Introduction

1. Elements of Digital Communication System

Digital Signal: A digital signal is discrete in time and has a finite number of output characters i.e. “discrete in time and discrete in amplitude”.

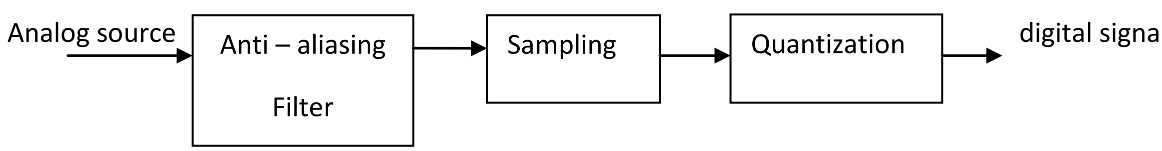
Remember that: digital is not equal to binary signal (0,1).

For M-ary symbols $M = 2^b$, where b is number of bits in the symbol.
If b=1, then M=2 *i.e.* a binary signal has two symbols.
So the modulator transmits $s_i(t)$, i = 0,1,…,M-1 distinct waveforms

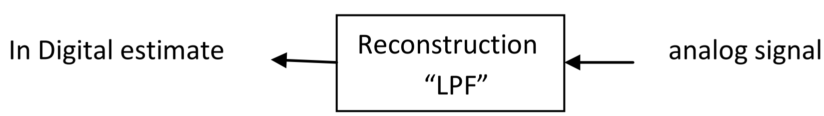
2. Analog to digital conversion “A2D”

Explain Nyquist sampling theorem.

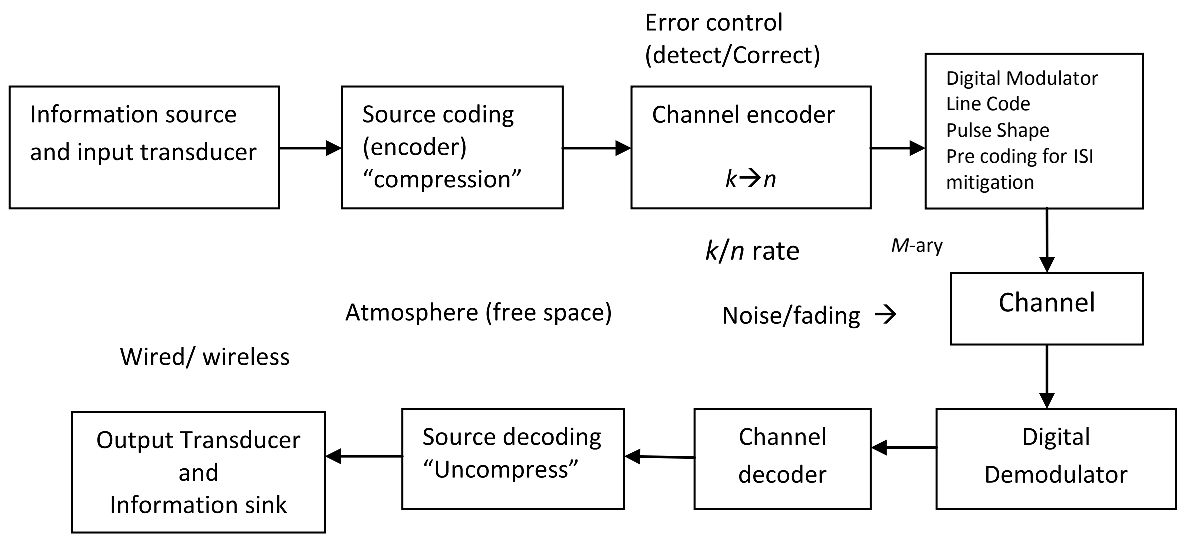
Are we human analog or digital?



If the original signal was analog:



3. Communications System Block Diagram



Is noise good or bad?

Thanks Allah for noise, if there were no noise, we would have no Job !

There are many types of noise (e.g. additive thermal noise)

Important Terms

Power, Bandwidth, Transmission rate, BER, cost, SNR, SER

BER (Bit Error Rate): The average probability of a bit-error at the output of the decoder is a measure of the performance of the demodulator- decoder combination.

But this is not always the best measure

Compare with FER (frame error rate) or SER(symbol error rate)

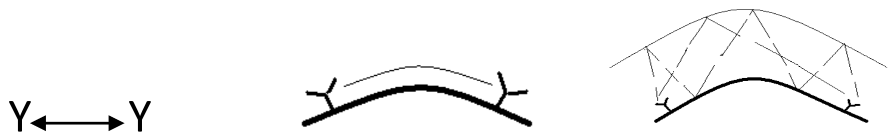
4. Communication Channels and their characteristics

Examples: wires/fiber optics/ underwater ocean "acoustics"
Data Storage media (Disks (magnetic/optical(DVD))

Additive noise (thermal noise) is common to all caused by solid state electronics.
The transmitted signal is affect by interference, signal attenuation, amplitude and phase distortion.

Comparison of co-axial to twisted pairs. (Bandwidth) (Usage) (Cross talk) shown in Figure 1.2-1 (Digital Communications, Proakis and Salehi)
Fiber optics (Trans- Atlantic/ Trans- Pacific) → uses LED/Laser.

Wireless antenna has at least $\lambda/10$ wavelength calculated using the equation $f_c \lambda = c$



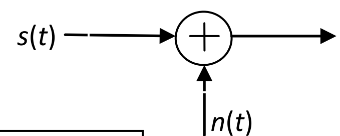
LOS Ground wave Sky wave

Major problems (signal fading due to multipath)

In the course website, there are 2 figures from the text and a link to a PDF figure for the frequency allocation in the US.

5. Mathematical Models for Communication Channels

Models represent the most important characteristics.



The additive noise channel

$r(t)=s(t)+n(t)$ ...(1)

Noise due to

- Electronic components generates thermal noise
- Interference in transmission

Thermal noise is usually characterized by Gaussian noise process. This is why we limit our model.

Additive Gaussian Noise channel (AWGN).

- Very widely used because 1) Applies to a broad class of physical communication channels
  2) Mathematically tractable.

Additive Gaussian Noise channel (AWGN) with attenuation

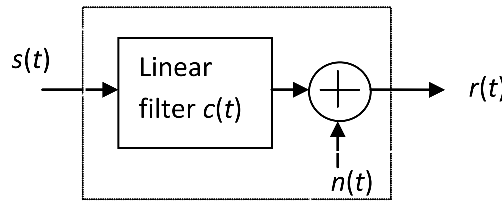
Received signal with signal attenuation and AWGN noise is given as

$r(t) = \alpha\, s(t) + n(t)$ ……(3) where α is the attenuation factor

The linear Filter channel

Filters (modeled as linear filter) are used frequently (e.g. to control the bandwidth)

$$r(t) = s(t) * c(t) + n(t)$$
$$\int_{-\infty}^{\infty} c(\tau) s(t-\tau) d\tau + n(t) \quad \text{.......(4)}$$



where $c(t)$ is the impulse response of the filter.

The linear time-invariant (LTI) filter channel

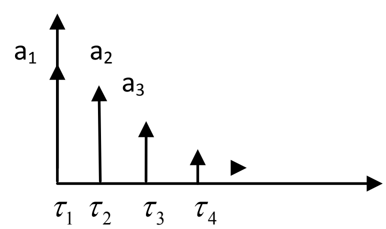
In more realistic form , the channel is expressed as $c(\tau;t)$ τ : elapsed time

$$r(t) = s(t) * c(\tau;t) + n(t) = \int_{-\infty}^{\infty} c(\tau;t) s(t-\tau) d\tau + n(t) \quad \text{......(5)}$$

Example: Mobile Cellular Radio Channel

A special case of mobile cellular radio

If $c(\tau;t) = \sum_{k=1}^{L} a_k(t) \delta(t-\tau_k)$ ......(6)



Substituting equation (6) in (5)

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

The received signal consists of L multipath components, where each component is attenuated by $\{a_n(t)\}$ and delayed by $\{\tau_k\}$.

6. A Historical Perspective.

1837 → Morse code

1875 → Baudot: fixed length code

1924 → Nyquist: ISI

1939 → Kolmogrov
1942 → Wiener } optimum linear filter (receiver)

1948 → Shannon: channel capacity $C = W \log_2(1 + \frac{P}{WN_0})$ bits/sec (Information theory)

1950 → Hamming

1965 → Wozencraft and Jacobs

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1993 → Berrou (1993) *et. al.* : turbo codes.