# 5.8 GHz Energy Harvesting of Space Based Solar Power Using Inkjet Printed Circuits on a Transparent Substrate

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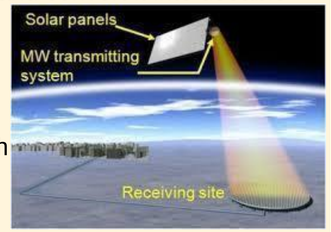
## Abstract

Space-based solar power satellites (SPS) can be used to gather solar energy in space and beam it on Earth through microwaves. We present a working design for a transparent, 5.8 GHz rectenna using a modified off-the-shelf desktop ink-jet printer to develop inexpensive ground stations harvesting microwave power. Preliminary tests show the ability of the prototype to convert microwaves into sufficient DC power to turn on an LED; moreover, the verified substrate transparency to ultraviolet radiations suggests the possibility of deploying ground stations above land usable for agriculture.

## Background

- Current Solar Power harvesting techniques require dedicated landmass
- Rectennas on transparent substrates can be used to collect microwave energy at 5.8 GHz sent by Space Solar Power Satellites and convert it into useable Direct Current (DC) power
- Circuits on transparent substrates will allow land to be used for both agriculture and energy harvesting
- Reducing costs of earth station manufacture will leverage the overall costs of SPS deployment.




## Printing Setup

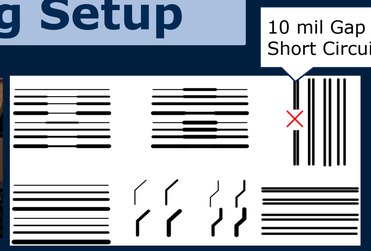




Fig. 1: Printing resolution

**Tab. 1 Printing Setup [1] Costs breakdown**

| Item | Cost ($) |
|---|---|
| 100 ml silver ink (NBSU-MU10) | 500 |
| Printer MFC-J5910DW | 159 |
| 100 PET sheet (NB3GUA4X100) | 142.22 |
| 6.2 mil conductive epoxy kit | 62.50 |
| 4 empty cartridges | 15.99 |
| 10 syringe filters | 15.16 |
| **Total** | **894.87** |

## Properties of Flexible Substrate

$$C = \frac{\epsilon_r * \epsilon_o * A}{D}$$

$\epsilon_r = 2.8$

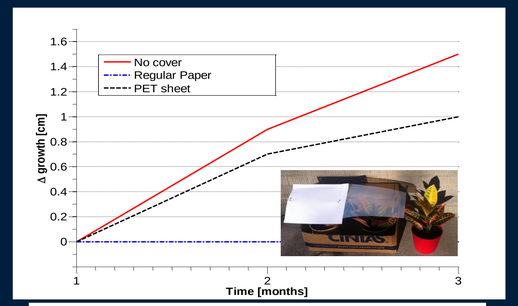
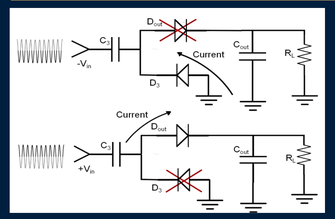
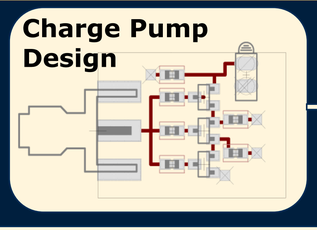



Fig. 2 Plant Growth vs. Time *(Croton Petra)*

## Charge Pump and Patch Antenna




A Rectenna composed of a Charge Pump [2] and a Patch Antenna [3] is used to collect RF signals and converts them into DC power

An LED requiring 1.8V is used for visual verification of power conversion. Discrete capacitors were used on the 1st printed prototype

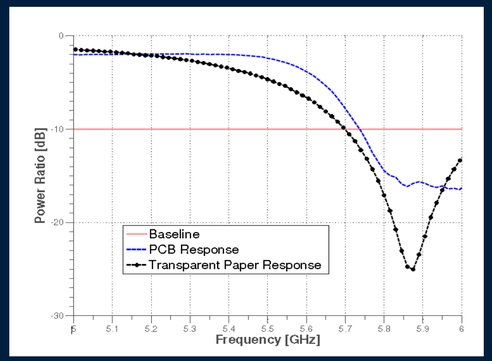
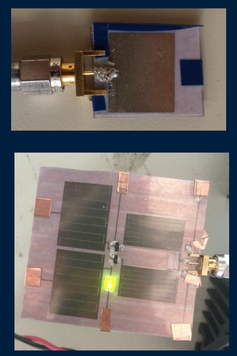



Fig. 3: Antenna $S_{11}$



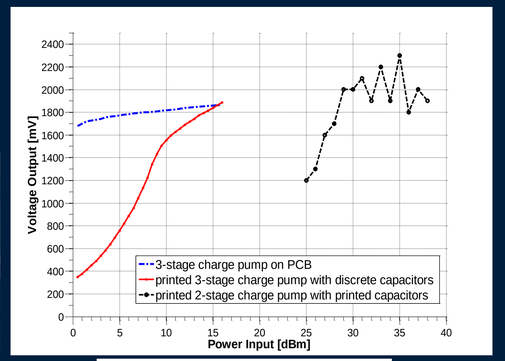
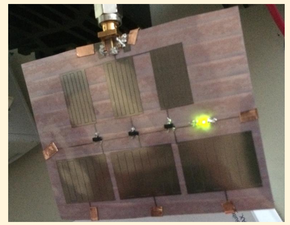



Fig. 4: RF to DC conversion

## Conclusions

- An off-the-shelf desktop printer using nano-particle ink has been tested (Fig. 1);
- The flexible substrate is transparent to the solar light necessary for the plant growth (Fig. 2);
- The printed patch antenna is well matched at 5.8 GHz (Fig. 3);
- Microwave power at 5.8 GHz has been converted into DC power (Fig. 4). The charge pump managed to collect 1.8 V needed to turn on LED;
- A 3-state working charge pump has been realized using printed capacitors;
- Printed antenna operating at frequency of 5.8 GHz with signal strength of 40 dBm turns on LED at a maximum distance of 2.5 cm (Fig. 5).



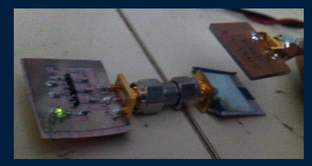


Fig. 5: 5.8 GHz RF signal at 40 dBm at 2.5 cm away

***Although the rectenna efficiency needs to be improved, the preliminary results suggest the possibility of harvesting energy from solar space satellites at low costs without sacrificing land use for agriculture***

## References

[1] Y. Kawahara et. al. *Instant Inkjet Circuits: Lab-based Inkjet Printing to Support Rapid Prototyping of UbiComp Devices.* Ubicomp 2013;

[2] U. Karthaus. *Fully Integrated Passive UHF RFID Transponder IC With 16.7-W Minimum RF Input Power.* IEEE Journal of Solid-State Circuits. Oct 2003.

[3] C. A. Balanis. *Antenna Theory and Design*. Wiley, 2nd ed 1997