Proposal of Breaking acoustic impedance law : A New paradigm for ultrasound imaging beyond bones

I. INTRODUCTION

Ultrasound imaging has revolutionized medical diagnostics with its non-invasive nature, real-time imaging capability, and cost-effectiveness. However, its utility is significantly constrained by the acoustic impedance mismatch between tissues. The acoustic impedance law, defined as Z=p.c (where p is density and c is the speed of sound in the medium), states that a significant portion of ultrasound waves are reflected at boundaries with large impedance differences. For example, the acoustic impedance of bone (Z=780) is much higher than that of soft tissue (Z=163), leading to substantial wave reflection at such interfaces. [1] This phenomenon creates an ”imaging barrier,” making it challenging to visualize regions beyond bone, such as the brain or spinal cord, using ultrasound.

This paper proposes a bold reexamination of the acoustic impedance law to overcome these limitations. The implications of breaking the acoustic impedance law go beyond improving ultrasound imaging. This advancement could revolutionize the principles underlying medical imaging, providing a more accessible and cost-effective alternative to expensive and less portable modalities like magnetic resonance imaging (MRI).

II. OBJECTIVE

To enable ultrasound imaging beyond bones by overcoming acoustic impedance limitations.

III. PROPOSED METHODOLOGY

Redefine Z to be an independent function of density, only being a function of speed of sound in each tissue.

According to the new concept of impedance, the amount of reflected sound waves will decrease if the boundary has high impedance mismatch, as expressed in the reflection coefficient equation (ρ) : 1001[2].

$$\rho = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2 \quad (1)$$

While Z1 and Z2 represent the impedances of two materials, as in Fig.1 .

At low frequencies, sound waves experience increased absorption, causing more energy to be lost as heat, which leads to significant attenuation. This challenge can be addressed by using harmonic waves, where the reflections consist of multiple frequencies, enhancing signal reception and improving imaging capabilities. as in Fig. 2

Moreover, to enhance resolution of the image, acquisition from different viewing angles, by using three ultrasound transducers simultaneously is a solution, and compounded to create a realistic high-resolution in depth image. [2]

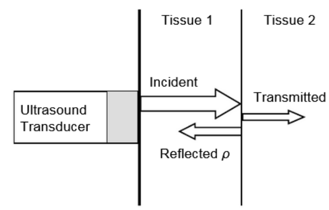

Fig. 1. Reflection and transmission of sound wave after hitting an interface. The relative intensities are determined by the acoustic impedances of the tissues.

[2]

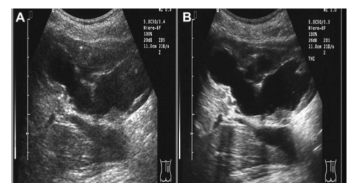

Fig. 2. A normal US, B harmonic US

IV. IMPACT

Modifying the impedance law allows for unprecedented access to structures shielded by bone. This could lead to:

- Improved diagnostics for conditions such as intracranial hemorrhage, stroke, or tumors.
- Enhanced imaging of joints, spinal structures, and other tissues encased in bone.

V. CONCLUSION

To sum up, by hypothesizing impedance independency from density will open the gate to image organs usual ultrasound could not image, and using more than one viewing angle will construct an image that can be classified to be very close to a (MRI) image but being more accessible ,cost efficient and time saving.

REFERENCES

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[2] Wachinger, C., Shams, R., & Navab, N. (2008). Estimation of acoustic impedance from multiple ultrasound images with application to spatial compounding. *2008 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*, 1–8.