A MRI Compatible 2D Ultrasonic Radiation Force Generator with 1024 Elements for Neuromodulation

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Background, Motivation and Objective

Neurological diseases such as Alzheimer and Parkinson affect the health of millions of people and are still lacking in treatment. Low intensity focused ultrasound (LIFU) recently draws substantial attention for non-invasive neurostimulaiton, which could provide a powerful solution for the treatment of neurological diseases. In addition, LIFU has also been shown to temporarily open the patient's blood-brain barrier (BBB) allowing the drug to reach the brain's lesion for treatment. Increasing the number of elements in the ultrasound array transducer allows for precise focusing in the brain. Magnetic resonance imaging (MRI) is commonly used to monitor the temperature and displacement caused by ultrasound to ensure a safe treatment. However, the ultrasound system may generate interference during the operation, which may affect MRI performance. Therefore, LIFU brain therapy requires an MRI-compatible large-scale array ultrasound system, which is still a challenging task for the society.

Statement of Contribution/Methods

An MRI-compatible ultrasound array system with 1024+ channels has been developed for LIFU therapy. The system is implemented by cascading at least eight 128-channel subsystems. Clock synchronization between subsystems, data loading and command delivery are achieved through fiber optics. The clock synchronization accuracy is up to picosecond. Each subsystem consists of five main circuit blocks: an FPGA-based digital board, multiple power amplifiers, high-speed power sensing circuits, low-pass filters, and matching circuit blocks. The system performs beamforming to form single or multi-points focus at any positions of the acoustic field by using the delay parameters. The system is designed with a shielded housing and filter circuits for EMC requirements and magnetic compatibility.

Results/Discussion

The system works well with a 3T MRI machine (uMR790, United Imaging), and there is no interference in the MRI images. The phase difference between channels is less than 10 ns. Therefore the phase error of the ultrasound system is less than four degrees when using 1 MHz center frequency transducer. The negative peak ultrasonic pressure can be higher than 1 MPa after passing the monkey skull. The designed system shows good performance for LIFU applications, and the primate animal study is ongoing in the lab.



Fig.1 (a) Block diagram of the ultrasound array system; (b) A prototype of 1024-channel ultrasound array system; (c) There is no significant interference in MRI images during the sonication; (d) Water column can be generated by the array system; (e) The water column can be produced by the array system in which the primate skull is presented in the ultrasound path.