Centre Tecnològic de Telecomunicacions de Catalunya

# Navigation & Positioning

## 1. RESEARCH UNIT STATEMENT

The improvement and democratization of navigation, positioning and related device technologies have the power to change people's lives for the better. This Research Unit aims to become a World-leading reference in bringing Global Navigation Satellite Systems (GNSS) and Device Technology to the people, either for scientific, business, or social endeavors.

## 2. OUTCOMES

- Scientific contributions: The staff forming this RU have a long publication track in prestigious (Q1) scientific journals and relevant conferences. When possible, we promote Open Access journals and magazines, in the line suggested by public funding entities.
- Technology Transfer: A special effort has been put in streamlining the process from the concept to the actual deployment in form factors widely adopted by the industry. This is expected to improve the delivery of research products in the form of technology transfer to companies and relevant entities. Wireless sensor technology for security and material characterization and new generation of wireless components for future communications systems are tailor made to address ongoing challenges.
- Return to Society: Knowledge and intelligence help in making better decisions. As they become more distributed, there is a spread, decentralization, and disaggregation of the ability to decide better. By releasing GNSS-SDR under an open-source license, in industry-standard distribution channels and form factors, we effectively contribute to empower Society by enabling fair open innovation based on satellite navigation systems, a key enabler for a myriad of applications and services related to Transport, Logistics, Mobility, Security and safety-related infrastructure, Internet of Things, Smart Grids, and many other relevant fields. New advances and improvements on Navigation and Positioning technologies are crucial for the optimization of multiple processes, thus contributing to their ecological sustainability.

## 3. RESEARCH LINE: SIGNAL PROCESSING FOR NAVIGATION

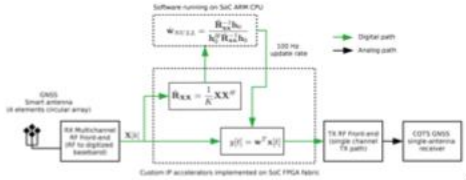
### Digital synchronization

Ranging of RF signals means achieving *extremely good* signal synchronization, understood as the proper estimations of time delay and Doppler shift. This is particularly challenging in GNSS, but the lessons learned can be readily exported to communication systems. A relevant success case is the application of joint synchronization and turbo/belief propagation-decoding schemes to Deep Space communication systems, in which the RU staff have a relevant track both in industry-funded projects and in scientific publications in top-quality journals.

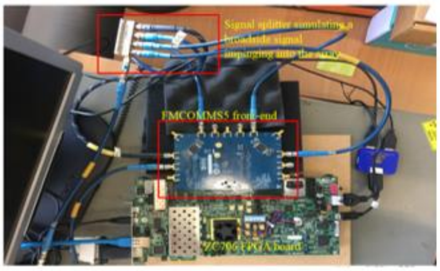
### Robust Navigation

In the field of navigation, robustness is a concept that encompasses the integrity and reliability of the obtained navigation solution. This includes signal authentication, hybridization of GNSS with other technologies, and the ability to mitigate unintentional or maliciously crafted interferences. This later case, also known as jamming, spoofing, or meaconing depending on the nature of the attack, is very relevant when GNSS is applied to critical key infrastructures, unmanned vehicles, or in Security, and can range from simple jamming sources that aim to overpower GNSS signals, to sophisticated spoofing or meaconing signals that aim to covertly mislead GNSS receivers.

In this topic, we take advantage of our solid background on antenna arrays for GNSS, Bayesian estimation, and on coding schemes to perform cutting-edge research on robust navigation solutions, with a stable collaboration with relevant customers and actors at national and international levels. Robustness encompasses the mitigation of all kinds of radiofrequency interferences (jamming, spoofing, meaconing) but also position integrity and signal authentication (a relevant issue in applications such as road tolling, logistics, and protection of key infrastructures) for the *trusted* GNSS receiver (*e.g.*, the forthcoming Galileo OSNMA service).




(a) Conceptual block diagram.

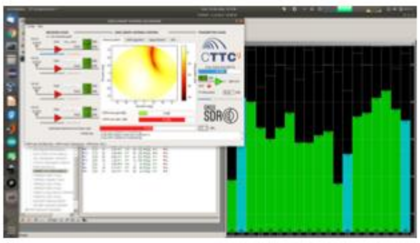



(b) Implementation based on Commercial–off–the–shelf components and SDR.

(c) Final prototype.

(d) Tests in anechoic chamber.

(e) (Authorized) field tests.



(f) Successfully getting position where other commercial receivers fail.

*Figure 1 - GNSS antenna array deployment.*

## Data Fusion

Data fusion is the process of integrating multiple data sources to produce more consistent, accurate, and useful information than that provided by any individual data source. When applied to navigation, it consists of the hybridization of GNSS with other technologies, such as inertial navigation systems (INS), other radio localization sources (UWB, WiFi, Bluetooth, etc.) and other heterogeneous data sources (cameras, radars, externally provided data, etc.). The applications are multiple, becoming a key enabler technology for Intelligent Transport Systems.

In this topic, this Research Unit takes advantage of its solid background on Bayesian estimation and its practical knowledge on the associated technologies to deliver state-of-the-art hybridization solutions for navigation and positioning systems, pushing both the theoretical and algorithmic side of data fusion and the capabilities of current technology to the limit.


(a) TIMON prototype mounted in drone.    (b) OBU with TIMON prototype.

*Figure 2 – Data Fusion applications.*

# 4. RESEARCH LINE: SOFTWARE-DEFINED RADIO

As stated on the Wikipedia:

*Software-defined radio (SDR) is a radio communication system where components that have been traditionally implemented in hardware (e.g., mixers, filters, amplifiers, modulators/demodulators, detectors, etc.) are instead implemented by means of software on a personal computer or embedded system. While the concept of SDR is not new, the rapidly evolving capabilities of digital electronics render practical many processes which were once only theoretically possible.*

In practice, SDR is a combination of Digital Signal Processing, professional programming best practices from the IT industry, and the electronics associated to the RF front-end. Achieving real-time in SDR deployments usually require pushing to the limits the capabilities of the underlying technologies, specifically the computational capabilities of the processor(s) executing them. Although the SDR concept is not new, it is still a hot research topic, as technology continues evolving.

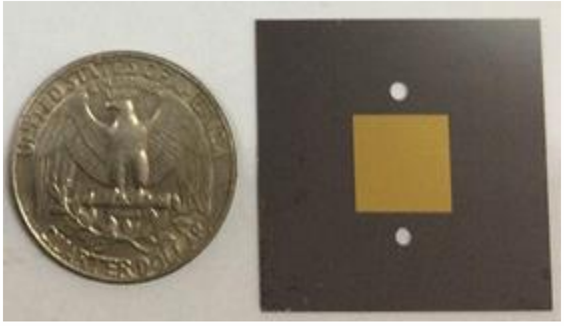
The approach proposed by this Research Unit consists of applying what is commonly referred to as ``DevOps'', a set of practices that combines software development (Dev) and IT operations (Ops), to SDR developments, with the objective to shorten the systems development life cycle and provide continuous delivery with high software quality. The goal is to establish the shortest path from a concept to its actual deployment, offering the possibility to quickly confront new algorithms with real-life signals and go beyond numerical simulations.

In this topic, this Research Unit offers its World-leading project GNSS-SDR as a practical showcase of the SDR approach capabilities and potential. The software can run on regular personal computers, but there is a version for embedded systems that can run on FPGA and ARM processors, allowing a smaller size, lighter weight, and lower power consumption for the overall receiver

## 5. RESEARCH LINE: Interdisciplinary driven sensors and microwave devices.

Sensor and device engineering implementation: from design to fabrication and testing. Large range of operating frequencies, from a few MHz to visible light wavelengths. Diverse technologies: Micro/nano fabrication, 3D printing, inkjet printing, laser machining, MEMS, superconductivity and LTCC. Reconfigurable and fixed device topologies. We develop microwave and optical sensors for the detection of gas, liquids, and solids, including RFID and wireless sensors. Microwave devices include passive components for wireless communications and unknown frequency identification circuits.

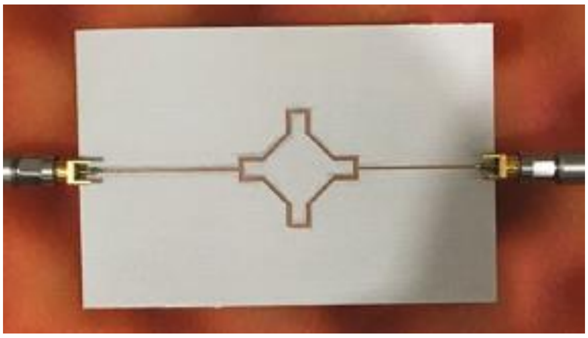
### Sensors



Microfabricated sensor head

3D printed gas cells

Gas sensor development



Planar sensor tags

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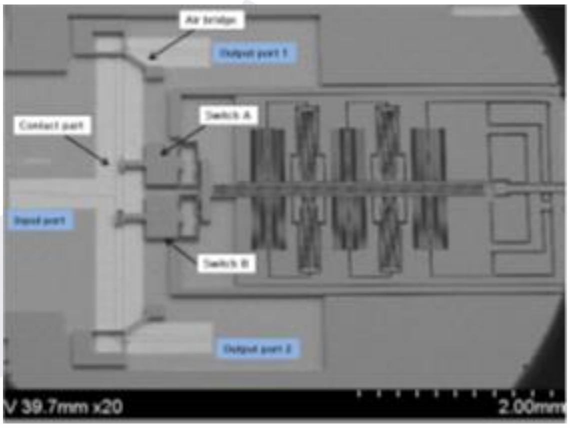
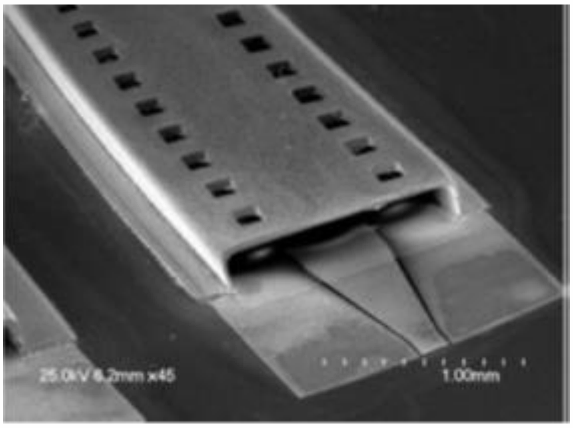
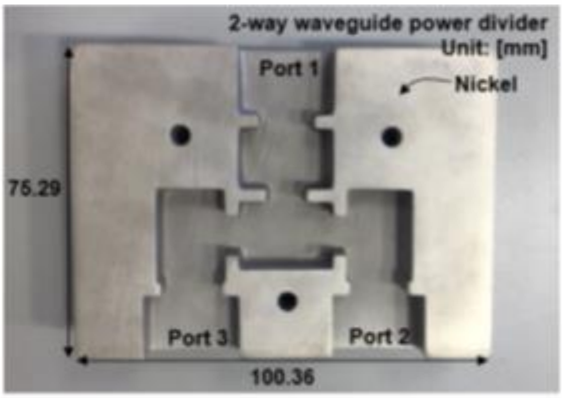
## Wireless devices



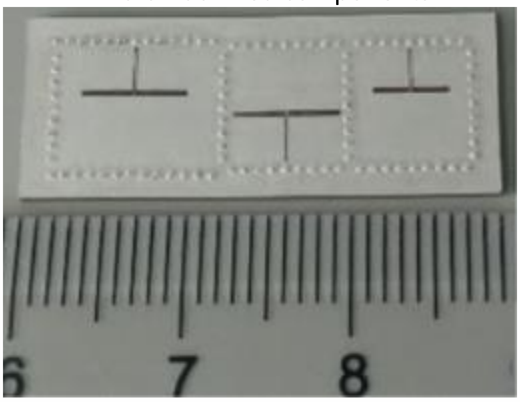
MEMS switch



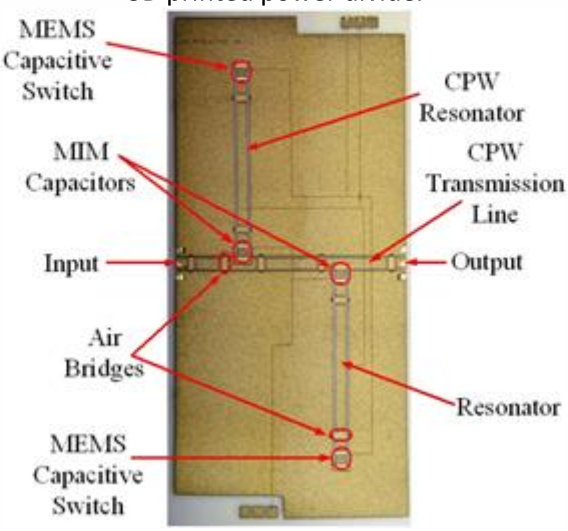
Micromachined components



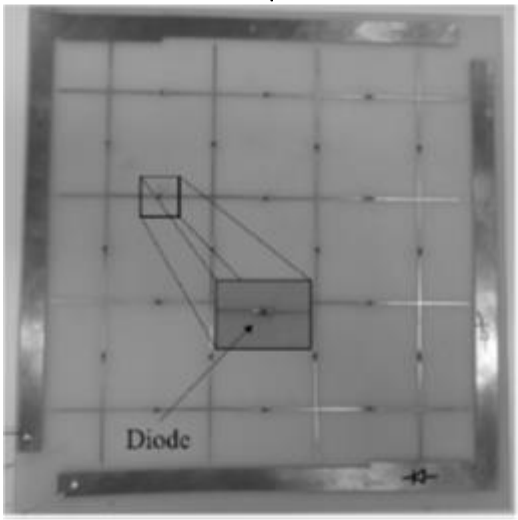
3D printed power divider



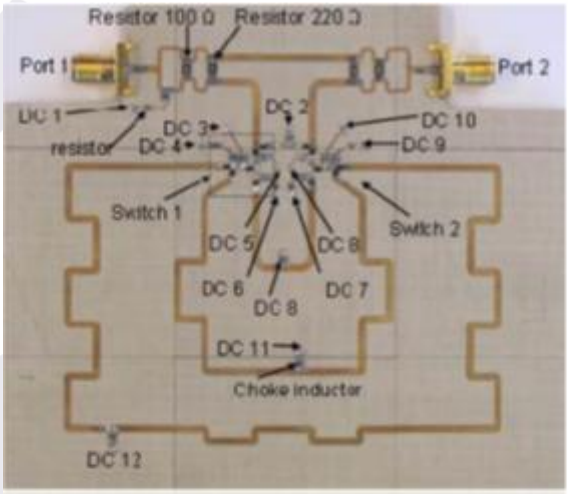
LTCC diplexer



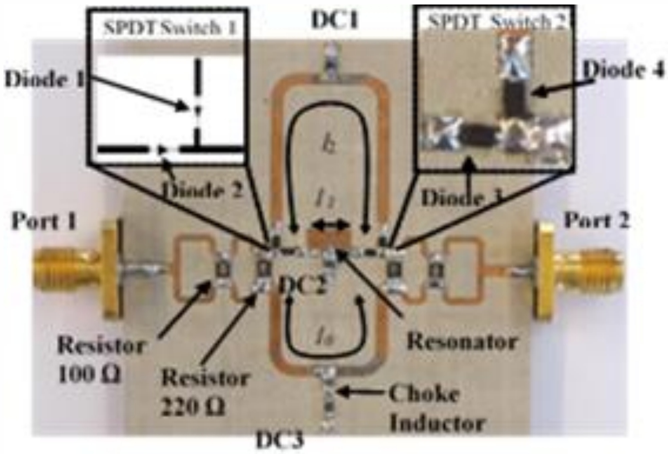
MEMS reconfigurable filter



Reconfigurable FSS




4 bit reconfigurable discriminator




Reconfigurable frequency discriminator

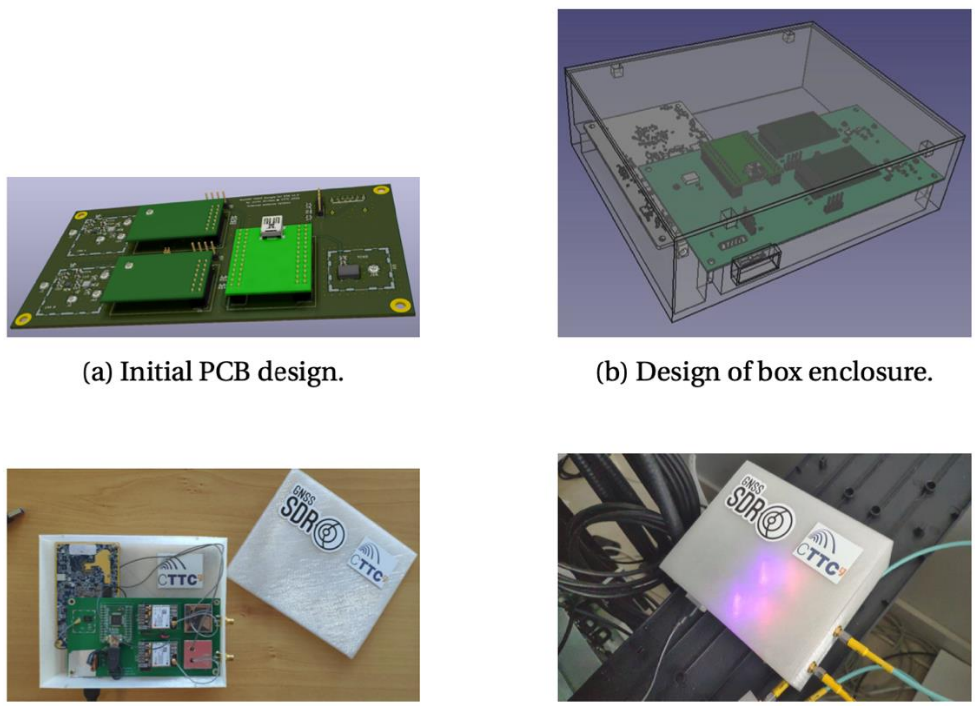

Parc Mediterrani de la Tecnologia - Building B4
Av. Carl Friedrich Gauss 7
08860 - Castelldefels
Barcelona (Spain)
www.cttc.es

# 6. RESEARCH LINE: DEPLOYMENT OF RESEARCH PRODUCTS

The aim is to contribute with a streamlined approach from concepts to products, thus helping to raise the Technology Readiness Level of our research products by design. In other words, bringing new concepts and ideas from their abstract conceptualization to their actual deployment in the shortest possible time and effort. In that sense, we try to learn from industrial best practices and apply them in a scientific, accountable fashion.

The objective of this research line is to go beyond bulky and clumsy prototypes that show concepts only working under controlled lab conditions and being able to provide industry-grade products and form factors with little extra effort. Concepts such as maintainability, reproducibility, scalability, the ability to provide updates in an accountable way, continuous integration and roll-out delivering come into play.

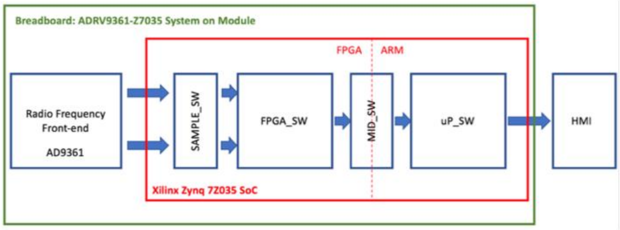
The ability to quickly generate fully customized, lightweight, low-consumption, and low-cost navigation devices, possibly hybridized with other communication systems, can be a key factor for meeting the Position, Navigation, and Time (PNT) requirements of the forthcoming generation of commercial satellite-based services established on Low Earth Orbits




(a) Initial PCB design. (b) Design of box enclosure.

(c) Fabrication. (d) Deployment.

*Figure 3 - Dual-band GNSS RF dongle design and deployment.*




(a) Initial block diagram.

(b) State-of-the-art System-on-Module embedded platform.


(c) Prototype fabrication.


(d) Space results.

*Figure 4 - Dual-band GNSS space receiver design and deployment.*