1. Computer the Fourier coefficients for signal \( f(t) \), where \( f(t)=1 \) for \( 0 \leq t \leq 1 \) and \( f(t)=0 \), \( 1 < t \leq 2 \).

**Solutions:**

\[
a_n = \frac{2}{T} \int_{0}^{T} f(t) \sin(2\pi nt) dt = \frac{2}{T} \int_{0}^{1} f(t) \sin(2\pi nt) dt = \int_{0}^{1} \sin(2\pi \frac{1}{2}t) dt = \int_{0}^{1} \sin(\pi nt) dt
\]

\[
= -\frac{\cos(\pi nt)}{n} \bigg|_{0}^{1} = -\frac{\cos(\pi n) - 1}{n} = \frac{1 - (-1)^n}{n}
\]

\[
b_n = \frac{2}{T} \int_{0}^{T} f(t) \cos(2\pi nt) dt = \frac{2}{T} \int_{0}^{1} f(t) \cos(2\pi nt) dt = \int_{0}^{1} \cos(2\pi \frac{1}{2}t) dt = \int_{0}^{1} \cos(\pi nt) dt
\]

\[
= \frac{\sin(\pi nt)}{n} \bigg|_{0}^{1} = 0
\]

\[
c = \frac{2}{T} \int_{0}^{T} f(t) dt = \frac{2}{T} \int_{0}^{1} f(t) dt = \int_{0}^{1} dt + \int_{1}^{2} 0 dt = 1
\]

2. If a binary signal is transmitted through a 4kHz noiseless channel, what is the maximum data rate? If the SNR of the channel is 20dB, what is the maximum data rate?

**Answer:**

Using the noiseless channel formula:

Maximum data rate = \( 2H \log_2 V \) bits/sec, \( H = 4 \) kHz = 4000 Hz

So maximum data rate = \( 2 \times 4000 \log_2 2 = 8000 \) bits/sec

If the SNR of the channel is 20dB, then \( 10 \times \log(S/N) = 20 \) dB

So \( S/N = 100 \)

Using the formula:

Maximum number of bits / sec = \( H \times \log_2 (1 + S/N) = 4000 \times \log_2 (1 + 100) = 4000 \times \log_2 (101) = 4000 \times 6.6582 = 26632 \) bits/sec

3. What is the Nyquist sampling theorem?

**Answer:**

Nyquist sampling theorem: If an arbitrary signal has been run through a low-pass filter of bandwidth \( H \), the filtered signal can be completely reconstructed by making only \( 2H \) (exact) samples per second. Sampling the line faster than \( 2H \) times per second is pointless because the higher frequency components that such
sampling could recover have already been filtered out. If the signal consists of \( V \) discrete levels, Nyquest’s theorem states:

\[
\text{Maximum data rate} = 2H \times \log_2 V \text{ bits/sec}
\]

4. Suppose the constellation of digital modulation scheme is: \((1,1), (1,-1), (-1,1),\) and \((-1,-1)\). What is the data rate of this scheme at 1200 baud?
Answer:
Since the scheme has 4 possible combinations, every symbol consists of 2 bits,
Data rate = \((2 \text{ bits/symbol}) (1 \text{ symbol} / (\text{baud*sec})) (1200 \text{ baud}) = 2400 \text{ bits/sec}\)

5. What is the modulation scheme used in ADSL?
Answer:
In ADSL channel, a modulation scheme similar to V.34 is used, although the sampling rate is 4000 baud instead of 2400 baud. The line quality in each channel is constantly monitored and the data rate adjusted continuously as needed, so different channels may have different data rates. The actual data are sent with QAM modulation, with up to 15 bits per baud.

6. Why the duration of a SONET frame is 125us?
Answer:
Since SONET is synchronous, frames are emitted whether or not there are any user data to send. Having 8000 frames/sec exactly matches the sampling rate of PCM channels used in all digital telephony system, we have \(1/8000 = 0.000125\), i.e., 125 us frame.

7. Suppose sequence \((-1 +1 -3 +1 -1 -3 +1 +1)\) is transmitted and the chip sequences for four users are:
   a. \(-1 -1 -1 +1 +1 -1 +1 +1\)
   b. \(-1 -1 +1 -1 +1 +1 +1 -1\)
   c. \(-1 +1 -1 +1 +1 +1 -1 -1\)
   d. \(-1 +1 -1 -1 -1 -1 +1 -1\)

Determine the signal that each user sent (assume that each user can transmit \(-1, 0, \) and \(+1\)).
Answer:
To determine the signal that each user sent, we can compute each of the normalized inner products:
   a. \((-1 +1 -3 +1 -1 -3 +1 +1) \ast (-1 -1 -1 +1 +1 -1 +1 +1)/8 = 8/8 = +1\)
   b. \((-1 +1 -3 +1 -1 -3 +1 +1) \ast (-1 -1 -1 +1 +1 +1 +1 -1)/8 = -8/8 = -1\)
   c. \((-1 +1 -3 +1 -1 -3 +1 +1) \ast (-1 +1 -1 +1 +1 +1 -1 -1)/8 = 0/8 = 0\)
   d. \((-1 +1 -3 +1 -1 -3 +1 +1) \ast (-1 -1 -1 -1 +1 +1 -1 -1)/8 = 8/8 = +1\)
8. What are the multiplexing schemes used in GSM systems?
Answer: TDM and FDM

9. In addition to voice service, what is the main service in 2G mobile communications systems?
Answer: Mobile data services