Time Division Multiplexing

1. In TDM what is frame synchronization and why is it needed and what is its cost?

2. The bandwidth for signals $x_1(t), x_2(t), x_3(t), \ldots, x_N(t)$ is $B_i=180$ kHz for $i=1\ldots N$. These signals are multiplexed using TDM. The resulting baseband TDM signal is then modulated using DSB-SC. The RF signal is assigned RF spectrum of 60MHz.
   a. Assuming Nyquist sampling find $N$.
   b. Given $N$ found above and assume PCM using 4 bits/sample what is the required RF bandwidth.
   c. Given each signal is sampled at 250,000 samples/sec with 8 bits/symbol (8 bits/sample) what is the frame time, slot time, bit time, bit rate and required RF bandwidth.
   d. Using the number users found in part c) find the additional bandwidth needed if a 10101010 bit pattern is used in the first time slot to obtain frame synchronization.
   e. What problem may arise using 10101010 bit pattern is used in the first time slot to obtain frame synchronization.

3. A TDM system has a frame time = 10 ms. The frame is divided into 20 time slots. Each time slot carries 168 bits. (These are some LTE parameters).
a. What is the slot time?
b. What is the Tb=bit time?
c. What is the total bit rate in b/s?
d. Suppose a user gets 8 time slots, what is the user bit rate (in b/s)?
e. What is the minimum transmission bandwidth?

4. Consider a PCM/TDM with following parameters
   \( K = \) Number of signals = 24; \( B_x = \) Bandwidth/signal = 3 kHz; \( \gamma = \) Number of bits/sample = 8
   a. Assuming Nyquist sampling that is the bit rate of the PCM/TDM signal.
   b. What is the minimum transmission bandwidth of the PCM/TDM signal in Hz.
   c. Assuming a linear quantizer how much is the Signal to Quantizing noise ratio \( (S/N)_q \) in dB improved by changing the number of bits/sample to \( \gamma = 12 \). see http://classes.engineering.wustl.edu/e-se488/Lectures/Lecture5a_QNoise.pdf
   d. Change the number of bits/sample to \( \gamma = 12 \). What is the minimum transmission bandwidth of the PCM/TDM signal in Hz.
   e. Discuss the trade-off between minimum transmission bandwidth and the Signal to Quantizing noise ratio \( (S/N)_q \).
5. Explain TDMA?

6. Explain TDD?

7. Baseband signals $x_1(t), \ldots, x_{100}(t)$ have the same bandwidth $B_x = 10\text{kHz}$, i.e., $B_{x_i} = 10\text{kHz}$, $i=1\ldots100$. Each signal $x_i(t)$ is sampled at 30kHz and coded with 4 bits/sample. Each user gets one timeslot/frame. These signals are multiplexed using TDM/PCM.
   a. What is the frame time?
   b. What is the slot time?
   c. What is the bit time and bit rate?
   d. Why is frame synchronization needed in TDM/PCM and what does it cost the system to provide frame synchronization?

8. Your company has 1 MHz of RF spectrum. How many users can be supported using the following multiplexing techniques? Each user has a baseband bandwidth of 25kHz. Clearly state any assumptions.
   a) TDM/PAM
   b) TDM/PCM with 8 bits/sample
   c) Using the number users found in part c) find the additional bandwidth needed if a 1010101010101010 bit pattern is used in the first time slot to obtain frame synchronization.
9. Ten baseband signals $x_1(t), \ldots, x_{10}(t)$ have the same bandwidth $B_x=50$ kHz, i.e., $B_{x_i}=50$ kHz, $i=1\ldots10$. These signals are multiplexed using TDM/PAM. Each signal $x_i(t)$ is sampled at 120 kHz. Assume impulse sampling.
   a. What is the frame time?
   b. What is the minimum transmission bandwidth for this TDM/PAM signal?
   c. A 12 bit quantizer is used to form a TDM/PCM signal. What is the bit rate for TDM/PCM signal?
   d. There will be no ISI when the TDM/PAM signal is input to a filter with an impulse response of $p(t)=\text{sinc}^2(2B_0t)$ with $B_0=600$ kHz. TRUE or FALSE. Circle the correct answer and justify

10. Compare TDMA to TDM.

11. Consider a PCM/TDM with following parameters
   $K=\text{Number of signals} = 32$
   $B_x = \text{Bandwidth/signal} = 15$ kHz
   $\gamma = \text{Number of bits/sample} = 8$
   a. Assuming Nyquist sampling that is the bit rate of the PCM/TDM signal.
   b. Minimum transmission bandwidth of the PCM/TDM signal
   c. Assuming a linear quantizer how much is the Signal to Quantizing noise ratio $(S/N_q)$ in dB improved by changing the number of bits/sample to $\gamma = 9$.
   d. Change the number of bits/sample to $\gamma = 9$. What is the minimum transmission bandwidth of the PCM/TDM signal
   e. Discuss the trade-off between minimum transmission bandwidth Signal-to-Quantizing noise ratio $(S/N_q)$. 

12. Four baseband signals \( x_1(t), x_2(t), x_3(t), x_4(t) \) have the same bandwidth \( B_x = 1 \) kHz. These signals are multiplexed using TDM/PAM to generate a transmitted signal \( y_{\text{TDM/PAM}}(t) \), assume impulse sampling is used.

a. What is the maximum time between samples of \( x_1(t) \) in \( y_{\text{TDM/PAM}}(t) \)?
b. What is the minimum transmission bandwidth for \( y_{\text{TDM/PAM}}(t) \)?
c. What is intersymbol interference, ISI?
d. The system is changed to TDM/PCM with a sample rate per signal of 3000 samples/sec and 8 bits/sample. What is the minimum transmission bandwidth for the \( y_{\text{TDM/PAM}}(t) \) signal?

13. TDM is used to send 8064 voice signals, each signal is sampled at 8000 samples/sec with 8 bits/sample.

a. What is the TDM bit rate?
b. If raised cosine pulse shaping is used with \( a = 1 \) what is the required bandwidth.

14. Consider the use of TDM for the transmission of 80 video channels. Assume each channel is bandlimited to 4.0 MHz.

a. What is the minimum bandwidth required for a TDM/PAM signal?
b. Find the minimum bandwidth for a TDM/PAM signal required when each video signal is sampled at 9,000,000 samples/sec.
c. Find the minimum bandwidth required when TDM/PCM is used with 8 bits/sample and 9,000,000 samples/sec.