IC1301 - WiPE

Wireless Power Transmission for Sustainable Electronics

WIPE related activities at Aalborg University

(IR-UWB and WPT for medium range battery-less RFID)

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WIPE

COST IC1301

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Agenda

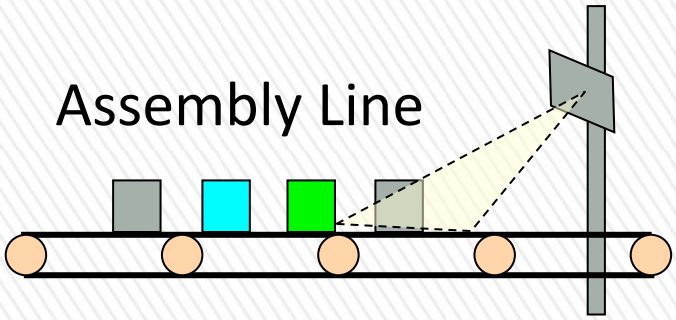
- Why medium range RFID, WPT and IR-UWB
- IR-UWB with MR WPT for medium range RFID
  - Magnetic resonance (MR) for medium range WPT
  - Low power IR-UWB front-end for battery-less data backscattering
- Conclusion
- Other WIPE related activities and plans for future activities

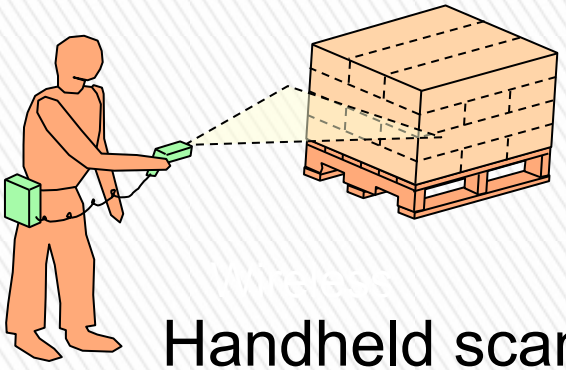
Why medium range RFID, WPT and IR-UWB

» RFID technologies for medium range (0.1m-1m) applications are needed

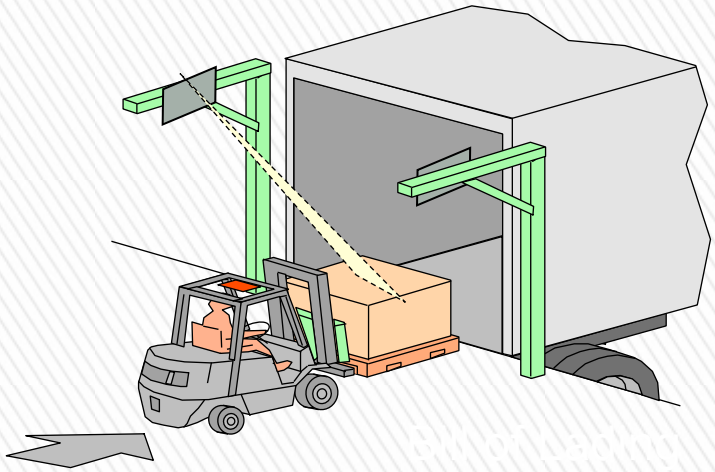
> Conventional passive RFID for cm-range applications

> Active RFID for > 10m-range applications





Handheld scanning



Shipping Portals

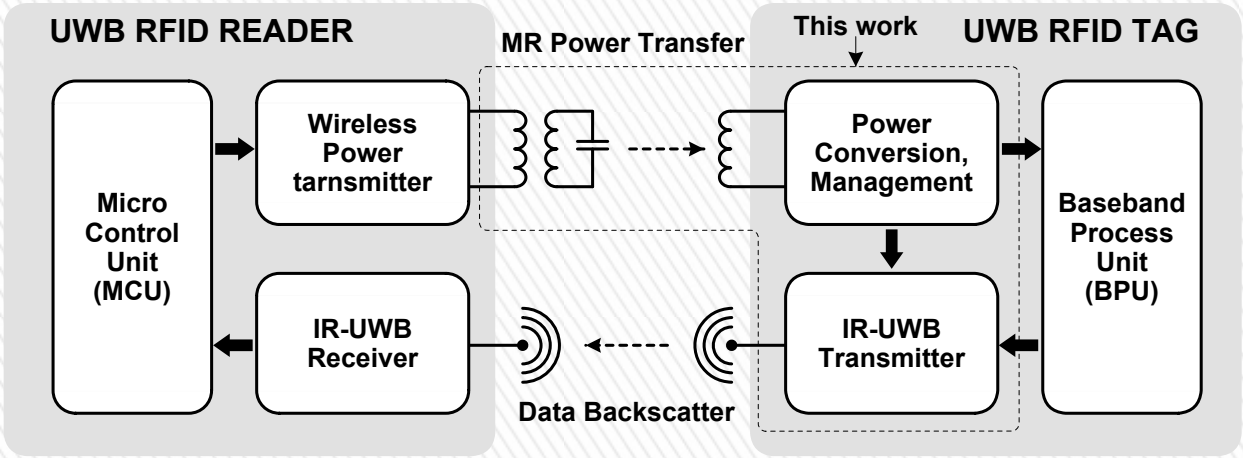
www.it.iitb.ac.in/~sri/talks/**rfid**-05.**ppt**

Why medium range RFID, WPT and IR-UWB

- Why WPT – Conventional power solutions are unsuitable for medium range RFID
  - Magnetic induction is only for a few cm
  - RF power transfer suffers from low efficiency (significant path loss) and stringent sensitivity requirement
- Why IR-UWB – communication technologies in conventional RFID are unsuitable for battery-less medium range RFID
  - Inductive coupling is only for cm-range data backscattering
  - Non-UWB long-range communication circuits are usually power consuming: requiring batteries

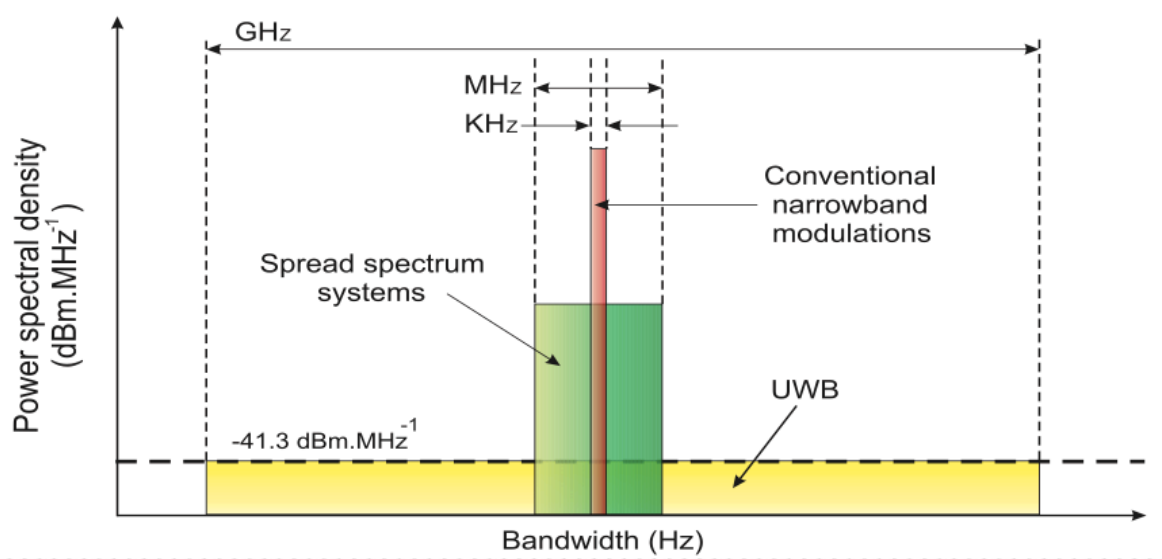
IR-UWB with MR WPT for medium range battery-less RFID

- MR WPT for reader-to-tag powering
- IR-UWB for data backscattering
- Asymmetric coil: large reader coil for extended range; small tag coil for compact size, resonance tag coil is not mandatory



Low power IR-UWB front-end – What is UWB

- UWB is a technology for transmitting information spread over a large bandwidth that should be able to share spectrum with other users
- Absolute bandwidth larger than 500 MHz or a relative bandwidth larger than 20% [FCC, 2002]

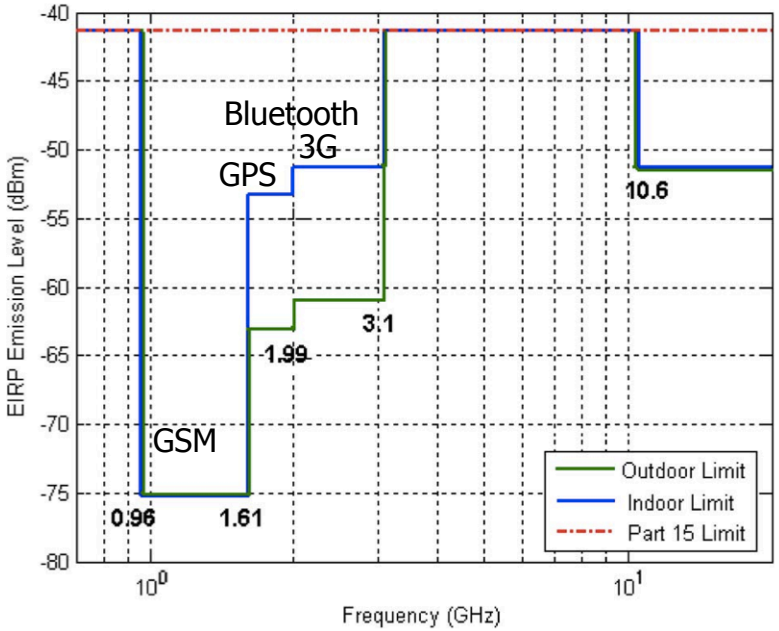


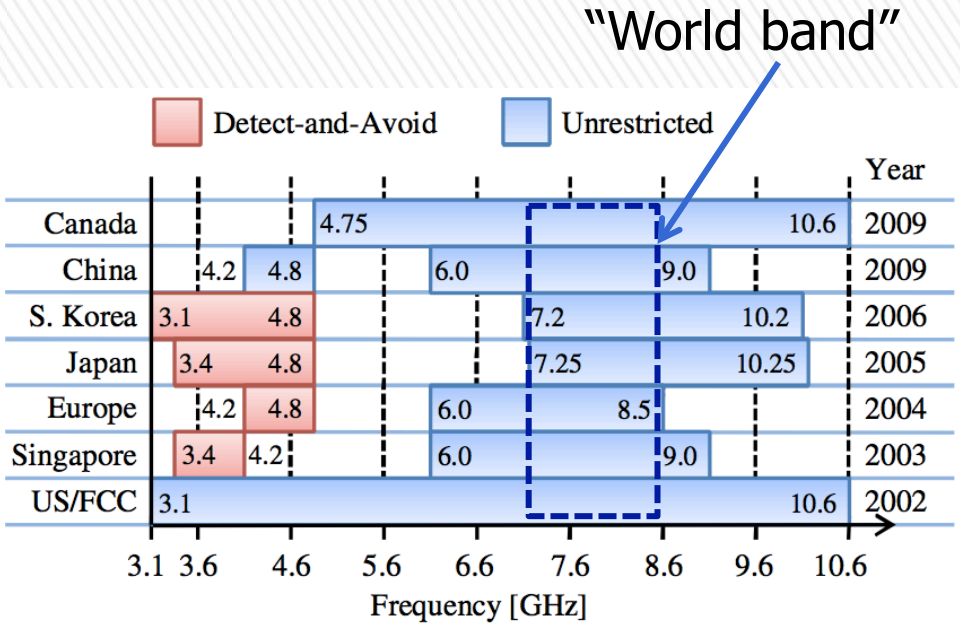
Low power IR-UWB front-end – What is UWB

- Power emission limits
- Frequency bands limits
- Interference mitigation limits

BW = 1.4 GHz

BW_{rel} = 12.5%





Low power IR-UWB front-end – What is UWB

» The Impulse-Radio UWB (IR-UWB) method employs transmission by means of ultra short duration pulses on the order of nanoseconds

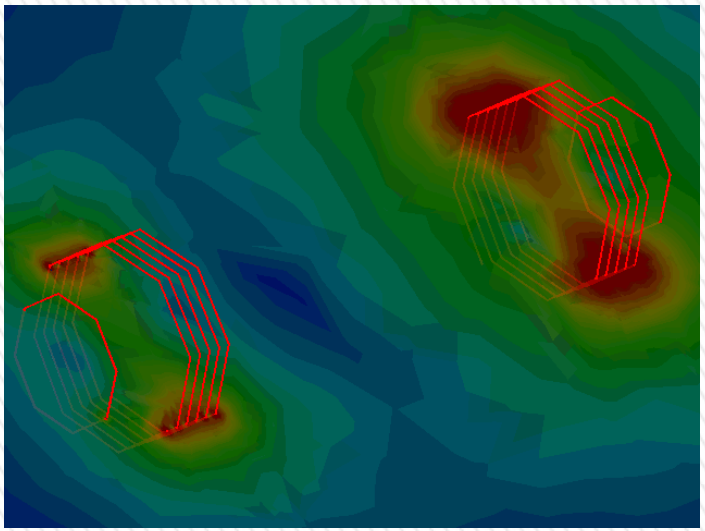
$$1/\tau[\text{sec}] \approx BW[\text{Hz}]$$

> Power efficient-low duty cycle
> Scalable data rates versus distance
> Precise localization
> Multipath signal can be exploited in a rake Rx

Magnetic resonance for medium range WPT

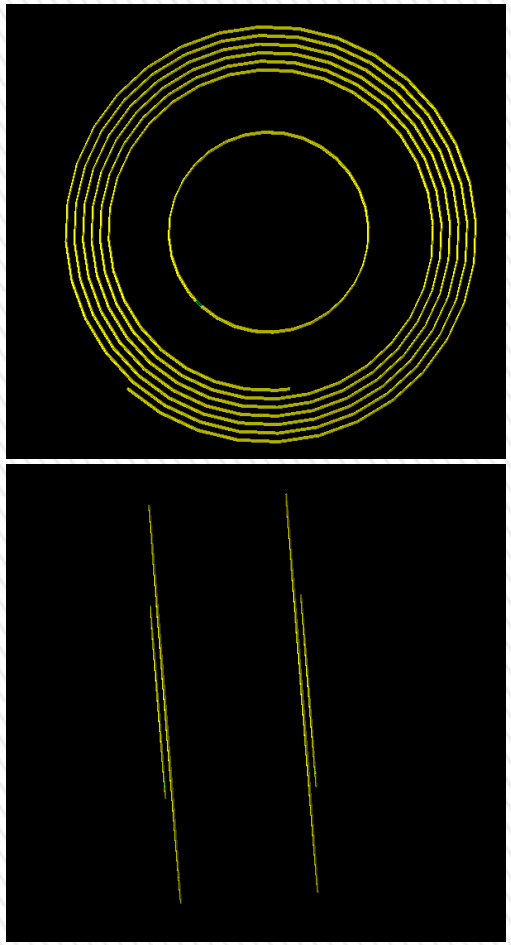
- High efficiency up to about 95%
- Power transfer range up to 5 meters[1]
- Capable of powering multiple devices simultaneously
- “Uniform” energy field within the target space

Simulated E-field (animation) using Agilent EMPro of a magnetic resonance wireless power transfer setup. The area between the Tx and Rx is filled with energy, while the field strength drops remarkably outside the area.

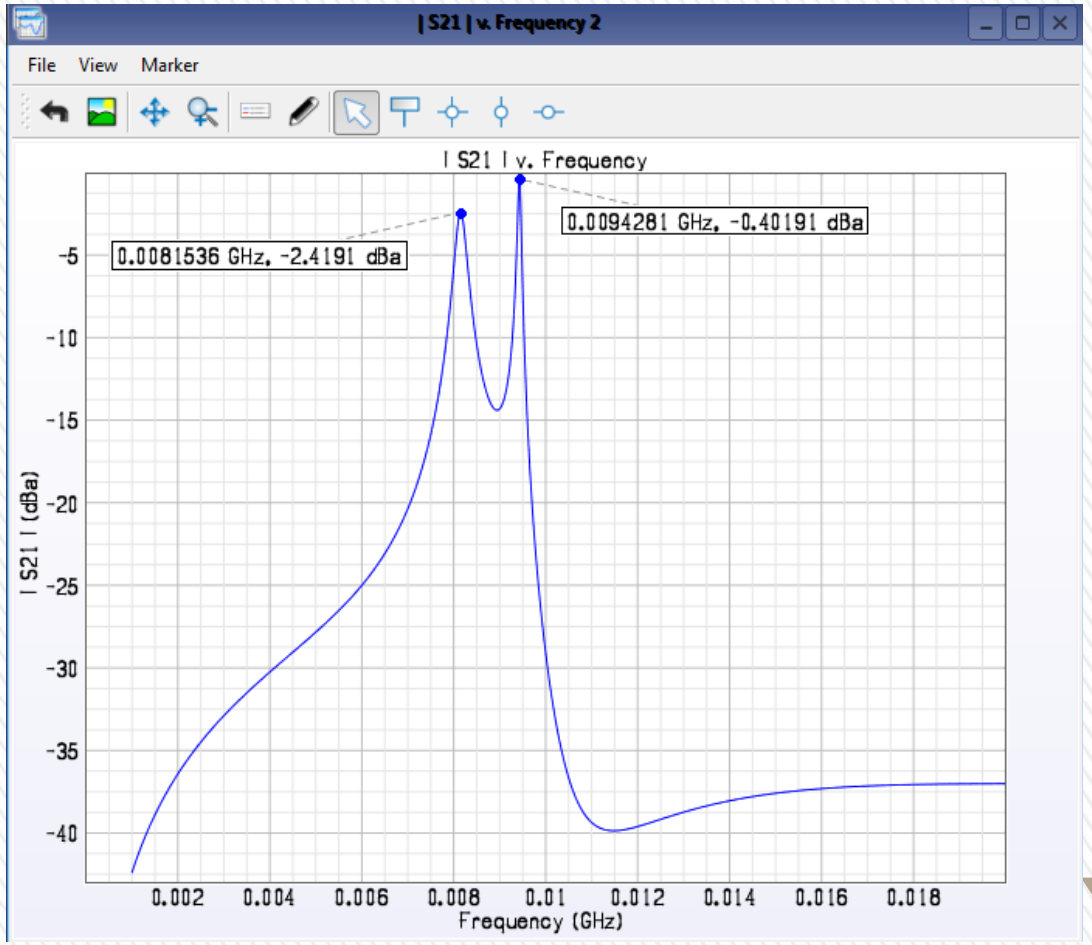


1: http://www.eurekalert.org/pub_releases/2014-04/tkai-wpt041714.php

Magnetic resonance for medium range WPT



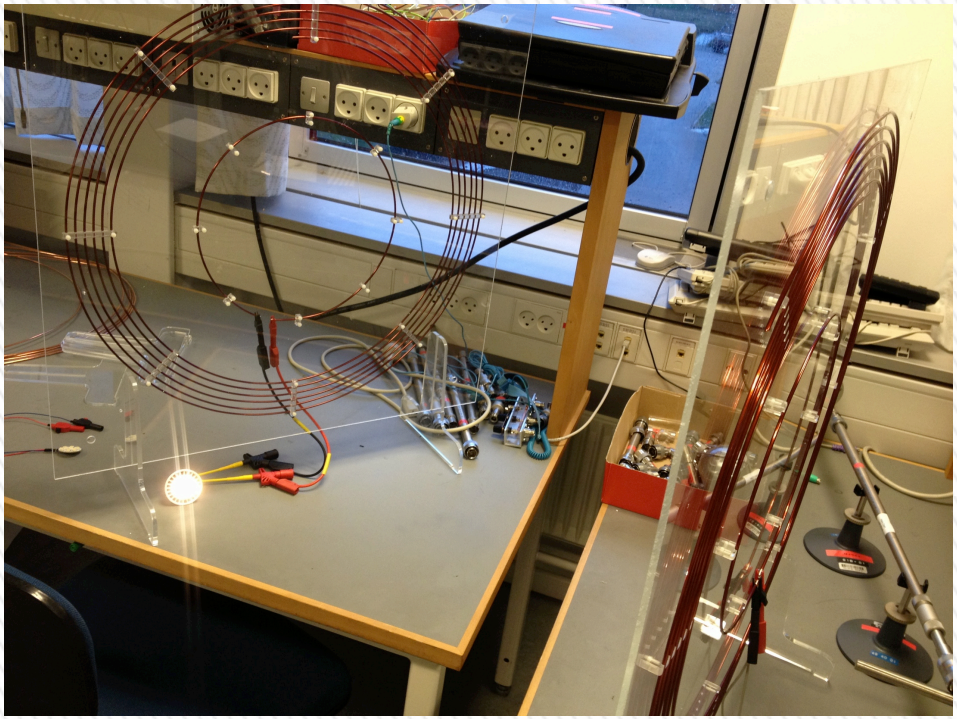
Simulation setup



Simulated $|S_{21}|$

Magnetic resonance for medium range WPT

- Outer coil diameter is 60 cm, inner coil diameter is 28 cm
- 6.5 MHz – 8.5 MHz with Tx-to-Rx distance from 10 cm to 50 cm
- Flexible coil position



An LED lamp bulb (full power 3.8 W) wirelessly powered by an ordinary RF signal generator with 50 Ohm source impedance.

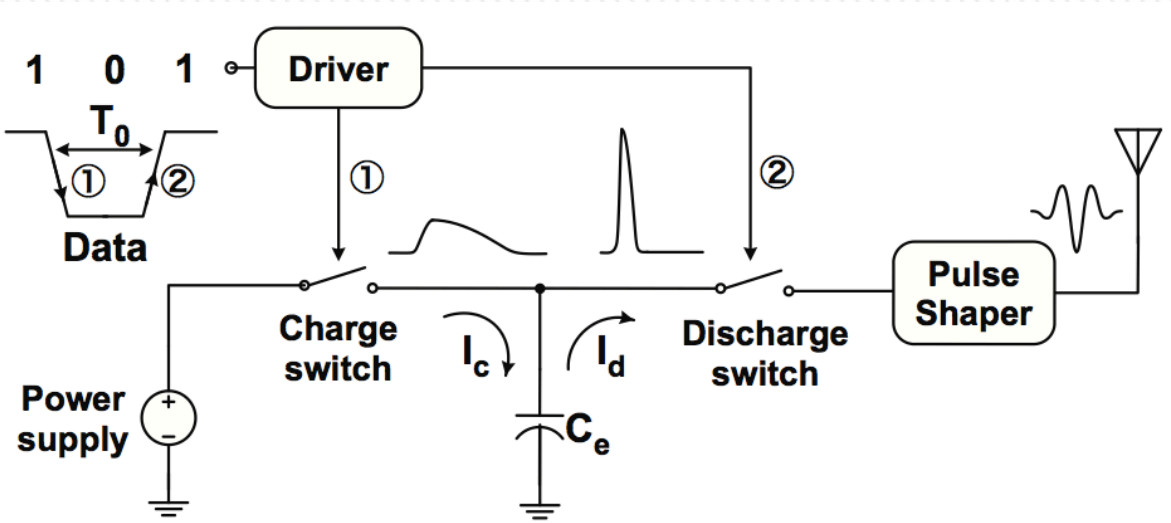
Low power IR-UWB front-end – IR-UWB's suitability for medium range RFID

- Potential for low power using simple CMOS transmitters
  - Suitable for battery or energy harvesting based devices
  - Low power is CMOS friendly
  - "Moore's Law Radio" - Data rate scales with the shorter pulse widths made possible with ever faster CMOS circuits
- Potential for low cost implementation
  - Nearly "all-digital" radio
  - Integration of more components on a chip
- Potential for small size implementation
  - Nearly "all-digital" radio

Low power IR-UWB front-end - low instantaneous power pulse generator

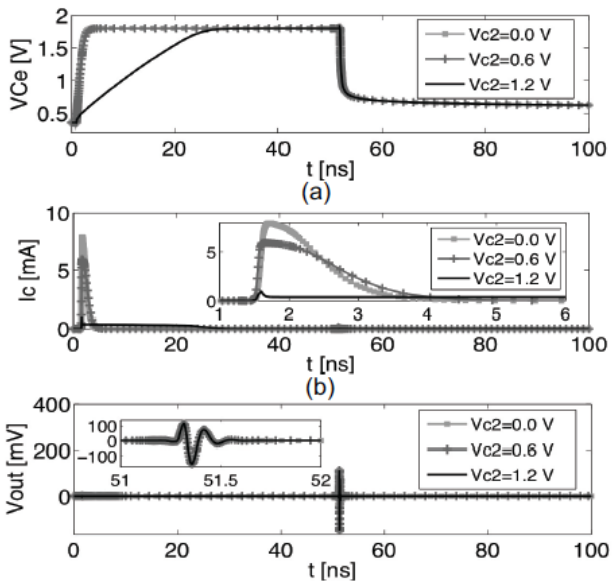
» The IR-UWB design has close ties to energy harvesting

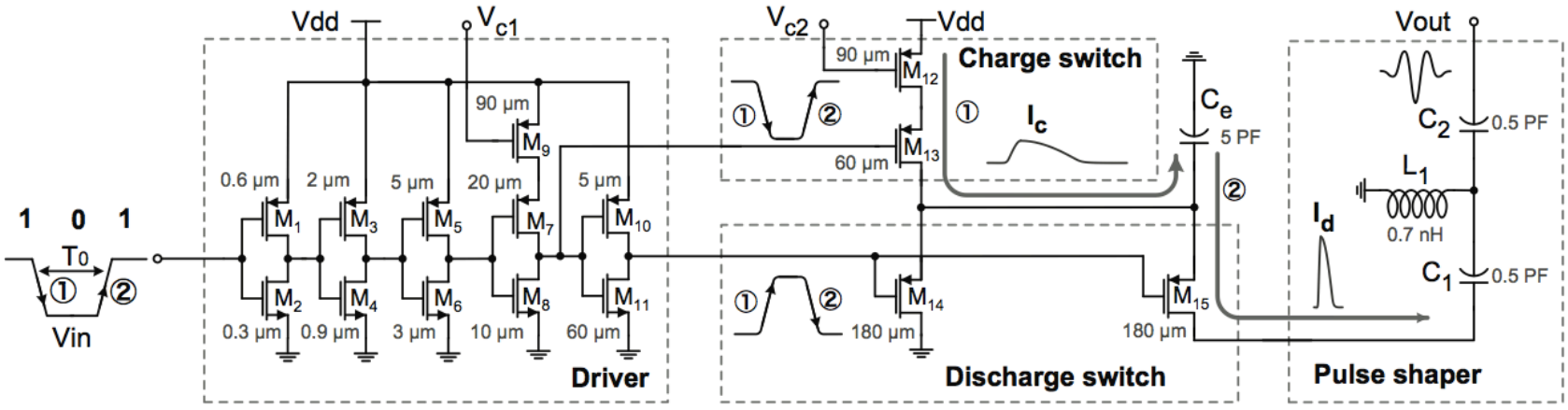
» With low energy power sources, meeting peak power requirements is always challenging



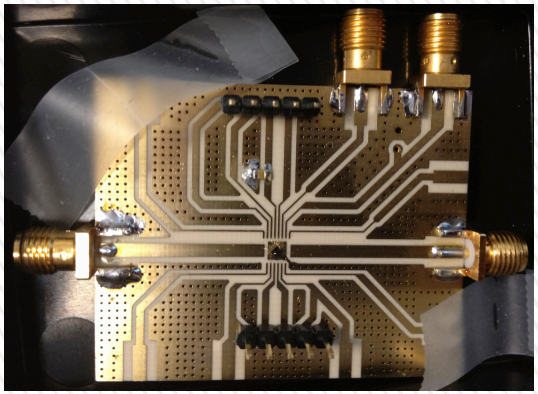
Low power IR-UWB front-end - low instantaneous power pulse generator

- Running a slow-charge and fast-discharge approach mitigates (parts of) the problem (one-pulse storage)
- Data-rate depends on the characteristics of the source

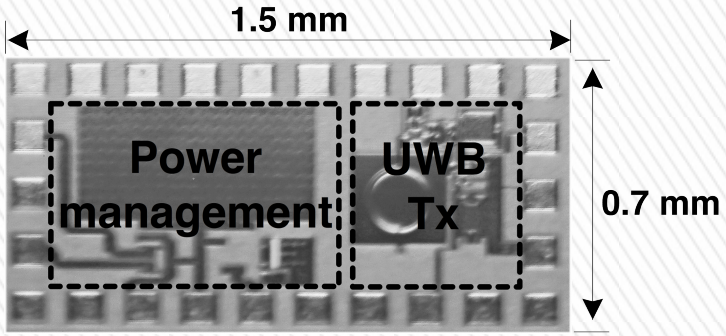




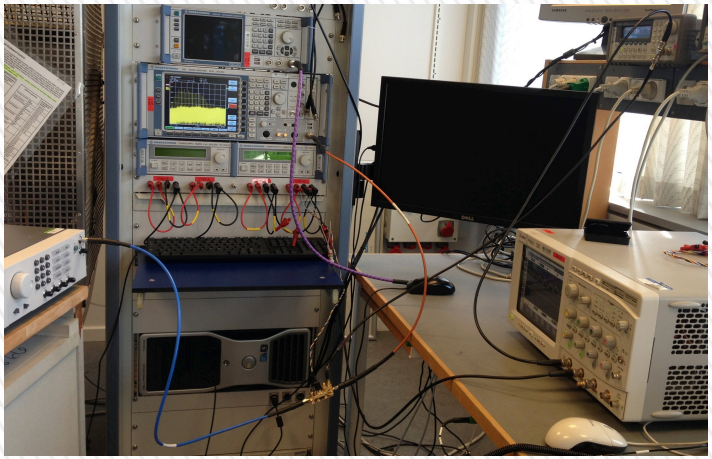
Low power IR-UWB front-end – power management and measurements



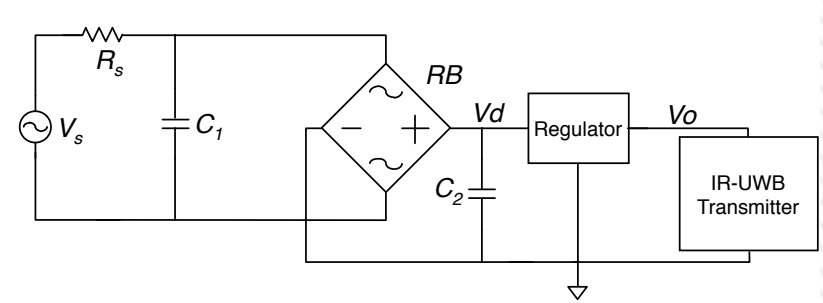
Test PCB



Microphotograph of the IR-UWB Tx with Power management



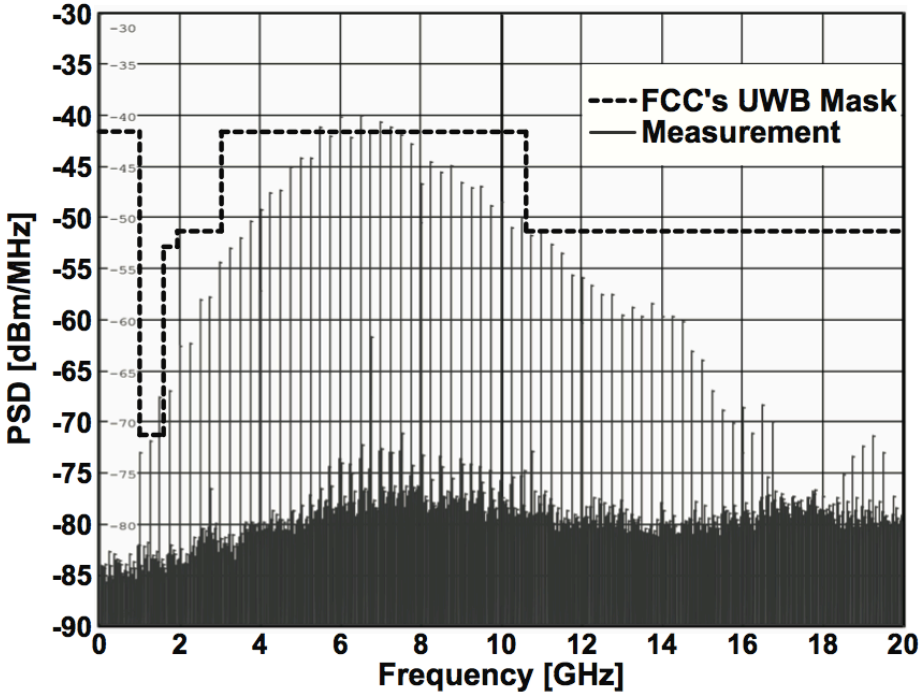
Measurement setup



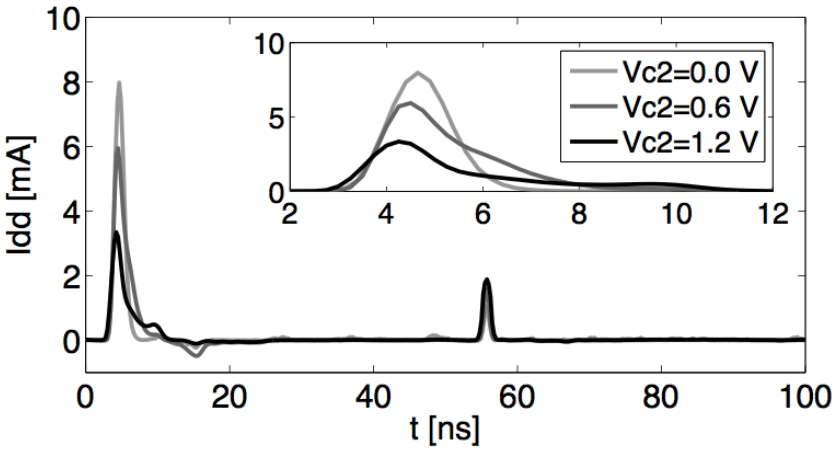
System block diagram
(V_s is 6.78MHz)

Low power IR-UWB front-end – power management and measurements

» Measured PSD with a PRR of 250 Mpps



Measured PSD of the UWB pulse signal



Measured total current

Low power IR-UWB front-end – power management and measurements

- Slow charge for energy storage and fast discharge for narrow pulse generation
- Low instantaneous power consumption (6-10.4mW)
- Supports OOK modulation
- Low average power consumption (5-18pJ/pulse)
- Average power 180μW@10Mbpb
- Chip area 0.16mm^2

TABLE I
COMPARISON OF MEASURED PERFORMANCE

Ref	CMOS [μm]	PRR [Mpps]	EP pJ/pulse	BW [GHz]	PP [mW]	Area [mm^2]
[3]	0.18	250	20	3-5	N/A	0.08
[4]	0.13	100	9	6.8	90	0.54
[5]	0.18	100	18	0.53	N/A	0.4
[6]	0.13	50	48	3.1-4.8	N/A	0.11
[7]	0.09	400	65	5.5	N/A	1.9
This work	**0.18**	**10** **250** **1000**	**18** **14.6** **5.0***	**7.5** **6.75** **6.0**	**6.0** **10.0** **10.4***	**0.16**

*: Simulation

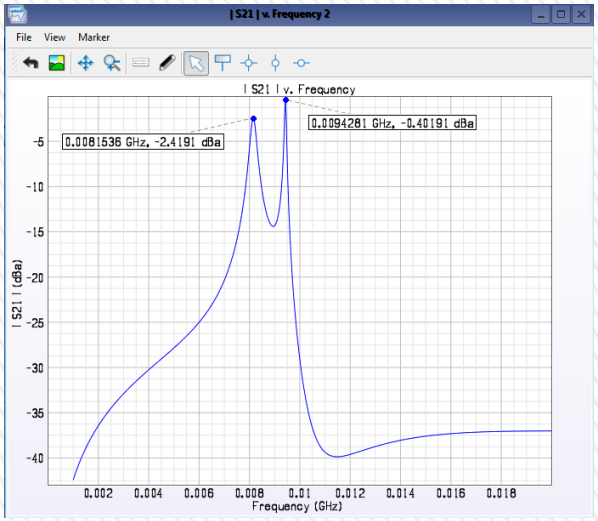
M. Shen, Y.-Z. Yin, H. Jiang, T. Tian, and J. Mikkelsen, "A 3-10 GHz IR-UWB CMOS Pulse Generator With 6 mW Peak Power Dissipation Using A Slow-Charge Fast-Discharge Technique," Microwave and Wire- less Components Letters, IEEE, vol. 24, no. 9, pp. 634–636, Sep. 2014.

Conclusion

- MR WPT is a promising powering approach for medium range RFID applications
- MR WPT has the potential to power multiple tags in the targeted area
- IR-UWB features microwatt power consumption, and is suitable for medium range RFID applications

Other WIPT related activities and future activities

- Simultaneous wireless information and power transfer using dual coupling frequencies
- Health issues in WPT and mitigation approaches: one of the barriers for WPT



Dual-frequency coupling

SAR measurement setup at AAU

Thank you … questions?

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