DIGITAL COMMUNICATION

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SUMMARY

DG is the transfer of data or information using digital signals over a point-to-point (P2P) channel. A P2P connection is a mode of communication between two communication endpoints

Main purpose of communication:
to transfer information from a source to a recipient via a channel or medium.

Basic block diagram of a communication system:
Source → Transmitter → Receiver → Recipient

Why is digital important?

It reduces costs as a result of time savings in processes. It decentralises production by facilitating mobility and remote communication. It improves operational efficiency and productivity. It opens the door to new business opportunities and revenue streams, enabling the creation of new products and services.

Why Digital Communications?

- Better voice quality. ...
- Noise preservation and noise reduction. ...
- Deliver more information. ...
- Greater portability and flexibility. ...
- Simple to use.

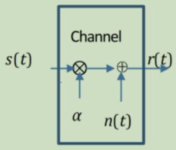
Performance metric for analog systems is fidelity, for digital it is the bit rate and error probability

Goals in Communication System Design

To
- maximize transmission rate, R
- maximize system utilization, U
- minimize bit error rate, Pe
- minimize required systems bandwidth, W
- minimize system complexity, Cx
- minimize required power,

Math for digital communication

$$r(t) = \alpha s(t) + n(t)$$



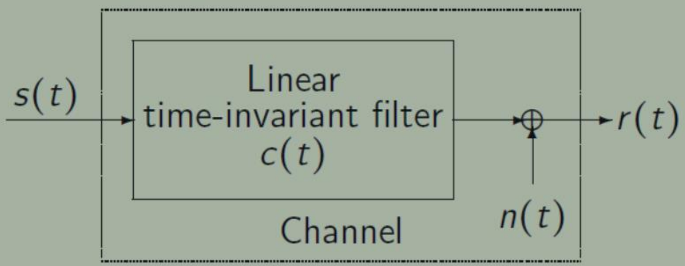
where

- α is the attenuation factor
- $s(t)$ is the transmitted signal
- $n(t)$ is the additive random noise (a random process, usually Gaussian)

Linear filter channel with additive noise

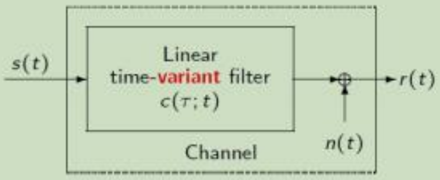
To meet the specified bandwidth limitation

Wireline telephone channel



$$\begin{aligned} r(t) &= s(t) \star c(t) + n(t) \\ &= \int_{-\infty}^{\infty} c(\tau) s(t-\tau)\, d\tau + n(t) \end{aligned}$$

Linear time-variant (LTV) filter channel with additive noise



- Underwater acoustic
- Ionospheric radio (Freq. <30M)
- Mobile celluar radio

$$\begin{aligned} r(t) &= s(t) \star c(\tau; t) + n(t) \\ &= \int_{-\infty}^{\infty} c(\tau; t) s(t-\tau)\, d\tau + n(t) \end{aligned}$$

- τ is the argument for filtering. “age ” variable
- t is the argument for time-dependence.
- The time-invariant filter can be viewed as a special case of the time-variant filter.

$c(\tau;t)$ usually has the form

$$c(\tau;t) = \sum_{k=1}^{L} a_k(t)\delta(\tau - \tau_k)$$

where

- $\{a_k(t)\}_{k=1}^{L}$ represent the possibly time-varying attenuation factor for the L multipath propagation paths
- $\{\tau_k\}_{k=1}^{L}$ are the corresponding time delays.

Hence

$$r(t) = \sum_{k=1}^{L} a_k(t)s(t - \tau_k) + n(t)$$

✓ **A Historical perspective in the development of digital communication**
The following below theorems/novel are very basic for digital communication

- Morse code (1837)
  - Variable-length binary code for telegraph
    - More frequent word uses shorter length, less frequent word uses longer length.
    - Dashes and dots
- Baudot code (1875)
  - Fixed-length binary code of length 5
  - Mark and space
- Nyquist (1924)
  - Determine the maximum signaling rate without inter-symbol interference over, e.g., a telegraph channel

CHAPTER - TWO

From this chapter, we have studied two main concepts:

(1) Band pass signal:- it is real signal ($X(f)=0$ for all $|f \pm f_0| > W$)

* Hermitian symmetric → the spectrum of a band pass

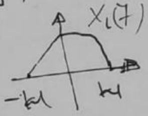
$$X(-f) = X^*(f) \quad \text{(Fourier transform)}$$

(2) Baseband (Low pass) signal:- complex signal - x_L

$$X_L(f) = 0 \quad \text{for all } |f| > W \rightarrow \text{bandwidth}$$

→ By time domain $X_L(t) = X_i(t) + jX_q(t)$ where $x_q(t)$ quadrature signal

And our goal is to relate $X_L(t)$ to $x(t)$ & vice versa



(3) Analytical signal $X_+(t)$

$$X_+(t) = \int_{-\infty}^{\infty} X_+(f) e^{j2\pi f t} df$$

$$= \int_{-\infty}^{\infty} X(f) u_{-1}(f) e^{j2\pi f t} df$$

$$= F^{-1}\{X(f) u_{-1}(f)\}$$ → Inverse Fourier transform.

$$= F^{-1}\{X(f)\} * F^{-1}\{u_{-1}(f)\}$$

$$= x(t) * \left[\tfrac{1}{2}\delta(t) + j\frac{1}{2\pi t}\right]$$

$$X_+(t) = \tfrac{1}{2}x(t) + j\tfrac{1}{2}\hat{x}(t)$$

$$\hat{x}(t) = x(t) * \frac{1}{\pi t} = \int_{-\infty}^{\infty} \frac{x(\tau)}{\pi(t-\tau)}$$ → real valued signal.

Key points

* Bandpass Signal
$$x(t) = \mathrm{Re}\{x_l(t)\, e^{j2\pi f_0 t}\}$$
real
→ Time domain
$$X(f) = \frac{1}{2}[X_l(f-f_0) + X_l^*(-f-f_0)]$$
frequency domain

* Analytic signal or pre-envelope
$$x_+(t) \rightarrow \text{Time-domain}$$
$$X_+(f) - \text{frequency domain}$$

* Lowpass equivalent signal or complex envelope
$$x_l(t) = (x(t) + j\hat{x}(t))\, e^{-j2\pi f_0 t}$$
$$X_l(f) = 2X(f+f_0)\, u_{-1}(f+f_0)$$

* envelope → $|x_l(t)| = \sqrt{x_i^2(t) + x_q^2(t)} = r_l(t)$

* phase $\theta_l(t) = \tan^{-1} \dfrac{x_q(t)}{x_i(t)}$

* $x_l(t) \rightarrow x(t) \rightarrow$ modulation

* $x(t) \rightarrow x_l(t) \rightarrow$ demodulation

* The modulation requires to generate $\hat{x}(t)$, Hilbert transform of $x(t)$.

$$x(t) \rightarrow \boxed{h(t) = \frac{1}{\pi t}} \rightarrow \hat{x}(t)$$

* The Energy of complex signal is
$$\mathcal{E}_s = \int_{-\infty}^{\infty} |s(t)|^2\, dt$$

$$\mathcal{E}_x = \int_{-\infty}^{\infty} |x(t)|^2\, dt$$
$$\mathcal{E}_{x_+} \int_{-\infty}^{\infty} |x(t)|^2\, dt$$
$$\mathcal{E}_{x_l} = \int_{-\infty}^{\infty} |x(t)|^2\, dt$$