Marco Maffei

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XXXIV Cycle - II year presentation

Inference via Spaceborne Radars for Space Situational Awareness

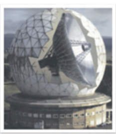
Problem: How can we support governmental strategies to aquire a "..capability to watch for objects and natural phenomena that could harm satellites in orbit?

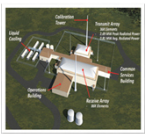
Idea: Augmenting SSA beside Ground Based Radars (GBRs):

Designing Spaceborne Radars (SBRs) in the Ka Band with and Active Electronically Scanned Array (AESA) antenna for Multi Target Tracking (MTT)

Keystones:

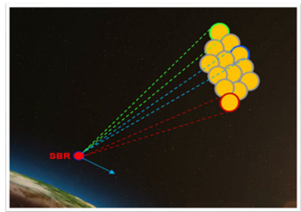
1. Laplacian orbit determinations.
2. Ancillary signatures estimates pertaining to the Radar Cross Section (RCS).


TIRA GBR (L Band). Mehrholz et al., 2002.

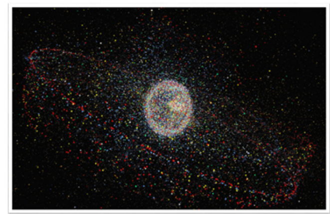

Space Fence GBR (S Band). Haimerl et al., 2016.

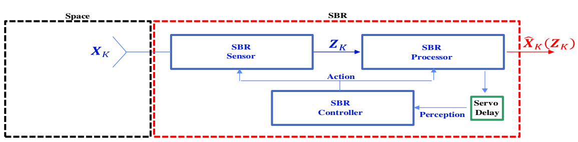

GESTRA GBR (L Band). Wilden et al., 2016.

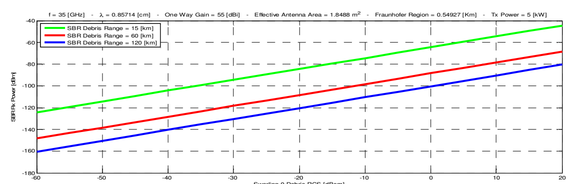

RAT-31 DL/M GBR (L Band). Vigilante et al., 2015.

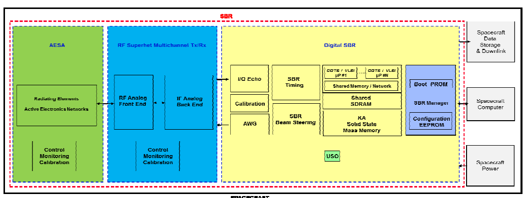


AESA based SBR raster scanning the FoV.

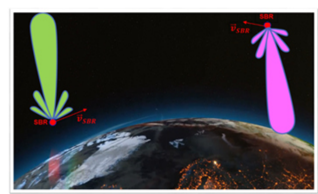

Debris swarms orbiting planet Earth.

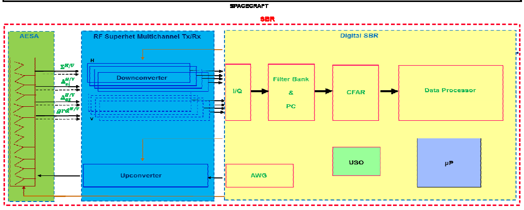






	Channel Phenomenology	
s_4	$s_4 < 0.1$	$0.1 \leq s_4 \leq 0.5$
Mechanical Perspective	free space vacuum	slabs of weakly turbulent plasma
EM Perspective	Isotropic linear homogeneous media	random media
Signal Perspective	AWGN channel	Rice channel

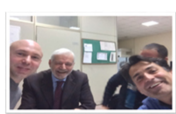




Features

1. Providing reliable debris tracks estimates $\hat{X}_K(Z_K)$ (whereby $Z_K \triangleq \{z_1,..,z_K\}$) is defined as the SBR set of K measurements and $X_K \triangleq \{x_1,..,x_K\}$ is defined as the debris state set of K dynamic positions from a time instant t_1 to a time instant t_k) from a Multi Target Tracking (MTT) perspective (based on either Measurement to Track Associations (MTA) tailored to multiple "*individual debris*" or on point process models tailored to "*debris clouds.*")
2. Estimating $\hat{X}_K(Z_K)$ according to a Bayesian formulation of the inference problem. Namely, allowing for the capability to exploit a-priori distributions for environmental debris density, target motion models, and interference; the capability to form a suitable likelihood-function based on the SBR sensor data acquisition; and finally the capability to combine the a-priori distributions and likelihood-functions into a suitable posterior distribution on target state.
3. Approximating debris motion models as moving along straight lines in 3D at constant hyper-velocities with no maneuvering and based on a linear Continuous White Noise Acceleration (CWNA) model representing the Near Constant Velocity (NCV) scenario with no need for Interacting Multiple Models (IMM)) and considering automatic tracking in limited time spans on the order of seconds.
4. Supporting the SBR processor decisions by an additional SBR controller, which perceives feedbacks data from the processor itself and, by virtue of a constrained optimization framework, performs in closed loop a retroaction on both the sensor and processor future behavior relying on the so-called perception-action-cycle paradigm for target tracking.

- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Bayesian Inference via Spaceborne Radars for Space Situational Awareness," Dissertation Draft (Chapters 1-2-3-4 complete)(Chapters 5-6 In Fieri).
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "On the Exploitability of the Ka Band for Spaceborne Radar Debris Detection and Tracking Measurements," 2019 IEEE International Workshop on Metrology for Aerospace, Torino, Italy, June 2019.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "On the Exploitability of the Ka Band for Spaceborne Radar Debris Detection and Tracking," Poster for Workshop on Mathematical Models for Science and Engineering, University of Napoli Federico II, September 11-13, 2020, Napoli, Italy.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Spaceborne Radar Functional Architecture for Debris Bayesian Inference," 2020 IEEE International Workshop on Metrology for Aerospace, Pisa, Italy, June 2020.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "An Ontology for Spaceborne Radar Debris Detection and Tracking: Channel-Target Phenomenology and Motion Models," submitted to IEEE AESS Systems Magazine, under review.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Spaceborne Radar Sensor Architecture for Debris Detection and Tracking," to appear on IEEE Transactions on Geoscience and Remote Sensing. Early Access on IEEE Xplore.
- 2020 IEEE Radar Conference 3MT Video Finalist (https://www.radarconf20.org/3-minute-thesis).


From left to right: Marco, Alfonso, Augusto, Antonio.

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

Detection aspects with a focus on Debris Detection in Plasma Media with Polarimetric Monopulse Spaceborne Radar.

Semi-analytic techniques for radar detection performance in plasma media with weak scattering.

Parameter estimation on monopulse unresolved targets (*Linear Noisy Inverse Problem solved via IAA with BIC or BSLIM with BIC*).

Instrument ambiguity function.

Tracking aspects with a focus on Bayesian multiple target tracking via:

Likelihood Functions housing SBR contacts and carrying out track association via Probabilistic Multiple Hypothesis Tracking (PMHT), Joint Probabilistic Data Association (JPDA) or bypassing (i.e. replacing) track associations directly with Intensity Filters (iFilter).

Unthresholded SBR data (namely the SBR Signal Processor output data) carrying out Maximum A Posteriori Penalty Function (MAP-PF) with the number of targets estimated via Likelihood Ratio Detection and Tracking (LRDT).

Combining iFilter and LRDT concepts via iLRT.

Time series analysis on polarimetric RCS signatures.