Row-column Array Imaging

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Three-dimensional ultrasound imaging necessitates the use of probes in which, the ultrasound beam can be focused in both the elevation and azimuth direction. This can be attained by using mechanically moving probes matrix arrays or row-column arrays.

Mechanically moving probes use a mechanical translation or rotation of the probe element to cover the volume. This often gives a good image quality for stationary objects, but the probes are mechanically complicated to manufacture and in general are not suitable for fast B-mode and flow imaging.

Traditional matrix array probes [1-5] have *N x N* elements, which even for small arrays gives a very large number of transducer connections (1024 for *N*=32). This makes them very difficult to use, as the number of scanner channels required is high (up to four Verasonics Vantage™ 256 systems must be used for one probe), and the data rates are correspondingly large. For example, it also limits their focusing ability, as the full width half max *(FWHM)* resolution is given by *FWHM = l F#*, where *l* is the wavelength, and the F-number *(F#)* is the ratio between the imaging depth and aperture width. Beam steering necessitates an element pitch of *l* /2 for the matrix array, and perfect focusing for a 32 x 32 array is, thus, only possible to 16 *l* for a fully populated array for *F#=1*. Having arrays with the same focusing ability as traditional phased or linear array would increase the element count to 64 x 64 = 4096 or even 192 x 192 = 36,864, which is impractical in terms of cables and scanner channels.

Row-column arrays (RCA) are a new matrix array type enabling the acquisition of volumetric data with a reduced number of elements [7-17]. An RCA 2-D transducer array consists of two orthogonal 1-D arrays as shown below with connections to either the rows or the columns [7,10,16]. Emissions can be made with either the rows or the columns, and the received channel signal is the combined signals from all elements in either a row or column. The individual matrix elements are not directly addressable, and the number of connections to the probe is therefore *2N*.

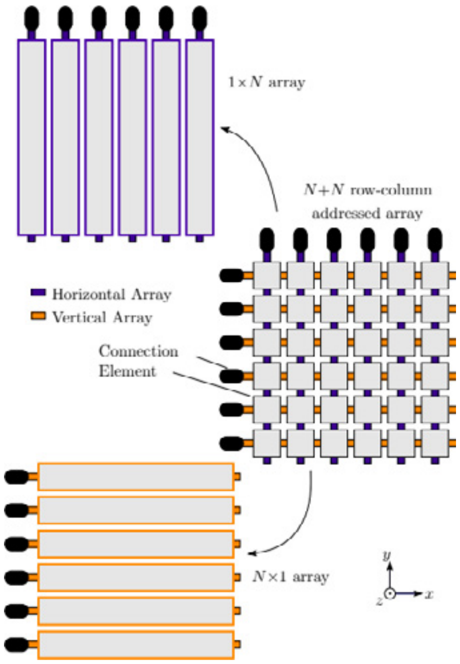

Fig. 1: Illustration of a row-column array, which can be interpreted as two orthogonal 1-D arrays. To the right is shown a 2-D transducer array, where each transducer element is addressed by its row or column index, effectively creating the two arrays shown to the left (from [16]).

RCAs can thus be made quite large without a prohibitive number of connections. A 128 x 128 RCA has 256 connections, and the *FHWM* resolution can be maintained down to 64 *l*, when the element pitch is *l* /2. A 1024 connection RCA would be able to maintain resolution down to 256 *l* and would have a size 64 times large than a fully populated matrix array with the same number of connections. Such RCAs have a very large penetration depth due to its size, as demonstrated in [18] and near ideal isotropic resolution can be attained with low side lobes [19]. The Point Spread Function *(PSF)* can be symmetric in both the azimuth and elevation direction, with a lateral Full Width Half Maximum *(FWHM)* of approximately 0.6 λ, close to the ideal *FWHM* [19].

The imaging strategies developed for other arrays cannot be directly employed on RCAs, as their geometry is different. The elongated elements give edge wave and focusing must be modified. Special beamformers taking this into account have been developed [16, 20] for proper focusing. New imaging schemes have to be devised, as focused emissions for scanning a 3-D volume may be too slow to yield acceptable volume rates. Synthetic aperture schemes have shown to be successful for yielding good B-mode image quality [18] with both a good resolution and contrast [19]. It has also been demonstrated that full velocity imaging can be attained at a high-volume rate with estimating all three velocity components for tensor velocity imaging [21-23], and it is possible to detect low velocity flow with such probes [24-25]. RCAs have also yielded functional imaging in a rat brain using plane wave emission [26]. Volumetric super resolution imaging has also been demonstrated for a 62 + 62 RCA operating at 3 MHz, where the volume resolution was increased by a factor of 18,880 [27].

Row-column arrays are in their early stages of development, where many applications are being investigated for high quality B-mode, velocity, super resolution, and functional imaging. While it is not fully clear what the best imaging schemes are or how the ideal array is fabricated, the arrays show a very significant potential for radically changing volumetric ultrasound imaging, making them very interesting for future research.

Row-column Array Imaging note contributed by Jørgen Jorgen Arendt Jensen from the Center for Fast Ultrasound Imaging, Department of Health Technology at the Technical University of Denmark.

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