Exp. 5 - Quadrature Amplitude Modulation - Answer Booklet

- **Name:** **Lab Date:**
- **Student No.:** **Day of the week:** **Time:**

3. Experiment

3.1 Basic QAM System

3.1.1 Matched Filters

The first order of business is to design your TX and RX (Matched) filters. You will use square root raised cosine filters with different excess bandwidths. The order of the filter is your choice. The filter should not be ”too short” (lower order) or it will not produce a frequency response as desired; it also should not be ”too long” (higher order), or you will be spending precious computation time in the filtering process. Make your choice and be prepared to justify it.

At this point you need to open just the filter model given, so that you can design the TX/RX filters and export them into a `Matlab` workspace variable. This is done via `File -- Export`, and the default variable name is `Num` (for ”numerator”). Make sure the variable you created is actually being called by all four filters in the QAM model.

Open now the first QAM model, and run it using the 90 percent excess bandwidth filters at first. Set the channel block to zero noise and zero phase distortion. This will be your “paradigm” of QAM systems. You should see an eye pattern similar to the one presented in Figure 1.

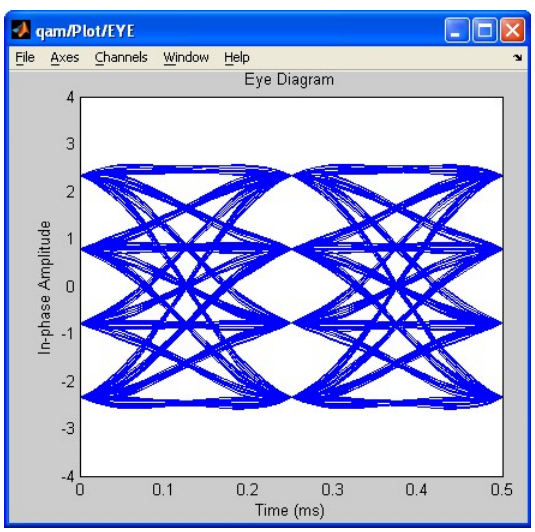

Figure 1. Eye Pattern, 90% Excess Bandwidth filters

- *Which filter order did you choose? Based on what criteria did you choose this order?*

- *Keeping the filter order, redesign the filters to have excess bandwidth of 30% first, and then 50%. That is: design the filter for 30%, export, run the system, repeat for 50%. Based on the eye diagrams you saw for each case, what is the advantage of using a greater excess bandwidth? Now based on the frequency response of the filter, is there a* **disadvantage** *to use a greater excess bandwidth? Draw frequency responses and resulting eye diagrams for filters with 30%, 50% and 90% excess bandwidth below.*

3.2 Understanding the System

- *Draw a simplified eye diagram representing what you see when you run the system. Explain how the multiple eyes are formed on the Eye Diagram. What is the advantage of having all traces cross at the same point? What could cause the traces* **not to cross** *at the same point? Is this pattern similar to one produced by a 4 PAM system?*

- *What is the advantage of using QAM over PAM, then?*

When you run the QAM simulation you should also see a constellation diagram, similar to Figure 2.

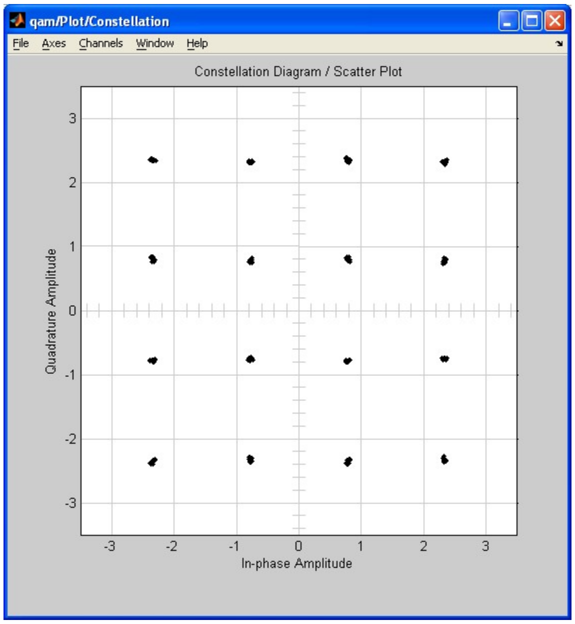

Figure 2. Constellation Diagram for 16 QAM

- *Create a table indicating what bit values correspond to what point in the diagram (look at the model). Be sure to indicate how I and Q form each point. Suggest below any needed modification in the system to ensure it is Grey encoded.*

Add noise to the signal path now. The noise switch is found in the channel block. With noise, your constellation should look like Figure 3 below.

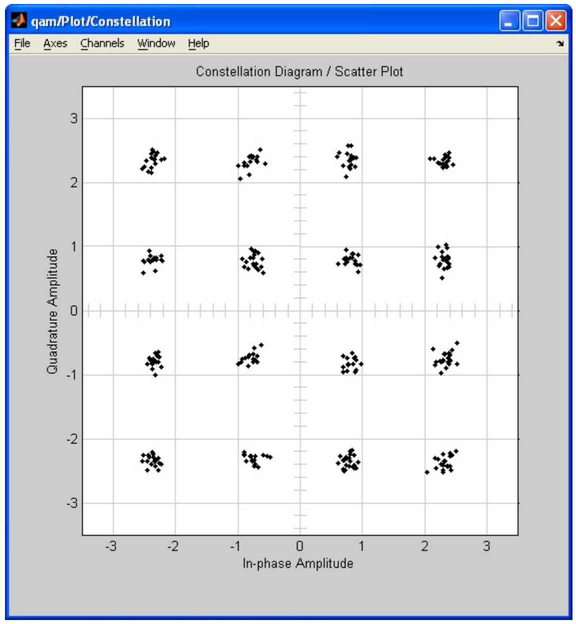

Figure 3. Noisy Constellation

- *Increase the noise gain until you observe the eye pattern closing, and look at the constellation diagram. How would the noise create trouble for the decision-making process?*

- *Assume you have two systems with the same transmitted power and subject to the same amount of noise. One is 16 QAM and the other 256 QAM (no need to draw the constellation for this one). On which of them you expect to have more difficulty making your decision? Why?*

- *If your TX and RX filters are* **not** *designed properly matched, you have ISI happening in your system. How would the eye pattern and the constellation diagram indicate the presence of ISI? Suggestion: modify the model to have ISI.*

- *Imagine that at some point you observe the constellation diagram as presented below. What kind of distortion is presented? How can you improve the receiver in order to fix this problem? (write your answer in the box below the figure)*

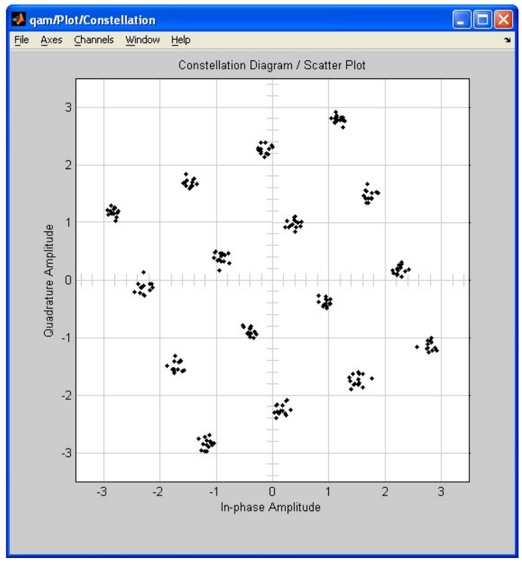

Figure 4. Rotated Constellation = Phase Distortion

- *Assume that you have two QAM systems running, and their outputs presen eye diagrams as shown below. Which of the two would you say utilizes less bandwidth? What indicates the difference in bandwidth? Would you be able to tell it from the constellation diagram? (Write your answer in the box below the figure)*

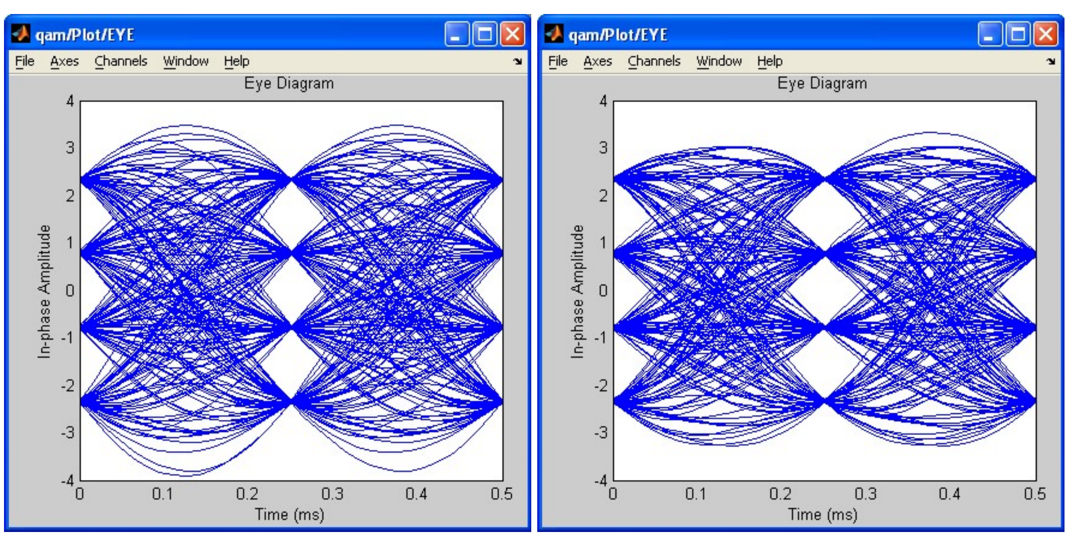

Figure 5. Eye Patterns Representing the Outputs of Two Systems

3.2.1 BER

Now close the first QAM system and open the second one. You will notice that the modulation and demodulation are done with different blocks, even though they accomplish the same result as the previous system you just ran. Note that there are scopes at different points for you to see the signal. This system has a more realistic channel model, with additive white gausian noise (AWGN), and it has a provision to calculate bit error rate (BER).

The bit error rate calculation takes in the two streams of bits and compares them, estimating the rate of bits in error, counting the errors and counting also the number of symbols. You may run the simulation until it indicates that it has collected at least 500 errors. Surely as the noise increases you will see more errors.

This is what you will explore now.

- *Change the E_b/N_o value for the AWGN, from the default value of 3 down to -3 in downward steps of 1. Observe the changes in the constellation. Draw a curve BER vs. E_b/N_o below and briefly explain what it means.*

Graph here

Explanation Here