Impact of Microwave Pulses on Microwave-Induced Thermoacoustic Imaging Applications

Xiong Wang[(1)], Daniel Bauer[(2)], Russell Witte[(2)], and Hao Xin* [(1)]
(1) Department of Electrical and Computer Engineering
(2) Department of Medical Imaging
The University of Arizona, Tucson, AZ, USA

Microwave-induced thermoacoustic imaging (TAI), combining the high contrast of microwave imaging and high resolution of ultrasound imaging, is a promising noninvasive imaging technique for breast cancer detection (R. A. Kruger *et al*, Radiology, vol. 216, 279-283, 2000). In order to efficiently detect a breast tumor by TAI, understanding the characteristics of the acoustic signal emanated by a tumor target is needed. Theories of thermoacoustic signal generation have been well established. The characteristics of the induced acoustic signal are principally contributed by three sets of factors: first, features of the microwave pulse including width, waveform (envelope of the microwave pulse) and carrier frequency; second, tumor dimension and morphology; and third, dielectric, acoustic and thermal properties of the biological sample containing both the tumor and background normal tissues. Here, our interest is focused on studying different pulse widths, pulse waveforms and tumor sizes. Although some effects of pulse width and target size have been reported, impact of pulse waveform and especially the combination of pulse width, pulse waveform and target size has not been addressed by previous research endeavors.

In this work, thermoacoustic signals generated by tumor targets with different sizes subject to microwave pulses with various widths and waveforms are theoretically investigated. Generated time-domain thermoacoustic pressure is solved analytically based on the absorbed microwave energy that is described by specific absorption rate in a target. Validity of the analytical approach is confirmed by finite-difference time-domain method. Time- and frequency-domain profiles and some key features of the acoustic signals are then obtained. Impact of the pulse width on acoustic signal peak-to-peak interval and image spatial resolution is developed. Detailed analyses are provided to interpret the underlying physics of the results. Square pulse is demonstrated to be superior in acquiring higher image resolution and signal-to-noise ratio, as shown in Fig. 1. This study is beneficial to optimizing the microwave pulse, determining an acoustic transducer to be used and evaluating the spatial resolution of the image in TAI.

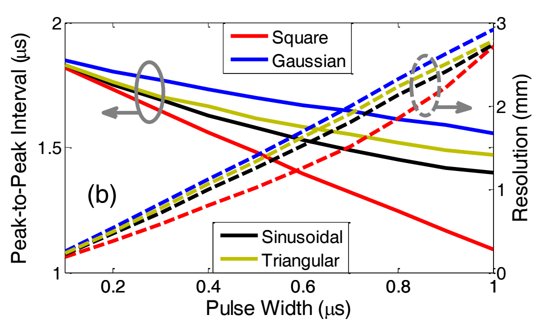

Fig. 1. Dependences of peak-to-peak interval and resolution on pulse width using a 1.5-mm-radius spherical target for four different pulse waveforms.