AMTBS: NAVISP PRESENTATION

2025/07/25

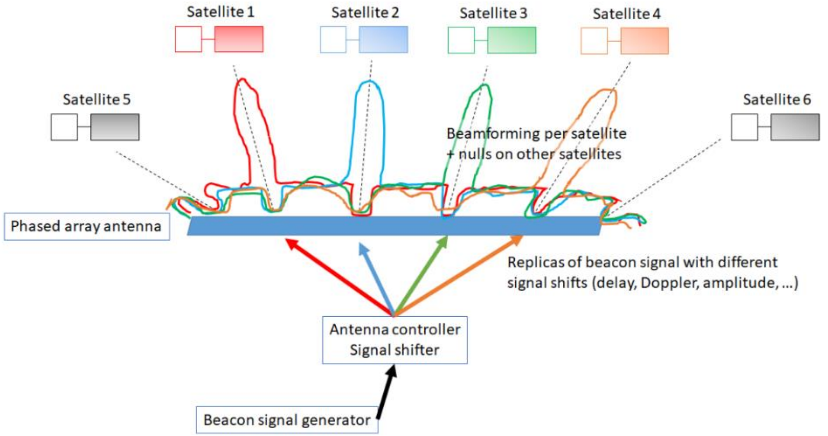
Date: 25/07/2025
Ref: xxxxx
Template: 83230347-DOC-TAS-EN-006

NAVISP EL1-070 : ADVANCED MEOSAR TEST BEACON SETUP

Main target: Develop a test beacon able to generate MEOSAR signals per satellite, in order to emulate trajectories with dynamics

Technology challenge: use Tx antenna phased-array to control multiple signals transmitted specifically to some Cospas-Sarsat satellites and not unwanted ones

KO
March 2023



FR
July 2025

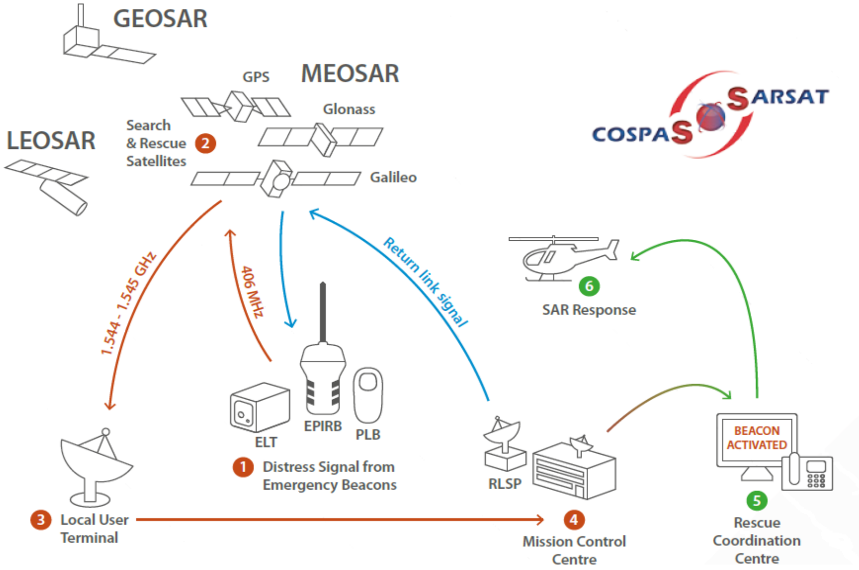
CONTEXT, OBJECTIVES

Cospas-Sarsat

/// The International Cospas-Sarsat Programme began as a joint effort of Canada, France, the United States, and the former Soviet Union in 1979.

/// The mission of the Programme is to provide accurate, timely and reliable distress alert and location data to help Search and Rescue (SAR) authorities assist persons in distress.

/// Since its start, it supported the rescue of 65000+ people, for instance 3000+ in 2023.



PARTICIPANTS	(Dec. 2023)
- Parties to the International Cospas-Sarsat Programme Agreement (ICSPA):	4
- Ground Segment Providers:	30
- User States:	9
- Ground Segment Operators:	2
Total number of Participants:	**45**

SPACE SEGMENT	(Dec. 2023)
- LEOSAR payloads (in operation):	5
- GEOSAR payloads (in operation):	10
- MEOSAR payloads (in operation):	50

GROUND SEGMENT	(Dec. 2023)
- LEO Local User Terminals (in operation):	54
- GEO Local User Terminals (in operation):	27
- MEO Local User Terminals (in operation):	26
- Mission Control Centers (MCCs) :	32

406 MHz BEACON POPULATION	(Dec. 2023)
- Registered:	2,390,000
- Estimated (registration-rate method):	3,170,000
- Estimated (production/replacement method):	2,190,000

Cospas-Sarsat MEOSAR history

/// The system was mainly relying on LEOSAR until late 2010’s, bethanks to:

- Independent localization capability (multi-burst FDOA location)
- Global coverage

/// It was completed by GEOSAR to reduce latency in covered areas, but loosing the independent location and the global coverage, and with a degraded sensitivity.

/// Since the 2000’s, the transition to MEOSAR was initiated, combining advantages of both systems:

- Global coverage (if enough MEOLUT can receive the signals)
- Independent localization
- Low-latency

/// MEOSAR relies on secondary payloads on GNSS constellations, ensuring a long-term service continuity.

/// MEOSAR payloads are transparent, allowing better evolutivity (but requiring enough MEOLUT for global coverage).

22/07/2025 extract

	Active	Under test
LEOSAR	3	2
MEOSAR (GAL)	27	0
MEOSAR (GPS) (*)	21	0
MEOSAR (GLO)	2	2
MEOSAR (BDS) (**)	6	0
GEOSAR	13	2

(*) for GPS, initial version not fully compliant to C/S reqs
(**) for BDS, available for ground testing

MEOSAR EoC (usable for rescue operations): December 2016

MEOSAR FoC (LEOSAR decommissioning): planned in 2025, pending global MEOLUT coverage.

Cospas-Sarsat MEOSAR and moving beacons

/// Why a focus on moving-beacons in MEOSAR ?

- ➔ Shortly after EoC, the operators noticed a degradation of performances for moving beacons (at sea). The results were aligned on LEOSAR ones while on land the performances were around 3 times better.
  - The MEOSAR satellite motion is much smaller than the LEOSAR ones, so the contribution of beacon motion on Doppler is higher
  - The MEOSAR location being in general better than the LEOSAR one, the loss due to beacon motion appears more easily
  - Independent positioning comes with an estimation of the error, whilch was optimistic for the moving cases

  - ➔ It appeared that the MEOLUTs had not been properly specified and tested for moving beacon cases.
  - This resulted in urgent activities on the specification, upgrade and test of the MEOLUTs, concluded by updates from 2020 (starting with European MEOLUTs) under IoC commissioning, covering the range from 0 to 5 m/s.
  - 3 means are identified for testing the robustness to beacon motion in the MEOLUTs:
    - Turnstyle mechanism
    - Drones
    - Cars
    - Actual vessels
    - Drifting buoys
    - ➔ However they go with their drawbacks

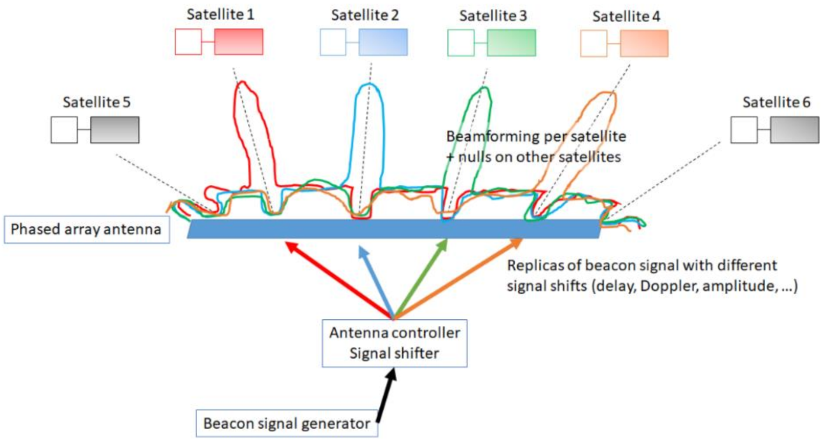
Main limitations of existing means: lack of average motion, lack of vertical motion, unwanted acceleration, lack of control on the instantaneous motion, limitations in test duration, cost, evaluation wrt MEOLUT distance, ...

- ➔ Following several major distress events on aircrafts (MH870, MS804, …), ICAO and C/S put a focus on the capability to at least detect and if possible localize distress beacons activated in flight (ELT(DT)). As per today, the global service for detection is provided, but the localization capbility is pending identification of test means.
- In addition, C/S includes a continuous Quality Monitoring System (QMS), which should also verify the behaviour of the system for the full range of specification, then including moving beacons.

The solution ➔ AMTBS

- The objective of AMTBS is to be able to transmit a defined signal per satellite, and not omnidirectionally.
- Each signal can then be shifted in transmission time and transmission frequency to emulate a different propagation delay and Doppler per satellite uplink, making sure that the echo is not received on other satellites (or it would create unconsistent TOAs and FOAs).
- The independant location, based on DTOA/DFOA, will then not report the actual transmitter location, but the shifted one, affected by the various impairments.
- The satellites, MEOLUTs and MCCs work exactly as if the beacon was actually moving: compatible with test requirements.

The system can also allow to generate other differences per satellite, such as acceleration, masking, errors in the message content to verify the decoding performances. It then allows to cover other use-cases, such as satellite sensitivity test to power sharing losses (without disturbing the others), management of alert dissemination within the operational system, …



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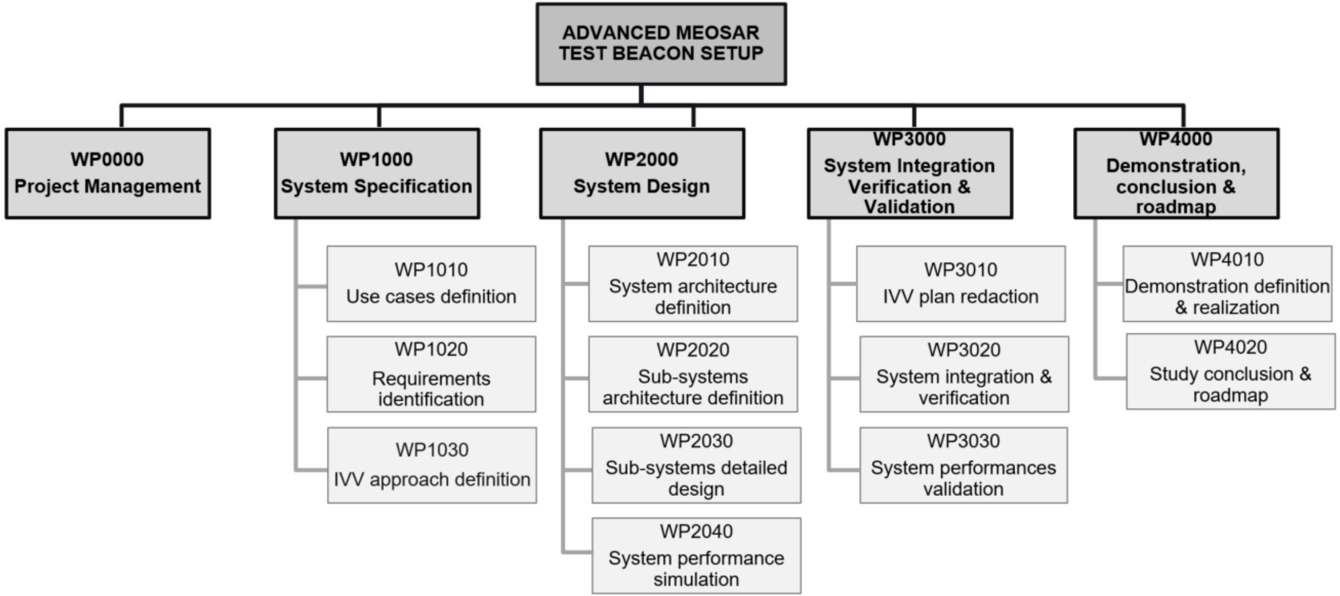
ACTIVITY

Work Logic



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Technical challenges

Reason	Challenges
Tx frequency = 406 MHz	1) Large elements, significant mecanical constraints 2) Need to long-range tests (no anechoid room)
Tx DBFN	3) Need to properly calibrate Tx chains to be sure of the transmission level, **including to transmit at nominal power to the actual satellites** 4) Need to minimize antenna coupling
Number of satellites in view	5) Need to cancel the signal in the direction of all other satellites (up to 15) : high constraints on the array design

Not a challenge:

- Tx power: only 5W per beam

This allows to oversize the maximum power to better balance the cancellation capability, including with possible degradation of the main beam.

- Tx bandwidth: only 100 kHz

- Signal shift generation: only SW and based on reuse of MEOLUT tools

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SYSTEM DESIGN: SW FOR PERFORMANCE EVALUATION

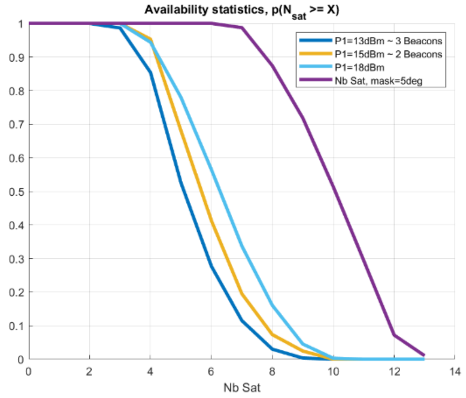
/// Inputs

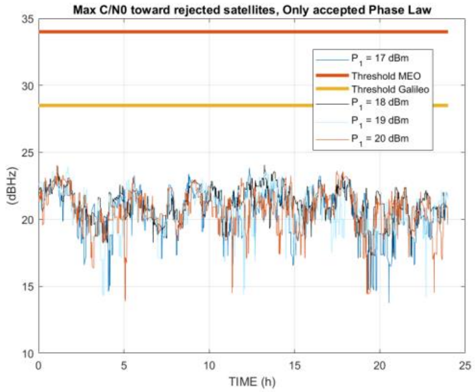
- Satellite constellation (LEO, MEO, GEO …) and processing time (24h, with 30s steps)
- ECEF positions of the antenna array and emulated beacon
- System model
  - Antenna array structure
  - Satellites elevation mask
  - Simulated antenna diagram
  - Broadcast power per channels
  - KPI Threshold
  - System defaults model (residual calibration error of amplitude and phase dispersion)
  - System integrity paramerters (maximum power per channels, total max power …)

/// Main

- Orbit propagation
- Phase laws estimation
- KPI estimation

/// Outputs: KPI statistics





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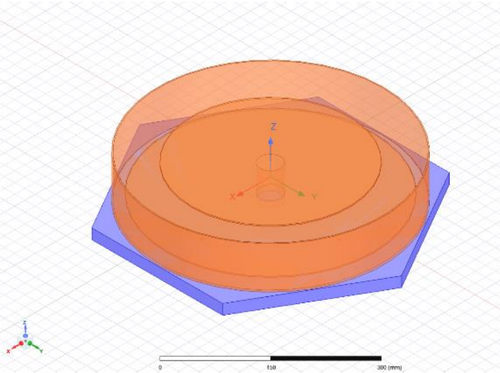
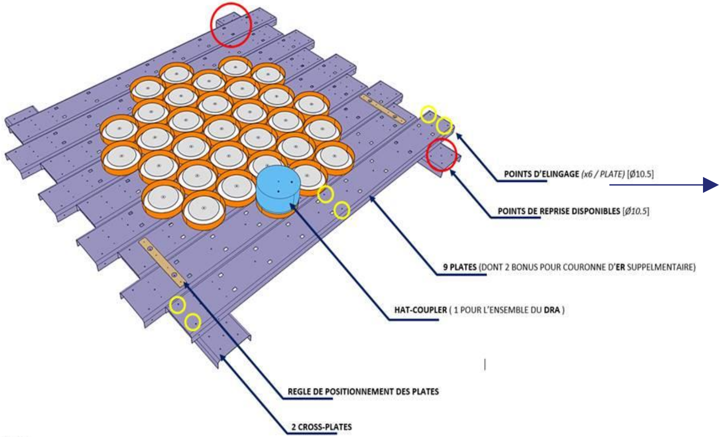
SYSTEM DESIGN: ANTENNA ARRAY

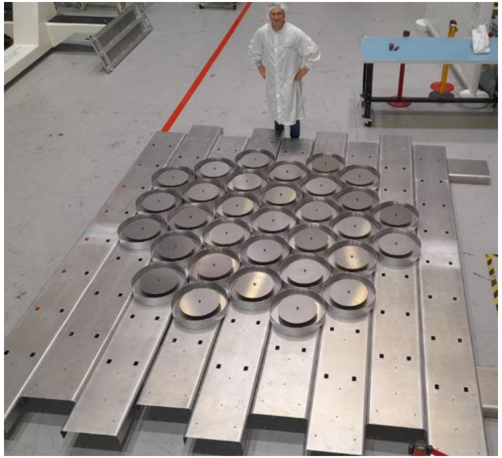
/// Proposed antenna: planar arrays with 32 RE

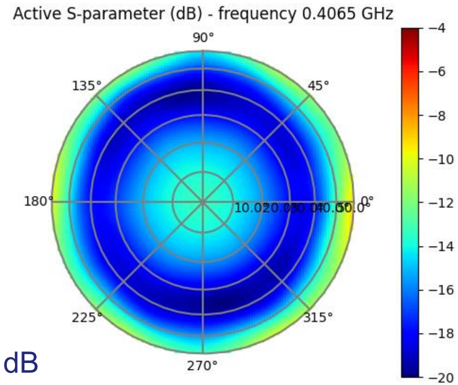
Main figures: 16m², 500 kg
Modular structure

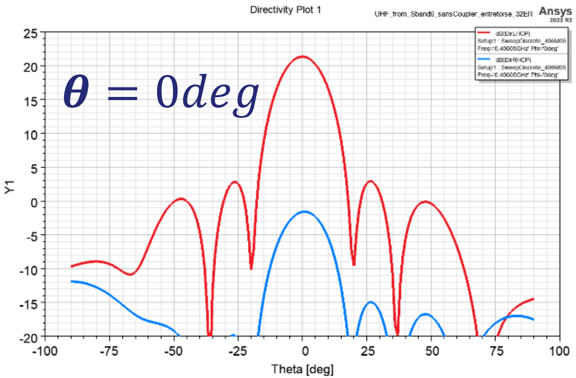
- Easy to move as each blades can carried manually
- RE can be easely added on the structure (for possible future extension)

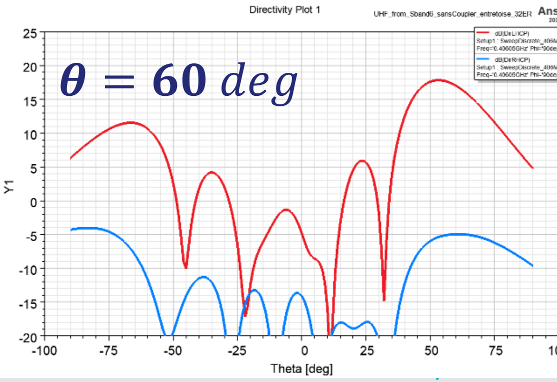










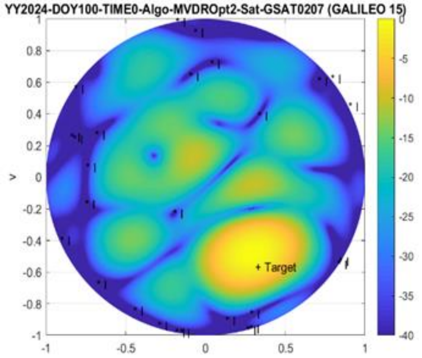


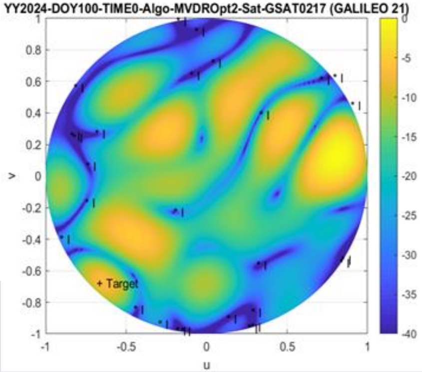
Worst case = -10 dB
Mean = -15 dB

SYSTEM DESIGN

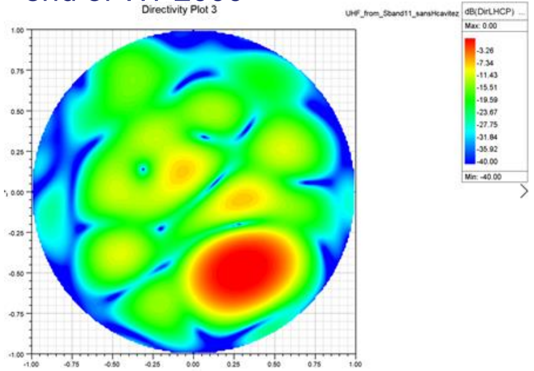
/// Accurate knowledge of the antenna diagram with coupling is necessary

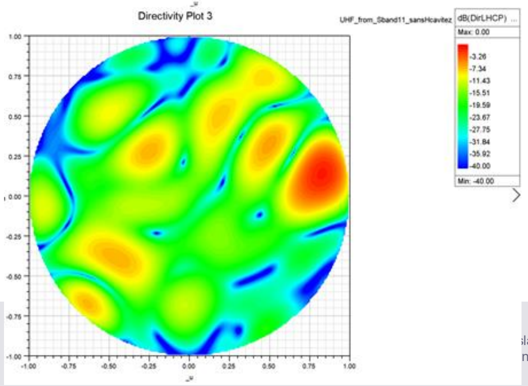
Directivity with preliminary diagram without coupling (begin of WP2000)

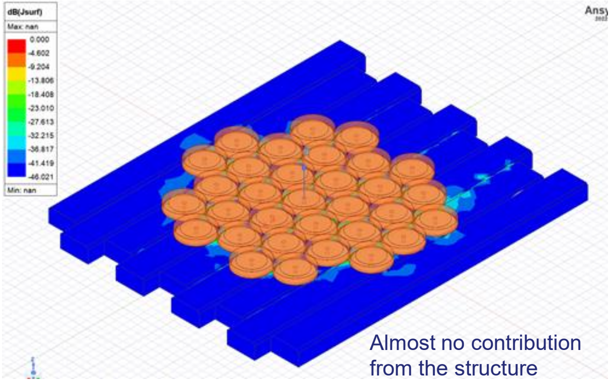




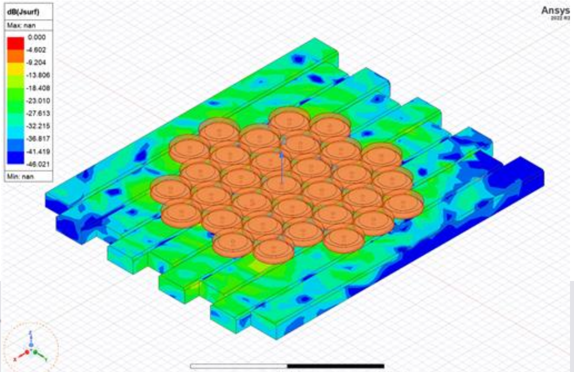
Directivity with coupling (structure and between RE), end of WP2000







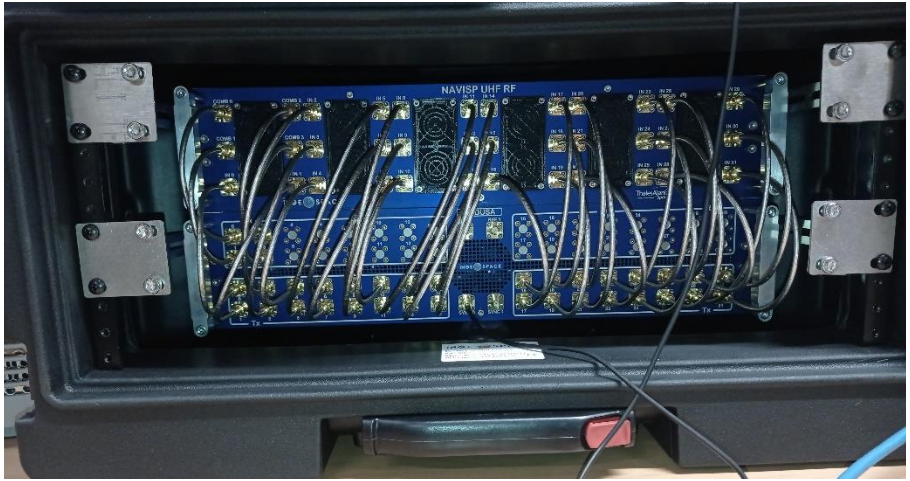
Elevation = 49 deg



Elevation = 15 deg

SYSTEM DESIGN: SDR CARD AND RF CHAINS

/// SDR card and RF chains developped in collaboration with IngeSpace



Front view

Back view

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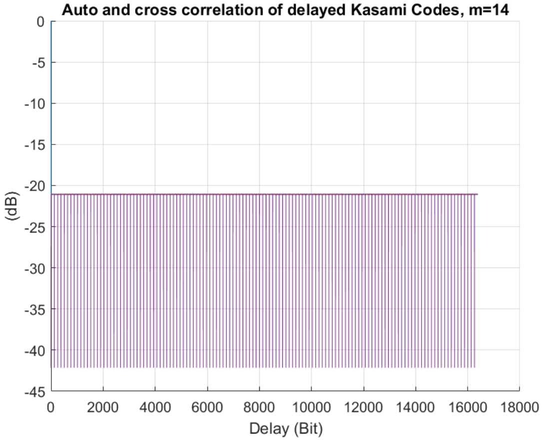
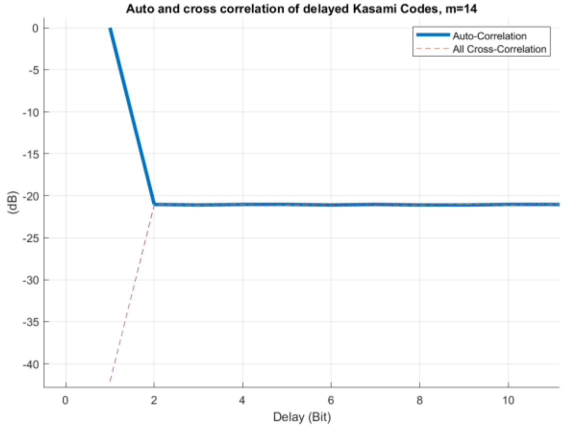
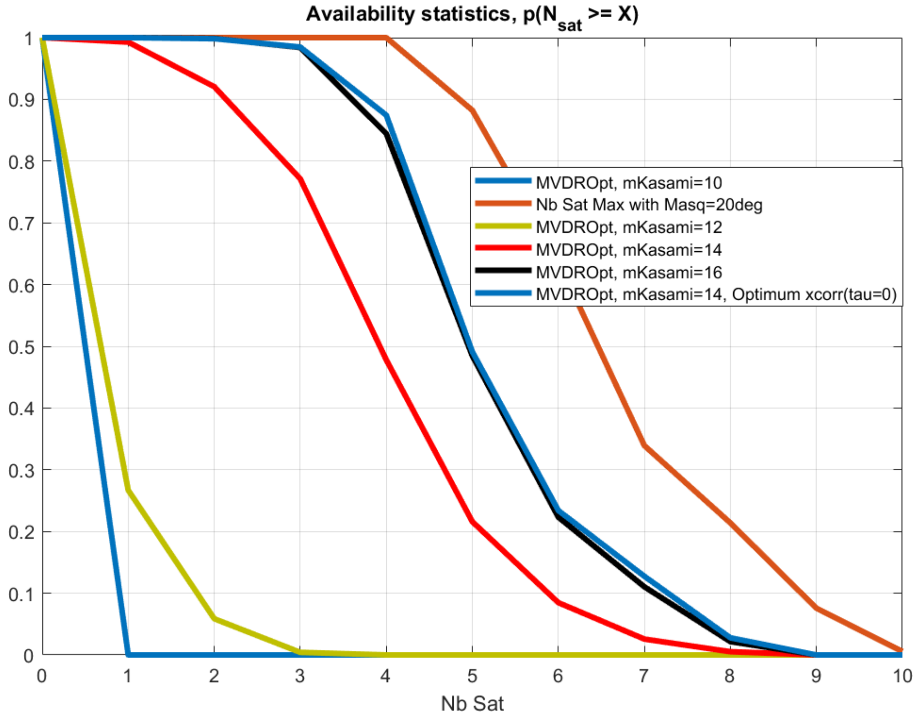
SYSTEM DESIGN: Calibration algorithms

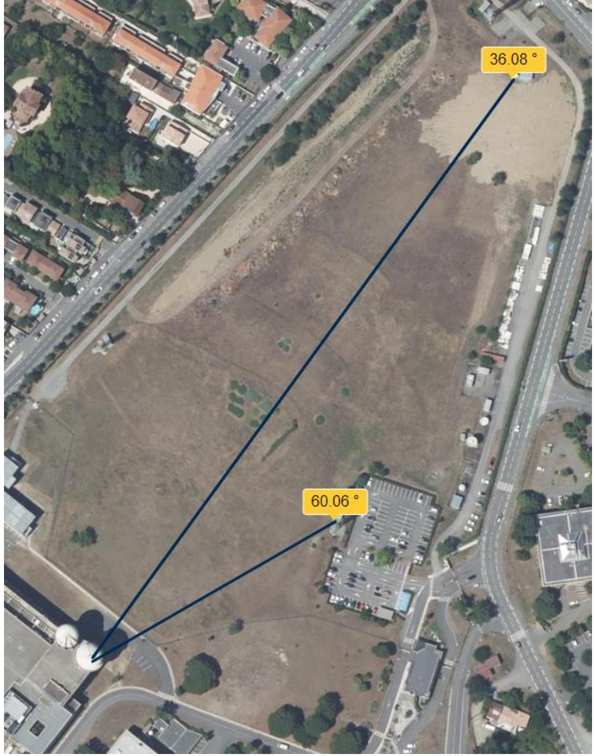
- Use shifted Kasami codes for minimum cross correlation in 0, and optimum amplitude and phase detection (one Kasami code per channels)







ANTENNA ARRAY TEST

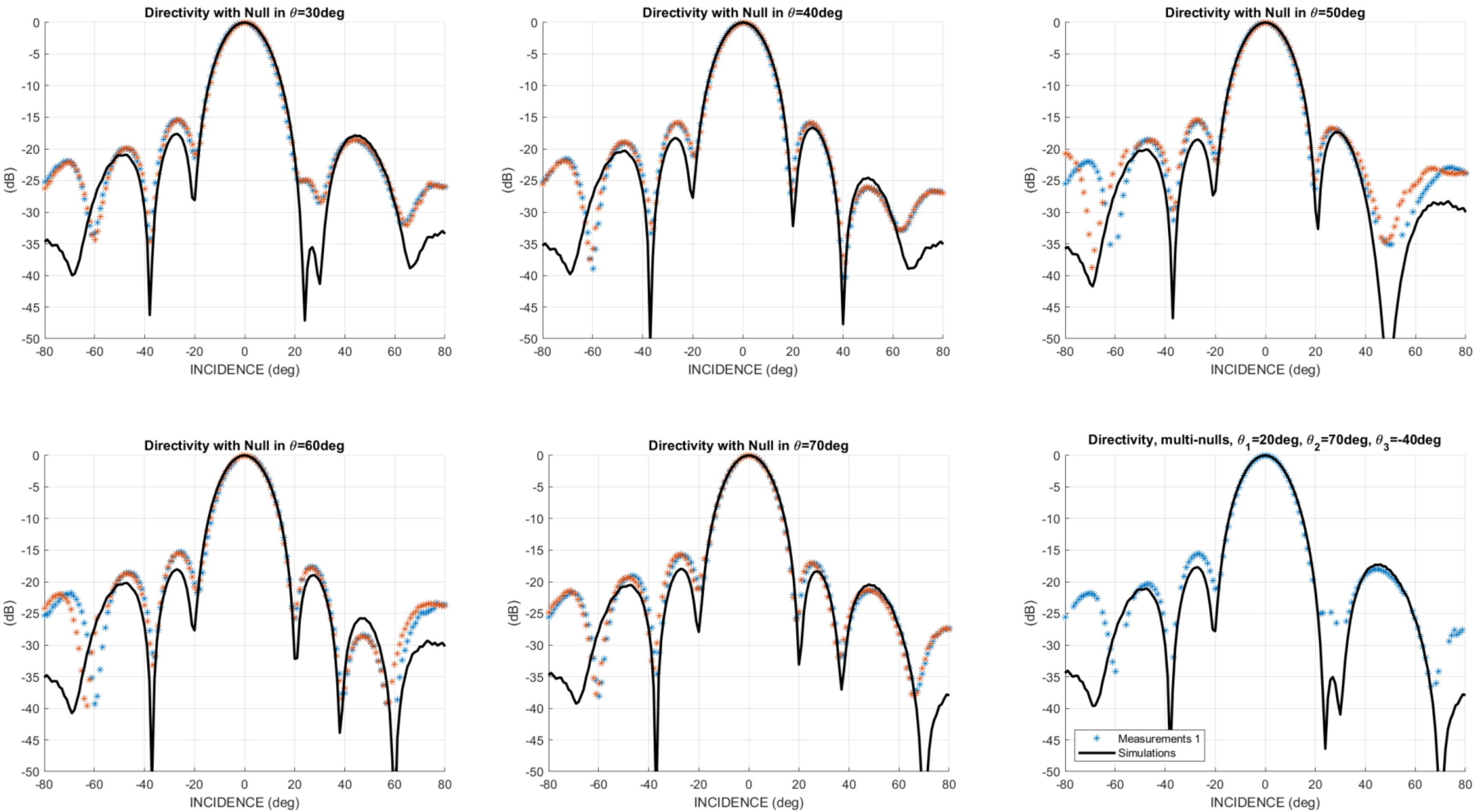


/// Far field propagation

/// Due to mechanical constraint → **Only 2D scan**

	Mast 3
Default Azimut / Elevation	60.23 deg / 0 deg
Radom / Mast range	150 m
Received Power at SDR level	-78.3 dBm

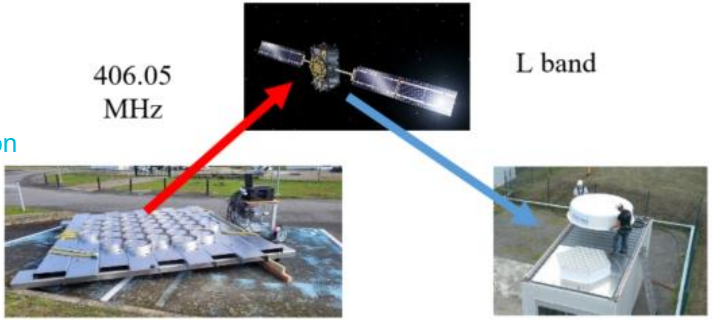
DIAGRAM VALIDATION



END TO END TESTS

/// Principle

- AMTBS broadcast toward GALILEO satellite only (nulling other GNSS and no transmission during LEO passes)
- Evaluate detection and localisation performances based on data from several MEOLUTs



/// AMTBS set ups

- Located in TAS-F: 43.54695 deg, 1.39012deg, 150 m
- “Manually” aligned with the North, East, Down (NED) frame with an attitude accuracy of 2, 3 degrees

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END TO END TESTS

Scenario	UTC
FGB, One satellite tracking	2025/03/25 8h58:30 – 50s – 9h30:40 ; 2025/03/27 12h21:30 – 50s – 12h39:20
FGB, Static $P_{beacon} = P_{AMTBS}$	2025/03/27 8h02:30 – 50s – 8h08:20
FGB, Static $P_{beacon} \neq P_{AMTBS}$	2025/03/27 8h10:00 – 50s – 8h28:20
SGB, Static $P_{beacon} = P_{AMTBS}$	2025/3/27, 14h30:0 – 50s – 14h48:20
SGB, Static $P_{beacon} \neq P_{AMTBS}$	2025/3/27,11h25:0 – 50s - 11h43:20
FGB, Slow motion	2025/3/27, 13h30 – 50s – 11h41:20
SGB, Slow motion	2025/3/27, 14h50:0 – 50s – 15h6:20
Fast Motion	2025/3/27, 9h40;0 – 50s – 10h00:20
Strong acceleration	2025/3/27, 10h02;0 – 50s – 10h20:20

/// Main results:

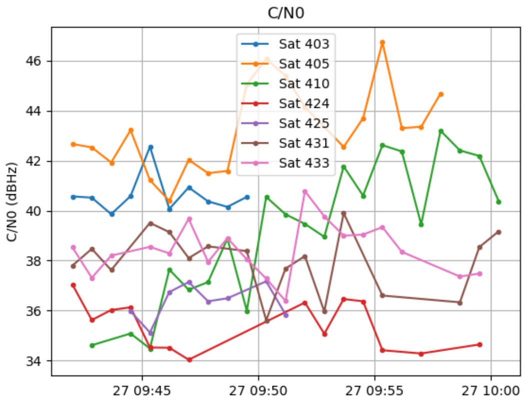
- Detection rate and localization accuracy in line with objectives
- Very good results on Fast motion and Strong acceleration tests

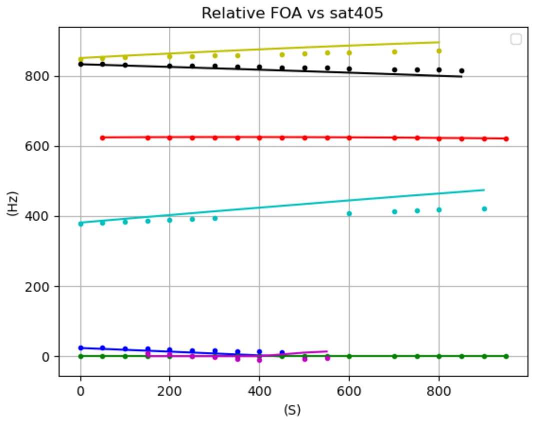
AMTBS concept for MEOSAR transmission control is successful !

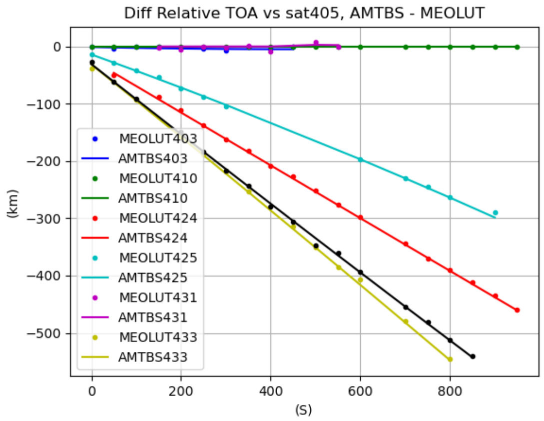
/// Several minor anomalies:

- One tuning algorithm anomaly on the case of GPS/GAL alignment in sky
- A SW error on the FOA shift generation (impact on one satellite)
- A 2° attitude error on the array leading to unperfect beamforming when satellites are closed
- Stronger impact of multipath than expected (C/N0 variation over time)

FGB FAST MOVING TEST







- ➔ Mean C/N0 = 40 dBHz for a target of 42 dBHz
- ➔ 80% of burst well detected
- ➔ The emulated FOA and TOA by AMTBS match with the MEOLUT FOA and TOA
- ➔ Until 7 satellites detected

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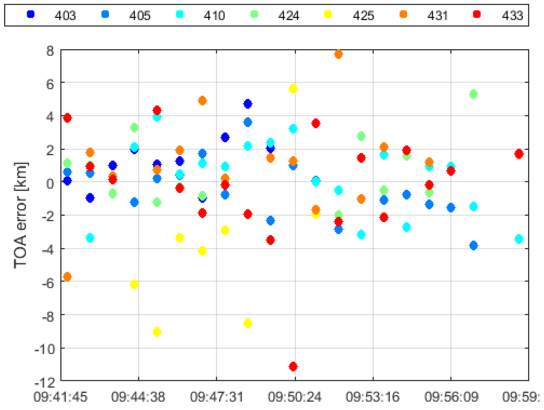
FGB FAST MOVING TEST, LOC PERFORMANCE (FROM CNES)

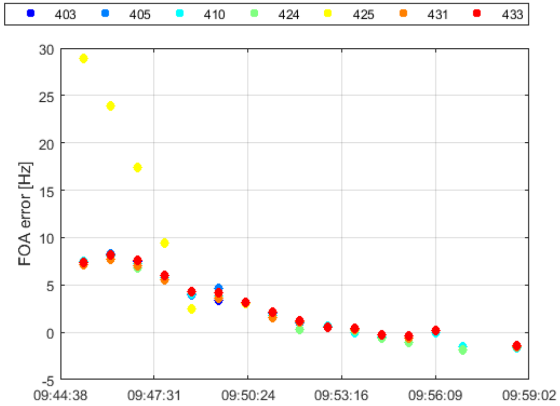
/// 4 localisations method tested: T 2D, T 3D, V 3D, V Hybrid

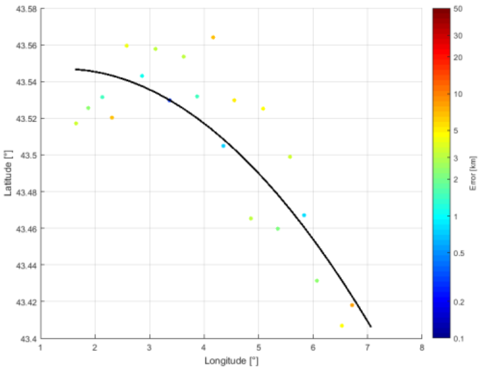
/// Data from CNES MEOLUT

/// Results:

- TOA and FOA ok, excepte for FOA on one satellite (425) due to a SW error in the Doppler shift calculation → AMTBS issue as observed also on MEOLUT Europe







Loc method	Nb used Burst (with and without 425 sat)	Error @95% (with and without 425 sat)
T 2D	21 / 21	7.15 km / 8.40 km
T 3D	17 / 17	24.8 km / 21.6 km
V 3D	17 / 18	99.96 km / 21.6 km*
V Hybrid	17 / 18	99.96 km / **10.4 km***

***Speed estimation error < 5 m/s**

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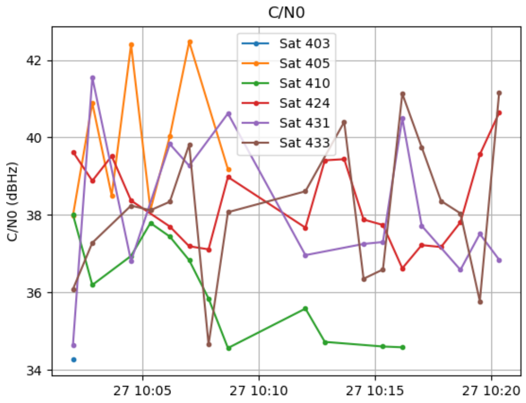
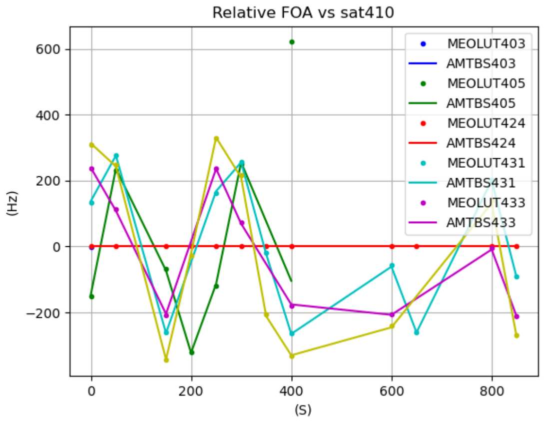
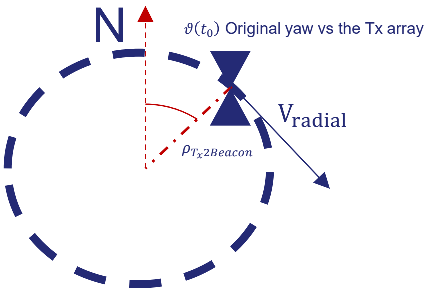
ThalesAlenia Space
a Thales / Leonardo company

FGB STRONG ACCELERATION (CIRCULAR TRAJECTORY)







$$\boldsymbol{P}_{beacon}(t) = \boldsymbol{P}_{AMTBS} + \rho \boldsymbol{u}(t)$$
$$\dot{\boldsymbol{P}}_{beacon}(t) = \rho\dot{\theta}\boldsymbol{v}(t)$$
$$\ddot{\boldsymbol{P}}_{beacon} = -\rho\dot{\theta}^2\boldsymbol{u}(t)$$

With $\rho = 20km$, $\|\ddot{\boldsymbol{P}}_{beacon}\| = 20m/s^2$

- ➔ Mean C/N0 = 39 dBHz for a target of 42 dBHz
- ➔ 80% of burst well detected
- ➔ The emulated FOA by AMTBS match with the MEOLUT FOA
- ➔ Generated Doppler drift by AMTBS fit with the estimated ones based on the MEOLUT I/Q (Figure 35), which validates the implementation

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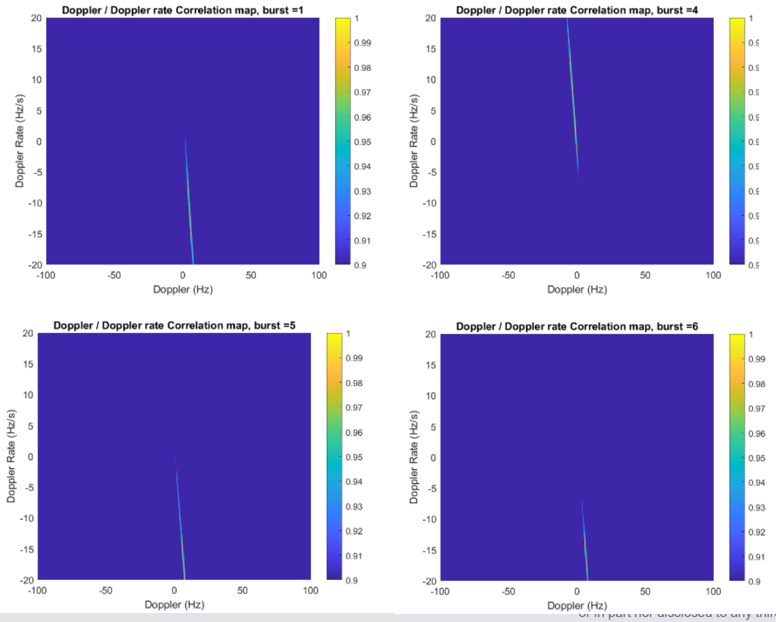
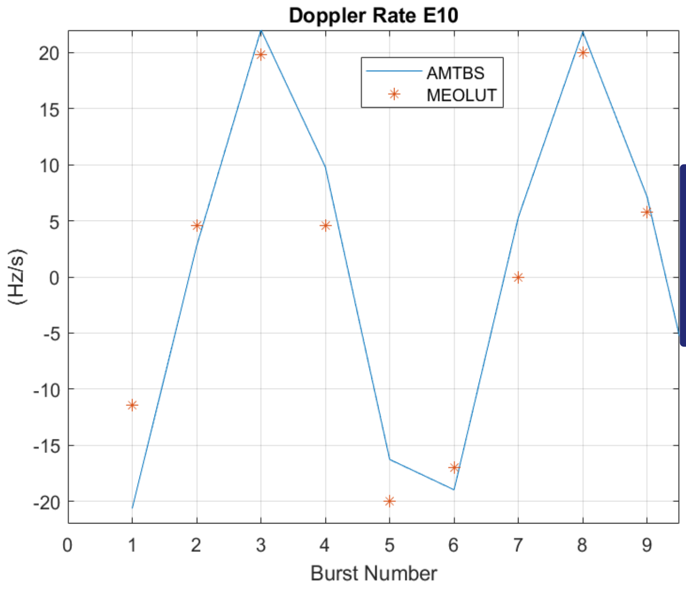
FGB STRONG ACCELERATION (I/Q DATA ANALYSIS)

/// Search acceleration pattern in raw I/Q samples

$$\tilde{r}(t,f,\dot{f}) = \int_{t}^{t+T_{int}} \tilde{s}_k(u)\, c_{FGB,ref}(u)^* \exp\left(-j2\pi\left(fu + \frac{1}{2}\dot{f}u^2\right)\right) du$$





Generated Doppler drift by AMTBS fitq with the estimated ones based on the MEOLUT I/Q

CONCLUSION

CONCLUSIONS

AMTBS works

- Good match between the generated TOA/FOA by AMTBS, and estimated ones by the MEOLUT
- Allows to emulate position changes and motion without changes on the MEOLUT processing
- Position error in line with Cospas/Sarsat expectations

AMTBS can emulate trajectory with very high dynamics

- Scenarios with V = 400m/s and a = 20m/s² tested

  ➔ Unlocks Cospas/Sarsat capacity to introduce requirements and tests for these cases

AMTBS was presented to Cospas-Sarsat through an information paper in May 2025, which received very positive feedback.

NEXT STEPS

AMTBS product

- Moves toward an industrial solution to get a Cospas-Sarsat product, providing testing capabilities to various countries, including QMS
- Priorities in details:
  - add a radome and optimize HW mechanical integration to drastically improve usability of the system
  - extend to 64 elements to reach better availability and anticipate additional satellites in view

DBFN Tx technology

- AMTBS has been built on a 10-year+ heritage on DBFN technology for low-band (C or lower) low-bandwidth (10 MHz or lower) applications, initiated with the MEOLUT (Rx DBFN, 64 elements, 2013), continued with MUAD GSTP (Tx DBFN PoC, 16 elements, 2019) and AWS (Rx DBFN, 256 elements, 2021). It is a new contributor to the development of the technology for ground-to-space applications.

Special thanks to:

ESA team: Aram Vroom, Elisa Galetti, Eric Bouton
CNES team: Yoan Gregoire, Didier Delcuvellerie
Ingespace team
Thales Alenia Space antenna and HW integration team