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SQUARE MICROSTRIP PATCH ANTENNA

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ABSTRACT:

When designing a wearable microstrip patch antenna for 2.4GHz frequencies, there are several important things to consider. This type of antenna is crafted to be low-profile and easy to deploy on flat surfaces, using a square microstrip patch design. It's specifically designed to work well with FR-4 (G-10) substrates, which have particular electrical properties. The FR-4 substrate, with a dielectric constant of 4.3 and a thickness of 1.5mm, serves as the antenna's base material. This substrate was chosen because it matches the desired operating frequency of 2.4GHz and has a low dielectric loss tangent (0.008), which means minimal signal losses in the antenna system. The antenna's resonant frequency of 2.4GHz is well-suited for typical wireless communication needs, especially in the Industrial Scientific Medical (ISM) band, which spans from 2.3GHz to 2.49GHz. This frequency range provides good coverage for practical applications. Engineers use advanced simulation software like CST Studio Suite 2023 to model and optimize the antenna's performance. A key

specification of this antenna is its directionality of 7.022dBi, which shows how effectively it can transmit and receive signals in specific directions. Overall, creating such an antenna requires balancing technical expertise.

Keywords: **Microstrip patch antenna, low-profile, wireless communication needs, FR-4 (G-10) substrates, dielectric loss tangent, transmitting and receiving signals, CST (COMPUTER STIMULATING TECHNOLOGY) Studio Suite 2023 learning edition.**

Cite this article:

1. INTRODUCTION

As the demand for faster speeds, reliable connectivity, and increased data storage continues to rise, advancements in 5G technology alongside Internet of Things (IoT) solutions are revolutionizing wireless capabilities. With 5G supporting data rates up to 10Gbps, a significant leap from 4G-LTE, wearable antennas are becoming essential components in many devices. Smartwatches incorporate small antennas for seamless wireless communication, while discreet button antennas are ideal for integration into wearable gadgets. Smart wristbands leverage compact antennas to enable Bluetooth and NFC features, and even glasses can integrate antennas for enhanced connectivity like Bluetooth or Wi-Fi. The choice of operating at 2.4GHz aligns with global communication standards (ISM category), ensuring compatibility with existing technologies like Wi-Fi, Bluetooth, and Zigbee. Microstrip antennas were chosen for their simplicity in manufacturing, small form factor, and cost-effectiveness, making them ideal for wearable technology. Tools like CST Studio Suite 2023 were used to analyze and optimize antenna performance, highlighting their suitability for modern design needs with efficient performance and affordability.

2. DESIGN OF ANTENNA

Design of single patch antenna

This paper presents a rectangular patch antenna designed for 3.5 GHz 5G applications, alongside recognition in the ISM (Industrial, Scientific, and Medical) category for global communication devices. The chosen substrate material, FR-4 [high resin], with a dielectric constant (εr) of 4.3 and a thickness of 1.5mm (about 0.06 in), is ideal for wearable applications due to its properties like low loss tangent (0.008). The antenna's geometry and operating frequency of 2.4 GHz are illustrated in Figures 1 and 2, with detailed dimensions provided in Table 1. Fabricating a microstrip patch antenna operating at 2.4 GHz involves several steps. Firstly, selecting the appropriate substrate material and calculating the patch shape based on desired resonance frequency and substrate characteristics. Secondly, determining the width of the microstrip feedline for impedance matching, followed by optimizing the ground-plane configuration for enhanced antenna performance. The antenna is then constructed using PCB techniques with precision in layout and shape. RF measurement equipment is employed to validate performance parameters like return loss and radiation characteristics. Subsequent adjustments are made based on test results, utilizing electromagnetic simulation tools for continuous optimization. Lastly, integrating the antenna into the system while considering installation and RF conditions ensures optimal performance for the intended application. This approach represents a systematic methodology for developing and deploying microstrip patch antennas tailored for specific frequency bands and applications.

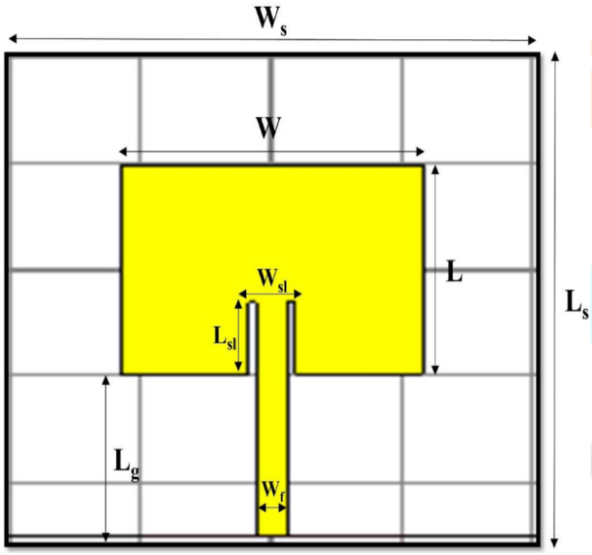


Figure 1: geometry of proposed square patch antenna

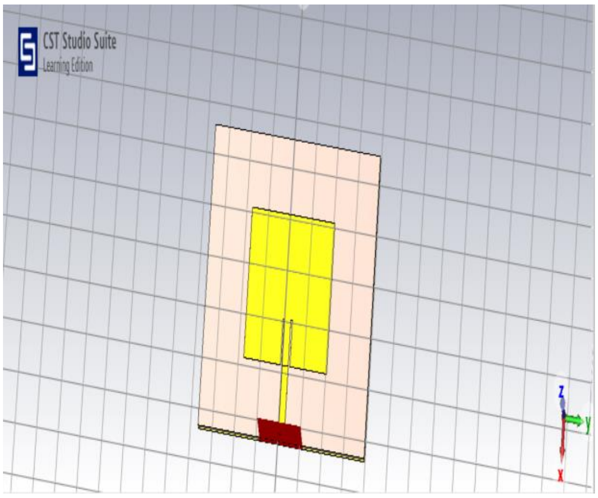


Figure 2: design of proposed antenna on CST

The design parameters of a rectangular microstrip patch antenna include key dimensions These parameters typically encompass the length (L) and width (W) of the patch, the substrate material's dielectric constant (ε_r) and thickness (h), the width and position of the feedline, and the size of the ground plane. The patch length (L) determines the resonant frequency (f_0) and is often set to approximately half-wavelength at the operating frequency, while the patch width (W) controls impedance and bandwidth.

Table 1: Design parameters of the antenna

COPPER THICKNESS	0.035mm
SUBSTRATE HEIGHT	1.5mm
LOSS TANGENT	0.008
DIELECTRIC CONSTANT	4.3
LENGTH OF SUBSTRATE	59mm
WIDTH OF SUBSTRATE	76mm
LENGTH OF PATCH	29.5mm
WIDTH OF PATCH	38mm
LENGTH OF FEEDER	14.75mm
WIDTH OF FEEDER	2.86mm for 50 ohm

3. MATERIAL AND METHODS

MATERIAL

Microstrip antennas are engineered to be compact, necessitating careful material selection. For this design, FR-4 (a high resin dielectric material) was chosen as the substrate due to its favorable dielectric constant of 4.3, which allows for reduced antenna dimensions while maintaining performance. The substrate thickness of 1.5 mm and the use of a 0.035 mm thick copper layer as the conductor were crucial decisions in achieving the desired antenna size and performance characteristics. Table 1 provides detailed specifications outlining the key parameters of the antenna design, reflecting the deliberate choices made to optimize performance within compact dimensions.

Table1: Antenna Specifications

ANTENNA SPECIFICATION	VALUE
SUBSTRATE	FR-4
DIELECTRIC CONSTANT	4.3
SUBSTRATE THICKNESS	1.5mm
CONDUCTING MATERIAL	COPPER
COPPER THICKNESS , CT	0.035mm
OPERATING FREQUENCY	2.4GHZ

The weight, feed weight and width of the single patch are determined using the formula from antenna theory. The width (W) and length (L) of patch can be calculated from the following mathematical formula. These calculations provide a starting point for designing a microstrip patch antenna. However, practical antenna design often involves iterative adjustments and simulations to fine-tune the dimensions and achieve optimal performance for specific applications and operating conditions.

Width of the patch:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

Effective dielectric constant (ε eff):

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

Length extension (△ L):

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$$

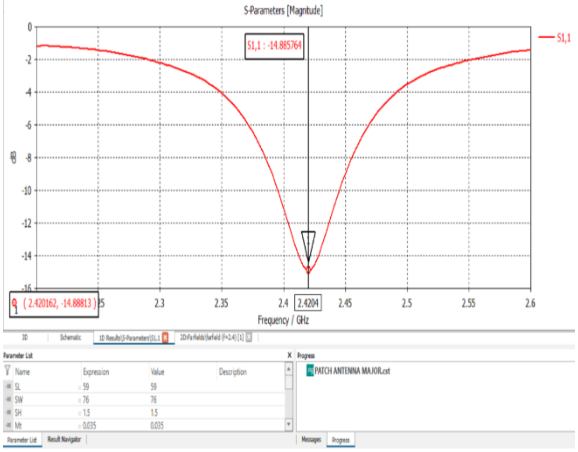
Length of patch:

$$L = L_{eff} - 2\Delta L$$

$$L = L_{eff} - 2\Delta L$$

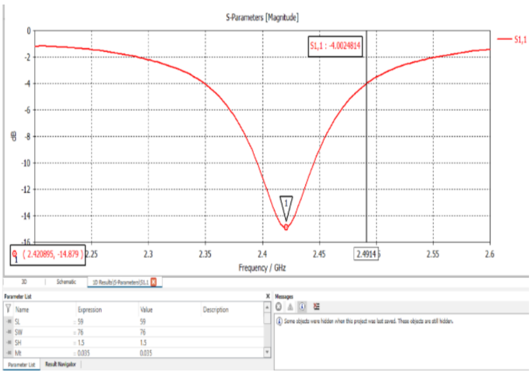
4. RESULTS AND DISCUSSIONS

Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7 illustrates the reflection coefficient and Farfield radiation in 3D and 2D polar model of single square shape microstrip patch antenna and VSWR characteristics. Figure 3 depicts the return loss characteristics of square patch antenna that resonates at 3.46 GHz with return loss of -14.88 dB. Figure 4 represent s-parameters of the proposed antenna. Figure 5 presents far field radiation pattern in 3D view. Figure 6 represents the farfield radiation pattern 2D polar view. In farfield plots, red areas indicate where the antenna is radiating the most energy in a specific direction.



Name	Expression	Value	Description
SL	= 59	59	
SW	= 76	76	
SH	= 1.5	1.5	
Mt	= 0.035	0.035	

Figure 3: Return loss of proposed antenna



Name	Expression	Value	Description
SL	= 59	59	
SW	= 76	76	
SH	= 1.5	1.5	
Mt	= 0.035	0.035	

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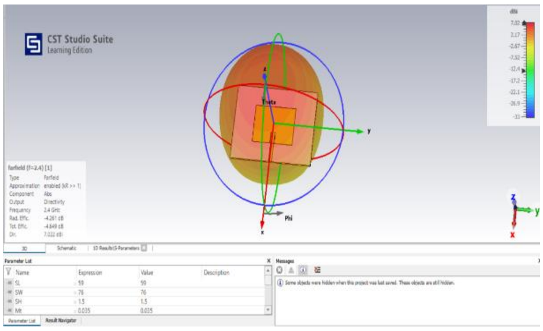
Figure 4: the s-parameters of the proposed antenna

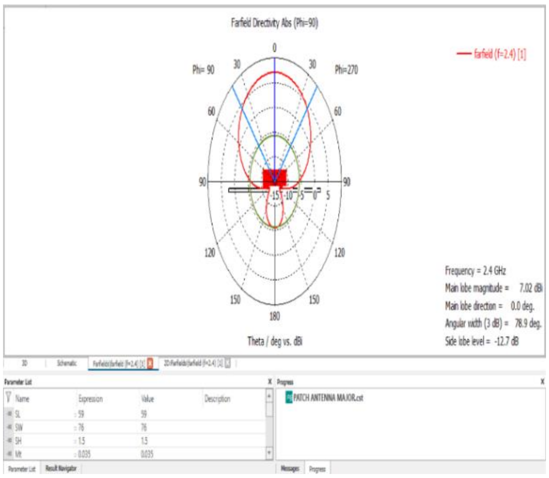


farfield (f=2.4) [1]
Type Farfield
Approximation enabled (kR >> 1)
Component Abs
Output Directivity
Frequency 2.4 GHz
Rad. Effic. -4.261 dB
Tot. Effic. -4.649 dB
Dir. 7.022 dBi

Name	Expression	Value	Description
SL	= 59	59	
SW	= 76	76	
SH	= 1.5	1.5	
Mt	= 0.035	0.035	

Some objects were hidden when this project was last saved. These objects are still hidden.

Figure 5: the Farfield radiation pattern 3D view



Frequency = 2.4 GHz
Main lobe magnitude = 7.02 dBi
Main lobe direction = 0.0 deg.
Angular width (3 dB) = 78.9 deg.
Side lobe level = -12.7 dB

Name	Expression	Value	Description
SL	= 59	59	
SW	= 76	76	
SH	= 1.5	1.5	
Mt	= 0.035	0.035	

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Figure 6: The Farfield radiation pattern 2D polar view

CONCLUSION:

The main goal of this project was to create a dual-band antenna tailored for Wireless Local Area Network (WLAN) applications, specifically targeting the 2.4 GHz frequency range. We utilized CST software for antenna design and simulation, conducting an extensive study on performance by experimenting with various parameters and slot configurations to understand their impact on the reflection coefficient. This iterative process allowed us to refine the antenna design for optimal performance. The resulting antenna demonstrated effectiveness within the ISM (Industrial, Scientific, and Medical) band used in communication devices, ensuring compatibility with popular wireless technologies like Wi-Fi, Bluetooth, and Zigbee. Looking ahead, potential future improvements could involve exploring different antenna shapes to enhance performance and further optimizing the size for practical integration into various devices and applications. This project highlights the continuous effort to innovate and adapt antenna technology to meet evolving wireless communication needs, aiming to enhance connectivity and efficiency across diverse wireless platforms.

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