PROBLEM 5.1. It is difficult to find an exact expression for the error probability for $M$-ary PSK, except for the special cases of $M = 2$ (binary antipodal signaling) and $M = 4$. Find an exact expression for the error probability $P_e$ of the minimum-distance detector for equiprobable 4-ary PSK in AWGN, expressed as a function of the SNR per bit.

PROBLEM 5.2.

(a) Consider a one-shot complex PAM using the alphabet shown below. The real part of the symbol is selected from $\{-5, -3, -1, 1, 3, 5\}$ and the imaginary from $\{-1, 1\}$.

(b) Assuming AWGN with PSD $N_0/2$ and minimum-distance detection, find $P_e$ exactly, expressed in terms of the average SNR per bit $\gamma = E_b/N_0$.

(c) Evaluate the power efficiency and bandwidth efficiency of this modulation scheme, and locate its position on the SNR-vs-bandwidth plane used to compare modulation schemes.

(d) Comment on the advantages and disadvantages of this modulation scheme, as compared to other modulation schemes considered in class.