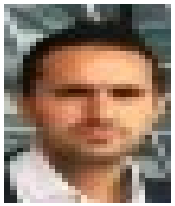
ESPCI PARIS | PSL

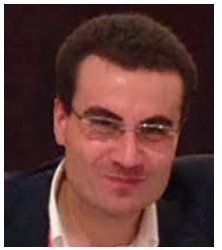
Communications ultra-basse énergie par rétrodiffusion de champ ambiant

Julien de Rosny, CNRS
Institut Langevin, ESPCI Paris, PSL

Collaboration






Institut Langevin : A. Ourir, Kammel Rachedi (PhD)

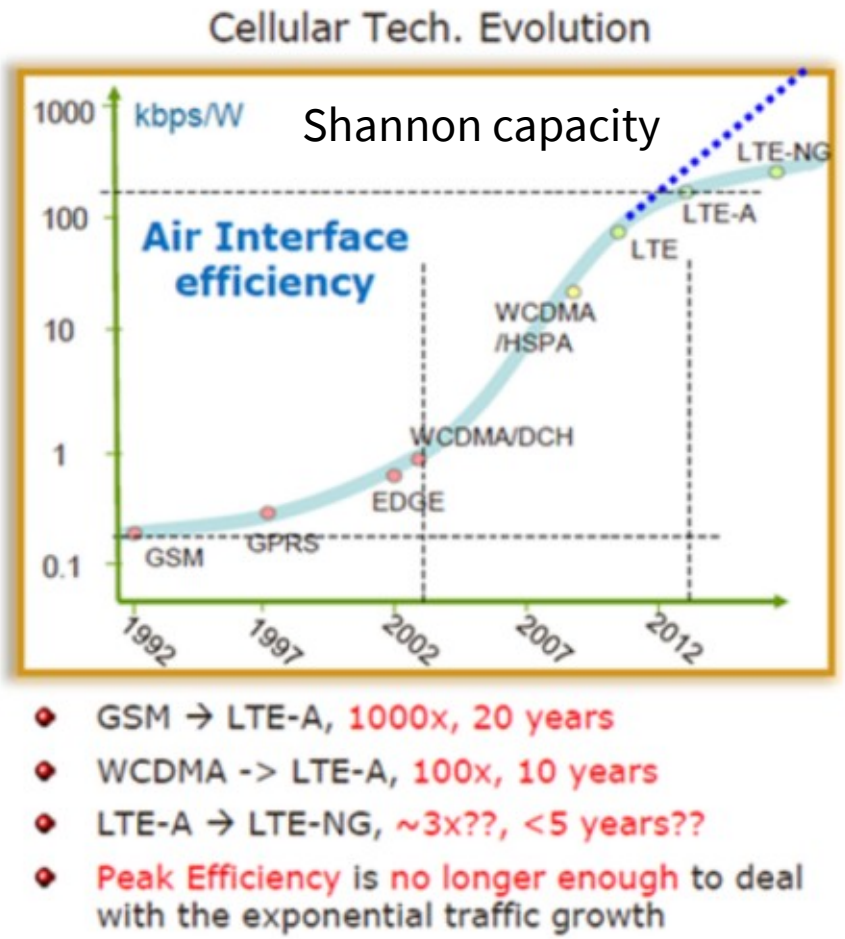
Orange labs : Dinh-Thuy Phan-Huy, Nissem Selmene (Post-doc), Dominique Barthel, Philippe Ratajczak

L2S -Centra ırco Di Renzo, Romain Fara (PhD)

orange™ Orange Labs

L2S Laboratoire Signaux & Systèmes

Telecom growth vs consumption



https://arxiv.org/pdf/1903.09627.pdf

2 Power consumption trends :

- ↘ **Better spectral efficiency**
- ↗ **New uses of smartphones → traffic demand growth**

Global increase

To reduce energy of access equipment :

- simplification network achitecture
- improvement of eletronics,
- new materials
- …

Solution based on RF field recycling

Communication with a mirror

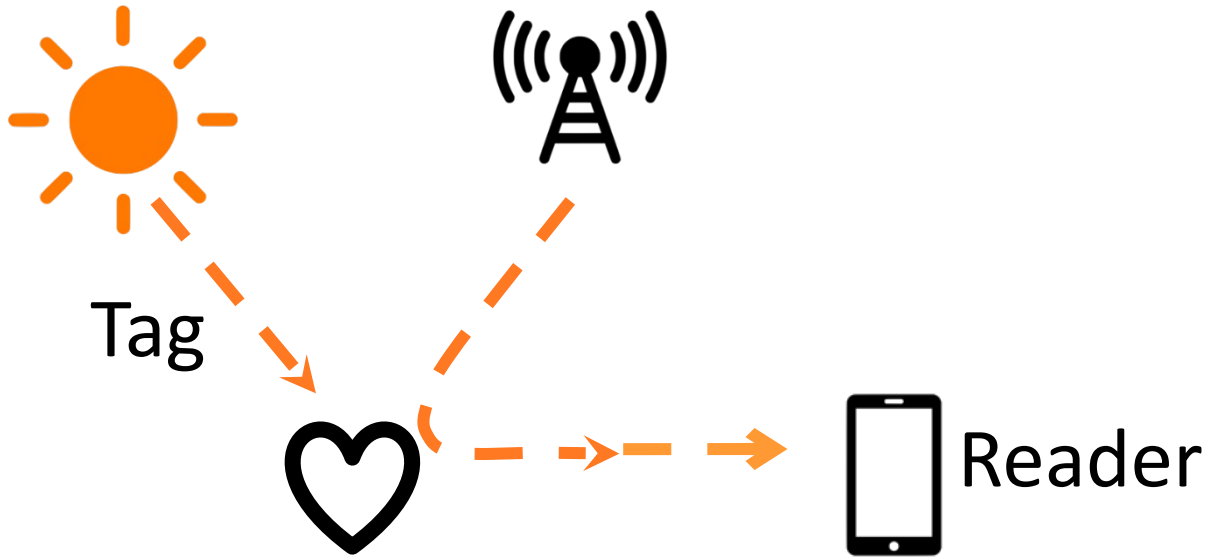
https://youtu.be/1qASGbRu6_o

Source of opportunity (sun) + variable scatterer

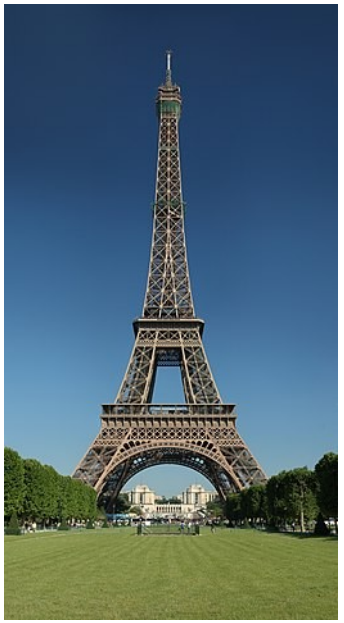
Transposition to RF

Energy source

Source of oportunity Radio wave source (TNT, 4G, Wifi, ...)

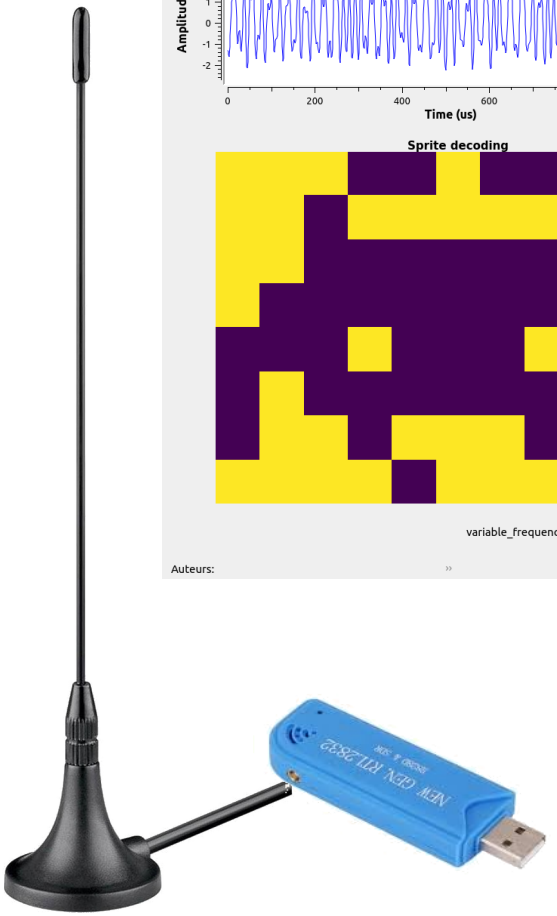


Demonstration

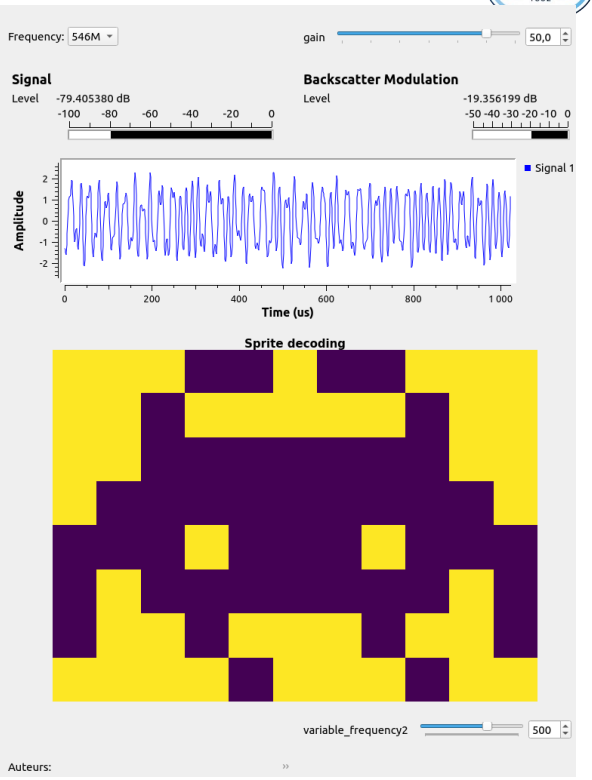


Source of opportunity
TV (~ 600MHz)

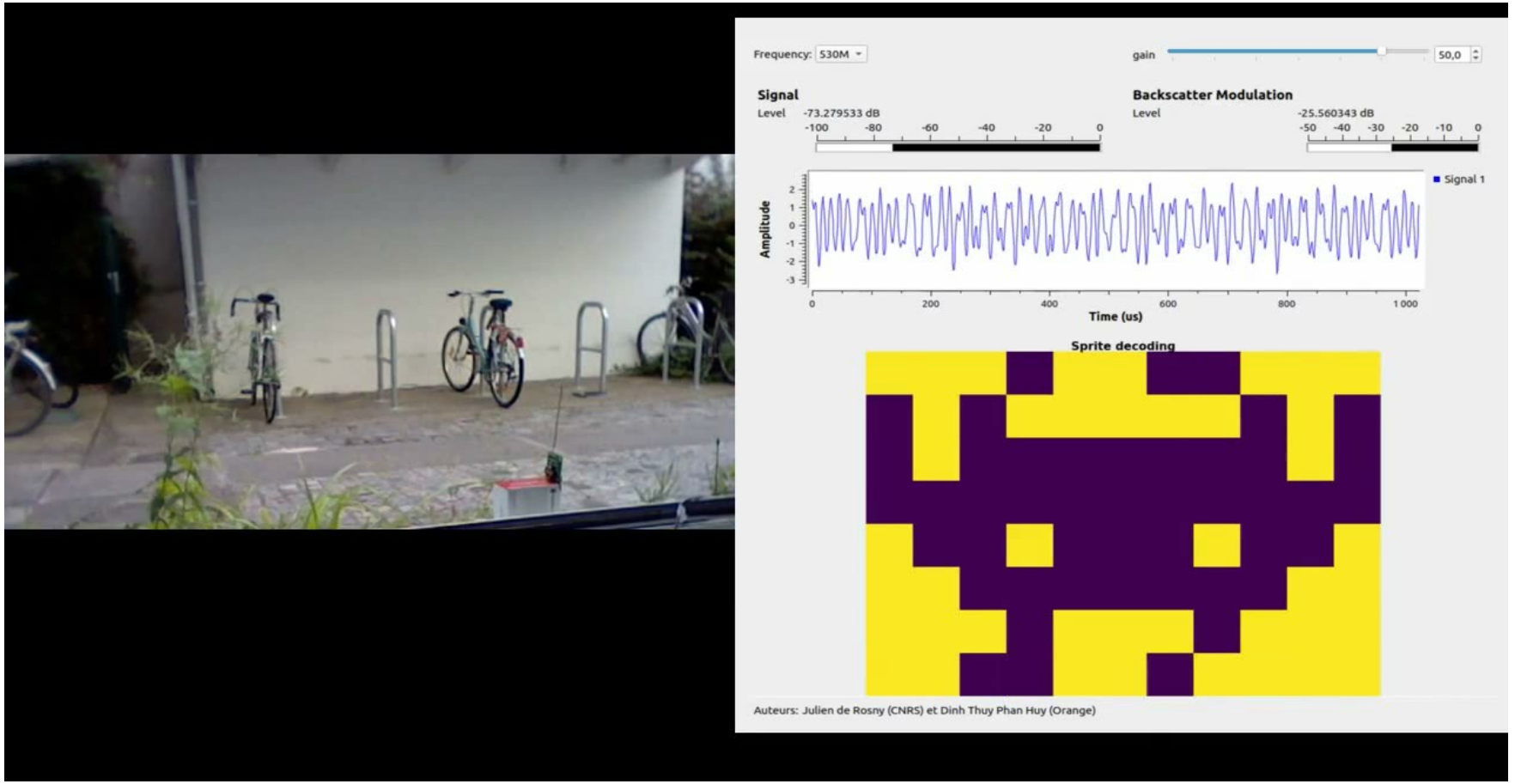
Tag



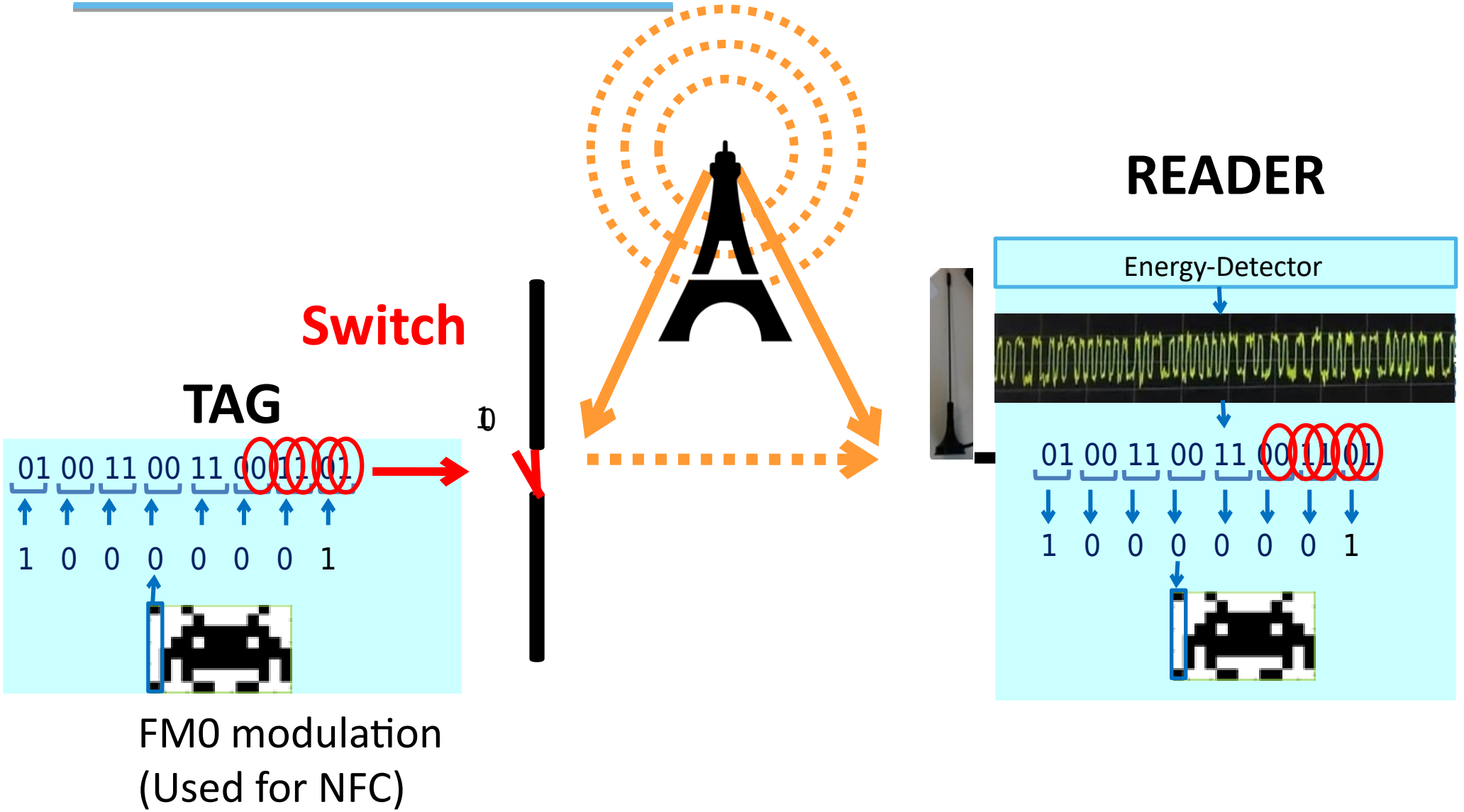
Receiver



Demonstration



How it works



FM0 modulation
(Used for NFC)

A bit of History

The Thing or Great Seal bug

660 MHz

Leon Theremin (1945)

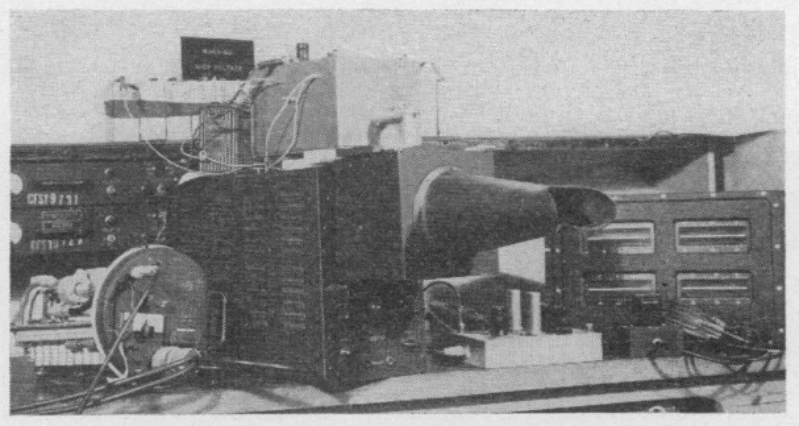
Previous works : identification, friend or foe IFF

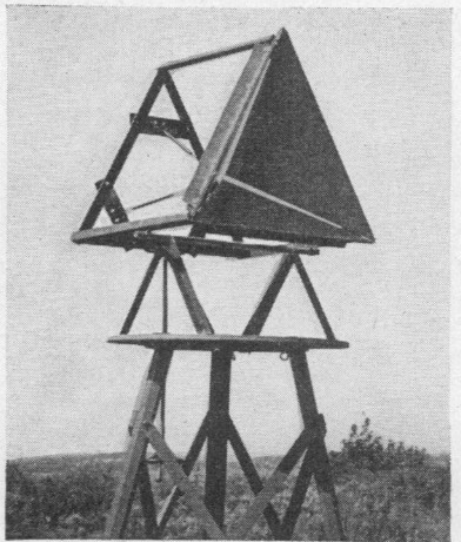
Backscattering communication

1196 PROCEEDINGS OF THE I.R.E. October

Communication by Means of Reflected Power*

HARRY STOCKMAN†, SENIOR MEMBER, IRE





S – Band / X- Band

1948 First complete works on backscattering coms

RFID History

Short-Range Radio-Telemetry for Electronic Identification, Using Modulated RF Backscatter

ALFRED R. KOELLE, STEVEN W. DEPP, AND ROBERT W. FREYMAN

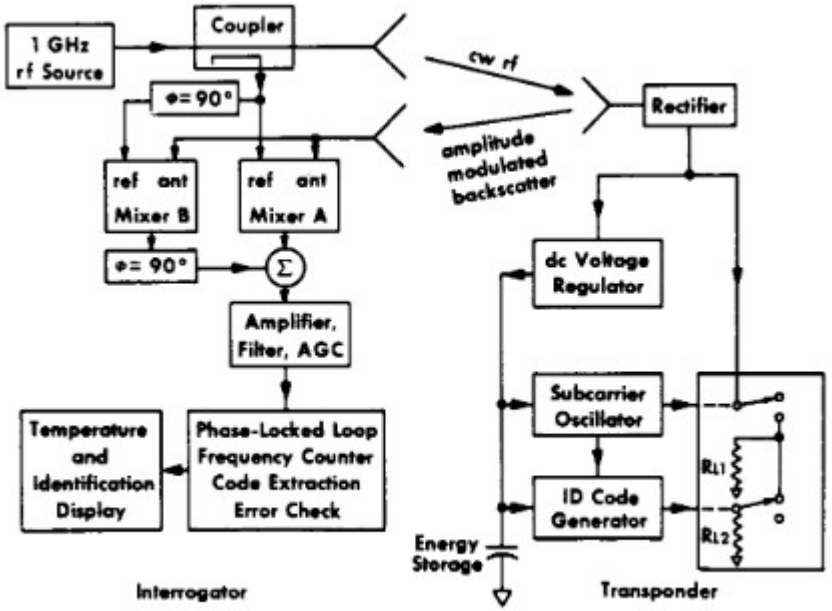


Fig. 1. Block diagram of interrogator and one transponder.

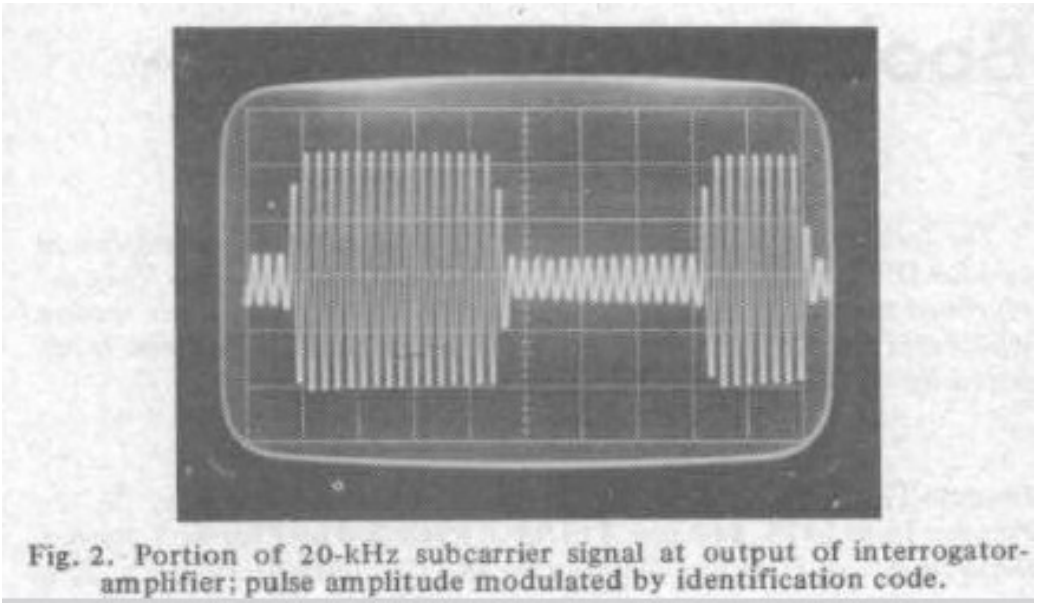


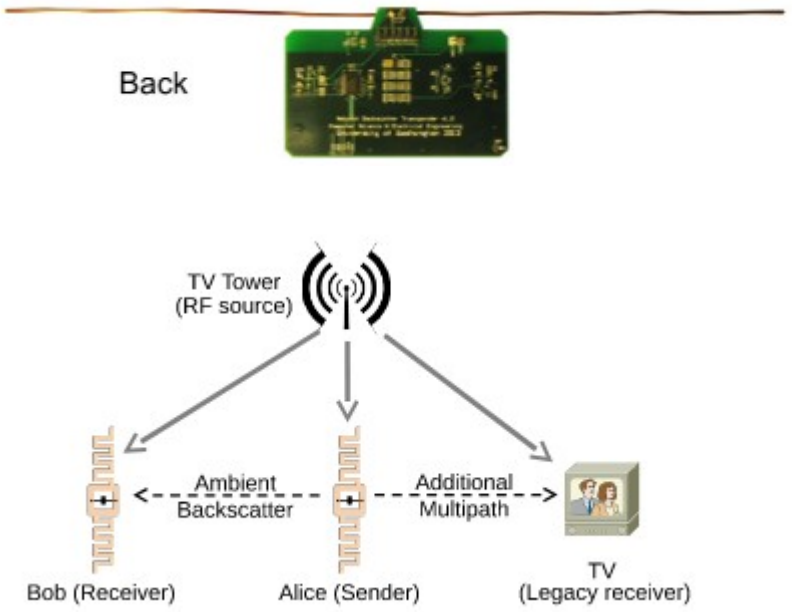
Fig. 2. Portion of 20-kHz subcarrier signal at output of interrogator-amplifier; pulse amplitude modulated by identification code.

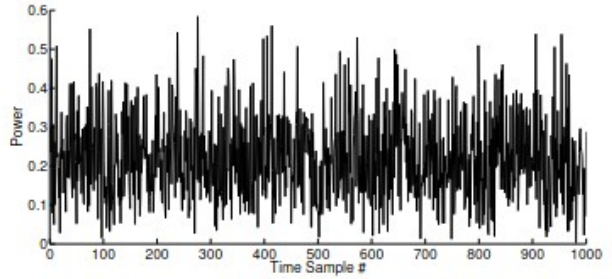
First complete RFID with energy harvesting

Ambient backscatter communications

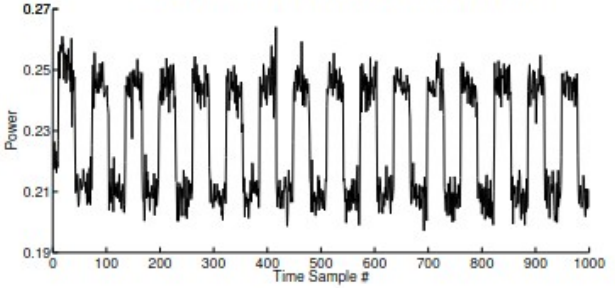
Ambient Backscatter: Wireless Communication Out of Thin Air

Vincent Liu, Aaron Parks, Vamsi Talla, Shyamnath Gollakota, David Wetherall, Joshua R. Smith
University of Washington
{liuv, anparks, vamsit, gshyam, djw, jrsjrs}@uw.edu





(a) Original TV plus Backscatter signal

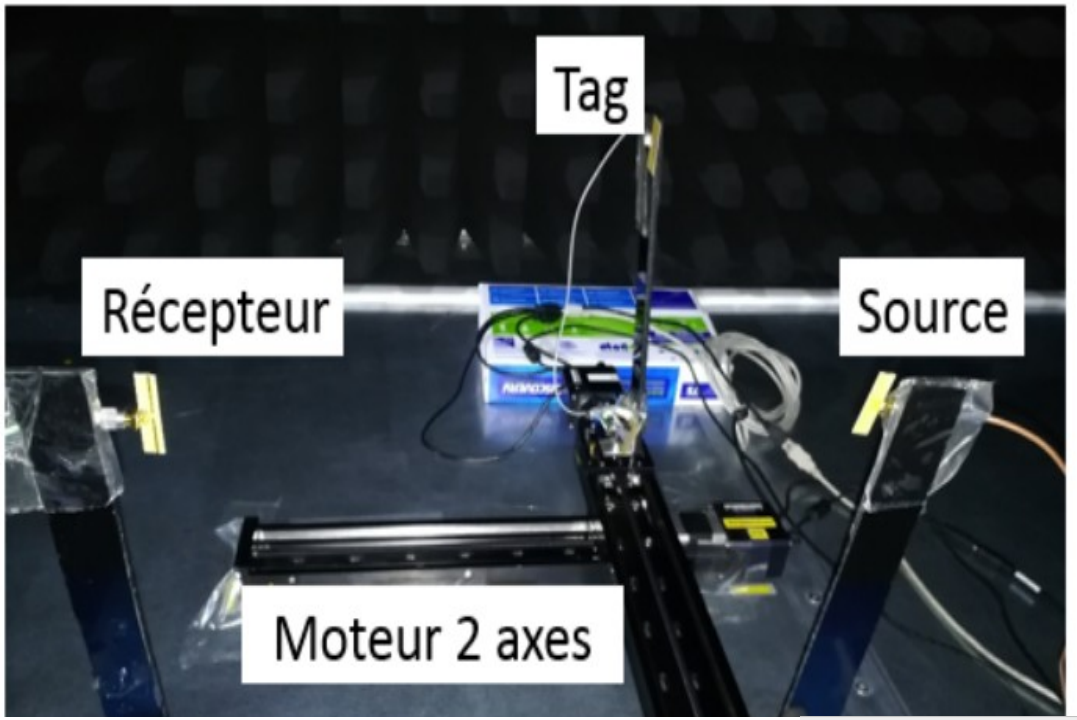


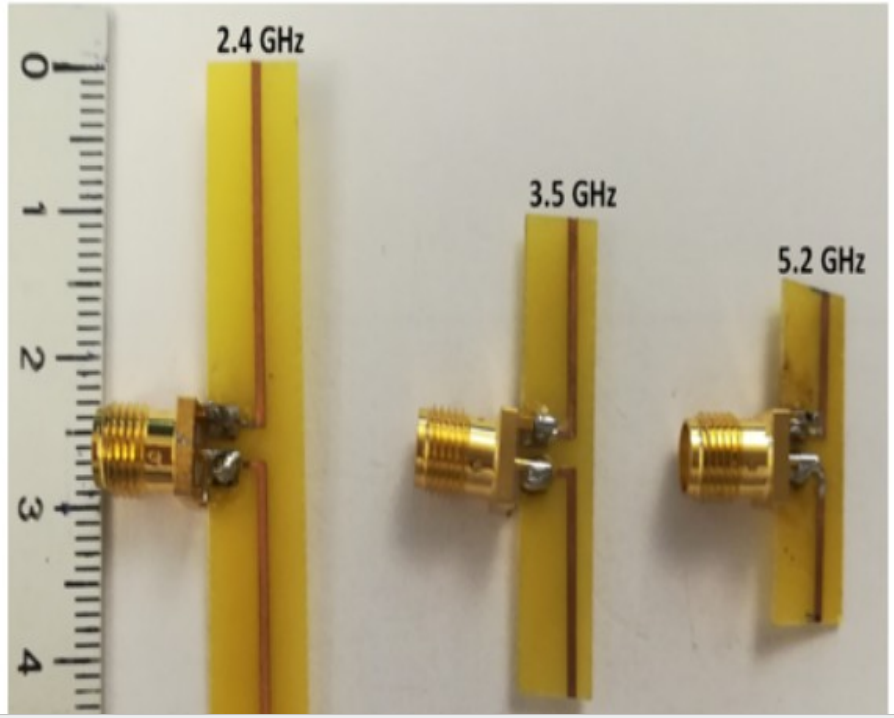
(b) Signal After Averaging

2013

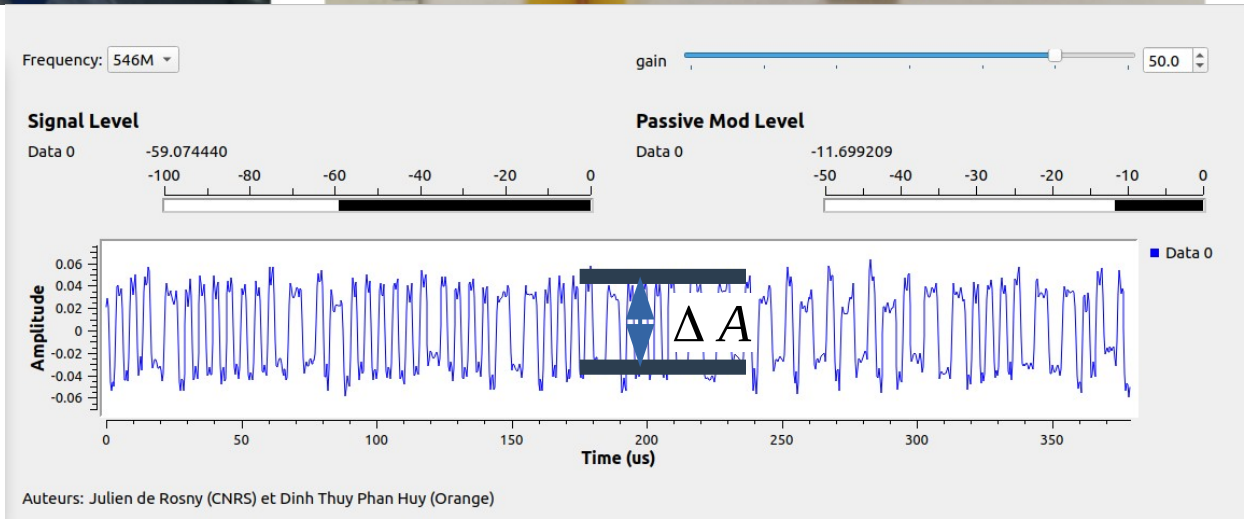
Laboratory set-up

Dipole antennas



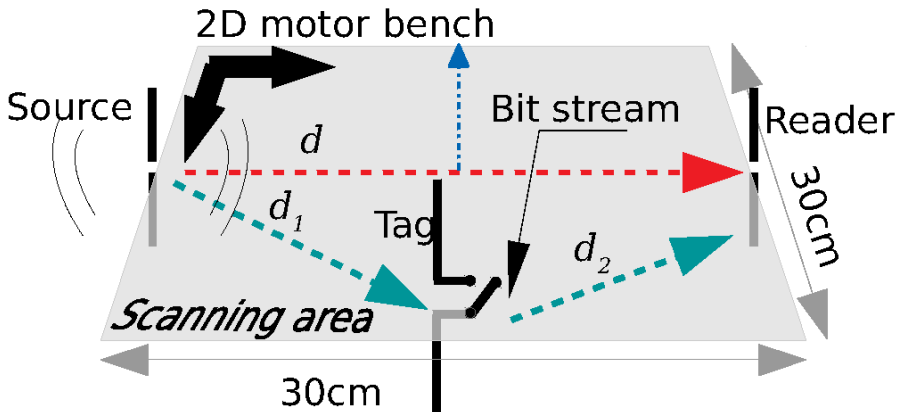


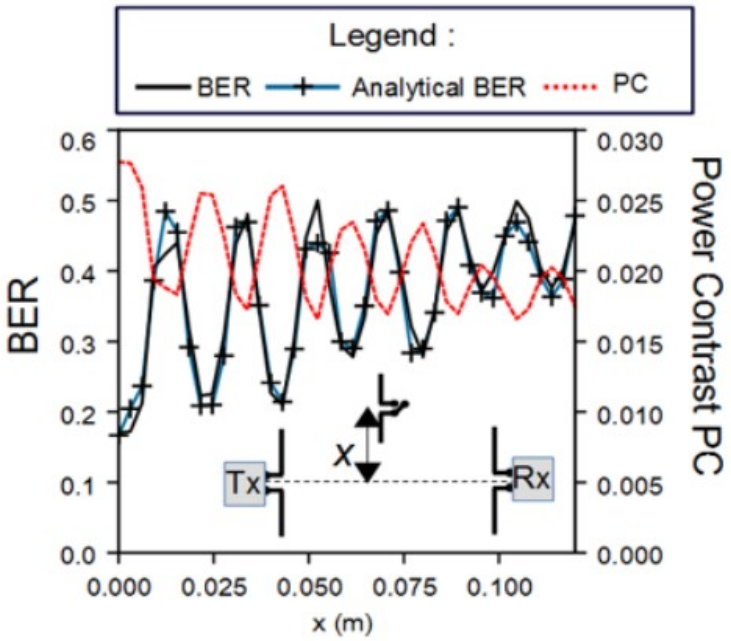
Low complexity switch



Interferences in free media

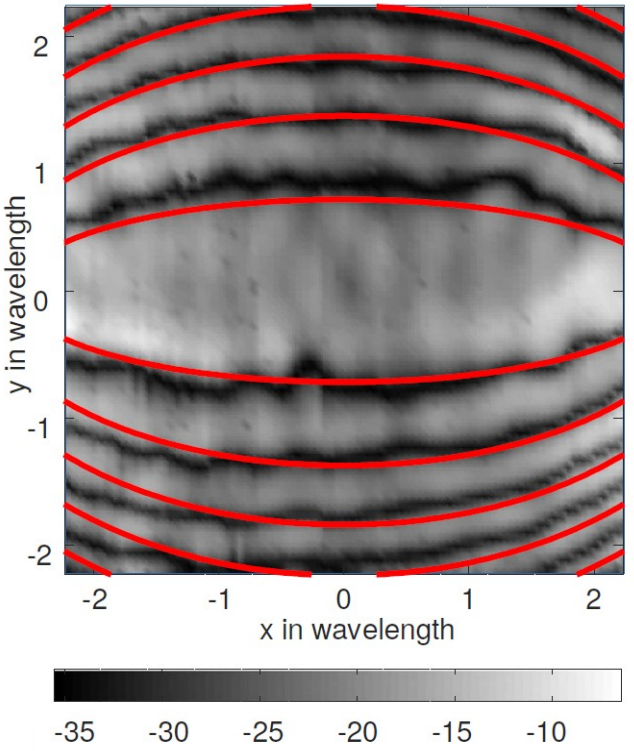
Classical transmission :





Bit Error Rate

$$PC = \frac{\Delta A}{A}$$



Modulation contrast map

Map depends on d_1+d_2-d : generate ellipses nodes

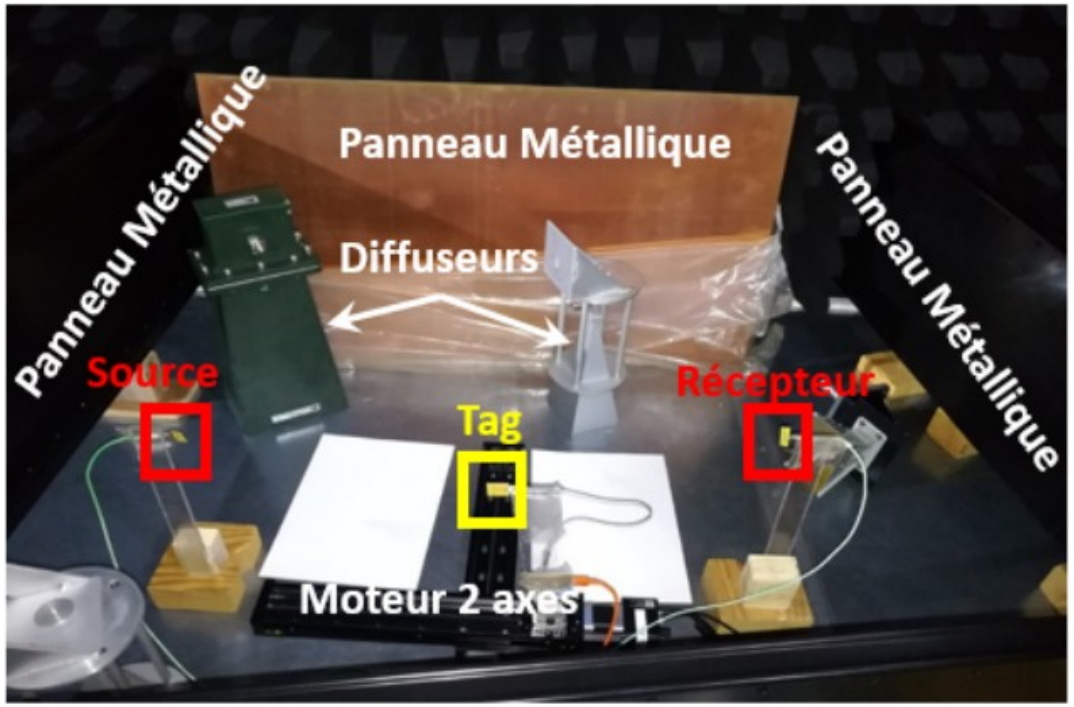
Interferences in free media

K. Rachedi, IEEE, et al. 2019

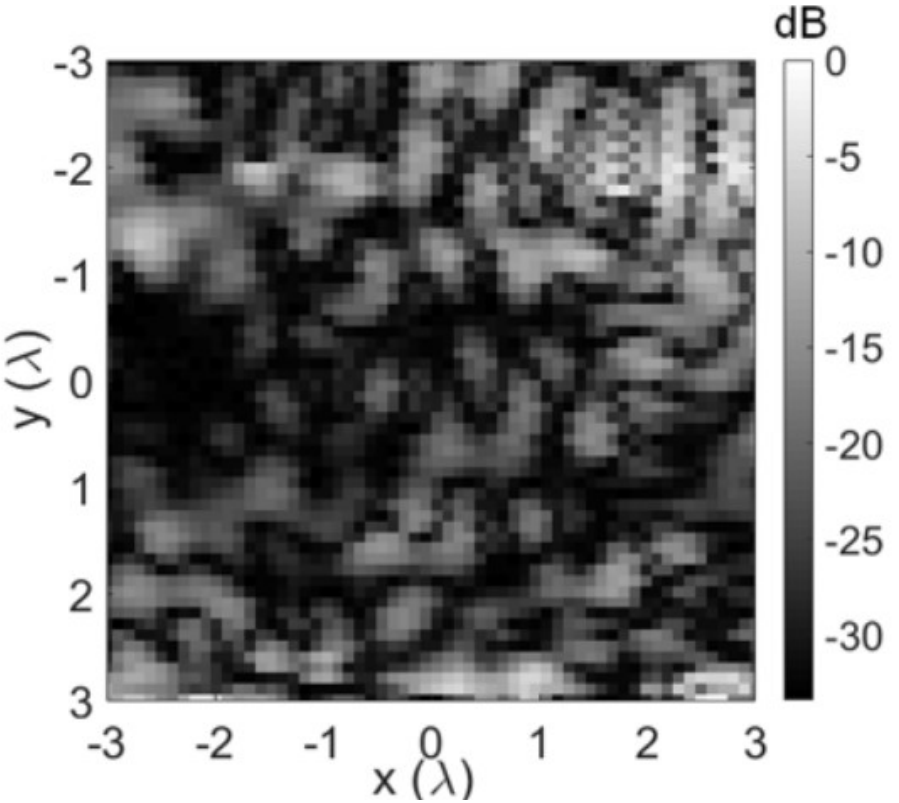
Highly cluttered medium

Medium with :

- reflective surfaces
- scatterers



Modulation contrast map



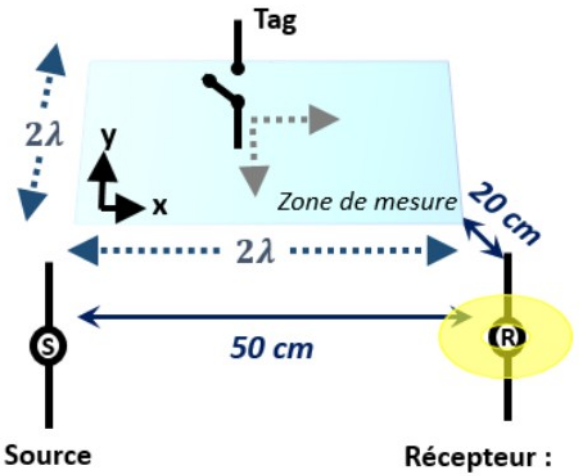
How to mitigate interferences ?

How to improve the link ?

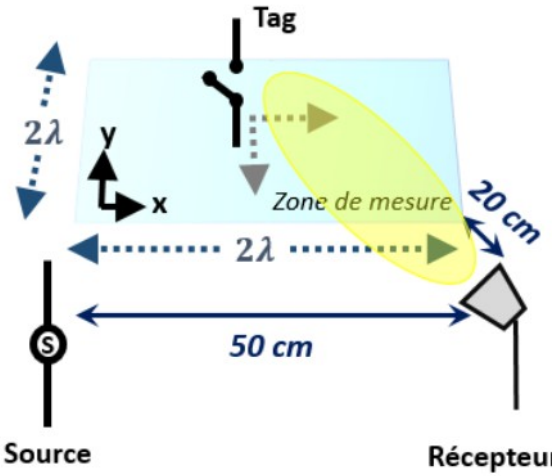
- Antenna directivity
- Polarization
- Reflective Intelligent Surface

Directive reader

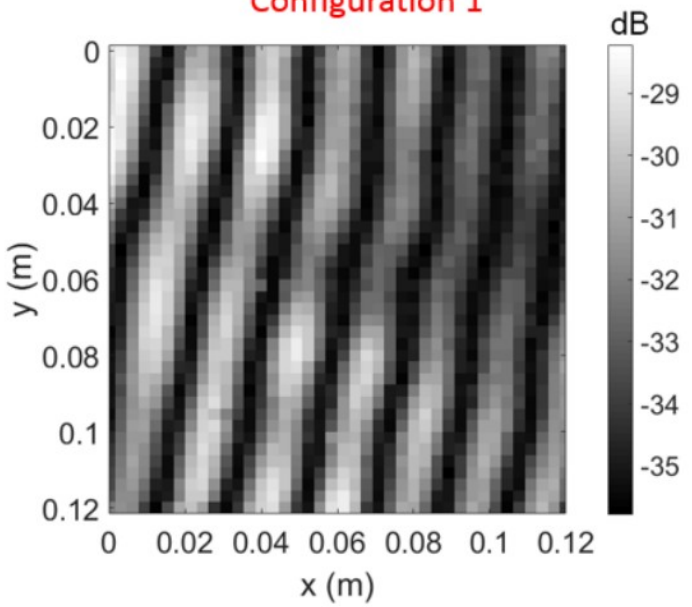
Configuration 1



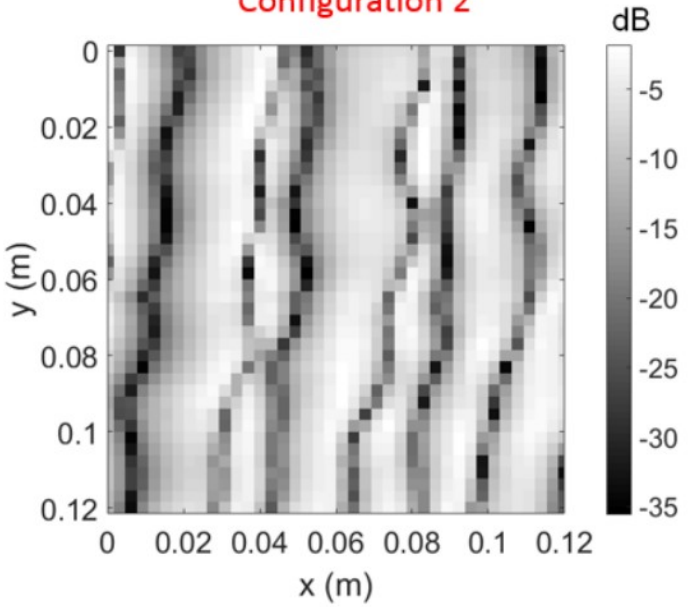
Configuration 2



Configuration 1



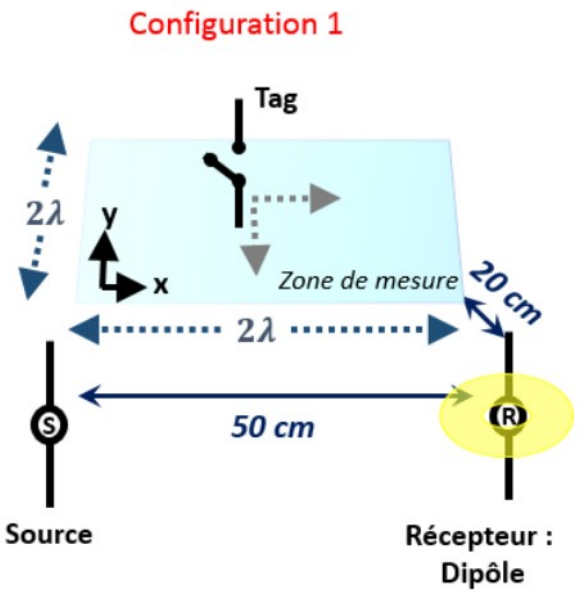
Configuration 2

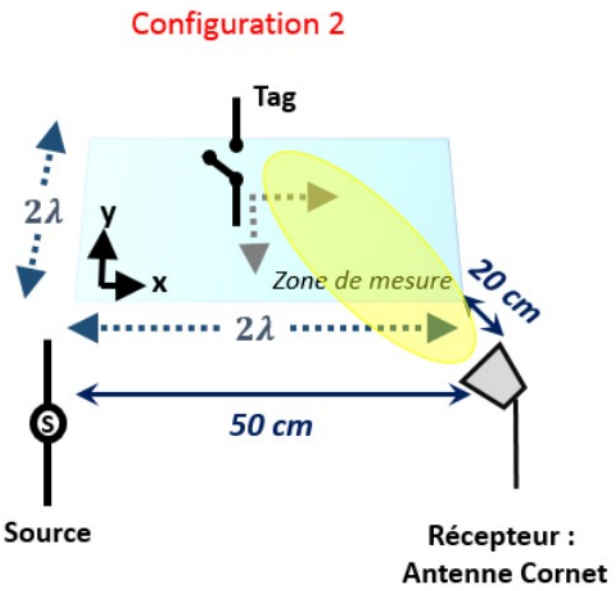


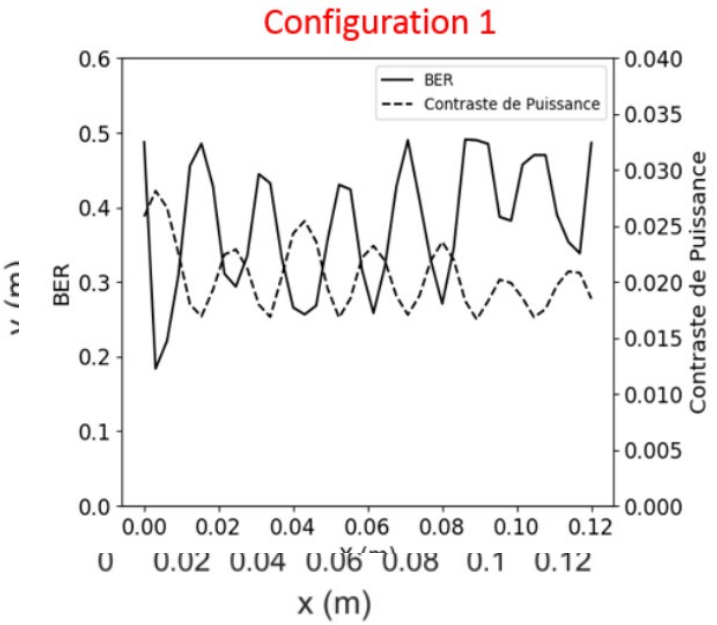
$$PC = \frac{\Delta A}{A}$$

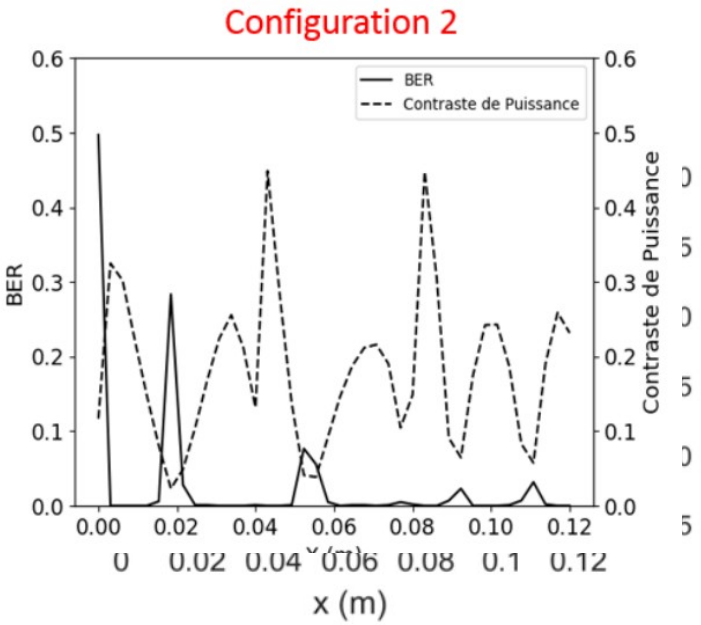
Directive reader improves the transmission

Directive reader



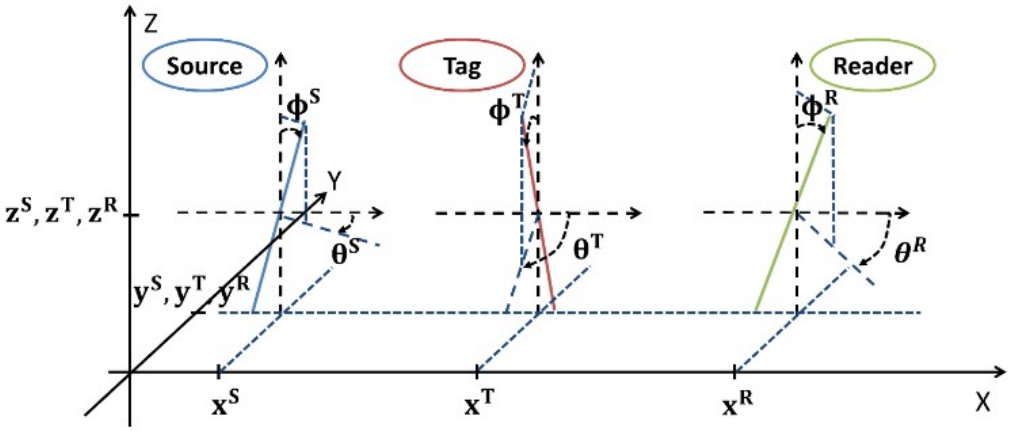






Directive reader improves the transmission

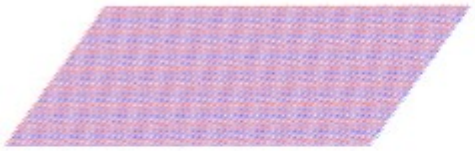
Polarization- LoS



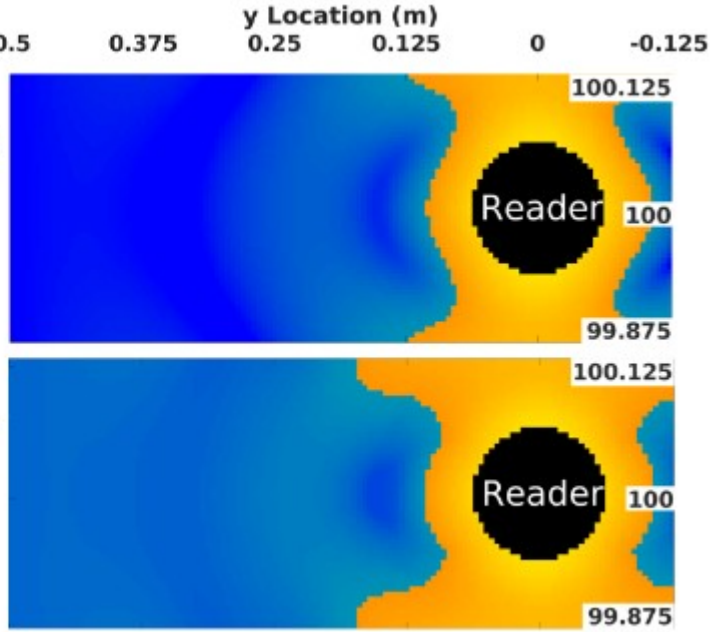
$$e_{\text{Reader}} = a(\vec{p}_{Tx} \cdot \vec{p}_{Tag})(\vec{p}_{Tag} \cdot \vec{p}_{Rx}) + b(\vec{p}_{Tx} \cdot \vec{p}_{Rx})$$

$$\theta_{Tag} = \frac{\theta_{Rx} + \theta_{Tx}}{2}$$

$$\theta_{Tag} = \frac{\theta_{Rx} + \theta_{Tx}}{2}$$



Optimal



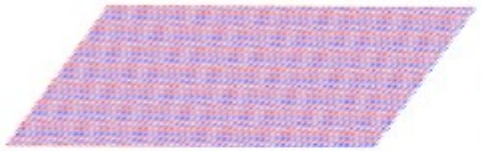
maps

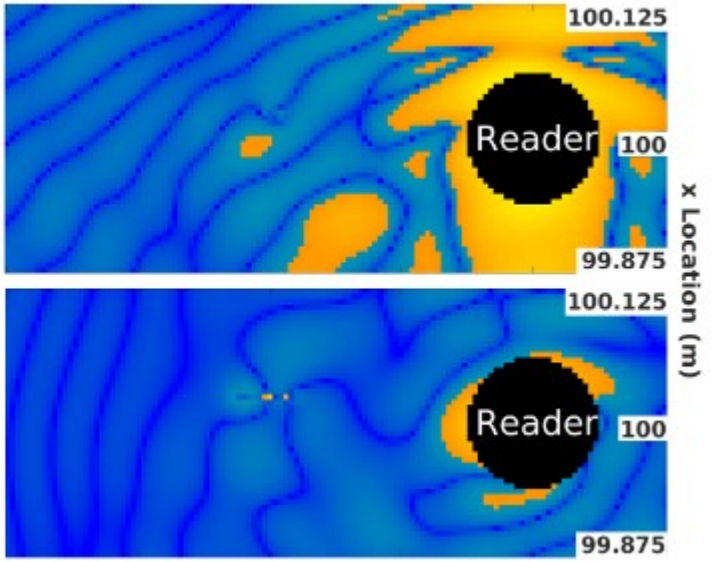
Fara et al., 2020, IEEE Open Journal of the Communications Society

Cluttered media – Simulations MoM

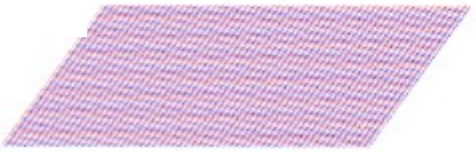
BER

$$\theta_{Tag} = \frac{\theta_{Rx} + \theta_{Tx}}{2}$$



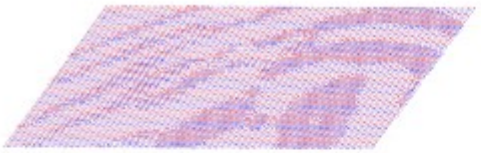


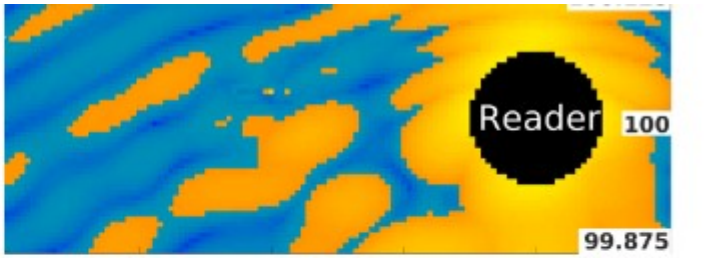
$$\theta_{Tag} = \theta_{Rx}$$



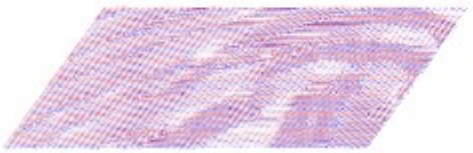
BER

Best config all polarization

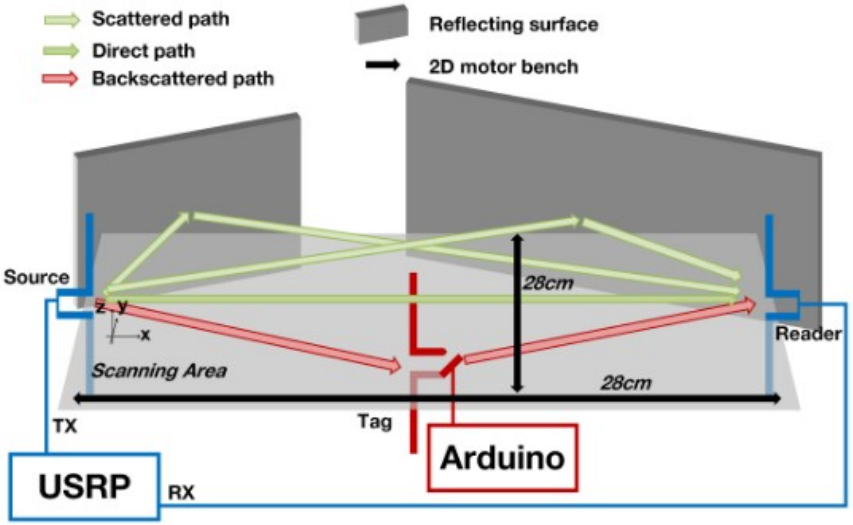


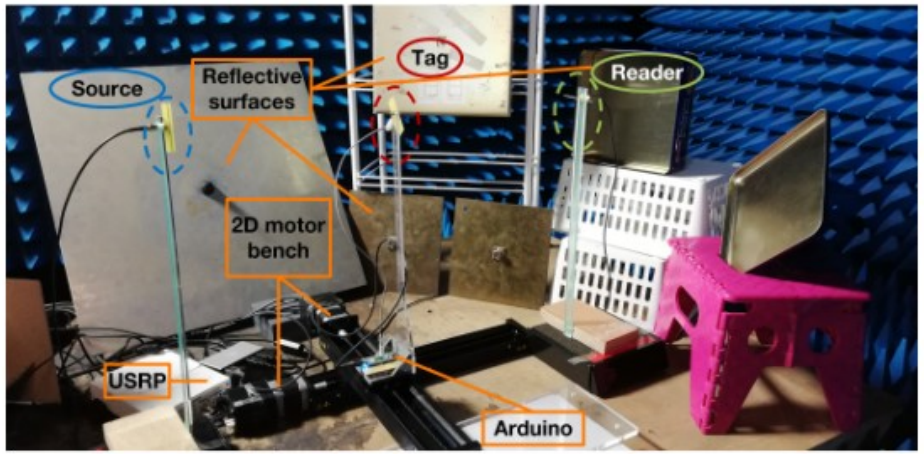


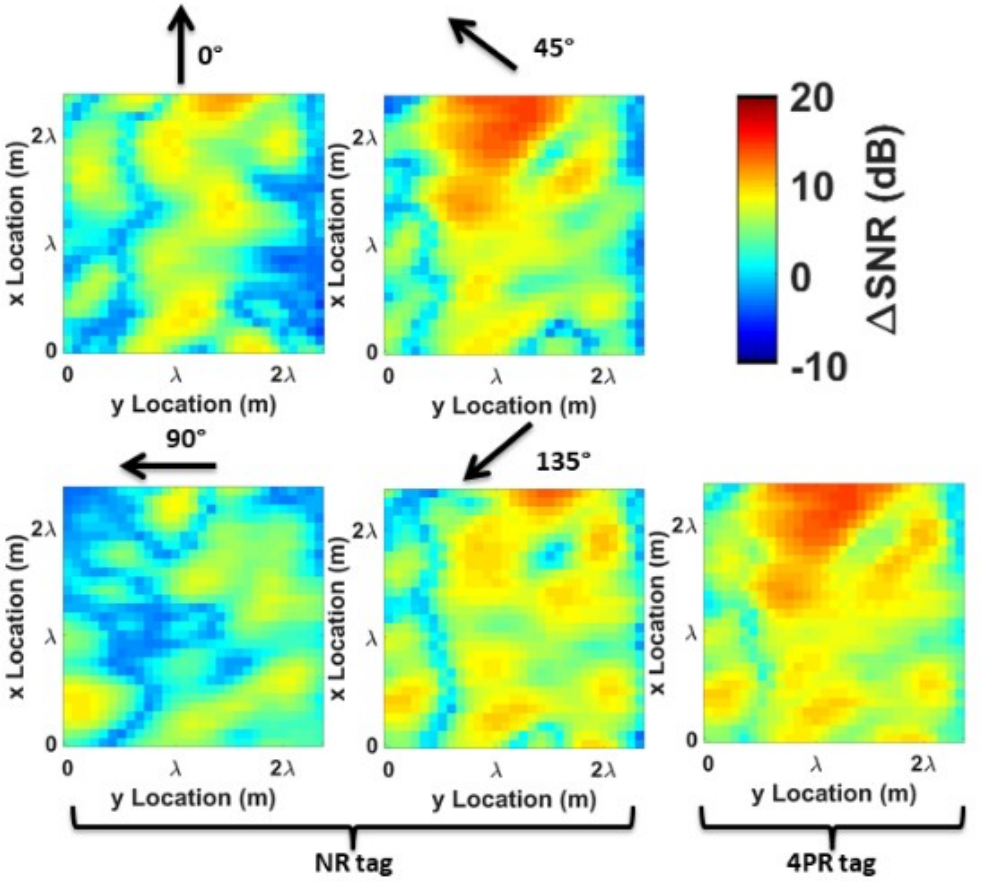
Best config between 4 polarizations



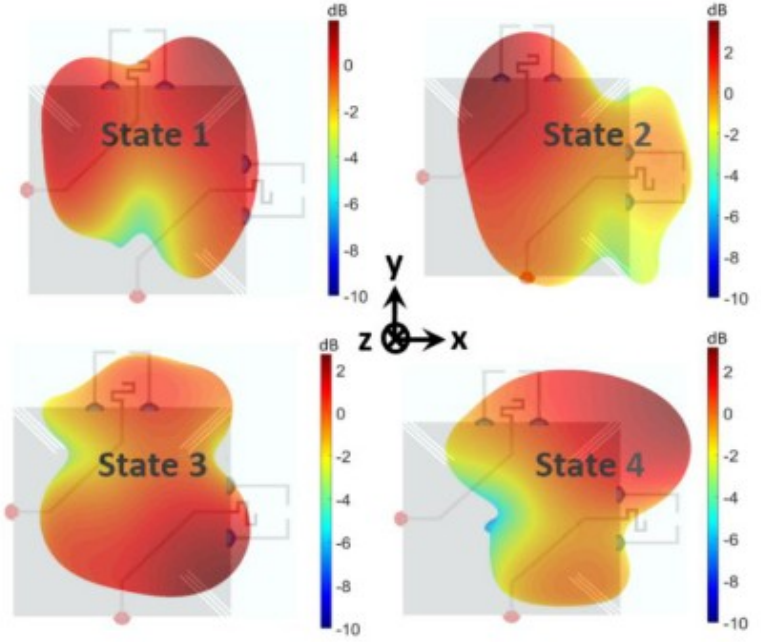
Polarization : experimental validation

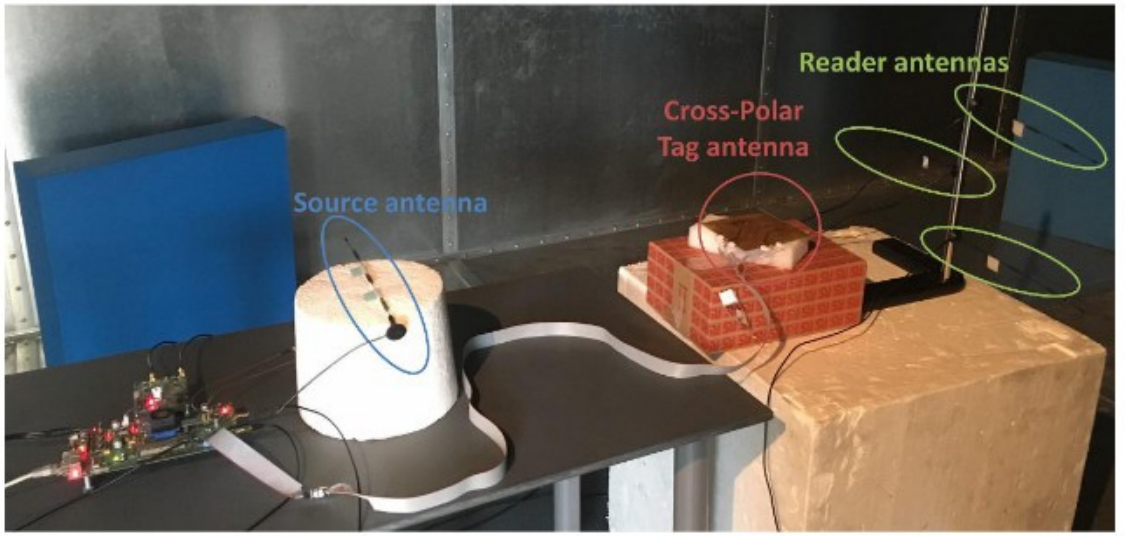


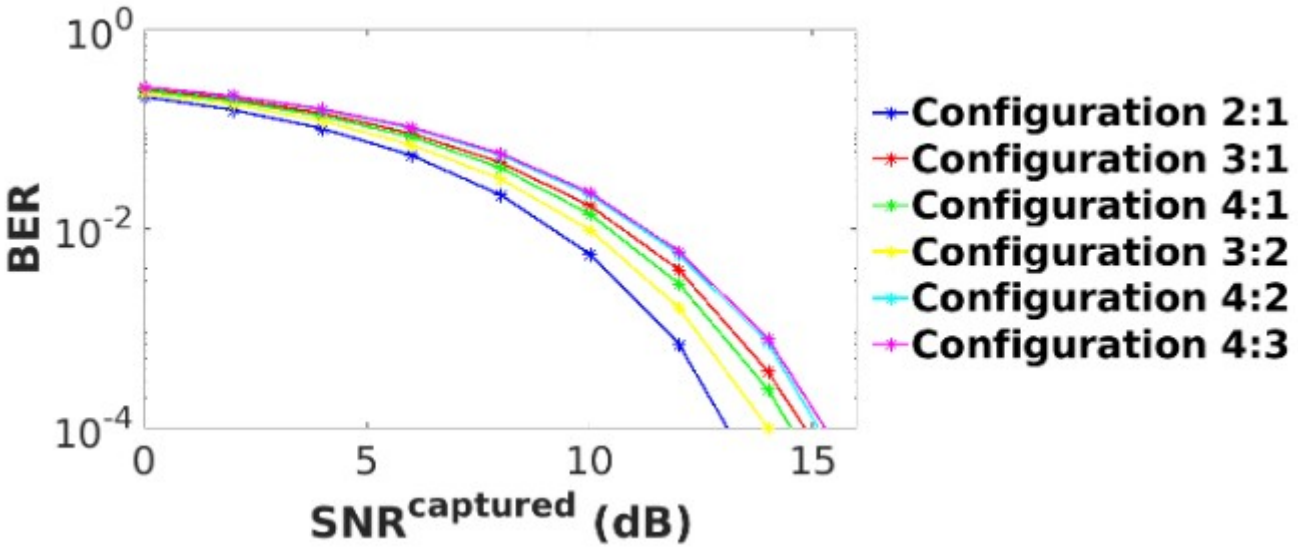




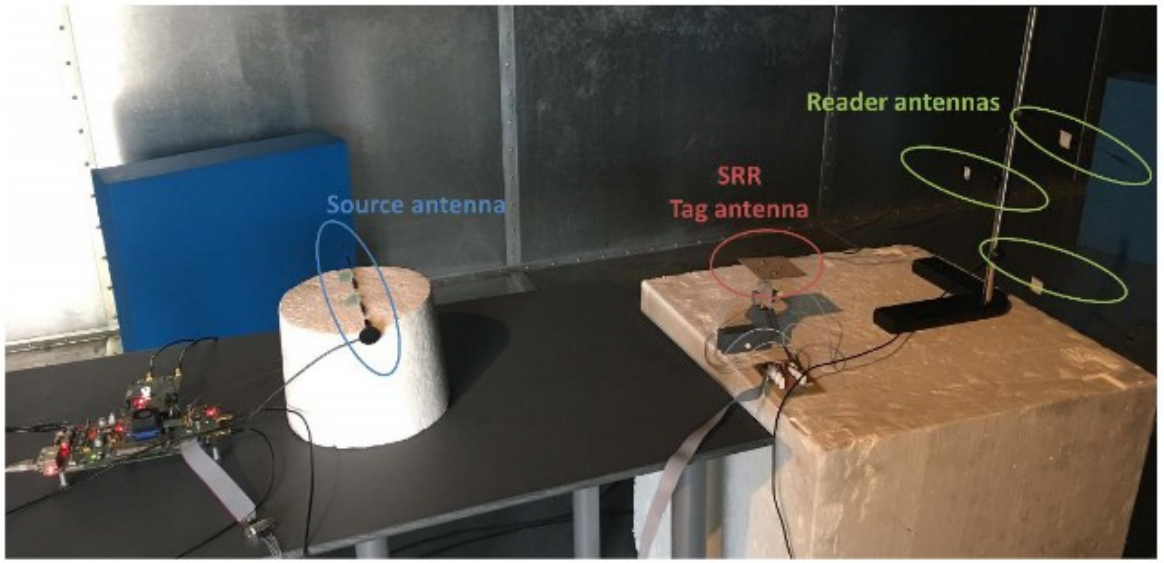
Experiment with directive & polarized antenna

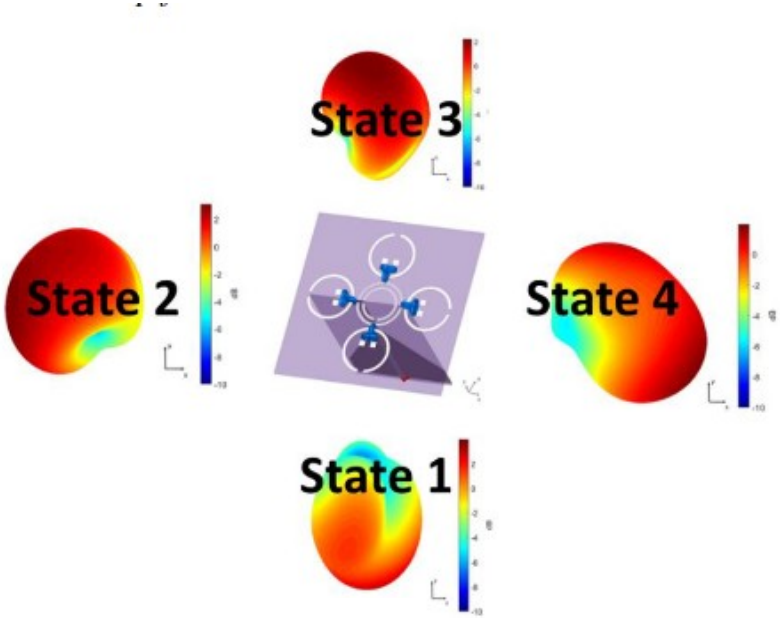


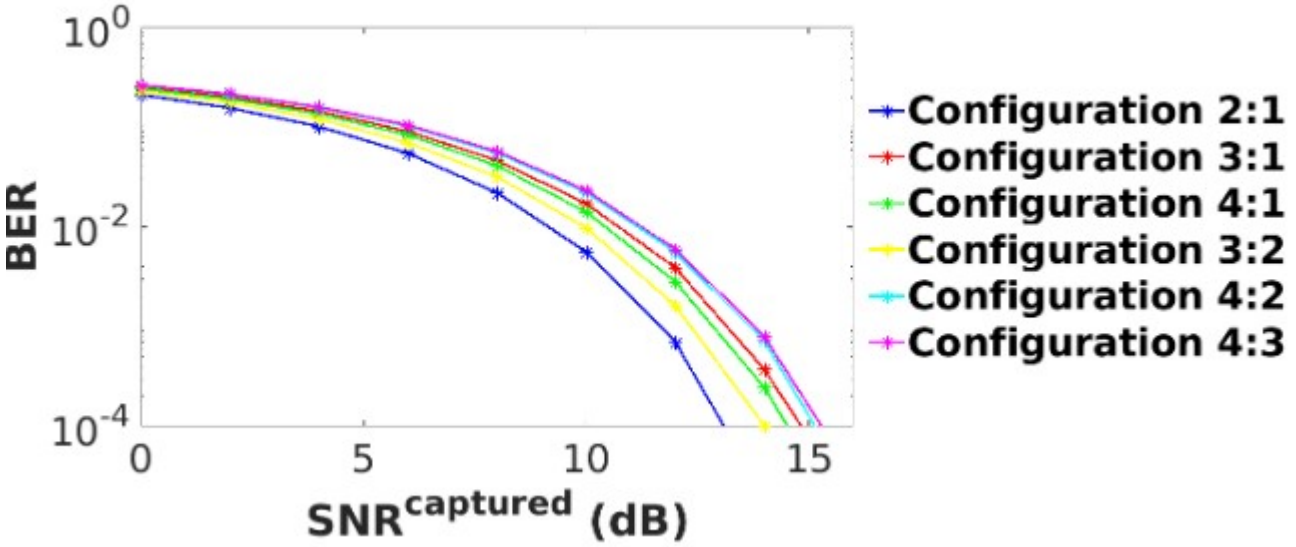




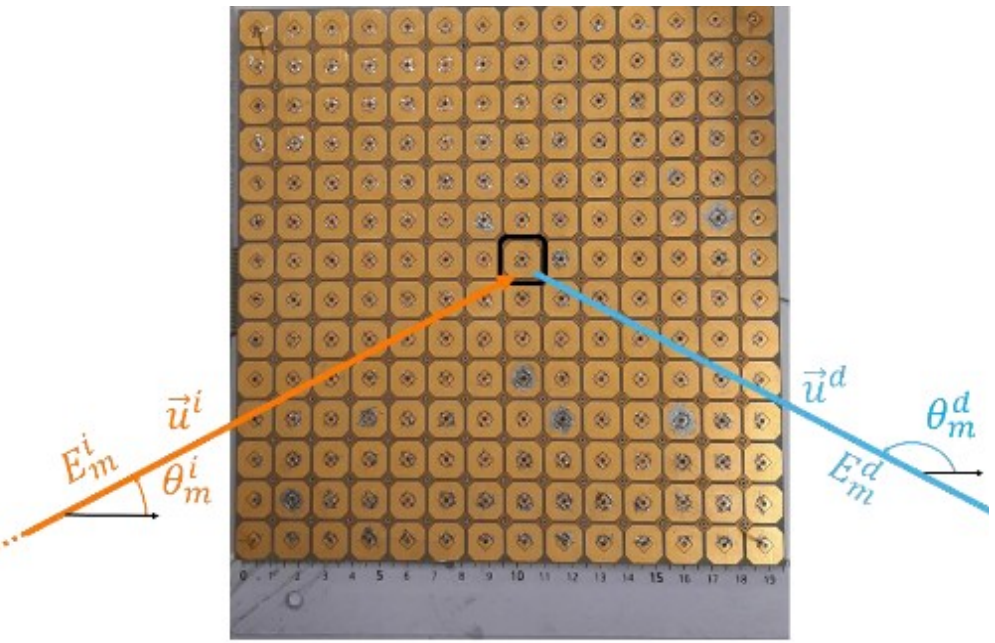
Experiment with SRR tag

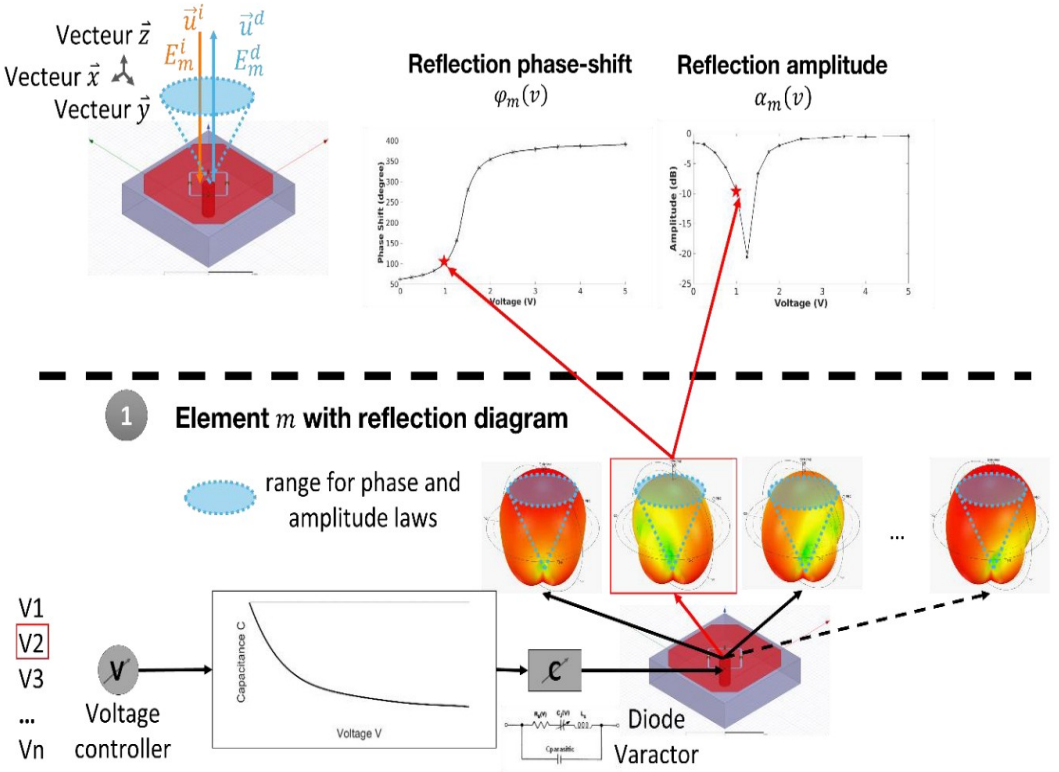






Reflective Intelligent Surfaces

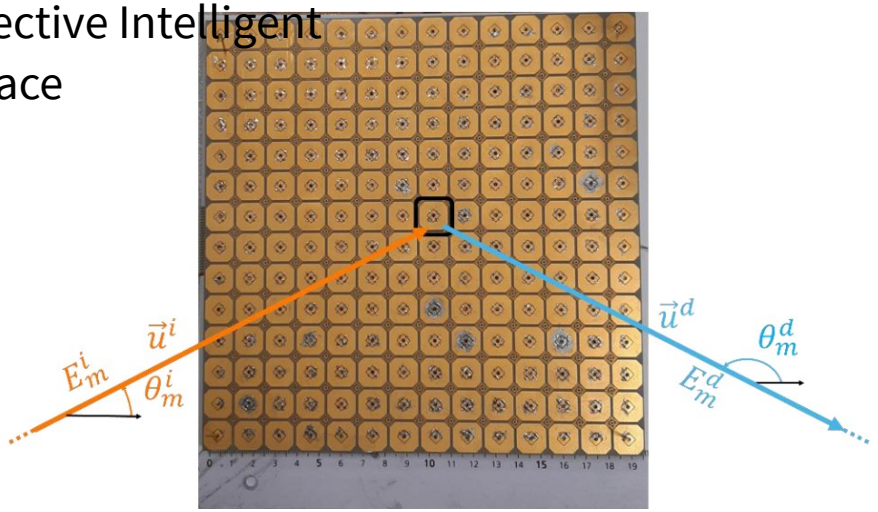




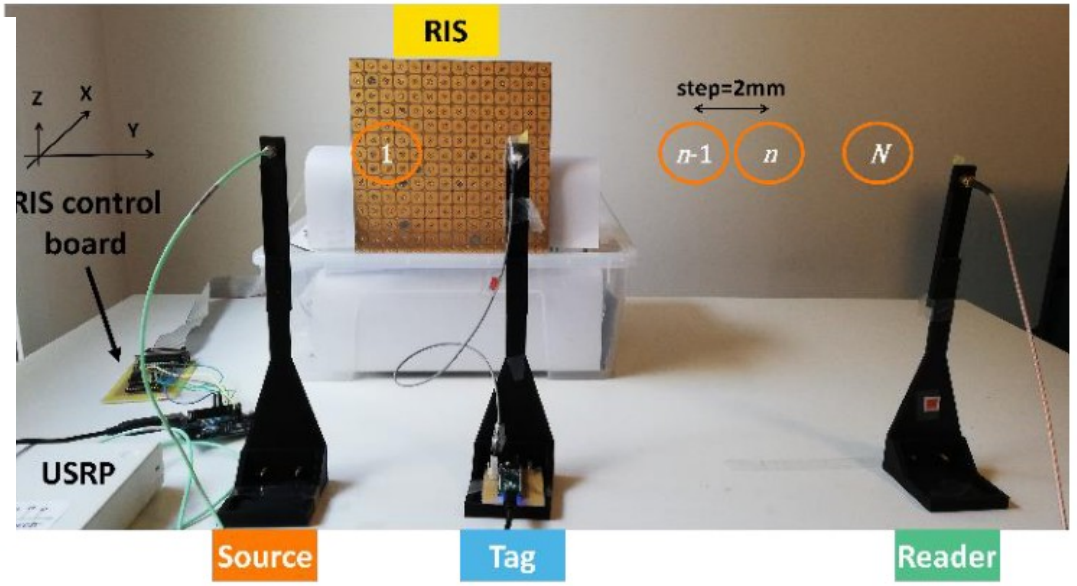
Fara, Roman, et al. IEEE Wireless Communications 29.1 (2022): 70-77.

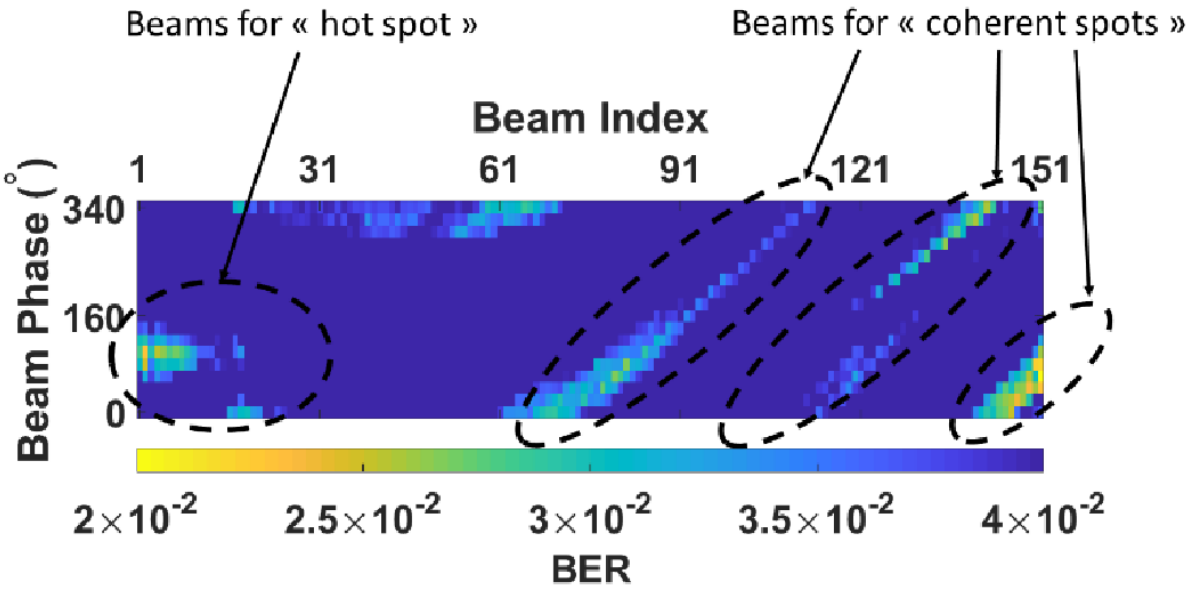
Reflective intelligent surface

Reflective Intelligent Surface



≠Specular reflection

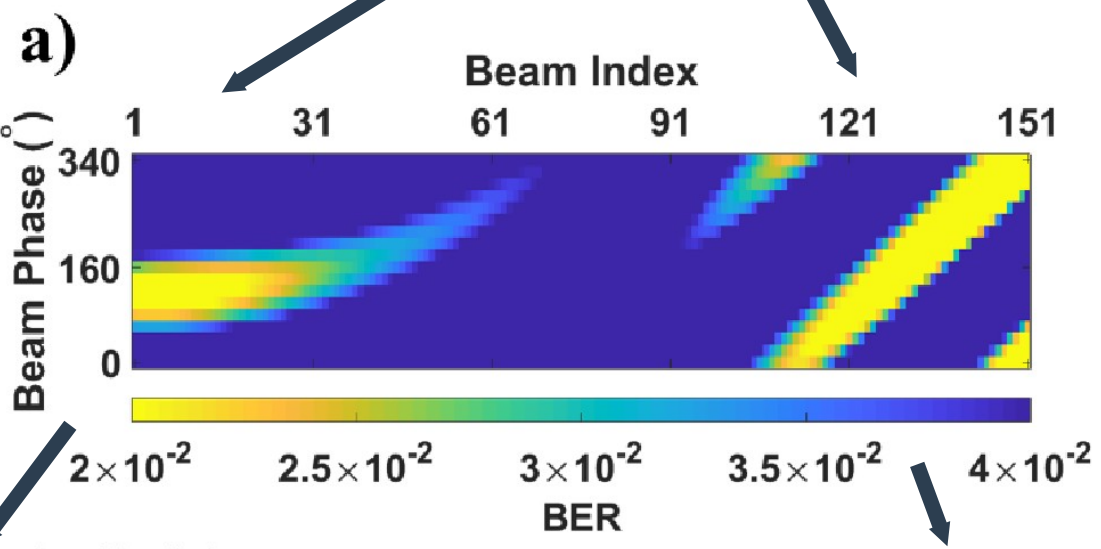


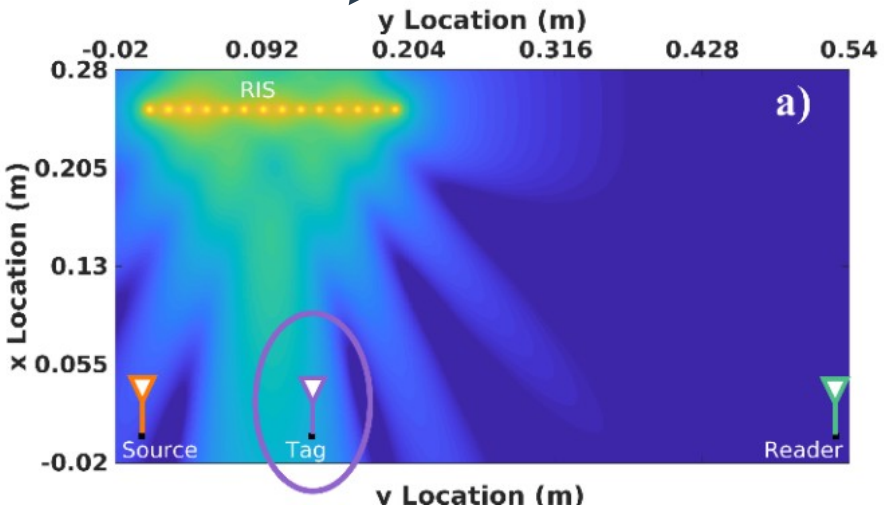


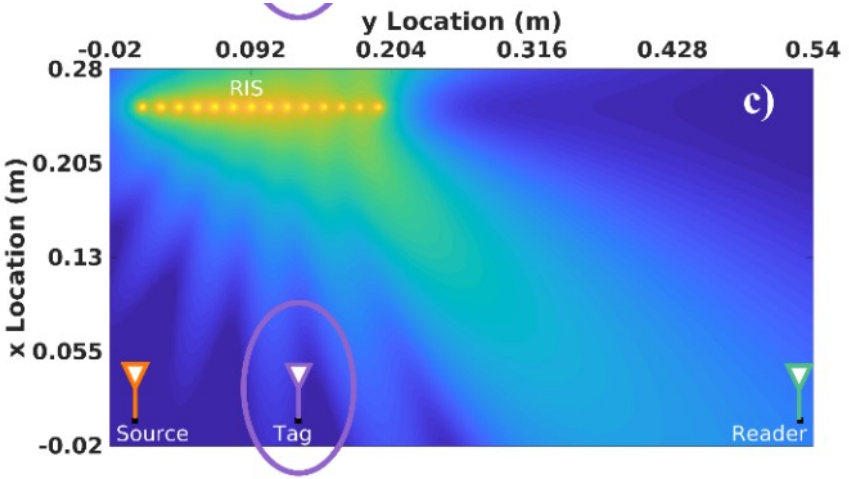
Reflective intelligent efficient for several positions of Tag and Reader

Reflective Intelligent Surface simulations (MoM)

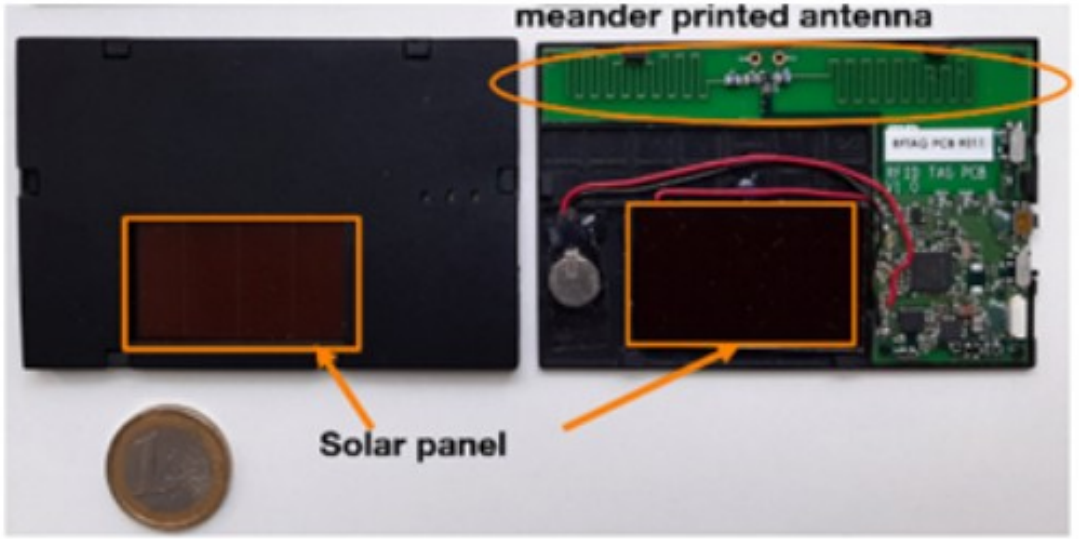
$$e_0 = a$$
$$e_1 = a + b \rightarrow \Delta I = |e_1|^2 - |e_0|^2 = |b|^2 + 2\Re(ab^*)$$

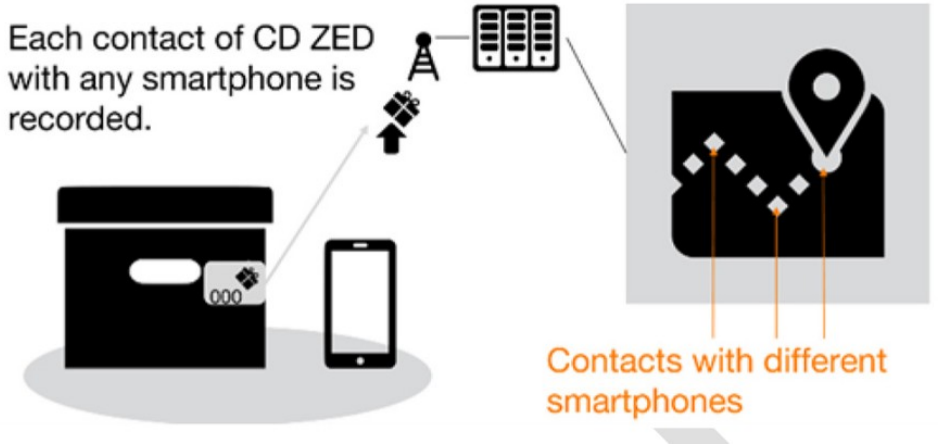






Prototype developed by Orange





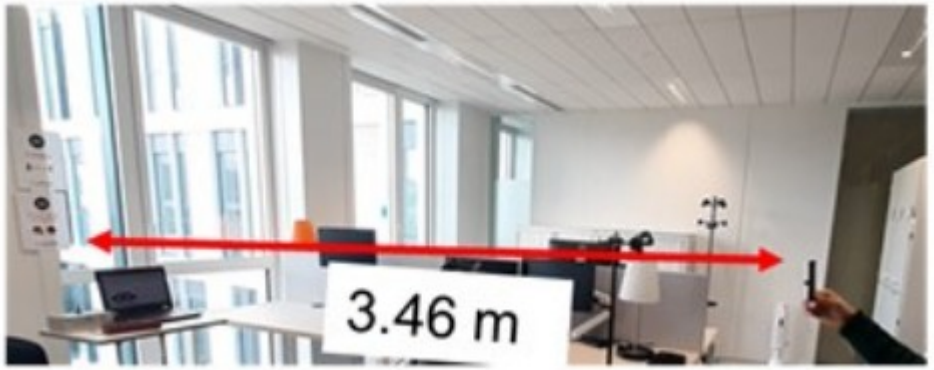
- Size of a credit card
- Very low energy consumption
- Powered by solar cell

Application : Crowd-Detectable Zero-Energy-Devices
Associated to a smartphone → localization

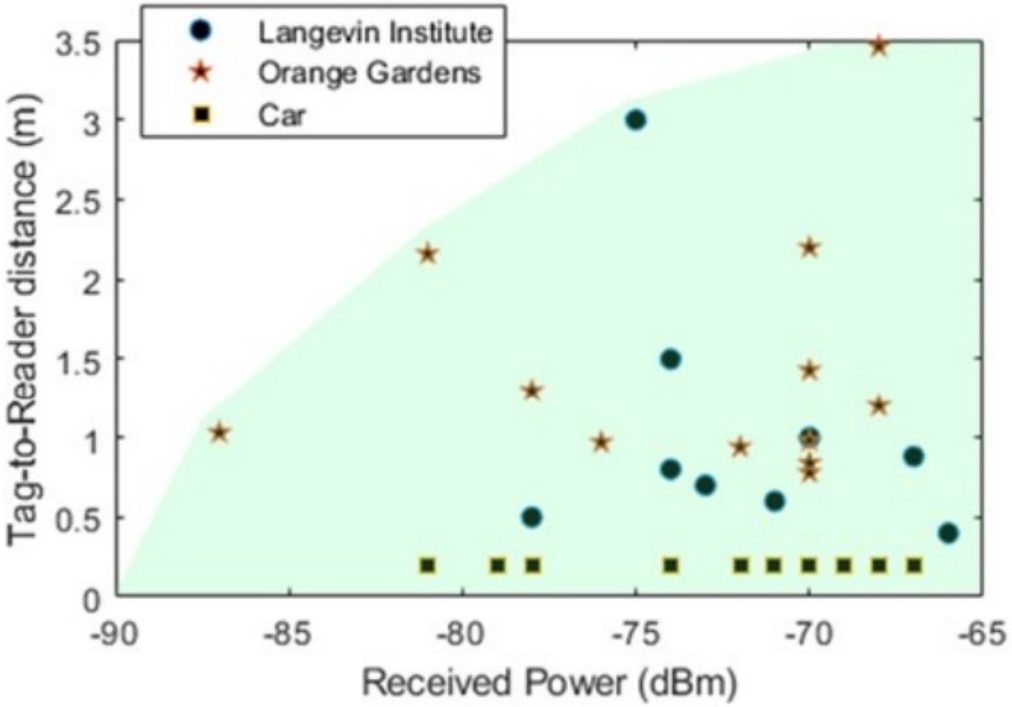
Phan-Huy et al., IEEE Journal of RFID 2022

Tests in various environments

Court yard



Office



Underground

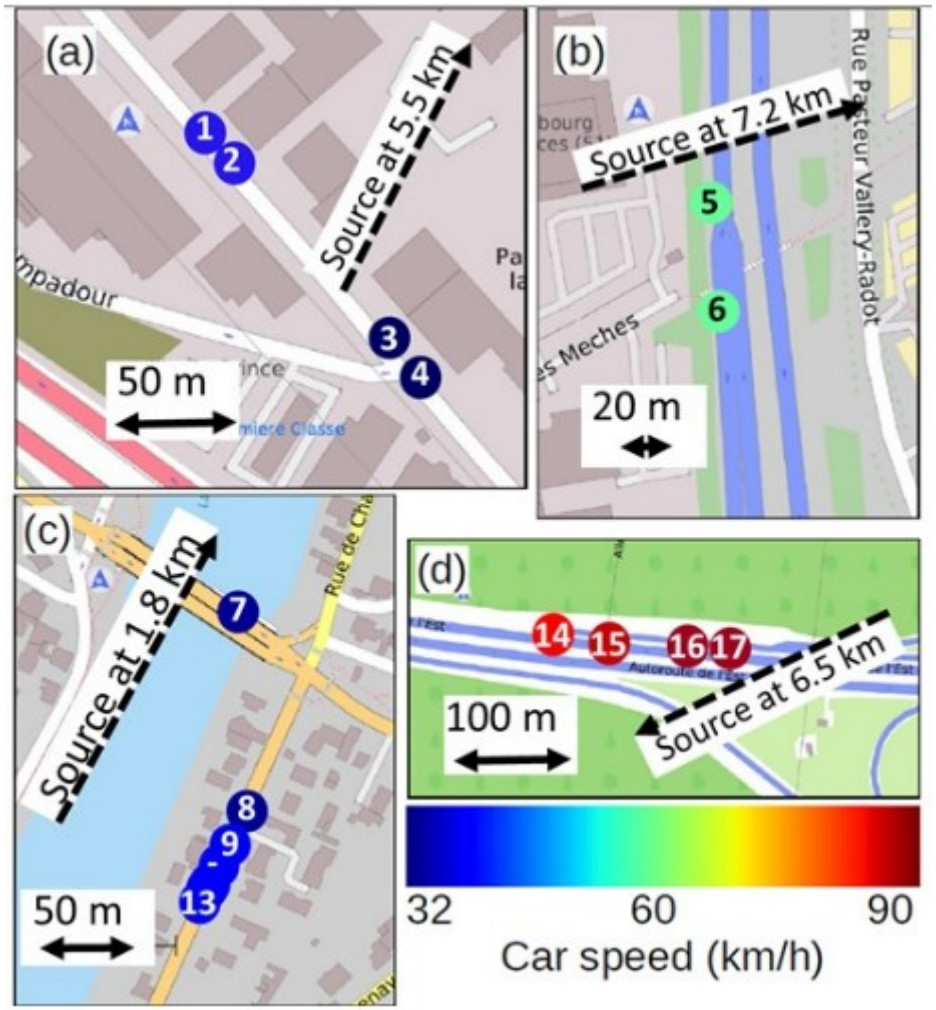
Park hill

Roof terrace

Tag range limited by the link power between the source and the receiver

Mobility tests

Test in a car



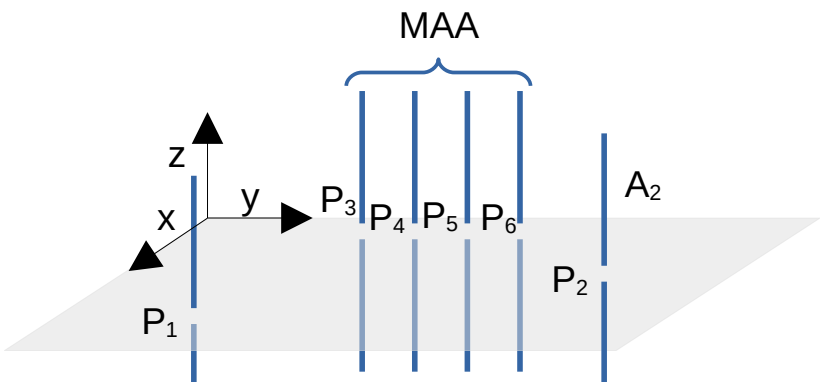
Free error transmission for various speeds and environment :

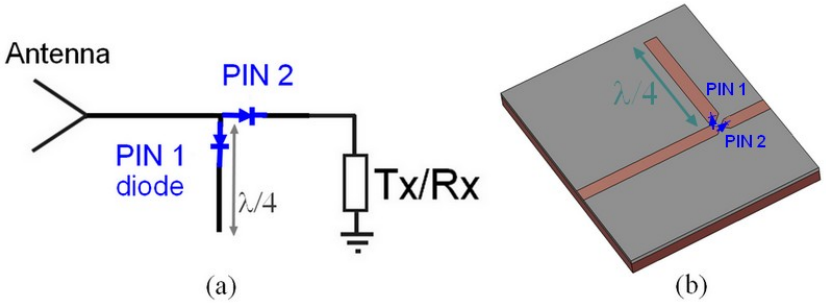
(a) and (c) : Street

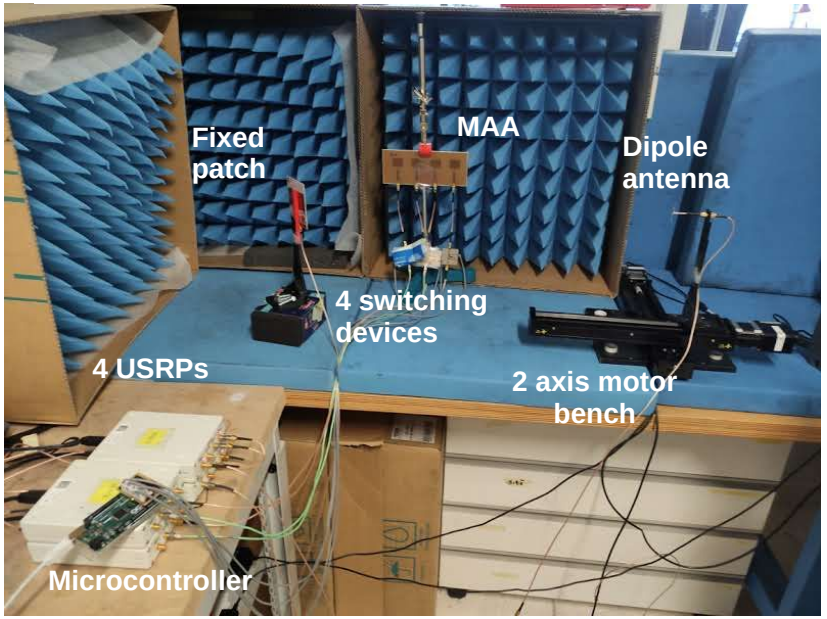
(b) and (d) : Highway

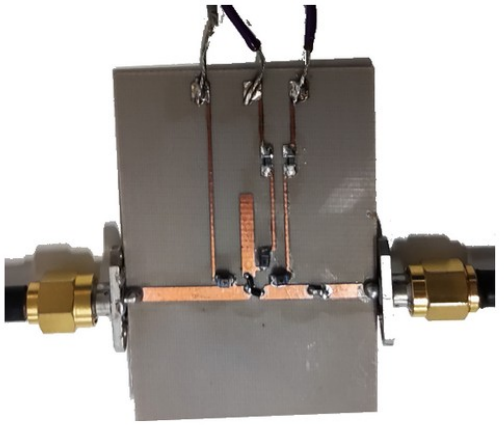
Velocities up to 90kmph

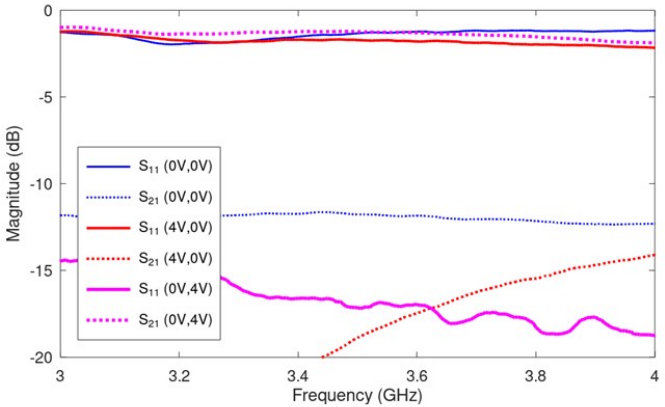
Multipurpose Array



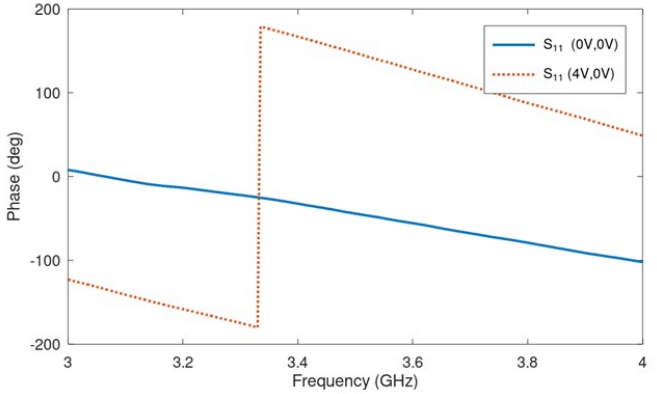





(a)



(b)

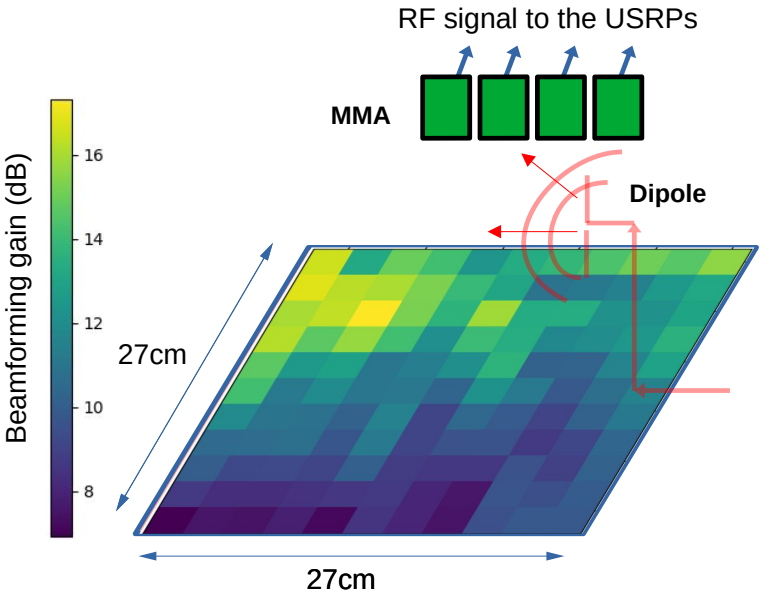


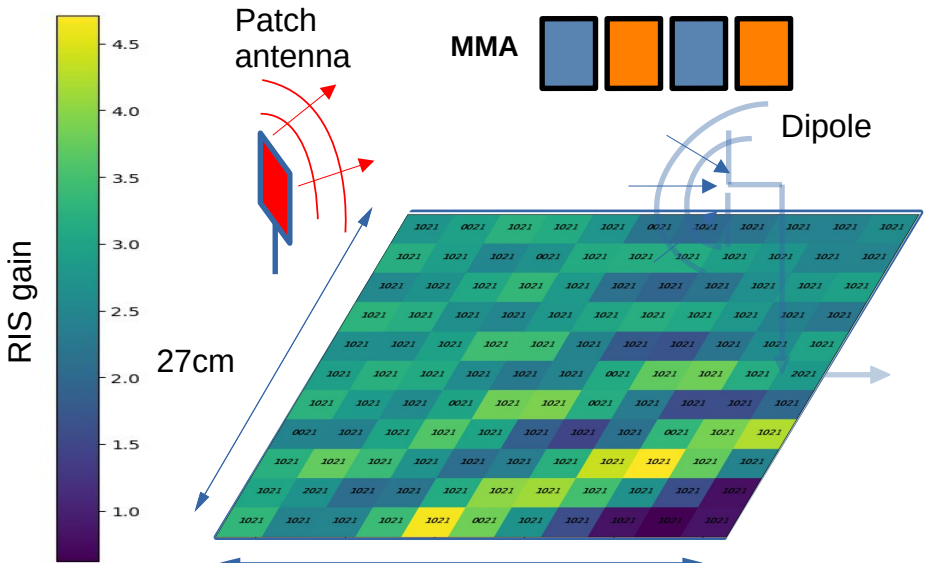
(c)

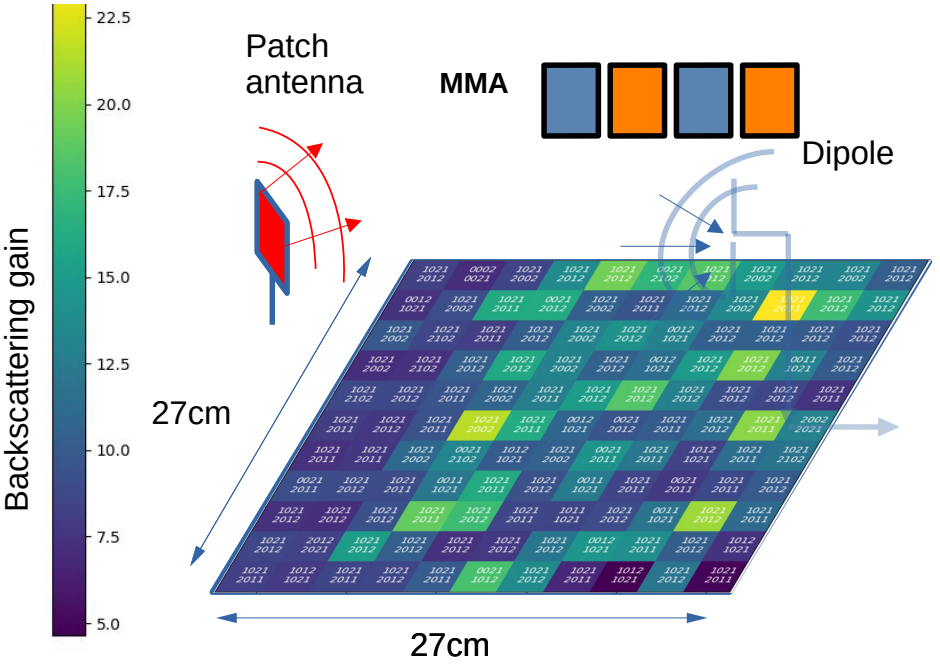
First results

3 working modes :

- MIMO
- Reflective Intelligent Surfaces (RIS)
- Backscatterer







Conclusions & perspectives

- New way to transmit information by recycling ambiant RF field
- Short range – low rate communications
- Most promising for IoT application (e.g., AirTag)

Current works

- Use several scatterers
- Use receiver with several antennas
- Model the interaction of the tag with RF field

Phan-Huy et al., IEEE Journal of RFID 2022

Thank you