INSTITUTE FOR SYSTEMS
AND COMPUTER ENGINEERING,
TECHNOLOGY AND SCIENCE

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17º Congresso Comité Português da URSI – Lisboa, Portugal

6G – The path towards a new paradigm of Communications and Sensing empowered by Reconfigurable Intelligent Surfaces

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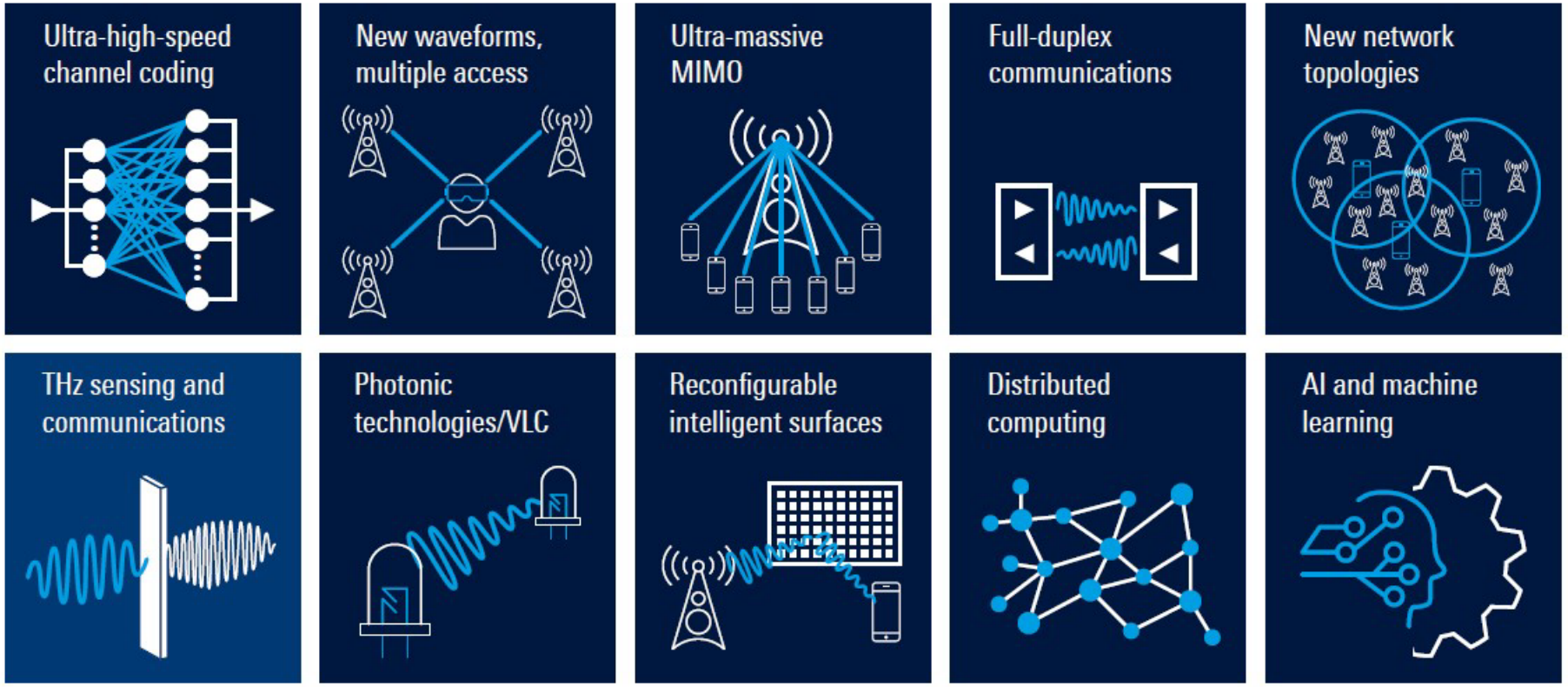
INESC TEC
24/Nov/2023

from knowledge generation to science-based innovation

Key technologies for 6G



(Source: Rohde & Schwarz)

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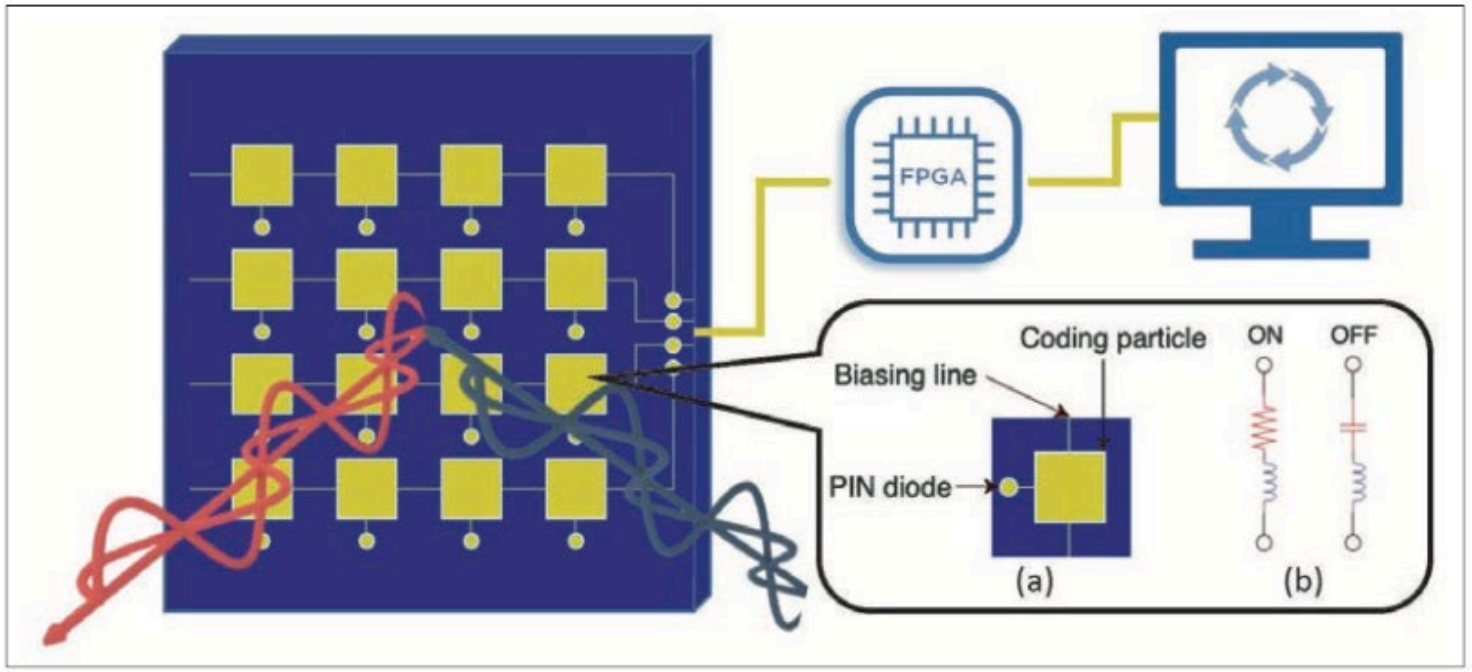
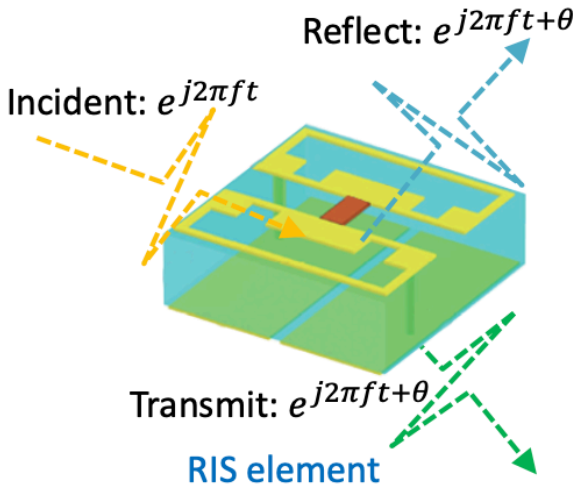
RIS - reconfigurable intelligent surface technology

Reconfigurable Intelligent Surface - RIS

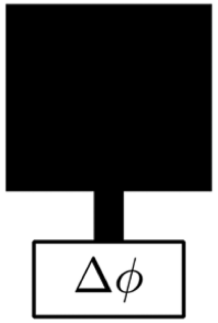




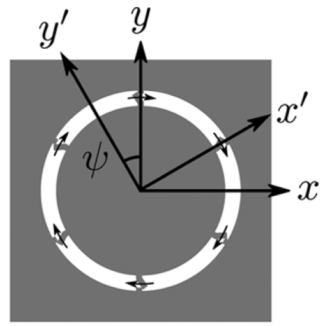
- Phase shift of the radiation is controlled by PIN or varactor diodes' bias voltages
- Programming of all diodes collectively realize different beamforming modes
- Cost and energy efficient: does not require a dedicated energy source for RF processing, decoding, encoding, or retransmission, and no added noise

RIS – unit cell fundamental approaches

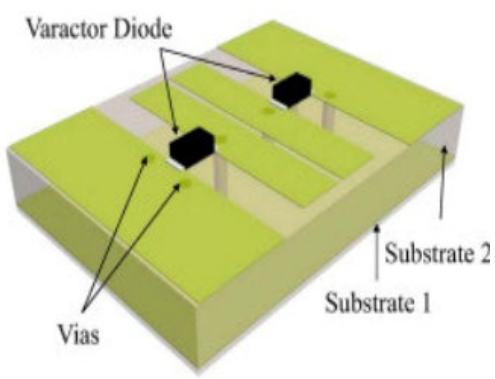
Tuneable resonator

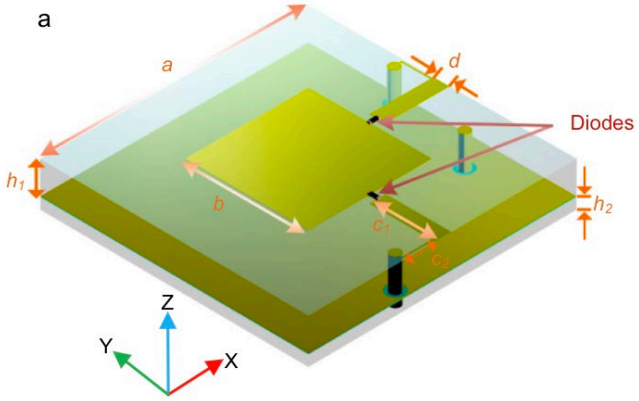


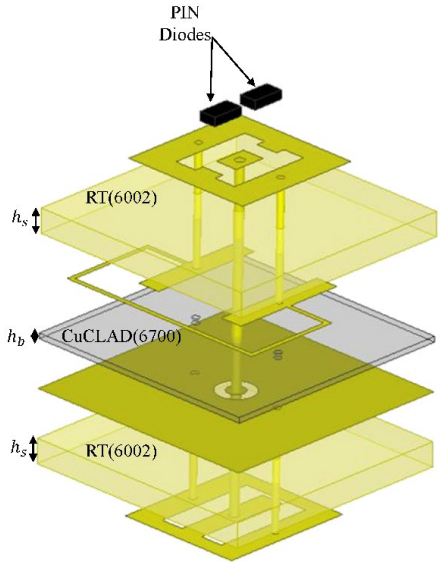
Guided wave



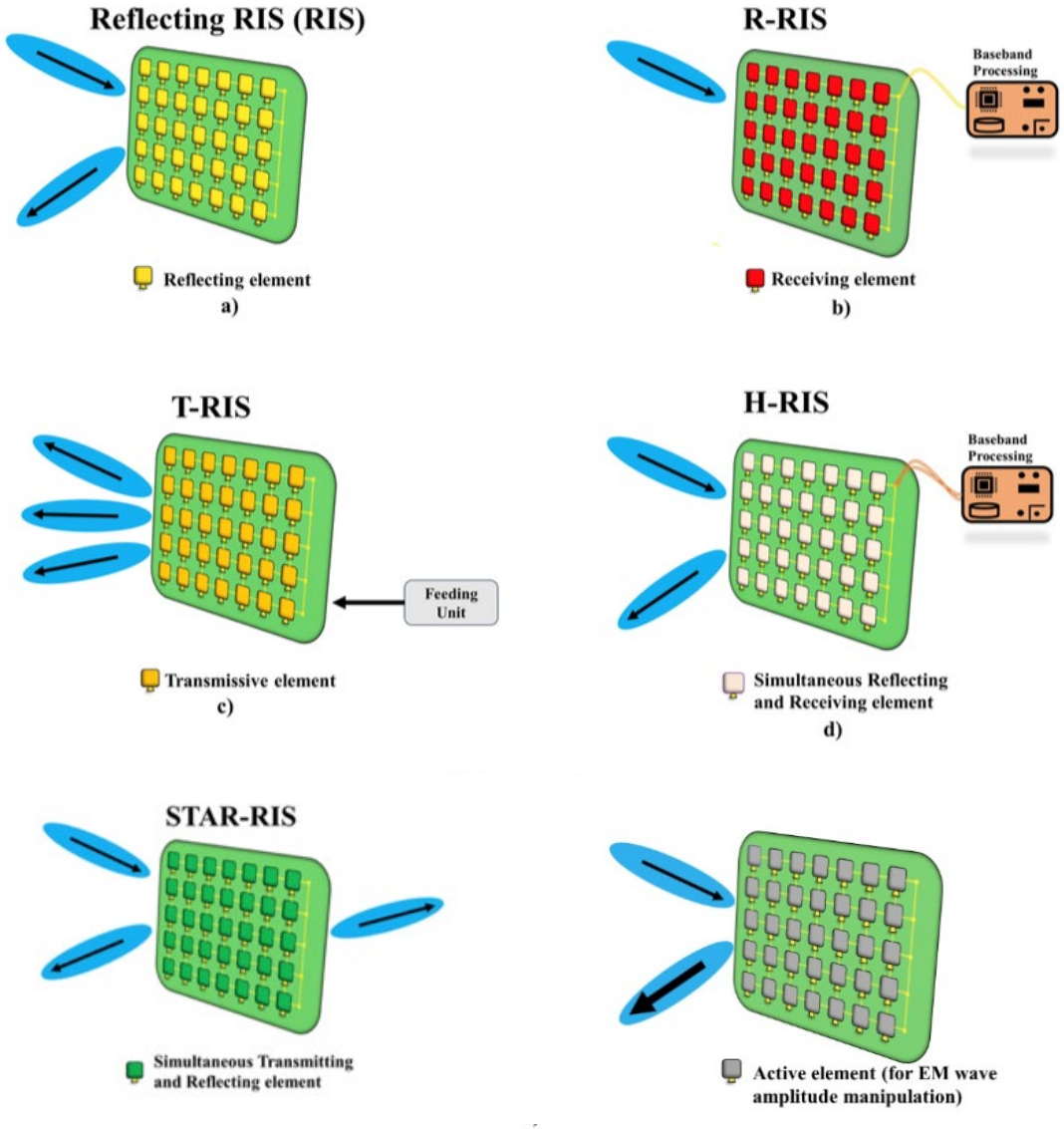
Element rotation

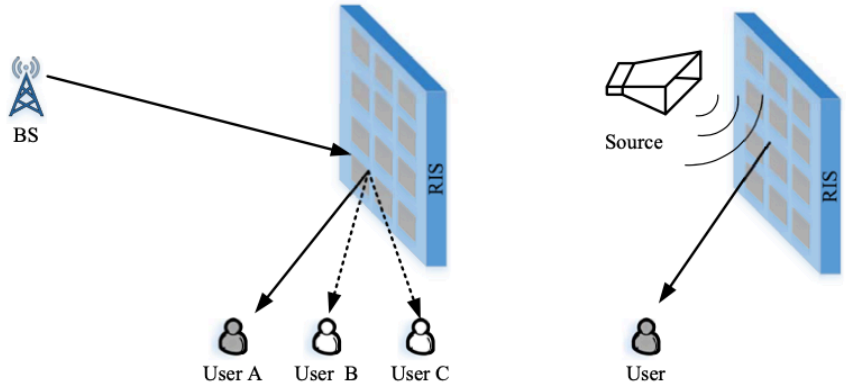






RIS – beam manipulation possibilities



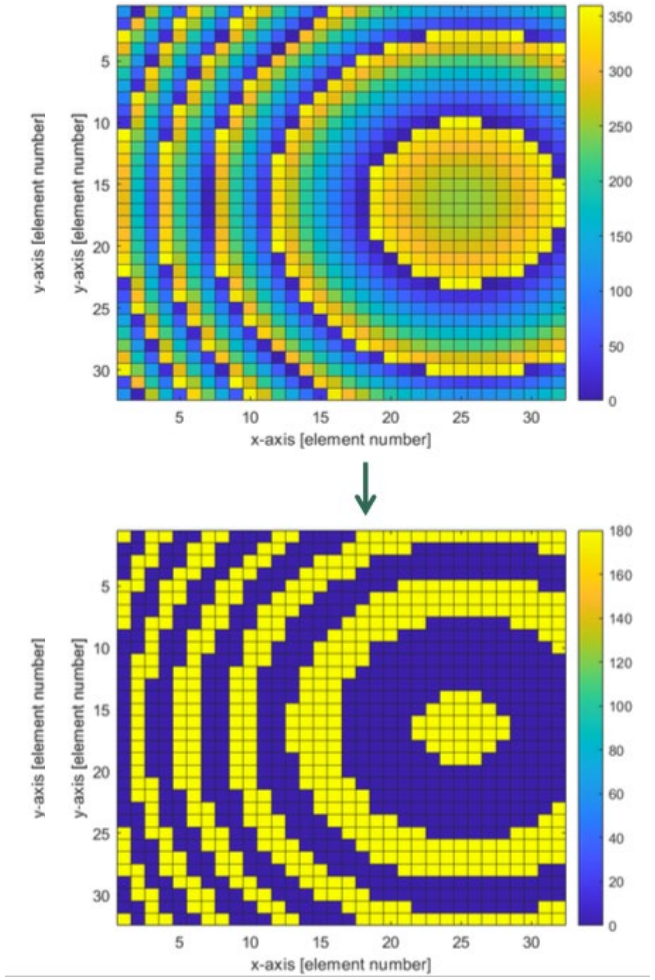


(a) Anomalous reflection (beam steering)

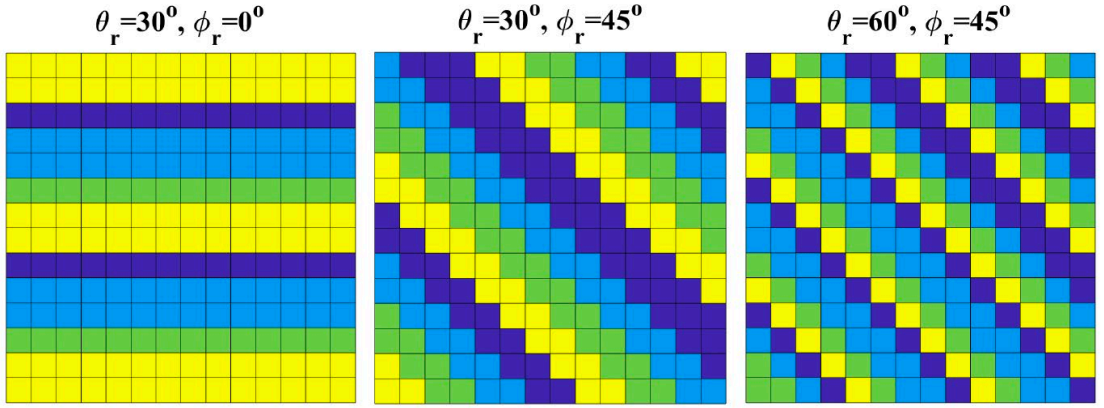
(b) Beamforming (beam focusing)

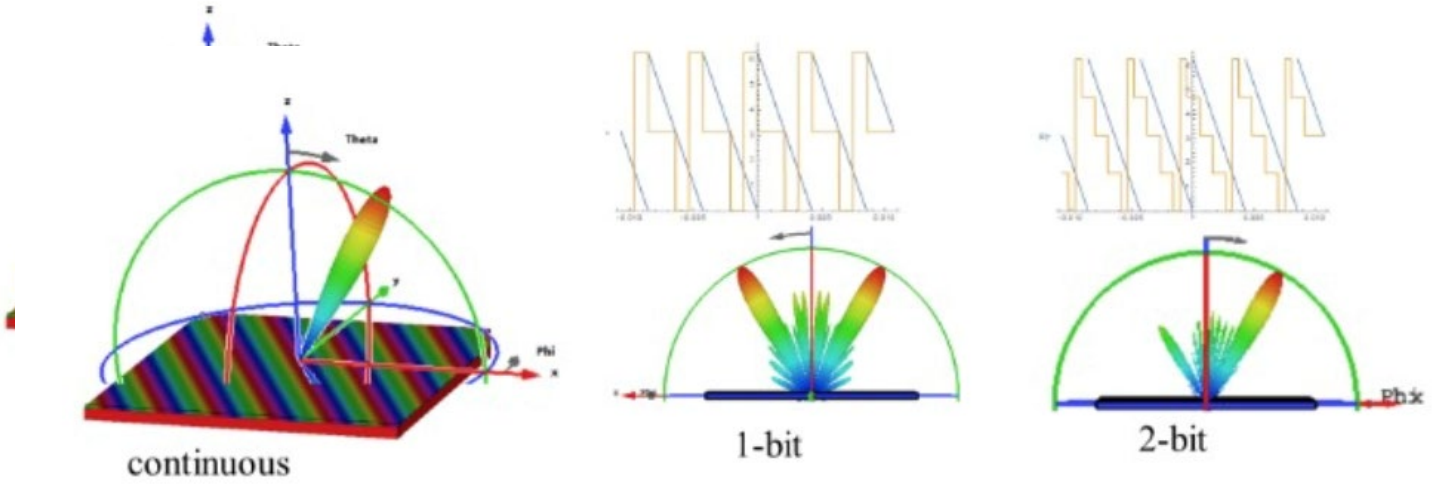
RIS - Continuous vs discrete tuneability

Near-field illumination



Far-field illumination





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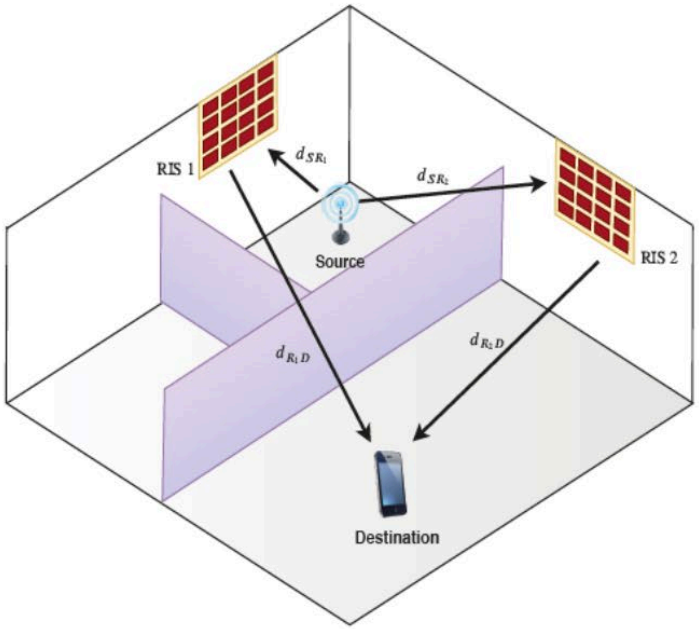
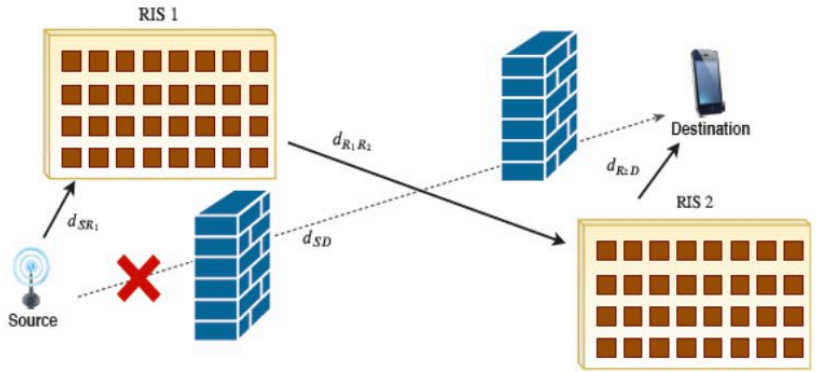
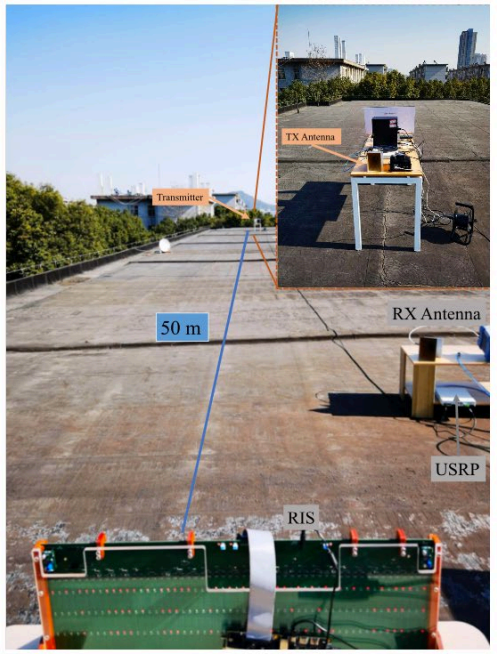
RIS applications

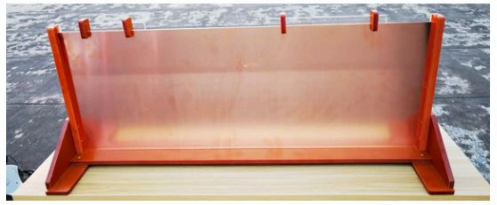
RIS – applications: Communications coverage extension



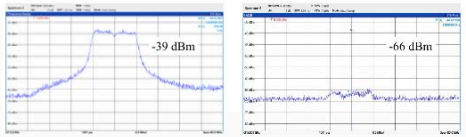




(a)



(b)

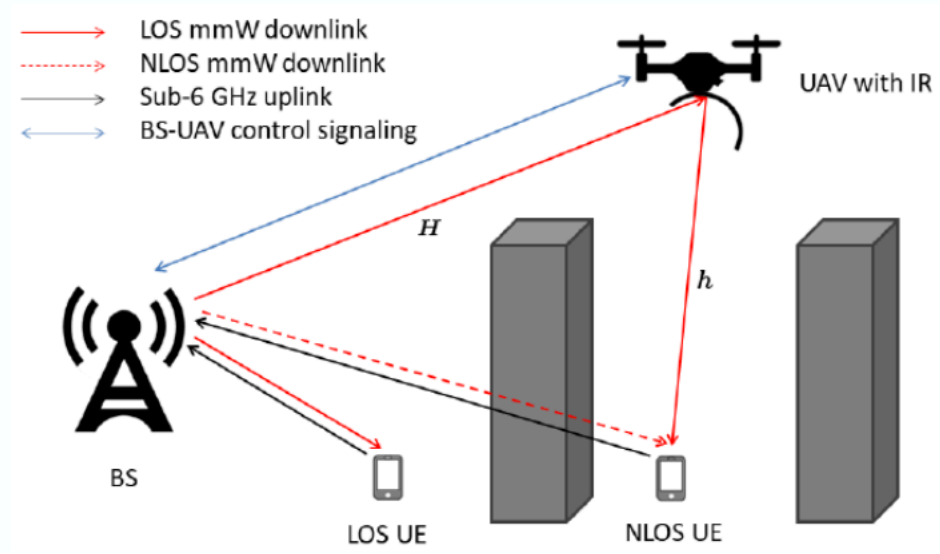


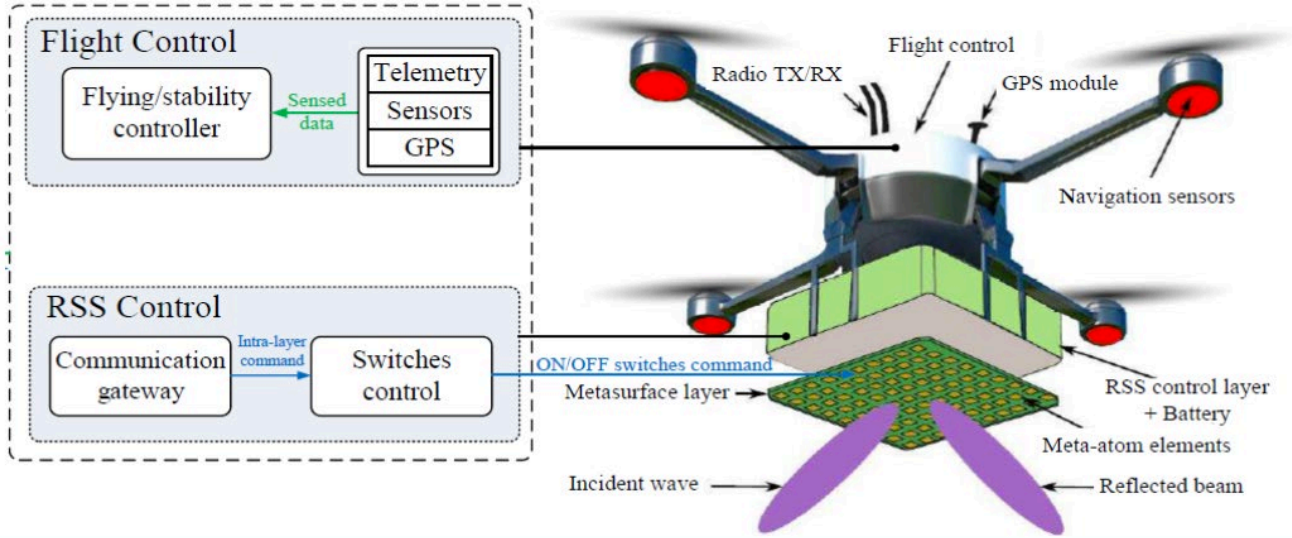
(c) (d)

Yildirim, A. Uyrus, E. Basar, '' Modeling and Analysis of Reconfigurable Intelligent Surfaces for Indoor and Outdoor Applications in Future Wireless Networks'', *arXiv:1912.07350*, Dec. 2019.

Pei, X., Yin, H., Tan, L., Cao, L., Li, Z., Wang, K., ... & Björnson, E. (2021). RIS-aided wireless communications: Prototyping, adaptive beamforming, and indoor/outdoor field trials. *IEEE Transactions on Communications*, *69*(12), 8627-8640.

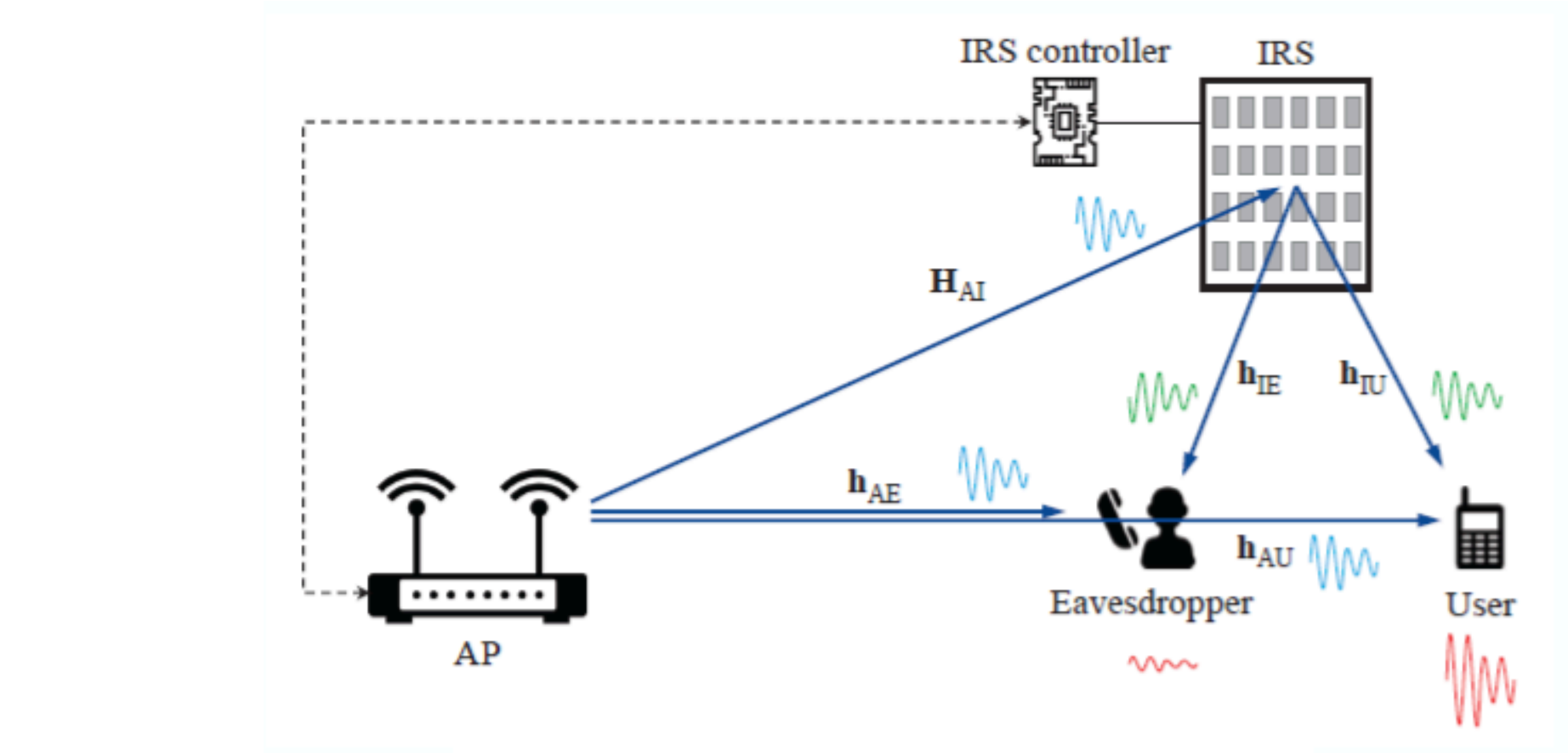
RIS – applications: UAV aided communications





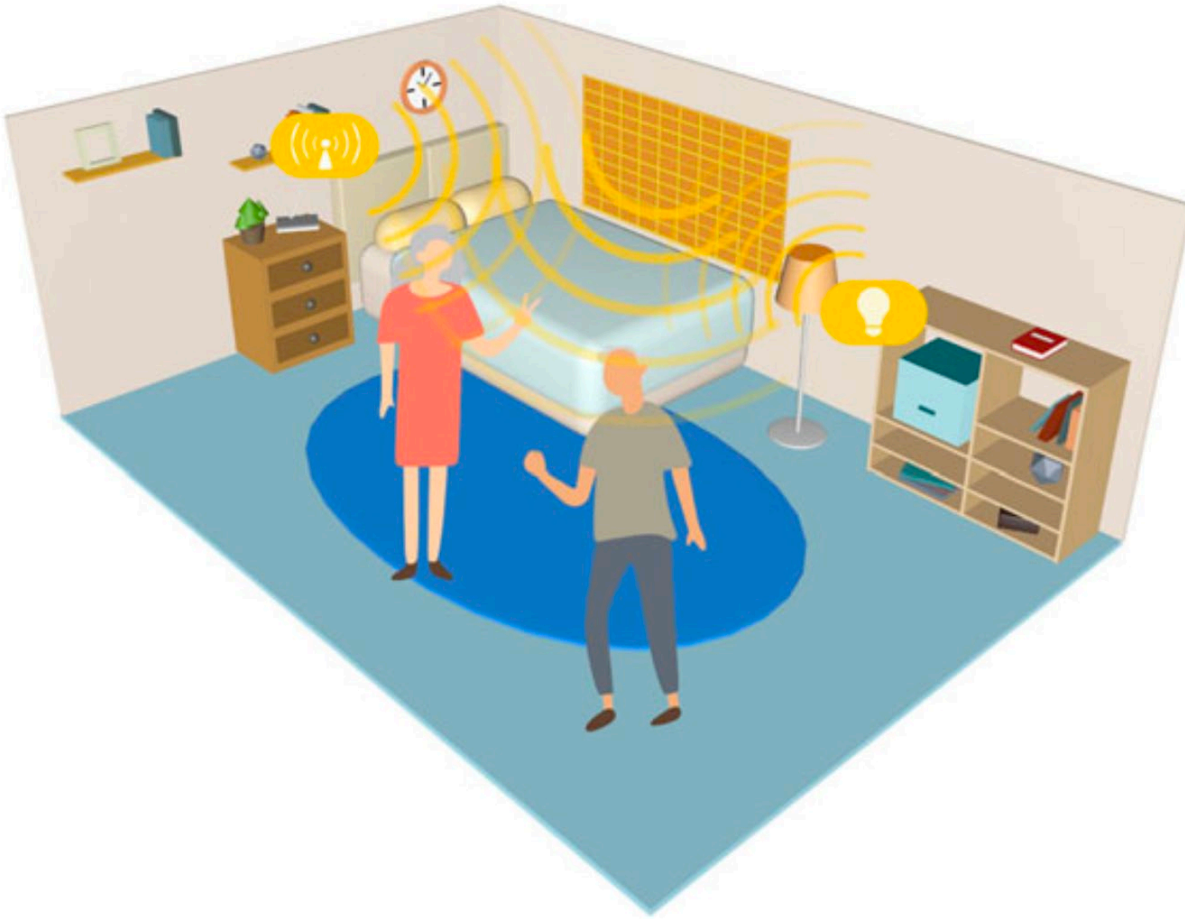
M. Bennis et al., ''Reflections in the Sky: Millimeter Wave Communication with UAV-Carried Intelligent Reflectors'', *arXiv:1908.03271*, Aug. 2019.
S. Alfattani et al., '' Aerial Platforms with Reconfigurable Smart Surfaces for 5G and Beyond'', *arXiv:2006.09328*, June 2020.

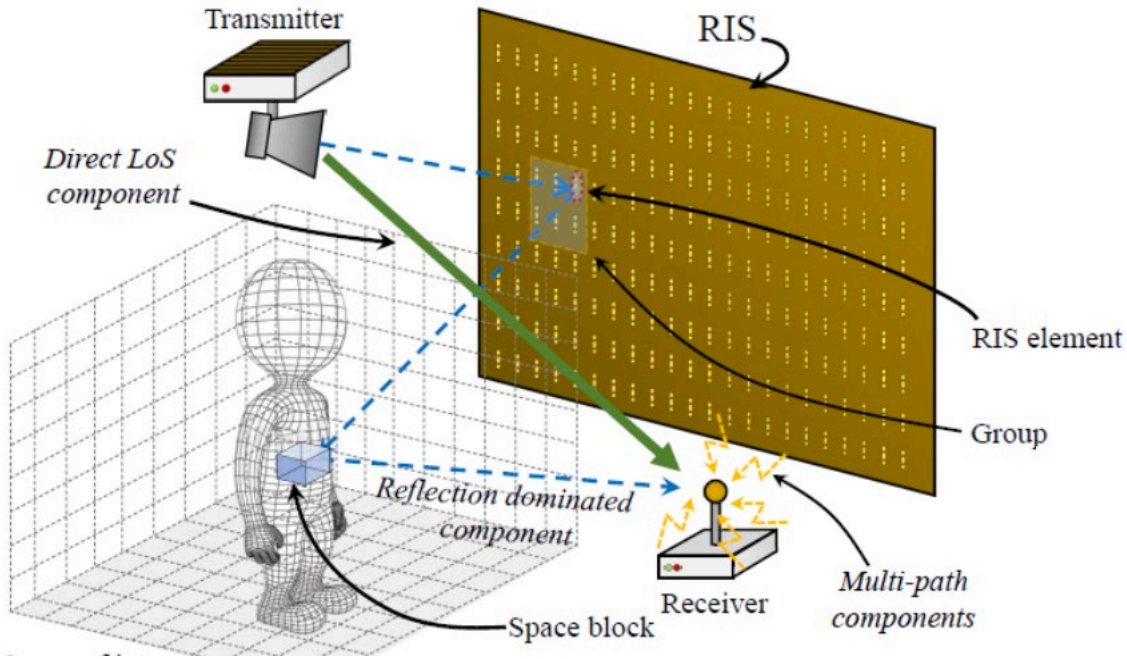
RIS – applications: Physical layer security



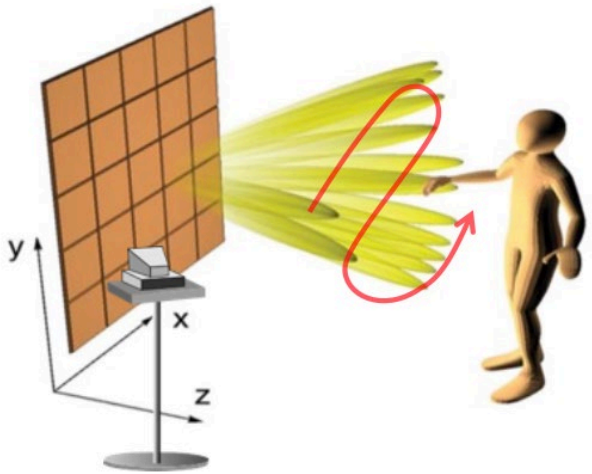
E Basar, Wireless Communications with Reconfigurable Intelligent Surfaces, September 2020.

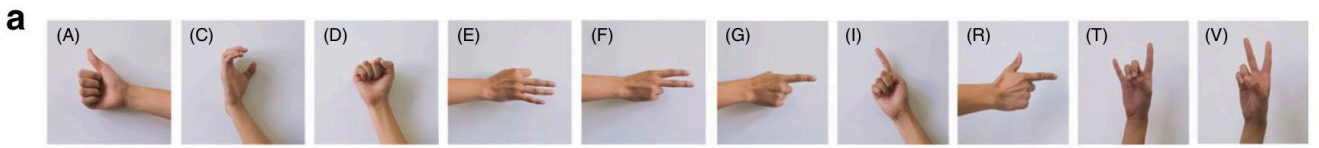
RIS – applications: sensing

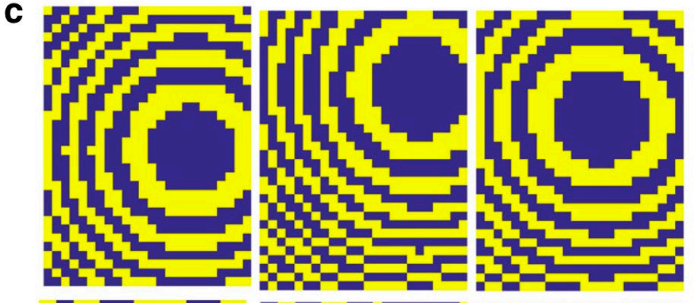




RIS – applications: sensing



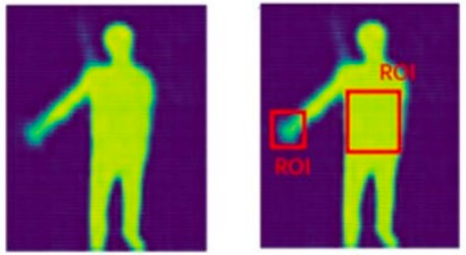


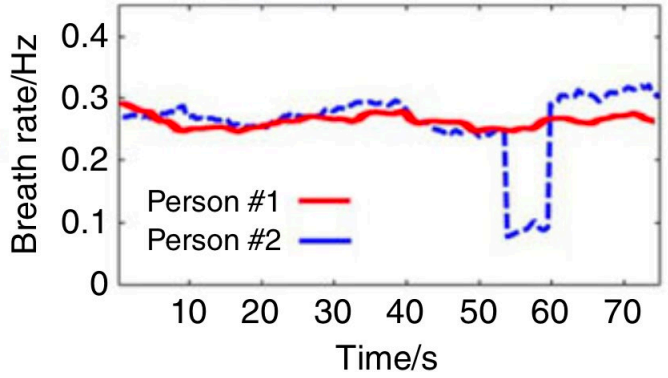


Identification of Hand-signs

Posture recognition

Imaging and ROI extraction





Identification of breathing

Li, L., Shuang, Y., Ma, Q., Li, H., Zhao, H., Wei, M., ... & Cui, T. J. (2019). Intelligent metasurface imager and recognizer. Light: science & applications, 8(1), 97.

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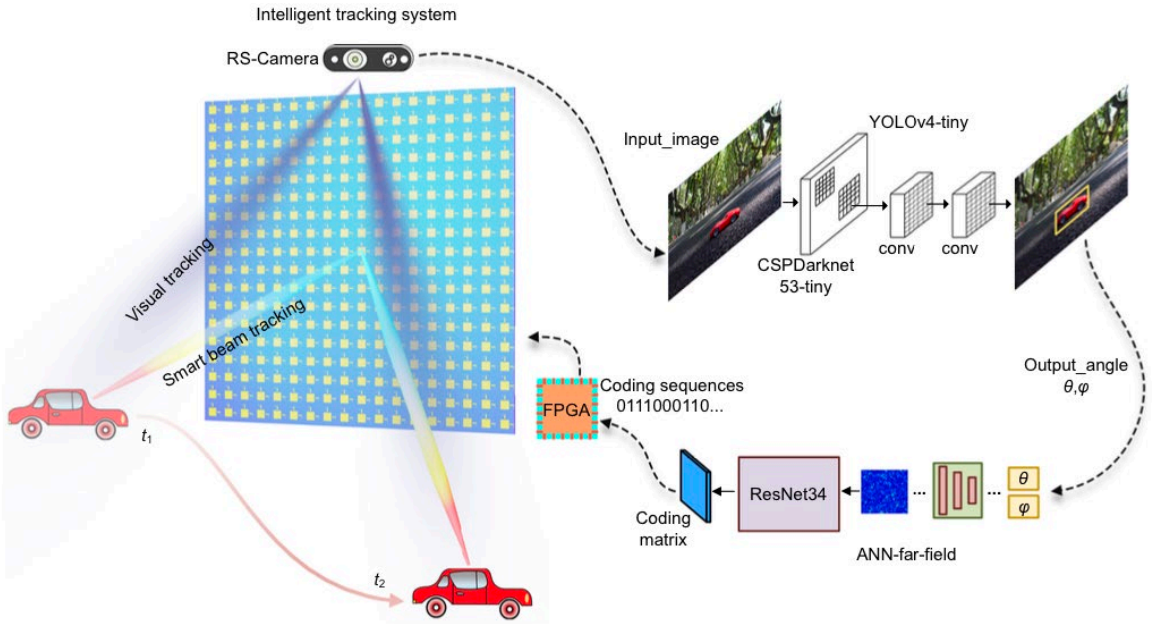
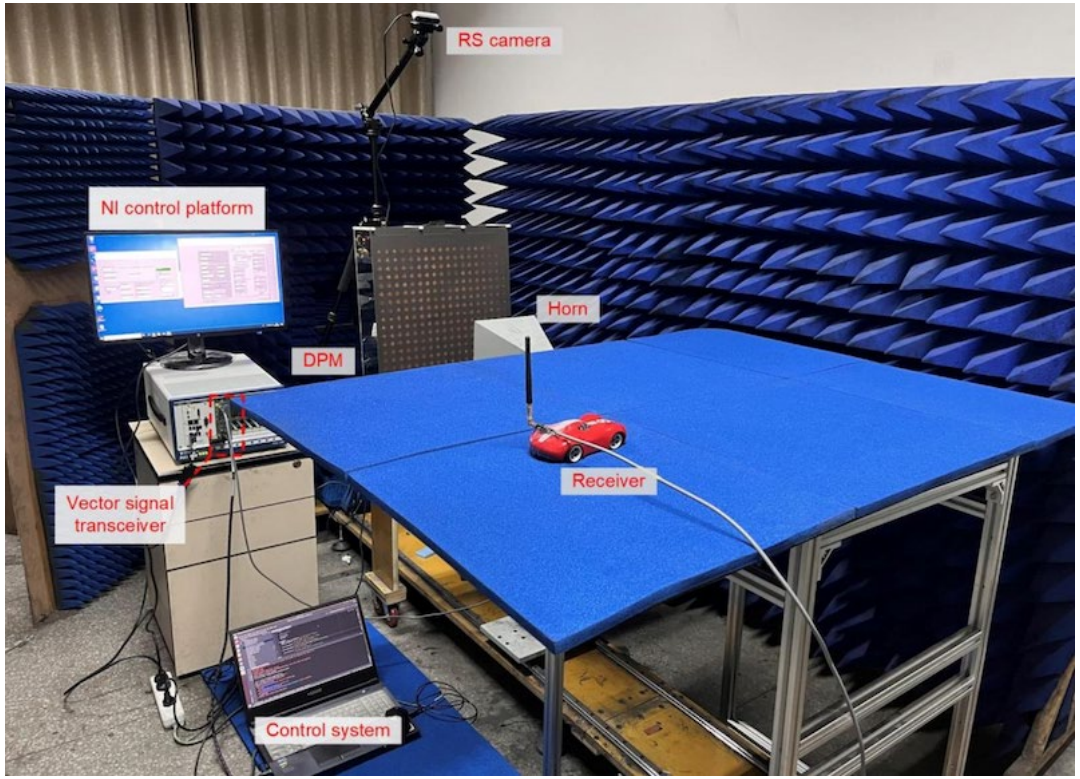
Vision-aided RIS

Vision-aided RIS



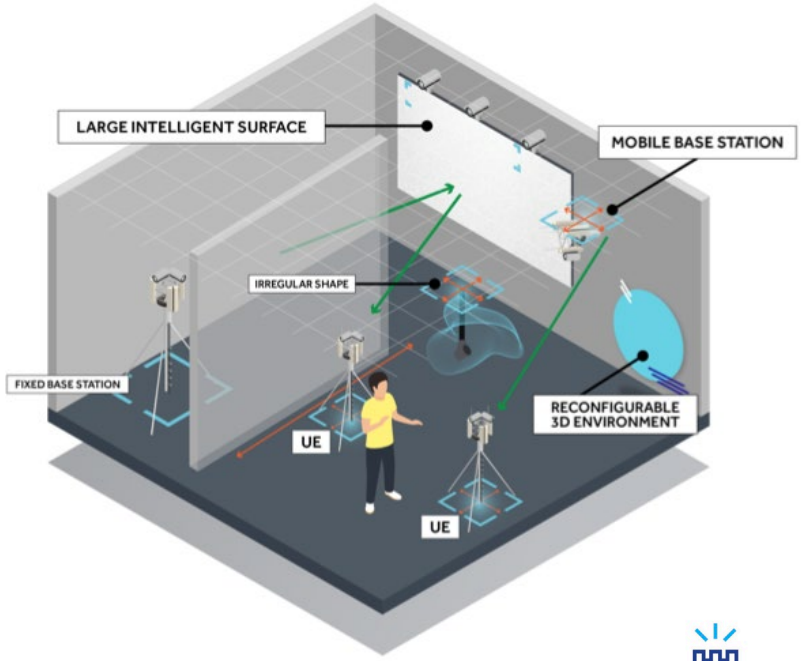


CONVERGE PROJECT (2023-2026)

CONVERGE
view-to-communicate and communicate-to-view

Telecommunications and Computer Vision Convergence Tools for Research Infrastructures

Goal: develop innovative toolset combining radio and vision-based communications and sensing technologies under motto “view-to-communicate & communicate-to-view” (Future integration in European SLICES-RI)



8 M€
Funding

Coordinator:
INESC TEC

3 Research Infrastructures (Porto, Oulu, Sophia-Antipolis)

5 Vertical markets: Telecommunications, Automotive, Health, Media, Industry

https://converge-project.eu/

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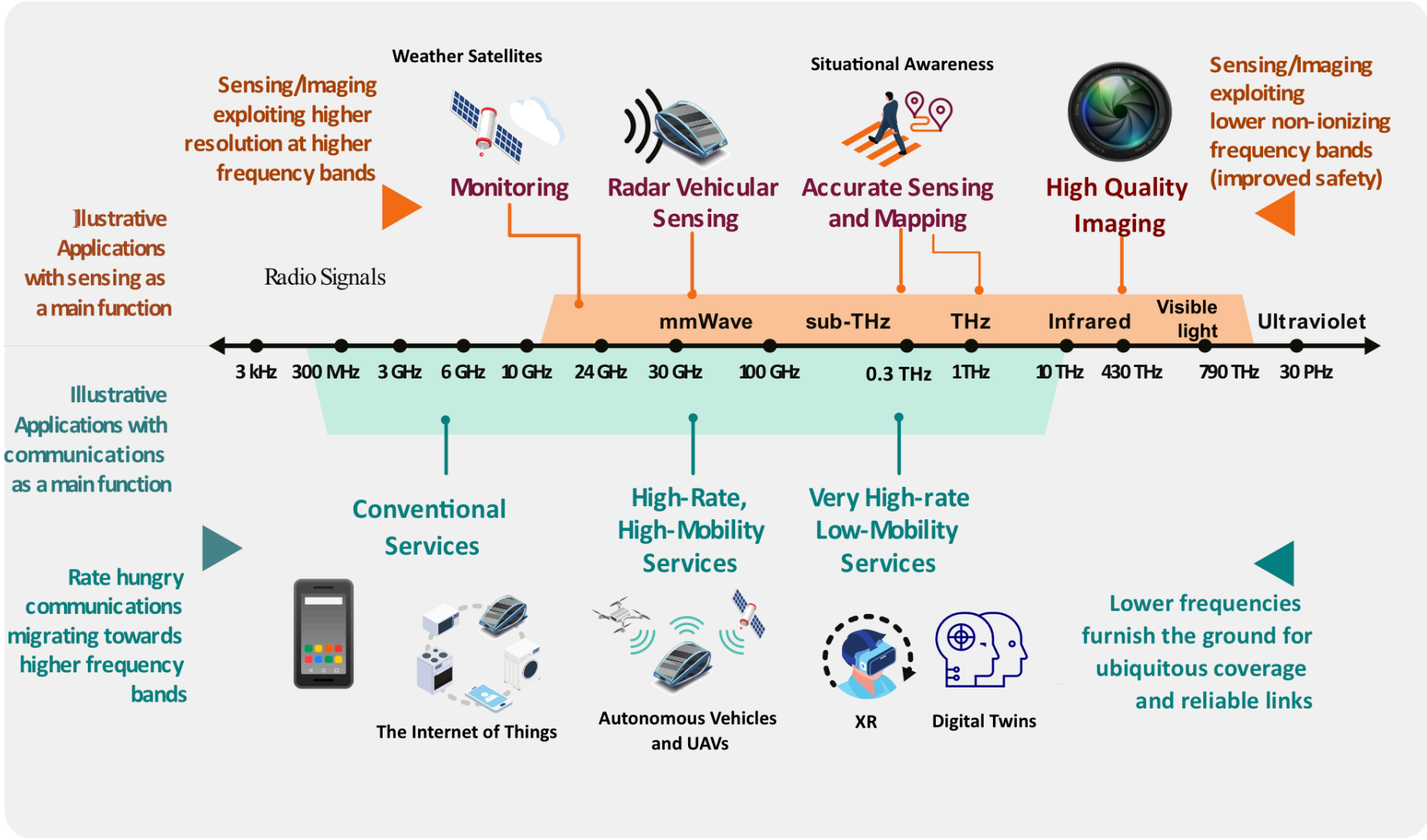
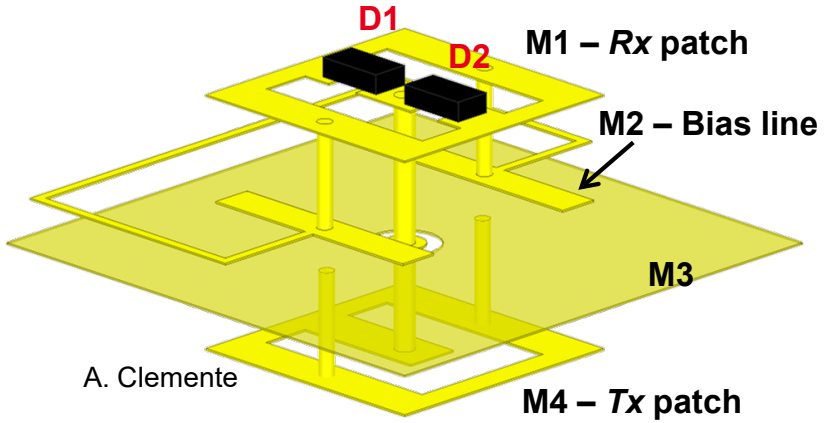
RIS @ sub-THz

Need for sub-THz RIS



Chaccour, C., Soorki, M. N., Saad, W., Bennis, M., Popovski, P., & Debbah, M. (2022). Seven defining features of terahertz (THz) wireless systems: A fellowship of communication and sensing. *IEEE Communications Surveys & Tutorials*, *24*(2), 967-993.

How to control a sub-THz RIS?

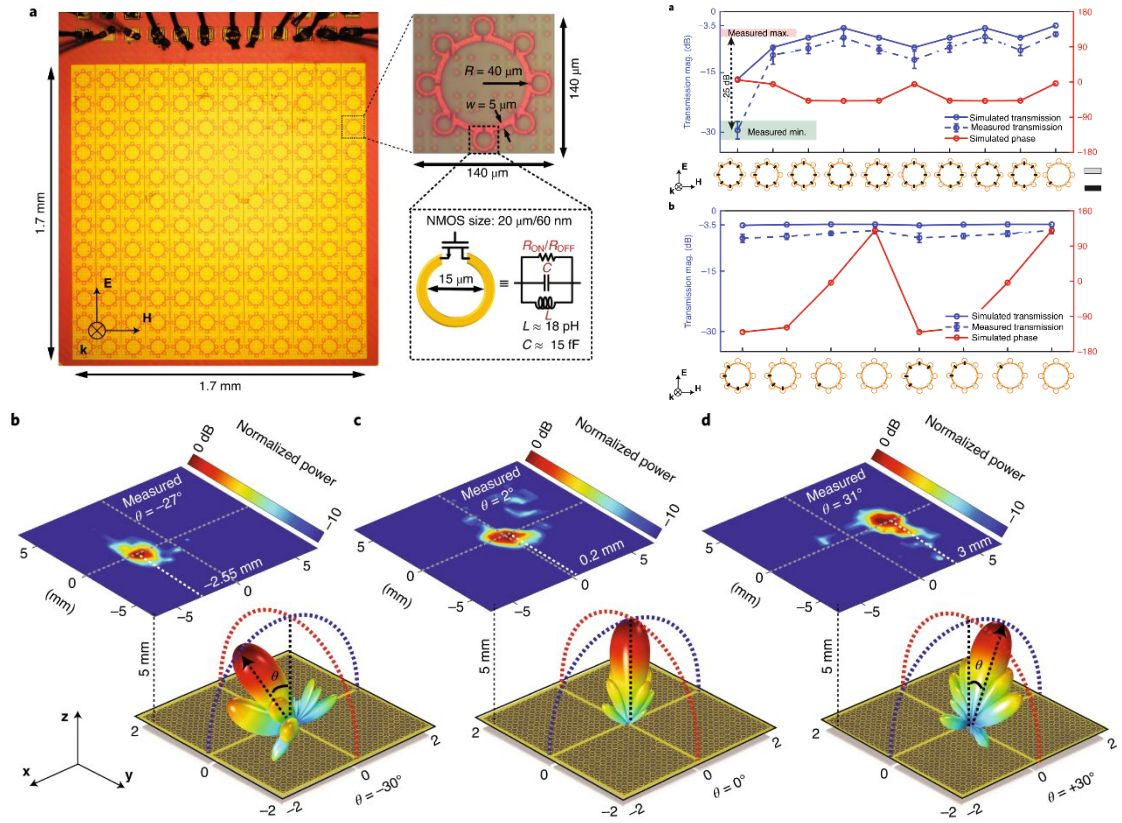


Pin diode is widely used in RIS, but:

- it is too big !
- cannot go up in freq., large capacitance
- it consumes a lot of power (10mA.1V 10mW)
- it is not integrable! (i.e. CMOS compatible)

- Advanced integration is necessary

Complementary metal–oxide–semiconductor (CMOS)-based chip control



https://doi.org/10.1038/s41928-020-00497-2

TERRAMETA PROJECT (2023-2026)

Reconfigurable Metasurfaces for Ultra-high-rate Wireless Communications

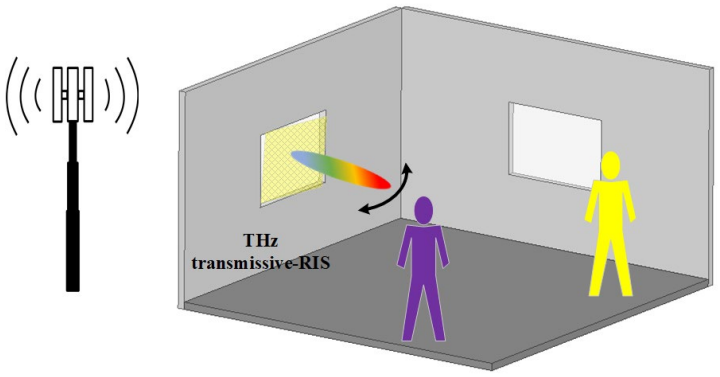
Goal: investigate ground-breaking technologies for 6G leveraging on THz Reconfigurable Intelligent Surfaces (RISs)

- Reconfigurable hardware: RF-SOI CMOS, SiGe BiCMOS, 2D-material and microfluidics based switches at 140 GHz
- Reflective and transmissive RIS architectures with sensing capability at 140 GHz and 300 GHz
- Signal processing algorithms for channel modelling and estimation, beam management, ultra-massive MIMO and localisation and sensing.

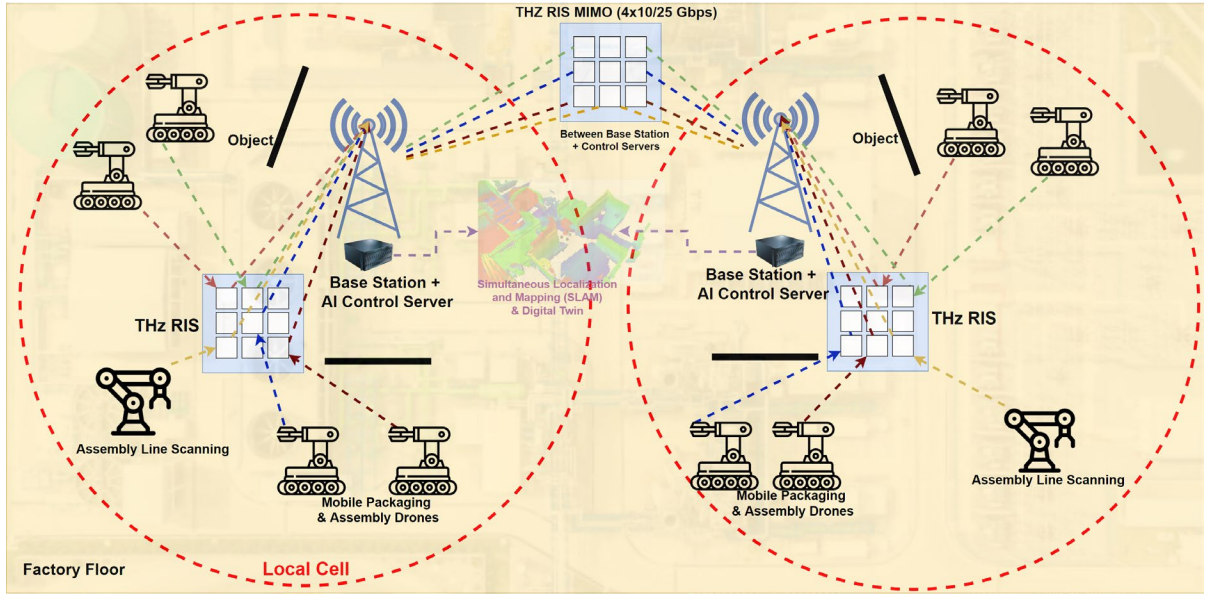
6 M€

Funding

Coordinator:
INESC TEC



Telecom scenario



Factory Floor - Industrial Edge environment

https://terrameta-project.eu/

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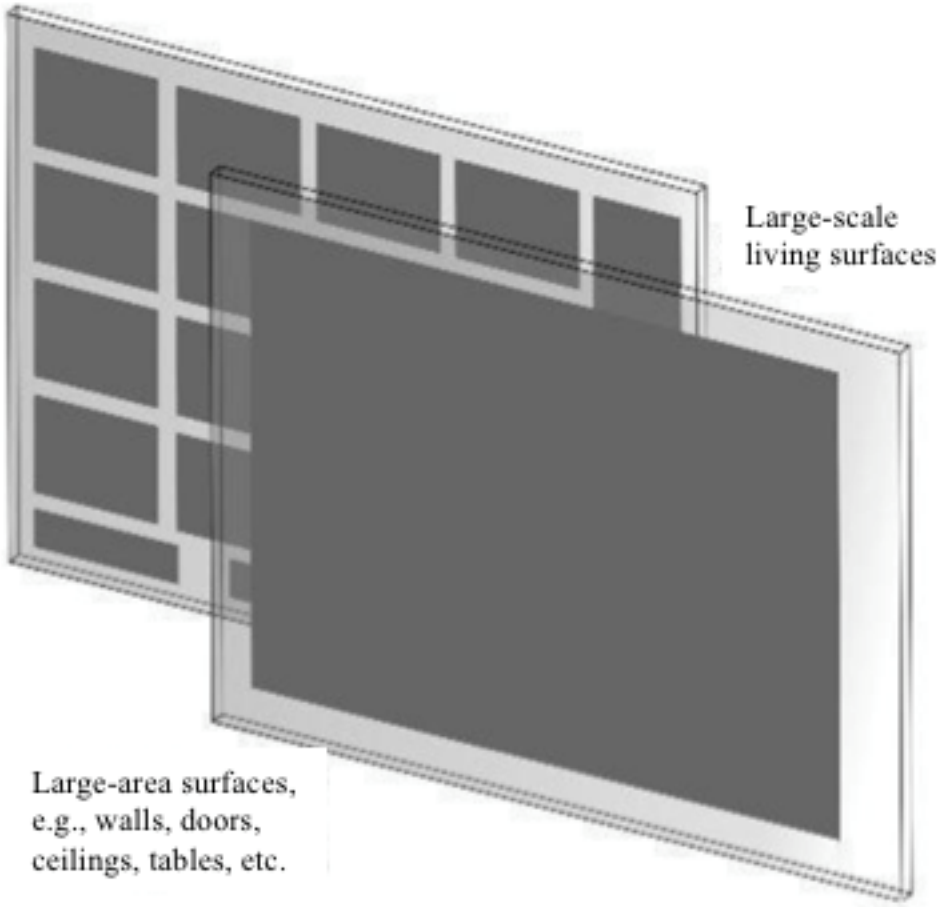
Towards fully printed RIS – large scale deployment and IoT

Large-scale reconfigurable surfaces

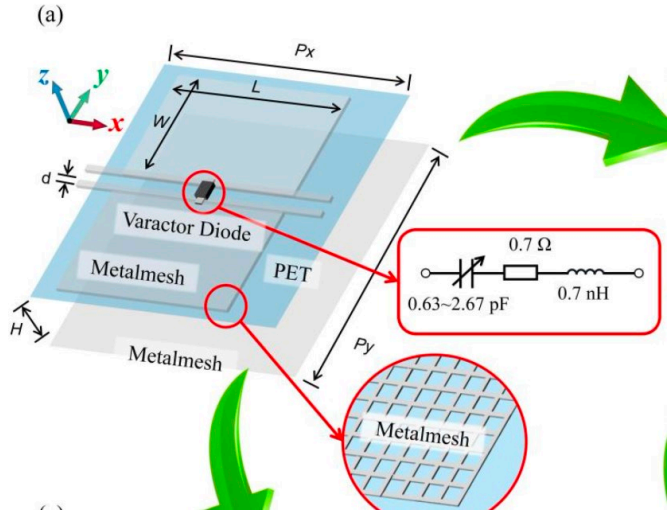
Living surface: a surface that is empowered by several key integrated functionalities including:

- wireless connectivity
- sensorial
- actuatorial
- processing capabilities

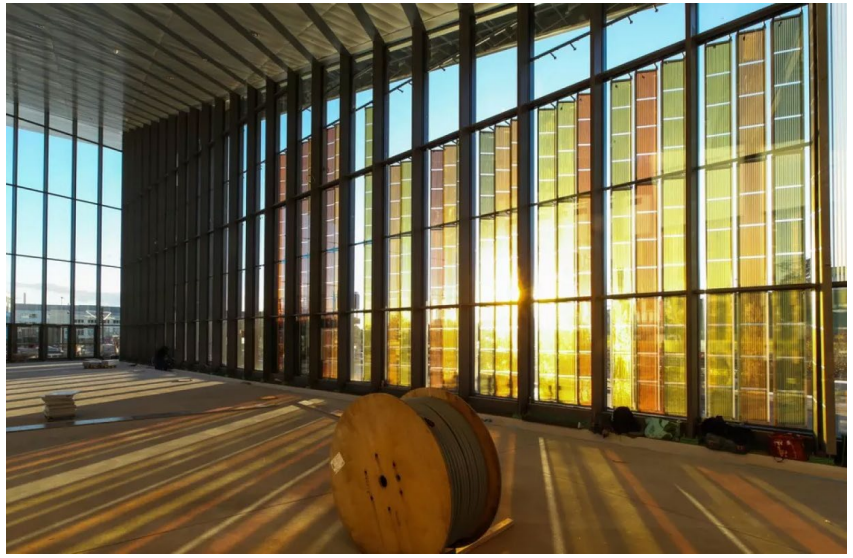


Transparent RIS?

- Investigation of environmentally friendly **substrates** and **conductors** is required for sustainable large-scale deployment
- Investigation of **transparency** viability by exploring different thickness of printed conductor metal mesh
- Investigation of **printed reconfigurability** technologies: e.g. 2D-materials



Building Windows



Building Facades

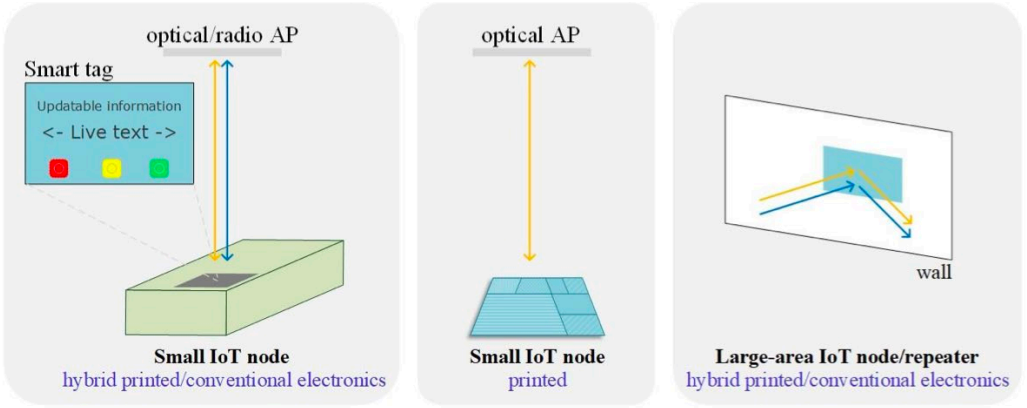
Building Roofs

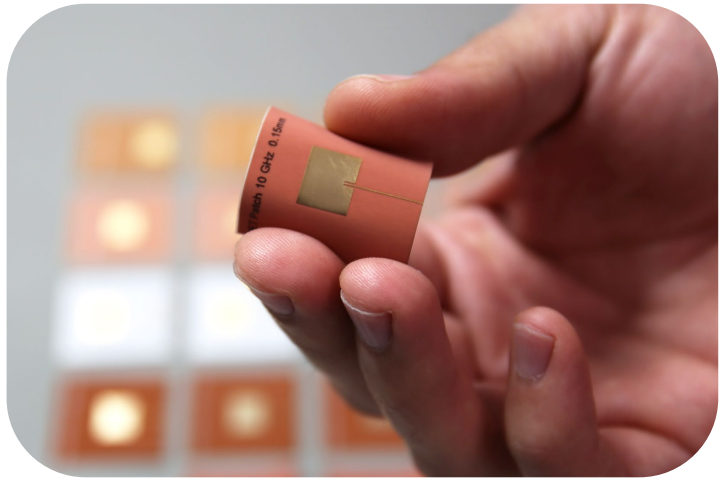
SUPERIOT PROJECT (2023-2026)

Truly Sustainable Printed Electronics-based IoT Combining Optical and Radio Wireless Technologies

Goal: developing a truly sustainable IoT system based on the use of optical and radio communications, and the exploitation of printed electronics technology.

- Energy-autonomous nodes
- Reconfigurable networks
- Use of printed electronics
- Dual-mode energy harvesting and positioning





5 M€

Funding

Coordinator:
Univ. Oulu

https://superiot.eu/

Thank you for your attention!

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