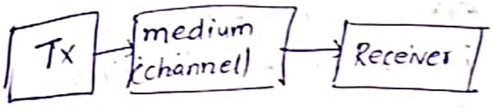
4

Communication ~~and~~ Systems (EE1360)

Intro to C.S - UPAMANYU Madhow

Project:
FM transmitter circuit

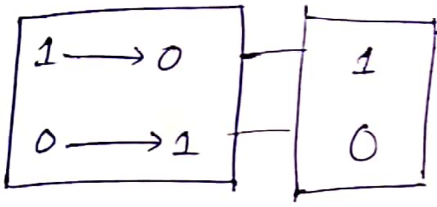


Qn's

Type of signal to send. | Does this channel impact my signal. | how to decode the ~~Tx~~ signal reliable.

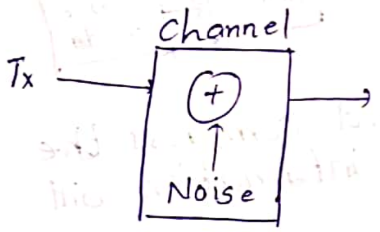
Ex:
① 1,0
②

Bit flipping channel

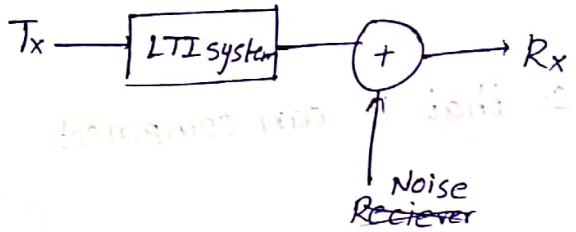


so the reciver has to flip again to get reliable Tx signal.

Analog Ex: AM, FM, AMPS (continous time, continous valued)
Discrete E
Digital Ex: Internet, 2G, 3G, 4G, 5G

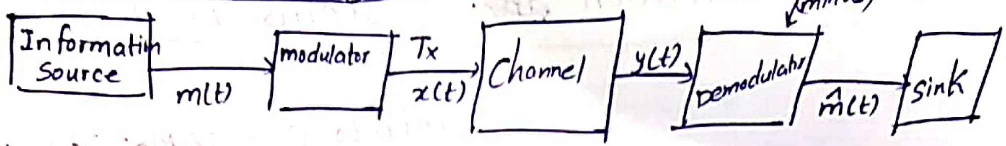


How to overcome ~~frome~~ the Noise problem.



$x(t) * h(t) + n(t) \longrightarrow r(t)$

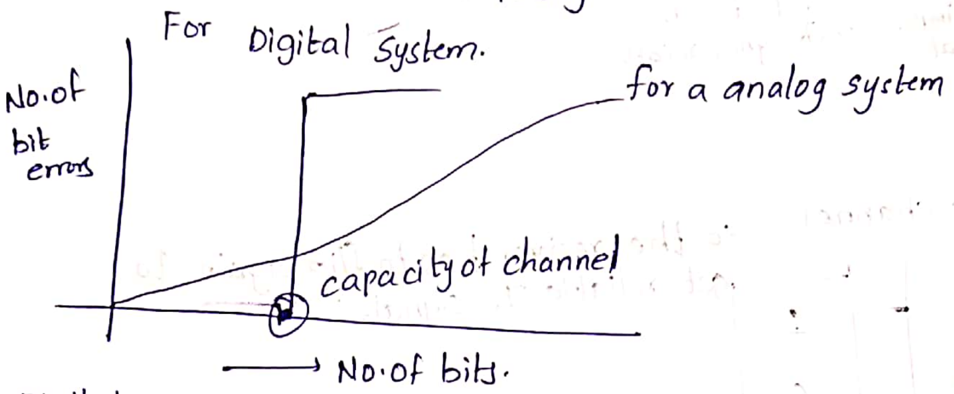
Analog communication System:



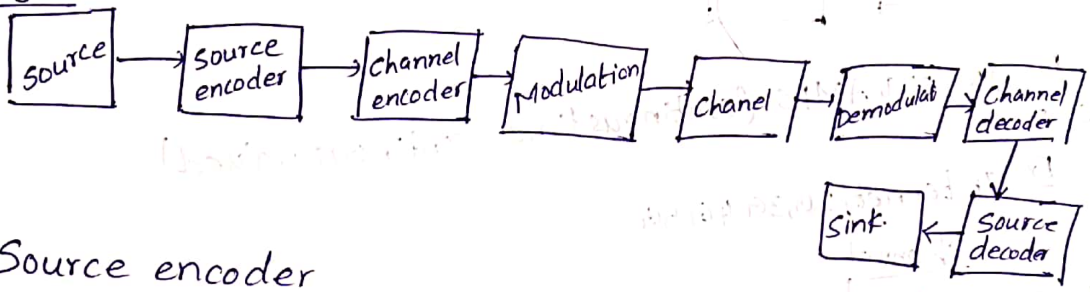
Shannon ~~channel~~

Information Theory (How many bits can I send through the channel?)

Every channel has a limit until to get ~~error~~ every bit sent in error free after that limit error will be 100%. That limiting value of bit is called capacity of channel.



Digital



Source encoder

It finds the similar patterns in the signal and compress the signal in such a way that none of the information will be lost from the signal.

If we compress the ~~data~~ bits more and more there will be some loss of ~~data~~ bits so there is a limit to compress that ~~data~~ bits.

Channel encoder

It adds redundency to the signal so that it can compensate the channel effect on the signal.

Polar coding

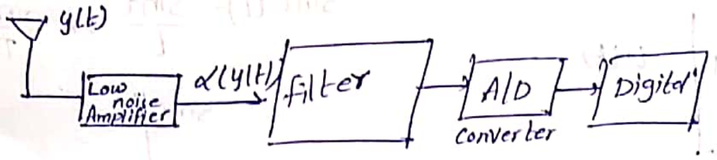
Turbo codes

LDPC code

Modulation

changes the bits into some continous form which can be sent through channel.

Mobile Reciever:

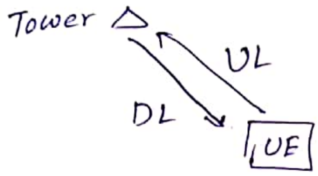


Friis Equation

$$P_r = \frac{P_t G_t G_r}{4\pi d^2} \times \frac{\lambda^2}{4\pi}$$

$\lambda^2/4\pi$ → Antenna Aperture → This depends on antenna size.

d → distance b/w T_x & R_x



$f_{UL} > f_{DL}$

But

$f_{UL} < f_{DL}$

900 MHz 1800 MHz

if we increase the frequency more but the power coming is from a battery.

If frequency increases the power recieved by the Tower may be zero or very less.

So more the frequency used the power lost is also more.

$m(t) \longrightarrow \hat{m}(t)$

$$\int_{\infty}^{-\infty} |m(t) - \hat{m}(t)|^2 \cdot dt \qquad e(t) = m(t) - \hat{m}(t)$$

→ error in the energy lost

no. of errors

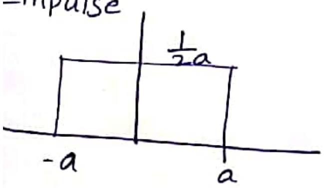
$$\text{Prob. of error} = \frac{\sum_{n=1}^{N} |m(n) - \hat{m}(n)|}{N}$$

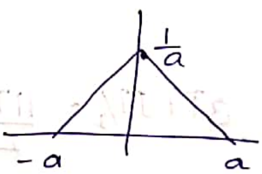
$$A\cos(2\pi f_0 t + \theta) = \mathrm{Re}\{A e^{j\theta} e^{j2\pi f_0 t}\}$$

$$A\cos(2\pi f_0 t)\cos\theta - (A\sin 2\pi f_0 t)\sin\theta$$

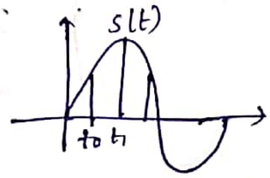
$$(A\cos\theta)\cos 2\pi f_0 t - (A\sin\theta)\sin 2\pi f_0 t$$

Impulse





$\lim_{a \to 0}$



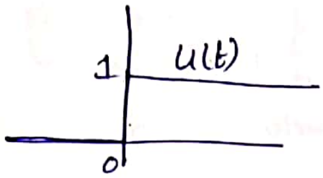
when s(t) is convoluted with δ(t) it gives s(t) at particular 't'.

$$\delta(t) = \begin{cases} 0 & t \neq 0 \\ ? & t = 0 \end{cases}$$

$$\int_{-\infty}^{\infty} \delta(t) \cdot dt = 1$$

$$\int_{-\infty}^{\infty} s(t)\,\delta(t - t_0) \cdot dt = s(t_0)$$

unit step:

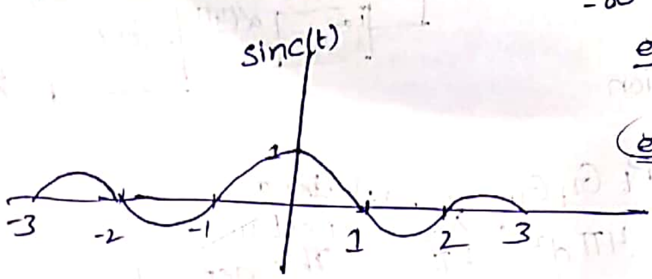


$$\text{sinc}(t) = \frac{\sin t}{t} \text{ or } \frac{\sin \pi t}{\pi t}$$

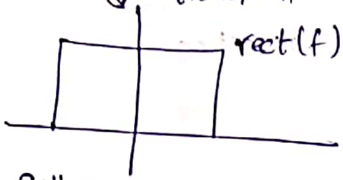
$$\int_{-\infty}^{\infty} \frac{\sin t}{t} e^{-j\omega t} dt$$

$$\frac{e^{jt} - e^{-jt}}{2jt} e^{-j\omega t}$$

$$\frac{e^{j(\omega t+1)} - e^{j(-1-\omega)t}}{2jt}$$



sinc(t) $\xrightarrow{}$ fourier transform

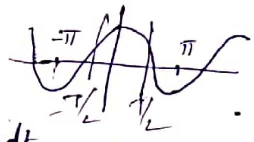


filter

Average:

$$\bar{x}(t) = \lim_{T_0 \to \infty} \frac{\int_{-T_0/2}^{T_0/2} x(t)\, dt}{T_0}$$

$$s(t) = A e^{j(2\pi f_0 t + \theta)} \qquad \boxed{\bar{S}(t) = 0} \qquad f_0 = \frac{1}{T_0}$$



$$= \lim_{T_0 \to \infty} \frac{\int_{-T_0/2}^{T_0/2} \cos(2\pi f_0 t + \theta)\, dt}{T_0} + j \frac{\int_{-T_0/2}^{T_0/2} \sin(2\pi f_0 t + \theta)\, dt}{T_0}$$

$f(-x) = -f(x)$

$f(-x) = f(x)$

$= \cancel{0 + 0 = 0}$

$$\left(\sin(2\pi f_0 t + \theta)\right)_{-T_0/2}^{T_0/2} \quad \left(-\cos(2\pi f_0 t + \theta)\right]_{-T_0/2}^{T_0/2}$$

$$-\cancel{\sin\theta} + \cancel{\sin\theta}$$

$$\sin(2\pi f_0 T + \theta) + \sin(\pi f_0 T - \theta)$$

$$\lim_{T \to \infty} \frac{2\sin(\pi f_0 T) \cos\theta}{T} \to 0$$

Energy:

$$E_{s(t)} = \int_{-\infty}^{\infty} |s(t)|^2 dt$$

$$s(t) = \begin{cases} 2 & 0 \le t \le T/2 \\ 2+j & T/2 \le t \le T \\ j & T \le t \le 2T \end{cases}$$

$$E_{s(t)} = 4(T/2) + 5 \times T/2 + 1 \times T = 3T + 5T/2 = \frac{11T}{2}$$

$$P_s = \lim_{T\to\infty} \frac{\int_{-T/2}^{T/2} |s(t)|^2 \cdot dt}{T} = \overline{|s(t)|^2}$$

If $E_s = A$ (fixed constant) $P_s = 0$

$(e^{j2\pi f_0} + e^{-j2\pi f_0})(e^{j4\pi f_0}$

$e^{j6\pi f_0} + e^{j2\pi f_0} + e^{-j2\pi f_0} + e^{-j\cos}$

$2\cos 6\pi f_0 t + 2\cos(2\pi f_0$

Ex:

① $s(t) = A e^{j(2\pi f_0 t+\theta)}$

$$E(s) = \int_{-\infty}^{\infty} \left| A e^{j(2\pi f_0 t+\theta)} \right|^2 dt = \cancel{\left[\frac{A^2}{4\pi f_0 j} e^{2j(2\pi f_0 t+\theta)} \right]_{-\infty}^{\infty}} = A^2 —$$

$p(s) = 0$

② $s(t) = A\cos(2\pi f_0 t+\theta)$

$$E(s) = \frac{A^2}{2}$$

$$s(t), r(t) \to \langle s(t), r(t) \rangle = \int_{-\infty} s(t)\, r^*(t) \cdot dt$$

If $f(t), g(t)$ are orthogonal signals then $\int_{-\infty}^{\infty} f(t) \cdot g(t) \cdot dt = 0$

LTI system:

$$x(t) \to \boxed{\text{system}} \to y(t)$$

$x_1(t) \longrightarrow y_1(t)$

$x_2(t) \longrightarrow y_2(t)$

$a x_1(t) + b x_2(t) \longrightarrow a y_1(t) + b y_2(t)$

$x_1(t-T) \longrightarrow y_1(t-\tau)$

$$x(t) \to \boxed{h(t)} \to y(t)$$

$$y(t) = x(t) * h(t)$$

$$= \int_{-\infty}^{\infty} x(\tau)\, h(t-\tau)\, d\tau$$

$$= \int_{+\infty}^{-\infty} x(t-y)\, h(y)\, dy \qquad \text{let } t-\tau = y$$

$$= \int_{-\infty}^{\infty} h(y)\, x(t-y) \cdot dy$$

$$= h(t) * x(t)$$

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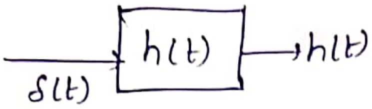
$h(t) \rightarrow$ impulse response

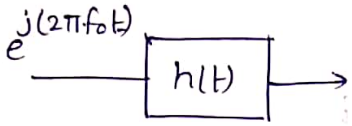


$$y(t) = \int_{-\infty}^{\infty} \delta(\tau)\, h(t-\tau) \cdot d\tau$$

$$\Rightarrow \delta(0) = 1$$

$$y(t) = h(t)$$

Ex:



$$y(t) = \int_{-\infty}^{\infty} e^{j(2\pi f_0 \tau)} \quad h(t-\tau) \cdot d\tau \quad = H(2\pi f_0 j)\, e^{j(2\pi f_0 t)}$$

<u>Fourier series:</u>

1. Periodic signal

$x(t+n\tau) = x(t) \quad n = ----1, 0, 1 ---$

$\tau \rightarrow$ Time period.

$x(t+T_0) = x(t) \quad T_0$ is smallest value

Then it is fundamental Period.

$f_0 = \frac{1}{T_0}$ fundamental frequency.

$$x(t) = \sum_{-\infty}^{\infty} x_n\, e^{j(2\pi f_0)nt} \qquad f_0 = \text{fundamental frequency.}$$

$$x_n = \frac{1}{T_0} \int_{-T_0/2}^{T_0/2} x(t) \cdot e^{-j2\pi f_0 n t} \cdot dt$$

$\delta(t)$ doesnot has fourier series because it is not periodic

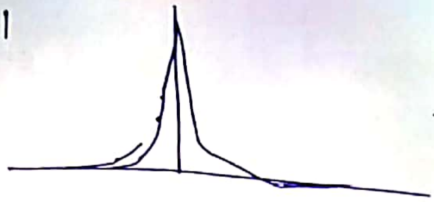
Ex: $y(t) = \sum \delta(t - nT_0)$ impulse train.

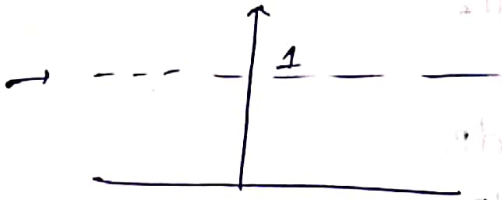
$$y_n = \frac{1}{T_0} \int_{-T_0/2}^{T_0/2} \sum \delta(t - nT_0)\, e^{-jk 2\pi f_0 t} \cdot dt$$

$$\cancel{y_0 = \frac{1}{T_0}}$$

$$\cancel{y_1 = \frac{1}{T_0} e^{-j2\pi f_0 T_0}}$$

$\delta(t) \to 1$





$u(t) \longrightarrow U_k$

$v(t) \longrightarrow V_k$

$\alpha u(t) + \beta v(t) \longrightarrow \alpha U_k + \beta V_k$

linear.

$u(t-d) \longrightarrow e^{-j2\pi k f d} U_k$

$u(t) = \text{real}$

$U_k^* = U_{-k}$

Parsevals Identity:

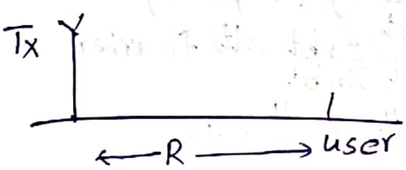
$$\int_{-\infty}^{\infty} u(t) V^*(t) \cdot dt = T_0 \sum U_k V_k^*$$

OFDM

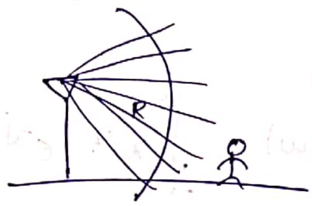
Erik Perins

People.

Link budget Analysis,



Cm path loss



$4\pi R^2$

$$G = \frac{4\pi A_e}{\lambda^2}$$

$A_e \to$ effective area

$\lambda \to$ Wavelength

$$I = \frac{P_t}{4\pi R^2}$$

$$P_L^{-1} = \frac{1}{I A_e} = \frac{1}{\frac{P_t}{4\pi R^2} \times \frac{\lambda^2}{4\pi}}$$

$$A_e = \frac{G\lambda^2}{4\pi}$$

Say $G=1$, $A_e = \dfrac{\lambda^2}{4\pi}$

$$P_L^{-1} = \frac{(4\pi)^2 R^2}{P_t \lambda^2}$$

$$P_R = P_t G_T G_R P_L^{-1}$$

$$P_R(dB) = P_t(dB) + G_T(dB) + G_R(dB) - P_L$$

$$\boxed{P_{(dB)} = 10 \log_{10}(P)}$$

$$P_t(dB) = 10 \log_{10}(P_t)$$

3600

$$P_t(dBm) = 10 \log_{10}\left(\frac{P_t}{10^{-3}}\right)$$

$$= 10 \log_{10} P_t + 30$$

* $f_c = 5GHz$

$P_t = 3W$

$G_T = 10 dB$

$G_R = 5dB$

$R = 5m$

calculate pathloss & the R_x power

A.

$P_t(dB) = 4.7$

$P_r(dB) = -40$

$P_L(dB) =$

$G_t(dB) = 10$

$G_r(dB) = 5$

$R_r(dB) = P_t(dB) + G_t(dB) + G_R(dB) + Losses(dB) + P_L(dB)$

Fourier Transform:

~~x(t)~~

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

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

Duality property H.W

$e^{-at}\cos bt\, u(t)$ fourier

$e^{-at}\sin bt$

$x(t) = e^{-at} u(t)$

$$\int_{-\infty}^{\infty} e^{-at} u(t)\, e^{-j\omega t}\, dt$$

$$= \int_{0}^{\infty} e^{-(j\omega + a)t}\, dt$$

$$= \frac{-1}{j\omega + a}(0-1) = \frac{1}{j\omega + a}$$

dB → decibels

P_2, P_1

$$\left(10\log_{10}\frac{P_2}{P_1}\right) dB$$

if given x dBm means $P_1 = 1$ milli watt

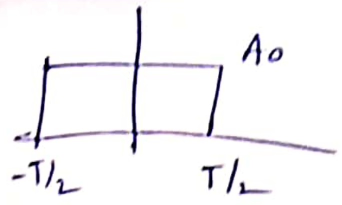
x dBW means $P_1 = 1$ watt

30dBm = 0 dBW

50 dBW + 30 dB ~~it cannot be added As 30dB is the power gain~~

$$10\log\frac{P_2}{1W} = 50 \qquad 10\log\frac{P_{Targ}}{P_2} = 30$$

$$\boxed{P_{Targ} = 10^8 W}$$



$$f(t) = \sum_{k=-\infty}^{\infty} c_k e^{j\omega k t}$$

$$c_k = \frac{1}{T_0}\int_0^{T_0} f(t)\cdot e^{-j\omega k t}\, dt$$

$$c_k = \frac{1}{T_0}\frac{A_0}{-j\omega k}\left(e^{-j\omega k T_0/2} - e^{+j\omega k T_0/2}\right)$$

$$= \frac{A_0}{T_0 j\omega k}\left(2j \sin \omega k T_0/2\right)$$

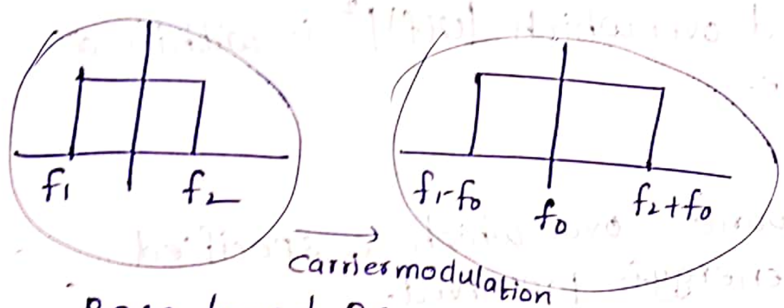
$$\mathrm{Sinc}(x) = \frac{\sin \pi x}{\pi x}$$

AT sinc (f. T) $\quad c_k = \frac{A_0 \sin(\pi k)}{\pi k}$

Area. sinc(f. Width) $\boxed{c_k = A_0 T \,\mathrm{sinc}(f\cdot T)}$

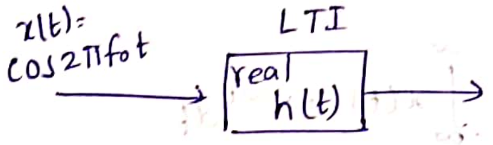
$u(t) \rightarrow U(f)$

$u(t)\, e^{j2\pi f_0 t} \rightarrow U(f-f_0)$



Base band DC=0 $\qquad$ Pass band DC>0

The modulation is done because we donot send the signals at zero frequency.



$$Y(j\omega) = H(j\omega)\, X(j\omega)$$

$$= \left(\int_{-\infty}^{\infty} (\mathrm{real})\, e^{-j\omega t}\, dt\right)\left(\int_{-\infty}^{\infty} \cos 2\pi f_0 t\, e^{-j\omega t}\, dt\right)$$

$$= \frac{\mathrm{real}}{-j\omega}\, e^{-j\omega t}\Big]_{-\infty}^{\infty} \cdot \frac{1}{2}\left[\frac{1}{-j\omega+2\pi f_0 j}\, e^{(-j\omega+2\pi f_0 j)t} + \frac{1}{-j\omega-2\pi f_0}\, e^{(-j\omega-2\pi f_0 j)t}\right]_{-\infty}^{\infty}$$

$$= \frac{\mathrm{real}}{j\omega}\, e^{-j\omega t} \quad t\to-\infty \cdot \frac{1}{2}\Big[$$

$$y(t) = \int_{-\infty}^{\infty} h(t-\tau)\, x(\tau)\cdot d\tau$$

$=$

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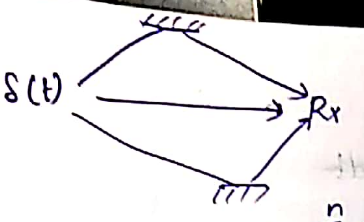


$\delta(t) \xrightarrow[h(t)]{} \sum_{i=1}^{n} \alpha\,\delta(t-T_i)$ — Multipathfading

then, $h(t) = \sum_{i=1}^{n} \alpha\,\delta(t-T_i)$

$$y(t) = \int_{-\infty}^{\infty} h(t-\tau)\, x(\tau)\cdot d\tau = \int_{-\infty}^{\infty} h(t-\tau)\,\delta(\tau)\cdot d\tau = h(t)$$

$y(t) = h(t)$ for $x(t) = \delta(t)$

Band width :- A measure of the band frequencies occupied by a signal

a. $U(f) \neq 0$

b. ~~Area~~ size of band over which $|U(f)|^2$ is within a fraction of peak value.

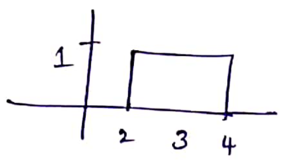
Ex: 3 dB

c. Size of smallest band over which a specified fraction of signal energy is preserved.

$$\int_{-\infty}^{\infty} |s(t)|^2 dt = \int_{-\infty}^{\infty} |S(f)|^2 df = E$$

Ex,

$u(t) =$



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

$$X(j\omega) = \int_{2}^{4} e^{-j\omega t} dt = \frac{+1}{j\omega}\left(e^{-2j\omega} - e^{-4j\omega}\right)$$

$\cancel{x(f) = \frac{1}{f}\left(e^{-2f} - e^{-4f}\right)}$

$x(f) = 2\,\text{sinc}(2f)\, e^{-6\pi f j}$

$\cancel{\int_{-\infty}^{\infty} |x^2(f)|\, df}$

Transducer

Physical variations $\longrightarrow$ Electric signals

To convert analog signal to digital signal the signal is first sampled and then quantised to make in digital signal form.

Regenerating the signal using repeaters
- Reshaping
- Equalisation
- Decisio making

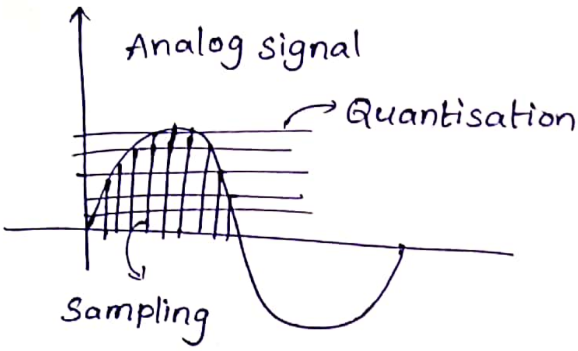
Why is digital better than analog?

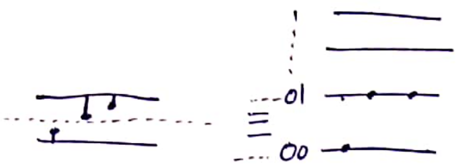
. Error due to noise is less.

2.

Analog	Digital
Short distance	long distance (because it has regenerative repeaters)
when noise is added complete signal is effected by noise.	only some bits in the signal are effected.
Encrypting is not possible.	Encryption (increases the secutrity to our signal)
Error detecting & correction not present.	Error detection and correction (Reduntant bits) (Parity bit)

Disadvantages
- Bandwidth increases
- Sampling and quantisations errors
- Hardware complexcity and cost.
- Synchronisation





OSI Model:

It has seven layers in OSI.

- Application
- Presentation
- Session
- Transport
- Network
- Datalink
- Physical

One layer below provides the services to the above layer.

The data received by the N^{th} layer is called service data unit and data given out by the Nth layer is protocol data unit.

SDU is concetenated with header, footer or both and produce 'PDU' for the next layer.

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