Guest Editorial Advanced Circuits and Systems for CR/SDR Applications

IN THE last few decades, the cognitive radio (CR) has emerged as a revolutionary concept to efficiently exploit the scarce radio electromagnetic spectrum. To this aim, this radio must be capable of sensing the electromagnetic environment in a dynamic fashion to subsequently adapt its transmissions to the inputs, with the objective to obtain reliable communications and/or data from the surroundings. The principle is not limited to wireless communications applications, but can also be extended to other scenarios where the radio electromagnetic spectrum is utilized, such as in remote-sensing systems.

The aforementioned dynamic spectrum management can only be accomplished by making use of advanced hardware and software concepts and technologies. The irremediable need of reconfiguration for these systems demands a flexible software-defined radio (SDR) able to support it, which additionally may permit the acquisition of multi-standard/multi-band services. As a result, many efforts have been detected in the circuits and systems area from many research institutions of private and public organisms with a view to implement the CR/SDR concept.

A variety of advanced architectures are being proposed as alternatives for the front-ends of these radios, all showing advantages and disadvantages. A direct sampling solution may be very flexible, but it requires expensive analog-to-digital and digital-to-analog converters in order to handle large signal bandwidths. A super-heterodyne architecture may have a large dynamic range, but the image bands and spurious signals related to the mixing stages may be a problem. Other approaches use a low, or even zero, intermediate frequency, but direct-current offsets and imbalances may become critical in this case. Six-port transceivers have also been proposed as interesting solutions for CR/SDR applications, but a design to simultaneously acquire signals coming from different bands may be very challenging. More sophisticated mixed-domain CR/SDR configurations based on the hybrid filter bank philosophy and frequency-sparse direct-sampling principles for receivers are showing promising results for broadband and multi-channel scenarios. Nevertheless, some design and performance shortcomings must still be solved in them.

As a consequence, the issue is still open and remains as an emerging technology. This special issue of the IEEE JOURNAL ON EMERGING AND SELECTED TOPICS ON CIRCUITS AND SYSTEMS (IEEE JETCAS) is focused on "advanced circuits and systems for CR/SDR applications." It is aimed to provide the reader with covering on recent research finding in the area of circuits, subsystems, architectures, and signal-processing and communication techniques for the CR/SDR paradigm.

The topics advertised in the call for papers of this special issue included, but were not limited to: 1) circuits and systems for CR/SDR applications, 2) multi-band/multi-purpose circuits for CR/SDR applications, 3) reconfigurable/tunable circuits for CR/SDR applications, 4) power-efficient circuits for CR/SDR applications, 5) advanced concepts for CR/SDR architectures, 6) transmitter design for CR/SDR applications, 7) all-digital transmitters, 8) receiver architectures for CR/SDR applications, 8) signal-processing techniques for CR/SDR-based radios, 9) behavioral modeling of multi-band radio systems, 10) distortion and impairment mitigation of CR/SDR systems, 11) digital and digitally-enhanced transceivers for CR/SDR applications, 12) CR/SDR communication techniques, and 13) implementation aspects of CR/SDR systems.

A total of 42 papers were submitted for consideration in this special issue, out of which 15 papers were finally accepted after a rigorous peer-review process. These numbers give rise to a very selective acceptance rate of 35.7%, which is in good agreement with the high-quality standards of previous issues of IEEE JETCAS and other journal publications of the CAS Society.

The 15 accepted papers have been grouped into four main categories as follows:

1) radio-frequency circuits for CR/SDR (five papers);
2) digital and mixed-mode subsystems for CR/SDR (two papers);
3) receivers and transmitters for CR/SDR (five papers);
4) signal-processing and communications techniques for CR/SDR (three papers).

A brief description of these papers, which are listed as they appear in the special issue, is provided below.

1) *Radio-frequency circuits for CR/SDR*: The first three papers deal with the relevant topic of power amplifiers for CR/SDR transmitters. The paper "Resistive Second-Harmonic Impedance Continuous Class-F Power Amplifier with over One Octave Bandwidth for Cognitive Radios," by Lu and Chen, reports an innovative technique to design highly-efficient broad-band harmonic-tuned power amplifiers. This method is applied to continuous class-F power amplifiers with their matching networks properly synthesized by means of a simplified real frequency approach. Experimental results of a proof-of-concept 525–1325-MHz power amplifier prototype featuring drain efficiency over 70%, output power higher than 39 dBm, and improved adjacent to channel power ratio are shown. The paper "A Hybrid Amplitude/Time Encoding Scheme for Enhancing Coding Efficiency and Dynamic Range in Digitally Modulated Power Amplifiers," by Xia *et al.*,

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explores the potential of mixing amplitude and time encoding in digitally-modulated power amplifiers to improve their performances. Such a combination of amplitude and time-domain techniques to optimally encode information enables to attain higher coding efficiency and dynamic range for this class of power amplifier. Measurements obtained for a WLAN signal corroborate the validity of the approach. In the manuscript "Compressed Sensing Based Joint-Compensation of Power Amplifier's Distortions in OFDMA Cognitive Radio Systems," by Ali *et al.*, a compressed-sensing-based linearization technique for power amplifiers directed at power-efficient OFDMA CR systems is proposed. As an added benefit, this joint-compensation methodology can be further enhanced through multiple measurements of the distortion signal in single-input multi-output scenarios. Numerical results are provided for a full communication system which includes channel effects, in order to attest the usefulness of this technique in terms of EVM and BER performances. The fourth paper, entitled "A 12 mW 40–60 GHz 0.18 μm BiCMOS Oscillator-less Self-demodulators for Short-range Software-defined Transceivers," by Yu *et al.*, describes key design issues for oscillators-less demodulators featuring broad operating range and low power consumption without impacting in the overall system sensitivity. A BiCMOS prototype using a new type of high gain wideband single-ended-input differential-output low-noise amplifier is fabricated and tested. It can work up to Gbps rates from 40 to 60 GHz with a sensitivity of -40 dBm. In "Design and Applications of a 300–800 MHz Tunable Matching Network," by Sánchez–Pérez *et al.*, an evolutionary approach for the optimum design of tunable matching networks is presented. Such a device is very desirable in flexible CR/SDR transceivers to provide adaptive interfaces between main building blocks of their transmitter and receiver chains. A prototype is developed and characterized and its benefits in several applications are shown, such as antenna mismatch compensation, antenna bandwidth extension, and power amplifier efficiency improvement.

2) *Digital and mixed-mode subsystems for CR/SDR*: The sixth paper, entitled "Survey and Analysis of Cyclostationary Signal Detector Implementations on FPGA," by Kosunen *et al.*, evaluates main trade-offs arising in cyclostationary-based spectrum sensing algorithms in terms of performance, hardware complexity, and power consumption for FPGA implementations. It is shown that, for a channel with a OFDM signal and AWG noise, important implementation benefits can be gained by accepting minor performance degradation. Useful guidelines are provided regarding the best algorithm to be incorporated in signal detectors for mobile CR-enabling devices. In "VLSI Design of a Monolithic Compressive-Sensing Wideband Analog-to-Information Converter," by Bellasi *et al.*, the first VLSI design of monolithic wideband compressive-sensing-based analog-to-information converter for CR/SDR applications is demonstrated. It exploits the sparseness property intrinsic to the RF spectrum, in terms of number of RF bands being active at certain moment, to outperform expensive and energy-inefficient high-rate analog-to-digital converters for the broadband sensing problem. A 28-nm CMOS prototype is built, featuring a RF signal acquisition speed up to 6 GS/s and a detection rate of active RF bands about 30 times below real-time.

3) *Receivers and transmitters for CR/SDR*: The eighth-to-tenth papers focus on the topic of CR/SDR receiver architectures. In the paper "Spectrum Sensing with High Sensitivity and Interferer Robustness Using Crosscorrelation Energy Detection," by Oude-Alink *et al.*, an integrated CMOS-receiver prototype exploiting cross-correlation principles for spectrum sensing is presented. It features a high linearity of $+25$ dBm IIP3 at a sensitivity of -184 dBm/Hz. Such performances assure a high-fidelity spectrum sensing in the presence of strong interferences and even for signals with a negative SNR. The paper "A Wideband Digital Receiver with Hard-Switching Mixers for Cognitive Radio," by Namgoong, reports an innovative concept of high-performance wideband digital receiver for CR/SDR systems. This receiver configuration employs hard-switching mixers as key elements. It outperforms more conventional structures based on analog harmonic-reject mixers in terms of energy detection sensitivity and necessary tuning range for the synthesizer. The problem of properly accounting the known impairments and imperfections in six-port receivers for CR/SDR systems is carefully studied by Hasan and Helaoui in the paper "Effort-Reduced Calibration of Six-Port Based Receivers for CR/SDR Applications." It describes a novel calibration procedure for this type of receiver, which dramatically reduces the number of calibration parameters without any sacrifice in the overall system performance. The devised approach is tested with a real implemented six-port receiver system using real communication signals. The eleventh manuscript, entitled "Linearized Multi-level $\Delta\Sigma$ Modulated Wireless Transmitters for SDR Applications Using Simple DLGA Algorithm," by Elsayed and Helaoui, reports a new linearization procedure for a type of $\Delta\Sigma$-modulator-based transmitter aimed at high-efficiency wideband SDR systems. This kind of transmitter exhibits, as main benefits, a good trade-off of power efficiency versus linearity and mitigation of the bandwidth constraints of the envelope elimination and restoration configuration without sacrificing complexity. Paper number twelve entitled "Experimental Evaluation of an Adaptive Nonlinear Interference Suppressor for Multimode Transceivers," by Habibi *et al.*, proposes the use of adaptive nonlinear interference suppressors as an efficient solution to mitigate undesired interfering effects in multi-mode transceivers. When compared to other interference-suppression alternatives, benefits of this technique are relatively low complexity and power dissipation. Experimental results for different types of constant- and varying-envelope interfering signals are presented to confirm the correct operation of this approach.

4) *Signal-processing and communications techniques for CR/SDR*: The paper "Choose Your Subcarriers Wisely:

Active Interference Cancellation for Cognitive OFDM," by Schmidt *et al.*, describes an ingenious procedure for active interference mitigation in OFDM-based CR systems. It consists of properly modulating a set of carefully selected cancellation subcarriers and has important benefits with regard to more classic related methods; for example, the avoidance of transmission of side information, transparency for the receiver operation, and lower computational cost. Simulations and tests with various hardware platforms are carried out to confirm the potential of the devised interference mitigation concept. In "Blind Opportunistic Interference Alignment in MIMO Cognitive Radio Systems," by Tsinos and Berberidis, the problem of properly exploiting available spatial holes in MIMO CR systems, thus beyond the time and frequency domain, is addressed. For this purpose, an access method referred to as "blind opportunistic interference alignment" is formulated. The performances of this technique are extensively evaluated at both the theoretical and simulation levels. The last paper, entitled "Space-Time Spectral White Spaces in Cognitive Radio: Theory, Algorithms and Circuits" by Wijenayake *et al.*, formulates different detection algorithms for space-time white spaces in CR. They take advantage of the spectral properties of plane wave signals received by a planar antenna array. Their implementations involve the proper design of four subsystems: antenna array, front-end processing, 3-D spatio-temporal array processing, and 1-D spectrum sensing. Simulation examples are shown for narrow- and wide-band signals in various conditions including, among others, different direction of arrivals, variations in the SNR, and multi-path effects.

Finally, we would like to express our deep gratitude to all the authors who submitted their papers to this special issue, either if they were accepted or not, and all the anonymous reviewers for their very valuable time and volunteering efforts which helped the authors to considerably improve the technical quality of the accepted papers. We would also like to thank very much the IEEE JETCAS Editor-in-Chief Professor Massoud Pedram and the IEEE JETCAS Deputy Editor-in-Chief Professor Manuel Delgado–Restituto for their unconditional support in the preparation of this special issue, as well as to all the members of the IEEE JETCAS Senior Editorial Board. Acknowledgement must also be extended to the IEEE JETCAS Editorial Assistant Ms. Annie Yu for her tremendous help and support during all the process of this special issue, from its beginning to its final compilation.

We sincerely hope that you enjoy this special issue!

ROBERTO GÓMEZ-GARCÍA, *Guest Editor*
Department of Signal Theory and Communications
University of Alcalá
Alcalá de Henares, Madrid, 28871 Spain

FADHEL M. GHANNOUCHI, *Guest Editor*
iRadio Lab
Department of Electrical and Computing Engineering
University of Calgary
Calgary, AB, T2N 1N4 Canada

NUNO B. CARVALHO, *Guest Editor*
Instituto de Telecomunicações
Universidade de Aveiro
Aveiro, 3810-193 Portugal

HOWARD C. LUONG, *Guest Editor*
Analog Research Lab
Department of Electrical and Electronic Engineering
Hong Kong University of Science and Technology
Kowloon, Hong Kong

Roberto Gómez-García (S'02–M'06–SM'11) was born in Madrid, Spain, in 1977. He received the Telecommunication Engineer and Ph.D. in electrical and electronic engineering degrees from the Polytechnic University of Madrid, Madrid, Spain, in 2001 and 2006, respectively.

Since April 2006, he has been an Associate Professor with the Department of Signal Theory and Communications, University of Alcalá, Alcalá de Henares, Madrid, Spain. His current research interests are the pursuit of new concepts to design fixed/tunable high-frequency filters and multiplexers in planar, hybrid and MMIC technologies, multi-function circuits, and novel software-defined radio and radar architectures for telecommunications, remote sensing, and biomedical applications. He is an Associate Editor for IET *Microwaves, Antennas and Propagation*. He is a Guest Editor for the IET *Microwaves, Antennas and Propagation* 2013 Special Issue on "Advanced Tuneable/Reconfigurable and Multi-Function RF/Microwave Filtering Devices."

Dr. Gómez-García is an Associate Editor for the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES and the IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS—I: REGULAR PAPERS. He is a Guest Editor of the IEEE JOURNAL ON EMERGING AND SELECTED TOPICS IN CIRCUITS AND SYSTEMS 2013 Special Issue on "Advanced Circuits and Systems for CR/SDR Applications." He is a member of the "IEEE MTT-S Filters and Passive Components" (MTT-8), "IEEE MTT-S Wireless Communications" (MTT-20), and "IEEE CAS-S Analog Signal Processing" Technical Committees.

Fadhel M. Ghannouchi (F'07) is currently a Professor, Alberta Innovates/Canada Research Chair and Director of the iRadio Laboratory, Department of Electrical and Computer Engineering, University of Calgary, Calgary, AB, Canada. His research interests are in the areas of RF and wireless communications, nonlinear modeling of microwave devices and communications systems, design of power- and spectrum-efficient microwave amplification systems and design of SDR systems for wireless and satellite communications applications. His research has led to over 600 refereed publications and 14 U.S. patents (six pending) and three books and three spin-off companies.

Dr. Ghannouchi is a Fellow of IET and a Fellow of Royal Society of Canada. He is the IEEE-MTT-S Emeritus Distinguish Microwave Lecturer.

Nuno B. Carvalho (S'92–M'00–SM'05) is a Full Professor at the Universidade de Aveiro, Aveiro, Portugal, and a Senior Research Scientist with the Instituto de Telecomunicações (IT), Universidade de Aveiro, where he coordinates the wireless communication thematic area and the Radio Systems Group. He coauthored *Intermodulation in Microwave and Wireless Circuits* (Artech House, 2003) and *Microwave and Wireless Measurement Techniques* (Cambridge Press, 2013). He has been a reviewer and author of over 200 papers in magazines and conferences. He co-holds four patents. His main research interests include software-defined radio front-ends, wireless power transmission, nonlinear distortion analysis in microwave/wireless circuits and systems, and measurement of nonlinear phenomena. He has recently been involved in the design of dedicated radios and systems for newly emerging wireless technologies.

Dr. Borges Carvalho is the Chair of the IEEE MTT-11 Technical Committee. He is a member of IEEE MTT-20, MTT-24, and MTT-26. He is an Associate Editor for the *IEEE Microwave Magazine* and the Chair of the URSI-Portugal Metrology Group.

Howard C. Luong (M'05–SM'02) received the B.S., M.S., and Ph.D. degrees in electrical engineering and computer sciences from University of California at Berkeley, Berkeley, CA, USA, in 1988, 1990, and 1994, respectively.

Since September 1994, he has joined the Electrical and Electronic Engineering faculty at the Hong Kong University of Science and Technology, where he has been a Professor. His research interests are in analog, RF, and mm-wave integrated circuits and systems for wireless and portable applications. He was a co-author of the two books entitled *Low-Voltage RF CMOS Frequency Synthesizers* (Cambridge University Press, 2004) and *Design of Low-Voltage CMOS Switched-Opamp Switched-Capacitor Systems* (Kluwer Academic Publishers, 2003).

Prof. Luong is currently serving as an IEEE Solid-State Circuits Society Distinguished Lecturer, an Associate Editor for IEEE RFIC Virtual Journal, a Guest Editor for IEEE JOURNAL OF EMERGING TECHNOLOGIES ON CIRCUITS AND SYSTEMS (JETCAS), and a technical program committee member of many conferences, including Custom Integrated Circuits Conference (CICC), European Solid-State Circuits Conference (ESSCIRC), Asian Solid-State Circuits Conference (A-SSCC), and IEEE International Symposium on Radio-Frequency Integration Technology (RFIT).