mm-Wave MIMO FM-CW Radar based Vital Signals Monitoring and Estimation of Heartbeat and Respiration Rates using Two-Wave models

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In recent years, it has been studied to measure the health of the human body without contact using millimeter-wave radar[1]. In this manuscript, we describe the measurement method of heartbeat and respiration by millimeter-wave FM-CW MIMO radar, and the evaluation method of heartbeat and respiration rates. The slant range and azimuth direction of human target can be known by FM-CW MIMO radar. In addition, from the time-series phase information of its beat spectrum, the sub-wavelength motion of the body surface can be measured. This motion is made by a mix of respiration and heartbeat. Therefore, separation of them is necessary for estimating vital signs (heartbeat and respiration rates). The various methods have been proposed. A digital filter is difficult to separate the heartbeats and respiration due to the presence of heartbeat harmonics. Other methods such as Arctangent Demodulation (ATD) and mathematical signal decomposition are considered. In this report, we propose other method to use a two-wave models of the small displacement related to respiration and heartbeat, and examines to estimate both rates by the time-series phase information of millimeter-wave MIMO FM-CW Radar signal. The two-wave models are as follows:

$$\delta_{two}(t) = \delta_r(t) + \delta_h(t) \tag{1}$$

where $\delta_r(t)$ is a phase of respiration and $\delta_h(t)$ is a phase of heartbeat. They are modeled as a sum of sine waves. A measured phase after phase unwrapping is expressed as $\delta_m(t)$. Then, we estimate the respiration and heartbeat rates as following equation

$$\Phi(t_0) = \int_0^T \left| w(t,t_0)\left\{\delta_m(t) - \left(\delta_r(t) + \delta_h(t)\right)\right\}\right|^2 dt \tag{2}$$

where $w(t, t_0)$ is a window function and t_0 is a center position of $w(t)$. T is an observation duration. At t_0, eq.(2) is minimized by adjusting sine wave parameters. In order to adjust the parameters, Particle Swarm Optimization (PSO) is used [2]. Some experimental results are shown.

References

[1] Masahiro Shibao, Akihiro Kajiwara. Heart-rate monitoring of moving persons using 79 GHz ultra-wideband radar sensor. IEICE Communications Express, Vol.9, No.5, p.125.,2020.

[2] P Rocca, M Benedetti, M donelli, D Franceschini and A Massa, "Evolutionary optimizatin as applied to inverse scattering problems", Inverse Problems, vol.25, Nov. 2009..