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 – Second 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

    - "2019 5G Italy" full time international PhD School, CNIT, December 2 - 4, 2019, Rome, Italy.
    - S. Barbarossa, " Learning in the 5G Edge Cloud," University of Roma Tor Vergata and IEEE AES Chapter, February 14, 2020, Rome, Italy. Seminar
    - "L. Callegaro, "The Redefinition of the International System of Units,"University of Roma Tor Vergata and IEEE AES Chapter, February 28, 2020, Rome, Italy." Seminar follow up wrt the same seminar held in 2019.
    - (Virtual) IEEE AESS Distinguished Lecture: Felix Govaers - An introduction to Track-to-track fusion and the distributed Kalman filter - September 16, 2020
    - (Virtual) IEEE AESS Distinguished Lecture: Mark Davies - Ultrawideband surveillance radar - September 17, 2020
    - (Virtual) IEEE AESS Distinguished Lecture: Alfonso Farina - Radar adaptivity: antenna based signal processing techniques - October 1, 2020
    - (Virtual) IEEE AESS Distinguished Lecture: Eli Brookner - Radar, phased arrays, metamaterials, stealth: advances and breakthroughs - October 8, 2020
    - (Virtual) IEEE AESS Distinguished Lecture: Luke Rosenberg - New concepts in maritime detection - October 12, 2020
    - (Virtual) IEEE AESS Distinguished Lecture: Walt Downing - Cubesats for deep space - November 5, 2020
    - (Virtual) Radar Summer School - IEEE Radar Conference - September 21-25, 2020.
    - (Virtual) Stochastic Geometry for Multiple Object Tracking - Tutorial - IEEE Radar Conference - September 21-25, 2020.
    - (Virtual) Analytic Combinatorics for Multi-Object Tracking - Tutorial - IEEE Radar Conference - September 21-25, 2020.
    - 2020 IEEE International Workshop on Metrology for Aerospace, Pisa, Italy, June 22-24, 2020
    - 2020 IEEE Radar Conference - September 21-25, 2020.

        NOTE Planned study and training activities canceled due to covid:

    - 12th International Summer School on Radar / SAR. 3-10 July 2020. Wachtberg, Germany. www.radarsummerschool.fraunhofer.de
    - 30th Summer PhD School of Information Engineering (SSIE) – "Silvano Pupolin" Machine learning theory: lectures on cutting edge machine learning theory, including, including, "a short course on Reinforcement Learning", "Convolutional Networks on graphs", "explainable artificial intelligence", "learning for non-stationary environments". 13-17 July 2020. Bressanone (BZ), Italia. http://ssie.dei.unipd.it/technical-program-2020/
    - 2020 IEEE - EURASIP Summer School on Signal Processing (S3P-2020) - Signal Processing for human-machine communication and interaction (SP-HMCI) is the eight edition of the Summer School technically co-sponsored by IEEE Signal Processing Society (SPS), via the Seasonal Schools in Signal Processing (S3P) initiative, the SPS Italy Chapter, and EURASIP. 7-11 September 2020. https://s3p2020.uniroma3.it/

Student: Name Surname **Tutor: Name Surname** **Cycle XXXIV**

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	Credits year 1								Credits year 2								Credits year 3			Total	Check
	Estimated	1	2	3	4	5	6	Summary	Estimated	1	2	3	4	5	6	Summary	Estimated	Summary			
Modules	18	1	1		2	1	1	6	9	1					4	5		0	11	30-70
Seminars	13		2	2	1	1		6	6			2		1	6	9		0	15	10-30
Research	34							0	42							0		0	0	80-140
	65							12	57							14		0	26	180

Year	Lecture/Activity	Type	Credits	Certification	Notes
1	"2018 5G International PhD School, CNIT, December 4-6, 2018, Rome, Italy."	Doctoral School	4.8	x	Credits Formula has been defined as 0.2 x # days x # hours
1	"2019 Radar Electronic Warfare Course,Cranfield University, February 4-8, 2019, Shrivenham, UK"	Doctoral School	8	x	
1	"L. Callegaro, "The Redefinition of the International System of Units," University of Roma Tor Vergata and IEEE AES Chapter, February 12, 2019, Rome, Italy."	Seminar	0.6	x	
1	"A. Lazzareschi Sergiusti, ""On the Design of Complex Systems: from Operational Requirements to Technical Specifications," University of Roma Tor Vergata and IEEE AES Chapter, February 12, 2019, Rome, Italy.	Seminar	0.6	x	
1	"E. Silva, "Applied Superconductivity in Italy" University of Roma TRE, April 8, 2019, Rome, Italy"	Seminar	1.6	x	
1	"G. Galati, "An Historical perspective of Radar Design and Development in Italy," CESMA and IEEE AES Chapter, April 9, 2019, Rome, Italy."	Seminar	0.6	x	
1	A. Farina, "Seminar on Cognitive Radar," Leonardo Company, May 9, 2019	Seminar	0.6	x	
1	"2019 IEEE-SPS/EURASIP Summer School on "Network and Data-driven Learning Fundamentals and Applications", May 20-24, 2019, Lecce, Italy."	Doctoral School	8	x	
1	3rd GTTI Workshop on Radar and Remote Sensing, 30-31 May 2019	Workshop	3.2	x	
1	2019 IEEE International Workshop on Metrology for Aerospace, June 19-21, Torino, Italy.	Workshop	4.8	x	
1	"S. Barbarossa, "Topological Signal Processing," University of Roma Tor Vergata and IEEE AES Chapter, July 2, 2019, Rome, Italy."	Seminar	0.6	x	
1	"Workshop on Mathematical Models for Science and Engineering, University of Napoli Federico II, September 11-13, Napoli, Italy."	Workshop	4.8	x	
			38.2		
2	"2019 5G Italy" full time international PhD School, CNIT, December 2 - 4, 2019, Rome, Italy.	Doctoral School	4.8	X	Credits Formula has been defined as 0.2 x # days x # hours
2	S. Barbarossa, " Learning in the 5G Edge Cloud," University of Roma Tor Vergata and IEEE AES Chapter, February 14, 2020, Rome, Italy. Seminar	Seminar	0.6	X	
2	L. Callegaro, "The Redefinition of the International System of Units," University of Roma Tor Vergata and IEEE AES Chapter, February 28, 2020, Rome, Italy." Seminar follow up wrt the same seminar held in 2019.	Seminar	0.6	X	
2	(Virtual) IEEE AESS Distinguished Lecture: Felix Govaers - An introduction to Track-to-track fusion and the distributed Kalman filter - September 16, 2020	Seminar	0.3		
2	(Virtual) IEEE AESS Distinguished Lecture: Mark Davies - Ultrawideband surveillance radar - September 17, 2020	Seminar	0.3		
2	(Virtual) IEEE AESS Distinguished Lecture: Alfonso Farina - Radar adaptivity: antenna based signal processing techniques - October 1, 2020	Seminar	0.3		
2	(Virtual) IEEE AESS Distinguished Lecture: Eli Brookner - Radar, phased arrays, metamaterials, stealth: advances and breakthroughs - October 8, 2020	Seminar	0.3		
2	(Virtual) IEEE AESS Distinguished Lecture: Luke Rosenberg - New concepts in maritime detection - October 12, 2020	Seminar	0.3		
2	(Virtual) IEEE AESS Distinguished Lecture: Walt Downing - Cubesats for deep space - November 5, 2020	Seminar	0.3		
2	(Virtual) Radar Summer School - IEEE Radar Conference - September 21-25, 2020.	Doctoral School	2	X	
2	(Virtual) Stochastic Geometry for Multiple Object Tracking - Tutorial - IEEE Radar Conference - September 21-25, 2020.	Doctoral School	1.6	X	
2	(Virtual) Analytic Combinatorics for Multi-Object Tracking - Tutorial - IEEE Radar Conference - September 21-25, 2020.	Doctoral School	1.6	X	
2	2020 IEEE International Workshop on Metrology for Aerospace, Pisa, Italy, June 22-24, 2020	Workshop	4.8	X	
2	2020 IEEE Radar Conference - September 21-25, 2020	Conference	8		
			25.8		

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3. Research activity
   a. Title: Inference via Spaceborne Radars (SBRs) for Space Situational Awareness (SSA).

   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 $\hat{\dot{p}}$ 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) DONE: 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 and 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) DONE: 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) IN FIERI: Investigating suitable frameworks for target detection and tracking:

a) Detection aspects with a focus on debris detection in plasma media with polarimetric monopulse SBRs. In particular, semi-analytic techniques are being adopted for radar detection performance in plasma media with weak scattering. Subsequent activities will be tailored towards parameter estimation on monopulse unresolved targets (as a linear noisy inverse problem solved via IAA with BIC or BSLIM with BIC), and possibly on instrument ambiguity function.

b) Tracking aspects on multiple targets via cognitive perspectives, following the work by Dr. K. Bell (et al.). Considering the limits of Poisson Point Processes (PPP) for hyper-velocity multi-target densities tracking via iFilters, adopting techniques from stochastic geometry, following the work by Dr. R. Streit (et al.), Dr. R. Mahler (et al.), Dr. A. Farina (et al.), Dr. B.-T. Vo and Dr. B.-N. Vo et al.) and machine learning following the work by Dr. S. Haykin (et al.)

c) Time series analysis on polarimetric RCS signatures,

4. Products

- 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 at https://www.radarconf20.org/3-minute-thesis.

5. Conferences and Seminars
   - 2020 IEEE International Workshop on Metrology for Aerospace, Pisa, Italy, June 22-24, 2020. Presentation 1 paper.
   - 2020 IEEE Radar Conference, Florence, Italy - September 21-25, 2020. Presentation 3MT Contest.

6. Activity abroad
   None - Covid blocked the plan to become a Ph.D. Visiting Scholar abroad for 1.5 months in summer 2020. A tentative list of host universities is set up to become a Ph.D. Visiting Scholar abroad for 2 months in summer 2021:
   - A) University of Cambridge, Cambridge, UK. (Simon Godsill).
     http://www.eng.cam.ac.uk/profiles/sjg30
   - B) Technical University of Munich, Munich, Germany. (Claudia Czado).
     https://www.professoren.tum.de/en/czado-claudia/
   - C) University of Connecticut at Storrs, Storrs, CT, USA.(Peter Willett).
     https://www.ee.uconn.edu/peter-willett/
   - D) McMaster University, Hamilton, Ontario, Canada. (T. Kirubarajan)
     https://www.ece.mcmaster.ca/~kiruba/
   - E) JPL- Radar Science and Engineering Section, Pasadena, Ca, USA.
     https://communicationstrackingradar.jpl.nasa.gov/sections/sec-334/

7. Tutorship
   The PhD candidate Marco Maffei has held a seminar in October 2020 at the University of Napoli Federico II under the guidance of Prof. Antonio De Maio on "Ontology for SBR Debris Detection and Tracking."

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