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Tonpilz Transducer Array for Wideband Sonar Applications

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Abstract*— A Tonpilz transducer has two distinct resonances; the flapping mode of the head mass and the longitudinal mode of the piston driver. These resonances are typically separated by few tens of kHz. The concept behind the electrical tuning method described in this paper is to introduce a system electrical resonance in the middle of the two mechanical resonances. This may be achieved by adding an inductor and a resistor in series with the transducer element. The electrical resonant frequency is chosen to be in the middle of the two mechanical resonances. The transducer capacitance together with the inductor, controls the position of the electrical resonance. The resistor is chosen to decrease the Q of the electrical resonance to optimize the flatness of the TVR over the required bandwidth. A light weight array using 12 Tonpilz transducers was designed and tested. The SPL obtained is typically 180 dB ref 1 µ Pa @ 1 m with a -6 dB bandwidth of more than one octave. With this method a 280% improvement in the bandwidth of the array is achieved.

Keywords—Tonpilz, transducer, electrical tuning, array, Sonar

I. INTRODUCTION

Tonpilz transducers are widely used in sonar applications because of their high power generation capability and robustness. These transducers have limited bandwidth, which is sufficient for most of the applications. However, there is a need for wideband high power acoustic projectors for detection and classification of underwater objects. Previous reported work either use multiple matching layers [1] or mechanically modify the front mass [2-4] to increase the -6 dB Transmit Voltage Response (TVR) to more than one octave. This paper discusses the use of electrical tuning to achieve a similar performance increase without altering the mechanical design of the transducer. This technique is cost effective and is used to develop a broadband light weight array.

II. DEVELOPMENT OF TONPILZ TRANSDUCER ARRAY

A. Transducer

Thales Australia's PZT ceramic TLZ -11 is used for the Tonpilz transducer stack. This material has low ageing rate and excellent voltage, temperature, and pressure stability. The basic design of the Tonpilz transducer consists of two ceramic rings sandwiched between a head mass and a heavy tail mass. A bolt at the centre gives compressive pre-stress to the structure. Cross-section of a conventional Tonpilz transducer is shown in Fig. 1.

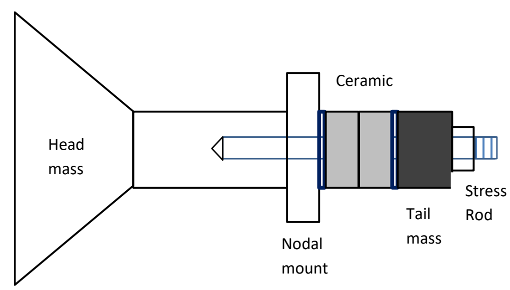

Fig. 1. Tonpilz transducer cross-section.

To achieve a desired sound pressure level (SPL) and beam pattern, twelve Tonpilz transducers in a dual-array configuration, with one array of seven and the other with five transducers was assembled. These sub-arrays may be driven individually or as a single array. Fig. 2 shows the assembled array.

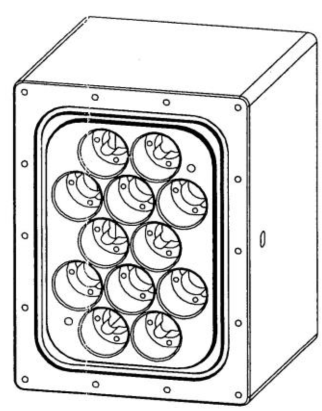

Fig. 2. Assembled array of twelve transducers.

Fig. 3 shows the TVRs of a typical transducer and a twelve element array before incorporating the electrical tuning. The -6 dB bandwidth of the transducer at the frequency of interest is around 10 kHz. The bandwidth of the twelve element un-tuned array is 16 kHz.

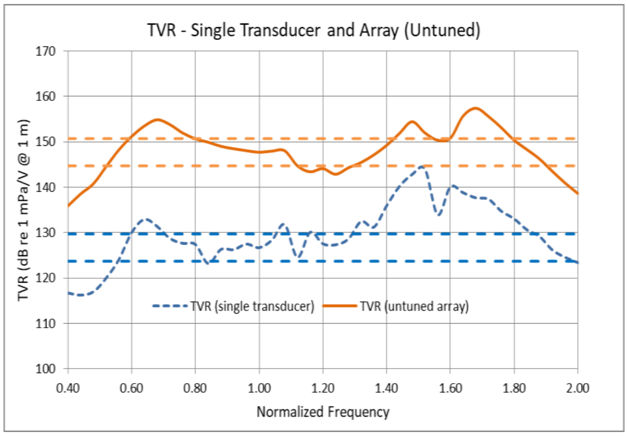

Fig. 3. Transmit Voltage Response of single element and array (un-tuned)

B. *Electrical Tuning*

A Tonpilz transducer has two distinct resonances; the flapping mode of the head mass and the longitudinal mode of the piston driver. These resonances are typically separated by few tens of kHz. Fig. 4 shows the measured impedance and phase of a typical transducer element used in this study. The different resonances of the transducer were modelled by lumped-parameter equivalent circuits [5].

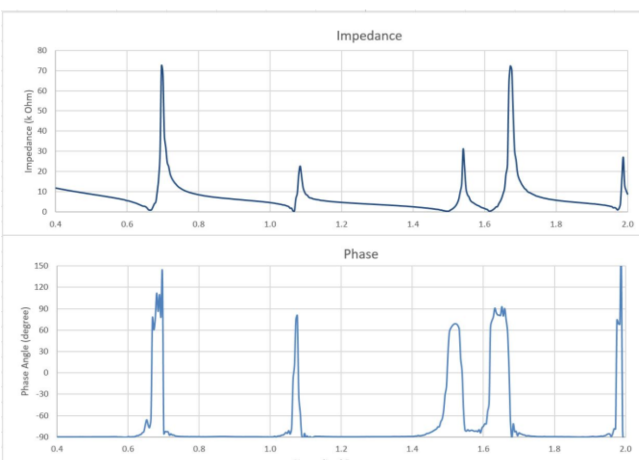

Fig. 4. Impedance and phase plot of a typical transducer

The concept behind the electrical tuning method is to introduce a system electrical resonance in the middle of the two mechanical resonances to achieve the desired wide bandwidth. This may be achieved by adding a matching network consisting of an inductor and a resistor. The tuning circuit is connected in series with the transducer elements, which are connected in parallel. The electrical resonant frequency is chosen to be in the middle of the two mechanical resonances. The transducer capacitance, together with the inductor, controls the position of the electrical resonance. The resistor is chosen to decrease the Q of the electrical resonance to optimize the flatness of the TVR over the required bandwidth.

III. Results and Discussions

Tonpilz transducers typically has 16 dB TVR variation across the frequency band of interest. Several combinations of inductance and resistance values, based on simulation, were tried to optimize the TVR response of the array in the frequency range of interest. In-water impedance of the tuned and un-tuned array is shown in Fig. 5.

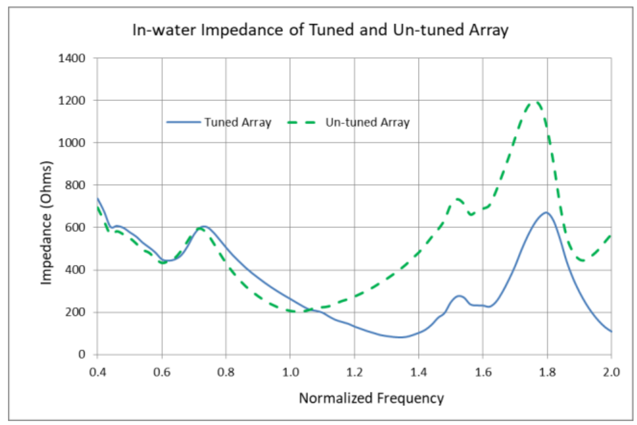

Fig. 5. In-water impedance of tuned and un-tuned array.

From the figure it may be noted that the impedance is substantially reduced for the tuned array above the centre frequency. However, there is a gradual shift in phase in this region (from inductive to capacitive). Fig. 6 shows the measured TVR response of the tuned and un-tuned array.

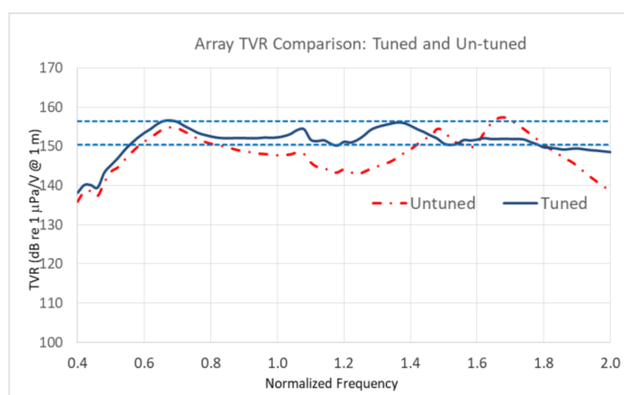

Fig. 6. Transmit Voltage Response of tuned and un-tuned array

This wide-band projector has a maximum measured TVR of 156 dB ref 1 μPa/V @ 1 m. The bandwidth increases to 61 kHz, which is more than 280% of the un-tuned array. The SPL obtained is typically 180 dB ref 1 μPa @ 1 m with a -6 dB bandwidth of more than one octave. A maximum SPL of 200 dB ref 1 μPa @ 1 m is achieved with 150 V_{RMS} CW. With a 10% duty cycle and an applied voltage of 500 V, SPL of 210 dB is achieved.

IV. Conclusion

Wideband performance for Tonpilz transducer array is achieved using electrical tuning. A 280% improvement in the bandwidth of the array is achieved by this method. The increase in bandwidth in the frequency range of interest is achieved without modifying the mechanical design of the transducer element.

References

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