Negative Capacitance Based Impedance Matching for Capacitive Micromachined Ultrasonic Transducers (CMUTs)

Ahmad Rezvanitabar[1], Evren F. Arkan[2], and F. Levent Degertekin[1,2], [1]School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA , USA, [2]George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, GA, USA

Capacitive micromachined ultrasonic transducer (CMUT) fabrication methods enable simple integration of transducers and electronics. Impedance matching between CMUTs and front-end electronics plays a significant role in reducing acoustic reflections from the CMUT surface while retaining high signal to noise ratio (SNR) and frequency bandwidth, which cannot be achieved by conventional inductive tuning. Here, we explore the use of negative capacitance, effectively canceling CMUT capacitance in a large frequency range, to obtain wideband impedance matching, and its implementation in an integrated transimpedance amplifier (TIA) based receiver.

The CMUT array model for non-collapse operation developed by Satir et al. [1], is used to simulate a single 250 x 250 µm size 2D CMUT array element, which is placed 15mm away from a perfect planar reflector. The CMUT element is comprised of square Si_3N_4 membranes of 52 µm width and 1.3 µm thickness operating at 90% of the collapse voltage. The pulse-echo response of the array element for different electrical terminations consisting of a parallel resistor and negative capacitor are simulated to investigate the effect on reflectivity and performance. The same model is then used to obtain the impedance of a CMUT element for TIA and negative capacitor circuit design.

Reflectivity, measured by the energy decay in the reflected pulses, for different R(-C) matching networks is shown in Fig. 1(a). As the negative capacitance approaches the CMUT element capacitance with resistive matching, the reflectivity is improved significantly. Fig. 1(b) shows an improvement in power transfer which is achieved by matching at interface. A TIA was designed for 88.9 dBΩ gain over 5 MHz bandwidth with 60° phase margin (Fig. 1(c)). As shown in Fig. 1(d), the TIA shows 5 MHz BW when the negative capacitive matching is applied, while it is less than 2.5 MHz without it, indicating an improved power transfer and bandwidth for the overall system.

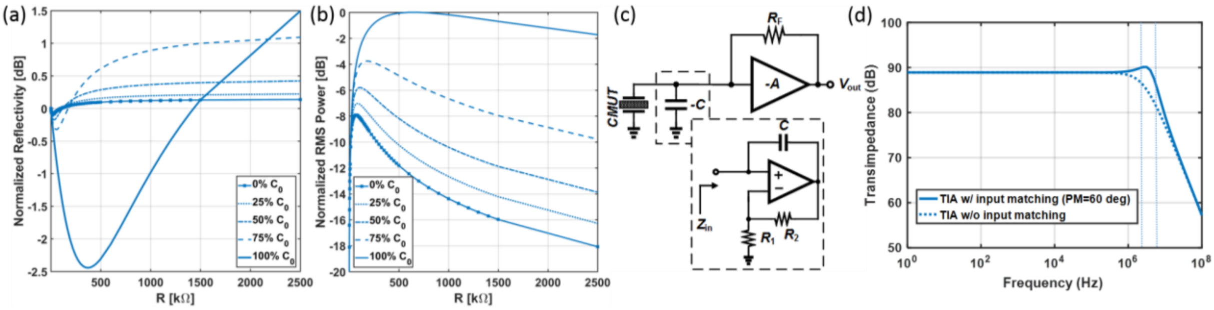

Fig. 1. (a) Normalized reflectivity for different values of matching network, (b) normalized power delivered by CMUT to the receiver, (c) negative capacitor topology with resistive feedback TIA, (d) transimpedance vs. frequency.

[1] S. Satir and F. L. Degertekin, "A nonlinear lumped model for ultrasound systems using CMUT arrays," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 62, no. 10, pp. 1865-1879, 2015.