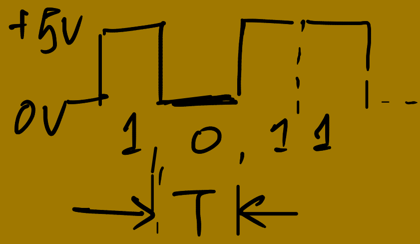
Performance Criteria ?

- Signal to Noise ratio (SNR)
- error rate (No. of bits received incorrectly) — DCS.
- Mean Squared Error (MSE)

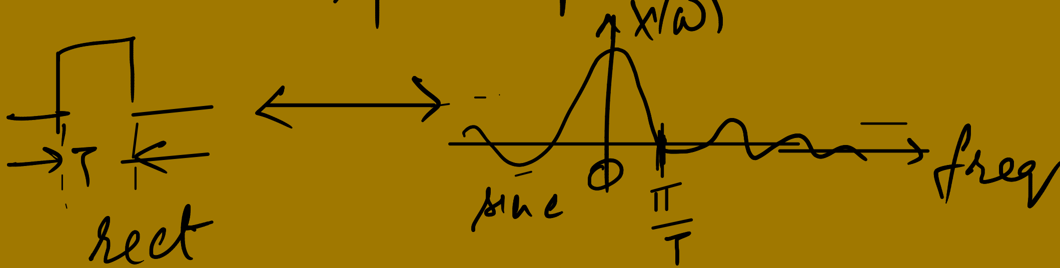
$$\mathcal{E} = \int_0^T (m(t) - r(t))^2 dt \rightarrow \text{Analog Comm. Sys.}$$

→ Q-factor

- Efficiency
- Bandwidth: 1 0 1 1 . . .



Data rate : $1/T = R$ bps



Bandwidth of a signal : $x(t) \longleftrightarrow X(\omega)$

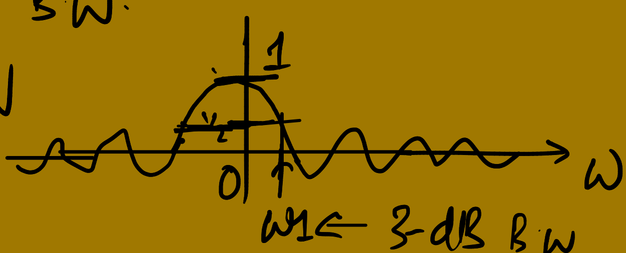
Baseband signals : ω_0 such that $|X(\omega)| = 0, \forall \omega > \omega_0$.

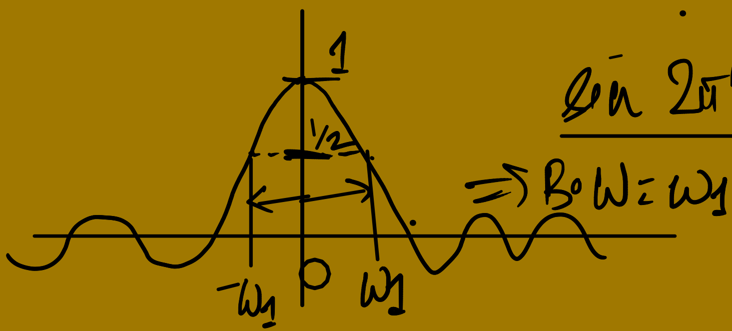
B.W Rect pulse is ∞.

Practical approximations for BW :

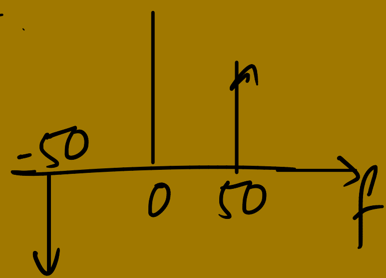
1 : Main lobe BW.

2 : 3-dB B.W





$\sin 2\pi 50t$



frequency: Rate of change of a signal.

negative frequency is a just a result of the chosen mathematical representation.

* **Trigonometric Fourier Series**:

$$x(t) = a_0 + \sum_{k=1}^{\infty} a_k \cos k\omega_0 t + \sum_{k=1}^{\infty} b_k \sin k\omega_0 t .$$

$$\omega_0 = \frac{2\pi}{T} \leftarrow \text{period of } x.$$

* **Exponential Fourier Series**

$$x(t) = \sum_{k=-\infty}^{\infty} c_k e^{jk\omega_0 t}, \quad \omega_0 = \frac{2\pi}{T} \leftarrow \text{period of } x.$$

$-\omega_0$, ω_0 are distinct

Not really distinct freq.!!!

3. **Fractional Power BW**

B.W reqd to capture a given fraction of the total power of the signal.

Review of Signals and Systems:

Classification of Signals:

→ Deterministic vs Random Signals
- $\sin(2\pi 50 t)$ — Noise
- message signal — Stock prices (w.r.t time)

→ Periodic vs Aperiodic

$\exists\, T \in \mathbb{R},\ T > 0$ such that

$x(t+T) = x(t),\ \forall\, t \in \mathbb{R}.$

Smallest such T is called the 'Period of x'.

→ Analog vs Discrete Signals

Analog → values typically over all or an interval of $\mathbb{R}$.

Discrete Signals → exist at distinct points in $\mathbb{R}$.

→ Energy vs Power Signals

Energy → Energy is finite

$$E_x := \int_{-\infty}^{\infty} x(t)^2\,dt = \|x\|_{L_2}$$

— Norm of the vector space of Energy signals

x is a Real-valued signal

If x is complex valued $\Rightarrow E_x = \int_{-\infty}^{\infty} |x(t)|^2\,dt = \|x\|_{L_2}$

A signal x is an <u>Energy signal</u> if $0 < E_x < \infty$.

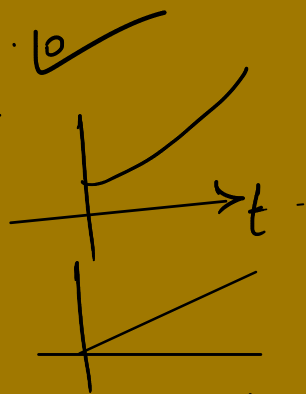
<u>Power Signal</u>:

$$P_x := \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} x(t)^2 \, dt.$$

A signal x is a Power signal if $0 < P_x < \infty$.

→ Any periodic signal → Power Signal.

- $x(t) = \tan t$
  <u>$x(t) = \text{sinc}\, t$</u>
- $x(t) = e^t$
- $x(t) = t$



→ No signal that is both Power and Energy signal.

<u>Fourier transform (4 versions).</u>

1. <u>Fourier Series</u> : Analog & Periodic Signals — Absolutely Integrable.

vector

Basis

$$1 \leftarrow x(t) = \sum_{n=-\infty}^{\infty} c_n \boxed{e^{jn\omega_0 t}}, \quad \omega_0 = \frac{2\pi}{T}$$

$$e^{j\omega_0 t} \quad \Bigg| \quad \cancel{e^{-j\omega_0 t}} \quad \Bigg| \quad x(t) = e^{-j\omega_0 t}$$

$$\{ e^{jn\omega_0 t} \mid n \in \mathbb{Z} \}. \qquad = \sin \omega_0 t$$

$n \geq 0$

2. Discrete-time Fourier transform (DTFT)

— Discrete Signals

— Aperiodic

$$x(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} X(\omega) e^{j\omega n} d\omega$$

$$\boxed{X(\omega) = \sum_{n=-\infty}^{\infty} x(n) e^{-jn\omega}} \rightarrow ②$$

$$X(\omega + 2\pi) = \sum_{n=-\infty}^{\infty} x(n) e^{-jn(\omega+2\pi)}$$

$$= X(\omega), \ \forall \omega \in \mathbb{R}$$

$\Rightarrow X(\omega)$ is periodic with period 2π !!!

↘ EFS coeff. are $x(n)$!!!

③ Discrete Fourier Transform (DFT).

~~(Discrete Time Fourier series)~~

— Discrete and Periodic (Period N)

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j\frac{2\pi}{N}nk}, \ k = 0, \ldots, N-1.$$

$$x(n) = \frac{1}{N} \sum_{n=0}^{N-1} X(k) e^{j\frac{2\pi}{N}nk}, \ n = 0, \ldots, N-1.$$

→ Only FT that can be implemented on a computer

(4) Continuous-time Fourier transform

- Continuous-time (Analog)
- Aperiodic

$$X(\omega) = \int_{-\infty}^{\infty} x(t)\, e^{-j\omega t}\, dt$$

$$x(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(\omega)\, e^{j\omega t}\, d\omega$$

- Labs will take place on Thursday 2:00-4:00pm.

Batch →	Team	Group
A	1	A1, ..., A17
B	2	B1, ..., B17
C	3	C1, ..., C16
D	4	D1, ..., D16
(ICT-CS) E	5	E1, ..., E16.