Coded Excitation Imaging for a CMUT Based Side Looking Intravascular Ultrasound Sensor

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Background, Motivation and Objective

Phased-array based electronic beam steering in IVUS prevents motion artefacts and complexity in mechanically rotating catheter construction, but has been hampered by sensitivity and bandwidth limitation in the past, leading to poor image contrast and resolution. We present a large-bandwidth Capacitive Micromachined Ultrasound Transducer (CMUT) based side looking Intravascular Ultrasound (IVUS) sensor for modulated excitation imaging, capitalizing on coded excitation transmission [1] to achieve greater transmitted pulse energy.

Statement of Contribution/Methods

A CMUT array with 40 µm membrane diameter and 39 µm element pitch was designed and manufactured. For characterization, a planar version of the 1-D CMUT array consisting of 48 elements is tested in water using a 0.2 mm needle hydrophone. Based on the CMUT array transmit response, we designed a Linear Frequency Modulation (LFM) signal incorporating < 0.5 mm deaf time and compensating the frequency response of the RF amplifier. We predict the properties of returned echo signal at the output of the CMUT using the ambiguity function. A 96-element CMUT array was rolled up to a catheter tip with 1 mm diameter and mounted on a PCB. We tested the designed LFM signal using the rolled-up CMUT array on a wire phantom with 15 µm in diameter wires, comparing the performance to imaging with a short-pulse transmission. An autopsy human coronary artery specimen was also imaged.

Results and conclusions

The transmit transfer function (TTF) depicted in (a) shows that the array in collapse mode at 30 V DC bias voltage has 130 % fractional bandwidth with center frequency of 20 MHz and transmit sensitivity of 27 kPa/V. Using the chirp signal, we collected pulse-echo signals and reconstructed the wire phantom (b) image using the rolled-up sample (c). We assessed the image quality and achieved 55 µm and 74 µm axial resolution using the impulse (d) and LFM (e), respectively and gained >8 dB in SNR by the LFM. A plaque image is shown in (f).

[1] Y.Takeuchi, Ultrasonics 1979;17:175

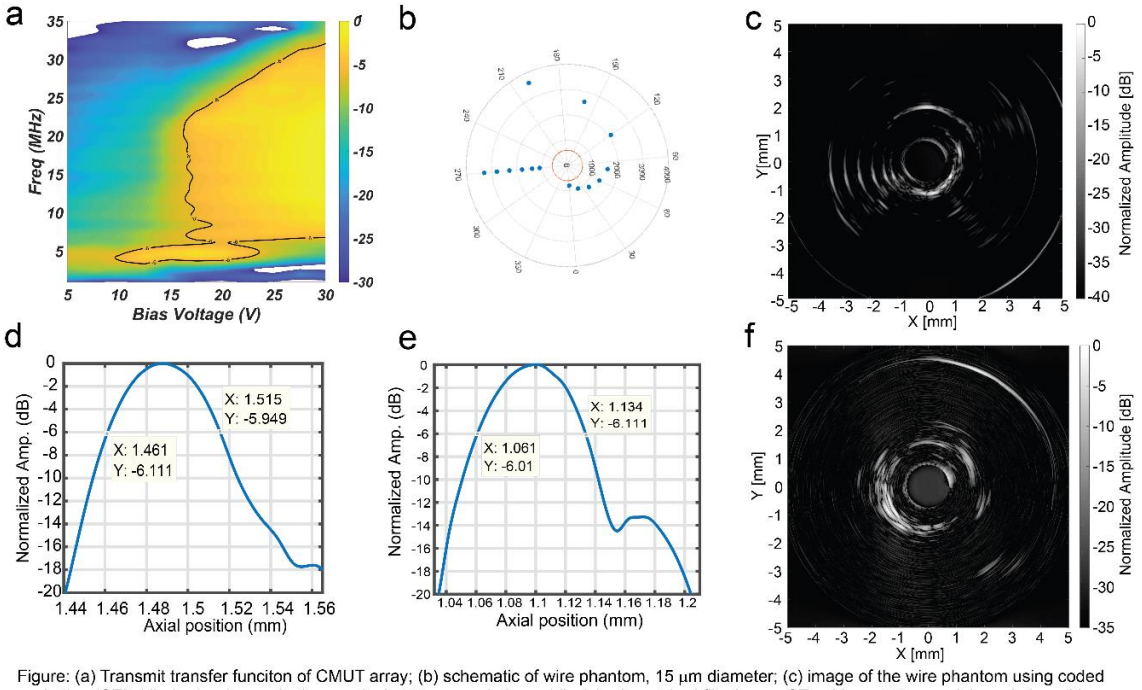

Figure: (a) Transmit transfer funciton of CMUT array; (b) schematic of wire phantom, 15 µm diameter; (c) image of the wire phantom using coded excitation (CE); (d) short-pulse excitation results in 55 µm resolution; while (e) mismatched filtering on CE achieves 74 µm axial resolution with an SNR gain of 8 dB. (f) Image of a human coronary atherosclerotic plaque ex vivo acquired with the sensor.