Experiment No.: 9

Title: Simulation study of Performance of M-ary QAM.

Roll No.: _________ Batch: __________

Date of Performance: _________________

Date of Assessment: ___________________

Particulars	Marks
Attendance (05)	
Journal (05)	
Performance (05)	
Understanding (05)	
Total (20)	
Signature of Staff Member	

Experiment No. 9

Title: Simulation Study of Performance of M-ary QAM.

Aim: To simulate and analyze the performance of M-ary Quadrature Amplitude Modulation (M-QAM) in an Additive White Gaussian Noise (AWGN) channel by observing the Bit Error Rate (BER) versus Signal-to-Noise Ratio (SNR).

Apparatus / Software Required:

1. MATLAB software (Communication Toolbox recommended)
2. Computer with MATLAB installed

Theory:

M-ary QAM is a digital modulation scheme where data is conveyed by changing both the amplitude and phase of the carrier wave. The modulation sends symbols representing bits, with each symbol mapped to a unique point in a two-dimensional constellation grid consisting of amplitude and phase variations. The larger the value of M (e.g., 16, 64), the higher the number of bits transmitted per symbol but with closer constellation points, which can increase error sensitivity. The modulated signal passes through an AWGN channel that adds noise, and the received symbols are demodulated to recover the transmitted bits. BER performance is analyzed over varying levels of SNR to evaluate system quality.

Procedure / Outline:

1. Generate a sequence of random data symbols corresponding to the modulation order M.
2. Modulate the data symbols using M-ary QAM modulation.
3. Pass the modulated symbols through an AWGN channel with different SNR values.
4. Demodulate the noisy received symbols back to data symbols.
5. Compare the transmitted and received data symbols to find bit errors.
6. Calculate and plot BER versus SNR curve to observe system performance.
7. Optionally observe the constellation diagram to visualize the effects of noise on symbol points.

Observation:

BER decreases as SNR increases. Higher-order QAM (larger M) carries more bits per symbol but has poorer BER performance at the same SNR due to closer constellation points. The constellation diagram blurs and spreads more with noise at lower SNR values.

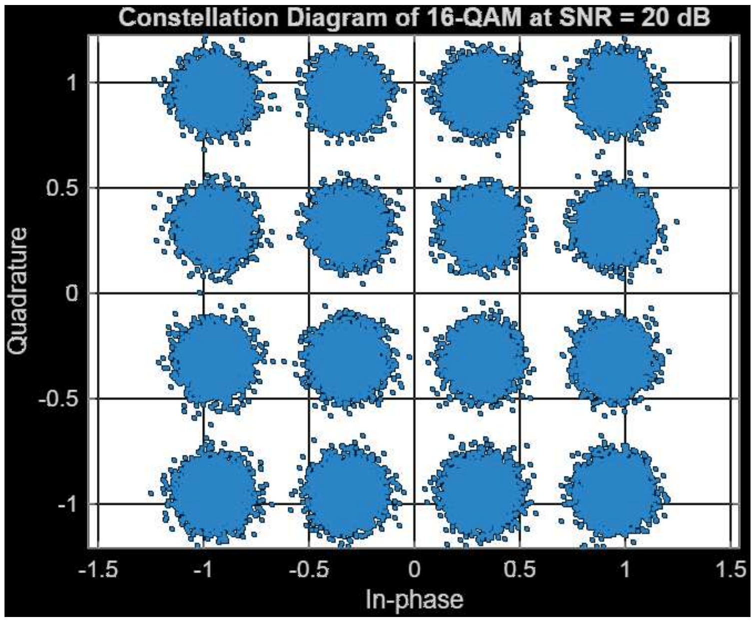
MATLAB Code Example:

```
clc;
clear all;
close all;

% Parameters
M = 16;                    % Modulation order (e.g., 16 for 16-QAM)
k = log2(M);               % Bits per symbol
numSymbols = 1e5;          % Number of symbols
snr_dB = 0:2:20;           % SNR range (in dB)
ber = zeros(length(snr_dB),1);

% Generate random data symbols
data = randi([0 M-1], numSymbols, 1);

% MANUAL QAM MODULATION
% Generate constellation points (square QAM)
m_side = sqrt(M);
if rem(m_side,1) ~= 0
    error('M must be a perfect square for square QAM (e.g., 4, 16, 64, 256).');
end

% Gray-coded mapping (optional but standard)
I = mod(data, m_side);
Q = floor(data / m_side);

% Center constellation around zero
I = 2*I - m_side + 1;
Q = 2*Q - m_side + 1;

% Normalized average power to 1
txSig = (I + 1j*Q);
txSig = txSig / sqrt(mean(abs(txSig).^2));

% TRANSMISSION OVER AWGN CHANNEL
```

```
for i = 1:length(snr_dB)
    SNR_linear = 10^(snr_dB(i)/10);
    signal_power = mean(abs(txSig).^2);
    noise_power = signal_power / SNR_linear;
    noise = sqrt(noise_power/2) * (randn(size(txSig)) + 1j*randn(size(txSig)));
    rxSig = txSig + noise;

    % MANUAL QAM DEMODULATION
    % Scale back to original amplitude range
    rxI = real(rxSig) * sqrt(mean(abs(txSig).^2));
    rxQ = imag(rxSig) * sqrt(mean(abs(txSig).^2));

    % Decision boundaries
    I_hat = round((rxI + m_side - 1) / 2);
    Q_hat = round((rxQ + m_side - 1) / 2);

    % Clip to valid range
    I_hat(I_hat < 0) = 0; I_hat(I_hat > m_side-1) = m_side-1;
    Q_hat(Q_hat < 0) = 0; Q_hat(Q_hat > m_side-1) = m_side-1;

    % Recombine to get detected symbols
    rxData = Q_hat * m_side + I_hat;

    % Count symbol errors
    numSymErr = sum(rxData ~= data);
    ber(i) = numSymErr / numSymbols / k;  % approximate BER
end

% PLOT BER vs SNR
figure;
semilogy(snr_dB, ber, '-o', 'LineWidth', 1.5);
grid on;
xlabel('SNR (dB)');
ylabel('Bit Error Rate (BER)');
title(['Performance of ', num2str(M), '-QAM in AWGN Channel']);
```

```
% CONSTELLATION DIAGRAM (last SNR)
figure;
plot(real(rxSig), imag(rxSig), '.', 'MarkerSize', 5);
axis equal; grid on;
xlabel('In-phase'); ylabel('Quadrature');
title(['Constellation Diagram of ', num2str(M), '-QAM at SNR = ', num2str(snr_dB(end)), ' dB']);
```

Output:



Conclusion: