



EE4513 Analog and Digital Communications Laboratory

Dennis Silage, PhD
silage@temple.edu



Non-Rectangular Constellation Quadrature Amplitude Modulation (QAM)

In this Laboratory the Quadrature Amplitude Modulator (QAM) as a general system for in-phase (I) and quadrature (Q) modulation and demodulation is utilized. The BER performance of *non-rectangular* constellation 8-QAM is to be investigated. The rectangular constellation 16-QAM digital communication system given in Figure 3.26 of the *Simulink* text is modified to analyze this system.

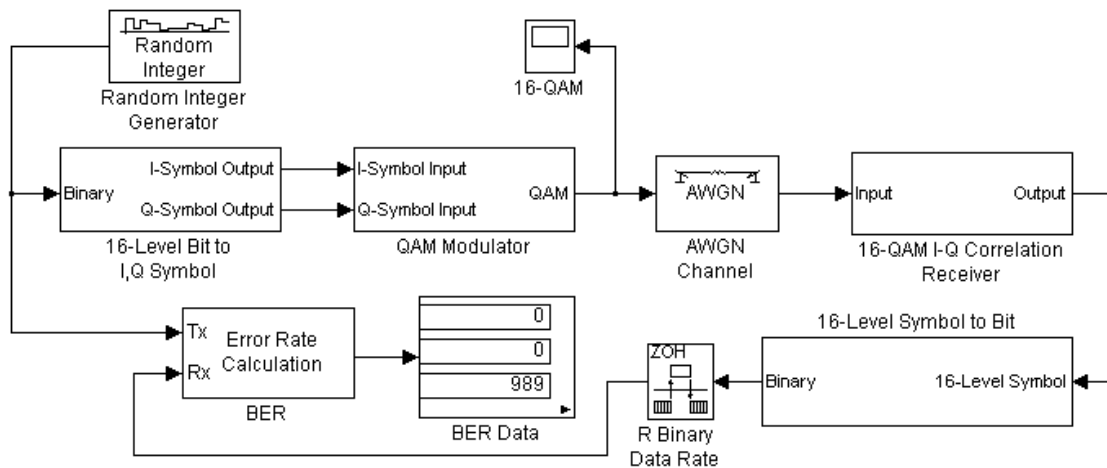
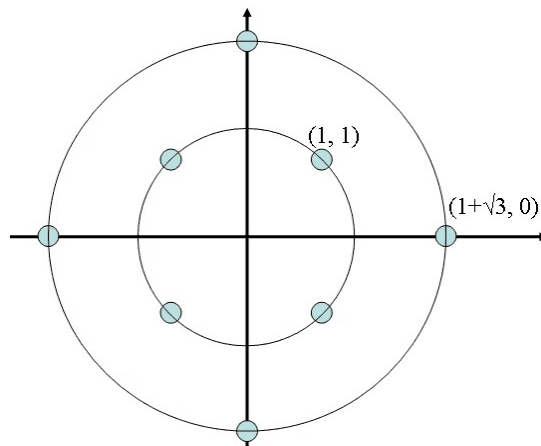


Figure 3.26

The *Simulink* simulation of rectangular 16-QAM (pp 120-127) is to be modified for this new digital communication system. You are to choose a *random carrier amplitude* from the values $A_C = 2.5, 5, 10$ or 15 V and a single *random bit rate* from $r_b = 2$ to 20 kb/sec in steps of 2 kb/sec.

$A_C = \underline{\hspace{2cm}}$ V $r_b = \underline{\hspace{2cm}}$ kb/sec

The actual transmitted symbol carrier



amplitude A_S is $A_C C_S$, where C_S is the nominal constellation amplitude for that tri-bit symbol. For example, the maximal in-phase (I, sine reference) amplitude is $A_C(1 + 3^{0.5}) = A_C(2.732)$.

You need to modify the 16-level bit-to-I,Q symbol subsystem in Figure 3.27 for these specified 8 levels. Map the *tri-bits* of the non-rectangular 8-QAM using a Gray code of your own design to mitigate adjacent symbol error and show your choice. A Gray-code mapping of tri-bits for 8-PSK could be modified for this non-rectangular 8-QAM. Verify that this is correct and show your symbol to tri-bit mapping.

You also need to modify the QAM modulator (Figure 3.28), the 16-QAM correlation receiver (Figure 3.30) and the 16-level symbol-to-bit subsystem in Figure 3.31 for 8 levels.

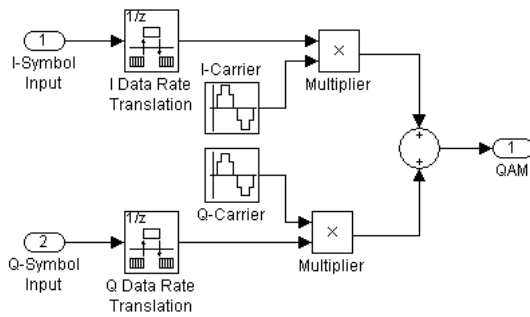


Figure 3.28

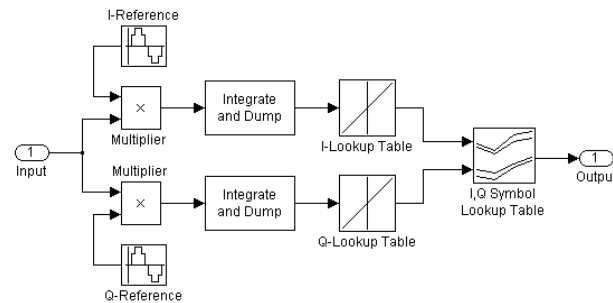


Figure 3.30

Determine the average energy per bit $E_{avg, b}$ and the *upper-bound* of P_b given by Eq. 3.73 (p. 127) of the *Simulink* text for this non-rectangular 8-QAM. Compare this to the *upper bound* of P_b for 8-PSK (Stern and Mahmoud Eq. 5.126 and 5.129).

The basic concepts of average energy per bit $E_{avg, b}$ and the *upper-bound* of P_b in QAM and Mary PSK are salient and will be considered on the Third Exam and Final Exam.

Determine the observed BER for this non-rectangular 8-QAM using the standard methodology that you have used in the Laboratory and the *first-null* spectral bandwidth. Compare this first-null bandwidth to that of 8-PSK at the same data rate r_b .

This is a multiple week Laboratory for Week 12 (starting November 16), the partial Week 13 (Thanksgiving) and Week 14 (starting November 30). The Laboratory is to be complete and due to the Instructor (*not* the TA) on Monday December 7th.