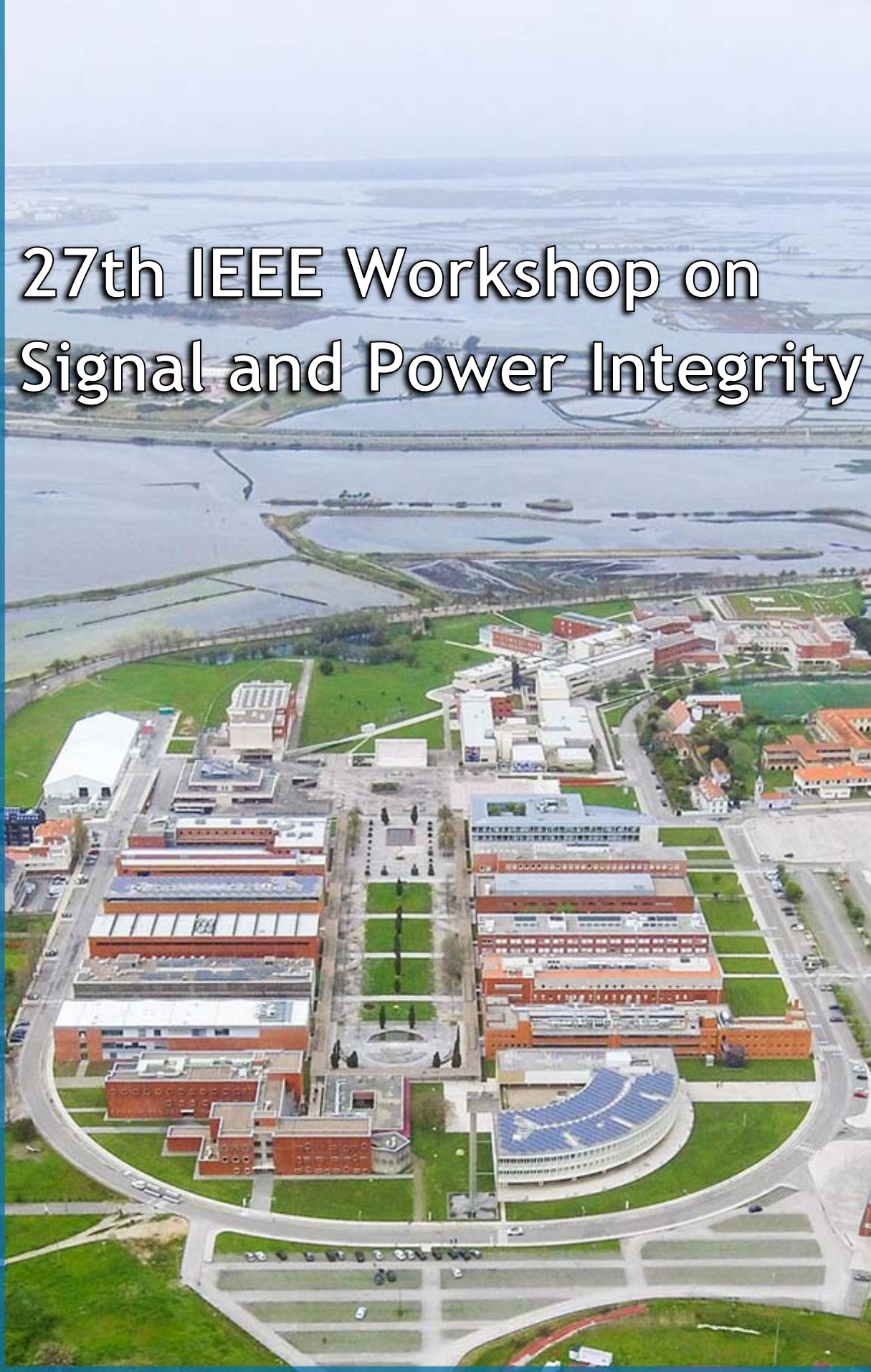
IEEE

SPI 2023

27th IEEE Workshop on Signal and Power Integrity



May 07-10, 2023

Aveiro, PORTUGAL

PROCEEDINGS

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IEEE CATALOG NUMBER: **CFP23SPI-ART**

ISBN: **979-8-3503-3282-7 © 2023 IEEE**

FOREWORD

We are glad to present the Proceedings of the 27th IEEE Workshop on Signal and Power Integrity (SPI 2023), held during May 7 - 10, 2023, at the University of Aveiro, Portugal.

It was an honor for us to serve as Workshop Chairs and Program Chairs in an event that has stood for almost three decades as a noteworthy forum of exchange on all aspects of Signal and Power Integrity, comprising the latest research and developments on design, characterization, modeling, simulation, and testing at the chip, package, board, and system level.

This year's edition fully returned to the in-person format, with 63 participants from 13 countries joining together for a technical program that included 23 oral presentations and 6 short communications, a tutorial regarding "*An Overview of Modeling Technologies for Linear and Nonlinear Electronic Devices*" and two keynotes entitled "*ENERGY sustainability for Net ZERO Radio Communications*" and "*Sense #Like a Bosch: How do our cars see the world in order to drive autonomously*", presented by invited speakers that stand as renowned names in the fields of Academia and Industry, and an Industry Forum organized by the Industry Advisory Board.

The Student Awards were also a relevant feature, as always, aiming to encourage graduate students to attend the workshop and present their current research work. Congratulations to Antonio Carlucci for winning the Best Student Paper and an IEEE Electronics Packaging Society Student Travel Grant with the paper entitled "*A Structured Krylov Subspace Projection Framework for Fast Power Integrity Verification*", and congratulations also to Federico Garbuglia for winning an IEEE Electronics Packaging Society Student Travel Grant with the paper entitled "*Modeling S-parameters of Interconnects using Periodic Gaussian Process Kernels*".

On behalf of the entire SPI 2023 Organization, we wish to thank the hosting Institutions: the Institute of Telecommunications and the University of Aveiro; the sponsoring IEEE societies: the IEEE Electronics Packaging Society (EPS), the IEEE Electromagnetic Compatibility Society (EMC-S), and the IEEE Microwave Theory and Technology Society (MTT-S); the private sponsors: Huawei and IBIS; and last but not least, the technical staff and all the volunteers who made possible this event. Our final grateful thanks go to all the SPI 2023 participants, hoping that the event has fulfilled their expectations. Join us again next year in Lisbon!

Joana Catarina Mendes & *Stefano Grivet-Talocia*, SPI 2023 Workshop Chairs

Antonio Maffucci & *Pedro Fonseca*, SPI 2023 Program Chairs

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15:00 – 17:30 **TUTORIAL**

An Overview of Modeling Technologies for Linear and Nonlinear Electronic Devices

Nowadays, computer aided design plays an unavoidable role in electronic circuit design, whether because practical linear systems are too complex to be handled by pencil-and-paper, or just because the system is inherently nonlinear and thus no closed form analysis or design solutions are possible. However, either the design engineers have a minimum understanding of what are the simulators' possibilities and limitations, or they may turn their computer aided design tasks into tiring and time-consuming torments.

This tutorial on modeling technologies for linear and nonlinear electronic devices addresses this challenge starting by a glimpse of the most common circuit simulation tools, to then focus on their most important bottleneck: the electronic devices models. Having in mind the widely known aphorism that all models are wrong but some are useful, we will begin with the very basic concept of a mathematical model and its two most important strategies, physics-based and behavioral modeling, and show why the equivalent-circuit models are the most widely adopted model types. Then, we will discuss the modeling tools for both linear and nonlinear, static and dynamic, lumped and distributed, electronic devices and illustrate these with examples usually found in signal integrity analysis.

José Carlos Pedro

Instituto de Telecomunicações & Universidade de Aveiro, Portugal

J. C. Pedro is currently a Full Professor with the University of Aveiro and the President of the Institute of Telecommunications, where he also leads the Wireless Circuits and Systems research group. His main research interests include active device modeling and the analysis and design of various nonlinear microwave circuits, in particular highly linear mixers and multicarrier power amplifiers. He is the leading author of two books and has contributed with more than 200 peer-reviewed papers and conference presentations.

J. C. Pedro is an IEEE Fellow. He was named Editor-in-Chief of IEEE Transactions on Microwave Theory and Technology for a 3 years term, served on the IEEE Portuguese MTT/AP/ED Joint Chapter and the MTT TC-3 Microwave Measurements Committee, and on organizing and technical program committees of a number of major conferences of his field, namely MTT-IMS and EuMC. He was an IEEE MTT-S Distinguished Microwave Lecturer from 2014 to 2016, and in 2016 was awarded the Microwave Distinguished Educator Award.

09:50 – 10:30 **KEYNOTE**

ENERGY sustainability for Net ZERO Radio Communications

Energy is central to all our activities, especially now, as electricity is needed for basic human survival. Nevertheless, the resources are limited. On certain occasions, we need to rely on the opportunity to have specific energy availability and energy on demand so that sensors, emergency communications, and ICT will continue to operate even if the energy grid is not there.

This talk will discuss the electricity generation problem and how to cope with the huge demand for ICT (Information Communication Technologies) technologies. We will address new paradigms for radio communications and alternatives to make energy available when needed and where needed. It is expected that Net Zero Radio alternatives will be available on the market in the future.

Nuno Borges Carvalho

Instituto de Telecomunicações & Universidade de Aveiro, Portugal

N. B. Carvalho is currently a Full Professor with the University of Aveiro and the Director of UA's Department of Electronics, Telecommunications and Informatics, as well as a Senior Researcher at the Institute of Telecommunications where he leads the Radio Systems research group. His main research interests include software-defined radio front-ends, backscatter communications, wireless power transmission, nonlinear distortion analysis, and measurements in microwave/wireless circuits and systems, and he has been involved in the design of dedicated radios and systems for newly emerging wireless technologies. He is the co-inventor of six patents, co-authored three books and has reviewed and authored over 200 papers in magazines and conferences.

N. B. Carvalho is an IEEE Fellow. He is the Editor-in-Chief of the Cambridge Wireless Power Transfer Journal, an associate editor of the IEEE Microwave Magazine, and a former associate editor of the IEEE Transactions on Microwave Theory and Techniques and IET Microwaves Antennas and Propagation Journal. He is a Distinguished Lecturer for the RFID Council and a previous Distinguished Microwave Lecturer for the IEEE Microwave Theory and Techniques Society. In 2023 he is the IEEE MTT-S President-Elect.

11:00 – 12:20 JITTER AND NOISE MODELING AND EQUALIZATION TECHNIQUES

Chair: Dries Vande Ginste

Jonguk Choi, Taeho Park, Jongjae Ryu, Chanyeong Jeong, Minseok Kang and Sungwook Moon

Samsung Electronics, South Korea

Advanced Phase Jitter Analysis with Power Noise Induced Jitter Flow in PCIe Gen3

Matthew Leslie (1), Randy Wolff (2) and Justin Butterfield (2)

(1) Siemens EDA, USA; (2) Micron Technology, USA

Simulating DDR5 Systems with Clocked Receivers

Lennart P. P. B. Bohl (1), Katharina Scharff (2), Xiaomin Duan (2), Dierk Kaller (2) and Christian Schuster (1)

(1) Hamburg University of Technology, Germany; (2) IBM Deutschland Research & Development GmbH, Germany

Bayesian Optimization of First-Order Continuous-Time Linear Equalization in High-Speed Links Including Crosstalk

Vinod Kumar Verma and Jai Narayan Tripathi

Indian Institute of Technology Jodhpur, India

Variability-Aware Modeling of Supply Induced Jitter in CMOS Inverters

14:00 – 15:00 INTERCONNECT MODELING AND SIMULATION

Chair: Igor Stievano

Jose Enrique Hernandez Bonilla (1), Golzar Alavi (1), Cheng Yang (2) and Christian Schuster (2)

(1) Robert Bosch GmbH, Germany; (2) Hamburg University of Technology, Germany

Measurement of Temperature and Humidity Dependance of Automotive-Grade Interconnects

Daniel Uebach, Thomas Kühler and Elmar Griese

University of Siegen, Germany

Techniques to Compensate Ion Depletion in the Coupling Region of Directional Couplers Manufactured by Field-Assisted Diffusion

Nicole Selezinski (1), Xiaomin Duan (2), Katharina Scharff (2), Dierk Kaller (2) and Hubert Harrer (2)

(1) Hamburg University of Technology, Germany; (2) IBM Deutschland Research & Development GmbH, Germany

Routing Length Impact on Differential Via Crosstalk Cancellation

15:00 – 16:00 SHORT COMMUNICATIONS

Chair: Antonio Maffucci

Vinod Arjun Huddar (1) and Shinyoung Park (2)

(1) Rambus, India; (2) Rambus, USA

Package Propagation Delay Dependency of Advanced Fly-By Routing For Next Generation DDR5

Ta-Yeh Lin, Shuw-Guann Lin, Yin-Cheng Chang, Chaoping Hsieh and Da-Chiang Chang

Taiwan Semiconductor Research Institute, Taiwan

A Broadband Sub-THz Band Stacked Transition of SIW-to-SIW

Harini Manoharan (1) and Frank Ebert (2)

(1) Valeo India Pvt Ltd, India; (2) Valeo Switches & Sensors, Germany

Power Integrity Analysis for High Current Digital Core & DDR Power and PDN Noise Impact on the LpDDR4 Timing Analysis for ADAS Automotive Application

Khitem Lahbacha (1), Giulia Di Capua (1), Gianfranco Miele (1), Antonio Maffucci (1), Thi Dao Pham (2), Djamel Allal (2), Gia Ngoc Phung (3) and Uwe Arz (3)

(1) University of Cassino and Southern Lazio, Italy; (2) Laboratoire national de métrologie et d'essais, France; (3) Physikalisch-Technische Bundesanstalt, Germany

Signal Integrity Analysis of Coupled Thin-Film Microstrip Lines (TFMSLs)

Sameer Vashishtha, Saiyid Mohammad Irshad Rizvi and Paras Garg

STMicroelectronics Pvt. Ltd, India

Signal Integrity Analysis of High Speed Link Analog Front End Receiver for Cost Effective Packaging Schemes

Keivan Kaboutari (1), Pedro Pinho (1), Majid Shokri (2), Changiz Ghobadi (2), Javad Nourinia (2), Zhale Amiri (2), Rahim Barzegari (2), Amir Siahcheshm (3) and Farnaz Shapour (4)

(1) Instituto de Telecomunicações, University of Aveiro, Portugal; (2) Urmia University, Iran; (3) Islamic Azad University, Salmas Branch, Iran; (4) Islamic Azad University, Urmia Branch, Iran

A Compact Four Elements Self-Isolated MIMO Antenna for X-Band Applications

16:00 – 16:10 IEEE TC-EDMS

Antonio Maffucci

University of Cassino and Southern Lazio, Italy

Activity of the IEEE EDMS Technical Committee

09:00 – 09:40 **KEYNOTE**

Sense #Like a Bosch: How do our cars see the world in order to drive autonomously

Imagine you no longer have to take the tedious task of driving your car to work, to school or to the supermarket. Imagine that instead you enjoy the ride by reading a book or watching your favorite movie. Imagine that car accidents are something from the past and you can go safely from one place to the other.

This is our vision for mobility at Bosch: with development of new sensors, key technologies and functionalities we are contributing to make our cars safer and to enable autonomous driving. We invent technology for life, we are Bosch, we move Bosch!

In this session, we will focus on our recent developments in terms of the sensors that make our cars able to perceive the surrounding area. Such sensors provide the necessary information to the “brain” of the car to perceive the driving scenario, process the information and make decisions autonomously.

André Albuquerque

Bosch Car Multimedia Portugal, S.A., Portugal

A. Albuquerque received his PhD in Physics Engineering (Optics) in 2017 and his MsC in Physics Engineering in 2011, both from the University of Aveiro, Portugal. He is a Team Leader and Optics Expert with expertise in fiber-based optical sensors, optical communications, non-linear optical effects, all-optical signal processing, optical metrology, diffractive optical elements and design, simulation, optothermal and tolerance analysis of optical systems. Currently he coordinates the research and development of the optical components in automotive LiDAR sensors for automated driving. He has over 15 publications in peer-reviewed journals and international conferences.

Tiago Afonso

Bosch Car Multimedia Portugal, S.A., Portugal

T. Afonso received his MsC in Aerospace Engineering (Avionics) in 2019 from the Instituto Superior Técnico, Portugal. He is a Team Leader in Radar Development with expertise in 3D positioning systems, real-time FPGA based motion algorithms, image processing, object detection, radar technologies, high speed distributed control systems and embedded systems programming. Currently he coordinates a development group responsible for providing the knowledge base for Radar sensors.

09:40 – 10:40 MACROMODELING AND MODEL ORDER REDUCTION

Chair: Ramachandra Achar

Vinay Kukutla (1), Ramachandra Achar (1) and Wai Kong Lee (2)

(1) Carleton University, Canada; (2) Gachon University, South Korea

TC-QR: Tensor Core-based QR Solver for Efficient GPU-based Vector Fitting

Tommaso Bradde and Stefano Grivet-Talocia

Politecnico di Torino, Italy

A comprehensive framework for training stable and passive multivariate behavioral models

Federico Garbuglia (1), Domenico Spina (1), Torsten Reuschel (2), Christian Schuster (3), Dirk Deschrijver (1) and Tom Dhaene (1)

(1) Ghent University - imec, Belgium; (2) University of Brunswick, Canada; (3) Hamburg University of Technology, Germany

Modeling S-parameters of Interconnects using Periodic Gaussian Process Kernels

11:10 – 12:30 POWER DISTRIBUTION NETWORKS

Chair: Heidi Barnes

Francisco Cano, Snehamay Sinha, Tapobrata Bandyopadhyay, Kevin Lavery, Shane Stelmach and Bill McCracken

Texas Instruments, USA

Techniques for Correlating Power Distribution Network Simulations with Physical Measurements

Heidi Barnes (1) and Robin Sercu (2)

(1) Keysight Technologies, USA; (2) Keysight Technologies, Belgium

DC IR Drop Steady State Estimate for Cascaded Switching Regulators

Antonio Carlucci (1), Stefano Grivet-Talocia (1), Scott Mongrain (2), Sid Kulasekaran (2) and Kaladhar Radhakrishnan (2)

(1) Politecnico di Torino, Italy; (2) Intel Corporation, USA

A Structured Krylov Subspace Projection Framework for Fast Power Integrity Verification

Ahsan Javaid (1), Ramachandra Achar (1) and Jai Tripathi (2)

(1) Carleton University, Canada; (2) Indian Institute of Technology Jodhpur, India

Efficient Estimation of PSIJ via Jitter Transfer Function and Knowledge-based Neural Networks

14:00 – 14:40 ADVANCED MEASUREMENTS AND CHARACTERIZATION

Chair: Uwe Arz

José Moreira (1), Sergey Churkin (2) and Olga Zhuravleva (2)

(1) Advantest, Germany; (2) Radiogigabit, Armenia

A Calibration Kit for a 5G-FR2 Band Double-Ridged Waveguide

Francesco de Paulis (1), Rick Rabinovich (2), Mike Resso (2) and Samuel Kocsis (3)

(1) University of L'Aquila, Italy; (2) Keysight Technologies, USA; (3) Amphenol, USA

Bandwidth Limits of Connector Wipe Stub for Reliable 224 Gbps Signaling

14:40 – 16:00 INDUSTRY FORUM

Chair: Stefano Grivet-Talocia

Olivier Bayet - *STMicroelectronics, France*

Marco De Stefano - *Huawei, Italy*

Xiaomin Duan - *IBM, Germany*

Benoit Goral - *Thales SIX GTS France, France*

Aurora Sanna - *STMicroelectronics, Italy*

Yutaka Uematsu - *Hitachi, Japan*

09:00 – 10:20 STOCHASTIC/SENSITIVITY ANALYSIS AND AI IN ELECTRONICS DESIGN

Chair: José Schutt-Ainé

Paolo Manfredi

Politecnico di Torino, Italy

Conservative Surrogate Modeling of Crosstalk with Application to Uncertainty Quantification

Martijn Huynen, Ruben Waeytens, Dries Bosman, Michiel Gossye, Hendrik Rogier and Dries Vande Ginste

Ghent University / imec, Belgium

Reduced-Order Stochastic Testing of Interconnects Subject to Line Edge Roughness

Mihai Telescu (1), Riccardo Trinchero (2), Noël Tanguy (1) and Igor Stievano (2)

(1) Univ Brest, Lab-STICC, CNRS, France; (2) Politecnico di Torino, Italy

Surrogate Eye Modeling for the Statistical Assessment of a Smart Textile Interconnect

Alexandre Plot (1,2), Benoit Goral (1) and Philippe Besnier (2)

(1) Thales SIX GTS France, France; (2) INSA Rennes IETR, France

Machine Learning Techniques for Defining Routing Rules for PCB Design

10:50 – 11:50 DESIGN AND MODELING GUIDELINES

Chair: Mihai Telescu

Yi Zhou, Bobi Shi and José Schutt-Ainé

University of Illinois at Urbana-Champaign, USA

Fast Latency-Insertion-Method-Based Eye Diagram Simulation Incorporating Crosstalk

Gia Ngoc Phung (1), Uwe Arz (1), Thi Dao Pham (2), Djamel Allal (2), Khitem Lahbacha (3), Gianfranco Miele (3) and Antonio Maffucci (3)

(1) Physikalisch-Technische Bundesanstalt, Germany; (2) Laboratoire national de metrologie et d'essais, France;

(3) University of Cassino and Southern Lazio, Italy

Recommendations for the Design of Differential Thinfilm Microstrip Lines

Joana Catarina Mendes (1,2), Luis A. Rodrigues (1,2), Sushmitha Kyatam (1,2), Luis N. Alves (1,2) and Luiz Pereira (2)

(1) Instituto de Telecomunicações, Portugal; (2) University of Aveiro, Portugal

Improving the reliability of power LEDs with diamond boards

14:00 – 18:00 **IBIS SUMMIT**

The IBIS Open Forum is pleased to announce a hybrid virtual/in-person IBIS Summit meeting following the *27th IEEE Workshop on Signal and Power Integrity* (*SPI 2023*) on Wednesday, May 10, 2023. This is the 25th IBIS Summit associated with events in Europe.

This IBIS Summit is intended to promote exchange of ideas and methods among users and developers of IBIS models as well as the IEEE EPS and EMC Society members. Those interested in presenting at or attending the event may register using the information below. We encourage IBIS Summit participants to also attend the *IEEE SPI 2023*.

The meeting is free and open to everyone. We look forward to seeing you either online or in Aveiro!

Randy Wolff
Chair, IBIS Open Forum

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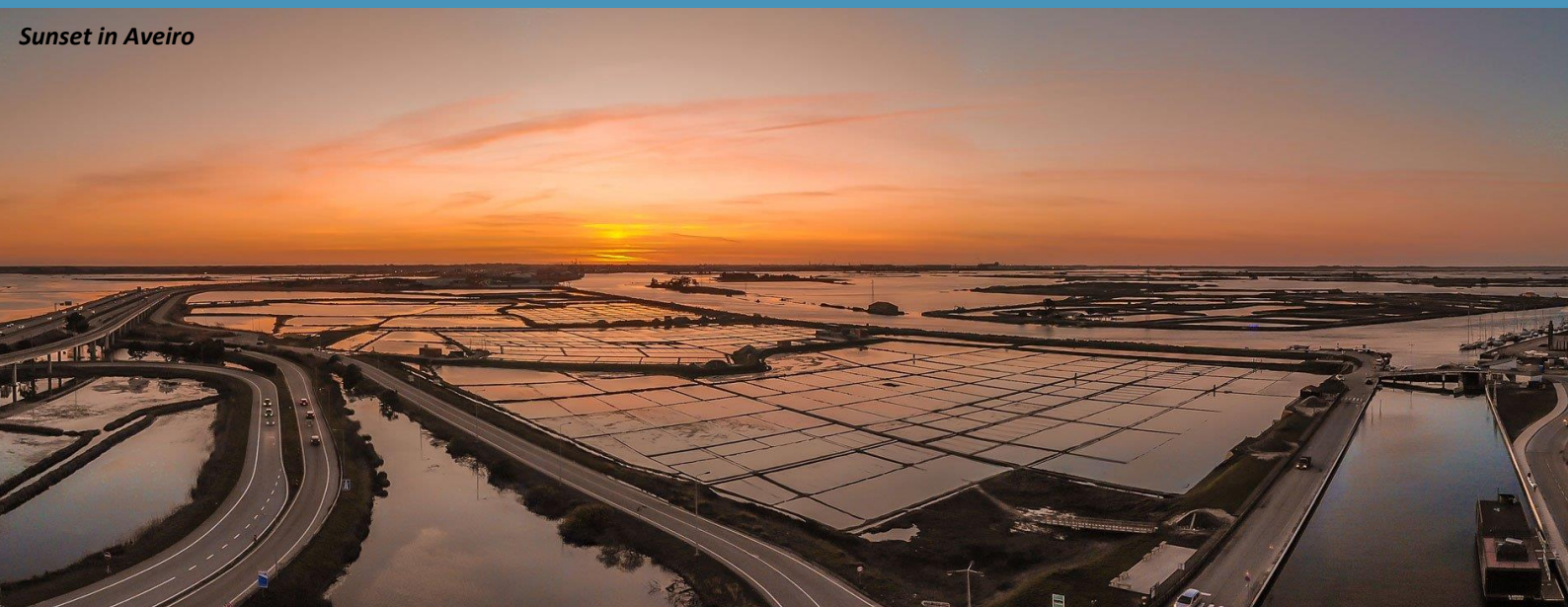
Institute of Telecommunications in Aveiro

Aerial view of the Santiago Campus



Sunset in Aveiro