Data Communication

Islamic University – Gaza
Engineering Faculty
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Problem Set Solu

Problem set

Problem 1
Assume that you are given the frequency domain representation of unknown signal shown below, Determine:

a. The signal found there.
b. The fundamental frequency and harmonics.
c. The Bandwidth.
d. Draw the time domain signal.

Problem 2
A voltage waveform of a signal follows the equation \( X(t) = 5\cos(10^3 \times t) \ V \), where \( t = \) time. What are the frequency, amplitude, radian frequency, and periodic time (period) of this signal?

**Frequency** = \( \frac{(10^3)}{(2\pi)} = 159.155 \)

**Amplitude** = 5

**radian frequency** = \( 10^3 \)

**periodic time** = 6.2832 ms

Problem 3
The input power of a 40-km cable system is 2W (power at the beginning of the cable). An amplifier with a 64-dB gain is installed 24 km from the input. Define the signal power level, dB, and absolute power at

1. the input of the amplifier and
2. the output of the system. The attenuation of the cable is 2.5 dB/km.

1. **The input of the amplifier** = 2mw
2. **The output of the system** = 0.5mw
Problem 4

The digital compact disc (CD) player is designed for a sound bandwidth of 20 kHz. Linear encoding with 16 bits per sample is used. Define
a) The minimum sampling rate
b) The minimum binary data rate per channel (left or right)
c) The maximum SQR

a) 40,000 samples per seconds
b) 640 kbps
c) 98.08 dB.

Problem 5

The input power of an amplifier is 2 mW and output power is 1W. What are the power levels (dBm) at the input and output and what is the gain of the amplifier in decibels?

26.99 dBm

Problem 6

Consider a Message is passed to this system:

Determine
a) The sampling rate? (Hint: the bit time is 125 μ sec)
b) The Max. Message bandwidth?
c) The Min. Required Bandwidth?

1bit ----- 125 μ sec
? ----- 1s
So the bit rate =1/125 μ

Bit rate = fs*n
\[
\frac{1}{125} \mu = fs \cdot 8 \\
\text{So sampling rate } = fs = \frac{1}{(125 \mu \cdot 8)} = 1\text{Khz}
\]

\[
Fs \geq 2 \cdot F_{\text{max}} = 2 \cdot BW \\
Fs(\text{min}) = 2BW \\
1K = 2BW \\
\text{So max BW } = 1K/2 = 500Hz
\]

\[
\text{Bit rate} = 2BW \log_2 I \\
\frac{1}{125}u = 2BW \cdot 8 \\
\text{So min BW} = 500Hz
\]

**Problem 7**

Derive the following formula \( SNR_{\text{dB}} = 6.02n + 1.76 \text{ dB} \)

**Problem 8**

PCM system uses a uniform quantizer followed by an 8 bit binary encoder. The Bit Rate of the system is equal to 256 Kbps.

1. What is the Max. message bandwidth for which the system operate satisfactory?
2. Determine the signal to quantized noise ratio?
3. You passed the output digits of PCM system into a Block Coding 8B/10B, what is the current Data Rate?
4. You passed the output digits of Block Coding into \( NRZ-I \) Line Coding What is the Min. channel Bandwidth required?

\[
\text{Bit rate} = fs \cdot n \\
256 = fs \cdot 8 \\
\text{So sampling rate } = fs = 32\text{Khz.}
\]

\[
Fs \geq 2 \cdot F_{\text{max}} = 2 \cdot BW \\
Fs(\text{min}) = 2BW \\
1K = 2BW \\
\text{So max BW } = 32K/2 = 16\text{KHz}
\]

\[
\text{SNR } = 6.02n + 1.76 \text{ db} \\
= 6.02 \cdot 8 + 1.76 \\
= 49.92\text{db}
\]

\[
N_{\text{old}} = 256\text{kbps}
\]
\[ N_{new} = N_{old} + (n_{old}) \times \frac{2}{8} \]
\[ N_{new} = \frac{10}{8} \times N_{old} \]
\[ = \left( \frac{10}{8} \right) \times 256 \text{K} \]
\[ = 320 \text{kbps} \]

\[ NRZI \text{ BW} = \frac{N}{2} \]
\[ = \frac{320}{2} \]
\[ = 160 \text{KHz} \]

**Problem 9**
Assume you need to digitize an audio signal whose bandwidth \( B = 15 \text{KHz} \), its amplitude between 0 and 4 volts.

**Determine**
1. The Min. Nyquist rate?
2. The value of Delta in order to quantize it to 256 Levels?
3. The quantization error or dB SNR?
4. The Min. possible Bit Rate?

\[ F_s = 2 \times F_{\text{max}} \]
\[ = 2 \times \text{BW} \]
\[ = 2 \times 15 \text{KHz} \]
\[ = 30 \text{KHz} \]

\[ n = \log_2 256 = 8 \]

\[ \text{SNR} = 6.02\ n + 1.76\ \text{db} \]
\[ = 6.02 \times 8 + 1.76 \]
\[ = 49.92\ \text{db} \]

\[ \text{Bit rate} = f_s \times n \]
\[ = 30 \times 8 \]
\[ = 240 \text{Kbps} \]

**Problem 10**
A digital signaling system is required to operate at 56000 bps. If the signal used has 8 levels and the signal to noise ratio is 25,356 to 1, what is the minimum required bandwidth of the channel?

1. What is the signal to noise ratio in decibels?
2. If the signal power is 5.002 w, what is noise power?
3. What is the maximum data rate?
**Problem 11**
A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one channel, what are the data rates if we use one harmonic, three harmonic, and five harmonics?

\[
\text{BW} = 6 \text{ MHz}
\]
1) BW from 0 Hz to \( f_{1\text{st harmonic}} \) = 6 MHz;
   Bit rate = \( 2 \times f_{1\text{st harmonic}} \) = \( 2 \times 6 = 12 \) Mbps
2) BW from 0 Hz to \( f_{3\text{rd harmonic}} \) = 6 MHz;
   \( f_{3\text{rd harmonic}} = 3 \times f_{1\text{st harmonic}} \)
   \( f_{1\text{st harmonic}} = 6 \text{ MHz} / 3 = 2 \text{ MHz} \)
   Bit rate = \( 2 \times f_{1\text{st harmonic}} \) = \( 2 \times 2 = 4 \) Mbps
3) BW from 0 Hz to \( f_{5\text{th harmonic}} \) = 6 MHz;
   \( f_{5\text{th harmonic}} = 5 \times f_{1\text{st harmonic}} \)
   \( f_{1\text{st harmonic}} = 6 \text{ MHz} / 5 = 1.2 \text{ MHz} \)
   Bit rate = \( 2 \times f_{1\text{st harmonic}} \) = \( 2 \times 1.2 = 2.4 \) Mbps

**Problem 12**
We measure the performance of a telephone line (4KHz of bandwidth). When the signal is 10 V, the noise is 5 mV. What is the maximum data rate supported by this telephone line?

\[
\text{Bit rate} = 4,000 \log_2 \left( 1 + \frac{10}{0.005} \right) = 43,866 \text{ bps}
\]

**Problem 13**
Assume a data stream is ‘110100000000010’ s. Encode this stream, using the following code schemes. How many changes (vertical line) can you find for each scheme?
a. Unipolar: 4 changes between bit.
b. NRZ-L: 4 changes between bit.
c. NRZ-I: 4 changes between bit.
d. RZ: 16 changes at the middle of each bit + 15 changes between bit.
e. Manchester: 16 changes at the middle of each bit + 11 changes between bit.
f. Diff. Manchester: 16 changes at the middle of each bit + 11 changes between bit.
g. AMI: 6 changes between bit.
**Problem 14**

A signal is sampled. Each sample represents one of four levels. How many bits are needed to represent each sample? If the sampling rate is 8000 samples per second, what is the bit rate?

- **Quantization** 2 bits/sample;
- **Bit rate** \( \text{8000} \times 2 = 16,000 \text{ bps} \)

**Problem 15**

5. We have sampled a low-pass signal with a bandwidth of 200 KHz using 1024 levels of quantization. Calculate the bit rate of the digitized signal.

- **Low pass signal**: frequency between 0 – 200 KHz
- **BW** = 200 KHz
- **Sampling rate** \( \geq 2 \times f_{\text{highest}} = 2 \times 200 \text{ KHz} \)
  \( \geq 400,000 \text{ samples /s} \)
- **Quantization** 10 bits/sample;
- **Bit rate** \( 400,000 \times 10 = 4 \text{ Mbps} \)
Problem 16

Answer the following questions:

1. Differentiate between a continuous signal and discrete signal.
2. What is a periodic signal? Explain.
3. Discuss the frequency domain concepts of electromagnetic signal.
4. Explain analog and digital repeaters.
5. Briefly discuss why digital transmission is preferred over analog transmission.
6. What is Nyquist sampling rate?
7. Discuss Shannon’s channel capacity.
8. Discuss various line coding techniques.
9. Explain different modulation techniques.
10. List different guided transmission mediums. Discuss properties of optical fiber cable.
11. What advantages and disadvantages are there to using fiber instead of unshielded twisted pair
12. Differentiate Flow control, Error Control