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Reflection FSS-Based Millimetre Slot Antenna with Gain Enhancement for 5G Networks

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ABSTRACT

In this paper a millimeter-wave (mm-wave) with rectangular shaped slot antenna is implemented at the operating frequency of 28 GHz to improve the efficiency of 5G networks using micro-strip technique for feeding. The main objective of utilizing slot is to enhance the antenna performance in terms of gain, directivity, bandwidth, efficiency, radiated power and accepted power. Rectangular slot antenna of required frequency bandwidth is utilized in the proposed model. Additionally to enhance antenna gain Frequency Selective Surface (FSS) is deployed which is designed using the similar fundamental mode of antenna and located at particular distance to attain desired gain improvement with appropriate dimension of 25 x 25 x 5 mm^3. By incorporating FSS into mm-wave rectangular antenna ensures 6.7 dBi of gain improvement and S11 ≤ -10 dB from 26 GHz to 29.8 GHz of bandwidth enhancement with improved radiation efficiency which are obtained from tested and experimental data. These results attained using proposed antenna are subsequently better when compared to existing antenna system. Thus, the proposed antenna with high gain efficiency makes it more suitable for 5G wireless communication applications.

Keywords: Millimetre-wave (mm-wave), Rectangular slot antenna, Frequency Selective Surface (FSS).

1 Introduction

The 5th Generation wireless communication networks are envisioned to attain remarkably enhanced communication latency with high data transmission rate thereby, enabling larger network coverage based on frequency. Due to increased usage of wireless communication devices it is an essential need to acquire compact and low-profile antennas achieving wider bandwidth and consistent gain. The advancement of wireless communications leads to substantial development of telecom industry which enables easy transmission of audio, data and multimedia without the need for physical wired connections [1].Hence antenna diversity plays vital role for improvement of 5G networks which is significantly evaluated using polarization diversity, pattern diversity, spatial diversity and transmitter/ receiver diversity. Moreover, antenna diversity is also measured in terms of shape and beam-width of radiation pattern which are essential for minimizing multi-path intervention which leads to reliable wireless communications [2].

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To achieve high bandwidth with reduced latency in 5G networks mm-wave technology is utilized due to its improved bandwidth which allows transmission of multi-gigabit per second data rates [3]. The usage of mm-wave antennas are significantly increased because of its compact size with minimal number of components which in turns enhances antenna performance [4]. Additionally mm-wave antennas are considered as promisingly better solution for improved antenna capacity with high gain [5]. In order to improve antenna performance efficiency FSS based reflector is utilized which produces various resonance frequency with remarkably reduced impedance bandwidth thereby, enhancing antenna performance in terms of gain and bandwidth [6]. FSS acts as spatial filters which allows only electromagnetic waves within desired frequency bad to pass through [7]. However, traditional FSS struggles with narrow and rippled bands along with grating lobe for low angle incidence [7]. Hence FSS with unit cell based on slots are utilized which provides interconnected metal surface [8]. These FSS enables better filtering by using high-order filter which is accomplished by cascading single layer structure to attain multi-layer structure [9].

For enhanced antenna functioning, antenna ports requires low mutual coupling which is impossible to attain in closely located antennas which in turn maximizes correlation between received signals thereby, affecting the antenna performance [10]. Hence, to overcome this situation rectangular shaped slot antenna is deployed which attains higher bandwidth with adequately thin substrate. Therefore, the integration of rectangular slot antenna with micro-strip line perpendicular to slot antenna achieves better performance with enhanced efficiency [11].

The proposed system is improvised mm-wave with rectangular shaped slot antenna in order to boost the bandwidth and improve efficiency of 5G wireless communication networks. FSS substrate is used in the antenna’s fabrication to increases antenna gain and assures minimal cost implementation. The reflection FSS-based millimeter slot antenna offers significant gain enhancement compared to conventional slot antennas. The proposed antenna design achieves wide bandwidth, which is crucial for 5G networks. Wide bandwidth allows the antenna to support various 5G frequency bands, enabling compatibility with different network deployments and ensuring efficient communication across different wireless channels. Therefore, designed antenna covers 5G MMW band with improved efficiency.

2 Recent Works

Bharath Reddy *et al* [2019] [12] have developed radiating micro-strip fed rectangular slot antenna to achieve enhanced polarization diversity with better transmission rates. To attain concurrent board-band of LHCP and RHCP and to enable synchronous transmission of right-handed (RH) and left handed (LH) of circularly polarised (CP) waves, radiating micro-strip antennas are utilised. Therefore, by deploying micro-strip fed rectangular antenna ensures efficient antenna performance with effective tuning capacity. However, this system struggles with computational complexity and high implementation cost.

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Fabian-Gongora ***et al*** **[2021] [13]** have developed split ring slot based antennas for enabling tri-band frequency selective surface unit. To attain significant deduction of mutual coupling among adjacent split ring slots, third resonant mode is utilised which also enables close band response and distinct band tuning. In order to ensure efficient tuning of FSS, the reactive loading with varactor diodes are located at better position among the split ring slots. Therefore by utilizing FSS for split based slot antenna assures reduced mutual coupling within the split ring and improves the antenna performance efficiency. Nevertheless, this system still struggles with transmission loss.

Qasem ***et al*** **[2022] [14]** have introduced Dual band mm wave based slotted square patch antenna using AFSS for improved 5G network applications. To attain effective tuning range for dual modes AFSS in deployed using spiral arms affirmed with four varactors. By utilising slotted square patch antenna ensures minimised antenna size with efficient dual-band operations. Therefore using AFSS for slotted square patch antenna assures better antenna performance with reduced number of component thereby, minimising the antenna size. Nonetheless, this system struggles with data security measures hence, it is essential to improve the security for secure wireless communication.

Alsudani ***et al*** **[2022] [15]** have implemented Micro-strip patch antenna using FSS as substrate for enhanced 5G communication networks in which the upper part of FSS substrate acts as passive bandpass filter and the lower part acts as passive bandstop filter. These filters are deployed to reflect discharge of radiation from ground plane thereby, enhancing the antenna performance making it suitable for 5G wireless communications. Therefore, using FSS substrate for micro-strip patch antenna ensures compact size, simple implementation and minimised fabrication cost. However, these antennas still struggle with minor bandwidth issues which need to be rectified.

Ishteyaq ***et al*** **[2021] [16]** have innovated double band planar printed slot antenna to attain high peak gain with better 5G wireless applications. This antenna contains rectangular radiating slot integrated with inverted stab on its upper edge concurrently with micro-strip feed line consisting of doubly folded T- shaped formation. Therefore, this system ensures efficient antenna performance with compact size thereby, reducing transmission loss with peak gain and improved total efficiency. However, this system still struggles with computational complexity.

3 Proposed Work Explanation

In this proposed system, reflection based FSS substrate is deployed to mm-wave rectangular slot antenna to attain enhanced antenna performance thereby, making it suitable for 5G network applications. Figure 1 illustrates the architecture of proposed antenna.

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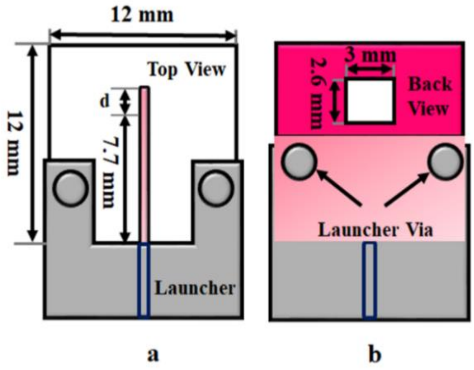

Figure 1: *Configuration of Slotted Antenna with Launcher (A) Top (B) Back*

Rectangular slot antenna is utilized for fundamental mode operation of desired frequency band and to increase the antenna gain, FSS is deployed with an appropriate dimension of 25×25×5 mm^3 which is located under the antenna at particular distance to provide desired gain augmentation. By inserting FSS based reflectors underneath antenna enhances antenna gain by 6.7 dBi. Further both antenna and FSS is implemented and tested whereby, the antenna with FSS achieved increased gain when compared to the antenna without FSS reflector. The test and simulation results uses the same pattern which makes it suitable for 5G network applications. To attain the simulation results, CST Microwave software Studio is deployed.

3.1 FSS reflector

FSS's are normally defined as planar structures that shows similar behavior of electromagnetic filters which are implemented to reflect electromagnetic waves. The reflection process works based on the type of element deployed in the array or bandpass or bandstop. Additionally, parameters of the elements involving thickness, dimensions, geometry, relative permittivity of the substrate and periodicity determines the performance efficiency of FSS. Various applications including reflector antennas, radomes, Radar Cross Section (RCS) works using FSS due to its low cost implementation, minimized weight, better capacity of integration and enhanced flexibility which makes it suitable for telecommunication system. Figure 2 represents FSS structure which acts as the super substrate.

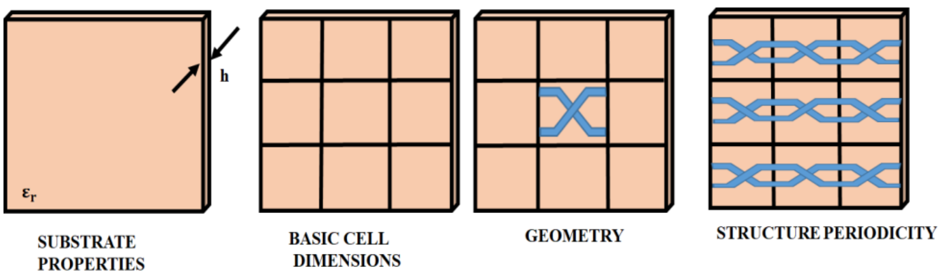

Figure 2: *FSS Architecture*

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One of the FSS property that attract scholars is the designing of more effective antennas which significantly enhance the antenna performance in terms of transmission capacity, reflecting electromagnetic waves, efficient usage of the spectrum and protecting the system from being diverted in unwanted directions. In order to direct the radiation pattern it is essential to use FSS as superstrate which makes it possible to attain desired radian performance. Hence, the integration of FSS enables one or more antenna operation properties to be changed thereby, enhancing the telecommunication system efficiency in terms of both energy and communication quality. Therefore, the minimized cost, simple implementation makes it essential to use FSS as a super-strate for 5G network.

4 Result and Discussion

This paper proposes the implementation of FSS based mm wave slot antenna which is designed to attain improved antenna performance with high gain and enhanced efficiency which in turn makes it suitable for 5G communication applications.

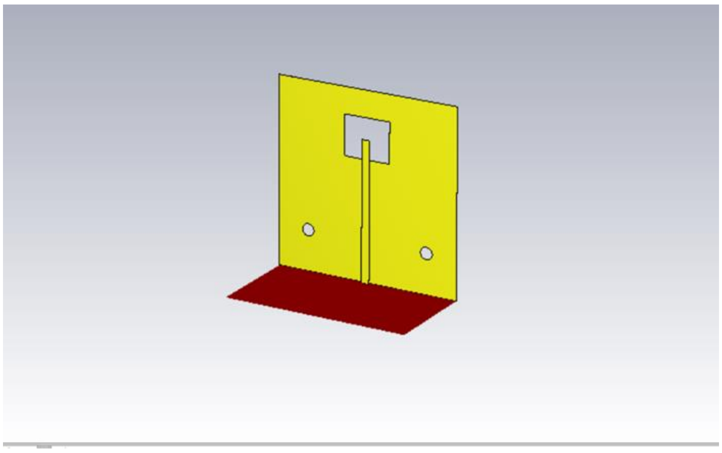

Figure 3: *Design of the proposed Antenna*

Figure 3 Represents architecture of the proposed FSS based rectangular slot antenna for 5g network which leverages the unique properties of FSS structures to enhance its performance in terms of gain, bandwidth, and radiation characteristics. FSS structures exhibit frequency-dependent transmission and reflection properties, allowing them to control the wave propagation characteristics. By carefully designing the FSS elements, it is possible to enhance the antenna's gain and improve its radiation efficiency.

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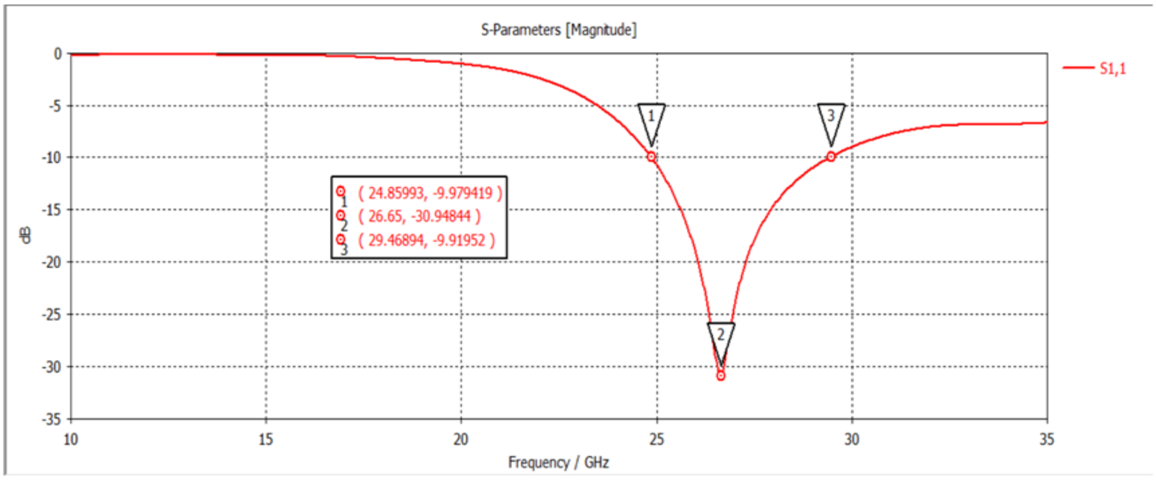

Figure 4: *S-Parameters*

Figure 4 Represents S-Parameters which consists of magnitude. In order to obtain power gain only the magnitude part is considered that is plotted against the frequency range from 10 to 35 GHz.

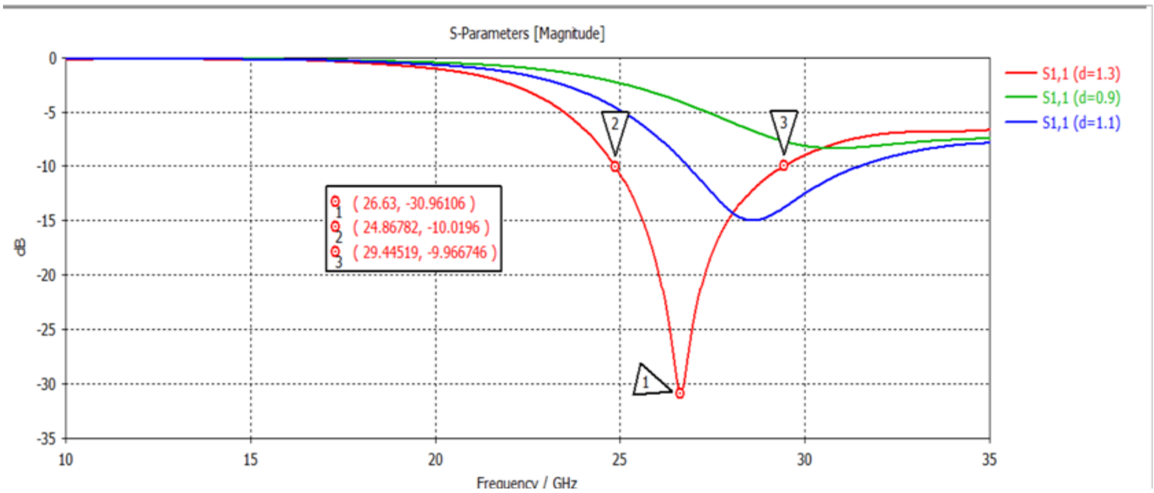

Figure 5: *Parametric Study of the proposed antenna*

Figure 5 Represents S-Parameters study based on real part that is plotted against the frequency range from 10 to 35 GHz. S-parameter representation consists of real and imaginary parts but to obtain the maximum power gain only the real part is considered.

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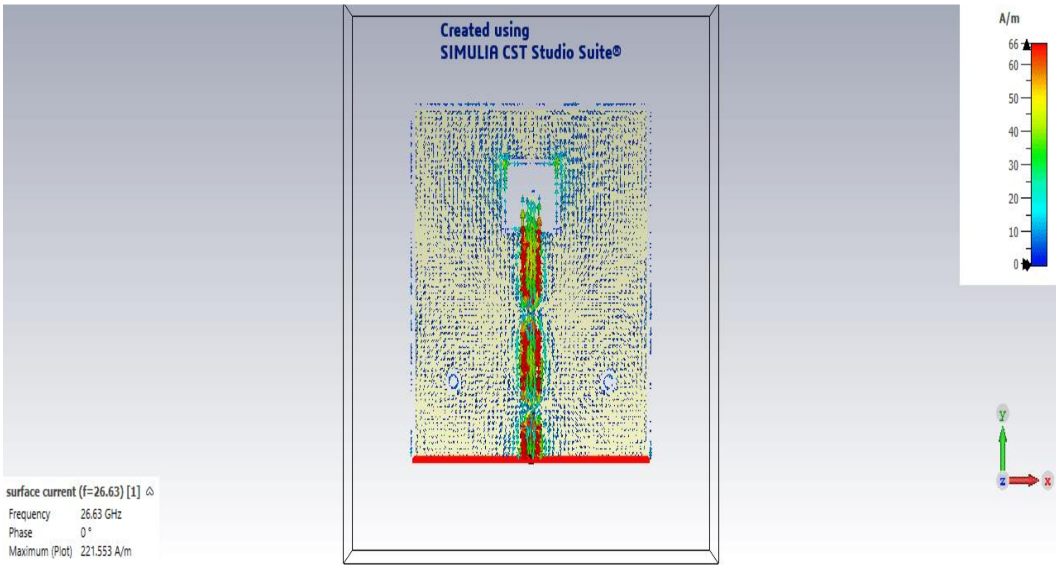

Figure 6: *Surface currents*

Figure 6 represents the surface currents which is an actual electric current that is induced by an applied electromagnetic field. In the above figure Surface current is evaluated using simulia CST Studio Suite.

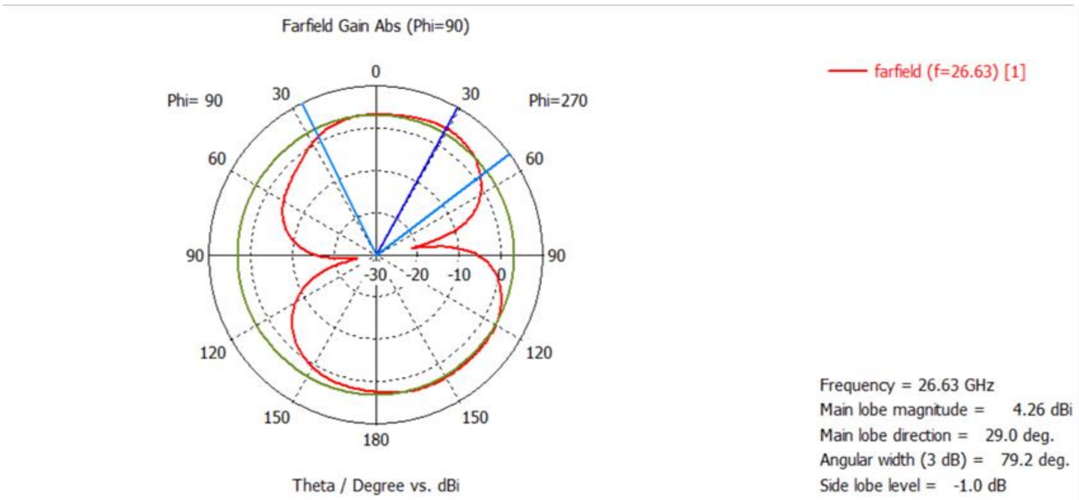

Figure 7: *Radiation pattern*

Figure 7 represents the radiation pattern using farfield gains which are normally the graphical representation of the antenna properties to determine how the antenna radiates energy as a function of space.

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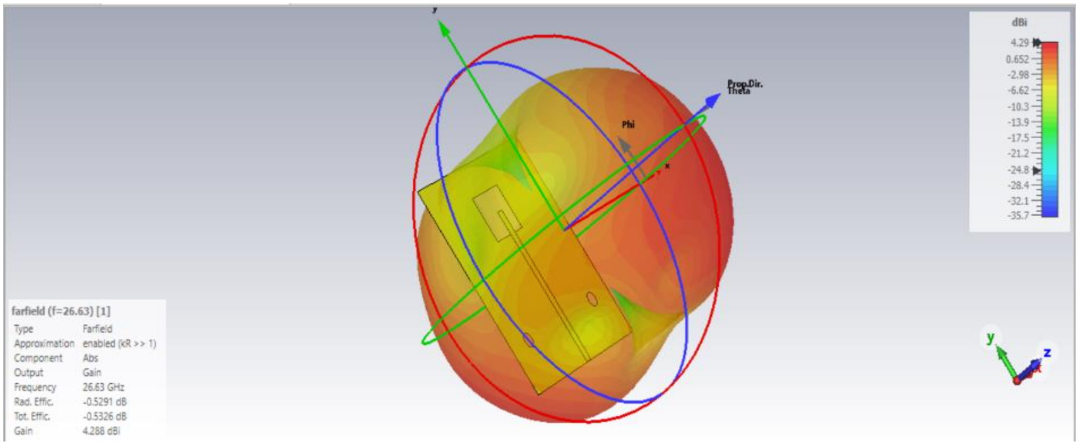

Figure 8: *3D GAIN*

Figure 8 Represents the 3D Plot gain of the proposed antenna in terms of graphical representation in which 3D plot gain is a graph that is used to evaluate the gain of an antenna performance on the basis of average scale, antenna gain and vertical radiation pattern.

5 Conclusion

A slot antenna with improved gain for upcoming 5G networks is presented. To accomplish the needed gain enhancement, FSS with unit cells is used. The proposed antenna has an overall size of 25×25×5 mm^3. The antenna without FSS-based reflectors obtained a bandwidth of S11 -10 dB and a gain of roughly 4.5 dBi from 26 GHz to 29.8 GHz. While the antenna incorporated with FSS achieved S11 -10 dB bandwidth and realized gain from 25.5 GHz to 30.8 G Hz and about 10.3dBi. A strong correlation between measured and simulated results is achieved, supporting the proposed antenna for upcoming 5G networks. Therefore, by utilizing FFS based reflectors ensures improved antenna performance with high gain, diversity and bandwidth making it apt for 5G wireless communication networks.

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