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Design of Microstrip Patch Antenna

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ABSTRACT—

Designing microstrip patch antenna has become important and very useful because of its affordability and quality in wireless communication channel. The proposed microstrip patch antenna design has 2.7 GHz bandwidth, -15.5 dB, 97% efficiency and also has some other parameters like 1.4 VSWR and 6.82 dB antenna gain, the operating frequency of this microstrip patch antenna is 27.5 GHz.

Keywords— microstrip patch, wireless communication channel, microstrip antenna, gain, bandwidth.

I. Introduction

A microstrip-patch antenna is commonly used for its low cost and compact design in RF applications and wireless systems. It is widely employed in wireless mobile communication, satellite applications, and wireless energy systems. The main disadvantage of using microstrip-patch antennas is their limited bandwidth, which makes them unsuitable for several applications. Some researchers have achieved remarkable achievements in improving the design of microstrip-patch antennas to overcome those limitations and enhance their performance.

Several methods have been proposed in [1], [2], [3], [4], and [5]. to enhance the bandwidth of the microstrip-patch antenna. These techniques include using patch or ground plane slots, applying metamaterial principles to enhance impedance bandwidth, and utilizing adjustable patches or ground planes. These methods have shown successful results that improve both the gain and bandwidth range of microstrip-patch antennas compared to traditional designs. In this paper, we present a design of a microstrip-patch antenna that aims to overcome the constraints of limited bandwidth and enhance overall performance.

For optimal performance, a microstrip-patch antenna must consider critical factors during the design. These factors include the shape and size of the patch, the substrate material and thickness, the feeding mechanism, and the presence of any additional structures or elements[6]. By selecting the proper shape and size of the patch, it is possible to achieve the desired resonance frequencies and radiation patterns. The substrate material and thickness play an important role in determining the impedance bandwidth of the antenna.

The feeding mechanism, such as a microstrip line or coaxial connector, directly affects the antenna's overall efficiency and radiation characteristics. When integrating these design considerations and approaches, we can facilitate the development of improved microstrip-patch antenna for many different applications such as wireless communications systems, cellular phones, radar systems, and satellite communications systems. These advancements in design and the progress of innovative techniques have led to significant improvements in the performance of microstrip patch antennas.

Microstrip Patch Antenna is an important part in modern communication systems, appreciated for its small size, simple manufacturing process, and ability to be used in a wide range of applications. The importance of the microstrip patch antenna depends on its ability to operate over a large spectrum of frequencies maintaining a relatively simple structure, making it an essential part in wireless communication, satellite technology, radar systems, and other applications. This work aims to analyze the challenges of Microstrip patch antenna design, examining its basic concepts, design parameters, and achievements.

The Microstrip Patch Antenna is a kind of planar antenna that has a radiating patch placed on one side of a dielectric substrate, with a ground plane located on the other side. The radiating patch, usually made of conductive materials such as copper, is commonly shaped as a square, rectangle, circle, or other geometric forms, selected depending on the desired use and required frequency properties. The performance of the antenna is affected by its size, substrate characteristics, and feeding methods.

Several parameters have significant effects on the efficiency and features of a microstrip patch antenna. The selection of the substrate material and its dielectric constant has a major impact on the impedance bandwidth, efficiency, and size of the antenna. FR4, Rogers, and Duroid are commonly used substrate materials, each with different dielectric characteristics. The resonant frequency, bandwidth, and radiation properties are determined by the size and shape of the radiating patch. The patch's dimensions, configuration, and positioning directly impact the antenna's impedance matching and radiation characteristics. The feed mechanism, such as microstrip line, coaxial probe, or aperture coupling, is essential for establishing the antenna's impedance matching and bandwidth. The size and shape of the ground plane affect the radiation pattern, impedance matching, and efficiency of the antenna. Variations in the dimensions and shape of the ground plane can modify the effectiveness of the antenna.

The design process of a microstrip patch antenna involves a sequence of processes and techniques with the goal of reaching its established parameters. Simulation software such as CST Microwave Studio, HFSS (High-Frequency Structural Simulator), and MATLAB help in the modeling and analysis of antenna properties. The typical process consists of Specification of the frequency range, gain, bandwidth, and other requirements suitable to the planned application. shape Selection and Optimization lies on the appropriate patch shape and size, keeping into consideration the required resonant frequency and bandwidth. Optimization techniques, such as parametric studies and genetic algorithms, improve the design parameters to achieve optimal performance. Substrate Selection depends on Choosing a suitable dielectric substrate according to the specified dielectric constant, loss tangent, and thermal characteristics. To design Feed Mechanism it must be Determined the optimal feed type and position for effective power transmission to the patch.

For running simulation and Analysis, it has to Apply simulation techniques to evaluate the antenna's performance, focusing on its radiation pattern, return loss, bandwidth, and impedance matching. Microstrip patch antenna provide multiple advantages, but there are still major challenges that remain in their development and implementation. The challenges are establishing a wide frequency range or bandwidth, minimizing losses, maintaining the quality of polarization, and handling the complexity of production.

Antenna gain is a definition of its capacity to focus radiation in a certain direction. The directivity of the antenna corresponds directly to its ability to concentrate output energy in a certain direction. When designing a high-gain microstrip patch antenna, it is important to take into consideration multiple factors, including the size, shape, geometry, and configuration of the antenna. using methods such as frequency selective surface reflectors, hybrid substrates, and negative permeability metamaterial can enhance antenna gain.

Efficiency is another important factor in the design of microstrip patch antennas. To achieve maximum antenna efficiency, it is essential to reduce any losses and optimize the power transmission between the antenna and the feeding network. Improving efficiency can be achieved by selecting suitable dielectric substrate materials and optimizing their thickness, in addition to designing a feed network that minimizes losses.

To optimize the bandwidth of the microstrip patch antenna design, several techniques can be applied. These include designing slots or applying patches to the radiating patch, using a stacked framework, or utilizing dielectric substrates with high permittivity. In addition, the utilization of proximity-coupled or gap-coupled microstrip patches may increase the antenna's bandwidth.

The reflection coefficient measures the level to which an antenna can effectively match the impedance of the feeding network. A lower reflection coefficient indicates an improved impedance match and reduced power reflection back to the source. To get an optimal reflection coefficient, it can be achieved by applying proper impedance matching techniques, such as the use of quarter-wave transformers or stubs.

Having a higher gain in a microstrip patch antenna can be a challenge, since these antennas are often known for their relatively low gain. Even so, there are methods that can be used to increase the antenna gain. This involves enhancing the size of the radiating patch, choosing an appropriate substrate with a high permittivity, and integrating other components like parasitic patches or reflectors to increase the overall gain.

To enhance the overall performance of the microstrip patch antenna, it is important to simultaneously consider all the design elements. This includes the careful selection of the suitable dimensions for the radiating patch, choosing a high-quality dielectric substrate with the desired permittivity, the optimization of the feed network design to minimize losses and maximize power transfer, and the use of impedance matching techniques to achieve a low reflection coefficient.

The voltage standing wave ratio (VSWR) measures the impedance matching between the antenna and the transmission line[7]. A low VSWR indicates a good impedance match with efficient power transmission, but a high VSWR indicates bad impedance matching and increased signal reflection. Microstrip patch antennas with a high VSWR can lead to lower efficiency, smaller bandwidth, and reduced overall performance. So it is important to properly design and enhance microstrip patch antennas to decrease Voltage Standing Wave Ratio (VSWR) and ensure excellent functionality across different applications. To improve the performance, directivity, and gain of the microstrip patch antennas, we may explore advanced techniques such as array elements and fractal geometry, which have the potential to improve VSWR and the overall performance of the antenna.

These antennas provide several benefits which have led to their extensive use in different fields. They also have a small physical expansion, lightweight, and may be easily integrated into complex systems. They have excellent radiation efficiency, low cost, and are easy to build. However, microstrip patch antennas have some drawbacks. A major disadvantage is their limited bandwidth, which limits their capacity to operate across a wide range of frequencies. Also, They have lower gain when compared to other types of antennas.

To solve these challenges, we can apply efficient design methods and optimization techniques, such as combining different configurations, substrates, and feeding systems. So it is necessary to explore new approaches such as fractal geometry and array elements to improve the efficiency, directionality, and amplification of microstrip patch antennas. To enhance the quality of these antennas, it is important to consider some parameters such as VSWR, array elements, dielectric substrate materials, feeding methods, and modern design strategies such as fractal geometry[8].

In the field of wireless communication systems, several major challenges require immediate solutions. First, there is an important requirement for complete research in the area of microstrip patch antenna design. The development in this field is essential to improve the efficiency, reliability, and capacity of antennas applied in different wireless systems[9].

Additionally, the increasing demand for higher transmission rates in wireless communication systems is a major problem[10]. Considering the growing quantity and complexity of data, it is important to improve the rate of data transmission to ensure an efficient and fast transfer of information.

Moreover, the release of the 5G wireless communication technology necessitates a requirement to increase its bandwidth. The existing bandwidth limitations limit the system's capacity to handle increasing data traffic and facilitate a wide range of connected devices[10]. Enhancing the bandwidth capacity of the 5G system is important to take full advantage of its possibilities to meet the increasing requirements of modern connectivity.

This paper aims to address many important goals in the field of wireless communication systems. The main objective is to create and implement a design of microstrip patch antenna. The main goal is to design an antenna system that significantly improves the network capacity, to enhance the efficiency and performance of wireless networks.

The paper also wants to increase the quality of the channel bandwidth. This objective is to expand the limits of channel capacity by increasing bandwidth to meet the growing data requirements and enable smooth communication across different devices and applications.

In addition, the primary objective in this work is to achieve significant isolation and minimize the loss of channel capacity. The main purposes of the wireless communication setup are to provide good isolation between system components and reduce channel capacity loss. These goals are important for optimizing the overall efficiency and dependability of the system. The last goal of this study is to enhance the capacity and efficiency of wireless communication systems through these three objectives.

II. Microstrip Patch Antenna Design

Design of Microstrip Patch Antenna

The parameters of our proposed microstrip patch antenna design are shown in the Table. 1. below. The design was made through the use of CST antenna design software. CST is one of the best antenna design tools widely used nowadays to design different types of antennas. Our antenna has achieved a good value of gain, which is 6.82 dB, and also a good bandwidth compared to other antenna designs which is 2.7 GHz. The presented design has also a return loss of -15.5 dB, which is good according to others. At the end of the paper, we will make a logical comparison between our antenna design and some of the other researchers' designs.

Table 1. Antenna parameters 1

Parameters symbols	Description of parameters	Value in (mm)
Ws	Width of the substrate	80
Ls	Length of the substrate	6
W	Width of the patch	4.236
L	Length of the patch	3.063
Wf	Width of the feed line	0.3
Lf	Length of the feed line	1.4685
Hs	Height of the substrate	0.787

The resulting design formulas are used for calculating the dimensions of the patch in terms of length as well as width.

$$W = \frac{c}{2fr}\sqrt{\frac{2}{\epsilon r+1}} \qquad [1]$$

The variables in question are as follows: c represents the velocity of light, fr represents the resonant frequency, and εr represents the dielectric constant of the substrate.

$$L = Leff - \Delta L \qquad [2]$$

The effective length of the patch, denoted as Leff, is given as follows::

$$\text{Leff} = \frac{c}{2fr\sqrt{\epsilon eff}} \qquad [3]$$

The effective dielectric constant, εeff, is defined as follows:

$$\epsilon\, eff = \frac{\epsilon r+1}{W} + \frac{\epsilon r-1}{W}\left(1+\frac{12h}{W}\right)^{-1/2} \qquad [4]$$

The extended incremental length, ΔL, is defined as follows:

$$\Delta L = 0.412h\frac{(\epsilon eff+0.3)(\frac{W}{h}+0.264)}{(\epsilon eff+0.258)(\frac{W}{h}+0.8)} \qquad [5]$$

Fig. 1 shows the proposed microstrip patch antenna geometry with dimensions (Ws×Ls). The dimensions used have shown in TABLE I.

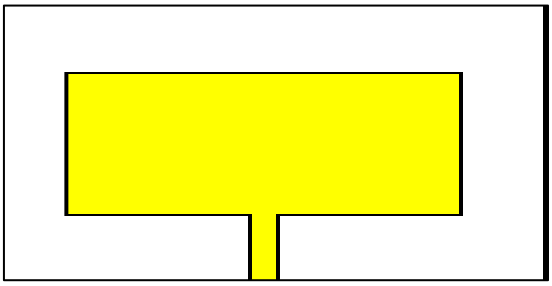

Fig.1. Proposed microstrip rectangular patch antenna.

III. SIMULATION RESULTS AND ANALYSIS

A. Return Loss

Return loss, or sometimes we say reflection coefficient, denotes the amount of power that is reflected from the antenna as a result of an impedance mismatch. The return loss, or the reflection coefficient, determines the efficiency of power transmission from the transmission line to the antenna. We found from our design that the return loss of this antenna is -15.5 dB, which is very good and reliable compared with the other microstrip patch antenna designs, and we also discovered that the bandwidth of the antenna is 2.7 GHz, which is good and effective according to other works.

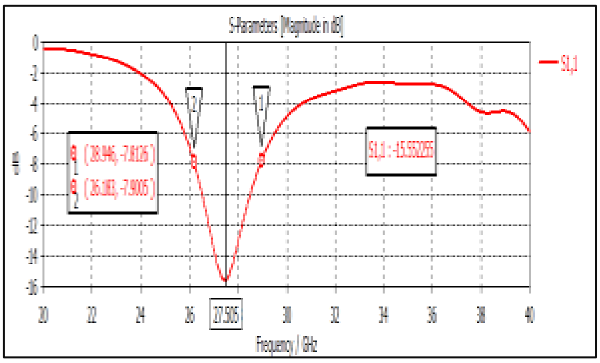

Fig. 2. Return loss

B. VSWR

The term VSWR stands for voltage standing wave ratio. It indicates the ratio of the maximum voltage to the minimum voltage along a transmission line. A higher value of VSWR corresponds to a higher impedance mismatch and higher power reflections, which signals a worse transmission efficiency. The VSWR of our antenna design has reached 1.4, indicating slight impedance mismatch and power reflection. Compared to other designs, this number marks an important result in terms of minimizing power reflections and maximizing transmission efficiency.

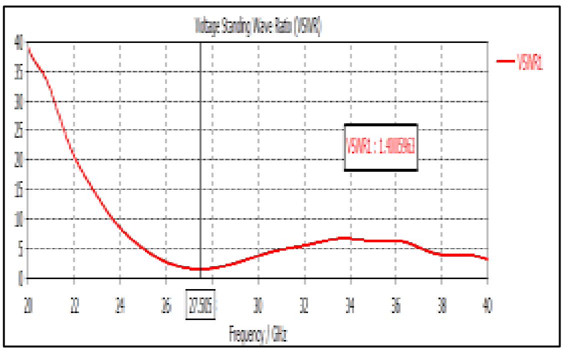

Fig. 3. VSWR 1

C. Shape of Radiation

The three-dimensional (3D) and the one-dimensional far-field of the antenna are shown below in Fig. 4. and Fig. 5. respectively. As I mentioned before the overall gain of this antenna is 6.82 dB.

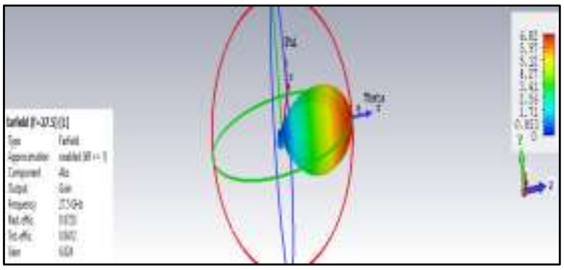

Fig. 4. Gain 3D

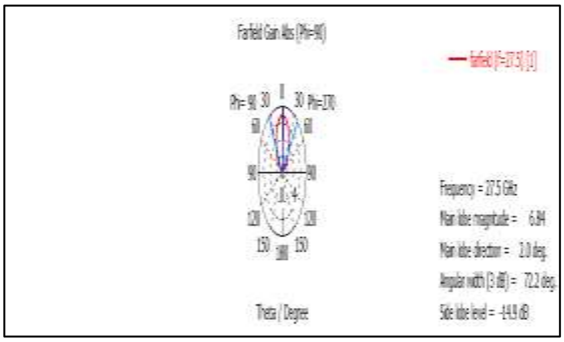

Fig. 5. Gain 1D

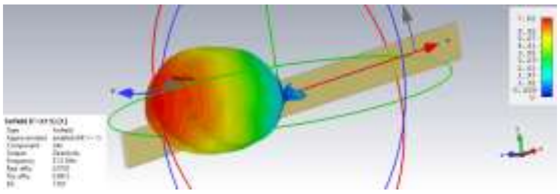

Fig. 6. Directivity

As shown in Fig. 4. gain is 6.824 dB and in Fig. 6. directivity is 7.021 dB.

So Efficiancy = $\frac{\text{gain}}{\text{directivity}} = \frac{6.824}{7.021} = 0.971$

Efficiancy = 97%

D. Conclusion

the design that we proposed has a gain of 6.82 dB, which is considered good for signal quality and improved performance. and also has a bandwidth of 2.7 GHz which is so good for data transmission and and capacity. The reflection coefficient, or return loss, of the proposed design is -15.5 dB, indicating that there is minimal power reflected back to the source. Additionally, the proposed design exhibits a better radiating efficiency of 97%, and also has a VSWR of 1.4, indicating that a large percentage of the incident power is radiated as electromagnetic waves. Based on the comparison and analysis, it can be concluded that the proposed design of the microstrip patch antenna shows promising results in terms of gain, bandwidth, and performance parameters such as reflection coefficient, voltage standing wave ratio and radiating efficiency.

References

1. Huang, J., Dong, G., Cai, J., Li, H., & Liu, G. (2021). A quad-port dualband MIMO antenna array for 5G smartphone applications. Electronics, 10(5), 542.

2. Dkiouak, A., Zakriti, A., & El Ouahabi, M. (2020). Design of a compact dual-band MIMO antenna with high isolation for WLAN and X-band satellite by using orthogonal polarization. Journal of Electromagnetic Waves and Applications, 34(9), 1254-1267.
3. Aziz, H. S., & Naji, D. K. (2020). Compact dual-band MIMO antenna system for LTE smartphone applications. Progress In Electromagnetics Research C, 102, 13-30.
4. Farahat, A. E., & Hussein, K. F. A. (2020). 28/38 GHz dual-band YagiUda antenna with corrugated radiator and enhanced reflectors for 5G MIMO antenna systems. Progress In Electromagnetics Research C, 101, 159-172
5. Ali, W., Das, S., Medkour, H., & Lakrit, S. (2021). Planar dual-band 27/39 GHz millimeter-wave MIMO antenna for 5G applications. Microsystem Technologies, 27(1), 283-292.
6. Abdelgwad, A. H. (2018). Microstrip patch antenna enhancement techniques. *International Journal of Electronics and Communication Engineering*, *12*(10), 703-710.
7. REMUS, D., MIRCEA, R., MIHAELA, A., SAMOILA, F., & STOICA, P. C. (2021). COMPUTATIONAL METHOD AND EXPERIMENTAL MEASUREMENT FOR DETERMINING VOLTAGE STANDING WAVE RATIO. *Annals of the University of Petrosani Electrical Engineering*, *23*.
8. Ali, S. A., Rafique, U., Ahmad, U., & Khan, M. A. (2012). Multiband microstrip patch antenna for microwave applications. *IOSR Journal of Electronics and Communication Engineering*, *3*(5), 43-48.
9. Kumar, K. K., & Prasanth, E. S. (2015, February). A novel design approach and simulation of frequency reconfigurable micro strip patch antenna for Wi-Fi, WLAN and GPS applications. In *2015 international conference on robotics, automation, control and embedded systems (RACE)* (pp. 1-4). IEEE.
10. Panda, S., Gupta, A., & Acharya, B. (2021). Wearable microstrip patch antennas with different flexible substrates for health monitoring system. *Materials Today: Proceedings*, *45*, 4002-4007.