Feedback — Communication System Exercises

You submitted this homework on **Wed 3 Apr 2013 2:15 PM CDT -0500**. You got a score of **0.00** out of **7.00**. You can attempt again, if you'd like.

Question 1

We want to examine both analog and digital communication alternatives for a dedicated speech transmission system. Assume the speech signal has a 5 kHz bandwidth. The wireless link between transmitter and receiver allows 200 watts pf power to be received at a pre-assigned carrier frequency. We have some latitude in choosing the transmission bandwidth, but the noise power added by the channel increases with bandwidth with a proportionality constant of 0.1 watt/kHz.

For a well-designed analog system, what is the signal-to-noise ratio of the received speech after demodulation?

Express your answer as a number (i.e., *not* in dB).

You entered:

Your Answer		Score	Explanation
	✘	0.00	
Total		0.00 / 1.00	

Question Explanation

The signal power is $200/2$ watts *after demodulation*. The quantity 0.1 watt/kHz amounts to N_0 since the noise power is N_0 $*$transmission bandwidth. Here, the transmission bandwidth is 10 kHz. In the demodulated signal, the noise power is

$\frac{1}{4}$ of the received noise power, giving us a noise power in the demodulated message of 0.25 watt. The resulting signal-to-noise ratio is 400.

Question 2

Turning to a digital system, how many bits must be used in the analog-to-digital converted to achieve the same signal-to-noise ratio?

Your answer must be the smallest integer that satisfies the criterion.

You entered:

Your Answer	Score	Explanation
✘	0.00	
Total	0.00 / 1.00	

Question Explanation

The SNR of a B-bit A/D converter is $\frac{3}{2}\,2^{2B}$. Solving $\frac{3}{2}\,2^{2B} \geq 400$ gives us $B \geq 4.03$, which means we need at least 5 bits in the A/D converter to achieve the same SNR.

Question 3

Is the bandwidth required by the digital channel to send the sampled signal without error greater or smaller than the required analog bandwidth?

Your Answer	Score	Explanation
Smaller		

- Larger
- The same

Total	0.00 / 1.00

Question Explanation

The channel's capacity $W\log_2(1+\mathrm{SNR})$ must be greater than the data rate for error-free communication to occur. The data rate is $5\cdot 10\times 10^3$ bps (10×10^3 is the sampling rate for a 5 kHz signal). As a trial value, set W, the channel's bandwidth in kHz, equal to the required analog bandwidth 10 kHz. The signal-to-noise ratio SNR is $\frac{200}{.1W}$.
Is $W\log_2\left(1+\frac{200}{.1W}\right)\Big|_{W=10} > 5\times 10^1$? We have $\log_2(1+200)>5$, which is true. So a smaller bandwidth is required by the capacity-achieving digital system than by an analog system.

Question 4

HDTV

In the United States (and maybe elsewhere), the initial standard set forth for high-definition television (HDTV) required that a 1035×1840 raster be sent at 30 frames/s for each of the three colors (red, green, blue). The least-acceptable picture received by the old analog standard at the edge of a transmitter's range had a signal-to-noise ratio of 10 dB that, for many technical reasons, equaled the signal-to-noise ratio before demodulation.
Using signal-to-noise ratio of the received image as a criterion, how many bits/sample *must* be used to guarantee a high-quality image, defined to have an SNR of 20 dB, can be received by any HDTV set located within the same broadcast region?

Type your answer as an integer.

You entered:

Your Answer		Score	Explanation
	✘	0.00	
Total		0.00 / 1.00	

Question Explanation

Because the three color images will be added and because noise powers add, require the received SNR be three times the requirement: $3 \cdot 100$. To find B, require $\frac{3}{2} 2^{2B} > 300$. Solving we find that $2^{2B} > 200$, which implies $B > 4$.

Question 5

Assuming the digital television channel has the same characteristics as an analog one, how much compression must HDTV system employ?

Express your answer as a compression factor, a number less than one.

You entered:

Your Answer		Score	Explanation
	✘	0.00	
Total		0.00 / 1.00	

Question Explanation

The channel's capacity is $6 \times 10^6 \log_2(1 + 10) = 20.76 \text{ Mbps}$. The raw data rate of the digital video is $1035 \cdot 1840 \cdot 3 \cdot B = 22.85 \text{ Mbps}$ for $B = 4$. The compression ratio must be at least $\frac{20.76}{22.86} = 0.91$.

Question 6

These last two questions have ignored the audio. The specification was to have CD quality sound. What is the data rate of the audio expressed as a fraction of the video data rate before compression?

You entered:

Your Answer		Score	Explanation
	✘	0.00	
Total		0.00 / 1.00	

Question Explanation

CD-quality audio has a sampling rate of 44.1 kHz with 16 bits/sample each of two channels. The data rate is therefore $44.1 \times 10^3 \cdot 16 \cdot 2 = 1.41 \text{ Mbps}$. Since the video data rate is 22.85 Mbps, the ratio is $\frac{1.41}{22.85} = 0.062$. As might be expected, the audio is a small fraction of the video data rate, which means considering the video well approximates the digital communication requirements. Including the audio, changes the compression ratio to $\frac{20.76}{22.86 + 1.41} = 0.86$.

Question 7

Digital Cellular Telephone

In designing a digital implementation of the wireless (cellular) telephone, the quality of the received voice signal (as measured by the signal-to-noise ratio) must be at least as good as that provided by wireline telephone systems (30 dB). The telephone signal's bandwidth should also be the same (3 kHz). The bandwidth of the allocated wireless channel is 4 kHz and the signal-to-noise ratio, measured 100 m from the transmitting tower, is 40 dB. The desired range for a cell is 1 km.

Can a digital cellular telephone system be designed to satisfy these criteria?

Your Answer	Score	Explanation
Yes		
No		
Not enough information has been provided.		
Total	0.00 / 1.00	

Question Explanation

The sampling rate must be at least $6\ \mathrm{kHz}$. To meet the received message signal-to-noise ratio of $30\ \mathrm{dB}$, we must have $\frac{3}{2}\, 2^{2B} \geq 1000$, which means $B \geq 5$. The source data rate is therefore $30\ \mathrm{kbps}$. As for the channel, we need only the bandwidth ($4\ \mathrm{kHz}$) and the channel signal-to-noise ratio at the edge of the cell. At a radius of $1\ \mathrm{km}$, the signal power will attenuate by a factor of 100 compared to what was measured at $100\ \mathrm{m}$, thereby making the signal-to-noise ratio at the edge of the cell $20\ \mathrm{dB} = 100$. The channel capacity C is $4 \times 10^3 \log_2(1 + 10^2) = 26.6\ \mathrm{kbps}$. Consequently, the capacity is lower than the data rate, meaning the system as specified **won't be successful**. Lossless compression could be used to reduce the data rate, but this is likely not to be sufficient. Need more channel bandwidth and/or a more powerful transmitter.