Noise Effect on the Performance of Nakagami Image in Ultrasound Tissue Characterization

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Abstract

Conventional ultrasonic B-mode images qualitatively describe tissue structures, but they are unsuitable for quantitative analyses of scatterer properties. Recent studies have developed an ultrasonic parametric imaging technique based on the Nakagami statistical distribution, and its ability to quantify scatterer concentrations has been confirmed. The aim of the present study was to further explore the performances of the Nakagami image under conditions of different signal-to-noise ratios (SNRs). Experiments on a tissue-mimicking phantom were carried out. The results show that the noise effect degraded the performance of the Nakagami image in tissue characterization. When the signal SNR decreased by 8 dB, the contrast-to-noise ratio (CNR) of the Nakagami image for the hyperechoic region decreased by 27%, and that of the hypoechoic one decreased by 80%. These results indicate that the Nakagami image behaves well in identifying regions with high scatterer concentrations but does not perform well when both the scatterer concentration and SNR are low.

Keywords: Nakagami distribution, Parametric image, Noise

1. Introduction

Ultrasound imaging exhibits a promising spatial resolution and many advantages over other medical imaging modalities, both of which are reasons why it is frequently utilized in clinical diagnoses. The grayscales of the B-mode image are determined according to the strengths of the echoes, which are related to changes in acoustic impedance in tissues. However, because the brightness of a B-mode image is influenced by various parameters, including the pulse transmitting energy, system gain, dynamic range, and image processing, such images provide a primarily qualitative description of the anatomy, which makes it difficult to quantify the tissue properties [1-4].

To simultaneously satisfy the requirements of both monitoring and characterizing tissues, ultrasound parametric images are typically used to complement the B-mode image for the goal of tissue characterization. A representative example of the ultrasound statistical parameter image may refer to the recently developed Nakagami image based on the parameter associated with the Nakagami distribution [5,6]. Simulation and *in vitro* experiments used to confirm the feasibility of the Nakagami parameter map in visualizing the properties of the scatterers. Results showed that the Nakagami image is useful to detect the local arrangements and concentrations of scatterers in a scattering medium. However, a previous study showed that the waveforms of the ultrasonic backscattered envelope varied with the decrease of signal-to-noise ratio (SNR) of backscattered signals. This leads to variations in the backscattering statistics and associated errors for the subsequent estimation of the Nakagami parameter which reduces the accuracy and sensitivity of the Nakagami parameter in detecting the variation of scatterer concentration [7]. This implies that the performance of the Nakagami image would be affected by noise effect. The present study explored the performance of the Nakagami image to characterize scatterer structures under conditions of different SNRs.

2. Background

2.1 Nakagami distribution

The Nakagami model has been applied to the statistical analysis of ultrasonic backscattered signals [8-11]. The Nakagami distribution is a general model used to describe all the scattering conditions encountered in medical ultrasound, including pre-Rayleigh, Rayleigh, and post-Rayleigh

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