A Study of Received Antenna Branch Selection Diversity Effect for Remote Heart Rate Measurement Based on mm-Wave SIMO Radar

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1. Introduction

We measured and estimated heart rate without contact using millimeter-wave wideband FMCW radar [1, 2], in which one Tx-Rx channel of 3Tx-4Rx multi-input multi-output (MIMO) channels had been employed. However, it has been figured out that there were non-negligible differences in signal-to-noise ratios (SNRs) between the channels. Comparing the heart rate estimation accuracies showed significant difference between received antenna branches (1Tx-4Rx channels) [3].

In this paper, we report the diversity effect of the received antenna branches by two selection methods: select branch once with best mean SNR of total data (method I) and select branch each sliding observation time window with best SNR of each time window (method II).

2. Proposed Method

Figures 1 and 2 show the configuration of the used radar module and the proposed radar signal processing flow. IF signals are extracted by mixing the radar transmitted and received signals, AD-converted, DC offset, and phase-unwrapped, and finally, the chest displacement signals are extracted in each antenna branch. The heartbeat frequency is estimated through time-frequency analysis of selected antenna branch signal with improved complete ensemble empirical mode decomposition with adaptive noise (ICEEMDAN). Here, a certain time window is slid by a time step for the obtained streaming data, and the heartbeat frequency is estimated for each time window, averaged over all the time windows, and finally, heart rate (beats per minute) is estimated. Two branch-selection methods are based on a specific SNR criterion as follows,

Method I) Calculate the mean SNR value of the total time window for each branch and select the best SNR branch.

Method II) Calculate the SNR for each branch and select the best SNR branch in each time window.

3. Experimental Result and Discussion

The radar module was based on TI's IWR1443 chip. Frequency bandwidth was 3.598 GHz (operating frequency was from 77 to 80.598 GHz), frame length, chirp length and slope were 50 msec, 51.4 μsec and 70 MHz/μsec, respectively. A radar module was placed facing a seated subject at about 1 m of distance. For the data analysis, the observation window length was 20 seconds, slide 1 second for the entire streaming data (60 seconds), and then forty heartbeat frequencies and SNRs were estimated. Here, for the SNR, we defined the signal and noise as the sum power of peak value and one sample before and after, and the power of all samples except the signal, respectively, in the estimated heartbeat frequency spectrum. Heart rate data with an ECG device was simultaneously obtained for reference. Table 1 shows the results of methods I and II for RMSE of estimated heart rate frequency compare to ECG data for four subjects. The RMSE for each branch data is also shown for reference. Selection diversity only improved some of the RMSE for all subjects. In the future, we will improve the heartbeat frequency estimation method with ICEEMDAN and the SNR criterion used for branch selection and increase the number of subjects for more reliable evaluation.

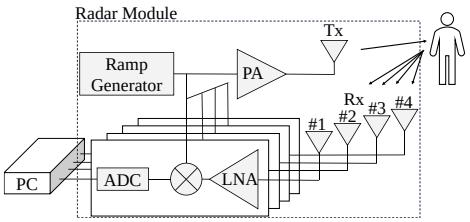

Fig.1 Block diagram of the FMCW radar module

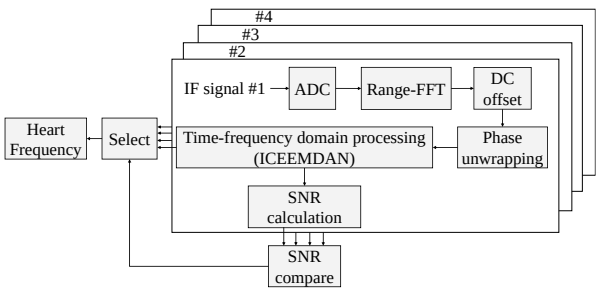

Fig.2 Signal processing flow

Table.1 Comparing of RMSE of the two methods [bpm]

Subject	Antenna branch					
	#1	#2	#3	#4	Sel. w/Method Ⅰ	Sel. w/Method Ⅱ
A	6.624	5.218	5.042	4.135	4.135	4.189
B	4.269	3.453	3.940	4.424	3.940	3.765
C	4.053	3.735	4.053	4.216	4.053	3.486
D	3.550	3.453	3.486	3.550	3.550	3.550

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References

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[3] R. Shigihara, et. al., "An Result of SNR Difference in Received Antennas in mm-Wave SIMO Radar for A Remote Heart Rate Measurement," ICETC2022, S1-5, Nov. 2022.