Remote, Contactless RF Vital Signs Sensing

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Remote, contactless, radio frequency (RF) sensing of vital signs paves the way towards unobtrusive, easy-to-use and continuous health monitoring at home, work and hospital environments. A vital signs RF-sensing demonstrator has been developed in the framework of the M3TERA H2020 project.

Remote, contactless, RF vital signs (VS) sensing is an emerging technology with potential applications from health and wellness at home, to hospitals, safety and assisting living. RF sensing permits unobtrusive measurement of vital signs at longer distances and lower power compared to other solutions (e.g., vision). It can operate under any lighting conditions without the need for special clothing or devices. The broad application space includes self-monitoring of VS for better lifestyle control, monitoring of persons with sensitive skin (e.g., newborns, burn victims, elderly), safety (e.g., VS of drivers, pilots), as well as, multi-person VS monitoring in assisted living environments.

M3TERA is a H2020 project which targets the design and development of a highly-integrated, cost and energy efficient, reconfigurable sub mm-wave system [1]. In the framework of M3TERA, a RF-sensing demonstrator has been designed and developed for the remote measurement of heart rate (HR) and breath rate (BR). The RF-sensor is based on measurement of small displacements that occur when a person breaths and when the heart beats. The chest movement ranges from 0.6 to 1.2 mm due to the beating of the heart and from 1 to 2 cm due to respiration (refer to Figure 1). The displacement can be captured via the modulation of the power and phase of an RF signal reflected at the surface of the body. The target prototype is an FMCW radar operating at the 122.25-123 GHz or the 57-66 GHz band. As a first step, in order to investigate and demonstrate the principles of remote VS sensing, a continuous wave reflectometer was designed and developed based on a Software Defined Radio (SDR) platform. The use of the millimeter wave (mm-wave) frequency band offers increased displacement resolution as well as good skin reflectance.

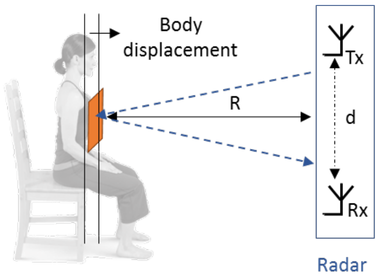

Figure 1: Radar-based VS measurement principle.

The laboratory system, which operates at 110 GHz, is comprised of a transmitter (Tx) and a receiver (Rx), as shown in Figure 1. The Tx signal is reflected by the body and the received (backscattered) signal is mixed with a Local Oscillator (LO). The intermediate frequency (IF) signal is IQ-demodulated in the digital domain. COTS components (RF generators, frequency multipliers, harmonic mixer, amplifiers) were combined with the SDR which was used for the reception of the IF signal (Figure 2).

The SDR platform provides the software tools for the development of the RF digital signal processing (DSP) and the VS estimation algorithms. Novel, low-cost 3D printed mm-wave antennas were designed and developed, optimized for the VS demonstrator at CSEM [2]. Link budget analysis indicates that both HR and BR can be extracted at distances up to 10 m, given typical noise figure (12 dB) and phase noise specifications.

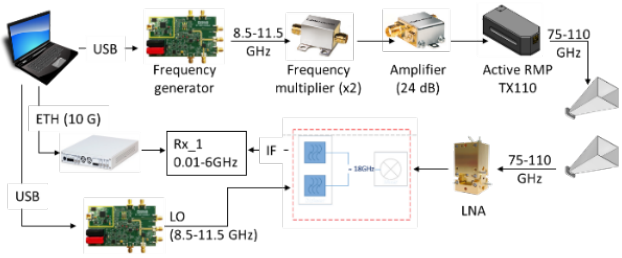

Figure 2: System setup.

Extraction of HR from the high-order BR harmonics is challenging and currently an open research problem. Various DSP algorithms were investigated for this purpose including wavelet decomposition, dynamic time wrapping, principle components analysis and dynamic harmonic notching. Figure 3 presents the results of the latter approach for the case of slow, sinusoidal-like breathing and fast, harmonic-heavy breathing. The effect of the breathing type on the quality of the HR estimation can be clearly observed.

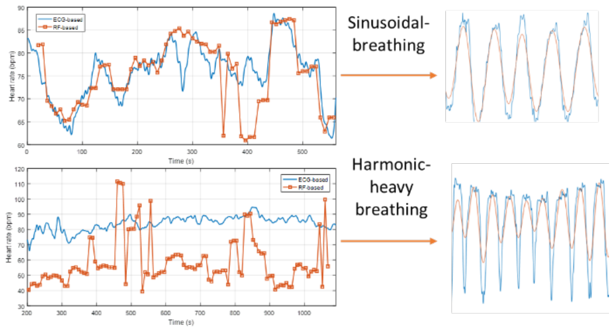

Figure 3: ECG-based (blue) and RF-based (orange) HR estimation during sinusoidal (top) and fast, harmonic-heavy (bottom) respiration.

The RF-sensing demonstrator has proven the feasibility of remote VS sensing. The next steps include the development of an FMCW radar which will provide the ability to track and monitor multiple persons in the same environment. Machine learning algorithms will be developed for the reliable separation of HR and BR. Further algorithmic development will target person tracking and compensation of motion artifacts.

[1] M3TERA (EU project under GA No 644039) www.m3tera.eu.

[2] O. Vorobyov, J. R. Farserotu, J.-D. Decotignie, "3D printed antennas for Mm-wave-sensing applications", ISMICT Int. Symposium on Medical Inf. and Comm. Tech., (2017).