Problem 6.20

(a) When the two-level sequence embodying

$$a_k = \begin{cases} +1 \text{ if symbol } b_k \text{ is } 1\\ -1 \text{ if symbol } b_k \text{ is } -1 \end{cases}$$
 (1)

is applied to the duobinary conversion filter, the sequence is converted into a three-level output defined by

$$c_k = a_k + a_{k-1} \tag{2}$$

The three levels of c_k are -2, 0, and +2. One effect of transforming Eq. (1) into Eq. (2) is to produce correlated three-level sequence c_k from an uncorrelated two-level sequence a_k .

The overall transfer function of the duobinary conversion filter is therefore defined by

$$H(f) = H_{\text{Nyquist}}(f)[1 + \exp(-j2\pi f T_b)]$$

$$= H_{\text{Nyquist}}(f)[\exp(j\pi f T_b) + \exp(-j\pi f T_b)]\exp(-j\pi f T_b)$$

$$= 2H_{\text{Nyquist}}(f)\cos(\pi f T_b)\exp(-j\pi f T_b)$$
(3)

For an ideal Nyquist channel, $B_0 = 1/2T_b$. Ignoring the scaling factor $1/T_b$, we may therefore write

$$H_{\text{Nyquist}}(f) = \begin{cases} 1, & |f| \le 1/2T_b \\ 0, & \text{otherwise} \end{cases}$$
 (4)

Substituting Eq. (4) into (3), we obtain

$$H(f) = \begin{cases} 2\cos(\pi f T_b)\exp(-j\pi f T_b), & |f| \le 1/2T_b \\ 0, & \text{otherwise} \end{cases}$$
 (5)

(b) From the first line of Eq. (3) and the defining Eq. (4), we find that the impulse response of the duobinary conversion filter is

$$h(t) = \frac{\sin(\pi t/T_b)}{\pi t/T_b} + \frac{\sin[\pi(t-T_b)/T_b]}{\pi(t-T_b)/T_b}$$

$$= \frac{\sin(\pi t/T_b)}{\pi t/T_b} + \frac{\sin[(\pi t/T_b) - \pi]}{\pi(t-T_b)/T_b}$$

$$= \frac{\sin(\pi t/T_b)}{\pi t/T_b} - \frac{\sin(\pi t/T_b)}{\pi(t-T_b)/T_b}$$

$$= \frac{T_b^2 \sin(\pi t/T_b)}{\pi t(T_b - t)}$$
(6)

(c) The original sequence may be detected from the duobinary-coded sequence using decision feedback, as shown by

$$\hat{a}_k = c_k - \hat{a}_{k-1} \tag{7}$$

A major drawback of this detection rule is that for the current detection \hat{a}_k to be correct, the previous detection \hat{a}_{k-1} has to be correct. If this requirement is not satisfied, we have error propagation.

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