A (NAIVE) DIGITAL RADIO

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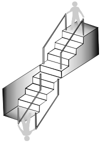


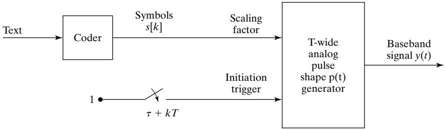
the big picture

An Illustrative Digital Communication System

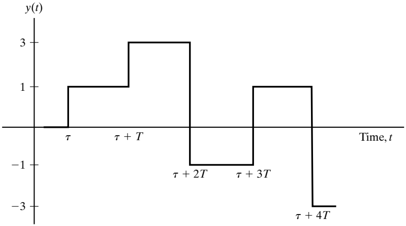
- Objective: Send text converted to a stream of bits from place 1 to place 2 through the analog medium in between.
- Coding: Use standard ASCII code to convert text to bits (using 8 bits per character)
- Transmitter: Use sequence of scaled rectangular pulses to convey bits singly, e.g., $1 \rightarrow +1$ and $0 \rightarrow -1$ or in clusters, e.g., $10 \rightarrow +1$, $01 \rightarrow -1$, $00 \rightarrow -3$, and $11 \rightarrow +3$. We choose pairs, so groups of 8 bits become clumps of 4 symbols.
- Receiver: Sample received pulse and convert symbols to bits, e.g., $1, 3, -1, 1, -3 \rightarrow 1000011011$, and then back to text.

Transmitter and Transmitted Pulse Sequence

- An idealized baseband transmitter



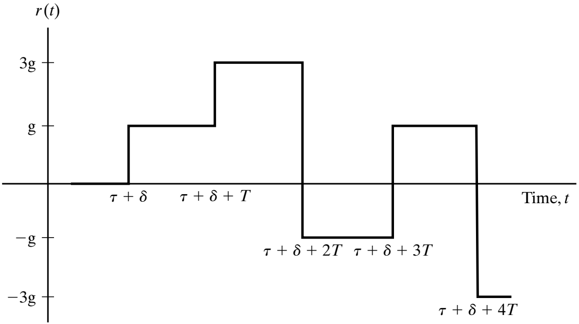
and transmitted (baseband) signal



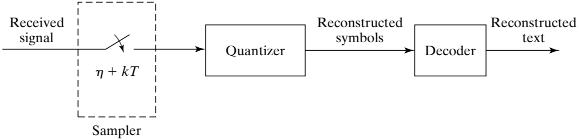
- The transmitted signal consists of a sequence of pulses, one corresponding to each symbol.
- Each pulse has the same rectangular shape though offset in time and scaled in magnitude.

Received Signal and Receiver

- In the ideal case, the received signal is the same as the transmitted signal though attenuated in magnitude and delayed in time.



- An idealized baseband receiver



Synchronization Issues

- Baud (symbol) timing
  - η selection for fixed T
  - top-dead-center

$$\eta = \tau + \delta + T/2$$

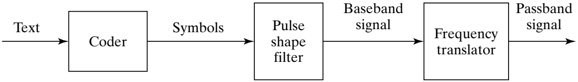
- Frame start determination
  - grouping symbols to decoder
  - example: $-1, -1, 1, -3, -1$; first 4 symbols decode to "X" and last four decode to "a"

Spectrum Sharing

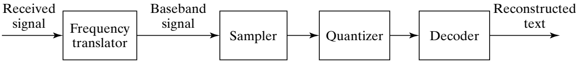
- Several user pairs should be able to communicate through same medium simultaneously in same geographical region.
- Interference avoidance achieved by disallowing use of same frequencies by different users in same geographical area.
- Bandwidth occupied by pulse shape/sequence is inversely related to rectangle width.
- More frequent symbol transmission achieved by narrower pulses increases exclusionary baseband spectrum requirement.
- If all frequencies in bandlimited baseband spectrum can be translated by same amount, several users could be multiplexed to different center frequencies without overlap.

Radio Frequency (RF) Communication System

- RF transmitter

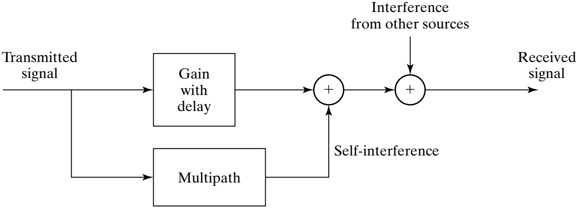


- RF receiver



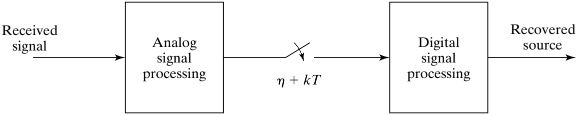
Practical Obstacles

- precise frequency translation required in receiver
- precise timing required in receiver
- multi-user interference occurs in received signal, e.g. since each user is not strictly bandlimited in frequency
- noise contamination of transmitted signal: in-band, out-of-band, narrowband, or broadband
- channel distortion: fading or multipath



Analog/Digital Signal Processing Split

- Due to cost and flexibility benefits, modern radio design is pushing the sampler (and subsequent digital signal processing) closer to the received signal, i.e. the output of the low noise amplifier driven by the antenna signal.



- Sample period $T_s \leq$ symbol period T.

An ASP/DSP Division of Labor

ASP:

- frequency translation to intermediate frequency
- out-of-band signal attenuation
- automatic gain control

DSP:

- downconversion to baseband
- carrier tracking
- symbol timing (via interpolation)
- channel compensation (via linear filtering)
- symbol decision (via quantization)
- frame synchronization (via correlation)
- decode symbols to message text

Walk This Way

Steps of increasing complexity and utility:

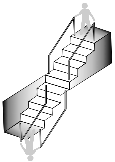
- *Naive digital communication* (chapter 1)
  - digits to waveforms and back again
  - synchronization matters
  - 3 parts: transmitter, channel, and receiver
- *Basic components* (chapters 2-3)
  - basic elements: oscillators, linear filters, samples, static nonlinearities, and adaptation
  - ordering: coding, pulse shaping, frequency translation, sampling, decision device, and decoding

Walk This Way (cont'd)

- *Idealized system* (chapters 4-9)
  - reception without impairments and with omniscience
  - start at the middle of the PAM system (i.e. the channel between the transmitter and receiver) and study the system in both directions.
  - simulate the resulting idealized receiver, which can be crippled by practical impairments.
- *Adaptive component* (chapters 10-14)
  - reception with impairments and without omniscience
  - peel back from the middle again, focusing primarily on additions in the receiver half intended to handle the anticipated impairments: carrier recovery, matched receive filtering, baud-timing, equalization, and coding

Walk This Way (cont'd)

- *Integration* (chapters 15-16)
  - putting it all together
  - receiver design methodology
  - PAM system design project



NEXT... We examine a digital PAM telecommunication system at the component architecture layer and settle on a particular processing ordering for the receiver.