**Electrical Engineering Department**

**Digital Communication Systems (802421) – G1**

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Term 1 (1436-1437)

First Exam, Thursday 09/01/1437 H

الرقم الجامعي: الاسم:

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Q1. Choose the correct answer: 15 *Marks*, 1 *Each*

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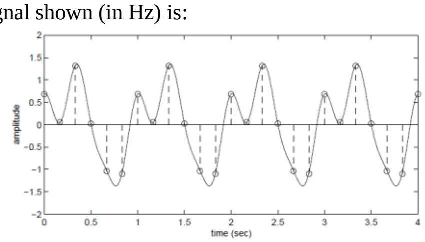
|---|---|---|
| 1. | Given the two signals:<br>$m_1(t) = \text{sinc}\,(200\pi t)$<br>$m_2(t) = \text{sinc}^2\,(80\pi t)$<br>The bandwidth of $m_1(t) * m_2(t)$ in Hz is: | a) 80<br>b) 100<br>c) 180<br>d) 280 |
| | | |
| 2. | The signal shown in the figure is sampled at a rate one and a half times higher than the Nyquist rate. The bandwidth $B$ of the signal shown (in Hz) is:<br><br> | a) 2.5<br>b) 2<br>c) 4<br>d) None of the above. |
| | | |
| 3. | The solution to aliasing problem is to use antialiasing filter with cutoff frequency equals: | a) $f_s/2$<br>b) $f_s$<br>c) $2B$<br>d) $B$ |
| | | |
| 4. | If a sinusoidal signal $m(t)$, band-limited to $B$ Hz is sampled at $B$ Hz, the reconstructed (recovered) signal at the receiver will be: | a) DC signal.<br>b) Same as $m(t)$ waveform but with different amplitude.<br>c) Same as $m(t)$ waveform but with different frequencies.<br>d) Non-sinusoidal AC signal. |
| | | |
| 5. | the first process in the A/D conversion is: | a) Sampling the message signal.<br>b) Converting the continuous-time message signal into discrete format.<br>c) Converting the analog message signal into digital format.<br>d) Removing the folded tail from the spectra of $m(t)$. |
| | | |
| 6. | In the block diagram of digital communication system, the output of the Source Encoder is: | a) PCM signal.<br>b) PCM binary code.<br>c) Discrete-time message signal.<br>d) PAM signal. |

**Commented [m1]:** The lower bandwidth.

**Commented [m2]:** No of samples per second is 6. This is the actual sampling rate in Hz.
$R_A = 6$ Hz $= 1.5\,R_N$
➔$R_N = 6 / 1.5 = 4$ Hz
➔$B = R_N / 2 = 2$ Hz

| | | |
|---|---|---|
| 7. | A PCM signal with 1 mV amplitude is to travel along 3000 km. If the amplitude is attenuated by 0.2 mV every 10 km, find the minimum number of regenerative repeaters required to withstand this distortion (given that the minimum amplitude which can be interpreted by the receiver as high voltage is 0.4 mV). | a) 50<br>b) 100<br>c) 200<br>d) 300 |
| 8. | If the number of quantization levels used in an A/D conversion is 16,389, the minimum number of binary bits per sample is: | a) 13<br>b) 15<br>c) 14<br>d) None of the above |
| 9. | In PPM modulation technique, which parameter of a periodic pulse train is varied (modified) by the sample values? | a) Amplitude<br>b) Width<br>c) Period<br>d) Location |
| 10. | When using pulse modulation in digital communication, we can transmit several baseband signals simultaneously by using: | a) TDM & FDM (as in analog comm.)<br>b) Only TDM (unlike analog comm.)<br>c) Only FDM (as in analog comm.)<br>d) TDM & FDM (unlike analog comm.) |
| 11. | A high-fidelity audio signal with bandwidth $B$ is sampled, digitized then binary-coded using PCM. The most practical values for $B$, $R_A$ and $n$ can be: | a) $B$ = 3.5 kHz, $R_A$ = 8 kHz, $n$ = 8<br>b) $B$ = 15 kHz, $R_A$ = 40 kHz, $n$ = 16<br>c) $B$ = 20 kHz, $R_A$ = 44.1 kHz, $n$ = 16<br>d) $B$ = 20 kHz, $R_A$ = 44.1 kHz, $n$ = 8 |
| 12. | In digital communication system, as $f_s$ increases: | a) Data rate ↑ & required bandwidth ↑<br>b) Data rate ↑ & required bandwidth ↓<br>c) Data rate ↓ & required bandwidth ↑<br>d) Data rate ↓ & required bandwidth ↓ |
| 13. | In digital communication system, data rate increases: | a) Linearly with $n$ and $L$<br>b) Linearly with $\log_{10} L$<br>c) Linearly with $2^n$<br>d) Linearly with $n$ and $\log_2 L$ |
| 14. | A signal $m(t)$ is sampled using Nyquist rate, then quantized into 16 levels. If the quantizer accepts 5 mV maximum amplitude, the quantization error lies in the range: | a) (– 0.3125 mV, 0.3125 mV)<br>b) (– 0.625 mV, 0.625 mV)<br>c) (0 mV, 0.3125 mV)<br>d) (0 mV, 0.625 mV) |
| 15. | Which one of the following pulse-modulation techniques is the most power-efficient (it requires less power to transmit)? | a) PWM<br>b) PAM<br>c) PPM<br>d) PCM |

**Commented [m3]:** Min. amplitude allowed is 0.4 mV
Every 10 km, amplitude is attenuated by 0.2 mV
➔Every 30 km, amplitude is attenuated by 0.6 mV and amplitude becomes 0.4 mV.
➔ No. of repeaters = 3000 / 30 = 100

**Commented [m4]:** $\log_2$ [ceiling(16,389)] = 15

**Commented [m5]:** PPM is also power efficient as the modulated parameter is the pulse position while amplitude and width are fixed.

However, with PCM, we can use a rectangular pulse for the bit **1** (as with PPM) and no pulse for the bit **0**, allowing more power to be saved.

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Q2. Five ECG signals, each of bandwidth 100 Hz are sampled at a rate 30% above the Nyquist rate, then transmitted simultaneously by binary PCM. The maximum acceptable uniform quantization error is $\frac{1}{6}$% of the peak signal amplitude $m_p$.

(*Note: please write the formula you use and the unit along each value you calculate*). 6 *Marks*

| | | |
|---|---|---|
| a) | Find the Nyquist rate $R_N$ for each signal.<br>$R_N = 2B = 2 \times 100 = 200\ sample/sec$ | ½ *mark* |
| b) | Find the actual sampling rate $R_A$ for each signal.<br>$R_A = 1.3R_N = 1.3 \times 200 = 260\ sample/sec$ | ½ *mark* |
| c) | Find the number of quantization levels $L$ used to quantize each signal.<br>$Max.\ quantization\ error\ is\ \frac{m_p}{L} = \frac{(1/6)}{100} m_p \Rightarrow L = 600$ | 1 *mark* |
| d) | Find the minimum number of binary pulses required to encode each sample.<br>$n = \lceil \log_2 L \rceil = \lceil \log_2 600 \rceil = 10\ bits/sample$ | ½ *Mark* |
| e) | Find the total data rate of the multiplexed transmitted signal.<br>$Data\ Rate = (nR_A)(5) = 10 \times 260 \times 5 = 13000\ bits/sec = 13\ kbps$ | 1 *Mark* |
| f) | Find the minimum channel bandwidth $B_T$ required to transmit this signal.<br>$B_T = \frac{Data\ Rate}{2} = \frac{13k}{2} = 6.5\ kHz$ | ½ *Mark* |
| g) | If $m(t)$ has a "mean-square" value of 0.1 Watt and the amplitude of each quantization level is 2 mV, find the resulting "signal-to-quantization-noise" (SQNR) ratio of the quantizer output (in dB).<br>$SQNR = 3L^2 \frac{P_m}{{m_p}^2}$ $[where\ P_m\ is\ the\ power\ of\ m(t), that\ is\ equal\ to\ 0.1\ W]$<br>$Amplitude\ of\ each\ level\ is\ \Delta v = 2\ mV = \frac{2m_p}{L} = \frac{2m_p}{600} \Rightarrow m_p = 600\ mV = 0.6V$<br>$\Rightarrow SQNR = 3 \times 600^2 \times \frac{0.1}{0.6^2} = 30{,}000$<br>$SQNR\ in\ dB = 10\log_{10}(30{,}000) = 54.77\ dB$ | 2 *Marks* |

**Useful relations:**

$\frac{W}{\pi}\text{sinc}(Wt) \xleftrightarrow{F} rect(\frac{\omega}{2W})$ $\frac{W}{2\pi}\text{sinc}^2(\frac{Wt}{2}) \xleftrightarrow{F} \Delta(\frac{\omega}{2W})$

$N_o = N_q = \frac{m_p^2}{3L^2}$ $\frac{S_o}{N_o} = 3L^2 \frac{\widetilde{m^2(t)}}{m_p^2}$

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