Designing a High Frequency Antenna Array for 5G New Radio and 5GHz with Interference Isolation

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Abstract- *This paper aims to design a Multiple Input Multiple Output (MIMO) microstrip antenna array using Electromagnetic Band Gap (EBG) and Defeated Ground Structure (DGS) methods.The proposed system can operate in the range of 3.2-5.75GHz with good impedance matching. This design is simulated using the high frequency structure simulator (HFSS). To validate the performance, the MIMO structure is fabricated and measured. The simulated and measured results are in good coherence, to obtain high isolation between antenna elements resulting in a low Envelope Correlation Coefficient (ECC). Other MIMO performance metrics such as the Total Active Reflective Coefficient (TARC)Channel Capacity Loss (CCL), Mean Effective Gain (MEG), and Diversity gain (DG) of the proposed structure are analyzed.*

Keywords- Multiple Input Multiple Output (MIMO), EBG, DGS, HFSS

I. INTRODUCTION

In recent years, an eminent increase of wireless devices, inadequate bandwidth, and limited channel capacity have substantially promoted efforts to develop advanced standards for communication networks. Subsequently, this has promoted the development of next-generation (5G) new radio communication systems . However, the available spectrum is limited and hence requires alternative ways of effective utilization of the available spectrum. MIMO (Multiple Input Multiple Output) serves as one of the promising solutions for effective utilization of spectrum. Antenna Array Also called an array antenna, antenna arrays are several antennas connected & arranged in a regular structure to form a single antenna.In general, MIMO comprises a set of two or more antennas that work together to achieve increased system capacity the use of MIMO increases link reliability and spectral throughput of the system. The major Advantages of Antenna Arrays are Increase in the overall gain, Provides diversity reception. Cancel out interference from a particular set of directions, Determines the direction of arrival of the incoming signals, Maximize the Signal to Interference Plus Noise Ratio (SINR). Though there are significant advantages in the use of MIMO antennas, they suffer from a mutual coupling effect. One method of reducing mutual coupling between antenna elements is by introducing decoupling elements including Electromagnetic Band Gap (EBG) structures, Defected Ground Structures (DGS). The etching of Defective Ground Structure (DGS) in the ground plane of microstrip antennas. A defect is introduced in the ground plane which is equivalent to current carrying current sink and infinite in length. Electromagnetic Band Gap (EBG) structures are periodic in nature which can be etched on metal or ground plane. EBG structures are also called as high impedance surfaces as they are capable of suppressing surface waves at certain frequency bands. Also the array antenna elements are orthogonally oriented to improve the isolation between ports.

Wireless communication needs small size, light weight, easy mountable antenna for effective performance.So an effective antenna design is required to embed in wireless devices. Microstrip patch antennas are the only solutions to the above problems having all the required properties. Microstrip patch antennas have found extensive application in wireless communication system due to their advantages such as low profile, conformability, low-cost fabrication and ease of integration with feed network. Microstrip antenna in its simplest form consists of a radiating patch (of different shapes) which is made up of a conducting material like Copper or Gold on one side of a dielectric substrate and a ground plane on the other side. It is used in communication systems due to simplicity in structure, conformability, low manufacturing cost, and very versatile in terms of resonant frequency, polarization, pattern and impedance at the particular patch shape and model

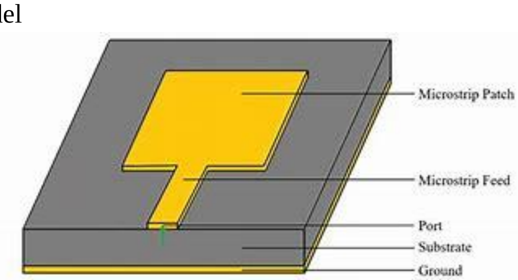


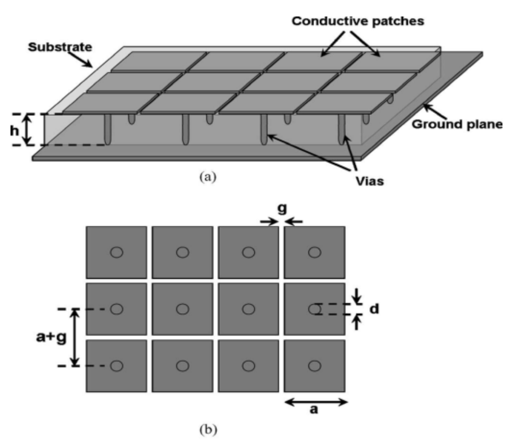
Fig:Basic Structure of Microstrip Patch Antenna

The proposed antenna is printed on an FR-4 substrate with a noticeable cost reduction. Each antenna element has a dimension of 15 mm × 23 mm × 1.6 mm. An ‘‘EL’’ slot into the radiating element and two identical stubs coupled to the partial ground are used to improve the impedance matching of 4.3 dielectric constant and 0.025 loss tangent. The antennas’ overall dimensions for all methods are the same as they approach 46 mm × 46 mm × 1.6 mm with increased isolation .Sourav Roy et al. [1] proposed a meta-inspired decoupling method to reduce the isolation with a bandwidth of 1.34 to 3.92 GHz and 4.34 to 6.34 GHz. The gain ranges from 3 to 5 dBi with dimensions of 100 mm × 60 mm × 1 mm and isolation of −10 dB. It is designed and fabricated on a jean’s substrate, which has a dielectric permittivity of 1.6 and loss tangent of 0.02Luo et al. [2] presented an H-shaped antenna placed in a square loop with FR-4 substrate while covering the band from 5.2 to 5.8 GHz with isolation of 14 dB between ports. The gain of the proposed antenna is approximately 5 dBi, and the efficiency approaches 80%. The antenna dimensions are 42 mm × 42 mm × 0.8 mm with a noticeable size reduction Wu et al. [3] presented VOLUME 10, 2022 This work is licensed under a Creative Commons Attribution 4.0 License. For more information, see https://creativecommons.org/licenses/by/4.0/ 19875 A. A. Megahed et al.: Sub-6 GHz Highly Isolated Wideband MIMO Antenna Arrays a four-port MIMO antenna array with a band notch that uses electromagnetic bandgap (EBG) to reduce mutual coupling. The band notch is centered at 4.6 GHz covering the band from 4 to 5.2 GHz with isolation of 17.5 dB between ports with dimensions of 60 mm × 60 mm × 1.6 mm using FR4 substrate. The relative permittivity, efficiency, and gain are 4.4, 90%, and 8 dBi, respectively. Several attempts have been made to improve the bandwidth by cutting the resonant slot inside the patch [4]. The main problem in designing a MIMO antenna array is mutual coupling. Numerous studies used various methods to decrease the effects of this problem. In [5], a two-port MIMO antenna array using defected ground structure (DGS) to obtain high isolation between ports with dimensions of 45 mm × 45 mm × 1.6 mm has been presented. The isolation is less than 14 dB. The gain and peak efficiency of the array are 4 dBi and 91%, respectively. The bandwidth ranges from 2.2 to 6.28 GHz. The antenna is designed on an FR-4 substrate.. In [6], a four-port MIMO antenna array with a size of 40 mm × 30 mm × 1.6 mm with a noticeable size reduction. The bandwidth ranges from 3.2 to 5.7 GHz, and it is fabricated on FR-4 substrate. The isolation of the antenna array using DGS is less than −10 dB, especially S31, and this result is not sufficiently good. The gain of the proposed antenna is about 3.5 dBi, and the efficiency approaches 82%. Meanwhile, Yang and Zhou [7] presented a circular patch and L-shaped as an isolating element decoupling structure with a compact size of 30 mm × 30 mm × 0.8 mm with a noticeable size reduction

II.ANTENNA CONFIGURATION AND DESIGN ANALYSIS

EGB Structure

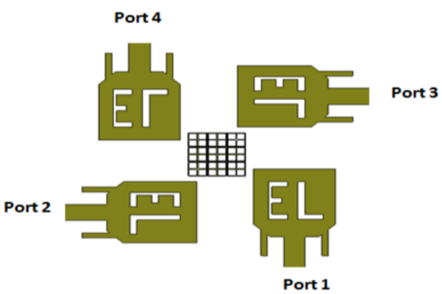
The EBG structure is designed on an FR4 substrate with a relative permittivity of εr = 4.3 and dielectric loss tangent of 0.025 and has a substrate thickness of 1.6 mm. The structure is modelled using ANSYS High Frequency Structural Simulator (HFSS). Electromagnetic band-gap (EBG) structure is a structure that creates a stopband to block electromagnetic waves of certain frequency bands by forming a fine, periodic pattern of small metal patches on dielectric substrates. EBG refers to such a stopband as well as to substances (medium to transmit electromagnetic waves) that have such a structure. The design evolution of the EBG structure comprises five stages. The effect of the strip length and reflection coefficient characteristics are given Figure 2. It is inferred that the increment in line length increases the electrical length of the EBG structure and thereby decreases the resonating frequency of the EBG structure. EBG is formed using thin lines which work as an inductor, and frequency shift happens due to the increase in the line concentration. To change frequency, the line lengths are modified to resonate at desired operating frequency by progressively increasing length of the strip This shifts operating frequency towards lower band, when there is an increase in line length.



The dimensions of the proposed antenna array are 46 mm × 46 mm × 1.6 mm, and center frequency of the designed patch antenna is 2.45 GHz. The spacing between antenna elements is chosen to be 0.3 λo according to the parametric study, where λo is a free-space wavelength. The antenna array covers the band from 3.2 to 5.75 GHz to serve NR sub-6 GHz The design is a four-port MIMO antenna array, where the elements are orthogonal to each other to reduce mutual coupling between ports The bandwidth ranges from 3.2 to 5.75 GHz at each port.

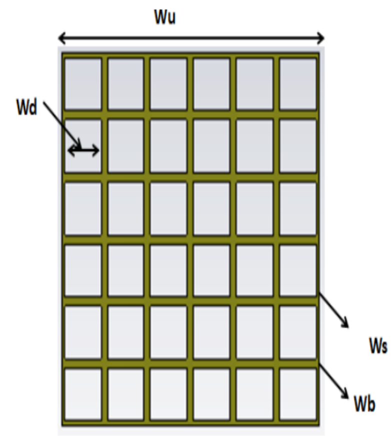
Wx	40	Wy	40	W4	8.8	g	0.1
W3	12	W5	0.2	W6	0.1		

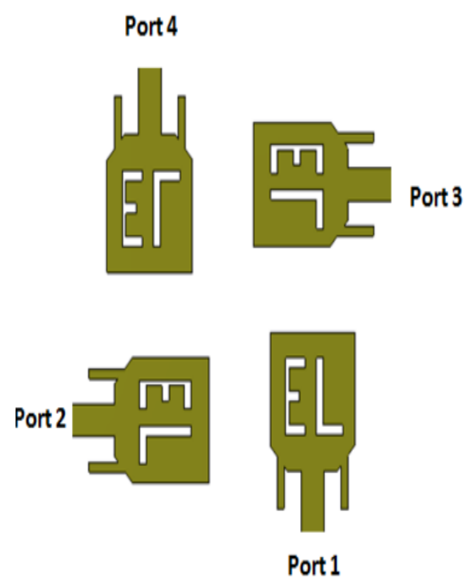
The EBG is introduced in the design to reduce mutual coupling which shows the isolation between ports in the four-port MIMO array without a decoupling network, where poor isolation in the desired band could be noticed. The isolation between ports after inserting EBG reaches a better value greater than −22 dB



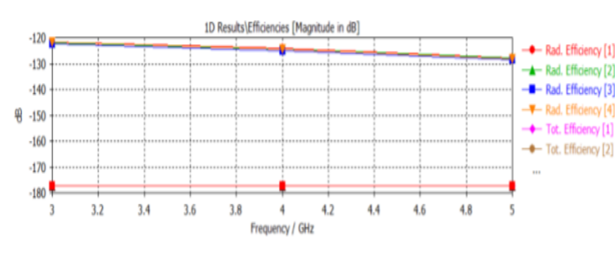
DEFECTED GROUND STRUCTURE

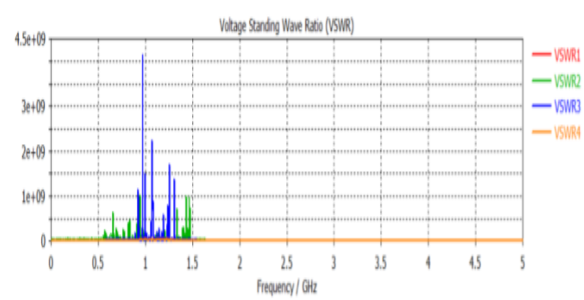
A defected ground structure (DGS) is a purposefully created defect on the ground plane of a printed microstrip board. It is typically created in the form of an etched-out pattern on the ground plane The proposed antenna is designed on FR-4 substrate with the same dimensions as the previous design and a square shape with slots etched on the backside of the design (on the ground). The dimensions of the proposed array are 46 mm × 46 mm × 1.6 mm. The fabricated antenna is shown in Figure 19. The equivalent circuit of the DGS structure is shown in Figure. The antenna array covers the band from 3.2 to 5.75 GHz to serve NR sub-6 GHz demonstrates the reflection coefficient at ports 2, 3, and 4. The bandwidth at each port ranges from 3.2 to 5.75 GHz. DGS is introduced in the design to reduce mutual coupling, as shown in Figure 22. The dimensions of DGS structure are Wd = 8.8, Wu = 1.2, Wb = 0.2, and Ws = 0.1 mm. The isolation between ports is greater than −22 dB . The efficiency and gain of the four-port MIMO array are 91% and 9 dBi, respectively . DG and ECC values reach 10 and less than 0.002, respectively (Figs. 25 and 26). The parameter TARC of the MIMO array is less than −25 dB

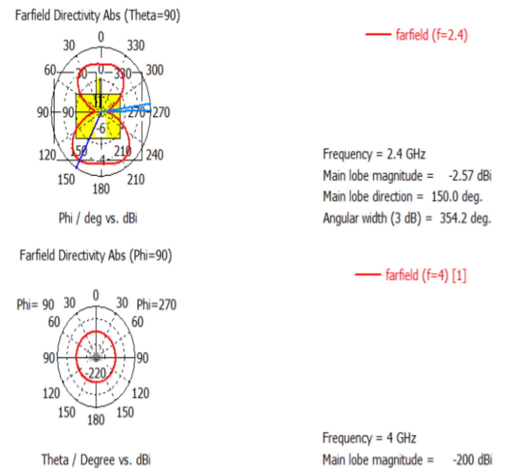


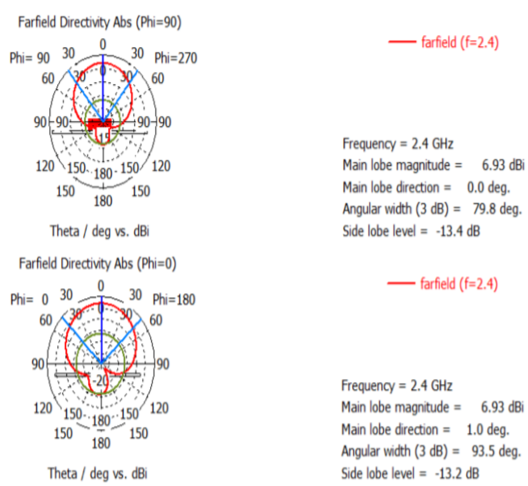


Some of the observed parameters are as follows'









III. HARDWARE & SOFTWARE USED

High Frequency Structure Simulator (HFSS 15.0.3): It is used to simulate the proposed antenna. The reason for choosing HFSS is that it uses FEM methods, which deals with very complex structures and it predicts accurate results. It is a high-performance full-wave electromagnetic field simulator for 3D volumetric passive device modeling. It integrates simulation, visualization, solid modeling, and automation in an environment that facilitates learning and where solutions to 3D electromagnetic (EM) problems are quickly and precisely attained.

Vector Network Analyzer: It is used for measurement of reflection coefficient. In the Vector Network Analyzer (VNA), the data is normally presented in the form of S-parameters and they are defined by measuring the voltage travelling waves between the ports

IV.RESULTS AND DISCUSSION

All methods of reducing mutual coupling achieve high isolation between ports and give satisfied MEG, CCL, TARC, DG, and ECC. The EBG and DGS methods are the best in isolation reduction. This is due to the presence of gaps between each unit and adjacent unit cells in the nine-unit cells in addition to the capacitance obtained from the dielectric gap between the top metallic patch and ground plane.

V.CONCLUSION

Antenna array concept is used to improve the better gain of different antennas by nullify the side lobes. This paper explains about a 4x4 microstrip patch antenna Arrays using HFSS 15.0.3 . In future this paper concentrates on manufacture of the proposed design and testing will be done

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