Cardiac Rate Estimation Using Continuous Wave Radar and Ultra Wideband Radar at Different Distances

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Continuous wave (CW) and ultra wideband (UWB) radar techniques have demonstrated potential performance in non-contact vital signs monitoring (C. Li, V.M. Lubecke, O.B. Lubecke, and J. Lin, IEEE Trans. Microw. Theory Tech., 61, 5, 2046-2060). CW radar has simple architecture, advantage of low cost and high accuracy in cardiac rate detection. Its performance in long-range vital signs monitoring has been proven (M. Baboli, A. Singh, N. Hafner, V. Lubecke, EMBC, 2012). UWB radar has demonstrated very promising results in indoor target localization, multiple vital signs detection and human gait analysis (Y. Wang, Q. Liu and A.E. Fathy, IEEE Trans. Geosci. Remote Sens., 51, 5, 3097-3107, 2013).

For both CW and UWB radars, typically used FFT signal processing method based on peak search is not accurate enough for the extraction of cardiac rate. For CW radar, arctangent demodulation with DC offset compensation (B.K. Park, B. Lubecke, and V.M. Lubecke, IEEE Trans. Microw. Theory Tech., 55, 5, 1073-1079), and complex signal demodulation techniques (C. Li and J. Lin, IEEE Trans. Microw. Theory Tech., 56, 12, 3143-3152) have been pursued for enhancement of respiratory and cardiac rates detection. These two techniques have been successfully extended and applied on UWB radar data for accurate cardiac rate extraction (L. Ren, Y. Koo, Y. Wang, and A.E. Fathy, BioWireleSS, 2015). However, these methods are not versatile enough for practical applications as the estimates are subject to error in the presence of noise.

To improve the signal to noise ratio (SNR) in the signal processing, state space method (SSM) has been established for heart rate estimates in a low SNR environment. (K. Naishadham, J.E. Piou, L. Ren, A.E. Fathy, IEEE Trans. Biomed. Circ. Sys., 2016). Furthermore, SSM can be used in conjunction with arctangent demodulation and complex demodulation methods to achieve both high accuracy and high SNR in vital signs detection.

In this paper, we will describe in detail the basic blocks of CW and UWB radars, and apply different algorithms on data extracted from measurements on a human subject at different distances. Experiments have demonstrated the performance of CW radar systems for cardiac rate detection with less than 3% error at 20 m distance with transmitted power at 12 dBm. This range limitation of vital signs monitoring for our UWB radar is adequate for indoor operation.