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Objective

The objective of this experiment is to evaluate the bit error rate (BER) performance of a 1/2-rate convolutionally encoded Direct Sequence Code Division Multiple Access (DS-CDMA) system over an Additive White Gaussian Noise (AWGN) channel using MATLAB simulation. The aim is to understand how convolutional coding and spreading improve the system's performance in the presence of noise.

Theory

A DS-CDMA (Direct Sequence Code Division Multiple Access) system is a type of spread-spectrum communication technique where each bit of data is multiplied by a high-rate pseudo-random noise (PN) code to spread the signal across a wider bandwidth. This spreading helps make the system more robust to interference and noise.

In this experiment, we also apply convolutional coding with a code rate of 1/2 to introduce redundancy, which allows the receiver to detect and correct errors. The output of the convolutional encoder is then BPSK modulated, spread using a PN sequence, and transmitted through an AWGN channel.

Convolutional Encoding

A 1/2-rate convolutional encoder means that each input bit produces two output bits. The encoder can be described using a trellis structure

◆ Spreading using PN Sequence

The encoded bits are mapped using **BPSK**:

$$0 \to -1, \quad 1 \to +1$$

Then each symbol is **spread** using a pseudo-random sequence $c = [c_1, c_2, ..., c_L]$, where each $c_i \in \{-1, +1\}$ and L is the **spreading factor**. The spread signal becomes:

$$x_i = s_i \cdot c = [s_i \cdot c_1, s_i \cdot c_2, ..., s_i \cdot c_L]$$

Transmission over AWGN Channel

The signal is transmitted through an AWGN channel, which adds noise to the transmitted signal. The received signal is given by:

$$r(t) = x(t) + n(t)$$

BER (Bit Error Rate)

The performance of the system is measured using **Bit Error Rate (BER)**, which is the ratio of the number of incorrect bits to the total number of transmitted bits:

$$\text{BER} = \frac{\text{Number of Error Bits}}{\text{Total Number of Bits}}$$

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Objective

The objective of this experiment is to simulate and evaluate the **bit error rate (BER)** performance of a **1/2-rate convolutionally encoded Direct Sequence CDMA (DS-CDMA) system** under two different wireless channels:

1. **Additive White Gaussian Noise (AWGN)**
2. **Rayleigh Fading Channel**

This helps in understanding how convolutional coding and spreading improve the robustness of the DS-CDMA system under different channel conditions.

🔬 Theory

This experiment evaluates the performance of a **1/2-rate convolutionally encoded DS-CDMA system** over **AWGN** and **Rayleigh fading** channels. In DS-CDMA, each data bit is multiplied by a pseudo-random noise (PN) code, spreading the signal over a wider bandwidth, which improves resistance to noise and interference. A **convolutional encoder** with rate 1/2 adds redundancy by converting each input bit into two output bits. This helps in error correction at the receiver using the **Viterbi algorithm**.

The encoded data is modulated using **BPSK**, where:

$$0 \rightarrow -1, \quad 1 \rightarrow +1$$

and then spread using a PN sequence. The **AWGN channel** adds Gaussian noise $n(t)$ to the signal:

$$r(t) = x(t) + n(t)$$

In the **Rayleigh channel**, the signal also experiences random fading $h(t)$:

$$r(t) = h(t)x(t) + n(t)$$

At the receiver, equalization is done (for Rayleigh), then the signal is despread, demodulated, and decoded. Finally, **Bit Error Rate (BER)** is calculated as:

$$\text{BER} = \frac{\text{Number of Errors}}{\text{Total Bits}}$$

This shows how coding and spreading enhance system performance in both noise and fading conditions.

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Objective

The objective of this experiment is to evaluate the **bit error rate (BER)** performance of a **1/2-rate convolutionally encoded DS-CDMA system** under **AWGN** and **Rician fading** channels using MATLAB simulation. The aim is to understand how convolutional coding and spreading improve reliability in the presence of noise and multipath fading with a dominant line-of-sight (LOS) path.

🔬 Theory

Direct Sequence CDMA (DS-CDMA) is a spread-spectrum system that multiplies each BPSK-modulated bit by a pseudo-random code to spread the signal over a wider bandwidth. To improve error correction, a **1/2-rate convolutional encoder** is used, where each input bit generates two coded bits. This redundancy helps the **Viterbi decoder** correct errors at the receiver. The modulated bits use **BPSK**, where:

$$0 \rightarrow -1, \quad 1 \rightarrow +1$$

The spread signal passes through either an **AWGN channel**, which adds Gaussian noise:

$$r(t) = x(t) + n(t)$$

or a **Rician fading channel**, which models multipath with a dominant direct path:

$$r(t) = h(t)x(t) + n(t)$$

Here, $h(t)$ includes both a strong LOS component and a scattered component. Equalization is applied at the receiver to compensate for channel effects. The signal is then despread, BPSK-demodulated, and Viterbi-decoded. Finally, **BER** is calculated as:

$$\text{BER} = \frac{\text{Number of Error Bits}}{\text{Total Transmitted Bits}}$$

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Objective

The objective of this experiment is to study and simulate the **Bit Error Rate (BER)** performance of a **differentially encoded OQPSK-based wireless communication system** in the presence of noise. The goal is to observe how differential encoding and offset modulation improve system performance in noisy environments, such as an AWGN channel.

🔬 **Theory**

OQPSK (Offset Quadrature Phase Shift Keying) is a variant of QPSK where the quadrature component is delayed by half a symbol duration. This reduces abrupt phase changes and limits signal envelope variation, making it suitable for non-linear channels. In OQPSK, symbols are split into **I (In-phase)** and **Q (Quadrature)** components, with Q delayed by T/2T/2T/2. The modulated signal is:

components, with Q delayed by $T/2$. The modulated signal is:

$$s(t) = I(t) \cdot \cos(2\pi f_c t) + Q(t - T/2) \cdot \sin(2\pi f_c t)$$

To avoid phase ambiguity in demodulation, **differential encoding** is applied before modulation. Each symbol is encoded based on the previous symbol:

$$d_n = b_n \oplus d_{n-1}$$

where b_n is the input bit, and d_n is the differentially encoded bit.

The signal is transmitted over an **AWGN channel**, which adds Gaussian noise:

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

At the receiver, differential demodulation is performed followed by BER calculation:

$$\text{BER} = \frac{\text{Number of Errors}}{\text{Total Transmitted Bits}}$$

This experiment helps us understand how OQPSK combined with differential encoding enhances performance in practical wireless systems.

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Objective

The objective of this experiment is to develop a MATLAB simulation for a wireless communication system that uses Interleaved Forward Error Correction (FEC) and BPSK digital modulation. The system's performance is observed at different stages (data, encoded, and modulated signals), and at least three waveforms are displayed to understand the signal transformation through the communication chain.

🔬 Theory

A wireless communication system often suffers from burst errors caused by noise and fading. To combat this, Forward Error Correction (FEC) is used along with interleaving. FEC adds redundancy to the transmitted data using codes like convolutional or block codes. Interleaving rearranges encoded bits to spread burst errors across multiple codewords, improving error correction.

After interleaving, **BPSK (Binary Phase Shift Keying)** is applied, where binary bits are mapped as:

$$0 \to -1, \quad 1 \to +1$$

The modulated signal is transmitted through an **AWGN channel**, represented as:

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

where $s(t)$ is the modulated signal and $n(t)$ is additive white Gaussian noise.

At the receiver, the signal is demodulated, deinterleaved, and decoded using the appropriate FEC decoding method. The **Bit Error Rate (BER)** is measured to evaluate system performance:

$$\text{BER} = \frac{\text{Number of Bit Errors}}{\text{Total Number of Bits}}$$

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Objective

The objective of this experiment is to simulate a wireless communication system using Interleaved Forward Error Correction (FEC) and QPSK (Quadrature Phase Shift Keying) digital modulation in MATLAB. The goal is to analyze the effect of interleaving and error correction on system performance and visualize at least three waveforms from different stages of the system.

🔬 Theory

Wireless channels often experience burst errors due to noise and fading, which can severely degrade communication quality. Forward Error Correction (FEC) codes add redundant bits to the data stream, enabling the receiver to detect and correct errors without retransmission. However, FEC alone may struggle with burst errors, so interleaving is applied to rearrange the encoded bits, spreading bursts over multiple codewords and improving error resilience.

In this system, the interleaved encoded bits are modulated using QPSK, which transmits two bits per symbol by shifting the phase of a carrier signal among four states:

$$s(t) = \sqrt{\frac{2E_s}{T}} \cos(2\pi f_c t + \theta_k)$$

where $\theta_k \in \{45^\circ, 135^\circ, 225^\circ, 315^\circ\}$ represents four phase shifts corresponding to bit pairs.

The signal is then transmitted over a noisy wireless channel, typically modeled as **AWGN (Additive White Gaussian Noise)**:

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

where $n(t)$ is Gaussian noise.

At the receiver, the signal undergoes demodulation, deinterleaving, and FEC decoding to recover the original data. Bit Error Rate (BER) is calculated to evaluate performance. Visualizing waveforms at various points (input data, encoded data, modulated signal) helps understand the impact of each processing step.

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Objective

The objective of this experiment is to simulate a wireless communication system using **Interleaved Forward Error Correction (FEC)** and **4-QAM (Quadrature Amplitude Modulation)** in MATLAB. The aim is to observe how interleaving combined with FEC improves error performance, and to display waveforms at different stages of the system such as input data, encoded/interleaved data, and modulated signals.

🔬 Theory

In wireless communication, noise and fading cause errors, especially burst errors that affect consecutive bits. **Forward Error Correction (FEC)** adds redundant bits to detect and correct errors without retransmission. To combat burst errors effectively, **interleaving** rearranges encoded bits so that burst errors are spread over multiple codewords, making them easier to correct.

After interleaving, the data is modulated using **4-QAM**, which transmits 2 bits per symbol by varying both amplitude and phase of the carrier signal. The 4-QAM symbol set can be represented as:

$$s_k = A \cdot e^{j\theta_k}, \quad \theta_k = \left\{ \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4} \right\}$$

where A is the amplitude and θ_k are the constellation phases.

The modulated signal passes through an **AWGN channel**, modeled as:

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

where $n(t)$ is Gaussian noise.

At the receiver, the signal is demodulated, deinterleaved, and decoded to recover the original data. The system's performance is evaluated by calculating the Bit Error Rate (BER). Plotting waveforms at various points helps visualize the signal transformation and effect of encoding and modulation.

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Objective

The objective of this experiment is to simulate an **Interleaved Forward Error Correction (FEC)** encoded wireless communication system employing **16-QAM (Quadrature Amplitude Modulation)** in MATLAB. The experiment aims to evaluate the system performance under noisy conditions and to visualize signal waveforms at different stages such as input data, encoded/interleaved data, and modulated signals.

🔬 **Theory**

Wireless communication channels often introduce noise and burst errors that degrade system performance. **Forward Error Correction (FEC)** codes add redundancy to the data stream, enabling the correction of errors at the receiver without retransmission. To combat burst errors effectively, **interleaving** rearranges the coded bits so errors spread across multiple codewords, improving the decoder's ability to recover data accurately.

After interleaving, data is modulated using **16-QAM**, which transmits 4 bits per symbol by varying both amplitude and phase of the carrier signal. The 16-QAM constellation contains 16 points arranged in a square grid, with symbols represented as:

$$s_{m,n} = A_m + jA_n, \quad A_m, A_n \in \{\pm 1, \pm 3\}$$

where A_m and A_n are amplitude levels.

The modulated signal passes through an **Additive White Gaussian Noise (AWGN)** channel:

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

where $n(t)$ is Gaussian noise.

At the receiver, the signal is demodulated, deinterleaved, and decoded to recover the original bits. The **Bit Error Rate (BER)** is calculated to evaluate system performance. Visualizing waveforms at the data input, encoded/interleaved data, and modulated signal stages helps understand the effect of coding and modulation.