

Wearable/Frugal Microwave Energy Harvesting Design Competition

Sponsoring MTT-S Technical Committees

MTT-26 (Wireless Energy Transfer and Conversion)
MTT-10 (Biological Effects and Medical Applications)
MTT-20 (Wireless Communication)

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Competition Summary

Competitors are required to design, construct, measure, and demonstrate a wireless energy harvester (in the following referred to as WEH) at 2.45 GHz, realized on cheap materials (such as paper, cardboard) with hand-cut adhesive copper (i.e., frugal), and capable of driving a small electronic device. This project will introduce students to the concept and implementation of efficient and wearable wireless energy harvesters. The efficiency of the harvester and the 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 2019 International Microwave Symposium held in Boston, Massachusetts. 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 2019 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), Biological Effects and Medical Applications (MTT-10) and Wireless Communication (MTT-20).

Detailed Competition Description and Rules

1. Any technology may be used for the design, but must be the result of student effort.
2. Use of commercially available components is allowed.
3. The demonstrator (Wireless Energy Harvester, WEH) shall allow for internal inspection by the judges.
4. The WEH shall be able to efficiently harvest a power density ranging from $1\mu\text{W}/\text{cm}^2$ to $10\mu\text{W}/\text{cm}^2$ at 2.45 GHz (linear polarization).
5. The maximum weight of the WEH should not exceed 50 grams.
6. The WEH should be thinner than 8mm
7. The WEH shall have no internal battery.
8. 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).
9. 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.
10. 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 $P_L(\mu\text{W})$ harvested by the WEH.
11. 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. Only one prototype per participating group is allowed.
12. Contestants should prepare a small poster (A3 size) 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.
13. **OPTIONAL:** Advanced contestants can demonstrate their problem-solving skills (and therefore their grade) by considering one (or both) of the following design specifications. This part is not mandatory.
 - o **Operation as an epidermal device** (placed directly on the skin). Measurement will be done by placing the WEH on/against a plastic "ziploc bag" filled with a phantom that mimics the body tissues.. The phantom will consist of bags of saline water comprised of 0.4% NaCl + 99.6% DI water (the percentage is by weight) resulting in a dielectric constant of around 81 (temperature and Tolerance in NaCl concentration on the day of the competition will affect the effective dielectric constant)

- **Frugal construction & design** (reducing the complexity and cost). It is suggested to build the WEH out of cardboard (for substrate) and copper/aluminum tape (for the trace and if needed, for the ground plane), see example in Appendix.
14. Typical judging measurement setup may be reproduced at the team's institution using a radiating linear antenna on a wooden (or plastic) table about 3 ft above ground with the WEH receiver in direct line of sight with the source. The setup can be easily calibrated using a spectrum analyzer and a $\lambda/4$ antenna at the position of the WEH.
 15. A judge cannot assign a grade to a design originating fully or partly from its university or its co-author.
 16. Few tuning minutes are given to each teams prior the measurement perform by the judges. Each official measurement will be done 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 judging criteria, will be the DC output power $P_L(\mu W)$ (normalized over 1 μW), divided by the area (calculated as the product of the two largest dimensions D_1 (cm) and D_2 (cm) of WEH device and normalized over 10 cm^2): For example, a rectenna which harvests 1 μW , and covers an area of 10 cm^2 has a figure of merit $EFoM = 0$ dB:

$$EFoM = 10 * \log_{10} \left[\left(\frac{P_L(\mu W)}{1(\mu W)} \right)^2 / \left(\frac{D_1(cm)D_2(cm)}{10(cm^2)} \right) \right] (dB)$$
$$P_L(\mu W) = \frac{V_L^2}{R_L}$$

2. Additionally the judges will assign the team a grade based on their designing process. Contestants should prepare a small poster (A3 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.
3. 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

Awards

This will be a single-level contest with an amount of \$2000 to be divide among the best selected designs. The teams that will demonstrate the best & Original performance will be given the opportunity to publish a common paper describing their designs in microwave magazine.

Appendix: Example of frugal rectenna parts design & fabrication (© E. V.)

