Curriculum Vitae

Name: **Augusto**
Last Name: **Aubry**

Currently working as ***Assistant Professor at the Department of Electrical and Information Technology Engineering, Università degli Studi di Napoli "Federico II", Naples, Italy.***

He has achieved both the first and the second-class national scientific qualification for the Competition Sector ***09/F2***.

Relevant information about the scientific and professional career

A) Education

- January 2011: PhD in Electronic and Telecommunications Engineering, Università degli Studi di Napoli "Federico II", Naples, Italy (Supervisors: Prof. E. Conte, Prof. A. M. Tulino. Title "MIMO Multiple Access Channel with Partial Channel State Information").
- June 2007: M.Sc. Degree with highest honors (summa cum laude) in Telecommunications Engineering, Universitá degli Studi di Napoli "Federico II", Naples, Italy (Supervisors: Prof. E. Conte, Prof. A. M. Tulino. Title "Caratterizzazione Informazionale di una Classe di Canali con Fading: Comunicazioni in Presenza di Rumore Moltiplicativo ed Additivo").
- November 2004: B.Sc. Degree with highest honors (summa cum laude) in Telecommunications Engineering, Universitá degli Studi di Napoli "Federico II", Naples, Italy (Supervisor: Prof. A. Napolitano. Title "Utilizzo di un Filtro Numerico Versatile per l'Elaborazione di Segnali per Telecomunicazioni: Interpolazione e Campionamento in Frequenza").

B) Professional Experience

- November 2007 - October 2010: Recipient of a student ship from the Italian Ministry of Public Instruction for a PhD position in Electronic and Telecommunications Engineering at the Universitá degli Studi di Napoli "Federico II", Naples, Italy. PhD Supervisors: Prof. A. M. Tulino and Prof. E.

Conte. Final defense: January 19th, 2011, with the thesis “MIMO Multiple Access Channel with Partial Channel State Information”.

- December 2010 - November 2011: Post-Doctoral researcher at the Department of Biomedical, Electronic, and Telecommunications Engineering, Università degli Studi di Napoli “Federico II”, Naples, Italy, funded by EOARD (European Office of Aerospace Research and Development) project.
- December 2011 - November 2013: Post-Doctoral researcher at the Remote Sensing Institute (IREA), CNR, funded by HABITAT (HArBour traffIc opTimizAtion sysTem) project.
- December 2013 - June 2014: Post-Doctoral researcher at the “Consorzio Nazionale Interuniversitario per le Telecomunicazioni” (CNIT), Italy, funded by Selex ES.
- June 2014 - March 2015: Post-Doctoral researcher at the Remote Sensing Institute (IREA), CNR, Italy, funded by HABITAT (HArBour traffIc opTimizAtion sysTem) project.
- April 2015 - March 2016: Post-Doctoral researcher at the Department of Electrical and Information Technology Engineering, Università degli Studi di Napoli “Federico II”, Naples, Italy, funded by SIRena (Sviluppo ed Industrializzazione di sistemi a Radiofrequenza e finestre elettromagnetiche).
- April 2016 - November 2016: Post-Doctoral researcher at the Department of Electrical and Information Technology Engineering, Università degli Studi di Napoli “Federico II”, Naples, Italy, funded by Adaptive Signal Processing for Radar and Communication Applications projects.
- December 2016-December 2018: Assistant Professor (without a tenure track) at the Department of Electrical and Information Technology Engineering, Università degli Studi di Napoli “Federico II”.
- Since December 2018: Assistant Professor (on a tenure track) at the Department of Electrical and Information Technology Engineering, Università degli Studi di Napoli “Federico II”.

C) Synthetic Description of Dr. Aubry's Research Activity

Dr. Aubry's research activity has been mainly focused on the design of innovative algorithms for adaptive radar signal processing. Precisely, advanced resource allocation procedures as well as sophisticated estimation/detection techniques have been conceived to enhance radar performance, with emphasis on

1. Waveform Design and Diversity.
   This research activity deals with the design of optimization-theory based procedures to synthesize radar transmit signals (possibly jointly with the receiver) aimed at improving system performance. These algorithms represent the key ingredient of the modern cognitive radar. In this context, the following technical contributions have been given: J.3, J.4, J.9, J.11, J.12, J.17, J.19, J.21, J.23, J.26, J.31, J.32, J.34, J. 38, J.40, J.41, J.49, J. 51, J. 52, J.62;
2. Knowledge-Based/Cognitive Radar Signal Processing and Structured Interference Covariance Matrix Estimation.

This research activity concerns the development of new estimation techniques that try to capitalize on a-priori information/environment cognition to grant accuracy improvements especially in training starved regimes. In this context, the following technical contributions have been given: J.2, J.7, J.8, J.10, J.13, J.14, J.37, J.39, J.45, J.50;

3. Adaptive Radar Detection.
   This research activity considers the synthesis of advanced receiver architectures to boost targets detection accounting for structured interference, steering vector mismatches, and data oversampling. In this context, the following technical contributions have been given: J.6, J.15, J,16, J.18, J.20, J.29, J.48, J.54, J.55, J.57, J.59;
4. MIMO Radar Signal Processing and Space Time Coding.
   This research activity focuses on the exploitation of the spatial degrees of freedom provided by the multiple antennas at both transmitter and receiver sides to improve radar capabilities, both for collocated and widely distributed configurations. In this context, the following technical contributions have been given: J.1, J.22, J.28, J.63.
5. Robust Receive Filters Design.
   This research activity accounts for the synthesis of advanced radar filters able to mitigate the deleterious effects of knowledge inaccuracies about the useful signal as well as the interference characterization. In this context, the following technical contributions have been given: J.27, J.30, J.35.

Additionally, Dr. Aubry has conducted research activities on the study of the phase noise impairments on radar performance (J.24, J.25). Besides, in the last two years some valuable contributions have been provided for the design of advanced radio-localization techniques (J.43, J.47, J.61) as well as in the assessment of some previously proposed waveform design algorithms and situational awareness strategies on real measured data (J.53, J.56). Finally, he has also given some technical contributions in the field of communication systems design and analysis mainly in the context of MIMO Multiple Access Channels (MAC), (J.5).
A detailed description of most of the above research activity can be found at the end of the present Curriculum Vitae.

Significant Indexes (updated to 14/7/2021)
GOOGLE SCHOLAR h-index: 30
GOOGLE SCHOLAR total number of citations: 3094
SCOPUS h-index: 28
SCOPUS total number of citations: 2545

Main scientific collaborations and related main publications

1. Prof. A. De Maio, Università degli Studi di Napoli "Federico II", Naples, Italy, J.2, J.3, J.4, J.6-J.21, J.23- J.32, J.34, J.35, J.37-J.62.
2. Dr. A. Farina, Selex Sistemi Integrati, Roma, Italy, J.2, J.3, J.4, J.6, J.8, J.9, J.10, J.13, J.17, J.21, J.24, J.25, J.31, J.38, J.53, J.56, J.60.
3. Prof. A. M. Tulino, Università degli Studi di Napoli "Federico II", Naples, Italy, J.1, J.5.

4. Dr. Y. Huang, Hong Kong University of Science and Technology, Hong Kong, J.21, J.28, J.30.
5. Prof. D. Orlando, Università Niccolò Cusano, Rome, Italy, J.15, J.16, J.18, J.20, J.29, J.36.
6. Dr. M. Naghsh, Isfahan University of Technology, Isfahan, Iran J.12, J.22, J.23, J.34.
7. Prof. M. Lops, Università degli Studi di Cassino e del Lazio Meridionale, Cassino, Italy, J.1.
8. Prof. S. Zhang, the Chinese University of Hong Kong, Hong Kong (now with University of Minnesota, US) J.11.
9. Prof. P. Stoica, Uppsala University, Sweden, J12.
10. Dr. M. Wicks, US-AFRL, Rome, New York, US, J.3, J.4.

Teaching

a. 2007-2008: teaching assistant in Digital Communications course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
b. 2008-2009: teaching assistant in Signal Theory course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
c. 2008-2009: teaching assistant in Information Theory and Codes course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
d. 2010-2011, 2011-2012, 2012-2013, 2013-2014: teaching assistant in Fundamentals of Telecommunications course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
e. 2012-2013, 2014-2015, 2015-2016: teaching assistant in Statistical Signal Processing course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
f. 2013-2014, 2014-2015: teaching assistant in Radar Systems course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
g. 2014-2015, 2015-2016: teaching assistant in Probability and Random Processes course (Università degli Studi di Napoli “Federico II”, Naples, Italy).
h. 2016-2017: Professor of Signal Theory course (Università degli Studi di Napoli "Federico II").
i. 2017-2018: Professor of Fundamentals of Telecommunications course (Università degli Studi di Napoli "Federico II").
j. 2018-2019: Professor of Fundamentals of Telecommunications course (Università degli Studi di Napoli "Federico II").
k. 2019-2020: Professor of Fundamentals of Telecommunications course (Università degli Studi di Napoli "Federico II").
l. 2019-2020: Professor of Radiolocalization and Satellite Navigation course (Università degli Studi di Napoli "Federico II").
m. 2020-2021: Professor of Fundamentals of Telecommunications course (Università degli Studi di Napoli "Federico II").
n. 2020-2021: Professor of Radiolocalization and Satellite Navigation course (Università degli Studi di Napoli "Federico II").
o. 2020-2021: Professor of Terrestrial and Satellite Radiolocalization Techniques course (Università degli Studi di Napoli "Federico II").
p. 2021-2022: Professor of Signal Theory course (Università degli Studi di Napoli "Federico II").
q. 2021-2022: Professor of Terrestrial and Satellite Radiolocalization Techniques course (Università degli Studi di Napoli "Federico II").

r. March 2015: lecturer in Statistical Signal Processing and Spectral Analysis course (WISCH, Work Into Shaping Campania's Home, project).
s. July 2015: lecturer in Radar Systems course (TELEMACO, Tecnologie abilitanti e sistemi innovativi a scansione ELEttronica del fascio in banda Millimetrica e centimetrica per AppliCazioni radar a bOrdo di velivoli, project).
t. July - September 2015: lecturer in Statistical Signal Processing course (TELEMACO, Tecnologie abilitanti e sistemi innovativi a scansione ELEttronica del fascio in banda Millimetrica e centimetrica per AppliCazioni radar a bOrdo di velivoli, project).

Scientific responsibility for international and national research projects, selected for funding based on calls that involved competitive peer review

1. Project: HABITAT (HArBour traffIc opTimizAtion sysTem), OR 3 "Sviluppo di Tecniche di Detection, Tracking and Prediction" in the context of Progetto PON (Programma Operativo Nazionale)". Start date 2011; period: 30 months. Role: Co-Responsibile of the research unit together with Dr. A. Pauciullo.
2. Project: RADAROPT (Radar wAvwform Diversity for spectrAlly cRowded envirOnments based on oPtimization Theory). Start date 2017; in progress.

Participation to international and national research projects, selected for funding based on calls that involved competitive peer review

1. Member of the European Office of Aerospace Research and Development (EOARD) project “Waveform Design and Diversity for Advanced Space-Time Adaptive Processing and Multiple Input Multiple Output Systems”. Start date: 2009; period: 36 months.
2. Member of the “SIRena” (Sviluppo ed Industrializzazione di sistemi a Radiofrequenza e finestre elettromagnetiche) project. Start date: 2011; period: 48 months.
3. Member of the “TELEMACO” (Tecnologie abilitanti e sistemi innovativi a scansione ELEttronica del fascio in banda Millimetrica e centimetrica per AppliCazioni radar a bOrdo di velivoli) project. Start date: 2013; period: 36 months.
4. Member of the “ARS01 00615 - OPL-APPS” (IIoT OPEN Platform e Applicazioni per il manufactoring) project. Start date:2019.
5. Member of the “S4E” (Sistemi di sicurezza e protezione per l'Ambiente Mare)” project. Start date: 2019.

Participation in editorial boards of recognized: journals, collections of books, encyclopedias and treatises

1. Associate Editor of IEEE Signal Processing Letters, 11/2015-11/2019.
2. Guest Editor of the Special Issue on EURASIP Journal on Advances in Signal Processing Journal “Advanced Techniques for Radar Signal Processing”, June 2016.
3. Associate Editor del “IEEE Transactions on Signal Processing”, since 11/2019.

Achievement of awards for scientific activity

1. Co-recipient of the 2013 best paper award (entitled to B. Carlton) of the IEEE Transactions on Aerospace and Electronic Systems with the contribution “Knowledge-Aided (Potentially Cognitive) Transmit Signal and Receive Filter Design in Signal-Dependent Clutter”.
2. IEEE Senior Membership. In recognition of professional standing, elected Senior Member by the Officers and Board of Directors of the IEEE.
3. Member of "IEEE AESS Radar Systems Panel".
4. Member of "IEEE AESS Professional Networking and Mentoring Program" (http://ieee-aess.org/mentor-profiles-technical-area-radar-systems).
5. Co-recipient of the 2013 IEEE Radar Conference Best Student Paper Award with the contribution "Extended Target Detection in Interference whose Covariance Matrix is Defined via Uncertainty Convex Constraints".
6. Co-recipient of 2018 best paper award of the 5th IEEE International Workshop on Metrology for Aerospace 2018, with the contribution “Assessing Spectral Compatibility Between Radar and Communication Systems on Measured Data”.
7. Co-recipient of 2020 best paper - runner up award of the 7th IEEE International Workshop on Metrology for Aerospace 2020, with the contribution “Constant Modulus Discrete Phase Radar Waveforms Design Subject to Multi-Spectral Constraints”.
8. In IEEE Radar conferences 2012, Atlanta, “Estimation of a Structured Covariance Matrix with a Condition Number Constraint for Radar Applications”, selected as finalist for the student session competition (receiving also a travel support grant).
9. In IEEE Radar conferences 2015, Arlington, “Phase Noise Modeling and its Effects on the Performance of Some Radar Signal Processors”, selected as finalist for the student session competition (receiving also a travel support grant).
10. Grant Award by "US ARMY" for the research activity conducted by Prof. A. De Maio and Dr. A. Aubry concerning the design of waveforms able to enhance radar performance while ensuring spectral compatibility with the surrounding systems. Additional developments have been funded by the project entitled: “Waveform Design via Constrained Optimization for Spectrally Crowded Scenarios", 2017.

Contracts with companies and achievements in technology transfer

1. Research agreement with Selex Sistemi Integrati, “Estimation of the Disturbance Covariance Matrix: Statistical versus Information Geometry Techniques” (Member of the Research Group) Rome, start date 2010.
2. Research agreement with Elettronica S.p.A., “Specific Emitter Identification” (Member of the Research Group) Rome, start date 2011.
3. Research agreement with Elettronica S.p.A., “Jamming Techniques to the GPS system” (Member of the Research Group) Rome, start date 2012.
4. Research agreement with Consilium Italy Srl, “Oil Spills Detection on the Sea Surface” (Member of the Research Group) Florence, start date 2012.
5. Research agreement with Elettronica S.p.A., “Sviluppo di un Simulatore per il Calcolo della Portata Radar in presenza di Cammini Multipli dovuti alla Superficie del Mare” (Member of the Research Group) Rome, start date 2013.

6. Research Agreement with Selex ES S.p.A., “Modelli Statistici per il Rumore di Fase nei Sistemi Radar e loro Effetto sulle Prestazioni di Algoritmi di Elaborazione del Segnale” (Member of the Research Group) Rome, start date 2013.
7. Research agreement with Elettronica S.p.A., “Tecniche e Tecnologie Applicabili su Piattaforme Unmanned: Contrasto a Radar Costieri e Campionamento Diretto” (Member of the Research Group) Rome, start date 2014.
8. Research agreement with Elettronica S.p.A., “Off-Board Decoy attivi e Chaff illuminate” (Member of the Research Group) Rome, start date 2015.
9. Research agreement with Elettronica S.p.A., “Emitter Identification per Emittenti AIS” (Member of the Research Group) Rome, start date 2016.
10. Research agreement with Elettronica S.p.A., “Studio di Tecniche di Contromisure Elettroniche a Radar ad Apertura Sintetica (SAR): Fase I” (Coordinator of the Research Group) Rome, start date 2016.
11. Research agreement with Elettronica S.p.A., “Studio di Tecniche di Contromisure Elettroniche a Radar ad Apertura Sintetica (SAR): Fase II” (Member of the Research Group) Rome, start date 2017.
12. Research agreement with MBDA S.p.A. “Studio di fattibilità su algoritmi avanzati in ambito navale: sviluppo strategie avanzate future di Electronic Counter-Counter Measures (ECCM)”, (Member of the Research Group), start date 2017.
13. Research agreement with MBDA S.p.A. “Cognitive Radar Multi-Target Tracking”, (Member of the Research Group), start date 2018.
14. Research agreement with Elettronica S.p.A., “Cognitive Radar Multi-Target Tracking", (Member of the Research Group) Rome, start date 2018.
15. Research agreement with Vitrociset S.p.A., “Supporto Specialistico Simulazione Radar Cheia ", Rome, start date 2020.

Some techniques/algorithms developed in the research agreements with companies are implemented (in the implementation phase) on real operating systems.

Other titles

A) Journal Refereeing Activity

Dr. Aubry is a Referee for the following journals:

- i. IEEE Transactions on Signal Processing.
- ii. IEEE Transactions on Aerospace and Electronic Systems.
- iii. IEEE Journal of Selected Topics in Signal Processing.
- iv. IEEE Signal Processing Letters.
- v. IEEE Communications Letters.
- vi. IET Radar, Sonar & Navigation.
- vii. EURASIP Journal on Applied Signal Processing.
- viii. Signal Processing (Elsevier).

B) Membership of Professional Organizations

Dr. Aubry is:

i. Senior member of the Institute of Electrical and Electronic Engineers (IEEE).
ii. Member of "AESS Radar System Panel (RSP)".
iii. Member of the NATO Panel Group “Machine Learning for Wide Area Surveillance" SET-ET-110.
iv. Member of the NATO SET-278 “Machine Learning for Wide Area Surveillance”.
v. Member of "AESS Professional Networking and Mentoring Program" (http://ieee-aess.org/mentor-profiles-technical-area-radar-systems).
vi. Member of Consorzio Nazionale per le Telecomunicazioni (CNIT).
vii. Member of Gruppo Telecomunicazioni e Tecnologie dell'Informazione (GTTI).

C) Participation to Technical and/or Organizing Conference Committee.

Dr. Aubry acted as:

i. Chair of the poster session "Signal Processing for Communications and Sensor Networks" at the IEEE Sensor Array and Multichannel Signal Processing Workshop (SAM) 2012, Hoboken, NJ, US, June 2012.
ii. Co-Chair of the session “Advanced Algorithms for Radar Detection” at the IEEE Radar Conference (RadarCon), 2017, Seattle, WA, US, 8-12 May 2017.
iii. Co-Chair of the session “Space SAR” at the IET Radar Conference, 2017, Belfast Waterfront Conference Centre, UK, 23-26 October 2017.
iv. Co-Chair of the session “Spectrum Sharing 1” at the IEEE Radar Conference (RadarCon), 2018, Oklahoma City, OK, US, 23-27 April 2018.
v. Co-Chair of the session “Radar Detection", IEEE Radar Conference (RadarCon), 2019, IEEE Radar Conference (RadarCon), 2019, Boston, MA, 22-26 April 2019.
vi. Co-Chair of the session “Waveform design & diversity”, IEEE International Radar Conference, Washington DC, USA, 28-30 April 2020.
vii. Co-Chair of the section “Radar waveform design/optimization", IEEE Radar Conference, Florence, IT, 21-25 September 2020.
viii. Co-Chair of the session “Advanced radar waveform design strategies", IEEE Radar Conference, Florence, IT, 21-25 September 2020.
ix. Member of the Technical Committee of the IEEE Radar Conference 2014, Cincinnati, Ohio, US, May 2014.
x. Member of the Technical Committee of the IEEE International Radar Conference 2015, Washington D.C., VA, US, May 2015.
xi. Member of the Technical Committee of the IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP) 2015, Cancun, Mexico, December 2015.
xii. Member of the Technical Committee of the IEEE Radar Conference 2016, Philadelphia, PA, US, May 2016.
xiii. Member of the Technical Committee of the Collaborative Conference

on Signal Processing 2016, Bangkok, Thailand, November 2016.

xiv. Member of the Technical Committee of the Collaborative Conference on Radar 2016, Orlando, VA, US, December 2016.
xv. Member of the Technical Committee of the IEEE Radar Conference 2017, Seattle, WA, US, May 2017.
xvi. Member of the Technical Committee of the IEEE International Workshop on Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP) 2017, Curacao, Dutch Antilles, December 2017.
xvii. Member of the Technical Committee of the IEEE Radar Conference 2018, Oklahoma City, OK, US, April 2018.
xviii. Member of the Technical Committee of the European Signal Processing Conference (EUSIPCO) 2018, Rome, Italy, September 2018.
xix. Member of the Technical Committee of the IEEE ICASSP 2019, Brighton, UK, May 2019.
xx. Member of the Technical Committee of the IEEE Radar Conference 2019, Boston, MA, USA, April 2019.
xxi. Member of the Technical Committee of IEEE Radar Conference 2020, Florence, Italy, September 2020.
xxii. Member of the Organizing Committee of IEEE Radar Conference 2020, Florence, Italy, September 2020 (Student Program Co-Chair).
xxiii. Member of the Technical Committee of International Radar Conference 2020, Washington D.C., USA, 2020.
xxiv. Member of the Technical Committee of IEEE ICASSP 2020, Barcelona, Spain, 2020.
xxv. Member of the Technical Committee of IEEE Radar Conference 2021, Atlanta, GA, USA, May 2021.
xxvi. Member of the Technical Committee of IEEE ICASSP 2021, Toronto, Ontario, Canada, June 2021.
xxvii. Member of the Technical Committee of IEEE Radar Conference 2022, New York City, NY, USA, May 2021.

D) International Research Experience

i. March 2009 - April 2009: visiting student researcher at the Department of Electrical Engineering, Princeton University B308 Engineering Quadrangle Princeton, NJ 08544, USA, to conduct research on MIMO channels in collaboration with Prof. A. M. Tulino.
ii. November 2009 - December 2009: visiting student researcher at the Department of Wireless Communications, Bell Laboratories, Alcatel-Lucent, 791 Holmdel-Keyport Rd Holmdel, NJ 07733, USA, to conduct research on MAC systems with partial CSI in collaboration with Prof. A. M. Tulino and Dr. S. Venkatesan.
iii. February 2012 - April 2012: visiting researcher at the Department of Mathematics, Hong Kong Baptist University, Hong Kong, to conduct research on optimization theory applied to radar signal processing in collaboration with Dr. Y. Huang.

iv. September 2016: visiting researcher at the Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, UK, to conduct research on wind farm mitigation techniques in collaboration with Dr. C. Clemente.
v. December 2017: visiting scientist at the NATO Science and Technology Organization Centre for Maritime Research and Experimentation (STO CMRE), La Spezia, Italy, to conduct research on covariance matrix filtering for adaptive environment learning.

E) PhD Students Supervision/Support to Supervision

Dr. Aubry coordinated/co-coordinated the research activities on "Waveform Design" and "Adaptive Signal Processing" of the following PhD students:

i. Luca Pallotta, PhD Student at Università degli Studi di Napoli "Federico II", Naples, Italy (Supersivor Prof. A. De Maio).
ii. Mohammad Karbasi, PhD Student at Sharif University of Technology, Faculty of Electrical Engineering, Tehran, Iran.
iii. Xu Cheng, PhD Student at School of Electronic Science and Engineering, National University of Defense Technology, Hunan Province, China.
iv. Mohammad Alaee, PhD Student at Isfahan University of Technology, Department of Electrical and Computer Engineering, Isfahan, Iran.
v. Angela Marino, PhD Student at Università degli Studi di Napoli "Federico II", Naples Italy.
vi. Marco Maffei, PhD Student at Università degli Studi di Napoli "Federico II", Naples Italy (Supersivor Prof. A. De Maio).
vii. Rong Yao, PhD Student at College of Mathematics Sichuan University Chengdu, Sichuan, China.
viii. Jianbo Li, PhD Student at College of Mathematics Sichuan University Chengdu, Sichuan, China.
ix. Dr. Xiaolin Du, Post-doc at Yantai University, China.
x. Lan Lan, PhD Student at Xidian University, China.
xi. Jing Yang, PhD Student at University of Electronic Science and Technology of China, China.
xii. Guodong Jin, PhD Student at College of Electronic and Information Engineering, Nanjing, China.

F) Reaserchers hosted at the Università degli Studi di Napoli "Federico II"

i. Mohammad Karbasi, PhD Student at Sharif University of Technology, Faculty of Electrical Engineering, Tehran, Iran, February - July 2013.
ii. Xu Cheng, PhD Student at School of Electronic Science and Engineering, National University of Defense Technology, Hunan Province, China, December 2014 - December 2015.
iii. Harun Taha Hayvaci, Professor at TOBB University of Economics and Technology, Department of Electrical and Electronics Engineering, Ankara, Turkey, May - July 2015.
iv. Mohammad Alaee, PhD Student at Isfahan University of Technology, Department of Electrical and Computer Engineering, Isfahan, Iran, November 2015 - July 2016.

v. Rong Yao, PhD Student at College of Mathematics Sichuan University Chengdu, Sichuan, China, November 2018 - October 2019.
vi. Jianbo Li, PhD Student at College of Mathematics Sichuan University Chengdu, Sichuan, China, November 2018 - October 2019.
vii. Xiaolin Du, Post-doc at Yantai University, China, September 2019 - August 2020.
viii. Lan Lan, PhD Student at Xidian University, China, July 2019 - June 2020.
ix. Jing Yang, PhD Student at University of Electronic Science and Technology of China, China, November 2019 - October 2020.
x. Guodong Jin, PhD Student at College of Electronic and Information Engineering, Nanjing, November 2019-October 2020.

G) Tutorials and Invited Lectures

i. "Waveform Design and Diversity for Radar Systems", Workshop to HABITAT project, Vietri, Italy, September 2013 (Co- Author together with Prof. A. De Maio).
ii. "Theory of Radar Detection and CFAR Techniques", EURASIP PhD Summer School, Pisa, Italy, September 2014 (Co- Author together with Prof. A. De Maio).
iii. "Nuovi Modelli Statistici per il Rumore di Fase nei Sistemi Radar e loro Effetto sulle Prestazioni di Algoritmi di Elaborazione del Segnale", Collaboration Day 2014, Rome, Italy, November 2014.
iv. "Radar Detection, Performance Analysis and CFAR", IEEE Radar Conference (RadarCon), 2017, Seattle, WA, US, May 2017 (Co-Author together with Prof. A. De Maio).
v. "Optimisation theory in advanced radar signal processing", IET Radar Conference, 2017, Belfast Waterfront Conference Centre, UK, October 2017 (Co-Author together with Prof. A. De Maio and Dr. A. Farina).
vi. "Radar Detection, Performance Analysis, and CFAR Techniques", IEEE Radar Conference (RadarCon), 2018, Oklahoma City, OK, US, April 2018 (Co-Author together with Prof. A. De Maio).
vii. "Radar Detection, Performance Analysis and CFAR", IEEE Radar Conference (RadarCon), 2019, Boston, MA, April 2019 (Co- Author together with Prof. A. De Maio).
viii. "Cognitive Radar Signal Processing", European Microwave Week 2020, Utrecht, Netherlands, January 2021 (Co-Author together with Dr. J. Guerci).

Description of the main research activity in radar signal processing field

1) Waveform Design and Diversity

Waveform Design & Diversity (WDD) is a recent paradigm that has been attracting a lot of research interest in radar and signal processing communities during the last decade. It refers to the radar waveform adaptation in several domains, such as spatial, temporal, spectral, and polarization, aimed at dynamically optimizing the radar performance for the particular scenario and tasks. This advanced and powerful feature is enabled by the new computing architectures, high-speed and off-the-shelf processors, arbitrary digital waveform generators, solid-state transmitters, etc., and provides unique capabilities enhancing radar detection, classification, identification, localization, and tracking performance over classical systems. In particular, WDD capable systems are able to respond to the even more stressing needs and requirements of demanding systems such as airborne early warning and homeland security.

In this context, in J.4, the problem of cognitive/knowledge-aided transmit signal and receive filter joint design for a radar system which operates in the presence of a possibly range-ambiguous signal-dependent interference is addressed. Specifically, it is assumed that the radar system has access to an environmental (possibly dynamic) database including a geographical information system, previous scans, meteorological data, some theoretical (or possibly empirical) electromagnetic reflectivity and spectral clutter models allowing the prediction of the actual scattering scenario. Hence, the synthesis of the transmit signal and the receive filter maximizing the Signal-to-Interference-plus-Noise Ratio (SINR) for a point-like target is considered. Other than an energy constraint, a similarity constraint on the probing radar signal is imposed so as to control certain characteristics of the transmitted waveform and fulfill some practical requirements. To tackle the resulting highly non-convex quadratically constrained fractional quartic problem, an innovative optimization procedure sequentially improving the SINR is devised exploiting some proved hidden convexities of the optimization problem. Each iteration of the algorithm, whose convergence is analytically proved, requires the solution of both a convex and a hidden convex optimization problem. Remarkably, the computational complexity is linear with the number of iterations and polynomial with the receive filter length. Finally, the performance analysis reveals the ability of the developed joint transmit-receive design to suitably shape the system cross-ambiguity function so as to enhance reverberation suppression and ensure significant SINR gains with respect to the traditional approach of adapting the receive side. The above framework is generalized in J.3 to account for unimodular radar waveforms. Both continuous and finite phase alphabet cases are studied, and the joint design problem is formulated as a non-convex, NP-hard, fractional quartic optimization problem. A technique with polynomial computational complexity that is based on SemiDefinite Relaxation (SDR) and randomization and randomization is proposed to get approximated optimal solutions in the steps of the proposed sequential algorithm. Numerical results show the effectiveness of the procedure.

In J.12, to account for unknown Doppler shift of the target, a max-min approach is followed and a novel method for Doppler robust joint design of transmit sequence and receive filter in the presence of signal dependent interference is devised. Specifically, the worst-case SINR at the output of the receive filter is adopted as the performance measure. Besides, the same set of constraints as in J.4 is forced on the transmitted signal. The resulting optimization problem is a non-convex max-min optimization with an infinite number of constraints that is shown to belong to a class of NP-hard problems. Thus, an algorithm with a polynomial computational complexity to generate a good sub-optimal solution for the aforementioned problem is developed. Precisely, a novel cyclic maximization strategy is devised to tackle a relaxed version of the design problem. Furthermore, a synthesis stage is considered to obtain optimized pairs of transmit sequences and receive filters which possess the desired Doppler robustness. The analysis shows that the sub-optimal solutions provided by the proposed algorithm lead to high-quality radar filter-signal pairs ensuring a considerable robustness with respect to the target Doppler shift with quite high SINR values compared to some counterparts available in the open literature.

In J.23, the framework of J.12 is extended to account for a receiver equipped with a filter bank. Hence, still assuming unknown the target Doppler frequency, the worst-case SINR at the output of the filter bank is considered as the figure of merit (to be optimized) so as to ensure target detectability regardless of its actual velocity. The resulting design problem belongs to a class of non-convex max-min optimization problems very hard to solve. Hence, a new optimization procedure that monotonically increases the worst-case SINR is developed leveraging on an effective equivalent reformulation of the original design. Each iteration of the algorithm, whose convergence to a stationary point is analytically proved, requires the solution of both a convex and a max-min fractional problem (i.e., a generalized fractional programming problem which can be globally solved resorting to the generalized Dinkelbach's algorithm). The performance analysis illustrates the capability of the procedure to ensure target detectability regardless of its actual Doppler shifts, with significant SINR gains with respect to both traditional approaches adapting the receiver side only and some related counterparts. In J.19, the joint transmitter/receiver design is addressed with reference to extended targets. In order to account for knowledge inaccuracies about Target Impulse Response (TIR) a novel design approach aimed at maximizing the worst-case SINR (with respect to the possible TIRs) under a Peak-to-Average Ratio (PAR) constraint on the transmitted signal is proposed. The performance analysis clearly shows the ability of the developed polynomial computational complexity algorithm to ensure a quite stable behavior of the SINR with respect to TIR uncertainties. Additionally, in the reported case studies, the constant modulus constraint induces a negligible performance loss with respect to the unconstrained design. Finally, in J.32, the robust joint design of the transmit waveform and filtering structure for polarimetric radar is considered. In particular, the worst case signal-to-interference plus noise ratio (SINR) at the output as the figure of merit to optimize under both a similarity and an energy constraint on the transmit signal, an iterative optimization procedure with ensured convergence properties is developed. The effectiveness of the proposed method is validated through experimental results (both on real and simulated data), underlining the performance improvement given by a full-polarimetric design.

In J.17, a new procedure to devise radar waveforms sharing desirable spectral features, so as to ensure coexistence with overlaid wireless networks, and optimal radar detection performance is proposed. It is supposed that the radar system has the ability to predict the behavior of surrounding licensed emitters, for instance, using a Radio Environmental Map (REM), containing geographical features as well as locations and activities of wireless transmitters. Hence, a novel design framework aimed at optimizing the transmitted waveform in terms of target detection probability while controlling the total interference radiated on the overlaid systems is introduced. Therein, a similarity constraint between the unit-energy transmitted signal and a reference waveform is forced too. The resulting problem is formalized as a nonconvex Quadratically Constrained Quadratic Programming (QCQP) problem and its feasibility and solvability are extensively studied. As to the feasibility, the concept of Interference/Similarity (I/S) achievable region is developed; it is the set of all the admissible interference and similarity levels that can be selected at the design stage. Remarkably, the convexity of the aforementioned set is shown and it leads to the achievability of all the I/S levels contained in the convex hull of any set of I/S feasible pairs. With reference to the solution technique, the conceived algorithm first relaxes the original problem into a convex one which belongs to the SemiDefinite Programming (SDP) problems class. Then, it derives an optimum code through a rank-one decomposition performed on an optimal solution of the relaxed problem. In particular, the entire procedure entails a polynomial computational complexity. At the analysis stage, the waveform performance is studied in terms of trade-off among the achievable SINR, spectral shape, and the resulting autocorrelation function. The results show that high SINR values and enhanced interference suppression capabilities can be traded off with a partial degradation in terms of autocorrelation properties. In J.21, the above framework is extended to account for a possible modulation of the transmitted waveform energy. By doing so, an enhanced spectral coexistence can be guaranteed enabling radar waveforms synthesis in conditions not allowed in J.21. Additionally, in J.31 and in C.22 design methodologies to include signal dependent interference are provided. Finally, in J.49, still in the context of waveform design granting spectral coexistence with some overlaid licensed emitters, a new optimization algorithm ensuring a local control on the interference energy radiated on each shared/reserved frequency bandwidth is performed. Along with a requirement on the maximum transmitted energy, a similarity constraint is enforced on the probing sequence in order to control significant waveform hallmarks, e.g., ambiguity function features. The optimization process is restricted to constant modulus waveforms for compatibility with current amplifier technology and is unprecedented in terms of synthesizing phase-only codes subject to multiple spectral compatibility constraints. The resulting optimization problem belongs to the class of NP-hard problems and a new iterative algorithm based on the Coordinate Descent (CD) method is utilized for code design. In each iteration, nonconvex optimization problems are globally solved in closed form through the computation of elementary functions. The overall computational burden of the algorithm is linear with respect to the code length and the number of iterations and is less then cubic with respect to the number of licensed emitters. Remarkably, the reported case studies illustrate the effectiveness of the new devised algorithm to finely control the injected interference while ensuring optimized radar performance at the price of other desirable radar signal features, such as sidelobe levels and/or range resolution. It is also worth pointing out that even if the constant modulus constraint in J.49 is relaxed the resulting radar waveform synthesis problem belongs to the class of NP-hard problems, as shown in J.26. Therein, a procedure based on the SDR and randomization paradigm is devised to synthesize in polynomial time high quality solutions. Moreover, it is shown that the obtained solution can be further improved through a sequential optimization algorithm able to monotonically increase the SINR value and achieve a stationary point of the formulated NP-hard problem.

In J.11 a cognitive approach to design phase-only modulated waveforms sharing a desired range-Doppler response (ambiguity function) is proposed. The idea is to minimize the average value of the ambiguity function of the transmitted signal over some range-Doppler bins, which are identified exploiting a plurality of knowledge sources. Specifically, the design problem is formulated as a complex quartic order polynomial optimization problem with constant modulus constraints forced to ensure phase-only modulated signals. After proving that the optimization problem falls into an NP-hard class, a polynomial-time optimization procedure (sharing monotonicity features) based on the Maximum Block Improvement (MBI) method and the theory of conjugate-partial-symmetric/conjugate-super-symmetric fourth order tensors is devised. Hence, the capability of the new technique to properly shape the range-Doppler response of the transmitted waveform is assessed also in comparison with some existing techniques highlighting its superiority and effectiveness. In J.9 an innovative game theory based radar waveform design strategy is developed. Finally, in J.34 the design of phase sequences with good (aperiodic) autocorrelation properties in terms of peak sidelobe level and integrated sidelobe level is addressed. The problem is formulated as a bi-objective Pareto optimization forcing either a continuous or a discrete phase constraint at the design stage. An iterative procedure based on the coordinate descent method is introduced to deal with the resulting optimization problems that are nonconvex and NP-hard in general. Each iteration of the devised method requires the solution of a nonconvex min–max problem. It is handled through a novel bisection method for the continuous case ad via an FFT-based approach for the discrete phase constraint. Additionally, a heuristic approach to initialize the procedures employing the lp-norm minimization technique is proposed. Simulation results illustrate that the proposed methodologies can outperform some counterparts providing sequences with good autocorrelation features especially in the discrete phase/binary case.

2) Structured Disturbance Covariance Matrix Estimation and Knowledge-Based/Cognitive Radar Signal Processing

Estimation of the interference covariance matrix is a relevant problem in radar signal processing field that naturally arises in several applications such as, to list a few, target detection, direction of arrival evaluation, sidelobe cancelling, secondary data selection, and leads to the so called adaptive radar signal processing strategies. Conventional adaptive architectures (such as Kelly receiver, Sample Matrix Inversion (SMI) filter, and spatial beamformers) resort to the sample covariance matrix of a secondary data set collected from range gates spatially close to the one under test to estimate the interference covariance. These algorithms are often very restrictive because they are based on the assumption that the environment remains stationary and homogeneous during the adaptation process. Precisely, they provide satisfactory performance when the secondary vectors share the same spectral properties of the interference in the cell under test, are statistical independent, and their number is higher than twice the useful signal dimension. The above requirements represent important limitations since in real environments the number of data where the disturbance is homogeneous (often referred to as sample support) is very limited. Besides, poor training data selection, in such adaptive algorithms, can result in a severe degradation of radar performance. A possible strategy to circumvent the lack of a sufficient number of homogeneous secondary data (required to achieve satisfactory performance) is to exploit some a-priori information about the scene illuminated by the radar, namely to perform a knowledge-based/cognitive processing to restrict the uncertainty region of the unknown parameters.

According to the above approach, in J.2 the Maximum Likelihood (ML) estimator of the interference covariance matrix is derived assuming a special covariance structure, i.e., the sum of a positive semi-definite matrix, describing colored interference and clutter, plus a term proportional to the identity, accounting for the white disturbance term, as well as a condition number upper-bound constraint. It is show that the formulated constrained optimization problem falls within the class of MAXDET convex optimization problems and an efficient procedure is developed for its solution. Precisely, the proposed algorithm requires the computation of the eigenvalue decomposition of the sample covariance matrix and the solution of a scalar convex optimization problem, whose complexity is linear with respect to the number of sample eigenvalues greater than one. As a consequence, the overall complexity enjoyed by the proposed estimator is dominated by the computational effort connected with the sample covariance matrix eigenvalues decomposition. The performance analysis shows that the new estimator can outperform some previously proposed estimators in terms of achievable SINR values especially in the presence of limited sample support thus confirming its effectiveness.

In J.10, the problem of detecting an extended target (or a distributed target), embedded in Gaussian noise with unknown but structured covariance matrix is dealt with. It is supposed that the data are collected by several channels (temporal, spatial, or spatial-temporal) and that the possible target is sought within multiple range cells. The target echo from each range bin is modeled as a deterministic signal times a deterministic but unknown scaling factor which accounts for the target response and may possibly vary from cell to cell. No availability of secondary data set free of signal components (as, instead, usually done in the open literature) is supposed, but some a-priori knowledge about the operating environment is exploited to force the covariance matrix to belong to a specific uncertainty set. The devised constrained ML estimators involve the eigenvalues decomposition of both a properly transformed sample covariance matrix as well as its modified version based on the data projected in the null space of the transformed useful signal. Additionally, it requires the solution of two optimization problems, which often can be solved with a polynomial computational complexity in several cases of practical interest. Hence, the GLRT detector for the hypothesis test under consideration is designed. Finally, the performance assessment of the devised class of GLRT detectors highlights that the proper use of a-priori information can lead to a detection performance quite close to the optimum receiver, which supposes the perfect knowledge of the interference plus noise covariance matrix, also in the absence of secondary data.

In J.14, a covariance matrix estimator which jointly accounts for some a priori knowledge available about the operating environment and training data (even if very limited) is proposed. The idea is to exploit multiple spectral a priori models for the covariance matrix of the disturbance and suitably combine them based on the training data to obtain an accurate estimate of the actual disturbance statistics. Precisely, the ML estimate of the interference covariance matrix fulfilling the above Knowledge Aided (KA) constraints is derived. It is shown that the estimation problem can be formulated in terms of a MAXDET convex optimization problem, which can be efficiently solved using interior point methods with a polynomial worst case complexity. This framework is then exploited to design some GLRT-like KA detectors which possibly perform a joint estimate of the covariance matrix and the target response. The analysis shows the capability of the proposed covariance matrix estimation framework to accurately predict the actual interference environment. Besides, from a detection point of view, the new receiving structures exhibit an acceptable performance loss with respect to the optimum benchmark detector and a significant performance gain over the conventional adaptive counterparts.

In J.7, two interesting properties of the Fast Maximum Likelihood (FML) covariance matrix estimator are proved. Precisely, it is shown that the FML estimator, devised via the ML approach, can be obtained according to a geometric paradigm minimizing either the Frobenius or the spectral norm of difference between the sought estimate (complying with the structural constraint imposed by the presence of a white disturbance term) and the sample covariance matrix, regardless of the statistical distribution of the data. These features thus confer robustness to the FML estimator.

In J.8, a new class of estimators that do not require any knowledge about the probability distribution of the sample support and exploit the characteristics of the positive-definite matrix space is introduced. Any estimator of the class is associated with a suitable distance in the considered space and it is defined as the geometric barycenter of some basic covariance matrix estimates obtained from the available secondary data set exploiting some a-priori information about its structure. Then, an adaptive detection architecture exploiting the new covariance matrix estimators to select homogeneous training data and the adaptive matched filter to perform the final decision about the target presence is proposed. The analyses conducted both on simulated and on KASSPER data, highlights the effectiveness of the new approach. The framework is extended to the geometric median among the basic estimates in J.13. Furthermore, in J.37, a new class of disturbance covariance matrix estimators for radar signal processing applications is introduced following a geometric paradigm. Each estimator is associated with a given unitary invariant norm and performs the sample covariance matrix projection into a specific set of structured covariance matrices. Regardless of the considered norm, an efficient solution technique to handle the resulting constrained optimization problem is developed. Specifically, it is shown that the new family of distribution-free estimators shares a shrinkage type form; besides, the eigenvalues estimate just requires the solution of a one-dimensional convex problem whose objective function depends on the considered unitary norm. For the two most common norm instances, i.e., Frobenius and spectral, very efficient algorithms are developed to solve the aforementioned one-dimensional optimization leading to almost closed form covariance estimates. At the analysis stage, the performance of the new estimators is assessed in terms of achievable Signal to Interference plus Noise Ratio (SINR) both for a spatial and a Doppler processing assuming different data statistical characterizations. The results show that interesting SINR improvements with respect to some counterparts available in the open literature can be achieved especially in the presence of a small number of secondary data. Finally, the problem of determining accurate and reliable inferences on the statistical characterization of the interference contributions composing the radar disturbance returns (i.e., heterogeneous clutter, jamming signals, and noise) has been addressed in J.39. The proposed estimation procedure (able to operate in training starved regimes capitalizing on a-priori information on the probed environment) is devised resorting to the novel optimization framework for non-concave (possibly NP-hard) resource allocation/decision making problems in wireless networks and radar systems, which is proposed in J.39, too. The developed optimization tool enjoys strong optimality claims, while at the same time requiring an affordable complexity in a wide range of applications. Specifically, the proposed approach combines the Maximum Block Improvement (MBI) method with sequential optimization theory, which, among available approaches, appear to strike the best balance between performance and complexity. Convergence results for the sequence of variable-blocks generated by the algorithm is provided, for the general case in which both the objective function and the feasible set are approximated. Specifically, in this general case, the proposed algorithm is still guaranteed to monotonically increase the value of the objective function after each iteration, and to ensure that any limit (cluster) point of the variable sequence is a first-order optimal point, i.e., Karush-Kuhn-Tucker (KKT) solution, under some mild technical assumptions. The novel convergence analysis (required for the more general scenario of non-convex feasible sets) represents the main technical contribution of this work from an optimization theory point of view. Besides, convergence results of the MBI plus sequential procedure when the non-convex feasible set is not approximated represent stand-alone a new relevant contribution. By specializing the previous result to the case in which only sequential optimization is used, it is also obtained a formal convergence result for the sequential optimization algorithm in the general case in which both the objective and the feasible set are approximated, and no concavity property is assumed about the approximation of the problem objective function. This represents a relevant result by itself, since available convergence results about the sequential method consider less general/different cases. Finally, it is shown that, along with the already mentioned radar application, several applications related to resource exploitation problems for communication systems, e.g., energy-efficient beamforming in

MIMO interference networks and power control for weighted sum-energy-efficiency optimization, can be tackled by the newly proposed optimization framework.

3) Adaptive Radar Detection

The design of Space-Time-Adaptive-Processing (STAP) algorithms to detect point-like targets buried in Gaussian disturbance with unknown interference covariance matrix has been an active area of research for at least the past two decades and, over the years, many solutions have been proposed. For this problem a Uniform Most Powerful (UMP) test does not exist because the Neyman-Pearson likelihood ratio receiver requires the perfect knowledge of the disturbance covariance matrix as well as the target amplitude and phase. As a consequence, a variety of different approaches and algorithms are explored in open literature under various settings in terms of interference environment and useful signal model. In this context, the following technical contributions have been given.

In J.15, the problem of detecting a signal known up to a scaling factor in the presence of both Gaussian disturbance with unknown covariance matrix and structured interference in the primary and secondary data is addressed. A new detector based on the Modified Generalized Likelihood Ratio Test (MGLRT) criterion is introduced and its Constant False Alarm Rate (CFAR) behavior studied. Remarkably, the devised receiver can be obtained projecting the received data in the null space of the structured interference to remove the unwanted disturbance and applying the classic Kelly's Generalized Likelihood Ratio Test (GLRT) in the compressed domain. The performance assessment shows that the proposed technique can guarantee a higher detection probability than conventional adaptive detectors as a result of the available a-priori information as long as the target steering vector does not lie in the interference subspace. In J.29, resorting to the invariance theory framework, a maximal invariant statistic for the above detection problem is derived. Specifically, it is shown that it is a bi-dimensional real valued vector given by the derived MGLRT and the Adaptive Matched Filter (AMF) computed in the reduced domain, i.e., the space orthogonal to the structured interference. Interestingly, this is the same statistic that describes all the invariant tests when the interference only belongs to the primary data. As a result, these invariant tests are robust to the presence of this form of outliers in the secondary data.

In J.18, the adaptive detection of point-like targets buried in Gaussian interference when the radar operates in the presence of a glistening surface that generates a spatially diffuse multipath is addressed. The multipath components, which distort the direct path return, are modeled as random quantities. Specifically, the target echo is described as the superposition of a deterministic signal with an unknown scaling factor plus a zero-mean complex normal random vector with an unknown covariance matrix. The former contribution accounts for the radar look direction path whereas the latter models the non-resolvable unknown echoes from the glistening surface. As customary, a set of secondary data, free of signal components and sharing the same spectral properties of the disturbance (clutter plus thermal noise) in the cell under test (primary data), is assumed available at the receiver. Based on the above assumptions, the line of sight mismatched component due to the diffuse multipath induces a covariance matrix mismatch between primary and secondary data. Hence, a GLRT-based detector constraining the primary data covariance matrix (including both multipath echoes and interference) to lie into a suitable neighborhood of the secondary data sample covariance matrix is devised to deal with the formulated hypothesis testing problem.

Remarkably, it is proved that the devised architecture can be obtained as a non-linear function of Kelly's and the Adaptive Matched Filter (AMF) decision statistics implying that the synthesized detector shares the desirable CFAR property with respect to the unknown parameters of the interference. Finally, the performance assessment highlights the effectiveness of the proposed approach to capitalize the diffuse multipath energy in order to improve target detection. Besides, the case studies show some interesting performance gains with respect to some existing decision schemes in the presence of diffuse multipath.

In J.16 and J.20 some GLRT-based adaptive decision schemes for point-like targets that exploit the oversampling of data at the output of the matched filter and the subsequent spillover of the target energy between consecutive samples are derived. The radar cross-section of the target is modeled as a deterministic but unknown complex term while Doppler frequency shift and direction of arrival of the signal impinging on the radar antenna are assumed known. Additionally, a set of secondary data is assumed available at the receiver to estimate the clutter statistics. Hence, two different operating scenarios are considered and adaptive detectors devised assuming a clutter dominated environment: the former assumes a homogeneous environment, where secondary data and the Cell Under Test (CUT) share the same spectral properties of the clutter in space-slow time domain; the latter considers a partially-homogeneous scenario, where the clutter covariance matrix in space-slow time domain of the CUT and that of secondary data coincide only up to a scaling factor. Remarkably, the proposed decision schemes ensure the desirable CFAR property with respect to the unknown parameters of the interference. The performance analysis reveals that the oversampling may yield superior performance in terms of both detection probability as well estimation accuracy of target position within the range bin.

Finally, in J.6 the design of SideLobe Blanking (SLB) architecture is addressed in the presence of homogeneous Gaussian interference with unknown spectral properties and an impulsive coherent jammer interfering with the receivers through the sidelobes of the antenna. Specifically, an advanced SLB structure with arbitrary invariant decision rules on both the main and the auxiliary channels is proposed. Thus, it ensures the CFAR property by construction. This system is canonical in the sense that it does not require any knowledge about target reflectivity and jammer power. A theoretical framework is provided to evaluate the performance of the new architecture obtaining integral expressions of the general blanking probability and detection probability. Hence, the results are specialized to the case where Kelly’s receiver is applied to both the SLB channels and closed-form expressions for all the probabilities in the blanking and the detection regions are derived. Finally, the performance analysis clearly reveals that with a careful selection of the parameters the presented SLB receiver can blank a jammer with high probability while keeping a high detection probability.

4) MIMO Radar Signal Processing and Space Time Coding

Multiple-Input Multiple-Output (MIMO) radar is a novel paradigm enabling enhanced performance over conventional phase-array radar in terms of target detection, identification, classification, and localization. The mentioned advantages are mainly originated from the ability of a MIMO system to transmit distinct waveforms via its probing antennas. Based on the antennas configuration, MIMO radars are categorized as widely-spaced and colocated. As to the former class, the spacing between transmit/receive antennas is large enough to generate a rich target scattering (angle/spatial diversity) and each receive antenna picks up multiple uncorrelated target echoes. Hence, spatial diversity and waveform diversity are exploited to contrast Radar Cross Section (RCS) fluctuations and improve target classification/identification as well as boost up detection performance. As to the latter, the closely placed antennas allow performing optimized spatial coherent processing by mean of waveform diversity providing benefits such as better parameter identifiability, enhanced target localization, improved target detectability, and more flexibility in the beampattern design.

In J.1 the design of suitable Space-Time Codes (STCs) for widely-spaced MIMO radar assuming a non-Gaussian target scattering model and temporally correlated Gaussian clutter is addressed. Precisely, two figures of merit for STC optimization under a semidefinite rank constraint are considered: 1) the lower Chernoff bound (LCB) to the detection probability of a canonical receiver based on GLRT criterion for fixed probability of false alarm; 2) the mutual information (MI) between the observations available at the receive nodes and the “channel response” generated by a point-like target, assumed present. Both receive and transmit power constraints are discussed. Thus, it is shown that both MI-optimal and LCB-optimal STCs have a simple canonical structure under suitable conditions of unitary invariance on the target scattering distribution: the same set of (clutter dependent) temporal codewords are employed at the transmit nodes, the only difference among the many solutions being the amount of power radiated by each antenna. In particular, such a spatial power allocation critically depends upon the adopted figure of merit, the specified power constraint, and the underlying scattering model. The performance analysis clearly highlights the effectiveness of the STC design to burst MIMO radar capabilities as well as that LCB-optimal coding is usually preferable to MI-optimal coding as far as detection performance is concerned. Besides, assuming Gaussian scattering at the code design stage results in small mismatch losses in terms of LCB, MI and detection probability.

In J.22, the robust joint design of the (slow-time) Space–Time Transmit Code (STTC) and Space–Time Receive Filter (STRF) for a colocated MIMO system assuming a moving point-like target embedded in signal-dependent interference is considered. Specifically, the worst-case SINR (over covariance matrices mismatches) is adopted as figure of merit, so as to account for possible information inaccuracies about the surrounding scene. In addition to an energy constraint, a similarity constraint is forced on the STTC to account for the shape of the transmitted signals. Furthermore, a control on the average value of the system Cross-Ambiguity Function (CAF) response over some range-Doppler-azimuth bins is provided. Hence, a polynomial time iterative algorithm which monotonically improves the worst-case SINR is devised; each iteration of the algorithm requires the solution of two (hidden) convex optimization problems. The performance analysis results show that significant SINR improvements over the traditional SISO and MIMO approaches, that employ adaptation on the receive side only, can be achieved jointly optimizing the transmitter and the receiver of a MIMO radar. Moreover, the analyzed study cases reveal the capability of the developed procedure to robustify the MIMO system against some possible knowledge inaccuracies about the illuminated environment.

In J.28, the design of robust MIMO waveform covariance matrices (for colocated architectures) that optimize the worst case (over steering mismatches) transmit beampattern assuming either the peak sidelobe level (PSL) or the integrated sidelobe level (ISL) as figure of merit is addressed. The potential mismatches associated with each steering vector are accounted for through a general framework based on the characterization of the steering uncertainty set through two double-sided, potentially non-convex, quadratic constraints. Besides, two suitable constraints are forced on the optimization variables. The former accounts for the width of the mainbeam, whereas the latter is either a uniform or a relaxed elemental power requirement allowing to control the amount of transmitted power. Hence, polynomial time procedures aimed at synthesizing the desired optimal MIMO waveform covariance matrices are devised. The results show that while some counterparts available in open literature may experience performance degradation when model mismatches are present, the new design techniques can often ensure improved performance.

5) Robust Receive Filters Design

The synthesis of optimized adaptive radar Doppler/spatial processors, aimed at fulfilling the more and more stressing radar performance requirements, has been a hot research activity within the radar community since 60's. In this context, a widely used figure of merit is the SINR and the optimal receiver, when both the useful signal signature and the disturbance covariance matrix are known, is the well known Capon filter. Unfortunately, these quantities are not known and its natural adaptive version, known as sample matrix inversion filter, experiences a severe performance loss when significant mismatches affect either the disturbance covariance matrix or the steering vector, for instance due to the presence of interfering targets or clutter discretes in the sample covariance matrix, antenna pointing errors, imperfect array calibration, large Doppler uncertainty sets, in-phase and quadrature components errors, lo list a few.

In J.30, the design of robust filters for radar pulse-Doppler processing is considered when the interference is a wide sense stationary random process. The SINR at the output of the filter is assumed as performance measure. To account for possible mismatches between the design and the operative conditions some specific uncertainty sets have been associated with both the target Doppler frequency and the interference covariance matrix. Besides, a constraint on the sidelobes of the filter response has been enforced to control the amount of interference energy produced by targets lying in the same range cell as the target of interest. The problem has been formulated as a constrained nonconvex max-min optimization problem whose solution procedure represents the main technical contribution of this paper. Specifically, resorting to the representation of non-negative trigonometric polynomials via Linear Matrix Inequalities (LMIs), the spectral factorization theorem, and the duality theory, a polynomial-time algorithm has been devised to synthesize an optimal solution to the robust Doppler filter design. The results of some interesting case studies highlight that the new class of filters may ensure enhanced worst-case performance (in terms of achieved SINR value) over some already available counterparts. As a consequence, the devised algorithm represents a viable means to mitigate the deleterious effects of modeling mismatches while keeping satisfactory SINR values.

In J.27, a polynomial-time procedure to handle a class of generalized fractional programming (GFP) problems with Toeplitz-Hermitian quadratics is developed exploiting the LMI representation of the finite autocorrelation sequences cone, the spectral factorization theorem, and the Dinkelback's algorithm. For the special case of Fractional Quadratic Programming (FQP) problems, a SDP reformulation of the resulting non-convex optimization by means of the Charnes–Cooper transformation is provided. This optimization tool is then applied to solve a relevant radar signal processing problem, i.e., the design of constrained radar Doppler processors able to enhance target delectability while ensuring small Doppler response in some specific bandwidths so as to allow robustness to interfering sources. Finally, in J. 35, a new derivation of the Capon spectral estimator is provided in this letter enriching the set of its possible interpretations. Specifically, it is shown that it defines the best rank-one approximation (according to any distance measure induced by a unitary invariant norm) of the data covariance matrix along the dyadic product specified by the useful signal direction. Remarkably, the Capon power estimate is obtained as solution to a convex optimization problem, which represents the starting point toward the development of a new class of robust estimators

6) Radar Phase Noise Modeling and Effects

Oscillators represent an essential part of radar systems and are commonly used to perform frequency and timing synchronization. They are exploited in Radio Frequency (RF) transmitters and receivers to provide the signal for frequency conversion (up-conversion and down-conversion), in digital systems to generate the clock signal to synchronize operations, and in analog-to-digital converters to provide the necessary reference phase (clock sampling and synthesis). Unfortunately, the outputs of the oscillators are not perfectly periodic and suffer from many imperfections, making difficult the availability of a precise time reference. Practical clocks are affected by phase and frequency instabilities producing the so-called phase noise. It consists of random and unwanted fluctuations that inevitably perturb the time-domain linearity of the phase of an ideal sinusoidal oscillation. Thus, assessing the effect of noisy oscillators on the performance of radar is a fundamental task.
In J.24, the radar signal model in the presence of phase noise is formalized. Specifically, a fast-time/slow-time data matrix signal representation is developed, where the undesired phase fluctuations, affecting the reference signal produced by real radar oscillators, are modeled via multivariate circular distributions. It is shown that composite power-law model is able to accurately fit some available real phase noise Power Spectral Density (PSD) measurements. Owing to the proposed framework, the performance assessment of coherent integration techniques in the presence of phase noise is conducted. Specifically, an analytic expression to predict the performance degradations experienced by MTI algorithms in terms of the improvement factor is provided. Remarkably, the phase noise affects the improvement factor directly through its characteristic function. At the analysis stage, it is shown that the phase noise effectively impairs radar performance; besides, it is highlighted a certain degree of robustness with respect to the actual phase noise multivariate circular distribution as long as the phase noise PSD model correctly represents the available measurements.
In the second part of the study, i.e., J.25, the signal model developed in J.24 is used to assess the performance of both Pulse Doppler Processing (PDP) algorithms and SLB techniques when phase noise and Gaussian interference (clutter plus noise) impair the data. Specifically, for arbitrary coherent integration techniques, analytically manageable expressions are derived for: 1) the false alarm probability and the detection probability of PDP algorithms and 2) the false alarm probability, the probability of blanking a coherent repeater interference, and the probability of blanking a target in the mainlobe of SLB processors. The results show that phase noise may marginally affect the performance of PDP and SLB processors as long as its PSD correctly represents the available measurements. Additionally, they reveal that coherent integration detectors exploiting matched filters provide a higher level of robustness against phase noise perturbations than the optimal coherent detector. Such a behavior reflects the proved max-min optimality of the mentioned detector.

Description of the main research activity in communication systems

1) Achievable Rate Region for Gaussian MIMO MAC with Partial CSI

The increasing demand for wireless communication services has been the starting point for many research activities and discussions about the best way to make a cleaver usage of the available resources, i.e., spectrum and power, to satisfy users' requirements. The amount of information that can be reliably delivered on a communication channel is significantly influenced by many factors defining the physical links such as user mobility, time varying obstacles, power and bandwidth limitations, to list a few. Most of the information theoretical studies on wireless communication channels have been conducted assuming the coherent reception of the signals, namely the exact knowledge of the channel state at the receive side. Nevertheless, in practice any channel estimation is noisy and also uses system resources. Therefore, it becomes important to understand the fundamental limits imposed by imperfect Channel State Information (CSI). In this respect, in J22 the study of a Multiple Access Channel (MAC) system where receiver and transmitters are equipped with multiple, possibly correlated, antennas, and only a partial CSI of the users is available at the receiver is conducted. The imperfect CSI is in the form of any statistic, conditioned on which the channel has a Gaussian distribution. Specifically, lower and upper bounds on the various mutual information terms defining the achievable rate region are derived assuming Gaussian inputs. The behavior of such inner and outer bounds is deeply analyzed proving that, under some mild technical conditions, asymptotically in either the number of users or the number of receiving antennas the gaps go to zero, i.e., the derived bounds are asymptotically tight. These results together with the expression of the lower bounds allow to interpret a MIMO MAC with imperfect receiver side CSI as a degraded MIMO MAC with perfect CSI. Hence, the provided sum rate lower bound is adopted as figure of merit to design optimized precoding and power allocation policies so as to enhance system performance. Next, the developed inner and outer bounds are exploited to analyze two scenarios of practical interest and assess the fundamental limits imposed by imperfect CSI: 1) Gaussian interference networks with cooperative receiver processing; 2) MIMO MAC affected by block fading. As to the former, the impact of the network cluster size, or degree of cooperation, on the system performance is analyzed showing that cooperation is in general beneficial also in the presence of channel estimation errors as well as the accuracy of the available CSI influences a possible cluster size selection. As to the latter, each block is divided into training and data transmission phases and the CSI at the receiver is obtained through the transmission of training sequences in each coherence block of the channel. Thus, the impact of training sequence selection on the final system performance is assessed and the optimization of the training signals, considering as performance metric either the trace or the determinant of the channel estimation error covariance matrix, is also performed. Finally, low- and high-SNR regimes are analyzed obtaining that: 1) the minimum required energy per information bit for each user equals that with perfect CSI at the receiver; 2) the wideband slopes achievable by the users equals to zero under some conditions on the partial CSI at the receiver; 3) the high-SNR slope is the same of the coherent case under some conditions on the partial CSI at the receiver.

Naples, July 14, 2021

Augusto Aubry

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Scientific Publications

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J.1 A. Aubry, M. Lops, A. M. Tulino, and L. Venturino, “On MIMO Detection Under Non-Gaussian Target Scattering”, IEEE Transactions on Information Theory, Vol. 56, No. 11, pp. 5822 - 5838, November 2010.

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Autocertificazione ai sensi degli artt. 46, 47 e 76 del D.P.R. n. 445/2000:
Io sottoscritto Augusto Aubry, nato a Napoli (NA) il 12/03/1983 e residente in viale Maria Cristina di Savoia n. 6, 80122, Napoli (NA), consapevole delle conseguenze penali derivanti da dichiarazioni false e mendaci, come disposto dall’art. 76 del D.P.R. n. 445/2000, attesto che tutto quanto riportato nel curriculum corrisponde a verità.