Noncontact Heartbeat Detection Using UWB Impulse Doppler Radar

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Nowadays, UWB radar systems have been used to remotely monitor subjects in many non-contact scenarios--monitoring and detecting through debris and walls. It can be used for non-contact measurements for various vital sign monitoring in different scenarios like space station astronaut monitoring, athletic performance monitoring from a distance and so on. UWB radar demonstrated very promising results in indoor target localization, and human gait analysis as well (Y. Wang, Q. Liu and A. E. Fathy, IMS Sym. Dig., 2012).

For heart rate and breathing, UWB Doppler radar utilizes non-contact way to detect the changes in the time of flight of narrow pulses emitted by the radar and reflected from the human chest. The respiration rate can be detected easily because of its strong Doppler signal, while it is hard to determine the heart beat rate as its amplitude is relatively very weak.

Various techniques have been pursued to enhance the heart beat signal like arctangent demodulation method with DC offset compensation (Byung-Kwon Park, Boric-Lubecke, O. and Lubecke, V.M., IEEE Trans. Microw. Theory Tech., 55, 5, 1073-1079), and complex signal demodulation technique (Changzhi Li and Jenshan Lin, IEEE Trans. Microw. Theory Tech., 56, 12, 3143-3152). Arctangent demodulation is very similar to CW radars and has resulted in a significant improvement in heart rate measurements. By applying arctangent method, the phase variation of the reflected pulses caused by the tiny periodic thorax displacements could be detected. Also, using the complex signal demodulation technique is used as well to cancel the unwanted random body movements of subjects could enhance non-contact vital sign detection including heart rate.

Meanwhile, in extracting vital signs from radar measurements, typical FFT transform methods, however, are not accurate enough for heart rate extraction. To improve the accuracy, state space method, originally developed for radar signal processing method has been established, and relatively small error has been observed in the heart rate estimates in a low SNR environment, and even in the presence of random body motion (K. Naishadham and J. E. Piou, IEEE Trans. Antennas Propagat., 56, 6, 1742-1751).

In this paper, we will discuss in detail the basic blocks of our UWB radar, compare results of the various enhancing techniques. We will demonstrate our heart rate and respiration rate measurements and our validation set-up. Experiments have demonstrated the capability of these methods for low power UWB radar systems for heart rate detection and direct recovery of thorax displacement amplitude with less than 4% error.