PRINCIPLES OF COMMUNICATIONS

Systems, Modulation, and Noise

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Quadrature-Amplitude-Shift Keying (QASK)

Another signaling scheme that allows multiple signals to be transmitted using quadrature carriers is *quadrature-amplitude-shift keying* (QASK), which is also referred to as *quadrature-amplitude modulation* (QAM). For example, M-QASK utilizes a signal structure similar to that of (8.32) but with the data sequences d_1 and d_2 each taking on $\sqrt{M}$ different possible levels. Thus, for example, we represent the transmitted signal in an arbitrary signaling interval for 16-QASK as

$$s_i(t) = \sqrt{\frac{2E_s}{T_s}}\,(A_i \cos \omega_c t + B_i \sin \omega_c t), \qquad 0 \le t \le T_s \tag{8.43}$$

where A_i and B_i take on the possible values $\pm a$ and $\pm 3a$ with equal probability. A signal-space representation for 16-QASK is shown in Figure 8.13(a), and the receiver structure is shown in Figure 8.13(b). The probability of symbol error for 16-QASK can be shown to be

$$P_E = 1 - [\tfrac{1}{4}P(C\,|\,\mathrm{I}) + \tfrac{1}{2}P(C\,|\,\mathrm{II}) + \tfrac{1}{4}P(C\,|\,\mathrm{III})] \tag{8.44}$$

where the probabilities $P(C\,|\,\mathrm{I})$, $P(C\,|\,\mathrm{II})$, and $P(C\,|\,\mathrm{III})$ are given by

$$P(C\,|\,\mathrm{I}) = \left[1 - 2Q\left(\sqrt{\frac{2a^2}{N_0}}\right)\right]^2 \tag{8.45a}$$

$$P(C\,|\,\mathrm{II}) = \left[1 - 2Q\left(\sqrt{\frac{2a^2}{N_0}}\right)\right]\left[1 - Q\left(\sqrt{\frac{2a^2}{N_0}}\right)\right] \tag{8.45b}$$

$$P(C\,|\,\mathrm{III}) = \left[1 - Q\left(\sqrt{\frac{2a^2}{N_0}}\right)\right]^2 \tag{8.45c}$$

In the preceding equations $a^2 = E_s/10$, where E_s is the average energy per symbol. The notation I, II, or III denotes that the particular probability refers to the probability of correct reception for the three types of decision regions shown in Figure 8.13(a). This error probability will be compared with that for M-ary PSK later. The error probability for 64-QASK or 256-QASK also can be obtained in a straightforward, but tedious, manner.

FIGURE 8.13 Signal space and detector structure for 16-QASK. (a) Signal constellation and decision regions for 16-QASK. (b) Detector structure for 16-QASK. (Binary representations for signal points are Gray encoded.)