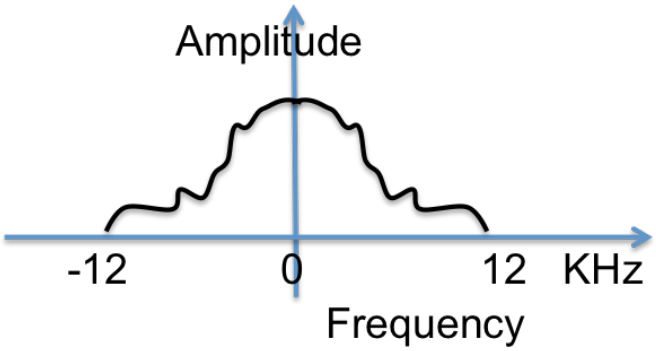
Tutorial 5, CS1031

1. Modulation and spectrum

A voice conversation has a frequency spectrum similar to the one shown in the figure below. You need to transmit the voice signal over a walkie talkie radio, operating at a carrier frequency of 500 MHz. The radio is digital, so you need to sample, quantise and modulate the signal.

a) Specify the sampling and quantization you would use and state what bandwidth do you require if the maximum number of levels allowed by your modulator is 64.
b) What could you do if you needed to reduce the bandwidth of the signal to less than 12KHz (still the maximum number of levels allowed by your modulator is 64).
c) Show a plot of the frequency spectrum of the modulated signal.



a) The max frequency is 12KHz, so the sampling should be at least 24KHz. The student should remember that for voice 8 bits sampling is enough.
a) With these constraints, the maximum bit rate would be 192Kb/s, leading with a 64-QAM modulation to a bandwidth of (1+d)xR/log2(L). Here d can be 0, so R/6 = 32KHz.
b) Here you should remember that a voice conversation can be cut down to 4KHz while still being understandable. This way, the sampling frequency becomes 8 KHz and the bit rate can be brought down to 64Kb/s, with a bandwidth occupancy of 10.6KHz.
c) The spectrum should show a figure centred around the 500MHz frequency, and with a width of 32KHz. The same is repeated in the negative part of the x axis.

2 Data rates

A server contains a file of 10 MB. Bearing in mind that you have a connection to this server of 1 Mbps, what would be the time between the moment the server starts to transmit and the moment that the client receives the last bit? Assume first a null propagation time and then a propagation time of 150 ms.

L=10 * 8 * 10^6 = 80 *10 ^6 //File length in bits
Tt= 80*10^6/(10^6) =80 s // Transmission times
Td= 0 V Td=150 ms //Delay times
Tt= 80 s V Td=80.15 s //Total transmission times

3. Signal digitisation

An audio recorder uses 16 bits to quantize a piece of music sampled at 32 kHz.

1. At what bit rate do you need to read the music to play it seamlessly?
   R= 16*32 * 10 ^ 3 = 512 kbps
2. If the range of the analogue to digital converter is between +3 Volt and -3 Volt (i.e., the amplitude axis expressed in Volts [V]), what is the size of each quantization interval assuming equal levels?
   Qi = 6/2^16 = 0.0000915527 V = 91.5527 μV

3. What happens if the input signals has an amplitude larger than 3?
   Since the maximum level that can be recorder is 3V any signal higher than that will be stored as a 3V signal. This is called clipping.