Internet das Coisas e Redes Veiculares (TP-546)

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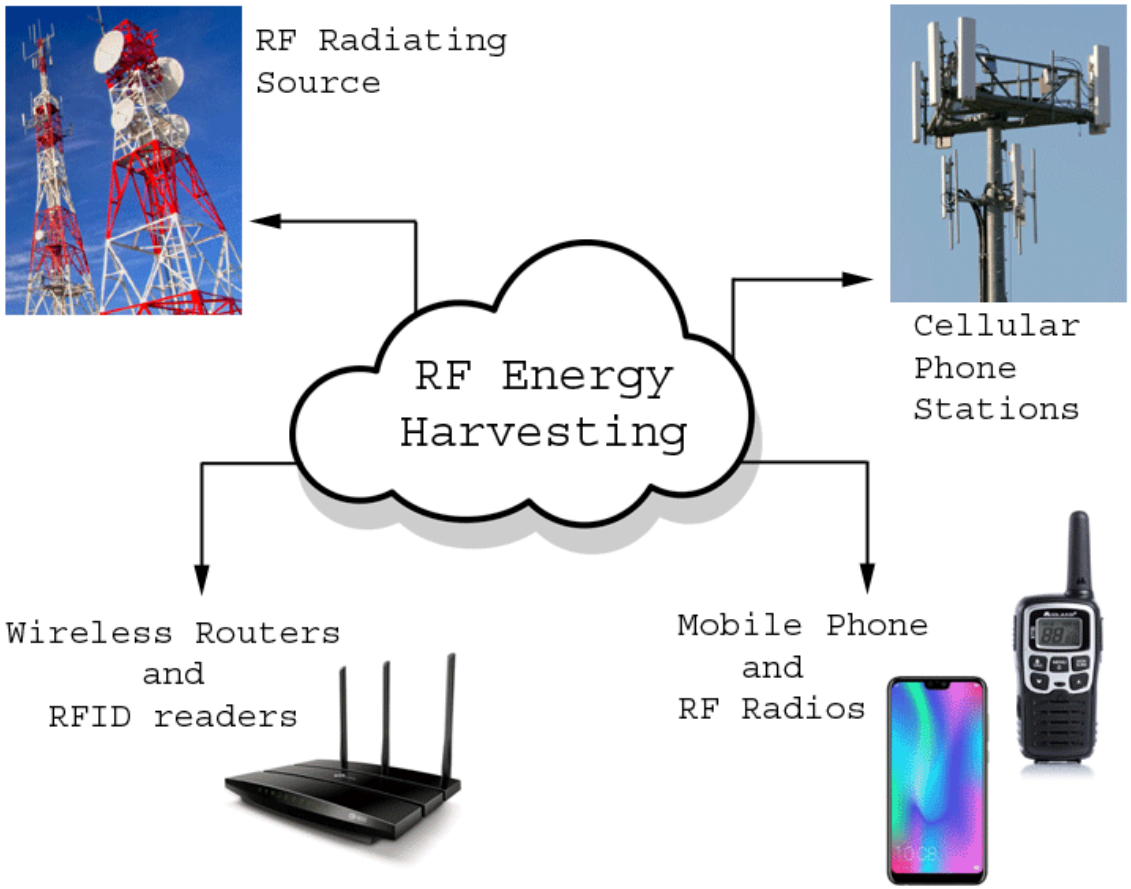
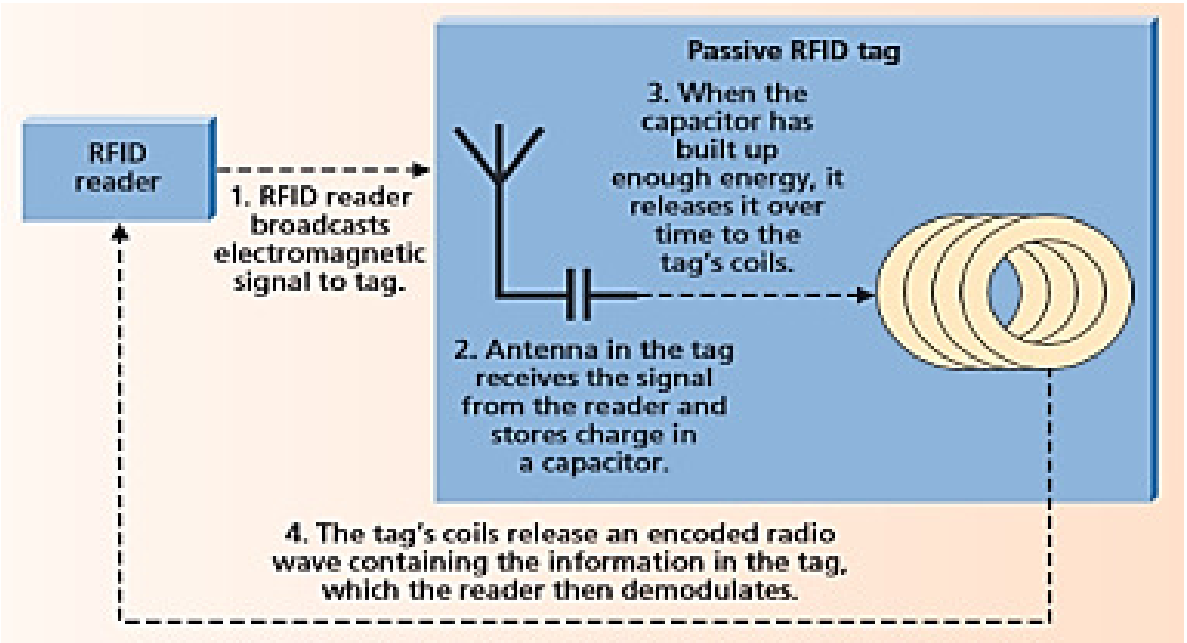
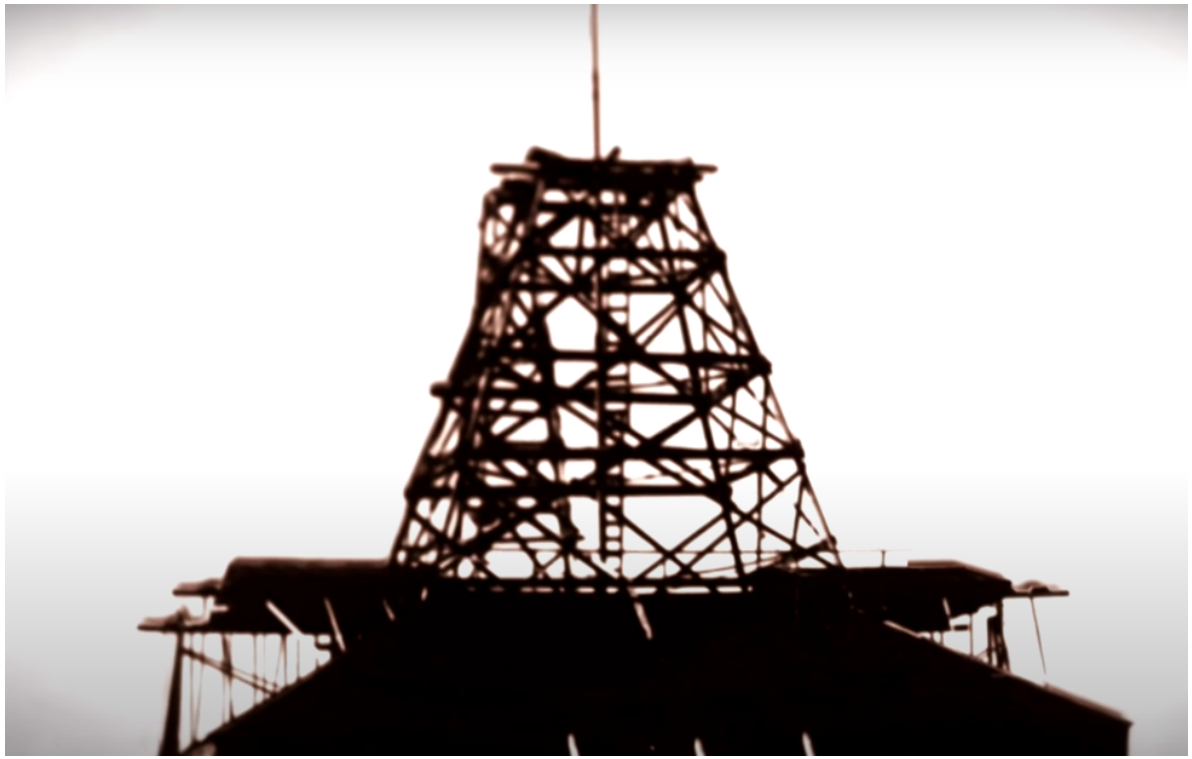
Captação de energia de sinais de radio frequência:



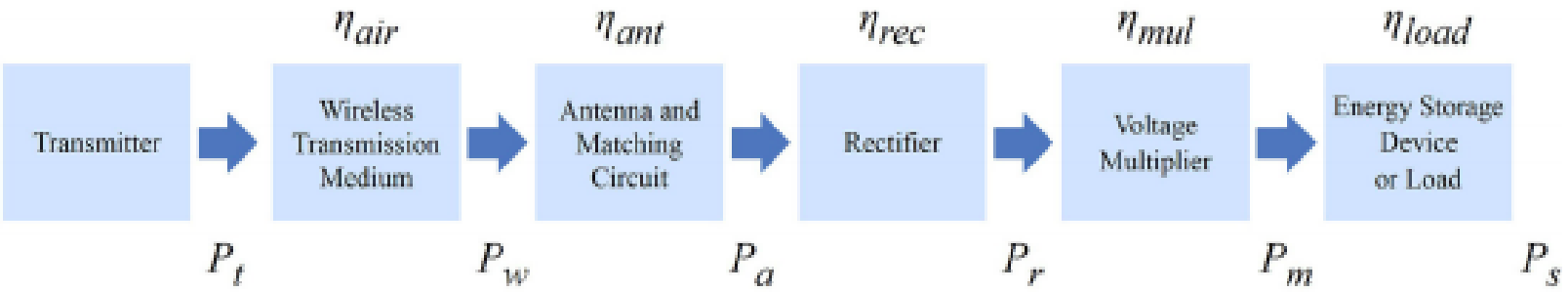
RFID


Passive RFID tag
RFID reader
1. RFID reader broadcasts electromagnetic signal to tag.
3. When the capacitor has built up enough energy, it releases it over time to the tag's coils.
2. Antenna in the tag receives the signal from the reader and stores charge in a capacitor.
4. The tag's coils release an encoded radio wave containing the information in the tag, which the reader then demodulates.



Tesla Conducts Impressive Wireless Electricity Experiments

`https://youtu.be/q0i67E48OV0`


η_{air}
η_{ant}
η_{rec}
η_{mul}
η_{load}
Transmitter
Wireless Transmission Medium
Antenna and Matching Circuit
Rectifier
Voltage Multiplier
Energy Storage Device or Load
P_t
P_w
P_a
P_r
P_m
P_s

Captação de energia de sinais ISDB-T

R. Shigeta et al., "Ambient RF Energy Harvesting Sensor Device With Capacitor-Leakage-Aware Duty Cycle Control," in IEEE Sensors Journal, vol. 13, no. 8, pp. 2973-2983, Aug. 2013

R. Vyas, H. Nishimoto, M. Tentzeris, Y. Kawahara and T. Asami, "A battery-less, energy harvesting device for long range scavenging of wireless power from terrestrial TV broadcasts," 2012 IEEE/MTT-S International Microwave Symposium Digest, Montreal, QC, 2012, pp. 1-3

- A colheita de energia através de sinais de tv é uma boa opção, por se tratar de uma banda onde quase todo o tempo há sinais trafegando e também pelo fato de estar presente em praticamente todos os ambientes.
- Como pontos negativos, podemos citar o fato de a fonte de transmissão, na maioria das vezes, ficar longe do receptor, visto que necessita-se de poucos transmissores para cobrir uma extensa área e também o tamanho da antena.

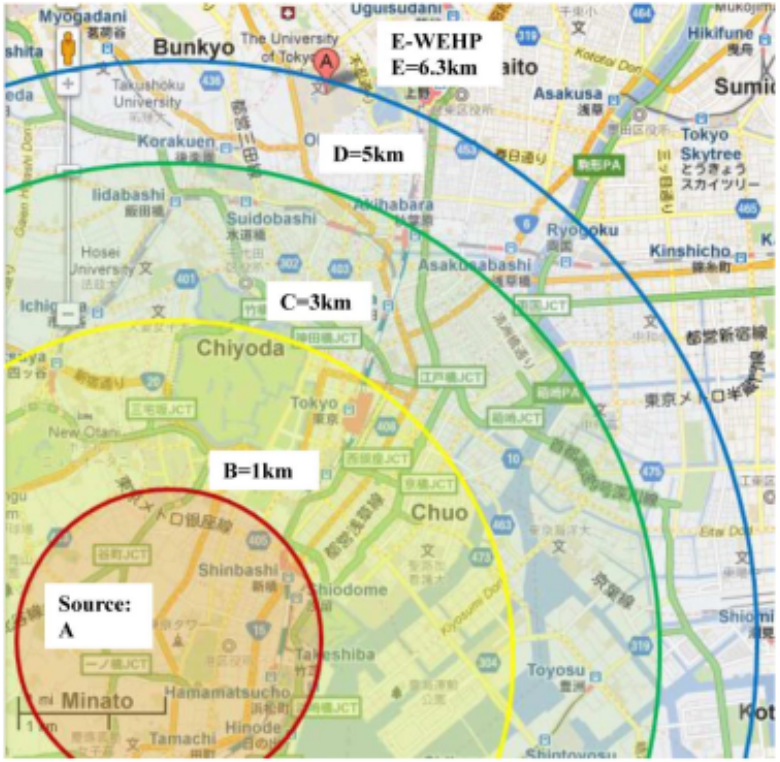
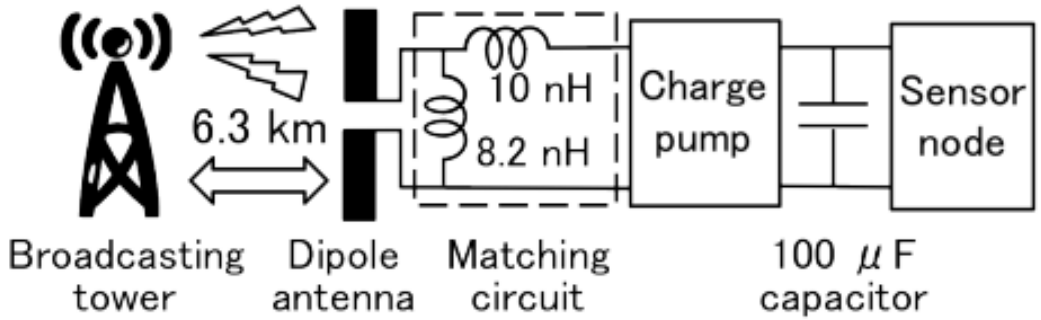
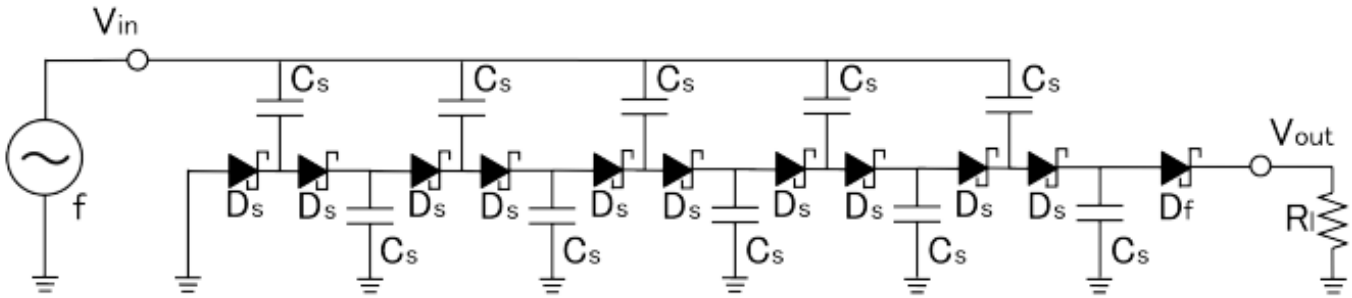


TABLE II
THEORETICAL AND MEASURED SINGLE-CARRIER AND CHANNEL POWER LEVELS USING E-WEHP ANTENNA (GAIN: 5–7.3 dBi)

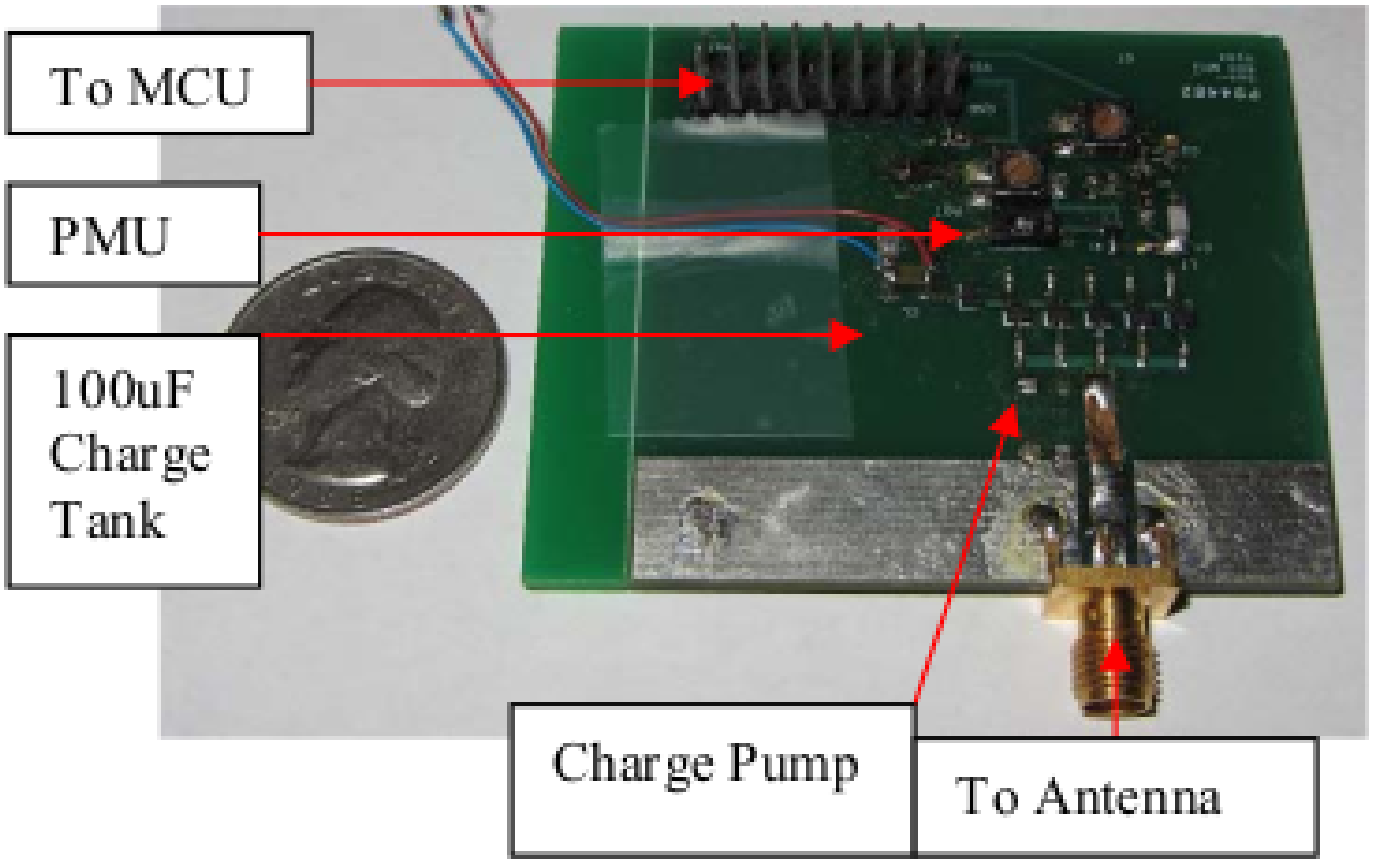
TV Channel Freq. (MHz)		A P_{TX} Power kW	B 1km µW	C 3km µW	D 5km µW	E 6.3km µW	
						theory	meas
JOMX 512-518	1-tone	5	0.32	0.26	0.21	0.19	0.008
	Channel		37.3	30.3	24.5	22.1	0.93
JO-RX/CX/TX/EX/AX/AB/AK 518-560	1-tone	48	3.6-4.1	2.9-3.4	2.3-2.7	2.2-2.5	0.1-0.25
	Channel		419-478	338-396	268-315	256-291	11.7-29
JOUD 560-566	1-tone	19	1.37	1.08	0.86	0.78	0.032
	Channel		160	126	100	91	3.73

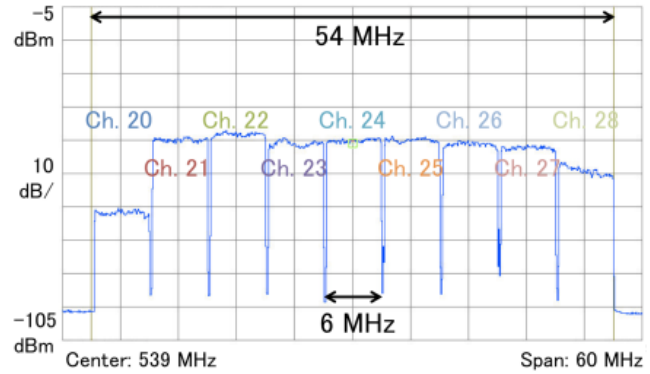

6.3 km
10 nH
8.2 nH
Charge pump
Sensor node
Broadcasting tower
Dipole antenna
Matching circuit
100 μF capacitor

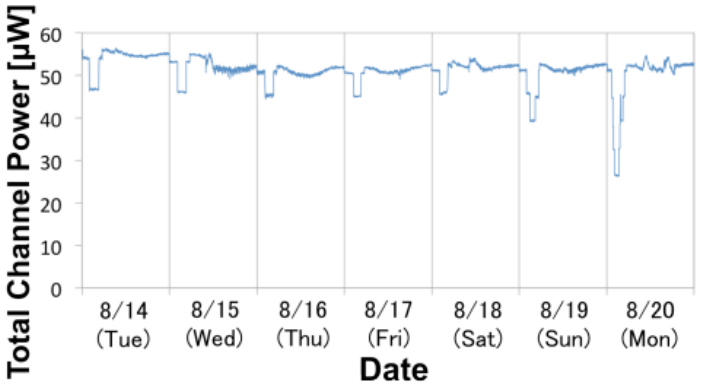
Retificador e multiplicador de tensão

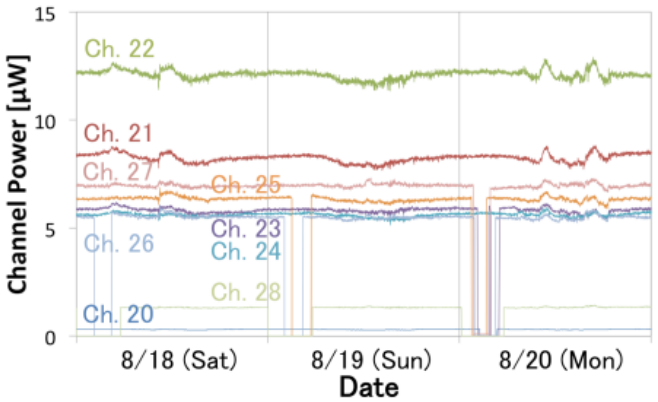


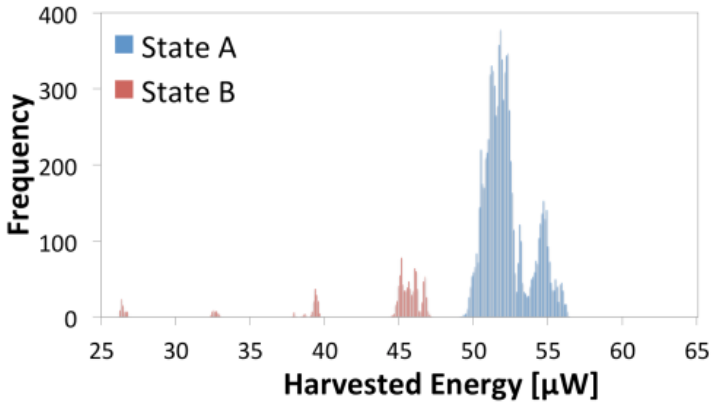
Input Frequency f: 540MHz, Number of Stages: 5
Stage Capacitor Cs: 15pF, Stage Diode Ds: Skyworks Solutions SMS-7630
Final Diode Df: Avago HSMS-286x, Load RI: 470k Ω

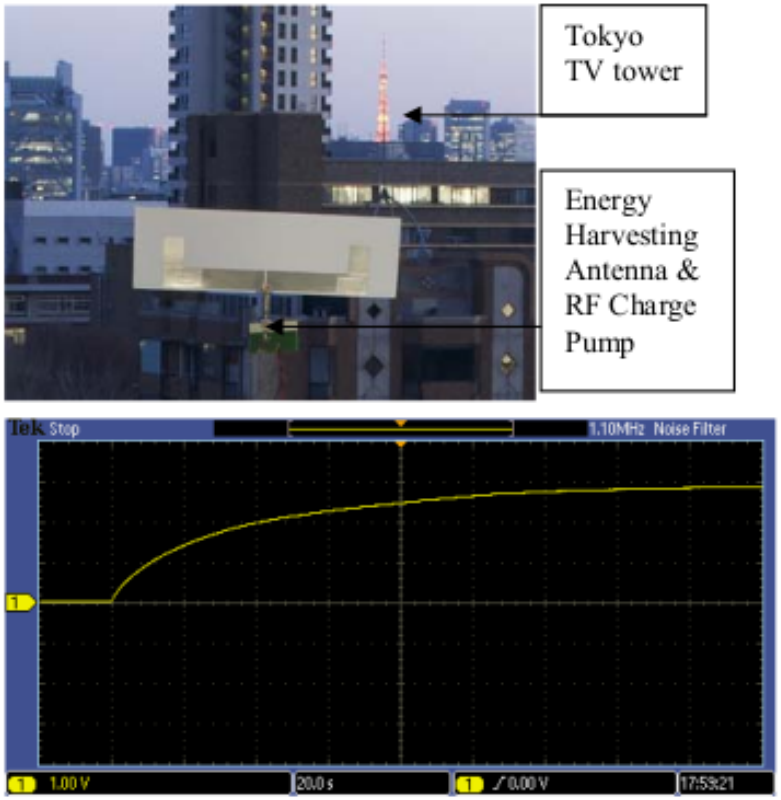

To MCU
PMU
100uF
Charge
Tank
Charge Pump
To Antenna


−5
dBm
54 MHz
Ch. 20
Ch. 22
Ch. 24
Ch. 26
Ch. 28
Ch. 21
Ch. 23
Ch. 25
Ch. 27
10
dB/
−105
dBm
6 MHz
Center: 539 MHz
Span: 60 MHz


Total Channel Power [μW]
60
50
40
30
20
10
0
8/14 (Tue)
8/15 (Wed)
8/16 (Thu)
8/17 (Fri)
8/18 (Sat)
8/19 (Sun)
8/20 (Mon)
Date


Channel Power [μW]
15
10
5
0
Ch. 22
Ch. 21
Ch. 27
Ch. 25
Ch. 23
Ch. 24
Ch. 26
Ch. 28
Ch. 20
8/18 (Sat)
8/19 (Sun)
8/20 (Mon)
Date


Frequency
400
300
200
100
0
State A
State B
25
30
35
40
45
50
55
60
65
Harvested Energy [μW]


Tokyo
TV tower
Energy
Harvesting
Antenna &
RF Charge
Pump
Tek Stop
1.10MHz Noise Filter
1.00 V
20.0 s
0.00 V
17:53:21

Captação de sinais de WI-FI:

Y. Chen and C. Chiu, "Maximum Achievable Power Conversion Efficiency Obtained Through an Optimized Rectenna Structure for RF Energy Harvesting," in IEEE Transactions on Antennas and Propagation, vol. 65, no. 5, pp. 2305-2317, May 2017

- A colheita de energia derivada da faixa de frequência Wi-Fi é uma boa opção quando se trata de aplicações que necessitam de mobilidade e escalabilidade;
- Isto se dá devido a antena para esta faixa ser muito pequena, ainda mais quando comparada com uma antena para colheita de sinais de tv digital;

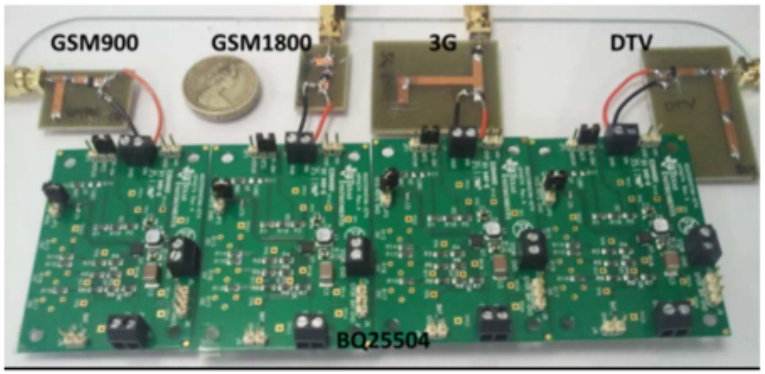
- Presente em ambientes urbanos, especialmente em áreas residenciais;
- Esta banda pode ser facilmente usada para colheita de energia e para comunicação, sendo possível realizar projetos que realizem as duas tarefas.
- Por outro lado, devido as baixas potências de entrada, somente pode ser utilizado para aplicações de baixo consumo de energia.

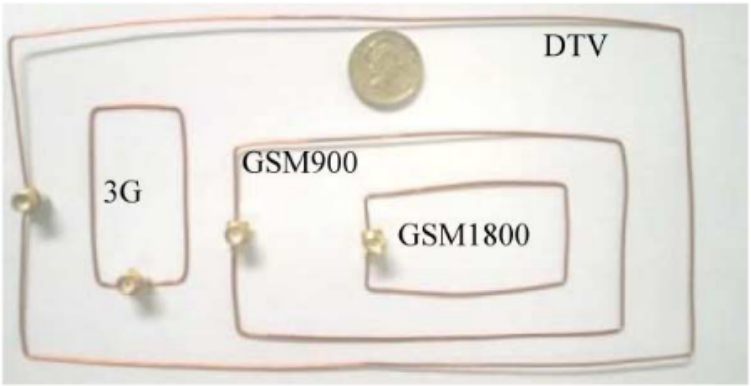
Captar de múltiplas frequências:

M. Piñuela, P. D. Mitcheson and S. Lucyszyn, "Ambient RF Energy Harvesting in Urban and Semi-Urban Environments," in IEEE Transactions on Microwave Theory and Techniques, vol. 61, no. 7, pp. 2715-2726, July 2013

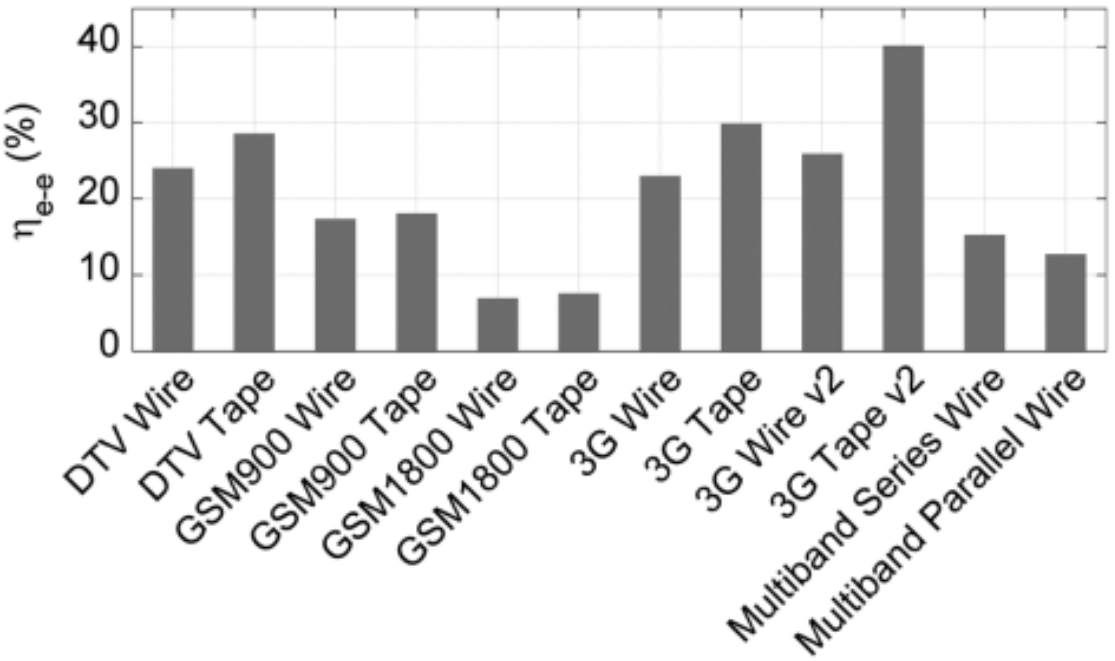
V. Kuhn, C. Lahuec, F. Seguin and C. Person, "A Multi-Band Stacked RF Energy Harvester With RF-to-DC Efficiency Up to 84%," in IEEE Transactions on Microwave Theory and Techniques, vol. 63, no. 5, pp. 1768-1778, May 2015.

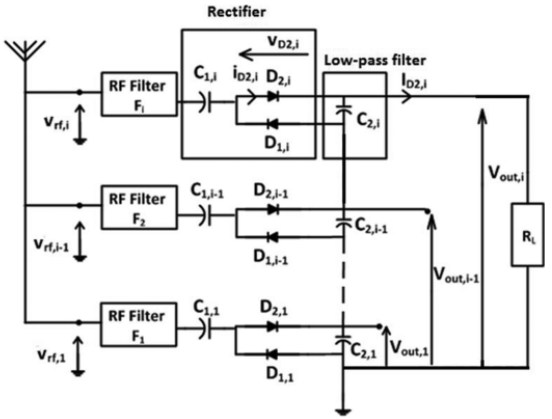
- Sinais multibandas concedem um resultado superior aos demais, devido ao fato de se obter sinais de diferentes frequências. Para ambientes que dispõem de diferentes sinais trafegando é adequado que se use esse método, para obter o máximo de sinais possíveis.

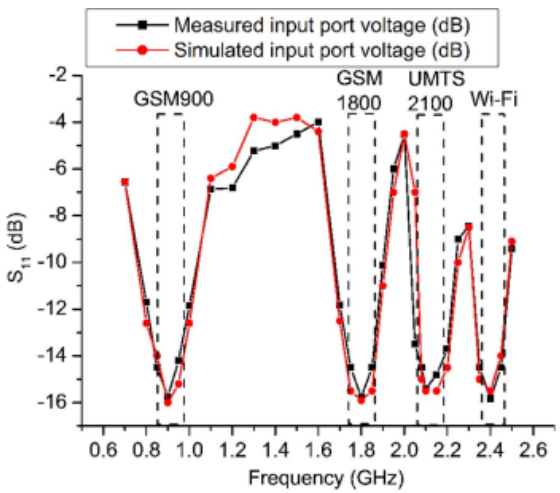


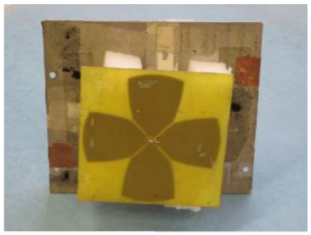


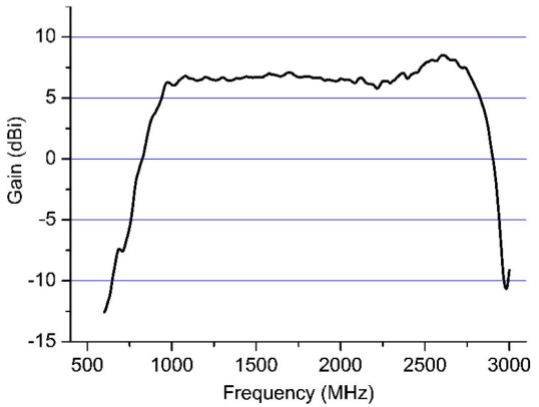
M. Piñuela, P. D. Mitcheson and S. Lucyszyn, "Ambient RF Energy Harvesting in Urban and Semi-Urban Environments," in IEEE Transactions on Microwave Theory and Techniques, vol. 61, no. 7, pp. 2715-2726, July 2013


40
30
20
10
0
η_{e-e} (%)
DTV Wire
DTV Tape
GSM900 Wire
GSM900 Tape
GSM1800 Wire
GSM1800 Tape
3G Wire
3G Tape
3G Wire v2
3G Tape v2
Multiband Series Wire
Multiband Parallel Wire

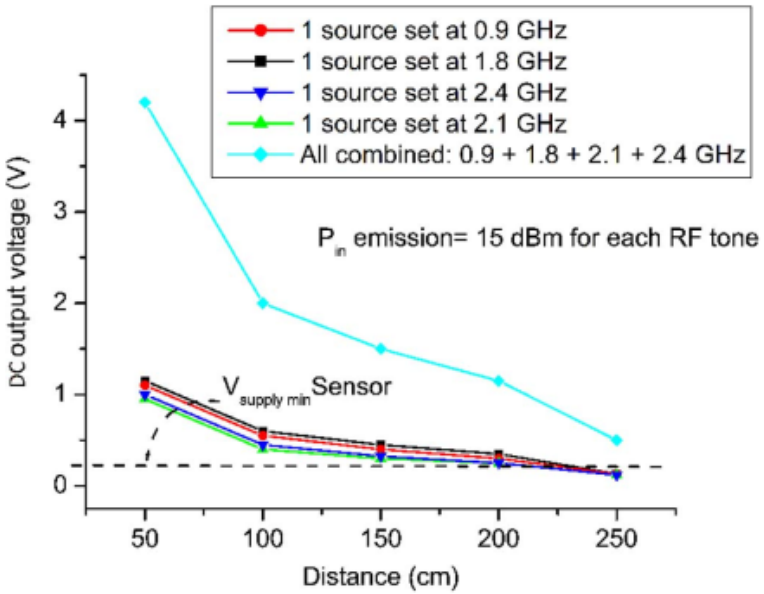


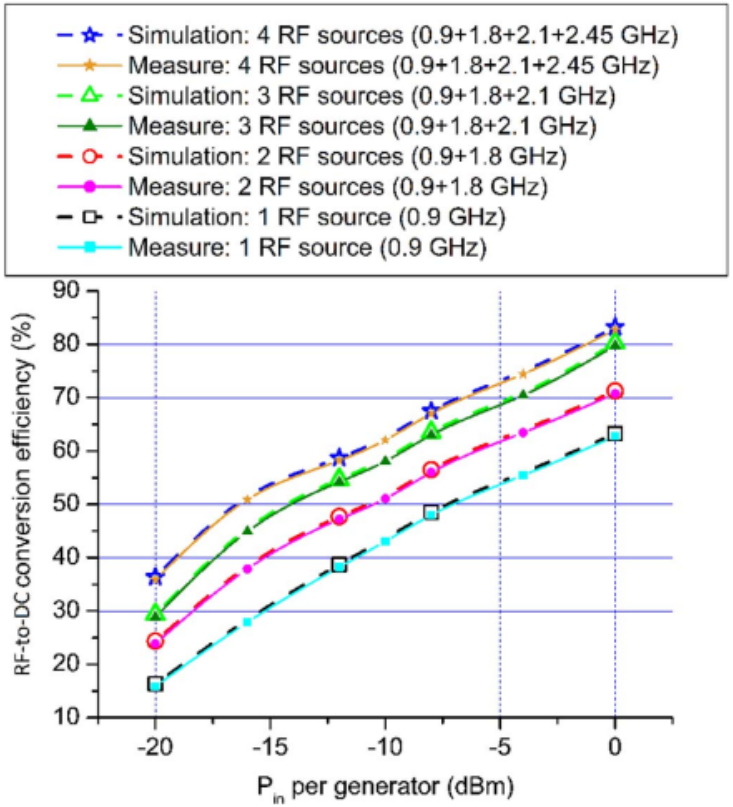






V. Kuhn, C. Lahuec, F. Seguin and C. Person, "A Multi-Band Stacked RF Energy Harvester With RF-to-DC Efficiency Up to 84%," in IEEE Transactions on Microwave Theory and Techniques, vol. 63, no. 5, pp. 1768-1778, May 2015.


1 source set at 0.9 GHz
1 source set at 1.8 GHz
1 source set at 2.4 GHz
1 source set at 2.1 GHz
All combined: 0.9 + 1.8 + 2.1 + 2.4 GHz
P in emission= 15 dBm for each RF tone
V supply min Sensor
DC output voltage (V)
Distance (cm)
0
1
2
3
4
50
100
150
200
250

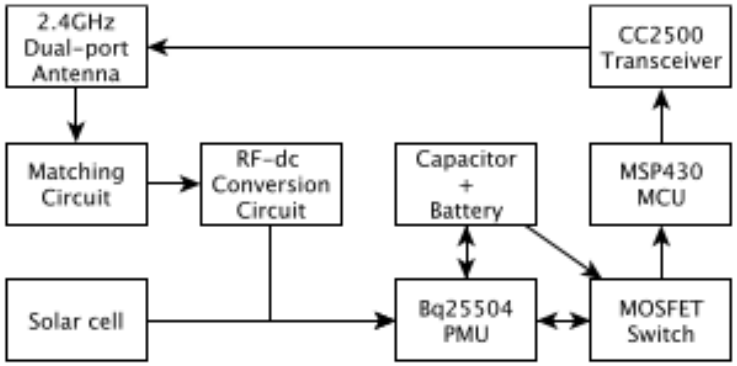

Simulation: 4 RF sources (0.9+1.8+2.1+2.45 GHz)
Measure: 4 RF sources (0.9+1.8+2.1+2.45 GHz)
Simulation: 3 RF sources (0.9+1.8+2.1 GHz)
Measure: 3 RF sources (0.9+1.8+2.1 GHz)
Simulation: 2 RF sources (0.9+1.8 GHz)
Measure: 2 RF sources (0.9+1.8 GHz)
Simulation: 1 RF source (0.9 GHz)
Measure: 1 RF source (0.9 GHz)
RF-to-DC conversion efficiency (%)
P in per generator (dBm)
10
20
30
40
50
60
70
80
90
-20
-15
-10
-5
0

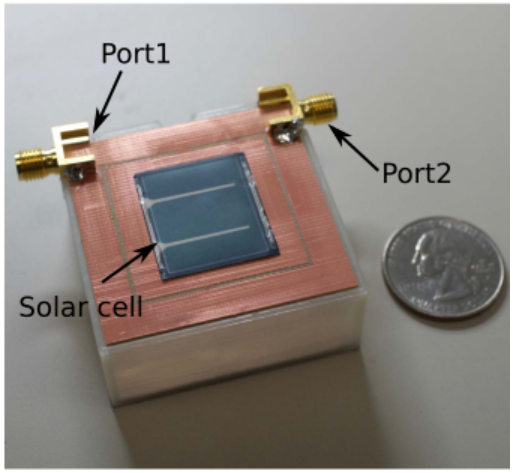
Solução Híbrida Solar-RF:

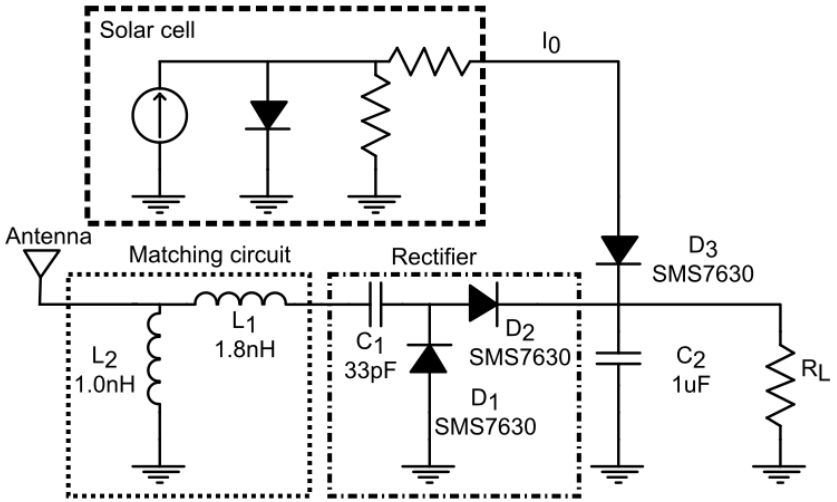
A captação de energia por sinais de RF gera potências muito baixas, é necessário uma alternativa para conseguir melhores resultados, sendo essa, a combinação com outras fontes.

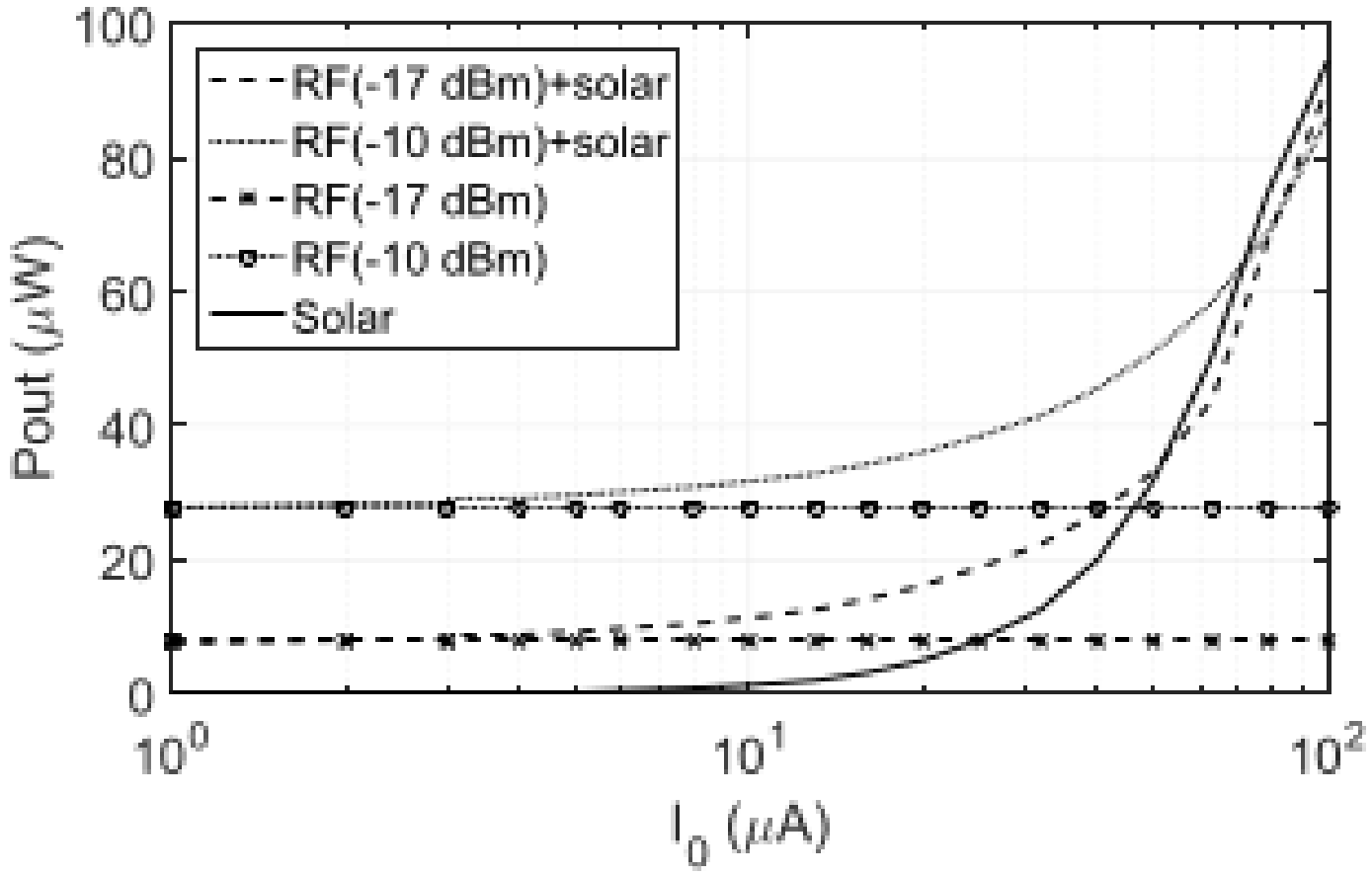
J. Bito, R. Bahr, J. G. Hester, S. A. Nauroze, A. Georgiadis and M. M. Tentzeris, "A Novel Solar and Electromagnetic Energy Harvesting System With a 3-D Printed Package for Energy Efficient Internet-of-Things Wireless Sensors," in IEEE Transactions on Microwave Theory and Techniques, vol. 65, no. 5, pp. 1831-1842, May 2017

- Uma alternativa para aumentar a energia final é combinando os diversos tipos de energia. Para aplicações onde se tem unidades de armazenamento de energia é interessante o uso dessa tecnologia, pois a energia adquirida consegue manter a bateria carregada enquanto ela alimenta um circuito.

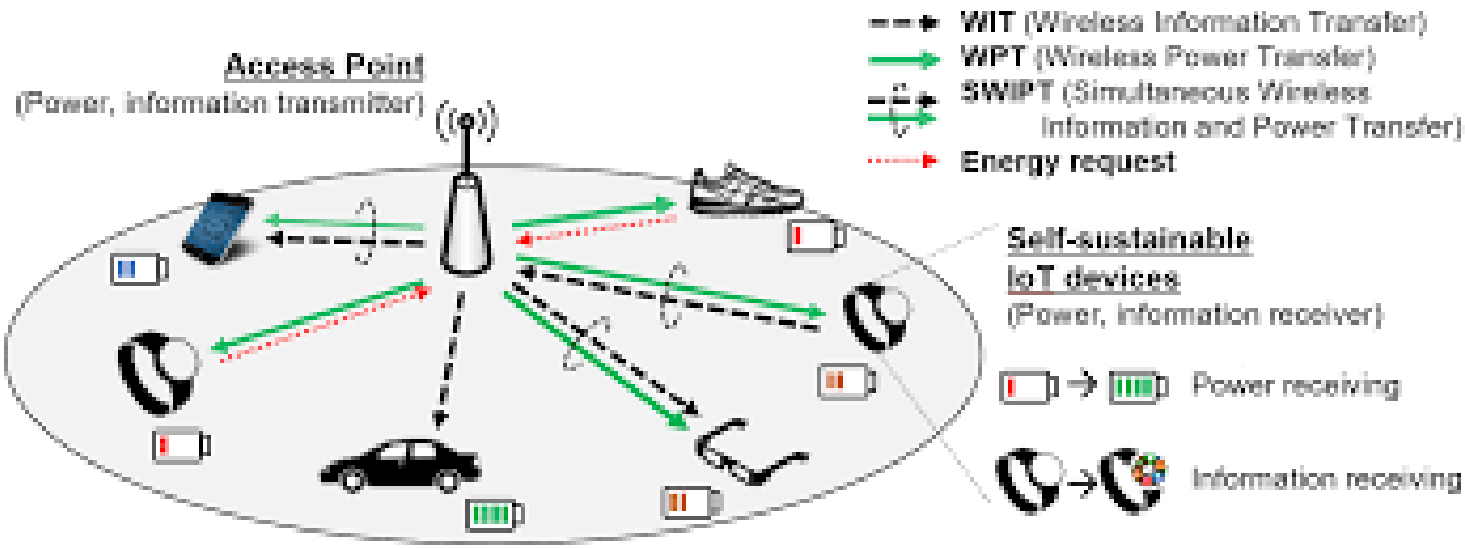

2.4GHz
Dual-port
Antenna
CC2500
Transceiver
Matching
Circuit
RF-dc
Conversion
Circuit
Capacitor
+
Battery
MSP430
MCU
Solar cell
Bq25504
PMU
MOSFET
Switch


Port1
Port2
Solar cell

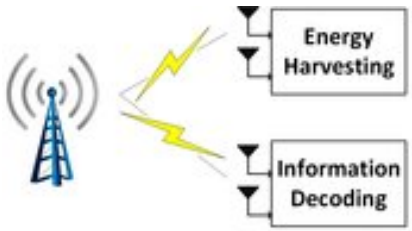

Solar cell
I_0
Antenna
Matching circuit
Rectifier
D_3
SMS7630
L_1
1.8nH
L_2
1.0nH
C_1
33pF
D_2
SMS7630
D_1
SMS7630
C_2
1uF
R_L


RF(-17 dBm)+solar
RF(-10 dBm)+solar
RF(-17 dBm)
RF(-10 dBm)
Solar
Pout (μW)
100
80
60
40
20
0
10^0
10^1
10^2
I_0 (μA)

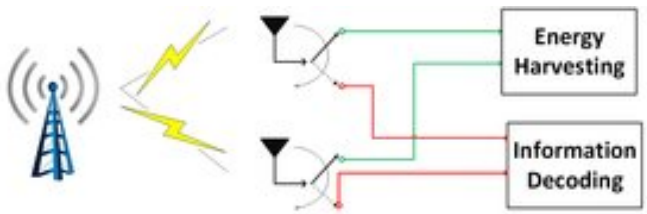
Técnicas de transferência simultânea de energia e informação.



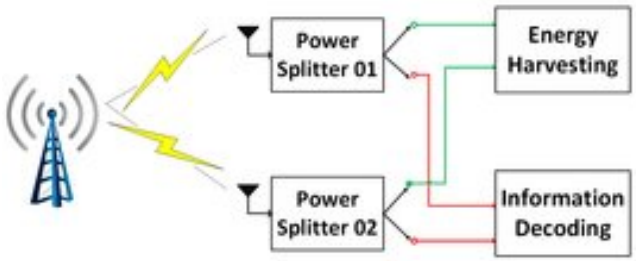
Técnicas de transferência simultânea de energia e informação.



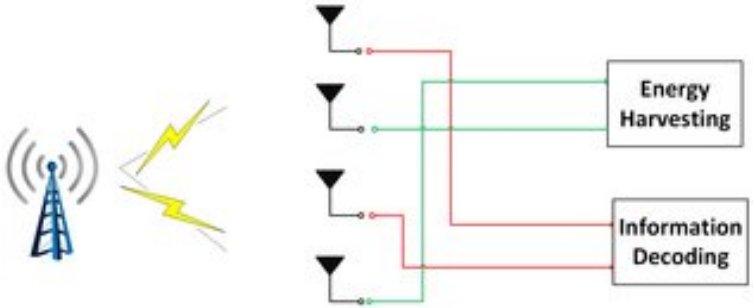
a) Separate Receiver Architecture



b) Time Switching Architecture

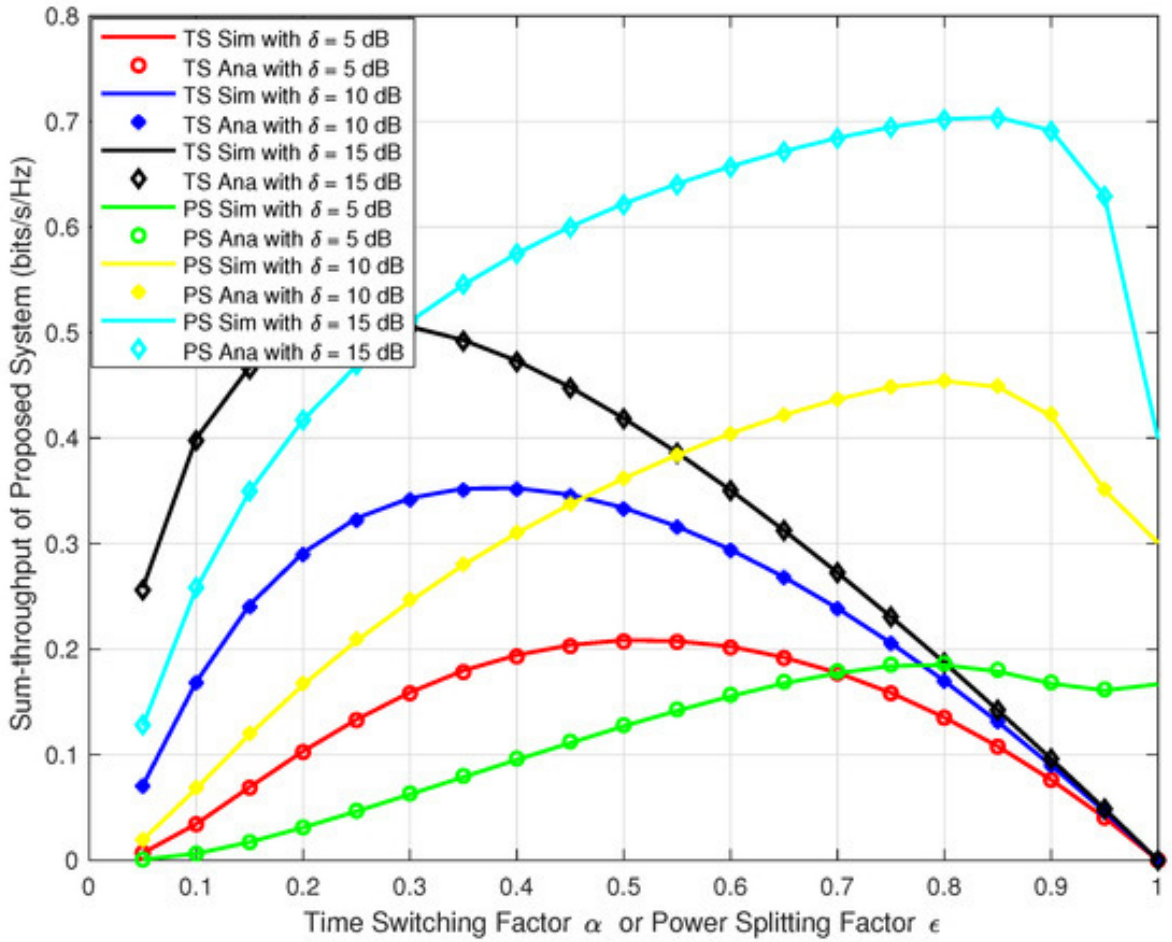


c) Power Splitting Architecture

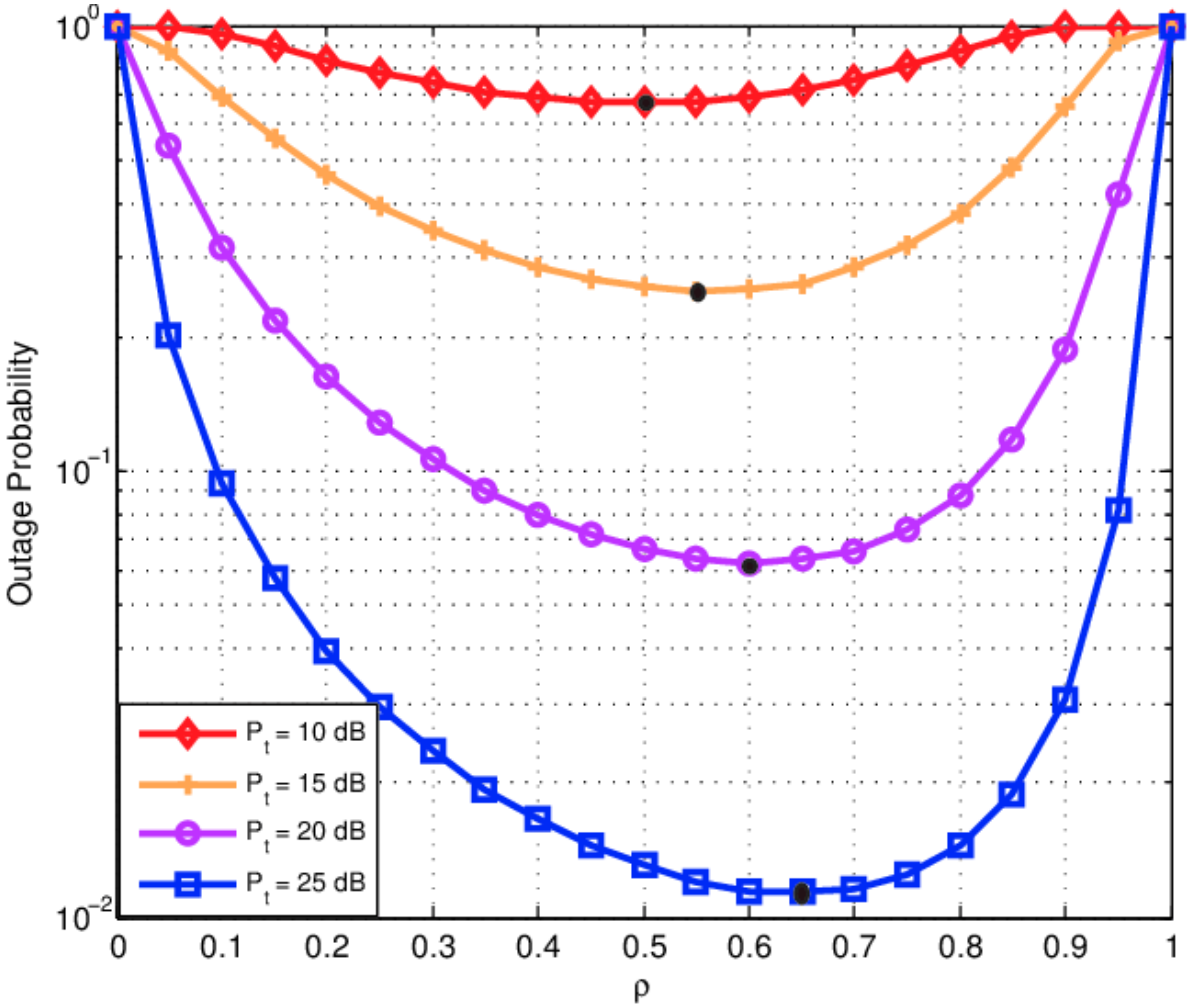


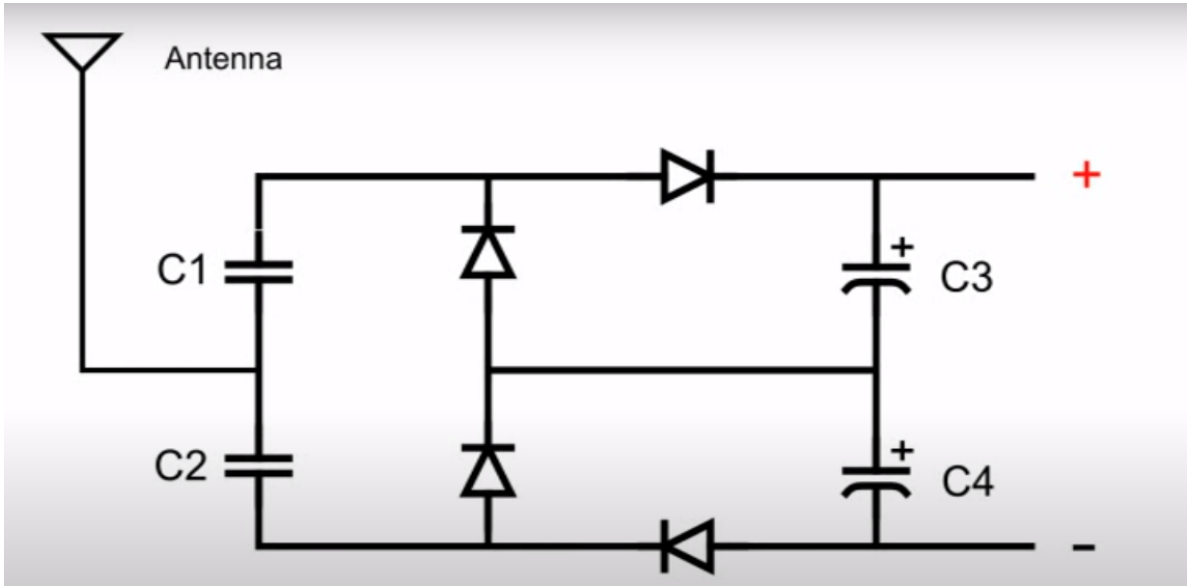
d) Antenna Switching Architecture

Time switching-Power splitting



Power splitting





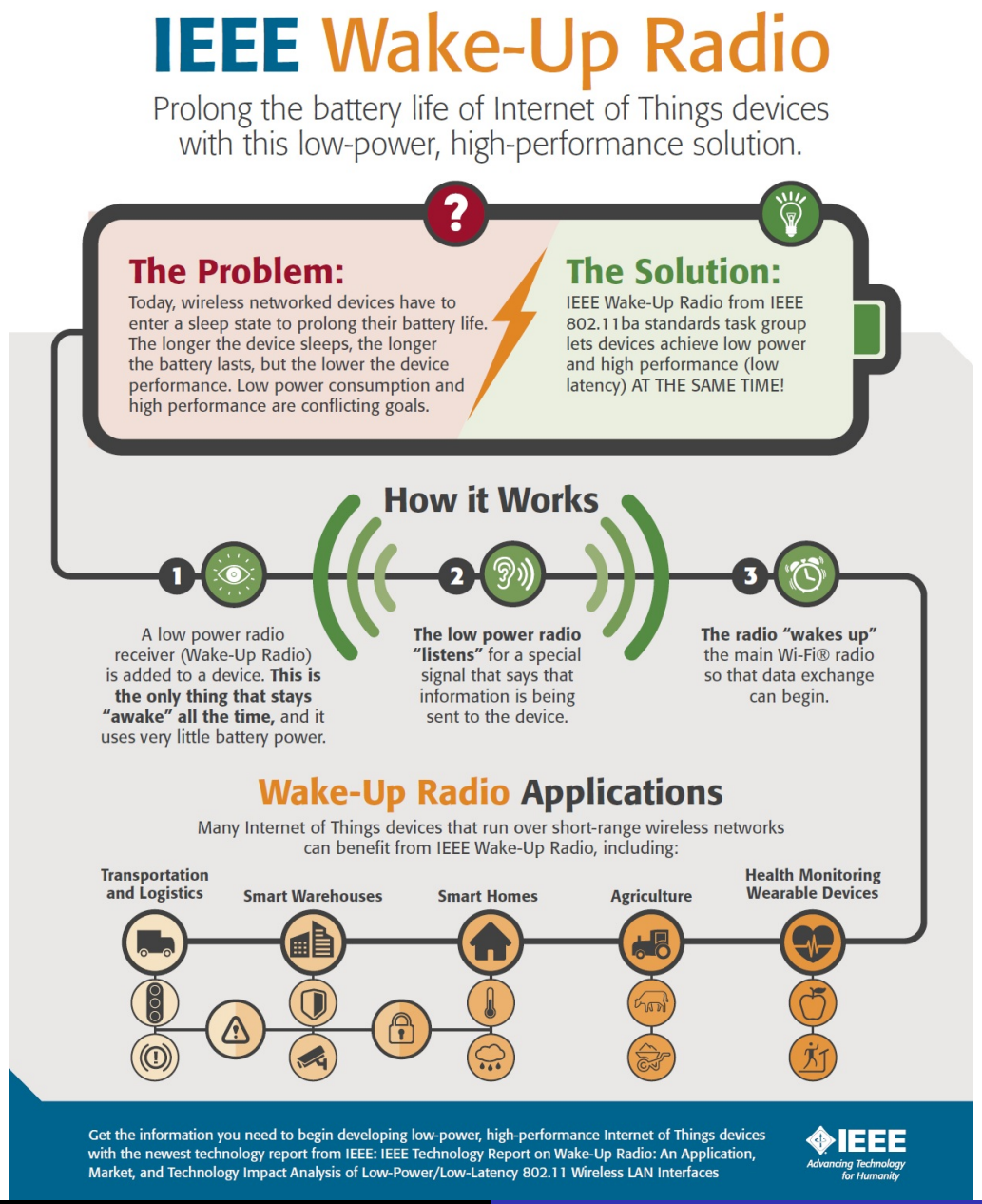
Energy Harvesting from Electromagnetic Signals - Rectenna
`https://www.youtube.com/watch?v=XpLCK88nVgU`

Energy Harvesting Demonstration
`https://www.youtube.com/watch?v=C7G7TyNL01Q`

Como manter um nó receptor em modo ultra baixo consumo e ao mesmo tempo deixar o circuito receptor ligado?

Wake-up Radios:

Os rádios Wake-up são geralmente projetados como um receptor de rádio secundário de potência quase zero, usado para acionar o rádio principal quando uma nova comunicação é iniciada.

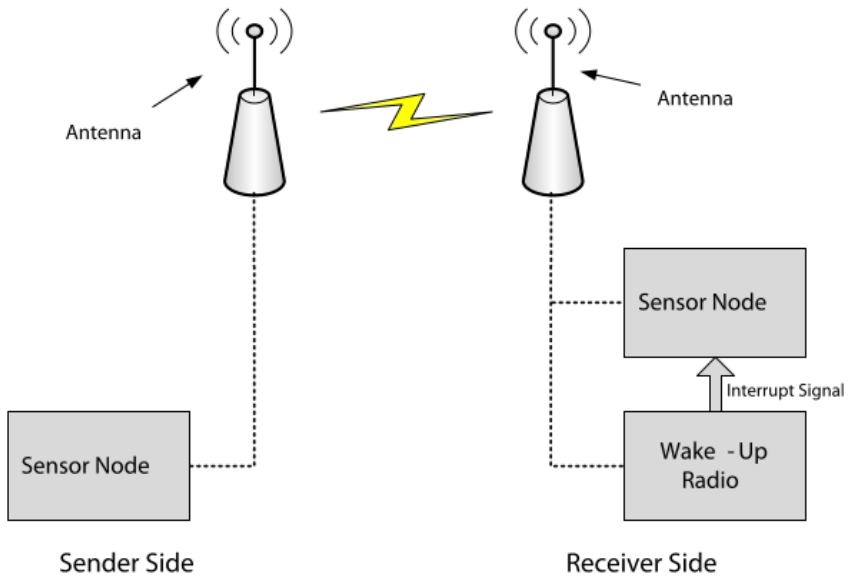

IEEE Wake-Up Radio
Prolong the battery life of Internet of Things devices with this low-power, high-performance solution.
The Problem:
Today, wireless networked devices have to enter a sleep state to prolong their battery life. The longer the device sleeps, the longer the battery lasts, but the lower the device performance. Low power consumption and high performance are conflicting goals.
The Solution:
IEEE Wake-Up Radio from IEEE 802.11ba standards task group lets devices achieve low power and high performance (low latency) AT THE SAME TIME!
How it Works
1
A low power radio receiver (Wake-Up Radio) is added to a device. This is the only thing that stays "awake" all the time, and it uses very little battery power.
2
The low power radio "listens" for a special signal that says that information is being sent to the device.
3
The radio "wakes up" the main Wi-Fi® radio so that data exchange can begin.
Wake-Up Radio Applications
Many Internet of Things devices that run over short-range wireless networks can benefit from IEEE Wake-Up Radio, including:
Transportation and Logistics
Smart Warehouses
Smart Homes
Agriculture
Health Monitoring Wearable Devices
Get the information you need to begin developing low-power, high-performance Internet of Things devices with the newest technology report from IEEE: IEEE Technology Report on Wake-Up Radio: An Application, Market, and Technology Impact Analysis of Low-Power/Low-Latency 802.11 Wireless LAN Interfaces
IEEE
Advancing Technology for Humanity

Picoradios:

- Tamanho e peso reduzidos;
- Baixo consumo;
- Captar energia do meio.
- Brasileiro contribuiu na pesquisa durante o pós doc na Universidade da California, Berkeley: Julio Leão da Silva Jr.

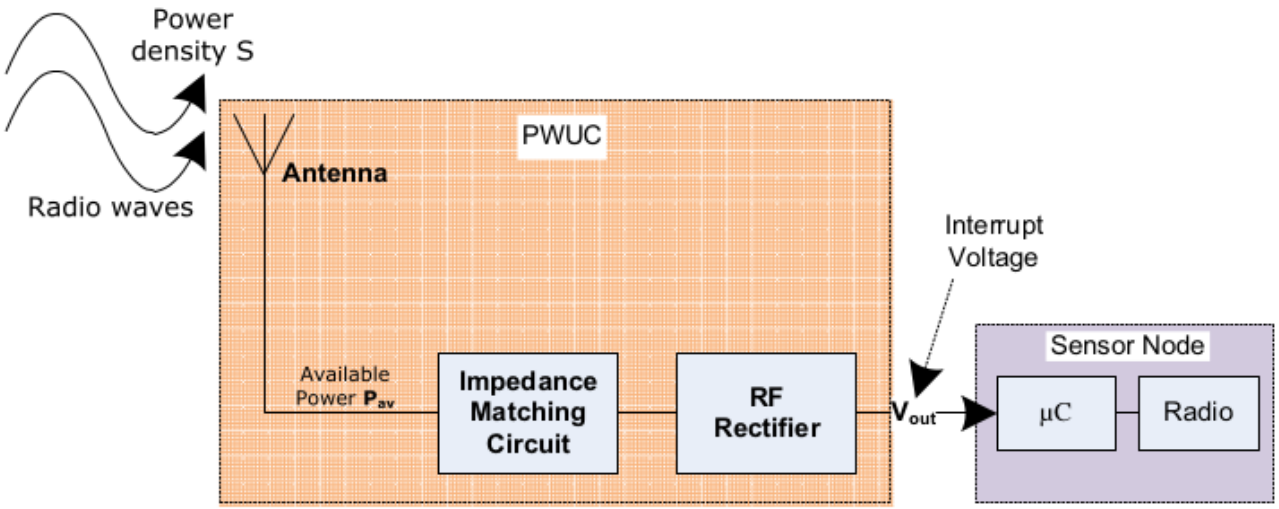
J. Rabaey, J. Ammer, J. L. da Silva and D. Patel, "PicoRadio: Ad-hoc wireless networking of ubiquitous low-energy sensor/monitor nodes," Proceedings IEEE Computer Society Workshop on VLSI 2000. System Design for a System-on-Chip Era, Orlando, FL, USA, 2000, pp. 9-12,

Wake-up radio

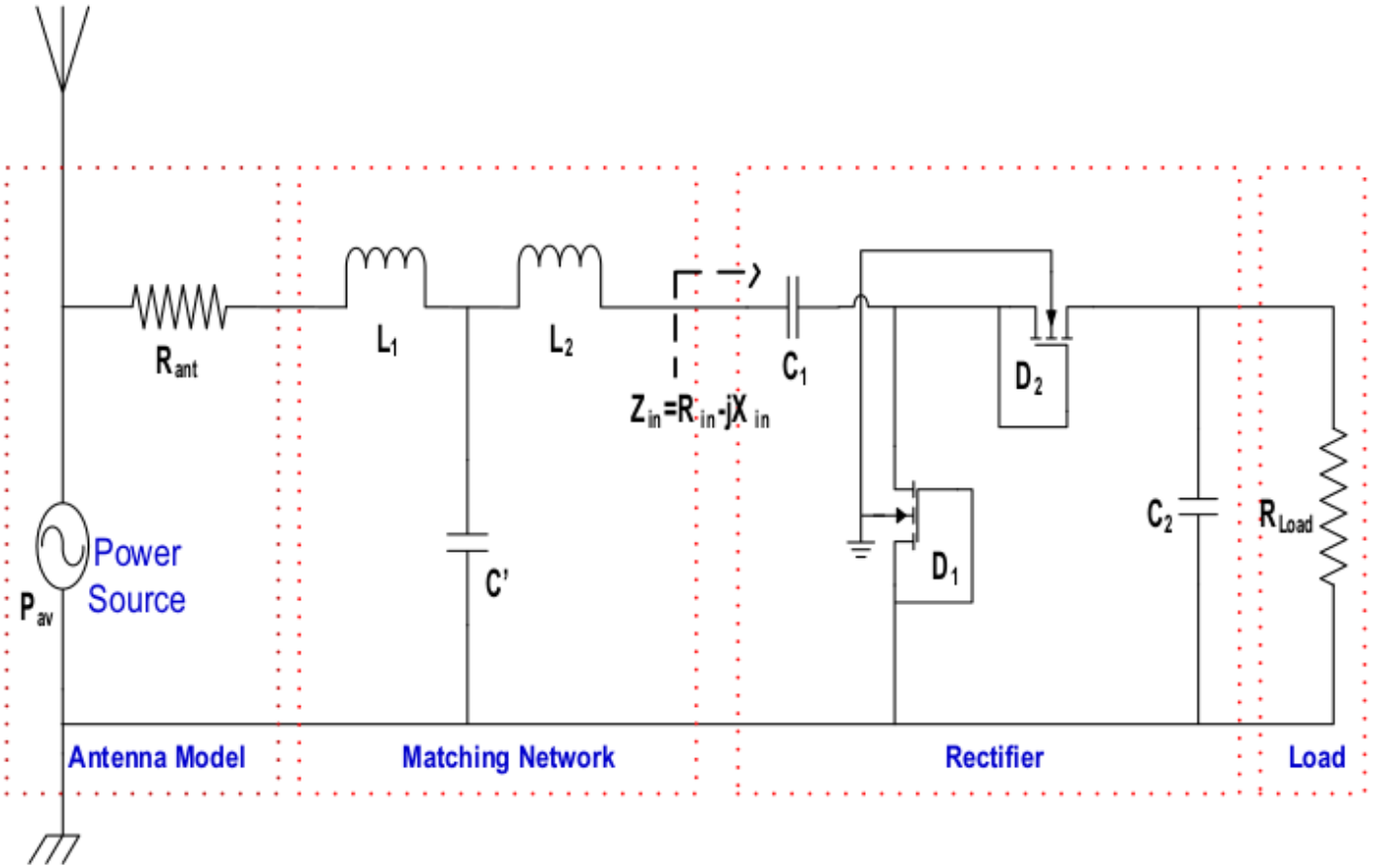


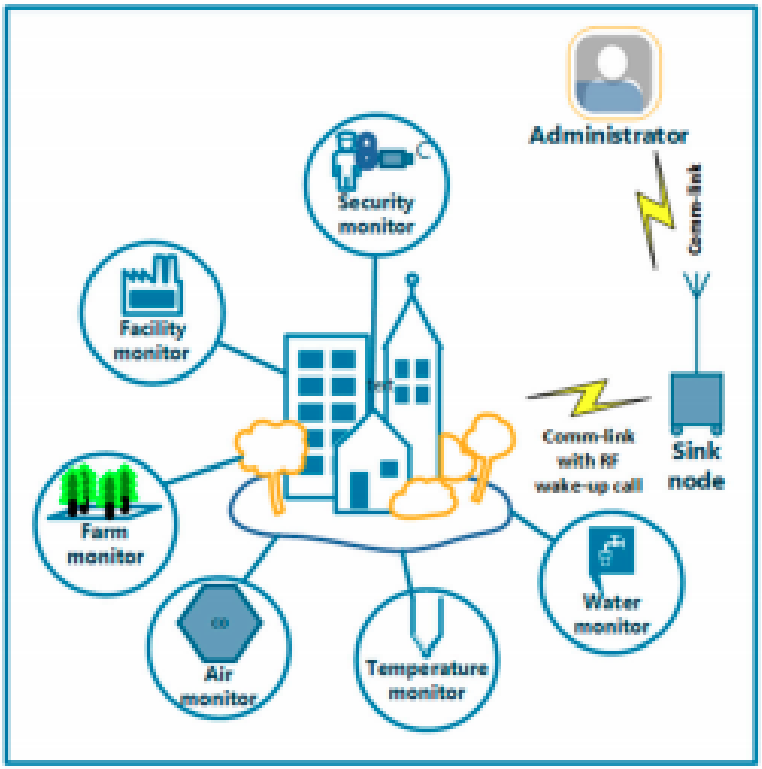
A Passive Wake-Up Circuit for Event Driven Wireless Sensor Network Applications Chandra Shekhar (Microelectronics Division, IIIT Allahabad, India), Shirshu Varma (IT Division, IIIT Allahabad, India), and M. Radhakrishna (Microelectronics Division, IIIT Allahabad, India) Journal of Circuits, Systems and Computers 2015 24:08

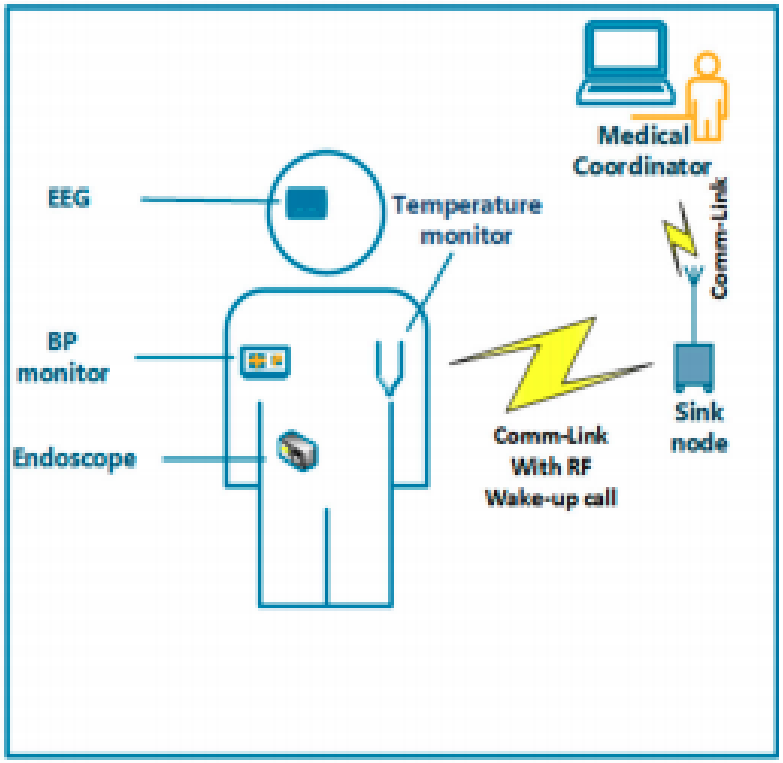
Wake-up radio



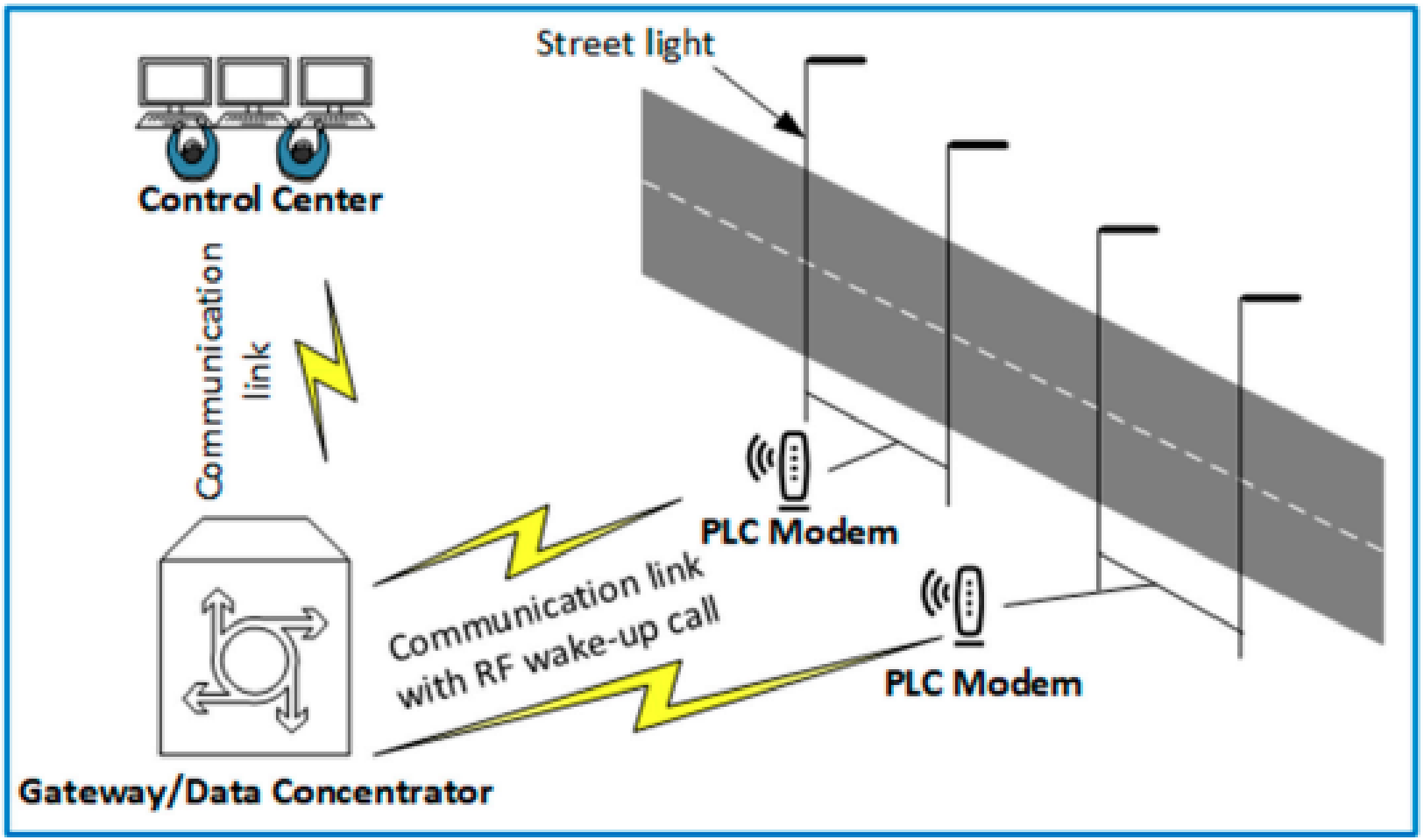
Wake-up radio: Circuito







Bello, H.; Xiaoping, Z.; Nordin, R.; Xin, J. Advances and Opportunities in Passive Wake-Up Radios with Wireless Energy Harvesting for the Internet of Things Applications. Sensors 2019, 19, 3078.



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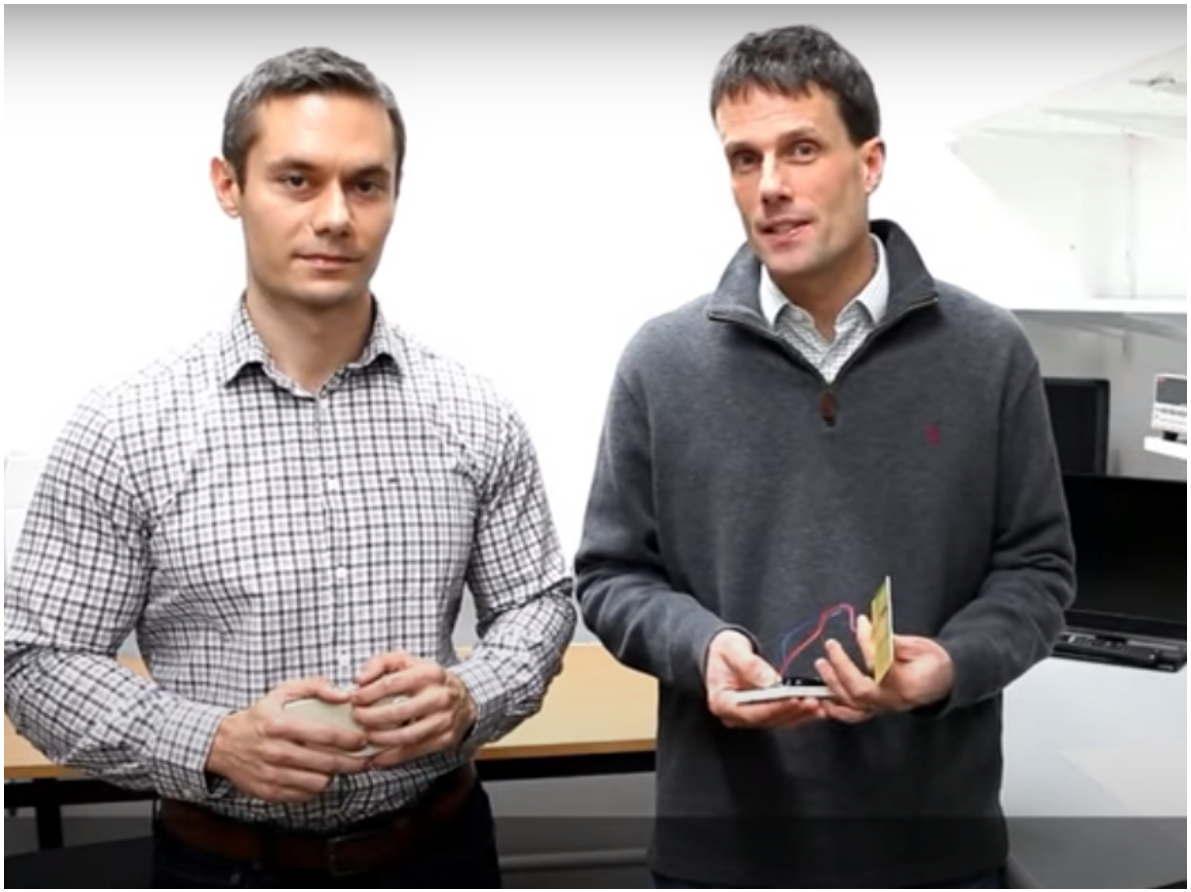

Zero-power circuit that listens for radio waves

`https://www.youtube.com/watch?v=ZOzvw6YIc7U`

Drone in Mid-Flight Uses Radio Waves to Recharge a Sensor on the Ground

`https://www.youtube.com/watch?v=fX2tt7etBDw&feature=emb_logo`

EnOcean

Batteryless wireless switches control light and shading

Batteryless wireless window contacts monitor window status

Batteryless wireless switches perform remote-control functions

Batteryless wireless door/window handles monitor door/window status

Occupancy sensors trigger lighting and climate control systems

Batteryless wireless control units allow for optimal climate conditions and maximum operating comfort

Wireless connectors control and monitor household appliances

Wireless actuators control radiators, room controllers govern underfloor heating

Networked smoke sensors set off fire alarms to trigger emergency response

Sunblind actuators control the sun-shade elements

EnOcean Alliance - the wireless standard for sustainable buildings
https://www.youtube.com/watch?v=YKYo6ns1i4o&t=3s