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Design of Ultrasound Scanner using Synthetic Aperture Technique

R. Agilesh Saravanan
Department of Electronics and Communication Engineering, Koneru Lakshmaiah Education Foundation, Guntur, Andhra Pradesh-522302, India
. E-mail: agilesh@kluniversity.in

ABSTRACT –

The astounding advancements in ultrasonic imaging are directly responsible for the rise of raw data delivered from the system's front end to the processing unit. This has resulted in bigger, more energy-hungry equipment, particularly an count of sensor is increases. The primary purpose of this work is to cut down on the quantity of transducer sensors used in ultrasound systems. In the realm of signal gathering and sensor development, compressed sensing (CS) is a cutting-edge method. It has been shown that compressive sensing (CS) can significantly cut down on the time and money spent on sampling and processing signals that are already sparse or compressible in nature. In this study, we present a sparsity-driven compressed sensing ultrasonic imaging method. The ultrasound imaging using Synthetic Aperture Technique presents a number of challenges that must be overcome. These include the need to process vast amounts of data and a high cap on the count of receivers that may be used. This study sets out to evaluate how well Phased Array Imaging and Synthetic Aperture (SA) Imaging carry out without the aid of compressed sensing techniques by contrasting the two. When compared to phase array imaging, SA's acquisition time is reduced.

Keywords: Synthetic Aperture, sparsity, sampling, resolution

I. INTRODUCTION

The Ultrasound-based diagnostic imaging involves the transmission of ultrasonic pulses into the tissue being studied. The array of transducer elements is then used to measure the reflected energy, which is caused by variations in tissue density and propagation speed [1]. Processing unit digitally integrates input from several elements using a technique known as beamforming [2-4] based on the acoustic reciprocity theorem. The signal-to-noise ratio (SNR) is significantly boosted as a result of this procedure. For digital beamforming to work, samples of the signals picked up by each active element must be sent to the central processing unit. Traditional methods require data sampling at a rate that is double the baseband bandwidth of the detected signals, in accordance with the well-established Nyquist-Shannon theorem[3]. The data needs to be sampled at much higher rates, often 3 to 5 times the center frequency of the transmitted pulse, in order to reduce the presence of artifacts caused by the digital implementation. High-frequency sampling is not usually a bottleneck in modern systems. On the flip side, as imaging technology improves, more and more components are added into each imaging cycle. That's why it's such a big engineering challenge to get a lot of data from the source to the processor. The compression of the sampled data is motivated prior to its transmission to the processing unit. Ultrasound (US) imaging generates a large amount of data, which might limit both real-time imaging and data storage. Compressive sampling (CS), also known as compressed sensing, is a relatively new theoretical framework that was first proposed in 2006 [4-6] with the goal of reducing the amount of data collected during the acquisition process. Selective measurement of a subset of relevant coefficients from a compressible signal, followed by reconstruction using optimization techniques, is a central topic in computer science. The key difference between this and compression, in which the signal is compressed after acquisition[7-8], is that the signal is collected or sampled in its compressed condition.

The purpose of this research is to create an ultrasound transducer that uses 64 elements or fewer. Using spatial samples, we have devised a method to reconstruct RF ultrasound (US) images. To begin, a brief introduction to compressed sensing theory is given. The concept of synthetic aperture transmitter aperture, in conjunction with coherent synthesis, is elucidated. This study first describes how the United States' image was reconstructed, then discusses the results of this process.

II.PROPOSED METHODOLOGY

The Fig 1 depicts the overall project timeline.These are high-level explanations of the thinking behind a project.Complete instructions are provided as

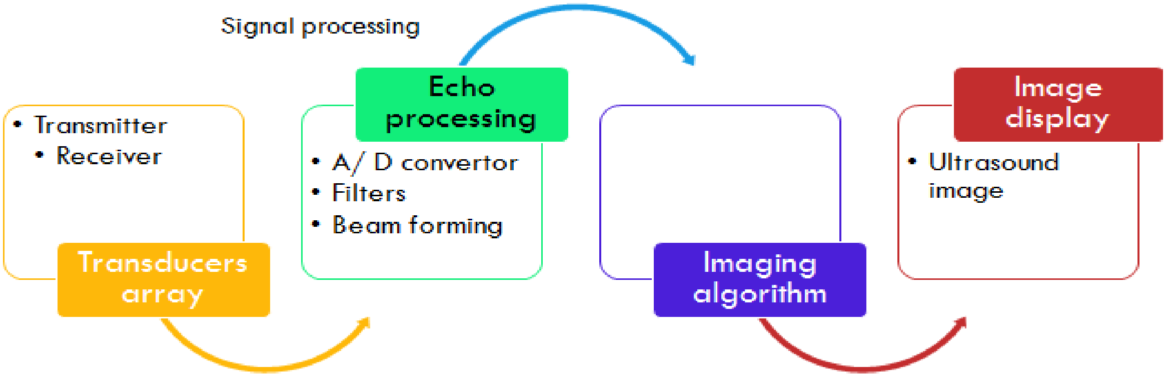


Fig.1. Block Diagram

A. SYNTHETIC APERTURE TECHNIQUE

Traditional ultrasonic imaging systems rely on a single transducer or linear array, and the clarity of the resulting image is directly proportional to the strength of the acoustic field generated by the device. The frame rate, which is essential for real-time imaging systems, is also severely limited by the sequential nature of classical ultrasound imaging, which includes the acquisition of an image line by line. Low frame rate imaging of moving structures can reduce diagnostic precision. The use of synthetic aperture (SA) imaging is one possible solution to this limitation. The SA technique is based on the notion of integrating information from nearby sources. The synthetic aperture technique has become an integral part of diagnostic imaging nowadays. Figure 2 shows an example of this. This strategy stands in juxtaposition to typical beamforming, which restricts imaging to a single line during reception. Therefore, the number of components used is proportional to the number of visualizations conducted for each image line. To create a single high-resolution image, an equal number of low-resolution photos are generated and combined.

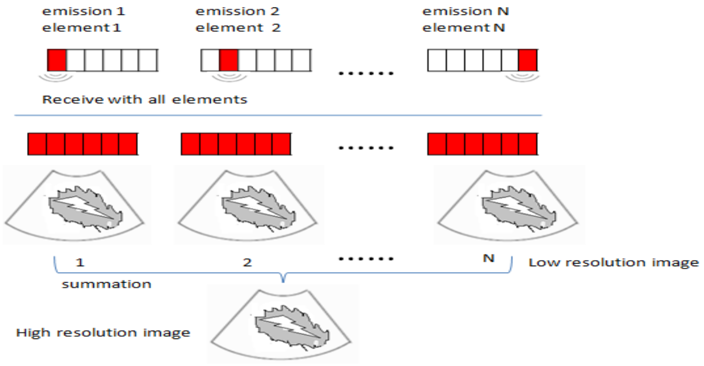


Fig.2. Synthetic Aperture (SA) block Diagram

Ultrasound imaging techniques using the synthetic aperture principle. In this case, synthetic aperture has helped bring down the cost and complexity of the underlying technology. There are a variety of proposed methods for creating a synthetic aperture for use in ultrasonic imaging. An alternative to the conventional phased array is the synthetic transmit aperture (SA). At any given time, an ultrasonic pulse is emitted by a single array element, and the resulting echo signals are picked up by all elements. This approach has the virtue of letting full dynamic focusing to be applied to both the transmit and receive, resulting in the best possible image quality.

III. RESULTS AND DISCUSSION

The simulation is done with the beamforming and Field II toolboxes. To process ultrasound B-mode images, a computer system phantom is created to mimic a real image. Commonly used for ultrasound imaging is a linear array (LA) transducer with 192 elements, 64 of which are "active" and responsible for actually transmitting the ultrasound signal. Initializes the focus distance to 50 millimeters. It takes more time than the SA method to generate an ultrasound B-mode image. The initial step involves placing a transducer at the phantom's epicenter and stimulating it with an impulse response; the transducer's specifications are listed in Table 1. Figure 3 shows the ultrasound image created by linear array imaging.

A. Reconstruction of US imsages via Linear Imaging

During each excitation cycle, all transducer components in a traditional phased array (PA) imaging system are used for both transmission and reception. The beam is directed and the plane is scanned using delay devices. The delays of transducer elements are adjusted based on the required focus range (depth) in order to produce dynamic (or composite) focus in the receive mode. In transmit mode, the focal point is often set at the geometric center of the depth range being photographed. The optimal lateral resolution is reached at the point of focus, where the lateral beamwidth is at its smallest. The lateral beamwidth expands as one advances away from the focal point. Ultrasound pictures created with linear array imaging have the spatial resolution shown in Fig. 3. However, this restriction can be gotten over by using numerous transmit beams throughout the examination of each sector, with each beam focused on a different depth range. This means that the data acquisition time for phased array (PA) imaging is significantly higher.

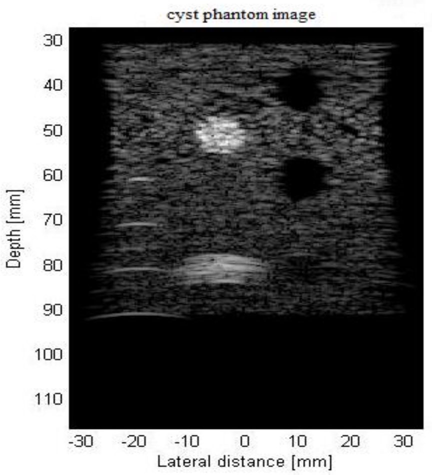


Fig.3.Linear array imaging of cyst phantom

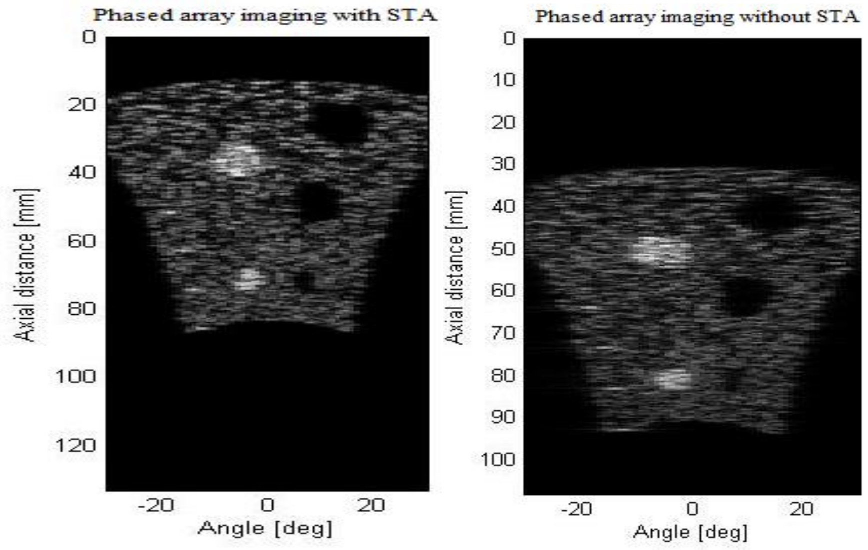
Parameter Name	**Linear array**		**Phased Array without SA**		**Phased Array with SA**	
	Notation	Value	Notation	Value	Notation	Value
No of transmit element	N_elements	64	N_elements	64	N_elements	64
No of receive element	N_elements	64	N_elements	64	N_elements	64
Apodization	Hamming		Hanning		Hanning	
No of emission	N	65	N	65	N	65
Central frequency	Fo	4 MHZ	Fo	4 MHZ	Fo	4 MHZ
Sampling frequency	Fs	100MHZ	Fs	100MHZ	Fs	100MHZ
Focus in transmit	Focus_r	50mm	Focus_r	50mm	Focus_r	50mm
Steering Angle	Sector	-	Sector	60	Sector	60

Table.1. Parameters for various imaging system modeled by Field II

B.Reconstruction of US imsages via Synthetic Aperture

In order to produce a ultrasound wave for use in N_element synthetic aperture imaging, many elements must be concentratedly transmitted at once. We imagine the core as a source from which a spherical wave spreads out in a constrained angular spectrum.

Figure 4.a depicts phantom reconstruction with a phased transducer array but no synthetic aperture. Accordingly, a number of 1st stage focused image lines from different emissions constitute a single image point. High-resolution image points are produced by a second-stage beamformer, which mixes data from many first-stage focused picture lines that each convey information about the image point's spatial position. In figure 4.b, we can see the reconstructed image that was formed by activating the transducer array. Here, we repeatedly activate the transducer array, and the generated image for each focus zone is combined to produce the high-quality end output depicted in Table 2.



(a) (b)

Fig.4.(a).Phased array imaging without Synthetic Aperture(SA), (b).Phased array imaging with Synthetic Aperture(SA).

Parameter Name	Linear array		Phased array without SA		Phased array with SA	
	Notation	Value	Notation	Value	Notation	Value
Acquisition time	t	35min42 sec	t	23min 16sec	t	11min 19sec
SNR	db	22	db	36	db	47

TABLE,2. COMPARISON PARAMETERS FOR VARIOUS METHODS

We use the synthetic transmit aperture (STA) technique to get the needed spatial resolution while cutting down on acquisition time. Using this method, sharply focused images can be created in real time throughout both the transmission and reception stages, without increasing the total time required for the acquisition process. In a typical SA imaging setup, as illustrated in Fig. 3, only one transducer element is used for transmission, while the others are used for receiving echoes.After each component has been stimulated, the resulting echoes are recorded and saved to a computer. Then, an appropriate method transforms the echo data into synthetic sharpness. One disadvantage of a SA imaging system is the increased amount of RFdata needed for picture reconstruction. The key advantages of a SA imaging system are the shorter time required to acquire data and the higher signal-to-noise ratio that is achieved.

However, unlike phased array imaging, a SA imaging system's frame rate can be significantly increased with the adoption of an equal time efficient algorithm for image reconstruction.

V.CONCLUSION

The proposed synthetic transmit aperture (STA) imaging Approch presents an alternate and more sophisticated approach to both phased array systems and linear array systems. When comparing STA with linear and phased array imaging techniques, it can be observed that STA yields superior spatial resolution. In practical application, the frame rate of a scanning transmission electron microscopy (STEM) imaging system is influenced by both the data acquisition time and the processing time required for image reconstruction. The research demonstrates that the STA approach effectively decreases the duration needed for RF-data gathering.As a result of the increasing complexity of data at the receiver's end. Sparse reconstruction is necessary in order to save costs and simplify the process of gathering data.In future applications, compressed sensing is employed at the receiver end to enhance the reconstruction quality of sparse signals.

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