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Effect of temperature on the generation of acoustic harmonics in a tissue-mimicking liquid

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In this study, the temperature dependence of acoustic harmonics generated by nonlinear ultrasound beam propagation in a mixture of 90% glycerol and 10% water (by volume) used as a tissue-mimicking liquid, was studied as a function of temperature from 26℃ to 46℃ at two different frequencies. Simulations were performed with a temperature-dependent Khokhlov–Zabolotskaya–Kuznetsov (KZK) nonlinear acoustic beam propagation model. Two single-element focused transducers with center frequencies of 5 and 13 MHz were used to transmit high pressure ultrasound signals. The ultrasound signals along the acoustic axis of each transducer were recorded using a needle hydrophone. The axial components of the fundamental (p1), the second (p2) and the third (p3) harmonics where calculated from the measured and simulated signals at temperatures of 26, 31, 36, 41 and 46℃ for both transmit frequencies. At the transmit frequency of 5 MHz, the peak values of the harmonics p1, p2, and p3, and their ratios p2/p1, p3/p1 increased by 35%, 189%, 573%, 113% and 396%, respectively in simulations and by 35% ± 2.5%, 223% ± 17%, 797% ± 38%, 138% ± 9% and 576% ± 31%, respectively in measurements as the temperature elevated from 26℃ to 46℃. The peak values of p1, p2, and p2/p1 increased by 256%, 1773% and 426%, respectively in simulations and by 205% ± 15%, 1411% ± 103%, and 394% ± 17%, respectively in measurements at 13 MHz for the same temperature range. Moreover, the p3 and p3/p1 increased by 597% and 311%, respectively in simulations and by 387% ± 31% and 204% ± 37%, respectively in measurements at 13 MHz as the temperature was increased from 36 to 46℃. The significant increase in the rate of generation of harmonics with temperature is due to the combined effects of increase in the nonlinearity parameter (B/A) and reduction in both the attenuation coefficient and the speed of sound with temperature in the medium.

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