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Design of Microstrip Patch Antenna for Fixed Mobile and Satellite 5G Communications

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Abstract : **Human evolution has always been significantly influenced by connectivity. It has influenced human history for generations, and the visualisation of the future is about to begin. Generations of wireless communications have emerged as a result of the desire for speed and perfection. Every communication generation update accelerates the electronic industry by many decades. After only a few years of introduction, 4G has now taken over. Furthermore, there is a strong push to realise the need for a fifth generation of communication networks. This study presents the design and simulation of a 5G-compatible microstrip patch antenna. At 43.7GHz, the antenna operates in the Extremely High Frequency (EHF) spectrum. Fire Resistant 4 (FR4) epoxy substrate material having a relative permittivity of 4.4 has been used. Further, the antenna has been analyzed for its return loss, VSWR, gain, radiation pattern and current distribution. The obtained results are verified to suit the requirements and are discussed for various applications.**

IndexTerms **– Microstrip patch antenna,EHF,FR4, VSWR, radiation pattern, permittivity.**

I. Introduction

Following TeliaSonera's 2009 commercial 4G debut, communication speeds grew from Turbo-3G to 80Mbps under ideal circumstances, a ten-fold improvement. Every sector on the planet has been profoundly impacted by 4G during the past ten years. A newer generation of communications networks is needed due to the ongoing evolution of human behaviour and the demands of rapidly changing industry. The current 4G network operates at a slightly lower frequency range than the fifth-generation (5G) network[1]. Using a frequency range of 28GHz to 100GHz, the system provides 10Gbps of data throughput. In addition, the 3GPP's definition of the 5G New Radio (NR) for the SMARTER programme contains three primary scenarios that the new network system must handle. In a network of communications, The coverage area and data rates of a communication network are always inversely proportional to one another. In order for 5G NR systems to be connected, substantial data rates must be attained over a large coverage area. Enhanced Mobile Broadband meets this exact criteria (eMBB). With the growing number of devices in a given region covered by a reasonable data rate, a high-reliability, low-latent network becomes necessary to provide essential mission communication. Some examples of essential mission communications are Tactile Internet, remote surgery, and autonomous vehicles. Under 5G NR, Ultra-Reliable Low Latency Communications (URLLC) handles this second scenario. When a big number of devices are connected within a small area, it is necessary to ensure that IoT devices deliver data at irregular intervals of time, and when a significant amount of data arriving irregularly must be handled, massive Machine Type Communication (mMTC) enters the picture.

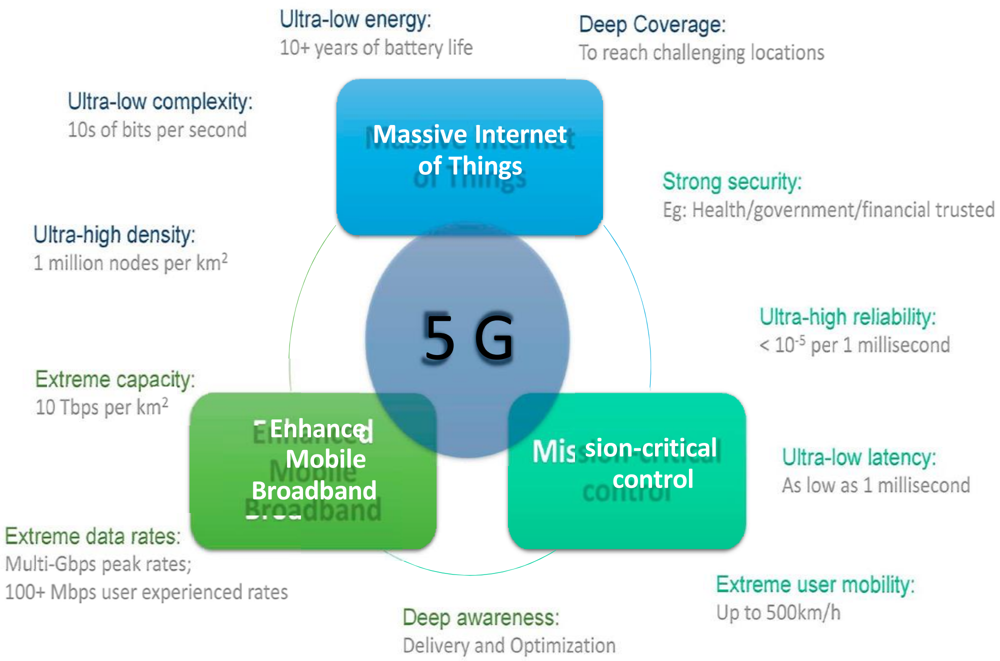

Fig. 1. 5G cases and their applications

In order for the devices to work with the upgraded global network, they must be immediately modified. The new network becomes redundant if the entire communication system is not reconfigured. On the other hand, the antennas would alter due to the rapid evolution. Therefore, it is imperative to recognise the need for building an antenna that operates inside the 5G communication range [3][4]. Crucially, among the most sought-after antennas in this regard are microstrip patch antennas. In most communication industries, microstrip antennas are the favoured option when low profile can be accommodated, owing to their small size and ease of production. One of the main advantages of the majority of smartphone adaptations is their capacity to miniaturize the complete circuit [5][6]. They are a popular choice since they provide designers the freedom to cut them into any desired shape or size.

Nomenclature

L_g Length of Ground
W_g Width of Ground
L_s Length of Substrate
W_s Width of Substrate
h Hight of substrate
L_p Length of Patch
W_p Width of Patch
L_f Feed length

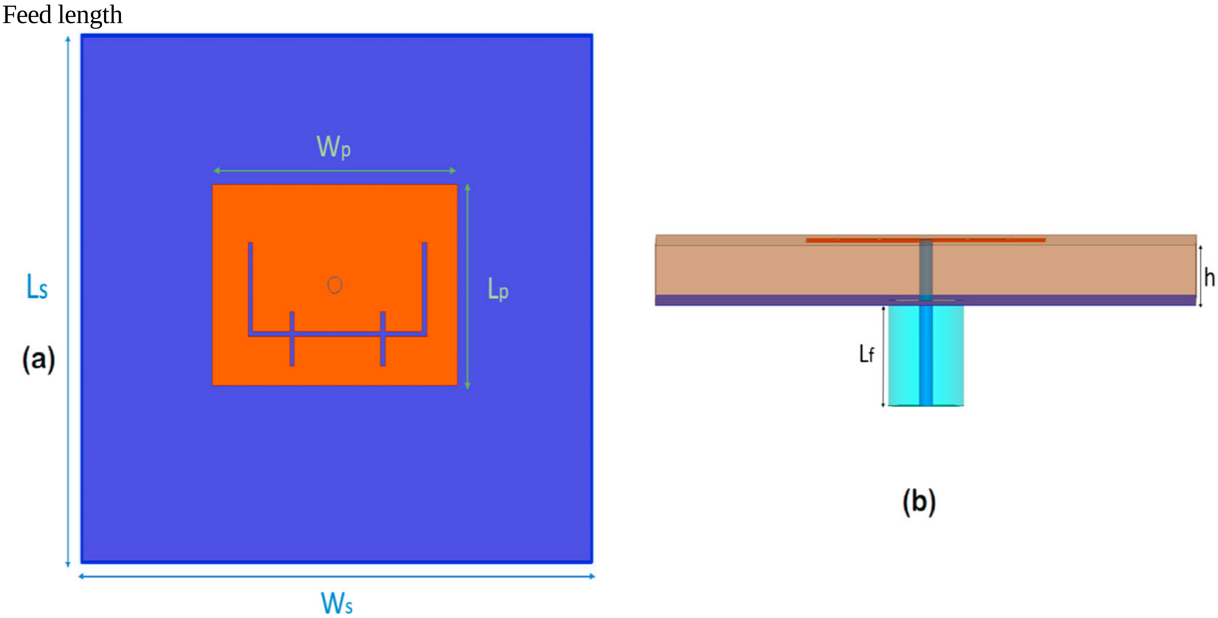

Fig. 2. (a)Top view of antenna. (b)Side view of antenna.

2. Antenna Design

Understanding the desired outcome and the necessary parameters is the first step in the antenna design process. Frequency is a crucial element. In addition, the antenna's mode of application will also be taken into consideration while choosing the substrate [7]. The physical dimensions of the antenna are determined when all the data has been decided. The antenna in this work is designed and simulated using Ansys High-Frequency Structure Simulator [HFSS v 15.0]. First, a 7.39 x 8.6 mm ground layer is constructed. This serves as the foundation for mounting the antenna [8] [9]. Since the substrate material's relative permittivity (ar) value mostly influences antenna behaviour, the thickness of the substrate material must be determined. The substrate's second layer is affixed to the ground layer [10]. The third and most active layer of the antenna is made up of radiating patch. Patch receives multiple types of feeds that are fed with current. Patch is fed with current with various types of feeds. The major feed techniques include:

- Microstrip line feed
- Coaxial Probe feed
- Aperture Coupling feed
- Proximity Coupling feed

The most basic type of feeding technique is microstrip line feeding. The conducting strip powers the patch through one end and is often smaller than the patch[11] [12]. Additionally, since feed and patch have to be etched on the same plane, this simplifies the fabrication process. Conversely, surface waves and false feed radiations are shown to be exactly proportionate to the height of the substrate. It is discovered that this proportionality impedes the antenna's bandwidth and causes undesired cross-polarization. The technology of the coaxial kind of feed allows the feed to be positioned inside the antenna at any desired location. The feed cylinder passes through the substrate material from the ground to the patch. It is discovered that the thickness of the substrate material affects impedance matching. It also lessens the impact of radiation that is not real. A narrow bandwidth is typically obtained when coaxial feed is used[13][14][15]. In contrast, an aperture coupling has a feed line positioned in between two substrate layers made of distinct dielectric materials. Because there are two substrates available, each substrate's thickness can be customised to fit the needs of the application. Because of its symmetry, this kind of feed produces less cross-polarization. Proximity coupling, also known as an electromagnetic coupling method, also has two substrates with feed positioned in between. Spurious feed radiation is eliminated with this kind of feeding. The bandwidth is usually high due to the increased thickness of the patch[16]. The antenna is made to measure 7.39 x 8.6 mm and has a substrate thickness of 0.8 mm. With a dielectric loss tangent of 0.02 and a relative permittivity of 4.4, the substrate is made of FR4 epoxy. Additionally, the 2.59 x 3.8 mm patch is put on the substrate. Two 0.6 mm diameter outer cylinders and a 0.2024 mm diameter inner cylinder make up the probe feed. Because of the configuration, the highest cylinder hits the patch while the lower cylinders seem to be sticking out of the ground. The measurements are displayed in Table I. In order to track changes in the gain, bandwidth, and resonant frequency of the suggested antenna, the geometric parameters are changed.

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Parameter	Dimension in mm	Parameter	Dimension in mm
L_g	7.39	W_g	8.6
L_s	7.39	W_s	8.6
L_p	2.59	W_p	3.8
H	0.8	L_1	1.4
L_2	0.6	L_3	0.2024
L_{so1}	1.18	L_{so2}	0.35
L_{so3}	0.25	W_{so1}	2.77
W_{so2}	1.34	–	–

Table 1. Antenna Parameters

3. Results and Discussion

Using The Ansys Hfss V.15.0 Simulator Tool, The Suggested Antenna Is Developed And Simulated. The Return Loss Of -23.3656 Was Achieved At 43.7ghz, As Fig. 3 Illustrates. In Practical Terms, The Mismatch Ratio Between An Antenna And The Feed Should Be Between 1 And 2. The Obtained Vswr For The Planned Antenna Was 1.18db At The Resonant Frequency, As Illustrated In Fig. 4. To Comprehend The Antenna Radiation Field, Radiation Patterns Are Shown In The E And H Planes. Additionally, A Constant Positive Number Is Anticipated For The Gain. Figures 5(A) And 5(B) Show That The Constructed Antenna Produces A Consistent Radiation Pattern And An Excellent Gain Of 4.35 At The Resonant Frequency, Respectively. Figure 6 depicts the distribution of surface current over the patch and feed at the resonant frequency. It is now important to note that each slot created in the antenna patch affects how the antenna behaves[17][18][19].

When simulated, the intended antenna often deviates from the theoretical predictions; these discrepancies are typically fixed by changing the slots. To achieve the desired outcomes, the designer must adjust several slotting procedures, which are typically accomplished by trial and error.

It is imperative to acknowledge the significance of 5G antennas as the globe excitedly awaits the arrival of 5G. The antenna is small and can be used as a 5G communication antenna in mobile phones. The antenna is also found to be appropriate for use in satellite applications because it operates in the Extremely High Frequency (EHF) range[20].

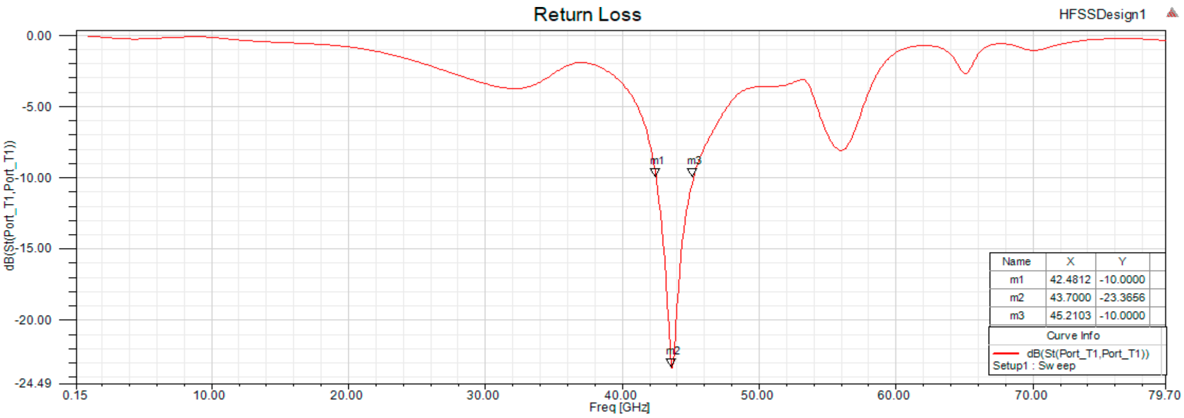

Fig. 3. Return loss versus frequency. The return loss of antenna should always be lesser than -10dB

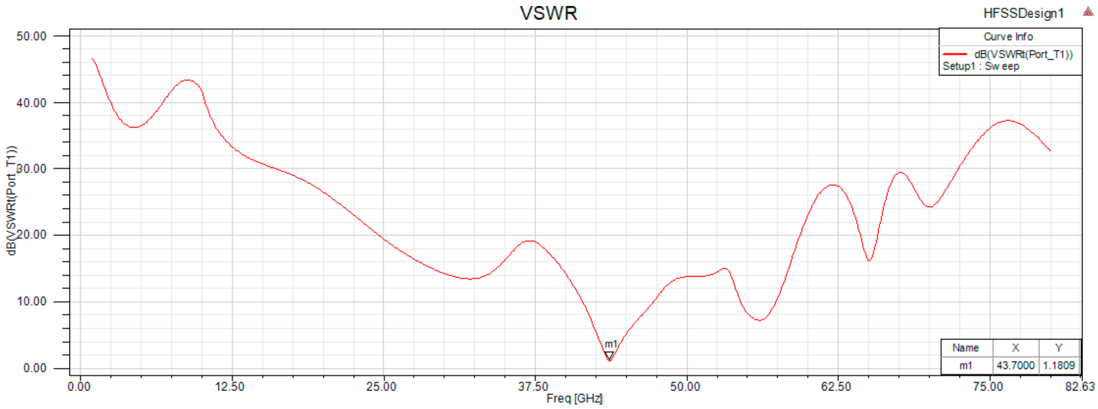

Fig. 4. VSWR of the antenna must practically be between the values of 1 and 2.

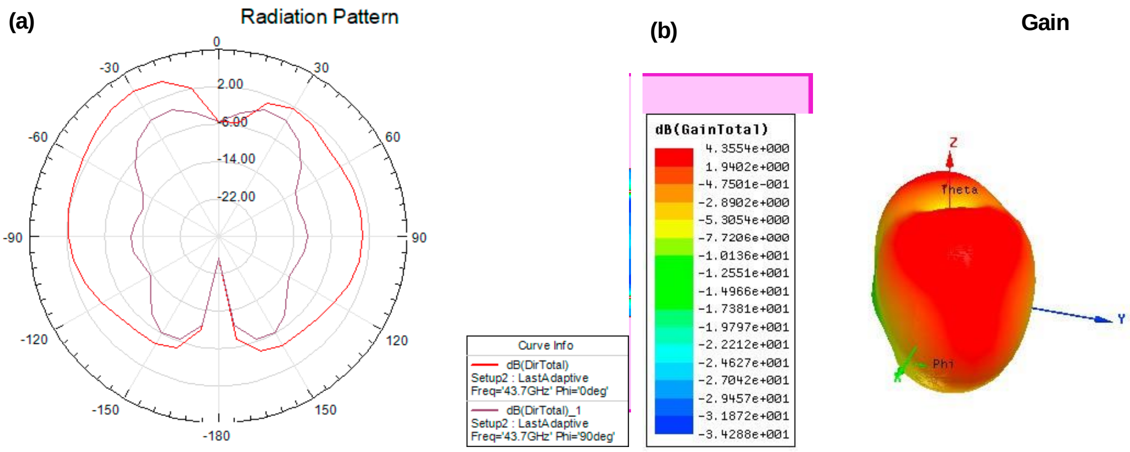

Fig. 5. (a). Radiation pattern of proposed antenna at 43.7GHz. (b)Gain of the proposed antenna at 43.7GHz.

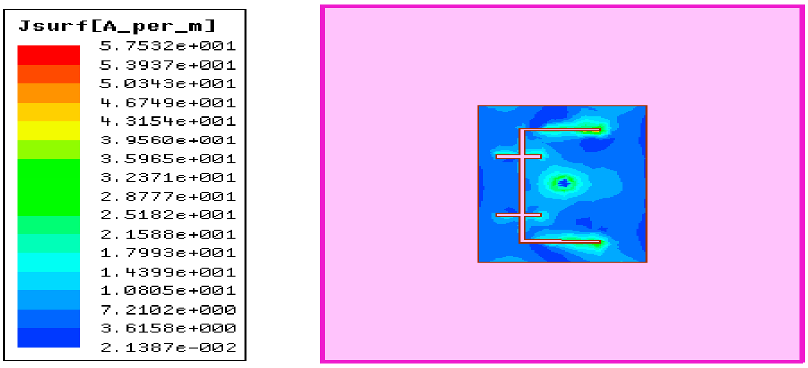

Fig. 6. Current distribution is a qualitative measure of how the current is owing in the antenna.

Since the wavelength of the EHF range corresponds to millimetre waves, any object whose dimensions exceed or equal the millimetre range would obstruct the signal. As a result, every object created by humans blocks the 5G signal[21][22]. The usage of massive MIMO antennas helps to prevent this issue. Massive MIMO refers to the use of an extremely high number of identical types of antennas for a single application, with the goal of having the Multiple Input Multiple Output (MIMO) antennas cover the barriers. Massive MIMO antennas and effective beam steering are used by the more recent 5G devices to boost throughput[23]. Furthermore, low-powered tiny base stations in small-cell cellular networks need to be modified[24]. This tiny base station manages small network cells and boosts local signal strength. Because of the developed antenna's appropriate gain and acceptable radiation pattern, it can also be employed in these tiny stations.

4. CONCLUSION

This study involves the design of a microstrip patch slot antenna for satellite and 5G connectivity. The Ansys HFSS v.15.0 simulation tool was used to carry out the design simulation. It is determined that the acquired findings meet the 5G communication antenna criteria. The frequency at which the antenna resonantly operates is 43.7GHz. The small antenna works well with both micro base stations and communication devices. The use of comparable sorts of multiple antennas is recommended since 5G requires Massive MIMO antennas. The impedance issue is lessened when the antenna is fed coaxially[25][26][27]. The construction of an antenna built for real-time 5G applications is one of the upcoming projects. The low power, low gain, limited bandwidth, and low It is necessary to address the microstrip antenna's low efficiency, low power, low gain, and restricted bandwidth[28][29]. To fit the real-time application situations, further antenna optimisation is necessary and will be implemented.

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