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Improving Signal-to-Noise Ratio and Imaging Speed in Magneto-Acoustic Imaging using Coded Excitation

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Abstract

In the field of early tumor diagnosis, magneto-acoustic imaging based on the magneto-acoustic effect provides valuable information about tissue characteristics. However, the signal-to-noise ratio (SNR) of the imaging results using the conventional single pulse method is limited, affecting both the imaging quality and speed. To address this limitation, we propose a processing method that utilizes coded excitation and pulse compression to enhance the SNR in magneto-acoustic imaging. Specifically, we introduce the widely-used Barker code, known for its effectiveness in ultrasonic signal processing, to improve the SNR of the magneto-acoustic signal. Through simulations on magneto-acoustic and pulse compressed signals under Barker coded excitation with varying bit lengths, we demonstrate the improved SNR achieved with the proposed method. Furthermore, experimental validation using pork and graphite slice samples confirms the effectiveness of the coded excitation approach. The results show that when a 16-bit Barker code is used as the excitation signal, the SNR of the magneto-acoustic signal improves by 20.9 dB. Moreover, compared to the single pulse excitation method, the coded excitation method significantly reduces processing time by 96.1% while achieving similar SNR improvement. In conclusion, the coded excitation method effectively enhances the SNR and imaging quality of magneto-acoustic signals, and it also improves the imaging speed in magneto-acoustic imaging.

Keywords: Magneto-Acoustic Imaging, Signal-to-Noise Ratio, Coded Excitation, Imaging Speed

I. Introduction

Dielectric characteristics provide valuable information about the physiological and pathological conditions of tissues, making them potential indicators for diagnosing related diseases. Magneto-acoustic imaging, based on the Hall effect, is an emerging modality that enables the imaging of electrical parameters and the sensing of micro-currents in biological tissues [1-3]. The signal-to-noise ratio (SNR) is a critical technical parameter in this imaging method, as it significantly affects the imaging quality and the accuracy of disease screening. However, the weak magneto-acoustic signals and the influence of high-frequency electromagnetic fields on the detector contribute to a low SNR [4]. Moreover, magneto-acoustic imaging primarily relies on single pulse excitation and the detection of magneto-acoustic response pulses to visualize the conductive distribution of tissues. To achieve high-resolution imaging, the duration of the single pulse should be minimized. Unfortunately, this short pulse duration, which carries conductivity information, leads to a low average power and subsequently reduces the SNR of the magneto-acoustic signal. The conventional approach of waveform averaging to improve SNR requires extensive signal acquisition and processing time, resulting in prolonged imaging duration and reduced efficiency [5-6]. Efforts have recently been made to enhance the SNR of the magneto-acoustic signal. One approach proposed by [6] utilized single frequency continuous wave excitation to improve SNR and measurement accuracy, although it faced challenges in reconstructing conductivity images. Another study by [7] explored frequency modulating and step-in frequency exciting methods to increase SNR, but encountered errors in multi-frequency measurements due to the narrow bandwidth of the transducer. Emerson et al. investigated differential frequency excitation using dual-frequency ultrasound for Magneto-acousto-electrical tomography (MAET) signals, resulting in an increased SNR but with limitations in resolution. Consequently,

increase the power of the magneto-acoustic signal, ultimately improving the SNR. Notably, since the frequency of the magneto-acoustic signal matches that of the excitation, the coded characteristics of the exciting signal can be utilized for further compression. Therefore, we introduce the coded excitation method, commonly used in radar and traditional ultrasonic imaging, to magneto-acoustic imaging.

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