Wireless Power Transfer (WPT) Systems

How to power up electronics without cables

October 8th 2015

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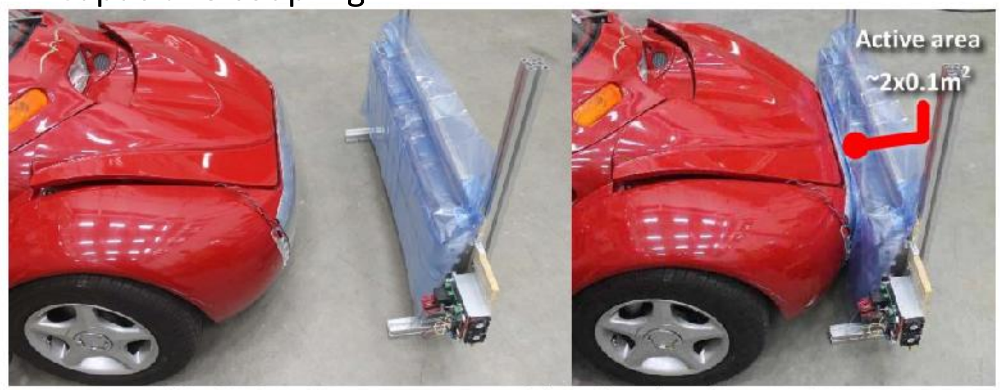
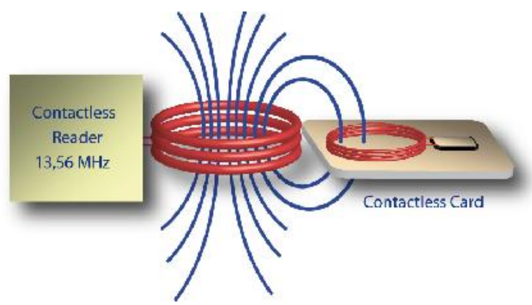
Inductive and Capacitive Coupling

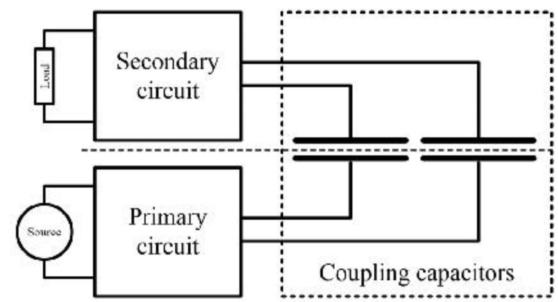
Powermat (Inductive coupling)

A4WP, Rezence (Magnetic Inductive coupling)

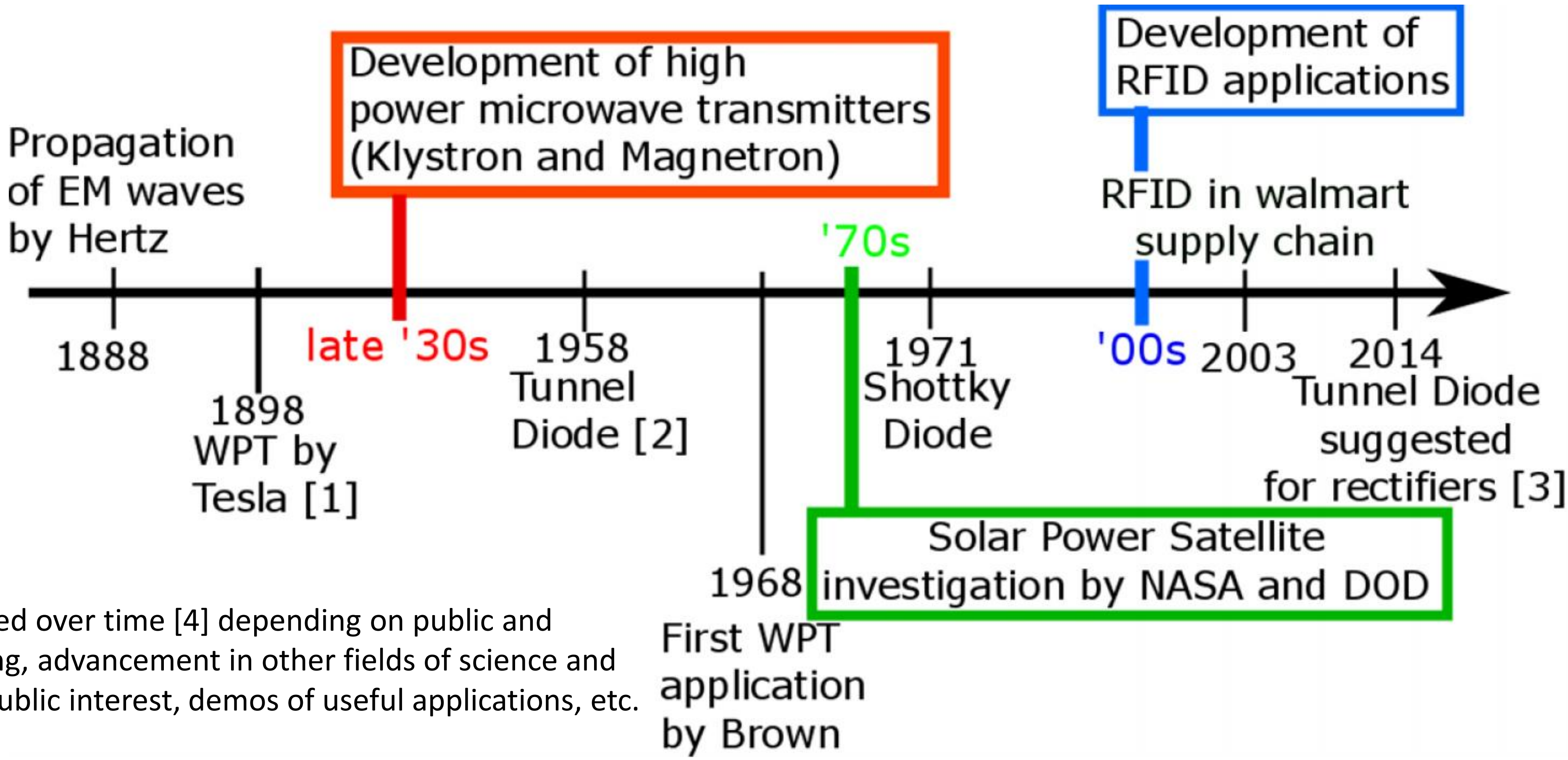
Capacitive coupling





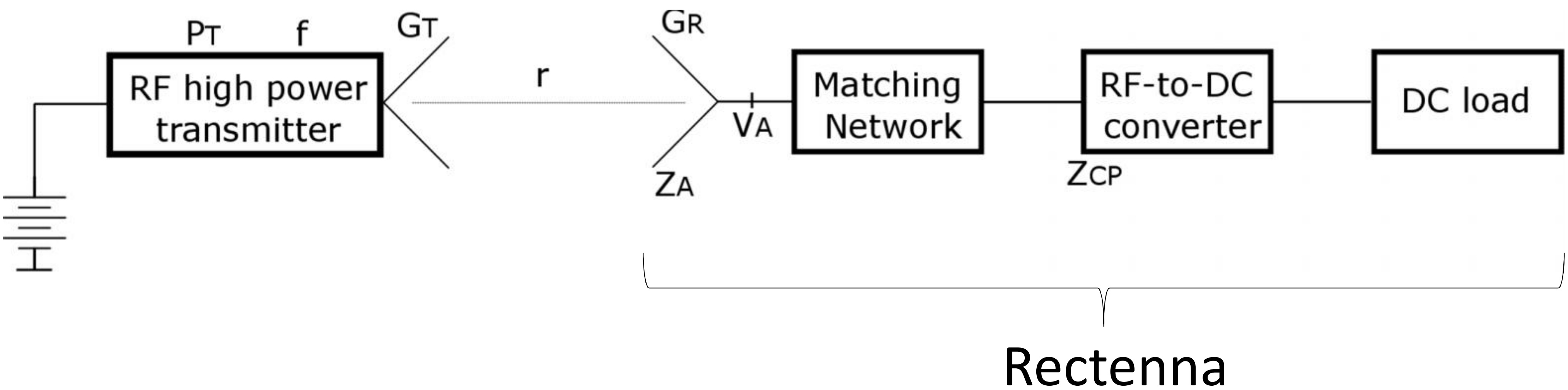


Wireless Power Transfer (Radiative Coupling)



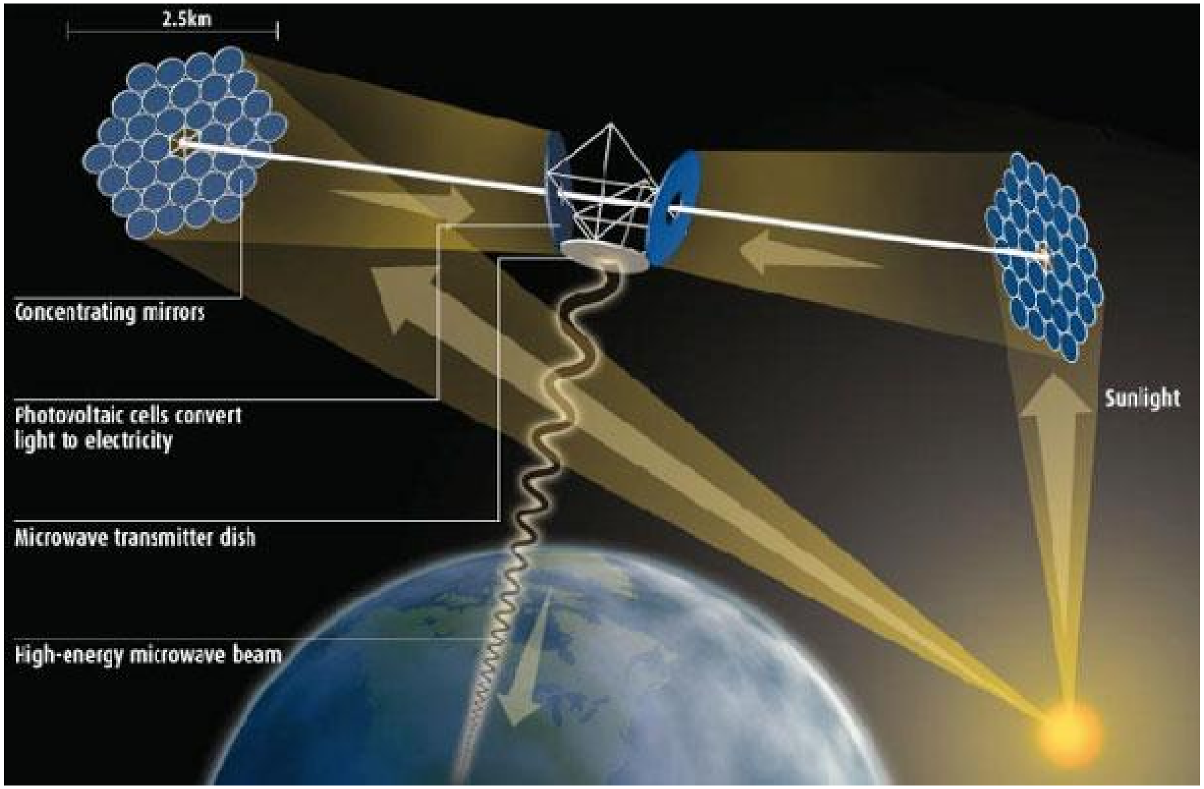
WPT developed over time [4] depending on public and private funding, advancement in other fields of science and technology, public interest, demos of useful applications, etc.

Wireless Power Transfer (Block diagram)



Video (min 10.17)

Wireless Power Transfer (Radiative Coupling)

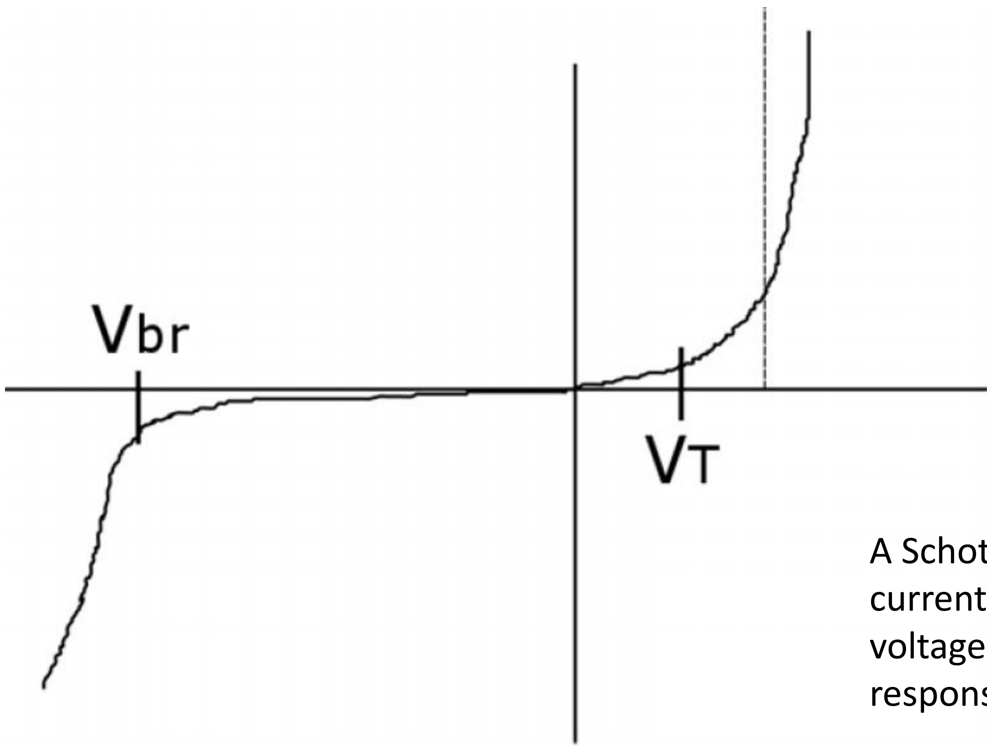


Solar Power Satellite (SPS)

Wireless Power Transfer (Radiative Coupling)

Passive RFIDs

Schottky diode IV curve



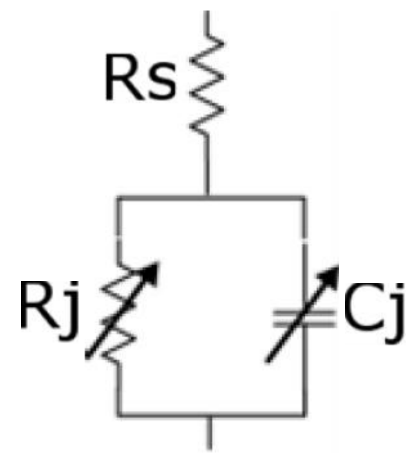
A Schottky diode, to perform as a valve that allows the current to flow only in one direction, needs to have a high voltage breakdown $|V_{br}|$, a low voltage trashold V_T and high responsivity (the “curviness”).

Schottky diode equivalent circuit

Rs series resistance

$C_j(f, P_{in})$ junction capacitance

$R_j(f, P_{in})$ junction resistance



Is saturation current

f_{co} cut off frequency

$$R_j \sim \frac{1}{I_s}$$

$$f_{co} \sim \frac{1}{C_j}$$

RF-to-DC converters

- Half wave rectifier
- One stage voltage doubler
- Dickson Charge Pump
- …

Performances of RF-to-DC converters are evaluated as the ratio between the DC power output and the RF power input:

Eff. = P_{DC}/P_{RFin}

RF-to-DC converter efficiencies in literature [5]

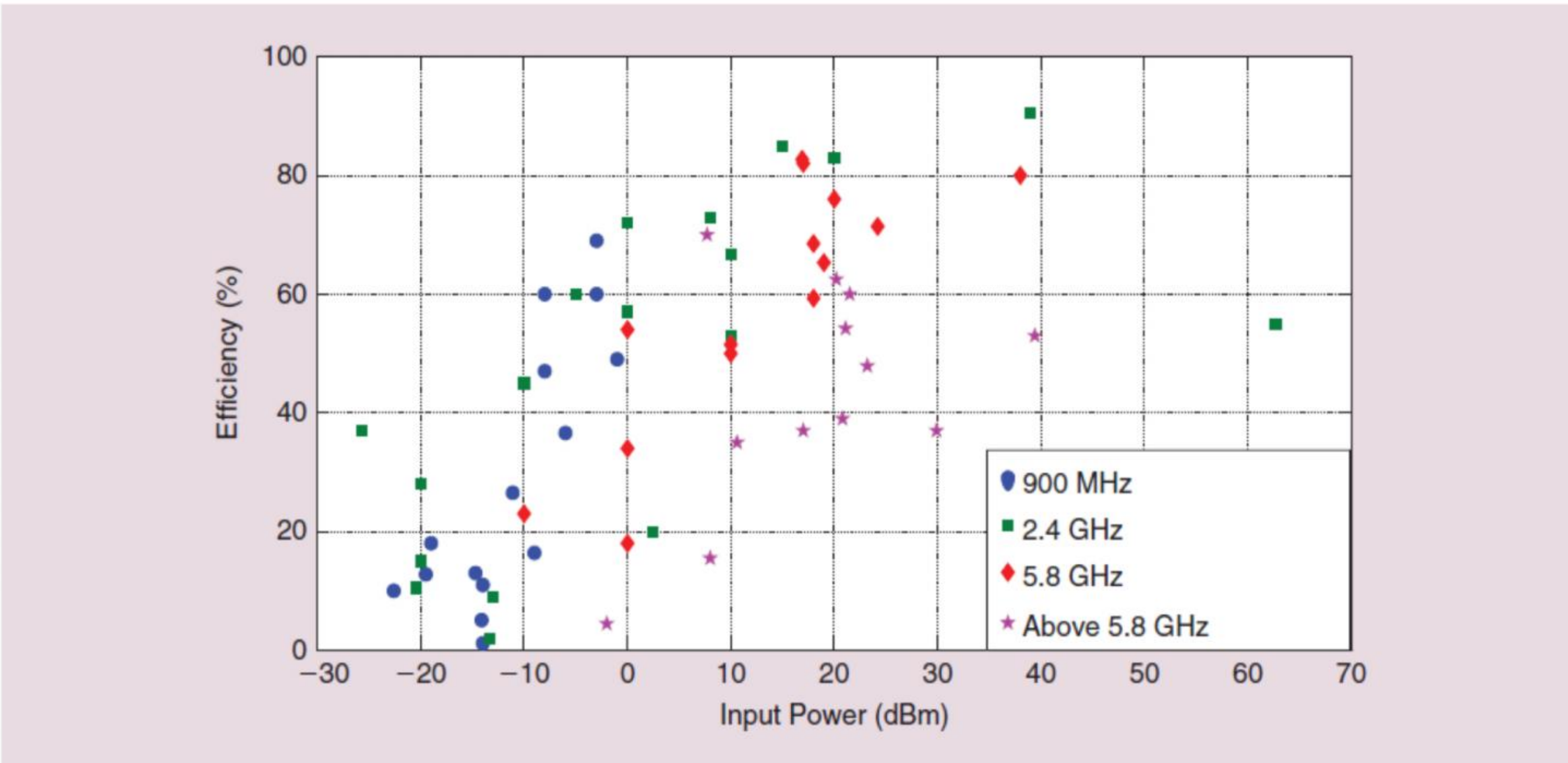
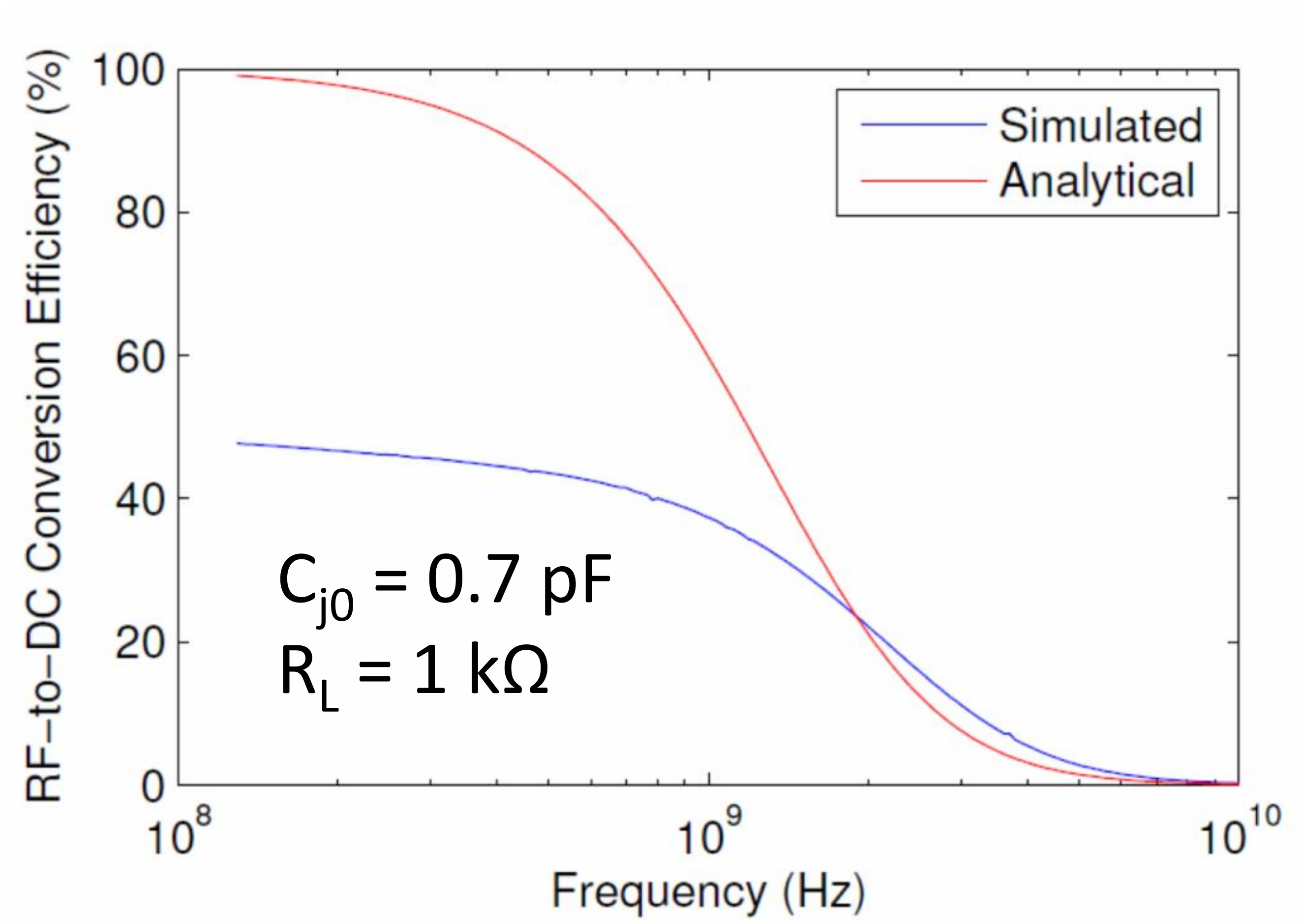


Figure 9. *State-of-the-art RF and microwave-energy conversion efficiencies. A variety of topologies including charge pumps and rectennas are used under a variety of load conditions and technologies (an earlier version of this figure was published in [14]).*

Effects of frequencies on efficiency [6]



What Schottky diode(s) could be used to have a high efficiency RF-to-DC converter for SPS applications at 5.8 GHz?

Part Number	Manufacturer	Saturation Current (uA)	Series Resistance (Ω)	Breakdown Voltage (V)	Zero-Bias Junction Capacitance (pF)
SMS7630	Skyworks	5	20	2	0.14
HSMS2850	Avago	3	25	3.8	0.18
HSMS2862	Avago	0.050	6	7	0.18
HSMS2820	Avago	0.022	6	15	0.7
1PS10SB82	NXP	0.010	5.6	17	0.978
STPS0520Z	STMicroelectronics	5.6	0.133	1.7	118

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Simulated results [6]

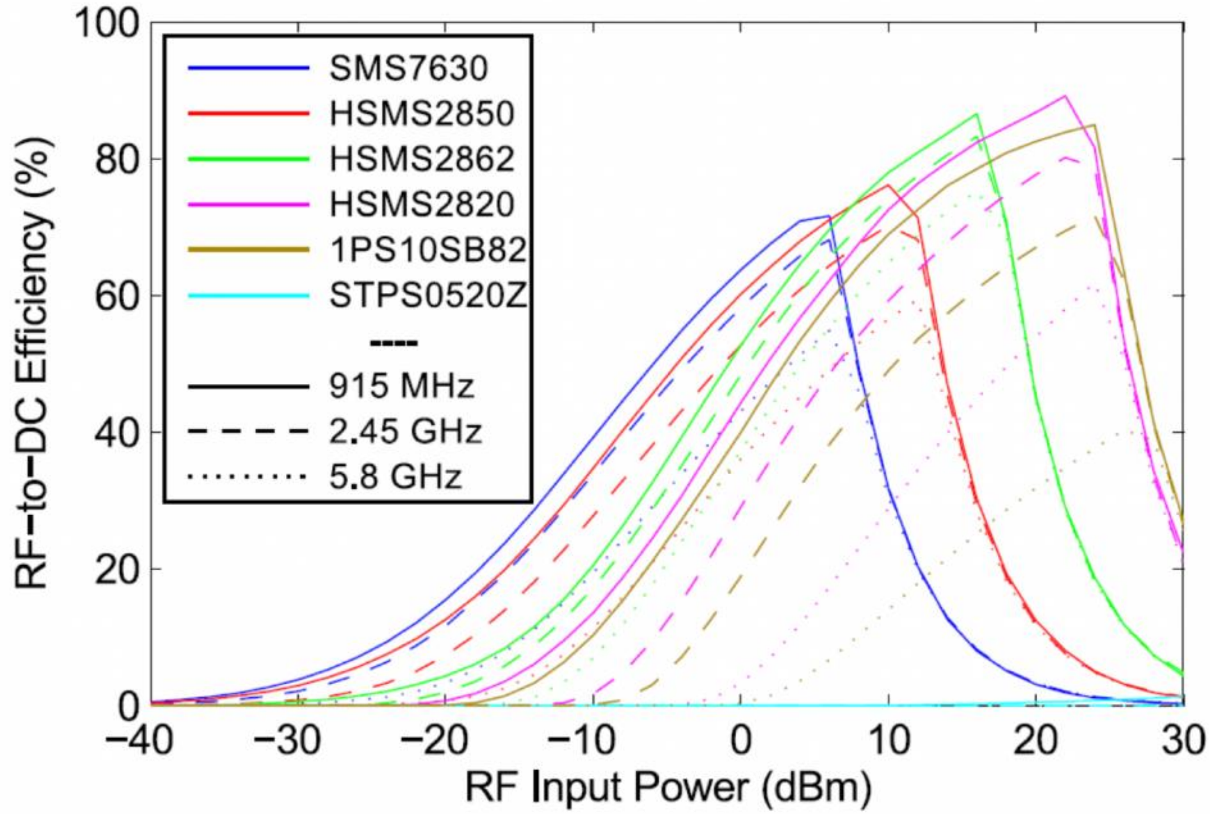

Fig. 10. RF-to-DC conversion efficiency with various diodes for a single-stage Dickson charge pump with a $1k\Omega$ load.

Problem

Using the chosen diode for the rectenna prototype, what will be the minimum distance r_{min} from a 5.8 GHz high power transmitter (Magnetron) at witch the diode will rectify the AC current?

P_T = 700 W

G_T = 15 dB

G_R = 6 dB

Bibliography

- [1] *The transmission of electrical energy without wires as a means for furthering peace,* Tesla. Elect. World Eng., Jan 1905
- [2] *New phenomenon in narrow germanium p-n junctions*, Esaki. Phys. Rev. vol. 109, Jan 1958
- [3] *Radio-Frequency Rectifier for Electromagnetic Energy Harvesting: Development Path and Future Outlook,* Hemour, Wu. Proceedings of the IEEE, 2014
- [4] *The History of power transmission by radio waves*, Brown. Microwave theory and techniques IEEE transactions 1984.
- **[5] *Harvesting Wireless Power*, Valenta, Durgin. IEEE microwave magazine 2014**
- **[6] *Parametric Analysis and Design Guidelines of RF to DC Dickson Charge Pumps for RFID Harvesting,* Marshall, Morys, Durgin. IEEE International Conference on RFID 2014**