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Ultrasound Therapy: Amplitude Modulation Technique for Tissue Ablation by Acoustic Cavitation

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Abstract : In recent years, non-invasive Focused Ultrasound (FU) has been utilized for generating bubbles (cavities) to ablate target tissue by mechanical fractionation. Intensities >10 kW/cm^2 are required to generate the inertial cavities. The generation, rapid growth, and collapse of these inertial cavities cause tissue fractionation and the process is called Histotripsy. The ability to fractionate tissue from outside the body has many clinical applications including the destruction of the tumor mass. The process of tissue fractionation leaves a void at the treated site, where all the affected tissue is liquefied to particles at sub-micron size. The liquefied tissue will eventually be absorbed by the body. Histotripsy is a promising non-invasive treatment modality. This paper presents a technique for generating inertial cavities at lower intensities (< 1 kW/cm^2). The technique (patent pending) is based on amplitude modulation (AM), whereby a low frequency signal modulates the amplitude of a higher frequency FU wave. Cavitation threshold is lower at low frequencies; the intensity required to generate cavitation in water at 10 kHz is two orders of magnitude lower than the intensity at 1 MHz. The Amplitude Modulation technique can operate in both continuous wave (CW) and pulse wave (PW) modes, and the percentage modulation (modulation index) can be varied from 0 % (thermal effect) to 100 % (cavitation effect), thus allowing a range of ablating effects from Hyperthermia to Histotripsy. Furthermore, changing the frequency of the modulating signal allows controlling the size of the generated cavities. Results from in vitro work demonstrate the efficacy of the new technique in fractionating soft tissue and solid calcium carbonate (Chalk) material. The technique, when combined with MR or Ultrasound imaging, will present a precise treatment modality for ablating diseased tissue without affecting the surrounding healthy tissue.

Keywords : focused ultrasound therapy, histotripsy, inertial cavitation, mechanical tissue ablation
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