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Abstract : The intent of this paper is to describe the first stages of potentially ongoing collaborative research between the United States Naval Research Laboratory's Underwater Sound Reference Detachment (USRD) and France's DCN Ingénierie centre Sud Département Lutte Sous-Marine (DCN/SUD/DLSM). The immediate focus of this collaborative work is on high Q electroacoustic transducer calibration in reverberation limited environments. This paper will be divided into three sections : the first one, a description of the motivating problem in reverberation limited measurements, the second one, a description of the two techniques developed by each laboratory, finally, research results and the activities necessary to complete the work in progress.

1. PROBLEM DESCRIPTION

Electroacoustic transducers are calibrated in controlled temperature and pressure environments (i.e., pressurised vessels) in order to evaluate the transducer's likely performance in ocean environments. With the development of lower frequency transducers, however, calibration in these confined regions is more difficult because echoes from boundaries interfere with the acoustic signal before the desired information can be acquired. Whether one is attempting to characterise a transducer's transfer function or beam pattern, the standard measurement technique is to record the steady state response when the transducer is excited by a stepped sinusoid at discrete frequencies across the desired range of frequencies or directions. Previously, the steady state amplitude and phase were recorded directly during the portion of the response signal occurring after the transient response dies out but before the arrival of echoes at the hydrophone. Clearly, if the transient response does not die out before the echoes arrive, the accurate measurements cannot be made using this technique. Many new designed projectors have a resonant frequency around 800 Hz but their output response transient part lasts up to 10 ms (sometime more) because of their high Q factor. It becomes impossible to measure such transducers in usual tanks because the reflected echoes from the tank boundaries arrive around 4 ms later than the direct signal. The goal of this research is to devise techniques for measuring the steady state response of such transducers in the presence of echoes.

2. DESCRIPTION OF TECHNIQUES

2.1 Suppressed transient turnon and turnoff method [1] : The problem of eliminating the transient part of a sinusoidal signal radiated in the surrounding fluid from an electroacoustic transducer is considered here. The purpose is to produce a sound wave in the fluid which is as similar as possible to a section of a steady-state sine, beginning and ending at zero crossings of the sine. The method is based on the use of an equivalent circuit for the transducer of interest. Knowing the circuit parameters accurately allows the proper transient suppressing drive to be computed analytically. In the case of a spherical transducer in water, the driving voltage wave form consists of a sum of a pedestal voltage, plus a ramp voltage, plus a sinusoidal voltage that is shifted with respect to the wave form that appears in the fluid. Least square fitting to the known analytical driving function, and direct measurement of the resulting steady-state pressure response, allows a transducer calibration to be carried out.

2.2 Multipath modeling [2] : In this technique, the observed data is used to estimate parameters in a signal model containing multiple arrivals of exponential signals. By minimising a least-squares error functional, estimates are obtained for the arrival times, complex frequencies, phases , and amplitudes for direct and reflected signal components. The desired response information is then the amplitude and phase for the steady-state component with the earliest arrival time, corresponding to the acoustic wave propagating along the direct path from the projector to the hydrophone.

2.3 Cross correlation technique [3]: From the cross correlation function between the input signal of the projector and the output signal of the receiving hydrophone, it is possible to remove the effect of the boundary echoes of the tank if the peaks of this function are narrow enough. Then the direct Fourier transform is applied to obtain the free cross spectrum which is used to work out the transfer function of the projector. The duration of the cross correlation function peaks must be short enough to apply the window. So input signals with an auto correlation function with narrow peaks must be used. In practice, we use a Gaussian Random Signal (GRS). These signals are adequate if the transducer does not reduce too much the bandwidth in the frequency domain of the input signal.

2.4 Directional receiving array [2] [4] : Another possibility is to use directional receiving array in low frequencies (500 to 2000 Hz). The characteristics of the receiving array must be chosen to reduce the contribution of the first annoyed echoes from the boundaries and to measure properly the direct signal. The idea, which is used to do such receiving array, is to locate omnidirectional hydrophones, regularly spaced, on two virtual circles which make up a dipole.

The parameters of this array (distance between the two circles, size of the array, numbers of hydrophones) were studied to reduce as much as possible a predicted error when this array is used to calibrate a projector. This predicted error is worked out by only assuming the four images of the projector, due to the confined environment, whose the contributions are not removed by the temporal windowing used in the pulse sound technique. A receiving array which is efficient between 500 Hz to 2000 Hz has been tested to study the feasibility of the technique (see Figure 1). It is synthesised by moving a single hydrophone located under a carriage which is controlled by a computer.

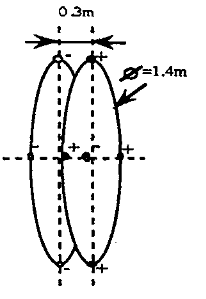

Figure 1

3. RESEARCH RESULTS

The multipath modeling method, the cross correlation technique, the directional receiving array technique, and the transient suppression technique were tested and evaluated for calibrating a 1 kHz resonant flexural disc transducer. The results of each techniques are compared to a reference curve, which was obtained for the transducer using conventional methods in a large lake where steady state is reached before echoes arrive at hydrophone.

3.1 Flexural disc projector results.

The multipath modeling method and the transient suppression technique yields results that very closely match the reference curve (Fig. 2). While there are some deviations between the reference curve and the results from the dipole array technique (Fig. 3) and the cross correlation technique (Fig. 4), these methods show a marked improvement over the conventional technique in the tank (Fig. 5). The dipole array results shown in figure 3 can be improved by using an adaptive diameter array.

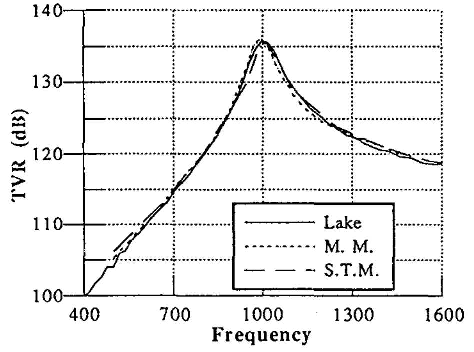

Figure 2 : Flexural disc : Multipath Modeling (16 averages). Suppression Transient Method.

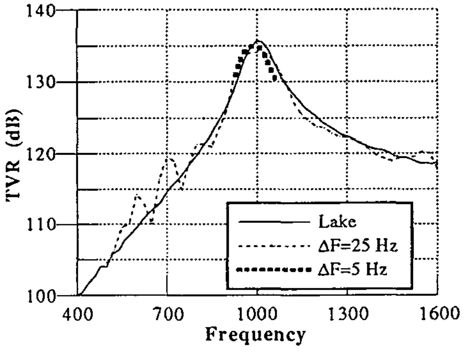

Figure 3 : Flexural disc - Directional Receiving Array. (0 average)

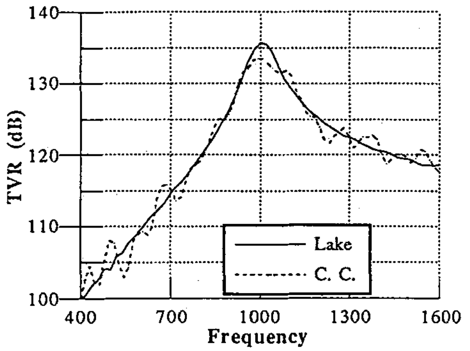

Figure 4 : Flexural disc - Cross Correlation technique. (0 average)

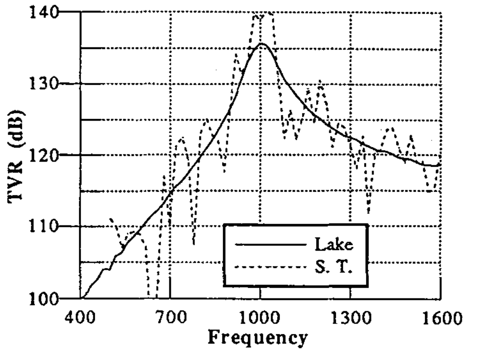

Figure 5 : Flexural disc - Standard Technique. (5 averages)

4. CONCLUSIONS AND FUTURE WORKS

We have demonstrated the feasibility of using the various techniques for calibrating high Q electroacoustic transducers in reverberate environments. The transient suppression technique, the multipath modeling method, and the directional sensor array technique appear most promising. We intend to use a hybrid of these methods for calibrating projectors whose radiation impedance changes depending upon the environment characteristics (e.g. double ended Janus Helmholtz projector).

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