



PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Marco Maffei

XXXIV Cycle

Training and Research Activities Report – Third Year

Tutor: Antonio De Maio – co-Tutor: Alfonso Farina, Augusto Aubry



1. Information

Marco Maffei

XXXIV Cycle- ITEE – Università di Napoli Federico II

No Fellowship

Advisor: A. De Maio – Co Advisors: A. Farina, A. Aubry

2. Study and Training activities

- Fraunhofer Institut Webinar Seminar - Nils Pohl, Reinhold Herschel, "High Resolution 240 GHz Radar with SiGe Chip," February 23, 2021.
- Leonardo Company Seminar - Alfonso Farina, Luca Timmoneri, "Radar Technology and Sustainability," February 25, 2021.
- Fraunhofer Institut Seminar - M. Friedrichsen, J. Schell, "Parasol: Passive Radar Controls Nighttime Identification of Wind Turbines," March 2, 2021.
- Fraunhofer Institut Seminar - Stephan Stanko, "Real Time SAR Live Aerial Imaging in all Weather," March 23, 2021.
- University of Napoli Federico II Course - A. Aubry V. Carotenuto A. De Maio, "Cooperative and Non cooperative Localization Systems," March April 2021.
- AESS DL - G. Schmidt, "Inside Apollo: Heroes, Rules, and Lessons Learned in the Guidance, Navigation, & Control (GN&C) System Development," April 1, 2021.
- AESS DL – A. De Maio, "CFAR Techniques for Radar Detection," April 6, 2021.
- AESS DL – A. Farina, "The Role of Multitarget Tracking Radar in Surveillance Systems," April 8, 2021.
- Fraunhofer Institut Seminar - W. Johannes, "Danger from Drones: Monitoring Airports with Millimeter Wave Radar," April, 20 2021.
- University of Napoli Federico II Course - A. Aubry V. Carotenuto A. De Maio, "Matrix Analysis for Signal Processing with Matlab Examples," April 2021.
- AESS DL – M. Davis, "Foliage Penetration Radar," April 22, 2021.
- AESS DL - U. K. Majumder, "Deep Learning Based Advanced SAR Automatic Target Recognition," April 27, 2021.
- AESS DL – W. Koch, "Ethically Aligned Data Fusion Systems," April 29, 2021.
- AESS DL – B. Rassa, "Importance of System Engineering in Today's Design Environment," May 4, 2021.
- Fraunhofer Institut Seminar – N. Egli, "Tira als Sensor im Bereich Space Situational Awareness (SSA)," May 11, 2021.
- AESS DL – E. Blasch, "Overview of High-Level Information Fusion Theory, Models, and Representations," May 11, 2021.
- AESS DL – L. rosenberg, "The importance of Sea Clutter Modeling," May 25, 2021.
- University of Napoli Federico II Course - A. Farina, "Advanced Topics in Radar Signal Processing," May 2021.
- AESS DL – W. Dawning, "Using Machine Vision Perception to Control Automated Vehicle Maneuvering," May 27, 2021.
- Fraunhofer Institut Seminar – R. Herschel, "The Horis Project - How radar helps to protect pedestrians," 8 June 2021.
- EURASIP-UDRC Summer School 2021 - University of Edinbugh - June 28- July 1, 2021.
- IEEE - EURASIP 8th Summer School on Signal Processing 2021 - University of ROMA TRE - 6-10 September 2021.
- AESS DL – D. Balir, "Tracking Maneuvering Targets in a World of Nettled Sensor," September 28, 2021.
- University of Naples Federico II Course – E. Carpentieri, "Electronic Scan Antennas for Radar Signal Processing Applications," September - October 2021.
- 2021 5G Italy – Ph.D. School, CNIT, November 30 – December 2, 2021.



3 ANNO - Lecture/Activity																		
High Resolution 240 GHz radar with SiGe Chip - February 23, 2021 - Fraunhofer Institut Webinar - Nils Pohl, Reinhold Herschel	Seminar	0.2		Credits Formula has been defined as	0.2	x	#	days	x	#	hoursperday							
Radar Technology and Sustainability - February 25, 2021 - Leonardo Company Seminar - Alfonso Farina, Luca Timmoneri	Seminar	0.4																
Parasol: Passive Radar Controls Nighttime Identification of Wind Turbines - March 2, 2021 - M. Friedrichsen, J. Schell - Fraunhofer Institut Webinar	Seminar	0.2																
Real Time SAR Live Aerial Imaging in all Weather - March 23, 2021 - Fraunhofer Institut Webinar - Stephan Stanko	Seminar	0.2																
Cooperative and Non cooperative Localization Systems - University of Napoli Federico II - A. Aubry V. Carotenuto A. De Maio - March April 2021	Course	3	X															
Inside Apollo: Heroes, Rules, and Lessons Learned in the Guidance, Navigation, & Control (GN&C) System Development - April 1, 2021 - G. Schmidt - AE	Seminar	0.2																
CFAR Techniques for Radar Detection - April 6, 2021 - A. De Maio - AESS DL	Seminar	0.2																
The Role of Multitarget Tracking Radar in Surveillance Systems - April 8, 2021 - A. Farina - AESS DL	Seminar	0.2																
Danger from Drones: Monitoring Airports with Millimeter Wave Radar - Fraunhofer Institut Webinar - April, 20 2021 - W. Johannes	Seminar	0.2																
Matrix Analysis for Signal Processing with Matlab Examples - University of Napoli Federico II - A. Aubry V. Carotenuto A. De Maio - April 2021	Course	2	X															
Foliage Penetration Radar - M. Davis - April 22, 2021 - AESS DL	Seminar	0.2																
Deep Learning Based Advanced SAR Automatic Target Recognition - U. K. Majumder - April 27, 2021 - AESS DL	Seminar	0.2																
Ethically Aligned Data Fusion Systems - W. Koch - April 29, 2021 - AESS DL	Seminar	0.2																
Importance of System Engineering in Today's Design Environment - Bob Rassa - May 4, 2021 - AESS DL	Seminar	0.2																
Tira als Sensor im Bereich Space Situational Awareness (SSA) - Nora Egli - May 11, 2021 - Fraunhofer Institut Webinar	Seminar	0.2																
Overview of High-Level Information Fusion Theory, Models, and Representations - E. Blasch - May 11, 2021 - AESS DL	Seminar	0.2																
The importance of Sea Clutter Modeling - L. Rosenberg - May 25, 2021 - AESS DL	Seminar	0.2																
Advanced Topics in Radar Signal Processing - University of Napoli Federico II - A. Farina - May 2021	Course	2	X															
Using Machine Vision Perception to Control Automated Vehicle Maneuvering - W. Dawning - May 27, 2021 - AESS DL	Seminar	0.2																
The Horis Project - How radar helps to protect pedestrians - R. Herschel - 8 June 2021 - Fraunhofer Institut Webinar	Seminar	0.2																
EURASIP-UDRC Summer School 2021 - University of Edinburgh - June 28- July 1, 2021	Doctoral School	6.4	x															
IEEE - EURASIP 8th Summer School on Signal Processing 2021 - University of ROMA TRE - P. Campisi - 6-10 September 2021	Doctoral School	5	X															
Tracking Maneuvering Targets in a World of Nettled Sensor - D. Blair - September 28, 2021 - AESS DL	Seminar	0.2																
Electronic Scan Antennas for Radar Signal Processing Applications - Enzo Carpentieri - University of Naples Federico II - September - October 2021	Course	2	X															
		24.2																





3. Research activity

- a. Title: Spaceborne Radar for Space Situational Awareness.
- b. Problem: How can we support governmental strategies to acquire a "...capability to watch for objects and natural phenomena that could harm satellites in orbit. The problem has been further refined with a bottom line question:

"How can a SBR for SSA be designed to allow estimating at a given time epoch t_0 the position \hat{p} and velocity \hat{v} of orbiting debris crossing the SBR Field of View (FoV)."

- c. Idea: Despite increasing demands for augmenting space-based monitoring capabilities for near-Earth SSA, there is no evidence of operative Spaceborne Radars (SBR) for debris detection and tracking. In the absence of SBR experimental data, one may certainly conjecture on the design of a novel cognitive-based payload transceiver with specific benefits for SSA with respect to ground based assets inference capabilities.
- d. Methodology: *Gedankenexperiment* to nurture SSA data fusion systems with novel spaceborne signatures estimations (via analysis and simulation) (no breadboarding).

e. Developments:

1) Providing a harmonizing ontological framework for the possible environmental scenario to cope with. The objective of such an ontology has been twofold:

a) introducing a nomenclature and an operative framework for SSA from a radar engineering perspective.

b) providing the conceptual modeling of reasonable channel-target phenomenologies as well as motion models for guiding radar design and paving the way for reasonable a priori formulations needed by Multi Target Tracking (MTT) Bayesian paradigms.

2) Outlining possible SBR payloads archetypes, beyond current Synthetic Aperture Radar (SAR) imaging purposes, as tailored to the general tasks of debris detection and parameter estimation pertaining to air-to-air Real Aperture Radars (RAR) taking into account legacy pulse Doppler radar systems.

In particular a novel SBR payload functional architecture for SSA has been described as a bespoke monopulse-based pulse Doppler radar in the Ka Band taking into account state-of-the art space-qualified technologies in both digital and RF domains. The envisaged architecture acquires a complex data hyper-cube and comprises a filter bank with a group of Doppler frequency offsets not for estimating a target radial velocity (due to the inherent ambiguity of the echo range-rate in cueing the debris range-rate) but rather as a means to enforce Doppler tolerance on the pulse compression scheme and avoid straddle losses. The adaptivity of such a pulse Doppler radar architecture allows including robust and selective debris detection schemes tailored to CFAR-like paradigms. Finally, specific parameter estimates from a burst of pulse echoes make provision for further Bayesian inference capabilities on small-size debris dynamic states as well as RCS related

signatures via time series analysis. For this latter purpose, the acquisition of echoes related to the motion of a debris for an elapse time up to several hundreds of milliseconds could be operatively extended to a few seconds, thus augmenting the time on target with additional measurement and gauging perspectives. By selecting an optimal transceiver configuration such that the SBR AESA transmit beam points the debris target minimizing a cost function (for example as per a joint waveform and beam control optimization), it would be possible to refine radiometric signatures insights.

3) Investigating radar detection in plasma media:

The effects of plasma turbulence on the detection performance of spaceborne radars (SBRs) for space situational awareness (SSA) have been investigated. Physical insights on both channel and target phenomenology have led to reasonable statistical models with a focus on the fading occurrence probability in case of weak scintillation. Consequently, the performance analysis of conventional radar detectors in additive white Gaussian noise (AWGN) has been provided in a monostatic configuration for either Rayleigh or Rice fluctuating targets, and considering Rice plasma scintillation as a function of the scintillation index s_4 . Numerical results have identified a paramount framework to characterize the influence of plasma turbulence on SBR detection performance for SSA. Finally, ancillary notes have made provision for tailoring the performance analysis also in the case of bistatic radar configurations.

4) Paving the way for futuristic Multiple Input Multiple Output (MIMO) SBRs via Code Division Multiplexing (CDM) for Track While Simultaneous Search (TWSS):

A futuristic archetype of a novel SBR in the Ka Band for SSA based on a Code Division Multiplexing (CDM) Multiple Input Multiple Output (MIMO) payload transceiver has been outlined. The functional architecture of the fully-polarimetric radar has been described including key comparisons with previous works based on Single Input Multiple Output (SIMO) diversities. SBR operations have been clarified via timing hierarchies in surveillance mode, the complex data hyper-cube structure, and the Low Pulse Repetition Frequency (L-PRF) Range and Range-Rate Search (RRRS) entailing a Track While Simultaneous Search (TWSS) contacts collection strategy. Ancillary details on the SBR functional architecture have addressed paramount insights to ponder critical MIMO aspects and pave the way for key research and development efforts. Finally, numerical results have provided a proof of concept for the nominal onboard processing tasks downstream the Analog to Digital Converter and upstream the CFAR block.

4. Products

- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Spaceborne Radar for Space Situational Awareness," Dissertation.
- 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, "Spaceborne Radar Functional Architecture for Debris Bayesian Inference," 2020 IEEE International Workshop on Metrology for Aerospace, Pisa, Italy, June 2020.
- De Maio, M. Maffei, A. Aubry, A. Farina, "Fading Occurrence Probabilities for Spaceborne Radar in Weak Plasma Scintillation," 2021 IEEE International Workshop on Metrology for Aerospace, Napoli, Italy, June 2021.
- M. Maffei, A. Aubry, A. De Maio and A. Farina, "An Ontology for Spaceborne Radar Debris Detection and Tracking: Channel-Target Phenomenology and Motion Models," in IEEE Aerospace and Electronic Systems Magazine, vol. 36, no. 6, pp. 18-42, 1 June 2021.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Spaceborne Radar Sensor Architecture for Debris Detection and Tracking," IEEE Transactions on Geoscience and Remote Sensing, 2021.
- A. De Maio, M. Maffei, A. Aubry, A. Farina, "Effects of Plasma Media with Weak Scintillation on the Detection Performance of Spaceborne Radars," IEEE Transactions on Geoscience and Remote Sensing, 2021.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "MIMO SBR via Code Division Multiplexing for Track While Simultaneous Search," under final revision to appear on IEEE Transactions on Geoscience and Remote Sensing.
- M. Maffei, A. Aubry, A. De Maio, A. Farina, "Fully Polarimetric Monopulse SBR for Space Situational Awareness," Book Chapter in fieri, IET.
- Finalist 3 Minute Thesis (3MT) Contest - 2020 IEEE Radar Conference. <https://www.radarconf20.org/3-minute-thesis>
- Best Conference Paper Runner Up - Special Session "Metrology for Radar Systems" - A. De Maio, M. Maffei, A. Aubry, A. Farina, "Fading Occurrence Probabilities for Spaceborne Radar in Weak Plasma Scintillation," 2021 IEEE International Workshop on Metrology for Aerospace.

5. Conferences and Seminars

- 2021 IEEE International Workshop on Metrology for Aerospace, Napoli, Italy, June 2021. Presentation 1 paper.
- Afternoon Seminar: SBR Signal Processor for Debris Detection and Tracking in Fall 2021 at the University of Napoli Federico II under the guidance of Prof. A. De Maio.

Training and Research Activities Report – First Year

PhD in Information Technology and Electrical Engineering – XXXIV Cycle

Marco Maffei

6. Activity abroad
None - Covid blocked all plans as a Ph.D. Visiting Scholar for 2 months in the summers of 2020 and 2021.

7. Tutorship
None