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Phase-Tracking Vital Sign Radar Using Frequency-Locked Loop

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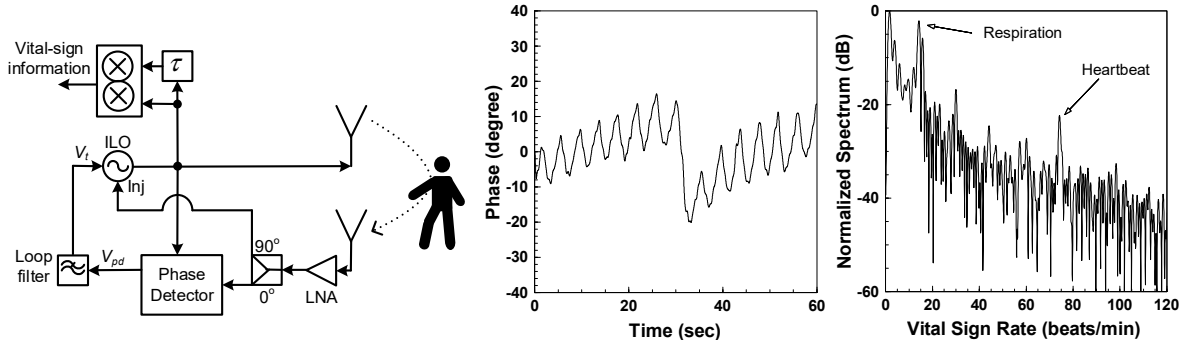
Vital sign radar can detect people's respiration rate and heartbeat rate without contact, so many related studies have been proposed. However, conventional vital sign radars typically suffer random body motion issue [1]. The random body motion causes the phase of the detected signal to change greatly and irregularly. This corrupts the weak and periodic phase change caused by vital sign. As a result, the sensing capability of conventional vital sign radars degrades dramatically under random body motions. To solve this issue, this work proposed a novel phase-tracking vital sign radar as shown in Figure 1 (a). The core of the radar is an injection-locked oscillator (ILO). The ILO transmits microwave signal toward the subject under test (SUT) and is injected by the signal reflected from the SUT. Meanwhile, the reflected signal is Doppler modulated by the vital sign of SUT during reflection. Since the phase of the ILO output signal varies with the phase of the injected signal within locking bandwidth, the vital sign information of SUT can be got by demodulating the ILO output signal. The ILO is highly sensitive to the injection signal [2] and therefore makes the proposed radar owing good vital sign detection sensitive under random body motion. Moreover, the proposed radar utilizes a frequency-locked loop (FLL) to track the phase of the reflected signal. As shown in Figure 1 (a), a phase detector is use to detect the phase difference between the transmitted and received signals. The detected results then feedback to tune the output frequency of the ILO. This feedback architecture makes the radar to become an FLL to track the phase of the reflected signal. According to the control theory, an FLL inherently track periodic phase changes and suppress nonperiodic phase changes. This makes the proposed vital sign radar immune to the random body motion effects.

To verify the vital sign sensing performance, a 2.4 GHz phase-tracking vital sign radar was implemented. The SUT was located 1 m in front of the radar with 1 min vital sign measurement. Figure 1 (b) presents the measured vital sign waveform. The SUT was stationary for the first 20 seconds. Then the SUT move his body randomly with a duration of 20 seconds. Finally, the SUT remains stationary for the last 20 seconds. It can be found that the waveform roughly varies with the SUT's respiration. Most of nonperiodic waveform variation caused by the random body motion was suppressed by the FLL. Figure 1 (c) presents the measured vital sign spectrum. The respiration and heartbeat signals can be observed easily in the spectrum even under random body motion. The respiration and heartbeat rate were about 14.2 and 74.2 beats/min, respectively. Evaluating all the measurement results, the developed radar performs quite well and can effectively detect the vital sign of an SUT.



(a) (b) (c)

Figure 1. (a) Proposed phase-tracking vital sign radar, (b) measured vital sign waveform under random body motion, (c) measured vital sign spectrum under random body motion.

References

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