Program for the

IEEE RFID 2022 Workshop on

DST

Digital Spectrum Twinning

17-19 May 2022

Table of Contents

Letter from the Organizers

Welcome to the kick-off edition of the Digital Spectrum Twinning workshop, hosted by IEEE RFID 2022 in Las Vegas, Nevada!

This workshop brings together an interesting group of speakers from many different areas – propagation modeling, wireless networking, RF engineering, logistics, and RFD – to explore the application of digital twin and parallel intelligence concepts to next generation spectrum sharing and wireless networking. This workshop has an interesting and eclectic blend of RF measurements, RF modeling, spectrum sharing, next-generation wireless technology, information science, and logistics.

The organizers are grateful that the workshop was so well-received by an outstanding array of researchers. This should be the start of a very valuable, continuing conversation about a new way to think about spectrum management and wireless technology.

In fact, the organizers are already looking forward to a blockbuster sequel to this workshop in Boston at the IEEE DTPI 2022 conference. It is our sincerest hope that, in the case of these workshop discussions, what happens in Vegas most definitely does *NOT* stay in Vegas.

Sincerely,

Your enthusiastic organizers,
Christopher R. Anderson, Gregory D. Durgin

Tuesday Talks: Session I

10:30 PT: *Opening Remarks, Invitation to Publish in IEEE JRFID Special Issue, IEEE DTPI 2022 Boston.*
Christopher R. Anderson, Naval Academy

Welcome! Introduction to the inaugural Workshop on Digital Spectrum Twinning at IEEE RFID 2022 and future opportunities in the area.

10:40 PT: *Evolution of the Digital Spectrum Twinning for Spectrum Management and Next-G Radio Technology.*
Gregory D. Durgin, Georgia Tech


Gregory D. Durgin

This talk discusses the history of digital spectrum twinning, explaining how the idea and general concept can benefit next-generation wireless networking and spectrum management technology. The concepts of digital twins and parallel intelligence does useful work in wireless communications as an organizing principle for emerging ideas in radio resource management. This talk provides one such illustrative example of how to apply these principles to a new method of spectrum access.

Bio: Prof. Gregory D. Durgin joined the faculty of Georgia Tech's School of Electrical and Computer Engineering in Fall 2003 where he serves as a professor. He received the BSEE (96), MSEE (98), and PhD (00) degrees from Virginia Polytechnic Institute and State University. In 2001 he was awarded the Japanese Society for the Promotion of Science (JSPS) Post-doctoral Fellowship and spent one year as a visiting researcher with Morinaga Laboratory at Osaka University. He has received best paper awards for articles coauthored in the IEEE Transactions on Communications (1998 Stephen O. Rice prize), IEEE Microwave Magazine (2014), and IEEE RFID Conference (2016, 2018, 2019) as well as the 3rd place 2020 Nokia Bell Labs Prize for “Hyper-RFID: a Revolution for The Future of RFID.” Prof. Durgin authored Space-Time Wireless Channels (2002), the first textbook in the field of space-time channel modeling which has influenced multiple generations of commercial cellular technologies. He is a winner of the NSF CAREER award as well as numerous teaching awards, including the Class of 1940 Howard Ector Outstanding Classroom Teacher Award at Georgia Tech (2007). He has served on the editorial staff for IEEE RFID Virtual Journal, IEEE Transactions on Wireless Communications, and IEEE Journal on RFID. He also serves as President Elect for the IEEE Council of RFID (CRFID). He served as an IEEE CRFID Distinguished Lecturer (2015-2018), IEEE CRFID VP of Conferences (2020-2021), and as general/executive chair of many IEEE conferences. His educational channel #profdurgin on YouTube instructs viewers on engineering electromagnetics and RFID-related topics, having drawn over 10,000 subscribers and nearly 1 million views. He is a frequent consultant to industry, advising numerous multinational corporations on wireless technology.

11:00 PT: *What Can Your Digital Twin Do For You...?*

Vartan Piroumian, VP Consulting

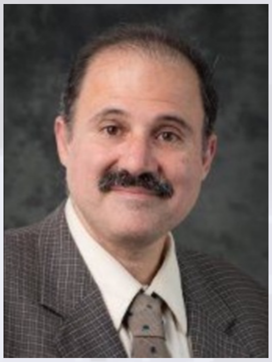
Vartan Piroumian

The term 'digital twin' just might be the most commonly heard technology term mentioned around the globe in the past few years. But what are digital twins really? And what would a digital twin of radio frequency spectrum be? What would be the right description of that spectrum and why? And how would you describe, characterize or specify the aspects of that spectrum for the purposes of defining associated digital twins?

This talk will begin by presenting some basics about digital twins—what they are, what the technology vision is for them and what you need to understand about them. The talk will then delve into the context of digital twins for the RF spectrum and how digital twins might be suitable and appropriate for representing the RF landscape or some specific part of the overall scope of the RF domain. Specifically, this talk will also broach the very important view point of digital twins and the Internet of Things (IoT); the RF arena involves a myriad number and type of hardware and software components that are real-world, physical devices. Those devices must be represented with fidelity by their respective digital twins in order to be useful and meaningful.

This talk will also present the architect's view point of the RF device landscape and introduce usage scenarios that will suggest ways in which digital twins as an enabling technology can enable the kinds of things that we can do with our RF spectrum.

11:20 PT: *Intelligent Radio: A Gateway to a Comprehensive Spectrum Twinning.*
Seyed “Reza” Zekavat, Worcester Polytechnic Institute


Seyed "Reza" Zekavat

This presentation introduces a new radio called Intelligent Radio (IR) that enables intelligent spectrum management in space and time and real-time digital spectrum twinning (DST). IRs are edge-enhanced Ultra-Wide-Band-Radios that receive information in real-time from a large number of resources that may include (but not limited to) mobiles, sensors, news outlets (e.g., via natural language processing), voice and internet, and use high speed computing and save and analyze data. A future of edge-enhanced radio access is based on extrapolated progress in circuit design, computation, and storage capacity, forcing all real-time computation to migrate from cloud datacenters to the network edge (e.g., access point or mobile device). This allows low-cost, high-quality, high-quantity measurements to be updated at the IR edge to enable a real-time DST. It is envisioned such system will not require trust from over-arching government or industry entities leading to spectrum democratization, and user-central wireless communication.

Bio: Seyed A. (Reza) Zekavat is a professor of Physics and a professor of Data Sciences at Worcester Polytechnic Institute (WPI). Before joining WPI, and till 2019, he was a professor of the Electrical and Computer Engineering Department of Michigan Technological University, where he founded the Wireless Positioning Lab of Michigan Tech ECE department. Zekavat received his Ph.D. from Colorado State University in 2002. He is the author of more than 170 peer-reviewed articles. He has authored the textbook "Electrical Engineering: Concepts and Applications" published by Pearson, and the editor of the book “Handbook of Position Location: Theory, Practice, and Advances,” published by Wiley/IEEE. He holds a patent on an active Wireless Remote Positioning System. Zekavat has also co-authored two books “Multi-Carrier Technologies for Wireless Communications,” published by Kluwer, and “High Dimensional Data Analysis,” published by VDM Verlag; and ten books chapters in the areas of adaptive antennas, localization, and spectrum sharing. Zekavat’s research interests are in wireless communications, positioning systems, software-defined radio design, dynamic and intelligent spectrum allocation, Radar theory, blind signal separation, and MIMO and beamforming techniques, feature extraction, and neural networking. Recently, he founded and chaired two Workshops on New Paradigms in Intelligent Spectrum Management and Regulations. He has also served as the Editorial Board of Springer Nature Special Issue on New Paradigms in Intelligent Spectrum Management and Regulations. Moreover, he has served on the editorial board of many Journals including IET Communications, IET Wireless Sensor System, Springer International Journal on Wireless Networks, and GSTF Journal on Mobile Comm. Zekavat is the founder of the Space Solar Power Workshop that is held @ the IEEE WiSEE conference. He has served as a steering committee and general chair of a large number of IEEE conferences and workshops. He is active on the technical program committees for several IEEE international conferences, serving as a committee chair or member.

11:40 PT: *The Digital Spectrum Twin: The Path to Achieving Realtime Efficient Spectrum Sharing.*
Adam Drobot*,* Chairman of OpenTechWorks Inc.

Adam Drobot

Spectrum sharing at its core is about the efficient allocation of a scarce resource subject to constraints. There are many options for how this can be accomplished but the recent history of actual deployments indicates that spectrum sharing regimes fall far short of optimum. It is useful in this context to consider the trends in the demand for spectrum, the approaches to spectrum allocation, required performance, the physics constraints of propagation phenomenology, and the range of technologies that can be applied in constructing communication network solutions.

The talk will describe a framework based on local spectrum sensing, collaborative sharing of data, propagation and interference modeling, and the use of Digital Twins for determining spectrum allocation, traffic admission, and performance at the local and network level. An important aspect of Digital Twins at the network level is the aggregation of distributed Digital Twins ranging from the intermediate to the most granular local levels. Within the framework Digital Twins reflect the capabilities of the physical communications elements (including end-user terminals), the computational and data storage technologies available at the nodes, and most important the protocols and algorithms as represented in hardware and software.

An overriding consideration is the shift by regulators from assigning spectrum for specific uses, to assigning spectrum for general purpose infrastructure that is de-facto shared by end-users. The infrastructure must, in turn, satisfy heterogenous performance requirements and support application that range from real-time critical to casual best effort communications and sensing. The journey to achieve an acceptable solution and subsequent adoption for efficient spectrum sharing is a long one and has many challenges. Early steps have been taken, and the talk will describe the experiences that have been reported. “Digital Spectrum Twins” offer an exciting path of accelerating and improving the art of the possible to prepare for the next generation of communication and sensor systems.

Bio: Adam is the Chairman of the Board of OpenTechWorks, Inc. He serves on the Boards of multiple early-stage companies. His activities are strategic consulting, start-ups, non-profits, and industry associations. In the past he was the President of Applied Research at Telcordia Technologies (Bellcore) and the company’s CTO, and before that the Senior Vice President for Science and Technology at SAIC/LEIDOS. Adam is a current member of the FCC Technological Advisory Council where he Co-Chairs the Working Group on Artificial Intelligence; the University of Texas Physics Department Advisory Council; and Chairman of FAMES USA a non-profit that organizes programs to attract disadvantaged youths to careers in STEM fields. In the past, he was on the Boards of the Telecommunications Industry Association (TIA) where he Chaired the Technology Committee; the Association for Telecommunications Industry Solutions (ATIS); the New Jersey Technology Council; the US DoT ITS Program Advisory Committee, and the University of Michigan Transportation Research Institute External Advisory Board.

Tuesday Talks: Session II

13:00 PT: *5G/FutureG and the Merger of Sensors to Enable Dynamic Spectrum Access.* Grant Lohsen, GTRI

Grant Lohsen

GTRI has been working in many areas of 5G. Of particular relevance to this conference is our work using open source 5G system components to build a frequency agile 5G RAN capable of supporting dynamic spectrum access and future G technology development. The current iteration of this system uses an rApp that announces the capabilities of the RAN (Supported GSCN, PRB, etc. configurations) and acts as a control interface for the RAN. In addition, a core component has been created that provides orchestration and spectrum monitoring capabilities. Finally, GTRI has integrated a spectrum sensor into the network that is used to automatically scan the environment and configure the gNodeB to the optimal frequency. Additionally, the sensor continues to scan spectrum even once the gNodeB is operational to detect potential interferes and reconfigure the gNodeB to a new interference free band. Future development includes using multiple gNodeBs at separate frequencies and forced handover by the orchestration component to perform this service without the User Equipment losing its connection within the network, hardware abstraction layers, and the development of a sensor plane to complement the existing control and user planes.

Bio: Mr. Grant Lohsen is the Chief Scientist of the Communications Sensing and Spectrum Division of GTRI. Mr. Lohsen received his Bachelors in Computer Engineering and Masters in Electrical Engineering from Georgia Tech and is currently working on completing his PhD. Mr. Lohsen has lead several communications projects including deploying the first mobile tactical 4G LTE to Afghanistan with an IATO to operate at Secret. Mr. Lohsen has led several Software Defined Radio (SDR) efforts including a TDMA waveform development effort, a custom waveform effort to perform precision navigation and timing (PNT) while communicating on the moon, development of a modular SDR hardware for UAS platforms. Mr. Lohsen has also served as the subject matter expert for radio integration, waveforms, and communications systems for multiple government customers. His research interests include propagation in cluttered environments, communications, and communications electronic warfare. Recently Mr. Lohsen has been focused on 5G and FutureG and is working on multiple 5G and FutureG efforts.

13:20 PT: *Demo: Managing Mobility within Radio Dynamic Zones.* Aashish Gottipati and Jacobus Van der Merwe, University of Utah

Aashish Gottipati

FlexRdz is a closed-loop, autonomous radio dynamic zone (RDZ) manager. FlexRdz seeks to enable safe operation of an RDZ through real-time control of deployed test transmitters. For this demonstration, we will present FlexRdz's management capabilities. Through three simulated scenarios, we will use FlexRdz to illustrate transmit leakage mitigation through digital twin modeling, interference mitigation via dynamic spectrum assignment, and user test protection through programmatic control of simulated test transmitters.

Bio: Aashish Gottipati is a CS master's student, advised by Jacobus Van der Merwe, at the University of Utah. His research interests include mobile & wireless networks, applied machine learning, and representation learning.

13:40 PT: *Resolving the Internet of *Every* Thing*, Megan Brewster, Impinj.

Megan Brewster

Every day, more and more physical items--including apparel, pharmaceuticals, packages, automotive parts, and even golf balls-- are connected to the Internet by digital identifiers enabled by technologies like RAIN RFID. The digital identifier is a universally unique number that acts like an address to that item's digital twin, linking the physical item to the digital world. The digital twin includes more information about the item including its history and ownership. However, today's IoT is comprised of many disconnected intranets of things, where individual companies or industries can look up their own items, but related parties or consumers cannot access the digital twins for items they own. To realize a true internet of *every* thing, we must deliver a web resolver that links the unique digital identifier associated with the physical item to its digital twin in the cloud. This presentation will describe the digital twin challenge and share an opportunity to solve it through the IEEE CRFID/RAIN Alliance prize challenge (https://www.herox.com/digitaltwins).

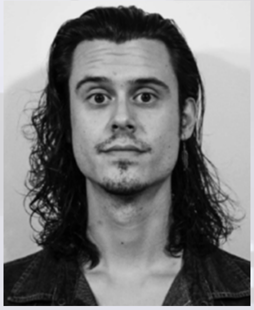
Bio: Megan Brewster is a technologist and policy entrepreneur who has worked at the forefront of innovation over the last 15 years. She is currently the vice president of advanced technology at Impinj. In this role, she brings clarity and strategy to the Impinj technology roadmap and fosters growth in emerging RAIN RFID opportunities to deliver the Internet of Every Thing. Prior to Impinj, Megan supported the co-creation of future mobility solutions by crowdsourcing transportation product designs and rapidly prototyping the ideas by direct digital manufacturing methods. She led the White House Office of Science and Technology Policy's advanced manufacturing and semiconductor portfolios. At GE Global Research, she investigated performance degradation mechanisms and developed next-generation chemistries for sodium metal halide batteries. Megan earned a Ph.D. in materials science and engineering from MIT with a minor in technology and public policy and a bachelor's degree from the University of Washington.

Wednesday Posters

14:45 PT: Poster: *Finding an Unknown Interference Source in POWDER via Time Difference of Arrival.*
Chia Ying Kuo, Neal Patwari, Washington University in St. Louis

Adaptive spectrum sharing between different systems and operators is being deployed in order to make use of the wireless spectrum more efficient. However, when the spectrum is shared, it can create situations in which an operator is unable to determine the identity of an interferer transmitting an unknown signal. This is the situation which the POWDER testbed found itself in, starting in late 2021. This thesis provides general purpose tools for operators to locate an unknown signal source in real world outdoor environments. We used cross-correlation between the signals measured at multiple time-synchronized base stations to estimate the time difference of arrival (TDoA) between each pair. Then, we used a TDoA localization algorithm to locate each unknown transmitted signal source. In particular, for POWDER, we applied these methods to estimate the source locations of multiple unknown interference signals detected in the citizens broadband radio service (CBRS) band with multiple static base stations as the receivers. The localization results are displayed in grid maps that indicate the most likely signal source coordinates of the unknown signals. Our tools are open source and available for other researchers to use to locate interferers near their deployed network.

14:45 PT: Poster: *Building the Twin: Spectral Sensing via Backscatter Technologies.*
Michael Varner, Georgia Tech


Michael Varner

Digital Spectrum Twins (DST) are a new means of documenting and representing a realistic environment's RF characteristics and spectral occupancy over time, establishing a priori knowledge to improve efficiency, support a variety of RF applications, and provide accurate simulation backgrounds. A key to establish and maintain the twin model is a robust spectral sensing network which monitor channel usage using low consumption devices. This work looks at the overlap between ambient scatter communications and its candidacy as a spectral sensing technology to enable DSTs. Special emphasis is placed on choosing appropriate channel codes and senor network deployment for robustness against small scale fading effects.

Bio: Michael A. Varner received the B.S.E.E. degree from the Rose–Hulman Institute of Technology in 2015 and the M.S.E.E. degree from Georgia Tech in 2017, where he is currently pursuing the Ph.D. degree. He joined the School of Electrical and Computer Engineering with the Georgia Institute of Technology in 2015. His previous research experience includes the development of retrodirective electromagnetic devices for emerging mm-Wave applications and radar signal processing techniques. He is currently performing research toward his doctoral dissertation in the fields of ambient scatter communication networks and propagation modeling of dense urban micro-cells for Dynamic Radio Zone and Digital Spectral Twin applications. He is a recipient of the Georgia Tech's Presidents Fellowship.

14:45 PT: *Poster: mmIDs for long-range cm-accuracy RTLS.* Jimmy Hester, Atheraxon


Jimmy Hester

Since its widespread commercial adoption in the form of passive RFID tags, backscatter communications have remained confined to short-distance communications—and for good reasons. However, recent advances relying on the meteoric rise in capabilities and accessibility of mm-wave components and systems—and the concomitant growing interest and maturation of retrodirective backscatter schemes—are opening a pathway for a new class of (semi)passive backscatter architectures with natural predispositions for ultra-low-energy and low-cost real-time localization system (RTLS) applications. This work will present the theoretical foundations undergirding these claims, review recent progress in this area, and suggest future directions and pathways in this emerging yet expansive and accessible field of research.

Bio: Jimmy G.D. Hester received his M.S. and Ph.D. in Electrical and Computer Engineering from the Georgia Institute of Technology, Atlanta, in 2014 and 2019, respectively. He is now the CTO and co-founder of Atheraxon, the company commercializing 5G/mmID technology. His areas of expertise include backscatter communications, mm-wave antenna design, radar systems design, radar signal processing, digital communications, inkjet printing, and nanomaterials-based sensing.

08:50 PT: ***Keynote:*** *Using NRDZ's to Shatter Spectrum Silos.* Christopher R. Anderson, US Naval Academy

Christopher R. Anderson

The wireless spectrum is a precious, finite, but infinitely renewable resource that has enabled unprecedented worldwide economic prosperity. With the explosive growth in 4th and 5th generation technologies, commercial wireless operators are increasingly demanding large contiguous allocations of spectrum, particularly in mid-band (sub 6 GHz) frequencies. It has been long established that the insatiable appetite for bandwidth is, however, outpacing regulators' ability to reallocate fiercely protected spectrum rights, leading to the current spectrum crunch. Superimposed upon this drama is the need to preserve and protect specific frequency bands (that are determined by the laws of physics) for scientific uses, such as radio astronomy or remote sensing that provide valuable scientific information. Although it is easy to quantify (and be swayed by) the monetary value placed on spectrum by cellular services, it is incontestable that accurate weather forecasts and a better understanding of the formation and evolution of galaxies, stars and planets have value. Compounding the problem is a siloed approach to regulating, utilizing, and jealously guarding spectrum that foments distrust between and among active and scientific spectrum users.

Bio: Christopher R. Anderson is currently an Associate Professor of Electrical Engineering at the United States Naval Academy (USNA). He is the Founder and Director of the USNA Wireless Measurements Group (WMG), a focused research group that specializes in spectrum, propagation, and field strength measurements in diverse environments and at frequencies ranging from 300 MHz to 28 GHz. He has over two decades of experience in radiowave propagation measurements and modeling, software-defined radios, and dynamic spectrum sharing. From 2016-2018 he served as a Visiting Researcher at the National Telecommunications Information Administration (NTIA) Institute for Telecommunication Sciences in Boulder, CO where he concentrated on developing propagation models for cluttered environments. His research has been funded by the National Science Foundation, the Office of Naval Research, NASA, the Defense Spectrum Organization, and the Federal Railroad Administration. Dr. Anderson is a former Editor of the IEEE Transactions on Wireless Communications and was a Guest Editor of the IEEE Journal On Selected Areas In Signal Processing Special Issue on Non-Cooperative Localization Networks. He was the General Chair of the 2018 NTIA International Symposium on Advanced Radio Technologies.

11:15 PT: *Pseudonymetry: Precise, Private Closed Loop Control for Spectrum Reuse with Passive Receivers.* Meles G. Weldebebriel, Neal Patwari, Jie Wang, Washington University in St. Louis

Meles G. Weldegebriel

Radio astronomy and other passive radio spectrum users have significant challenges avoiding interference from wireless communication systems. Even distant transmitters sometimes interfere with passive users. We propose Pseudonymetry, a system that provides (primary) passive users a means to turn off the transmissions of the particular (secondary) wireless transmitter that interferes with it. By controlling the specific transmitter rather than an entire geographical region, Pseudonymetry could increase the spectrum available for wireless systems while ensuring rapid clearing of interferers as necessary for passive use. Pseudonymetry adds a low-rate watermark to the secondary (intended) transmitted signal to carry a random, anonymous pseudonym. We show the ability of a passive receiver to decode the watermark, even from a signal received with very low SNR. The passive receiver posts to a centralized database to provide feedback to the secondary transmitters so that they know to vacate the band. We provide analysis that captures the trade-offs in the design of Pseudonymetry, and show initial evidence that a simple amplitude modulation watermarking scheme could enable reliable detection at a distant passive receiver, while resulting in minimal degradation to the error performance of the intended secondary receiver.

Bio: Meles G. Weldegebriel is a 2nd year PhD student in the department of Electrical and Systems Engineering at Washington University in St. Louis. Before he joined WashU in February 2021, he was a lecturer and Dean of Mekelle Institute of Technology – Mekelle University, Mekelle, Tigray. He obtained his Master of Technology in Electrical Engineering in 2009 from Indian Institute of Technology Bombay, Mumbai, India.

11:35 PT: *Signal Strength Measurements Using Smartphones.* Monisha Ghosh, Notre Dame University

Monisha Ghosh

Smartphones today contain radios in multiple frequency bands: low (< 1 GHz), mid (1 – 7 GHz) and high (> 24 GHz), covering all the cellular and Wi-Fi bands. The modems constantly measure reference signal power for all cellular and Wi-Fi signals, even if not actively transmitting or receiving data. We describe a methodology for collecting signal strength measurements using APIs on smartphones to read these values directly from the modems on the phones, every few seconds, and uploading the data. We then describe some insights extracted from the signal strength data, combined with speedtests, collected in Chicago over the last 2 years.

Bio: Dr. Monisha Ghosh is a Professor of Electrical Engineering at the University of Notre Dame. She is also the Policy Outreach Director for SpectrumX (https://www.spectrumx.org/), the first NSF Center for Spectrum Innovation. Her research interests are in the development of next generation wireless systems: cellular, Wi-Fi and IoT, with an emphasis on spectrum sharing and coexistence and applications of machine learning to improve network performance. Prior to joining the University of Notre Dame in 2022, she was the Chief Technology Officer at the Federal Communications Commission, a Program Director at the National Science Foundation, Research Professor at the University of Chicago and spent 24 years in industry research at Bell Labs, Philips Research and Interdigital. She obtained her B.Tech from IIT Kharagpur and Ph.D. from USC. She is a Fellow of the IEEE.

Preliminary Call for Participation, DST Workshop at IEEE DTPI 2022

IEEE DTPI 2022 Workshop on Digital Spectrum Twinning – Call for Participation

This workshop explores the emerging field of *Digital Twins* and its applicability to modeling and monitoring radio spectrum. We explore the concept of *digital spectrum twinning* – maintaining updated, cloud-based databases of radio spectrum usage to enable spectrum sharing, location-based services, network optimization, spectrum valuation, new technology development, and other applications – to enable next-generation wireless communications.

Topics Include

Adapting Digital Twins to Spectrum	Space-based RF Observations	National Radio Dynamic Zones (NRDZ)
Adaptive/Site-Specific Propagation Modeling	Radiometry Hardware	Emerging Location-Based Services
Crowd-Sourced RF Propagation Measurements	Low-powered Sensing Technology/IoT	New Spectrum Sharing Methods
Novel Spectrum Sensing Networks	Digital Twin Tech. Relevant to Spectrum	Frequency Agile Radio Systems
Fog Computing Techniques for Spectrum	Network Densification Studies	Computation on the Network Edge
Cloud Storage for Digital Twins	Geographical Information Systems	Privacy/Data Protection
Number Resolution for RFID	Cooperative Radio Communications	Quantum Computing Applications
CBRS-related Spectrum Management	Encryption and Security	Radio Astronomy Usage
5/6G and Beyond	Decentralized Databases/Blockchain	Spectrum Policy
Propagation Modeling	Passive Radio Spectrum Usage	Related Applications

The Workshop on Digital Spectrum Twinning accepts several submission types:

Abstracts, Tutorials, and Demos: lightly-reviewed summaries of proposed oral presentations. Submit abstracts via e-mail to Greg Durgin (durgin@gatech.edu) by 1 September 2022.

Papers: peer-reviewed manuscripts intended for publication on *IEEExplore*. Manuscripts should be 2-6 pages (2 col, IEEE format), submitted by the advertised conference paper deadline. See IEEE DTPI 2022 call-for-papers for submission instructions.

Check the IEEE DTPI 2022 website for announcements, conference program, and more. Participation and attendance in the DST Workshop is included for IEEE DTPI 2022 registrations.