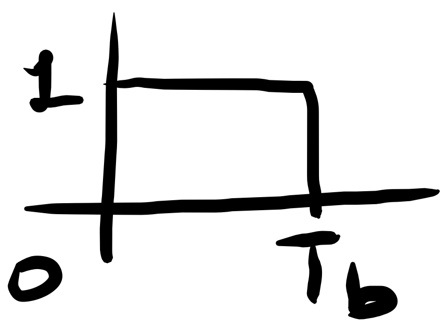
$S_y(f) = |P(f)|^2 S_a(f)$ — (1) — PSD → power spectral density

1. Why $p(t) =$



010

$0 \to T_b \to 2T_b$ benefit → no ISI

loss:- B.W. consumption

B.W. depends directly on $|P(f)|^2$ from eq. (1) & fig 1 above

$P(f)$ → sinc function

it exists from $-\infty$ to ∞.

This requires for distortionless reception of $y(t)$, channel

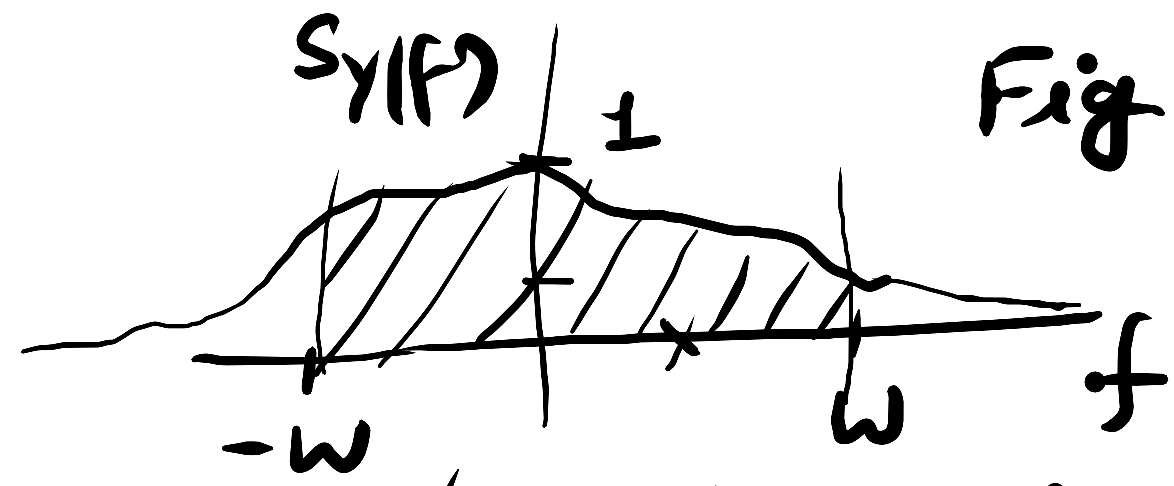


Fig. 1

↳ this region will contain 99% of the total power/energy in the signal

W → is chosen that way

Hence, W acts as a good measure of B.W.

must be of ∞ bandwidth - not possible in reality. → Most real world channels are band-limited due to physical processes involved. Hence a part of the Txd signal's spectrum is curtailed.

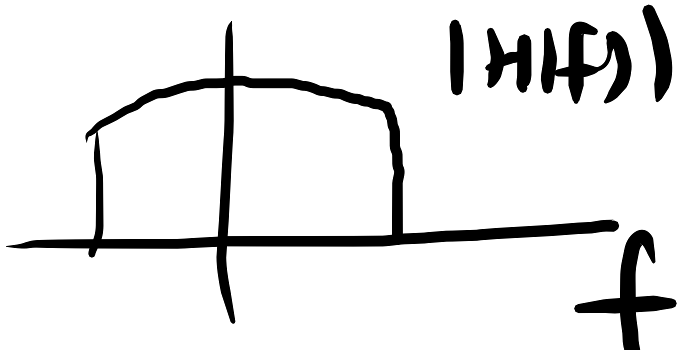
This phenomenon is equivalent to

$$P(f) \times \text{rect}(f/2B') \quad -(2)$$

B' is the B.W. of the channel.

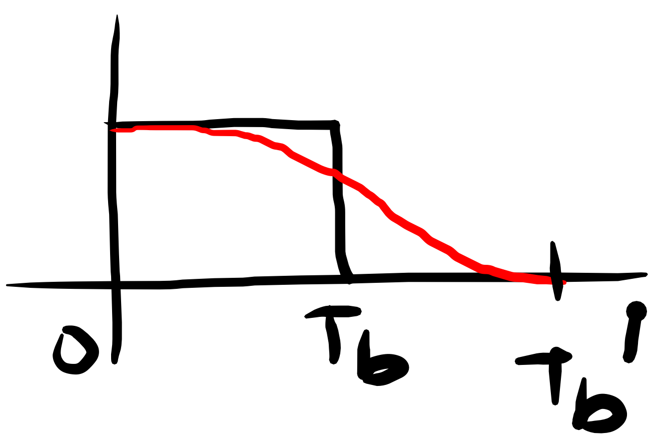
So, considering (2), the time domain pulse signals are spread out (conv. with sinc in time) leading to ISI.

→ Recap:- Non-ideal channel



also leads to ISI. But this can be compensated at the Rx. if channel estimation using pilot signals is done & equalization is performed at the Rx.

Let's focus on the other source of ISI, which is time-limited pulse. If we allow pulse to extend beyond T_b to let its spectrum die early (see fig below)



→ but then this leads to pulse from 0 to T_b' interfering with pulse which starts at T_b → hence again ISI

→ Way out — Nyquist criteria for pulse design.

→ ISI is not noise # addition of noise → separate mechanism which we will study later

1. Nyquist 1st criterion for zero ISI.

Choose a pulse with non-zero amplitude at its center (say $t=0$) & zero amp. at $t = \pm nT_b$ ($n = 1, 2, 3, \ldots$) T_b: separation b/w successive Txd. pulses.

Thus, $p(t) = \begin{cases} 1, & t = 0 \\ 0, & t = \pm nT_b \end{cases}$ — ③ $(T_b = 1/R_b)$

$R_b \rightarrow$ bit rate

Now, Tx of R_b bits/sec req. a min. of $R_b/2$ Hz B.W.

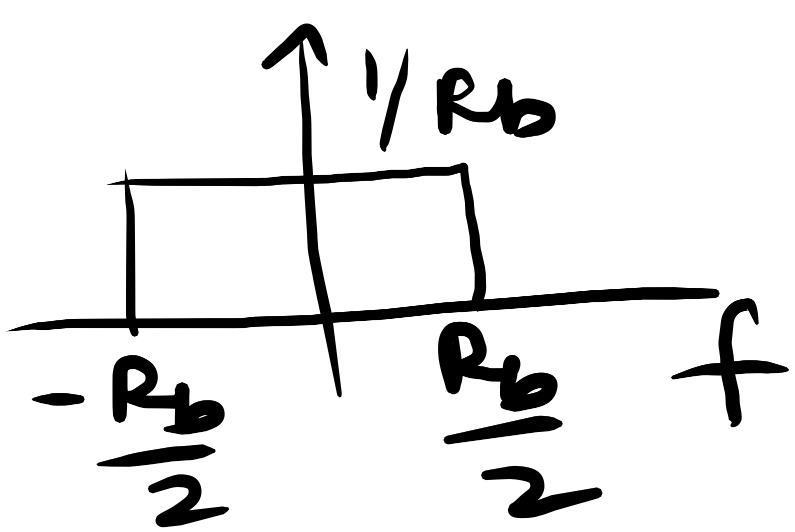
2 bits $\longrightarrow$ 1 Hz

$\rightarrow$ Find a pulse $p(t)$ which satisfies ③ & has the min. B.W. $R_b/2$ Hz.

Ans – $p(t) = \text{sinc}(\pi R_b t)$

as, $\text{sinc}(\pi R_b t) = \begin{cases} 1, & t=0 \\ 0, & t = \pm n T_b \text{ or } \pm \dfrac{n}{R_b} \end{cases}$

F.T. of $p(t) = \dfrac{1}{R_b} \Pi(f/R_b)$



Motivation for Nyquist criteria :– Pulses are allowed (3) to overlap yet shaped to cause zero (or controlled) interference with all other pulses at the decision making instants.

Issues with sinc pulse :-

1. Wait ∞ time to generate it, as it starts from $-\infty$. Truncation will $\uparrow$ B.W. from $\frac{R_b}{2}$ Hz.