UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee PhD
information technology
electrical engineering

DIETI. UNINA

Marco Boddi

Novel algorithms for Direction-of-Arrival estimation in radar and communication problems

Tutor: Prof. A. De Maio

Cycle: XXXVII Year: 2

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My background

- **Master Science degree:** Telecommunications Engineering at the University of Pisa
- **Research group/laboratory:** Radar Signal Processing and Electronic Defense Research Group (RSPRG) at UniNa, DIETI
- **Tutor:** Prof. A. De Maio
- **PhD start date:** 01/11/2021, XXXVII Cycle
- **Scholarship type / Partner organization:** ad-hoc agreement with the Italian Government, Presidency of the Council of Ministers

Research field of interest

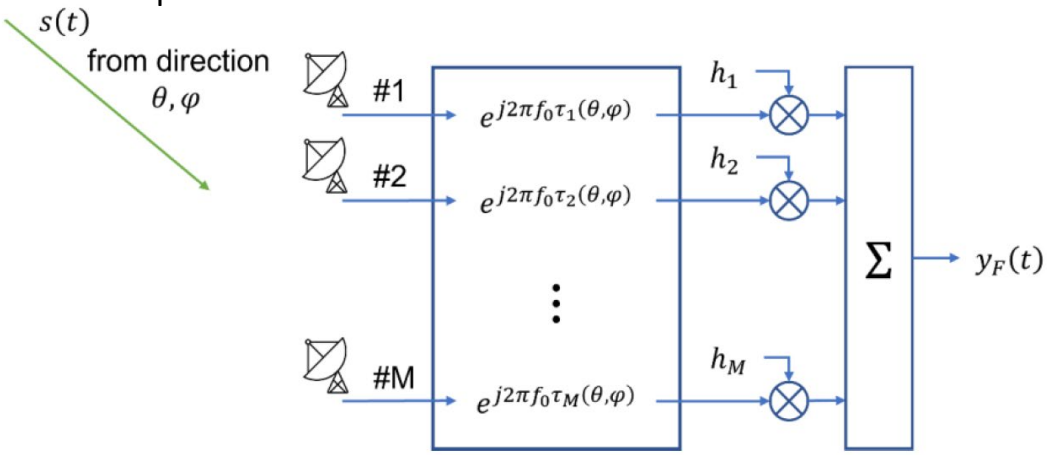
- **Radar and digital communication signal processing**
  - Antenna array / multi-channel processing
  - Non cooperative radio-localization
  - Direction-of-Arrival estimation
  - Signal recognition and classification
  - Compressive sensing

Summary of study activities

- **Study activities**
  - Spectral analysis
  - Compressive sensing and sparse representation techniques
  - Iterative optimization methods
- **Ad hoc PhD courses / schools**
  - On the challenges and impact of Artificial Intelligence in the Insurance domain
  - Summer school “Frontier Technologies for «Space 2.0» Communications “
- **Courses borrowed from MSc curricula**
  - Terrestrial and satellite radio-localization
- **Other courses and seminars**
  - “WiFi and Bluetooth Low Energy: architecture and Security” by CNIT Rome
  - “2023 virtual distinguished lecturers series”, by IEEE AESS
- **Conferences / workshops attended**
  - NATO SET-319 Specialist Meeting on “New Mathematical Frontiers for Multi-Dimensional Radar Systems”, Edinburgh, 21-23 Feb 2023
  - NATO Lecture Series SET-257 RLS on “Compressive Sensing Techniques for Radar and ESM Applications”, Rome, 15-16 May 2023

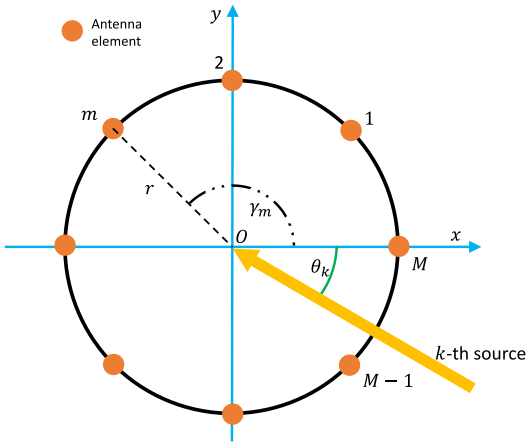
Research activity: Overview (1)

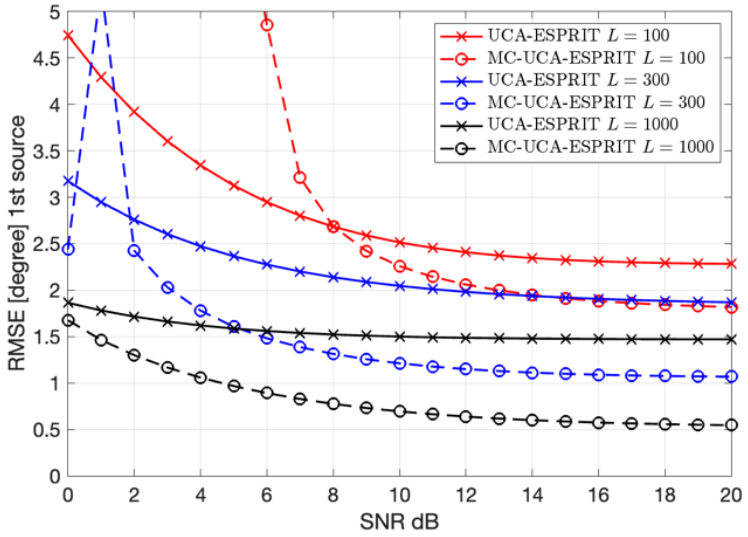
- **Problem of interest**
  - Estimate the **Direction-of-Arrival (DoA)** of radio signals. Main assumptions:
    - Non cooperative emitters and unknown signal formats;
    - Processing based on signal samples available at a receiving antenna array.
  - (some) Areas of applications:
    - Electronically-Scanned-Array (ESA) radars;
    - Search&Rescue operations, natural disasters relief;
    - Environmental protection and spectrum management authorities;
    - Military strategic and tactical situation awareness;
    - Radio navigation and air/maritime traffic monitoring;
    - Radio mobile networks management and optimization.



Research activity: Overview (2)

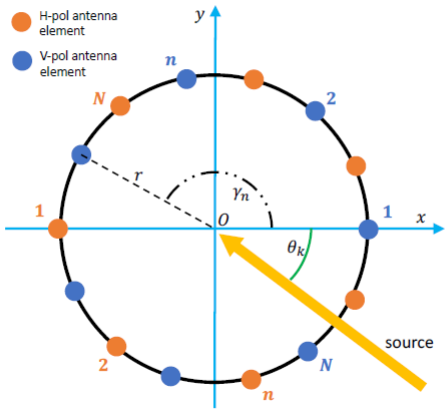
- **Research objectives and contributions**
  - Problem: joint array calibration and DoA estimation under antenna coupling conditions
  - Objectives:
    - Identify suitable mathematical transformations in order to yield to the situation to an equivalent Uniform Linear Array, with a Modelling Error Matrix, starting from the assumptions of circular antenna array and a symmetric circulant Toeplitz structure for the antenna coupling matrix;
    - Obtain an online iterative optimization method (MC-UCA-ESPRIT) capable of estimating Direction of Arrivals, Modelling errors and calibration terms, covariance matrix;
    - Obtain convergence and accurate estimates with few data snapshots and low Signal-to-Noise ratios.





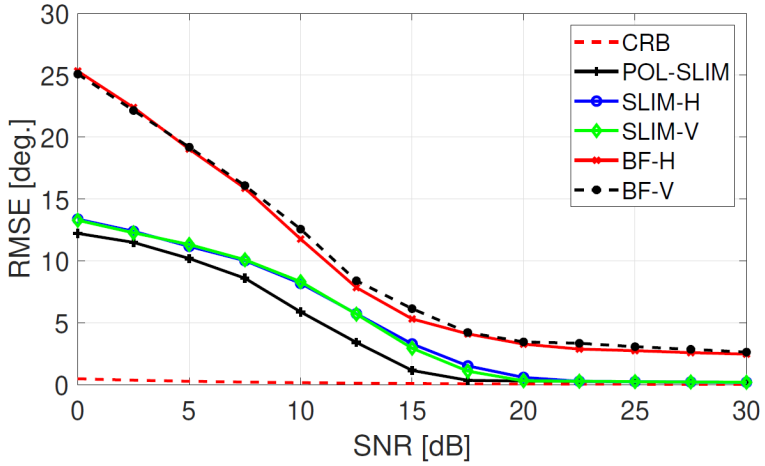
Research activity: Overview (3)

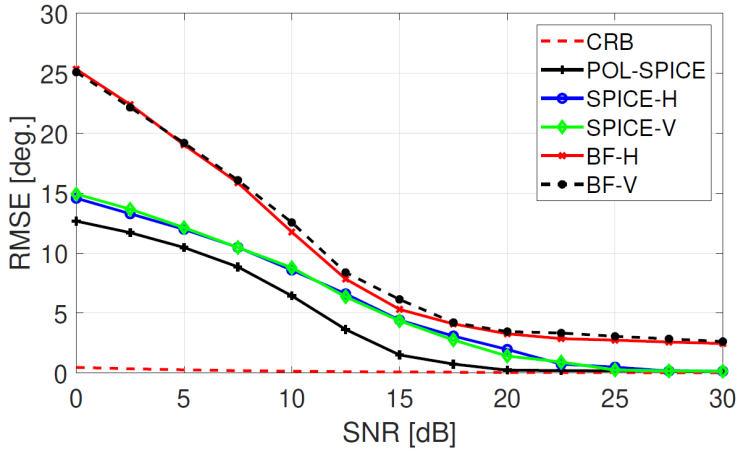
- **Research objectives and contributions**
  - Problem: characterize dual-polarization arrays for DoA estimation
  - Objective:
    - Derive a mathematical framework for the description of the DoA estimation problem with concentric / collocated circular arrays with orthogonal polarizations
    - Derive the mathematical solution for conventional DoA estimators (Maximum Likelihood, Conventional BeamFormer, Capon - Minimum Variance/Power Distortionless Response)
    - Derive performance bounds for Doa Estimation (e.g. Cramer-Rao lower bound)
    - Prove robustness of the dual-pol array and combined pol estimators with respect to unknown or changing polarization states



Research activity: Overview (4)

- **Research objectives and contributions**
  - Problem: extend sparsity techniques for DoA iterative estimation techniques in dual polarization arrays
  - Objective:
    - Derive a mathematical framework for the description as a sparse problem
    - Apply and adapt iterative sparse learning estimators:
      - POL-SPICE (Polarimetric Sparse Iterative Covariance-based Estimation)
      - POL-SLIM (Polarimetric Sparse Learning via Iterative Minimization)
    - Evaluate performances for the new estimators, show accuracy and robustness w.r.t. conventional estimators





Research activity: Overview (5)

- **Near future directions, methodologies and intended contributions:**
  - Extend the estimation methods and mathematical framework in order to deal jointly with multiple dimensions (frequency, azimuth, elevation, polarization, range, etc.)
  - Adapt theoretical models to deal with radio scenarios of specific interest (starting from passive direction finding in HF)
  - Model and architecture validation through on-field measurements with commercial-grade SDRs

Products

- **Conference papers**

[C1]	M. Boddi, M. Rosamilia, A. Aubry, and A. De Maio, “Iterative Direction-of-Arrival Estimation for a Uniform Circular Array in the Presence of Mutual Coupling”, presented at the NATO SET-319 Specialist Meeting, 2023. *
[C2]	M. Boddi, M. Rosamilia, A. Aubry, and A. De Maio, “Polarimetric Sparse Iterative Procedures for DOA Estimation”, submitted and accepted, IEEE Tech Defense, 2023.

* Awarded as «Best Paper – Young scientist»

Thanks for your attention

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