Tutorial 6, CS1031

1. Modulation and spectrum

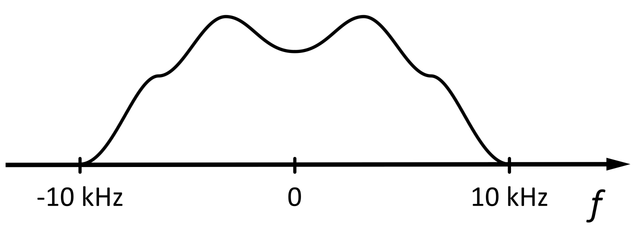
A digital radio system is being designed for a digital radio station. The system needs to reproduce high-fidelity music, using 16 bits per sample quantisation, with each signal composed of two channels (i.e., for stereo transmission) each with maximum frequency of 22kHz.
(a) What is the bit rate generated by the system?
(b) What is the lowest digital modulation (QAM or PSK) you can use that fits in the frequency band between 1.2300 GHz and 1.2306 GHz?

(a) The total rate is equal to 2*2*22*16=1.408Mb/s.

(b) The frequency band is 0.6 MHz, which needs to fit a rate of 1.408Mb/s. Since in modulation the bandwidth equals the symbol rate, 1.408/0.6= 2.34, so a value of n=3 tends to be selected. Hence, either an 8-PSK or 8-QAM should be selected.

2. Modulation and spectrum

To transmit a voice signal over a walkie talkie radio, with a frequency spectrum similar to the one shown in the figure below, we use the carrier frequency of 400 MHz. The radio is digital, thus, you need to sample, quantize and modulate the signal.
(a) Specify the sampling rate and quantization you would use and state what bandwidth you require if the maximum number of levels allowed by your digital modulator is 16.
(b) What could you do if you needed to reduce the bandwidth of the signal to less than 10 kHz (still the maximum number of levels allowed by your modulator is 16).
(c) Show a plot of the frequency spectrum of the modulated signal.



(a) The max frequency is 10 kHz, so the sampling should be at least 20 kHz. For voice 8 bits sampling is enough. With these constraints, the maximum bit rate would be 20*8 = 160 kb/s. Since, the bandwidth can be found

through $(1+d)*(R/\log_2(L))$, utilizing a 16-QAM modulation, while considering d = 0, $B = R/\log_2(16) = 160/4 = 40$ kHz.
(b) Here you should remember that a voice conversation can be cut down to 4 kHz while still being understandable. This way, the sampling frequency becomes 8 kHz and the bit rate can be brought down to 64 kb/s, with a bandwidth occupancy of 16 kHz.
(c) The spectrum should show a figure centered around the 400MHz frequency, and with a width of 40 kHz. The same is repeated in the negative part of the x axis.

3. Digital multi-level modulations

You need to transmit the following sequence of bits over a transmission channel, using a 8-ASK digital modulation: 100110010111001011.

(a) Draw a plot of the square wave signal representing the baseband multi-level transmission in the time domain

(b) Draw a plot of the modulated signal in the time domain.

(c) Draw a plot of the modulated signal in the frequency domain using the following parameters: the symbol rate of the modulated signal is 1 Mbaud, the carrier frequency is 100MHz and the value of d for the modulation is equal to 1.

(a) The first step is to break the sequence into groups of 3: 100 110 010 111 001 011, then divide the positive y axis of the plot into 8 equally spaced levels.
(b) You should draw a sinusoidal signal, whose amplitude varies for each symbol depending on the amplitude assigned to each triplet of bits being transmitted. The sine waves should be symmetrical respect to the x axis.
(c) The shape used for the frequency spectrum is not important, what matters is the calculation of the right bandwidth occupancy, placing the spectrum around the 100MHz frequency and plotting it also in the negative part of the x axis. It is important to remember the difference between bit rate and symbol rate. The bandwidth of the signal will be $(1+d)*S = 2$MHz.

4. Comparing analogue and digital modulations

(a) What is the main difference between digital and analog modulations?

(b) Which one is more resilient against noise? Explain why.

(a) In analogue modulation the modulating signal is continuous, in digital is discrete, i.e. can only take a discrete number of levels. The number of levels depends on how many bits (n) per symbol I transmit, following the rule L=2^n.

(b) Digital modulation is more resilient, because unless the noise is strong enough to change bit values, the original signal can be reconstructed exactly. In Analogue instead any noise, even small, will contribute to deteriorate the quality of the signal.