Case Study

Application	*Acoustics*
Product	*M2i.4931-exp Digitizer* *4 Channel 30 MS/s 16 Bit* *M2i.6022-exp AWG* *4 Channel 20 MS/s 14 Bit*

High Amplitude Time Reversal Focusing of Acoustic Waves

The ability to focus waves offers interesting possibilities in a number of fields such as communications, ultrasound, nondestructive testing (NDT), medical science and audio. For example, in biomedical applications, focused ultrasound can be used in lithotripsy procedures for treating kidney stones or to target brain tumors. Similarly in NDT, the TR process has been used to help locate and characterize defects in solid materials. In addition, it can be used to create high amplitude focusing of ultrasound for a non-contact source used for nondestructive evaluation.

One method to focus waves is Time Reversal (TR) signal processing. The technique can be employed for intentional wave focusing using remotely placed signal sources. At the Acoustics Research Group, Department of Physics and Astronomy, Brigham Young University, in the USA, research is being undertaken where the TR technique is used to focus sound with high amplitudes in a room. The aim is to create a virtual source of spherical waves with sufficient intensity that nonlinear acoustic propagation can be studied.

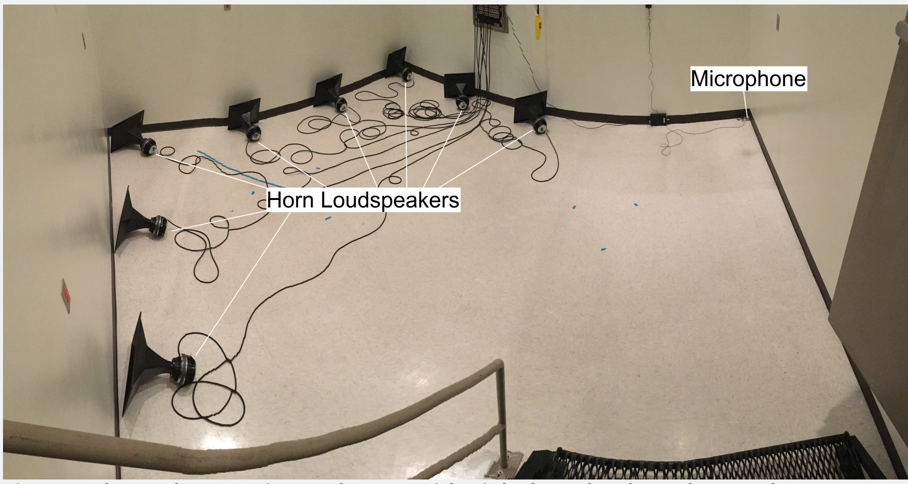

Figure 1 shows the experimental setup with eight horn loud speakers and a microphone positioned inside the reverberation chamber.

The TR signal processing method focuses sound waves from remotely placed sources using a forward and backward step. During the forward step, an impulse response (or transfer function in the frequency domain) is obtained for a source and a receiver. The impulse response is then reversed in time and, if required, additional processing can be applied. During the backward step, the reversed impulse response is broadcast from the source and focusing of sound is achieved at the receiver location.

At Brigham Young University a high amplitude focus of sound is created in a reverberation chamber. TR focuses waves to a selected location that converge from all directions to produce the focus, and then diverge from that location. As such, the divergence of the waves after TR focusing may be considered a virtual source.

To achieve high focal amplitude an experimental setup was designed that consisted of eight BMS 4590 coaxial compression drivers with horns attached to the drivers. One 0.3175 cm (1/8 inch) 375 40DP GRAS free-field microphone with a 26AC GRAS preamplifier was used for the measurements. The microphone has a specified dynamic range upper limit of 175 dB (178 dB peak or 15.9 kPa) for a ±1 dB precision. A 12AA GRAS microphone power supply is used to power the microphone.

The signals used for the experiments are created in MATLAB and output via two, 4-channel

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Spectrum M2i.6022-exp Arbitrary Waveform Generator (AWG) cards. The output from the Spectrum cards is amplified with two, 4-channel Crown CT4150 amplifiers and then routed through patch panels via Speakon cables into the reverberation chamber and then to the horn drivers.

The signal acquisition from the microphone and GRAS preamplifier is done with one, 4-channel Spectrum M2i.4931-exp digitizer card. A sampling frequency of 50 kHz is used and the digitizer has 16 bit precision.

Brian Anderson, Associate Professor at Brigham Young University, noted “I have looked into using many different types of generation and acquisition cards and determined that Spectrum cards offer the most cost-effective solution for the ultrasonic frequency range of interest to us. The combination of multiple channels, synchronous generation and acquisition, and high sampling frequencies were ideal for our work in the development of ultrasonic nondestructive evaluation techniques. We have also used these cards for nonlinear acoustics measurements of sound in rooms where the high sampling frequencies allowed us to characterize the steep waveforms we encountered.”

A panoramic photograph of the setup for the high amplitude focusing experiments is shown in Figure 1.

The University studies found that to produce the highest amplitude focus of sound the best impulse response modification method was achieved by using a technique known as the clipping method. With the eight horn loudspeaker sources driven by the Spectrum AWG’s in a reverberation chamber an optimal clipping threshold of 9.05 kPa (173.1 dB peak) was achieved.

Experiments conducted at lower amplitudes and scaled appropriately to the highest amplitude result provide evidence that TR focusing at these high amplitudes is a nonlinear process. Figure 2 shows some results with 2a) plotting scaled sound pressure level spectra for the entire focal signals with four different input amplitudes, 2b) the spectral differences (subtracting the level 1 spectrum), 2c) the spectra for the portion of each focal signal before the focal times, from time zero up until 10.4 s and 2d) the same spectra portions subtracted from the level 1 spectrum.

The results indicate that the compression magnitudes were nonlinearly increased with higher focusing amplitudes

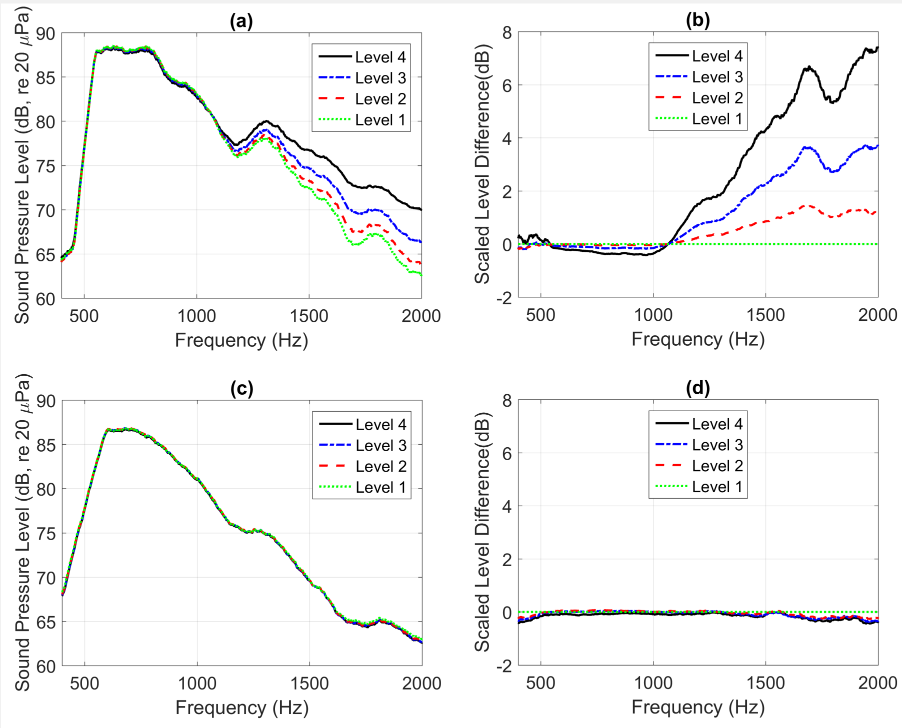

Figure 2 shows the results the non-linear nature of TR focusing when using different input amplitudes whereas rarefaction magnitudes are nonlinearly decreased with higher focusing amplitudes. A decrease in low frequency energy and an increase in high frequency energy in the spectra of the linearly scaled focal signals, along with linear scaling observed before the time of focusing, suggests that the observed distortions are due to amplitude-dependent wave steepening effects.

For a more complete presentation of the TR research undertaken at Brigham Young University, including a study on how to optimize the quality of the sound focal spot, a journal article is available for download to ASA members here:

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Experiment description and copyright by Brian Anderson, Associate Professor at Brigham Young University, Provo, Utah