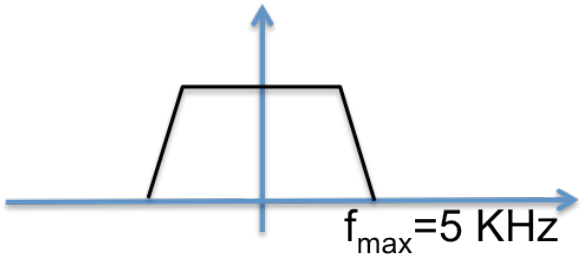
Tutorial 4, CS1031

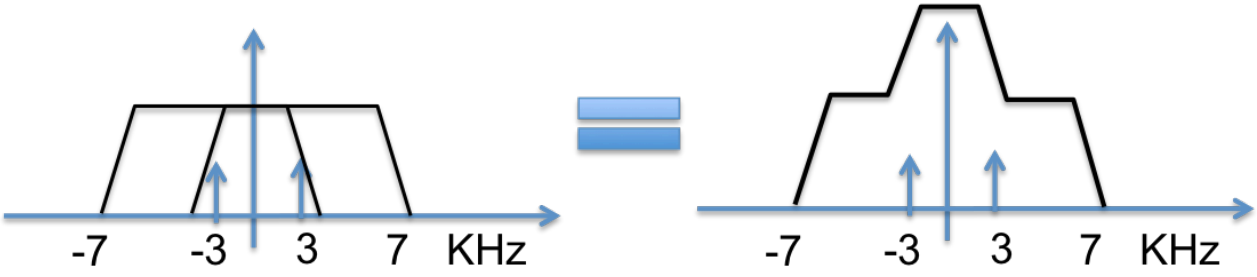
1. Modulation and spectrum

Consider a baseband signal with the power spectrum as in the figure below.



1. Explain what happens to the spectrum of the signal when the signal is multiplied by a sinusoid wave of frequency equal to 20 KHz. Then plot the resulting power spectrum, showing all the relevant frequency values in the x axis.
   This is amplitude modulation of a signal. The operation will move the entire spectrum plot up by 20 KHz (which becomes the new centre frequency). A mirror copy is also created in the negative part of the spectrum. The plot should look like this:

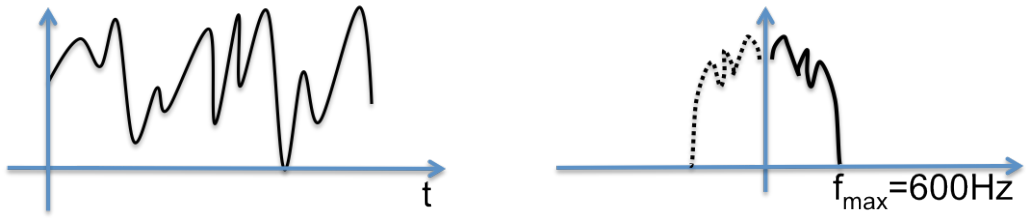
2. Show the power spectrum plot of the same signal when it is modulated with a sinusoid wave of frequency equal to 2 KHz. Then explain whether this creates any issue.
   In this case the sinusoid frequency is smaller than the maximum frequency, so the signal will only move by 2 KHz, which is not enough to clear the spectrum from the negative axis and will cause distortion. The plot should look like this



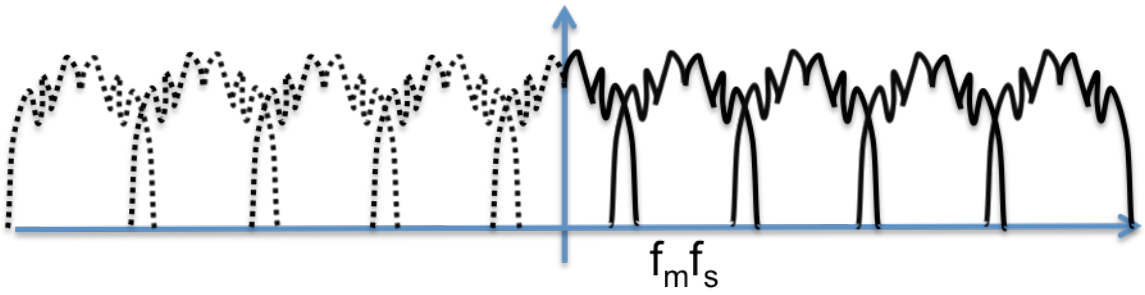
2. Fourier transform and signal digitisation

The figure below shows a signal in the time domain (on the left) and its associated spectrum (on the right). You are trying to digitalise the time-domain signal by sampling it at difference frequencies of, respectively, 1KHz, 1.2KHz and 1.4KHz.

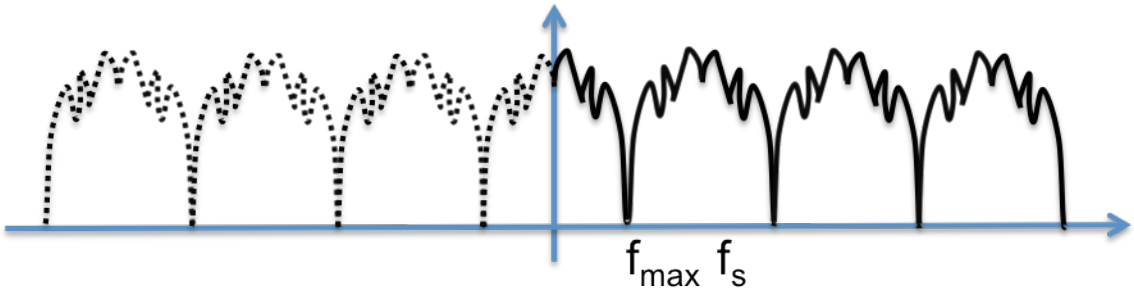
Show with a frequency plot, the spectra generated by a Discrete-Time-Fourier-Transform (DTFT) at the three different sampling frequencies, then give a detailed description of your drawings, and state whether information is lost during each of these sampling processes.



In the first case we have under sampling as the signal is sampled below the Nyquist sampling rate. In the frequency plot this can be seen ad the middle of the second copy is at less than the double of f_max, thus the copies of the spectra overlap. In this case information is lost.



In the second case the sampling is at exactly the Nyquist frequency: the spectra are adjacent to each other and no information is lost.



In the third case we are over sampling: the distance between the spectra is more than required and there is no loss of information. The maximum sampling frequency tells us the maximum frequency that

we are able to see in the spectrum diagram, after which we get copies of the original spectrum.