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RF-INDUCED THERMOACOUSTIC TOMOGRAPHY

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Abstract- **We present our study of pulsed-microwave-induced thermoacoustic tomography under a circular measurement configuration in biological tissues. A wide beam of short-pulse microwave (radio-frequency, RF) energy is used to illuminate a sample from the bottom. An unfocused ultrasonic transducer with a small aperture is used to record the thermoacoustic signals from the side. A backprojection method based on a rigorous theory is used to reconstruct the cross-sectional image from the measured data. The reconstructed image agrees with the original sample very well.**
Keywords **– Microwave, Thermoacoustic, Tomography**

I. INTRODUCTION

Pulsed-microwave-induced thermoacoustic tomography combines the advantages of both ultrasound spatial resolution and microwave absorption contrast [1]–[4]. With this technique, a very short microwave pulse (<1 microsecond) heats a sample; the sample then absorbs the microwave energy in a confined time and simultaneously generates temporal thermoacoustic waves, which are strongly related to the locally absorbed microwave energy. The thermoacoustic signals have a wide frequency range up to ~ MHz and carry the information about microwave absorption distribution with millimeter spatial resolution. In practice, microwaves at 300 MHz ~ 3 GHz with 0.1 ~ 1 μs pulse are often adopted, which provide several centimeters penetration depths in biological tissues. Due to the bounded water and salt that exist in cancer cells, a tumor absorbs more microwave energy and generates more intense thermoacoustic waves than the surrounding tissues [5], [6]. The wide range of absorption values among various tissues makes it possible to achieve a high image contrast. In addition, the long penetration depth allows this technique to detect interior tumors.

In this paper, a study of pulsed-microwave-induced thermoacoustic tomography under a circular measurement configuration in biological tissues is presented.

II. METHOD

A schematic view of the circular measurement system for our study is shown in Fig. 1. A plexiglass container is filled with mineral oil. An unfocused transducer is immersed inside it and fixed on a rotation device. A step motor drives the rotation device and then moves the transducer scan around the sample on a horizontal x-y plane, where the transducer horizontally points to the rotation center. A sample is immersed inside the container and placed on a holder, which is made of thin plastic material that is transparent to the microwave. The transducer (V323, Panametrics) has a central frequency of 2.25 MHz, and a diameter of 6mm. The microwave pulses transmitted from a 3-GHz microwave generator have pulse energy of 10 mJ and a pulse width of 0.5μs. A function generator (Protek, B-180) is used to trigger the microwave generator, control its pulse repetition frequency, and synchronize the oscilloscope sampling. Microwave energy is delivered to the sample by a rectangular waveguide with a cross section of 72 mm × 34 mm. The signal from the transducer is first amplified through a pulse amplifier, then recorded and averaged 360 times by an oscilloscope (TDS640A, Tektronix), and finally transferred to a personal computer for imaging.

We assume the tissue to have inhomogeneous microwave absorption and a relatively homogeneous acoustic property. The speed of sound c in most soft tissue is relatively constant at ~1.5 mm/μs. If challenged to detect small size tumors, we can safely remove the low-frequency component. In addition, the wavelengths of the high-frequency thermoacoustic waves are much smaller than the detecting distances between the thermoacoustic sources and the transducers. If small absorption sources are located on a z plane, a set of circular measurement data on the same plane can be sufficient to yield a good cross-sectional image. For a delta illuminating function $I_0\delta(t)$, the spatial absorption function $A(x,y)$ at z_0 plane can be calculated by the following integral in the circular configuration [4]

$$A(x,y,z_0) \propto \int d\varphi_0 \frac{1}{t}\frac{\partial p(\mathbf{r}_0,t)}{\partial t}\bigg|_{t=\frac{|\mathbf{r}-\mathbf{r}_0|}{c}}, \qquad (1)$$

where $p(\mathbf{r}_0,t)$ is thermoacoustic pressures measured on the circular surface $\mathbf{r}_0=(\rho_0,\varphi_0,z_0)$ that encloses the sample.

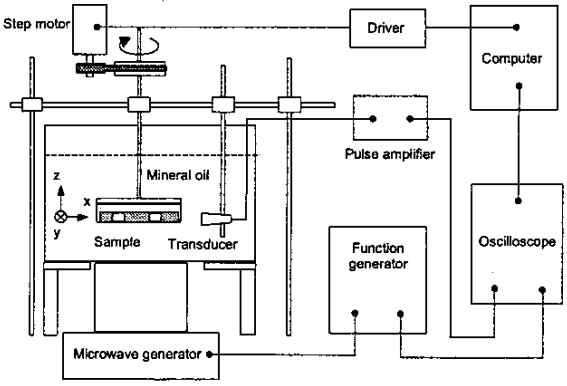

Fig. 1. Schematic view of the circular measurement system

III. Results and Discussion

A phantom sample was imaged by our microwave-induced thermoacoustic tomography system. Three small absorbers, which were made of muscle, were buried about two centimeters depth inside a large fat base, as shown in Fig. 2 and 3. The transducer rotationally scanned the sample from 0 to 360 degrees with a step size of 2.25 degree. The reconstructed image produced by our backprojection method is shown in Fig. 4, which agrees with the original sample very well. The relative locations and sizes of those thermoacoustic sources perfectly match the buried objects in the original sample.

IV. Conclusion

We have presented our study on pulsed-microwave-induced thermoacoustic tomography by a circular measurement configuration in biological tissues. The reconstructed image of a phantom sample agrees with the original values very well. The result demonstrates that pulsed-microwave-induced thermoacoustic imaging is a promising technique for use in detecting small tumors buried in biological tissues with microwave absorption contrast and ultrasound spatial resolution (~ mm).

Acknowledgment

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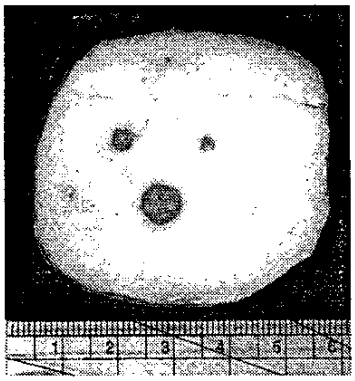

Fig. 2. The cross-section of the original sample.

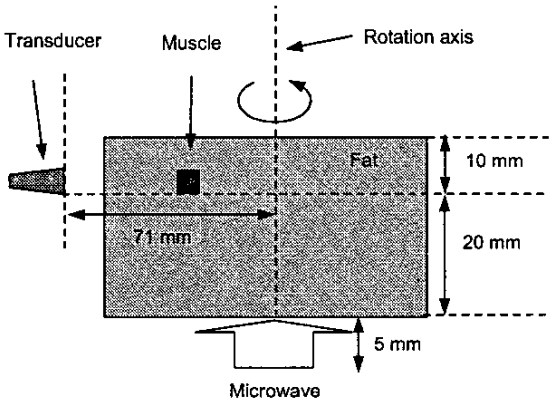

Fig. 3. The side-view of the original sample.

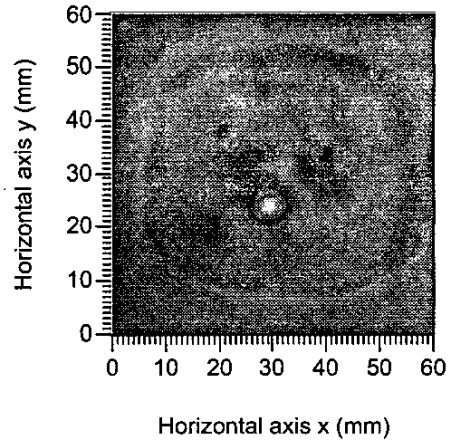

Fig. 4. The reconstructed image.