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Guest Editorial Introduction to the Special Section on Women's Research in Antennas and Propagation Section (WRAPS)

I. INTRODUCTION

WOMEN in research and engineering encounter multiple barriers that impede their progress and contributions. Persistent gender bias and stereotypes result in unequal treatment and assumptions about women's capabilities, often discouraging them from pursuing or advancing in science, technology, engineering, and mathematics (STEM) careers. The lack of visible female role models further limits inspiration and mentorship opportunities, making it harder for women to envision success in these fields. Additionally, the absence of gender-sensitive policies in many institutions fails to accommodate the unique challenges women face, such as managing family responsibilities, which can affect their ability to engage in high-impact research.

Furthermore, women are frequently assigned non-technical roles, limiting their professional development and reducing their visibility in critical technical areas. In professional networks, they may struggle to access key discussions and collaborations, which restricts their inclusion and advancement. These issues highlight the need for systemic changes, including better policies, equal opportunities, and support networks, to create a more inclusive and equitable environment for women in STEM.

Despite these barriers, the system is gradually improving to better support women's research in engineering. Increased awareness of gender inequality has led to initiatives and policies aimed at promoting diversity and inclusion in STEM fields. More institutions are implementing gender-sensitive practices, providing mentorship programs, and encouraging work-life balance, which helps women overcome traditional obstacles.

The field of antennas and propagation is a rapidly growing field with a wide range of applications, from wireless communications to radar to satellite navigation. However, women are underrepresented in this field. The IEEE Antennas and Propagation Society (AP-S) has put a priority on encouraging women's participation in the field. Dr. A. Poddar, Chair of IEEE AP-S Chapter Activity Committee and co-chair of IEEE AP-S COPE (Committee on Promoting Equality) has collected valuable data in terms of the number of AP-S members by gender and grade. The number of AP-S members in 2024 passed 12,000. While the growth of members is seen across different groups, the growth in female members in the past three years is promising. As it can be seen from Figure 1 the number of female members was 971 in 2022 which in less than 3 years it is almost doubled. The number of female members at the end of October 2024 is 1,947. The percentage of women members to the total number of members has grown from 10% to 16.9%. This growth is also visualized in Figure 2. This growth shows that society has been on the right track in attracting women to the field.

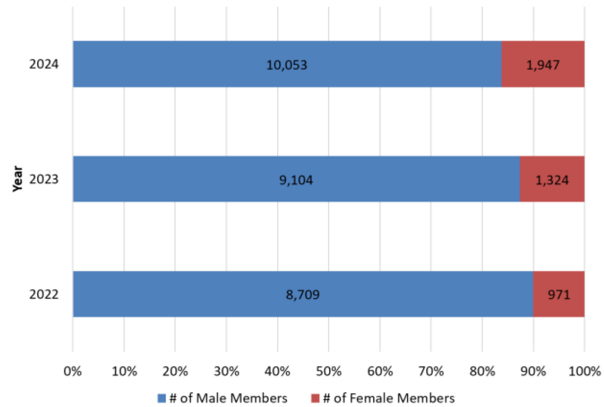

FIGURE 1. The number of IEEE AP-S members in the past 3 years.

Women in the AP-S are making significant contributions to research and innovation, often producing groundbreaking work in various disciplines. This special section highlights only a few exemplary cases of women-led research, showcasing their achievements and demonstrating the positive impact of these advancements in supporting women in the AP-S.

II. CONTRIBUTIONS

Ten articles have been accepted for publication in this special section on "Women's Research in Antennas and Propagation Section (WRAPS)". These articles cover four distinct topics: Advances in antenna design, Beamforming and Wireless

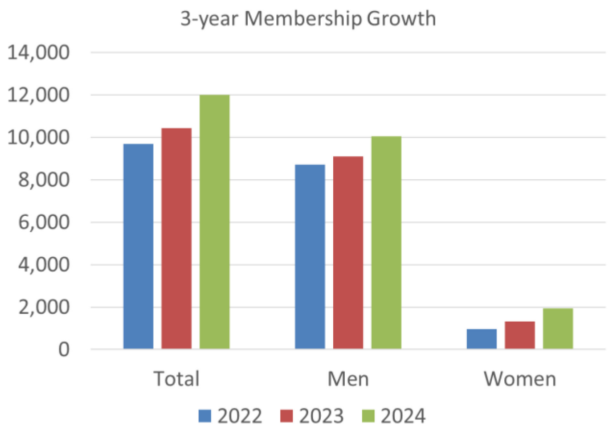

FIGURE 2. The growth of IEEE AP-S members in the past 3 years, separated by gender.

Fading Channels, Wireless Power Transfer Systems, and Biomedical Imaging and Antennas.

A. ADVANCES IN ANTENNA DESIGN

In the first article, Iqbal et al. introduced a wideband, high-gain circularly polarized slot antenna based on a metasurface design with non-uniform slots [A1]. These slots broaden the bandgap, enhancing impedance bandwidth and mode coupling at an optimal fixed feed location, resulting in an improved 3-dB axial ratio and gain. With a compact size, the antenna achieves a 48.74% impedance bandwidth. A 2×2 array provides a higher gain. This design is suited for WiMAX, C-band, and radar applications.

Ma et al. developed a simple and cost-effective shared aperture antenna module to improve spectrum resource utilization and enhance the performance of multifunctional communication systems [A2]. The antenna features a multiplexed structure that combines a microwave patch antenna and a millimeter-wave substrate integrated waveguide slot array for 5G N78 and N257 applications, achieving high isolation between low- and high-frequency channels. The millimeter-wave band operates with a 45° oblique polarization, and the separate feed network for each radiating unit enables the beam scanning in both the E- and H-planes. This antenna demonstrates a wideband coverage, high gain, and broad-angle performance.

Khajeim and Mirzavand investigated the impact of vehicle structures, particularly metallic parts, on the performance of a transparent circularly polarized antenna installed on the vehicle windshield [A3]. An absorber layer on the vehicle floor was proposed to mitigate performance degradation caused by the vehicle components' effects, which minimizes reflections and improves radiation performance. The absorber layer enhances the specific antenna's performance and benefits multiple windshield-mounted antennas. The radiation characteristics of the antenna can be improved by optimizing the antenna's windshield placement. The antenna achieves a stable axial ratio beamwidth even with vehicle occupants present.

B. BEAMFORMING AND WIRELESS FADING CHANNELS

Willhammar et al. provide a study focusing on the industrial environments' fading channels [A4]. Ultra-reliable low-latency communication (URLLC) is essential for 5G and beyond, especially in industrial settings. Massive multiple-input multiple-output (MIMO) technology, with its extensive antenna arrays, enhances reliability through user separation, array gain, and channel hardening. Willhammar et al.'s testing in a 3.7 GHz factory environment revealed that increasing antennas reduces channel gain variations, steepening the cumulative distribution function (CDF) of gains. Distributed arrays further stabilize large-scale power variations, creating a channel resembling an independent identically distributed (i.i.d.) Gaussian channel. Massive MIMO, thus, offers a promising solution for reliable connectivity in reflective, shadowed environments.

Khan et al.'s paper [A5] introduces an innovative beamforming approach for a 2×2 antenna array using characteristic mode theory. Four rectangular patch antennas on an FR-4 substrate, resonating at 2.4 GHz, were analyzed with characteristic mode analysis (CMA) to gain insights into surface currents and radiation patterns. By exciting specific modes, the authors achieved dual-beam capabilities, allowing multibeam reconfigurability by adjusting port phase combinations. This process offers multidimensional coverage and improved beam scanning, making it a valuable method for future reconfigurable array designs. Prototype measurements aligned well with simulations, validating the approach.

C. WIRELESS POWER TRANSFER SYSTEMS

Saha et al. introduce a novel theoretical model for calculating received power and power transfer efficiency (PTE) in a phased-array-based RF wireless power transfer system, focusing on the near-field region [A6]. The proposed method provides an accurate and uniform approach to calculating PTE in both Fresnel and reactive near-field zones, surpassing traditional models like the Friis and Goubau equations. A unidirectional 4×4 transmitter array and a bi-directional receiver are implemented to verify the model's accuracy through simulations and experimental validation. This system can steer the beam to different locations while maintaining constant PTE.

Nadali et al. present a novel printed dual-band dual-polarized antenna designed for ambient radio frequency (RF) energy harvesting, aimed at reducing reliance on batteries for sustainable wireless networks [A7]. This antenna achieves a wide circularly polarized bandwidth of 610-968 MHz, in addition to a linearly polarized bandwidth for the GSM/4G 1800 MHz band. The integration of this antenna with rectifying circuits demonstrates its potential to meet the diverse demands of ambient RF energy harvesting, significantly enhancing the sustainability of low-power electronic devices.

D. BIOMEDICAL IMAGING AND ANTENNAS

Khattak et al. review recent advancements in antenna designs for biotelemetry and healthcare, analyzing over 60 IEEE journal papers published in the past five years [A8]. Each study's simulation or practical results are summarized in this review paper, highlighting their performance insights and key limitations. Khattak et al. propose a novel antenna design optimized for the 5.8 GHz ISM band, featuring a compact 7.7×6 mm^2 size, a mean gain of 1.2 dB, and over 51% efficiency when in contact with the body, positioning it to outperform existing designs.

Vanhari et al. consider quantitative microwave imaging (MWI) and solving the inverse scattering problem (ISP) associated with it [A9]. In their study, they compared regularization techniques—Truncated Singular Value Decomposition (TSVD), Tikhonov regularization, and the truncated Landweber algorithm—within the established Born Iterative Method (BIM) and Distorted Born Iterative Method (DBIM) frameworks. By examining optimal regularization parameters for various structures, their work addresses a gap in the literature, providing insights into improving ISP solution accuracy and stability and establishing a baseline for future microwave imaging applications.

Alemaryeen and Noghanian focus on the design of antennas for implanted wireless biomedical devices for monitoring and therapies as it relates to thermal analysis [A10]. Designing antennas for these devices requires careful consideration of efficiency and safety, particularly regarding tissue heating and regulatory compliance. Key design parameters—such as antenna orientation, power, tissue type, and bioheat model settings—strongly affect thermal performance and patient safety. This study uses simulations and experiments, involving a dipole antenna in a high-dielectric environment, to evaluate temperature distribution and guide optimized, safe antenna designs for biomedical applications.

APPENDIX: RELATED ARTICLES

[A1] K. Iqbal, Q. U. Khan, and Z. Ahmed, "Compact high gain wide-band circularly polarized non-uniform metasurface antenna through improved mode coupling," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1432–1439, Dec. 2024, doi: 10.1109/OJAP.2024.3361381.

[A2] D. Ma et al., "Simple and low-cost shared-aperture antenna module for 5G N78 and N257 applications," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1440–1445, Dec. 2024, doi: 10.1109/OJAP.2024.3367711.

[A3] M. F. Khajeim and R. Mirzavand, "Enhancing transparent circularly polarized antenna performance for automotive applications," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1446–1454, Dec. 2024, doi: 10.1109/OJAP.2024.3462697.

[A4] S. Willhammar, L. V. D. Perre, and F. Tufvesson, "Fading in reflective and heavily shadowed industrial environments with large antenna arrays," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1455–1464, Dec. 2024, doi: 10.1109/OJAP.2024.3388327.

[A5] M. Khan, T. Murad, and N. Lusdyk, "Beamforming analysis of dual beam antenna array using theory of characteristic modes," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1465–1475, Dec. 2024, doi: 10.1109/OJAP.2024.3449752.

[A6] N. Saha, E. P. Alvarez, and I. Mahbub, "A novel theoretical modeling of the received power for phased array-based wireless power transfer system in the near-field region," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1476–1488, Dec. 2024, doi: 10.1109/OJAP.2024.3407658.

[A7] K. Nadali, N. K. Maurya, P. McEvoy, and M. J. Ammann, "A dual-band dual-polarized antenna for harvesting in cellular and digital terrestrial television bands," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1489–1498, Dec. 2024, doi: 10.1109/OJAP.2024.3407050.

[A8] R. Y. Khattak, Q. Z. Ahmed, S. Shoaib, P. I. Lazaridis, and T. Alade, "Recent advances in antennas for biotelemetry and healthcare applications," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1499–1522, Dec. 2024, doi: 10.1109/OJAP.2024.3462289.

[A9] R. A. Vanhari, A. Bakhtafrouz, and S. Noghanian, "Performance analysis of iterative methods in microwave imaging with various regularization techniques," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1523–1538, Dec. 2024, doi: 10.1109/OJAP.2024.3468334.

[A10] A. Alemaryeen and S. Noghanian, "Electromagnetic and thermal co-analysis of an implanted dipole antenna," *IEEE Open J. Antennas Propag.*, vol. 5, no. 6, pp. 1539–1550, Dec. 2024, doi: 10.1109/OJAP.2024.3483277.

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