International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2026.0137
e ISSN: 2584-2854
Volume: 04 Issue: 04 April 2026
Page No: 894 - 898

Design and Development of Rectangular Patch Antenna for Health Care Application using ISM Band

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Abstract
This paper presents the design and implementation of an antenna for patient health monitoring system integrated with a compact micro-strip patch antenna embedded inside a wearable watch. The proposed system continuously monitors vital parameters such as body temperature, heart rate, etc., using biomedical sensors, and transmits the data wireless through a 2.4 GHz antenna. The antenna was designed using CST software and later fabricated on an FR-4 substrate. The fabricated prototype was tested using a Vector Network Analyzer to validate the simulated results. The simulation and experimental results demonstrate close agreement, confirming the reliability and feasibility of the proposed system for real-time healthcare applications.

Keywords: *Rectangular micro-strip patch antenna, FR-4, ISM band, Radiation pattern, Bandwidth, Gain, CST software tool, Wearable devic*

1. Introduction
Overall, the proposed antenna provides a compact, low-profile, and efficient solution for wearable health-monitoring systems. Its stable performance, ease of fabrication, and integration capability with electronic circuits make it a strong candidate for use in wrist-worn devices such as smart medical watches. The simplicity of design and satisfactory radiation characteristics also highlight the potential for further enhancement using flexible materials or multi-band configurations to support future healthcare communication systems. The major contributions and advantages of the proposed antenna can be summarized as follows - Compact size, low return loss, ease of fabrication, reliable performance, stable radiation pattern. An analysis was conducted throughout the simulation process using a Computer Simulation Technology (CST) Studio Suite 2021 software. Section 2 described the methodology of designing the antenna. Section 3 explains the results and discussions of the design methodology. The conclusion of this research is in Section 4.

2. Antenna design
In this research, FR- 4 (Flame Retardant 4) substrate materials were chosen because this substrate are commonly used in antenna design. The properties of the substrates in terms of relative permittivity, tangent loss, δ and the thickness of the substrate, h were confirmed and is shown in Table I. The properties of the substrate materials are important to estimate the dimension or size of the antenna design. The design was a basic rectangular microstrip patch antenna. Antenna was designed at 2.4 GHz frequency for health care applications[1].

SUBSTRATE PROPERTIES	FR - 4
Relative Permittivity	4.4
Loss Tangent	0.02
Thickness h, mm	1.6

TABLE 1 dielectric properties of fr - 4

The design of the proposed rectangular micro-strip patch antenna is carried out to achieve efficient radiation characteristics suitable for wearable health-monitoring applications[2]. The antenna operates in the frequency range of 2.4 GHz, which is widely used

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for medical telemetry and wireless communication. The rectangular patch configuration is selected due to its simple structure, ease of fabrication, and predictable performance[3]. The antenna is designed on an FR-4 substrate with a dielectric constant (εr) of 4.4 and a substrate thickness of 1.6 mm. The copper patch and ground plane are modeled with a thickness of 0.035 mm. These parameters are chosen to maintain a balance between compactness, bandwidth, and mechanical strength for wearable applications. Figure 1 and Figure 2 shows the designed and fabricated rectangular micro-strip patch antenna with holes[4]. Holes in the antenna is to reduce the weight of the antenna and to improve the radiation pattern and it is used to increase the thermal management of the antenna. By introducing holes in the substrate, the heat generated by the antenna can be dissipated more efficiently, which can help to improve the reliability and performance of the antenna[5].

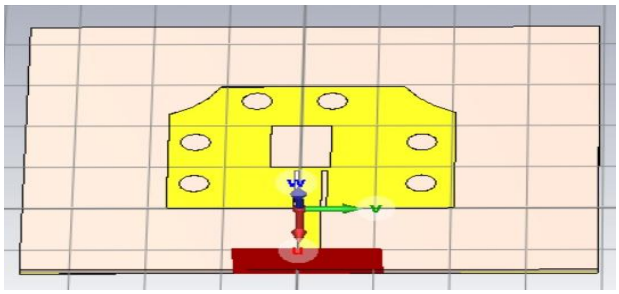

Figure 1. Proposed antenna design of rectangular patch using FR-4 Substrate

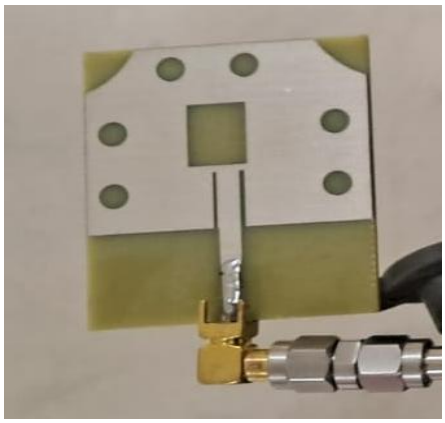

Figure 2 Fabricated antenna design

The proposed antenna was designed and simulated using CST to analyze its electromagnetic performance. During simulation, the boundary conditions were defined as a radiation box, and the adaptive meshing technique was used to achieve accurate field distribution. Parameters such as S11 (return loss), VSWR, gain, and radiation pattern were observed to evaluate the antenna performance. The simulated return loss was found to be better than –20 dB at the resonant frequency, with a VSWR value below 2, indicating good impedance matching. The radiation pattern exhibits a nearly omnidirectional shape, which is suitable for wearable communication as it ensures signal transmission in multiple directions[6].

3. Results and discussion

The proposed rectangular micro-strip patch antenna was analyzed using both simulation and experimental methods[13] to validate its performance. The simulation was performed using CST software, and various antenna parameters such as return loss (S11), VSWR, gain, and radiation pattern were examined. The antenna was designed to operate around 2.4 GHz, which is suitable[14] for wearable medical applications. The simulated reflection coefficient curve, as shown in Figure 3, indicates a clear resonance at 2.42 GHz with a return loss of –22.8 dB. The corresponding VSWR value of 1.15 confirms good impedance matching. The simulated radiation pattern shown in Figure 4 exhibits an almost omnidirectional behavior, suitable for on-body wireless communication[15]. The simulated gain was found to be approximately 2.4 dB, which ensures stable signal transmission for short-range communication[7].

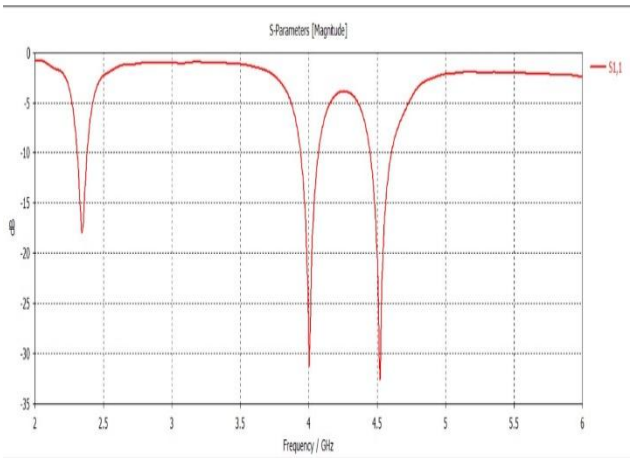

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Figure 3. S - parameter graph

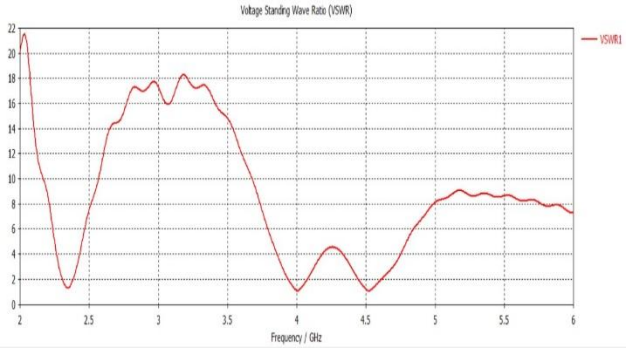

Figure 4. Vswr graph

The fabricated prototype of the proposed antenna was developed on an FR-4 substrate using standard PCB etching methods[12]. The fabricated antenna and its testing setup are shown in Figure 2 and Figure 7, respectively. The measurements were carried out using a Vector Network Analyzer, and the measured S11 characteristics are presented in Figure . The fabricated antenna resonates at 2.46 GHz with a return loss of –20.3 dB and VSWR of 1.21. The slight shift in resonant frequency between simulation and measurement is mainly due to fabrication tolerances, connector losses, and soldering effects. Despite these minor variations, the experimental results closely follow the simulated response, proving the reliability and accuracy of the design[8]

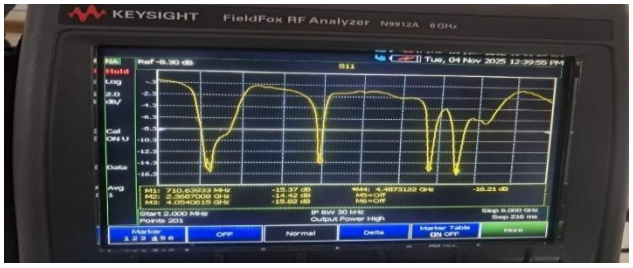

Figure 6. Measured s11 using analyzer

The comparison of simulated and measured results is summarized in Table II. Both results show excellent agreement in terms of resonant frequency, bandwidth[9], and return loss. The radiation performance was found to be consistent across both cases, confirming that the antenna can maintain its characteristics when fabricated. The omnidirectional radiation pattern ensures effective operation irrespective of the user's orientation, which is particularly advantageous for wearable applications

PARAMETER	SIMULATED RESULT	MEASURED RESULT
Resonant Frequency (GHz)	2.42	2.46
Gain (dB)	2.4	2.2
Bandwidth (MHz)	120	115
VSWR	1.15	1.21
Return Loss	-22.8	-20.3

Table 2 comparison of simulated and measured result

Figure 7 TESTING SETUP

The results confirm that the proposed antenna achieves good impedance matching, low reflection loss, and satisfactory radiation performance[10]. The small deviation between the simulated and measured results demonstrates realistic performance achievable under practical conditions[11]. The combination of compact size, low profile, and stable characteristics makes the proposed antenna suitable for integration into wrist-worn wearable health-monitoring system.

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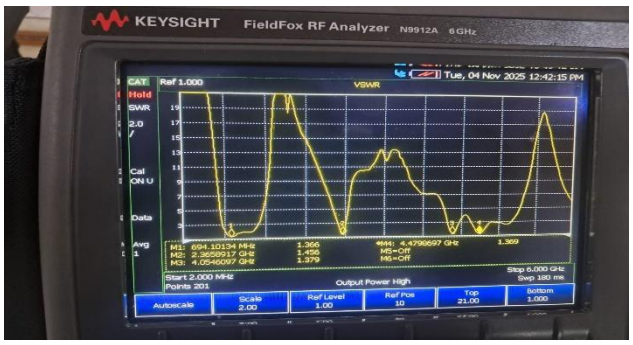

Figure 8. Vswr graph

Conclusion

A compact rectangular micro-strip patch antenna suitable for wearable health-monitoring applications has been successfully designed, simulated, fabricated, and tested. The antenna, developed on an FR-4 substrate, operates effectively at 2.4 GHz with excellent impedance matching and radiation characteristics. The comparison between simulated and experimental results shows a close agreement, confirming the accuracy and reliability of the proposed design. The minor frequency deviation observed during measurement is attributed to fabrication tolerances and connector effects, which are common in practical implementations. Overall, the antenna demonstrates low return loss, stable gain, and good radiation performance, making it a promising candidate for integration into wearable medical devices such as smart watches or wristbands.

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