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RÉSEAUX, INFORMATION, SOCIÉTÉ NUMÉRIQUE

Demi-journée de restitution des projets
Sophia Antipolis, 7 Mars 2022

I-LL-WIN

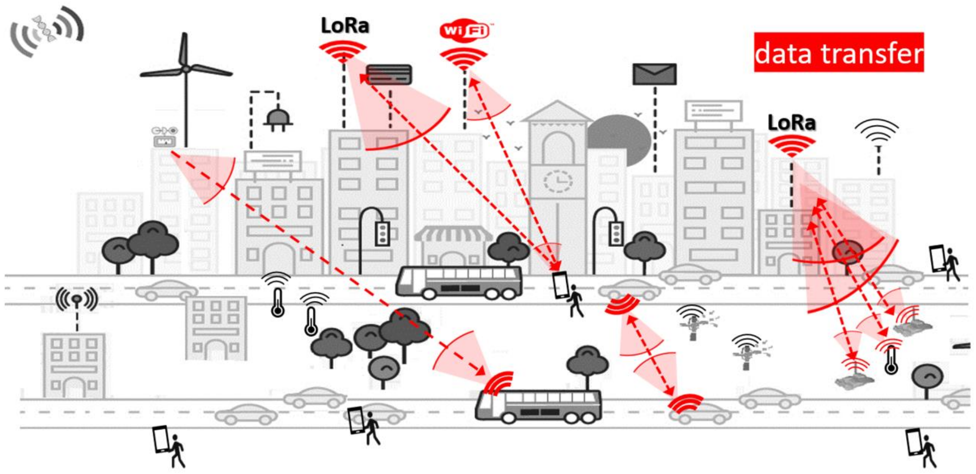
Improved LocaLization in Wireless IoT Networks

Leonardo Lizzi

Outline

- Context and objectives
- Issues and updated work plan
- Project research activities
- Project outcomes
- Conclusions and future work

Context



LOCATION DATA

Low Power Wide Area Networks (LPWAN):

- Long communication range (exceeding few kilometers) and low data rate (up to few kbps)
- Low cost, low power consumption and low bandwidth, make localization in these networks particularly challenging.

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The objective is the development of a localization system in LPWAN IoT networks.

Improving the location accuracy at 3 different levels:

- **Physical level**: designing of miniature integrated reconfigurable antenna solutions (LEAT).
- **Network level**: optimizing the IoT network configuration to allow the extraction of the best features for location estimation (INRIA).
- **Data level**: developing a suitable machine learning algorithm based on the extracted features and additional environment data.

LEAT
LABORATOIRE D'ELECTRONIQUE ANTENNES ET TELECOMMUNICATIONS

Inria
inventeurs du monde numérique

FBK
FONDAZIONE BRUNO KESSLER

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Issues:

- **COVID-19 Pandemic**: impossibility to attract/hire students, impossibility to access to the lab and to the equipment, impossibility to buy components, etc.
- **Resignation of FBK contact person**: impossibility to develop the machine learning algorithm.

2 out of 5 internships +1 PFE

Updated work plan:

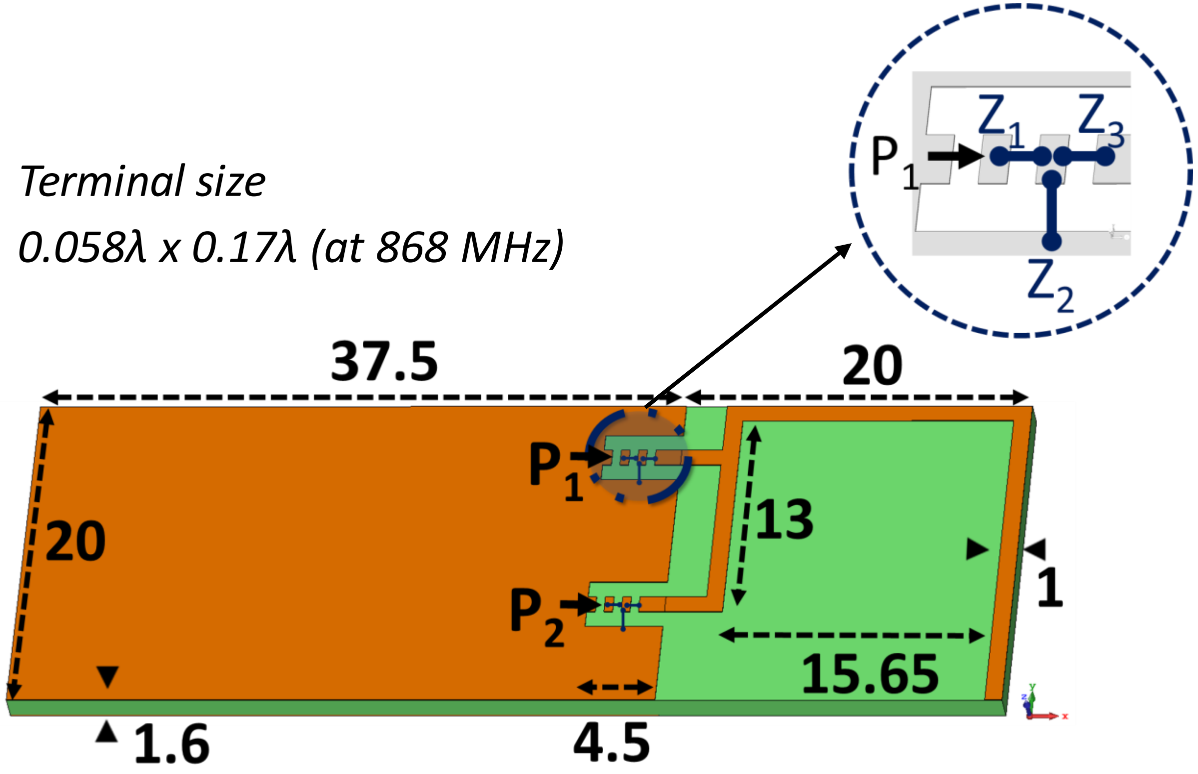
- **Physical level**: multiple antenna solutions (1 PhD student + 2 interns)
- **Network level**: experimental study on a time-of-flight based localization technique (1 PFE student)
- **Data level**: agreement with a new group at FBK working on indoor localization. Possibility to test the antennas developed at LEAT in a real scenario and comparison with the localization approaches developed at INRIA

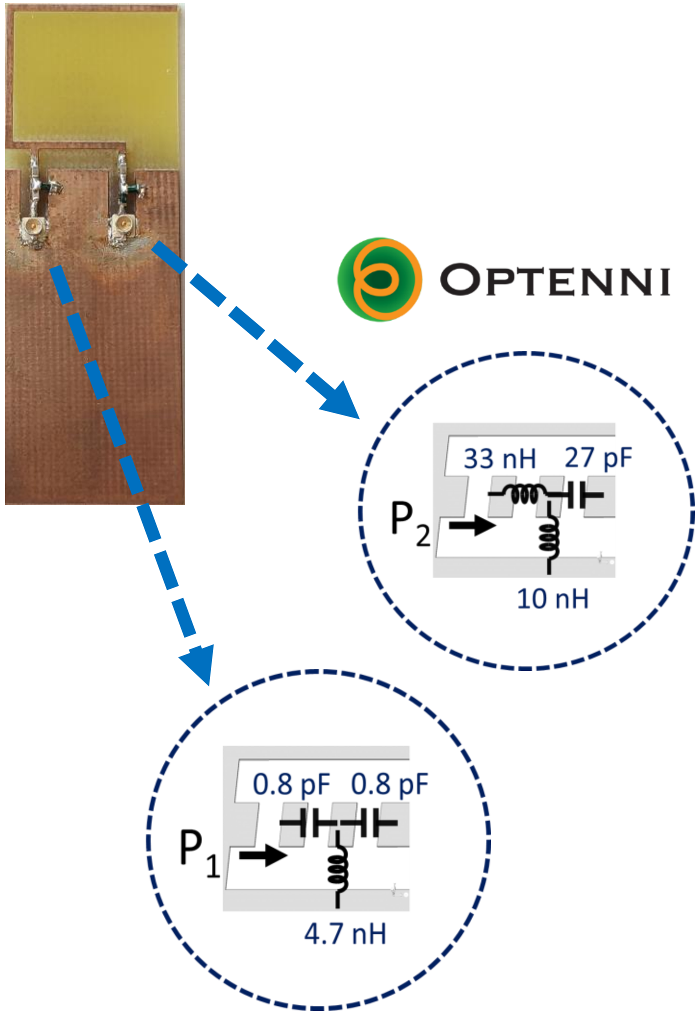
LoRa-GPS Integrated Antenna

- Multi-access single structure antenna with matching network
- To avoid switches in multi-standard IoT terminals
- Space saving, cost saving, more efficient solution

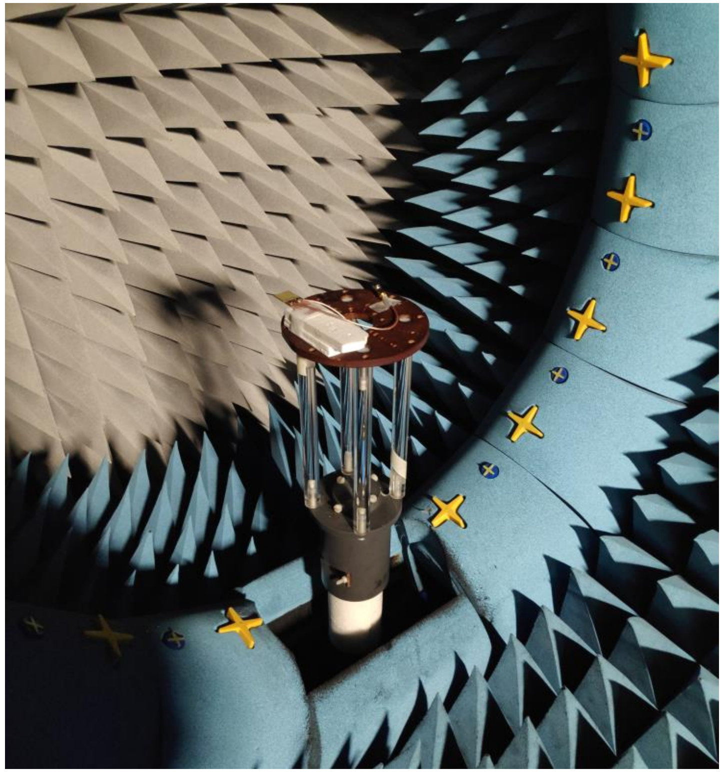
Terminal size

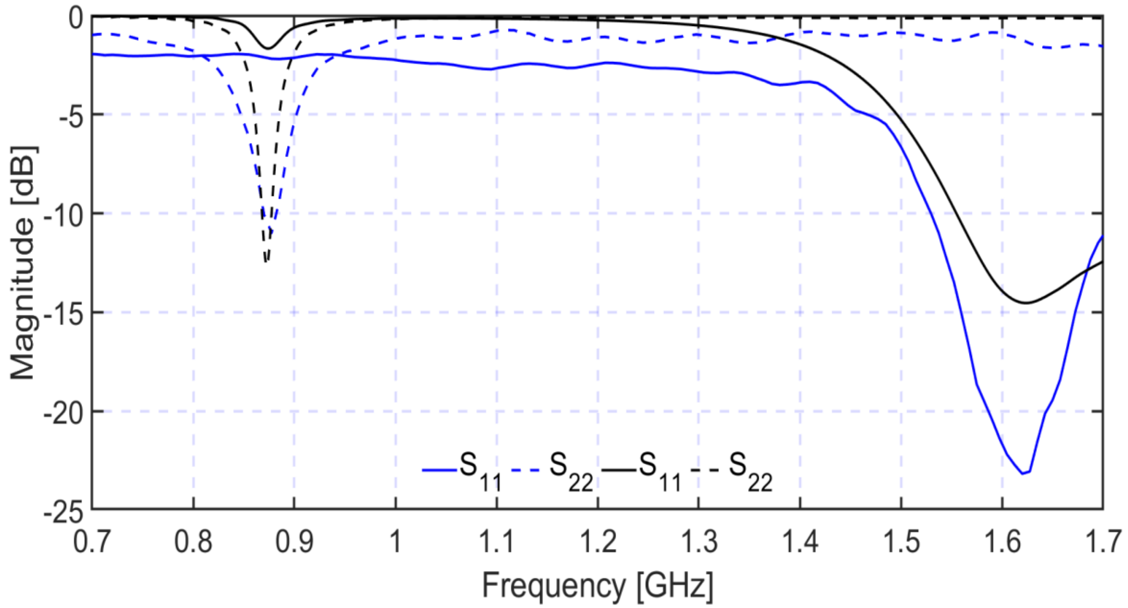
0.058λ x 0.17λ (at 868 MHz)





LoRa-GPS Integrated Antenna





Miniature CP Antenna

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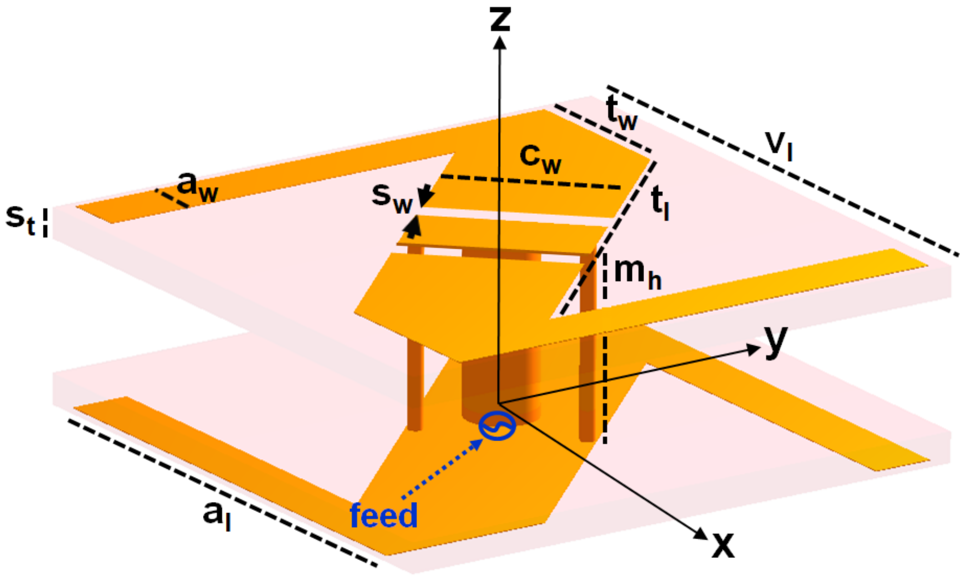
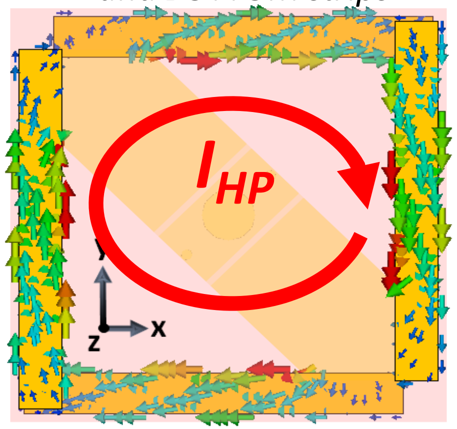
- Integration of an Alford loop and a wire-patch antennas
- To increase robustness to the multipath fading
- Miniature and low-cost solution

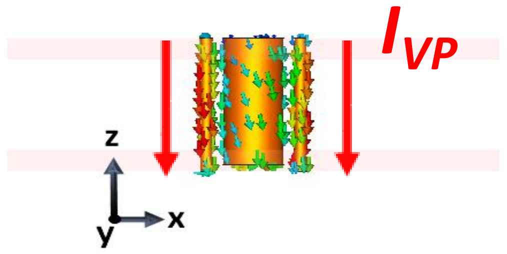


Total height: $0.081\lambda_0$
length: $0.252\lambda_0$
at 2.44 GHz

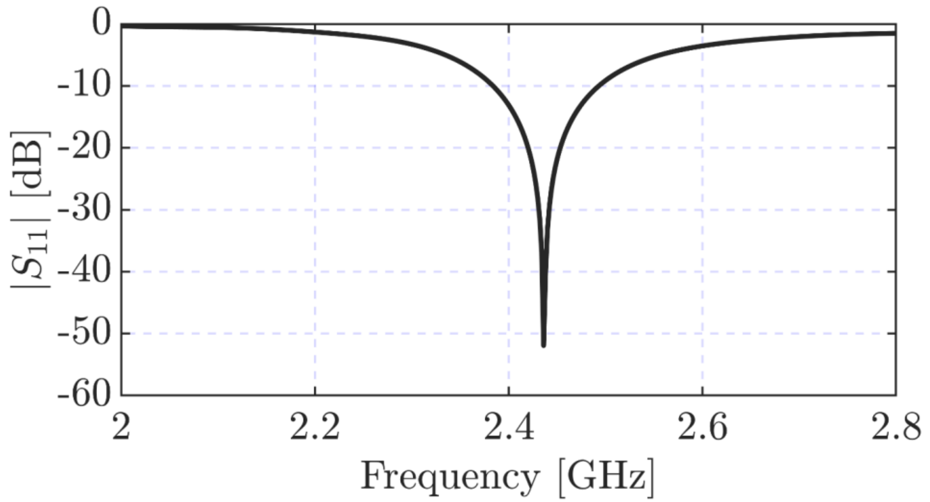
Branches of the TOP and BOTTOM strips

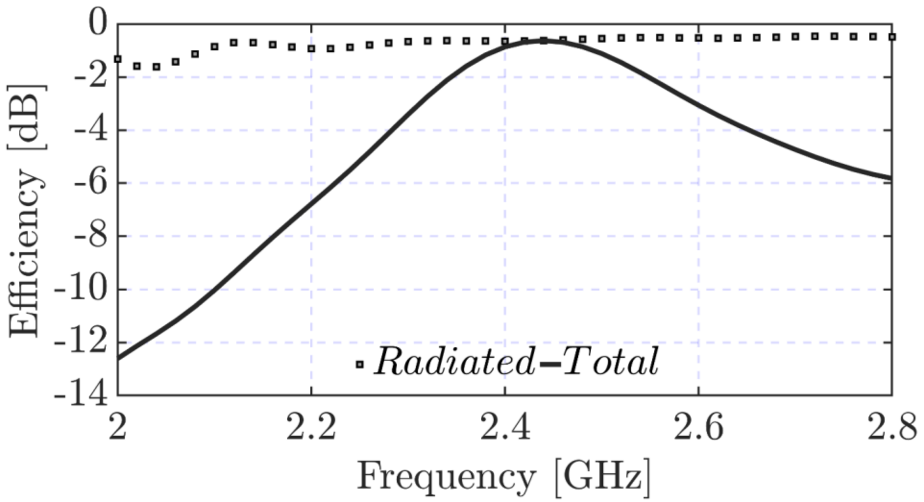


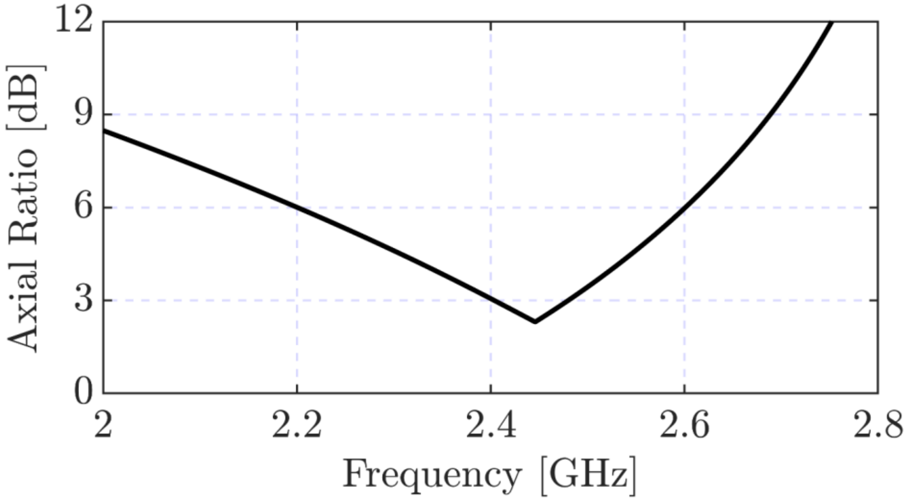
Surface current distribution at 2.44 GHz on the wire-patch radiator

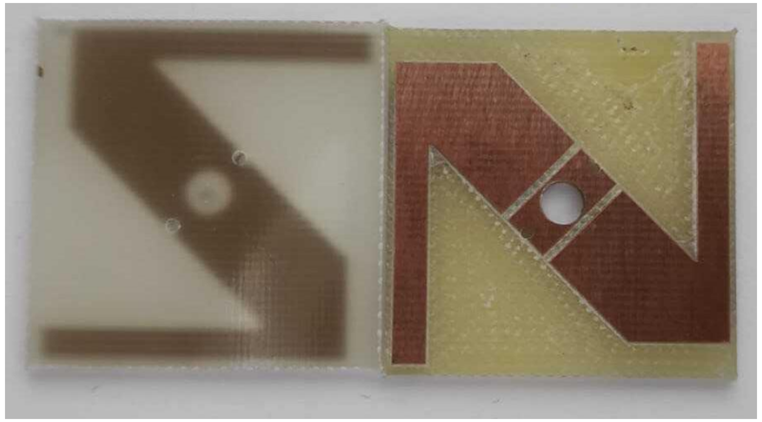


Miniature CP Antenna







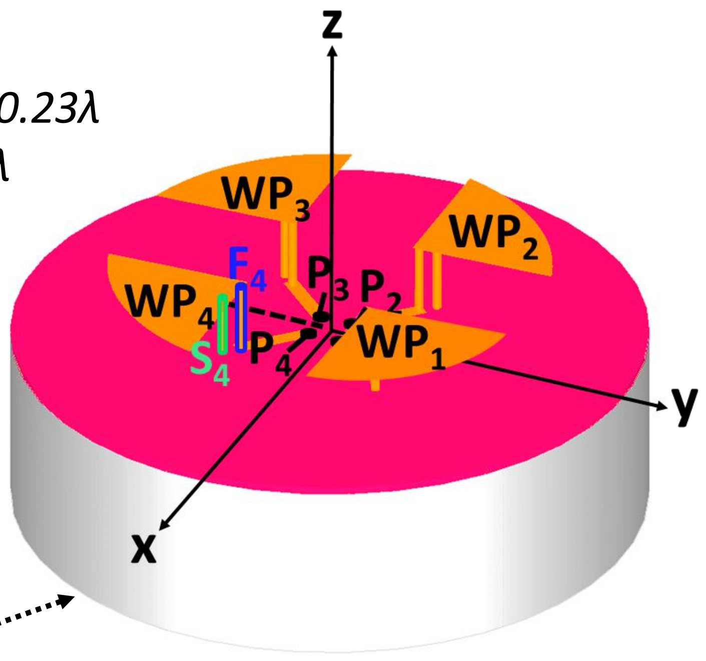


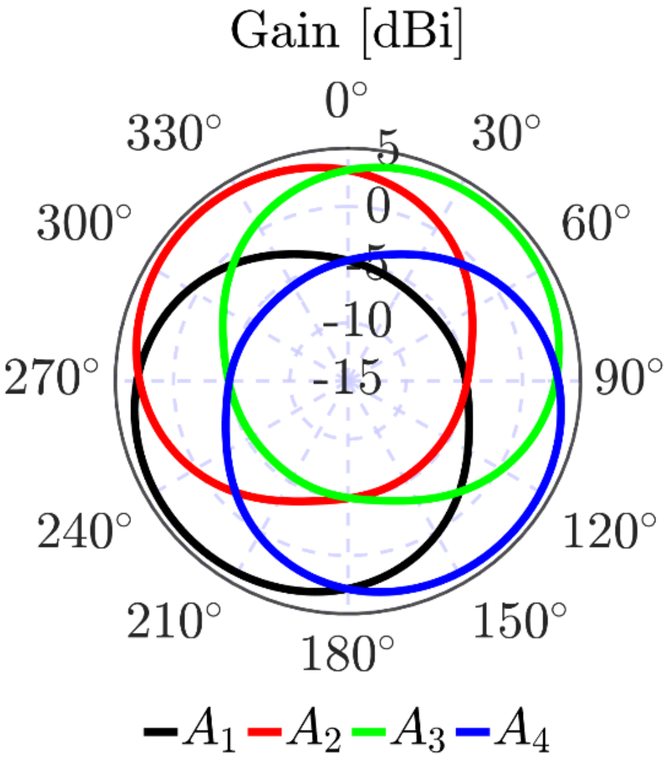
bottom *top*

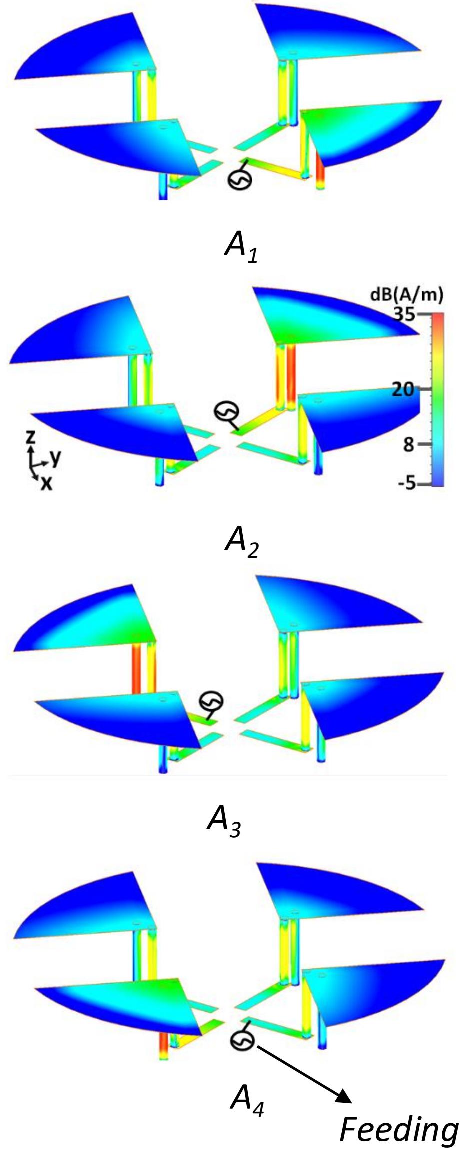
Pattern Reconfigurable Antenna

- 4-element wire-patch antenna array
- To reduce interference in massive IoT networks
- Low-cost and easy-to-realize solution

Total height: 0.23λ
Radius: 0.28λ
at 2.44 GHz

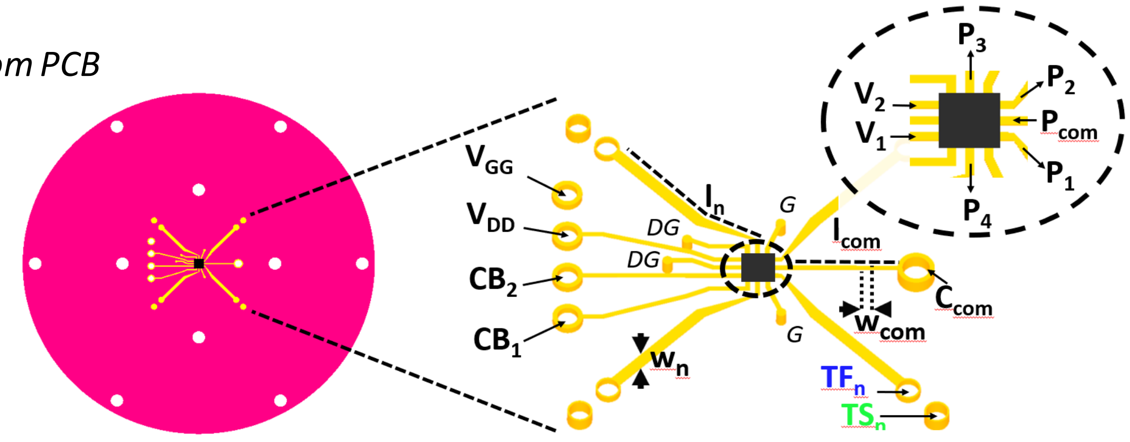




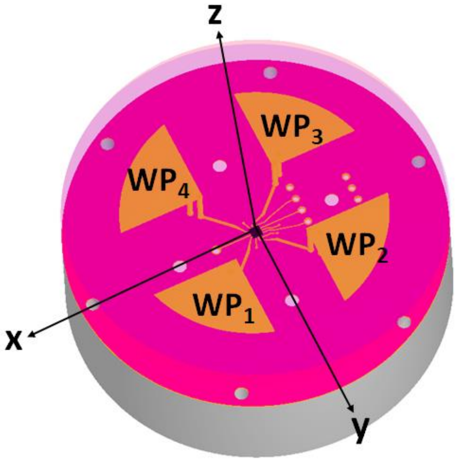


Pattern Reconfigurable Antenna

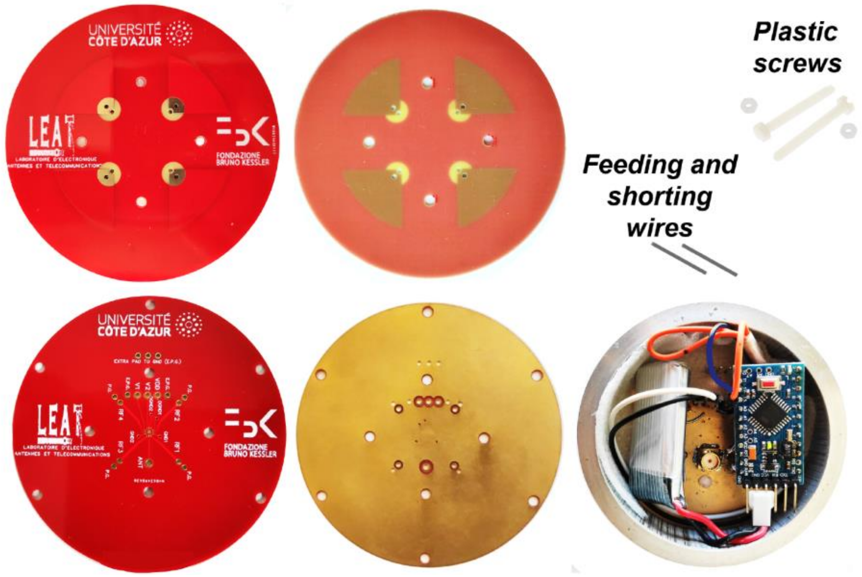
Bottom PCB



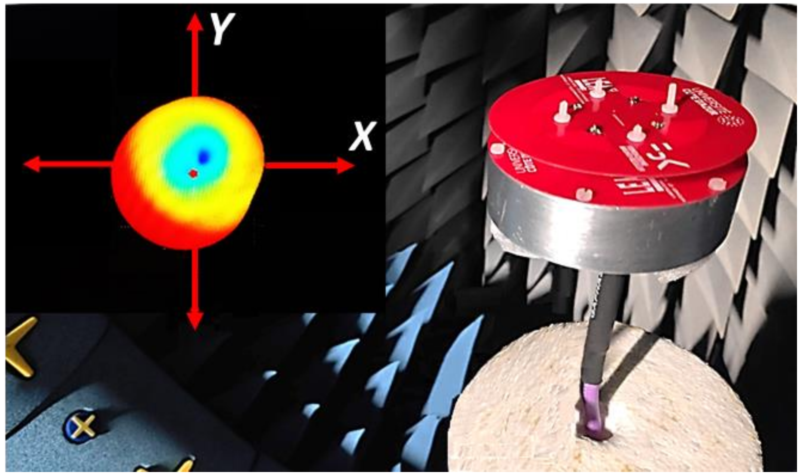
Implementation of reconfiguration mechanism



Realization and integration

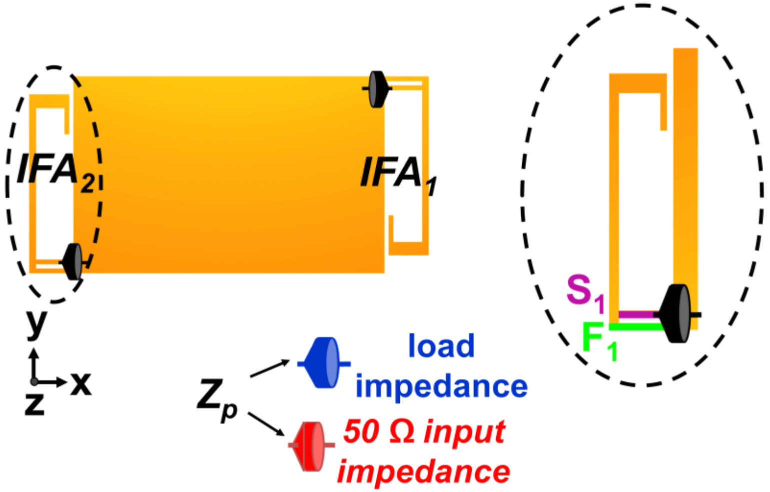


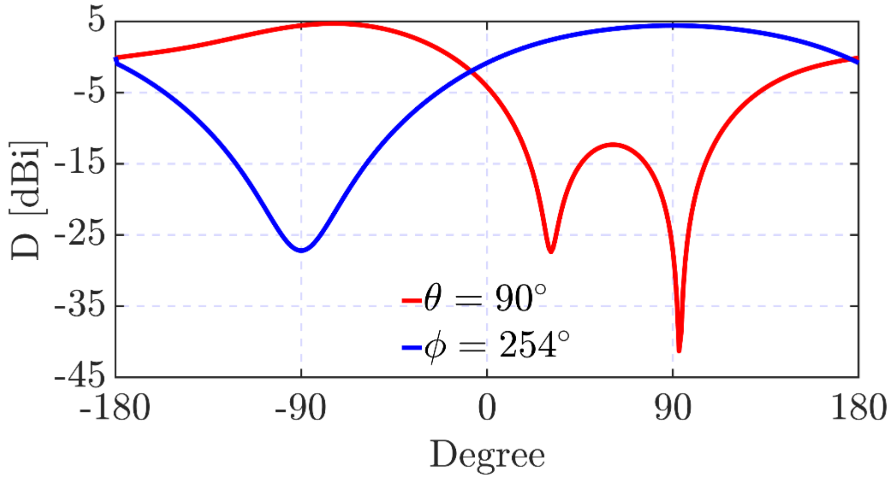
Measurement

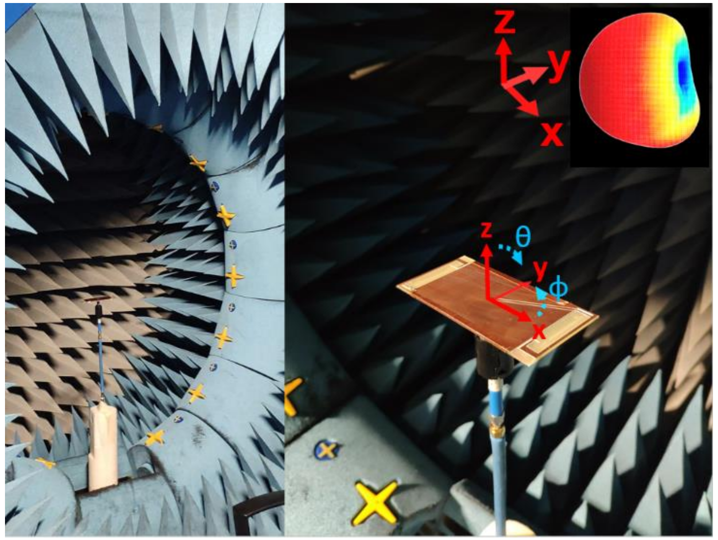


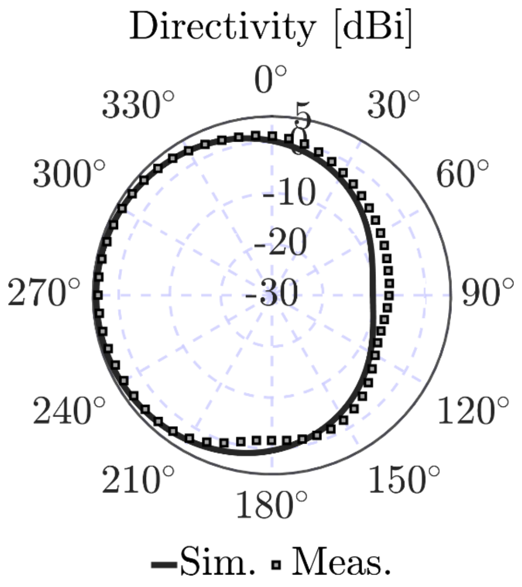
Pattern Reconfigurable Antenna

- 2-elements printed IFA array
- To reduce interference in massive IoT networks
- Terminal integrated solution



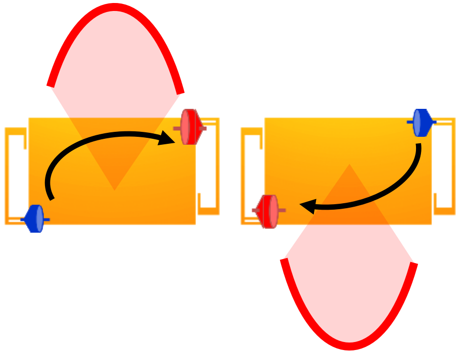






Reconfiguration

Rotating the ***loads*** *over the parasitic elements*



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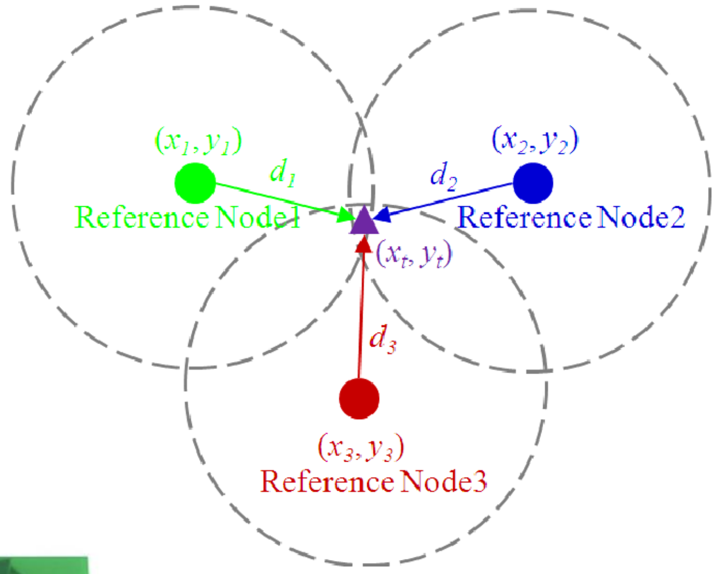
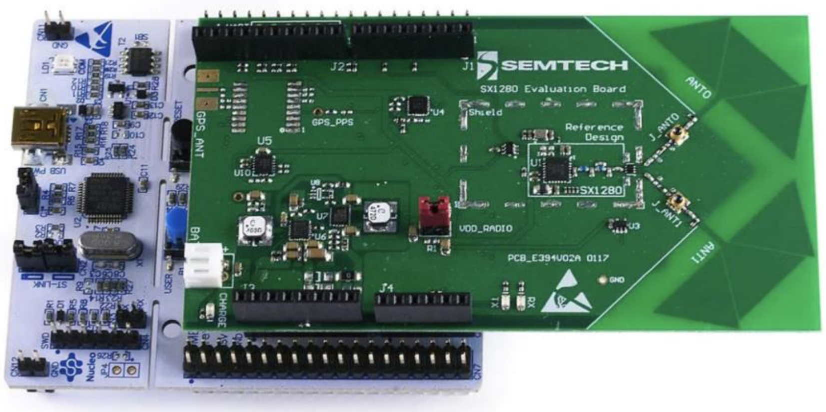
Triangulation-based localization

- Nodes are localized using estimated distances from reference nodes
- Estimation can be done using received signal strength indicator (RSSI)
- Another approach is to use hardware ranging techniques



LoRa based approach

- Use of Semtech LoRa SX1280 chip with ranging capabilities
- Boards tested in indoor environment (corridor, room)
- Compared with RSSI methods
- It requires clock synchronization

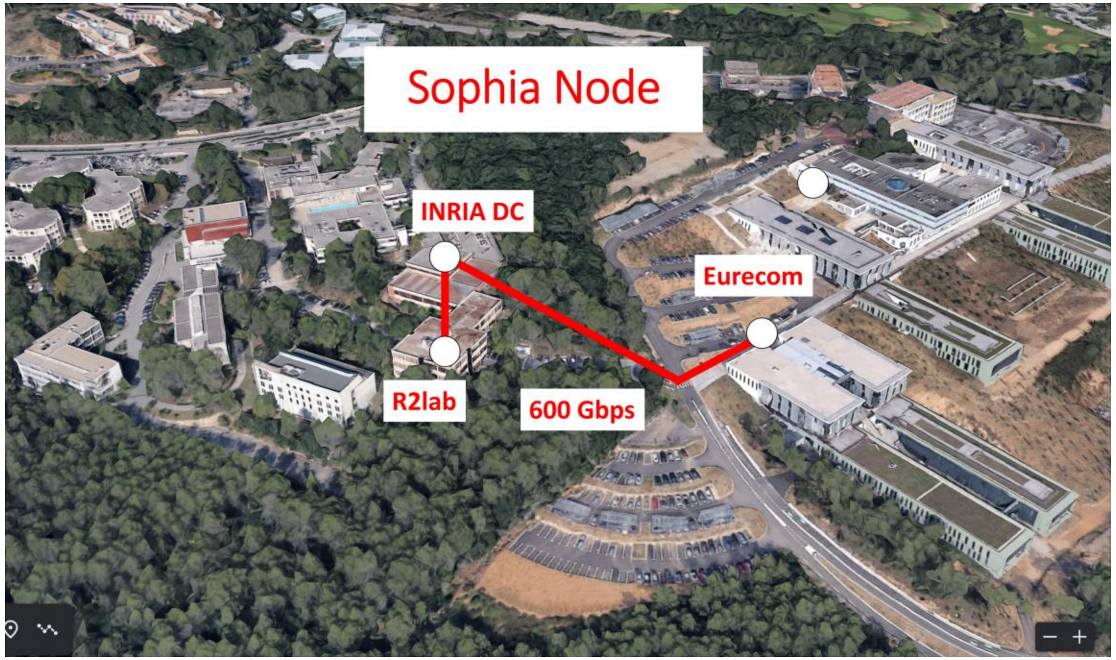


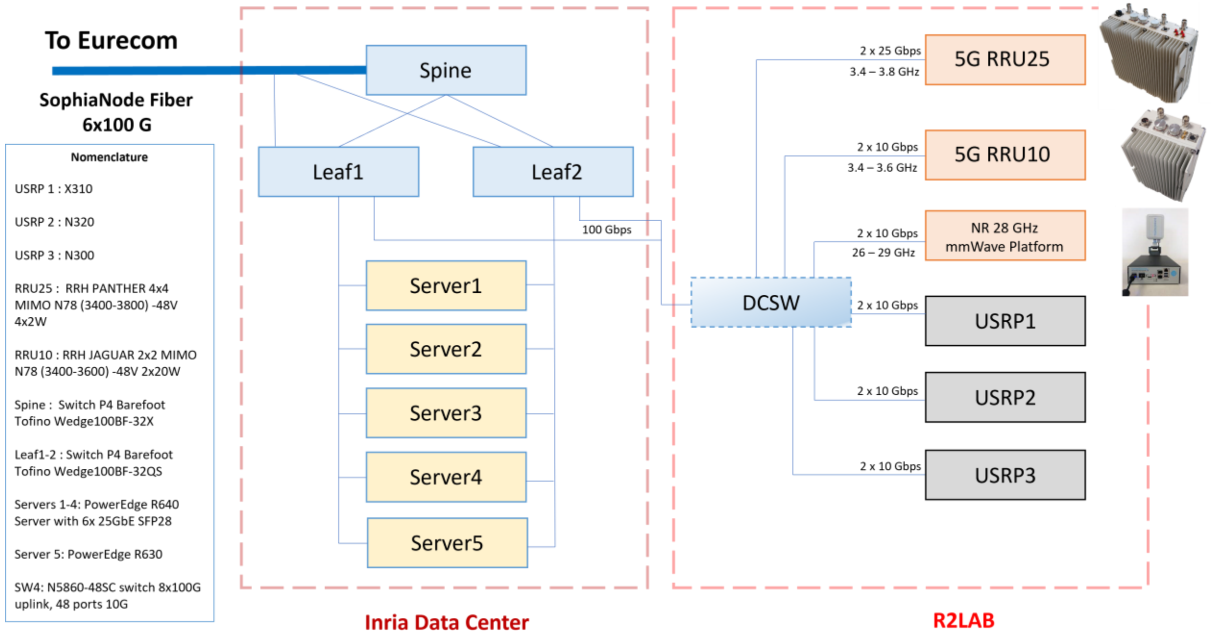
Triangulation-based localization

- Larger scale measurements impossible to the lack of students

SophiaNode Plateform (5G+ testbed)

- Large number of connections in 5G mMTC communications
- Purchase of a P4 Wedge 32QS programmable switch (server cluster)





Project Outcomes

Publications:

- 2 journal papers, 5 international conferences, 1 internal report

Collaborations:

- Collaboration with FBK still in progress
- Test of I-LL-WIN pattern reconfigurable antennas with the indoor Bluetooth-based indoor localization algorithm developed in FBK

Funded projects:

- H2020 PASSEPARTOUT project (2021)
- Development of a network of miniature, hyperspectral optical based sensors to monitor environmental air quality in urban areas
- Total funding: 7M€, LEAT funding: 210k€
- LEAT: reconfigurable antenna systems for the transmission of the collected data

PASSEPARTOUT
Photonic Sensors for Pollution Monitoring

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Conclusion and Future Work

- Development of solutions to improve localization accuracy in LPWAN networks at both the physical and network level
- Development of multiple antenna solutions suitable for localization-based IoT applications
- Study of a time-of-flight based ranging estimation technique
- Outcomes in terms of publications, collaborations, and project funding
- Integration and extension in the SophiaNode project and in 5G scenarios

I-LL-WIN Publications

[1] L. Santamaria, F. Ferrero, R. Staraj, L. Lizzi, "Electronically Pattern Reconfigurable Antenna for IoT Applications," IEEE Open Journal of Antennas and Propagation, vol. 2, pp. 546–554, 2021, IEEE Open Journal of Antennas and Propagation. doi: 10.1109/OJAP.2021.3073104.

[2] L. Santamaria, F. Ferrero, R. Staraj, L. Lizzi, "Slot-based Pattern Reconfigurable ESPAR Antenna for IoT Applications," IEEE Transactions on Antennas and Propagation, pp. 1–1, 2020, IEEE Transactions on Antennas and Propagation. doi: 10.1109/TAP.2020.3044399.\

[3] L. Santamaria, T. Q. K. Nguyen, F. Ferrero, R. Staraj, L. Lizzi, "Compact Antenna Approaching the Lower Q-factor Theoretical Bound Suitable for IoT Applications," in 2021 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, Dec. 2021, p. 2.

[4] V. Mastrosimini, L. Santamaria, M. Grande, F. Ferrero, R. Staraj, L. Lizzi, "Miniaturized Omnidirectional Circularly Polarized Antenna for IoT Applications," in 15th European Conference on Antennas and Propagation (EUCAP 2021), Virtual Conference, Mar. 2021.

[5] L. Santamaria, L. Lizzi, F. Ferrero, R. Staraj, "An Optimization Driven Method for the Synthesis of Reconfigurable Parasitic Antenna Arrays," in 2020 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting, ISSN: 1947-1491, Jul. 2020, pp. 1659–1660. doi: 10.1109/IEEECONF35879.2020.9329627.

[6] L. Santamaria, L. Lizzi, F. Ferrero, R. Staraj, "Compact 4-Element Radiation Pattern Agile Antenna for Spatial Filtering in IoT Networks," in 14th European Conference on Antennas and Propagation (EUCAP 2020), Copenhagen, Denmark, Mar. 2020.

[7] L. Santamaria, T. Q. K. Nguyen, L. Lizzi, F. Ferrero, R. Staraj, "2-Port Antenna with Matching Network for Dual-band IoT Terminal," in 2019 IEEE International Symposium on Antennas and Propagation USNC/URSI National Radio Science Meeting, Jul. 2019.

[8] Amal Krimi, "Cooperative Localization in LoRa Low Power Wide Area Networks", rapport PFE Master IFI/UBINET, février 2021, encadré par W. Dabbous, T. Turletti et L. Lizzi.

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