**Simulation of a Full Digital Communication System**

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**1. Introduction**

This report presents the implementation and analysis of a complete digital communication system simulation. The system involves the transmission of an audio signal through a quantization process, pulse shaping using a raised cosine filter, transmission through an Additive White Gaussian Noise (AWGN) channel, and final reconstruction at the receiver. The project evaluates the system's performance by comparing bit error rate (BER) under different Signal-to-Noise Ratio (SNR) conditions.

**2. System Overview**

The digital communication system is divided into three key stages:

1. **Quantization:** Conversion of the continuous-valued audio signal into a discrete bit stream.
2. **Pulse Shaping:** Application of a raised cosine filter to shape the transmitted symbols for efficient transmission.
3. **AWGN Channel Transmission & Reception:** Simulation of noise interference and application of a matched filter at the receiver for signal reconstruction.

**3. Implementation Details**

**3.1 Quantization**

* The original audio signal (helloWorld.wav) is loaded and played.
* The signal is quantized using a **2-bit quantizer**, resulting in L = 2^2 = 4 quantization levels.
* The quantized signal is mapped to a bitstream representation.
* The quantized signal is played for perceptual evaluation.

**3.2 Pulse Shaping**

* Binary polar signaling is used, where 0 and 1 are mapped to -1 and 1, respectively.
* A **raised cosine (RC) pulse** with a roll-off factor r = 0.25 is used to shape the signal.
* The bit stream is **upsampled** before convolution with the raised cosine filter to generate the transmitted symbols.
* A **time-domain plot** of the shaped symbols is generated.

**3.3 AWGN Channel and Reception**

* The shaped symbols are transmitted through an AWGN channel with a given **SNR (in dB)**.
* The received signal is processed using a **matched filter** to maximize the SNR.
* The symbols are sampled at every bit duration and **threshold detection** is applied to recover the transmitted bits.
* The empirical **Bit Error Rate (BER)** is computed and compared to the theoretical BER using the **Q-function** approximation.
* The quantized levels are reconstructed from the received bitstream, and the recovered signal is played for evaluation.

**4. Results and Analysis**

**4.1 Audio Quality Evaluation**

* The original audio, quantized audio, and received audio were played to subjectively assess quality degradation.
* The 2-bit quantization results in noticeable distortion due to the coarse quantization levels.

**4.2 Signal Visualization**

* The transmitted and received signals were plotted to observe distortions introduced by noise.
* The raised cosine pulse effectively reduces inter-symbol interference (ISI).
* The matched filter output enhances the received signal, making it easier to decode.

**4.3 BER Performance**

* BER was computed for varying SNR values (-5 dB to 10 dB).
* A **semilog plot of BER vs. SNR** was generated to compare empirical and analytical results.
* As expected, the BER decreases as SNR increases, demonstrating the system’s robustness to noise at higher SNR values.

**5. Conclusion**

This project successfully simulated a digital communication system, demonstrating key concepts such as quantization, pulse shaping, and matched filtering. The BER performance aligns well with theoretical expectations, validating the system's accuracy. Future work could explore higher quantization levels, alternative pulse shaping techniques, and channel coding for improved performance.