Transcranial Ultrasonic Propagation and Enhanced Brain Imaging Exploiting Focus due to the Skull

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***Abstract*—The reliable transcranial ultrasonic imaging of brain inner structures for diagnostic purposes is investigated in this work utilizing the Total Focusing Method technique. The major disadvantage of the latter, namely the artifacts due to the spherically propagating wave, is eliminated by exploiting the skull properties to focus the ultrasonic signal. Numerical simulations in realistic scenarios indicate the significant potentials of this imaging method.**

***Index Terms*—linear array, non-destructive evaluation, synthetic aperture, ultrasonography.**

I. Introduction

The reliable imaging of brain for diagnostic purposes is a critical procedure since the early detection of possible anomalies is crucial for a successful therapy. Although, ultrasonography is a very popular biomedical diagnostic technique [1], its transcranial application is not preferred due to the ultrasonic propagation degradation in skull.

However, the acoustic properties of the latter can be combined to the powerful Total Focusing Method (TFM) [2] to acquire accurate tomographic images of brain. Specifically, the skull tends to focus a spherical wave, thus inherent artifacts of TFM are avoided. Consequently, advanced signal processing procedures are not required and the temporal brain imaging is significantly enhanced.

II. Total Focusing Method Details

In TFM an array of transducers is utilized and at each time step only one array element is transmitting a nearly spherical wave. The back-scattered signal is received by every element in all directions and the specific direction can be acquired by applying different delays to signals received by different elements, thus this process is practically a dynamic focusing at the receiver and forms a low resolution image at each stimulation. The summation of all acquired low-resolution images results in the formation of the final high-resolution image and the dynamic focusing at transmission is synthesized.

III. Enhanced Images due to Skull Focusing

Various numerical simulations utilizing k-space pseudospectral method are conducted in a realistic biomedical environment. Specifically, the computational setup includes a thick layer of skull, healthy tissues and a spherical edema with their corresponding acoustic properties [3]. The TFM image reconstruction in Fig. 1 reveals that the absence of skull presents artifacts due to the spherical wave excitation and further signal processing is required to clear the image. On the other hand, the focusing due to the skull facilitates artifact free image reconstruction, while phantom echoes (under the sphere) can be eliminated through pre-processing steps.

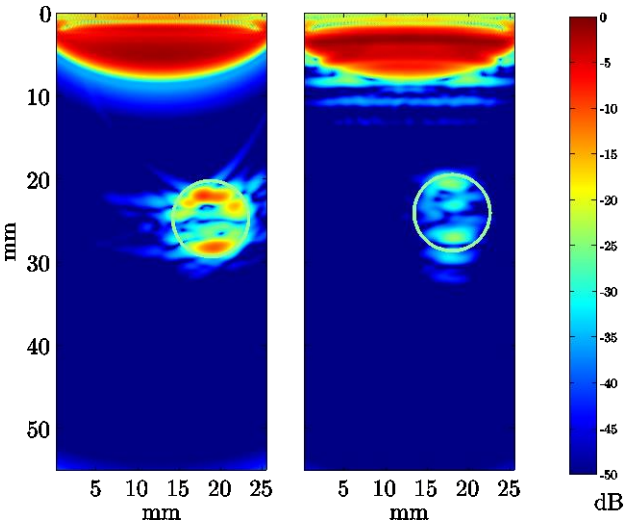

Figure 1: Ultrasonic imaging of a bulky structure using TFM with absence (left) and presence (right) of skull.

IV. Conclusion

The enhanced transcranial ultrasonic imaging utilizing the TFM technique has been discussed in the present paper. The focusing of the spherical acoustic wave due to the skull has been combined with the traditional TFM. Numerical analysis in a realistic biomedical setup indicated that although the back-scattered signal is weaker, the final image is free of artifacts.

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