

# High-Sensitivity Motion Sensing Radar

## Sponsoring MTT-S Technical Committees

MTT-28 Biological Effects and Medical Applications  
MTT-23 Wireless Communications

## Coordinators

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## Competition Summary

A radar sensor design competition is open to all students registered at an educational institution. Competitors are required to design, fabricate, and demonstrate a high sensitivity (as measured by the motion amplitude that can be detected), fast-response, low-power portable mono-static radar. This project will introduce students to modern radar motion sensors.

## Detailed Competition Description and Rules

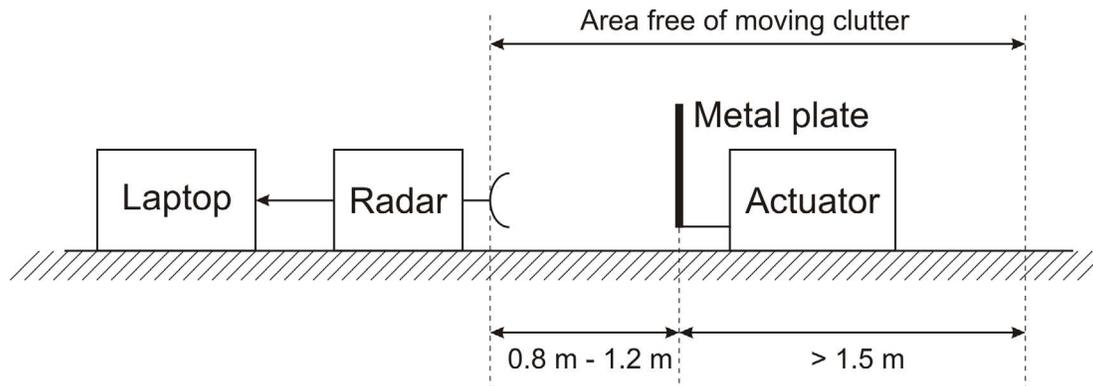


Figure 1. Setup of the testing and judging environment

1. Fig. 1 shows the testing and judging environment. The radar sensor needs to detect and measure the mechanical motion of a metal plate (size 12 cm x 8 cm) that it is periodically moving. Only the fundamental component of the periodic motion is to be detected and measured. During the calibration stage, the team can locate the radar in a range between 0.8 m to 1.2 m to the metal plate. No moving clutter will be allowed 1.5 m behind the vibrating moving plate in the line-of-sight direction. Depending on the alternatives provided by the convention center, the space between the radar and the metal plate can be a flat surface (one-table solution), or open air (two-table solution). If the one-table solution is possible, that will be the deployment used for all the experiments.
2. 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. The actuator can produce several periodic displacements of the metal plate with peak amplitudes of only 10  $\mu\text{m}$ , 0.1 mm, 0.5 mm, 1mm, and 2.0 mm and frequencies of only 0.4, 0.5, 0.6, 0.7, and 0.9 Hz.
3. 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 of everything in the radar system except for the laptop. This means 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.

## Evaluation Criteria

### 1. Calibration phase

The judges will tell the team how to use the actuator to set up different motions of the metal plate. After this, each team will be given 15 minutes to set up and calibrate their radar before the official measurements. This calibration phase is very important, since the actuator has small errors in the amplitude and the frequency of the established motion. The calibration time can also be used to correctly point the radar and to situate it in the range of 0.8 m-1.2 m to the metal plate.

### 2. Phase 1. Determination of unknown frequencies with known amplitudes

The amplitude will be set up to 2.0 mm, 0.5 mm, and 10  $\mu\text{m}$ , with unknown frequencies that can be repeated. The team will take note of the measured frequencies. The judges will take note of the needed time to do each measurement. The maximum detection time is 50 s.

**3. Phase 2. Determination of unknown amplitudes with known frequencies**

The frequency will be set up to 0.9 Hz, 0.6 Hz, and 0.4 Hz, with unknown amplitudes that can be repeated. The team will take note of the measured amplitudes. The judges will take note of the needed time to do each measurement. The maximum detection time is 50 s.

**4. Phase 3. Determination of unknown amplitudes and frequencies**

The actuator will be set up to three randomly-chosen unknown configurations (unknown amplitudes and frequencies). The team will take note of the measured amplitudes and frequencies. The judges will take note of the needed time to do each measurement. The maximum detection time is 50 s.

**5. Determination of DC power consumption**

The DC power consumption will be measured as the product of the actual supply voltage and current. The power supply provided by the organization is unknown. If the power supply is not sensitive enough and the team does not provide another power supply to actually measure the DC power consumption, the score for this section will be 0 points. This measurement will be done with 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 eliminated from the competition.

**6. Determination of weight**

A scale will be used to determine the weight of the radar.

**7. Determination of final score**

The score of this competition will be calculated for each team according to Table II that only applies when the corresponding measurement is correct.

**Table 1.** Answer sheet for the teams.

	<b>University:</b>	
	<b>Phase 1</b>	
	<b>Motion Amplitude</b>	<b>Detected Frequency</b>
	2 mm	
	0.5 mm	
	10 $\mu$ m	
	<b>Phase 2</b>	
	<b>Motion Frequency</b>	<b>Detected Amplitude</b>
	0.9 Hz	
	0.6 Hz	
	0.4 Hz	
	<b>Phase 3</b>	
	<b>Detected Frequency</b>	<b>Detected Amplitude</b>
<b>Meas. 1</b>		
<b>Meas. 2</b>		
<b>Meas. 3</b>		

**Table 2.** Scoring table.

Phase 1 (P1)			Phase 2 (P2)			Phase 3 (P3)		
Amp.	Det. time	Score	Freq.	Det. time	Score	Meas.	Det. time	Score
2 mm	$t_d < 10$ s	10	0.9 Hz	$t_d < 10$ s	40	Meas. 1	$t_d < 10$ s	100
2 mm	$10 < t_d < 25$ s	6	0.9 Hz	$10 < t_d < 25$ s	30	Meas. 1	$10 < t_d < 25$ s	80
2 mm	$t_d > 25$ s	4	0.9 Hz	$t_d > 25$ s	20	Meas. 1	$t_d > 25$ s	60
0.5 mm	$t_d < 10$ s	20	0.6 Hz	$t_d < 10$ s	50	Meas. 2	$t_d < 10$ s	100
0.5 mm	$10 < t_d < 25$ s	15	0.6 Hz	$10 < t_d < 25$ s	40	Meas. 2	$10 < t_d < 25$ s	80
0.5 mm	$t_d > 25$ s	10	0.6 Hz	$t_d > 25$ s	30	Meas. 2	$t_d > 25$ s	60
10 $\mu$ m	$t_d < 10$ s	40	0.4 Hz	$t_d < 10$ s	60	Meas. 3	$t_d < 10$ s	100
10 $\mu$ m	$10 < t_d < 25$ s	30	0.4 Hz	$10 < t_d < 25$ s	50	Meas. 3	$10 < t_d < 25$ s	80
10 $\mu$ m	$t_d > 25$ s	20	0.4 Hz	$t_d > 25$ s	40	Meas. 3	$t_d > 25$ s	60
<b>DC power consumption (<math>P_{DC}</math>)</b>			<b>Weight (<math>W_g</math>)</b>					
Range		Score	Range		Score	<b>Total Score:</b>		

$P_{DC} > 1 \text{ W}$	20	$W_g > 100 \text{ g}$	20	$\text{Score}_{P1,2\text{mm}} + \text{Score}_{P1,0.5\text{mm}} +$ $\text{Score}_{P1,10\mu\text{m}} + \text{Score}_{P2,0.9\text{Hz}} +$ $\text{Score}_{P2,0.6\text{Hz}} + \text{Score}_{P2,0.4\text{Hz}} +$ $\text{Score}_{P3,\text{Meas1}} + \text{Score}_{P3,\text{Meas2}} +$ $\text{Score}_{P3,\text{Meas3}} + \text{Score}_{PDC} +$ $\text{Score}_{Wg}$
$100 \text{ mW} < P_{DC} < 1 \text{ W}$	40	$10 \text{ g} < W_g < 100 \text{ g}$	40	
$10 \text{ mW} < P_{DC} < 100 \text{ mW}$	60	$5 \text{ g} < W_g < 10 \text{ g}$	60	
$1 \text{ mW} < P_{DC} < 10 \text{ mW}$	80	$W_g < 5 \text{ g}$	80	
$100 \mu\text{W} < P_{DC} < 1 \text{ mW}$	100			
$P_{DC} < 100 \mu\text{W}$	120			

**Table 3.** Scoring sheet for the judges.

<b>University:</b>					
<b>Phase 1</b>					
<b>Motion Amplitude</b>	<b>Actual Frequency</b>	<b>Detected Frequency</b>	<b>Answer Correct?</b>	<b>Detection Time</b>	<b>Score</b>
2 mm					
0.5 mm					
10 $\mu\text{m}$					
					$S_{P1} =$
<b>Phase 2</b>					
<b>Motion Frequency</b>	<b>Actual Amplitude</b>	<b>Detected Amplitude</b>	<b>Answer Correct?</b>	<b>Detection Time</b>	<b>Score</b>
0.9 Hz					
0.6 Hz					
0.4 Hz					
					$S_{P2} =$
<b>Phase 3</b>					
<b>Measurement</b>	<b>Actual Freq./Amp.</b>	<b>Detected Freq./Amp.</b>	<b>Answer Correct?</b>	<b>Detection Time</b>	<b>Score</b>
Meas. 1	/	/			
Meas. 2	/	/			
Meas. 3	/	/			
					$S_{P3} =$
<b>DC power consumption, weight, and total score</b>					
<b>DC Power Consumption</b>		<b>Weight</b>		<b>Total Score</b> ( $S_{P1} + S_{P2} + S_{P3} + S_{PDC} + S_{Wg}$ )	
$P_{DC}$	Score	$W_g$	Score		
	$S_{PDC} =$		$S_{Wg} =$		

Testing and judging of the radar will be performed at the 2020 International Microwave Symposium (IMS). On the date of the competition, at least one member of the design group must show up to complete all the



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measurements. The team with the highest total score will be selected as the winner. The judges of this competition will be radar experts who are not solely affiliated with one institute.

1. Additionally the judges will assign the team a grade based on their designing process. Contestants should prepare a small poster (24x32cm size) describing the specificities of their prototype and their designing experience: the tradeoff they have been facing and justifying their choices. Optional design consideration will be taken into account in this part. The Contestants should be able to answer the judge's questions regarding the design.
2. Distance/transfer efficiency and the grade will be summed up (weight 1:1) to provide the final mark that will be used to designate the winning design.

## How to Participate

Participants must register to the IMS Student Design Competition according to the rules posted on the IMS-2020 homepage. At the same time as the registration to IMS-2020 is made, the competitors must also register with the organizers of the competition. This is done by sending 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](mailto:fkw@mail.ee.nsysu.edu.tw) with the subject line "IMS-2020 SDC11 competition" no later than the official deadline announced on the IMS-2020 SDC homepage.

At least one member from each team must be present at the competition held during the IMS-2020. After the registration period ends, a time-table for the competition day will be made available, with the schedule of the 15 minutes slots of the participating teams. If no team member is present at the competition site within its slot, then the team may be considered as absent.

Please also see the general IMS student design competition rules on the IMS-2020 SDC homepage.

<http://dpdcompetition.com/sdc/>

## 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 student(s) must have been 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 principally the effort of the student(s).





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4. At least one of the students on a team must register for and attend the conference to demonstrate their design for evaluation during the contest day at IMS'20.
5. The students should use the email address issued by their respective institutions for all communication regarding the competitions, rather than their 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. Participants will be recognized at the Student Awards Luncheon at the 2020 International Microwave Symposium.

