Research and Development in Academia and Industry in Area of Ultrasonic Electronics for Medicine

医用超音波エレクトロニクスにおける学術研究と製品開発

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1. Introduction

Research activities in many areas are driven by science at heart and benfits in mind. The former is rather personal and changes only gradually, but the latter changes in time and depends on whom your are working for. The benefit to be pursued in industry is the competitiveness of the product in the market. In academia, it may similarily be the competitiveness in the area of research, but also can be to respond to the curiosity of the supporters who are paying taxes and tuition.

The reproduciblity of the results required in industry and academia is very different. In industry, the result must be reproduced by the users of the product millions of times under many variable conditions. At the biginning of a new technology, the result may be reproduced only under limited condition, but the unltimate reproduciblity must be reached through the development. It is really hard to judge whether a new technology with a limited reproducibility shall gain its allowable level after a certain length of development in the near future. In academia, even the reproduciblity under only limited condition is allowed if the result answers to the curiosity of the supporters.

Another requirement in industry is that a new technology to be newly adopted to a product should not sacrifice any performance of the pre-exisiting products in competition in the market.

The last four decades of research in nonliner ultrasonics for medicine show how the benefit decribed above can change in time. Imaging of the nonlinear ultrasonic parameter B/A of a medium[1] was proposed in the early 1980's. Although the study was performed in collaboration between academia and indusiry, it did not reach to the market as a procuct.

In the early 1990's, the use of nonliner echo from microbubbles was proposed for blood flow imaging[2], in which a bandpass filter was used to extract the second harmonic component from the echo to improve the specificity to blood flow. This techonology was not quickly adopted to the products beacause the bandpass filter significantly sacrificed the high resolution of ultrasonic echo imaging.

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Pulse inversion (PI) method was then proposed[3]. Although transmit and receive needed to be doubled and highly linear receive circuits were required, this method did not sacrfice the high ultrasonic resolution, and number of modified methods[4] were proposed.

Nonlinear echos can be received from tissue, even without microbubbles, due to nonlinear propagation of the transmit wave. Therefore, extracting the second harmonic component from the echo may not be the best way if the microbubble / tissue specificity is important. Triplet pulse (3P) method[5,6] was conceived to solve this problem. Its principle is shown in **Fig. 1**. Unlike PI method, not only the fundamental but also the second hramonic are cancelled by 3P method, and the other nonlinear components such as the 1.5th harmonic specific to microbubbles can be extracted.

Use of stablized microbubbles in ultrasonic diagnosis did not become as common as initially expected. However, PI method is nowadays adopted to most production machines of ultrasonic diagnosis for extracting the nolinear component of tissue echos rather than microbubbles to perform tissue harmonic imaging.

Microbubbles, whether it is introcuced hypodermically or ultrasonically generated in situ, can enhance the therpeutic effect of ultrasound[7]. For this purpose, microbubbles must be located at the tissue to be treated, and the location should be confirmed by microbubble-specfic imaging such as 3P imaging. Some of the results from the researches underway on this purpose[8,9] are shown below.

2. Material, Method, Results and Discussion

3P as well as PI imaging were performed at a transmit frequency of 1.74 MHz using Vantage 256 (Verasonics). A Dopller phantom with Sonazoid was used to test imaging of stablized microbubbles. The result is shown in **Fig. 2**. The highest specifity of microbubbles over tissue mimicking background, more than 15 dB higher than PI, was achieved by 3P imaging.

A block of freshly excised chiken breast tissue was used to test imaging of cavitation microbubbles, which was generated by a high intensity focused

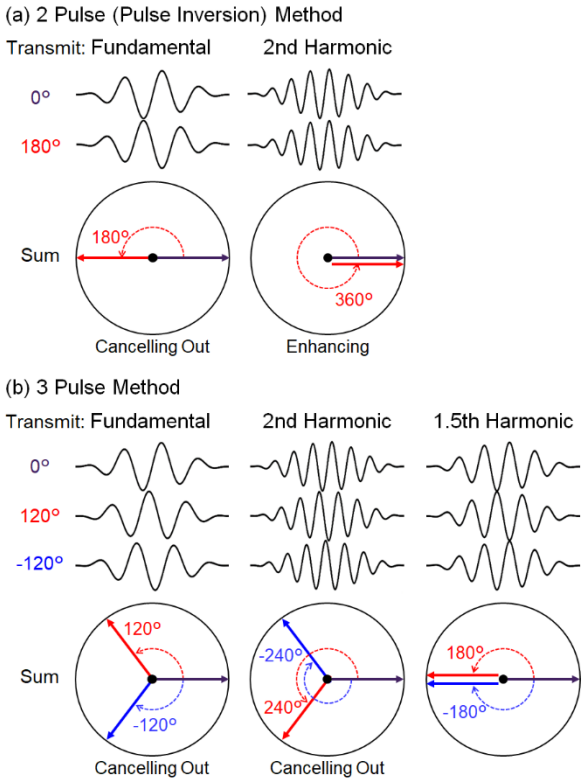

Fig. 1 Principle of triplet pulse compared with pulse inversion imaging method.

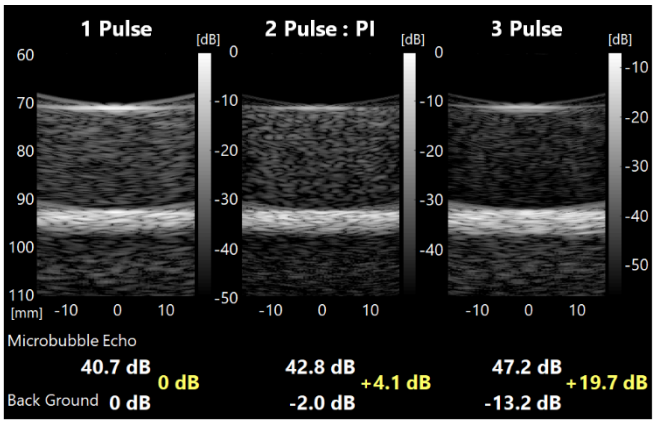

Fig. 2 Imaging of stabilized microbubbles in Doppler phantom at 1.74 MHz.

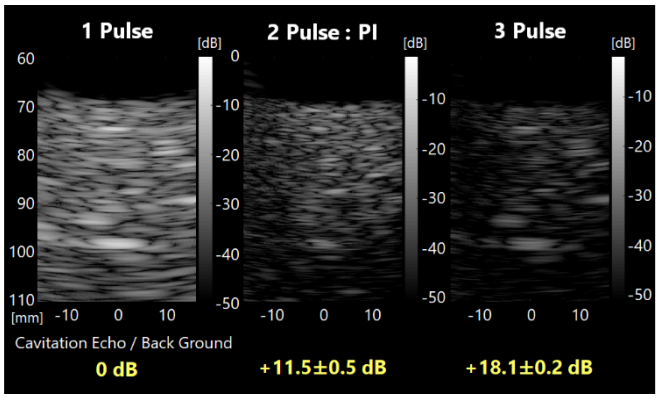

Fig. 3 Imaging of cavitation microbubbles generated by HIFU at 1.25 MHz in excised tissue.

ultrasound (HIFU) transducer (Imasonic) at 1.25 MHz. The result is shown in **Fig. 3**[8]. The highest specificity of cavitation microbubbles over tissue background, more than 6 dB higher than PI, is demonstrated by 3P imaging.

Selective imaging of cavitation microbubbles is a key for the quality control of cavitation enhanced HIFU treatment[7]. 3P method seems to be suitable to such imaging.

3. Conclusion

Research activities are driven by science at heart and benfits in mind. Although the latter can change significantly in time and so on, brushing up the former through your experiences may lead you to some success in a long run.

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