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▶ **To cite this version:**

E. Badescu, L. Petrusca, D. Friboulet, H. Liebgott. Experimental cross-talk reduction for 3D multi-line transmission. IEEE International Ultrasonics Symposium, Oct 2018, Kobe, Japan. pp.1-4, 10.1109/ULTSYM.2018.8579857 . hal-01894165

**HAL Id: hal-01894165**
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Submitted on 24 Mar 2019

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# Experimental cross-talk reduction for 3D multi line transmission

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***Abstract*— The necessity of frame rate enhancement is particularly important in 3D echocardiography since full-volume acquisitions at a quality comparable to 2D imaging require increasing the number of transmissions. Despite the potential of Multi Line Transmission (MLT) in providing high frame rates while preserving the image quality, this method has a non-negligible limitation: the presence of cross-talks artefacts. The objective of this study was to investigate experimentally if cross-talk reduction can be achieved by replacing the typical alignment of the transmissions parallel to the element lines or columns by an alignment along the transverse diagonal of the transducer. The results showed that the diagonal transmission provides a better axial resolution than the linear one. Additionally, as the principal cause of cross-talk artefacts is the interference between the main lobe and the side lobes of parallel transmissions, we measured the values of these lobes in the two cases. The main lobe was up to 5% higher than the side lobe for the linear transmission and up to 25 % higher for the diagonal one. However, the cross talk reduction was achieved with the cost of Contrast to Noise Ratio (CNR), which was three times lower for the diagonal transmission compared to the linear one.**

***Keywords—high-frame rate, Multi-Line Transmit, 3D ultrasound imaging***

## I. Introduction

Three-dimensional (3D) echocardiography offers important advantages over the conventional 2D echocardiography. By introducing a third dimension, it avoids the dependence of the measurements on plane positioning, geometric modeling and assumptions regarding the chamber shape. Despite its potential in improving the accuracy of measurements, 3D echocardiography is still rarely adopted in common clinical practice. One of the causes of its infrequent usage is its poor temporal resolution. Many methods have been proposed to increase the temporal resolution, such as decreasing the lines density, the sector size, using Multi Line Acquisition (MLA) [1], Diverging Waves (DW) [2], and Multi Line Transmission (MLT) [3]. Among these methods, MLT presents the advantage of offering high volumes rates at preserved image quality, competitive with the one of conventional echocardiography [3]. However, a limitation of this method is that it is prone to cross-talk artefacts which appear as a result of the interference between the main and the side lobes belonging to different parallel transmissions.

Several methods have been proposed to reduce these artefacts. One possibility would be to divide the bandwidth of the transducer into multiple sub-bands that correspond with different simultaneous transmissions [4]. Each of the parallel transmit pulses are generated in a different bandwidth**.** However, the main limitation of this technique is the degradation of the axial resolution as a result of the bandwidth division. Cross-talk reduction with less impact on axial resolution can be achieved by using a Tukey apodization in both transmit and receive as proposed in [5]. But the limitation of this method is the degradation of the lateral resolution. Filtered-Delay Multiply and Sum Beamforming (F-DMAS) has been proposed for improving the lateral resolution while providing a better suppression of the cross-talk [6]. A drawback of this method is the reduced CNR when compared with non-apodized DAS. Another strategy that allows obtaining an improved lateral resolution compared to Tukey apodization proposes using a predefined set of apodizations based on low complexity adaptive beamforming (LCA) [7].

Additionally, distributing the simultaneous transmissions along the three dimensional geometry of the insonified medium is another approach that can be used for a better separation of the parallel beams and thus for reduced cross-talk artefacts. Such approaches, using a rhombus [8] and a diagonal disposition [9] of the simultaneous transmissions have been already proposed in literature. However, due to the difficulty in implementing this technique in practice, they were limited to simulations, synthetic implementations and hydrophone measurements and they have not been tested yet in real experimental conditions.

The objective of this study is the experimental validation of cross-talk reduction by replacing the typical alignment of the transmissions parallel to the element lines or columns by an alignment along the transverse diagonal of the transducer.

## II. Methods

### *A. 3D Acquisition system*

The data were acquired using a Verasonics 1024-channels imaging platform synchronized as explained in [10]. A Vermon probe was used to transmit 8 simultaneous focused beams 128 times in order to acquire a 32 by 32 volume.

### *B. Transmission scheme*

In this study we used both a linear (Fig. 1) and a diagonal (Fig. 2) transmission scheme for comparing the results obtained with the two approaches.

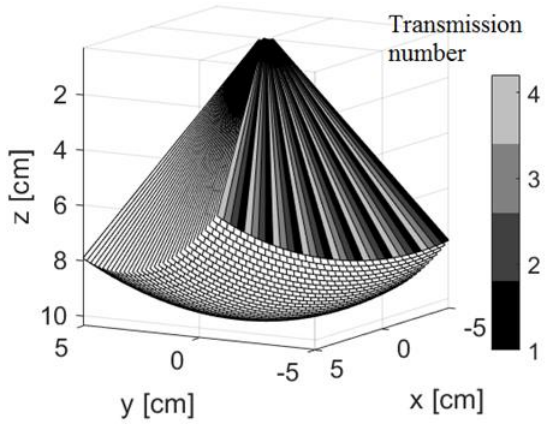



Fig. 1. Linear transmission scheme for 8 MLT

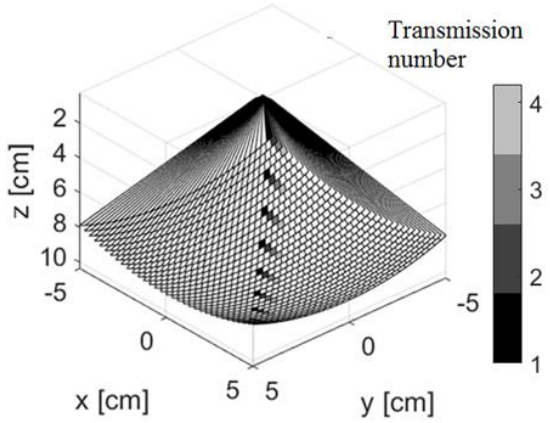



Fig. 2. Transmission scheme for 8 MLT along the transverse diagonal of the transducer

### *C. Image quality metrics*

The effects of the two transmission schemes on the image quality were evaluated using a Gammex (Sono410 SCG) phantom for resolution measurements and CNR on a hypoechoic cyst. Additionally, we used a CIRS (054GS) phantom for assessing the CNR on a hyperechoic cyst. The CNR was calculated using equation (1) and the resolution was computed using full width at –6 dB.

$$CNR = 20\log_{10}\left(\frac{|\mu_{bck} - \mu_{cyst}|}{\sqrt{\sigma_{bck}^2 + \sigma_{cyst}^2}}\right) \quad (1)$$

where $\mu_{bck}$, $\mu_{cyst}$ are the means and $\sigma_{bck}^2$, $\sigma_{cyst}^2$ are the corresponding variances of the background and the cyst regions calculated for a B-Mode image.

## III. Results

We first evaluated the impact of using different transmission schemes on the Gammex phantom. Hence, we show in Fig. 3 the comparison between the results using the linear transmission scheme (left) and the diagonal transmission scheme (right) for both XZ (A, B) and YZ planes (C, D). The axial resolution values measured at the focal point (5 cm) are provided in Table I.

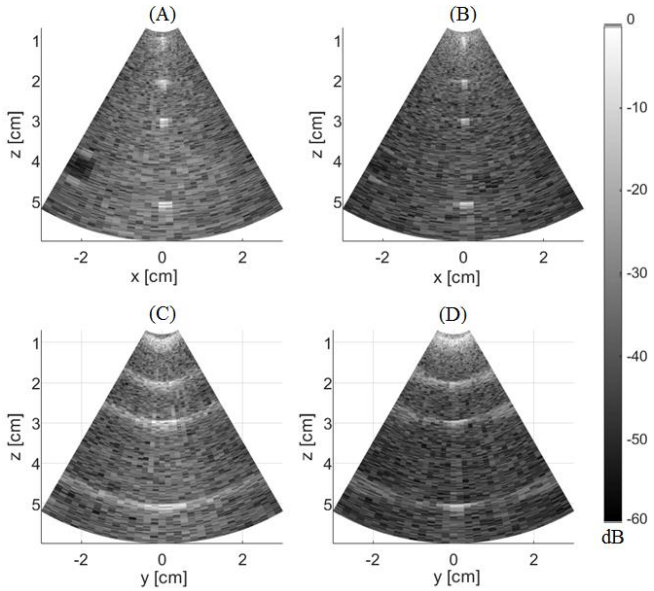



Fig. 3. Comparison between the 8 MLT Gammex phantom results using the linear transmission scheme (left) and the diagonal transmission scheme (right) for both XZ (A, B) and YZ planes (C, D).

TABLE I: AXIAL RESOLUTION FOR DIFFERENT TRANSMISSION SCHEMES

| Sequence/ Image quality | 8 MLT Linear Transmission | 8 MLT Diagonal Transmission |
|---|---|---|
| Axial Resolution at focal point (5 cm) | 1.14 mm | 0.45 mm |

In order to highlight the difference between the main and side lobes obtained with the two transmission schemes, we show in Fig. 4 the axial profiles at the center of XZ (A) and YZ (C) planes. The regions of interest around the focal point, marked by the black rectangle, were normalized around [0, -60 dB] for a quantitative evaluation of these differences. The measured values are provided in the zoomed regions presented in B and D.

By using the same phantom and by changing the imaged region of the volume and the focal point (compared to Fig. 3), the CNR on a hypoechoic cyst was evaluated. A qualitative comparison between the results for the linear transmission scheme (A) and the diagonal transmission scheme (B) is provided in Fig. 5 for the XZ plane. The same comparison is shown in Fig. 6, for the hyperechoic cyst imaged using the CIRS phantom. Additionally, for a quantitative analysis, we provide in Table II the CNR for the hypoechoic and hyperechoic cysts placed in the focal point (4 cm for both Fig. 5 and Fig. 6).

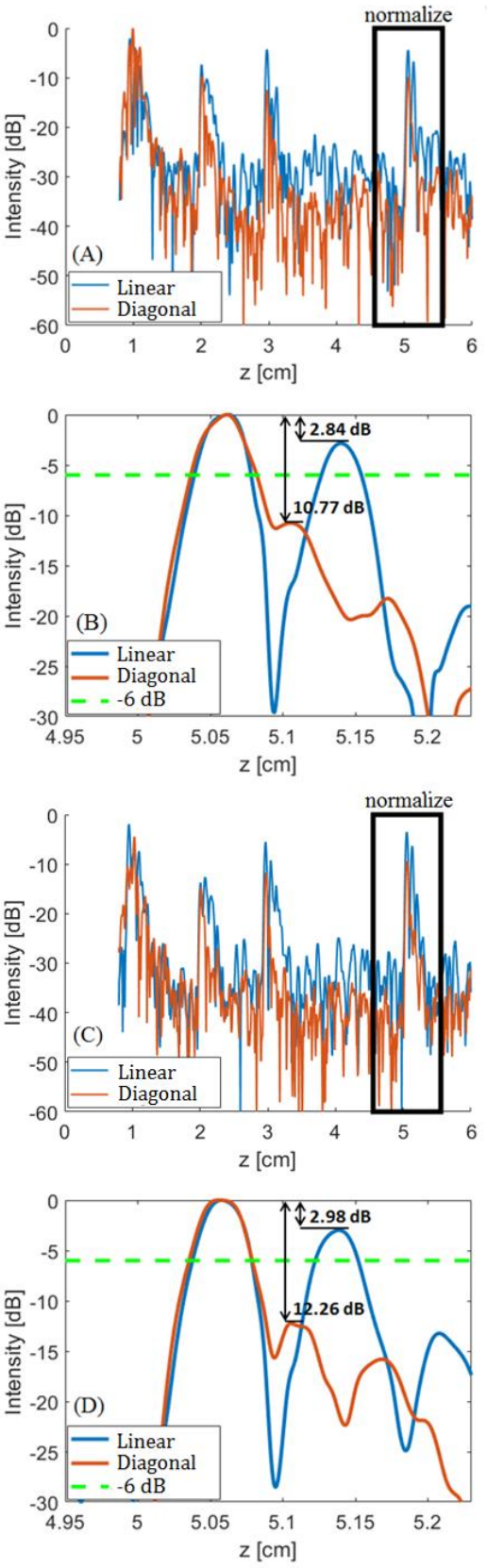



Fig. 4. Axial profiles at the center of the XZ (A) and YZ (C) planes, and their corresponding zoomed regions (B, D), after normalizing the region of interest (black rectangle) between [-60, 0] dB. The difference between the main and the side lobe is shown for each case.

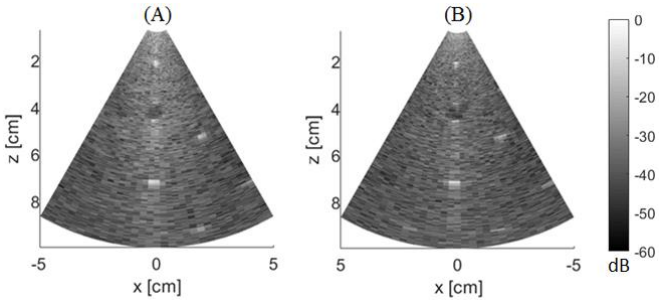



Fig. 5. Comparison between the 8 MLT Gammex phantom results using the linear transmission scheme (left) and the diagonal transmission scheme

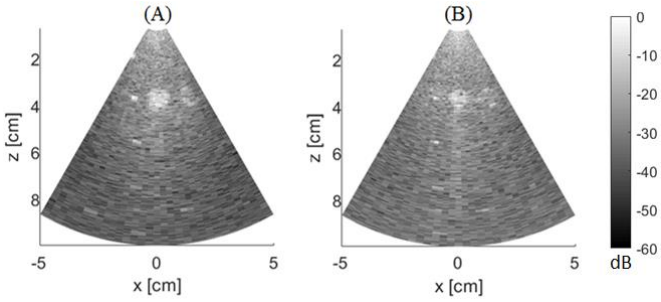



Fig. 6. Comparison between the 8 MLT CIRS phantom results using the linear transmission scheme (left) and the diagonal transmission scheme

TABLE II: CNR FOR DIFFERENT TRANSMISSION SCHEMES

| Sequence/ Image quality | 8 MLT Linear Transmission | 8 MLT Diagonal Transmission |
|---|---|---|
| CNR at focal point (4 cm) for a hypoechoic cyst | 0.91 dB | -2.17 dB |
| CNR at focal point (4 cm) for a hyperechoic cyst | 5.97 dB | 2.03 dB |

## IV. DISCUSSION

This study was focused on improving the transmission scheme for a better separation of the simultaneous focused beams. As shown in Fig. 2, by aligning the transmissions along the transverse diagonal of the transducer, the spacing between the simultaneous transmissions was increased. That resulted in thinner axial resolution targets for the images obtained using the diagonal transmission scheme compared those obtained using the linear one, for both XZ and YZ planes (Fig. 3). The axial resolution values measured at the focal point confirmed this observation (Table I). Moreover, the axial profiles provided in Fig. 4 showed that there was indeed a non-negligible difference between the main and the side lobes when the two transmission schemes were used. While the difference was just 2.84 dB for the linear transmission, it increased to 10.77 dB when the diagonal transmission was used for the XZ plane (B). Similarly, for the YZ plane, the difference was 2.98 dB for the first case and 12.26 dB for the second one (D). Overall, the main lobe was up to 5% higher than the side lobe for the linear transmission and up to 25 % higher for the diagonal one. As the cross-talk appears as a result of the main and side lobes interactions, a higher difference can be associated with a lower cross-talk level.

Despite the negative impact of the linear transmission on the resolution, the higher superposition of the beams provided higher main lobes intensity (Fig. 4 A, C) for depths higher than 1 cm, compared to the diagonal transmission. This can explain the brighter intensity appearance of Fig. 5A (obtained for a linear transmission) compared to Fig. 5 B (obtained for a diagonal transmission), especially for the background region surrounding the hypoechoic cyst which was used for computing the CNR. According to equation (1) used for CNR calculation, we expect higher absolute difference between the background and the cyst ($|\mu_{bck} - \mu_{cyst}|$). For similar differences in variances between the two transmission schemes this may lead to a better CNR for the linear transmission. The values presented in Table II, confirmed the qualitative evaluation, showing a CNR which was 3 times higher for the linear transmission. Similarly, although the hyperechoic cyst in Fig. 6 (B) was better defined than the one in Fig. 6 (A) due to the better resolution, the contrast seemed higher for the linear transmission (Fig. 6 (A)). The calculated values in Table II showed indeed the same CNR ratio of 3 between the two transmission schemes.

Although we improved the resolution obtained using a linear transmission scheme by distributing the beams in diagonal, the contrast was affected. The compromise between cross-talk reduction and other image quality metrics were also reported by other authors. For instance, [11] showed that a Tukey apodization can reduce significantly the cross-talk, but with the compromise of the lateral resolution. Other studies proposed using filtered delay multiply and sum (FDMAS) beamforming for limiting the cross-talk but this was achieved at the cost of a the CNR degradation compared to conventional DAS [6].

## V. Conclusion

The results presented in this study showed that the MLT cross-talk artefacts could be reduced by aligning the simultaneous transmissions in diagonal. However, the contrast was affected compared to the linear transmission.

## Acknowledgment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 642612, VPH-CaSE (www.vph-case.eu). This work was performed within the framework of the LABEX PRIMES (ANR-11-LABX-0063) of Université de Lyon, within the program "Investissements d'Avenir" (ANR-11-IDEX-0007) operated by the French National Research Agency (ANR). Two of the Verasonics systems were cofounded by the FEDER program, Saint-EtienneMetropole (SME) and Conseil General de la Loire (CG42) within the framework of the SonoCardioProtection Project leaded by Dr Pierre Croisille.The authors would like to thank LabTAU for their contribution in the development of the 32x32 probe prototype as well as for the providing us the probe and two Vantage 256 systems.

## References

[1] O. T. von Ramm, S. W. Smith, and H. G. Pavy, "High-speed ultrasound volumetric imaging system. II. Parallel processing and image display," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 38, no. 2, pp. 109–115, Mar. 1991.

[2] J. Provost, C. Papadacci, J. E. Arango, M. Imbault, M. Fink, J.-L. Gennisson, M. Tanter, and M. Pernot, "3D ultrafast ultrasound imaging *in vivo*," *Phys. Med. Biol.*, vol. 59, no. 19, pp. L1–L13, Oct. 2014.

[3] L. Tong, H. Gao, and J. D'hooge, "Multi-transmit beam forming for fast cardiac imaging-a simulation study," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 60, no. 8, pp. 1719–1731, Aug. 2013.

[4] L. Demi, J. Viti, L. Kusters, F. Guidi, P. Tortoli, and M. Mischi, "Implementation of parallel transmit beamforming using orthogonal frequency division multiplexing-achievable resolution and interbeam interference," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 60, no. 11, pp. 2310–2320, Nov. 2013.

[5] L. Tong, H. Gao, and J. D'hooge, "Multi-transmit beam forming for fast cardiac imaging-a simulation study," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 60, no. 8, pp. 1719–1731, Aug. 2013.

[6] G. Matrone, A. Ramalli, A. S. Savoia, P. Tortoli, and G. Magenes, "High Frame-Rate, High Resolution Ultrasound Imaging With Multi-Line Transmission and Filtered-Delay Multiply And Sum Beamforming," *IEEE Trans. Med. Imaging*, vol. 36, no. 2, pp. 478–486, Feb. 2017.

[7] G. Zurakhov, L. Tong, A. Ramalli, P. Tortoli, J. D'hooge, Z. Friedman, and D. Adam, "Multiline Transmit Beamforming Combined With Adaptive Apodization," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 65, no. 4, pp. 535–545, Apr. 2018.

[8] A. Ortega, J. Provost, L. Tong, P. Santos, B. Heyde, M. Pernot, and J. D'hooge, "A Comparison of the Performance of Different Multiline Transmit Setups for Fast Volumetric Cardiac Ultrasound," *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 63, no. 12, pp. 2082–2091, Dec. 2016.

[9] B. Denarie, T. A. Tangen, I. K. Ekroll, N. Rolim, H. Torp, T. Bjastad, and L. Lovstakken, "Coherent Plane Wave Compounding for Very High Frame Rate Ultrasonography of Rapidly Moving Targets," *IEEE Trans. Med. Imaging*, vol. 32, no. 7, pp. 1265–1276, Jul. 2013.

[10] L. Petrusca, F. Varray, R. Souchon, A. Bernard, J.-Y. Chapelon, H. Liebgott, W. N'Djin, and M. Viallon, "Fast Volumetric Ultrasound B-Mode and Doppler Imaging with a New High-Channels Density Platform for Advanced 4D Cardiac Imaging/Therapy," *Appl. Sci.*, vol. 8, no. 2, p. 200, Jan. 2018.

[11] L. Tong, A. Ramalli, R. Jasaityte, P. Tortoli, and J. D'hooge, "Multi-Transmit Beam Forming for Fast Cardiac Imaging - Experimental Validation and In Vivo Application," *IEEE Trans. Med. Imaging*, vol. 33, no. 6, pp. 1205–1219, Jun. 2014.