



« l'énergie au cœur des ondes – ressources et environnement : gestion intelligente ».

New 6G challenges: the time for electromagnetic field awareness has come

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Future
networks



Dinh-Thuy PHAN HUY:

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Background:

- Degree in engineering from Supelec (2001). Ph. D. in electronics and telecommunications from the National Institute of Applied Sciences (INSA) of Rennes, France (2015).
- 2001, joined France Telecom R&D (now Orange Innovation), France.
- Coordinator of French collaborative research projects TRIMARAN (2011-2014) and SpatialModulation (2016-2019). 5G PPP projects (2012-2017): METIS, Fantastic 5G, mmMAGIC and 5GCAR.
- >40 patents and >50 papers.

Currently:

- EU Flagship project Hexa-X and Hexa-X II on *6G*.
- Leader of workpackage on sustainability & security in EU project RISE-6G on *reconfigurable intelligent surfaces for 6G*.
- Leader of Orange internal research project on *Backscattering*
- Delegate at European Telecommunications Standards Institute Industry Specification Group on *Reconfigurable Intelligent Surfaces* (ETSI ISG RIS).
- Industry Liaison Officer for IEEE Communications Society Emerging Technology Initiative on *Reconfigurable Intelligent Surfaces* (ETI-RIS)

Awards & recognition:

- Irène Joliot Curie Prize – category Woman-Research-Enterprise (2018) from the French Ministry of Education and Research.
- Grand Prize of Electronics of General Ferrié (2018) from the French Soc. of Electricity, Electronics & Information and Comm. Technologies
- Economical Impact of Digital Encounters (2016) from the French National Research Agency;
- Senior Orange Expert of the Future Networks Orange Experts community (since 2011).
- IEEE senior member.
- Best Paper Awards: *2021 IEEE RFID-TA Best Paper, 2022 IEEE ComSoc Outstanding Paper, 2021 EURASIP JWCN Best Paper, 2018 IEEE PIMRC Track 3&4 Best Paper*

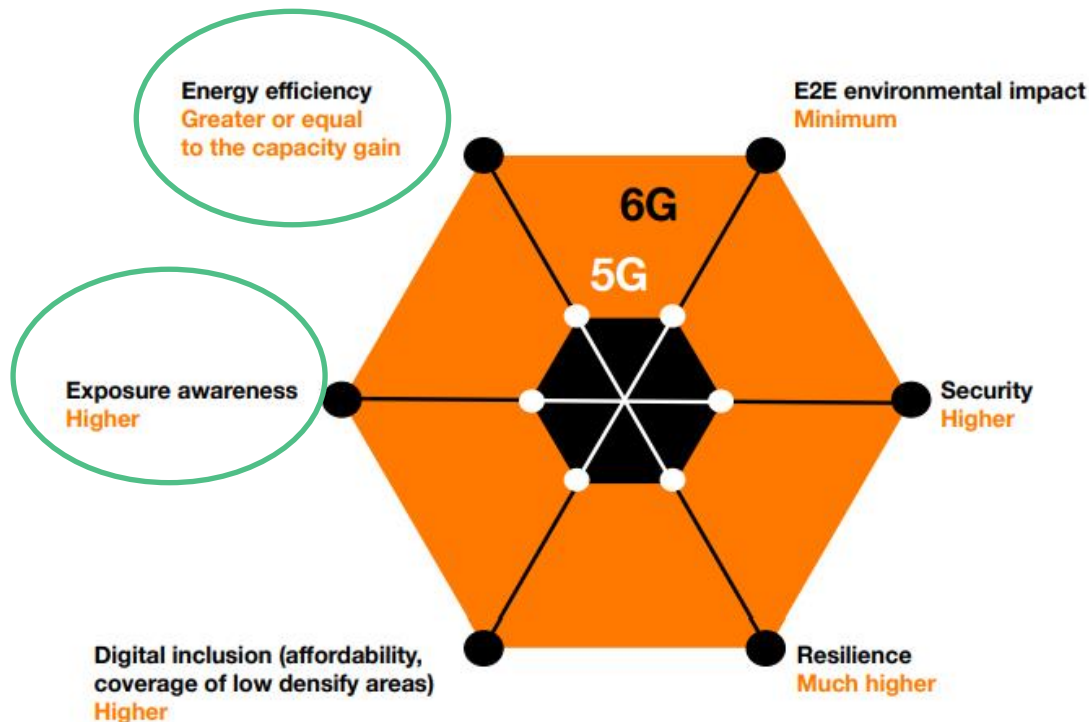
Research interests:

- wireless communications & mobile networks
- beamforming, time reversal, spatial modulation,
- *backscattering and intelligent reconfigurable surfaces.*



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Orange's Vision for 6G



<https://oran.ge/386d9US>

2 examples of
electromagnetic field (EMF) aware
radio technologies
for future mobile networks:

Reconfigurable intelligent surface (RIS)

Ambient Backscatters in mobile networks

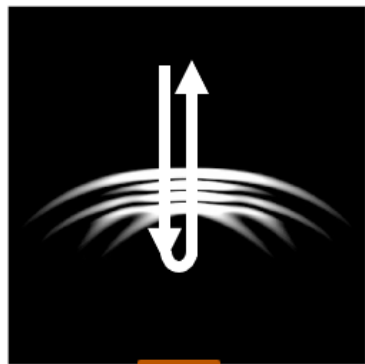
Figure 2: Orange's vision for 6G societal requirements

Reconfigurable Intelligent Surface (RIS)



A Reconfigurable Intelligent Surface (RIS) is ...

- ... an intelligent mirror (reflective RIS)



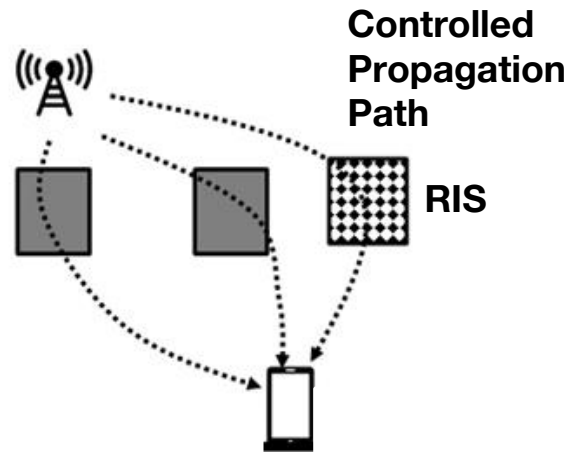
RIS

Configuration 1



RIS

Configuration 2

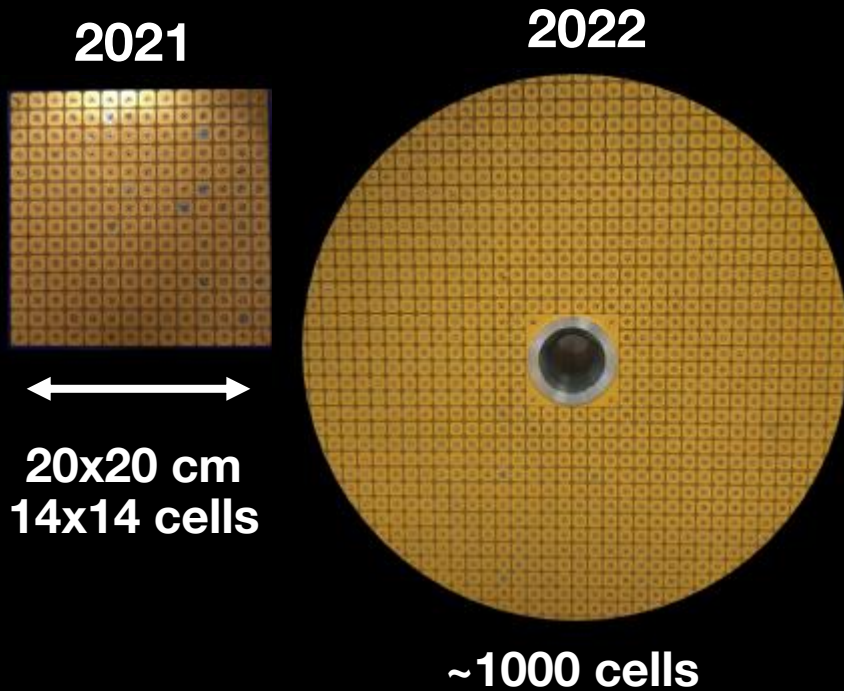


- ... a « Passive » Relay (low energy)
- Smart Radio Environments for 6G.

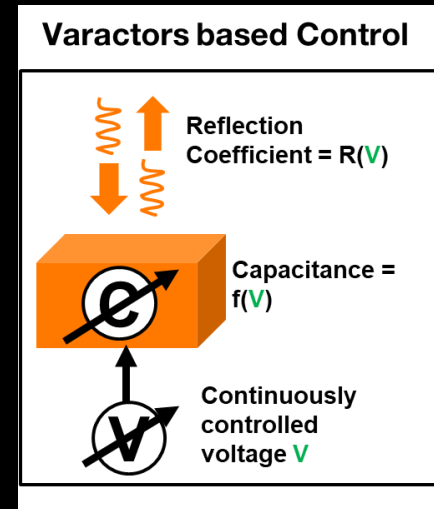
• M. Di Renzo, M. Debbah, DT Phan-Huy, A. Zappone, MS Alouini, C. Yuen, V. Sciancalepore, G. C Alexandropoulos, J. Hoydis, H. Gacanin, J. de Rosny, A. Bounceur, G. Lerosey, M. Fink "[Smart radio environments empowered by reconfigurable AI meta-surfaces: An idea whose time has come](#)" in *EURASIP Journal of Wireless Communications 2019*, 2021 Eurasip JWC Best Paper Award.

• M. Di Renzo ; K.s Ntontin; J. Song; F. H. Danufane; X. Qian; F. Lazarakis; J. De Rosny; D.-T. Phan-Huy, O. Simeone; R. Zhang; M. Debbah, G. Lerosey, M. Fink, S. Tretyakov, S. Shamai "[Reconfigurable Intelligent Surfaces vs. Relaying: Differences, Similarities, and Performance Comparison](#)," in *IEEE OJCOMS*, vol. 1, pp. 798-807, 2020

1st Network Operator in Europe to experiment RIS

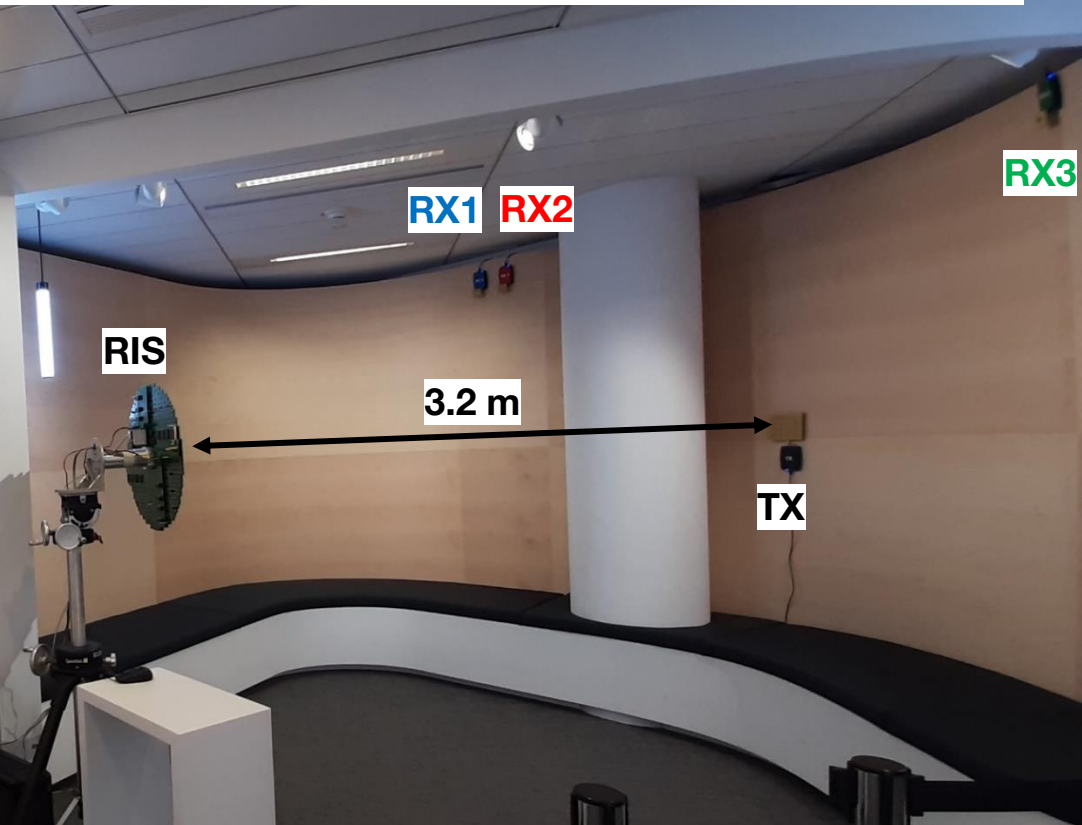
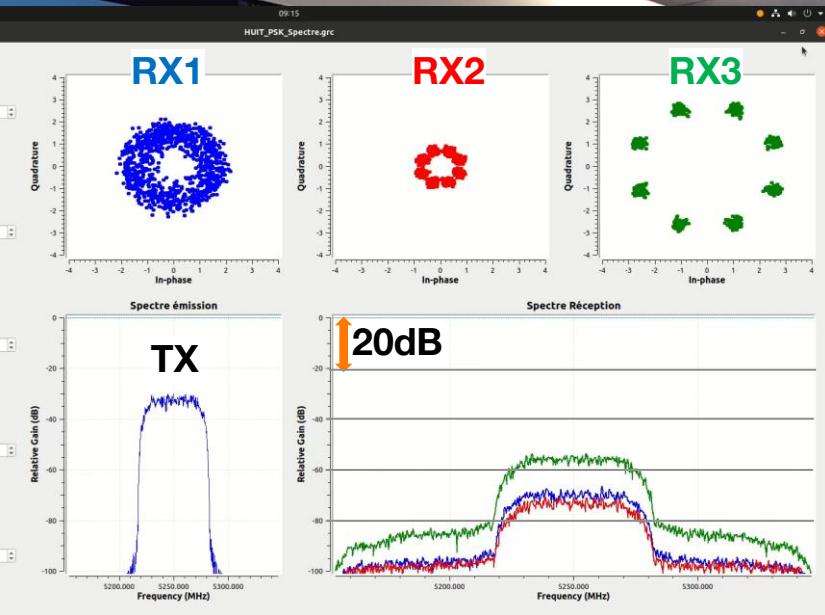


Orange's first RIS prototypes are « un-plugged » reflect array antennas with continuously controllable reflection phase shifting



- R. Fara, P. Ratajczak, D. -T. Phan-Huy, A. Ourir, M. Di Renzo and J. de Rosny, "A Prototype of Reconfigurable Intelligent Surface with Continuous Control of the Reflection Phase," in IEEE Wireless Communications magazine, vol. 29, no. 1, pp. 70-77, February 2022.
- P. Ratajczak, P. Brachat, J. Fargeas, J. Baracco, "C-band active reflectarray based on high impedance surface," in Proc. IEEE International Symposium on Phased Array Systems and Technology, Waltham, USA, Oct. 2013.

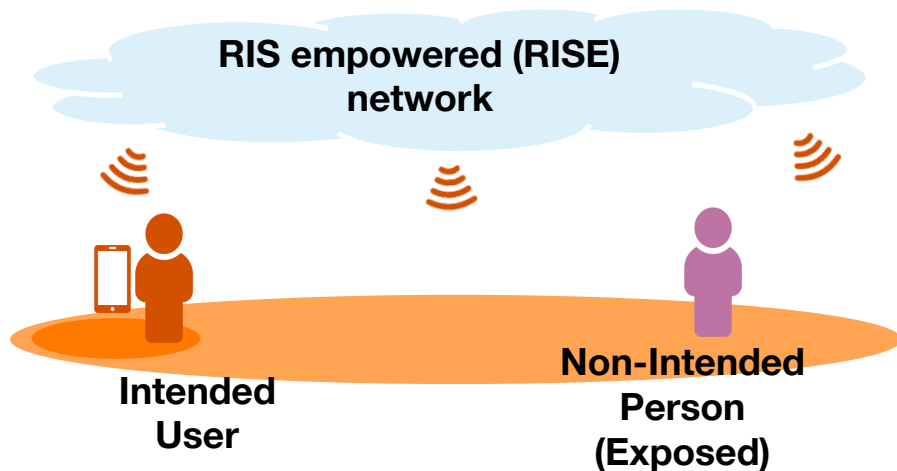
Live demo at Orange Research and Innovation Exhibition (October 2022)



- [Research and Innovation Exhibition - Hello Future Orange](#)
- P. Ratajczak, P. Brachat, J. Fargeas, J. Baracco, "[C-band active reflectarray based on high impedance surface](#)," in Proc. IEEE International Symposium on Phased Array Systems and Technology, Waltham, USA, Oct. 2013.

Two types of Electromagnetic Field Exposure (EMFE) that a RIS can help to reduce

Inter EMFE



Self EMFE



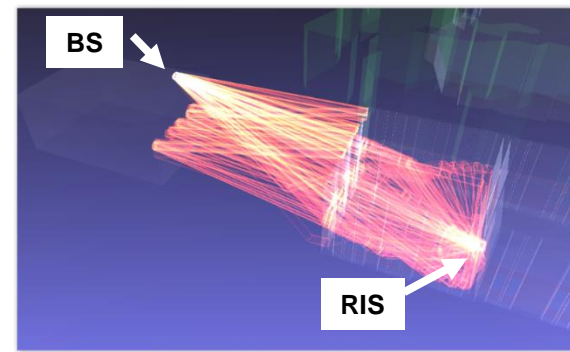
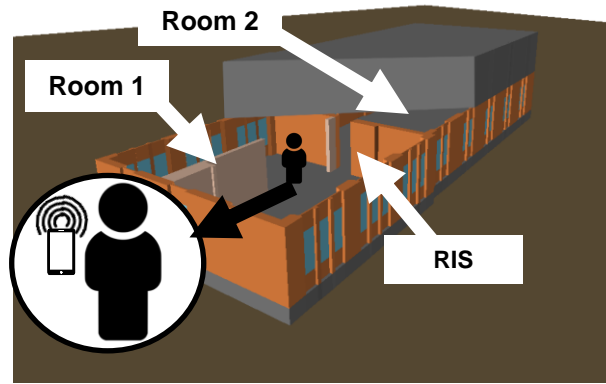
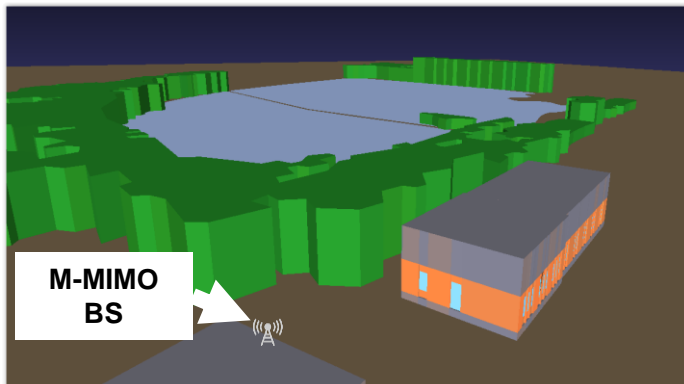
**Non-Intended User (exposed) = Intended User
=
Can Help Intentionally to lower down EMFE**

- EC Strinati, G C. Alexandropoulos, H Wymeersch, B Denis, V Sciancalepore, R D'Errico, A Clemente, DT Phan-Huy, E De Carvalho, and P Popovski, "[Reconfigurable, Intelligent, and Sustainable Wireless Environments for 6G Smart Connectivity](#)," in IEEE Communications Magazine, vol. 59, no. 10, pp. 99-105, October 2021.
- EC Strinati; G C. Alexandropoulos; V Sciancalepore;; M Di Renzo; H Wymeersch; DT Phan-Huy;; M Crozzoli; R D'Errico; E De Carvalho; P Popovski; P Di Lorenzo;; L Bastianelli; M Belouar; JE Mascolo; G Gradoni; S Phang; G Lerosey; B Denis, "[Wireless Environment as a Service Enabled by Reconfigurable Intelligent Surfaces: The RISE-6G Perspective](#),"in Proc. 2021 EuCNC/6G Summit, 2021, pp. 562-567.

Self EMFE aware BF assisted by RISs For M-MIMO at sub-6 GHz



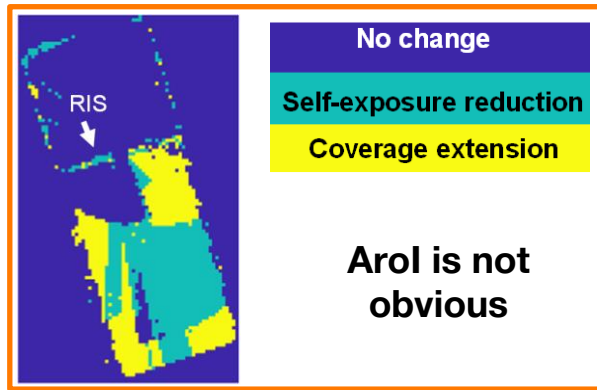
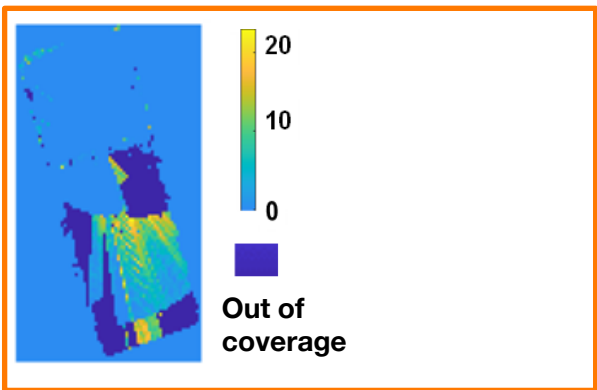
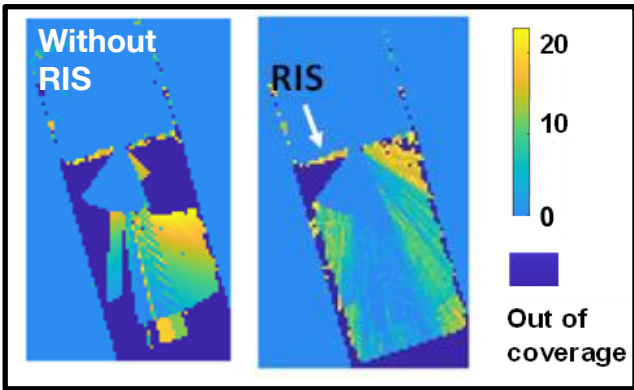
Voice Call with target QoS



Smartphone transmit power (dBm) to reach target QoS

Smartphone transmit power reduction (dB) thanks to RIS

Areas of Influence (Arol) of the RIS

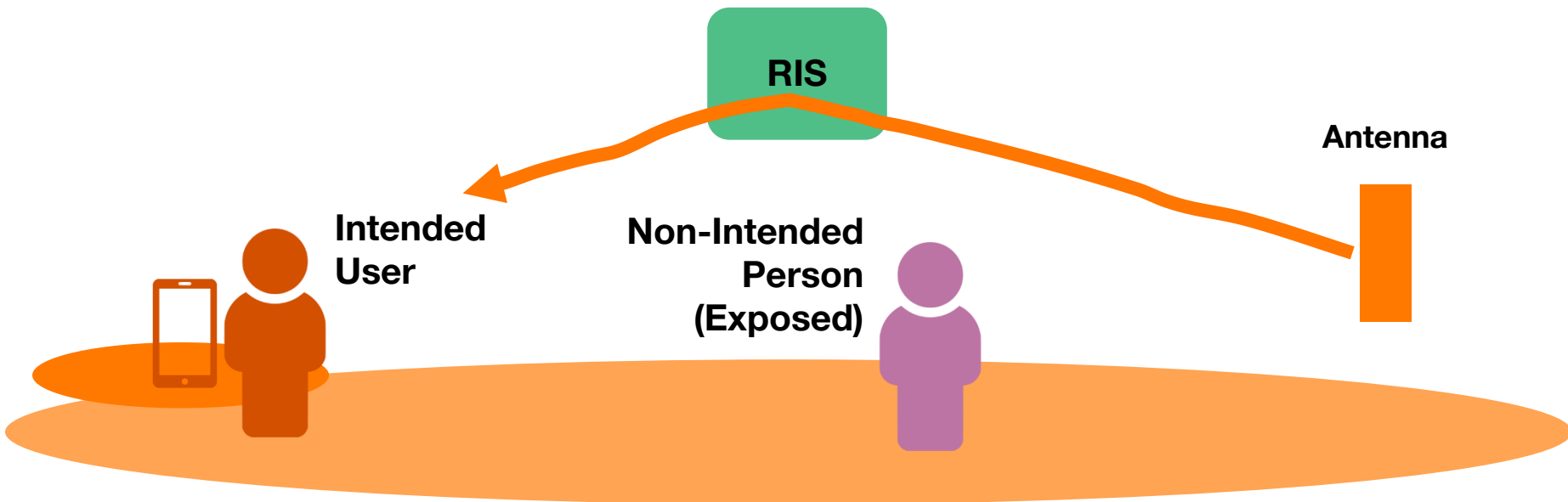


QoS= Quality of service M-MIMO = Massive Multiple Input, Multiple Output, BS= Base Station, UE = User Equipment

Creating and Operating Areas With Reduced Electromagnetic Field Exposure Thanks to Reconfigurable Intelligent Surfaces, IEEE SPAWC 2022

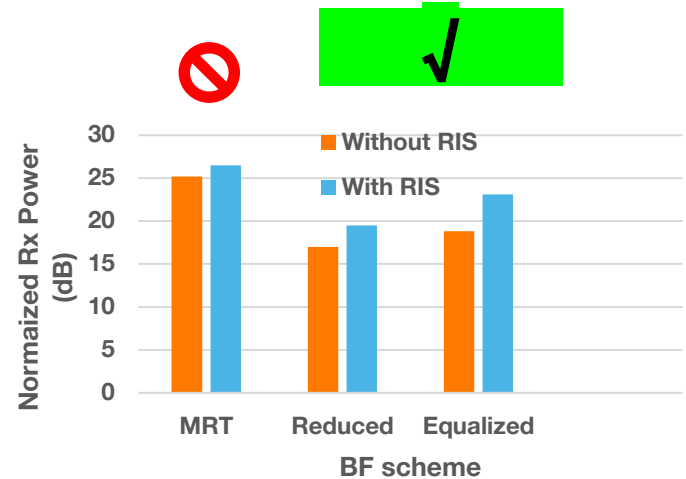
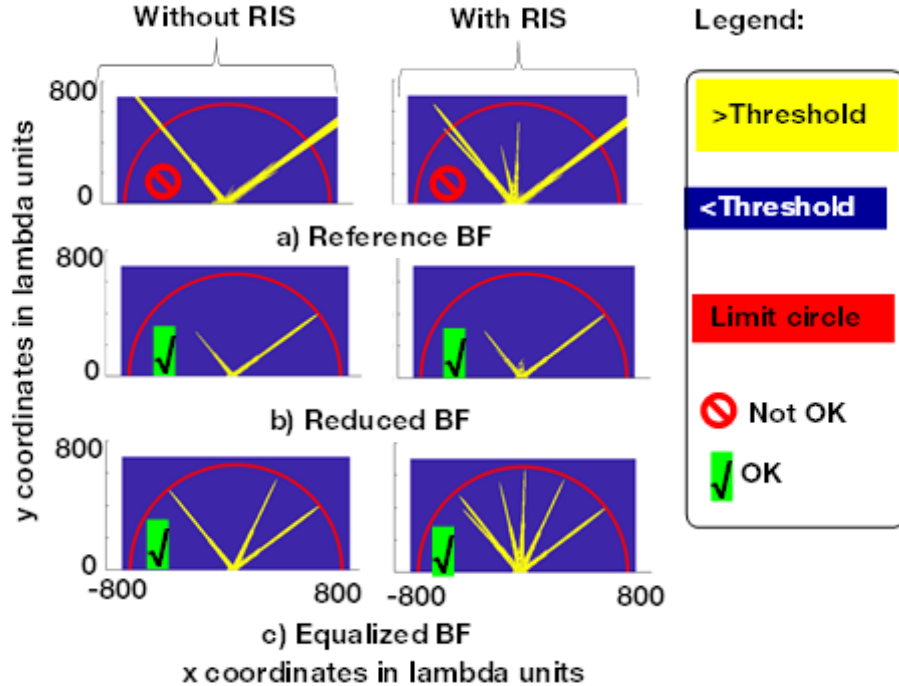
"New 6G challenges: the time for electromagnetic field awareness has come," DT Phan-Huy, URSI Days 21-22 march 2023.

Inter EMFE aware beamforming assisted by RISs For M-MIMO at mmwaves



Inter EMFE aware beamforming assisted by RISs For M-MIMO at sub-6 GHz

BS targets the same UE for more than 6 minutes.

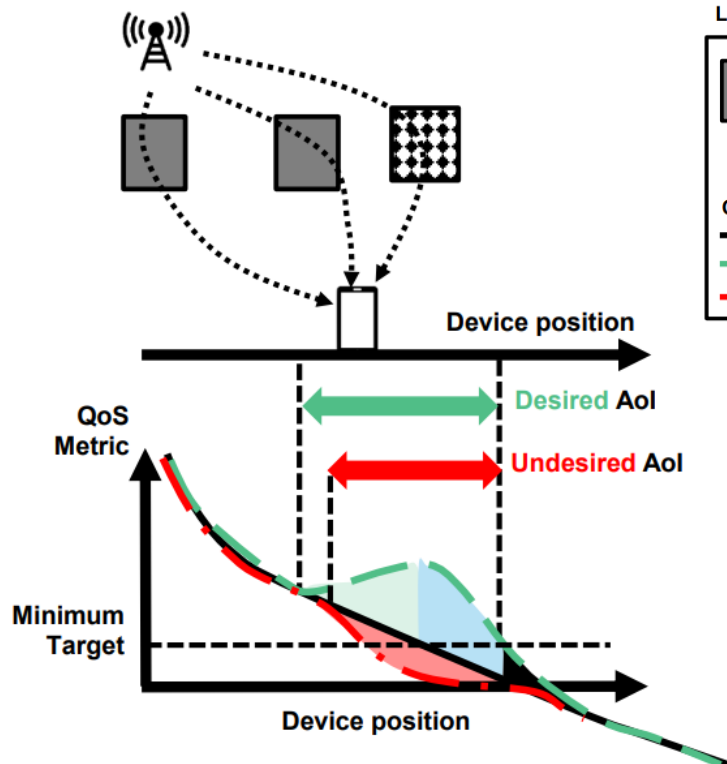


Also investigated:
MU-MIMO at sub-6GHz

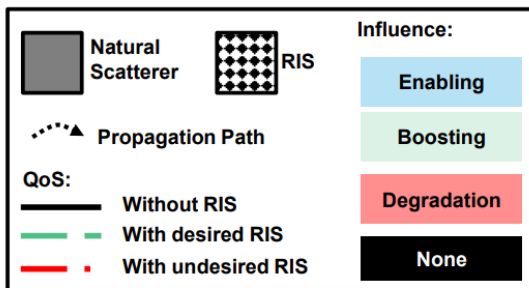
- N. Awarkeh, D.-T. Phan-Huy, R. Visoz, M. di Renzo "A Novel RIS-Aided EMF-Aware Beamforming Using Directional Spreading, Truncation and Boosting", *EuCNC & 6G Summit 2022*, Grenoble, June 2022.
- N. Awarkeh, D.-T. Phan-Huy, M. di Renzo "A Novel RIS-Aided EMF Exposure Aware Approach Using an Angularly Equalized Virtual Propagation Channel", *EuCNC & 6G Summit 2022*, Grenoble, June 2022.
- N. Awarkeh, D.-T. Phan-Huy and R. Visoz, "Electro-Magnetic Field (EMF) aware beamforming assisted by Reconfigurable Intelligent Surfaces," *IEEE 2021 SPAWC*.
- Y. Yu, R. Ibrahim, D.-T. Phan Huy "EMF-Aware MU-MIMO Beamforming in RIS-Aided Cellular Networks," *IEEE Globecom 2022*.
- Y. Yu, R. Ibrahim, D.-T. Phan Huy "Dual Gradient Descent EMF-Aware MU-MIMO Beamforming in RIS-Aided 6G Networks," *WiOpt 2022*.
- H. Guo, DT Phan-Huy, T. Svensson "Electromagnetic Field Exposure Avoidance thanks to Non-Intended User Equipment and RIS," *IEEE Globecom 2023*.

Two new deployment challenges with RIS: Area of Influence (**Arol**) and Bandwidth of Influence (**Bol**)

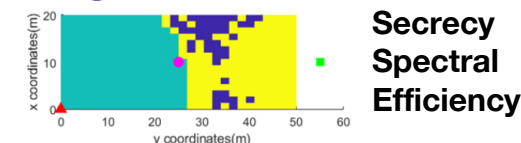
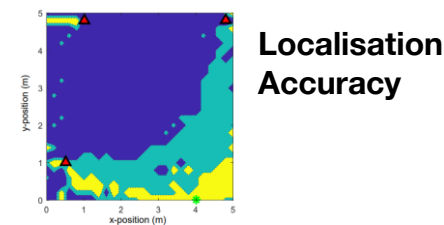
New Deployment challenges with RIS: Area of Influence (Arol) instead of coverage Area



Legend:



Enabled, boosted, no change



RIS-Aware Network Planning: The Rennes Train Station Case

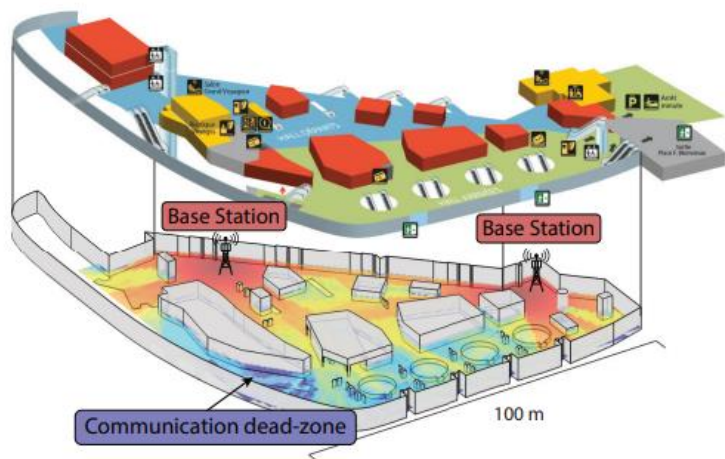
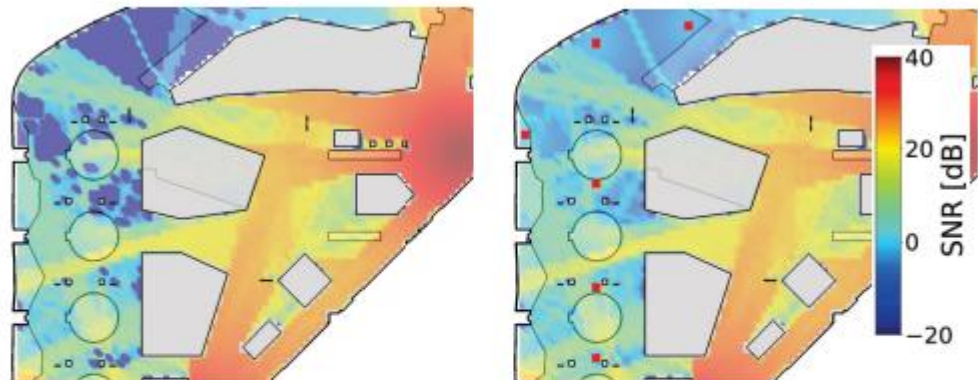


Fig. 1: Railway station topographic map and related power heatmap showing the dead-zone problem (Rennes, France).

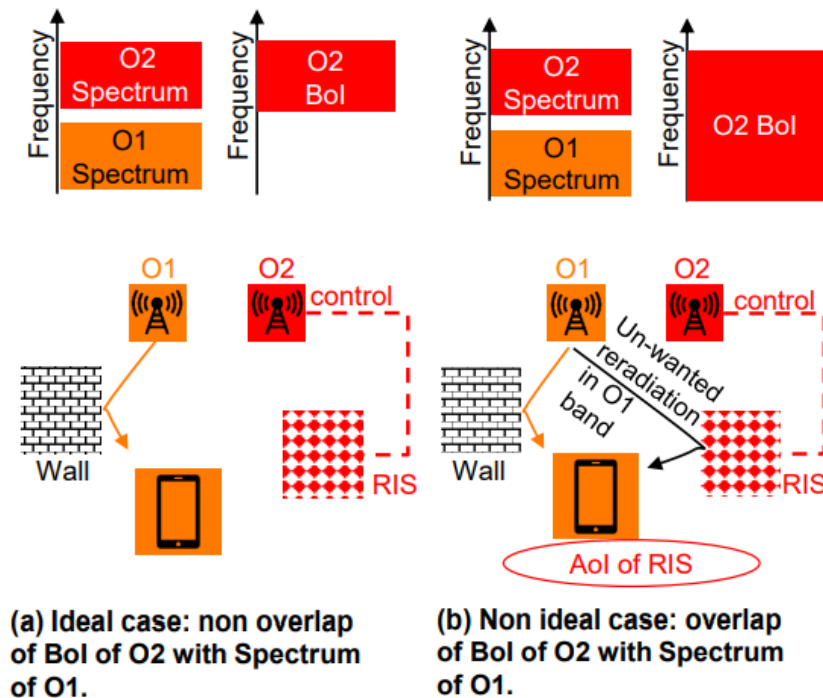


(a) SNR heatmap with $L = 0$ (b) SNR heatmap with $L = 6$ RISs (red squares).

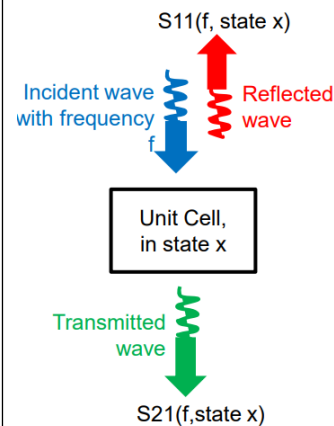
Fig. 6: SNR heatmap in the dead zone (see Figure 1) of the Rennes station obtained via ray-tracing simulations.

New Deployment challenges with RIS:

Coexistence between operators challenge

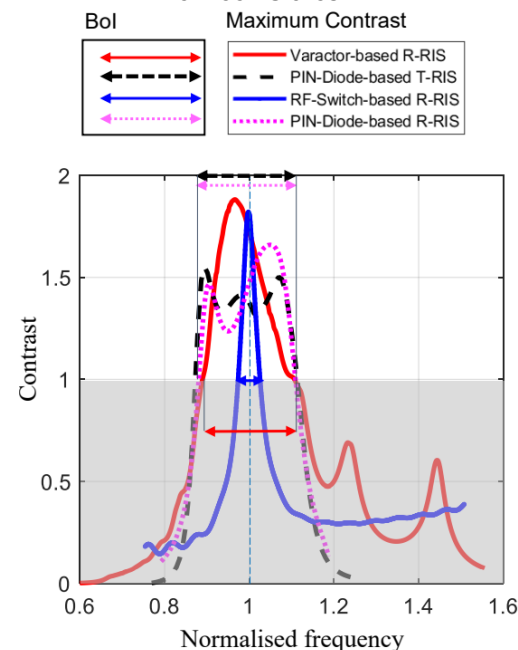


Bol(s) of existing RIS prototypes



(a) S-Parameters for state x.

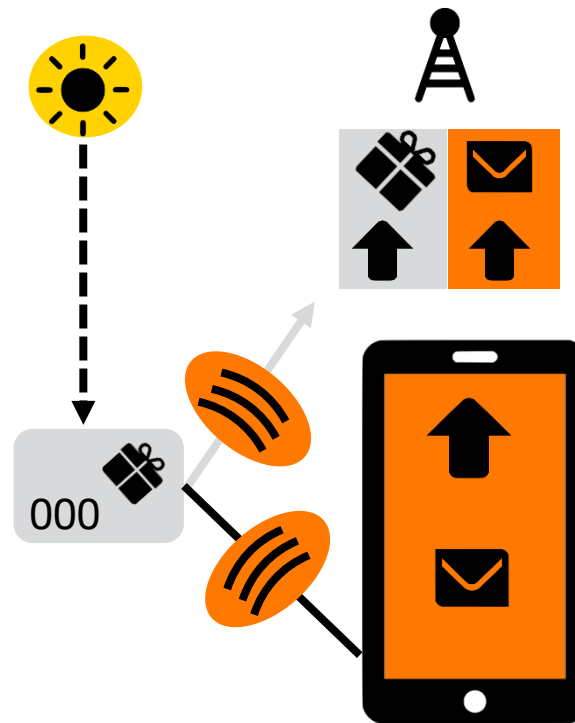
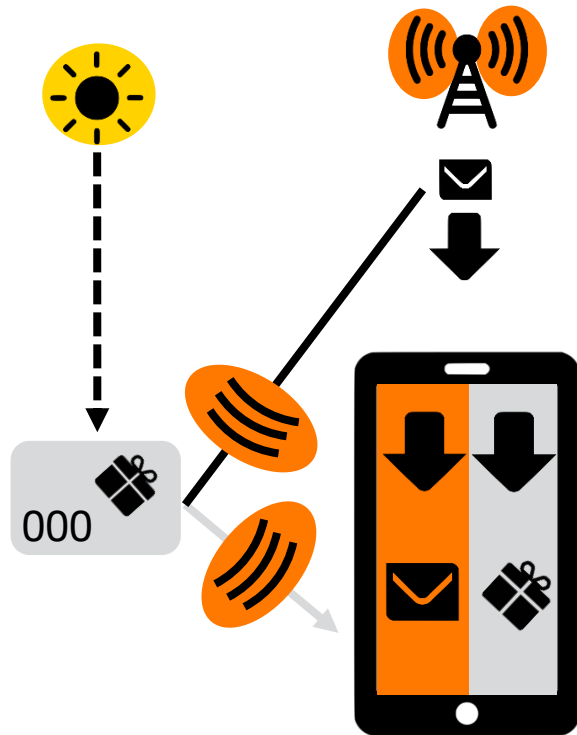
Maximum Contrast Between States



Ambient Backscatters in Mobile Networks

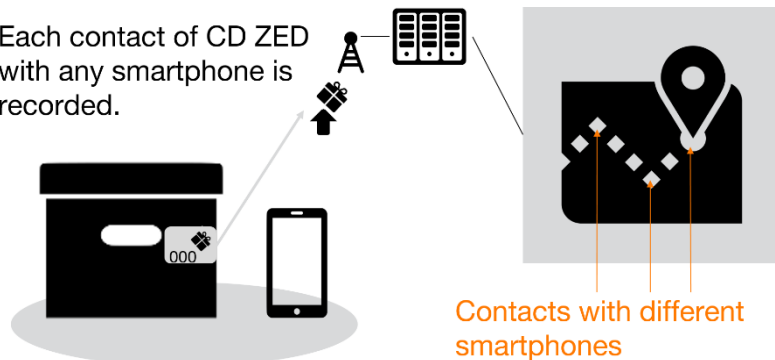


Ambient Backscatter in Mobile Networks: Crowd-Detectable Zero-Energy-Device (CD ZED) concept

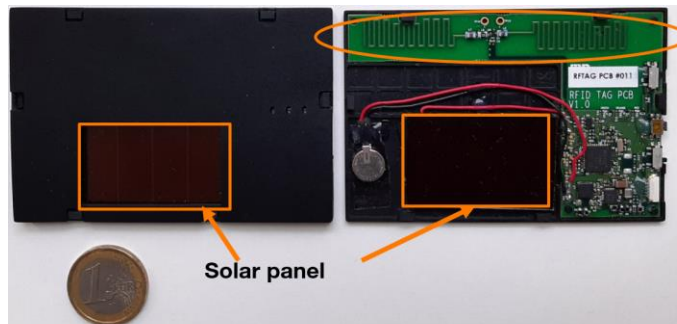


Asset tracking « Out-Of-Thin Air »

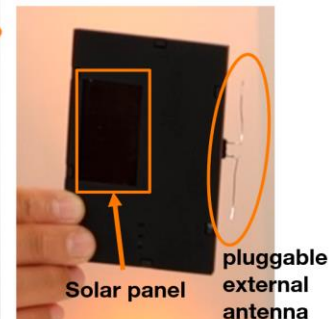
Each contact of CD ZED with any smartphone is recorded.



Orange Prototypes of CD ZEDs



a) Solar tags with backscattering TV and 4G



a) Solar tag backscattering 5G

- [2021 Mobile World Congress](#) CD ZED Demonstration, Barcelona, June 2021
- D. -T. Phan-Huy, D. Barthel, P. Ratajczak, R. Fara, M. d. Renzo and J. d. Rosny, "[Ambient Backscatter Communications in Mobile Networks: Crowd-Detectable Zero-Energy-Devices](#)," 2021 IEEE RFID-TA, 2021, pp. 81-84. 2021 IEEE-RFID-TA Best Paper Award.
- D. -T. Phan-Huy, D. Barthel, P. Ratajczak, R. Fara, M. d. Renzo and J. d. Rosny, "[Ambient Backscatter Communications in Mobile Networks: Crowd-Detectable Zero-Energy-Devices](#)," 2022 IEEE Journal of RFID. Extended version of the RFID-TA Conf. Paper.
- [2021 Mobile World Congress](#) CD ZED Demonstration, Barcelona, June 2021.

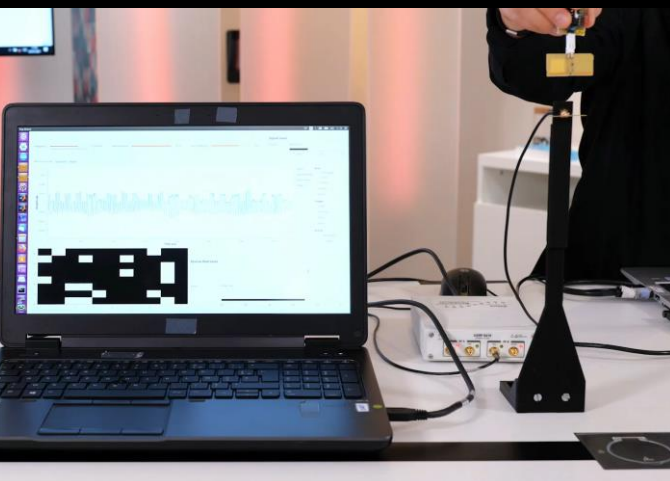
Experiments with Ambient Sources

Orange commercial 5G (5G Ericsson small cell)

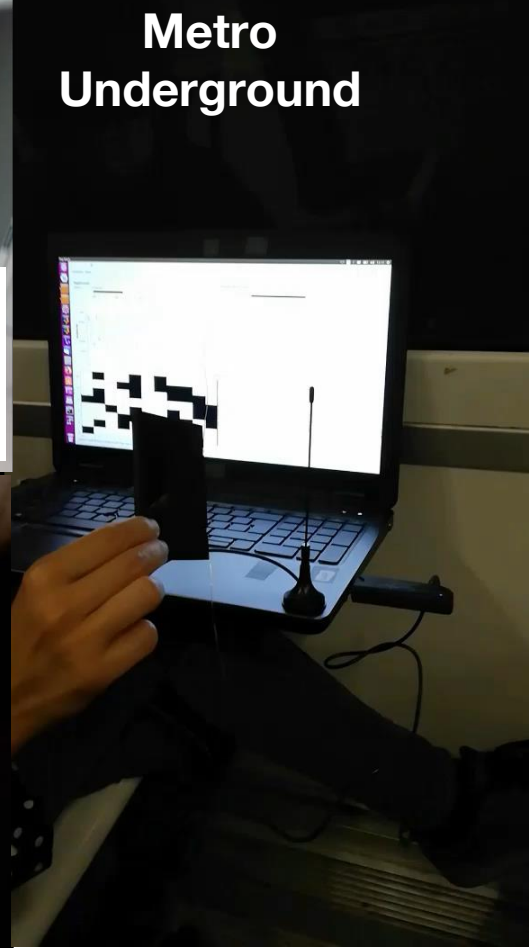


Indoor
4 meters
range

Metro Underground



High Speed Train



Pilot Based Detection of Tags. Robust to data traffic variations

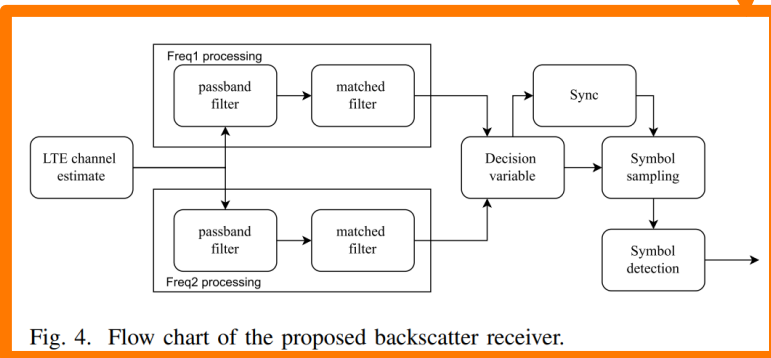
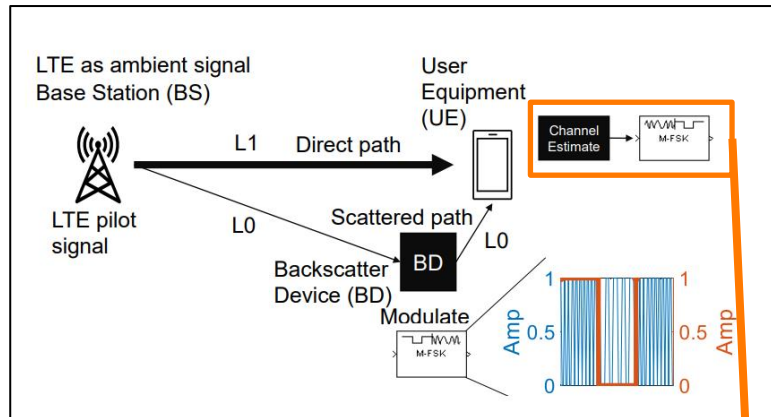
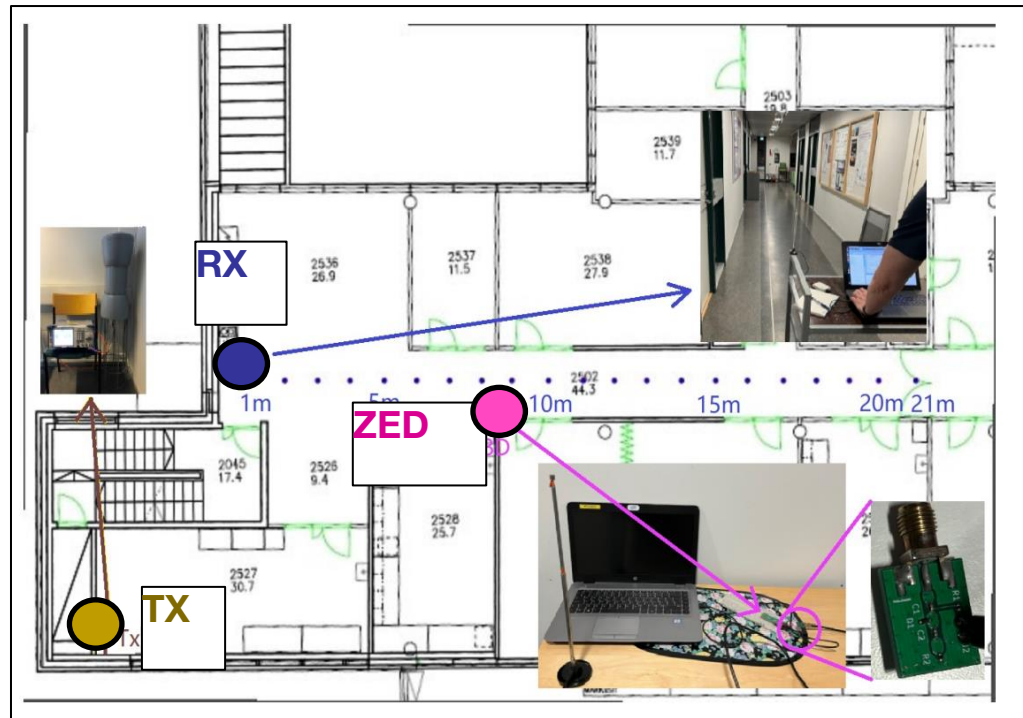


Fig. 4. Flow chart of the proposed backscatter receiver.



First Tests in Univ. Aalto, Espoo, Finland

- K. Ruttik, X. Wang, J. Liao, R. Jäntti and P. -H. Dinh-Thuy, "Ambient backscatter communications using LTE cell specific reference signals," 2022 IEEE 12th International Conference on RFID Technology and Applications (RFID-TA), Cagliari, Italy, 2022, pp. 67-70.
- Jingyi Liao, Xiyu Wang, Kalle Ruttik, Riku Jantti, Phan-Huy Dinh-Thuy "Ambient FSK Backscatter Communications using LTE Cell Specific Reference Signals," submitted to IEEE JRFID.

Conclusion and what's next

RIS and Ambient Backscatters are promising **Electromagnetic Field (EMF) aware** radio technologies for future mobile networks such as 5G+/6G.

RIS challenges, which investigate **with our partners**:

- Area of Influence (**Aroi**) and Bandwidth of Influence (**Bol**) characterization
- **Coexistence** between operators, RIS-aware network **planning** & engineering
- ETSI ISG RIS pre-standardisation

Ambient Backscattering challenges, which we investigate **with our partners**:

- Experiments on **advanced real-time receivers** (Univ. Aalto), Open Air Interface
- 3GPP Release 18 RAN SI on « Ambient IoT .
- More **use cases**

We need **more research & standardisation** on **EMF-aware radio technologies**

Thank you.

