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Fast Phase Demodulation Method for Heterodyne Φ-OTDR

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Abstract: An effective phase demodulation method for heterodyne-detection-based phase-sensitive OTDR systems is proposed to accelerate the phase demodulation process based on the Spatial Phase Shifting (**SPS**) technique. The proposed method experimentally achieved >100% computation speed improvement compared to the conventional methods, while maintaining an equivalent phase demodulation performance.

I. Operation Principle

Because the original heterodyne detected Φ-OTDR signal $I(t)$ is a bandpass signal with its center frequency equal to Δf, a constant phase shift $\theta = 2\pi\Delta f \Delta t$ exists between $I(t)$ and its adjacent signal $I(t+\Delta t)$ along the FUT. Therefore, The SPS operation generates the orthogonal signal $Q(t)$ from $I(t)$ using simple trigonometric relations:

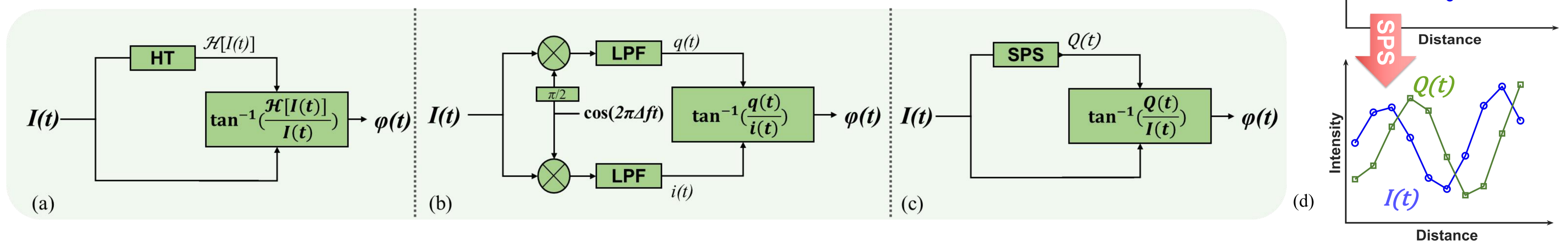$$Q(t) = \frac{I(t)\cos\theta - I(t+\Delta t)}{\sin\theta}.$$

Fig. 1. Working principles of phase demodulation methods for heterodyne detected Φ-OTDR signal based on (a) Hilbert Transform (HT), (b) digital I/Q, and (c) the proposed SPS methods. (d) An example of SPS operation.
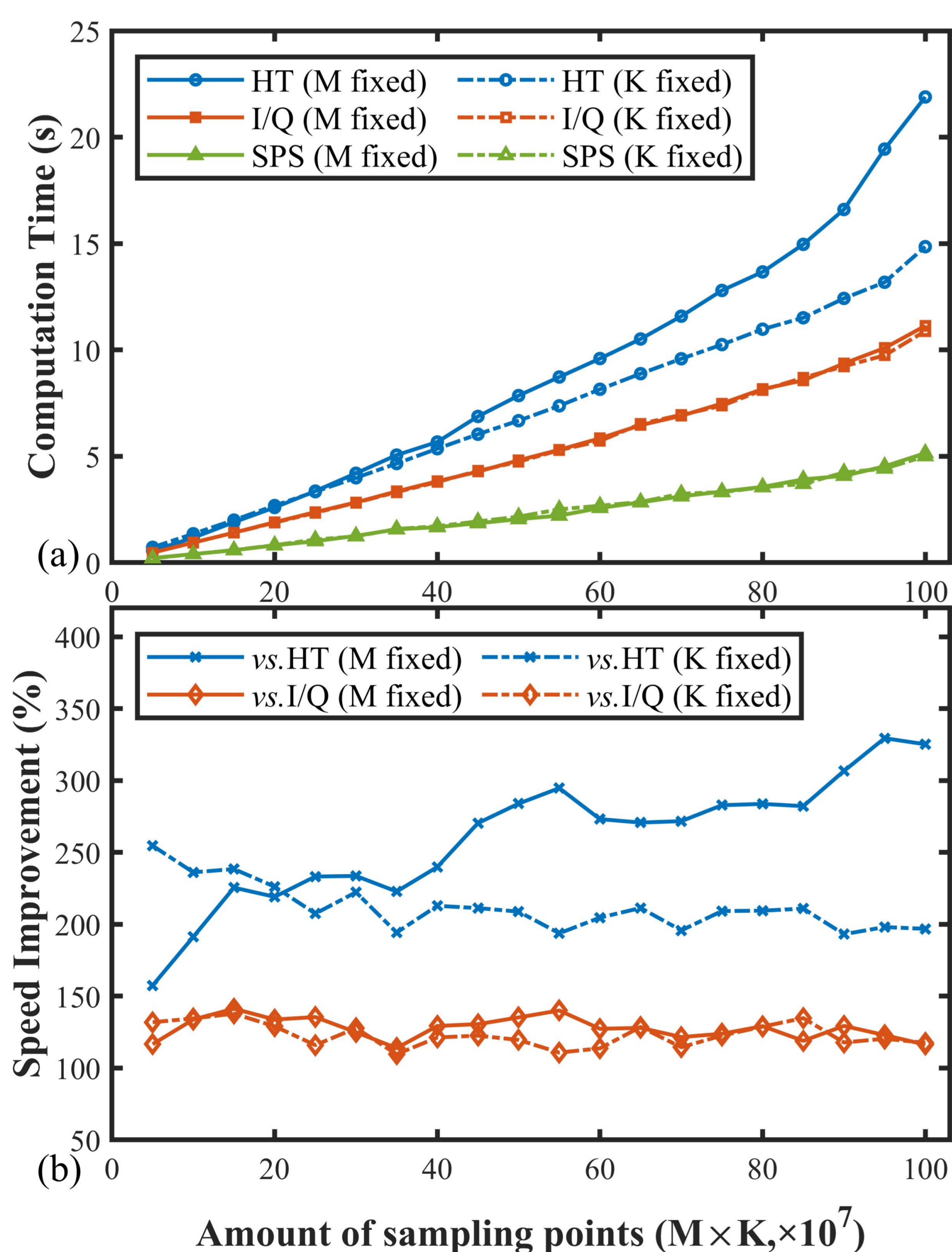
II. Computation Speed

Fig. 2. Computation time (a) and speed improvement of SPS (b) with fixed trace amount. Computation time (c) and speed improvement of SPS (d) with fixed FUT length.
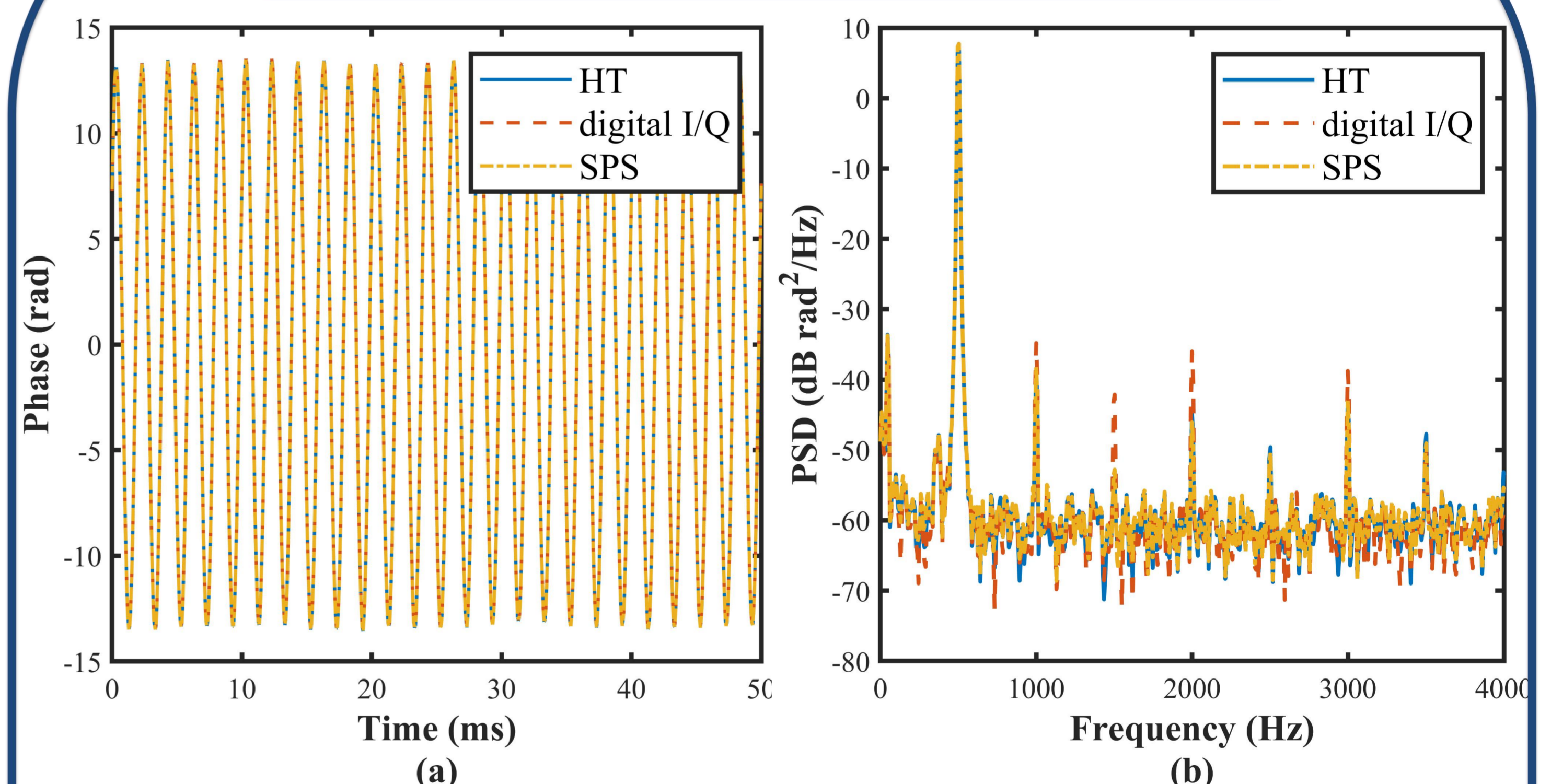
III. Sensing Performance

Fig. 3. Phase demodulation results (a) and the corresponding PSDs (b) obtained by the three methods.
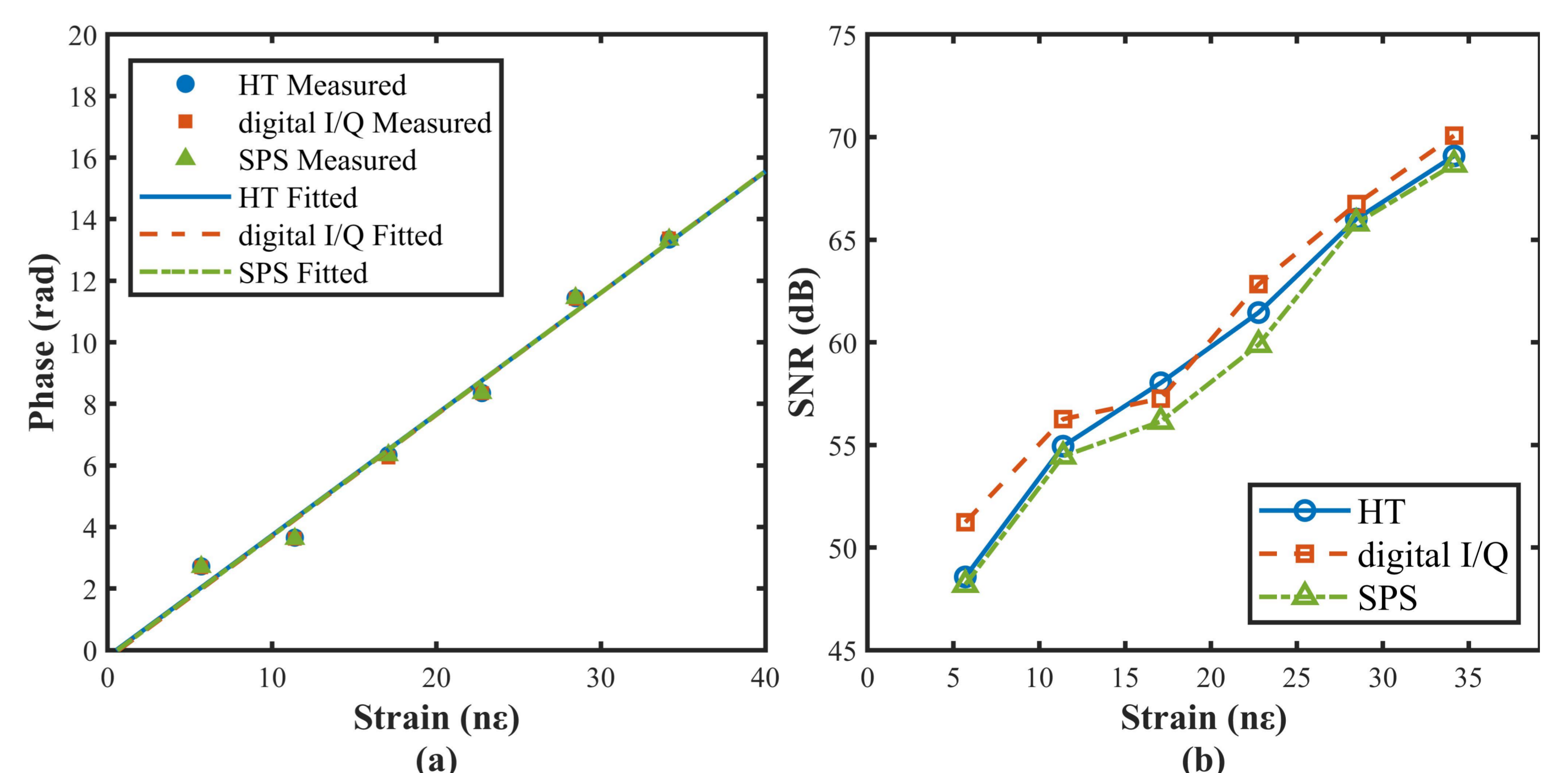

Fig. 4. Linear fitting results (a) and the corresponding SNR (b) obtained by the three methods under different strain amplitudes.

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