NC STATE UNIVERSITY

Electrical and Computer Engineering

A Design and Modeling Software Tool for Prototyping for Ultrasonic Transceivers

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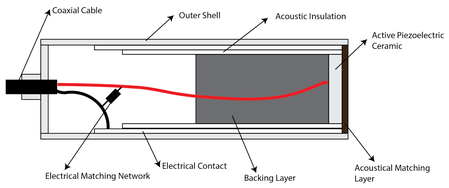
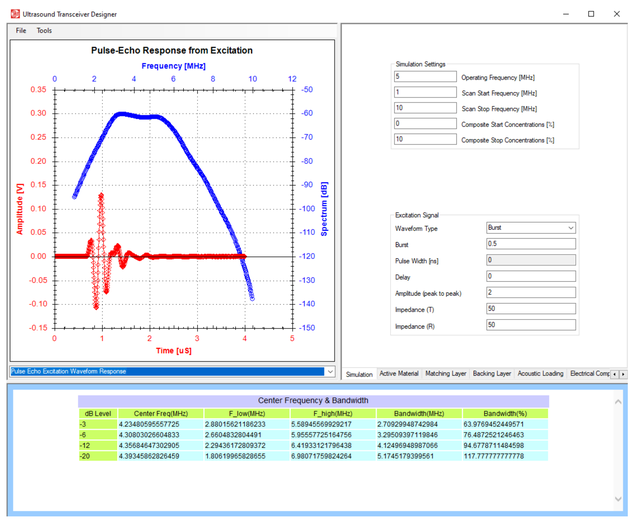
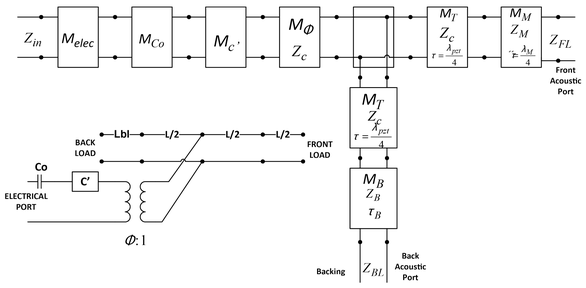


The Ultrasonic Transceiver Designer (UDT) determines the optimal material properties of the piezoelectric ceramic used in a transceiver, along with the matching and backing layer properties to ensure the desired system response. The design tool assists in developing a biomedical ultrasonic transceiver with a pulse-echo response within 1 dB of the desired specification.



TRANCEIVER MODELING

The implementation of KLM (Krimholtz, Leedom, Matthaei) model allowed for rapid development and optimization of the transceiver. This model include elements such as active material source impedance and the matching and backing layers electrical and mechanical impedance using the following two-port model.



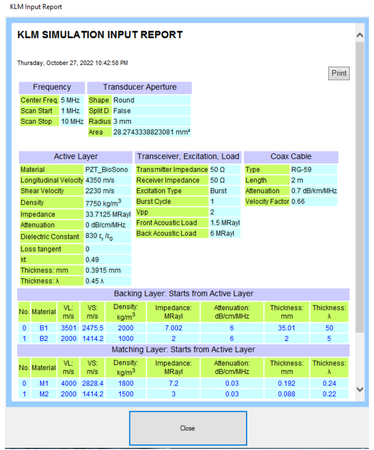
The KLM equivalent model of the transmitter and receiver is formed by the dot product of the individual components' matrices. The transmitter transfer matrix (MT) and the receiver transfer matrix (MR) for the system transfer function is shown (1) and (2).

$$\begin{aligned} M_T &= \begin{bmatrix} A'_T & B'_T \\ C'_T & D'_T \end{bmatrix} \\ &= M_{elec} * M_{C0} * M_{C'} * M_{\phi} \\ &* \quad [M_T * M_B * Z_{BL}]_{par} * M_T * M_F \end{aligned} \tag{1}$$

$$\begin{aligned} M_R &= \begin{bmatrix} A'_R & B'_R \\ C'_R & D'_R \end{bmatrix} \\ &= M_M * M_T * [M_T * M_B * Z_{BL}]_{par} \\ &* \quad M_{\phi} * M_{C'} * M_{C0} * M_{elec} \end{aligned} \tag{2}$$

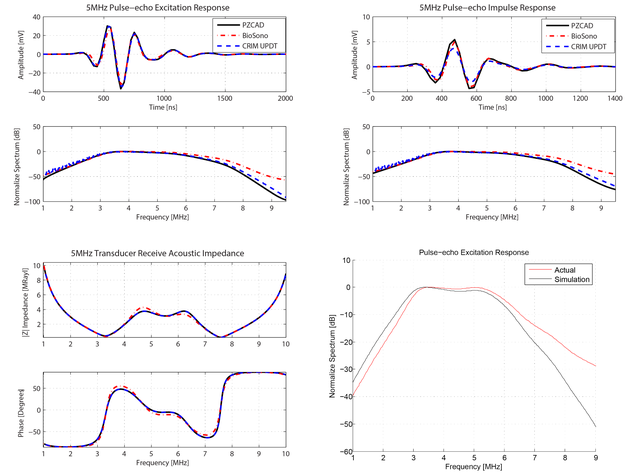
PROTOTYPING

The UDT modeling tool was used to develop a 5 MHZ ultrasonic transceiver with a transmitting power of 1 W using a 3 mm radius PZT5 active layer, two backing layers, and two matching layers according to the UDT simulation. The model includes additional components such as electrical tuning networks and cable impedance.



VALIDATION AND RESULTS

A pulse-echo response of an acquired 5 MHz ultrasonic transducer is used to validate the UDT. The time-domain and frequency-domain evaluation. The newly developed 5 MHz transducer is compared to PiezoCAD and BioSono, a competitive transceiver modeling tool. The characteristics of the simulated impedance of all three simulators are very similar. The full-spectrum percent deviation of the PiezoCAD and BioSono from the UDT is less than 11 percent. The deviation at the desired operating frequency is less than 0.20 percent.



ACKNOWLEDGMENT

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The source code and executables for the UDT are available at

https://bitbucket.org/livingston_ai/ultrasound_transceiver_design_tool

[1] M. R. S. R. Lorenzo Capineri, Leonardo Masotti, "Ultrasonic transducer as a black-box: Equivalent circuit synthesis and matching network design," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 40, 1993.
[2] E. M. Martha Castillo, Pedro Acevedo, "Klm model for lossy piezoelectric transducers," Ultrasonics, vol. 41, pp. 671–679, 2003.
[3] S. G. A. R. Selfridge, "Klm transducer model implementation using transfer matrices," in Ultrasonics Symposium, 1985.
[4] C. G. Oakley, "Calculation of ultrasonic transducer signal-to-noise ratios using the klm model," Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 44, pp. 1018–1026, 1997.
[5] G. Whitworth, "Discussion of one-d piezoelectric transducer models with loss," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 48, 2001.
[6] R. S. Cobbold, Foundations of biomedical ultrasound. Oxford, 2007.
[7] D. L. C. Lewis F. Brown, "Ultrasound transducer models for piezoelectric polymer films," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, vol. 36, 1989.