High-Sensitivity Motion Sensing Radar

Sponsoring MTT-S Technical Committees

TC-28 MTT Biological Effects and Medical Applications Committee

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Competition Summary

This SDC aims to introduce students to vital sign sensing radars, which are open to all students registered at an educational institution. With the reference signals, participating teams are required to design, fabricate, and demonstrate a radar system that balances portability (power consumption, weight, and size), performance (accuracy and response time), and potential in practice.

Evaluation Criteria

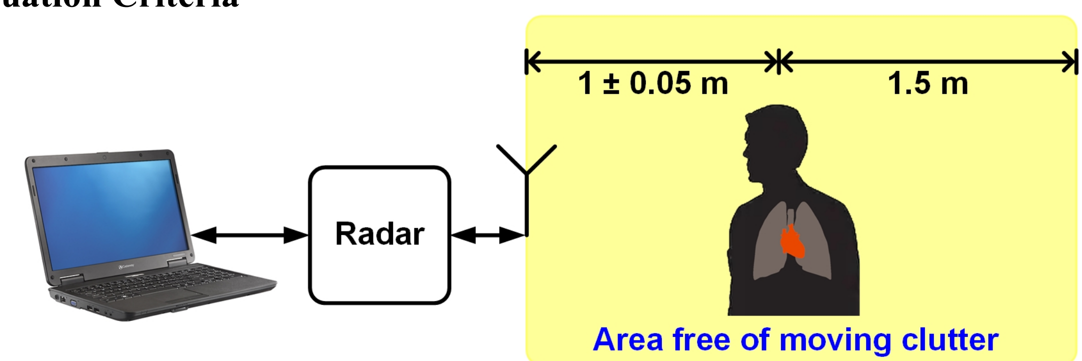

Figure 1. Experimental setup for radar-based vital sign monitoring

Fig. 1 shows the testing and judging environment. The radar sensor needs to detect and measure the cardiopulmonary activities of a seated subject who is breathing normally. Only the fundamental frequencies of respiration and heartbeat need to be detected and measured. During the sensing period, the radar can be located in a range between 0.95 m to 1.05 m from the subject. No moving clutter will be allowed 1.5 m behind the subject in the line-of-sight direction. In addition, the team may prepare and use a tripod to make the radar antenna face the chest of the seated subject.

A power supply with a single DC voltage output up to 15 V will be provided to power up the radar, no battery is allowed on the radar. The DC power consumption will be measured as the product of the actual supply voltage and current. The power consumption must be the same during all the measurements. During the sensing period, a respiration belt and an electrocardiography (ECG) device will be utilized to provide the ground truth of vital signs of the subject.

As seen in Fig. 1, the radar sensor can be connected to a laptop, smart phone, or tablet using a single cable for real-time signal processing. The cable can be used to transmit analog/digital signal through USB/audio port. But no dc power can be transferred from the laptop/smartphone/tablet to power the radar. If USB data acquisition cable (e.g., NI 6008/6009 or FTDI USB to serial converter cable) is used, the power drawn by the unit for data acquisition function will not be counted because of the difficulty in measuring the power. However, it should be noted that the weight of the data acquisition unit will be counted; and if two teams have the same score, the team not using USB data acquisition will be ranked higher. Energy harvesting from ambient sources is not allowed. The weight of the radar sensor will be measured as the total weight in the radar system except for the laptop, i.e., the antenna, SMA connectors, SMA cables, radar front-end, ADC (if any) and signal cables will all be counted into the weight of the radar sensor.

Detailed Competition Description and Rules

- Each team has **25-minute** competition time to calibrate their radar and complete at least **one 2-minute measurement**. In other words, the best result measured within the competition time can be chosen to evaluate the performance. Moreover, if each team wants to prove the work's potential such as clutter immunity, low cost, or multiple vital sign sensing capability, please also complete the experiment in the period.

- Due to the signal processing techniques and the subject's random body motion, each team can choose **1-minute radar sensing result** to evaluate the performance compared with the reference signals provided by the respiration belt and ECG device. It should be noted that the accuracies of respiration and heartbeat should be provided from the same measurement, and should be consecutive, e.g., 10~70 s or 30~90 s. Each team has to prepare the instruments and algorithms to provide the ground truth references of respiration rate variability (RRV) and heart rate variability (HRV), and submit the measured accuracies and explain the potential of their works with proof in **10 minutes**.

- The DC power consumption and weight of the radar will be measured by calculating the product of the actual supply voltage and current. The power supply model provided by the organization is unknown. If the power supply is not sensitive enough and the team does not provide another power supply to measure the DC power consumption, the score for this section will be 0 points. This measurement will be done using the actuator set up with a configuration chosen by the team. The team must demonstrate to the judges that, at least, the frequency of the motion is being correctly measured by the radar. Otherwise, the team will be disqualified from the competition.

Evaluation Criteria

The reference signal of respiration is provided by the low-pass filtered result measured by the respiration belt, and the cutoff frequency is set to be 0.5 Hz. With the aid of peak-detection function in MATLAB, the peak-to-peak interval for respiration, PPI_R_{ref} can thus be obtained. Similarly, the peak-to-peak interval for heartbeat, PPI_H_{ref}, can be obtained by the R-R intervals of the ECG waveform. Compared with the results, PPI_R_{radar} and PPI_H_{radar}, measured by the radar with customized algorithms, the average accuracies of respiration and heartbeat, AA_R and AA_H, are defined as

$$AA\_R = \sum_i \left(1 - \frac{\left| PPI\_R_{ref,i} - PPI\_R_{radar,i} \right|}{PPI\_R_{ref,i}} \right)$$

and

$$AA\_H = \sum_j \left(1 - \frac{\left| PPI\_H_{ref,j} - PPI\_H_{radar,j} \right|}{PPI\_H_{ref,j}} \right)$$

where i and j are respectively the index numbers. For example, if the subject exhibit 10 breaths and 90 heartbeats in one minute, the respiration belt and ECG will respectively show 9 PPI_R_{ref} and 89 PPI_H_{ref}.

The score of this competition will be calculated for each team according to Table 1.

Table 1. Scoring table

DC power consumption (P_{DC})		**Weight (W_g)**	
Range	**$Score_{PDC}$**	Range	**$Score_{Wg}$**
P_{DC} > 500 mW	5	W_g > 200 g	5
100 mW < P_{DC} < 500 mW	10	100 g < W_g < 200 g	10
10 mW < P_{DC} < 100 mW	15	10 g < W_g < 50 g	15
P_{DC} < 10 mW	20	W_g < 10 g	20
$Score_{accuracy}$: (AA_R+ AA_H)*0.2			
$Score_{potential}$: < 20			

And the total score is given by

$$\mathbf{Score_{total} = Score_{accuracy} + Score_{PDC} + Score_{Wg} + Score_{potential}}$$

How to Participate

Participants must register for the IMS Student Design Competition according to the rules posted on the IMS-2022 homepage. At the same time, the competitors must also send an e-mail containing the name of the team members and their contact details (e-mail preferred) to Fu-Kang Wang, fkw@mail.ee.nsysu.edu.tw with the subject line “IMS-2022 SDC competition” no later than the official deadline announced on the IMS-2022 SDC homepage.

Student Eligibility Criteria

1. Students may enter as individuals or as a team. There may be no more than four students on a team. Each student may be a member of only one team. Each team may submit up to two entries but can receive an award for only one entry.
2. To enter a competition, the participant(s) must be full-time student(s) (enrolled for a minimum of nine hours per term as graduate students or twelve hours per term as undergraduates) during the time the work was performed. There is no restriction on age.
3. The student(s) must have a signed statement from their academic advisor that the work is mainly carried out by the student(s).
4. The students should use the email address issued by their institutions for all communication regarding the competitions, rather than personal emails (e.g., Gmail, Hotmail).

Awards

The first-place winning team will receive a prize of $1000 and will be invited to submit a paper describing his/her project to the IEEE Microwave Magazine. The second- and third- place winning ,teams will receive a prize of $600 and $400, respectively.