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Ultra-Wide Band (10 GHz Bandwidth) Microstrip Patch Antenna for Millimeter Wave - 5G Applications

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Abstract— *This paper introduces a microstrip patch antenna (MPA) for fifth Generation (5G)/ millimeter-Wave (mm-Wave) applications for frequencies > 50 GHz. The proposed antenna is designed and simulated on a flexible substrate of cotton jean having ε_r =1.76, δ =0.078, and a height of 1 mm. The designed antenna operates over an impedance bandwidth of 10 GHz with a maximum gain of 6.167 dBi. The antenna patch's largest dimension is 2.82mm (0.52687 λ) and the ground is 8 mm (1.499 λ), whereas λ is calculated at the center frequency of impedance bandwidth.*

Keywords— ***5G, mmWave, Microstrip Patch.***

I. INTRODUCTION

A next-generation communication system (5G) has gone under tremendous development in the recent past [1] [2]. 5G technologies are still vigorous and untamed entity for the researchers, as the existing challenges that 5th Generation faces are not yet addressed by 4th Generation i.e., Provision of Consistent Quality Experience, Higher Data Rates, Security, Gigantic Device Connectivity, Reduced Cost, Higher Capacity, High Throughput, Smart network software's, D2D communication, Heterogeneous networks (Small cells) and Massive MIMOs.

To make 5th Generation technologies viable in the market a thorough examination of the existing multiple access techniques within the installed networks is required as they are on the verge and need substantial improvement to suffice for the existing problems. As current multiple-access technologies will work for the next 50 years i.e., OFDMA, and to change the existing system for just 5G networks is not economically feasible. According to the survey wireless users spends 80% of the time indoor and 20% outdoor so to coupe for the urges of the users and to tackle the challenges 5G network architect will offer a solution to differentiate between inside and outside setups as to reduce the penetration loss and increase spatial efficiency. This is where the concept of massive Multiple Input Multiple Output (MIMO) technology emerges [3] [4]. In 5G this MIMO will be geographically dispersed and will be consisted of 100 [5] or more antenna units to utilize more of the huge capacity gains and will be installed for outdoor utilization. Ultra Wide band (UWB), Wi-Fi, Visible Light communication, mm-wave communications, and Small Cell are preferred as they are for small range, indoor communications and have large data rates. And the other technological concept within the 5G is the introduction of device to device (D2D) [6], Machine to Machine (M2M) communication which will bring a remarkable improvement in communication range, channel reliability, spectral efficiency, and system communication because it enables the spatial diversity realization. Along with that, 5G communication systems infer that: all mobile devices must be capable of interacting with other devices that are within the vicinity of it. As the existing conventional antennas that are currently installed in portable devices which are found in smartphones are not suitable for handling 5G higher frequencies applications as set by the Federal Communications Commission (FCC) of the United States in July 2016. Meanwhile, industry-related 5G is still at disagreement on what will become of it, apart from its advantages and disadvantages: there are a lot of prominent signs of upcoming things [7] and it has been anticipated in [8] that it will max-out its performance in merely 10 years from the time of its launch. Whereas according to the survey [9] the rate at which the data traffic between 2020 and 2030 is foreseen to increase by 55% annually, generating 5,016 Exabyte data in a single month by 2030. To meet these ends techniques like Machine Learning (ML) and Quantum Computing will play significant roles in enhancing the overall performance of the networks, optimization, and improve data-driven decision capabilities of the systems [10] [11] [12].

In this paper single microstrip patch antenna on a flexible substrate for 5G applications at frequencies > 50 GHz, is designed and simulated. As the utilization of electronic devices and gadgets is increasing day by day where as they are scaled-down in size, power utilization, by new assembling and state of the art electronic manufacturing technologies. Owing to the recent miniaturization of wireless communication electronic devices, improvement in the use of textile materials in wearable technologies has been observed [13]. Presently wireless electronic devices are cost-effective and bring ease to human society by providing portability [14]. Among the other various applications of wearable wireless electronic technology, one of the most prominent applications is the utilizations of the wearable hardware in medical care systems and wearable sensor-based wellbeing control monitoring systems to communicate information from patient to specialist remotely as are examined and discussed in [15] [16] [17]. The development of wearable textile technology in recent years is rapidly increasing, since their increasing demands in numerous applications namely navigation, radar, sportswear, health monitoring, public safety, tracking, military, portable communication, and in the civil domain are noticed [18] [19].

The principal aim of the textile based wearable antenna is to improve the existing living standard by creating electronic gadgets on textile material (fabric) which can be effortlessly incorporated onto attire. The textile artifact wherein electronic gadgets and sensors are incorporated on to clothing's to become body-worn is alluded to as e-textiles or wearable technology. These wearable innovations are a blend of both electronic innovation and textile material, which makes simple accessories of ordinary life activities. Functional advancement of the wearable electronic idea was presented in 1950; a large portion of the exploration focused on planning a wearable PC's and numerous successful designs are introduced in [20] [21]. E-textile can be amalgamated on to embellishments and kits like glasses, watches, shirts, caps, and so on. Whereas, common users are benefitted from both in the case of smart/e-textile where textile and electronic technologies are combined. Very smart and passive/active smart are some of generations of the smart/e-textile as reported and discussed in detail in [22]. It is investigated in [23] that flexible substrate should be used in the design of wearable electronics gadgets to make it flexible, light, and foldable by exploring two flexible layers of metals to design a multichip.

An antenna is one of the essential parts of any wireless communication system, including the partially deployed 5G wireless communication system. Owing to its low cost, lightweight, easily available, and ease of integration with cloths, textile materials are preferable and adoptable in the design of wearable antennas. A wearable antenna used in wireless communication systems usually has a substrate of textile materials that are having a low dielectric constant, mostly below 3, recuperate the impedance bandwidth, and reduces the surface wave losses [24]. Furthermore, designing of compact size wearable antenna with a wider impedance bandwidth is a challenging task [25]. Simple planar wearable antennas are comprised of fabric materials used as substrate-like cotton, jeans, and cordura mostly, that are usually flexible and comfortable to wear and can be easily used in stacking configuration as well.

II. DESIGN PROCEDURE

The proposed MPA is designed for 5G applications for a frequency ranging from 51 GHz – 61 GHz. the patch size is smaller in size which is favorable for compact applications. Here in following the summary of the design procedure.

Substrate Selection and Conducting Material

Proposed MPA is designed on a cotton jean i.e. (flexible substrate) with εr of 1.76, δ of 0.078, and height of 1 mm [26]. For patch and ground, adhesive copper tape is used with the thickness of 0.035 mm as used in [27].

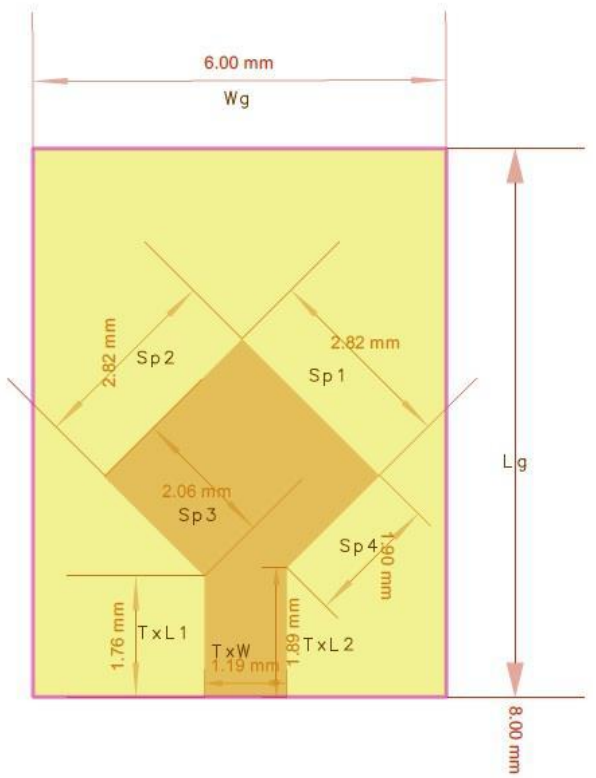

Fig.1: Proposed Antenna Design with Dimension

Dimension Calculation

Initial dimensions for the rectangular patch antenna were calculated from [28] at a center frequency of 56 GHz. The dimensions were further optimized to get the desired results. The largest dimension of the radiating patch resulted in 2.82 mm and ground's 8.00 mm.

Geometrical Shape

The shape of the antenna was modified and the nominal uneven rectangular shape and was rotated at 45 degrees to get the diamond-shaped structure with bottom edge cut for matching purposes.

Transmission Line

The transmission line was matched to the patched using loaded dimensions which can be seen in Fig.1 above.

III. RESULTS AND DISCUSSIONS

The proposed antenna is simulated in Advance Design system ADS-2016.01 and the antenna performance parameters are obtained at the frequency range of 51 GHz – 61 GHz. The analysis of proposed antenna is computed over the following parameters i.e., VSWR, return loss S11, gain, directivity, radiation pattern, and efficiency.

S11

Figure 2 shows the S11 plot of the proposed design. The results illustrate that the simulated antenna provides an impedance bandwidth of 9.85 GHz (17.55 % of Fractional Bandwidth).

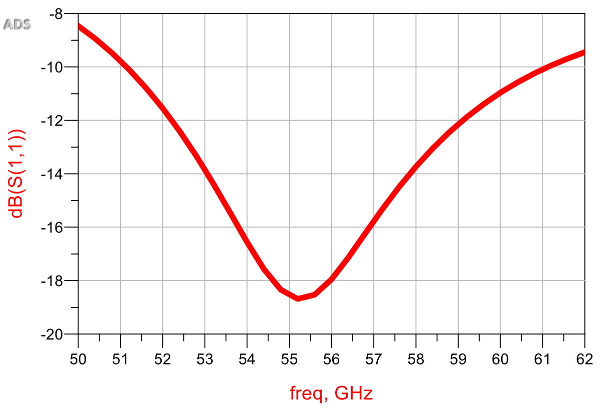

Fig.2: S11 Plot of the Proposed Antenna

VSWR

The simulated VSWR shown in figure 3 shows that the antenna is matched throughout the impedance bandwidth depicting values VSWR < 2 asset standard for the antenna design requirements.

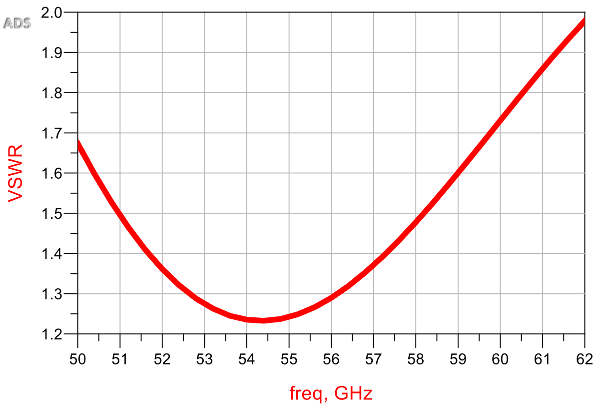

Fig.3: Plot of VSWR

Gain and Directivity

Antenna gain and directivity of the simulated antenna from Fig.4 and Fig.5 can be observed as both increase with the increasing frequency and is maximum at 61 GHz. The simulated gain and directivity range from (4.934 dBi to 6.167dBi) and (8.052 dBi – 9.171 dBi) respectively.

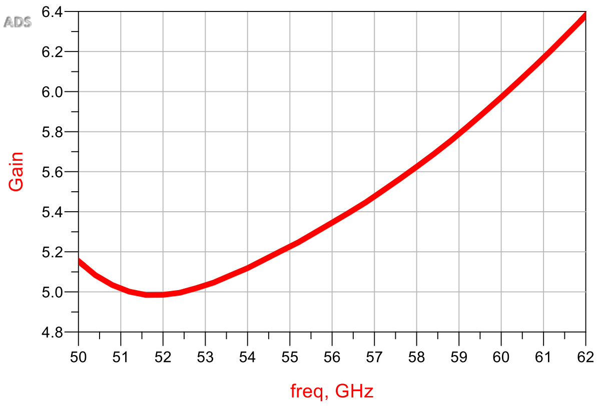

Fig.4: Simulated Gain Plot

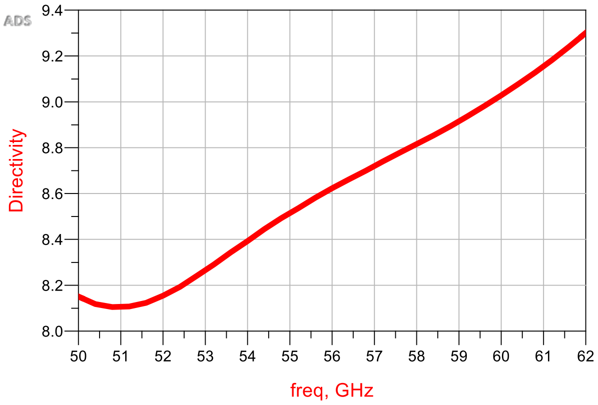

Fig.5: Simulated Directivity Plot

Radiation Pattern

The radiation pattern of the simulated antenna in the E and H Plane is shown in Fig.6 and Fig.7 below at a frequency of 55.78 GHz. The antenna radiates two main lobes and is directive in nature.

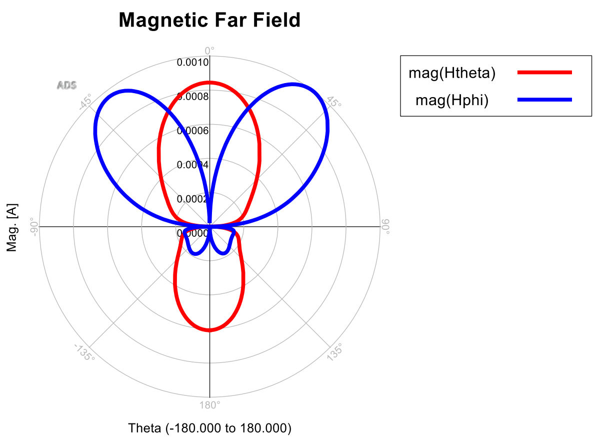

Fig.6: Simulated H-plane (Far Field) Polar Plot

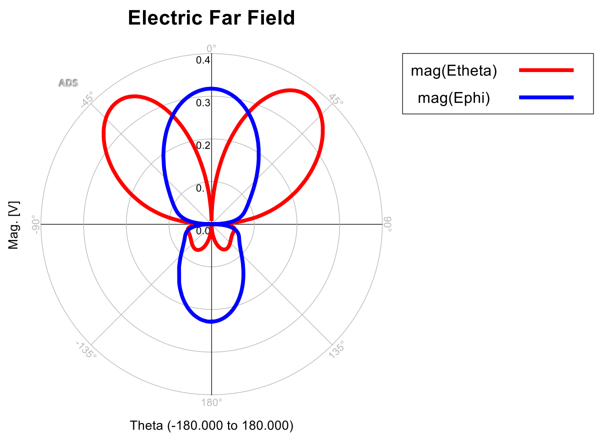

Fig.7: Simulated E-Plane (Far Field) Polar Plot

Efficiency

The efficiency of the proposed simulated antenna as shown in Fig.8

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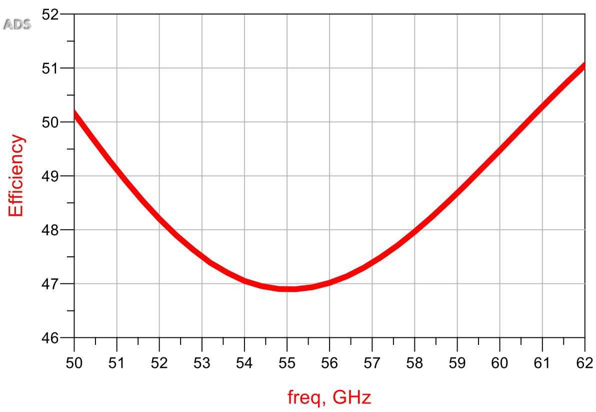

Fig.8: Simulated Efficiency Plot

IV. CONCLUSION

In this manuscript, a novel 5G antenna (Flexible) is designed and simulated at the frequency range of 51 GHz - 61.0 GHz (9.85 GHz of Impedance bandwidth) which provides a maximum gain of approximately 6.167 dBi and maximum directivity of 9.171 dBi. The inspected result shows that the said design can be used in future 5G applications at higher frequencies.

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