Introduction to Communications Engineering

IT4593E

Đỗ Công Thuần, Ph.D.

Dept. of CE, SoICT, HUST

Email: thuandc@soict.hust.edu.vn

Thông tin chung

- Tên học phần: **Nhập môn kỹ thuật truyền thông**
- Mã học phần: **IT4593E**
- Khối lượng: **2 TC (2-1-0-4)**
- Lý thuyết và bài tập: **10 buổi lý thuyết, 5 buổi bài tập**
- Đánh giá học phần:

  30% QT (kiểm tra + bài tập/project + chuyên cần-quiz)

  70% CK (trắc nghiệm + tự luận)
- Tài liệu tham khảo:
  - Lecture slides
  - Lecture notes
  - Textbooks, ví dụ ***Communication Systems Engineering***, 2nd Edition, by John G. Proakis Masoud Salehi
  - Internet

Part 2: Digital Modulations

Lec 10: Phase Shift Keying (PSK)

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2-PSK: characteristics

1. Bandpass modulation
2. One-dimensional signal space and antipodal binary constellation (equal to 2-PAM)
3. TX filter $p(t)cos(2\pi f_0 t)$
4. Information associated to the carrier phase = Phase Shift Keying

2-PSK: constellation

SIGNAL SET $M = \{s_1(t) = +\alpha\, p(t)\cos(2\pi f_0 t)\,,\; s_2(t) = -\alpha\, p(t)\cos(2\pi f_0 t)\,\}$

Information associated to the impulse amplitude
BUT
we can also write

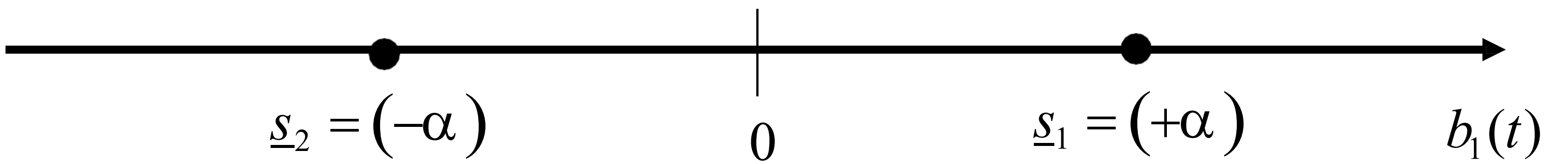
SIGNAL SET $\boxed{M = \{s_1(t) = +\alpha\, p(t)\cos(2\pi f_0 t)\,,\; s_2(t) = +\alpha\, p(t)\cos(2\pi f_0 t - \pi)\,\}}$

Information associated to the carrier phase

2-PSK: constellation

Vector $b_1(t)=p(t)\cos(2\pi f_0 t)$ $(d=1)$

VECTOR SET $M = \{s_1 = (+\alpha), s_2 = (-\alpha)\} \subseteq R$



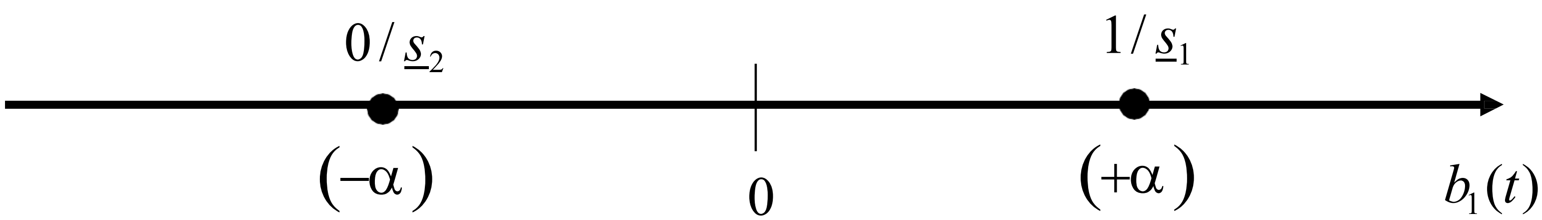
2-PSK: binary labeling

(example)

$$e : H_1 \leftrightarrow M$$

$$e(1) = \underline{s}_1$$

$$e(0) = \underline{s}_2$$



2-PSK: transmitted waveform

$m = 2 \rightarrow k = 1$ $\boxed{R = R_b}$ $\boxed{T = T_b}$

Transmitted waveform $$s(t) = \sum_{n=-\infty}^{+\infty} a[n] b_1(t - nT)$$

where $$a[n] \in \{+\alpha, -\alpha\}$$

$$b_1(t) = p(t)\cos(2\pi f_0 t)$$

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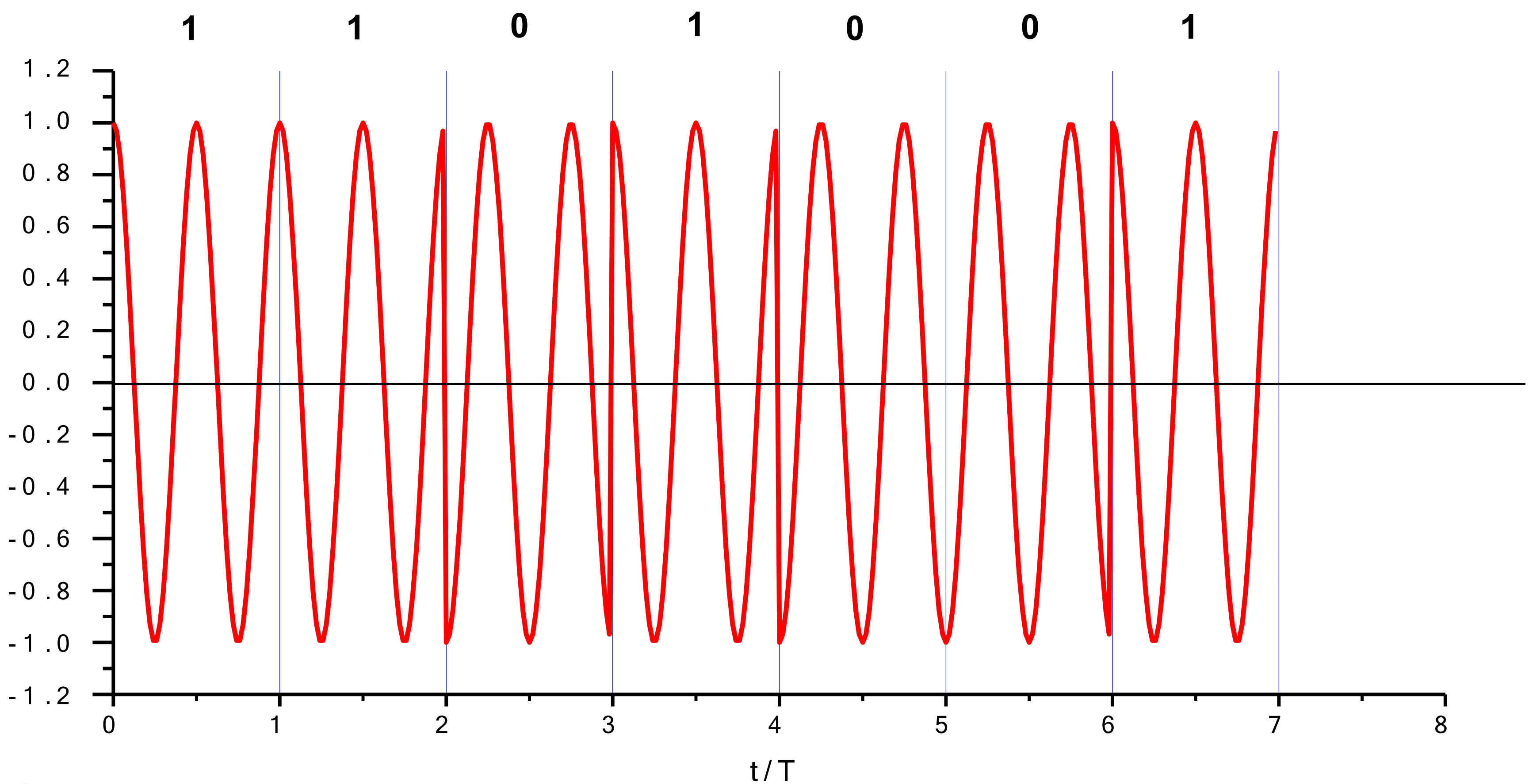
2-PSK: transmitted waveform

example for $p(t) = \frac{1}{\sqrt{T}} P_T(t)$

$f_0 = 2R_b$

$\alpha = \sqrt{T}$



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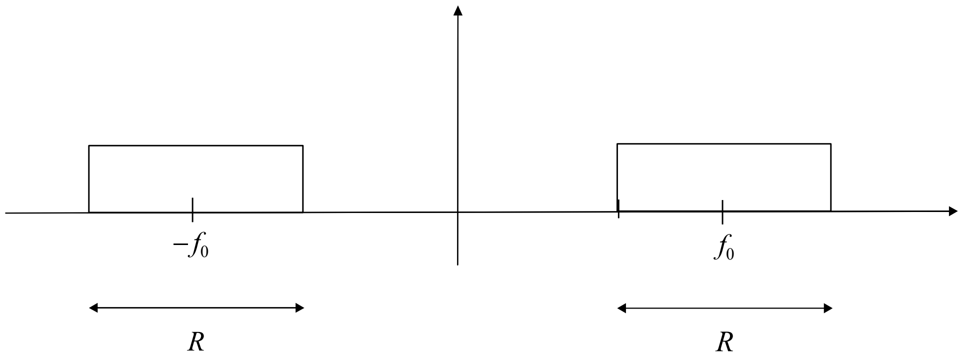
2-PSK: bandwidth and spectral efficiency

Case 1: $p(t)$ = ideal low pass filter



Total bandwidth
(ideal case)

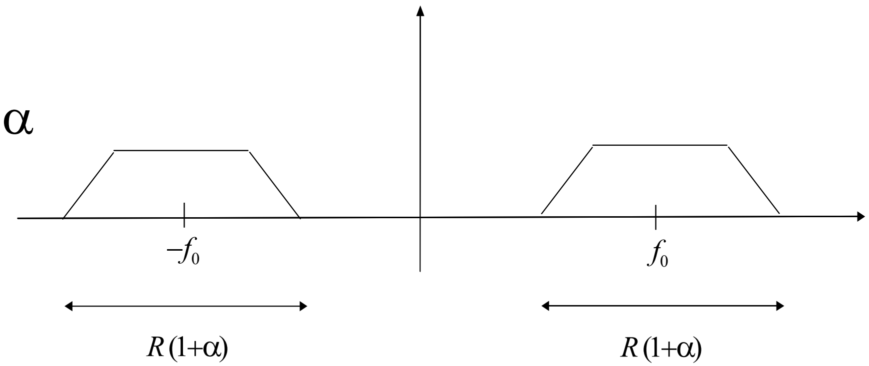
$$\boxed{B_{id} = R = R_b}$$

Spectral efficiency
(ideal case)

$$\boxed{\eta_{id} = \frac{R_b}{B_{id}} = 1\ bps / Hz}$$

2-PSK: bandwidth and spectral efficiency

Case 2: $p(t)$ = RRC filter with roll off α



Total bandwidth $B = R(1+\alpha) = R_b(1+\alpha)$

Spectral efficiency $$\boxed{\eta = \frac{R_b}{B} = \frac{1}{(1+\alpha)}\ bps/Hz}$$

Exercise

Given a bandpass channel with bandwidth B = 4000 Hz, centred around f_0=2 GHz, compute the maximum bit rate R_b we can transmit over it with a 2-PSK constellation in the two cases:

- Ideal low pass filter
- RRC filter with α = 0.25

2-PSK: modulator

The transmitted waveform is given by $$s(t) = \sum_n a[n] b_1(t - nT)$$

where $$b_1(t) = p(t)\cos(2\pi f_0 t)$$

Then we must generate $$s(t) = \sum_n a[n] p(t - nT)\cos(2\pi f_0 (t - nT))$$

We choose f_0 multiple of $R=1/T$

It follows $$\cos(2\pi f_0 (t - nT)) = \cos(2\pi f_0 t - 2\pi f_0 nT) = \cos(2\pi f_0 t)$$

Then we can generate $$\boxed{s(t) = \left[\sum_n a[n] p(t - nT)\right]\cos(2\pi f_0 t)}$$

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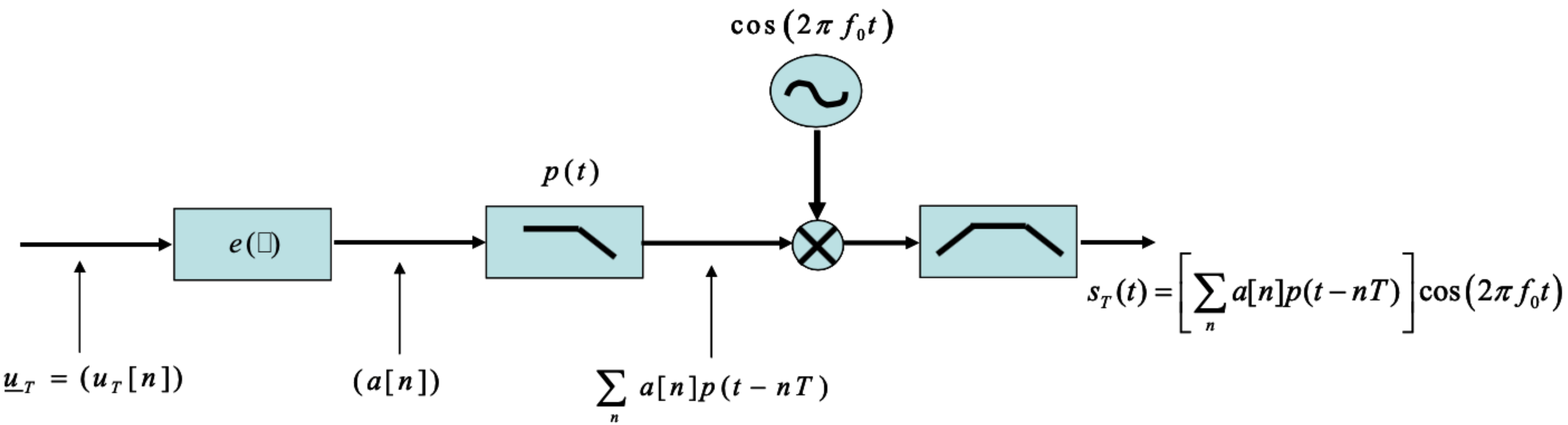
2-PSK: modulator



2-PSK: demodulator

Given the received signal $\rho(t)$

the received symbol is obtained by projecting it on the vector $b_1(t) = p(t)\cos(2\pi f_0 t)$

$$\rho[0] = \int_{-\infty}^{+\infty} \rho(t) b_1(t) dt = \boxed{\int_{-\infty}^{+\infty} \rho(t) p(t) \cos(2\pi f_0 t) dt}$$

This projection could be computed by using a matched filter

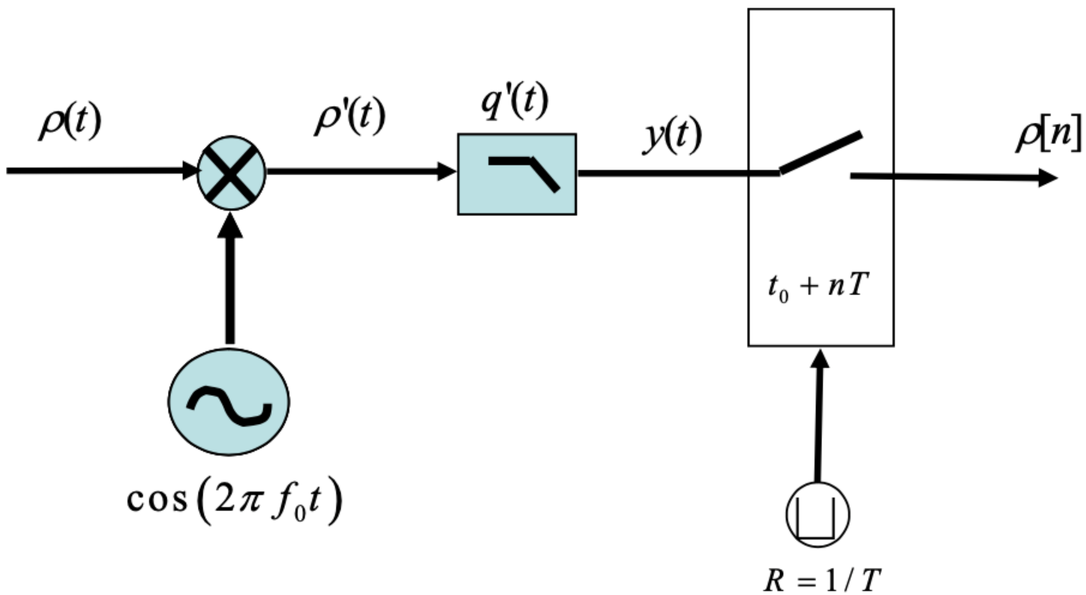
$$q(t) = b_1(T - t) = p(T - t)\cos(2\pi f_0 (T - t))$$

2-PSK: demodulator

As an alternative, we can work as follows:

1. Given the received signal $\rho(t)$ multiply it by $\cos(2\pi f_0 t)$

2. Use a filter matched to $p(t)$: $q'(t) = p(T-t)$



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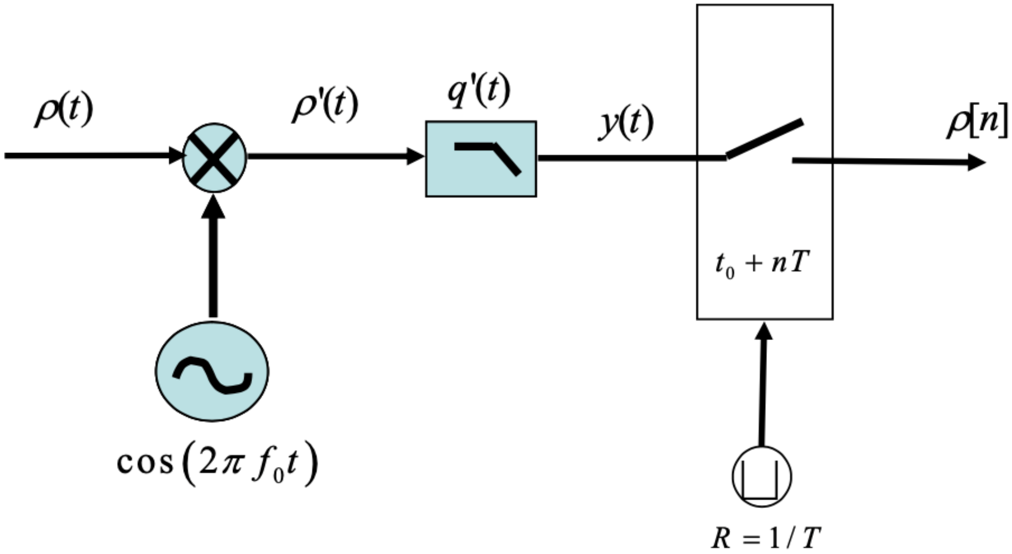
2-PSK: demodulator

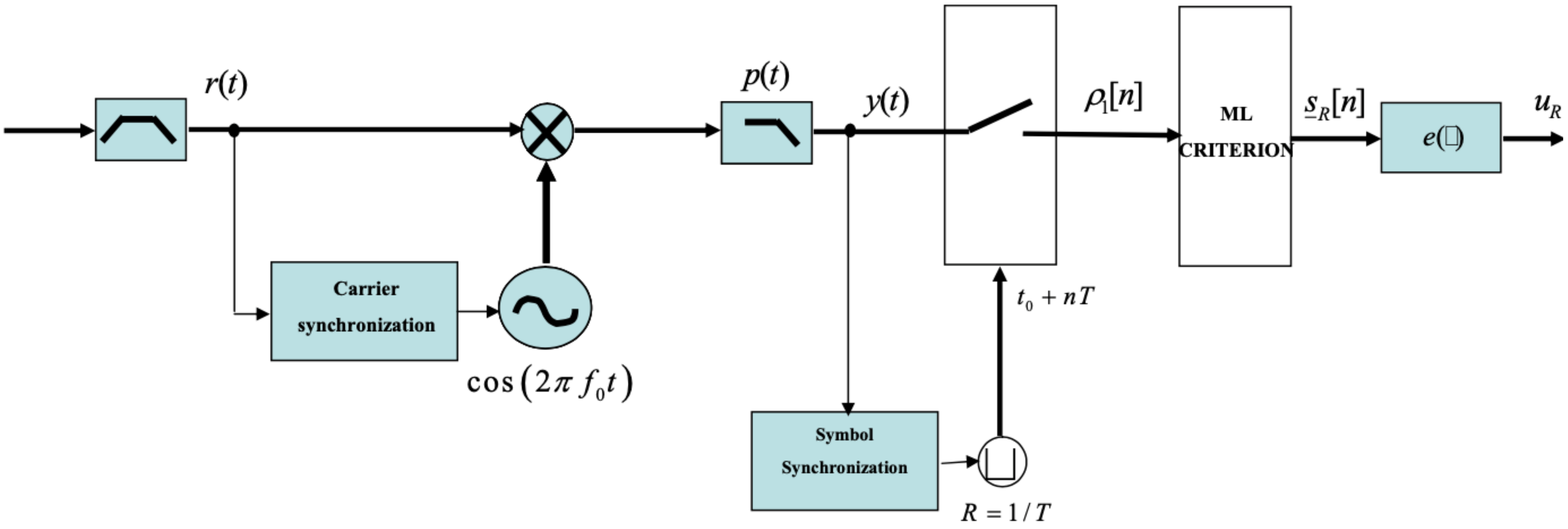


By sampling the matched filter output waveform we obtain

$$y(t) = \int_{-\infty}^{+\infty} \rho'(\tau) q'(t-\tau) d\tau = \int_{-\infty}^{+\infty} \rho(\tau) \cos(2\pi f_0 \tau) p(T - t + \tau) d\tau$$

$$y(t = T) = \boxed{\int_{-\infty}^{+\infty} \rho(\tau) \cos(2\pi f_0 \tau) p(\tau) d\tau = \rho[0]}$$

2-PSK: demodulator



2-PSK: interpretation

We generate a baseband signal

$$v(t) = \sum_n a[n] p(t - nT)$$

Multiplication by cosine shifts the spectrum around f_0

$$s(t) = v(t)\cos(2\pi f_0 t)$$

2-PSK: interpretation

At the receiver side, multiplication by cosine generates

$$s(t)\cos(2\pi f_0 t) = v(t)\cos(2\pi f_0 t)\cos(2\pi f_0 t) = v(t)\cos^2(2\pi f_0 t) = v(t)\left[\frac{1+\cos(2\pi\left(2f_0\right)t)}{2}\right]$$

This signal enters the matched filter $q(t)=p(T-t)$.

It is a low pass filter: the high frequency component around $2f_0$ is eliminated.

Only the baseband component $v(t) = \sum_n a[n]p(t-nT)$ survives.

The matched filter output is then equal to $a[n]$ when sampled at $t_0 + nT$

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2-PSK: analytic signal

The 2-PSK transmitted waveform

$$s(t) = \left[\sum_n a[n] p(t - nT) \right] \cos(2\pi f_0 t)$$

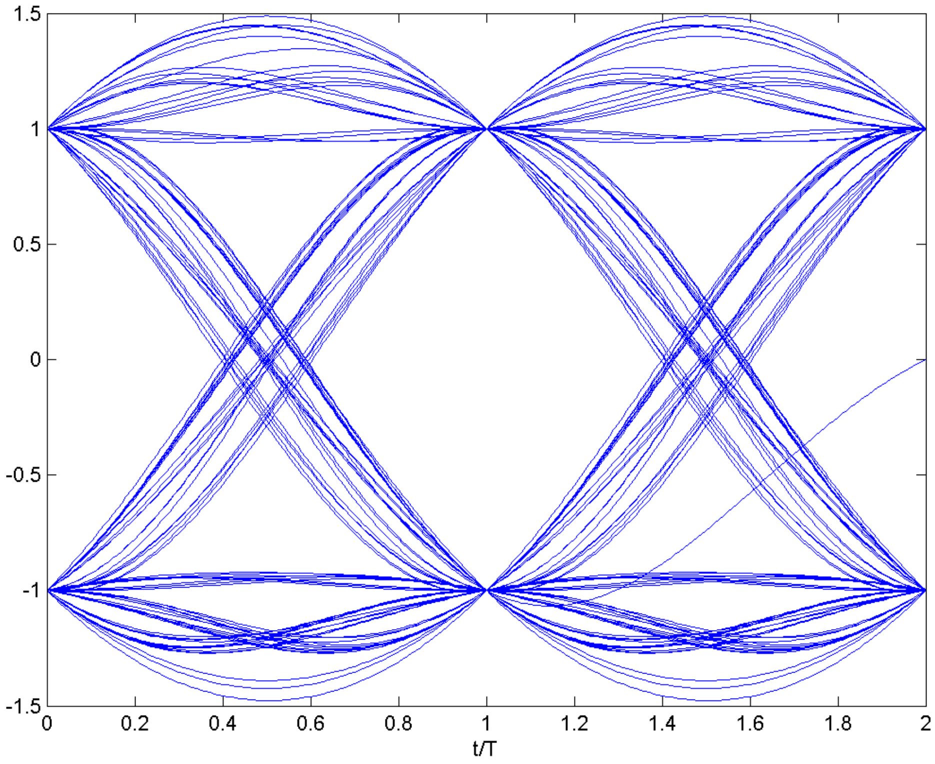
can be written as

$$s(t) = \mathrm{Re}\left[\dot{s}(t) \right] = \mathrm{Re}\left[\sum_n a[n] p(t - nT) \, \mathrm{e}^{j 2\pi f_0 t} \right]$$

where $\dot{s}(t)$ is called the **analytic signal** associated with $s(t)$

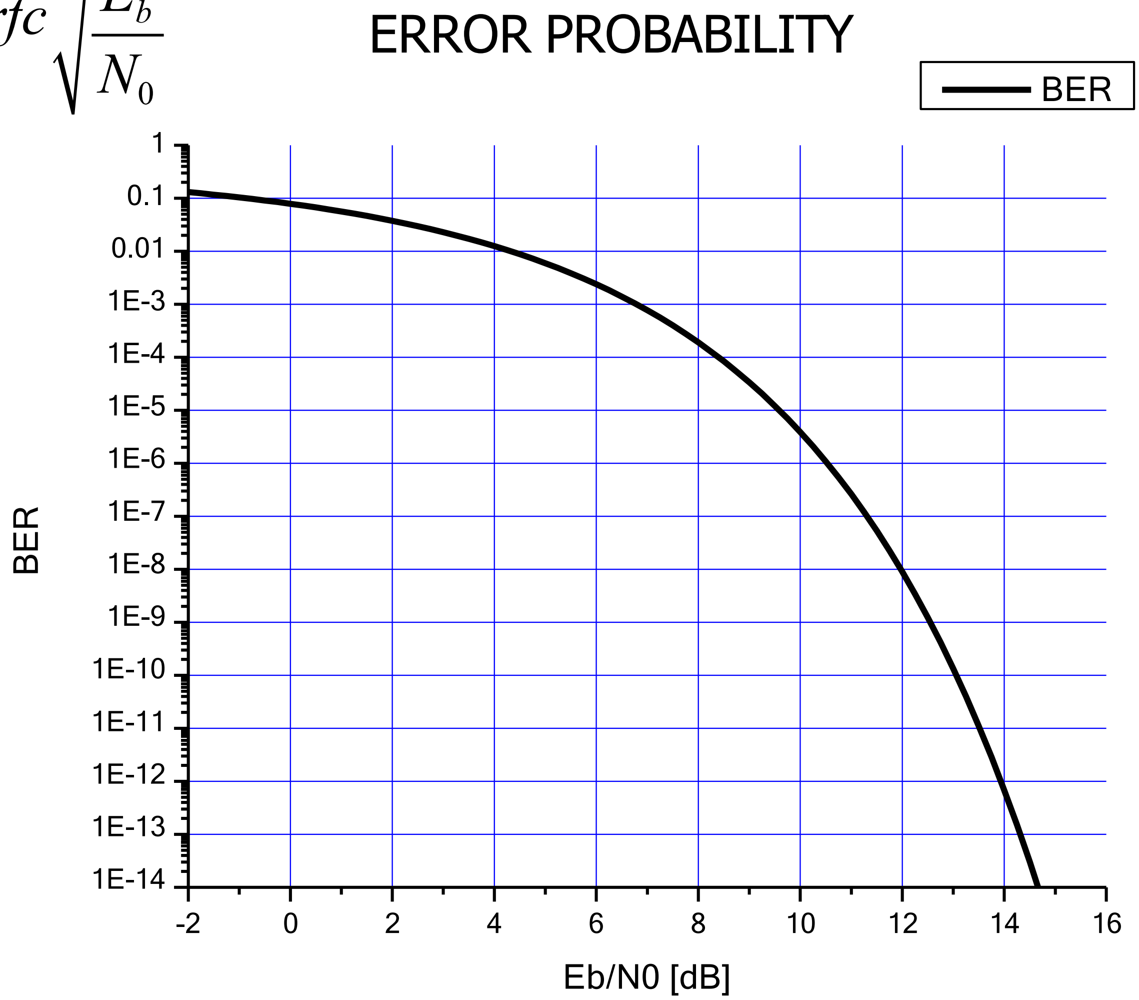
2-PSK: Eye diagram

2-PSK constellation with RRC filter (α = 0.5)



2-PSK: error probability

$$BER = \frac{1}{2} erfc\sqrt{\frac{E_b}{N_0}}$$



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