EE3008 Test 2

(1:00-2:30pm, Mar. 30, 2020)

Question 1 (30 marks)

For each of the following random signals $X(t)$:

a. $X(t)=s(t)+n(t)$. $s(t)$ and $n(t)$ are independent WSS processes. $s(t)$ has mean 1 V and power 2 W and $n(t)$ has mean 0 V and power 0.1 W.

b. $X(t)=\sum_{k=-\infty}^{\infty} Z_k \cdot \omega(t-kT_0)$. $Z_k = Z$ is a discrete random variable with equal probability to be 1 V and -1 V. $\omega(t)$ is a narrow rectangular pulse with amplitude 10 V and duration 0.1 ms. $T_0 = 100$ ms.

c. $X(t)=m(t)\cos(2\pi f_c t)$. $m(t)$ is a WSS process with mean 0.5 V and power 1 W.

Determine:

1. Mean (6 marks);
2. Autocorrelation function (12 marks);
3. Power (12 marks).

Question 2 (40 marks)

For a 4-bit midriser with a dynamic range from -4 V to 4 V:

1. Determine the step size, maximum quantization error, and quantization error power. (6 marks)
2. Determine the output bit sequence of sampled values (0.34 V, -0.011 V, -1.57 V, -2.06 V) using Gray coding. Show your detailed steps, including the quantized values and natural codes assigned to each one. (12 marks).
3. If the number of quantization levels is doubled, how many dBs will the SQNR increase? (5 marks)
4. A uniformly distributed random signal $x(t)$ with bandwidth 2 kHz is sampled at the Nyquist rate and then applied to the above 4-bit midriser.
    1) If the SQNR is measured to be 20dB, determine the dynamic range of $x(t)$. (5 marks)
    2) If the bit sequence is modulated by using 4-ary PAM, determine the minimum required channel bandwidth for 95% in-band power, and the corresponding symbol rate. (8 marks)
    3) If the channel bandwidth is 5 kHz, determine the minimum value of M if M-ary PAM is used to transmit the bit sequence with 90% in-band power. (4 marks)

Question 3 (30 marks)

An audio signal with bandwidth 15 kHz is sampled at a rate 30% above the Nyquist rate, quantized into L=65536 levels, and modulated by the digital waveform shown in Fig. 1. For the source audio signal, it is measured that the ratio of its peak amplitude to the square root of its power is 10.

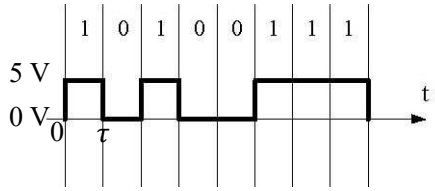

Fig. 1

1. Determine the output SQNR (in the form of dB) of the quantizer. (7 marks)
2. Determine the bit period τ. (5 marks)
3. Determine the power of the modulated signal. (6 marks)
4. Determine the required channel frequency range for 90% in-band power. (3 marks)
5. Specify how to reduce the required channel bandwidth by half without changing the bit rate. (3 marks)
6. For a channel with the frequency range of [99.4 MHz, 100.4 MHz], determine whether the modulated signal can pass it through with 90% in-band power. If no, list one modulation technique that can. If yes, further determine whether the modulated signal can pass the channel with 95% in-band power. Provide justification for your answer. (6 marks)