

Computer Facilities and Network Management

BUS3150

Tutorial - Week 6

***** FOR TUTORS ONLY *****

The answers provided here are only brief guides. If you have any comments or suggestions for improvement to this, please let me know so that your improvements may be included in this document.

Objective of this tutorial:

The objective of this tutorial is to strengthen the conceptual understanding of the material covered in the lecture by reflecting on the material in small groups. The tutor will provide feedback to enhance your understanding and diminish misunderstandings, if any.

How to participate in the tutorial:

Form groups of four to five students in each and discuss the answers for the following reflective questions with the group members. After spending about ten minutes for each question, discussing with group members, discuss your solutions with the tutor and other groups. The tutor will provide feedback on your solutions.

Question 1 - For the bit stream 1010011101, sketch the waveforms for the following signal encoding techniques (space for answer provided in Figure 5).

- (a) NRZ-L
- (b) NRZ-I (the signal level for the preceding bit was low).
- (c) Pseudoternary (the most recent preceding 0 bit was a negative voltage).
- (d) Bipolar AMI (the most recent preceding 1 bit (AMI) was a negative voltage).
- (e) Manchester
- (f) Differential Manchester
- (g) ASK
- (h) FSK
- (i) BPSK

Question 2 - The 8B6T encoding scheme takes 8 bits of binary data and encodes them using 6 ternary signal elements. Recall that each ternary signal element can take on one of three values (positive, negative and zero voltage). The table shown in Figure 1 is a portion of the 8B6T code table. The complete table maps all possible 8-bit patterns to a unique code group of 6 ternary symbols. The 8B6T encoding scheme is an example of a block coding scheme which is used in 100BASE-T4 (100 Mbps Fast Ethernet over twisted pair, discussed later in the semester). Figure 2 shows an example of encoding hexadecimal 37000009_{16} or in binary $00110111000000000000000000001001_2$ using NRZ-L, Manchester (used in 10BASE-T) and 8B6T.

- (a) When considering synchronisation of the receiver, why is the NRZ-L signal a problem in this example?

The long string of 0's contain no transitions on which the receiver's clock can synchronise. For NRZ-L, this is a problem for any long string of 1's or 0's. (NRZ-L can also create a DC component.)

- (b) How does the Manchester signal solve the synchronisation problem of part (a)?

Manchester uses a transition in the middle of each bit period to encode 1's and 0's. If the transition is a low to high, a 1 is encoded. If the transition is a high to low, a 0 is encoded. Therefore, this scheme guarantees at least one transition for each bit transmitted. The receivers clock can synchronise using this transition. (Manchester had no DC component.)

- (c) What cost does the Manchester signal incur in achieving this synchronisation?

For every bit sent, Manchester produces up to two transitions. This is evident in Figure 2 where the long string of 0's is encoded. Since the signal can change twice for every bit period, the maximum modulation rate is twice the bit rate, unlike NRZ-L whose modulation rate equals the bit rate. Doubling the modulation rate doubles the bandwidth required for the signal.

- (d) The 8B6T signal also solves the synchronisation problem. How?

Examining the table in Figure 1 we can see that the code set is chosen to maximise the average number of transitions per code group. That is, each code contains one or more pulses. We are therefore guaranteed to have one or more transitions for every six ternary signal elements. We can use these transitions to synchronise the receivers clock. (The codes are also designed to maintain DC balance so that the average voltage on the line is 0.)

The end of Chapter 16 in Stallings provides more details on 8B6T.

- (e) The 8B6T has a lower bandwidth requirement than the NRZ-L signal for the same data rate. Why is this the case?

Since 8 binary bits are mapped to 6 ternary symbols, there are at most 6 changes of the output signal for each 8 bits of data. Therefore the modulation rate is $6/8$ ($3/4$) the data rate.

For example, if we have a channel with enough bandwidth to carry 25 Mbaud (million changes of the signal per second), then that channel can carry $25 \times \frac{8}{6} = 33\frac{1}{3}$ Mbps. If we have three channels over which we send data, then we have $3 \times 33\frac{1}{3} = 100$ Mbps. This is what Fast Ethernet over 100BASE-T4 does (100 = 100 Mbps, BASE = baseband signal, T = twisted pair, 4 = four twisted pair wires).

- (f) Why is the 8B6T signal more difficult for the receiver to sample in the presence of line noise, than the NRZ-L signal?

Like all ternary signals, the receiver has to differentiate between three different voltage levels, rather than two. When there is noise on the line, differentiating these voltage levels is more difficult for the receiver.

Question 3 - Pulse Code Modulation (PCM) is a technique used to transform analog data to digital data. Figure 3 shows how Pulse Amplitude Modulation (PAM) samples are taken at a rate $2B$ (once every $1/2B$ seconds) for a signal with bandwidth B . Each PAM sample is approximated by being quantised into one of 16 different values. Reflect on the fact that it is impossible to recover the original signal exactly.

- (a) At what point is the information required to recover the original signal lost?

Some may be tempted to say during sampling. However if we sample at $2B$, we can recover the original signal. The point where information is lost is during the quantisation stage. That is, the point where we approximate the analog pulses (PAM) with a finite precision binary value.

(b) What changes, if any, can you make to overcome this problem?

We can improve the situation by using non-linear quantisation (small quantisation intervals for low amplitudes and large quantisation intervals for large amplitudes). We can also allocating more bits to represent each sample. This will increase the resulting data rate. We can not, however, truly recreate the original signal after quantisation. We can only ever approximate the original signal.

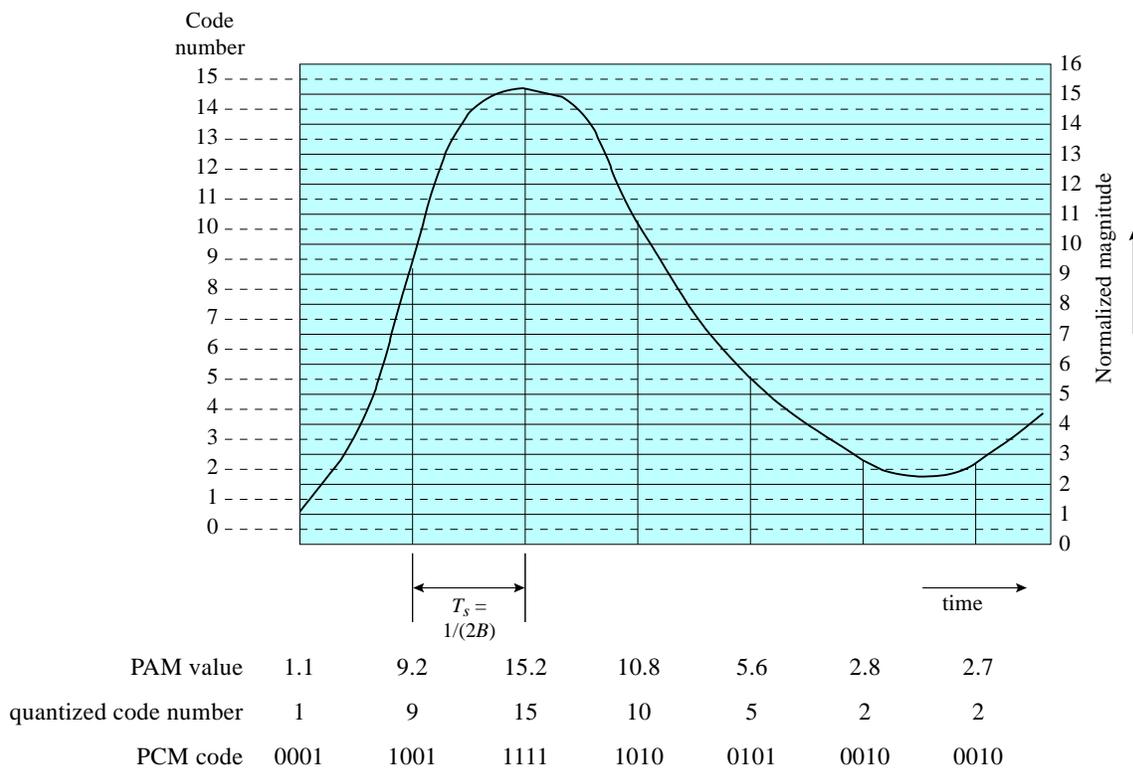


Figure 3: Pulse Code Modulation (PCM) Example.

Question 4 - The bipolar-AMI waveform representing the binary sequence "0100101011" is transmitted over a noisy channel. The received waveform is shown in Figure 4. It contains a single error. Locate the position of the error and explain your answer.

The error is at bit position 7, where there is a negative pulse. For AMI, positive and negative pulses are used alternately for binary 1. The pulse in position 7 represents the third binary 1 in the data stream and should have a positive value.

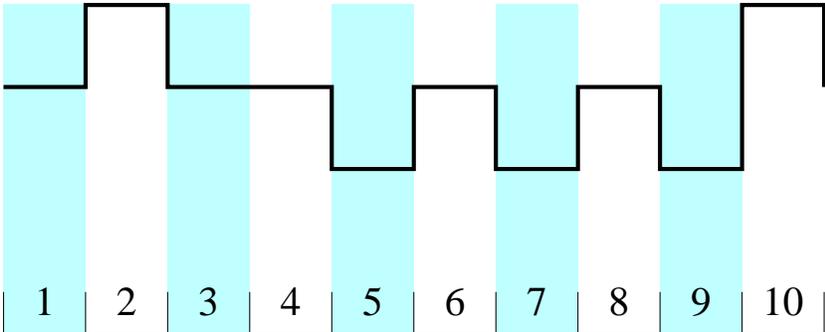


Figure 4: A Received Bipolar-AMI Waveform.

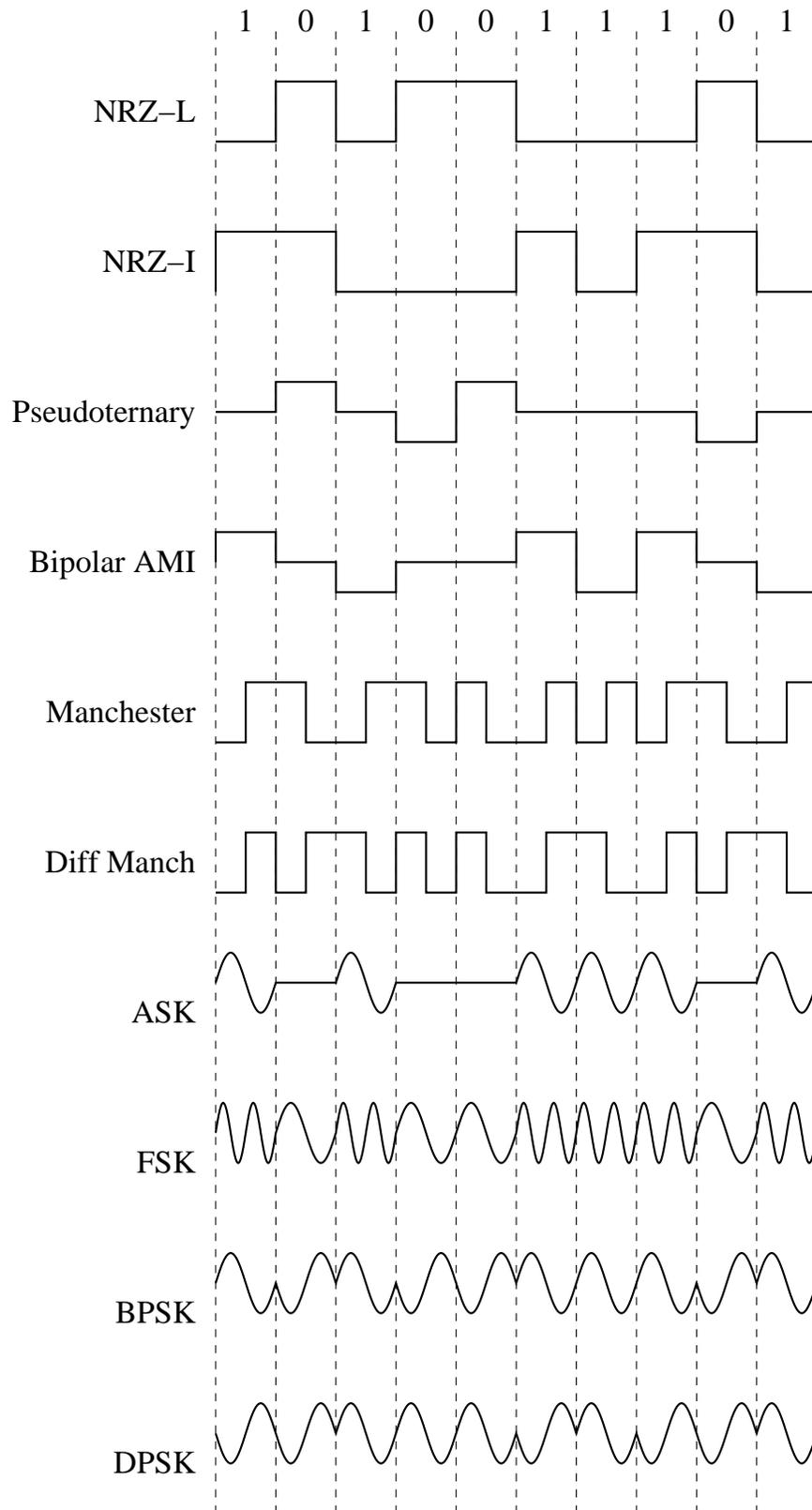


Figure 5: ANSWER for Question 1