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A HIFU excitation scheme to reduce switching-induced grating lobes and hard tissue interface heating

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Background, Motivation and Objective

Arbitrary excitation waveforms are desirable in HIFU array systems. In trans-skull therapy this is necessary to compensate for phase aberrations and achieve even heating of the skull. To facilitate this, wave form generators and large, costly class A RF amplifiers are used. High element counts are commonplace and so the portability of these systems is greatly reduced. We propose using switched mode excitation to miniaturise these systems. Unfortunately, the curvature of therapeutic arrays and the inherent harmonic content of switched circuits induces harmful grating lobes into the therapeutic field of view. The advent of higher bandwidth transducers makes harmonic cancellation imperative. 3rd harmonic reduction (3HR) PWM can be used to negate these grating lobes but cannot implement amplitude control. We propose the use of the HRPWM technique to negate switching induced grating lobes and modulate output power to reduce hard tissue heating.

Statement of Contribution/Methods

A concave therapeutic array is tested. The electronic focus is set to 40 mm laterally and −50 mm axially. A bone layer is placed in front of the transducer with non-uniform attenuation. In the model, attenuation is considered to contribute entirely to absorbency and temperature rise is considered to be proportional to power intensity. In addition to ideal analog excitation, bipolar, 3HR and HRPWM switched mode excitation schemes are tested. The pressure profiles produced by each excitation scheme are compared with that of the ideal, analog excitation. The temperature rise at the hard tissue boundary under each array element is measured. The ratio of the local temperature rise to maximum temperature rise is calculated and plotted across the array.

Results/Discussion

Analog excitation results in the most energy at the focal point and guarantees uniform heating. Bipolar excitation induces grating lobes into the field of therapy and heats the tissue unevenly (~15% variation). 3HR is able to negate harmful grating lobes but also heats the tissue unevenly (~15% variation). 3HR and bipolar excitations also broaden the focal region, whereas HRPWM does not. The presented HRPWM excitation scheme is the only switched scheme that is able to both reduce grating lobes and hard tissue heating variation (~5%) to a satisfactory level.