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High Frequency Circuits and Systems For Imaging

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Abstract: Many consider high frequency ultrasonic imaging to be the next frontier in ultrasound. It has a wide range of clinical applications, from imaging the eye and skin to imaging small animals. Small animal imaging has recently attracted a lot of attention for testing the efficacy of drugs and gene therapy. Commercial high frequency scanners, also known as "ultrasonic biomicroscopes," or UBMs, all use mechanically scanned single element transducers with frequencies ranging from 30 to 60 MHz and frame rates of 30 frames per second or less. High frequency linear arrays and imaging systems in the 20-50 MHz range have been developed to address problems with UBMs such as mechanical motion and fixed focusing. Current efforts in the development of high frequency ultrasonic imaging will be reviewed in this paper, and potential biomedical applications will be discussed.

Keywords: high-frequency ultrasound transducer; pre-matching circuit; ultrasound instrument

I. INTRODUCTION

Non-destructive testing, imaging, acoustic trapping, and therapeutic instruments have all made use of ultrasound. High-frequency (15 MHz) ultrasound offers higher spatial resolutions while scarifying target sensitivity for the same triggering power as low-frequency (15 MHz) ultrasound. High-frequency ultrasound has recently been highlighted for applications in dermatology, ophthalmology, small animal imaging, intravascular ultrasound, acoustic tweezers, and acoustic cell sorters due to these benefits. [1-5]

Ultrasound transmitters, receivers, and transducers make up ultrasound instruments. Power amplifiers, preamplifiers, and limiters are the last and first stages of the front-end circuits of ultrasound transmitters and receivers; the power amplifiers trigger the ultrasound transducers, the preamplifiers amplify the echo signals received from the ultrasound transducers, and the limiters block unwanted high-voltage signals from the power amplifiers. These elements are strongly linked to the performance of ultrasound instruments [6-7].

Unfortunately, the performance of high-frequency ultrasound transducers, which are among the most important components in ultrasound instruments, is typically lower than that of low-frequency ultrasound transducers; thus, high-frequency ultrasound transducer sensitivity is limited because the size of the piezoelectric material is inversely proportional to the frequency of the ultrasound transducer. Because the maximum tolerable voltage is proportional to the size of the piezoelectric material, the maximum applied voltages generated by the ultrasound transmitters that trigger the ultrasound transducers should decrease as the frequency of the ultrasound transducers increases. Matching circuits must therefore be used to improve the performance of high-frequency ultrasound transducers. [8] Most matching circuits used in ultrasound instruments are integrated with ultrasound transmitters, limiting the maximum voltage of the components and possibly the performance of the transmitters. Matching circuits are typically composed of a series capacitor and a parallel inductor, a series inductor and a parallel capacitor, or a Pi- or T-network made up of capacitors and inductors.

Because it is more difficult to control the amplitude and bandwidths of the echo signals generated by ultrasound transducers, current matching circuits use a matching function with the ultrasound transmitter. However, an ultrasound receiver operating at low voltage, such as bandwidth and gain, is easier to control externally than an ultrasound transmitter operating at high voltage; thus, we designed a matching circuit for an ultrasound receiver. Because the designed pre-matching circuit is located between the limiter and the preamplifier, it allows for component selection for the maximum voltage rating. [9-13]

Unfortunately, the electrical impedances of ultrasound transducers vary with frequency, making matching broadband frequency ranges between resonant and anti-resonant frequency ranges difficult and complex. Matching circuits are currently being developed to match the transmitter's and ultrasound transducer's operating frequencies. These matching-circuit topologies are commonly used in radio frequency (RF)/wireless/communication instruments that must operate in narrow-band frequency ranges due to frequency-band selection in some applications. Furthermore, the absolute values of the frequency range between the resonant and anti-resonant frequency ranges are wider for high-frequency transducers than for low-frequency transducers. As a result, they may reduce the sensitivity or bandwidth of high-frequency ultrasound transducers, as well as the image resolutions of ultrasound instruments. As a result, the developed pre-matching circuits are intended to match the electrical impedances of ultrasound transducers over a wide frequency range between the

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resonant frequency and anti-resonant frequency ranges, thereby improving the amplitude and bandwidth of high-frequency ultrasound transducers. [14]

II. HF ARRAY IMAGING

Mechanical scanners' problems can be solved by using annular array or linear array technology. These issues can be addressed in part by using HF annular arrays with dynamic 2-D focusing. Because mechanical motion is still involved in annular arrays, linear arrays that generate an image by electronically sweeping a beam would be a better solution. Linear ultrasonic array systems outperform signal element and annular imaging systems, which require mechanical scanning to form an image slice. Array systems can achieve higher image frame rates because they use electronic scanning to form an image slice.

Furthermore, the emitted sound beam can be directed and dynamically focused in the image plane. Finally, the absence of movable parts makes these arrays less likely to endanger patients. Small kerf (the gap between two elements) width, large electrical impedance mismatch, and increased crosstalk are the three major challenges in HF linear array fabrication. To minimise grating lobes, the pitch, or distance between the centres of two elements, in linear array and linear phased array design must be less than 1λ and 0.5λ, respectively.

This means that at 30 and 50 MHz, the pitch must be less than 50 m and 30 m, respectively.The element size in linear arrays should be as large as possible to ensure good sensitivity. As a result, the kerf width should be kept as small as possible, making dicing with current dicing machines difficult, if not impossible. A complicating factor is that, in the absence of a suitable kerf filler, the crosstalk level will increase due to the smaller kerf width. It should be noted that in phased arrays, element size should be carefully chosen to ensure a wide steering angle. [15-22]

III. OBJECTIVES

1. Research into high frequency circuits and imaging systems
2. The frequency at which ultrasound transducers are tested varies.
3. Create fully integrated imaging systems with on-chip antennas that take advantage of the high level of integration.
4. To calculate the resonant frequency in air, device capacitance, and parasitic capacitance.

IV. REVIEW OF LITERATURE

Ritter et al, Michau et al, Cannata et al, and Brown et al used piezoelectric composites in their designs. A new technology known as cMUT (capacitive micromachined ultrasonic transducer) that employs micromachined electromechanical system (MEMS) technology appears to hold great promise. Currently, the pitch of HF linear array designs exceeds one, and their performance is not yet comparable to that of commercial linear arrays at lower frequencies. This means that much progress can still be made in linear arrays in this frequency range. Developing linear arrays at 50 MHz or higher, as well as phased arrays at 30 MHz, remains a technical challenge. [23-26] Jiang et al. investigated the performance degradation caused by noise in power supply lines in deep submicron CMOS devices. The researchers proposed a statistical modelling technique for power supply noise that included inductive I noise and power net IR voltage drop, which was then combined with a statistical timing analysis. Their experimental results show that when this noise effect is taken into account, the circuit critical path delays increase by 33% and 18%, respectively, for circuits implemented on these two technologies. [27]

According to Cui et al., the increasing speed of digital circuit design and the density of printed circuit board (PCB) layouts frequently result in more difficult electromagnetic interference (EMI) problems. A primary EMI coupling path can be the coupling between a high-speed digital line and an I/O line, with the attached cable acting as a dominant radiator. They created a multi-stage modelling approach in which EMI modelling was created for coupling between transmission lines and the attached cable as an EMI antenna. Finally, the EMI for the coupled noise driving the attached cable was calculated. [28]

V. RESEARCH METHODOLOGY

The Electronic Circuits and Systems (ECS) group analyses, designs, and synthesises advanced high-performance and/or low-power electronic circuits and electromagnetic structures. From new millimetre wave and terahertz circuits and devices to complex systems on a chip such as mixed signal circuits, RF transceivers, phased arrays, power electronics, and biomedical circuits, these are all available. Books, educational and development journals, government papers, and print and online reference resources were just a few of the secondary sources we used to learn about the composition, use, and consequences of high frequency circuits and imaging systems.

VI. RESULT AND DISCUSSION

High-frequency arrays have been built and tested in both linear and ring array configurations. Electrical impedance in air and pulse-echo response in immersion were measured on wafer-bonding arrays (Figure 1). For pulse-echo testing, these arrays were wire bonded to the single-channel, 5-V electronics. The arrays created through the surface-micromachining process were tested in pulse-echo mode. Sixteen array elements were wire bonded to the high-voltage electronics array's 16 channels. Under collapse-mode bias conditions, the surface-micromachined ring array was also tested. Table 1 [29] summarises these devices.

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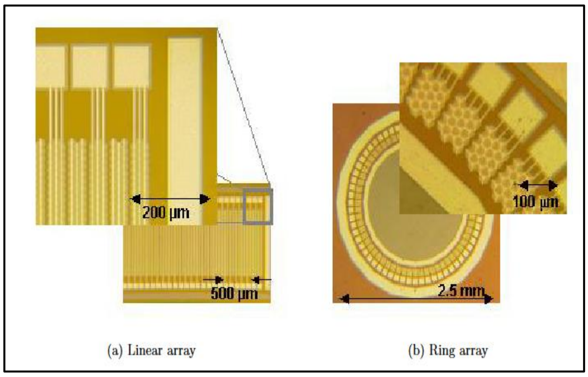

Figure 1 Wafer-bonded arrays

Table 1. Parameters of CMUTs tested

	Wafer bonded		**Surface micromachined**	
	Linear	Ring	Linear	Ring
Membrane material	Silicon	Silicon	Silicon nitride	Silicon nitride
Membrane thickness (µm)	1.0	0.5	0.4	0.4
Insulation thickness (µm)	0.3	0.1	0.08	0.08
Gap distance (µm)	0.2	0.1	0.015	0.15
Membrane radius (µm)	6	10.5	6	13
Cells per element	195	16	110	9
Element pitch (µm)	50	102	36	102
Elements in array	64	64	64	64
Resonant frequency in air (MHz)	70	17	50	28

A vector network analyzer was used to measure electrical impedance. (Hewlett-Packard Co., Palo Alto, CA, model 8751A). A high voltage DC supply was used to bias the arrays (model PS310, Stanford Research Systems, Inc., Sunnyvale, CA).

The resonant frequency in air, device capacitance, and parasitic capacitance are all determined by these measurements. Table 1 summarises the results, and Figure 2 depicts the impedance measurements [30].

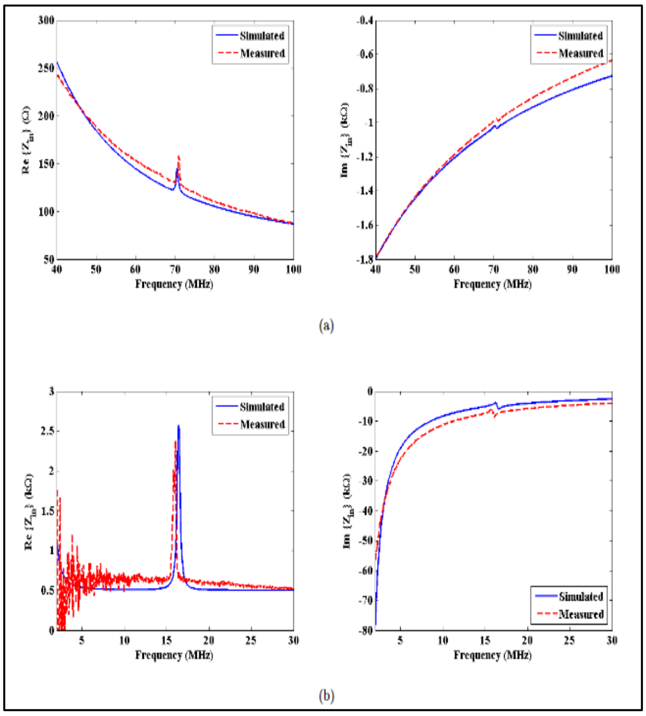

Figure 2: Electrical input impedance in air of wafer-bonded devices: (a) Linear array real and imaginary impedance; (b) Ring array real and imaginary impedance.

VII. CONCLUSION

This review paper discusses recent advances in high-frequency ultrasonic imaging, including transducers and systems operating at frequencies greater than 30 MHz. There is discussion of potential preclinical and clinical applications. There is no reason to believe that HF imaging systems with capabilities comparable to current clinical scanners will become more widely available in the near future, and their applications will be expanded into other biomedical disciplines.

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