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REGULAR ARTICLE

Improving Performance Using 2 × 2 Single Element Massive MIMO Antenna in 6G Devices

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In modern days, wireless communication is enhanced importantly in 6G growing in the Massive MIMO (Multiple Input Multiple Output) technologies. The Interference is increased in the MIMO antenna and inefficient in 5G specification which proves to the conventional methods. The two truncated linear patches of antenna size 9.2 m, 7.1 mm at the top layer with the ground performance of 37.6 mm × 33.4 mm in the substrate. The dimension of the 2 × 2 MIMO antenna for 37.6 mm, 33.4 mm, 1.6 mm is proposed to be designed to improve by the 6G specification. With a core frequency of 6.6 GHz, the proposed Massive MIMO with 6G is regulated to function between the 3.19 to 5.10 GHz range. The study displays an ultimate gain of 22.4 dBi, an imaging range of ±25°, and an average gain deviation of 3.3 dB at 5.6 GHz. The proposed system is obtained to improvise the performance by HFSS simulated results for operating frequency by Massive MIMO antenna to provides the directivity as 4.6 with a relative permittivity of 4.4 and isolation as 15 dB. Further, the gain of 10.16 dBi with a radiation efficiency of 80 % has been achieved by the insertion of the 2 × 2 single-element Massive MIMO Antenna which is capable of spatial multiplexing by the 6G application.

Keywords: 6G, Massive MIMO, HFSS, ISI, Mobile communication, Single element.

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1. INTRODUCTION

These days, Communication over wireless networks is become a commonplace aspect of everyday life, allowing people to exchange data at rapid speeds and share information worldwide at any time. Since connecting to the internet has become essential in our daily lives, the introduction of LTE, which offers exceptional throughput, data transfer rates, information transmission speeds, and spectrum efficacy, has made users' lives easier and allowed them to blissfully browse the internet at any moment [1] and [2].

This increases the appeal of using gadgets like laptops, smartphones, and computers, which call for more sophisticated radio frequency and communications parts [3]. Because of their lightweight construction, low profile, and simplicity to incorporate with additional electronic elements, microstrip patch antennas are widely used in contemporary communication systems. Applications for them include medical equipment, wireless communication, radar systems, as well as communication through satellites.

Reflected arrays are considered the most compatible and cost-effective approach but their bandwidth is comparatively narrower than that of planar arrays and reflectors because of the intrinsic restricted bandwidth characteristics of the microstrip elements along with the fluctuating phase delay caused by various path lengths among the feed to each component. The phase response of the components fabricated on a flat surface is what causes the creation of a concentrated or shaped beam whilst highlighted by a feed.

A number of methods have been put out to increase reflectarray antenna bandwidth. In layered patches of different sizes were employed in a multilayer design. In bigger reflectarrays, aperture-coupled patches with phase-delay lines are used. Multilayer structures, however, are more likely to be complex, heavier, and more expensive to fabricate. As a result, a single-layer reflectarray reduces the alignment problems present in multilayer phase shifting elements and is more economical. Furthermore, it has been suggested to use metamaterials, namely metasurfaces, to miniaturize reflectarrays.

A wide bandwidth was demonstrated in a single layer by a subwavelength element or a multi-resonant element. While connected aperture phase delay lines were utilized on different layers of the patches in a prior work for a wide 1-dB gain bandwidth, they were attached to the components in the identical layer in subsequent investigations [21, 22]. Broadband architectures utilizing dielectric metamaterials and polarization-rotating components were introduced in earlier research. A wide bandwidth has also been achieved through the employment of various phase synthesis techniques.

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Despite their broadband nature, the single-layer reflectarrays stated above nevertheless have several drawbacks. A thick substrate was used in to produce a 360° phase range with a sub-wavelength element-based broadband reflectarray. Multi-resonant and polarization-rotating broadband reflectarrays have intricate geometric configurations that require laborious computer modeling and simulations of individual components to determine their ideal performance.

In a similar way the highest possible gain for an expanded bandwidth is decreased by current methods for phase accumulation in a single layer. With their inexpensive price and simple construction, customizable reflective along with programmable metasurfaces have become a viable option for beam scanning, scattering manipulation, and polarization conversion. Such metasurfaces still need time to form, though, and have seldom ever been documented for a wide 1-dB gain bandwidth.

The microstrip patch with a *H* shaped antenna has drawn interest since it can enhance important performance metrics while being compact. The unique *H*-shape arrangement boosts radiation efficiency, optimizes impedance matching, and expands bandwidth. Because of its small size, it can be used in applications that need for very effective miniature antennas. Microstrip patch antennas are usually designed and optimized using electromagnetic simulations. In this work, an *H*-shaped microstrip patch antenna operating at a specific frequency is designed, simulated, and characterized using CST Microwave Studio, a potent tool for resolving intricate electromagnetic issues. A coaxial probe, a popular and useful feeding method because of its ease of use and efficiency in obtaining good impedance matching, feeds the antenna. To reduce return loss and guarantee that the antenna resonates effectively at the desired frequency, the feed position is adjusted.

The need for microstrip patch antennas with high gain and multiband operating frequencies has increased due to the quick advancement of wireless technology. The application of Multiband microstrip patch antennas are used in a variety of devices, including gaming consoles, computers, and cell phones. Certain microstrip patch antennas have distinct features, such as low antenna profile, extremely light weight, wide bandwidth, good gain, and resemblance to a conventional assembly procedure. A microstrip patch antenna generally has a few disadvantages, such as low strength, interference, and a narrow bandwidth. The developers must seek out and maximize the accessible RF elements in the mobile wireless network in order to meet all of the demands of the wireless communication community. Humans today communicate wirelessly thanks to Multiple-Input Multiple-Output (MIMO) advancement, It was invented and frequently utilized in handheld wireless connections that offer substantial data rates and outstanding channel capacity. In order to enhance channel capacity, transmission rates, link dependability, and accessibility to networks, MIMO technology uses several antennas on the system's input as well as output sides for communication to take advantage of multiple path fading [4]. This study's main goal is to investigate the *H*-shape microstrip patch antenna's functionality.employing through simulations, paying particular attention to important aspects including gain, radiation patterns, return loss, and effectiveness. The viability of the suggested antenna design for usage in high-frequency signals and its applications, specifically in wireless and satellite communication systems, is assessed by analyzing the CST simulation results.

Low-profile, planar, high-gain, along with multimodal antenna emitters are necessary to address the ever-increasing needs for wireless communication services in the contemporary environment [5, 6]. To substantially decrease the physical dimensions of the antenna and enable it to be put on the same structure for numerous purposes simultaneously, a multiband either multifrequency functioning in an identical radiator is crucial [7, 8]. According to this viewpoint, self-multiplexing antennas constructed using cavity-backed substrate integrated waveguides (SIW) are Much more widely used and popular options because they provide more alluring attributes like small size, high efficiency, reduced back-lobe electromagnetic radiation small port-to-port mutual coupling, and simplicity of circuit variation [9, 10]. The primary duty is the execution to cover the bandwidth. Increasing the substrate thickness, using a substrate with a low dielectric constant, using various impedance matching, feeding techniques, and using multiple resonators are some of the well-known methods for increasing the data transmission of antennas. Both sending and receiving data are possible with the antenna. Thus, it is the fundamental portion of the microwave communication. It is a device designed to efficiently send and receive electromagnetic waves. This research uses a multiband antenna that is strengthened by a coaxial probe. HFSS software is used to simulate the antenna.For various multiband procedures, including dual-, triple-, quad-, and hexaband functions, numerous teams of researchers have thus created self-duplex, self-diplexing, self-triplexing, self-quadruplexing, as well as self-hexaplexing antennas powered by SIW cavity-backed technological advances [11-15]. In order for every element to function as a half-mode SIW resonator that emits via a separate longitudinal position which holds the open-end of half-mode SIW, and this was identified in [16-18], a rectangular opening is cut on top of the SIW, dividing the chamber into two different sections that can be delighted with the proper feed.

For LTE applications, this leads to the creation and modeling of a MIMO H-shaped dielectric resonator antenna (DRA). Ceramic DRA containing a tanning loss of 0.0019 along with a dielectric constant of 10 was employed in this study.

In essence, the Rectangular-shape DR is divided into multiple pieces to create the H-shape DR. By lowering the most efficient permeability of the complete DR volume, this raises the impedance over the bandwidth (BW) of the proposed DRA [19]. This study uses CST software to construct and simulate a MIMO H-shaped DRA with two distinct input mechanisms at Ports 1 and 2. For layout verifications, the simulation-based outcomes of simple rectangular form DRA are contrasted with the produced modeled MIMO H-shape DRA findings.

This work is structured in the following manner: The detailed introduction and its literature survey is explained in detail in section 1. The analysis of the MIMO antenna's design concepts, procedure, and decoupling mechanism is covered in detail in Section 2. Antenna performance, including gain patterns, efficiency is analyzed in Section 3 by contrasting antennas with and without decoupling structures. The design procedure, techniques, and outcomes of the MIMO antenna created in this paper are compiled in Section 4.

2. DESIGN OF AN ANTENNA

2.1 Configuration of Antenna

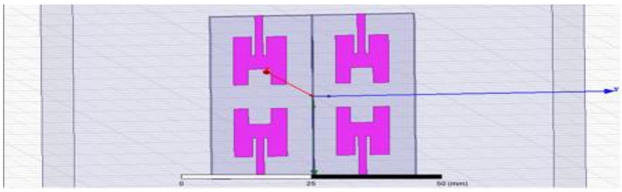

Fig. 1 – *H*-Shaped antenna design

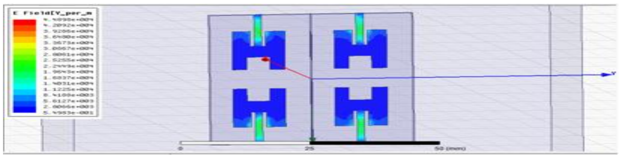

Fig. 2 – *E*-Field of the antenna design

As seen in Figures 1 and 2, the *H*-shaped antenna's Transmission of magnetic and electrical fields produced high voltages of 9.76 V/m and electrical currents of 9.423 A/m.

Figure 3-7 displays the Polar Regions projection on the configuration of an H-shaped patches of microstrip antenna. The structure is simulated using the dimensions mentioned above. This design operates at 2.40 GHz, and the resultant return loss is – 15.07 dB. At this frequency, a gain of 1.43 dB is achieved. The reflection coefficient (S11) vs. frequency plot in Figure 2 shows that the antenna begins operation at 2.37 GHz (marker m1) and ends operation at 2.42 GHz (marker m2). The antenna's core frequency is 2.4 GHz (marker m3). In this instance, the antenna's bandwidth is 44 MHz.

3. RESULTS AND ITS DISCUSSION

The gain (dB) versus frequency (GHz) for an antenna or RF structure that was generated with HFSS is shown in the provided XY plot. The *X*-axis shows the frequency band ranging from 1 GHz to the range of 10 GHz, along with the *Y*-axis (dB(GT/Total)) shows the total gain (GT) in decibels. The gain's variation across this frequency range is depicted in this Figure 3.

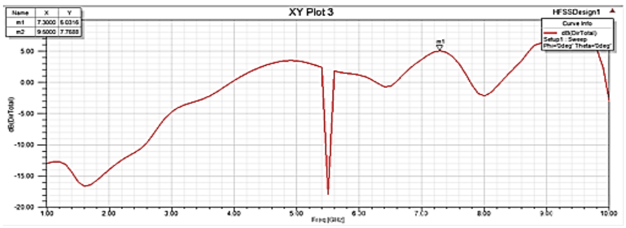

Fig. 3 – Total Gain of the suggested antenna design

Figure 3 shows that the gain fluctuates, demonstrating frequency-dependent functionality. A notable decrease in gain at 5.5 GHz indicates a notch or resonance, which may be the result of interference, destructive interference, or a feature of the structure's fundamental architecture. In contrast, performance peaks around 7.3 GHz, where the gain reaches about 6.0916 dB.

The structure's general effectiveness over the bandwidth of the spectrum is indicated by this gain response, with certain frequencies showing greater or worse signal performance. In antenna design, this information is critical since optimum radiation effectiveness and signal strength depend on optimizing gain at desired operating frequencies.

It shows an antenna's or an RF structure's overall gain response over a broad frequency range. The Figure 4 shows how the gain changes, exposing important performance traits that are necessary to assess the system's radiation effectiveness. Critical stages in the gain response are indicated by a number of markers. The comparatively low gain of 2.4403 dB at 2.3 GHz indicates inefficient radiation at this frequency. Better performance is indicated by the gain, which progressively improves as the frequency rises to 6.7034 dB at 2.8 GHz and 7.0568 dB at 4.8 GHz. Thus, the total average gain variation of an antenna increases significantly to 16.6426 dB at 5.5 GHz, however there is a dramatic decrease right after, indicating resonance or signal attenuation at this frequency.

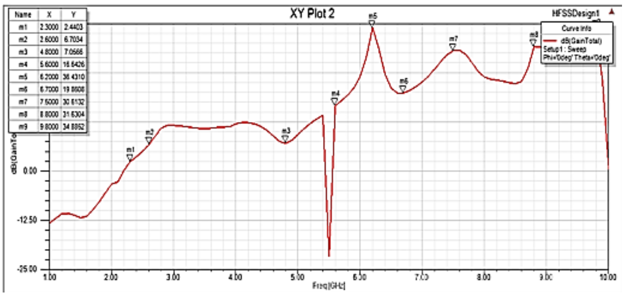

Fig. 4 – Total Gain variation of an antenna

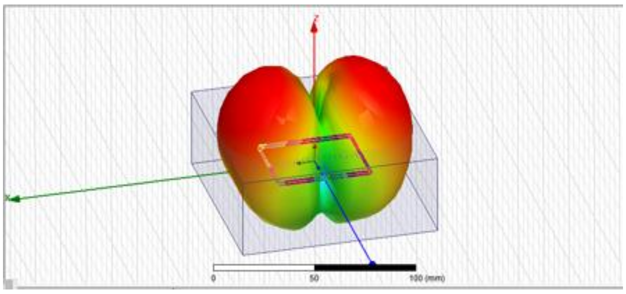

Fig. 5 – Directivity of *H*-shaped antenna

Following this peak, the gain is seen to decrease at 6.7 GHz to 19.0802 dB, then increase once more at 7.0 GHz to 31.6034 dB. At 8.0 GHz and 9.0 GHz, the gain remains high, reaching 31.6034 dB and 34.8852 dB, respectively.

The abrupt drop at 5.5 GHz raises the possibility of a notch or destructive interference, which could be caused by reflections, parasitic resonances, or performance-affecting material characteristics.

To guarantee constant performance throughout the operating range, design improvement may be required if there is a dip at particular frequencies.

Both the *E*-plane (Electric) and *H*-plane (magnetic) electromagnetic field radiation patterns are described, displaying the antenna's directional performance as well as any possible side-lobe levels. Fig. 5 shows the 3D radiation distribution of an *H*-shaped microstrip patch antenna. The *H*-shaped patch antenna with microstrip has better transmission pattern, total gain, as well as orientation than the square patched antenna. Figures 10 and 11 show a 3D polar representation of an H-shaped patch antenna's gain along with directivity of the signal.

As depicted in Figure 6, this antenna operates at 2.45 GHz and yields an average return loss of – 11.06 dB. Thus, the antenna signal begins operating at 2.451 GHz (marker m1) and stops operating at 2.46 GHz (marker m3), as seen in Fig. 6. The antenna's core frequency is 2.456 GHz (marker m2). In this instance, the antenna's bandwidth is 13 MHz. Here, Kevlar, a substrate with a dielectric constant of 3.6, is utilized. With the exception of the substrate and feed position, all other dimensions are the same. To maximize the results, the feed location must be adjusted.

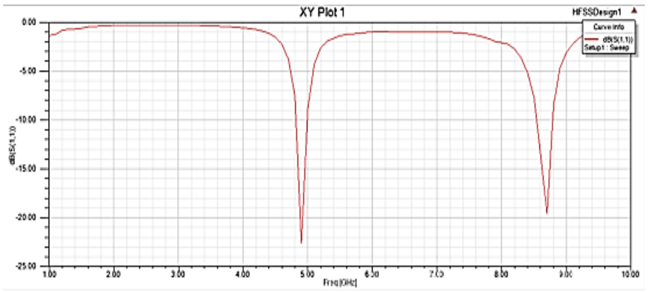

Fig. 6 – Return loss

Figure 7 shows the tri-band *H*-shaped antenna patch characteristics, with resonance frequencies of 3.8, 4 and 7.3 GHz. All three peaks experience sufficient range vital for return loss, meaning it is higher than 10 dB.

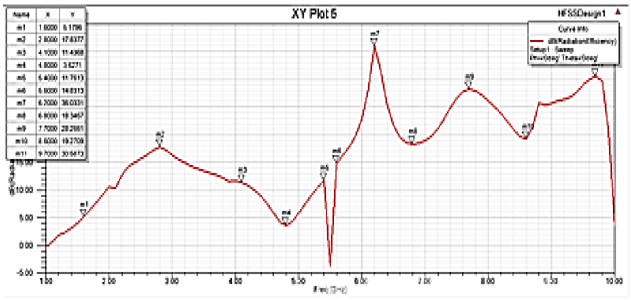

Fig. 7 – VSWR of planned *H*-shaped patch antenna

Plotting the reflected signal coefficient, or yield return loss departure, of the proposed antenna reveals that it yields return losses of – 15.32 dB and – 19.2 dB, correspondingly, for two distinct sets of frequency bands, 5.32 GHz and 9.89 GHz, all of which are considered acceptable. Additionally, its radiation pattern shows the direction that yields the best results.

4. CONCLUSION

The performance of an *H*-shaped patch of microstrip antenna with a 13.81 GHz resonance wavelength is the main emphasis of this paper's design, simulation, and characterization. With a notable return loss of – 26.18 dB, far higher than the usual threshold of – 10 dB, the return loss analysis verified excellent impedance matching and ensured effective power transfer to the antenna. With a simulated gain of 7.05 dB, the antenna demonstrated its appropriateness for applications needing moderate to high gain. The frequencies of 3.81 GHz, 4.2 GHz, and 7.32 GHz are used to replicate an *H*-shaped microstrip patched antenna. The results show that an *H*-shaped antenna with patches is specifically suitable for 5G applications because of its superior performance. It offers the maximum bandwidth spectrum of 9 %, gain of 7.32 dB, directivity of 7.0268 dB, Return loss of – 17.1413 dB, – 17.8731 dB, – 13.234 dB, as well as VSWR of 1.3628, 1.3263, and 1.643 at 3.81 GHz, 4.10 GHz, and 7.13 GHz.

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Покращення продуктивності за допомогою 2 × 2 одноелементної масивної MIMO-антени у 6G пристроях

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У сучасному світі бездротовий зв'язок значно покращився в 6G завдяки розвитку технологій Massive MIMO (Multiple Input Multiple Output). Рівень перешкод в антені MIMO збільшується, і вони стають неефективними в специфікації 5G, що підтверджує переваги традиційних методів. Дві усічені лінійні ділянки антени розміром 9,2 м, 7,1 мм у верхньому шарі з наземною продуктивністю 37,6 мм × 33,4 мм на підкладці. Розмір антени 2 × 2 MIMO для 37,6 мм, 33,4 мм, 1,6 мм пропонується розробити для покращення відповідно до специфікації 6G. З основною частотою 6,6 ГГц, запропонована Massive MIMO з 6G регулюється для роботи в діапазоні від 3,19 до 5,10 ГГц. Дослідження показує граничне посилення 22,4 дБі, діапазон зображення ±25° та середнє відхилення посилення 3,3 дБ на частоті 5,6 ГГц. Запропонована система отримана для покращення продуктивності за допомогою результатів моделювання HFSS для робочої частоти за допомогою масивної MIMO-антени, що забезпечує спрямованість 4,6 з відносною діелектричною проникністю 4,4 та ізоляцією 15 дБ. Крім того, коефіцієнт підсилення 10,16 дБі з ефективністю випромінювання 80% був досягнутий завдяки вставці одноелементної масивної MIMO-антени 2 × 2, яка здатна до просторового мультиплексування за допомогою 6G застосування.

Ключові слова: 6G, Масивна MIMO, HFSS, ISI, Мобільний зв'язок, Одинарний елемент.