A 2.4 GHz Rectifier Insensitive to the Angle of Incidence of Incoming Waves

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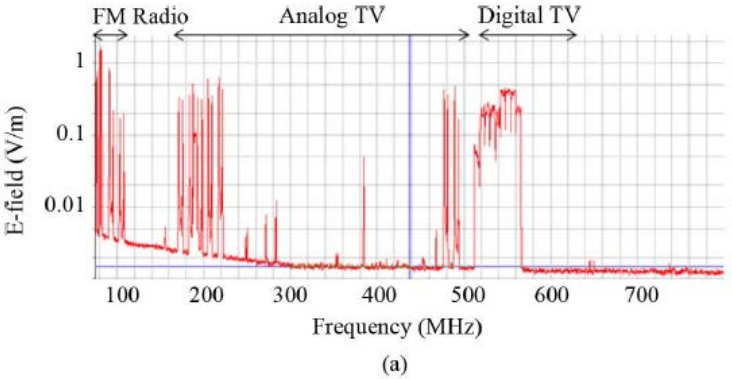
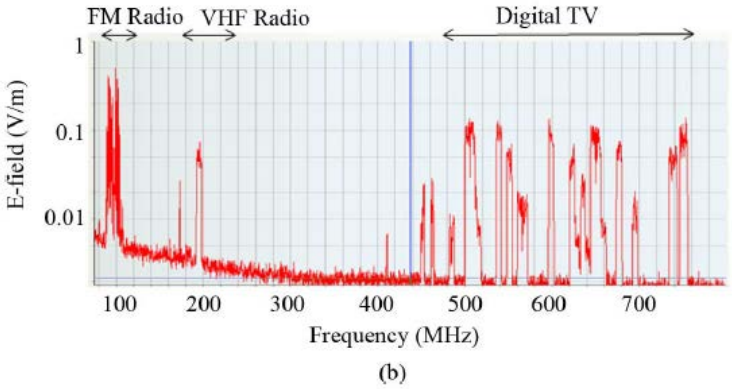
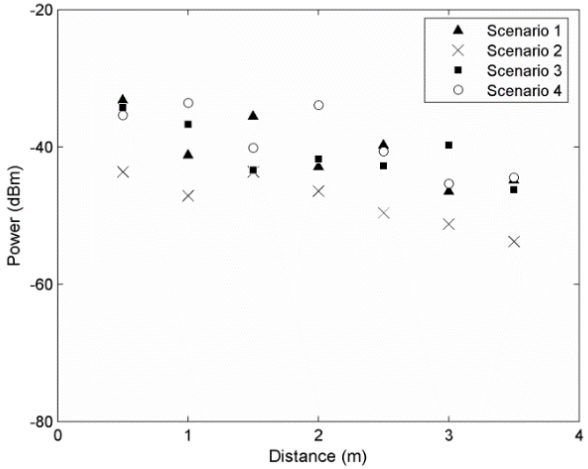
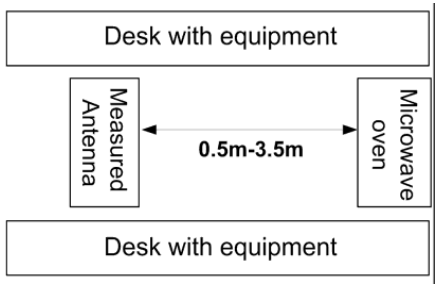
Ambient RF Energy







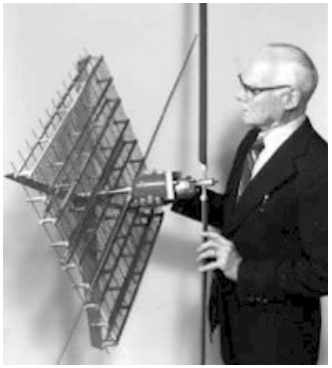


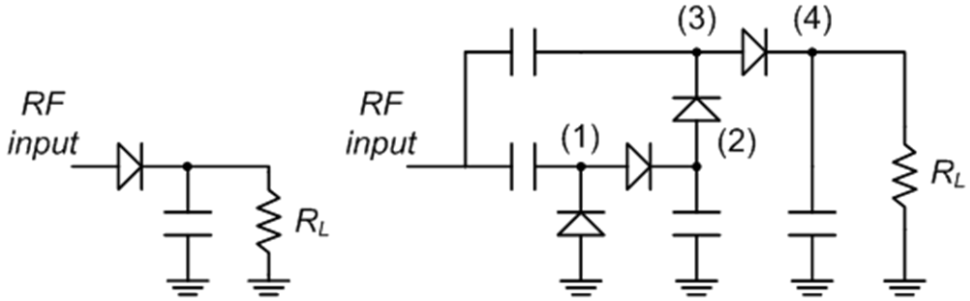
R. Vyas, B.S. Cook, Y. Kawahara and M. M Tentzeris, "E-WEHP: A Battery less Embedded Sensor-Platform Wirelessly Powered From Ambient Digital-TV Signals," Microwave Theory and Techniques, IEEE Transactions on , vol.61, no.6, pp.2491,2505, June 2013

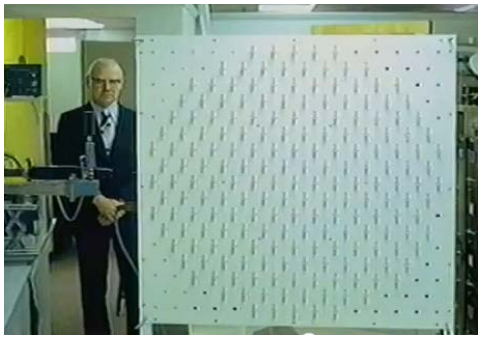
RF Energy Harvesting

Key element: Rectenna (Brown US3434678, 1969).

Rectifier circuits: envelope detector,
charge pump circuits Schottky diodes,
low / zero barrier diodes

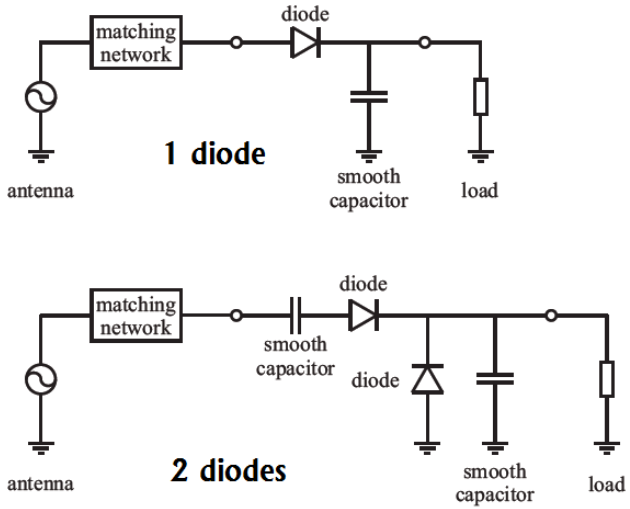


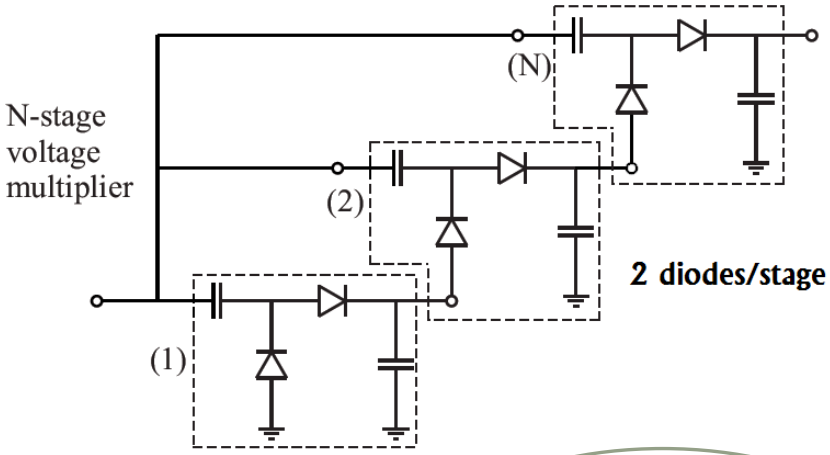




Reported UHF rectifier efficiencies for available input power levels in the order of 10 µW are approximately 20 %, and increase to > 50 % for available power levels of 100 µW.

RF Energy Harvesting





$$\eta = \frac{P_{DC}}{P_{RF}} = \ldots = \frac{V_R^2/R}{P_{RF}}$$

Goal: maximize η

Wilkinson Combiner Rectifier

Idea ?

- RF rectifier + RF Wilkinson combiner

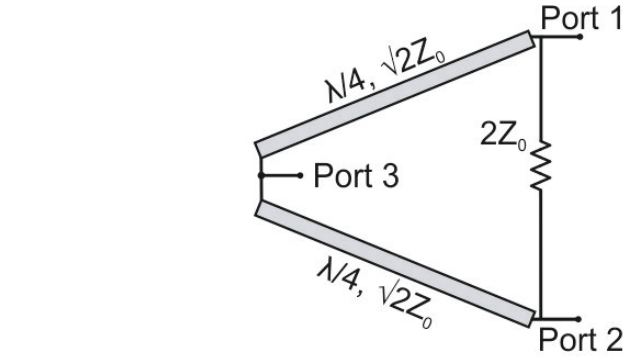
Novelty?

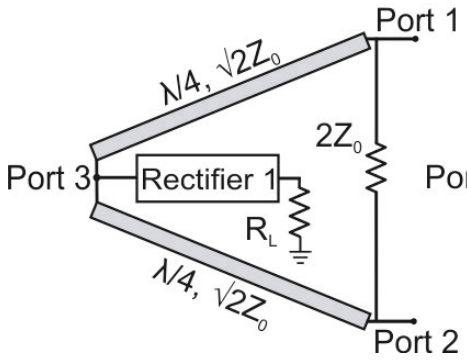
- Replace the isolator Resistor
- Second power recycle circuit

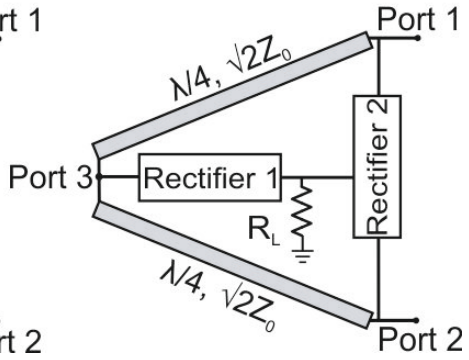
Result?

- Increased efficiency range

for a wide range of incident angles

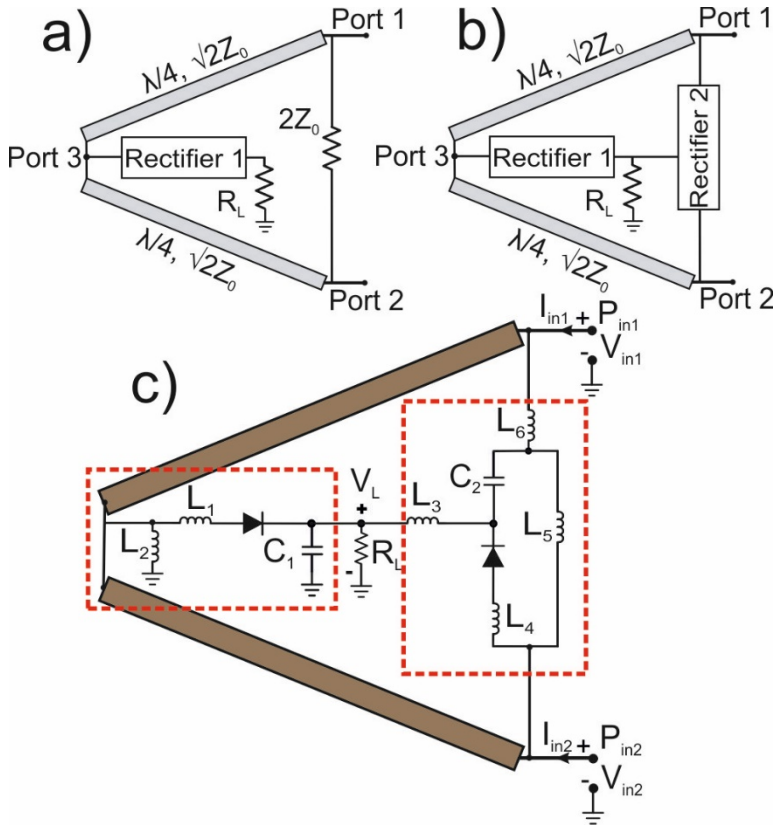






Combiner circuit

- Two Wilkinson RF inputs + DC combiner through the two rectifiers.
- Operating frequency 2.4 GHz -> RFID readers
- Two single diode rectifier circuits
- L matching networks
- P_{in}=-20 dBm



Design & Optimization

- Goal: increase RF-to-DC efficiency
- Single low cost diodes: SMS7630-040LF
- FR-4 lossy substrate: $\varepsilon_r = 4.58$, $\tan\delta = 0.022$, copper thickness 35 μm.

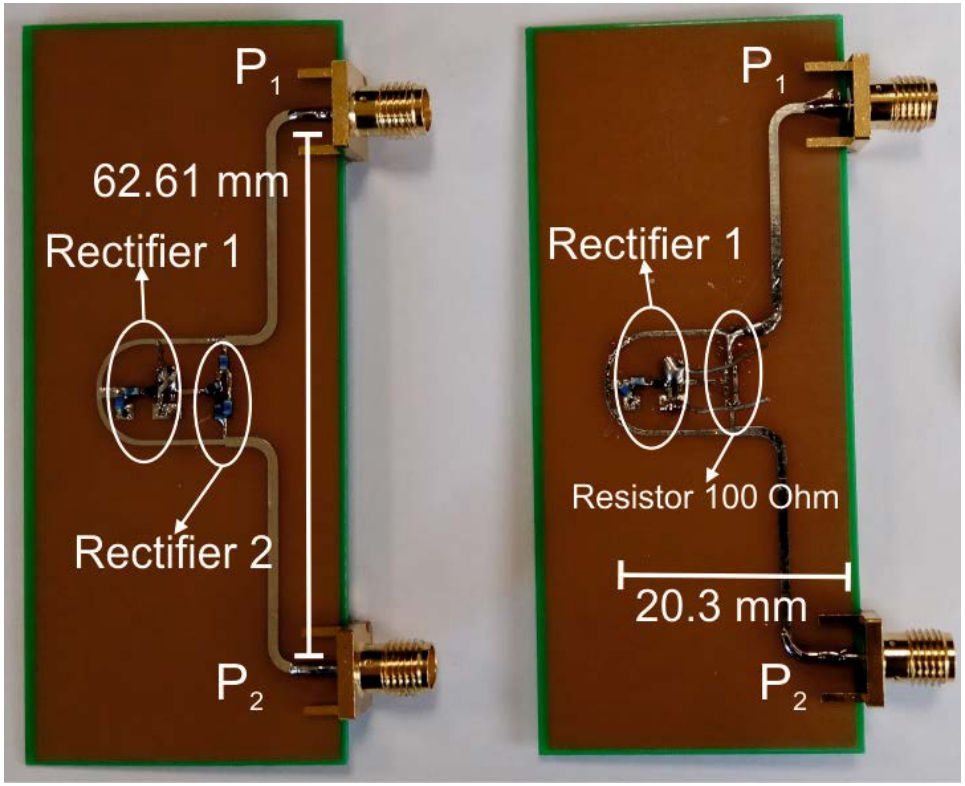
- ADS Keysight Technologies ->HB analysis
- Optimization with degrees of freedom Ci, Li, Ri

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_L^2 / R_L}{P_{in,1} + P_{in,2}}$$

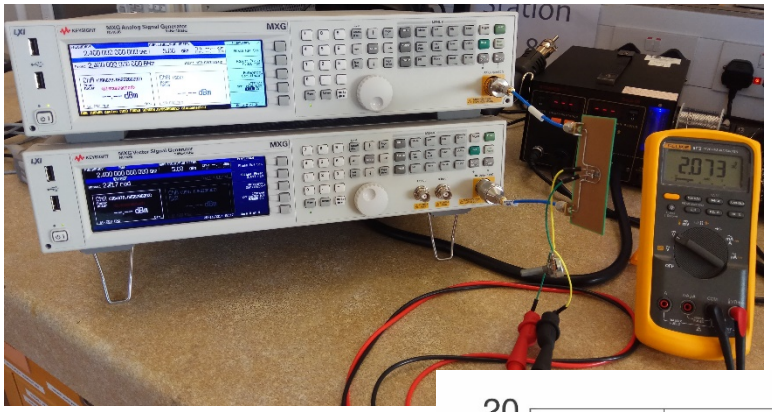
Fabrication

Two circuits

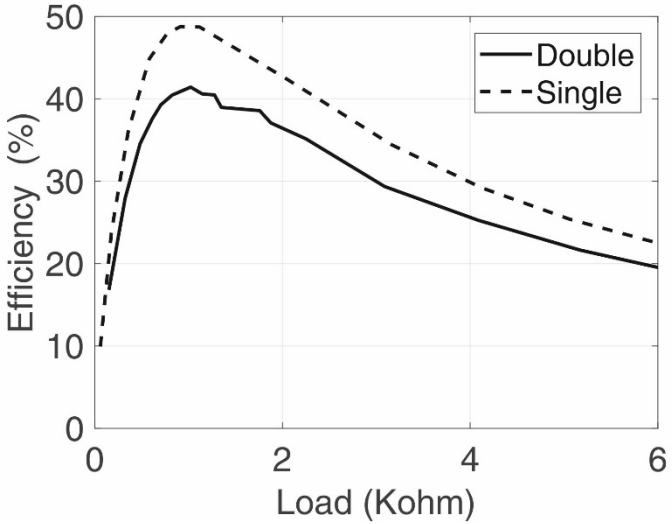
- Single (rectifier + 100 Ohm resistor)
  - Optimal RL=1762 Ohm
- Double (2 rectifiers)
  - Optimal RL=1559 Ohm

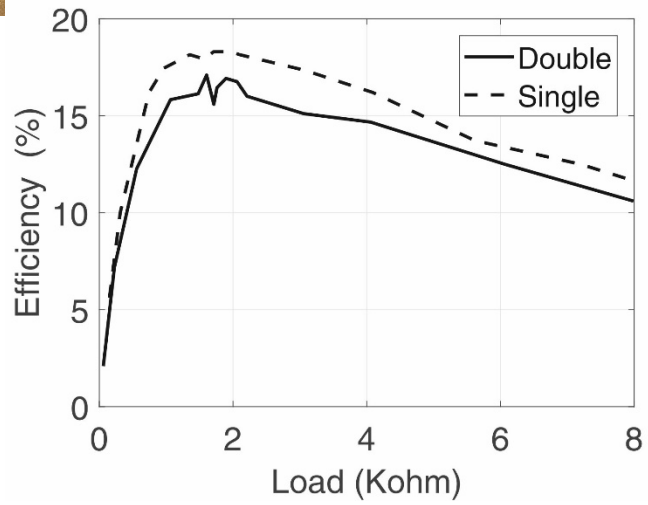


Testing



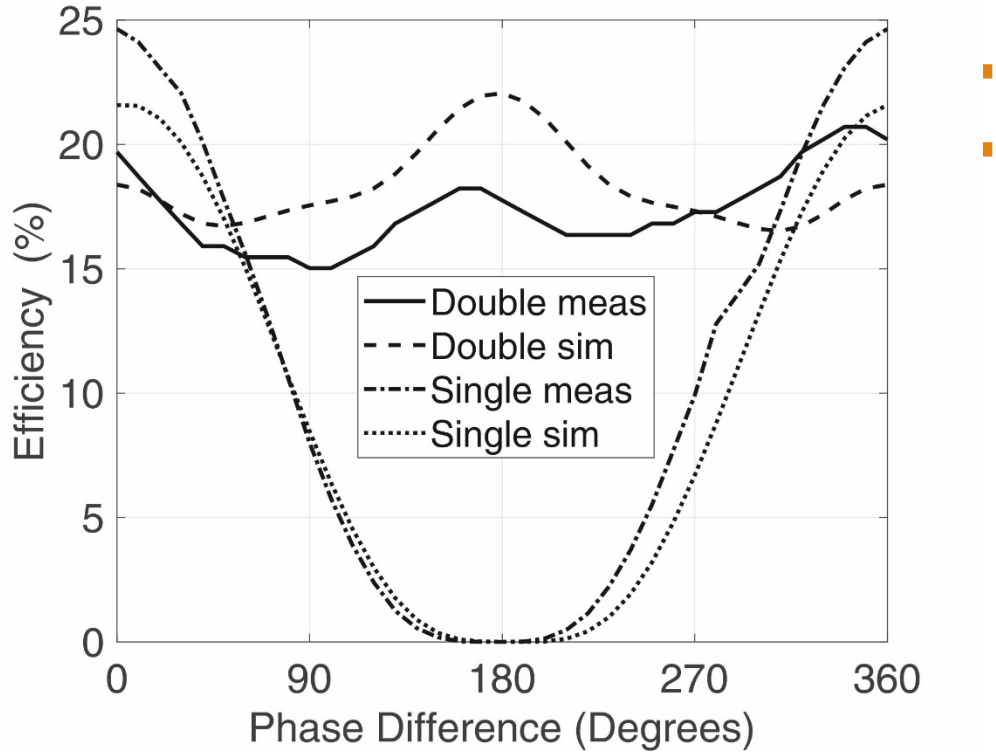
- Pin= 0 dBm
- Δφ= 0 (in-phase)



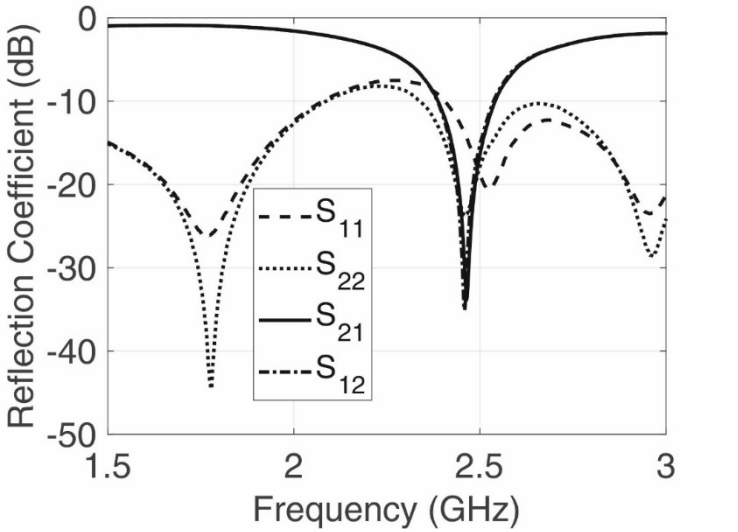


- Pin= -20 dBm
- Δφ= 0 (in-phase)

Results



- Pin=-20 dBm
- Phase different from 0-360 degrees.

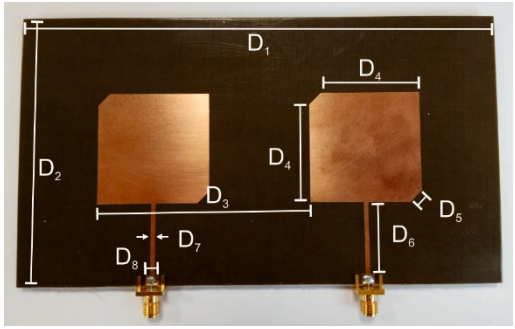


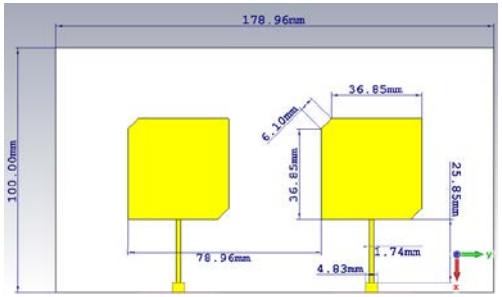
Summary

- High efficiency for low power input rectifier.
- Wilkinson combiner
- Novel circuit collects energy when input phase difference is not zero.

Future Goals

- Future rectenna design for RF energy harvesting
- Patch antennas measurement





Thank you for your attention !

Questions ?

Acknowledgment

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