EXPERIMENT NO. 08

TITLE: QPSK Modulation and Demodulation over an AWGN Channel

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PROBLEM STATEMENT: In this software experiment, you need to simulate the transmission and reception via quadrature phase shift keying (QPSK) over an additive white Gaussian noise (AWGN) channel

KEY COMPONENTS: This is a software experiment. You can use standard functions in MATLAB. Avoid use of any in-built functions for QPSK and bit-error calculation specific calculations.

BRIEF THEORY:

QPSK (Quadrature Phase Shift Keying) is a popular modulation scheme used in digital communication systems to transmit data over a wireless or wired channel. It is a form of Phase Shift Keying (PSK) that uses four different phases to represent two bits of data. In QPSK, the carrier signal is split into two quadrature components, I (in-phase) and Q (quadrature), and each component is modulated with a different phase shift of either 0, 90, 180, or 270 degrees, corresponding to the four possible symbol values of (0,0), (0,1), (1,0), and (1,1), respectively. QPSK can transmit twice as much data as Binary PSK (BPSK) using the same bandwidth and power, making it an efficient modulation scheme for many digital communication applications.

In this experiment, we will simulate the transmission of QPSK-modulated signals over an AWGN (Additive White Gaussian Noise) channel and measure the bit error rate (BER) performance of the system. The experiment consists of the following steps:

1. Generate a sequence of random binary bits.
2. Map the binary bits to QPSK symbols using a mapping table.
3. Add AWGN to the QPSK signal to simulate noise in the channel.
4. Demodulate the received signal and map the QPSK symbols back to binary bits.
5. Calculate the bit error rate (BER) as the ratio of the number of incorrectly received bits to the total number of bits.

The experiment will be repeated for different levels of SNR (Signal-to-Noise Ratio) to observe the effect of noise on the BER performance. In addition, we will extend the experiment to compare the BER performance of basic QPSK modulation with that of QPSK modulation using Gray mapping.

By performing this experiment, we seek to better understand the QPSK modulation scheme and learn how it performs in the presence of noise. The experiment also provides an opportunity to explore, simply, the trade-off between bandwidth efficiency and error performance in any digital communication systems.

FORMAL DESCRIPTION OF THE EXPERIMENT:

Stepwise procedure:

1. Start by generate a random sequence of binary bits for “data”; for instance, you can fix N=1024 bits.
2. Perform QPSK modulation of this data stream. For this experiment, you need not generate the passband equivalent signal but work in the baseband. Clearly document the mapping of bits to QPSK symbols.

3. Now to simulate the noisy channel, add zero mean AWGN noise of a particular variance to the transmitted symbols.

4. Now perform demodulation and recover estimate of the transmitted bits.

5. Calculate bit error rate (BER) for the end-to-end setup. Repeat the calculation for multiple runs (say 250) and use the averaged value of BER instead of BER for a single run for the same noise variance value.

6. Repeat the experiment for different values of noise variance. Now generate a bit error rate (BER) versus signal-to-noise ratio (SNR) plot. Compare with the analytical expression of BER. Recall that the transmit power is fixed but the noise variance is changing in your experiment. Also, generate a bit error rate (BER) versus SNR plot, where SNR is in dB.

7. Now perform QPSK modulation and demodulation where the symbols are Gray code encoded. Again, repeat the entire experiment and generate the BER versus SNR plots.

8. Choose a wide range of SNR ("low" to "high" SNR) to see the best behavior of the BER versus SNR curve.

OUTCOMES AND RESULTS

1. Include step-by-step results and plot as necessary.
2. Comment on the following:
    a. Present the analytical expression for BER (as a function of SNR) and compare the simulated BER with it. Do they compare well? Does multi-run averaging (for each value of noise variance or SNR help in smoothing the curve?
    b. Does Gray-coded QPSK scheme perform better for any range of SNR values?
    c. Do comment on any interesting observations you make during the experiment.