Editorial

Special Section on Waveform Diversity from the Fifth International Waveform Diversity and Design Conference, Niagara Falls, Canada

It is our great pleasure and singular honor to introduce this Special Section of the IET Journal on Radar, Sonar & Navigation, dedicated to the Fifth International Waveform Diversity and Design Conference (WDD) that was held in Niagara Falls Canada from 3–10 August 2010. WDD is an international conference devoted to bringing together researchers and technologists from diverse backgrounds and specialties to facilitate the exchange of ideas, research, and technologies for dynamically adapting waveforms to their propagation environments. Specific objectives include developing analytical methodologies and new hardware technologies for system applications in sensors, communications, navigation, and countermeasures.

Since its inception in 2004, the conference has been held roughly biennially, and worldwide interest in WDD has remained steady. The smaller (on the order of 100–200 attendees), more intimate nature of this conference make it ideal for discussions among participants and the free flow of ideas.

Waveform Diversity involves manipulating the degrees of freedom of waveforms to enhance target detection, bit error rate, and the efficacy of countermeasures. Degrees of freedom that can be varied include pulse repetition frequency, carrier frequency, coding, jitter, polarization, bandwidth, amplitude, pulse width, spatial characteristics, and frequency shaping.

Waveform Diversity is an exciting field that has elicited interest from the scientific community in recent years due to advances in electronics and computing. Commercial applications range from remote sensing of the environment to navigation and communications. As a result of increased public demand for mobile phones and other wireless devices, the telecommunications manufacturing industry has dominated advances in waveform technology in recent years. Research efforts on expanded channel capacity, time-frequency coding, spatial modulation, and power efficiency have yielded dramatic improvements in performance, while providing an order-of-magnitude reduction in system costs.

Today, significantly more wireless users operate in proximity, occupying only a portion of the spectrum used by just one customer a decade ago.

These developments in the telecommunication industry have piqued the interest of the radar community, which has greatly expanded its Waveform Diversity programs in the last decade. In fact, interest in Waveform Diversity has reached a level where the IEEE Radar Systems Panel defined it in its updated Standard of Radar Definitions (IEEE Std 686TM-2008 21 May 2008):

Adaptivity of the radar waveform to dynamically optimize the radar performance for the particular scenario and tasks. May also exploit adaptivity in other domains, including the antenna radiation pattern (both on transmit and receive), time domain, frequency domain, coding domain and polarization domain.

Major catalysts for the formation of WDD as a conference theme were hardware advances in waveform generation, timing and control, electromagnetics, and signal/data processing that are greatly increasing the performance of RF devices, which in turn are enabling significantly more flexibility in design freedoms for radar and communication systems. Consequently, system designers are confronted with emerging and compelling changes in requirements such as more efficient spectrum usage, higher sensitivities, transmitter/receiver agility, greater information content, improved robustness to errors, etc. This improved flexibility, coupled with dynamic reprogrammability, permits the generation of adaptive waveforms that optimize a user’s specific application. Moreover, improved analog-to-digital converters and integrated analog circuitry allow direct digital synthesis of signals without the need for complex mixing stages and baseband processing. Finally, the phase accuracies in these transceivers improve system performance in the temporal and spatial domains.

Perhaps the most significant application for Waveform Diversity is a more efficient use of the highly coveted electromagnetic (EM) spectrum. The EM spectrum has become increasingly crowded in recent years, and all indications are that this trend will continue with no end in sight. Efficient use of bandwidth is essential to meet the needs of the wide variety of competing technological disciplines (communication, navigation, countermeasure, sensor) that use waveform design. Traditionally, these
disciplines have been treated and operated as separate technologies, and the lack of interchange between them is a major problem, given the paucity of available spectrum and their appetites for more bandwidth. Although the importance of waveform design and specification for these disciplines has long been recognized, it is only relatively recent advances in hardware technology that are enabling a much wider range of design freedoms to be explored for efficient and non-interfering spectrum use.

The requirements for spectral conformity are often specified by spectral masks, which will become even stricter as a consequence of government policies like the National Broadband Plan in the US. In the next ten years, this Broadband Plan mandates the release of 500 MHz of previously allocated spectrum for sale. Since the FCC currently has only 50 MHz of available spectrum to release, this plan has significant and deleterious ramifications for other users like the radar community. These impacts will likely be induced by changes in which users have spectral primacy (radar demoted, telecommunications promoted). Increased regulations on present applications, and the implementation of dynamic spectrum access. The situation in the US is a microcosm of what is transpiring in the global EM community. These developments and the fierce competition for spectrum are fueling worldwide interest in WDD.

This Special Section features 3 papers from WDD 2010, at which more than 50 contributions from 12 nations around the world were presented. In addition, WDD 2010 attracted 92 participants from 9 nations. The conference reflected, and will continue to reflect, the state-of-art in WDD theory and technology and showed perspectives for future activities in this area. The 3 papers were selected for publication following a review process and represent significantly expanded versions of the papers published at the conference.

The first paper in this Special Section, ‘Non-contiguous Multicarrier Waveforms in Practical Opportunistic Wireless Systems,’ by Pagadarai et al. explores the efficacy of dynamic spectrum access (DSA) for communication applications under real world conditions. The operation of DSA requires sensing the available spectrum combined with spectral agility to make maximum use of the available spectral resources. Because the DSA wireless transmission has secondary status, the key challenge is in the management of the interference induced to the primary spectral occupants. The authors address this issue through the use of non-contiguous multicarrier modulation coupled with spectral shaping.

The second paper, ‘Designing Transmitters for Spectral Conformity: Power Amplifier Design Issues and Strategies,’ by Baylis et al. addresses the spectral constraints placed on radar systems by regulatory agencies. Major contributors to spectral spreading in these high-power radars are the power amplifiers (PAs). PA designers use several methods to maximise linearity and efficiency, and the methods of predistortion, feed-forward, envelope tracking, Doherty, and Linear Amplification using Nonlinear Components (LINC) are discussed in this paper. Tradeoffs and challenges inherent in these design approaches are surveyed.

In the third paper, ‘Waveform and Aperture Design for Low Frequency RF Tomography,’ Sego et al. examine the potential of waveform and aperture designs at low frequencies, in combination with tomographic techniques and thinned spatial sampling, for simultaneously exploiting the available resolution and reducing the aperture time. In particular, they extend earlier 3-dimensional monostatic work to obtain narrowband, bistatic, multi-frequency results. Applications include remote archeological survey of ruins through foliage and searching for voids in collapsed structures and underground.

The organisers of the WDD conference are grateful to the IET for their cooperation and for their generous offer to include these expanded papers in this issue. We are indebted to the authors for their cooperation and for their excellent contributions which will, it is hoped, provide a doorway into the very interesting WDD research of the last decade. Finally, but most importantly, the assistance of the reviewers is greatly appreciated in ensuring the rigor of the selection process and the quality of the published papers.

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Eric L. Mokole has nearly 30 years of experience in conducting and leading radar-related research and development. He received his bachelor’s degree in applied mathematics from New York University in 1971, a master’s degree in mathematics from Northern Illinois University in 1973, two master’s degrees, one in physics and the other in applied mathematics, and his doctorate in mathematics from the Georgia Institute of Technology in 1976, 1978, and 1982, respectively. He was an Assistant Professor of Mathematics at Kennesaw College in Georgia from 1982 to 1983. From 1983 to 1986, he worked for the Electronic Warfare Division of the Naval Intelligence Support Center in Washington DC. Since 1986, he has been employed in various roles by the Radar Division of the Naval Research Laboratory in Washington DC. In particular, from 2001 to 2005, he was Head of the Surveillance Technology Branch. After serving as Acting Superintendent of NRL’s Radar Division from 2005 to 2008, he resumed the position of Branch Head.

Dr. Mokole is a Fellow of the IEEE. He has over 70 conference/journal articles, book chapters, and reports and is co-editor/co-author of 4 books (Ultra-Wideband, Short-Pulse Electromagnetics 6,7; Physics of Multiantenna Systems and Broadband Processing; and Principles of Waveform Diversity and Design). Professional activities include: IEEE AES Radar Systems Panel; Government Liaison of USNC-URSI; Committee Member of MSS National Symposium; US Member, Vice Chair (2009–2011), and Chair (2011–2013) of NATO’s Sensors and Electronics Technology Panel; US Navy Lead of Program Committee for MSS Tri-Service Radar Symposium; AMEREM/EUROEM High-Power Electromagnetics Committee; Founding Member of Tri-Service Waveform Diversity Working Group.

Shannon D. Blunt received the Ph.D. in electrical engineering from the University of Missouri in 2002. From 2002 to 2005 he was with the Radar Division of the Naval Research Laboratory in Washington, D.C. Since 2005 he has been with the Department of Electrical Engineering and Computer Science at the University of Kansas where he is now an Assistant Professor in the Electrical and Computer Engineering Department.
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Prof. Blunt received the AFOSR Young Investigator Award in 2007. He is a member of the IEEE Aerospace & Electronic Systems (AES) Radar Systems Panel and is the General Chair for the 2011 IEEE Radar Conference in Kansas City. He is also an Associate Editor for IEEE Transactions on Aerospace & Electronic Systems and is on the Editorial Board for IET Radar, Sonar, & Navigation. He has over 70 refereed publications, 10 patents, and is co-editor of the recent book *Principles of Waveform Diversity & Design*. 