Analysis of Human Vital Signs Using Millimeter-Wave Radar and ESPRIT Algorithm

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Remote health monitoring and vital sign tracking is a burgeoning industry accompanied by considerable academic research activity. Several technologies have been employed to measure breathing rates and heartbeats in the human body such as sonar, accelerometers, image processing, infrared sensors, and radar. Among them, a miniaturized mm-wave radar has the potential to resolve an extreme level of detail with different vital signs simultaneously and at a distance away from the body.

Researchers such as Alizadeh *et al.* [*M. Alizadeh, et al., "Remote Monitoring of Human Vital Signs Using mm-Wave FMCW Radar," in IEEE Access, vol. 7, pp. 54958-54968*] have investigated methods to analyze human breathing and heart rate data from mm-wave radar using fast Fourier transform and have correlated that performance to traditional medical skin-contact sensors with accuracy of over 80%. Ahmad *et al* [*A. Ahmad et al, "Vital signs monitoring of multiple people using a FMCW millimeter-wave sensor," 2018 IEEE Radar Conf. 2018, pp. 1450-1455*] used a similar mm-wave radar setup and applied spectral filtering and heuristic modeling to extract the vital sign frequencies. Despite this progress, there is still a need for accurate and efficient analysis of raw radar data to extract the precise human breathing and heart rate.

In this work, we propose a unique approach to analyzing the patterns of human breathing and heart rate using phase tracking FMCW mm-wave radar. We aim a Texas Instruments AWR1642™ and DCA1000EVM™ radar assembly toward three test subjects and measure the phase delay of a certain range bin across time. The phase data of the mm-wave radar is selected since it is extremely sensitive to small bodily perturbances like the heartbeat which cannot be easily measured by a doppler radar. These phase vs time data are fed into the super-resolution algorithm ESPRIT [*R. Roy and T. Kailath, "ESPRIT-estimation of signal parameters via rotational invariance techniques," in IEEE Transactions on Acoustics, Speech, and Signal Processing, vol. 37, no. 7, pp. 984-995,1989*] which decomposes the time domain information into separate wave modes. The breathing (0.1-0.2 Hz) and heartbeat (0.8-1.3 Hz) are extracted and verified by comparing the ESPRIT results to a wearable heart rate sensor and controlling the breathing rate during testing.