Principles of Communications
ECS 332

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7. ISI and Pulse Shaping

Office Hours:

BKD, 4th floor of Sirindhralai building

Monday	**9:30-10:30**
Monday	**14:00-16:00**
Thursday	**16:00-17:00**

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

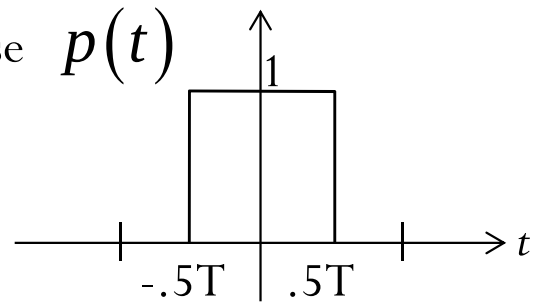
binary (base 2) representation of the decimal numbers

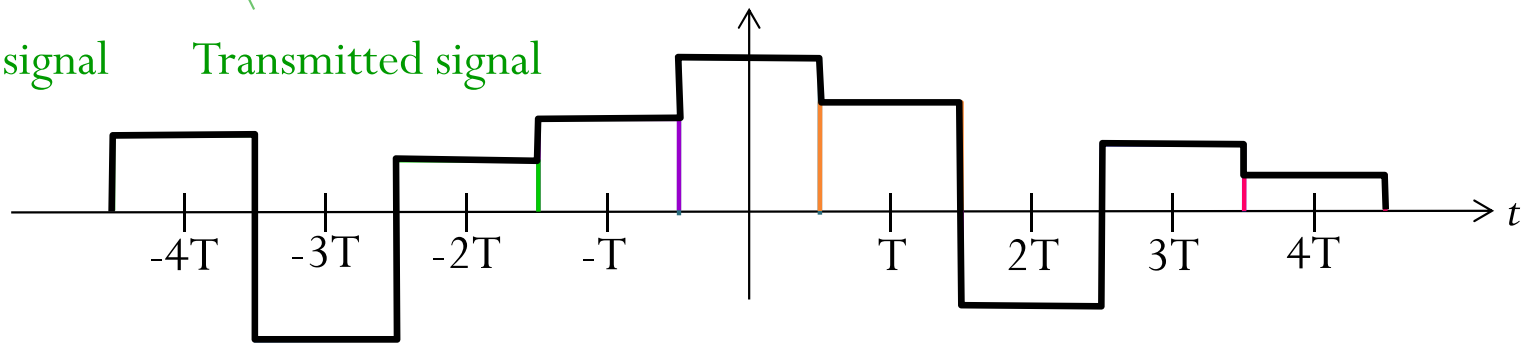
PAM: Pulse Amplitude Modulation

Assume

$$y(t) = x(t)$$

Received signal Transmitted signal



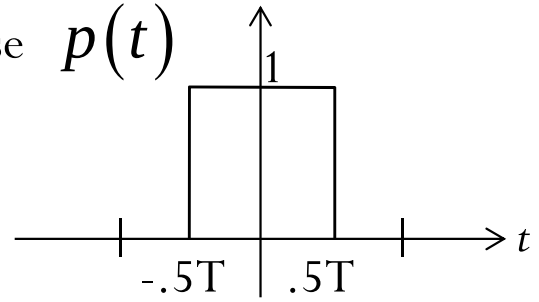


$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

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

PAM: Pulse Amplitude Modulation

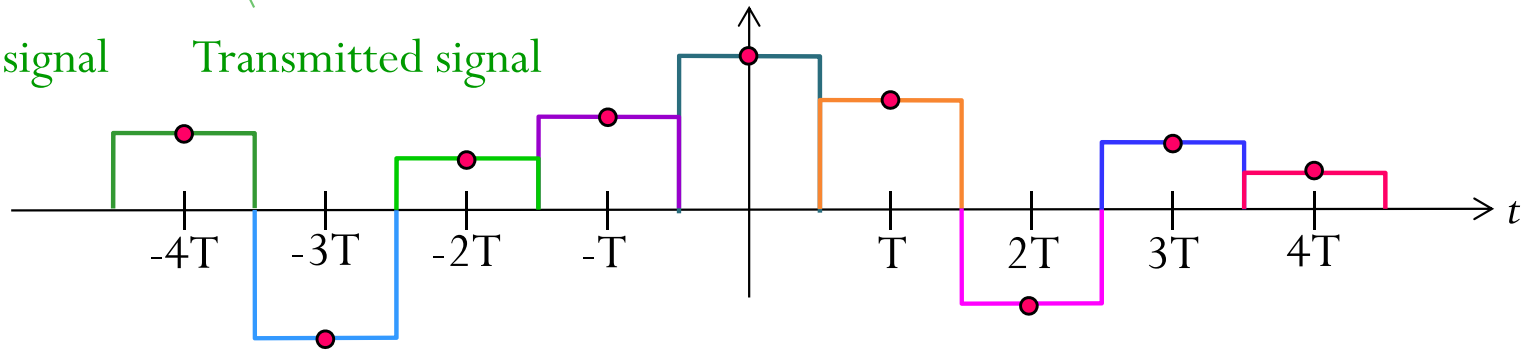
Pulse $p(t)$



Assume

$$y(t) = x(t)$$

Received signal — Transmitted signal



$$\vdots$$

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

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

Also assume

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

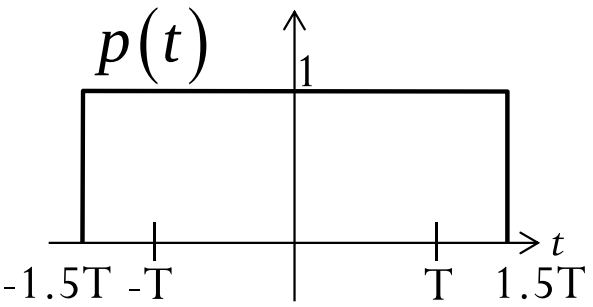
$$\tilde{m}[n] = m[n]$$

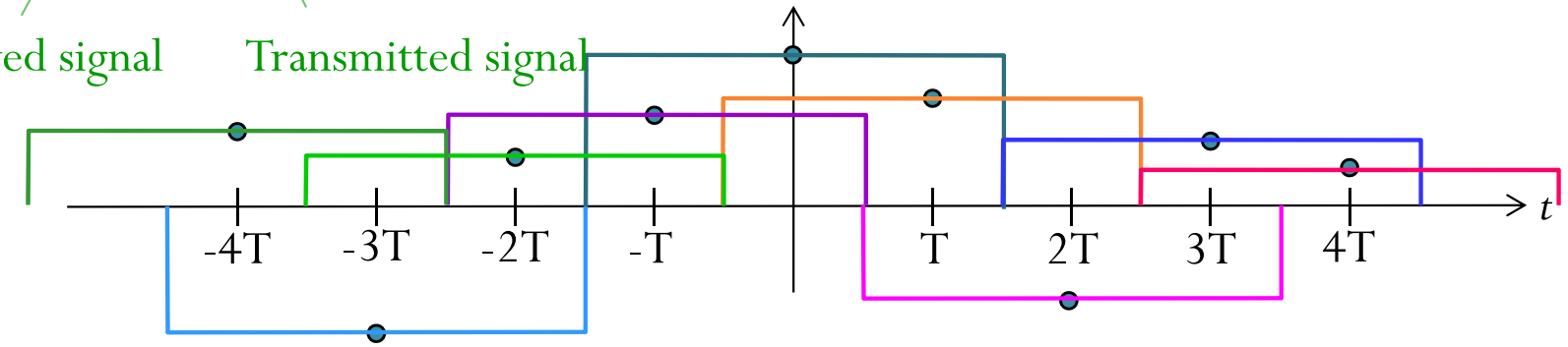
No ISI

ISI: Inter-Symbol Interference

$y(t) = x(t)$

Received signal Transmitted signal





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

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

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

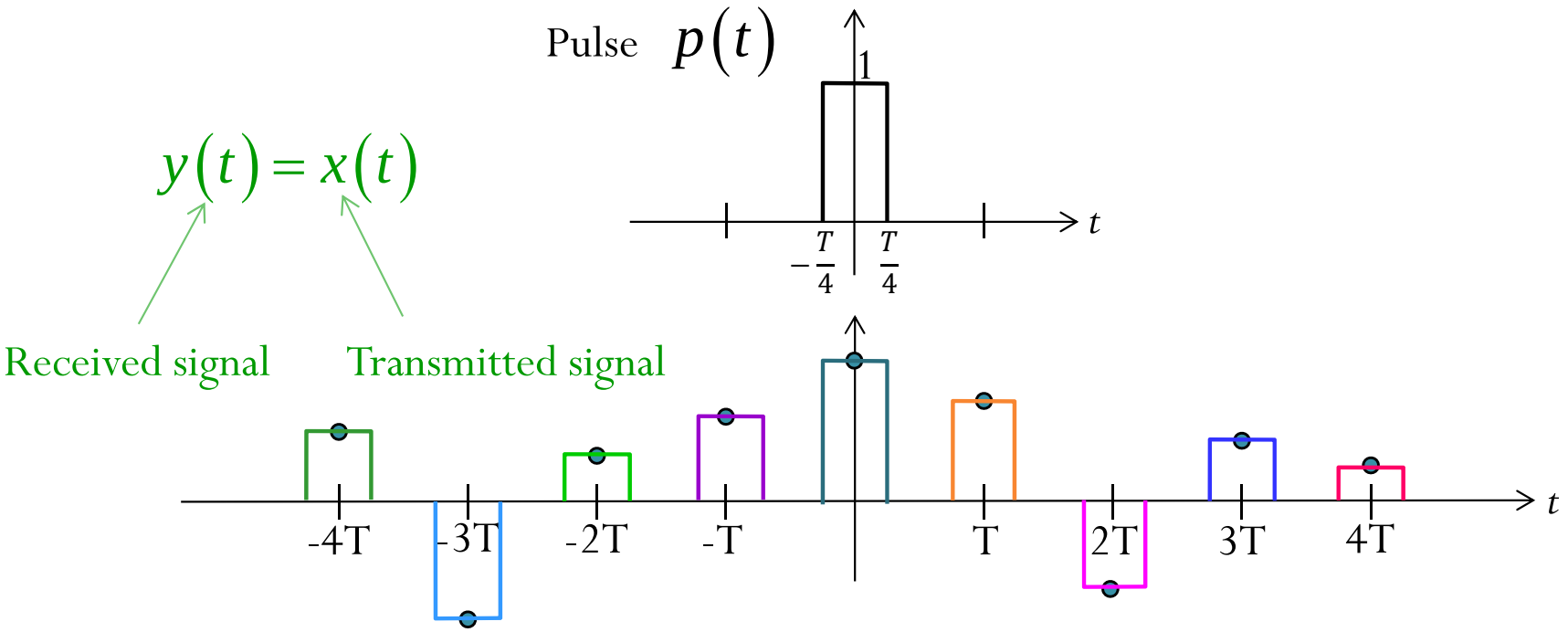
$$\hat{m}[0] = m[-1] + m[0] + m[1]$$

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

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

Suffer ISI

No-ISI Example



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

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

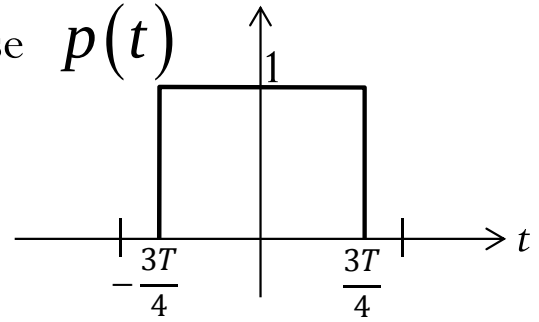
$$\hat{m}[-1] = m[-1]$$
$$\hat{m}[0] = m[0]$$
$$\hat{m}[1] = m[1]$$
$$\vdots$$

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

No ISI

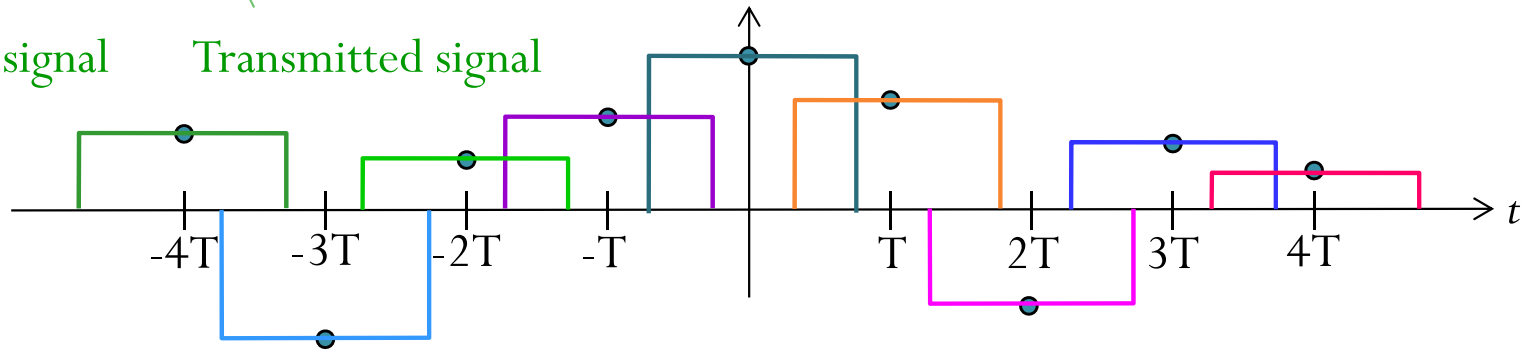
No-ISI Example

Pulse $p(t)$



$y(t) = x(t)$

Received signal Transmitted signal



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

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

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

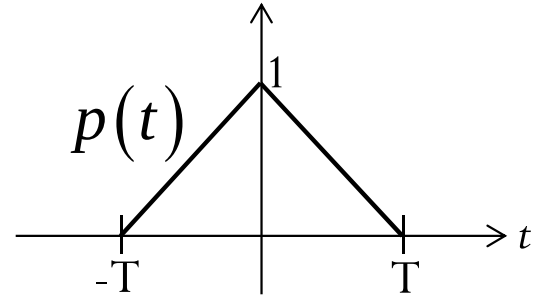
$$\hat{m}[n] = m[n]$$

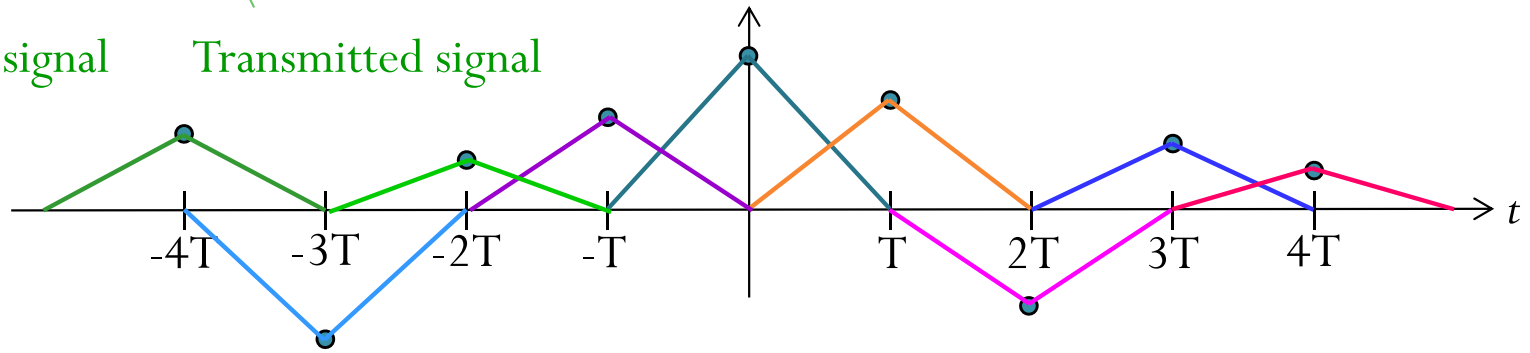
No ISI

No-ISI Example

$y(t) = x(t)$

Received signal Transmitted signal





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

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

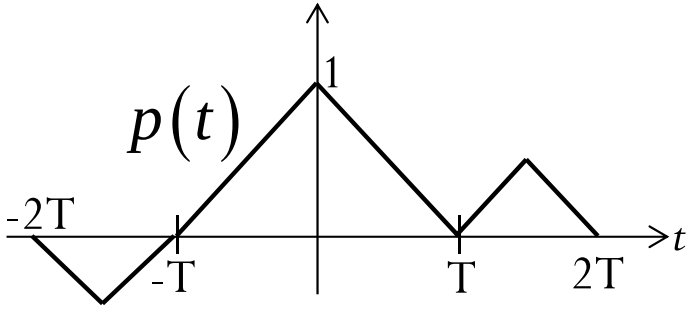
$$\hat{m}[n] = m[n]$$

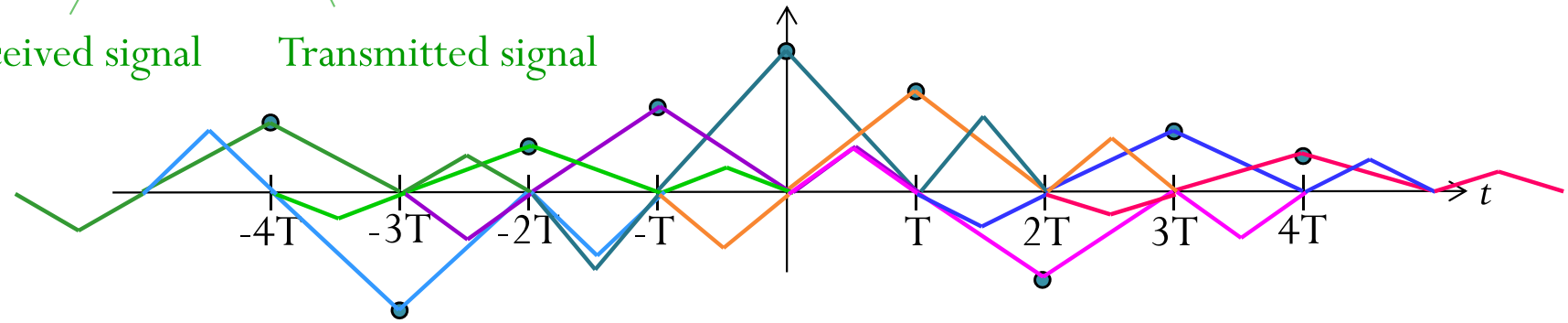
No ISI

No-ISI Example

$y(t) = x(t)$

Received signal Transmitted signal





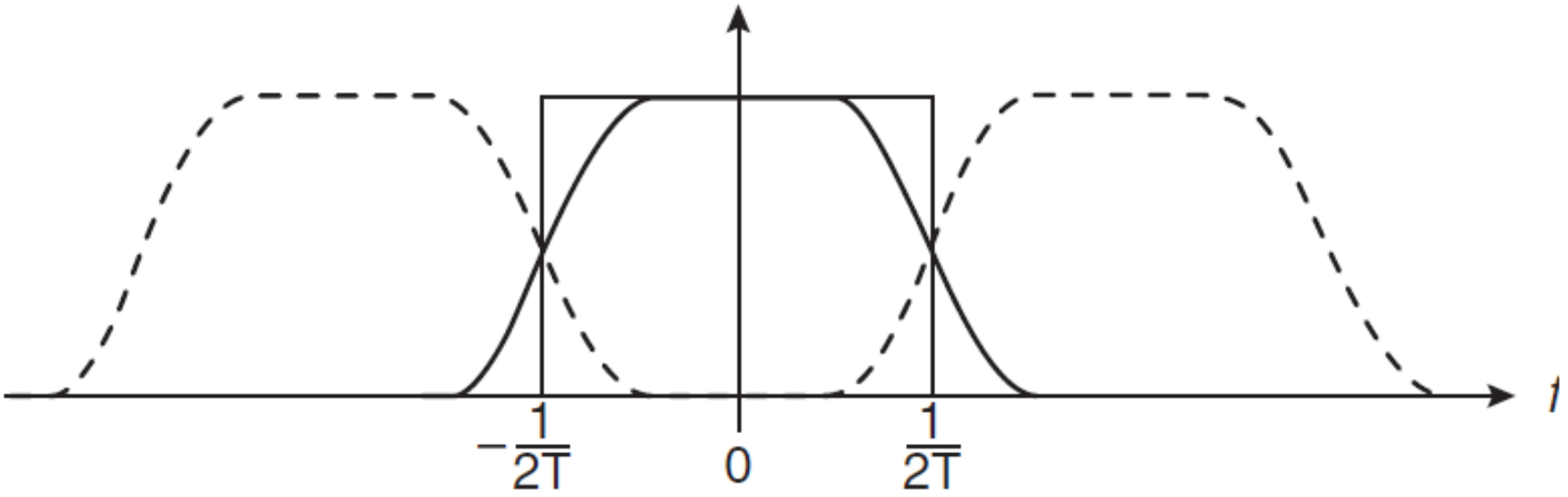
$$x(t) = \sum_{n=-\infty}^{\infty} m[n]\, p(t - nT)$$

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

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

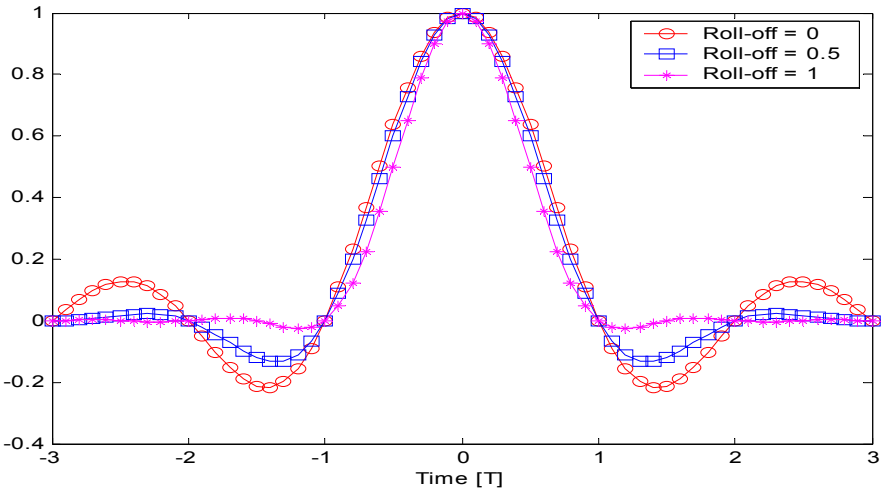
No ISI

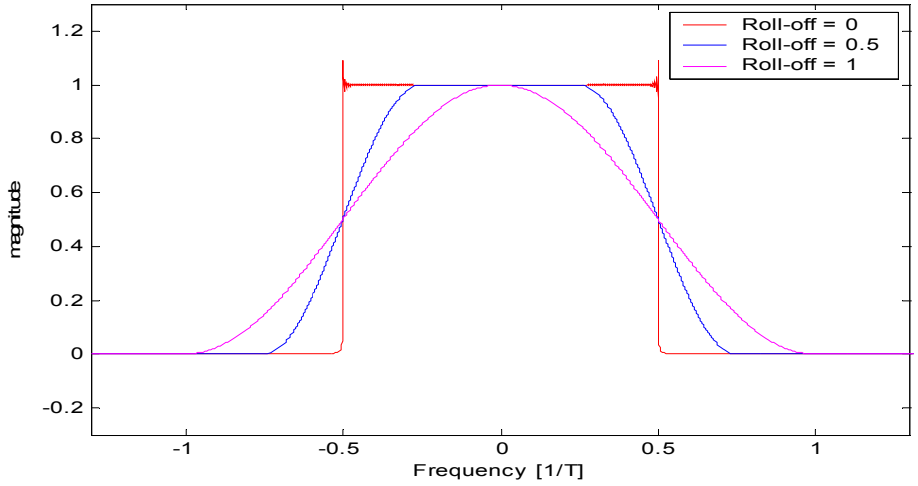
Nyquist criterion



[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.

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

$$= \frac{\cos\dfrac{\alpha\pi t}{T}}{1-\dfrac{4\alpha^2 t^2}{T^2}}\frac{\sin\dfrac{\pi t}{T}}{\dfrac{\pi t}{T}}$$