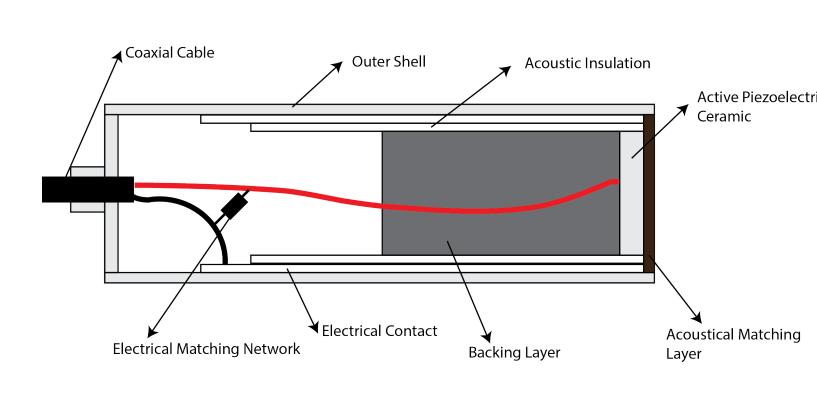
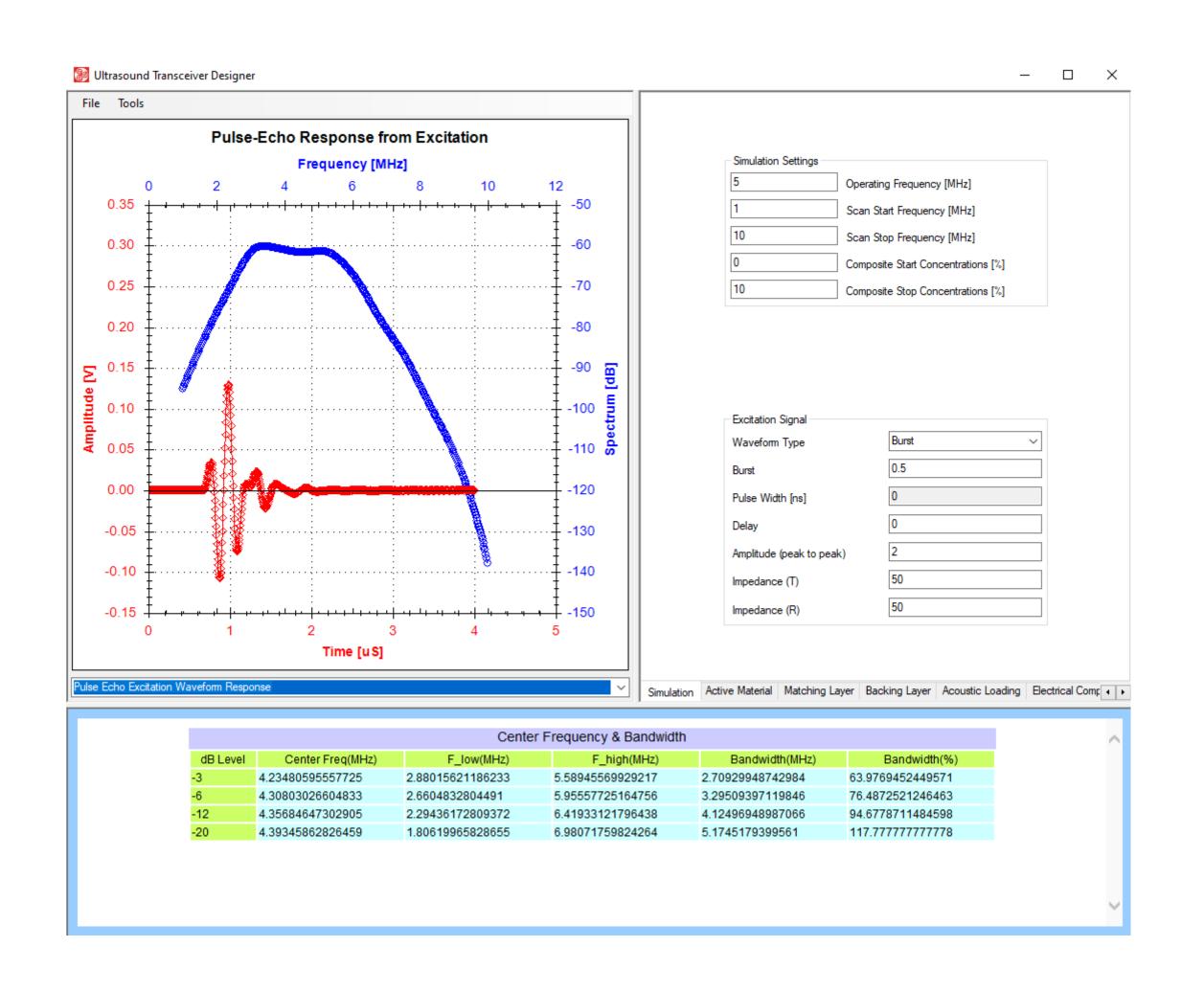
Electrical and Computer Engineering



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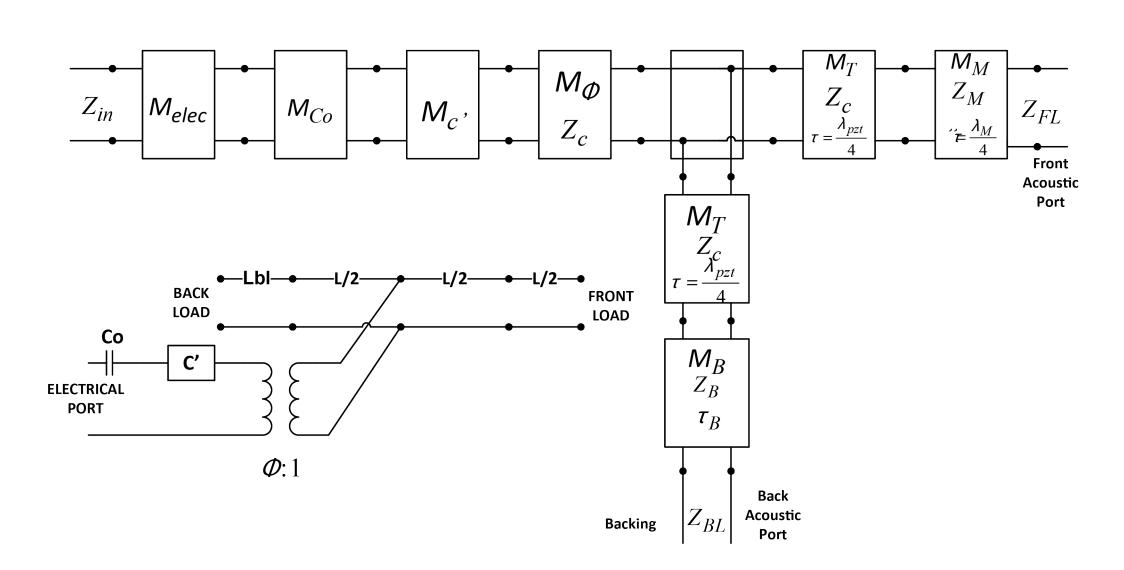
The Ultrasonic Transceiver Designer (UDT) determines the optimal material properties of the piezoelectric ceramic used in a transceiver, along with the matching and backing layer properties to ensure the desired system response. The design tool assists in developing a biomedical ultrasonic transceiver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

$$M_T = \begin{bmatrix} A'_T & B'_T \\ C'_T & D'_T \end{bmatrix}$$

= $M_{elec} * M_{C0} * M_{C'} * M_{\phi}$ (1)
* $[M_T * M_B * Z_{BL}]_{par} * M_T * M_F$

$$M_R = \begin{bmatrix} A'_R & B'_R \\ C'_R & D'_R \end{bmatrix}$$

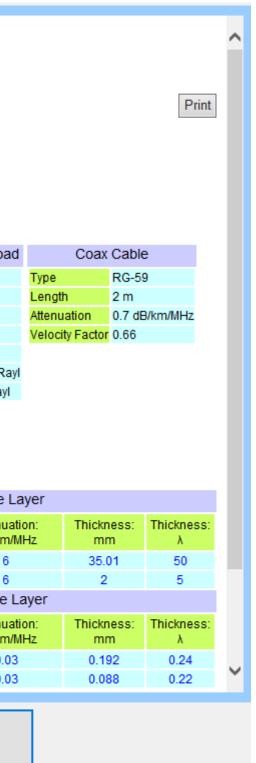
= $M_M * M_T * [M_T * M_B * Z_{BL}]_{par}$ (2)
* $M_\phi * M_{C'} * M_{C0} * M_{elec}$

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.

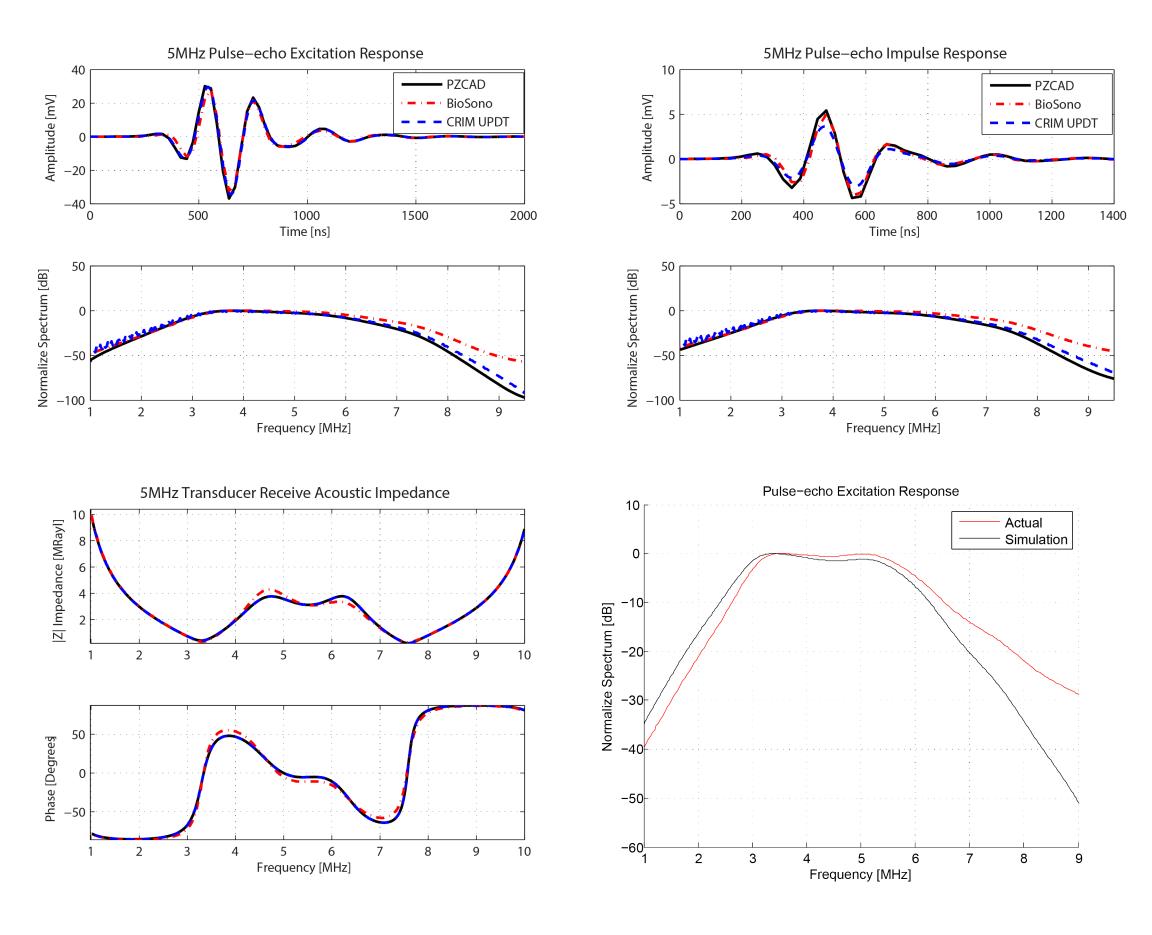
K	KLM Input Report									
KLM SIMULATION INPUT REPORT										
	Thur	Thursday, October 27, 2022 10:42:58 PM								
	_									
		Frequency			Transducer Aperture					
		nter Freq.			e Roun	d				
		an Start			it D False					
	Sca	an Stop	10 MH		is 3 mm					
				Area	28.27	4333	8823081 mm²			
	Active Layer						Transceiver, Excitation, Loa			
	Mai	-								
		Material Longitudinal Velocity			PZT_BioSono		Transmitter Impedance Receiver Impedance		50 Ω	
	Shear Velocity			-	2230 m/s		Excitation Type		Burst	
	Density				7750 kg/m ³		Burst Cycle		1	
	Impedance				33.7125 MRayl		Vpp		2	
	Attenuation				0 dB/cm/MHz		Front Acoustic Load		- 1.5 MR	
	Dielectric Constant				830 ε, /ε ₀		Back Acoustic Load		6 MRay	
	Loss tangent				0					
	kt			-	0.49					
	Thickness: mm			0.3915 mm						
Thickness: λ				0.45 λ	0.45 λ					
Backing Layer: Starts from Active										
	No.	Material	VL: m/s	VS: m/s	Densi kg/m	_	Impedance: MRayl		Attenu dB/cm	
	0	B1	3501	2475.5	2000)	7.002		6	
	1	B2	2000	1414.2	1000)	2		6	
	Match						ning Layer: Starts from Active			
	No.	Material	VL: m/s	VS: m/s	Densi kg/m	-	Impedance: MRayl		Attenu dB/cm	
	0	M1	4000	2828.4	1800)	7.2		0.0	
	1	M2	2000	1414.2	1500)	3		0.0	
						Close				
					L .					

A Design and Modeling Software Tool for Prototyping for Ultrasonic Transceivers



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

We are grateful to Carolon Inc., Rural Hall, NC, USA, for providing funding for the technology developed in this research.

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, "KIm 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.

Fred Livingston (<u>filiving@ncsu.edu</u>) Eddie Grant (egrant@ncsu.edu)

The source code and executables for the UDT are