**Lab 1：Baseband QAM Modem**

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| **Introduction**  **1.Basic Principles of 16-QAM Modulation/Demodulation:**  Orthogonal amplitude modulation is the use of the orthogonal spectrum of modulated signals within the same bandwidth to achieve two parallel data information transmission. Its channel bandwidth utilization is the same as that of single sideband modulation, and is mainly used in high-speed data transmission systems. The baseband symbol waveform is divided into I and Q channels through serial parallel conversion, and then undergoes level conversion (00 converted to -1,01 converted to -3,10 converted to 1,11 converted to 3). It is multiplied by the corresponding carrier and then added to complete QAM modulation.    The demodulation principle of QAM is shown in the following figure. The QAM signal is further divided into I and Q channels and multiplied by the corresponding carrier. After passing through a low-pass filter, sampling decisions are made, and the determined I and Q channel symbols are merged. I channel is the odd position symbol of the final symbol sequence, and Q channel is the even position symbol of the final symbol sequence, restoring the original symbol sequence.    **2. Constellation diagram:**  In analog modulation, the changes in carrier parameters are based on continuous analog information. In digital modulation, the changes in these carrier parameters (amplitude, frequency, and phase) are determined by discrete digital signals. In this sense, there is no essential difference between digital modulation and analog modulation. The digital modulation signal only needs to represent discrete modulation states, which are called symbol points on the vector diagram, and the combination of symbol points is called constellation diagram.  The constellation diagram defines the mapping relationship between the signal distribution of modulation technology and the modulation digital bits.    X‐axis: in‐phase component; Y‐axis: quadrature component. A signal can be represented by one point on the constellation.  **3. Symbol mapping table:**  Symbols are the discrete states of information modulation carriers, also known as vectors, which are closely related to the carrier and modulation methods, symbol mapping table is a method of mapping digital signals to analog signals, typically used for digital modulation. In digital modulation, the process of converting digital signals into analog signals requires the use of symbol mapping tables to map digital signals onto corresponding analog signal symbols, in order to achieve the transmission of digital signals.  Bit mapping bit code-----constellation      **4. Maximum likelihood estimation (MLE):**  In statistics, maximum likelihood estimation (MLE) is a method of estimating the parameters of an assumed probability distribution, given some observed data. This is achieved by maximizing a likelihood function so that, under the assumed statistical model, the observed data is most probable. The point in the parameter space that maximizes the likelihood function is called the maximum likelihood estimate.  Let ,, …,be the overall ~() The sample of(=(, , …,)=(). Call () is a likelihood function, if there is a statistic = (, , …, ) causes ()= , , …, ), then (, , …, ) isMaximum likelihood estimation, abbreviated as MLE.      Using maximum likelihood estimation to determine the bit codes represented by symbol maps in constellation diagrams, reducing errors  **5. AWGN theoretical bit error rate**  Theoretical error rate refers to the probability of errors occurring in signal transmission under ideal conditions without other interference. For the 16QAM modulation method, the theoretical bit error rate can be estimated by calculating the signal-to-noise ratio (SNR). For 16QAM modulation in AWGN channels, the theoretical bit error rate can be calculated using the formula: BER=(3/2) \* (1-1/) \* Q (), where M represents the number of symbols modulated (16), Q represents the Gaussian Q function, and SNR represents the signal-to-noise ratio.  **Lab results & Analysis**：  **1.16-QAM modulation/demodulation simulation (program diagram, programming process, simulation results):**  **modulation**    **demodulation**    **simulation results**      2. **2/4/16/64-QAM error rate curve with increasing SNR and analysis of noise resistance performance:**  We are using Matlab for plotting the curves and the code used is as follows:  M1=2;  M2=4;  M3=16;  M4=64;% 调制阶数  snr\_dB = -10:0.5:20; % 不同的信噪比范围（以dB为单位）  snr\_dB1 = -10:0.5:20;  snr\_dB2 = -10:0.5:20;  snr\_lin = 10.^(snr\_dB/10); % 将信噪比转换为线性值  % 计算理论误码率  ber\_theoretical1 = 3/2 \* (1 - 1/sqrt(M1)) \* qfunc(sqrt(3/2 \* snr\_lin / (M1-1)));  ber\_theoretical2 = 3/2 \* (1 - 1/sqrt(M2)) \* qfunc(sqrt(3/2 \* snr\_lin / (M2-1)));  ber\_theoretical3 = 3/2 \* (1 - 1/sqrt(M3)) \* qfunc(sqrt(3/2 \* snr\_lin / (M3-1)));  ber\_theoretical4 = 3/2 \* (1 - 1/sqrt(M4)) \* qfunc(sqrt(3/2 \* snr\_lin / (M4-1)));  % 绘制信噪比与误码率曲线  snr\_dB1(42)=nan;  snr\_dB1(43)=nan;  semilogy(snr\_dB1, ber\_theoretical1,snr\_dB2, ber\_theoretical2,snr\_dB, ber\_theoretical3,snr\_dB, ber\_theoretical4);  ylim([0.000001,1])  xlabel('SNR (dB)');  ylabel('Bit Error Rate (BER)');  title('QAM SNR vs BER');  grid on;  The final drawn image is as follows:    To analyze the anti-noise performance of 2/4/16/64-QAM BER variation curve with increasing SNR, we can conclude that:   1. Typically, as the signal-to-noise ratio increases, the BER decreases. This is because the increase in signal-to-noise ratio allows the receiver to more accurately distinguish between different modulation symbols. 2. 64-QAM should have a lower BER than 2-QAM for the same SNR. It is because as the higher the number of modulation points and the more complex the modulation method, the lower the BER at the same SNR. 3. The BER is higher when the SNR is lower, when methods such as more error correction coding or improved channel estimation may be required to improve system performance.   3. **USRP Implementation of 16-QAM Modulation System (Constellation Diagram):** | |
| **Experience**   1. **Problem**   I didn't know how to succinctly express the symbol mapping table during the supplementary process of modulation and demodulation vi in the 16QAM and 64QAM programs.   1. **Gain**   Enhanced understanding of QAM modulation and demodulation. QAM modulation is a commonly used modulation technique that can transmit multiple bits of data over limited bandwidth channels. It combines amplitude and phase modulation to represent digital information by combining the amplitude and phase of two orthogonal carriers. More data bits can be transmitted within a limited spectrum. By increasing the modulation order, such as 16QAM, 64QAM, etc., higher data transmission rates can be achieved. Also more comfortable with Labview applications. | |
| **Score** | 100 |