

FSS Integrated Antennas for Modern Wireless Applications

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Abstract— This paper presents an extensive overview of the integration of Frequency Selective Surfaces with various antenna structures. The research presents various design parameters, including unit cell geometry, dielectric substrate, periodicity, placement of the FSS layer above and below the antenna and antenna configuration to achieve better radiation characteristics. In, this review paper the importance of FSS in improving important antenna performance in terms of gain, directivity, and bandwidth is also presented. The recent researchers also highlighted the latest applications of FSS integrated antenna structures in modern wireless communication systems.

Keywords— *FSS(Frequency Selective Surface), MSPA(Microstrip Patch Antenna), ISM(Industrial, scientific and medical), DGS(Defected Ground Structure).*

I. INTRODUCTION

Many investigations have been carried out throughout history to find effective antennas that can satisfy the growing need for sophisticated communication. Large bandwidth, high gain, directed radiation, ease of manufacture, and affordability are all necessary features for these antennas [1],[2]. Numerous methods have been widely employed to boost antenna gain. One such method is using epsilon-near-zero (ENZ) materials

[3-5]. Alternatively, patch geometry [6],[7] or add a superstrate, such as an electromagnetic band gap (EBG) [8], [9].

A variety of techniques have been developed and implemented to enhance microwave component performance [10, 11]. The researchers used metamaterials as faulty ground structures to create patch antennas with dual bands and enhanced gain. In [12], fishnet metamaterials were used as DGS to boost the gain of a double band PIFA antenna from 3 dB to 8 dB. The researchers presented a double band patch antenna with decent gain for Ku-band applications made on both H- slotted Deflected Ground Structure and Substrate incorporated waveguide in [13]. FSS is another attractive structure that greatly enhances gain of an antenna. It was first intended to control the Tx (transmission) and Rx (Reflection) characteristics of an incident radiation wave. It is a planar, infinite unit cells array arranged consistently on a dielectric substrate [14,15]. The unit cells near the resonant element are composed of metallic patches or aperture elements that exhibit perfect transmission or reflection, respectively [16]. The FSS can be placed on top of the antenna or on its back, depending on the type of work and applications [17,18]. To improve their performance, FSS can be included into dielectric resonator antennas (DRAs) and other antenna types in addition to patch antennas [19].

For gain augmentation, the number of FSS integrated antennas is stated in literature. In the review report, a few of them are investigated and discussed. [16] describes a small wideband antenna. The FSS-loaded antenna is 46 mm by 46 mm by 28.2 mm and operates in the 2.82–19.94 GHz wideband. After loading FSS beneath the antenna, the gain increases by 3.3 dBi.

Researchers have created a number of high-gain antenna designs in order to meet the strict requirements of 5G mobile communication systems (21–26). There are several ways to increase gain, such as array layout (21, 22), an electromagnetic band gap (EBG)-based structure (23), and an FSS-equipped A four-element MIMO antenna at 38.9 GHz has been proposed in (24) to increase gain from 8 dB to 10 dB. As examined in (25), a circular patch with a circular slot and two via is used in conjunction with a partly reflecting surface (PRS) loading to produce broadband and high-gain features.

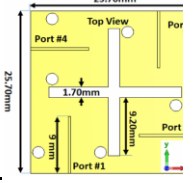
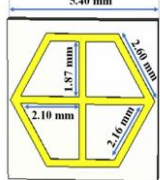
Enhanced bandwidth, better impedance matching, and the capacity to completely incorporate active or passive components are among the benefits of ground-plane slot microstrip antennas [27]. Additionally, combining antennas with FSS designs can improve specific antenna properties. In the literature, combinations of several microstrip antenna types and FSSs have been suggested [28–32]. In [28], an FSS is used to boost a patch antenna's broadside gain at the X band by about 7 dB. In [29], the use of an FSS superstrate layer increases the gain and impedance bandwidth of an aperture linked microstrip patch

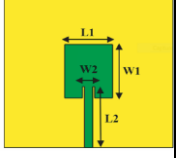
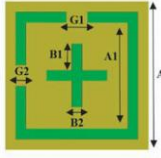
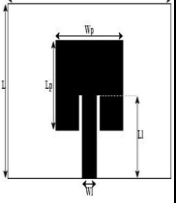
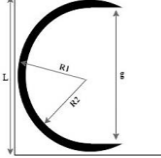
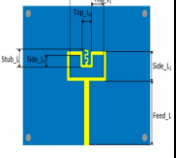
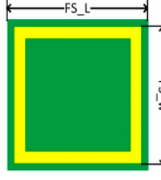
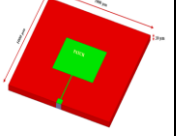
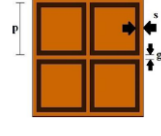
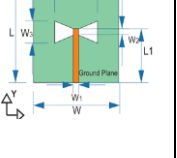
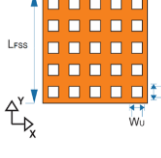
antenna. In [30], an EBG structure is proposed to reduce mutual interaction between meander line MIMO antennas. A conformal metamaterial lens-based radome is used in [31] to suppress surface waves, reduce side-lobes, and increase gain. A small FSS multilayer device composed of reactive impedance surfaces is used in [32] to convert linear polarization into circular polarization.

II. LITERATURE SURVEY

Table 1. shows the comparative analysis of various types of Antennas Integrated FSS structures along with their design parameters, Unit cell FSS structure with its above or below the antenna, Performance of the structure and their applications.

TABLE I. COMPARATIVE ANALYSIS OF VARIOUS AUTHORS

Referen	Structure of Antenna	Unit cell FSS structure	Performan ce	Applicati ons
[33]			The results of proposed structure show the operating bandwidth frequency of 25.5 GHz up to 30 GHz insertion loss ≤ -22 dB and maximum gain of 8dBi.	5G commun ication
[34]				

Referen	Structure of Antenna	Unit cell FSS structure	Performan ce	Applicati ons
[35]			Gain enhancement with FSS layer integration from 3.18 dB to 8.98 dB.	For 5G Sub-6 GHz applications
[36]			Gain enhanced from 3.9 to 5.4 dB, a 1.5-fold improvement. The bandwidth also increased to 230.94 MHz.	Vehicle-to-vehicle communications
[37]			Wider bandwidth of 13% at 2.45 GHz and 27% at 5.8 GHz and peak gain of 6.8 dB at 2.45 GHz and 9.0 dB at 5.8 GHz.	ISM communication
[38]			Improved bandwidth from 1230 GHz to 2260 GHz in the required frequency band and improved gain and directivity by 3.73 dBi.	Terahertz communication
[39]			Increased gain and bandwidth is achieved.	WLAN, WiMAX and 4G and 5G mobile communication system

III. CONCLUSION

Various structures of Antenna with FSS layer integrated are analysed in this review paper. On the basis of study given by various researchers, it has been presented that the performance of

antenna increased with FSS layer integration either above or below the antenna in terms of gain, bandwidth, directivity and efficiency. Resultant antenna integrated FSS structures realized by various authors shows various applications in the wireless communication system. In this paper, an overview of the development of various antenna integrated FSSs that have been documented up to this point, primarily on periodic arrays. It is suggested that more antenna configurations with non-periodic FSSs be investigated. Another open research topic is antenna integrated non-periodic FSS for ultra-wideband applications.

REFERENCES

- [1] Additive manufacturing technology and the potential applications,” Heliyon, vol. 10, no. 6, Mar. 2024, doi: 10.1016/j.heliyon.2024.e27785.
- [2] G. C. Huang, M. F. Iskander, M. Hoque, S. R. Goodall, and T. Bocskor, “Antenna array design and system for directional networking,” IEEE Antennas and Wireless Propagation Letters, vol. 14, pp. 1141–1144, 2015, doi: 10.1109/LAWP.2015.2391199.
- [3] L. Cheng, K. Huang, Y. Wang, and F. Wu, “Dynamic tunable deflection of radiation based on epsilon-near-zero material,” Photonics, vol. 10, no. 6, p. 688, Jun. 2023, doi: 10.3390/photonics10060688.
- [4] M. Bayat and J. Khalilpour, “A high gain miniaturised patch antenna with an epsilon near zero superstrate,” Materials Research Express,

- vol. 6, no. 4, Jan. 2019, doi: 10.1088/2053-1591/aa4c46.
- [5] C. Cheng, Y. Lu, D. Zhang, F. Ruan, and G. Li, "Gain enhancement of terahertz patch antennas by coating epsilon-near-zero metamaterials," *Superlattices and Microstructures*, vol. 139, Mar. 2020, doi: 10.1016/j.spmi.2020.106390.
- [6] G. Singh and A. P. Singh, "On the development of a modified triangular patch antenna array for 4.9 GHz public safety WLAN," *Advanced Electromagnetics*, vol. 8, no. 4, pp. 24–31, Sep. 2019, doi: 10.7716/aem.v8i4.1091.
- [7] S. Akinola, I. Hashimu, and G. Singh, "Gain and bandwidth enhancement techniques of microstrip antenna: a technical review," in *Proceedings of 2019 International Conference on Computational Intelligence and Knowledge Economy, ICCIKE 2019*, Dec. 2019, pp. 175–180, doi: 10.1109/ICCIKE47802.2019.9004278.
- [8] W. El May, I. Sfar, J. M. Ribero, and L. Osman, "A millimeter-wave textile antenna loaded with EBG structures for 5G and IoT applications," *2019 IEEE 19th Mediterranean Microwave Symposium (MMS)*, Hammamet, Tunisia, 2019, pp. 1–4, doi: 10.1109/MMS48040.2019.9157278.
- [9] Y. Alnaiemy and L. Nagy, "Improved antenna gain and efficiency using novel EBG layer," in *SOSE 2020 - IEEE 15th International Conference of System of Systems Engineering*, Proceedings, Jun. 2020, pp. 271–276, doi: 10.1109/SoSE50414.2020.9130494.
- [10] Nakmouche, M. F., A. M. M. A. Allam, D. E. Fawzy, and D. B. Lin, "Low profile dual band H-slotted DGS based antenna design using ANN for K/Ku band applications", *8th Int. Conf. Electr. Electron. Eng. ICEEE*, 2021.
- [11] Nakmouche, M. F., H. Taher, D. E. Fawzy, and A. M. M. A. Allam, "Development of a wideband substrate integrated waveguide bandpass filter using H-slotted DGS," *The 6th IEEE Conference on Antenna Measurements & Applications (CAMA)*, Oct. 2019.
- [12] M. F. Nakmouche and M. Nassim, "Impact of metamaterials DGS in PIFA antennas for IoT terminals design," *The 6th International Conference on Image and Signal Processing and their Applications*, Nov. 2019.
- [13] Nakmouche, M. F., A. M. M. A. Allam, D. E. Fawzy, H. Taher, and M. F. A. Sree, "Dual band SIW patch antenna based on H-slotted DGS for Ku band application," *The 7th IEEE International Conference on Electrical and Electronics Engineering*, Apr. 2020.
- [14] Munk, B. A., *Frequency Selective Surfaces: Theory and Design*, Wiley, New York, 2000.
- [15] Sakran, F. and Y. Neve-Oz, "Absorbing frequency-selective surface for the mm wave range," *IEEE Trans. Antennas Propag.*, Vol. 56, No. 8, 2649–2655, 2008.
- [16] Vardaxoglou, J. C., *Frequency Selective Surfaces: Analysis and Design*, Wiley, New York, 1997.
- [17] Kushwaha N, Kumar R. Design of slotted ground hexagonal microstrip patch antenna and

- gain improvement with FSS screen. *Prog Electromagnet Res B* 2013; 51:177–99.
- [18] Hussain M, Awan WA, Alzabidi MS, Elkamchouchi DH. Self-Decoupled Tri Band Mimo Antenna Operating Over ISM, WLAN and C-Band for 5G Applications. *WLAN and C-Band for 5G Applications*.
- [19] Akbari M, Gupta S, Farahani M, Sebak AR, Denidni TA. Gain enhancement of circularly polarized dielectric resonator antenna based on FSS superstrate for MMW applications. *IEEE Trans Antennas Propag* 2016;64(12):5542–6.
- [20] Kundu S. A compact uniplanar ultra-wideband frequency selective surface for antenna gain improvement and ground penetrating radar application. *Int J RF Microwave Comput Aided Eng* 2020;30(10):e22363.
- [21] Yang, X. X. et al. Broadband Dual-Polarized endfire array with compact Magneto- electric planar Yagi antenna for mm-Wave terminals. *IEEE Access*. 9, 52708–52717 (2021).
- [22] Sufian, M. A. et al. Series fed Planar Array-based 4-port MIMO Antenna for 5G mmWave IoT Applications. In Proceedings of the Asia-Pacific Microwave Conference (APMC), Yokohama, Japan, 29 November–2 pp. 880–882. (2022).
- [23] Shoaib, N. et al. MIMO Antennas for Smart 5G Devices. *IEEE Access*. 6, 77014–21 (2018).
- [24] Ibrahim, A. A., Ali, W. A. E., Alathbah, M. & Sabek, A. R. Four-Port 38 ghz MIMO antenna with high gain and isolation for 5G wireless networks. *Sensors* 23 (3557), 2023 (2023).
- [25] Jinkyu Jung, W. A., Awan, D., Choi, J. & Lee Niamat Hussain and Nam Kim. Design of high-gain and low-mutual-coupling multiple-input–multiple-output antennas based on PRS for 28 GHz applications. *Electronics*. 12, 4286 (2023).
- [26] Zhang, Z. & Pan, Z. Time domain performance of reconfigurable filter antenna for IR-UWB, WLAN, and wimax applications. *Electronics* 8 (9), 1–12 (2019).
- [27] T. T. Le, H. H. Tran, and H. C. Park, “Simple-structured dual-slot broadband circularly polarized antenna,” *IEEE Antennas Wireless Propag. Lett.*, vol.17, no.3, pp. 476-479, Mar. 2018.
- [28] L. Kurra, M. P. Abegaonkar, A. Basu, and S. K. Koul, “FSS properties of a uniplanar EBG and its application in directivity enhancement of a microstrip antenna,” *IEEE Antennas Wireless Propag. Lett.*, vol.15, no. 1, pp. 1606-1609, Jan. 2016.
- [29] A. Pirhadi, H. Bahrami, and J. Nasri, “Wideband high directive aperture coupled microstrip antenna design by using a FSS superstrate layer,” *IEEE Trans. Antennas Propag.*, vol. 60, no. 4, pp. 2101-2106, Apr. 2012.
- [30] X. Tan, W. Wang, Y. Yu, Y. Liu, and A. A. Kishk, “Enhancing isolation in dual-band meander-line multiple antenna by employing split EBG structure,” *IEEE Trans. Antennas Propag.*, vol. 67, no. 4, pp. 2769-2774, Apr. 2019.

- [31] D. De and P. K. Sahu, "Design of and endfire microstrip antenna for aircraft collision avoidance system," *IEEE Antennas Wireless Propag. Lett.*, vol.18, no. 5, pp. 996-1000, May 2019.
- [32] S. M. A. M. H. Abadi, N. Behdad, "Wideband linear-to-circular polarization converters based on miniaturized-element frequency selective surfaces," *IEEE Trans. Antennas Propag.*, vol. 64, no. 2, pp. 525-534, Feb. 2016.
- [33] Shaymaa M. Gaber¹, Radwa A. Kareem & Ahmed A. Ibrahim, "High isolation quad ports MIMO antenna loaded with FSS for 5G communication", *Scientific Reports |* (2025) 15:20167 | <https://doi.org/10.1038/s41598-025-05616-7,2025>.
- [34] Sania Tariq .et.al., "Frequency selective surfaces-based miniaturized wideband high-gain monopole antenna for UWB systems", *International Journal of Electronics and Communications, Elsevier (AEU)*, 2023.
- [35] Mohammad F Nakmouche .et.al, "Development of a High Gain FSS Reflector Backed Monopole Antenna Using Machine Learning for 5G Applications", *Progress In Electromagnetics Research M*, Vol.105,183–194, 2021.
- [36] Chengming Shi et.al., "Gain Enhancement of a Dual-Band Antenna with the FSS", *Electronics* 2022, 11, 2882. <https://doi.org/10.3390/electronics11182882>.
- [37] SELVAKUMAR GEORGE et.al., "Implementation of FSS substrate on microstrip patch antenna for terahertz communication", *JOURNAL OF OPTOELECTRONICS AND ADVANCED MATERIALS* Vol. 24, No. 7-8, p. 338 – 346, July – August 2022.
- [38] Augusto César Rebouças de Brito et.al., "Effects of an FSS Reflector on a Microstrip Line Fed Bow-Tie Slot Antenna", *Journal of Microwaves, Optoelectronics and Electromagnetic Applications*, Vol. 19, No. 3, DOI: <http://dx.doi.org/10.1590/2179-10742020v19i38>, September 2020.
- [39] R.V.S. Ram Krishna and R. Kumar, "Slotted ground microstrip antenna with FSS reflector for high-gain horizontal polarisation", *ELECTRONICS LETTERS*, Vol. 51 No. 8 pp. 599–600 16th April 2015.