

- [4] A. Wahid, M. Srinivasan, and P. H. Rao, "CSRR Loaded Microstrip Array Antenna With Low Sidelobe Level," *IEEE Antennas and Wireless Propagation Letters*, vol. 14, 2015, pp. 1169-1171.
- [5] Q. Umar Khan, Dilaawaiz Fazal, and Mojeeb bin Ihsan, "Use of Slots to Improve Performance of Patch in Terms of Gain and Sidelobes Reduction," *IEEE Antennas and Wireless Propagation Letters*, vol.14, 2015, pp. 422-425.
- [6] Stanislav Ogurtsov, Slawomir Koziel, "Systematic approach to sidelobe reduction in linear antenna arrays through corporate-feed controlled excitation," *IET Microwaves, Antennas & Propagation*, vol. 11, no. 6, 2017, pp. 779-786.
- [7] S. Ananthi and S. Dhanasekaran, "Front-to-Back Ratio Improvement of a Microstrip Patch Antenna by using Co-Planar Rod Parasitic Elements for 1.8 GHz Wireless Applications," *International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)*, Aug. 2017, pp. 1610-1613.
- [8] Neng-Wu Liu et al., "A Low-Profile Differential-Fed Patch Antenna with Bandwidth Enhancement and Sidelobe Reduction under Operation of TM₁₀ and TM₁₂ Modes," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 9, 2018, pp. 4854-4859.
- [9] Amirashkan Darvish and Ataollah Ebrahimzadeh, "Improved Fruit-Fly Optimization Algorithm and its Applications in Antenna Arrays Synthesis", *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 4, 2018, pp. 1756-1766.
- [10] Divya Chaturvedi, Arvind Kumar and Singaravelu Raghavan, "An Integrated SIW Cavity-Backed Slot Antenna-Triplexer," *IEEE Antennas and Wireless Propagation Letters*, vol. 17, no. 8, Aug. 2018, pp. 1557-1560.
- [11] Warren L. Stutzman, Gary A. Thiele, *Antenna Theory and Design* (John Wiley & Sons, 3rd Edition, 2013).
- [12] C. Kumar and D. Guha, "Reduction in cross-polarized radiation of microstrip patches using geometry independent resonant-type defected ground structure (DGS)," *IEEE Trans. Antennas Propag.*, vol. 63, no. 6, June 2015, pp. 2767-2772.
- [13] F. Y. Zulkifli, E. T. Rahardjo, and D. Hartanto, "Radiation properties enhancement of triangular patch microstrip antenna array using hexagonal defected ground structure," *Progr. Electromagn. Res. M*, vol. 5, 2008, pp. 101-109.
- [14] C. Kumar and D. Guha, "Nature of cross-polarized radiations from probed circular microstrip antennas and their suppression using different geometries of defected ground structure (DGS)," *IEEE Trans. Antennas Propag.*, vol. 60, no. 1, Jan. 2012, pp. 92-101.
- [15] C. Kumar, D. Guha, "Asymmetric Geometry of Defected Ground Structure For Rectangular Microstrip: A New Approach to Reduce its Cross-polarized Fields," *IEEE Trans. Antennas Propag.*, Vol. 64, Issue 6, June 2016, pp. 2503-2506.
- [16] Y. J. Sung, C. S. Ahn, and Y. S. Kim, "Size reduction and harmonic suppression of rat-race hybrid coupler using defected ground structure," *IEEE Microw. Wireless Compon. Lett.*, vol. 14, no. 1, Jan. 2004, pp. 7-9.
- [17] S. W. Ting, K. W. Tam, and R. P. Martins, "Miniaturized microstrip low-pass filter with wide stop band using double equilateral U-shaped defected ground structure," *IEEE Microw. Wireless Compon. Lett.*, vol. 16, no. 5, May 2006, pp. 240-242.
- [18] D. Guha and Y. M. M. Antar, Eds., *Microstrip and Printed*

Antennas New Trends, Techniques and Applications, Hoboken, NJ, USA: Wiley, 2010, ch. 12.

- [19] Chirag Garg and Magandeep Kaur, "A Review of Defected Ground Structure (DGS) in Microwave Design," *Intern. Jour. Innov. research elec., electro., instr. and control eng. (IJIREICE)*, vol. 2, no. 3, 2014, pp. 1285-1290.

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