Experiment Number: 01

Name of the Experiment:

To write a MATLAB program to evaluate performance of a 1/2-rated convolutionally encoded DS CDMA system with AWGN channel.

Objectives:

The objective of this MATLAB program is to evaluate the performance of a Direct Sequence Code Division Multiple Access (DS-CDMA) system that uses convolutional coding with a rate of 1/2. The system will be tested in an AWGN channel and its performance will be measured using Bit Error Rate (BER) analysis.

Experimental Requirements:

Laptop / Desktop computer, MATLAB software.

Theory:

A 1/2-rated convolutionally encoded DS-CDMA system in an AWGN channel is used in wireless communication to enhance data reliability and resist noise. DS-CDMA spreads each users signal over a wide bandwidth using spread coding, allowing multiple users to share the same channel efficiently. Convolution encoding adds redundancy, enabling the receiver to correct error introduced by noise and interference. A 1/2 rated convolutional encoder generates two output bits for every one input bit, improving error correction but requiring more bandwidth. The AWGN channel models realworld wireless environment where noise follows a Gaussian Distribution.

The system works by first encoding the input data using convolutional encoding, followed by a spreading with DS-CDMA. The spread signal then modulated using BPSK and transmitted through the AWGN channel.

At the receiver end the signal then demodulated, despreaded and decoded to recover the original data with reduced error.

The performance evolution is based on Bit Error Rate, coding gain and processing gain. The uncoded BER for BPSK in AGWGN is given by

$$P_b = Q\sqrt{\frac{2E_b}{N_0}}$$

where E_b/N_0 is the energy per bit to noise power spectral density ratio and $Q(x)$ is the Q-function representing the probability that a random Gaussian variable exceeds x.

For a 1/2-rated convolutionally encoded system the approximate BER improves to

$$P_b \approx \frac{1}{2} Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Experiment Number: 02

Name of the Experiment: Write a MATLAB program to evaluate performance of a 1/2 rated convolutionally encoded DS CDMA system in AWGN and Rayleigh fading channel.

Objective: The objective of a 1/2 rated convolutionally encoded DS-CDMA system to enhance the reliability of wireless communication by spreading the signal for multiple user access and using error correction to reduce the impact of noise and fading. This improves Bit Error Rate performance, ensuring more accurate data transmission in AWGN and Rayleigh fading channel.

Experimental Requirements: A laptop/desktop computer, installed software MATLAB.

Theory: Wireless communication is everywhere from mobile phones, and satellites to military systems. A 1/2 rate convolutionally encoded DS-CDMA system is used to improve reliability in such conditions

DS-CDMA is a technique that spreads the signal over a much wider bandwidth using a unique code for each other. This allows multiple users to transmit data simultaneously without interfe-ring with each other. Spreading improves resistance aganist noise and interference.
Convolutionatly encoding is a method that adds redundency to transmit data, making error correction possible at the receiver. A 1/2 rated convolutional encoder generates two output bits for every input bit, meaning the transmission rate doubles, but the reliability increases.
AWGN channel is the simplest channel model. It assumes that only disturbance to transmit the signal is Gaussian Noise. The noise has a normal distribution meaning the signal is affected equally at all frequencies.
In real world wireless systems, signals reflects of different objects causing multipath propagation This leads to fading where the received signal strength varies over time
Rayleigh fading models the effect when there is no direct line of sight between transmitter and receiver, which is common in wireless communication.

To ~~BER~~ evaluate performance, we use BER Bit Error Rate, which measures the probability of a bit being received correctly. BER for AWGN (for BPSK) is

$$P_b = Q\left(\sqrt{2\frac{E_b}{N_0}}\right)$$

Where E_b/N_0 is the signal to Noise Ratio per bit
$Q(x)$ is the Q-function which gives the probability of error
With 1/2 rated convolutional encoding the BER improves to

$$P_b \approx \frac{1}{2} Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Bit Error Rate for Rayleigh fading channel

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{E_b}{E_b + N_0}}\right)$$

Experiment Number: 03

Name of the Experiment: Write a MATLAB program to evaluate performance of a 1/2-rated Convolutionally encoded DS CDMA system in AWGN and Rician fading channel.

Objective: The objective of the experiment is to evaluate the performance of a 1/2 rated convolutionally encoded DS CDMA system under different wireless channel conditions - AWGN and Rician fading. By analyzing the system's performance we aim to understand the impact of noise and fading on data transmission, assess the effectiveness of error correction coding and determine how the presence of Line-of-sight component influences communication reliability.

Experimental Requirements: A laptop/desktop PC. Application software MATLAB.

Theory: Wireless communication systems face different channel conditions that affect their performance. A 1/2-rated convolutionally encoded DS-CDMA system spreads the signal across a wide bandwidth for multi-user access and applies error correction encoding to minimize transmission errors. To evaluate its performance we analyze its behavious in AWGN and Rician fadding channels which represents different real world transmission conditions.

In DS-CDMA, multiple users shares the same bandwidth by spreading their signals with unique codes. This technique reduces interferences and improves security.

A $1/2$ rated convolutional encoder generates two output bits for every two input bits, introducing redundency for error correction at the receiver. The AWGN channel models a communication link where the only disturbance is the white Gaussian noise. The noise power is measured ~~at~~ using signal-to-noise ratio. This is the simplist channel model, commonly used as a baseline for performance analysis.

Unlik AWGN, the Rician fading channel accounts for multipath propagation, where signals arrived at the receiver using multiple paths. Rician fading occurs when there is a strong direct line of sight component along with scattered signal. The severity of fading is controlled by the Rician K factor, which represent the ratio of the direct path power to the scattered power.

- High K-factor → Strong LOS (similar to AWGN)
- Low K-factor → More scattered path similar to Rayleigh fading

Bit error rate (BER) of AWGN channel

for BPSK modulation in an AWGN channel the BER is given by

$$P_b = Q\left(\sqrt{2\frac{E_b}{N_0}}\right)$$

With convolutional encoding (1/2 rate) the BER improves, approximately given by

$$P_b = 1/2\, Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

The BER for Rician fading channel

for BPSK in a Rician fading channel, the BER is given by

$$P_b = Q(\sqrt{2\gamma})\, e^{-K} \sum_{m=0}^{\infty} \frac{K^m}{m!} I_m\left(2\sqrt{K(K+1)\gamma}\right)$$

Where

K is the Rician K factor

$I_m(x)$ the modified Bessel function of first kind

$\gamma = E_b/N_0$ is the average SER per bit.

When $K \to 0$ the channel behaves like Rayleigh fading

When $K \to \infty$ the channel behaves like AWGN

Experiment Number: 04

Name of the Experiment: To write a MATLAB program to study of the performance of a differentially encoded OQPSK based wireless communication system.

Objective: The objective of introducing and studying Offset QPSK (OQPSK) is to solve a key problem in conventional QPSK systems:- sudden 180° phase shift can cause the signal envelop to drop to zero, leading to signal distortion after nonlinear amplification.
We want to avoid envelop nulls (zero-crossing) that cause signal distortion. Allowing the signal to be amplified using nonlinear and hard limited RF amplifiers which are more power efficient than the linear amplifier.

Experimental Requirements: Computer/Laptop Simulation software MATLAB.

Theory: QPSK is a digital modulation technique that transmit data by changing the phase of the carrier signal. It uses four different phase angles 0°, 90°, 180° and 270° so each symbol represents two bits. The binary data

is split into two streams: one modulates in-Phase (I) and the other modulates the Quardrature (Q) carrier, which is 90° out of phase.
In QPSK both I and Q signal can change at the same time. The simultaneous change can cause a sudden 180° phase shift which lead's the signal amplitude to drop to zero briefly. The zero crossing can be distorted when it is passed through the non linear amplifier causing spectral spreading and signal degradation. To avoid this. QPSK needs linear amplifier which are less power efficient.
Offset QPSK or OQPSK is a variation of QPSK that avoids 180° phase shifts. It achieves this by delaying the Q component by half a bit period. As a result, I and Q never change at the same time - only one change at a time limiting the phase change to a maximum of ±90°.
The offset prevents the signal amplitude from dropping to zero, even after pulse shaping. Because of this, OQPSK can be amplified using non linear amplifiers without significant distortion making it more power efficient and suitable for mobile system.

Mathematical Expression / Logical Flow

QPSK signal can be represented as

$$S(t) = I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t)$$

where,

$I(t), Q(t) \in \pm 1$ $\because$ Both can change at same time

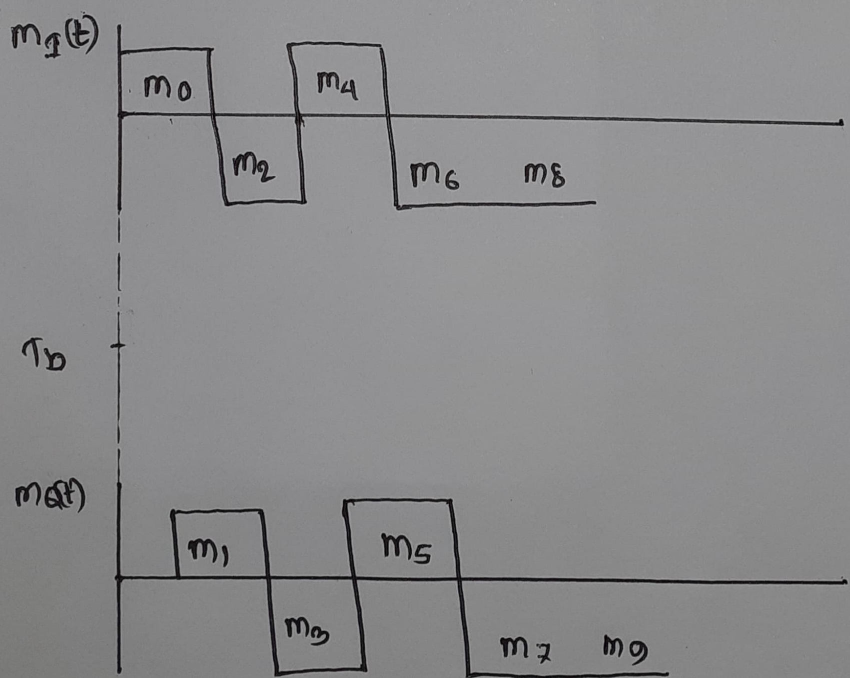
In Offset QPSK

$$S(t) = I(t)\cos(2\pi f_c t) - Q(t - T_b)\sin(2\pi f_c t)$$

Where

$T_b = \frac{T_s}{2}$ the bit duration

$Q(t)$ is delayed by T_b



Experiment Number: 05

Name of the Experiment: To develop a MATLAB Source to simulate and interleaved FEC encoded wireless communication system with implementation of BPSK modulation technique showing at least three waveform generated at different sections of the simulated system.

Objective: The goal of the system is to ensure reliable wireless communication even in the presence of noise and interference. We achieve this by

1. Using forward error correction to detect and correct errors at the receiver
2. Applying interleaving to spread brust errors over time
3. Modulating the signal using Binary Phase Shift keying, a simple but robust digital modulation technique

By doing this we aim to improve data accuracy and reduces the chances of transmission errors

Experimental Requirements: Computer / Laptop
Simulation software MATLAB

Theory: A wireless communication system is often affected by noise, fading and interference. To improve the reliability two key techniques are used

1. FEC (Forward Error Correction): This is a method where extra bits (called redundant) are added to the original data before transmission. These bits helps the receiver identify and correct error without needing retransmission. Common FEC codes includes convolutional codes and block codes

2. Interleaving:
Wireless channel sometimes introduces brust errors - a group of consecutive bits get corrupted. Interleaving spreads the bits of the message overtime, so that if a brust error occurs, it only affects the scattered bits from different message. This makes error correction easier.

3) BPSK (Binary Phase Shift Keying) : BPSK is a modulation technique where each bit (0 or 1) is represented by a signal with different phase

Bit 0 → Signal with phase 0°

Bit 1 → Signal with phase 180°

Number of the Experiment: 06

Name of the Experiment: To develop a MATLAB source to simulate an Interleaved FEC encoded wireless communication system to implementation of QPSK Digital modulation technique. and showing at least theree waveforms generated at different section of the simulated system.

Objective: The main object is to simulate a wireless communication system that can reliably transmit data even in the presence of noise and error. We aim to:

1. Use forward error correction (FEC) to detect and correct bit errors.
2. Apply interleaving to protect aganist brust errors
3. Use Quandrature phase shift keying (QPSK) for efficient digital modulation
4. Observe the sytem's performance by analyzing waveform at key stages

Experimental Requirements: Desktop/Laptop computer simulation software MATLAB.

Theory:

* Forward Error Correction

FEC is a technique used to add extra bits to the original message before sending it. These extra bits help the receiver detect and correct any error without needing to ask for retransmission. This is very useful in wireless communication where sending data again and again may be slow or costly

* Interleaving

Interleaving rearranges the order of the bits after FEC. ~~Its~~ main purpose is to spread out the errors caused by sudden interference (like noise and spike). ~~Whiout~~ Without interleaving, several error might hit one codeword and make it undecodeable with interleaving, those error get spread across different codewords, making them easier for FEC.

At the receiver, deinterleaving ~~plus~~ puts the bits back to their original order before decoding them.

* QPSK Modulation:

QPSK is a digital modulation technique that sends two bits at a time using four different shifts of a carrier signal.

00 → Phase 0°

01 → Phase 90°

10 → Phase 270°

11 → Phase 180°

This means QPSK is twice as efficient as BPSK because it sends two bits per symbol instead of one. It also balance bandwidth efficiency with noise performance, which is the perfect for wireless application.

Mathematical Representation:

Each symbol is QPSK can be represented by a cosine wave with a certain phase

$$s(t) = \sqrt{2P} \cos(2\pi f_c t + \phi)$$

Experiment Number: 07

Name of the Experiment: To develop a MATLAB source to simulate an Interleaved FEC encoded wireless communication system with implementation of 4-QAM digital modulation technique. and showing at least three waveforms generated at different section of the simulated system.

Objective: The main goal is to design and analyze a wireless communication system that combines
- (*) forward Error Correction to correct the errors at the receiver without retransmission.
- (*) Interleaving to protect the data from burst error caused by noise or fading
- (*) 4-QAM (Quandrature Amplitude modulation) to efficiently transmit data using both phase and amplitude change.

Experimental Requirements: Desktop/Laptop computer and simulation software MATLAB.

Theory:

Forward Error Correction (FEC): FEC is a technique where extra redundant bits are added to the original message. These bits help the receiver detect and correct error without need retransmission. Common techniques include block code like Hamming code ~~and~~ or convolutional codes. for example in a (7,4) Hamming code, every 4 bits of the data are converted into 7 bits by adding 3 parity bits

Interleaving

Interleaving is a method that rearranges the order of the encoded bits before ~~re~~transmission. So, if a burst error occurs and damages several bits in a row, they will likely belong to different codewords after deinterleaving. This makes easier for the decoder to recover the original message using FEC.

4 QAM Modulation

4QAM modulation technique where each symbol represents 2 bits by varying both amplitude and phase of the signal. It is often visualized using a constellation diagram with four points, each representing a pair of bits

$00 \rightarrow +1 + 1j$

$01 \rightarrow +1 - 1j$

$10 \rightarrow -1 + 1j$

$11 \rightarrow -1 - 1j$

This method is more bandwidth efficient than simpler modulation like BPSK because it transmits twice as much data per symbol.

Mathematical Expression (Simplified)

Each modulation symbol in 4-QAM can be expressed as complex number

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

Where,

$I(t)$ is the in phase component (bit 1)

$Q(t)$ is the quadrature component (bit 2)

f_c is the carrier frequency.

The transmitted waveform is a combination of two orthogonal sine waves, each modulated by different bit of the output.

Experiment Number: 08

Name of the Experiment: To develop a MATLAB source to simulate an Interleaved FEC encoded wireless communication system with implementation of 16 QAM digital modulation technique and showing at least three waveforms generated at different section of the simulated system.

Objective: The main objective of the simulation is to develop and analyze a wireless communication system that uses

- Forward Error Correction to detect and correct errors
- Interleaving to reduce the effect of brust error.
- 16-QAM to improve spectral efficiency.

The simulation aims to show how each component transforms the data and improves systems performance in noisy environments. We will observe waveform at three key stages

1. Before Modulation.
2. After interleaving and encoding.
3. After 16-QAM Modulation

Experimental Requirements: Desktop or Laptop computers, simulation software MATLAB

Theory:

* Forward Error Correction

FEC is a technique where the sender adds redundant bits to the original signal to the original data so the receiver can detect and correct errors without asking for retransmission.

Common codes: Hamming codes or Convolutional coding.

For example, A Hamming (7,4) code takes 4 data bits to form a 7-bit codeword.

Interleaving:

Interleaving is used after FEC to spread burst error across multiple codewords

It rearranges the bits in a matrix-like fussion before transmission. At the receiver the process is reverse

16 QAM

16-QAM stands for 16-level Quandrature Amplitude Modulation. It is a digital modulation technique used to transmit data by varying both the amplitude and phase.

of the carrier signal.

In 16 QAM

* Each symbol (signal unit) represents 4 bits of data
* There are 16 unique symbols in data
* These symbols are represented as points on a constellation diagram, using different amplitude and phase

So 16 QAM is a hybrid of amplitude modulation and phase modulation.

Because we have 4 bits we can have $2^4 = 16$ combinations. So 16-QAM has 16 distinct signal points each representing one unique 4-bit pattern. For example

Bits	Symbol
0000	symbol 1
0001	symbol 2
⋮	
1111	symbol 16