From MHz to THz: Systems and Applications

THIS Special Issue is formed by collecting 46 regular papers on the topic of systems and applications, which reflects the latest progress in microwave systems and applications from MHz to THz. All those 46 papers are divided into six subtopics, namely, digital predistortion of RF power amplifiers (five articles), radar systems and applications (14 articles), wireless systems (nine articles), detectors and imaging (ten articles), microwave applications (five articles), and microwave power transfer technologies (three articles).

Digital Predistortion of RF Power Amplifiers (PA)

PA is an essential component in wireless systems, which has nonlinear characteristics in nature of operating in large-signal levels. At the same average power level, a signal with a higher peak-to-average power ratio (PAPR) is more sensitive to PA's nonlinearity, resulting in performance degradations and higher power consumptions. Many linearization techniques have been proposed, among them, digital-predistortion (DPD) is widely considered as the most promising linearization technique due to its flexibility and high performance. Numerous different DPD models have been proposed in the literature to meet different scenarios.

Active antenna arrays are becoming an essential technology in the emerging 5G wireless, the nonlinear distortion is known to be beam-dependent and fast DPD adaptation is thus required, such that the nonlinear distortions can be suppressed as the beam is steered. Therefore, it is very crucial to reduce the complexities of DPD algorithms.

In order to reduce the complexities, different techniques have been proposed to design a composite model by aggregating multiple small models. Besides manually designed models, the structure of DPD models can also be optimized using machine learning techniques. In [A1], Jiang proposed a LFS DPD method based on the BOTDNN model which can maintain the performance comparable to that at full feedback sampling rate even at ultra-low feedback sampling rate.

A closed-loop MP structure in combination with a modified version of the SO learning to update the DPD model coefficients has been adopted in [A2] by Campo, where several low-complexity solutions for estimating and manipulating the inverse covariance matrix (ICM) needed in SO learning had been developed. A hardware efficient basis-propagating selection (BAPS) model is proposed in [A3] by Cao in this Special Issue to reduce the running complexity while maintaining excellent linearization performance. In [A4], Li presented a novel real-time model switching technique to reduce the computational complexity of DPD models. The model can dynamically switch between different model terms and coefficients. The switching process is realized via a decision tree model which is jointly optimized with the model coefficients using a novel iterative alternate minimization algorithm. It can reduce the DPD adaptation complexity by multiple orders of magnitude because only low-dimensional matrixes are involved using the proposed approach. It is desirable to generate and update the model automatically, a novel DPD generator to synthesize the desired DPD model coefficients directly from the PA features is proposed in [A5] by Wang where a complete dynamic DPD solution is developed for MU MIMO systems, which can effectively update DPD models based on the operating conditions using the DPD generator and track the slow-varying PA behavior by efficiently identifying the core PA models in the background.

Radar Systems and Applications

There has been a growing interest in the convergence of radar sensing and communication systems, not only the coexistence of both systems, but also their co-design by sharing the same hardware platform and therefore having common transmit and/or receive signals, while distinct processing strategies are adopted to obtain communication data and estimate parameters of radar targets. An overview of the four state-of-the-art modulation schemes for joint radar-communication (RadCom) systems has been presented in [A6] by Oliveira. A novel hardware and spectrum resources-efficient mm-wave RadCom system featuring high capacity (for communication) and high resolution (for radar) is proposed and experimentally demonstrated in [A7] by Bai.

The remaining 12 papers in this Special Issue are covering various radar applications, reflecting the state-of-art work in the field.

Wireless Systems

Since the introduction of the modern digital mobile communication (2G), wireless communications have become the MUST have of present society, and Cisco predicted [1] that the total number of global mobile subscribers will grow from 5.1 billion (66% of the population) in 2018 to 5.7 billion (71% of the population) by 2023 and global mobile devices will grow from 8.8 billion in 2018 to 13.1 billion by 2023, the number of mobile devices will be almost double of the global population by 2023. The explosive growth in user demand with broader bandwidth and more complex modulations requires large capacity and high-speed rate for the fifth-generation (5G) communication systems and beyond, resulting in a steady shift of carrier frequencies toward higher mmWave band and THz-transmission window above 220 GHz.

A systematic understanding of the role of frequency-dependent sideband asymmetry in the RF path on the performance of high-speed direct-conversion transceivers operating at very high carrier frequencies is presented in [A8] by Grzyb where an analytical model of this impairment with the TX/RX operating jointly is developed and verified with the experiments using 0.13-um SiGe technology.

The modulated signals of various standards have become overcrowded within a limited frequency spectrum. Therefore,

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the method used for managing the interference between the signals is very important. A blocker tolerant RX front end that employs a dual-band N-path balun-LNA for 5G NR sub-6-GHz cellular applications is presented in [A9] by Shin *et al.* without executing any IIP2 calibration.

Due to the need for high-speed communications in the state-of-the-art communication systems, the carrier aggregation technique can fully utilize the unoccupied frequency bands. This approach leads to challenges about the wireless front-end design in concurrent dual-band or multiband operations. Circuitry sizes, power consumptions, and intermodulation products are set to emerge in such systems because two or more wireless front-ends are seemingly indispensable for RF signals over individual frequency bands. The first concurrent dual-band transmitter using only one multiport network is realized by Cheong *et al.* [A10], allowing the generation of dual RF signals with only one LO source. Besides, multiple bands and digitally reconfigurable transceivers are alternative approaches presented in [A11] by Alhamed and in [A12] by Yang *et al*. The latest progress in phased-array systems have also been presented in the remaining papers.

Detectors and Imaging

Besides wireless applications another important application of microwaves is detection and imaging, particularly for millimeter waves and terahertz waves; THz imaging benefits from a number of unique properties of THz bands, being realized in CMSO technologies for low-cost and room-temperature operations. The fabricated 3 × 3 CMOS multi-chip imaging-array operating at 300 GHz is reported by Song in [A13]. The remaining papers of this subtopic cover various implementations of detectors as well as circuitry innovations.

Microwave Applications

This part consists of five papers for microwave applications in microwave heating systems and breast cancer diagnosing and treatments.

Microwave Power Transfer Technologies

Wireless power transfers (WPTs) have drawn much attention both in the literature and practical applications. Among various WPT techniques, microwave power transfer (MPT) has the potential to transmit power over a long distance irrespective of the receiver's (Rx) location, more suitable for remote-monitoring applications. To transmit power to multiple targets, a multitone modulation scheme for multiple beamforming is introduced in [A14] by Park and Ku with a 4 × 4 DBF system operating at 5.8 GHz. Rectifiers are very crucial for the power conversion efficiency of MPTs, and two different rectifiers and implementations have been introduced in [A15] and [A16].

We do hope this Special Issue will bring your interest in exploring more advanced microwave systems and microwave-related various applications.

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Appendix: Related Articles

[A1] C. Jiang *et al.*, "Block-oriented time-delay neural network behavioral model for digital predistortion of RF power amplifiers," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1461–1473, Mar. 2022.

[A2] P. P. Campo *et al.*, "Inverse covariance matrix estimation for low-complexity closed-loop DPD systems: Methods and performance," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1474–1489, Mar. 2022.

[A3] W. Cao, S. Wang, P. N. Landin, C. Fager, and T. Eriksson, "Complexity optimized digital predistortion model of RF power amplifiers," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1490–1499, Mar. 2022.

[A4] Y. Li, X. Wang, and A. Zhu, "Reducing power consumption of digital predistortion for RF power amplifiers using real time model switching," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1500–1508, Mar. 2022.

[A5] X. Wang *et al.*, "Digital predistortion of 5G multi-user MIMO transmitters using low-dimensional feature based model generation," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1509–1520, Mar. 2022.

[A6] L. G. de Oliveira, B. Nuss, M. B. Alabd, A. Diewald, M. Pauli, and T. Zwick, "Joint radar-communication systems: Modulation schemes and system design," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1521–1551, Mar. 2022.

[A7] W. Bai *et al.*, "Photonic millimeter-wave joint radar communication system using spectrum-spreading phase-coding," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1552–1561, Mar. 2022.

[A8] J. Grzyb, P. Rodríguez-Vázquez, S. Malz, M. Andree, and U. R. Pfeiffer, "A SiGe HBT 215–240 GHz DCA IQ TX/RX chipset with built-in test of USB/LSB RF asymmetry for 100+ Gb/s data rates," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1696–1714, Mar. 2022.

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[A13] K. Song, D. Kim, J. Kim, J. Yoo, W. Keum, and J.-S. Rieh, "A scalable 300-GHz multichip stitched CMOS detector array," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1797–1809, Mar. 2022.

[A14] I. Park and H. Ku "Multiple beamforming using multi-tone signals for microwave power transfer system," *IEEE Trans. Microw. Theory Techn.*, vol. 70, no. 3, pp. 1975–1982, Mar. 2022.

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