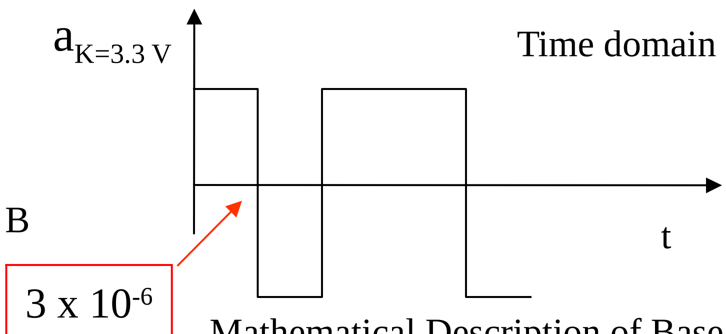
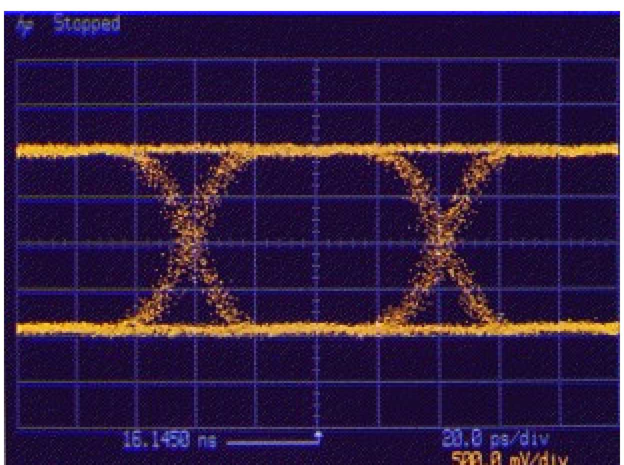
Base Band Signal

Definition: Signal transmitted near zero frequency range without frequency modulation.

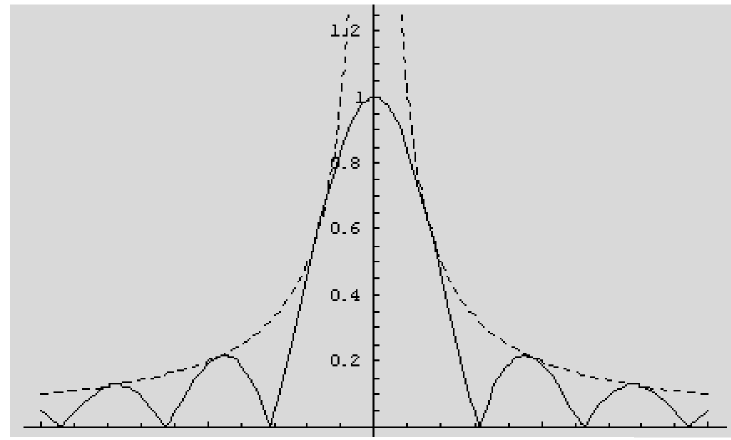
Time domain



Mathematical Description of Base Band Signal, see lecture notes.



Frequency domain



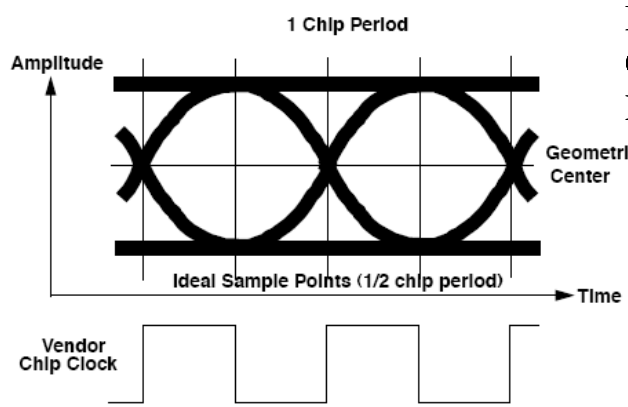


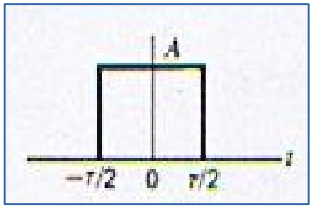
Figure 149—Chip clock alignment with baseband eye pattern

Eye Pattern: Characterization of Base Band Signal

IEEE 802.11b Standard pp. 56

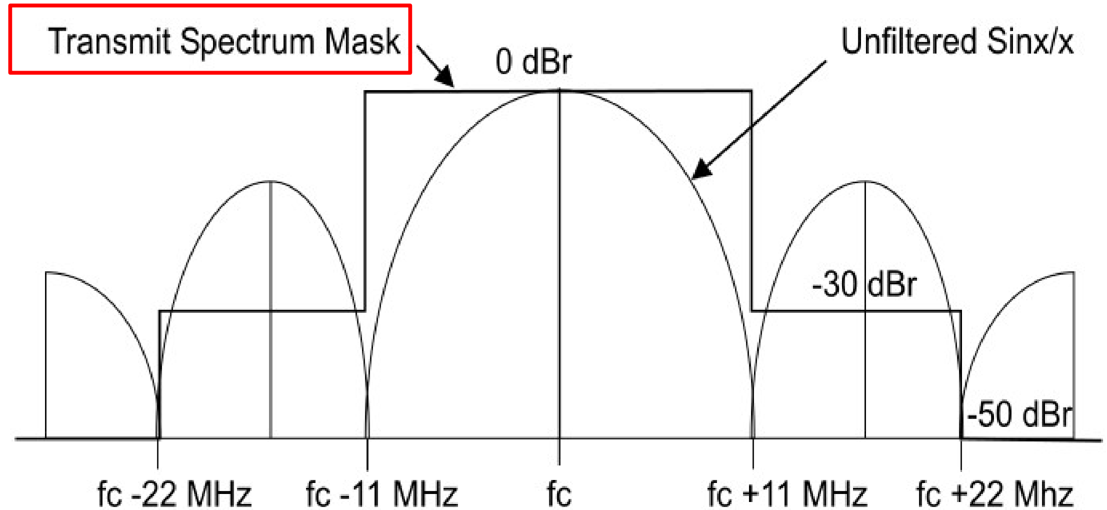
Base Band Signal Formulation

Time domain



$$g(t) = \begin{cases} A & \text{for } [-T/2, T/2] \\ 0 & \text{otherwise} \end{cases} \quad \ldots(1)$$

$$\boxed{A\tau \frac{\sin \pi f \tau}{\pi f \tau}} \quad \ldots(2)$$



Frequency domain

Figure 145—Transmit spectrum mask from IEEE 802.11 b, pp. 60

Example: Calculation of bandwidth

Let equation (2) = 0, then we have
Pi * f * T = k * Pi
Let k=1 for the first pair of zero crossings, we have

$$f = 1/T$$

Counting both sides of the spectrum, we have

$$\boxed{BW = 2/T}$$

(after modulation, otherwise, the bandwidth is half of that)

Bandwidth and Channels

Table 105—High Rate PHY frequency channel plan

CHNL_ID	Frequency (MHz)	X'10' FCC	X'20' IC	X'30' ETSI	X'31' Spain
1	2412	X	X	X	—
2	2417	X	X	X	—
3	2422	X	X	X	—
4	2427	X	X	X	—
5	2432	X	X	X	—
6	2437	X	X	X	—
7	2442	X	X	X	—
8	2447	X	X	X	—
9	2452	X	X	X	—
10	2457	X	X	X	X
11	2462	X	X	X	X
12	2467	—	—	X	—
13	2472	—	—	X	—
14	2484	—	—	—	—

IEEE 802.11b, pp. 49

Table 111—North American operating channels

Set	Number of channels	HR/DSSS channel numbers
1	3	1, 6, 11
2	6	1, 3, 5, 7, 9, 11

IEEE 802.11b, pp. 49

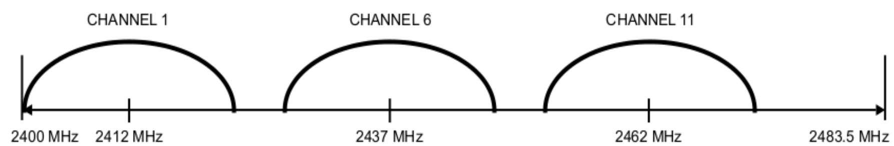


Figure 141—North American channel selection—non-overlapping

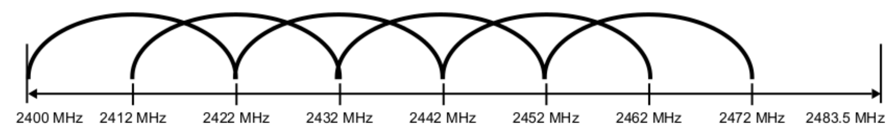
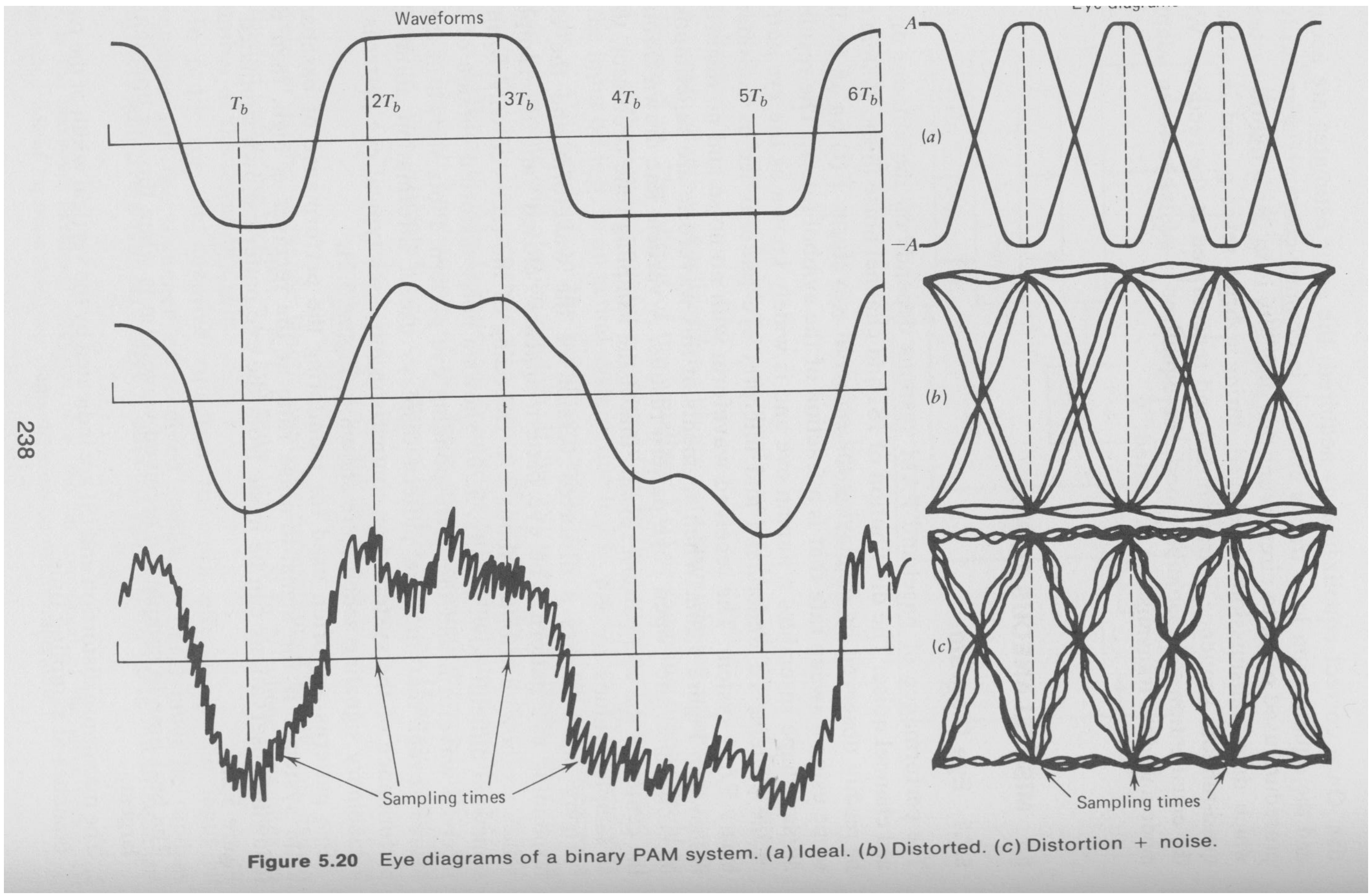


Figure 142—North American channel selection—overlapping

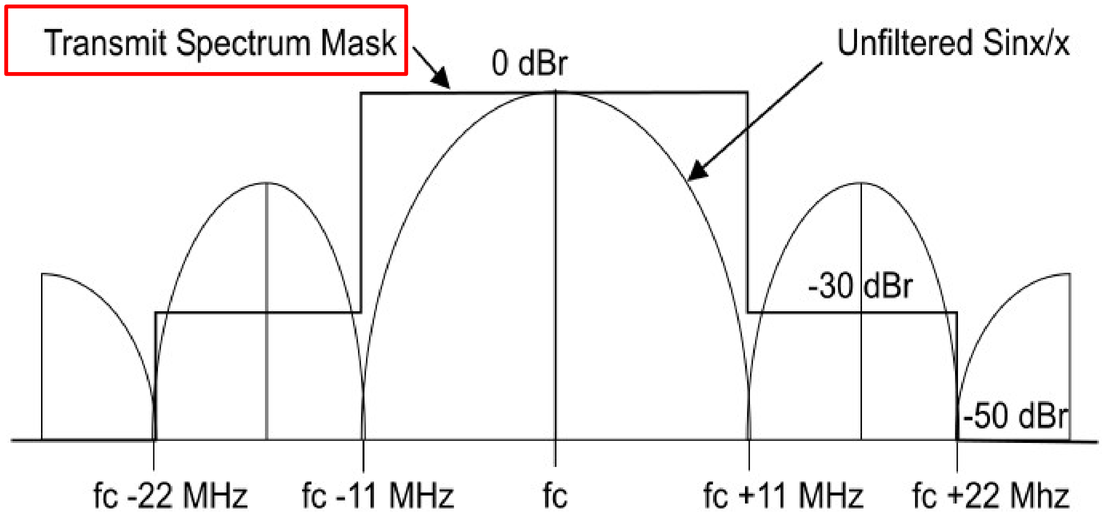
Example: find bandwidth, estimate bit rate

Eye Patterns of Base Band Signals



Reference: Digital and Analog Communication Systems, by K. Sam Shanmugam

Transmit Spectrum Mask



Frequency domain

Figure 145—Transmit spectrum mask
from IEEE 802.11 b, pp. 60

Example: Using DFT (Discrete Fourier Transform)
Design to analyzes transmit spectrum mask

$$\boxed{X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} kn} \qquad k = 0, \dots, N-1}$$

$$\begin{bmatrix} \omega_N^{0\cdot 0} & \omega_N^{0\cdot 1} & \ldots & \omega_N^{0\cdot (N-1)} \\ \omega_N^{1\cdot 0} & \omega_N^{1\cdot 1} & \ldots & \omega_N^{1\cdot (N-1)} \\ \vdots & \vdots & \ddots & \vdots \\ \omega_N^{(N-1)\cdot 0} & \omega_N^{(N-1)\cdot 1} & \ldots & \omega_N^{(N-1)\cdot (N-1)} \end{bmatrix}$$

https://en.wikipedia.org/wiki/Discrete
_Fourier_transform

Review

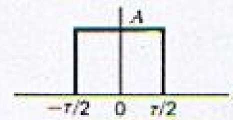
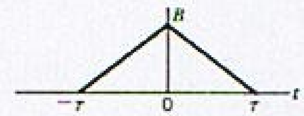
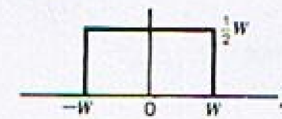
$$X(f) = \int_{-\infty}^{\infty} x(t)\exp(-j2\pi ft)\,dt$$

$$x(t) = \int_{-\infty}^{\infty} X(f)\exp(j2\pi ft)\,df$$

$$\int_{-\infty}^{\infty} |x(t)|^2\,dt = \int_{-\infty}^{\infty} |X(f)|^2\,df$$

Table C.1. Transform theorems.

Name of theorem	Signal	Fourier transform
(1) Superposition	$a_1x_1(t) + a_2x_2(t)$	$a_1X_1(f) + a_2X_2(f)$
(2) Time delay	$x(t - t_0)$	$X(f)\exp(-j2\pi ft_0)$
(3) Scale change	$x(at)$	$\lvert a\rvert^{-1}X(f/a)$
(4) Frequency translation	$x(t)\exp(j2\pi f_0t)$	$X(f - f_0)$
(5) Modulation	$x(t)\cos 2\pi f_0t$	$\frac{1}{2}X(f - f_0) + \frac{1}{2}X(f + f_0)$
(6) Differentiation	$\frac{d^nx(t)}{dt^n}$	$(j2\pi f)^nX(f)$
(7) Integration	$\int_{-\infty}^{t} x(t')\,dt'$	$(j2\pi f)^{-1}X(f) + \frac{1}{2}X(0)\delta(f)$
(8) Convolution	$\int_{-\infty}^{\infty} x_1(t - t')x_2(t')\,dt' = \int_{-\infty}^{\infty} x_1(t')x_2(t - t')\,dt'$	$X_1(f)X_2(f)$
(9) Multiplication	$x_1(t)x_2(t)$	$\int_{-\infty}^{\infty} X_1(f - f')X_2(f')\,df' = \int_{-\infty}^{\infty} X_1(f')X_2(f - f')\,df'$

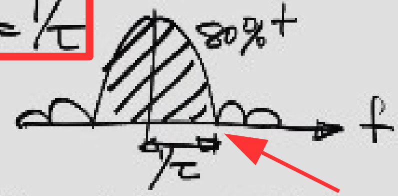
(1)		$A\tau\frac{\sin \pi f\tau}{\pi f\tau} \triangleq A\tau\,\text{sinc}\, f\tau$
(2)		$B\tau\frac{\sin^2 \pi f\tau}{(\pi f\tau)^2} \triangleq B\tau\,\text{sinc}^2\, f\tau$
(3)	$e^{-\alpha t}u(t)$	$\frac{1}{\alpha + j2\pi f}$
(4)	$\exp(-\lvert t\rvert/\tau)$	$\frac{2\tau}{1 + (2\pi f\tau)^2}$
(5)	$\exp[-\pi(t/\tau)^2]$	$\tau\exp[-\pi(f\tau)^2]$
(6)	$\frac{\sin 2\pi Wt}{2\pi Wt} \triangleq \text{sinc}\, 2Wt$	
(7)	$\exp[j(2\pi f_ct + \phi)]$	$\exp(j\phi)\delta(f - f_c)$
(8)	$\cos(2\pi f_ct + \phi)$	$\frac{1}{2}\delta(f - f_c)\exp(j\phi) + \frac{1}{2}\delta(f + f_c)\exp(-j\phi)$
(9)	$\delta(t - t_0)$	$\exp(-j2\pi ft_0)$
(10)	$\sum_{m=-\infty}^{\infty} \delta(t - mT_s)$	$\frac{1}{T_s}\sum_{n=-\infty}^{\infty} \delta\left(f - \frac{n}{T_s}\right)$
(11)	$\text{sgn}\, t = \begin{cases} +1, & t > 0 \\ -1, & t < 0 \end{cases}$	$-\frac{j}{\pi f}$
(12)	$u(t) = \begin{cases} 1, & t > 0 \\ 0, & t < 0 \end{cases}$	$\frac{1}{2}\delta(f) + \frac{1}{j2\pi f}$

From Digital and Analog Communications, By S. Shanmugam, John Weiley and Sons

10-1-2018 DFT And Power Spectrum

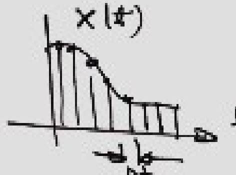
CMPE245 Oct. 1st, 2018, HL. 21.

Example: $A\tau \frac{\sin \pi f \tau}{\pi f \tau}$, $\boxed{B.W.(w/o\ MOD) = 1/\tau}$



Energy Computation: Step 1. Define D.F.T. (Discrete Fourier Transform). given $x(t) \leftrightarrow X(f)$ Continuous.

↓ Sampling In Time Domain



$$\boxed{X(m) = \frac{1}{N} \sum_{n=0}^{N-1} x(n) e^{-j2\pi \frac{mn}{N}}} \quad \ldots (1)$$

$x(n)$

↓ Sampling IN Freq. Domain

Where: $n = 0, 1, 2, \ldots, N-1$, Time Index for A period;

$m = 0, 1, 2, \ldots, N-1$, Freq. Index for A period;

$x(n+kN)$ — $X(m) = X(m+kN)$

N: No. of pts per period.

"$\frac{1}{N}$ Scaling" Energy Distribution:

$$\boxed{P(m) = Sqrt\{Re^2[X(m)] + Im^2[X(m)]\}} \quad \ldots (2)$$

$P(m)|_{m=m_0=0} = ?$ DC. $m=1$, Fundamental Freq.

Question: Total Energy = ? $E_{Tot} = \sum_{m=0}^{N-1} P(m)$ ...(3), $E_{B.W.} = \sum_{m=0}^{m'} P(m)$ ...(3A)

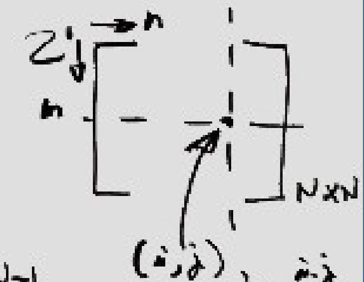
10-1-2018 DFT And E_nxn Matrix

$$\lambda \triangleq E_{BW} / E_{Tot} = \sum_{m=0}^{m'} P(m) \Big/ \sum_{m=0}^{N} P(m) \quad \ldots(4)$$

Note:

1° $E_{N \times N}$

2°



$$W_N^{i \cdot j} = e^{-j 2\pi \frac{i \cdot j}{N}} \quad \ldots(4^*)$$

Question: How to Compute Power Spectrum?

Suppose: $X(0) = \frac{1}{2}$; $X(1) = 1 + j \cdot 2$.

$X(2) = 1 - j2$; $X(3) = \frac{1}{4}$ $(N = ?)$

$$E_{Tot} = P(m)_{m=0} + P(m)_{m=1} + P(m)_{m=2} + P(m)_{m=N-1=3}$$

$$= \sqrt{\left(\tfrac{1}{2}\right)^2 + 0^2} + \sqrt{(1)^2 + 2^2} + \sqrt{(1)^2 + 2^2} + \sqrt{\left(\tfrac{1}{4}\right)^2}$$

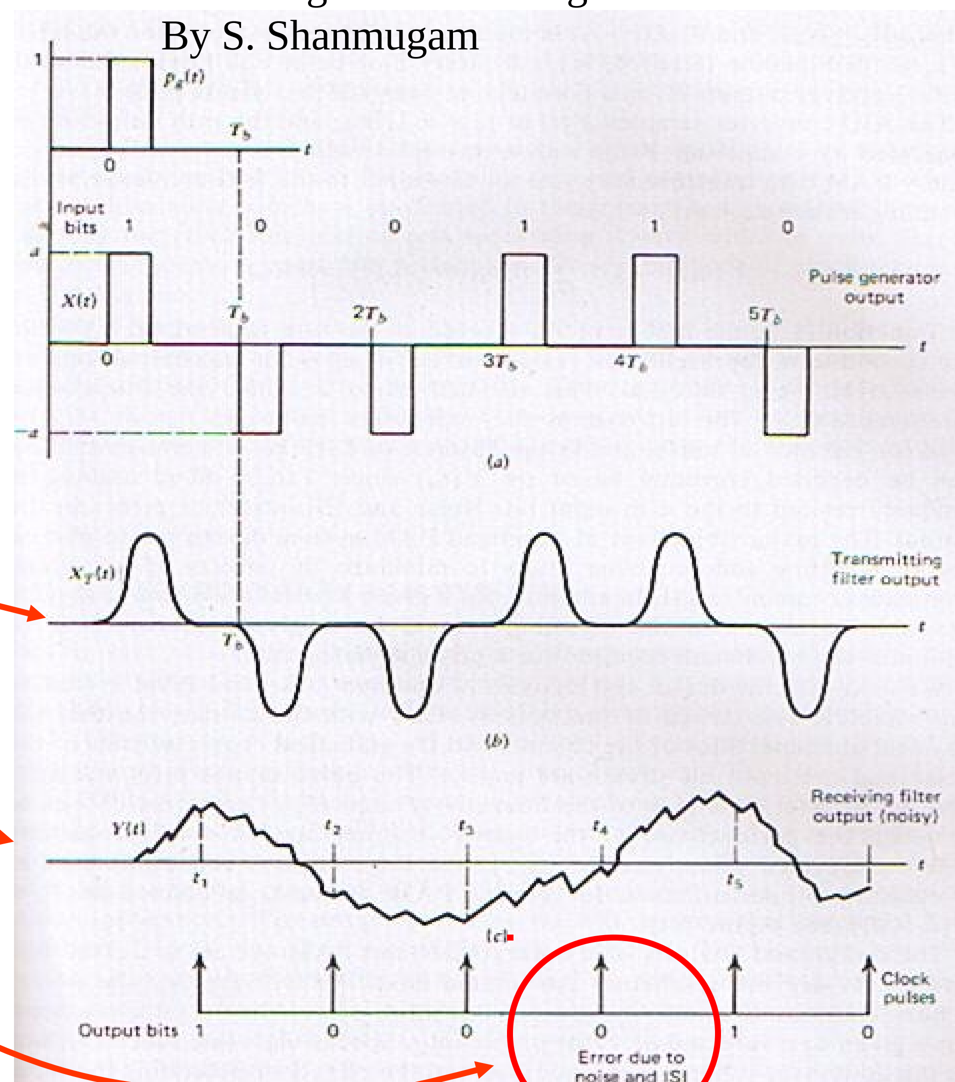
$$X(m) = \frac{1}{N}\left[x(0) W_N^{0 \cdot m} + x(1) W_N^{1 \cdot m} + \cdots + x(N-1) W_N^{(N-1) m}\right]$$

$$= \frac{1}{N}\left(W_N^{0 \cdot m}, W_N^{1 \cdot m}, \ldots, W_N^{(N-1) m}\right) \begin{pmatrix} x(0) \\ x(1) \\ \vdots \\ x(N-1) \end{pmatrix}$$

$$\begin{bmatrix} X(0) \\ X(1) \\ \vdots \\ X(N-1) \end{bmatrix} = \frac{1}{N} E \begin{bmatrix} x(0) \\ x(1) \\ \vdots \\ x(N-1) \end{bmatrix} \quad \ldots(4)$$

Based Band Signal w/o Modulation

From Digital and Analog Communications
By S. Shanmugam

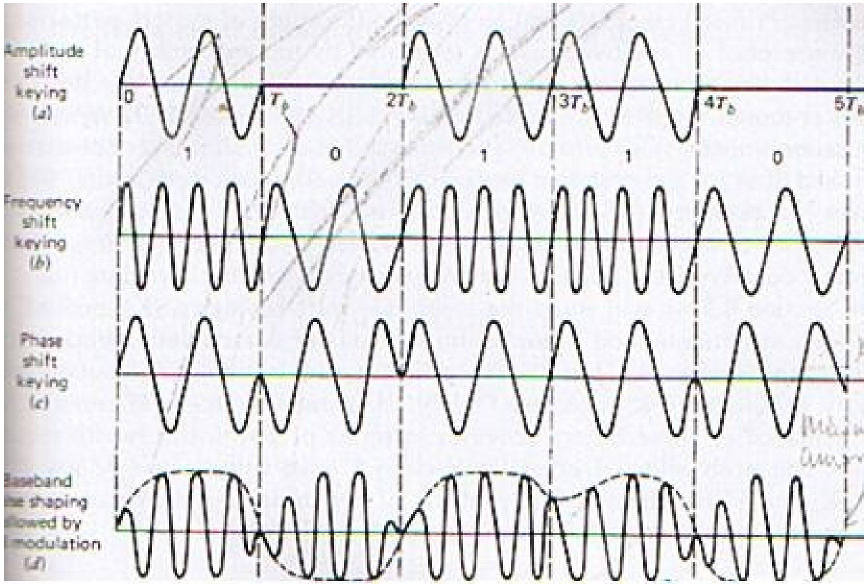


Transmitting Filter Output

Receiving Filter Output

Error

ASK, FSK, PSK



ASK

FSK

PSK

Base Band Shaping +
Analog Modulation
(DSB)