Tutorial 6, CS1031

1. Time division multiplexing (TDM) of digital channels

A new digital high-definition phone system is being tested, able to capture voice frequencies up to 20KHz, and is **being encoded** using 16 bits per sample. The system can carry 24 such channels using Time Division Multiplexing.

1. What is the total bit rate of the multiplexed system?
2. What is the minimum bandwidth required to transmit the multiplexed stream over a **baseband multi-level** coding system that uses 3 bits per symbol?
3. What is the minimum bandwidth required to transmit the multiplexed stream over a 256-QAM **modulation** ?

1. Each channel needs at least a 40KHz sampling rate, which at 16 bits per channel generate a data rate of 640Kb/s. Since the multiplexing is in the time domain, in order to get the total data rate we only need to multiply the channel rate by the number of channels, so the total rate is 15.360Mb/s.
2. The formula for baseband multilevel transmission is B= S/2 = R/(2*n). Thus we have B= 15.360/(2x3) = 2.56MHz . No guard bands are required here, as the multiplexing is operated digitally in the time domain.
3. The signal modulation creates a shift in the frequency domain, which brings also the negative frequencies into play. Thus in general a modulated signal has a minimum bandwidth that is double that of the baseband signal.

   The formula is B= S = R/n = 15.360/8 = 1.92MHz.

2. Frequency division multiplexing (FDM) of digital channels

A company has a transmission medium with a 2-MHz bandwidth (**baseband**). The company needs to create 10 separate channels through FDM for a **total bit rate** of at least 10 Mbps, and it has decided to use a QAM modulation. Guard bands of 10KHz are required between channels. What is the minimum number of bits per symbol the modulation needs to deliver? What is the number of points in the constellation diagram for that modulation? Assume d=0.

First, we calculate the bandwidth for each channel = (2 MHz-90KHz) / 10 = 191 KHz. We then find the value of n for each channel:

B = (1 + d) × S = (1+d) x R/n → n = (1+d) x R / B
→ n = (1 Mbps/191 KHz) = 5.2 → round to the next higher integer value = 6

We can then calculate the number of levels: L = 2^n = 2^6 = 64. This means that we need a 64-QAM technique to achieve this data rate.