Design of Retro-Directive Calibration Target Antenna for bi(multi) static SAR mission: the Harmony case

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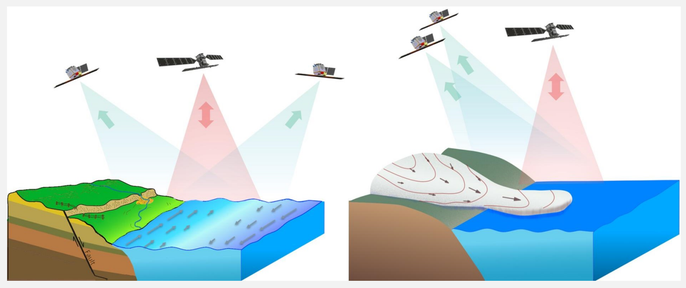
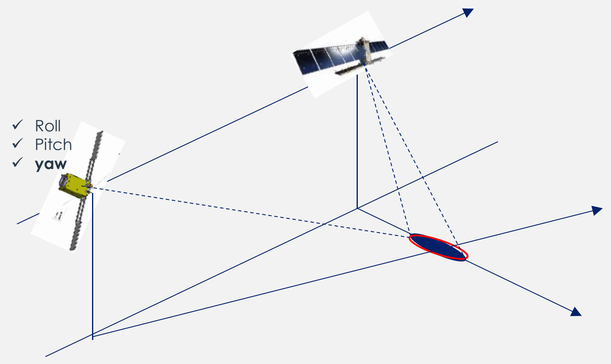
HARMONY is the next Earth Explorer 10 Mission:

- **the along track bistatic phase** (left), where the two passive SARs fly ahead and after the S-1 at a large along track distance in the range 250-400 km;
- **the across track bistatic phase** (right), where the two HARMONYs fly on the same side of S-1, with in addition, an across track displacement.





The highly bistatic acquisition geometry envisaged for HARMONY brings specific requirements from the **SAR calibration** point of view.

- for the purpose of performance optimization, the HARMONYs perform the SAR acquisition with a specific **attitude** law, including three rotations.

Coherent Active Transponder

SAR CAT solution designed by ARESYS combines all the current state -of-the-art SAR transponder functionalities with advanced new features.

SAR Calibration
Constant RCS
Localization
IRF

Achieved by Passive Calibrators

SAR TX Antenna
Pattern Characterization

Achieved by *digiRad*

SAR RX Antenna
Pattern Characterization

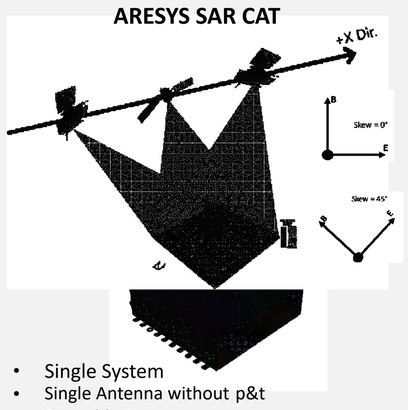
Achieved by Radar beacon generator

Polarimetry
Polarimetric Antenna Calibration

Achieved by multiple mechanically moved antennas

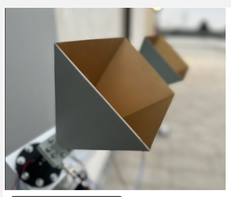
The resulting SAR CAT system has compact size and makes it for easier use.

ARESYS SAR CAT



- Single System
- Single Antenna without p&t
- Steerable Beam
- Electronic Polarization Skew
- Digital Computational Power of SmarT
- Adds *echoRad* Capabilities for Synthetic Scene Retransmission

CAT overview

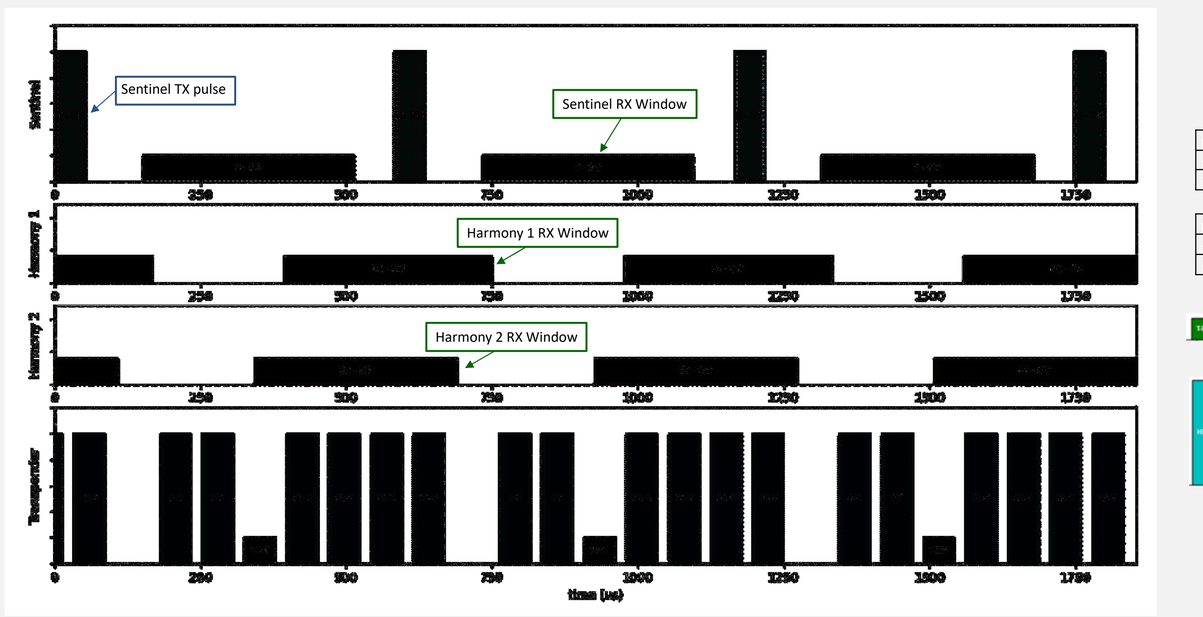


➔ Equivalent CAT RCS is given by the ratio between EIRP and incident Power Density

CAT operative modes

	Transponder operative mode			
	Mode 1	**Mode 2**	**Mode 3**	**Mode 4**
	Receiver Mode	**Active Transponder Mode**	**Beacon Mode**	**S1 mimicking Mode**
Objectives/usage	1. TX antenna pattern characterization	1. Calibration constant 2. Localization 3. IRF	1. RX antenna pattern characterization from RGC data	1. As for Mode 2 + the possibility of synthesizing the retro tx signal
Premission Phase	Retrieving of S/C position from dead reckoning data.			
	Computation of antenna pointing for each S/C			
	Electronic steering and polarization skew			
Operation Phase	Fast-time synchronization (10-100 ms required) OPTIONAL		Fast-time synchronization (10-100 ms required)	
	DoA estimation (optional)			
	Storage of incoming pulses for TX antenna pattern estimation	Continuous retransmission of incoming pulses with controllable delay and very stable equivalent RCS	Computation of simplified pulses LUT	Computation of S1 mimicking pulses according to S1 mode and orbit
			Constant TX power transponder mode	

CAT timeline for bistatic SAR calibration



Harmony 1	IW1
SWST (us)	393.82
SWL (us)	356.17

Harmony 2	IW1
SWST (us)	342.99
SWL (us)	347.21

Transponder RX window from Sentinel

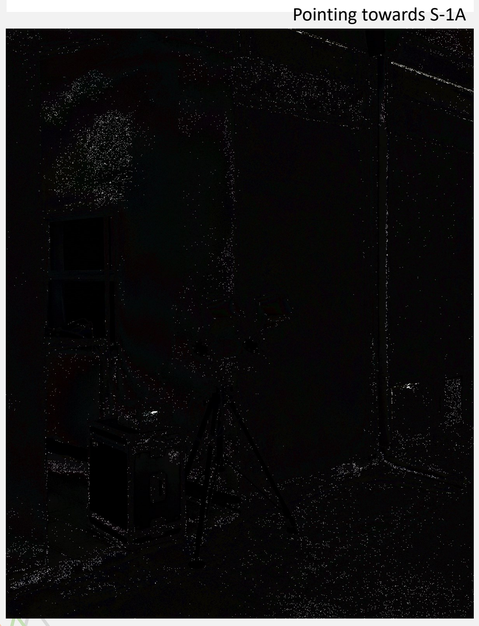
Transponder regenerated pulse

Full time division to either prevent antenna cross talk or allow the usage of single antenna

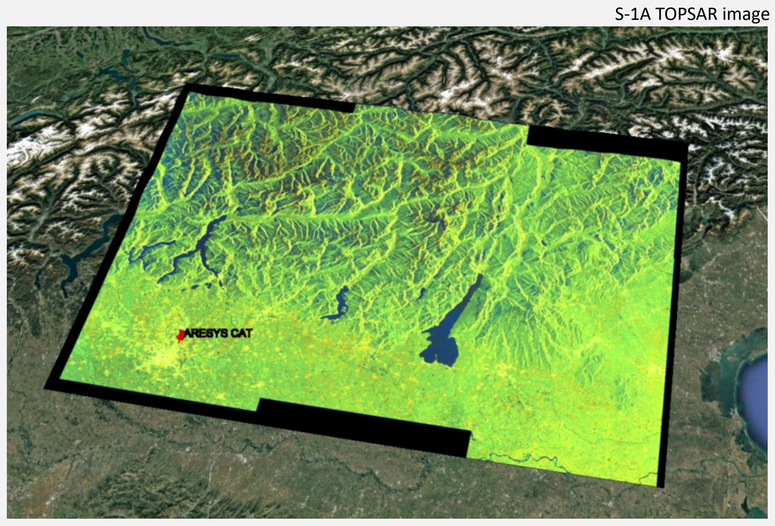
Sentinel-1A RX experiment @ARESYS

Breadboard setup

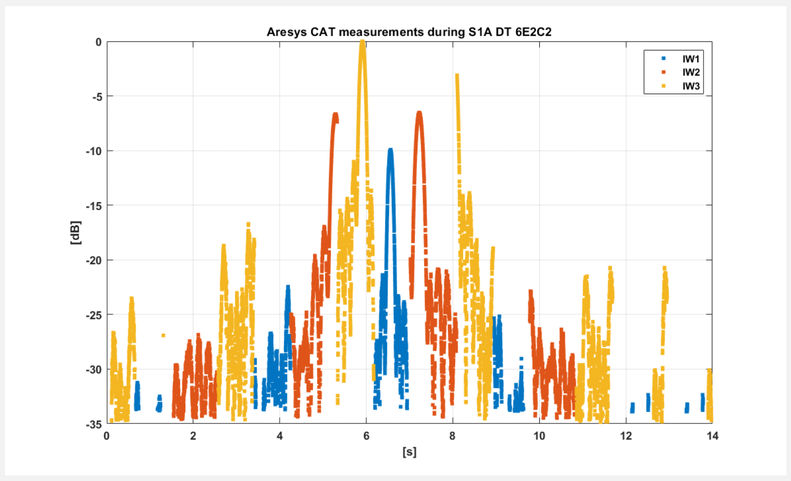
Pointing towards S-1A



S-1A TOPSAR image



As a first operative test of the CAT under development, we were able to record the Tx pulses of Sentinel-1A, during its overpass over Milano on the 24th October 2024 (data take ID 6E2C2). The CAT was located within the IW3 sub-swath and oriented toward the expected position of the satellite.



The CAT was operated in Rx-only mode for 14 seconds and its sensitivity allowed us to measure the Tx pulses from all the three TopSAR IW sub-swaths down to many pattern sidelobes.