UAT

Rectennas for energy harvesting of RF for feeding low power devices

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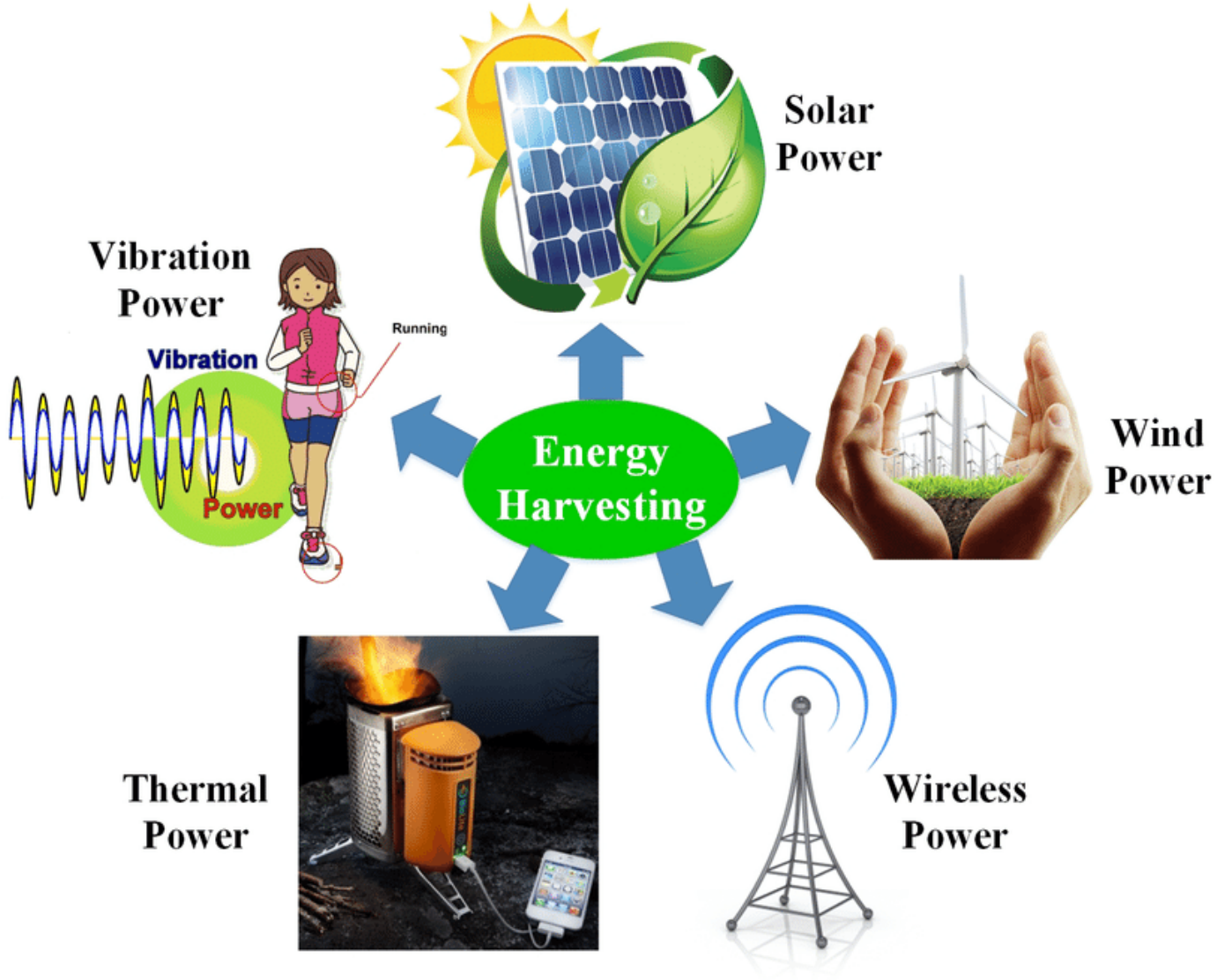
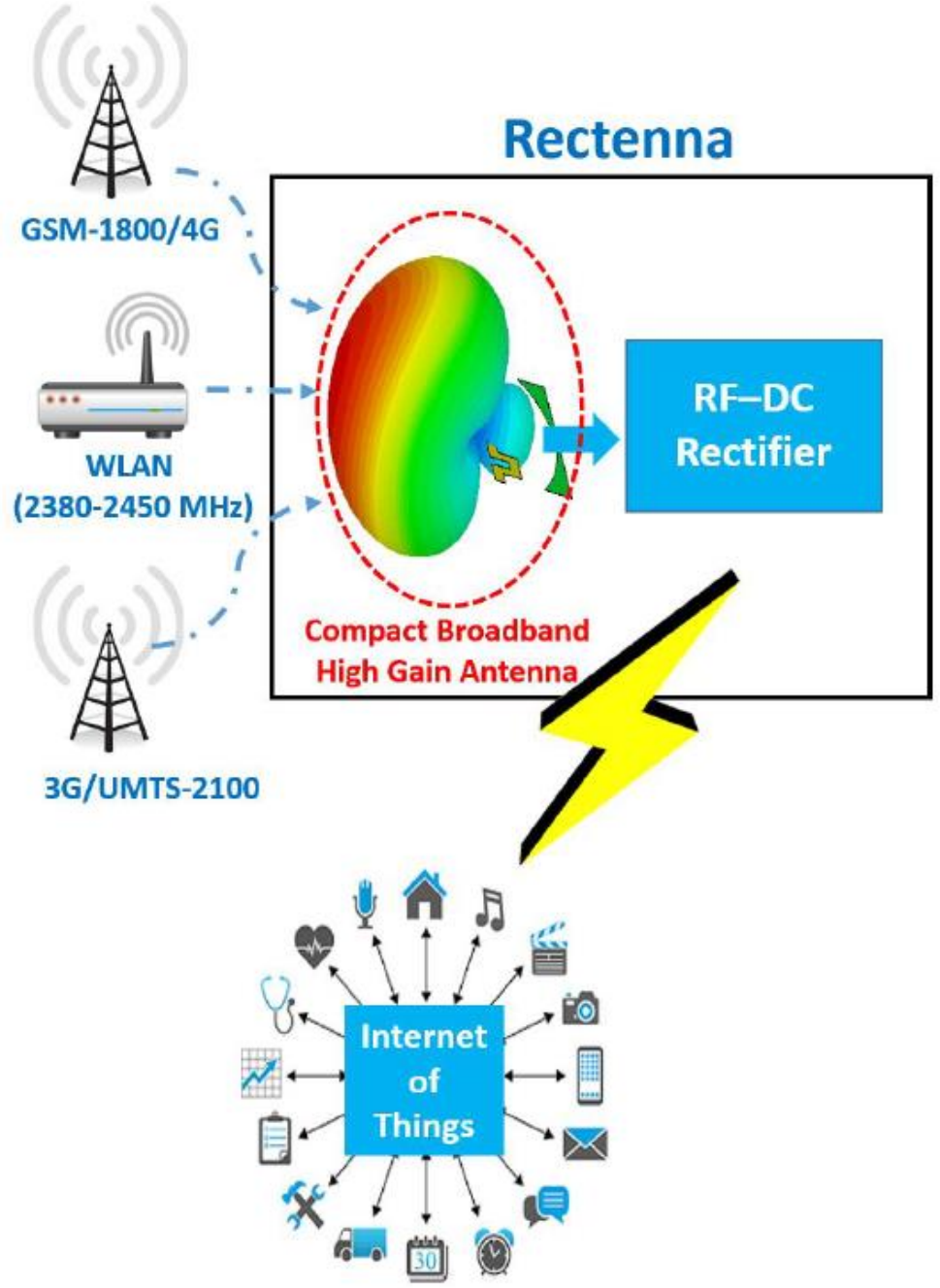
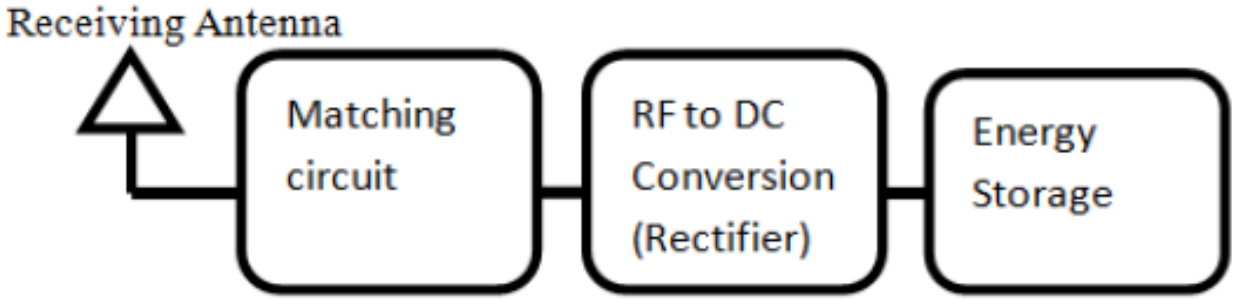
The energy harvesting is the process in which the energy from external sources is captured and storaged to feed low power devices.



What is a Rectenna?



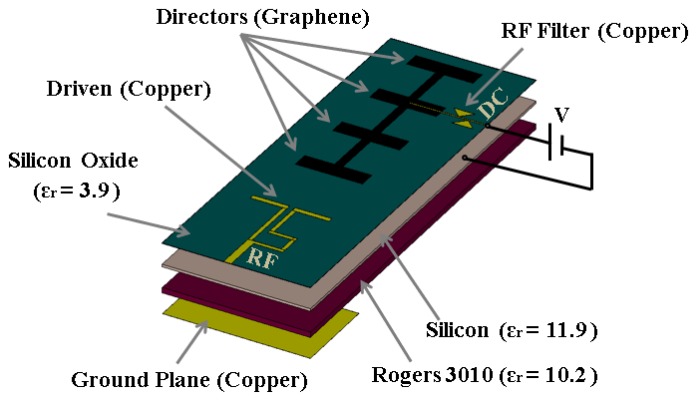


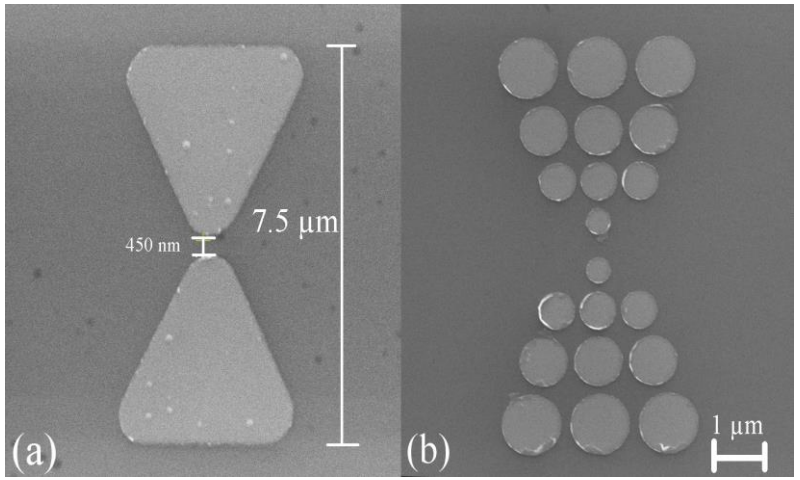
What are the design challenges?

- Antenna
  - Shape
  - Size
  - Material
  - Polarization
  - Frequency
- Matching circuit
  - Filter
  - Quarter wave transformer
- Rectifying circuit
  - Type of diode
  - Number of stages

Antenna

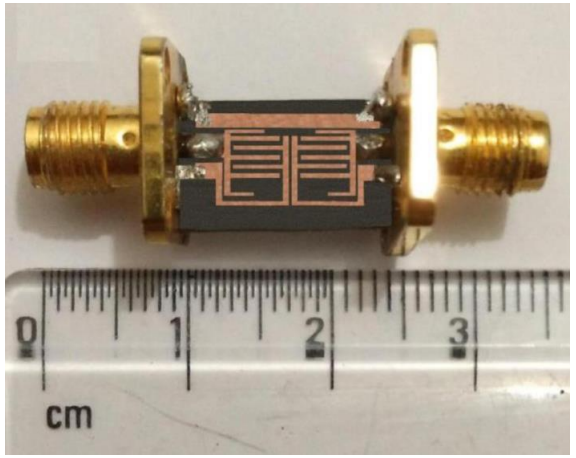
Any antenna designer must model a particular shape of the antenna and give the radiation parameters such as gain, impedance, VSWR, S-arameter, frequency range, polarization, so on

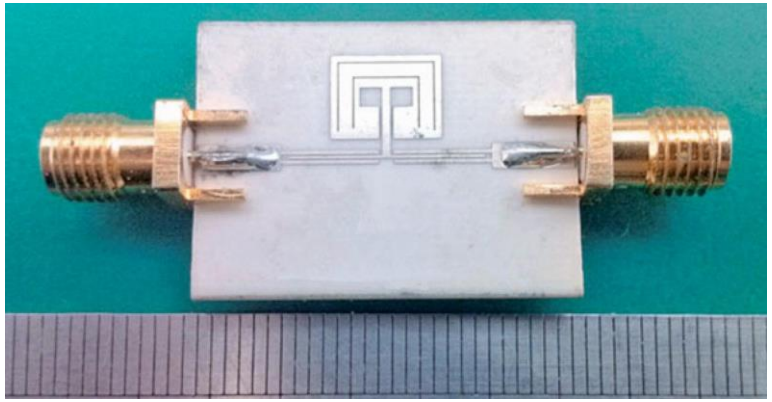


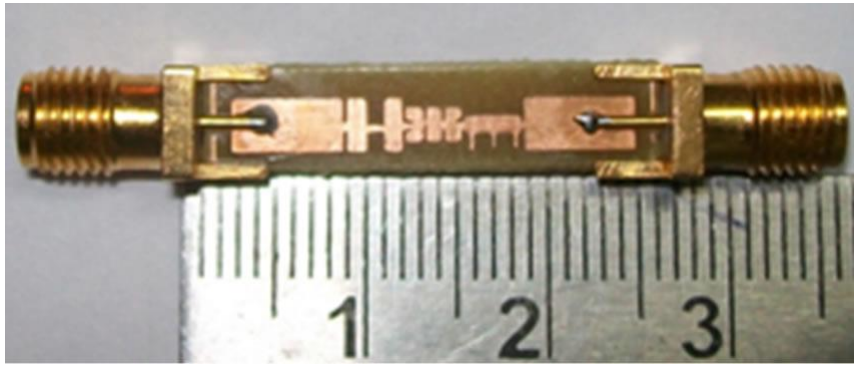


Matching circuit

Here, the design problem consists in find an structure to match the antenna impedance and the rectifier impedance.
The coils and capacitors must be printed on board circuits.
We normally use filters to reject any harmonic because of the diodes.

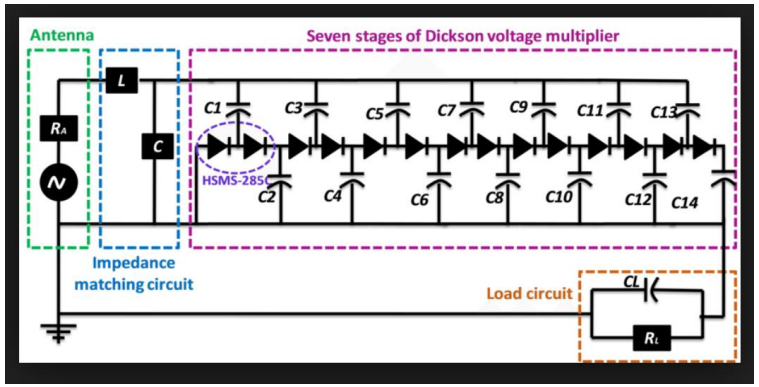


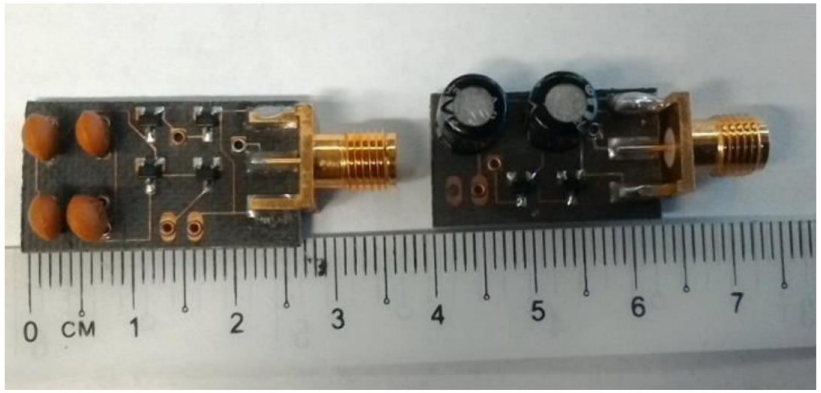


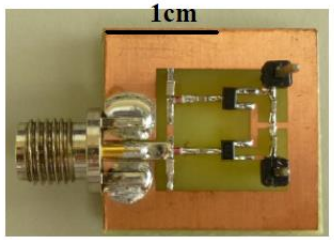


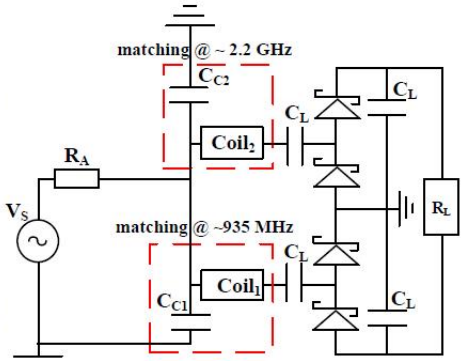
Rectifying circuit

Here, it is important to design a circuit with some stages to obtain more voltage, however, many of the capacitors or coils must be also printed on board.



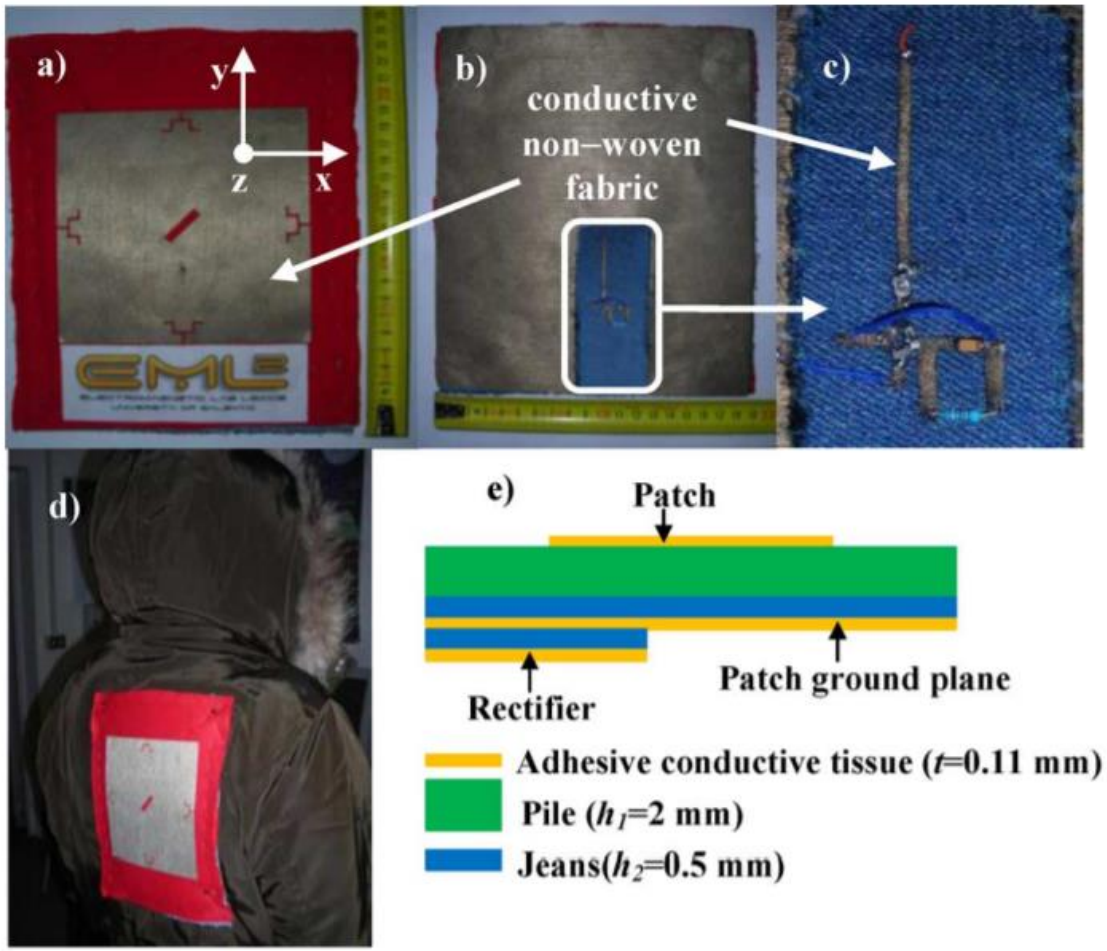






Example 1

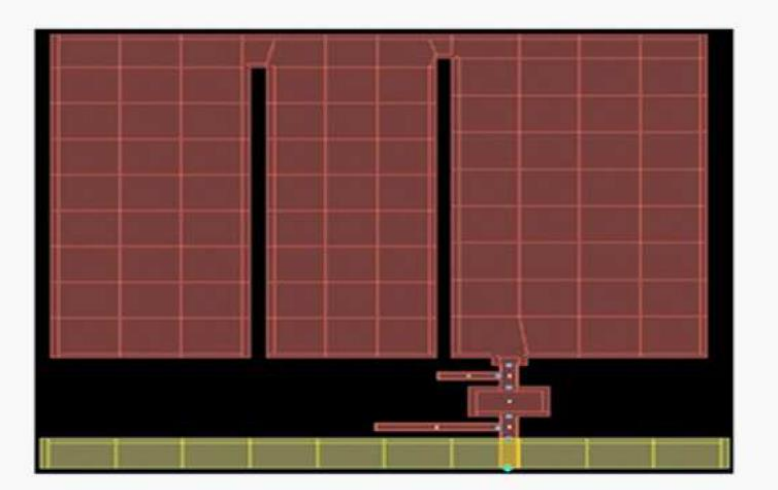
A textile rectenna for 800 MHz band obtain 14uw/m^2

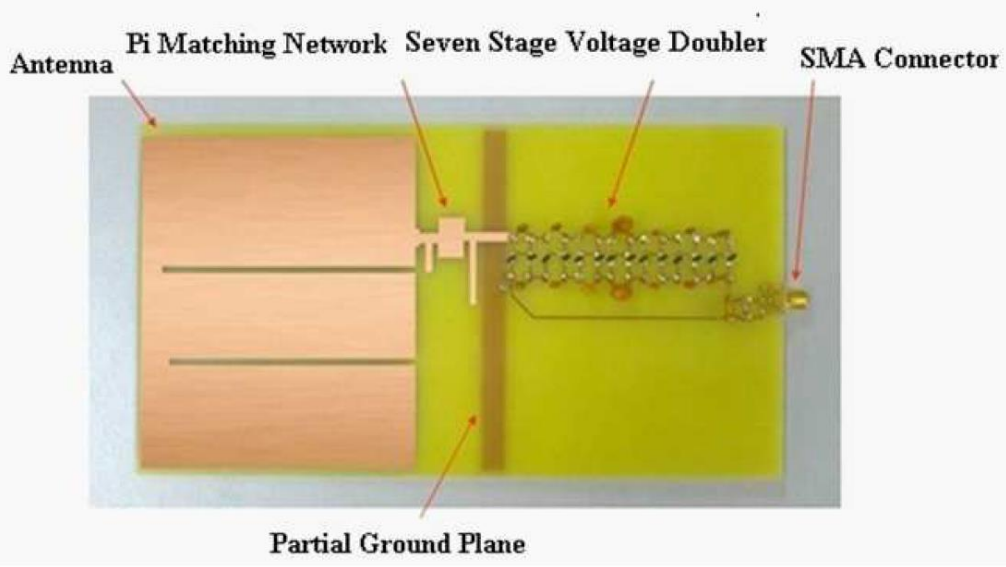


G. Monti, L. Corchia and L. Tarricone, "UHF Wearable Rectenna on Textile Materials," in *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 7, pp. 3869-3873, July 2013.

Example 2

Energy harvesting system at GSM-900 MHZ, this system can obtain 2.9 volts by means of a rectangular patch antenna on a FR susbtrate and a 7-stage rectifier circuit.





Md Din, N., Chakrabarty, C. K., Bin Ismail, A., Devi, K. K. A., & Chen, W. Y. (2012). Design of RF energy harvesting system for energizing low power devices. *Progress in Electromagnetics Research*, *132*, 49-69.

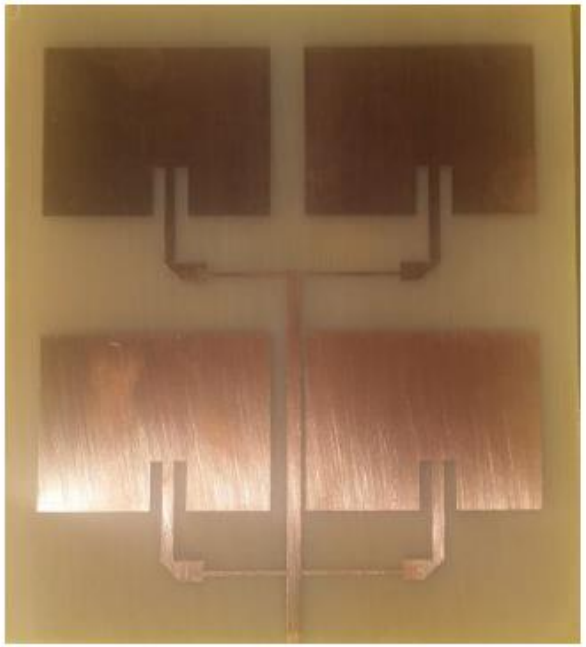
Example 3

This other system operates at 2.45 GHz. Its main novelty is a 40.1% of rectifying frequency.

CHUC, Doan Huu; DUONG, Bach Gia. Design, Simulation and Fabrication of Rectenna Circuit at S-Band for Microwave Power Transmission. *VNU Journal of Science: Mathematics-Physics*, 2014, vol. 30, no 3.

Example 4

A patch rectenna array of 4 rectangular elements at GSM-1800 MHz with a gain of 9.2dBi.



Sharma, T., & Saini, G. Microstrip Antenna Array for RF Energy Harvesting System, Vol. 45, No. 45, 2016.

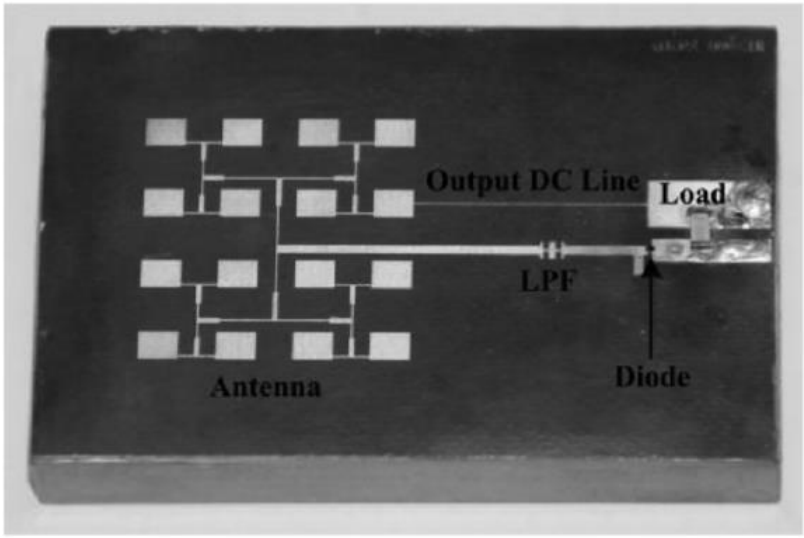
Example 5

This other research reported a circular rectenna array of 6 elements at 915MHz for energy harvesting.

XIE, Fangyi; YANG, Guo-Min; GEYI, Wen. Optimal design of an antenna array for energy harvesting. *IEEE Antennas and Wireless Propagation Letters*, 2013, vol. 12, p. 155-158.

Example 6

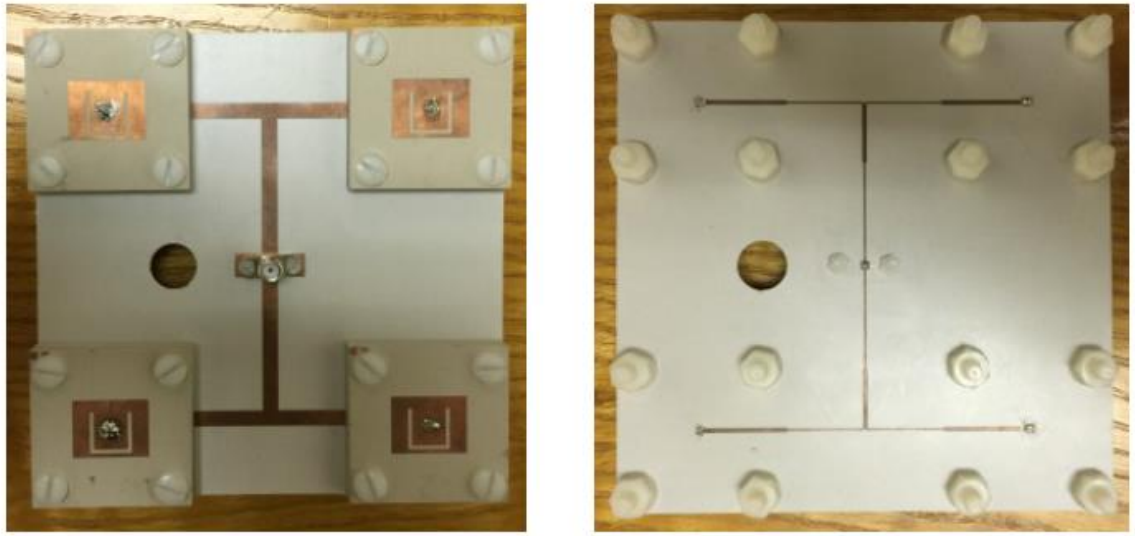
This other research presented a rectenna array of 16 elements at 35.7GHz with a rectifying efficiency of 67%.



Mavaddat, A., Armaki, S. H. M., & Erfanian, A. R. (2015). Millimeter-Wave Energy Harvesting Using 4X4 Microstrip Patch Antenna Array. *IEEE Antennas and wireless propagation letters*, *14*, 515-518.

Example 7

A microstrip patch rectenna arrays at 2.4 GHz with 100mV of DC output voltage:



GUDAN, Kenneth, et al. Ultra-low power 2.4 GHz RF energy harvesting and storage system with− 25dBm sensitivity. En *RFID (RFID), 2015 IEEE International Conference on*. IEEE, 2015. p. 40-46.

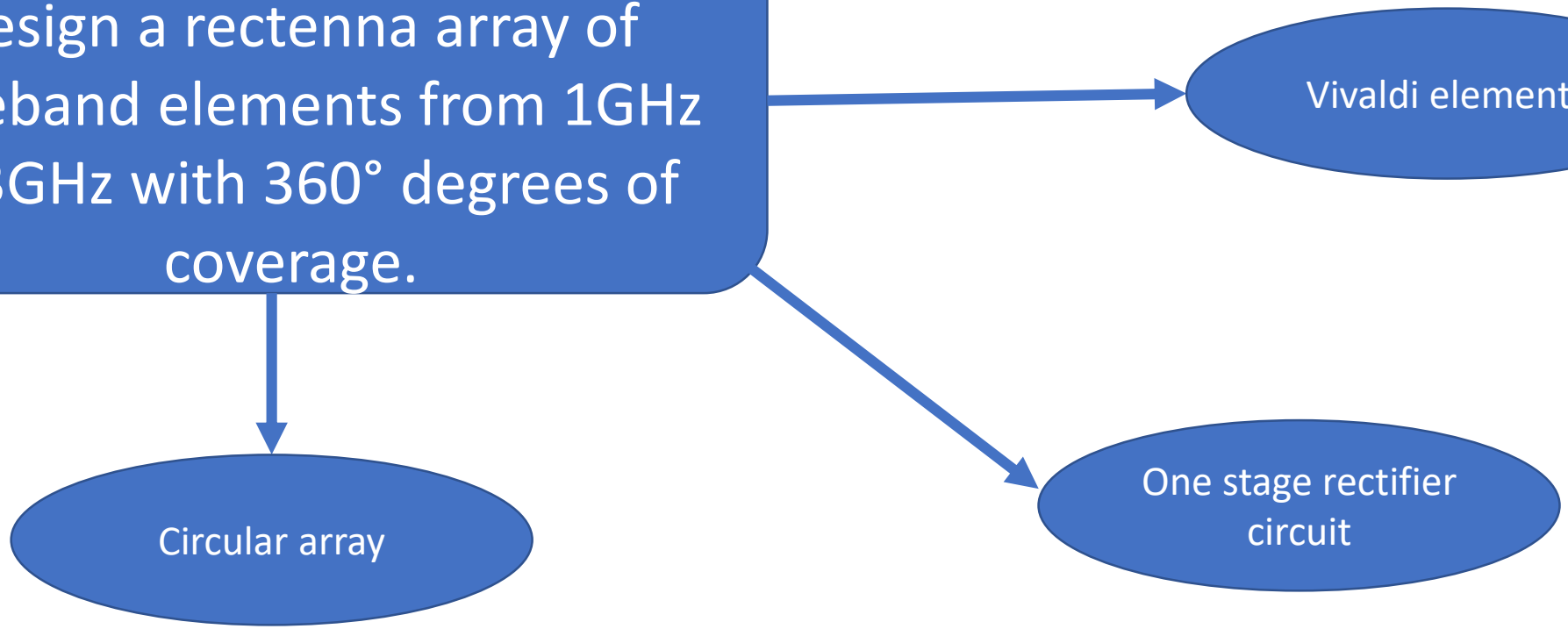
Comparative

Type	Frequency	DC OUTPUT	Size	Rectifier	Pattern
Rectangular textil patch	876 MHz	1.42 v	139mmx240mm	Built-in 1 stage doubler	Low gain
Rectangular patch	900 MHz	2.9 v	85mm x 106 mm	Built-in 7 stages doubler	Low gain
Rectangular patch	2.45GHz	9.7v	Not provided	Non integrated	Low gain
Rectangular patch	5.8 GHz	9.8 v	Not provided	Non integrated	Low gain
4-element rectangular patch array	1.78GHz	Not provided	144 mm x 130 mm	Non integrated	Directive / Moderate gain
6-element rectangular patch antenna array	915MHz	Not provided	300 x 300 mm	Non integrated	Directive / Moderate gain
16-element rectangular patch antenna array	35.7GHz	3v	30mm x 30mm	Integrated	Directive / Moderate gain
4-element rectangular patch	2.4 GHz	100mV	120mm x 120mm	Non integrated	Directive / Moderate gain

Wideband example

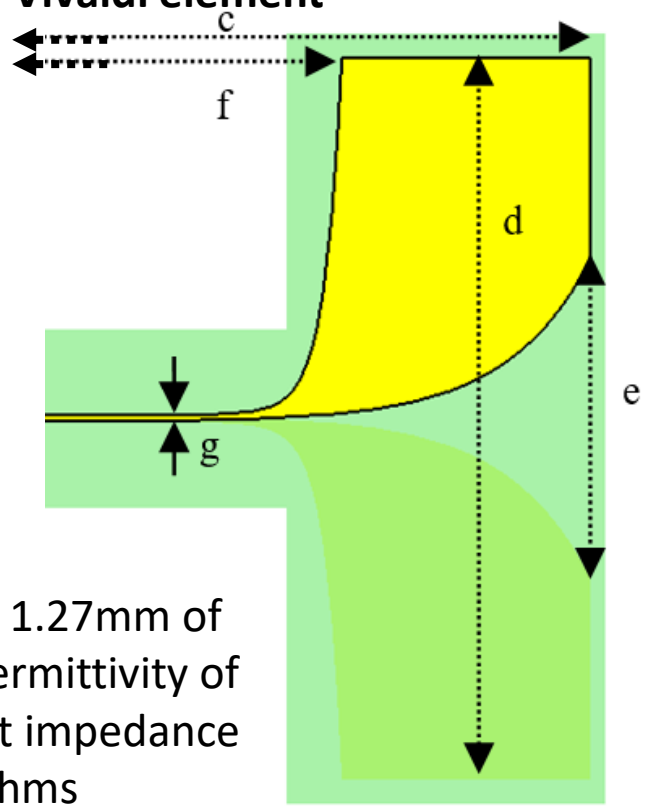
<u>Objective:</u>

Design a rectenna array of wideband elements from 1GHz to 3GHz with 360° degrees of coverage.

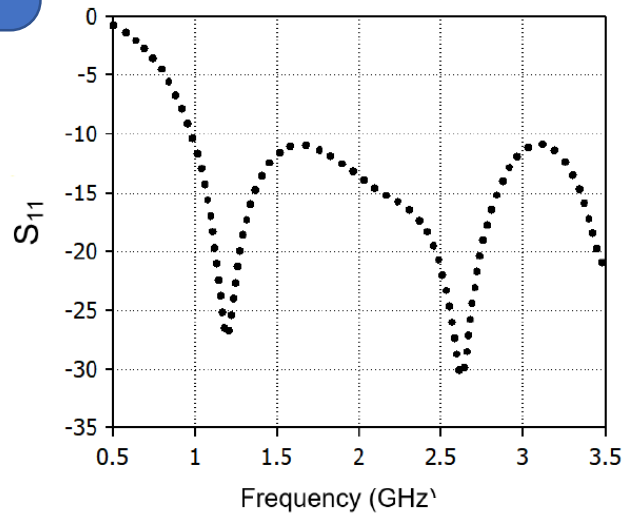


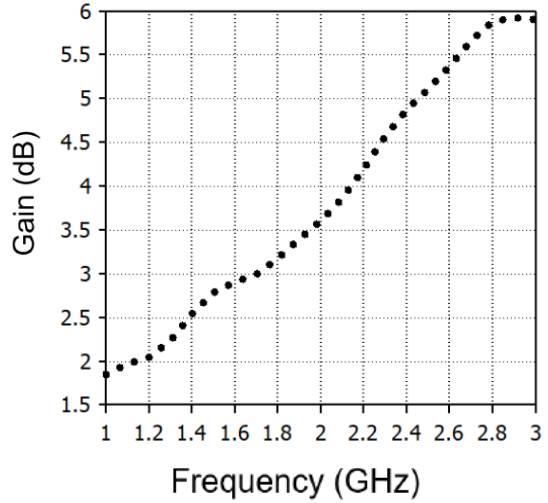
Wideband example

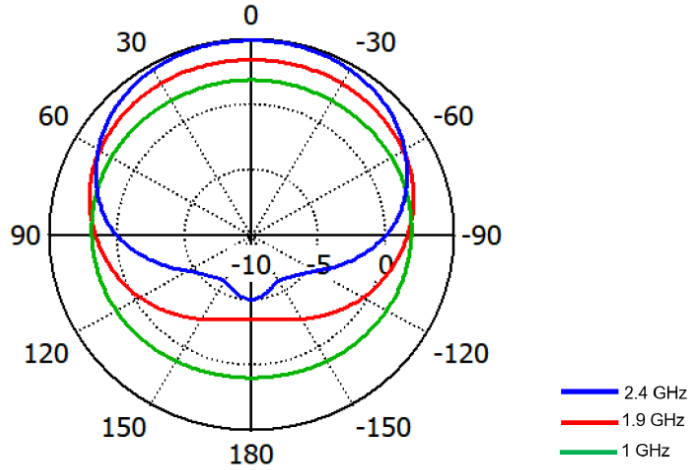
Vivaldi element



FR4 Board with 1.27mm of thickness and permittivity of 4.3. The element impedance is 100 ohms

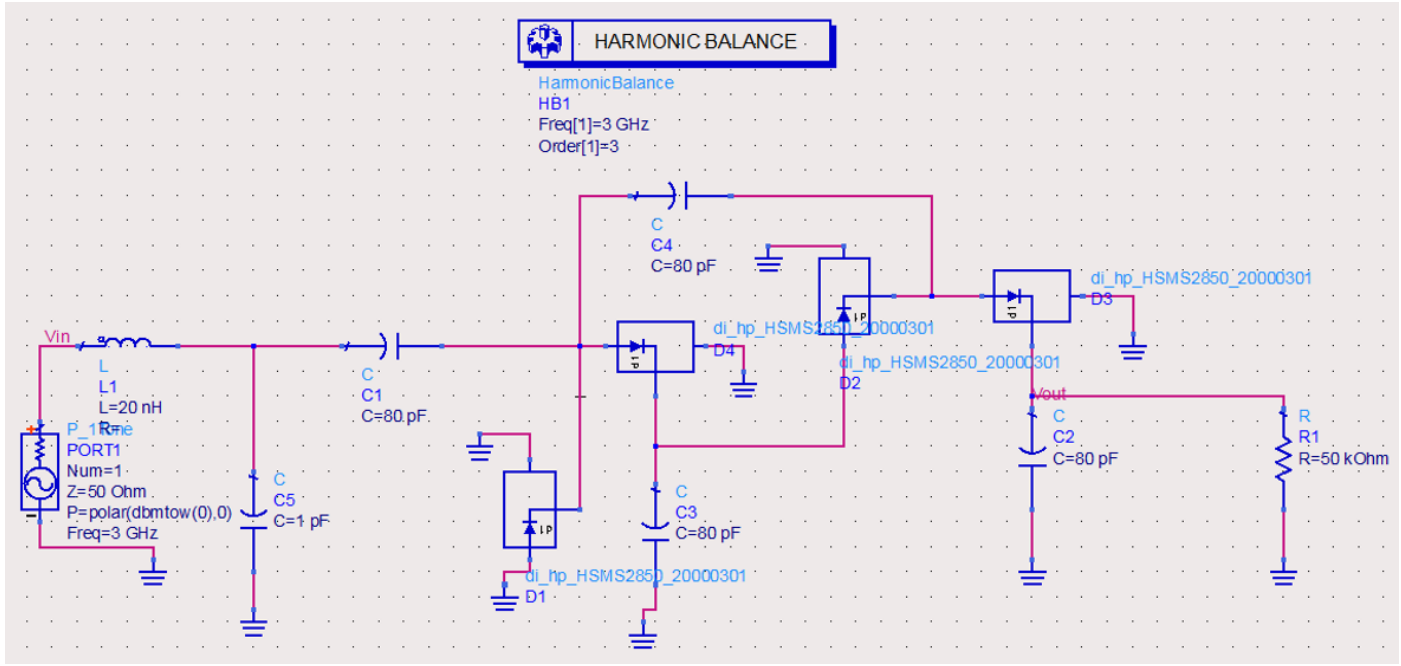


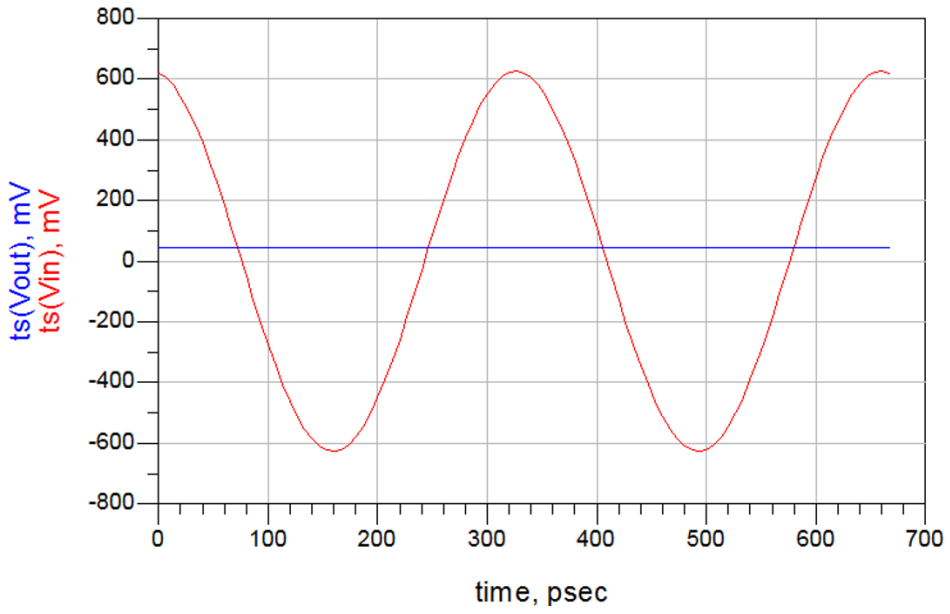




Wideband example

Rectifier circuit

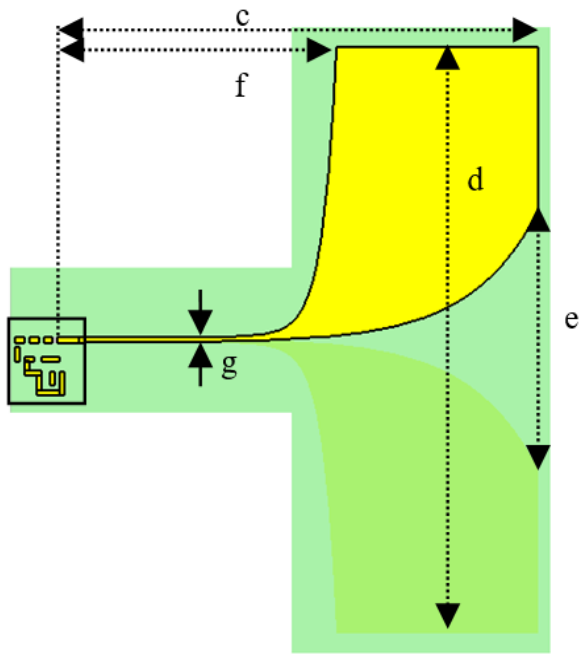




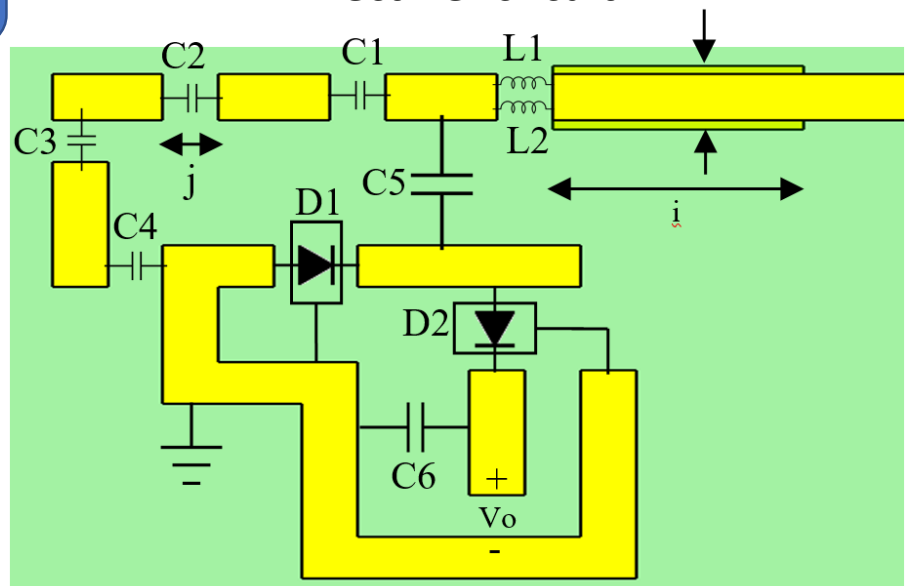
1 stage rectifier circuit with 4 Schottky diodes

Wideband example

Rectenna Element



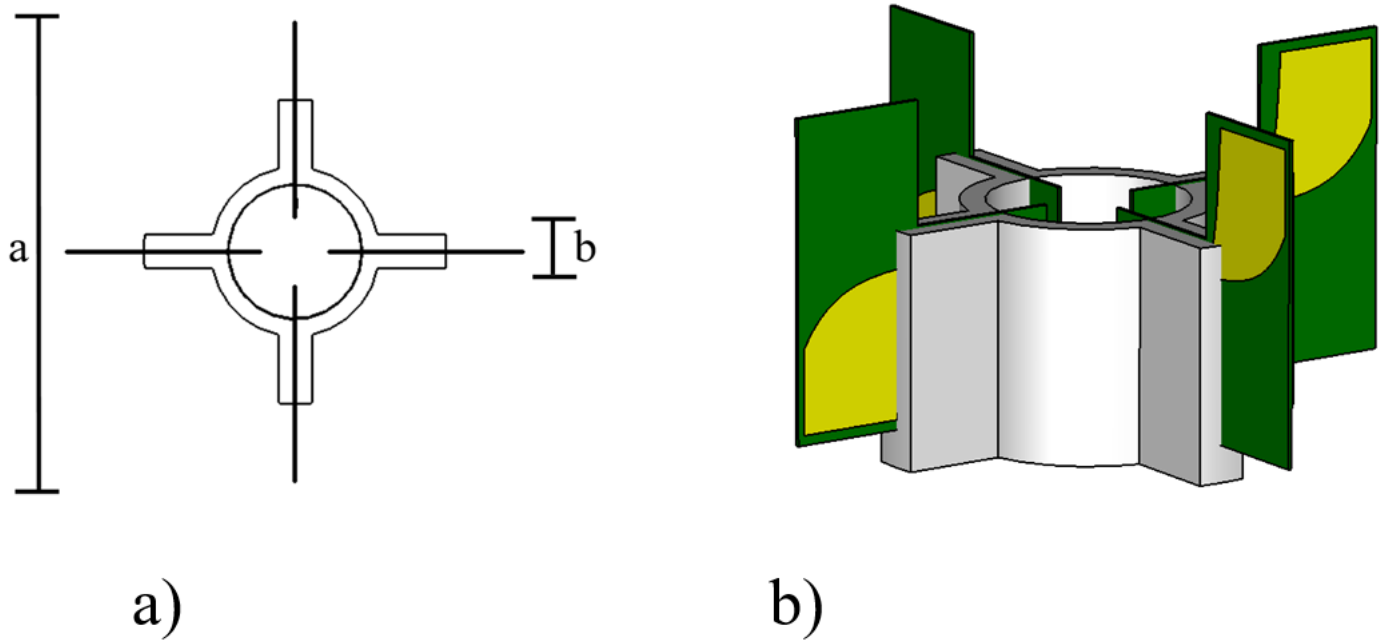
Rectifier circuit



c	d	e	f	g	h
98mm	122mm	53.7mm	54.93mm	1.1mm	1.54mm
i	**j**	**L1/L2**	**C1 to C4**	**C5 to c6**	**D1 /D2**
4.5mm	1mm	22nh	0.1pf	82pf	HSMS2850

Wideband example

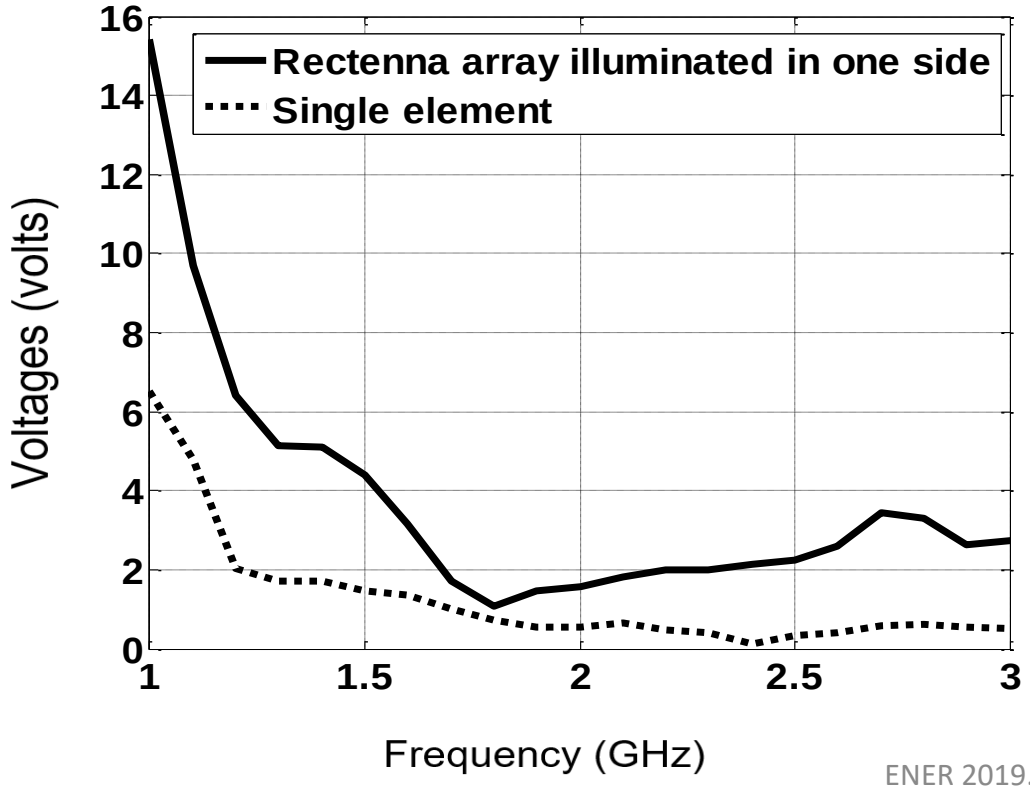
Circular Rectenna Array mounted in a 3D printed base

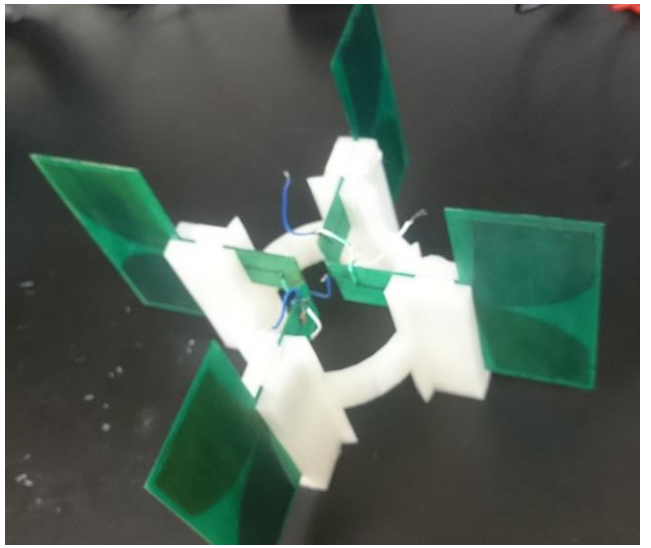


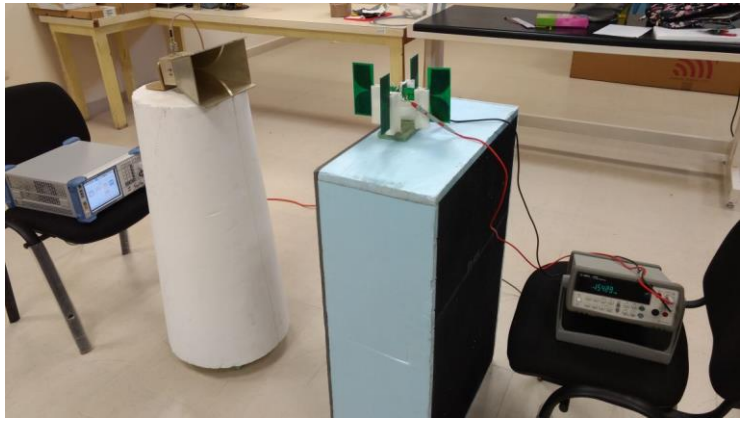
Rectenna array structure: a) top view and b) perspective view.

Wideband example

The rectifying efficiency was 39%.







Conclusions

- The energy harvesting by using rectennas is other alternative to feed low power devices.
- Some important issues are in current designs, however, this technology is still emerging and has potential applications for near future.
- Future works are mainly oriented to miniaturized the rectennas.

THANK YOU