5.8 GHz Energy Harvesting of Space Based Solar Power using Inkjet Printed Circuits on a Flexible, Transparent Substrate

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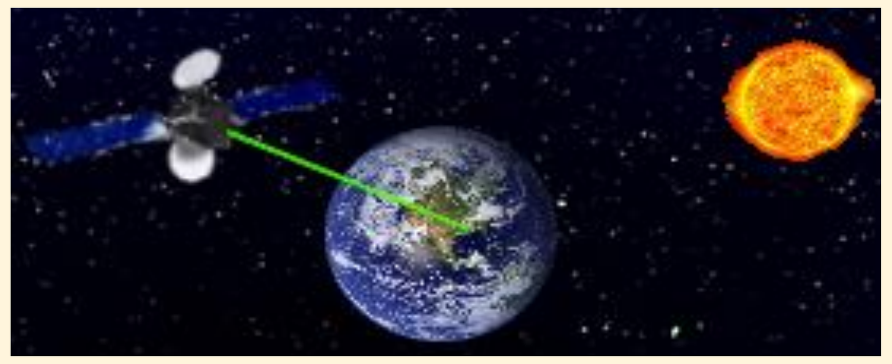
Overview

A Space Solar Power System (SSPS) can be a feasible source of renewable energy, which in the future may yield 1.2GWe [1], enough to supply a medium city [2]. Satellites receive continuous solar power that can be sent to Earth through microwaves and converted in usable energy.



Objective

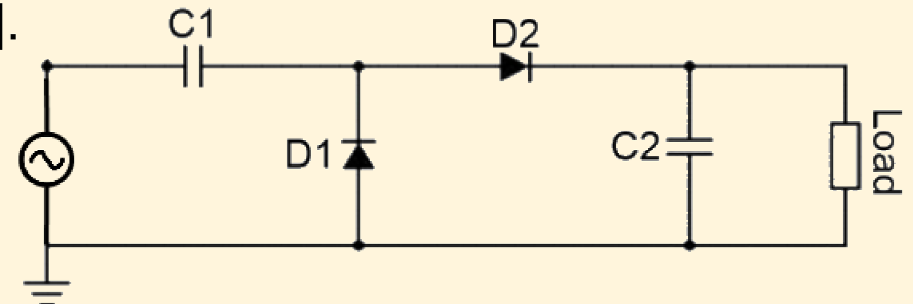
Our goal is to implement an affordable ground station to receive a 5.8 GHz microwave transmission and convert that into DC power using silver inkjet printed circuits on a cheap, transparent, flexible substrate.

The power received (W) from a satellite can be calculated as:

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2 \quad (1)$$

1) Replicate the real scenario (satellite to ground station) in lab settings using a magnetron.

2) Build a *rectenna* to receive power transmitted from magnetron.
- Rectennas (the combination of an antenna and rectifier) can be used to convert RF energy to DC power [3].



3) Print rectenna on a flexible substrate using inkjet printing, reduce number of components to assemble, reduce prototyping cost and time.
- Silver inkjet printing [4] opens a venue for fast, cheap PCB manufacturing for high-frequency applications and large-area circuits.
- The rectenna can printed on a flexible, transparent sheet of polyethylene terephthalate (PET).

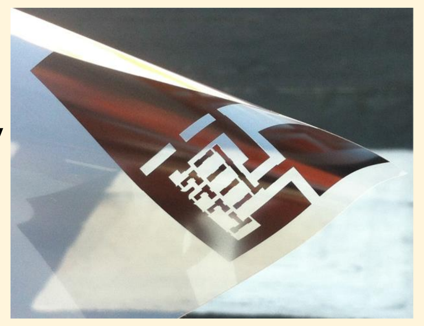
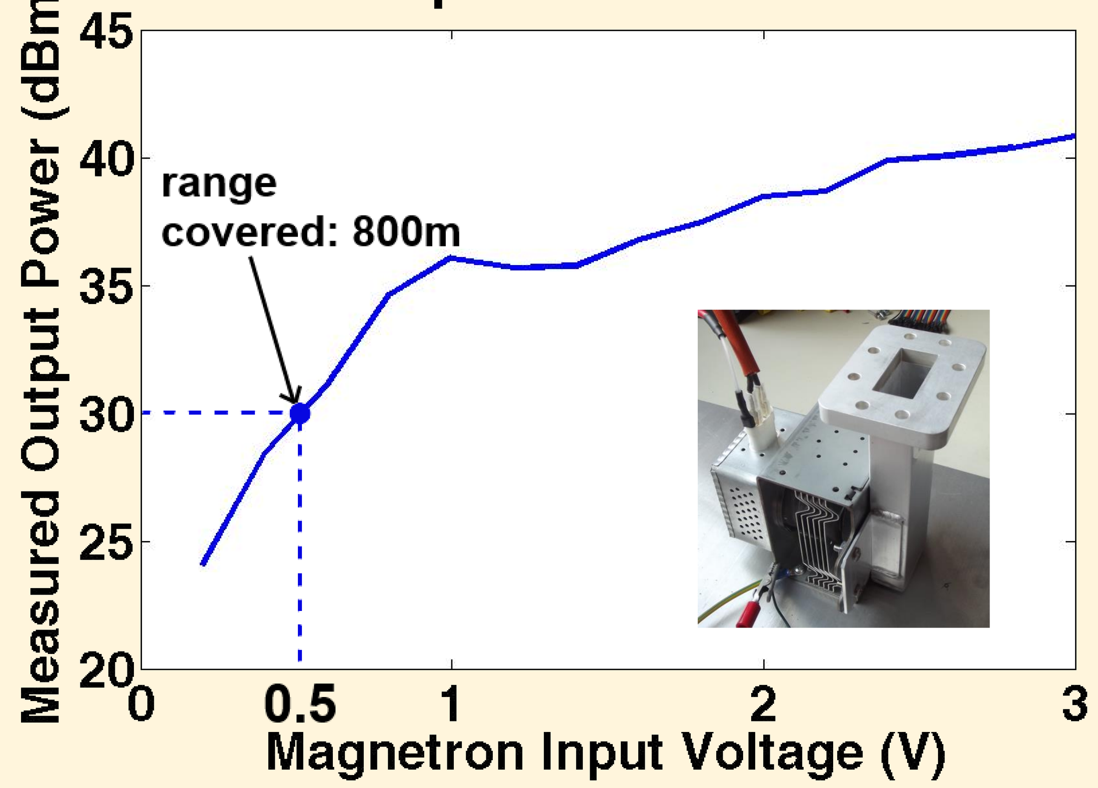


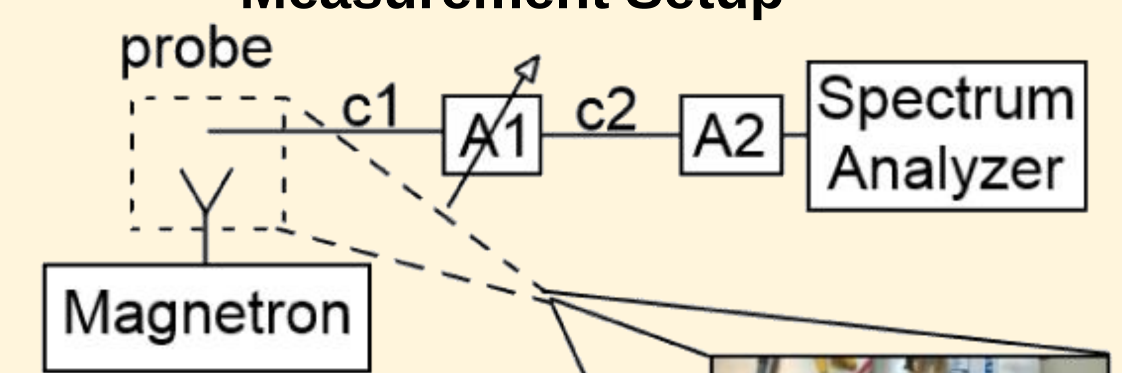
Fig. 1: Example of an inkjet printed circuit

5.8 GHz Magnetron Tuning

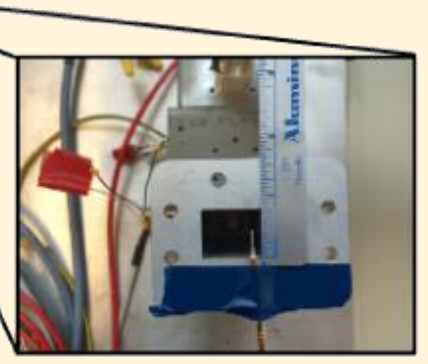
Magnetron Voltage vs Measured Output Power



Measurement Setup

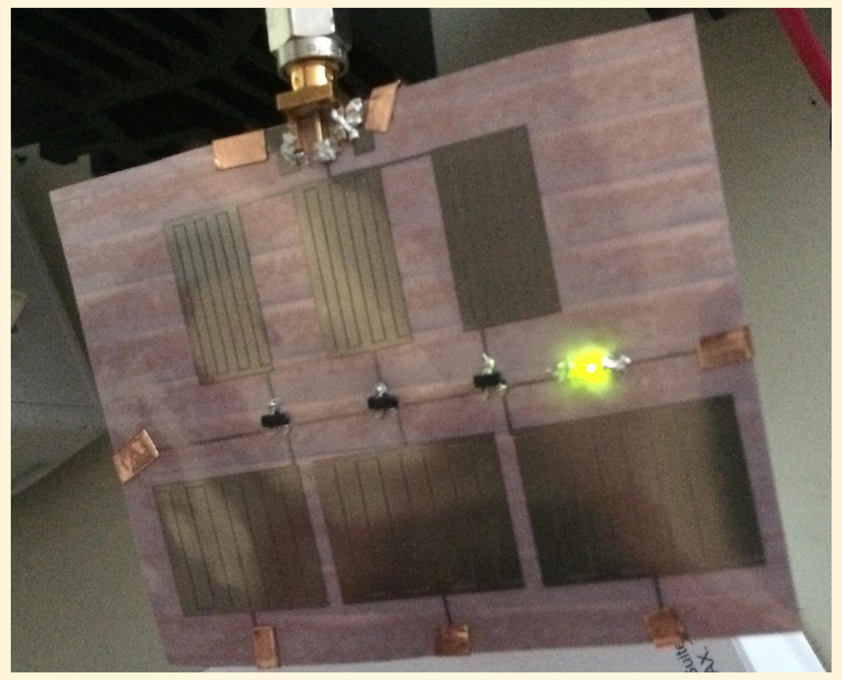


Labels	Description
c1	coaxial cable 1
A1	variable attenuator (used 20dB, 30dB)
c2	coaxial cable 2
A2	30dB attenuator
probe	1.1708dB
total attenuation:	
A1@20dB	56.1708 dBm
A1@30dB	64.6708 dBm

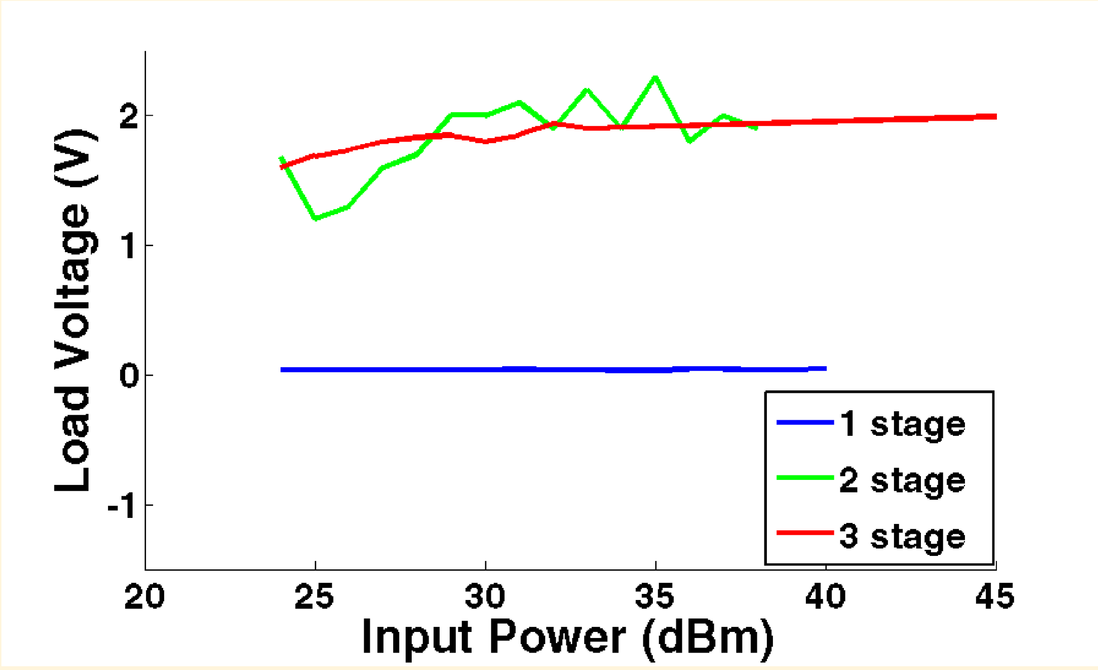


Rectifier Setup and Results

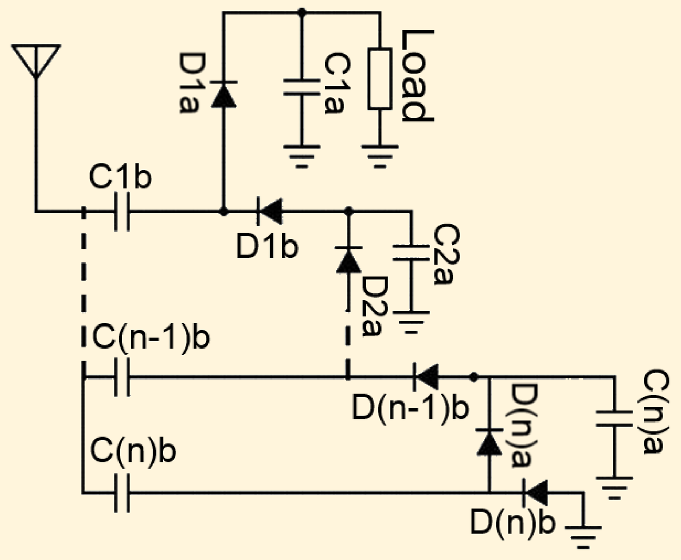
Three Stage Rectifier with Interdigitated Capacitors Turning on an LED Load at 5.8GHz



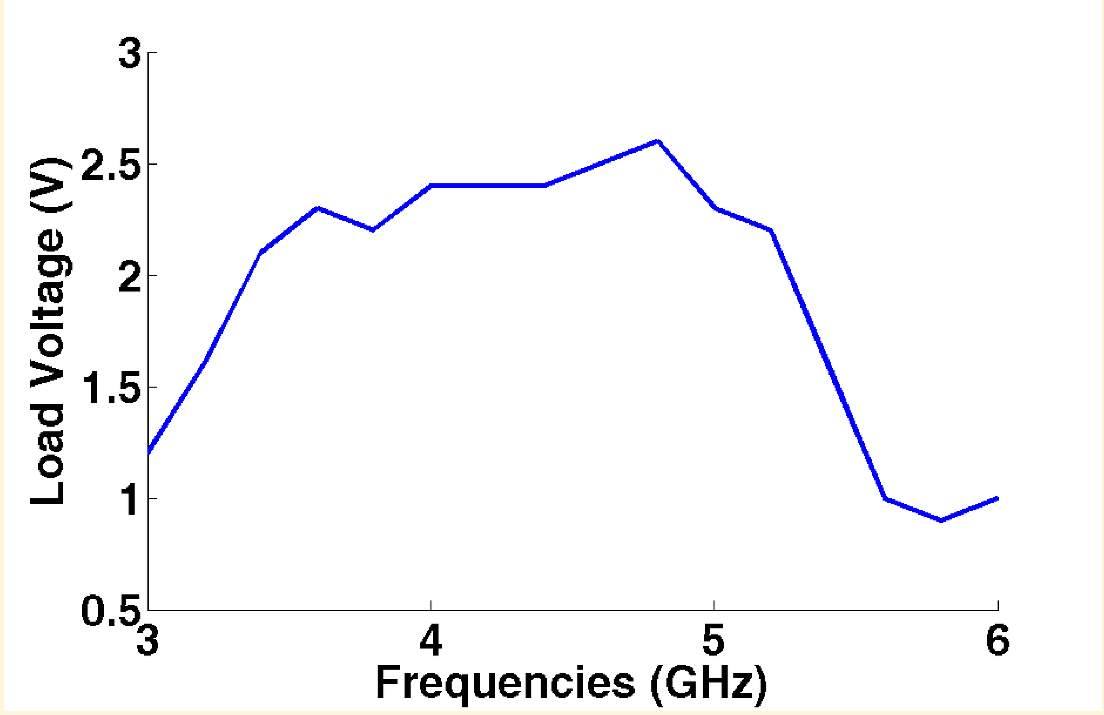
5.8GHz Input Power vs Load Voltage



Rectifier General n-stage Schematic and Prototypes



Stage 2 Rectifier with Interdigitated Capacitors Frequency vs Load Voltage



Observations

- A magnetron output of 30 dBm allows to replicate a SSPS system in outdoor settings (800 m)
- The printed two and three stages rectifier are capable of reaching the threshold voltage to turn on an LED (10 dBm)
- The rectifiers, with the minimum number of lumped components requires at least 25 dBm of RF power to turn on the LED.
- Interdigitated capacitors are more stable the more interweaving 'digits' are added

Future Work

- Optimize the rectifier large to small capacitance ratios
- Improve the rectifier design to achieve higher matching at 5.8 GHz
- Measure the losses of the substrate
- Test loads that require more power such as charging a cell phone or turning on an LED Display
- Print antenna and rectifier (rectenna) as a single unit
- Test the wireless power transfer between the magnetron and the rectifier.

References

[1] R.M. Dickinson, "Magnetron directional amplifier space solar power beamer concept design," in 35th IECEC Proc., Las Vegas, NV, 2000, pp. 1469-1479.

[2]http://www.businessdictionary.com/definition/gigawatt-GW.html. [Accessed: 31- March-2015].

[3] D. M. Dobkin, "The RF in RFID", Newnes, 2007.

[4] Yoshihiro Kawahara, Steve Hodges, Benjamin S. Cook, Cheng Zhang, Gregory D.Abowd, "Instant Inkjet Circuit: Lab-based Inkjet Printing to Support Rapid Prototyping of UbiComp Devices", 2013.

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