PRINCIPLES OF COMMUNICATIONS

UNIT-2

LECTURE-8

Definition of Bandwidth

- *"Bandwidth is defined as a band containing all frequencies between upper cut-off and lower cut-off frequencies."* (see Figure 1)

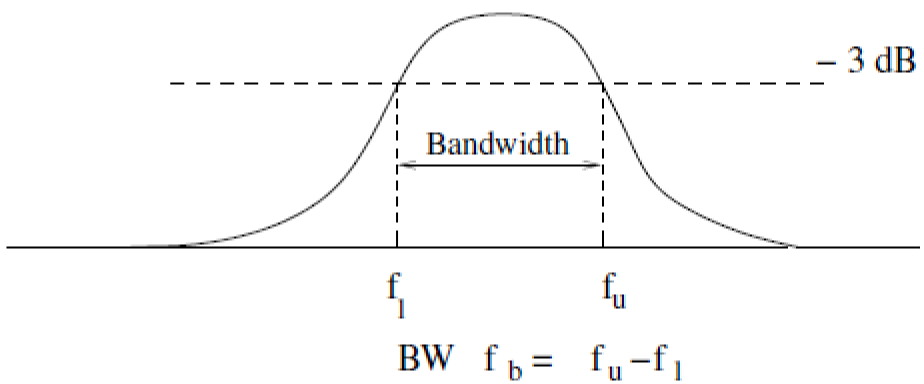

Figure 1: Bandwidth of a signal

Upper and lower cut-off (or $3dB$) frequencies corresponds to the frequencies where the magnitude of signal's Fourier Transform is reduced to half ($3dB$ less than) its maximum value.

• Importance of Bandwidth

- Bandwidth enables computation of the power required to transmit a signal.

  * Signals that are band-limited are not time-limited
  * Energy of a signal is defined as:

$$E = \int_{-\infty}^{+\infty} |x(t)|^2 dt$$

  * Energy of a signal that is not time-limited can be computed using Parsevals Theorem[a]:

$$\int_{-\infty}^{+\infty} |x(t)|^2 dt = \int_{-\infty}^{+\infty} |X(\omega)|^2 d\omega$$

[a] The power of a signal is the energy dissipated in a one ohm resistor

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∗ Multiple signals (of finite bandwidth) can be multiplexed on to a single channel.

- For all pulse signals, duration of the pulse and its bandwidth satisfies inverse relation between frequency and time.

$$\text{duration} \times \text{bandwidth} = \text{constant}$$

- wider the pulse $\Longrightarrow$ smaller is the bandwidth required

- wider the pulse $\Longrightarrow$ Inter-Symbol-Interference is an issue

– ideally a pulse that is narrow and has a small bandwidth is required

- Noise equivalent Bandwidth:

Let, a white noise signal with power $N_0/2$ be fed to an arbitrary Low Pass Filter (LPF) wwith transfer function $H(\omega)$. Then, output noise power is given by

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\begin{aligned}
N_{out} &= \frac{1}{2\pi}\frac{N_0}{2}\int_{-\infty}^{+\infty} |H(\omega)|^2 \, d\omega \\
&= \frac{N_0}{2\pi}\int_{0}^{+\infty} |H(\omega)|^2 \, d\omega
\end{aligned}
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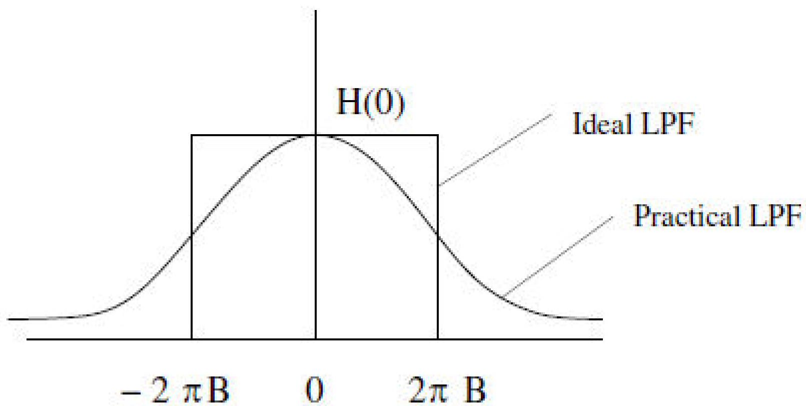

Figure 2: Ideal and Practical LPFs

For an ideal LPF,

$$N_{out} = N_0 B H^2(0)$$

$$\Longrightarrow B = \frac{\frac{1}{2\pi}\displaystyle\int_0^{+\infty} |H(\omega)|^2 \, d\omega}{H^2(0)}$$