Measurement transducer impulse response using an exponential Sine Sweep method

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Content

I. Introduction

The impulse method, which is based on recording measuring signal, can be used to obtaining transfer function of common electroacoustic systems and their impedance. Also, physical phenomena occurring in the ultrasonic transducers can be observed and diagnosed in detail when the impulse method in association with digital processing of the signal.

One of these methods with sweep sinus requires an anechoic chamber in order to delete the influence of the room and get a good signal-to-noise ratio. On the other hand, using a quasi-anechoic chamber give the possibility of the measurement in a small room.

In this paper, the method proposed by A. Farina to get the impulse response in rooms is implemented in electromechanical transducers and an ultrasonic transducer through exponential sweeps. For several reasons, sweeps are a far better choice for transfer-function measurements than noise sequences MLS.

II. Method

In order to test the method in twice sorts of transducers, an anechoic chamber was used to reduce the number of reflections in the walls, floor, and cell in the case of electromechanical loudspeaker transducer. In the second case with piezoelectric ceramic PZT a sweep sinus was emitted in a water medium. In both cases, to avoid reflections from surfaces the signal has been cut before the first reflection according to the size of each room. Also, in both cases, the same method to obtain the impulse response was used.

The signal emitted depends on the frequency response of the transducer evaluated whereby an exponential sine sweep is generated in a width band suitable

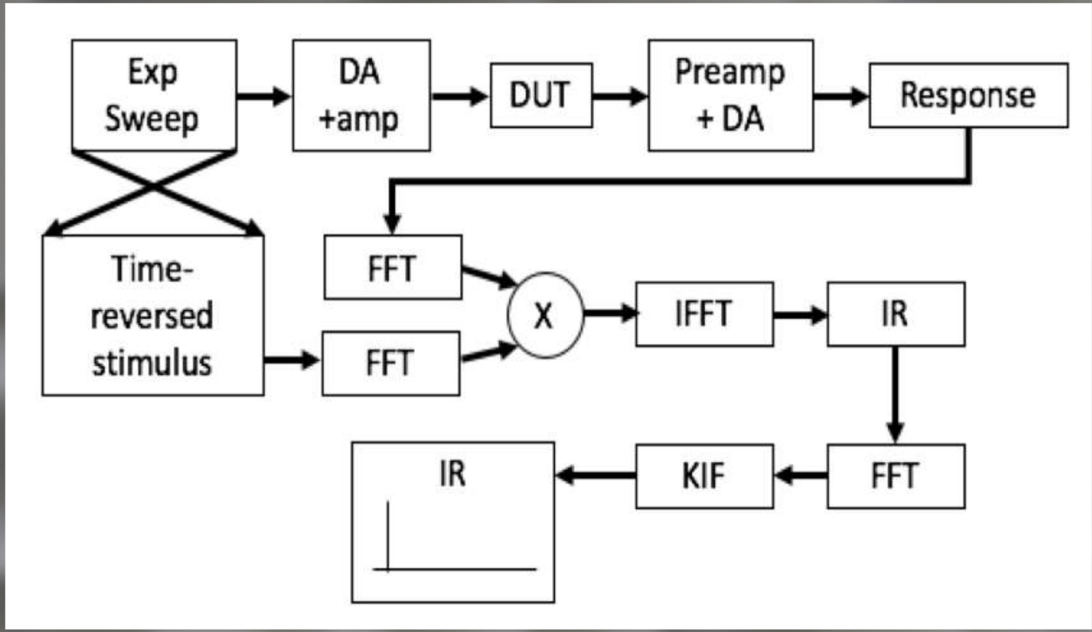
$$x(t) = sin\left[\frac{2\pi f_1}{\ln\left(\frac{f_2}{f_1}\right)} \cdot \left(e^{\frac{1}{T}\ln\left(\frac{f_2}{f_1}\right)} - 1\right)\right]$$

Where $\boldsymbol{f_1}$ and $\boldsymbol{f_2}$ are the initial and end frequencies of the signal respectively and $\boldsymbol{T}$ represent the time.

II. Method

Once the signal has been emitted by the device under test (DUT) and record in digital system acquisition (DAQ), the spectrums of the record and the inverse signal emitted are multiplied to get the impulse response.

General scheme of the process



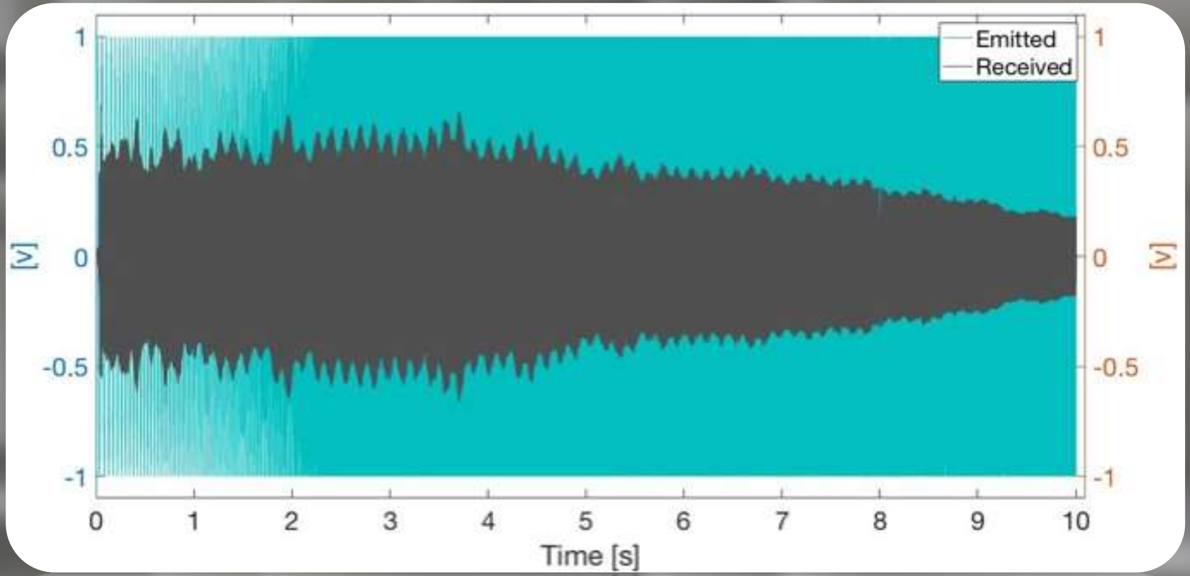
The pre-riging effect produced at low frequency due to to sound car can be corrected by:

$$H(f) = FFT[h(f)] \rightarrow C(f)\frac{Conj[H(f)]}{Conj[H(f)]\cdot H(f)+\varepsilon(f)} \rightarrow c(t) = IFFT[C(f)]$$

The filter is gets in the frequency domain as a conjugated operation where $\boldsymbol{\varepsilon}(\mathbf{f})$ is a small, frequency-dependent regularization parameter. Finally, an IFFT brings back the inverse filter to time domain.

III. Electromechanical transducer measurement

A sweep sinus measurement with a single microphone was performed. A loudspeaker Genelec 8010A was set up over a flat surface separated from floor 1.6 meters. A receiver is a Behringer ECM 8000 microphone separated 1 meter of the source



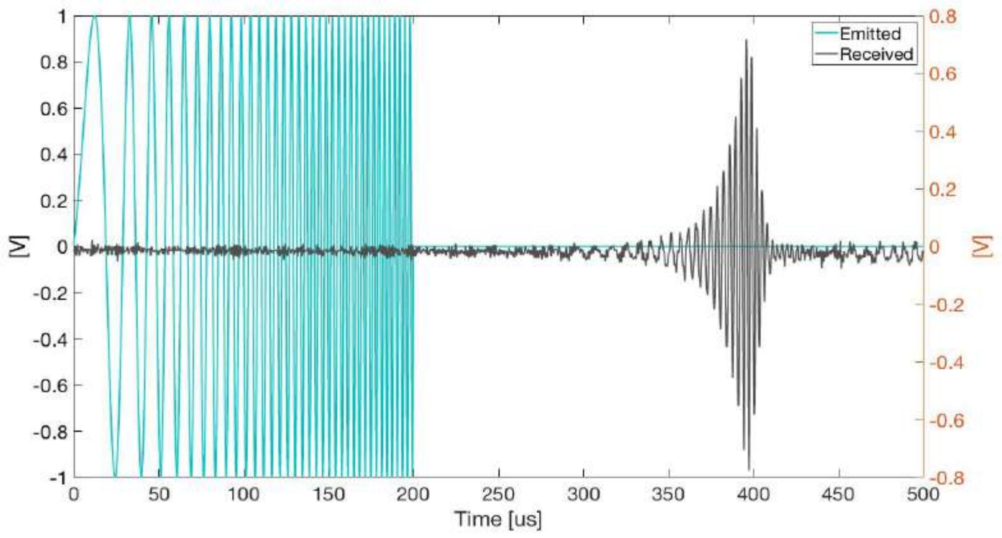
- Sample rate: 48kS/s.
- Signal sweep from 20hz to 20kHz.
- M-Audio sound card.
- Signal calibrated to 91dB with white noise

The instantaneous sweep power should be controllable according to the frequency just being swept through. With this, it avoids the saturation on the sound card.

IV. Underwater transducer measurement

The process of impulse measurement was assessed in a couple of RESON TC 4034 transducers. The experimental environment is a water tank with a water volume of $0.64\ \mathrm{m}^3$. Both similar sensors are separated $30\mathrm{cm}$ each other and a national instrument DAQ acquisition system was used with a sample rate of $10\ Ms/s$.

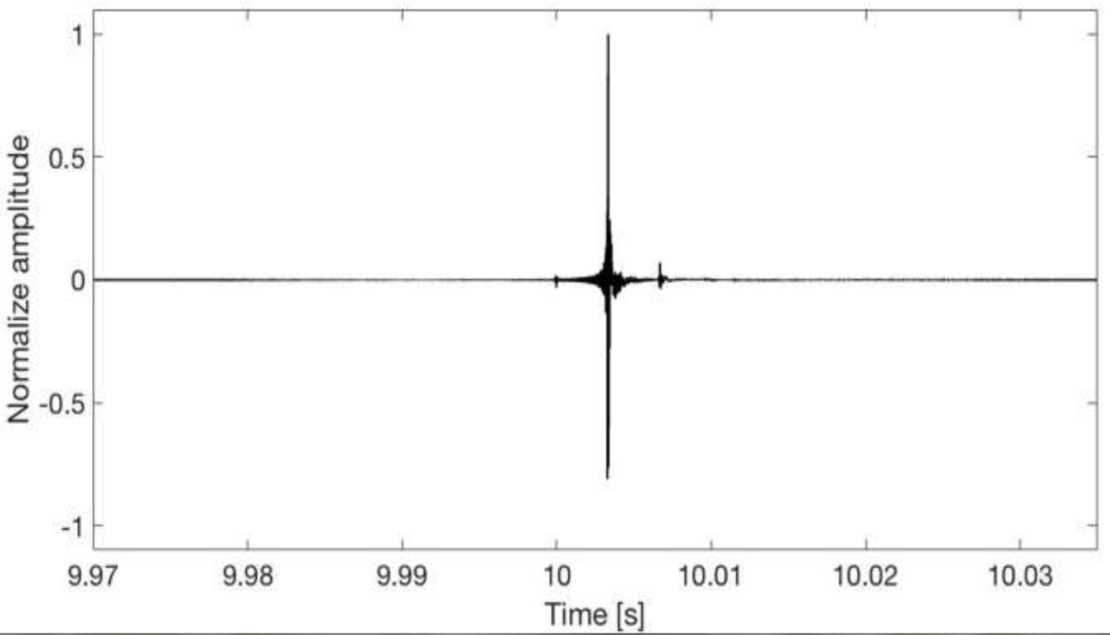
The exponential sweep signal emitted has a duration of $200\mathrm{us}$.

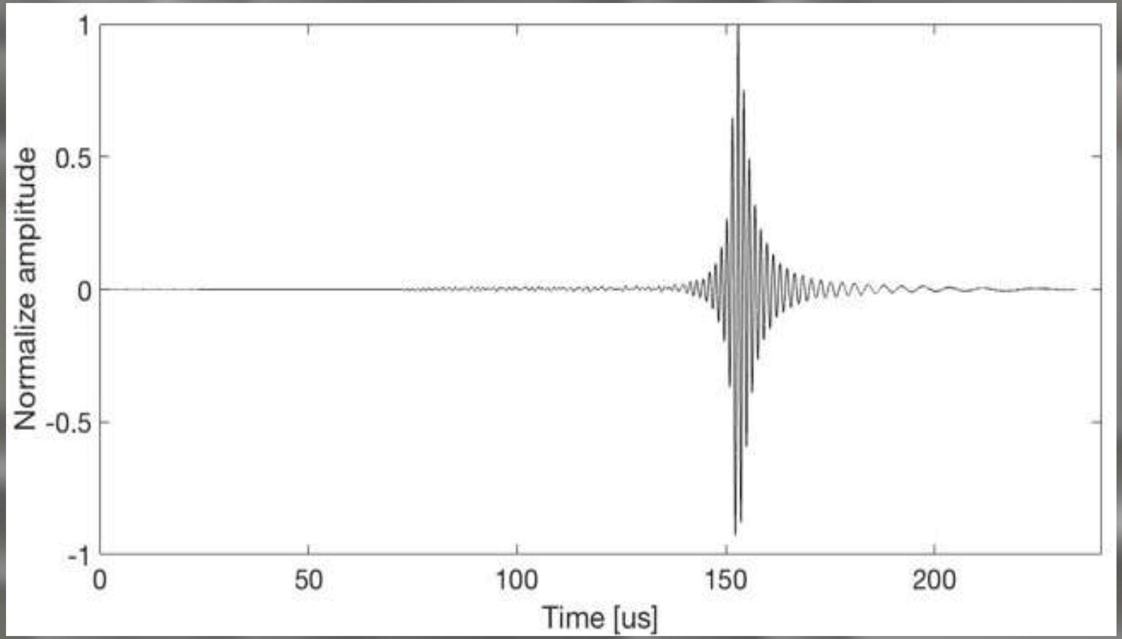


This sweep was recorded for $\mathbf{500us}$ and in order to suppress all reflections a time window of $\mathbf{210us}$ was used to extricate the direct signal from the file before the first scatter appear and delete the electromagnetic signal from the electric components.

V. Results

As a result of the experiments, the impulse response from devices has been calculated according to the method described.





IR of the loudspeaker in an anechoic chamber.

IR of underwater sensor.

VI. Conclusions

- Impulse measurement of a mechanical and ultrasound transducer can be got with the method described in this paper. This made possible to derive a general procedure for calculating these responses, which can be used for different transducer.

- With the exponential sweep technique, it is possible to simultaneously deconvolve the linear impulse response of the system and to selectively separate each impulse response corresponding to the harmonic distortion orders considered. With this information, it is possible to determine, for example, the kind of signals should be sent to each transducer when the signal expected is known.

- The impulse response deconvolution process is realized by lineal convolution of the measured output with the analytical inverse filter processed form the excitation signal. Using lineal convolution allows time-aliasing problems to be avoided. In fact, even if the time analysis window has the same length as the emitted signal, the tail of the system response may be lost, but this will not introduce time aliasing.

- Experimental with piezoelectric transducer shows that it is possible to suppress reflection from given surface of the experiment and obtain good results spite of the increase of the noise. In order to perform an objective comparison of the impulse response qualities, the optimal signal-to-noise ratios achievable for each transducer have been compared.

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