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Performance analysis of Conformal Slotted Hexagonal Patch Antenna

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Abstract: This paper presents the design and performance analysis of a hexagon-shaped microstrip patch antenna and a slotted hexagon patch antenna for wideband wireless communication applications. The proposed antennas were designed and simulated using CST Microwave Studio on three different substrate materials, namely FR4 (εr = 4.3), Rogers RO3003 (εr = 3.0), and Polyimide (εr = 3.5), to investigate the influence of dielectric properties on antenna characteristics. The conventional hexagon patch antenna achieved wideband operation with impedance bandwidths of 3.9 GHz, 4.4 GHz, and 4.2 GHz for FR4, Rogers RO3003, and Polyimide substrates, respectively. To further enhance the antenna performance, a slot was introduced into the hexagonal patch, and conformal analysis was carried out under bending angles of 25°, 30°, 35°, 40°, and 45°. The slotted antenna maintained stable resonant frequencies, wide impedance bandwidths, and acceptable gain values under all bending conditions. Among the investigated substrates, Rogers RO3003 exhibited the best performance with a maximum bandwidth of 4.47 GHz and a gain of 3.5 dB, while Polyimide demonstrated excellent flexibility and impedance matching characteristics with a return loss of −48.7 dB. The proposed antenna structures provide wide operating frequency coverage from approximately 1.9 GHz to 6.4 GHz, making them suitable for WLAN, WiMAX, Sub-6 GHz 5G, IoT devices, wireless sensor networks, wearable electronics, and conformal communication systems.

Keywords: Rogers RO3003, Polyimide, Wideband Antenna, Sub-6 GHz 5G, WLAN, WiMAX, CST Microwave Studio.

1. Introduction

The low profile, lightweight structure, compact size and easy fabrication have made the microstrip patch antennas one of the most popular technologies utilized in modern wireless communication systems. These antennas are comprised of a metallic patch printed onto a dielectric substrate with a ground plane on the other side. They are compatible with the integrated circuit and planar manufacturing processes, which are suitable for several applications such as satellite communications [1], radar systems, wireless local area network (WLAN), 5G communications, and Internet of Things (IoT) devices. Microstrip patch antennas have advantages of low cost, mechanical strength and can be installed on curved surfaces [2]. They, however, have narrow bandwidth and low gain as their drawbacks, which have encouraged intensive research on the bandwidth enhancement and performance improvement methods. Because of these versatility and adaptability, microstrip patch antennas are still a major component in the development in advanced communication systems [3]. A flexible antenna with high robustness is proposed for wireless body area networks (WBANs) in-body communications. A hexagon slot structure fed by a coplanar waveguide (CPW) is used to achieve a wide bandwidth of 34.4%. The in-body gain is increased to −3.36 dBi with a parasitic patch.

The proposed antenna has such advantages so that the antenna becomes insensitive to the frequency shift and gain reduction due to the variation of environment. Besides, the proposed low-profile antenna on a flexible substrate is well-fit for wearable applications [1]. Proposed a novel microstrip patch antenna (MPA) loaded with circular slots and partial ground plane for RF energy harvesting applications in the shape of a hexagon. With the help of circular slots and partial ground plane, the return loss, gain

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and impedance characteristics of the antenna were enhanced, and efficient harvesting of RF energy was achieved in the frequency range 1.5–5.5 GHz. The radiation efficiency of the antenna was 75-90%, and the radiation pattern was omnidirectional with the maximum gain of 4.56 dBi [2]. A miniaturized hexagonal patch antenna with fractal defected ground structure (DGS) and split ring resonator (SRR) based defected micro strip structure (DMS) was designed for GSM1800, C band and WiMAX application. Compared to the state-of-the-art design, the proposed design provided significant size reduction and quad-band operation at 1.85, 3.05, 4.2 and 5.4 GHz, with stable radiation characteristics and compact dimensions [3]. A conformal wide-slot antenna with a hexagonal slot structure on a circular cylindrical surface was proposed which was fed by capacitively coupled parasitic patches. The antenna showed an excellent wide impedance bandwidth of 62% in the frequency range of 3.38 GHz to 6.38 GHz, which is suitable for broadband wireless communication applications [4].

A dual-band circular patch antenna with novel hexagon shaped slot is proposed for WiMAX and 5G NR applications. The antenna was designed and fabricated on FR4, and it was able to operate on dual band at 3.47 GHz and 6.96 GHz, and the measured results confirmed its superior radiation and return loss performances [5]. A compact microstrip patch antenna is proposed which has multiple radiating slots and a partial ground plane is designed for operating at around 6 GHz for Sub-6 GHz 5G applications, having a peak gain of 3.2 dB and a wide impedance bandwidth for 5G N102 band communication [6]. A THz antenna with a modified hexagon-shaped ultra-wideband (UWB) design on a polyimide substrate was proposed which was capable of using a wide impedance bandwidth of 0.34-2.4 THz, a peak gain of 7.96 dBi with a high radiation efficiency of 98%, which was preferable for THz imaging, sensing, biomedical, and indoor wireless communication applications [7].

A compact CPW-fed flexible antenna with hexagonal radiating patch was proposed on liquid crystal polymer (LCP) substrate to cover ultra-wide bandwidth (UWB) with frequency band from 5.2 to 41GHz for UWB, WLAN, C, X, Ku, K, Ka band and millimeter-wave application [8].A super wideband antenna printed on Rogers RT/Duroid 5880 substrate was proposed, achieving an ultra-wide impedance bandwidth of 7.44–138.26 GHz, high radiation efficiency (92–97%), and circular polarization at multiple resonant frequencies, making it suitable for X, Ku, K, Ka, V-, and W-band applications [9]. This offers a wearable, on-body compact and low-profile flexible broadband antenna for wearable and on-body applications using PDMS. Proposed antenna has a wide operating band of 3.7 GHz to 6.25 GHz with a peak gain of 4 dBi and the radiation efficiency is higher than 95% when bending. Moreover, SAR analysis validates the safety compliance, making the antenna suitable to the 5G, WLAN, ISM, and healthcare wearable communication systems [10]. The flexible and conformal UHF antennas show the potential of substrates like PI, PDMS, PTFE, PET and Rogers laminates for advanced wireless and sensing applications. It reviews the performance, benefits and drawbacks of different flexible antenna structures, and highlights their emerging use in partial discharge (PD) diagnostics of the high-voltage equipment. Moreover, the authors list out the main challenges associated with substrates, environmental durability, and the antenna performance, and suggest future research directions of reliable UHF based PD detection system [11].

The size of conventional microstrip antenna design is reduced to 78% by using 2.45 GHz wearable WBAN and 5.38 GHz wearable WLAN antennas with miniaturized size using low-cost denim substrate material. The antenna exhibits dual-band impedance bandwidths of 2.37–2.51 GHz and 4.99–5.72 GHz, with the measured results agreeing well with the simulated results. Moreover, the antenna exhibited stable performance in free space and on-body environments, which is suitable for wearable electronic devices, access control and workforce identification [12]. A wideband conformal four-port MIMO antenna was proposed for 5G NR mmWave V2X communications, which is symmetrically arranged L-shaped slots inserted in T-shaped patch fed by a CPW structure. The antenna had an ultra-wide impedance bandwidth of 18.85–45.12 GHz (26.27 GHz bandwidth), with an isolation of more than 28 dB and a peak gain of 15.42 dBic. In addition, the antenna was shown to be stable in both planar and conformal environments, thus making it a good candidate for use in future connected vehicle communications systems [13].

A semi-flexible arrowhead-slot super wide band (SWB) antenna design with a defected ground structure (DGS) and chamfered ground plane was proposed for 5G and wearable IoT applications to achieve better bandwidth performance. The antenna achieved an ultra-wide impedance bandwidth of 3.1–99.17 GHz (95.93 GHz) with a peak gain of 6.91 dBi while maintaining a compact size of 22 × 28 × 0.508 mm^3. Moreover, stability in bending and time domain showed its suitability for flexible wearable and next-generation wireless communication systems [14]. A conformal I-slot circular patch antenna, designed on the spherical structure by 3D printing methods with polylactic acid (PLA), was presented for wireless communication in the changing environment. The antenna geometry was optimized by differential evolution algorithm, and the optimized antenna's measured results were compared with the simulation, which resulted in a good agreement, confirming the validity of the design method. Also, experimental testing was performed using a spherical communication module, which

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showed satisfactory data transmission, making the antenna appropriate for dynamic wireless communication systems, such as spherical robots and throwable devices [15].

Considering this motivation, the problem statement has been framed to design antenna with simple geometry and extends which has a minimal deviation in the resonance characteristics under bending conditions. The present work reports hexagonal patch antenna with hexagonal slot linear microstrip patch design and analysis in planar and conformal conditions. Further this paper is organized as follows, in which the basic hexagonal patch antenna design is presented in Section 2.1, while the hexagonal patch antenna with hexagonal slot and analysis is presented in Section 2.2. The conformal configuration and the analysis details are given in Section 2.3, and the final conclusions are provided.

2. Design and Methodology

Because of its compact size, large impedance bandwidth and multi-band and UWB wireless application, a hexagon-shaped microstrip patch antenna was chosen. The antenna is made up of a radiating patch of hexagon shape, microstrip feed line, dielectric substrate and ground plane. To investigate the effect of the dielectric constant on the antenna performance, three different substrate materials such as FR4, Rogers RO3003 and Polyimide were also used for the proposed hexagon patch antenna [16]. The relative permittivity (εr) of FR4 is 4.3, which gives a small size of the antenna, but it also can lead to a higher dielectric loss. Rogers RO3003 has a lower dielectric constant of 3.0, which provides improved radiation efficiency, gain and bandwidth characteristics. Polyimide (with a relative permittivity of 3.5), offers a compromise between size reduction and antenna performance, and is also available for conformal applications. The resonant frequency, impedance bandwidth, return loss and gain of the antenna are strongly affected by the variation in dielectric constant.

2.1. Hexagonal Patch Antenna

First, the conventional hexagonal patch antenna was designed and optimized to work at 3.2–3.3 GHz. The size of patch and feed line was adjusted to get the proper bandwidth and impedance matching. The resonant frequency, return loss, gain and bandwidth were calculated for the same antenna geometry but different substrate materials [17]. The antenna performance was evaluated using the following parameters such as resonant frequency (fr), reflection coefficient (S11), operating frequency range, impedance bandwidth and gain. The geometry of hexagonal patch antenna is shown in Fig.1

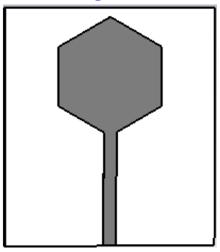

Fig. 1 The geometry of the Hexagonal microstrip patch antenna

The geometric parameters of the Hexagonal microstrip patch antenna are included in Table 1.

Table 1: Antenna dimensions of the Hexagonal microstrip patch antenna

Antenna dimensions	Values (mm)
Ls	52
Ws	46
Wg	40
Lg	24
Wf	2.8
Lf	25
h	1.6
t	0.035
a	14

The simulated S11 plot shows that multiband behaviour exists with many resonant frequencies. The return loss is good at levels below –47 dB at 3.4 GHz, meaning that the device has a low power reflection level and good impedance matching [18]. There are other resonances which can be seen at 2.4 GHz, 5.4 GHz, 8.5 GHz, and 11 GHz with S11 values of less than −10 dB is shown in Fig.2. The result shows the appropriateness of the antenna for the application of multiband wireless communication, which has efficient radiation performance.

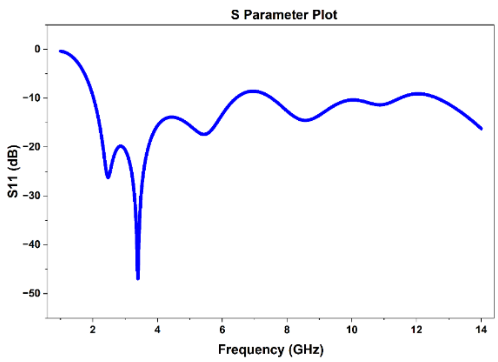

Fig. 2 Simulated reflection coefficient (S_{11}) of the Hexagonal microstrip patch antenna

The radiation pattern plot illustrates the radiation characteristics of the antenna, with maximum gain of around 3.41 dB, at 3.39GHz. The radiation pattern of a hexagonal patch antenna is shown in Fig. 3.

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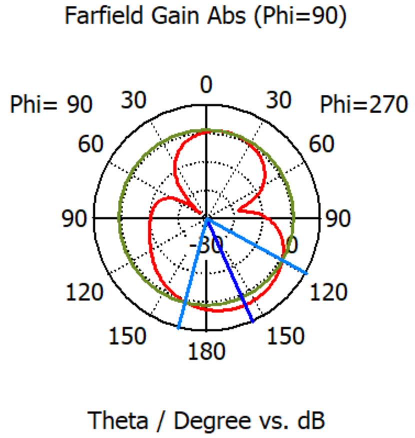

Fig. 3 Far-field radiation pattern (Φ = 90° plane) of the hexagonal patch Antenna at the resonant frequency

The antenna was designed with CST Microwave Studio and to study the impact of substrate materials on the performance of an antenna on three different materials: FR4 (εr = 4.4), Rogers RO3003 (εr = 3.0), and Polyimide (εr = 3.5) is shown in Fig.4. The simulated results show that the antenna designed on FR4 substrate resonates at 3.2 GHz with return loss of −28.9 dB, has a frequency range of 1.9–5.8 GHz, a bandwidth of 3.9 GHz and a gain of 2.9 dB. For Rogers RO3003 substrate [19], the antenna resonates at 3.3 GHz and achieves a better return loss, −46.7 dB, over the frequency range of 2.0–6.4 GHz with a bandwidth of 4.4 GHz and a gain of 3.4 dB. The antenna designed using Polyimide substrate, in a similar fashion, resonates at 3.3 GHz, has a return loss of −36.5 dB, a frequency range of 1.9–6.1 GHz, a bandwidth of 4.2 GHz and a gain of 3.3 dB.

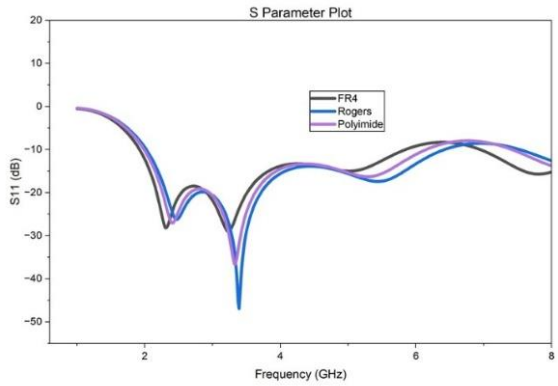

Fig. 4 S-parameter plot of the hexagonal patch Antenna with different substrate materials

As per performance comparison the Rogers RO3003 substrate exhibits the best characteristics of return loss −46.7 dB, bandwidth 4.4 GHz and gain 3.4 dB. Polyimide has similar properties and provides flexibility for conformal applications [20]. FR4 may be cheap but is not particularly high gain or high bandwidth. All three substrates resonate around 2.4 GHz and 3.3–3.4 GHz, indicating suitability for wireless communication applications. The study confirms that the antenna characteristics are greatly affected by the choice of substrate. Based on the results, it can be concluded that Rogers RO3003 material is the most appropriate for the hexagon patch antenna in the frequency range 2–6.4 GHz due to its superior impedance matching, wider bandwidth and higher gain. The performance comparison of hexagonal patch antenna with FR4, Rogers RO3003 and Polyimide is shown in Table. 2.

Table. 2. Comparison of Hexagonal Patch Antenna with different substrates

S.No.	Substrate	Minimum S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	FR4	-28.9 dB	3.2	3.9
2	Rogers	-46.7 dB	3.39	4.4
3	Polyimide	-36.5 dB	3.32	4.2

2.2. Hexagonal Patch Antenna with Hexagon Slot

The hexagonal patch antenna with hexagonal slot is implemented and is shown in Fig. 5

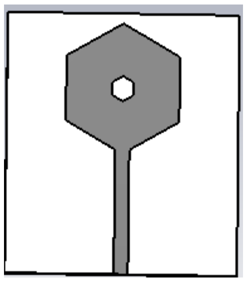

Fig. 5 The geometry of the Hexagonal microstrip patch antenna with hexagonal slot

The Hexagonal patch with hexagonal slot antenna has a minimum return loss of around −35 dB at 3.5 GHz, which is good for excellent impedance matching and power transfer [21]. Further resonances are seen at ~2.5 GHz (−24 dB) and ~5.5 GHz (−17 dB) which meet the S11 < −10 dB requirement is shown in Fig. 6. The results show good reflection characteristics and validate the usability of the antenna in broadband wireless communication applications.

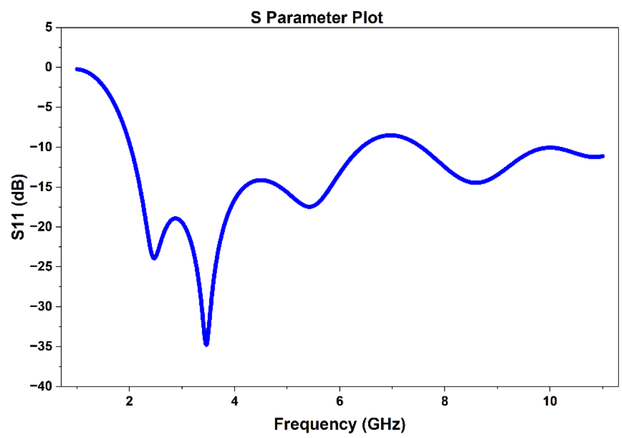

Fig. 6 Simulated reflection coefficient (S_{11}) of the hexagonal patch antenna with hexagonal slot

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The radiation pattern plot illustrates the radiation characteristics of the antenna [22], with maximum gain of around 3.5 dB, at 3.45 GHz. The graph of the radiation pattern of a hexagonal patch antenna is shown in Fig. 7

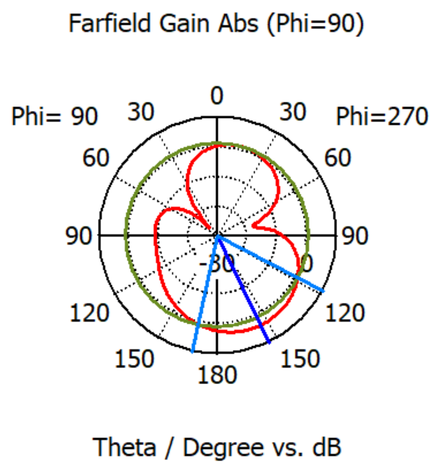

Fig. 7. Far-field radiation pattern ($\Phi = 90°$ plane) of the hexagonal patch Antenna with hexagonal slot at the resonant frequency

The reflection coefficient performance of the hexagonal patch with Hexagonal slot antenna with FR4 substrate, Rogers substrate and Polyimide substrate are shown in the Fig. 8. All three substrates have a large resonance at around 3.4 GHz, with the lowest return loss (RL) of around −48.7 dB for polyimide [23], meaning that it has the best impedance matching. The Rogers substrate has a minimum S11 of around −34.6 dB, whereas the FR4 substrate has an S11 of about −30.3 dB at the same resonance frequency. Rogers substrate provides better matching than FR4 and is suitable for high-frequency and mm Wave antenna applications due to its low dielectric loss. The operating frequency of all three substrates lies around 3.3–3.4 GHz, while Polyimide demonstrates superior return loss performance, making it highly suitable for flexible and conformal antenna applications. The results indicate that the Polyimide substrate has the best reflection properties and is the most appropriate material for improving the performance of the antenna.

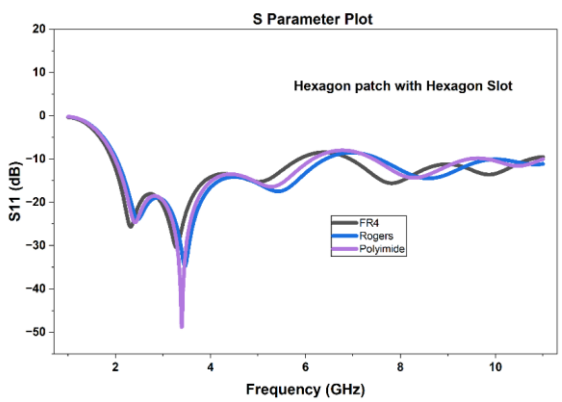

Fig. 8 S-parameter plot of the hexagonal patch Antenna with hexagonal slot for different substrate materials

The performance comparison of hexagonal patch with hexagonal slot antenna with FR4, Rogers RO3003 and Polyimide is shown in Table. 3.

Table. 3. Comparison of Hexagonal Patch Antenna with hexagonal slot for different substrates

S.No.	Substrate	Minimum S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	FR4	-30.3	3.26	3.9
2	Rogers	-34.6	3.45	4.4
3	Polyimide	-48.7	3.38	3.9

2.3. Conformal Hexagonal Patch Antenna with Hexagonal Slot

To study the impact of substrate materials and conformal bending on the performance of an antenna, a slotted Hexagon shaped conformal microstrip patch antenna is shown in Fig. 9. The antenna was first optimized using a normal (bending angle=0°) and then tested with conformal bending angles of 25°, 30°, 35°, 40°, and 45°. The resonant frequency (fr), reflection coefficient (S11), operating frequency range, impedance bandwidth and gain were used to evaluate the performance.

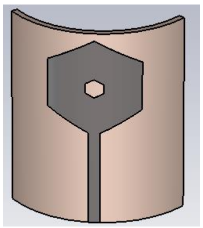

Fig. 9 Conformal configuration of hexagonal patch Antenna with hexagonal slot

The substrate materials used for this study are FR4, Rogers RO3003 and Polyimide, which have relative permittivity of 4.4, 3.0 and 3.5, respectively. The polyimide was considered as it is flexible and suitable for conformal and wearable antenna applications. Then, the antenna was bent at different bending angles 25°, 30°, 35°, 40°, and 45° on cylindrical surfaces and conformal analysis was carried out.

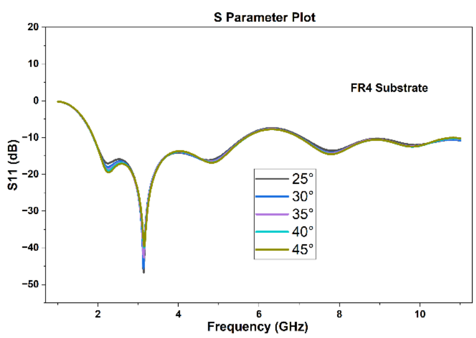

Fig. 10 Comparison of Reflection coefficient of conformal (25° - 45° bent) configurations for the hexagonal patch Antenna with hexagonal slot with FR4 substrate

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The antenna resonated at 3.2 GHz under normal condition with the return loss of -30.3 dB, bandwidth of 3.9 GHz and gain of 3 dB for FR4 substrate. The antenna maintains a nearly constant operating frequency around 3.15 GHz for all bending angles, indicating good structural stability under conformal conditions. Conformal bending resulted in a resonant frequency around 3.1 GHz and return loss ranging from −47 dB to −40 dB. Its operating frequency range is 1.9-5.6 GHz and the bandwidth remains approximately 1.40 GHz for all bending conditions, demonstrating stable wideband behaviour and gain of 2.5-2.7 dB and is shown in Fig. 10. The results indicate that the proposed antenna is suitable for conformal and flexible wireless communication applications, maintaining good performance even under significant bending. The performance comparison of conformal hexagonal patch with hexagonal slot antenna with FR4 substrate is shown in Table. 4.

Table. 4 Comparison of conformal Hexagonal Patch Antenna with hexagonal slot with FR4 substrate

S.No.	Bending Angle	S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	25°	-46.4	3.1	3.8
2	30°	-45.6	3.1	3.8
3	35°	-42.3	3.1	3.8
4	40°	-39.5	3.1	3.8
5	45°	-38.9	3.1	3.8

The frequency, return loss, bandwidth and gain of the antenna at the normal condition were 3.4 GHz, -34.6 dB, 4.4 GHz and 3.5 dB for conformal configuration with Rogers RO3003 substrate is shown in Fig. 11. The resonant frequency was kept stable at 3.35 GHz during conformal analysis with a return loss of from −25.5 dB to −27 dB. The antenna's operating frequency range was around 1.98 to 6.16 GHz and the maximum bandwidth was 4.47 GHz with the gain varying from 2.96 to 3.1 dB.

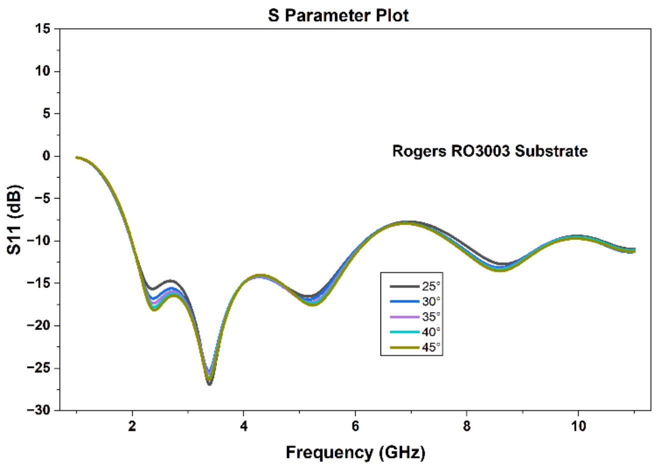

Fig. 11 Reflection coefficient comparison of conformal (25° - 45° bent) configurations for the hexagonal patch Antenna with hexagonal slot with Rogers RO3003 substrate

The performance comparison of conformal hexagonal patch with hexagonal slot antenna with Rogers RO3003 substrate is shown in Table. 5.

Table. 5 Comparison of conformal Hexagonal Patch Antenna with hexagonal slot with Rogers RO3003 substrate

S.No.	Bending Angle	S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	25°	-27.0	3.35	4.2
2	30°	-26.2	3.35	4.2
3	35°	-25.8	3.35	4.2
4	40°	-25.5	3.35	4.2
5	45°	-26.5	3.35	4.2

The best impedance matching was obtained for the antenna with the Polyimide substrate with return loss of −48.7 dB at 3.4 GHz under flat conditions. The antenna with conformal configuration is shown in Fig. 12. The frequency range was 2-6.1 GHz, the bandwidth was 4.1 GHz and the gain was 3.46 dB. With bending, the resonant frequency was slightly from 3.26 to 3.30 GHz and return loss was from −29.4 dB to −31.4 dB. The bandwidth was kept in the range of 3.9-4.0 GHz and the gain improved from 2.6 dB to 3.0 dB with increase in bending angle.

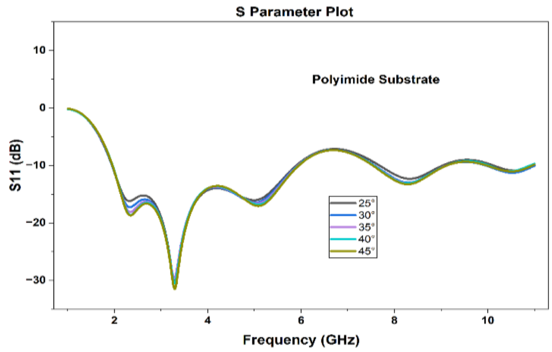

Fig. 12. Reflection coefficient comparison of conformal (25° - 45° bent) configurations for the hexagonal patch Antenna with hexagonal slot with Polyimide substrate

The performance comparison of conformal hexagonal patch with hexagonal slot antenna with Polyimide substrate is shown in Table. 6. The results demonstrate that the proposed conformal antenna can maintain stable performance under different bending conditions, making it suitable for wearable, flexible, aerospace, and conformal wireless communication applications.

The overall comparison of hexagonal patch antenna in normal and conformal conditions is shown in Table. 7. The comparative analysis shows that the slotted hexagon patch antenna has good conformal deformation ability. Rogers RO3003 has the largest bandwidth of 4.47 GHz while Polyimide has excellent impedance matching properties and is more flexible. Thus, the proposed design can be applicable to conformal, wearable and wideband wireless communication applications.

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Table. 6 Comparison of conformal Hexagonal Patch Antenna with hexagonal slot with Polyimide substrate

S.No.	Bending Angle	S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	25°	-30.5	3.2	3.9
2	30°	-30.8	3.2	3.9
3	35°	-31.0	3.2	4
4	40°	-31.2	3.2	4
5	45°	-31.5	3.2	3.9

Table. 7 The overall comparison of hexagonal patch antenna in normal and conformal conditions

S.No.	Substrate	Condition	Minimum S11 (dB)	Operating Frequency (GHz)	Bandwidth (GHz)
1	FR4	Normal	-28.5	3.30	3.9
		Bending (25°–45°)	-46.4	3.1	3.8
2	Rogers RO3003	Normal	-46.7	3.39	4.4
		Bending (25°–45°)	-27.0	3.35	4.2
3	Polyimide	Normal	-49.0	3.35	1.40
		Bending (25°–45°)	-31.5	3.2	4

2.4. Fabricated Antenna and Experimental Results

Fabricated structure of hexagon patch antenna with hexagon slot and measurement setup is shown in Fig.13.

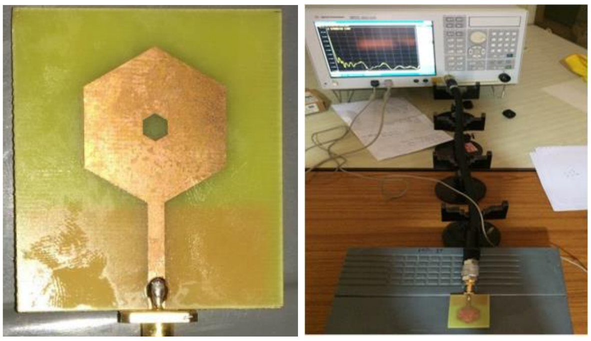

Fig.13 Fabricated Structure and Experimental Setup of the Antenna

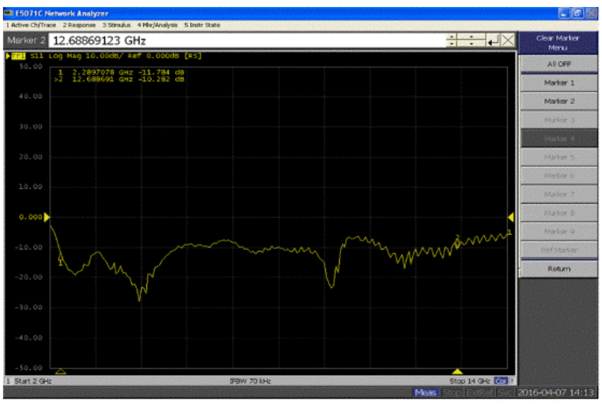

Fig.14 Measured return loss for Hexagonal boundary patch with Hexagonal slot

Practical results of the fabricated antenna are compared with simulation results. Return loss and operating frequencies are in close agreement. So the practical gain will also be in close agreement with simulated gain. Deviations in simulated and practical results can be attributed to open air measuring environment.

3. Conclusion and Future Work

The design and analysis of a Hexagon Shaped Microstrip Patch Antenna and a Slotted Hexagon Patch Antenna were carried out with three different substrate materials such as FR4, Rogers RO3003 and Polyimide. The effects of the properties of the substrate and of conformal bending on antenna performance were studied with respect to resonant frequency, return loss, operating frequency bandwidth, impedance bandwidth and gain. The conventional hexagon patch antenna has been designed to be wideband for all the substrate materials. Of these, the overall performance was best for Rogers RO3003 with a resonant frequency of 3.3 GHz, a return loss of −46.7 dB, an operating frequency range of 2-6.4 GHz, a bandwidth of 4.4 GHz, and a gain of 3.4 dB. However, the performance of polyimide was also comparable at 4.2 GHz bandwidth and 3.3 dB gain, and FR4 showed acceptable results at 3.9 GHz bandwidth with 2.9 dB gain. To improve the antenna performance, a slot was added in the hexagonal patch, and conformal analysis was also carried out for the bending angle from 25° to 45°. The results showed the slotted antenna had stable resonant frequencies and wide impedance bandwidths even when it was bent.

The Rogers RO3003 based antenna had the largest bandwidth in the conformal configuration, while the Polyimide based antenna was extremely pliable, with good impedance matching in the flat configuration (return loss of −48.7 dB), and performing well under deformation. For FR4 substrate, the operation was stable but with relatively low gain values. In conclusion, the slotted hexagon patch antenna proposed in this work exhibits excellent wide band performance, good gain characteristics and strong conformal stability. The findings show that the most optimal substrate for maximum bandwidth is Rogers RO3003 and for flexible substrates and wearable applications, the most suitable is Polyimide. Consequently, the proposed antenna is a promising solution for the design of wideband and conformal as well as next-generation wireless communication systems in the 2–6.4 GHz frequency band. The envisioned antenna can be used in a wide range of wireless communication networks such as WLAN, WiMAX, sub-6 GHz 5G Communication, Internet of Things (IoT) devices, wearable and body centric networks, wireless sensor networks (WSNs) and conformal communication platform. The antenna has a large operating bandwidth (about 2~6.4 GHz), small size, and

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stable performance when bending, making it a potential candidate for the future development of wideband and flexible wireless communication applications.

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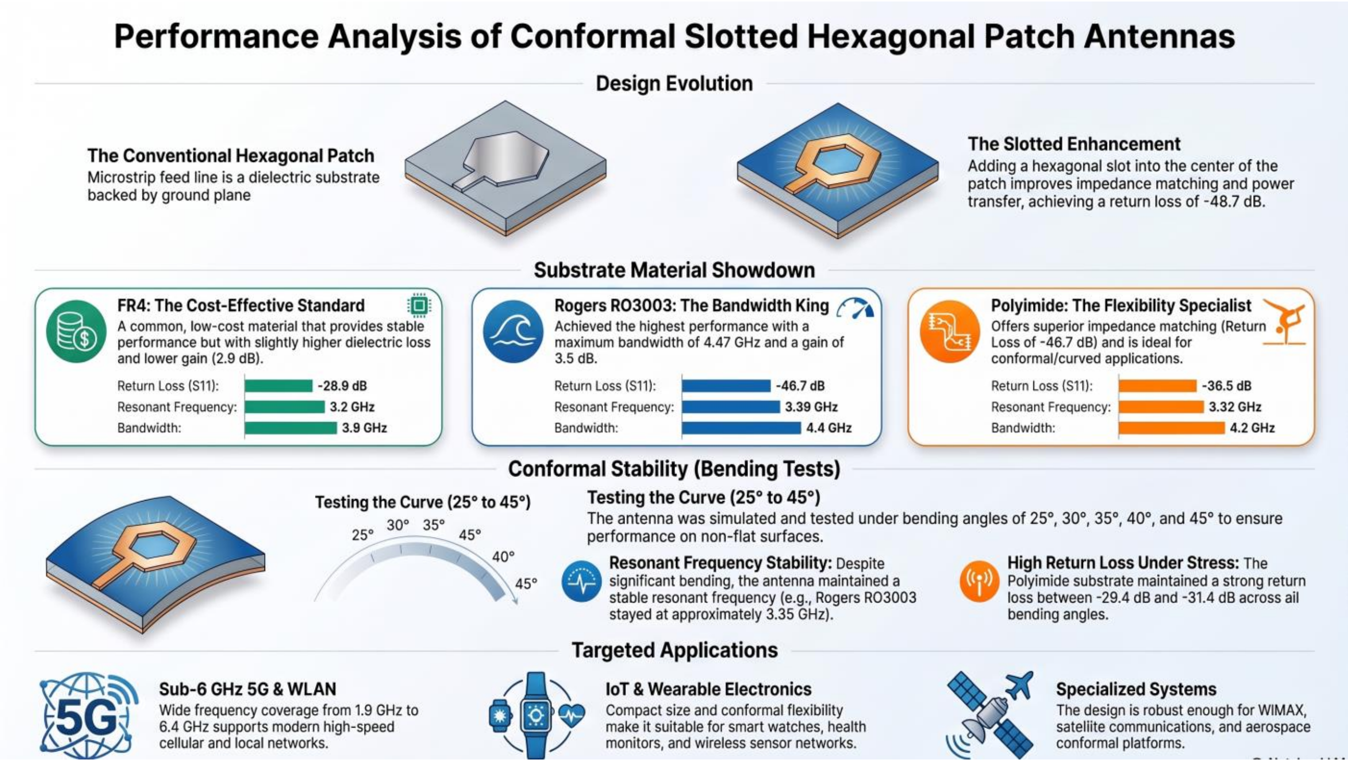

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