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## Experimental challenge\*: Echo, echo, echo

Introduction to digital signals

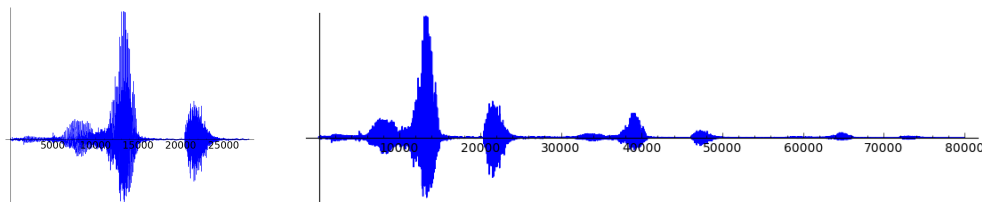
Deadline: End of the course

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### Experimental part

This is a simple experiment to do with Octave or Matlab. You only have to look up in the documentation the commands to read digital audio (`audioread`, `wavread` in older versions) and to play it (`sound` or `soundsc`) or to store it (`audiowrite`, `wavwrite` in older versions).

When sound meets a distant obstacle it is reflected and come back to the source. A simple model for echo is to sum to a signal a displaced version of itself attenuated by a factor  $A$ . We assume that there is another obstacle (a wall) just behind the emitter and hence we also add the  $n$  times displaced signal with a factor  $A^n$  until  $A^n$  is negligible. Write a program simulating echo taking as input a sample of voice and the distance  $d$  to the object (note that the speed of sound is  $343m/s$  and the distance  $d$  is covered twice). Try to adjust the attenuation to produce a realistic effect. For  $d$  like 100 you should get something like the echo in the mountains and for  $d$  like few meters you should get an effect of “empty room”.



Voice signal

Distant echo mildly attenuated ( $d = 100$ ,  $A = 1/5$ )

Technically, in acoustics the name *echo* refers to only one reflection ( $n = 1$ ), instead of many as we consider here. With this jargon, our case is a toy model of *reverberation*. In the most realistic simulations it takes into account the phase change of the reflected signal, the different responses of different frequencies and even the situation of multiple obstacles.

### Mathematical part

Find a formula relating the Fourier transform of a signal (as smooth as you wish) and the Fourier transform of the echo. Taking the inverse transform, write the integral operator mapping the signal into its echo. If you have software to compute integrals numerically, an interesting exercise is to check numerically that it works as expected for instance for Gaussian signals.

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\*Some experiments are classical, some are my idea and others come from specific sources. In the latter case I have omitted the reference here on purpose to force the students to work on their own. If you are the author, please do not get angry. I intend to incorporate the references to the final version of the notes.