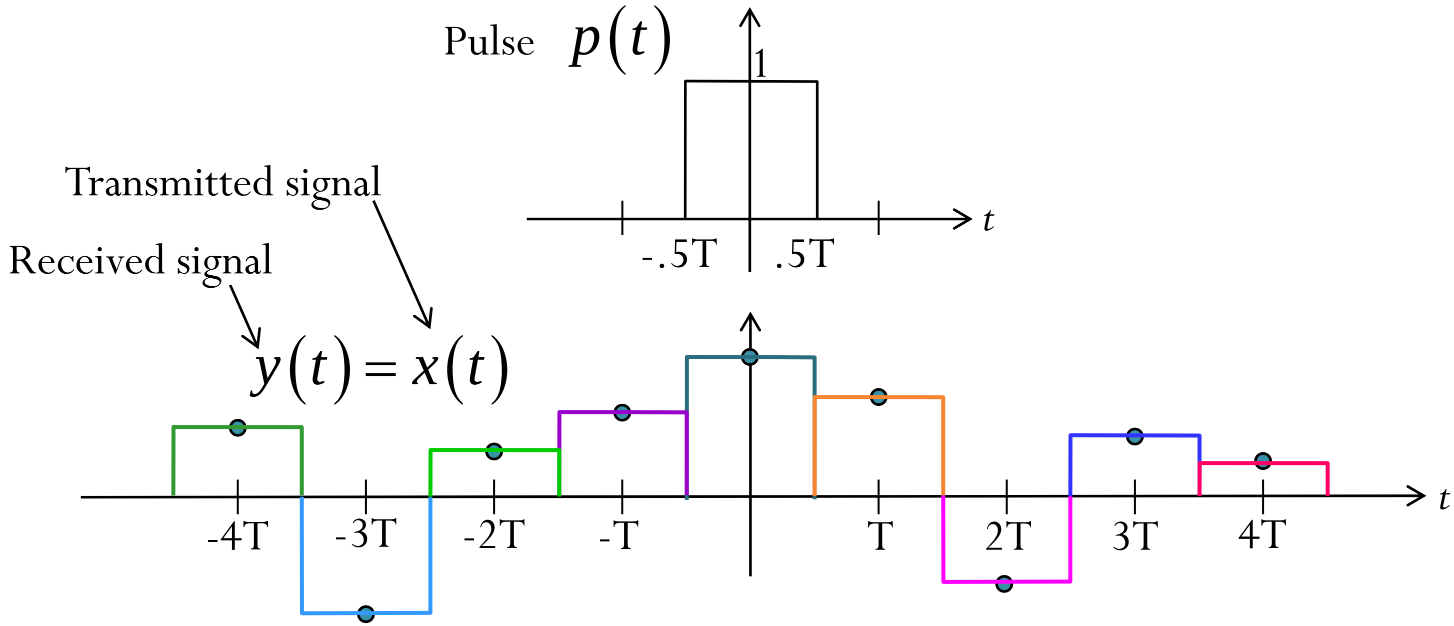
PAM: Pulse Amplitude Modulation



$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

$$\hat{m}[n] = y(t)\big|_{t=nT} = x(t)\big|_{t=nT}$$

$$\vdots$$

$$\hat{m}[-1] = m[-1]$$

$$\hat{m}[0] = m[0]$$

$$\hat{m}[1] = m[1]$$

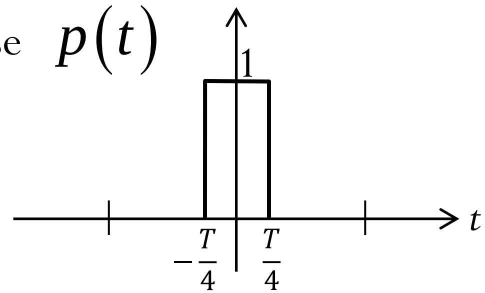
$$\vdots$$

$$\tilde{m}[n] = m[n]$$

No ISI

PAM: Pulse Amplitude Modulation

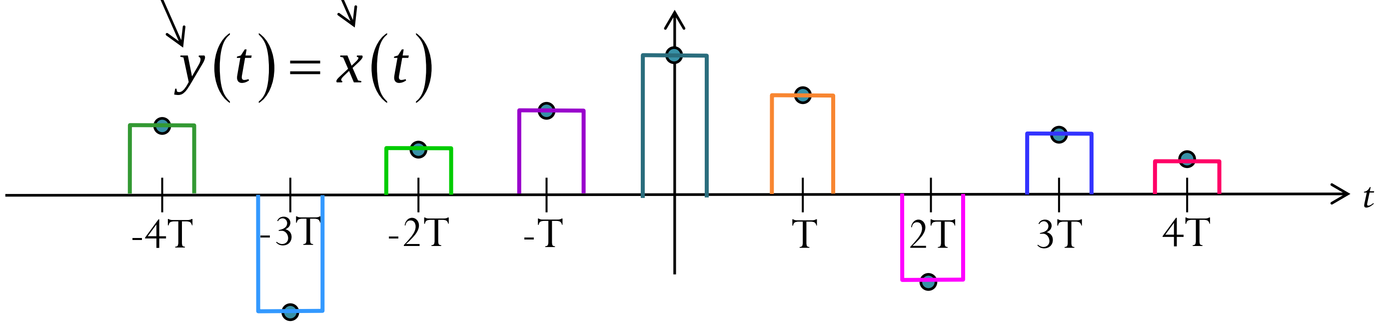
Pulse $p(t)$



Transmitted signal

Received signal

$y(t) = x(t)$



$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

$$\hat{m}[n] = y(t)\big|_{t=nT} = x(t)\big|_{t=nT}$$

$$\vdots$$

$$\hat{m}[-1] = m[-1]$$

$$\hat{m}[0] = m[0]$$

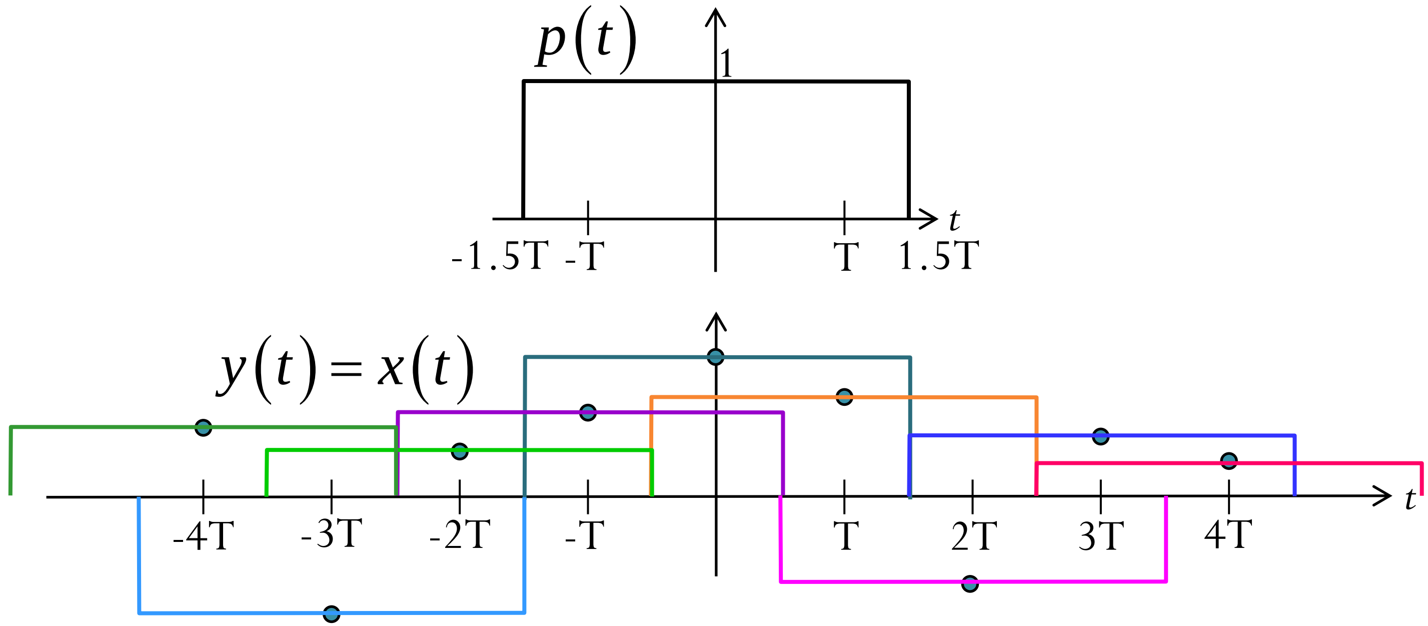
$$\hat{m}[1] = m[1]$$

$$\vdots$$

$$\hat{m}[n] = m[n]$$

No ISI

ISI Inter-Symbol Interference



$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\,p(t-nT)$$

$$\hat{m}[n] = y(t)\big|_{t=nT} = x(t)\big|_{t=nT}$$

$$\vdots$$

$$\hat{m}[-1] = m[-2] + m[-1] + m[0]$$

$$\hat{m}[0] = m[-1] + m[0] + m[1]$$

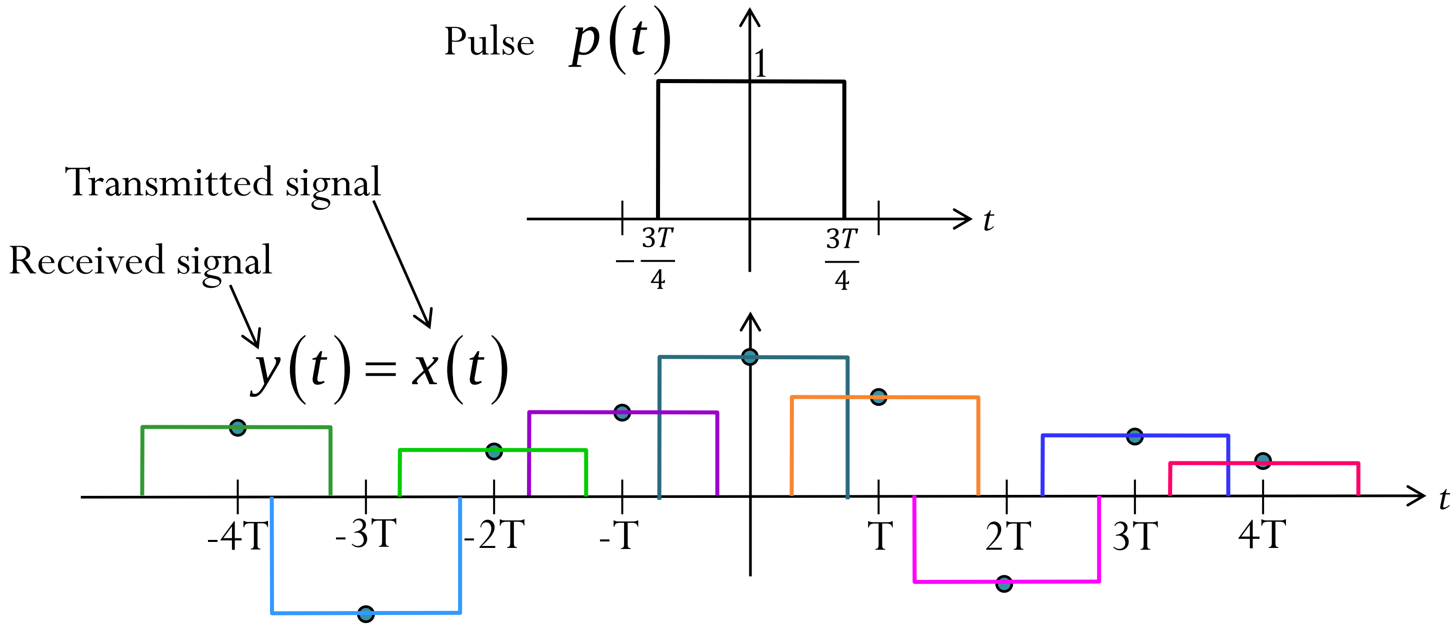
$$\hat{m}[1] = m[0] + m[1] + m[2]$$

$$\vdots$$

$$\hat{m}[n] \neq m[n]$$

Suffer ISI

ISI Inter-Symbol Interference



$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

$$\hat{m}[n] = y(t)\big|_{t=nT} = x(t)\big|_{t=nT}$$

$$\vdots$$

$$\hat{m}[-1] = m[-1]$$

$$\hat{m}[0] = m[0]$$

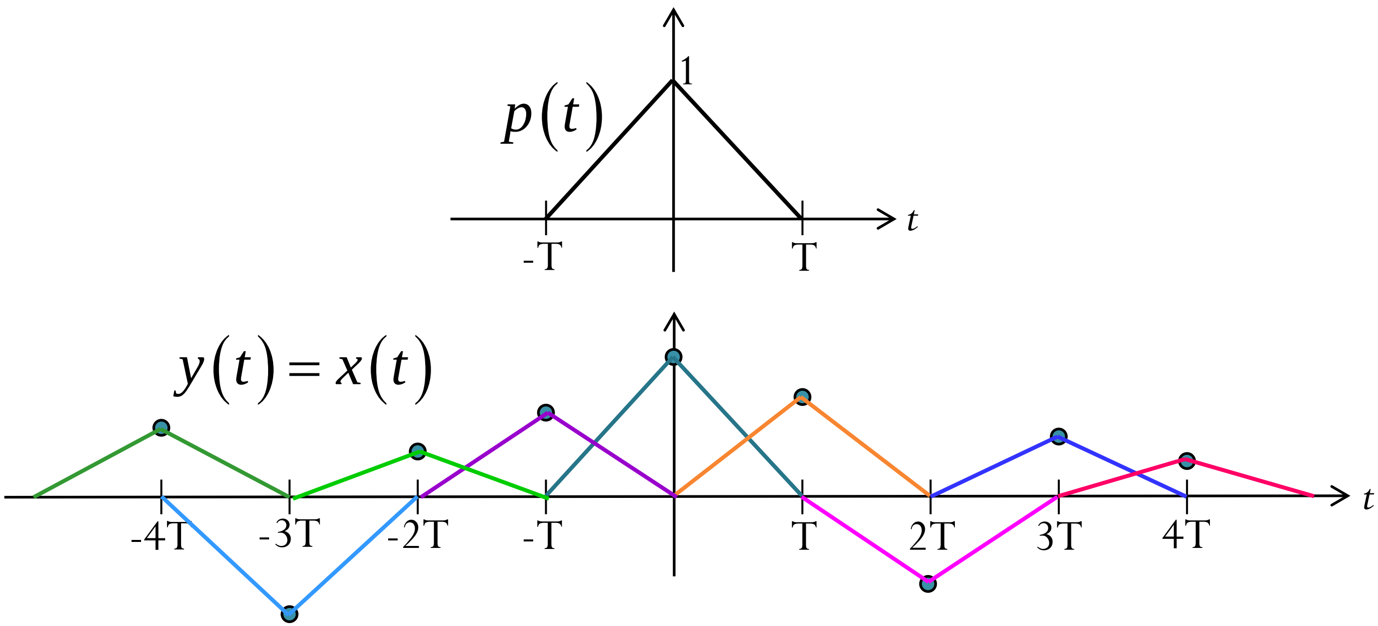
$$\hat{m}[1] = m[1]$$

$$\vdots$$

$$\hat{m}[n] = m[n]$$

No ISI

ISI Inter-Symbol Interference



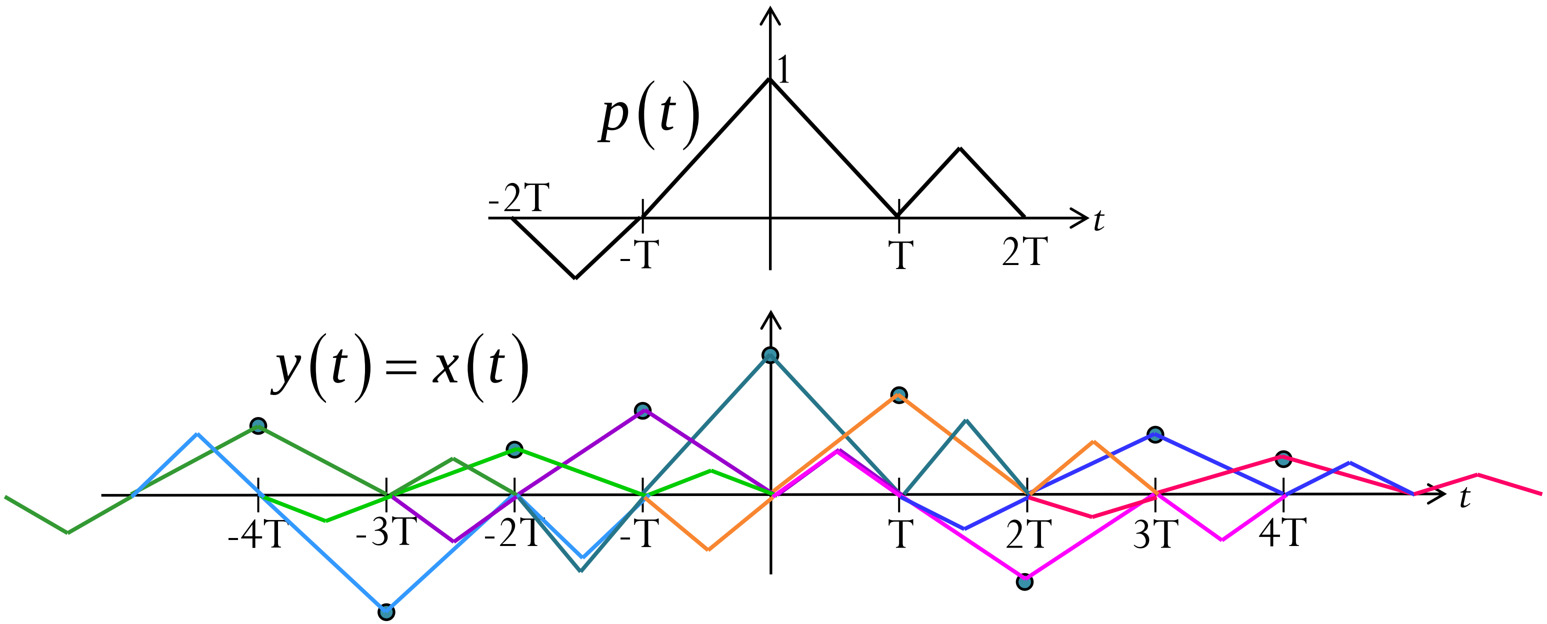
$$x(t)=\sum_{n=-\infty}^{\infty} m[n]\,p(t-nT)$$

$$\hat{m}[n]=y(t)\big|_{t=nT}=x(t)\big|_{t=nT}$$

$$\hat{m}[n]=m[n]$$

No ISI

ISI Inter-Symbol Interference



$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\,p(t-nT)$$

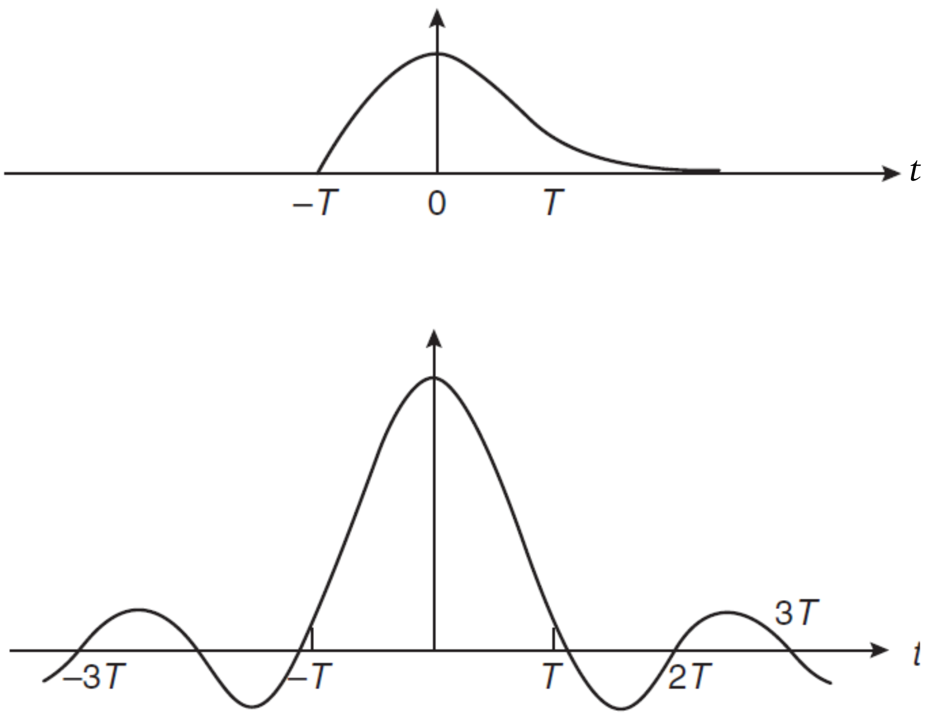
$$\hat{m}[n] = y(t)\big|_{t=nT} = x(t)\big|_{t=nT}$$

$$\hat{m}[n] = m[n]$$

No ISI

ISI

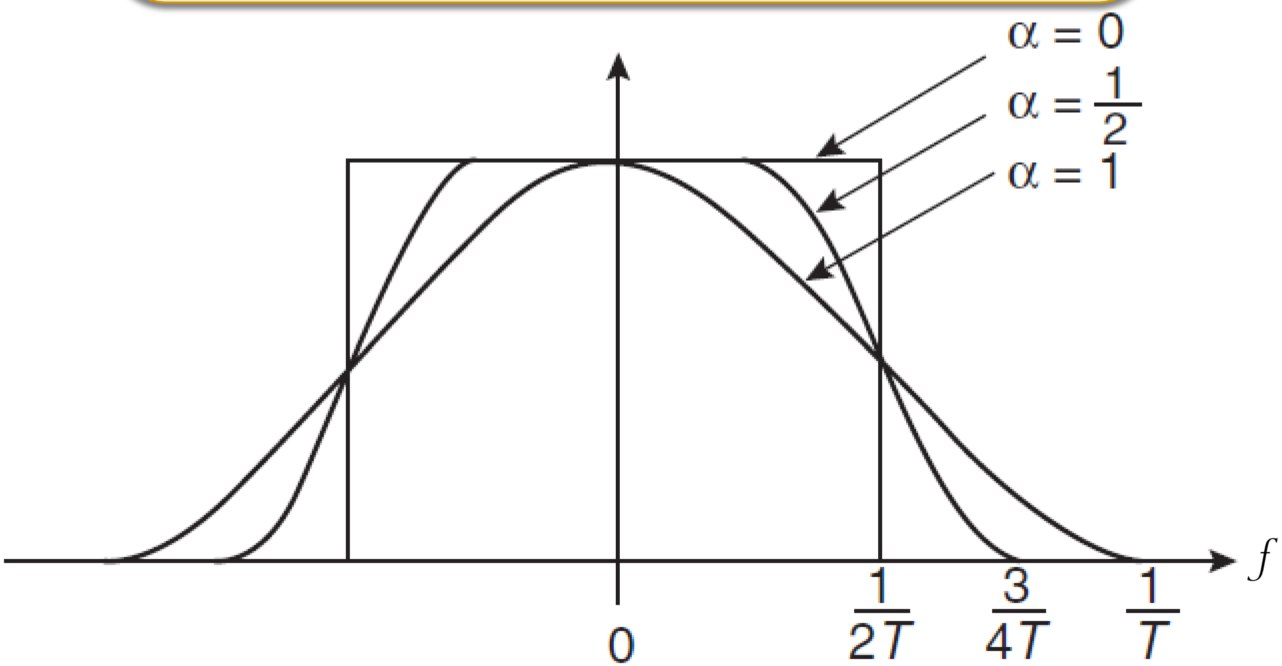
- Some pulses displaying intersymbol interference.



[Blahut, 2008, Fig 2.8]

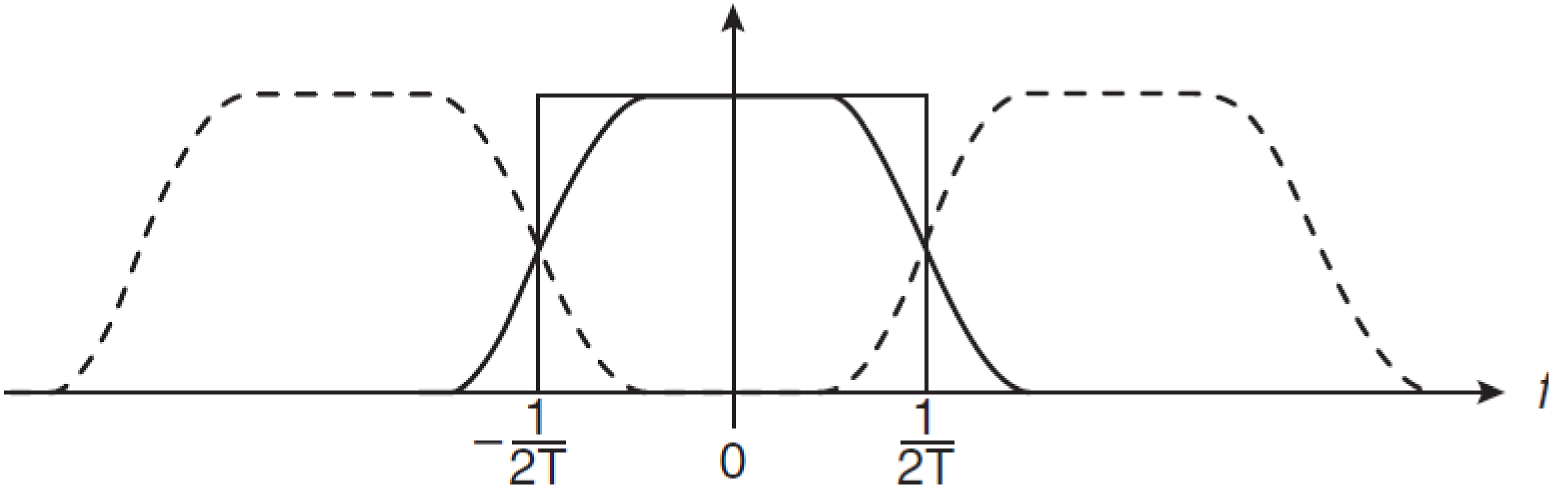
Spectra of Raised Cosine Pulses

$$P_{\mathrm{RC}}(f;\alpha)=\begin{cases} T, & 0\le |f| \le \frac{1-\alpha}{2T} \\ \frac{T}{2}\left(1+\cos\left(\frac{\pi T}{\alpha}\left(|f|-\frac{1-\alpha}{2T}\right)\right)\right), & \frac{1-\alpha}{2T}\le |f| \le \frac{1+\alpha}{2T} \\ 0, & |f|\ge \frac{1+\alpha}{2T} \end{cases}$$



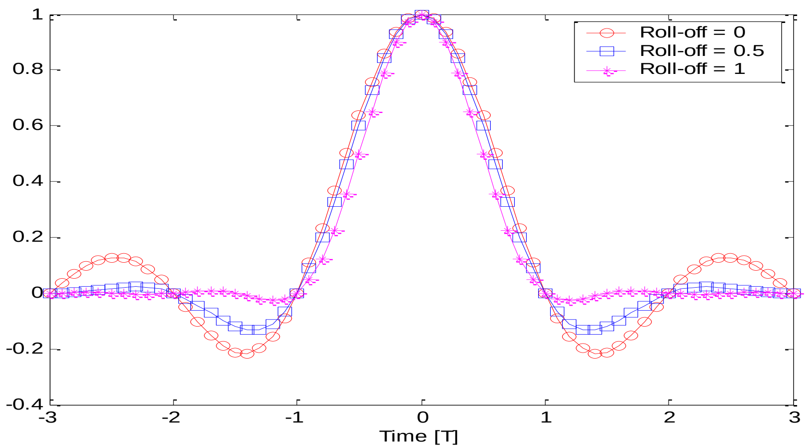
[Blahut, 2008, Fig 2.10]

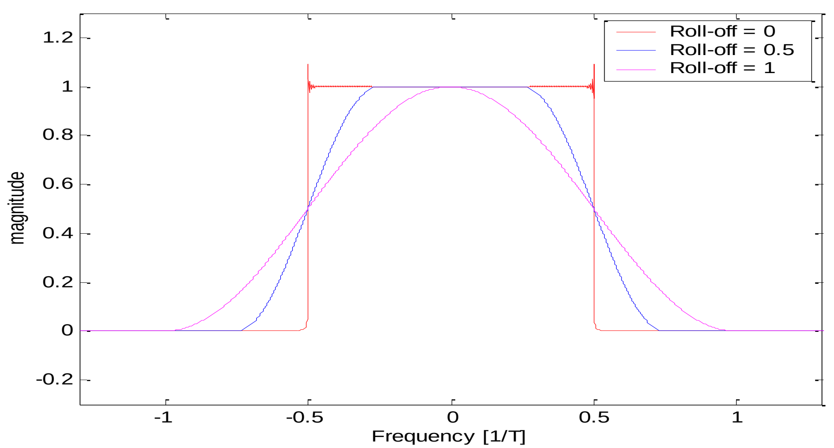
Ny quist criterion



[Blahut, 2008, Fig 2.9]

Raised Cosine Pulses





For fixed nonzero α, the tails decay as $1/t^3$ for large $|t|$.

Although the pulse tails persist for an infinite time, they are eventually small enough so they can be truncated with only negligible perturbations of the zero crossings.

$$p_{\mathrm{RC}}(t;\alpha) = \frac{\cos\frac{\alpha\pi t}{T}}{1-\frac{4\alpha^2 t^2}{T^2}}\operatorname{sinc}\frac{\pi t}{T} = \frac{\cos\frac{\alpha\pi t}{T}}{1-\frac{4\alpha^2 t^2}{T^2}}\frac{\sin\frac{\pi t}{T}}{\frac{\pi t}{T}}$$

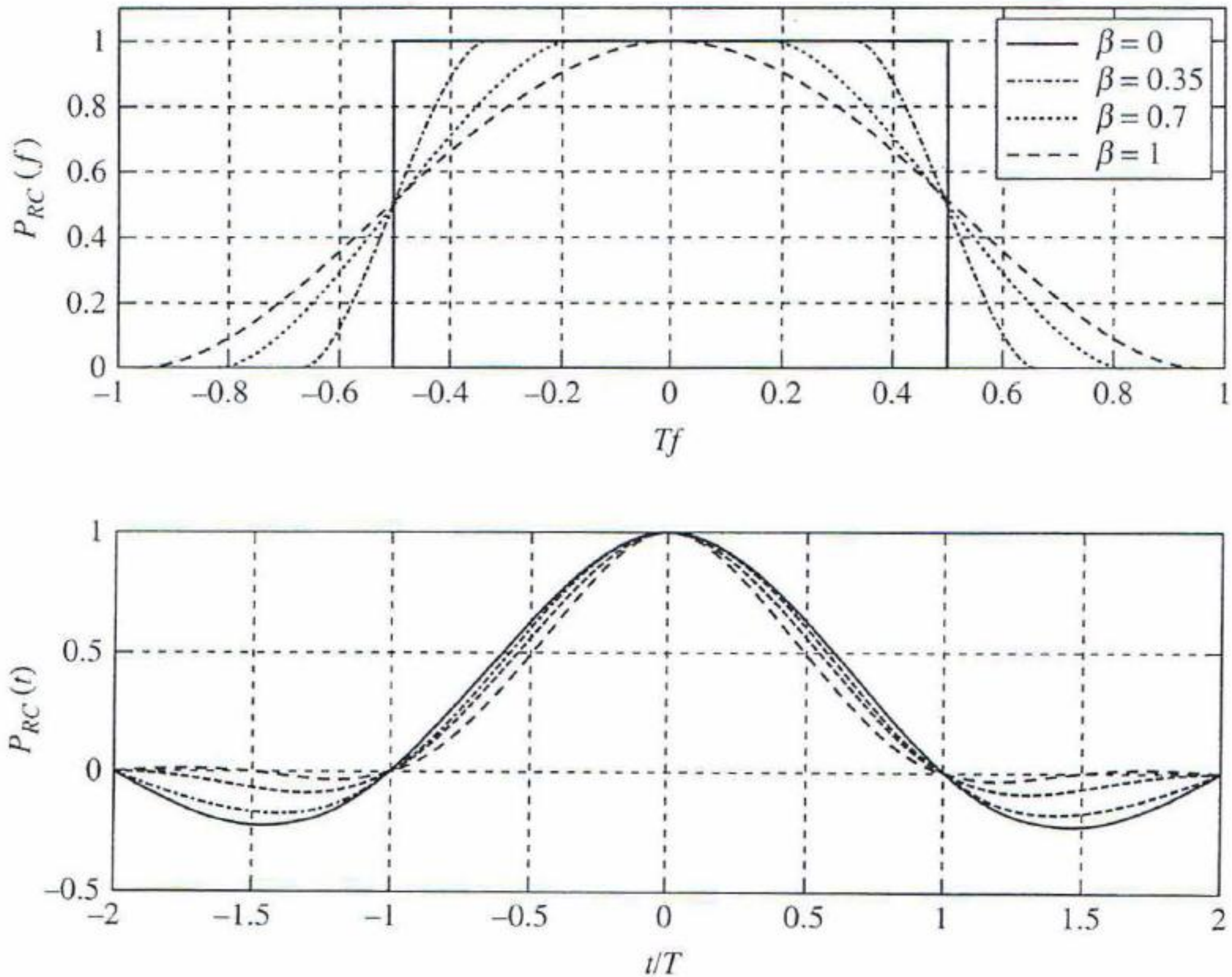
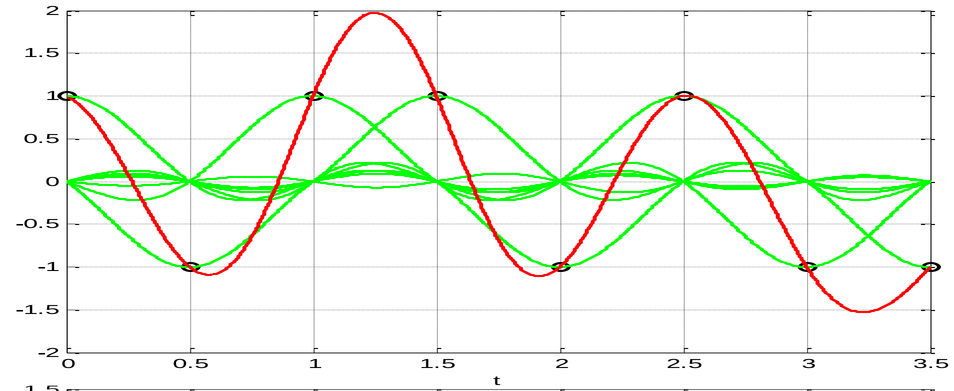


Figure 4.7
(a) Raised cosine spectra and (b) corresponding pulse responses.

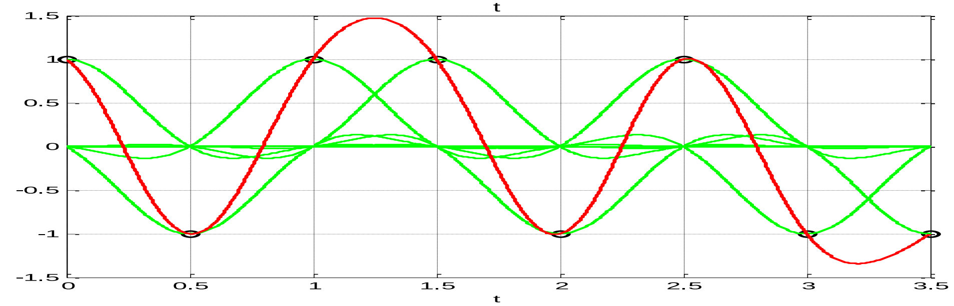
Ex.

$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

$$p(t) = p_{RC}(t;0)$$



$$p(t) = p_{RC}(t;0.5)$$



$$p(t) = p_{RC}(t;1)$$