

NEWSLETTER

Achievements, Impact & Future Directions

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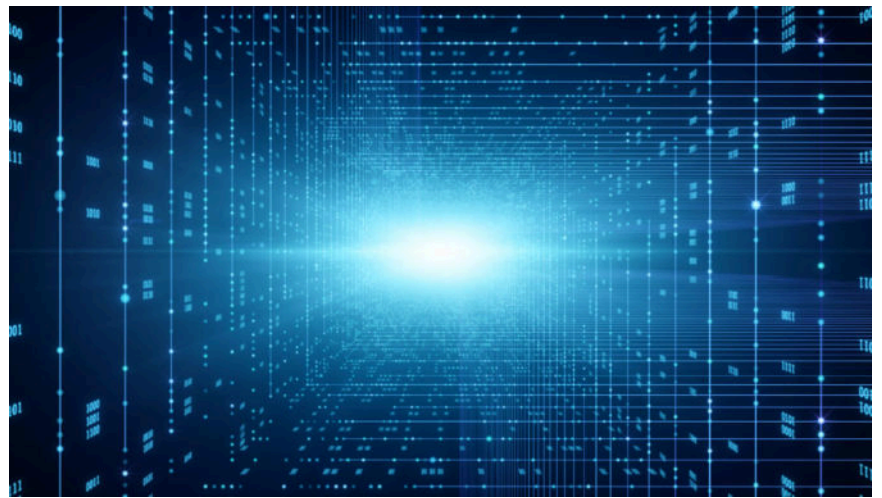
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APOLLO

Advanced Signal Processing Technologies for Wireless Powered Communications

The **APOLLO** project is an ERC Consolidator Grant that has delivered pioneering advances in wireless power transfer and next-generation communication systems. By developing a rigorous bottom-up, cross-layer framework, the project established new mathematical models for energy harvesting circuits, characterized fundamental information–energy trade-offs, and introduced innovative waveform, modulation, and system-level designs under realistic hardware constraints. Importantly, the project opened high-risk, high-gain interdisciplinary directions by bridging wireless power transfer with quantum communication theory, proposing wireless-powered quantum optical systems and connecting classical energy harvesting with quantum-optimal detection principles. Through both theoretical breakthroughs and experimental validation, the ERC Consolidator Grant has positioned Europe at the forefront of sustainable, energy-autonomous, and quantum-enabled wireless networks for the 6G era and beyond.



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Main Achievements

The ERC APOLLO ERC Consolidator Grant has delivered pioneering advances in wireless power transfer and next-generation communication systems, positioning Europe at the forefront of sustainable and energy-autonomous technologies for the 6G era and beyond. By combining fundamental theory with experimental validation, the project has generated transformative scientific and technological results with global impact.

- Established new theoretical foundations for simultaneous wireless information and power transfer (SWIPT), rigorously characterizing information–energy trade-offs under realistic hardware non-linearities.
- Developed advanced waveform and modulation techniques that significantly enhance energy harvesting efficiency while preserving communication reliability.
- Integrated wireless power transfer with emerging 6G technologies, including massive MIMO, intelligent reflecting surfaces, and fluid antenna systems, enabling energy-autonomous network architectures.
- Opened a new interdisciplinary direction by bridging wireless power transfer with quantum communication theory, introducing wireless-powered quantum optical systems.
- Validated key concepts through software-defined radio (SDR) prototypes and hardware implementations, demonstrating practical feasibility.
- Produced 142 high-impact scientific publications and strengthened international collaboration networks.

Through high-risk, high-gain research and strong engagement with academia, industry, and society, APOLLO has reinforced Europe’s scientific leadership and laid the foundations for future sustainable, intelligent, and quantum-enabled wireless communication systems.



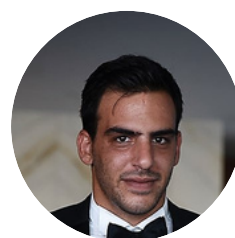
People Behind the Success



Behind the success of the APOLLO stands a dynamic and highly productive research team. Throughout its lifetime, the project supported 16 talented researchers, creating a strong and collaborative scientific environment. Among them, five successfully completed their doctoral studies, delivering high-quality and impactful contributions to the field of wireless communications. Several team members have since continued their careers in leading industrial and academic institutions worldwide, transferring the expertise developed within APOLLO to new research and technological settings.

Importantly, a significant number of researchers remain active within our laboratory, advancing new research initiatives funded through competitive programmes that build directly upon APOLLO's scientific foundations.

The project's legacy therefore extends well beyond its technical achievements; it has supported and developed young researchers, strengthened long-term research excellence, and established a sustainable and internationally visible ecosystem for future innovation in wireless and quantum-enabled communications.



Project's Results

Over the course of the project, we achieved significant scientific and technological results that have substantially advanced the field of wireless powered communications. The project produced more than 142 scientific publications in leading international journals and conferences, reflecting both the depth and breadth of our research activities.

At the core of our research work was the development of a new bottom-up, cross-layer design methodology for wireless systems that jointly transfer information and energy. We introduced accurate mathematical models for energy-harvesting circuits, enabling for the first time a rigorous theoretical analysis of realistic hardware non-linearities. These models allowed us to characterize the fundamental trade-offs between data transmission and power transfer, establishing new performance limits for next-generation wireless networks.

Beyond theory, we designed innovative waveforms, modulation schemes, and transmission strategies tailored to 5G and beyond systems, integrating technologies such as massive MIMO, intelligent reflecting surfaces, fluid antennas, and mobile edge computing. Importantly, we incorporated safety constraints, hardware imperfections, and system-level considerations, ensuring that our solutions are not only theoretically sound but also practically viable.

A major strength of the project was its experimental validation. Using SDR platforms and advanced circuit simulations, we implemented and tested key concepts in real-world prototypes. This strong interaction between theory and experimentation ensured that our research outcomes are robust, scalable, and aligned with emerging technological needs.

Overall, the project has laid strong foundations for sustainable, energy-efficient, and future-proof wireless communication systems, while reinforcing the long-term growth and international visibility of our research team.

One never notices what has been done; one can only see what remains to be done.

-MARIE CURIE-

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Publications

The scientific achievements of ERC APOLLO are reflected in an outstanding body of work comprising 142 peer-reviewed publications in leading international journals and conferences. These contributions span fundamental theory, system-level innovation, and experimental validation, shaping the research landscape of wireless power transfer (WPT) and simultaneous wireless information and power transfer (SWIPT).

Across its work packages, APOLLO advanced mathematical modeling of energy harvesting circuits, established fundamental information–energy limits, introduced innovative waveform and modulation designs, integrated WPC into 5G/B5G architectures, and validated key concepts through SDR-based prototypes and circuit-level implementations. The breadth and depth of these publications demonstrate both scientific excellence and lasting impact on next-generation wireless systems.

142 Publications

75 Journals

67 Conferences

INDICATIVE PUBLICATIONS

[A1] Zhang, G. Zheng, I. Krikidis, and R. Zhang, “Specific absorption rate-aware beamforming in MISO downlink SWIPT systems,” *IEEE Transactions on Communications*, vol. 68, pp. 1312--1326, February 2020.

[A2] P. Mukherjee, C. Psomas, and I. Krikidis, “Differential chaos shift keying-based wireless power transfer with nonlinearities,” *IEEE Journal of Selected Topics in Signal Processing, Special Issue on Signal Processing Advances in Wireless Transmission of Information and Power*, vol. 15, pp. 1185--1197, August 2021.

[A3] C. Skouroumounis and I. Krikidis, “Fluid antenna with linear MMSE channel estimation for large-scale cellular networks,” *IEEE Transactions on Communications*, vol. 71, pp. 1112- 1125, February 2023. [112 citations]

[A4] I. Krikidis, C. Psomas, A. K. Singh, and K. Jamieson, “Optimizing configuration selection in reconfigurable-antenna MIMO systems: physics-inspired heuristic solvers,” *IEEE Transactions on Communications*, pp. 8010-8023, December 2024.

[A5] I. Krikidis, “Tesla meets Helstrom: a wireless-powered quantum optical system,” *IEEE Wireless Communications*, vol. 14, pp. 3957-3961, December 2025.

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Dissemination activities

The ERC APOLLO project achieved broad international impact through a comprehensive dissemination strategy that actively connected academia, industry, policy stakeholders, and society. The project generated 142 high-quality scientific publications and supported the organization of numerous IEEE workshops, special sessions, keynotes, and invited lectures worldwide, significantly strengthening Europe's leadership in wireless power transfer and next-generation 6G technologies. Strong collaboration with industry was fostered through invited talks and research interactions with leading industrial laboratories, while engagement with stakeholders and policy makers included presentations and contributions to discussions related to emerging wireless technologies, highlighting the strategic and technological relevance of the research.

At the societal level, the APOLLO team actively participated in Researchers' Night events, public lectures, and open webinars, bringing cutting-edge wireless and energy-autonomous communication technologies closer to citizens and school students, and promoting STEM awareness among younger generations.

The excellence and international recognition of the project were further reflected in major distinctions, including ERC Proof of Concept grants and the elevation of the Principal Investigator to IEEE Fellow, underscoring the scientific leadership and global impact achieved through the project.



Innovation Driving Sustainable Growth

Over **€3M** secured
+10 New Projects

The scientific advances generated by the ERC APOLLO project have translated into sustained research growth, securing more than €3 million in additional competitive funding at both European and national levels. The project's core innovations led to two ERC Proof of Concept (ERC PoC) grants, confirming their strong innovation and commercialization potential. At the European level, the group further strengthened its presence by securing three Smart Networks and Services Joint Undertaking (SNS) projects, participating in a Marie Skłodowska-Curie Doctoral Network (MSCA DN), and contributing to mobility and collaboration initiatives under Erasmus+ and MSCA Staff Exchange (MSCA SE).

In parallel, we attracted national dual-use funding, demonstrating the broader strategic relevance and technological maturity of our research outcomes. By expanding into complementary research directions and consolidating international partnerships, these new projects build upon the original vision, reinforcing our capacity to deliver high-impact research

while ensuring the long-term sustainability and strategic growth of the group. This momentum confirms APOLLO's catalytic role in shaping a resilient, innovation-driven, and future-oriented research ecosystem.



"Scientific ideas prove their value when they create lasting structures, not temporary results."



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National funding

RISE



Wave.



QUESTING
Connecting to the future

Larissa

AGRILORA



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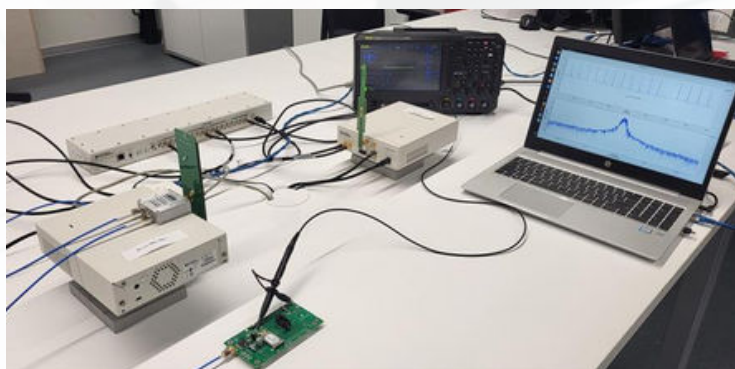
A network infrastructure to communicate and energize

Research Infrastructure

DRIVING INNOVATION AND COLLABORATION

Within the framework of the APOLLO project, key research infrastructure was acquired and systematically deployed to support advanced experimental activities in wireless communications. The same infrastructure was subsequently leveraged in follow-up research projects that originated from concepts developed within APOLLO, thereby extending the scientific and technological impact of the initial investment. The acquired equipment substantially strengthened the laboratory's experimental capabilities, enabled rigorous prototype validation, and facilitated sustained collaboration with academic and industrial partners.

USRP Software Defined Radio



The USRP Software Defined Radio platform was deployed as a flexible real-time testbed for over-the-air implementation and validation of wireless communication algorithms. It supported the implementation and experimental assessment of PHY-layer signal processing techniques, including MIMO schemes and beamforming strategies. The platform enabled prototyping of custom transmission and reception architectures and supported joint experimental works with external research institutions.

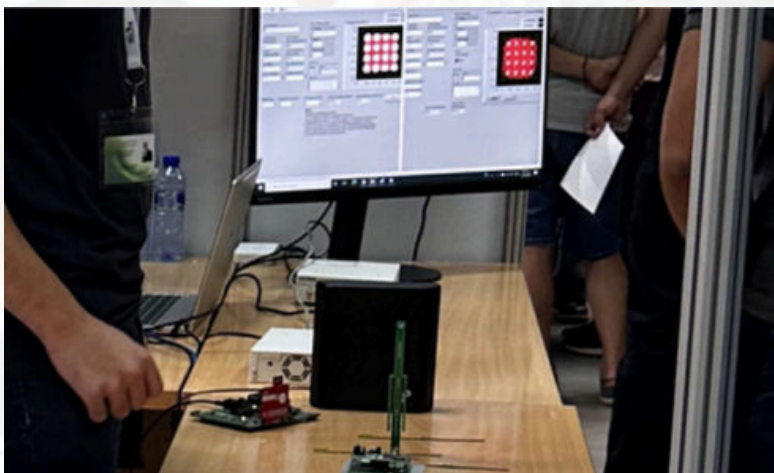
Quantum Computing



The SPINQ Gemini Mini was acquired to explore quantum computing methodologies relevant to optimization and signal processing problems in wireless networks. The system was used for educational, exploratory, and proof-of-concept investigations of quantum algorithms, including variational and hybrid quantum-classical approaches.

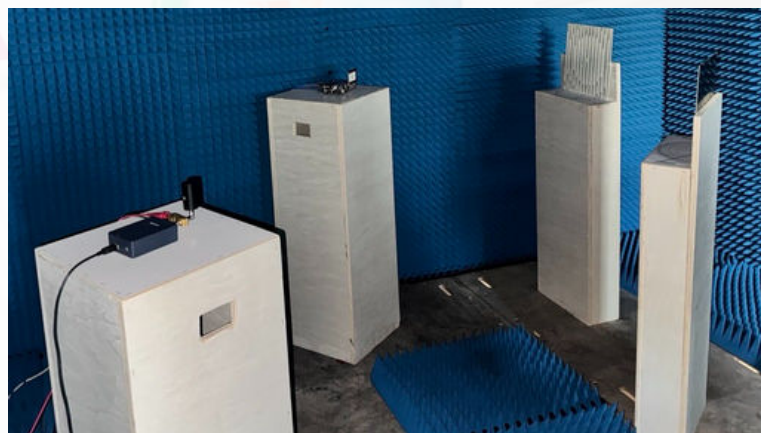
Powercast Energy Harvesting

The Powercast Energy Harvesting module was utilized for the development and experimental validation of RF-based wireless power transfer and energy harvesting systems. It supported quantitative evaluation of RF-to-DC conversion efficiency under realistic propagation conditions and enabled experimental validation of SWIPT theoretical frameworks.



Reflecting Intelligent Surfaces (RIS) and mmWave equipment.

In addition, Reflecting Intelligent Surfaces (RIS) and mmWave equipment, were acquired to enable controlled experimental studies at high frequencies. This infrastructure allowed experimental evaluation of RIS-assisted beam steering, propagation control, and link-level performance at mmWave bands. The integrated setup supported channel measurements, validation of reconfigurable environment concepts, and experimental assessment of theoretical concepts.



Closing Remarks



Rather than slowing us down, these developments pushed us to rethink assumptions, refine our methodologies, and strengthen the interdisciplinary foundations of our work.

Within this context, we believe that our research contributed to this ongoing transformation. By addressing fundamental questions and developing new design principles for sustainable and energy-aware wireless systems, we aimed not only to advance a specific field, but also to support a broader technological shift toward more efficient, resilient, and future-oriented communication infrastructures.

I would like to express my deepest gratitude to my dedicated collaborators and team members, to those who remained and continue to build upon this foundation, and to those who have moved forward to pursue their careers along different paths. Without their talent, commitment, creativity, and resilience, APOLLO would not have been possible, nor would it have inspired the new directions that now shape our future research. Each member of the team has left a meaningful imprint on this journey.

We hope that, through our collective effort, we have added a meaningful stone to the foundation of scientific progress, helping knowledge move one step forward. The completion of this project does not mark an end, but rather a transition. We will continue exploring new research directions that have already emerged from this work, with the same passion, dedication, and intellectual curiosity that guided us from the beginning.

Science advances through continuity, collaboration, and the courage to explore the unknown. With this spirit, we move forward.

As Principal Investigator, I look back on this journey with gratitude and a strong sense of responsibility. During this period of profound societal and scientific change, the project evolved, adapted, and contributed to this broader transformation.

We navigated unprecedented challenges during the COVID-19 pandemic, facing severe restrictions in mobility, limited physical interaction, and disruptions in laboratory access and international collaboration. For a significant period, we operated without a fully established laboratory environment, and our team was distributed across separate buildings and locations, making coordination and experimental work particularly demanding. Despite these constraints, the team demonstrated remarkable resilience, maintaining scientific productivity under exceptionally difficult circumstances. Today, we are especially grateful to have relocated to the impressive new premises of the Faculty of Engineering, where during the final four months of the project we were finally able to work together in a unified and inspiring research environment.

At the same time, the scientific landscape was rapidly reshaped by major quantum information processing in artificial intelligence, machine learning, and emerging communication paradigms.

PRINCIPAL INVESTIGATOR



IOANNIS KRIKIDIS

“Thank you to everyone who made APOLLO possible. It was a shared journey of vision and resilience, and I am proud of what we achieved together.”



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