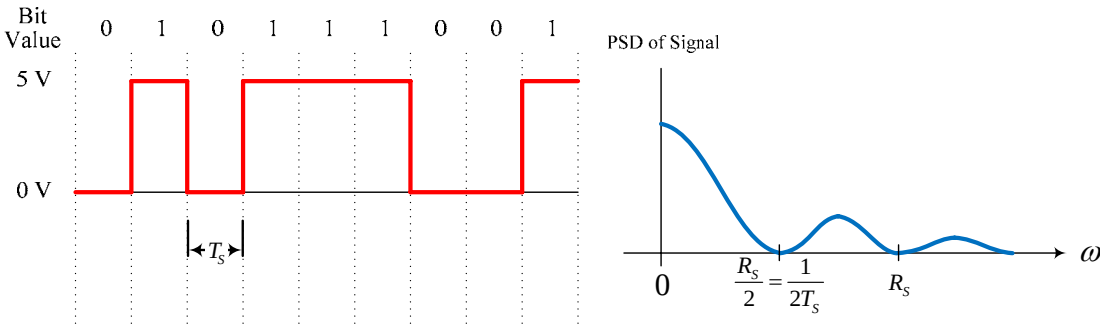
Ref: A. Leon Garcia and I. Widjaja, *Communication Networks*, 2nd Ed. McGraw Hill, 2006
Latest update of this lecture was on 29-11-2010

Lecture 20: Digital Transmission Fundamentals

Line Coding

The reality is that information sources that provide digital data actually provide numbers that are not suitable for transmission on any channel as they are. An analog to digital converter (ADC) that converts an analog audio signal to a digital format provides sample values every 50 to 100 microseconds. The sample values must be formatted in a proper way to make them suitable for transmission through the communication channel. When each digital value is represented using a pulse for each bit (in binary communication) or a pulse for multiple bits simultaneously (for M-ary communication), the produces signal generated by stacking different pulses is called a line code. To put it in a simple way, the process of line coding is using the digital data obtained from an information source to generate a voltage signal that represents the information. There are different forms of line codes that can be used to represent the information. The terms Return to Zero (RZ) and Non–Return to Zero (NRZ) will be used in describing these signal. Some line codes are shown next along with their power spectral densities, advantages and disadvantages:

1. **Unipolar (On–Off) Non-Return to Zero (NRZ):** In this form of line codes, a bit of 1 is represented by some positive voltage (+5 volts for example) and a bit of 0 by 0 volts (justifying calling this signal On–Off). The pulses corresponding to binary 1 remain at the positive voltage for the whole duration of the bit period (it does not return to zero at any time during the bit period justifying calling this line code NRZ).



Advantages:

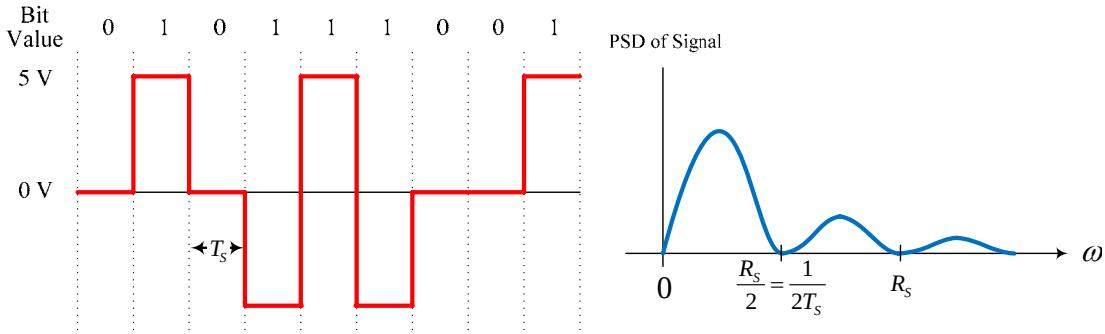
1. Very simple to generate (has only two levels which can be easily generated using simple digital electronics)
2. Spectrally efficient (requires the minimum amount of bandwidth for a specific bit rate)

Lecture 20: Digital Transmission Fundamentals

Disadvantages:

1. Does not provide any form of bit or frame synchronization (for long sequences of ones or zeros, the transmitter and receiver may get unsynchronized)
2. Does not provide any form of error detection.
3. Generally has non-zero DC (even if voltages of -5 V and +5 V are used, unless the number of zeros and number of ones are equal). This may be a problem for some communication systems that cannot transmit DC values.

2. **Bipolar Non-Return to Zero (NRZ):** In this line codes, a bit of 1 is represented in an alternating form by some positive voltage (+5 volts for example) once and the next time a bit of 1 appears it will be represented by the same voltage but with a negative value (–5 volts). A bit of 0 is represented by zero volts. The pulses corresponding to binary 1 remain at the positive and negative voltages for the whole duration of the bit period (they do not return to zero). The advantage of this line code over the Unipolar (On–Off) NRZ is that it has zero–DC value because bits of 1 alternate in using the positive and negative voltages. A line code with zero–DC is desired in some applications that require that the transmitted signal to have no DC.



Advantages:

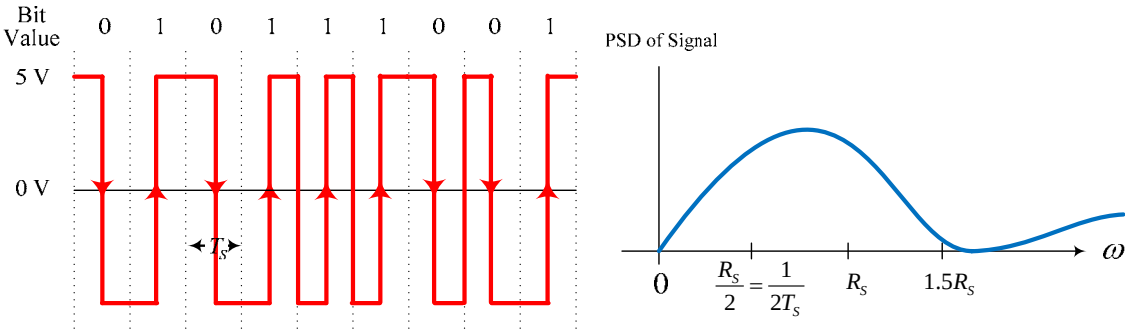
1. Spectrally efficient (requires the minimum amount of bandwidth for a specific bit rate)
2. Provide synchronization between the transmitter and receiver for long sequences of Logic 1.
3. Allows some form of error detection (since two consecutive logic 1's are represented by a positive and negative pulses, if the receiver detects two consecutive pulses that have the same polarity (both are positive or both are negative), it can easily detect that there must have been an error in the transmission).
4. Has zero DC value regardless of the number of Logic 1s and Logic 0s in the information to be transmitted.

Lecture 20: Digital Transmission Fundamentals

Disadvantages:

1. Does not provide synchronization information for long sequences of zeros.
2. Requires more sophisticated electronics to be generated because it uses signals with 3 levels (for example, +5, 0, and -5 V)

3. **Manchester (Bi-Phase):** In this line code, a bit of 0 is represented by some positive voltage for the first half of the bit period and some negative voltage for the second half of the bit period. A bit of 1 is simply the negative of the zero bit so it is represented by the negative voltage for the first half of the bit period and the positive voltage for the second half of the bit. **Unlike previously discussed line codes, which carry the information in the levels of the pulses, since each of the two binary values (0 and 1) in this line code are transmitted using pulses that have half of their duration being a high voltage (or positive voltage) and the other half being a low voltage (or negative voltage), the information is not carried in the levels but in the transition from high to low voltage or vice versa in the middle of the pulse representing each digital bit. A transition from high to low may represent a zero while a transition from low to high would then represent a one.** This line code is very good for insuring synchronization between the transmitter and receiver. For consecutive bits that are equal, a transition may occur at the border of bits. These transitions are simply ignored and do not carry information.



Advantages:

1. Provides full synchronization information for long sequences of zeros and long sequences of ones. Also, this line code can easily be used to also provide frame synchronization information by simply transmitting bits with both of their two parts being high voltage or both are low voltage, where the transmitter can use this method to signal to the receiver that a byte, for example, has ended and a new byte it starting.
2. Allows some form of error detection (since a bit has two parts, so if the two received parts of a bit have the same value, an error may have happened (this assumes that frame synchronization as discussed in point 1 above is not used)

Lecture 20: Digital Transmission Fundamentals

3. Has zero DC value regardless of the number of Logic 1s and Logic 0s in the information to be transmitted.

Disadvantages:

1. Requires more bandwidth for transmission (approximately 1.6 times the bandwidth of the previous line codes) since there are more transitions in the signal of this line code compared to the previous line codes for the same bit rate.
2. Although this line code has only two levels, it slightly more complicated to generate compared to Unipolar NRZ line code.