科目：通訊系統(通訊原理)(300H)　　　　校系所組：中央大學通訊工程學系（甲組）
　　　　　　　　　　　　　　　　　　　　　　　　交通大學電子研究所（乙B組）
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1. (15%) The power spectrum density of a random process $X(t)$ is shown in Figure P1.

　(a) (5%) Derive and sketch the autocorrelation function $R_X(\tau)$ of $X(t)$.

　(b) (5%) What are the DC and AC power contained in $X(t)$?

　(c) (5%) What sampling rates will give uncorrelated samples of $X(t)$? Are the samples statistically independent?

　[Hint: Let A and B be two random variables. We say that A and B are uncorrelated if E[AB]=E[A]E[B], where E[.] is the expectation of a random variable.]
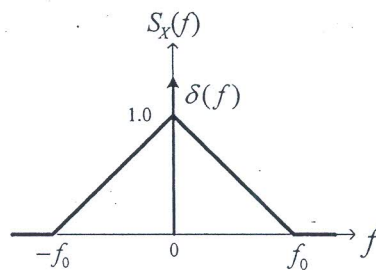

Figure P1

2. (10%)　A discrete-time tapped-delay-line equalizer has N-tap coefficients, where N is odd. The weighting coefficients are symmetric to the center tap, that is, the coefficients satisfy the condition

$$w_n = w_{N-1-n} \qquad 0 \le n \le N-1$$

　(a) (5%) Derive the frequency response of the equalizer in terms of $w_0, w_1, ..., w_{(N-1)/2}$.

　(b) (5%) Does this equalizer have a linear or nonlinear phase response? Please verify it.

3. (10%) The signal

$$x(t) = \begin{cases} A\cos(2\pi f_c t) & 0 \le t \le T \\ 0 & elsewhere \end{cases}$$

is applied to a linear filter with impulse response

$$h(t) = x(T-t)$$

Assume that the frequency $f_c = n/T$, where n is a large integer.

　(a) (5%) Derive the frequency and phase responses of the filter.

　(b) (5%) Sketch the spectrum of the output signal.

注意：背面有試題

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4. (15%) Considering the analog modulation system shown in Figure P4, the input signal $m(t)$ has the maximum amplitude $A_m = 10$ volt and bandwidth $W = 15$ kHz. In the FM modulator, the carrier frequency is f_c, and the frequency sensitivity is k_f kHz/volt. The characteristic of the nonlinear device is $v(t) = a_1 s(t) + a_2 s^2(t) + a_3 s^3(t) + a_4 s^4(t)$, where a_i for $i = 1, 2, 3, 4$ are constants. The center frequency of the band-pass filter is $f'_c = 20$ MHz.
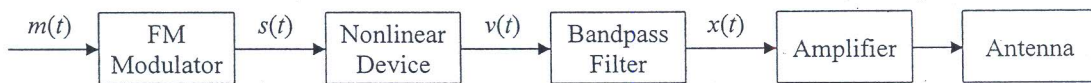

Figure P4

(a) (5%) Represent the signal $v(t)$ as a function of the input signal $m(t)$ in the form

$$v(t) = \sum_i A_i \cdot \cos(B_i).$$

(b) (5%) If the FM modulated signal $x(t)$ with the largest frequency deviation is desired and $k_f = 10$ kHz/volt, determine the carrier frequency f_c of the FM modulator and the minimum bandwidth B of the band-pass filter.

(c) (5%) If the FM modulated signal $x(t)$ with the smallest frequency deviation is desired, determine the carrier frequency f_c and the maximum allowable k_f of the FM modulator.

[Hint: The FM modulator output $s(t) = \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\, d\tau\right]$.

$2\cos(\alpha) \cdot \cos(\beta) = \cos(\alpha - \beta) + \cos(\alpha + \beta)$. Carson's rule: $B_T \cong 2(D+1)W$, where D is the ratio of the frequency deviation to the message bandwidth.]

5. (15%) Consider the set of four finite-energy signals $s_m(t) = \exp(j2\pi f_m t + \phi_m)$, $0 \le t \le T$, for $m = 1, 2, 3, 4$, where $f_1 < f_2 < f_3 < f_4$ are integer frequencies and ϕ_m are independent random phases.

(a) (5%) Find the minimum value of T that makes this set of signals mutually orthogonal.

(b) (5%) If the solution T' obtained in (a) is adopted, determine the maximum number of additional mutually orthogonal signals $s_m(t) = \exp(j2\pi f_m t + \phi_m)$ that can be obtained in the frequency range $f_1 \le f_m \le f_4$ for the case with $f_1 = 100kHz$, $f_2 = 135kHz$, $f_3 = 220kHz$, and $f_4 = 310kHz$.

(c) (5%) Redo (b) with $T = 3T'$.

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6. (21%) The two baseband signals shown in Figure P6 are used to transmit a binary sequence with equal probabilities over an additive white Gaussian noise channel.
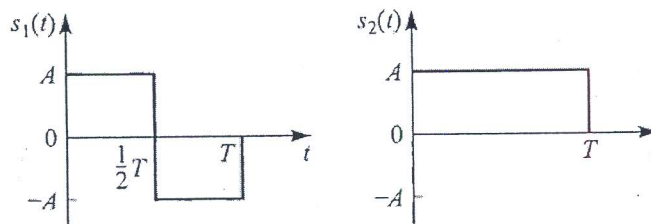

Figure P6

The received signal can be expressed as

$$r_i(t) = s_i(t) + z(t), \quad 0 \le t \le T, \quad i = 1, 2$$

where $z(t)$ represents the noise and is a zero-mean Gaussian noise process with autocorrelation function

$$R_z(\tau) = E[z(t)z(t+\tau)] = \sigma_z^2 \delta(\tau)$$

(a) (3%) Suppose the receiver is implemented by means of coherent detection using two matched filters, one matched to $s_1(t)$ and the other matched to $s_2(t)$. Please sketch the impulse responses of the matched filters.

(b) (3%) Sketch the noise-free responses of the two matched filters when the transmitted signal is $s_2(t)$.

(c) (3%) Suppose the receiver is implemented by means of two cross-correlators (multipliers followed by integrators) in parallel. Please sketch the output of each integrator as a function of time for the interval $0 \le t \le T$ when the transmitted signal is $s_2(t)$.

(d) (3%) Compare the sketches in parts (b) and (c). Are they the same? Explain briefly.

(e) (3%) Find the cross-correlation coefficient ρ_{12}, determine the basis function(s), and sketch the constellation for $s_1(t)$ and $s_2(t)$.

(f) (3%) With optimal detection, please derive the probability of error for this binary communication system in terms of $erfc(.)$ or $Q(.)$ where $erfc(x) = \dfrac{2}{\sqrt{\pi}} \int\limits_x^\infty \exp(-z^2) dz$, and

$Q(x) = \dfrac{1}{\sqrt{2\pi}} \int\limits_x^\infty \exp\left(-\dfrac{z^2}{2}\right) dz$.

(g) (3%) Now assume that with probability of p the link between the transmitter and the receiver is out of service and with a probability of 1-p this link remains in service. When the link is out of service, the receiver receives only noise. The receiver does not know whether the link is in service. What is the resulting error probability for this case with p = 1/3?

注意：背面有試題

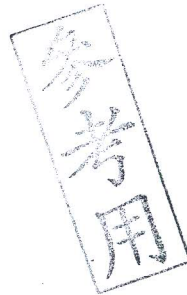7. (14%)　Consider transmission of the binary sequence $b_k \in \{0,1\}$ with time index k over a binary Differential PSK system with symbol duration T_b and symbol energy E_b. The b_k is differentially encoded to $d_k \in \{0,1\}$ such that

$$d_k = \begin{cases} d_{k-1}, & \text{if } b_k = 1 \\ \overline{d}_{k-1}, & \text{if } b_k = 0 \end{cases}$$

where $\overline{d}_{k-1}$ represents the 2's complementary of d_{k-1}. The transmit signal for the encoded symbols 1 and 0 are designed such that

$$s_1(t) = \begin{cases} \sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t), & 0 \le t \le T_b \\ \sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t), & T_b \le t \le 2T_b \end{cases}$$

$$s_0(t) = \begin{cases} \sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t), & 0 \le t \le T_b \\ -\sqrt{\dfrac{2E_b}{T_b}}\cos(2\pi f_c t), & T_b \le t \le 2T_b \end{cases}$$

(a)(5%) Design and plot the block diagram of the DPSK transmitter.

(b)(5%) Assume transmission over AWGN channel with zero mean and variance $N_0/2$. The received signal is $x(t) = s_i(t) + n(t)$. Please devise the optimal decision rule of the DPSK.

(c)(4%) Based on the decision rule in (b), please design and plot the block diagram of the DPSK receiver.