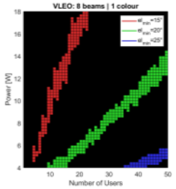
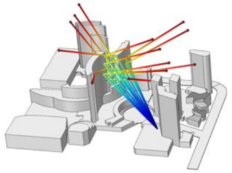
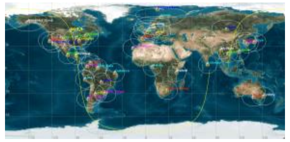
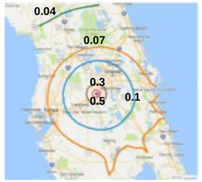
Grupo de Radiación
Universidad Politécnica de Madrid

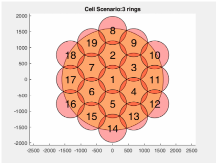
Feb 5, 2025 – Jornada Ciencia e Industria de la AEE – UAH

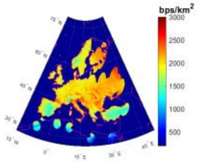
Radiation Group - Research areas

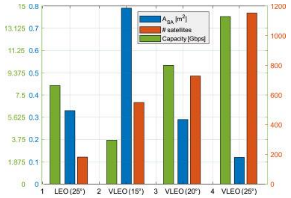


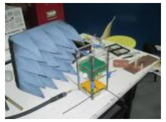
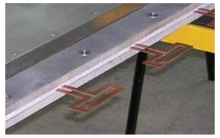


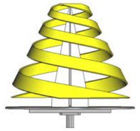




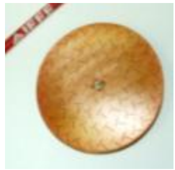
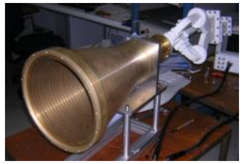
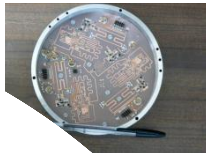


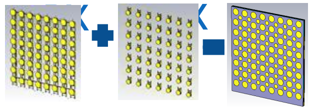
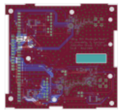
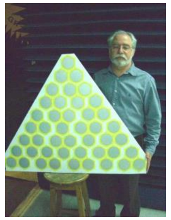
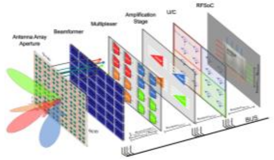
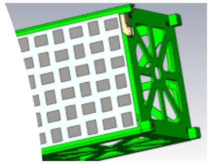
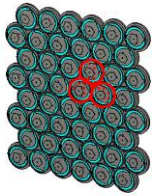




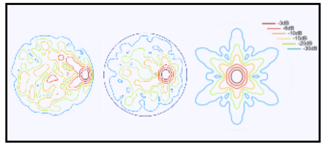
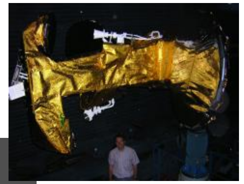
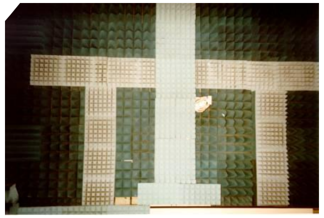
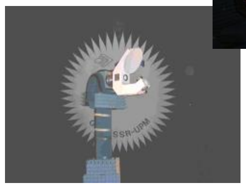



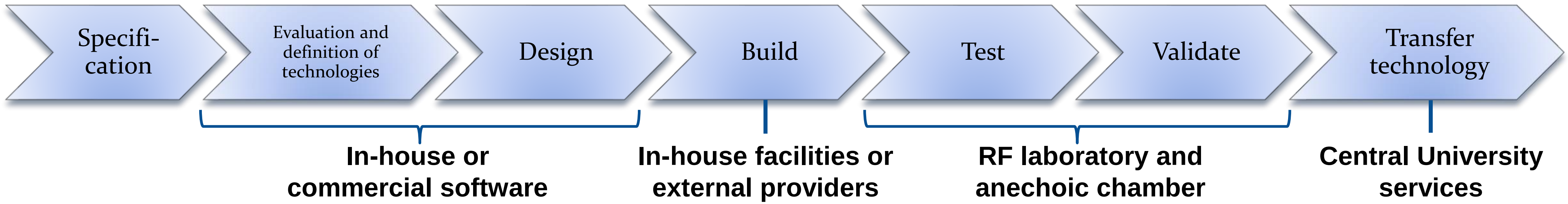









How do we work and partner

- How do we work
  - We aim at covering the whole lifecycle of a technology



- Partnerships and funding:
  - Long-term collaboration with **research groups** worldwide
  - Intensive technology transfer via **contracts** with industry and external services
  - **Competitive** funding from national and regional calls
  - **International** competitive projects under calls of European Commission (H2020, HE), European Space Agency in consortiums partnering with private sector

Antenna array for scientific mission payload

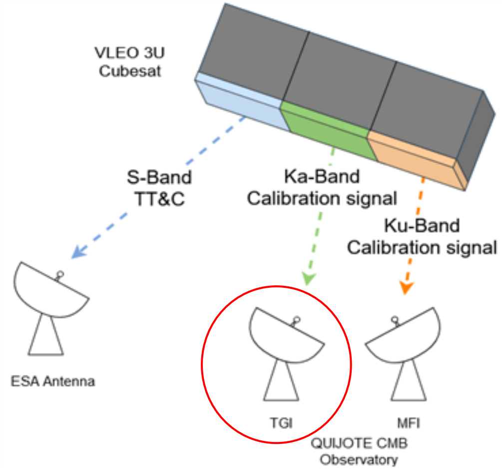
Patch Array Microstrip Antenna for a Microwave Polarization Calibration Cubesat (PI: Dr. M. Salas)

- Calibrate instrument on ground to measure the polarization of the cosmic background noise (CMB)
- 3U cubesat to calibrate QUIJOTE experiment
- Calibration of the polarization of radiotelescopes not feasible using ground set-ups

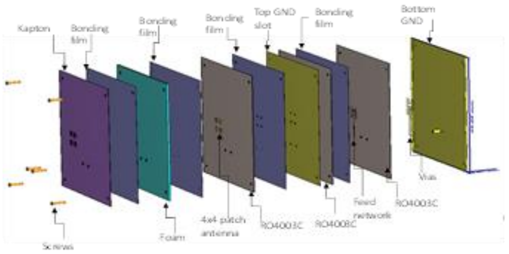
Challenges

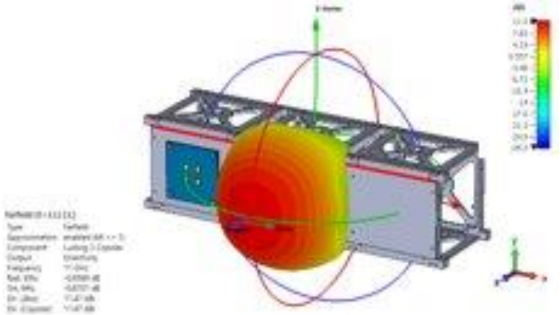
- Polarization purity (XPD > 45, 52 dB)
- 2 frequency bands (Ku, Ka)
- Limited space on-board for antenna allocation

QT-1 and QT-2 radiotelescopes (IAC, Canary Islands)

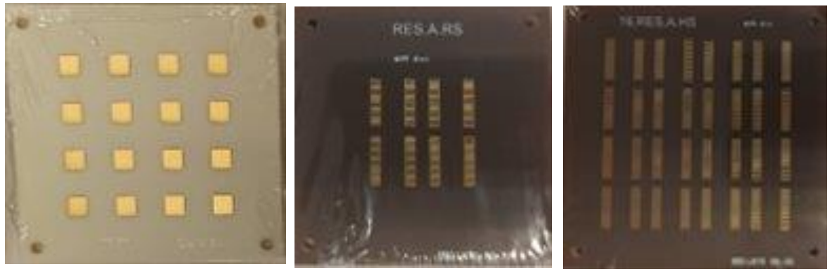


Conops of the CUBIQU mission





Multilayer structure of the patch antenna array antenna (thickness<4mm, <100g)



Manufactured layers of the antenna array (100x100 mm)

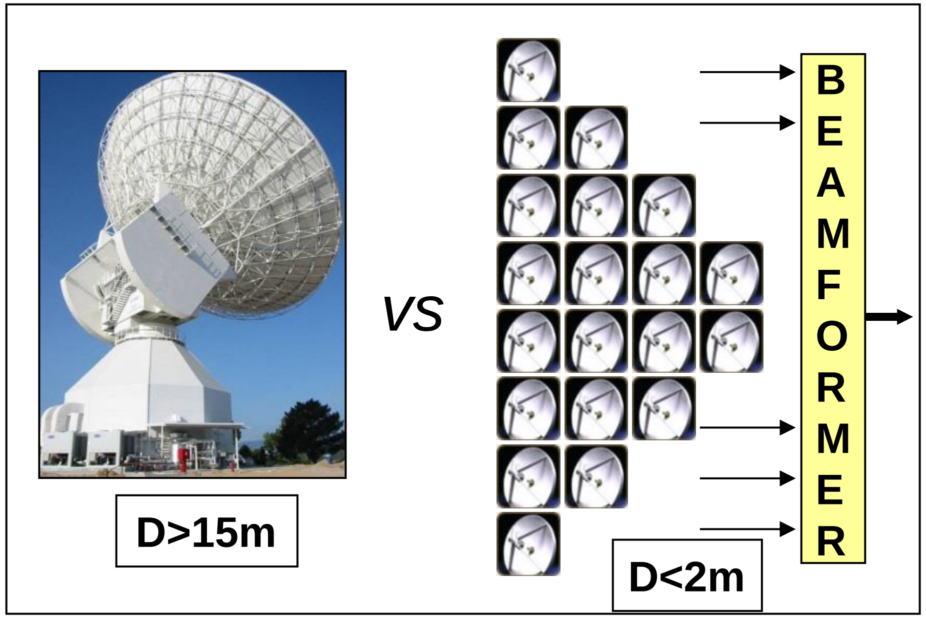
Antenna arrays for satellite communications

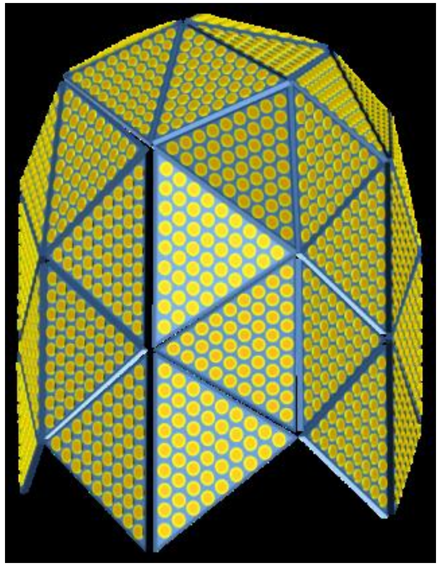
Design of steerable and reconfigurable ground station antenna arrays for satellite communications

- Overcome the limitations of large parabolic dishes
- Improve time of visibility with satellites

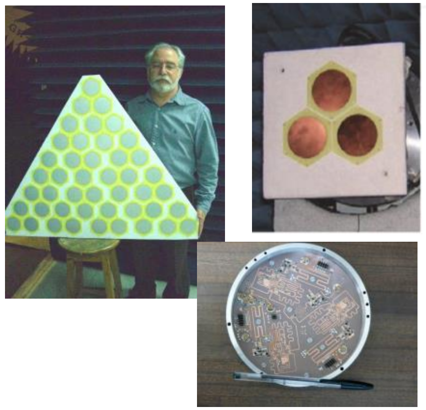
Challenges

- Optimize the antenna array geometry and antenna allocation
- Implement and design the most adequate beamforming algorithm (mission dependent)
- Design of transparent calibration techniques
- Integrate antenna, RF, control, processing, calibration procedures

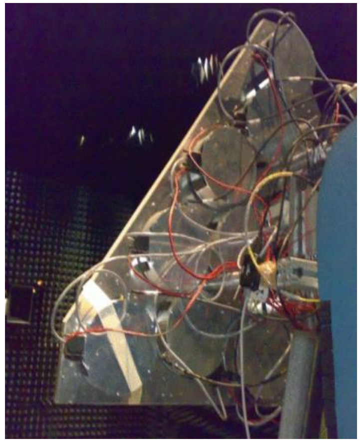




Geometries and handover to increase visibility



Manufacturing



Set-up in anechoic chamber for calibration and antenna pattern measurement

Antenna arrays for satellite communications

Development of a feed array for MEO tracking antennas (PI: Prof. Dr. J. M. Fernández)

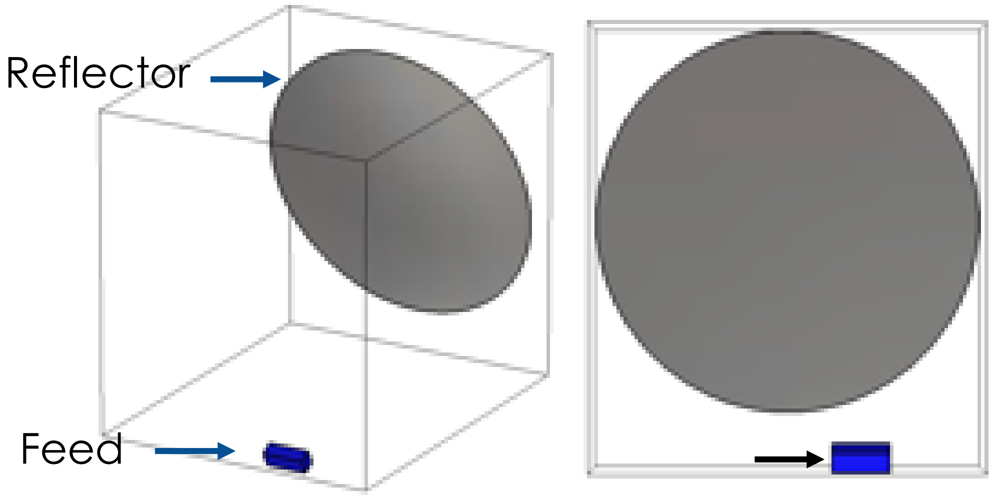
(on-going project)

Challenges

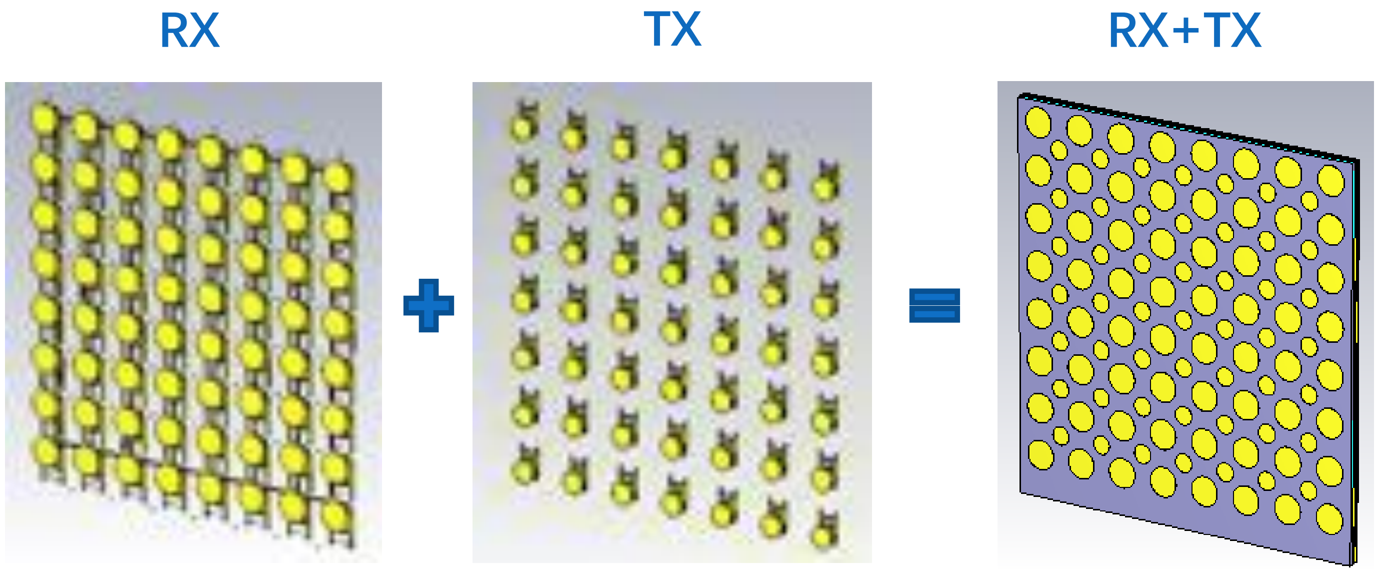
- Widely separated frequency bands in tx (27.5-30 GHz) and rx (17.7-20.2 GHz)
- Integration of tx and rx antenna in the same aperture

Solution:

- Interlaced tx and rx antennas in the same feed aperture
- Planar antenna array technlogy



1. Terminal antenna concept



2. Feed antenna concept

Antenna arrays for satellite communications

Development of a feed array for MEO tracking antennas (PI: Prof. Dr. J. M. Fernández)

Challenges

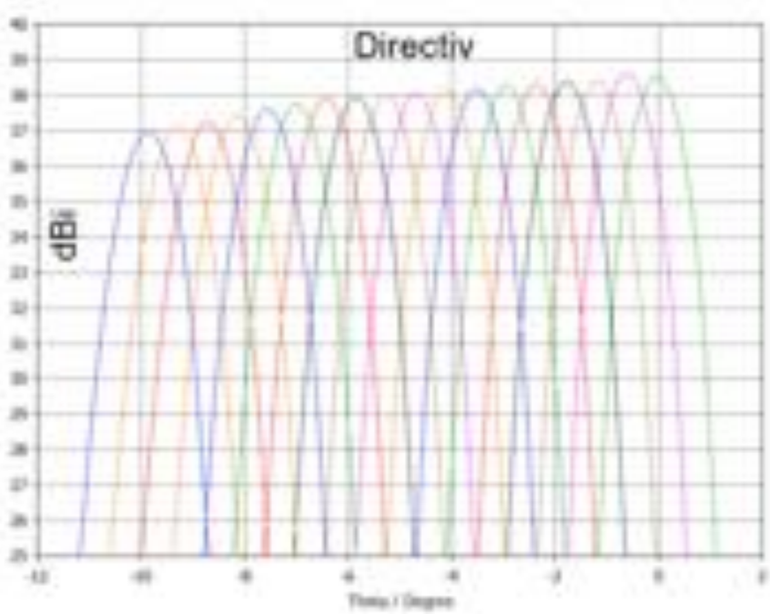
- Widely separated frequency bands in tx (27.5-30 GHz) and rx (17.7-20.2 GHz)
- Integration of tx and rx antenna in the same aperture

SES

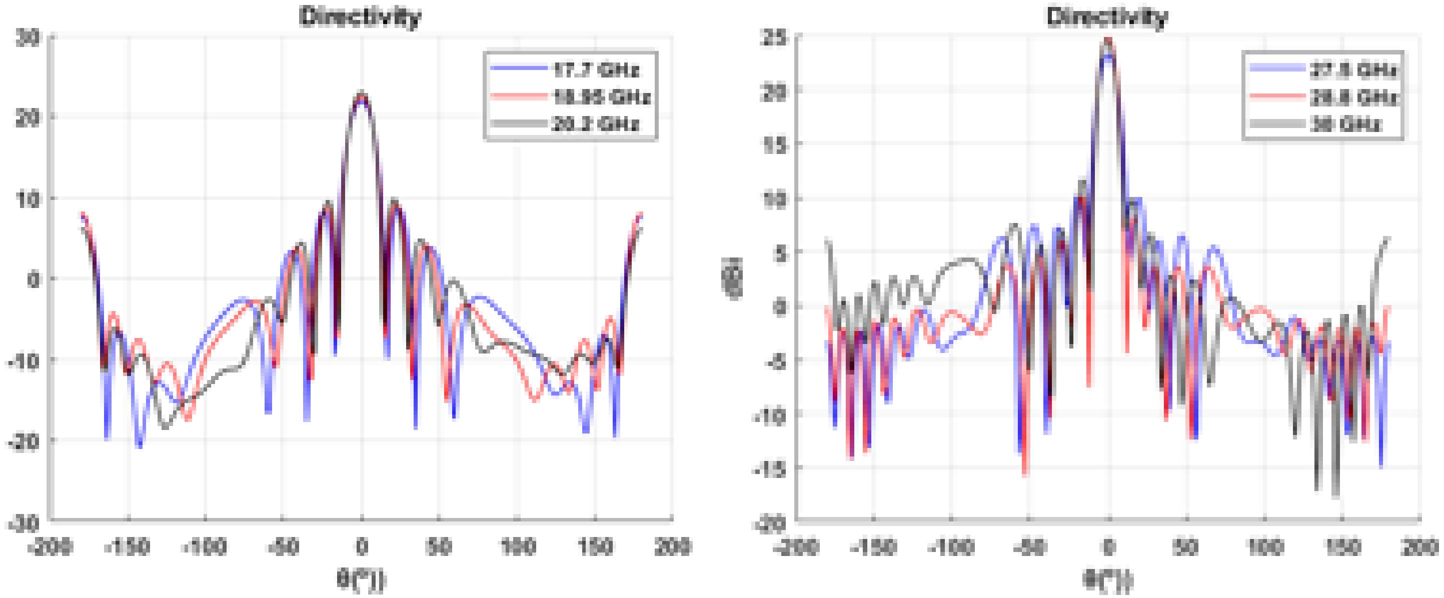
(on-going project)

Solution:

- Interlaced tx and rx antennas in the same feed aperture
- Planar antenna array technology



3. Scanning performance



4. Radiation patterns in rx and tx bands

Performance evaluation of SatCom systems

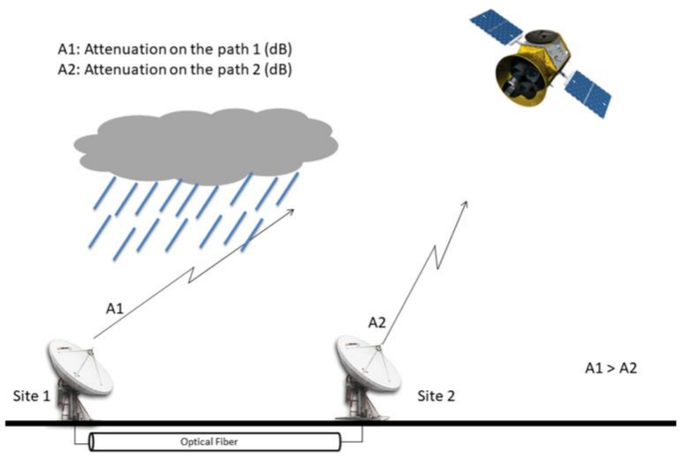
Evaluation of gateway (GW) diversity requirements to maximize wide HTS feeder link availability (PI: Prof. Ramón Martínez)

Challenges

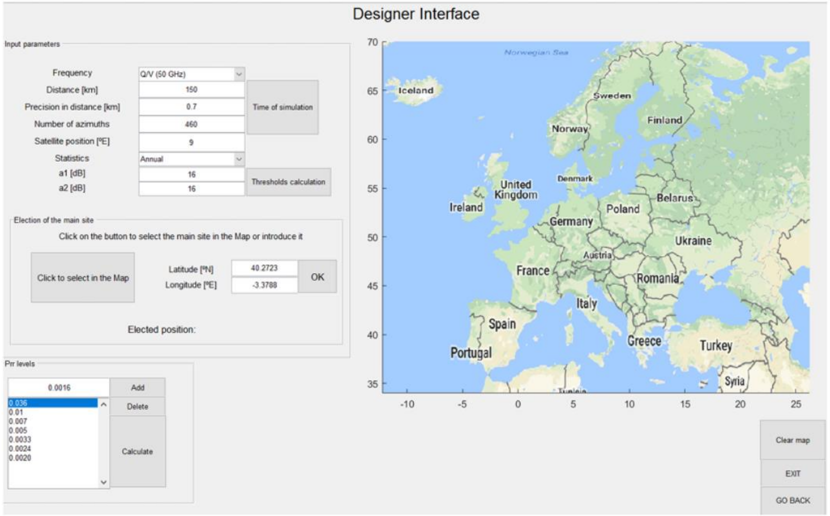
- Minimum distance between GW sites for a given availability at >40 GHz bands
- Determine the best locations around a given gateway for a given outage probability

Solution:

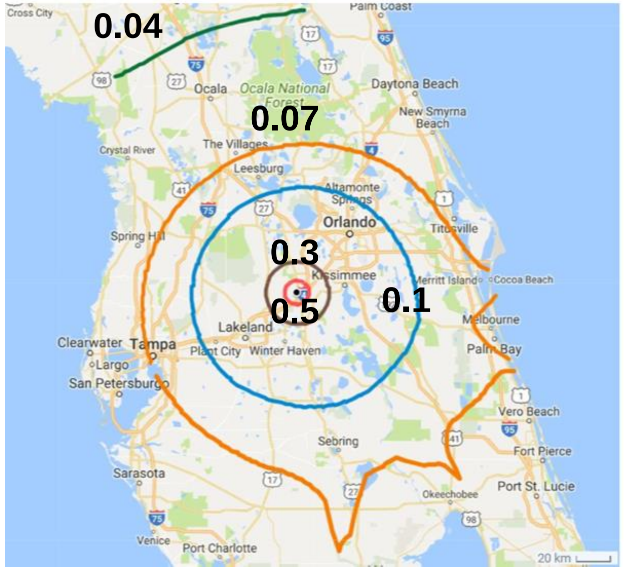
- Planning tool to obtain contour levels with candidate locations for a given availability and analysis of GW switching using rain time-series



1. GW diversity concept



2. Designer tool



3. Annual Prr (%) contour levels in Orlando in Q/V bands (61W).

Radio Resource Allocation in SatCom systems

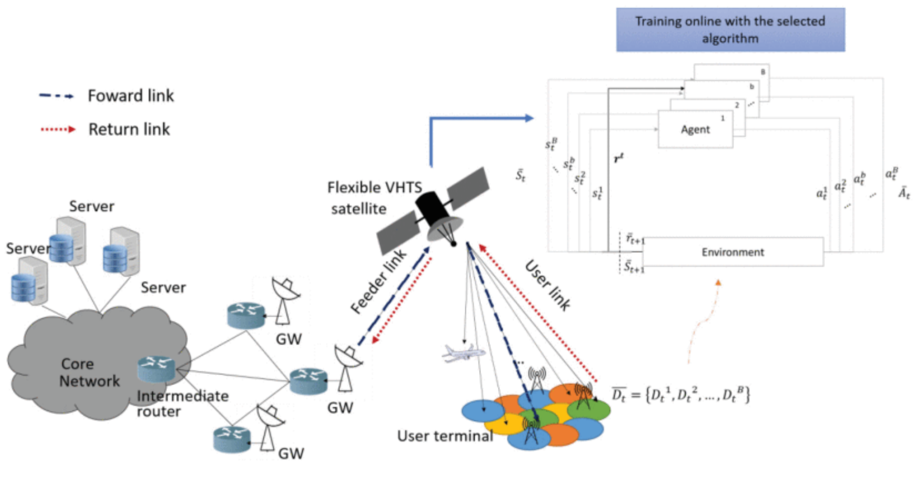
Resource management in GEO VHTS satellite systems using machine learning (PI: Prof. Ramón Martínez)

Challenges

- **Dynamically manage radio resources (power, bandwidth, beamwidth) in VHTS**
- **Propose system architecture for a practical application**

Solution:

- **Evaluation of (Deep) RL-based techniques compatible with transparent payloads**



1. System architecture

$$\min_{P_t^b, BW_t^{bc}, \theta_t^b} F_1 \rightarrow F_1 = \frac{\beta_1}{B}\sum_{b=1}^{B}|C_t^b - D_t^b| + \frac{\beta_2}{B}\sum_{b=1}^{B} EIRP_t^b + \frac{\beta_3}{B}\sum_{c=1}^{N_c}\sum_{b_c=1}^{B_c} BW_t^{b_c}$$

subject to

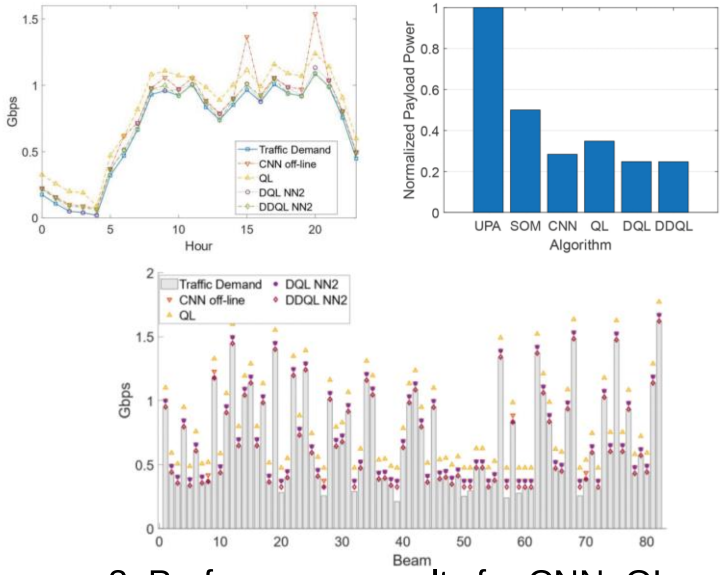
$$\begin{cases} C_t^b \geq D_t^b, & if\ P_t^b < P_{max,b}, \theta_t^b < \theta_{max} \\ & or\ BW_t^{bc} < BW_{max,b} \\ C_t^b = C_{max}, & if\ P_t^b = P_{max,b}, \theta_t^b = \theta_{max} \\ & and\ BW_t^{bc} = BW_{max,b} \end{cases}$$

$$\sum_{b=1}^{B} P_t^b \leq P_{max,S}$$

$$\sum_{b_c=1}^{B_c} BW_t^{bc} \leq BW_{max,c}$$

$$\theta_t^b \epsilon \{\theta_1, \theta_2, \ldots, \theta_{max}\}\ \forall\, b, t$$

2. Problem formulation



3. Performance results for CNN, QL, DQL and DDQL

Resource allocation with beam-hopping in LEO and VLEO satellites adapted to 5G NTN requirements (PI: Prof. Ramón Martínez)

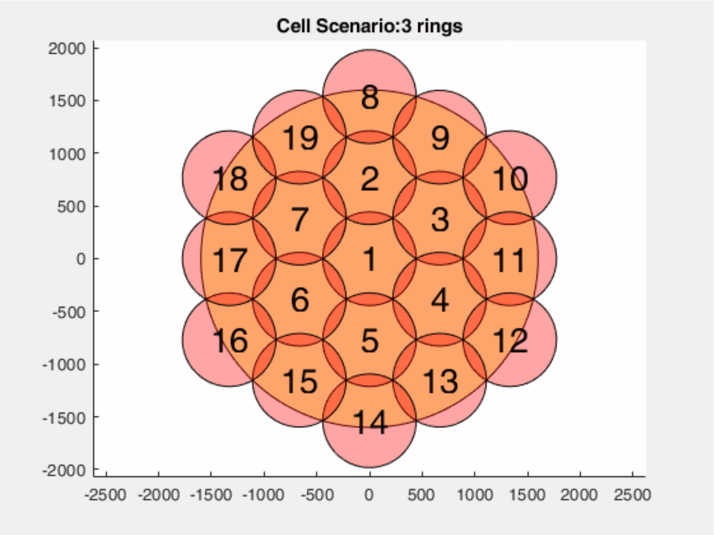
Challenges

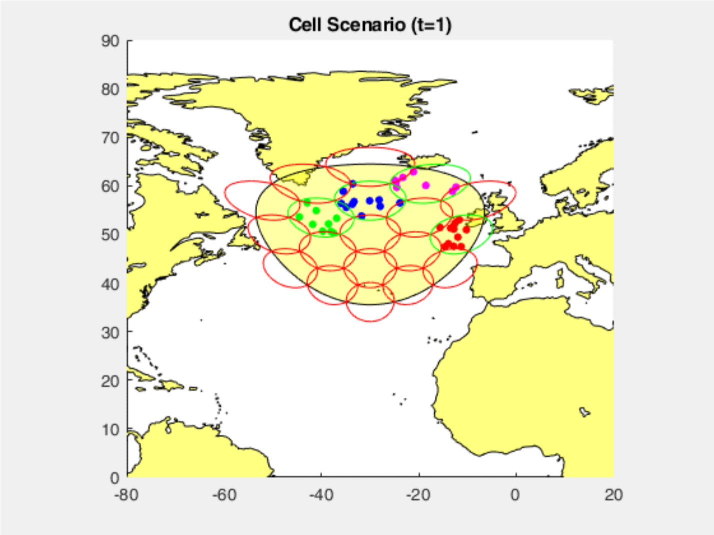
- **Fulfil 5G Non-Terrestrial Network (NTN) frame timing and link budget requirements**
- **Calculate/Optimize the resource allocation problem (illumination time, bandwidth, power)**

Beam-hopping: fast sequential illumination to areas where demand is requested using narrow beams using an antenna array with beamforming in the satellite

Traffic demand changes irregularly with time over a given service area.

- Assign comm resources (power, bandwidth) where needed, not uniformly.
- Increase of spectral efficiency thanks to frequency reuse.
- Reduction of payload requirements: ↓power, ↓mass and ↓cost .





Beam-hopping concept

Radio Resource Allocation in SatCom systems

Optimization of radio resource allocation with beam-hopping in LEO and VLEO satellites adapted to 5G NTN requirements (PI: Prof. Ramón Martínez)

Solution:

- **Architect an on-board antenna and system design**
- **Evaluate diverse approaches to evaluate beam-hopping (demand-based, GA, analytical-MILP) considering technology constraints and platform requirements**

$$\min_{[Ill],[B],[P]} \boldsymbol{\alpha} \cdot \sum_{s=1}^{\#u} \left| D_s - \left(\sum_{i=1}^{\#t} O_{s_{|i}} \right) \right| + \boldsymbol{\beta} \cdot \sum_{l=1}^{\#c} TTS_{c_j} \left(\frac{\sum_{s=1}^{\#u} [UpC]_{|(l,s)}}{\#u} \right)$$

s. t.

$$C1: \sum_{s=1}^{\#u} [P]_{(s,t)} \leq P_T, \quad \forall t \in \{1, \#t\}$$ (*max. power restriction*)

$$C2: [B]_{(:,:,t)}^{\;T} \cdot [AdjU] \cdot [B]_{(:,:,t)} \leq \#b \cdot \mathbf{1}, \quad \forall t \in \{1, \#t\}$$ (*band interf. restriction*)
as per co-cell restriction

$$C3: \left(\mathbf{1} - [Ill]_{(:,t)}\right)^T \cdot \left([UpC] \cdot [P]_{(:,t)}\right) = 0, \quad \forall t \in \{1, \#t\}$$ (*power - illumination*)

$$C4: \left(\mathbf{1} - [Ill]_{(:,t)}\right)^T \cdot \left([UpC] \cdot \left(\sum_{j=1}^{\#b} [B]_{(:,j,t)} \right) \right) = 0, \quad \forall t \in \{1, \#t\}$$ (*band - illumination*)

$$C5: \sum_{l=1}^{\#c} [Ill]_{(l,t)} \leq \#_{beams}, \quad \forall t \in \{1, \#t\}$$ (*simultaneous beams - illumination*)

Resource allocation problem model (demand-based)

Radio Resource Allocation in SatCom systems

Resource allocation with beam-hopping in LEO and VLEO satellites adapted to 5G NTN requirements (PI: Prof. Ramón Martínez)

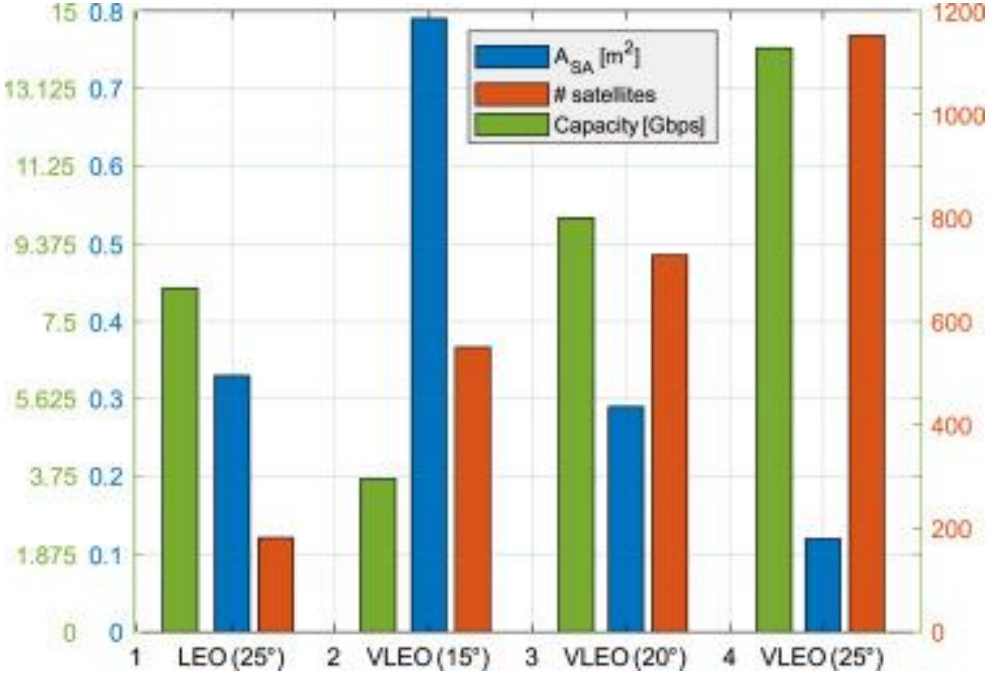
Solution:

- **Architect an on-board antenna and system design**
- **Evaluate diverse approaches to evaluate beam-hopping (demand-based, GA, analytical-MILP) considering technology constraints and platform requirements**
- **Trade-off analysis of platform, capacity, size of the constellation, cost**

POLITÉCNICA

MIT AEROASTRO

Massachusetts Institute of Technology



Results (demand-based). Impact on the power requirements of the platform (solar array), constellation size, and satellite capacity.

ETSIT UPM

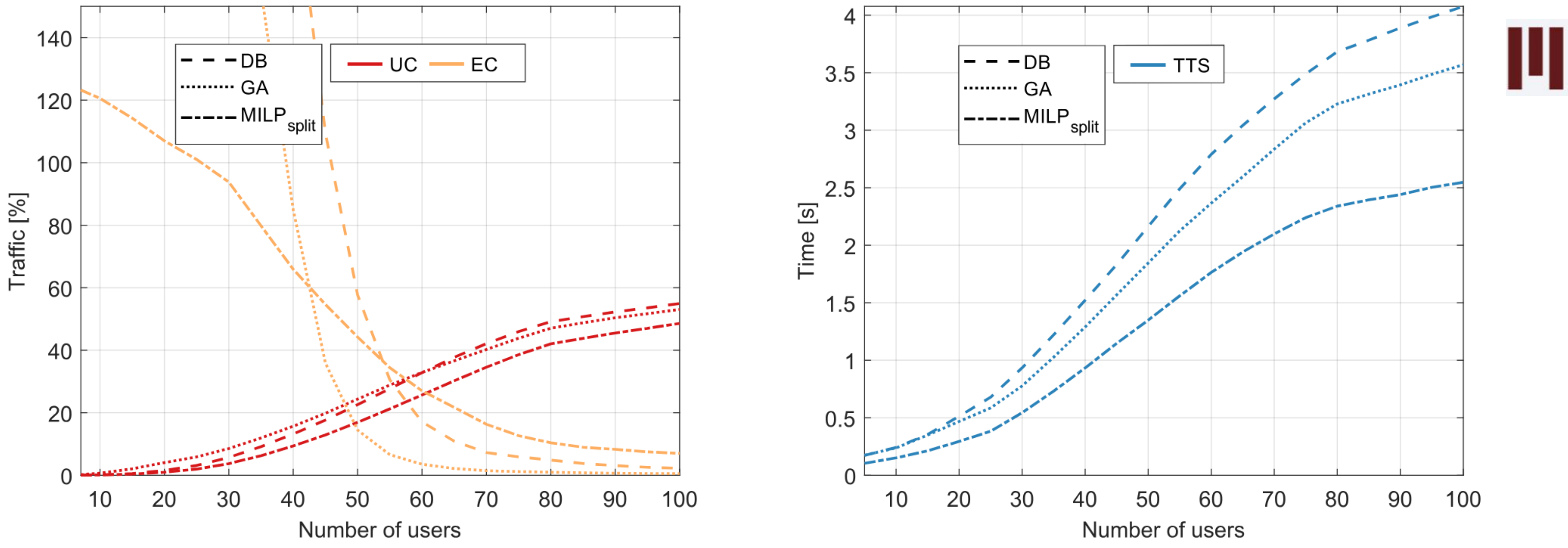
iptc Information Processing and Telecommunications Center

Radio Resource Allocation in SatCom systems

Resource allocation using beam-hopping in LEO for 5G NTN requirements (PI: Prof. Ramón Martínez)

Solution:

- **Architect an on-board antenna and system design**
- **Evaluate diverse optimization approaches to evaluate beam-hopping (demand-based, GA, analytical-MILP)**
- **Analytical solution based on MILP formulation**



Results comparison of demand-based, GA, MILP Split optimization for Unserved and Extra Traffic, and Time-to-Serve (TTS)

Radio Resource Allocation in SatCom systems

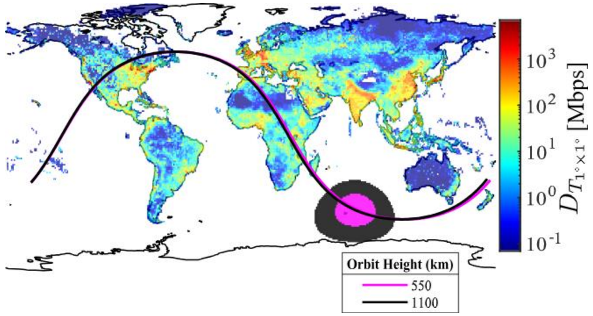
Power profile of satellite constellations for extra services such as image processing, space cloud, space edge computing (PI: Prof. Ramón Martínez)

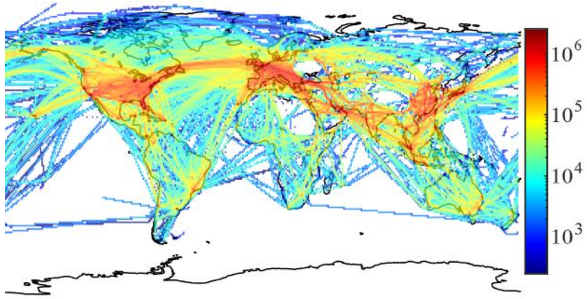
Challenges

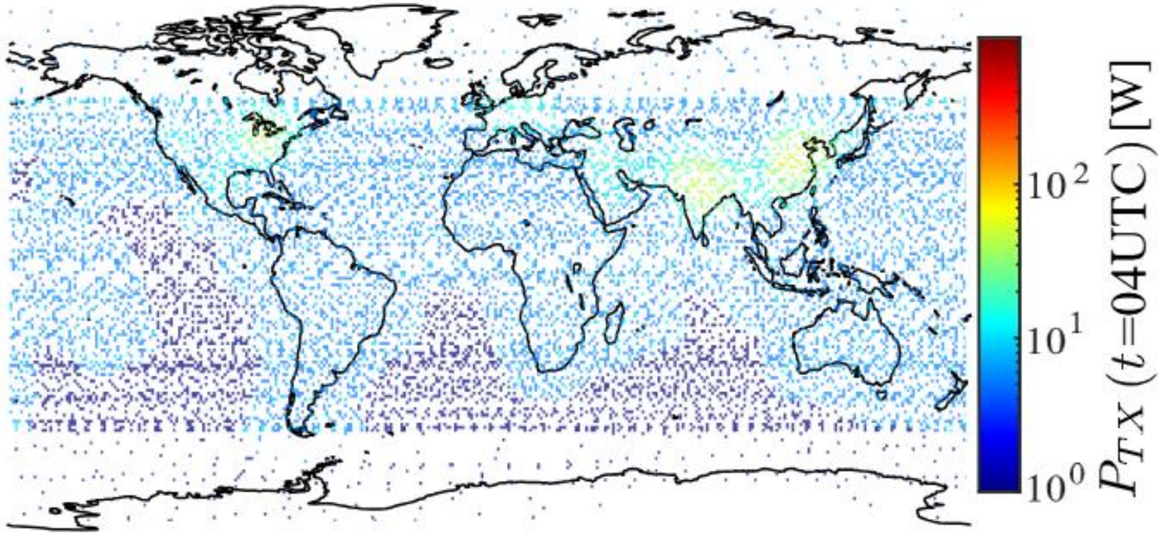
- **Understand how power is consumed on-board depending on traffic demand**
- **Novel traffic modelling considering time, area, terrestrial and aerial customers**

Solution:

- **Based on the traffic demand model, calculate the power profile of the satellite**
- **Ellaborate off-loading decisions using the power profile and the constellation as a network**





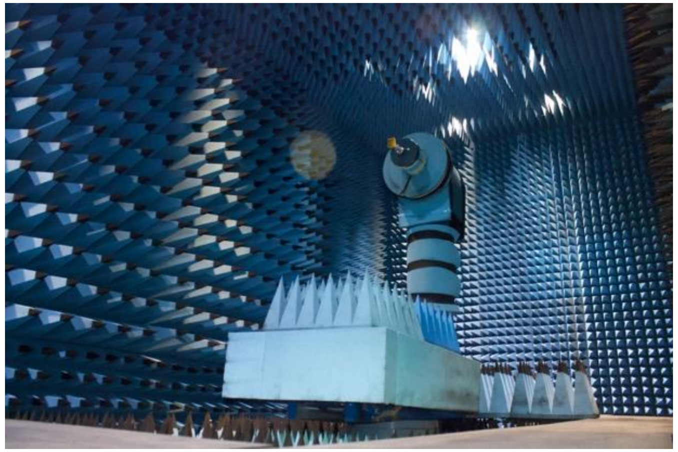


Power profile of the constellation

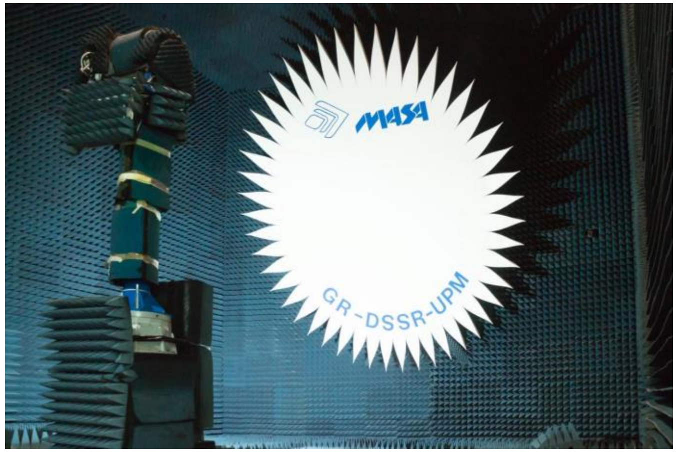
LEHA (Antenna Testing Laboratory)

GR-UPM has been working on Antenna Measurement Systems since 1980

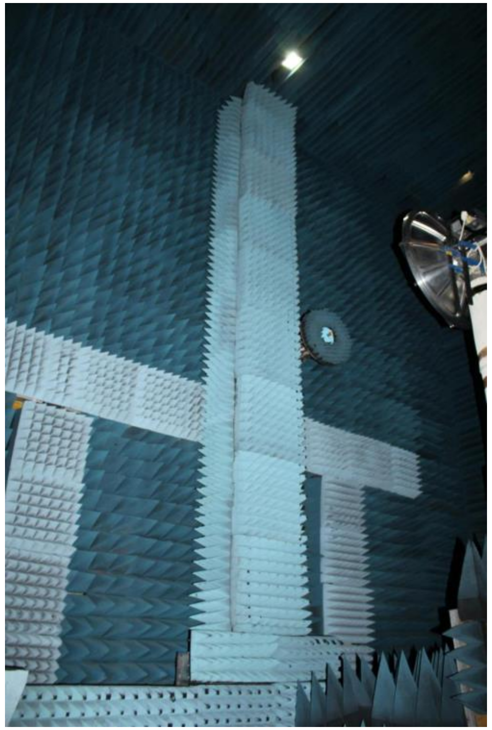
Near Field Spherical System
7.3 x 4.3 x 4.3 m, 660 MHz - 110 GHz



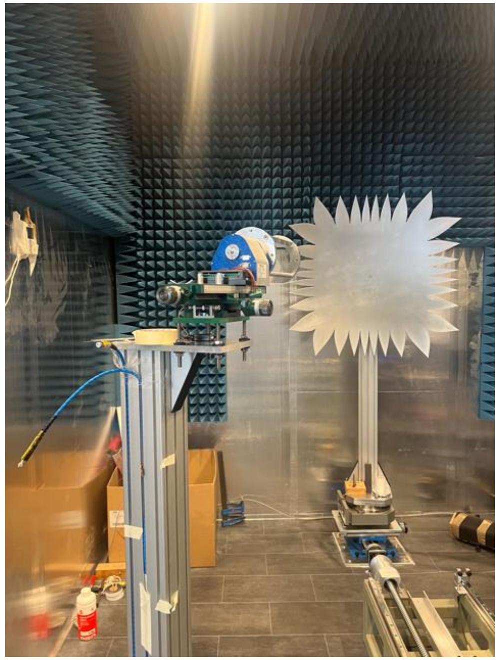
Gregorian Compact Range
15L x 8W x 7.5H m, 6 - 110 GHz



Planar system
4.75 x 4.75 m,
660 MHz - 110 GHz

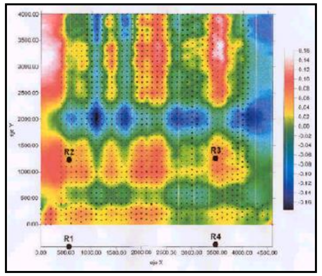


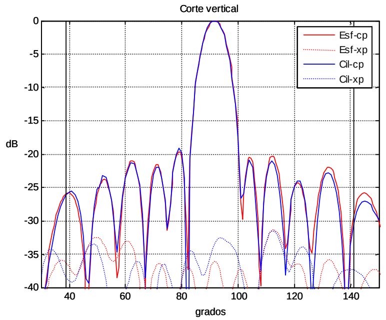
mmWave system
5.5 x 3.3 x 3.3 m
40 - 300 GHz



RF instrumentation

In-house software for near-to-far field transformation, calibration and operation





LEHA-UPM is recognised with **ISO 17025 accreditation** for antenna measurement.

ENAC
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Grupo de Radiación
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