Student Design Competition
for IMS2016 in San Francisco, CA 22-27 May 2016

Your TC number and name of your TC:

MTT-26: **Wireless Energy Transfer and Conversion**
MTT-24: **RFID Technologies**
MTT-20: **Wireless Communications**

Primary contact name(s), email address, and phone number (of host or competition leader(s)):

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The title of your Student Design Competition:

Wireless Energy Harvesting (WEH) Design Competition

A short abstract or summary describing the competition:

Competitors are required to design, construct, measure, and demonstrate a broadband wireless energy harvester capable of harvesting commercial telephony bands from 698MHz to 894MHz . This project will introduce students to the concept and implementation of efficient antenna, efficient matching circuit, and efficient RF to DC conversion. Harvesting efficiency (as defined in rules) and novelty of the design will be the leading criteria in selecting the winning design. Testing and judging of the harvesters will be performed at the International Microwave Symposium. A member of the design group must be present at the testing to assist with the evaluation. The winner of the competition will be recognized at the Student Awards Luncheon at the 2016 International Microwave Symposium. Faculty members are encouraged to introduce this as a project for their students in order to acquaint them to system and circuit level design. This competition is sponsored by the technical committee on Wireless Energy Transfer and Conversion (MTT-26), RFID Technologies (MTT-24) and Wireless Communication (MTT-20).

Which prizes will you offer and will this be a one level competition with all students combined or a two level contest so that undergraduates are judged separately from graduate students?

This is a one level competition (undergraduate and graduate student combined)
1st prize: $1000,
2nd prize: $600,
3rd prize: $400,

Brief description of competition and rule(s). Make this as long as you want.

Wireless Energy Harvester (WEH) Design Competition Rules
1. Any technology may be used for the design, but must be the result of student effort.
2. Use of commercially available components and subsystems is allowed.
3. The WEH shall allow for internal inspection of the circuitry by the judges.
4. The WEH shall be able to harvest power from the following mobile telephony bands:
   - 698-806 MHz (3G/ 4G/ MediaFlo/ DVB-H)
   - 806-824 MHz (LTE)
   - 824-849 MHz (GSM, 3G)
   - 851-869 MHz (GSM, 3G)
   - 869-894 MHz (GSM, 3G)
5. The WEH shall be able to efficiently harvest a power density ranging from 1µW/cm² to 10µW/cm²
6. A wireless source will be located in the competition room. The polarization of the wireless source will be linear vertical polarization. The radiating antenna will be setup on a wooden (or plastic) table (about 3 ft above ground) and the WEH receiver will be positioned on a table of similar height, with direct line of sight of source.
7. The WEH receiver must have its own stand, if needed, so that it can be placed (in proper orientation) on the flat test table by itself. Holding the WEH by hand is not allowed during testing. The stand should be detachable from the WEH receiver otherwise it will be considered part of the WEH receiver unit and count towards the area of the WEH receiver.
8. The WEH shall have no internal battery.
9. The WEH output power shall be calculated as the total DC power delivered to a load R_L that will be chosen by the competing team. The load should NOT be soldered to the WEH. The load has to be detachable in order for the judges to measure its value at DC. The DC power, P_L, will be obtained by measuring the DC voltage (V_L) across the load and calculating V_L^2/R_L. Note that different orientations of WEH antennas may present different DC powers at the receiving location. The DC power will be taken from the receiver orientation set up by the design team in its stand-alone position (when held by stand, not by hand).
10. The WEH receiver should have a DC (V_L) and ground (GND) pin to facilitate the DC load voltage measurement. The pins should be in the form of a header or TWO wires allowing the judges to attach banana clips. The measurement will be performed using a pair of clips which will NOT be considered when measuring the overall size of the WEH.
11. The maximum weight of the WEH should not exceed 50 grams.
12. The WEH should be planar and in any case its third dimension should not exceed 0.5 cm.
13. The WEH shall derive its energy from the wireless energy source only. It may not contain any solar cell, chemical cell, vibration cell, etc. The judges may measure the DC power at the

receiver load when the wireless source is not turned on, deduct the DC power obtained from the DC power obtained when the wireless source is turned on, and consider the difference as the power $P_L(uW)$ harvested by the WEH.

14. Testing and judging of the harvesters will be performed at the 2016 International Microwave Symposium. A member of the design group must be present at the testing to assist with the evaluation. Only one harvester design per participating group is allowed.

15. A judge cannot assign a grade to a design originating fully or partly from its university

16. Each WEH receiver will be measured once. No tuning is allowed after the official measurement is conducted. The decision of the judges shall be final.

EVALUATION CRITERIA

1. The efficiency figure of merit (EFoM), to be used as the first judging criteria, will be the DC output power $P_L(uW)$ (normalized over 10 uW), divided by the area (calculated as the square of the largest dimension D(cm) of WEH device and normalized over 150 cm^2):

$$\text{EFoM} = 10 * log10 \left[\left(\frac{P_{L,total}(uW)}{10 \ (uW)} \right)^2 / \left(\frac{D_1 * D_2 \ (cm^2)}{150 \ (cm^2)} \right) \right] \quad (dB)$$

The total output power will be measuring each frequencies individually and not simultaneously:

$$P_{L,total}(uW) = \left(P_L(uW) \right)_{700 \ MHz} + \left(P_L(uW) \right)_{800 \ MHz} + \left(P_L(uW) \right)_{900 \ MHz}$$
$$P_L(uW) = V_L^2 / R_L$$

The WEH must have a minimum of 1 uW at each frequency
$$\left(P_L(uW) \right)_{700 \ MHz} > 1 \ uW$$
$$\left(P_L(uW) \right)_{800 \ MHz} > 1 \ uW$$
$$\left(P_L(uW) \right)_{900 \ MHz} > 1 \ uW$$

For example, a rectenna which harvests 10uW, and covers an area of 150 cm^2 has a figure of merit EFoM = 0 dB.

2. Additionally the judges will assign rectenna a grade based on its designing process. Contestants should prepare 2-3 slides describing the specificities of their prototype and their designing experience: the tradeoff they have been facing and justifying their choices. They should be able to answer the judge's questions regarding the design.

3. The figure of merit and the grade will be summed up to provide the final mark that will be used to designate the winning design

Any further questions regarding this competition can be addressed to the competition organizers.