The main GRETA project results, for energy efficient radio identification and localization

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GRETA objectives

Tomorrows' tags:

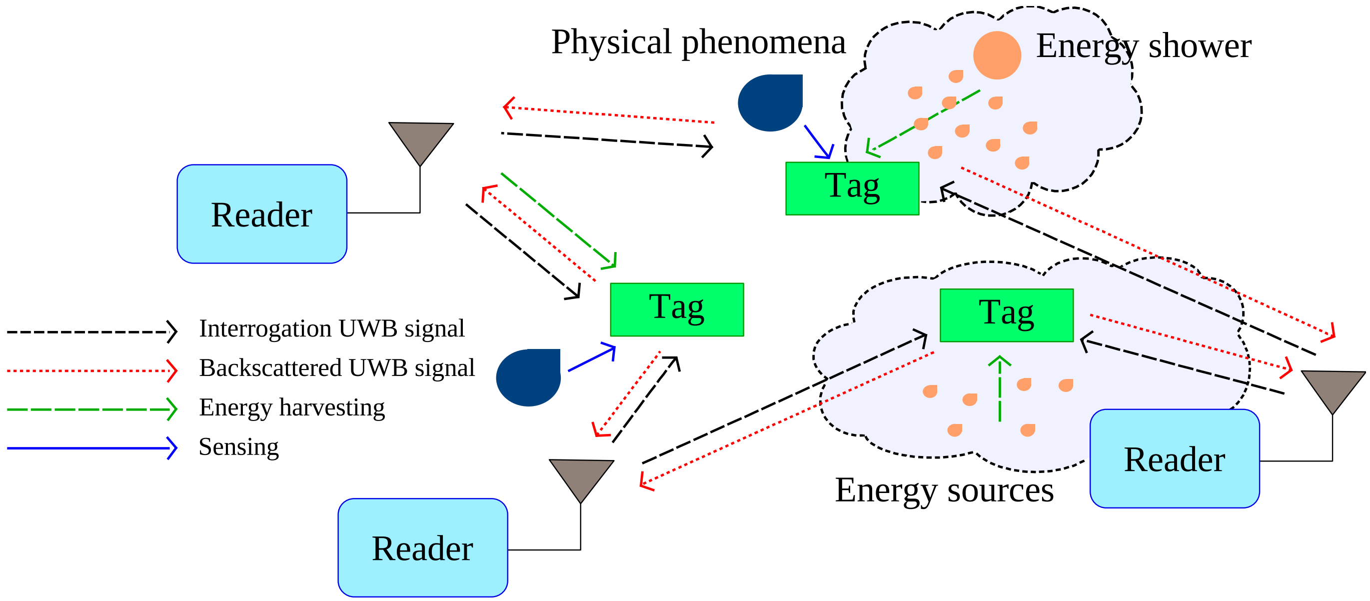
- localizable with sub-meter precision even in indoor scenarios or in presence of obstacles;
- small-sized (with an area in the order of a few square centimeters) and lightweight (without cumbersome batteries);
- eco-compatible (made with recyclable materials as paper);
- energy-autonomous;
- easy to be integrated in goods, clothes and packages;
- low-cost to permit the employment of several tags in the environment;
- capable of sensing physical quantities of the environment.

GREen TAgs and sensors with ultra-wide-band identification and localization capabilities

GRETA objectives

Integration of the concepts of

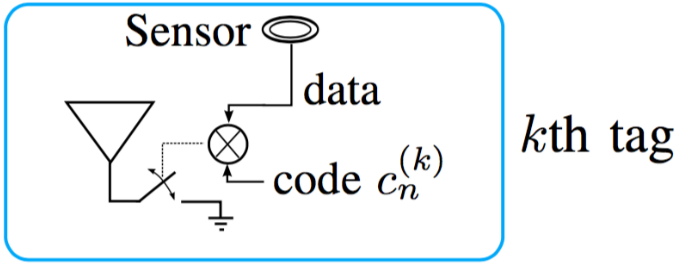
- Radiofrequency identification (RFID)
- Wireless sensor networks (WSN)
- Real time locating systems (RTLS)



GREen TAgs and sensors with ultra-wide-band Identification and localization capabilities

UWB-RFID: Main issues

The GRETA tag exploits the UWB backscattering mechanism



- ***The poor link budget***

Due to the two-hop communication scheme, the received signal backscattered by the tag is very weak.

- ***The multi-tag management***

When adopting UWB backscatter communication, no anti-collision protocol can be implemented due to the extremely simple tag front-end and the absence of any receiver and processing unit at tag side.

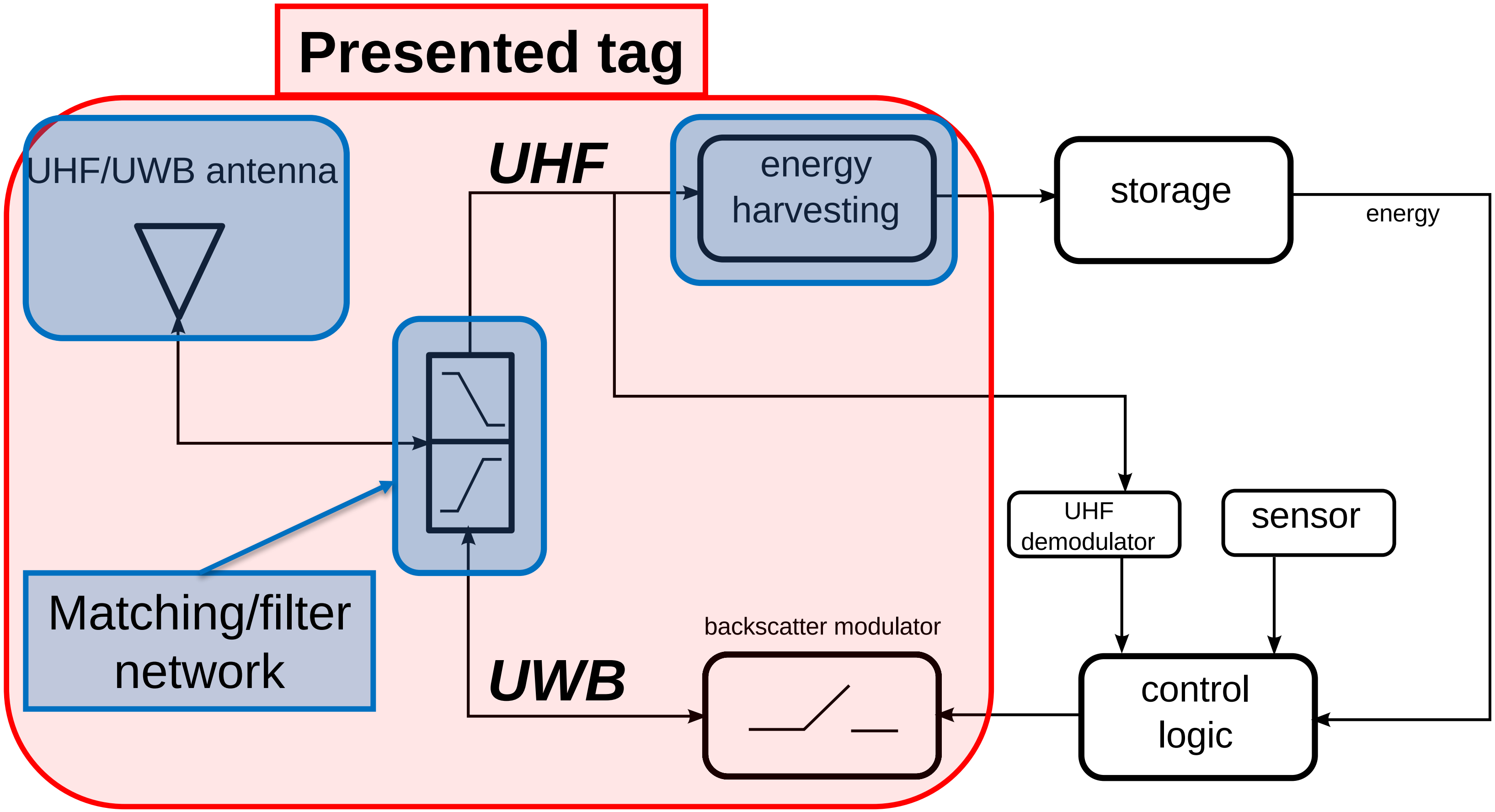
- ***The energy-related aspects***

The circuitry at tag side (UWB switch, control logic and sensors) must be properly powered so energy-harvesting techniques have to be considered.

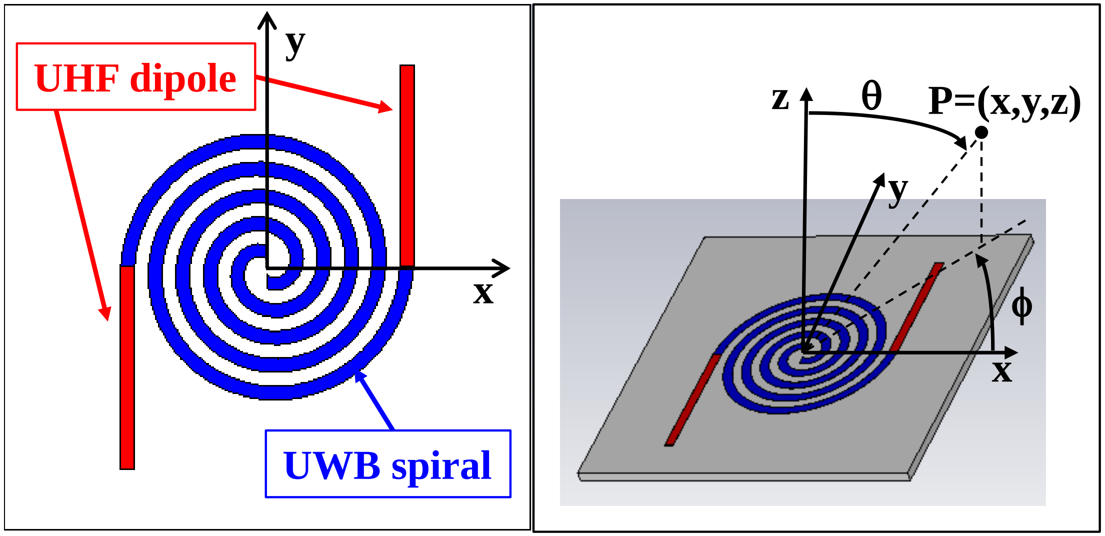
Joint adoption of UWB and UHF signaling

UWB Stand-Alone Tag

UWB for communication (Tag ID, sensor data) and localization
Energy-harvesting and synchronization through the UHF link



Integrated UWB-UHF Antenna



Unique antenna:
- one port
- size reduction
- direct future UWB-UHF RFID chip connection

- Archimedean Spiral antenna
  - European [3.1-4.8] GHz UWB band

UWB Backscattering communication and localization functionalities

- Dipole Antenna
  - European 868 MHz RFID band

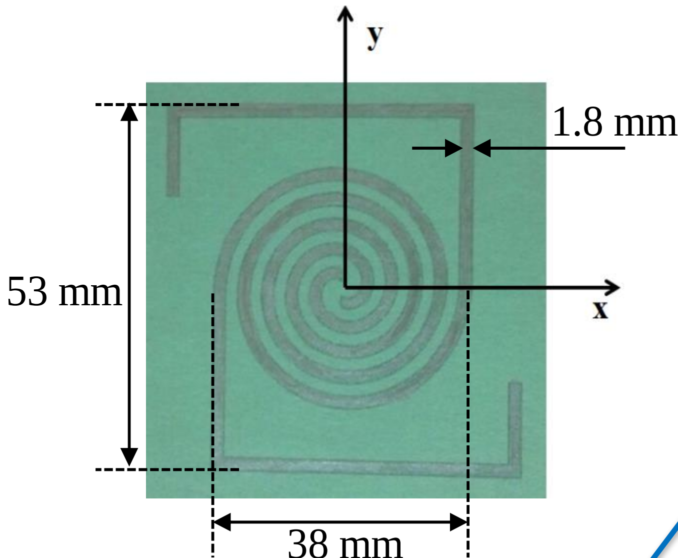
UHF Energy Harvesting
→ enhanced functionalities (e.g. sensors, range extension, etc.)

Fantuzzi, M.; Masotti, D.; Costanzo, A., "A Novel Integrated UWB–UHF One-Port Antenna for Localization and Energy Harvesting," *IEEE Transactions on Antennas and Propagation*, vol.63, no.9, pp.3839-3848, Sept. 2015

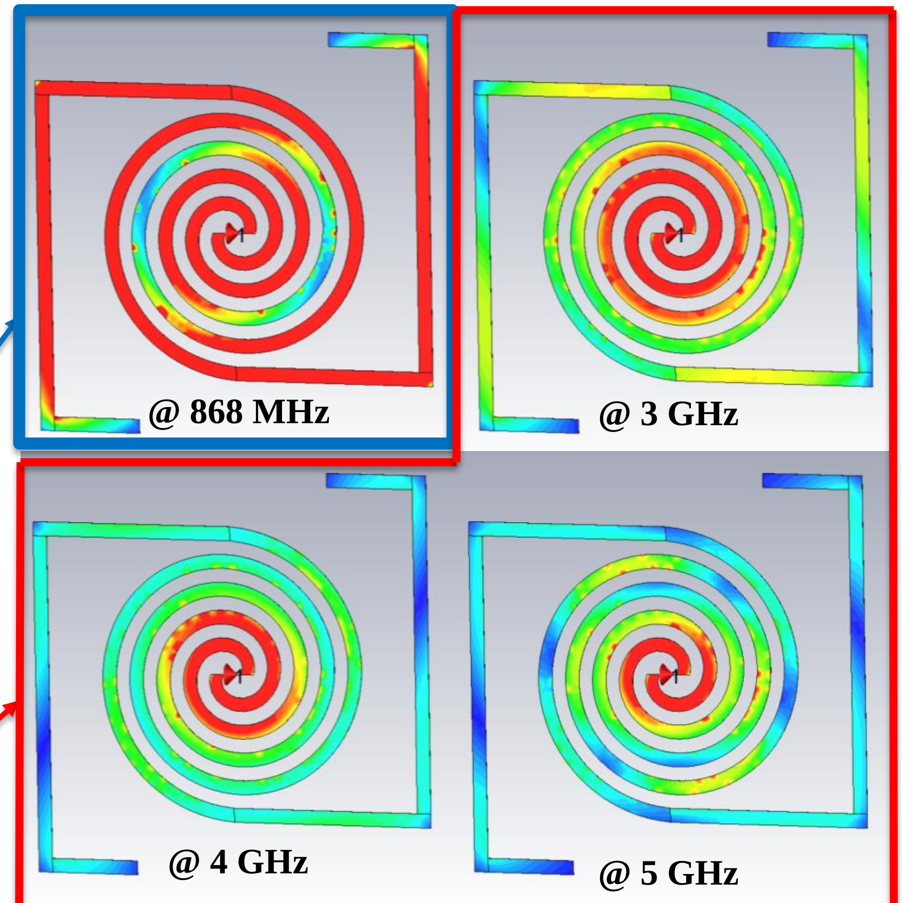
Integrated UWB-UHF Antenna

Paper prototype

(ε_r=2.85, tan(δ)=0.053 @ 4GHz)



Antenna surface current



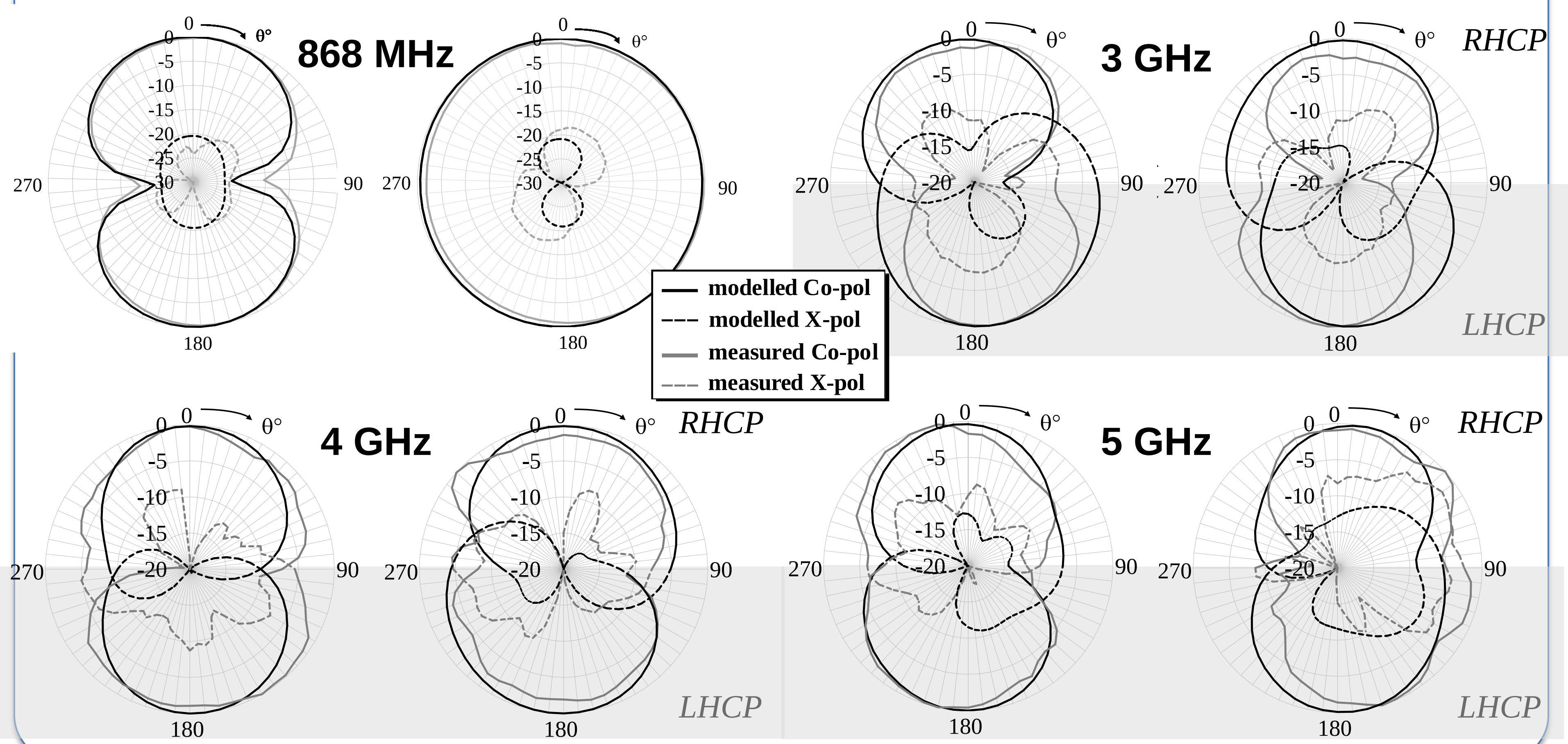
UHF band: 1.5 λ behavior of the dipole

Autosimilarity: active zone moving in the UWB band

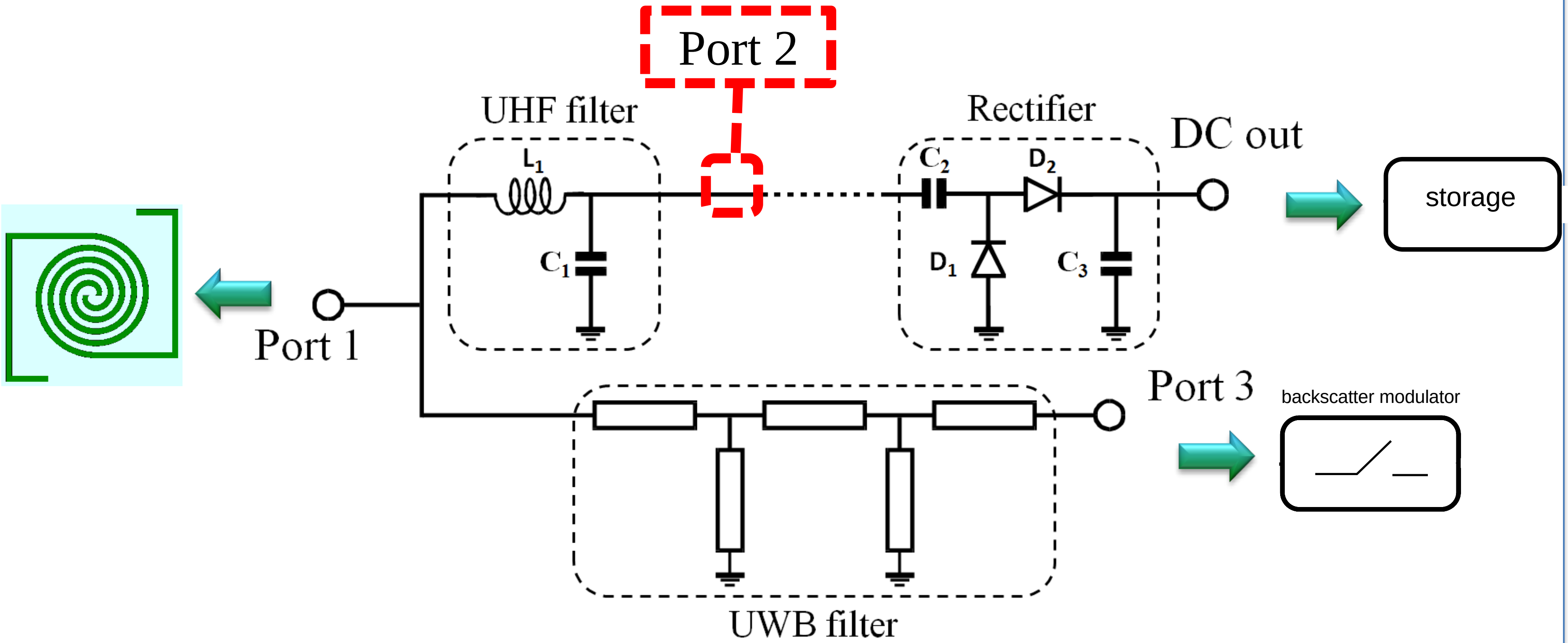
Integrated UWB-UHF Antenna

Antenna performance – radiation patterns

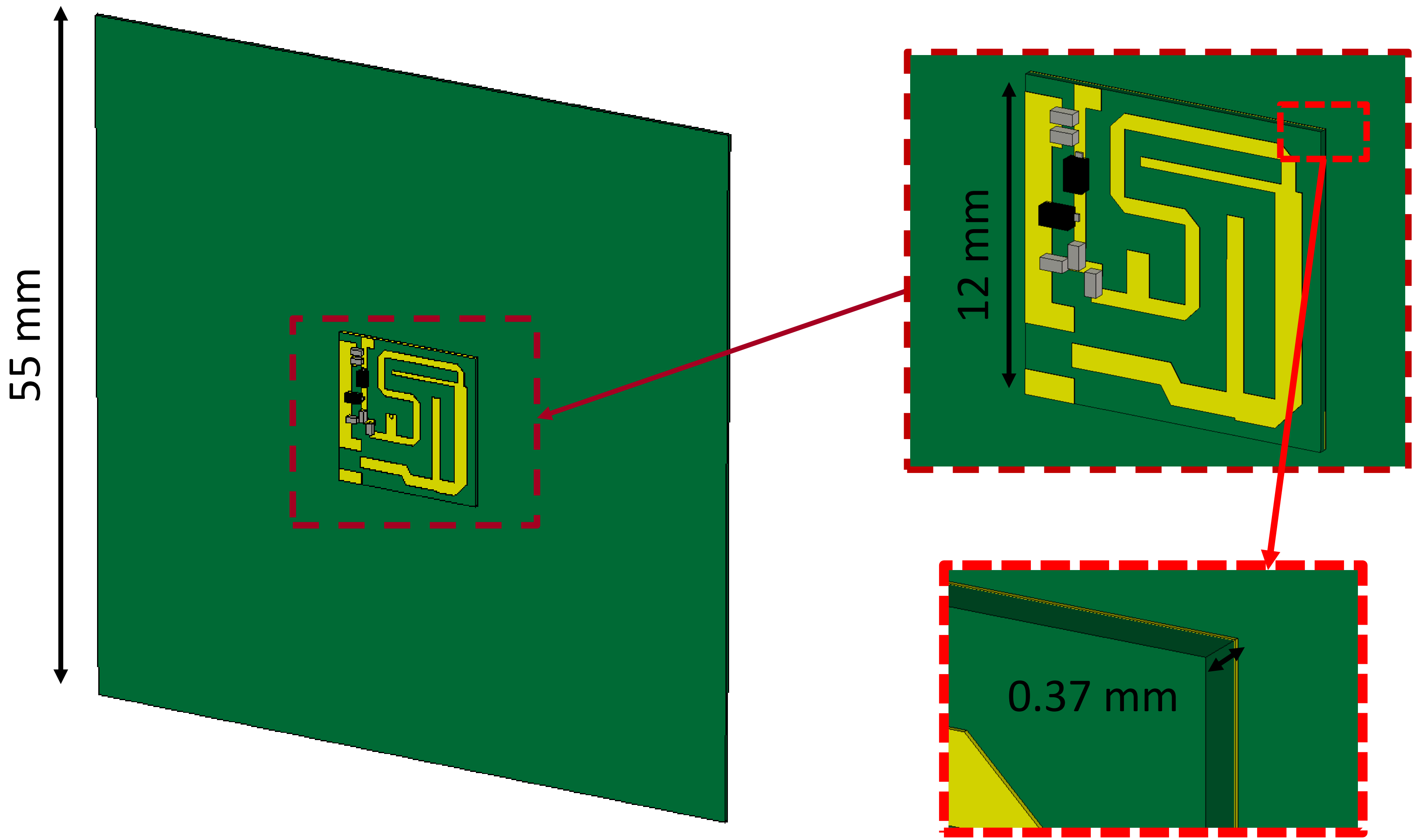
Normalized CO and CROSS polarized components (dB)



UHF-UWB diplexer



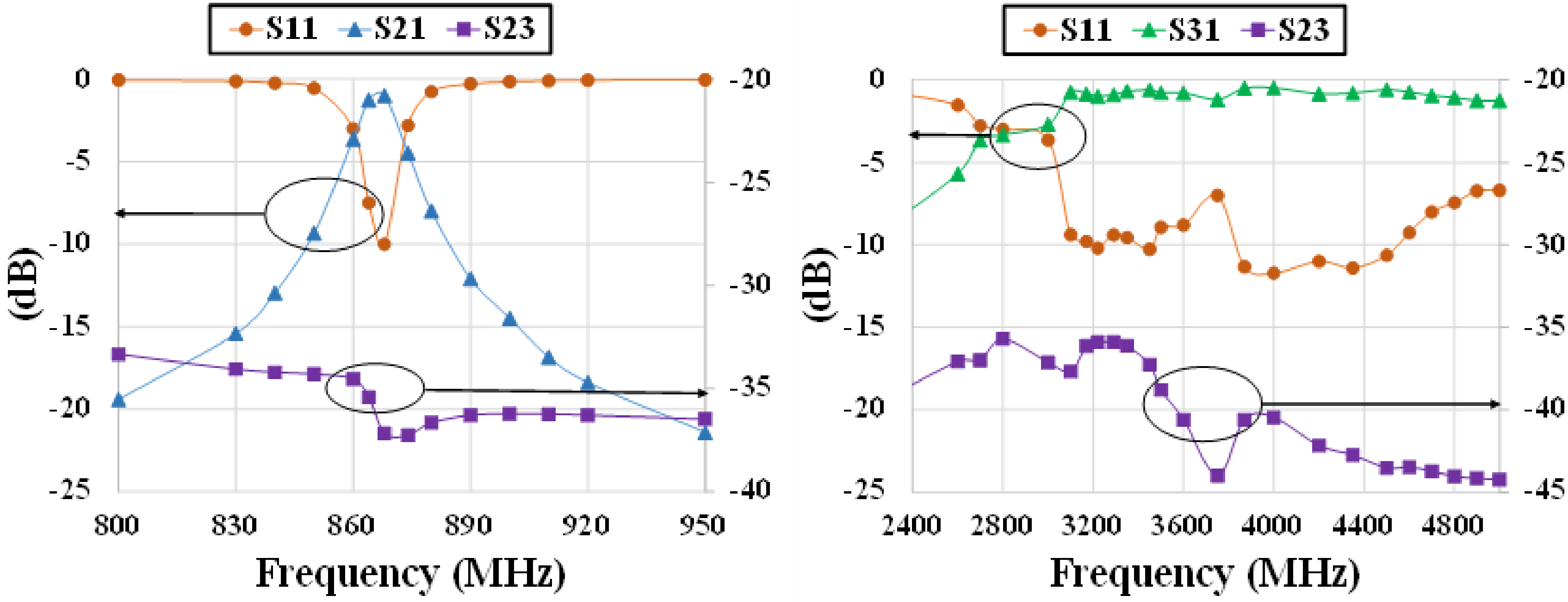
Final paper prototype



Diplexer filter and decoupling

Filter performance:

- Insertion loss in UHF band: ~ 1.5 dB
- Insertion loss in UWB band: ~ 2 dB
- **High decoupling** between port 2 (UHF) and 3 (UWB)

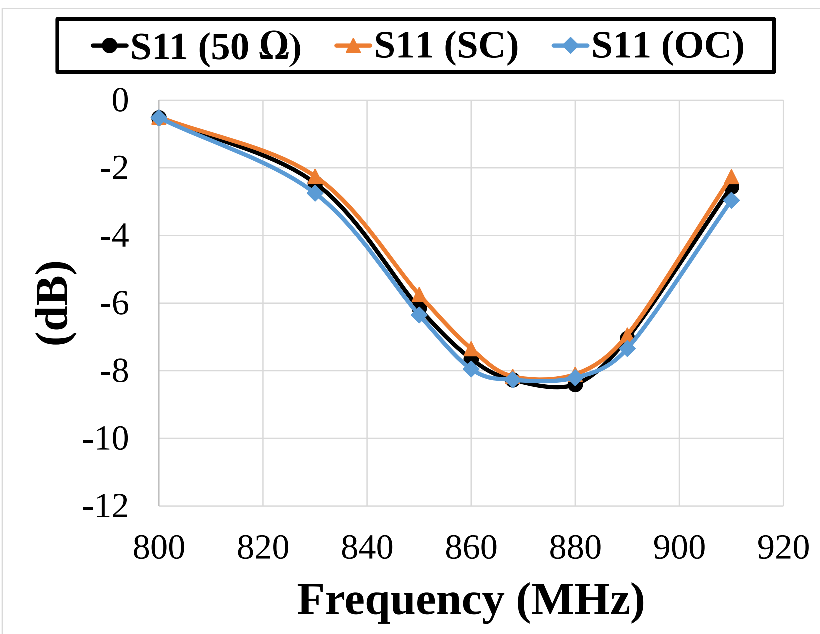


Diplexer filter and decoupling

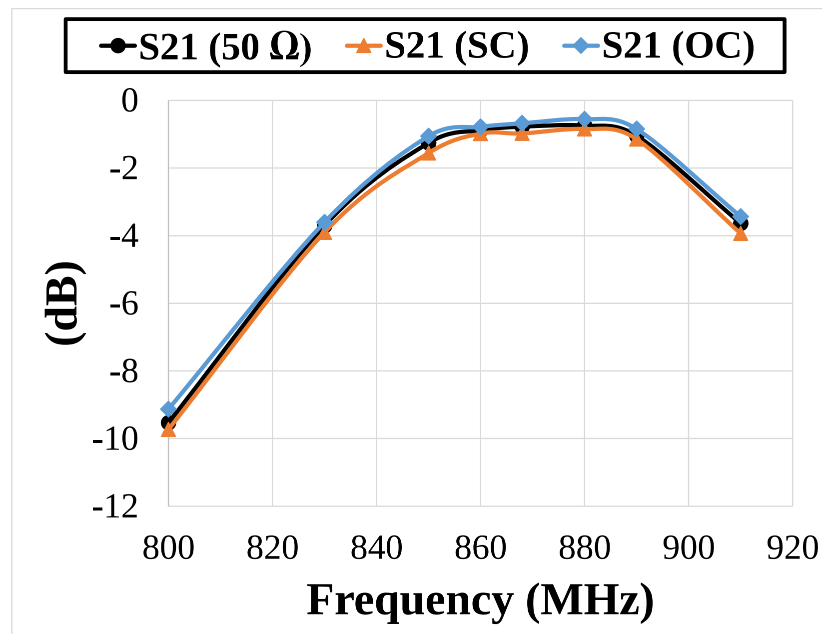
UHF performance with respect to different UWB loading condition:

- 50 Ω, short circuit, open circuit

S11

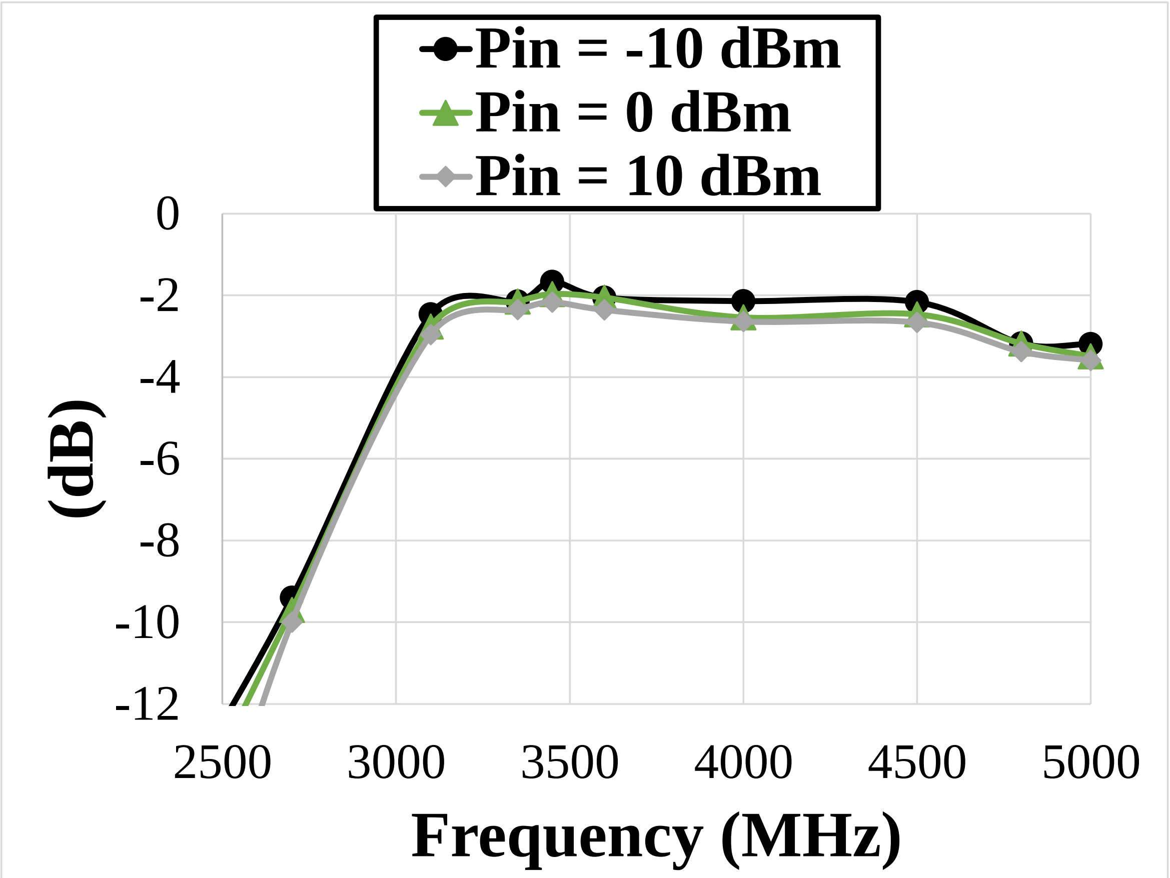


S21

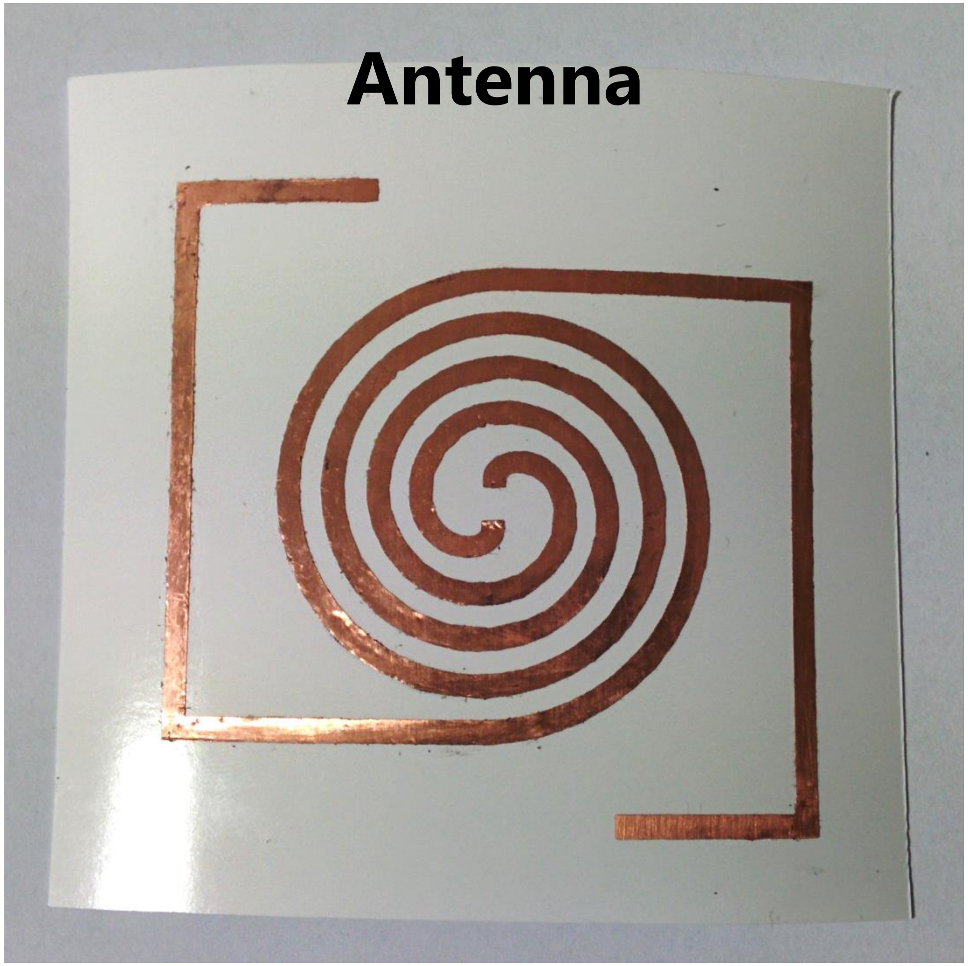


Diplexer filter and decoupling

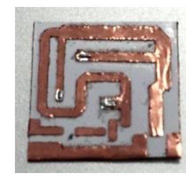
UWB band insertion loss for different incident power levels:



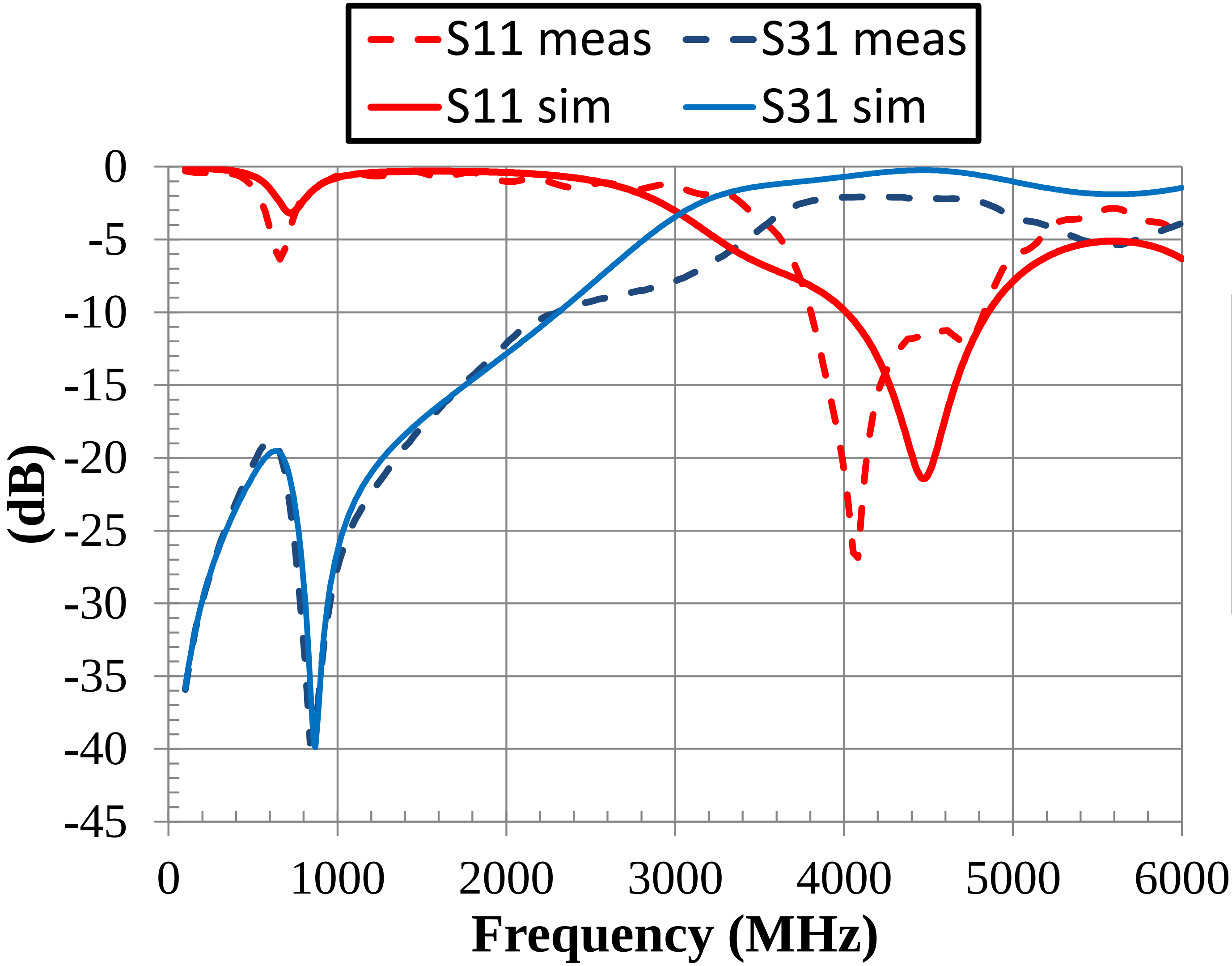
UniPG – UniBO tag on paper implementation



Diplexer

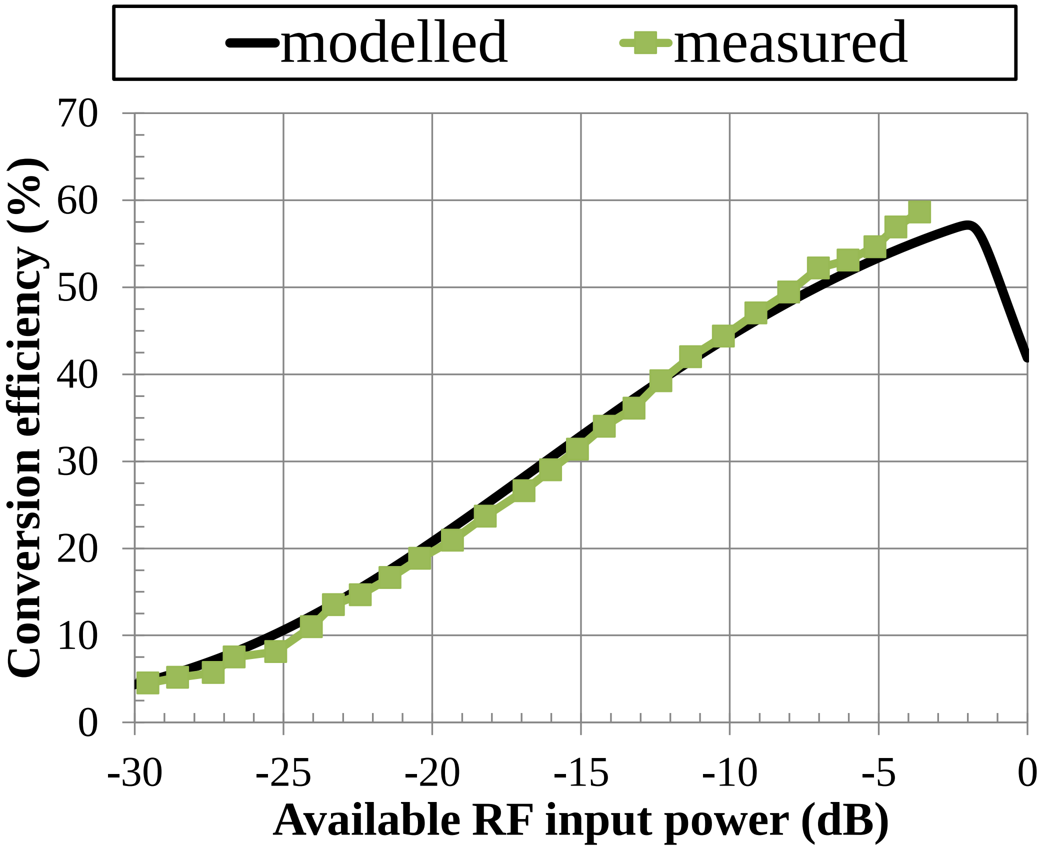


Prototype measurements

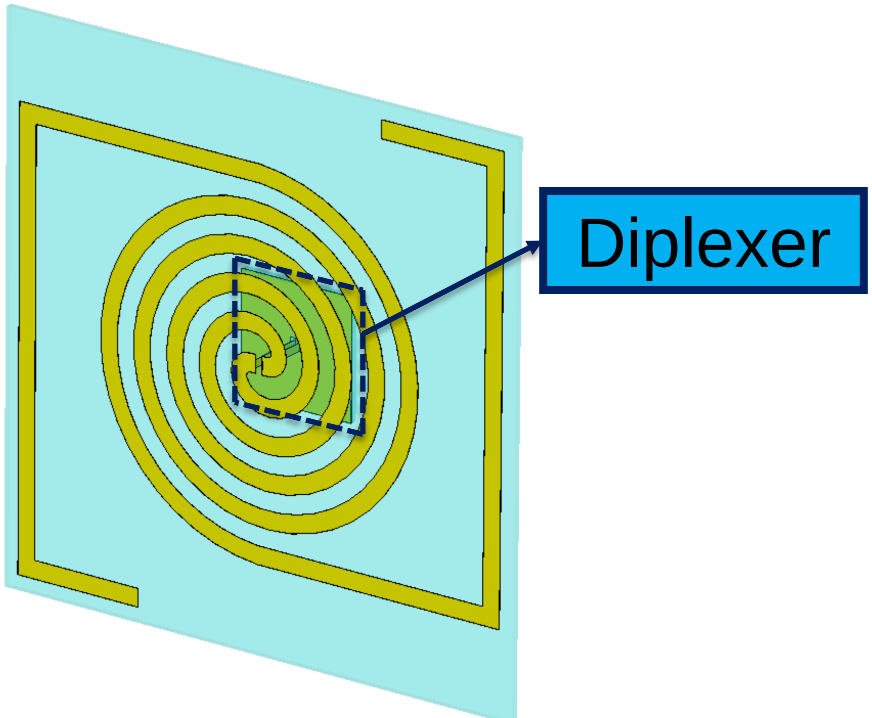


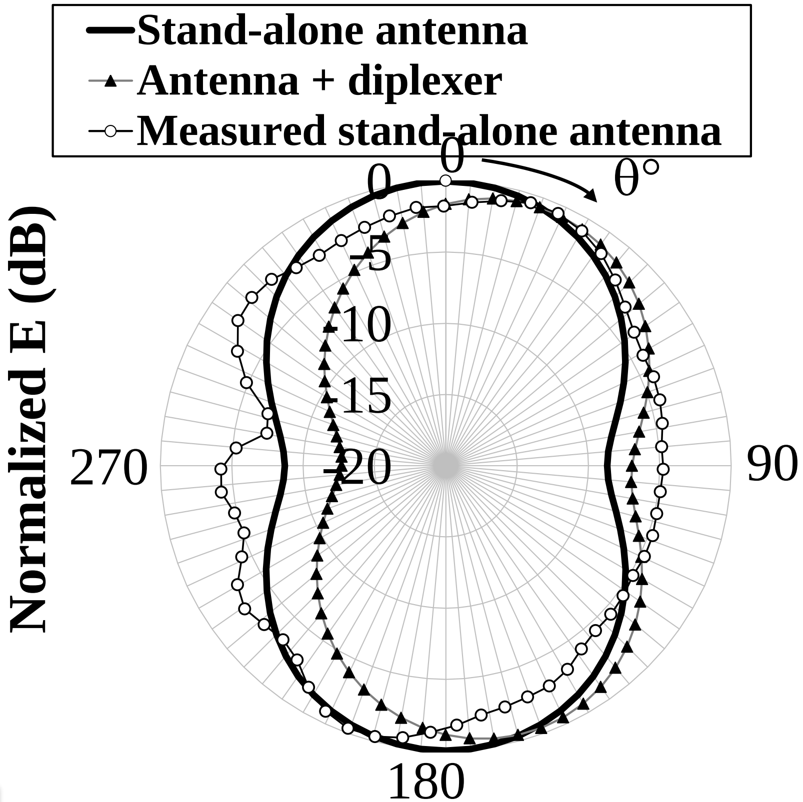
Measured S-parameters at UWB port

Conversion efficiency



Antenna – Diplexer influence





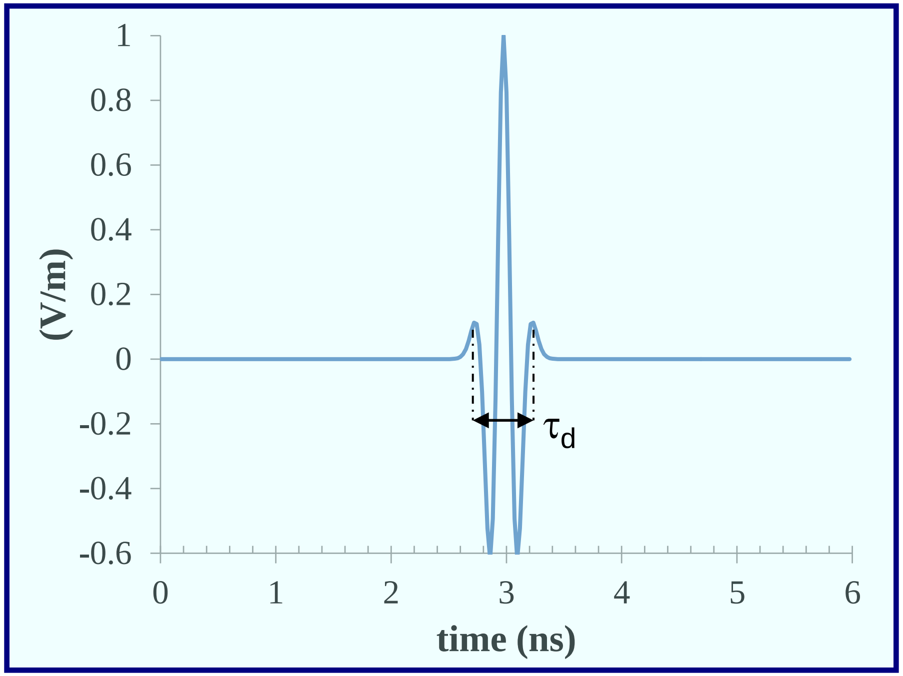
The antenna behavior is affected by the presence of the matching/feeding network because of the absence of a ground plane

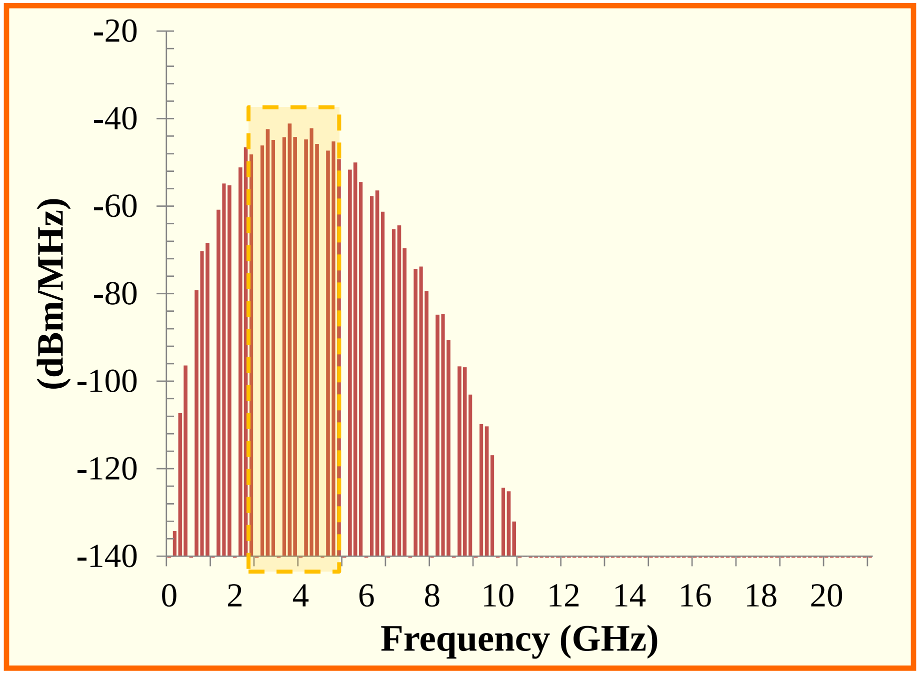
Diplexer influence on **UWB backscattering communication**

UWB pulses description

- ***Time*** domain
  - Periodic sequence of pulses (fourth derivative of Gaussian pulse)
  - Period $T_p = 6$ ns
  - Pulse duration $\tau_d = 300$ ps

- ***Frequency*** domain
  - Periodic regime with fundamental frequency $f_{UWB} = 1/T_p = 166.67$ MHz
  - $N_H = 64$ harmonics

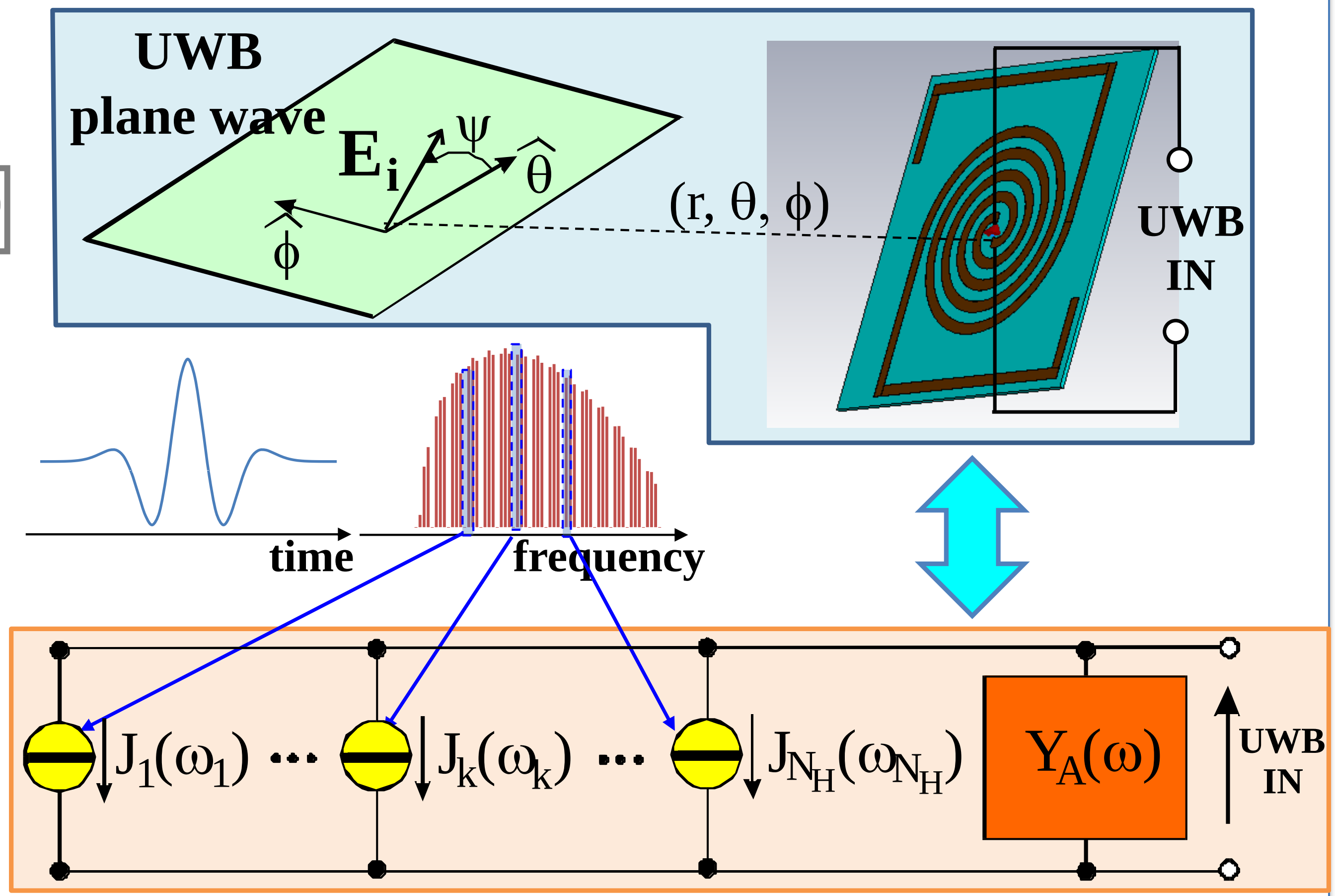




Equivalent circuit representation

Incident UWB plane wave with a linearly polarized electric field

$$\mathbf{E_i} = E_i\left(\cos\psi\ \hat{\vartheta} + \sin\psi\ \hat{\phi}\right)$$



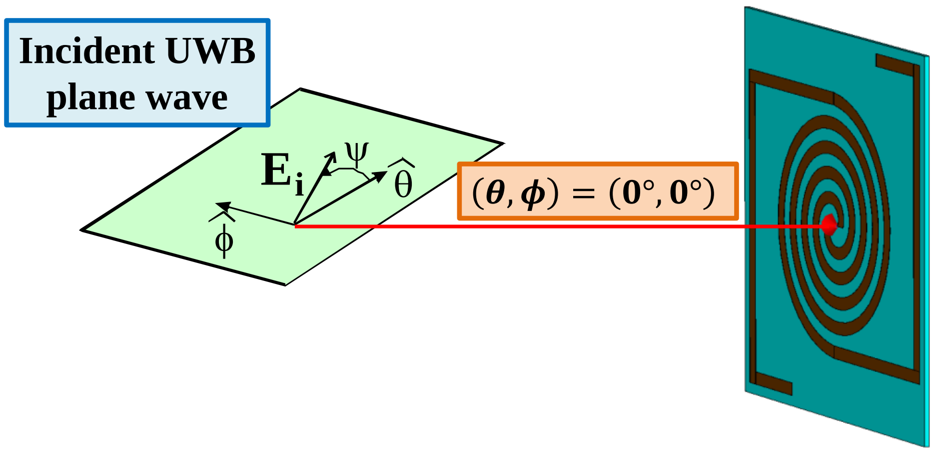
Reciprocity theorem

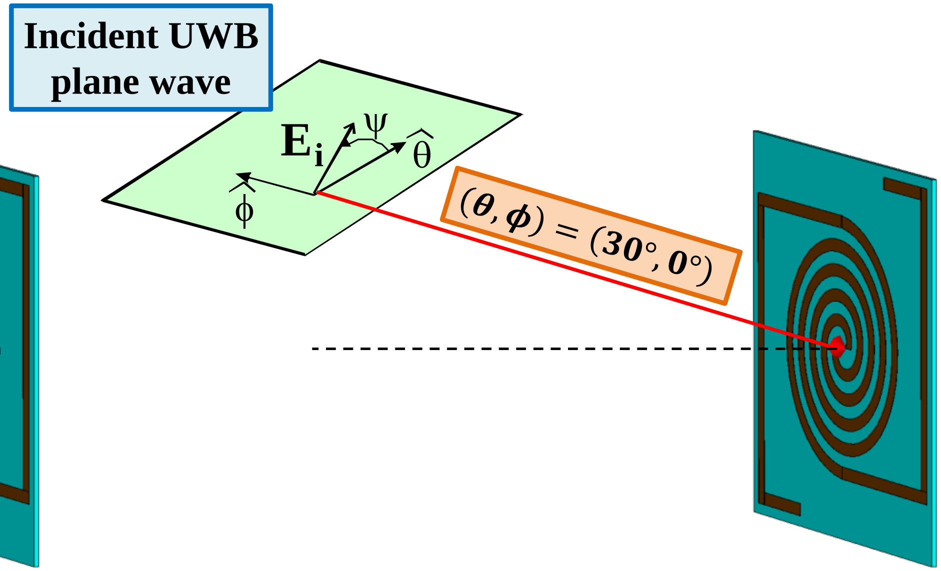
$$J_k(\omega_k) = j\,\frac{\left[1+R_0 Y_A(\omega_k)\right]}{U}\,\frac{2\lambda_k r e^{j\beta r}}{\eta}\,\mathbf{E}_i(\omega_k)\cdot\mathbf{E}_R(\mathbf{r};\omega_k)$$

$\mathbf{E_R}$: field radiated by the receiving antenna in Tx mode

UWB communication performance

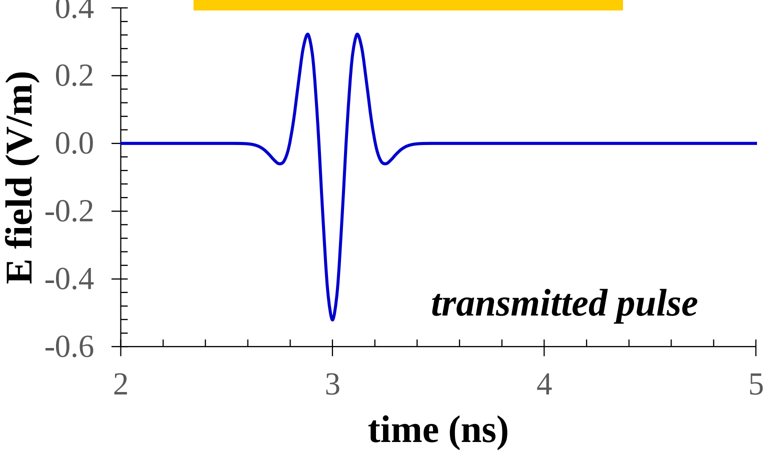
Distortion effects of the antenna are compared for different incoming directions $(\boldsymbol{\theta}, \boldsymbol{\phi})$ and different polarization of the incident plane wave $(\boldsymbol{\psi})$ at a fixed distance $r = 1$ m



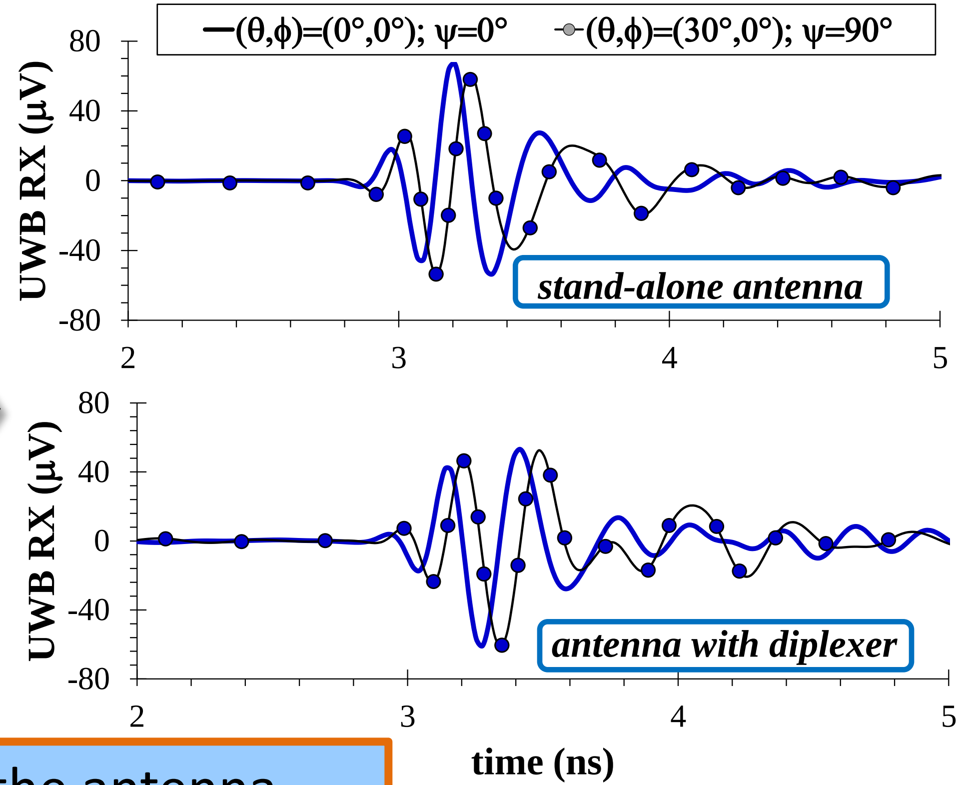


UWB communication performance

Negative polarity



Linear distortion of antenna/diplexer subassembly

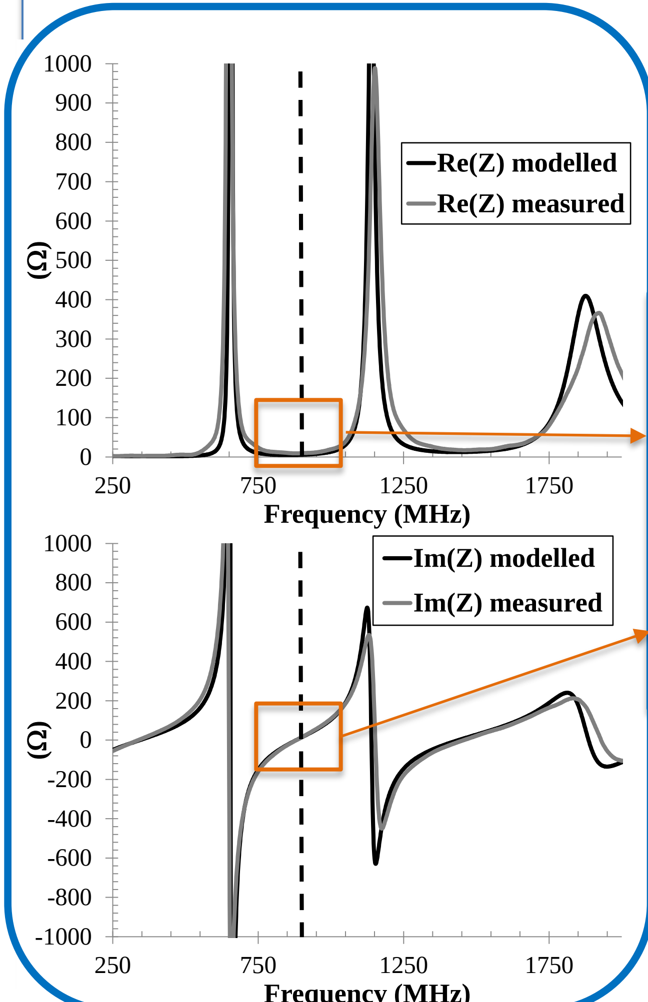


The presence of the diplexer behind the antenna does not weaken system performance → **UWB communication works** properly

Thank you for the kind attention

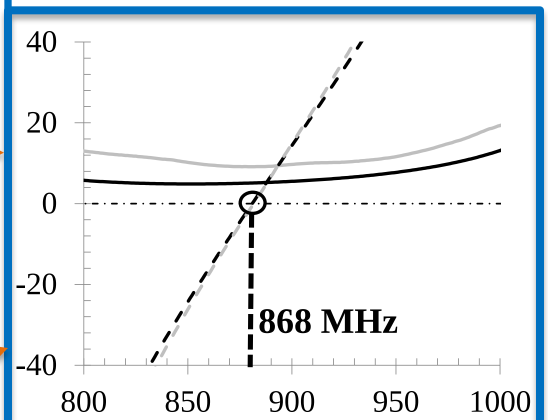
Integrated UWB-UHF Antenna

Antenna performance – antenna impedance



UWB

Real part almost constant



UHF

- imaginary part ~ 0 Ω
- real part ~ 10 – 15 Ω