International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

Design the Circular Bow-Tie Microwave Antenna for Bio-Medical Applications

Dr. D. Lalitha Kumari[1], *N.J yothika Gnana Chandrika*[2]
[1]*Assistant Professor, Dept. of ECE, JNTUACE Ananthapuramu, Andhra Pradesh, India.*
[2]*PG Scholar, Dept. of ECE, JNTUACE Ananthapuramu, Andhra Pradesh, India.*
Email: *dlalitha.kumari29@gmail.com*[1], *jyothika.namala64@gmail.com*[2]

Abstract

The rapid advancement of wireless biomedical systems necessitates the development of compact, efficient, and reliable antennas capable of operating across multiple frequency bands. Traditional designs, such as bow-tie antennas, offer broadband performance but often face drawbacks including limited selectivity, reduced isolation, and lower suitability for medical applications. To overcome these limitations, this study introduces a dual circular patch antenna integrated with a metasurface layer. The design objective is to enhance the performance of bow-tie antennas for microwave applications in biomedical and biological phantoms, using metasurfaces within a transmission line model. The metasurface facilitates improved impedance matching, enhances directivity, and minimizes mutual coupling, thereby ensuring stable multi-band operation. Simulation results demonstrate notable improvements in directivity making the antenna well-suited for biomedical applications such as microwave imaging, implantable devices, and wireless body area networks. The proposed circular patch design further emphasizes the effectiveness of metasurfaces in achieving safer, more accurate, and efficient biomedical communication systems.

Keywords: *Metasurface, Stripline Feed Antenna, Impedance Matching, Bio-Medical Applications, Microwave Imaging.*

1. Introduction

Over the past two decades, the rapid growth of wireless communication has driven the need for compact, efficient, and multi-band antennas. Applications such as GPS, ISM devices, WLAN, and emerging IoT systems demand miniaturized, multifunctional designs that ensure reliable performance under diverse conditions. Biomedical engineering increasingly relies on wireless technologies for diagnostics, therapy, and patient monitoring. Applications such as implantable sensors, wearable devices, and WBANs require compact, biocompatible, and efficient multi-band antennas to ensure reliable connectivity for functions like ECG monitoring, glucose tracking, drug delivery, and medical telemetry. Traditional antenna geometries, such as the Bow-Tie configuration, have been employed in biomedical systems due to their broadband characteristics. While effective in covering wide spectral ranges, many biomedical applications require precise and selective operation within designated frequency bands. Typical examples include the Medical Implant Communication Service (MICS, 402–405 MHz), the Industrial, Scientific, and Medical (ISM, 2.4 GHz) band, Wireless Local Area Networks (WLAN, 2.4–2.7 GHz), and the Global Positioning System (GPS, 1.57 GHz). In biomedical antenna applications, biological tissues introduce detuning and impedance mismatch because of their high permittivity and conductivity. To address this, a metasurface is introduced between the antenna and the tissue, functioning as an impedance matching layer. Using a transmission line model, the tissue is approximated as a homogeneous medium with inductive impedance behaviour around the operating frequency (2.4 GHz). To counter this, the metasurface is designed with an opposite capacitive response, ensuring overall impedance balancing. The unit cells of the metasurface are etched on an FR4 substrate and arranged in an array, allowing capacitive behaviour that neutralizes the inductive effect of tissue. Wideband antennas such as the Bow-Tie are often unsuitable in these scenarios, as they tend to receive unwanted signals outside the target band, thereby increasing susceptibility to interference. Furthermore, inadequate isolation between bands can degrade overall system efficiency and reliability. These limitations pose critical challenges for biomedical devices, where consistent performance and patient safety are paramount. As a result, antenna designs that ensure controlled frequency selectivity, enhanced isolation, and optimized multi-band operation are essential to address the stringent requirements of contemporary biomedical communication systems. Microstrip patch antennas have emerged as a promising solution for biomedical applications owing to their compact dimensions, lightweight structure, conformal geometry, and ease of integration with medical electronics. A critical aspect of their design is the feeding technique, which directly influences impedance matching, radiation efficiency, and isolation. Among various options, stripline feeding provides distinct advantages, including improved impedance matching, reduced spurious radiation, and superior port-to-port isolation. These characteristics are particularly vital in body-centric communication systems, where electromagnetic compatibility, reliability, and patient safety are primary considerations. The motivation behind this study arises from the increasing demand for biomedical antennas capable of operating efficiently in close proximity to human tissues while offering multi-band functionality, compact form factor, and stable radiation performance. In contrast to conventional broadband designs, such as the Bow-Tie antenna, which typically lack frequency selectivity and suffer from poor isolation, the proposed approach aims to address challenges related to cross-talk, mutual coupling, and interference in multi-port biomedical communication systems. The proposed dual circular patch antenna, energized via a stripline feed, is designed to overcome the limitations of conventional structures by delivering reliable operation across multiple biomedical communication bands. It accommodates GPS for medical navigation and transport, ISM for wireless health monitoring, and WLAN for hospital communication networks. By carefully optimizing its geometry and substrate properties, the antenna ensures safe, interference-resilient, and energy-efficient wireless connectivity, making it well suited for biomedical environments. Its circular geometry supports polarization control and reliable radiation, while dual patches enable GPS, ISM, and WLAN band coverage. The stripline feed enhances confinement, reduces coupling, and minimizes interference. Simulations demonstrate strong impedance matching ($S_{11} < -10$ dB) and high isolation ($S_{21} \approx -38$ to -52 dB), confirming efficient and safe wireless performance. The Bow-Tie antenna has been utilized in biomedical applications such as medical telemetry and wearable communication systems due to its wide impedance bandwidth and simple structural design. Its triangular flare geometry enables broadband radiation; however, this feature can be disadvantageous in medical environments. The wideband response often leads to the reception of unwanted frequencies, potentially causing interference with critical medical equipment. In addition, when employed in multi-port biomedical systems, the Bow-Tie antenna demonstrates poor isolation, resulting in increased mutual coupling between adjacent channels. Therefore, while suitable for general broadband communication, the Bow-Tie is less appropriate for biomedical applications, where precise frequency selectivity, high isolation, and stable radiation in proximity to biological tissue are essential. The antenna is primarily intended for integration into implantable sensors, wearable health monitors, hospital IoT networks, and GPS-assisted medical transport systems. Future extensions of this work may involve adapting the design for 5G-enabled biomedical communication, ultra-wideband medical imaging, and multi-antenna MIMO configurations to support advanced healthcare applications.

2. Literature Survey

E.Razzicchia, I.Sotiriou, H. Cano-Garcia, E. Kallos "Feasibility study of enhancing microwave brain imaging using metamaterials, IEEE Trans. 2019".[1]

Razzicchia, Sotiriou, Cano-Garcia, and Kallos (2019) presented a feasibility study on the use of

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

metamaterials to enhance microwave brain imaging (MWI), aiming to overcome the inherent challenges of weak scattering and low sensitivity in detecting brain abnormalities such as stroke. In this work, they proposed integrating thin metamaterial layers—specifically split-ring resonator (SRR) arrays—into the imaging setup to manipulate the near-field behaviour of antennas and increase interaction with brain tissue. Through simulations and preliminary experimental assessments, the study demonstrated that metamaterial superstrates could significantly improve antenna matching, enhance coupling, and amplify the contrast of scattered signals. By placing metamaterial sheets between the antennas and the head phantom, the researchers observed stronger field penetration and more detectable differences between healthy and abnormal tissues. The relevance of this work lies in its pioneering role in applying metamaterials for biomedical microwave imaging, introducing a hardware-based method to boost sensitivity without relying solely on advanced reconstruction algorithms. The key findings showed that metamaterial loading improved signal strength and contrast, supporting clearer image reconstructions in simulated stroke detection scenarios. While the study was limited to simplified head phantoms and focused mainly on feasibility, it established a foundation for later studies (e.g., their 2021 work on metasurface-enhanced antennas) that further validated and optimized the concept. Thus, this paper marked an important step in demonstrating that metamaterial integration could be a practical pathway to enhance the diagnostic capability of MWI systems.

A.S.M.Alqadami, N.Nguyen-Trong, A.E.Stancombe "Compact flexible wideband antenna for on-body electromagnetic medical diagnostic systems, IEEE Trans.2020".

The study introduces a compact, flexible, wideband monopole antenna explicitly engineered for on-body electromagnetic medical diagnostics. Its standout material choice is a custom high-permittivity flexible substrate, enabling miniaturization while maintaining wideband performance and effective unidirectional radiation. The antenna's flexibility and conformability make it well-suited for curved body surfaces, offering a comfortable and practical wearable solution. The material combination allows for a low-profile design, enabling seamless integration within wearable diagnostic systems. In summary, important merits include: compactness, flexibility, wide operational bandwidth, and compatibility with on-body usage. Despite its numerous advantages, the antenna design displays a couple of limitations. Material-wise, the high-permittivity custom substrate—while enabling miniaturization—may lead to manufacturing complexity and cost compared to conventional dielectric substrates, potentially affecting scalability for mass production. Also, as with many on-body antennas, performance can degrade when conforming to the body: detuning, shifts in resonant frequency, and impedance mismatch may occur depending on posture or body location, potentially reducing reliability in practical deployment. In summary, while the design presents an innovative solution for wearable medical diagnostics—combining compactness, flexibility, and broadband capability—it faces challenges in material cost and consistent performance across different body conformations.

S.Diana, D.Brizi, C.Ciampalini, G.Nenna, "A compact double-ridged horn antenna for ultra-wide band microwave imaging, IEEE Trans.2021".

The authors present a novel, compact double-ridged horn (DRH) antenna tailored specifically for ultra-wideband (UWB) microwave imaging, with dimensions approximately 30% smaller than conventional commercial DRH antennas—measuring around 151 mm × 108 mm × 146.6 mm. The paper outlines a comprehensive design approach: starting with theoretical design guidelines, they validate the concept using electromagnetic simulations—both in free space and in proximity to biological loads, which confirms the antenna's strong radiating capabilities and robustness under realistic conditions. Critically, the antenna achieves a very broad operational band, maintaining VSWR < 3 across 1–9 GHz, a performance well-suited to microwave imaging applications Following

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

simulation, a physical prototype is fabricated and experimentally measured, confirming the design's validity and practical feasibility. Additionally, the authors evaluate radiation safety by assessing Specific Absorption Rate (SAR), and establish that SAR remains well below regulatory limits, ensuring suitability for use near human operators. A key merit of this DRH antenna lies in its compact form factor while preserving a wide operating frequency range, an achievement made possible by leveraging the ridged horn structure, which lowers cutoff frequency and broadens bandwidth. This makes it highly attractive for biomedical imaging systems—such as portable or wearable microwave scanners—where space is at a premium. The robust performance in both simulated and experimental scenarios, including near human tissue, demonstrates its practical utility. The inclusion of SAR safety assessment further bolsters its suitability for clinical or near-body environments.

Amjad Iqbal, Muath Al-Hasan, Ismail Ben, Mabrouk, "Biotelemetry and Wireless Powering of Biomedical Implants Using a Rectifier Integrated Self-Duplexing Implantable Antenna".

Iqbal, Al-Hasan, Mabrouk, and colleagues (2021) proposed a rectifier-integrated self-duplexing implantable antenna designed for biotelemetry and wireless powering of biomedical implants. The antenna was engineered to simultaneously support wireless data transmission and energy harvesting, eliminating the need for separate transmitter and receiver antennas within the implant. The self-duplexing design enabled concurrent uplink and downlink communication, while the integrated rectifier efficiently converted received RF signals into usable DC power. Experimental validations demonstrated that the antenna achieved reliable communication at medical implant frequency bands with high rectification efficiency, making it well suited for powering low-power biomedical devices. The design's primary merits include functional integration (antenna + rectifier), reduced implant size, improved power transfer efficiency, and full-duplex communication capability, which are critical for modern implantable biomedical systems. However, the approach also has limitations the complexity of integration may increase fabrication cost, and self-duplexing can introduce isolation challenges, potentially leading to interference between transmit and receive paths. Despite these drawbacks, the study is highly relevant to the proposed bow-tie circular patch antenna with an impedance matching metasurface at 2.56 GHz, as both aim to enhance biomedical antenna performance in tissue environments. While Iqbal et al. focus on implantable power and telemetry, the metasurface-based approach provides improved impedance matching, tissue penetration, and multi-band selectivity, offering a complementary path toward safer and more efficient biomedical wireless systems.

E.Razzicchia, Pan Lu,Wei Guo, "Metasurface Enhanced Antennas for Microwave Brain Imaging".

Razzicchia, Lu, and Guo proposed the use of metasurface-enhanced antennas for microwave brain imaging, addressing challenges of weak scattering and poor antenna matching in conventional systems. The paper studies whether loading near-field brain-imaging antennas with engineered metasurfaces (MTS) can boost microwave imaging (MWI) performance for stroke detection in the 0.5–2.0 GHz band. In their experiments, printed monopole antennas loaded with a Jerusalem-cross metasurface superstrate were tested in a glycerol–water coupling medium on stroke-mimicking gel phantoms. The metasurface improved return loss by about 3 dB and boosted inter-antenna transmission by up to 8 dB, leading to clearer reconstructions of hemorrhagic and ischemic targets. These results demonstrated that metasurface integration offers a simple hardware-level approach to increase sensitivity and signal-to-noise ratio without requiring changes to imaging algorithms. Beyond liquid-coupled systems, the authors also introduced a simulated air-coupled design using a printed square monopole with a split-ring metasurface superstrate. This configuration improved return loss by 5 dB and amplified target-induced signal differences by up to 25 dB, showing potential for liquid-free, portable brain imaging helmets. The main merits of this work lie in its clear

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

performance gains and feasibility for clinical portability. However, the approach is still limited to phantom experiments and 2D reconstructions, with challenges such as fabrication cost, conformal integration on real head geometries, and dependency on robust imaging algorithms.

3. Implemented Method

3.1. Introduction

This work presents the design, simulation, and optimization of a stripline-fed dual circular patch antenna developed for multi-band biomedical wireless communication. The antenna is optimized to operate efficiently within the GPS (1.59 GHz), ISM (2.4 GHz), and WLAN (2.4–2.7 GHz) frequency bands, which are widely employed in medical monitoring and healthcare systems. Compared with the reference bow-tie antenna, the proposed design demonstrates notable improvements in frequency selectivity, port-to-port isolation, and radiation stability, thereby offering enhanced reliability for biomedical environments. The key design principle lies in the use of dual circular patches, which generate multiple well-defined resonant frequencies, while a stripline feeding technique ensures improved impedance matching and minimizes unwanted radiation. By carefully tuning the patch dimensions and feed configuration, the antenna achieves reflection coefficients (S_{11}) consistently below –10 dB across all target bands, along with excellent port isolation (S_{21}) exceeding –38 dB. Performance evaluation with biological tissue phantoms confirms that the antenna maintains stable coupling and efficient radiation characteristics in lossy environments, ensuring dependable wireless links for biomedical applications. All aspects of the design and validation were performed using CST Microwave Studio, a full-wave 3D electromagnetic solver extensively used in antenna research. The software enabled accurate modeling of antenna geometry, assignment of material properties, and application of realistic boundary conditions, while its optimization routines supported fine-tuning of critical parameters. This simulation framework ensured that the antenna performance was analyzed under conditions closely resembling practical biomedical scenarios, thereby providing reliable and predictive results.

The development methodology for the proposed antenna comprises the following steps:

- Formulated the theoretical foundation for circular patch resonance and stripline feeding.
- Designed the initial antenna geometry in CST using analytically derived dimensions.
- Applied iterative optimization to refine key structural parameters.
- Conducted parametric analysis to evaluate the effect of geometric variations.
- Validated performance across targeted frequency bands through full-wave simulations.

3.2. Antenna Geometry

The proposed antenna is designed with a dual circular patch geometry fabricated on an FR4 substrate and excited via a stripline feed. Each circular patch is dimensioned and positioned to resonate at different frequencies, and their combined response ensures effective coverage of the GPS, ISM, and WLAN bands. In the final layout, the patches are etched on the top surface of the dielectric, while a continuous ground plane is incorporated on the underside of the substrate to provide stable operation and well-controlled radiation characteristics. The implemented antenna incorporates dual circular patches as the primary radiating elements, designed to generate electromagnetic fields at well-defined resonant frequencies. The initial patch dimensions, particularly the radii, are calculated using the standard circular patch resonance equation, while further optimization is performed through CST simulations to achieve precise frequency alignment and enhanced performance. The patches are excited using a stripline feed positioned within the dielectric layers, which ensures balanced excitation and improved impedance matching. This feeding technique also provides excellent port isolation, a critical requirement for maintaining stable and efficient multi-band operation in biomedical environments. The structure is realized on an FR4 dielectric substrate, selected for its affordability, mechanical strength, and ease of fabrication. With a dielectric constant of $\varepsilon r = 4.3$, the substrate

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

characteristics are carefully integrated into the design equations to achieve accurate resonance prediction.

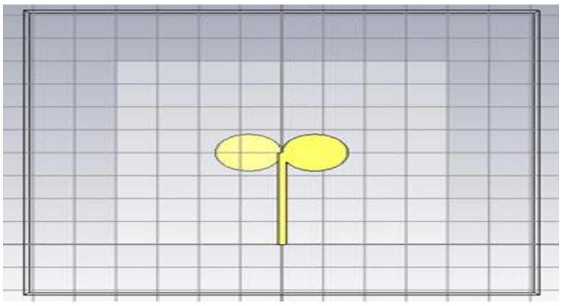

Figure 1 **Circular Bow-Tie Antenna**

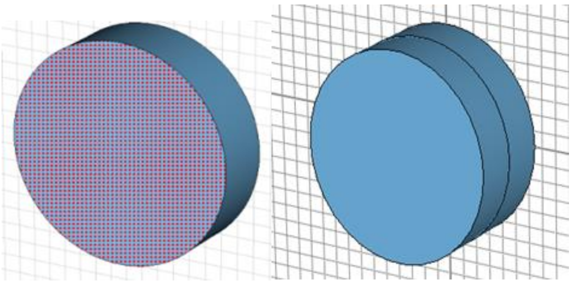

Figure 2 **Circular Structure of an Antenna**

Name	Expression	Value	Description
Sw	= 80	80	Substrate width
Sl	= 80	80	Substrate Length
h	= 1.6	1.6	Sub Thickness
wf	= 2	2	Feed_width
Lf	= 40	40	Feed_Length
t	= 0.035	0.035	Copper Thickness
R1	= 16	16	Circle Radius

Figure 3 **Dimensions of Antenna**

The implemented antenna incorporates dual circular patches as the primary radiating elements, designed to generate electromagnetic fields at well-defined resonant frequencies. The initial patch dimensions, particularly the radii, are calculated using the standard circular patch resonance equation, while further optimization is performed through CST simulations to achieve precise frequency alignment and enhanced performance. The patches are excited using a stripline feed positioned within the dielectric layers, which ensures balanced excitation and improved impedance matching. This feeding technique also provides excellent port isolation, a critical requirement for maintaining stable and efficient multi-band operation in biomedical environments.

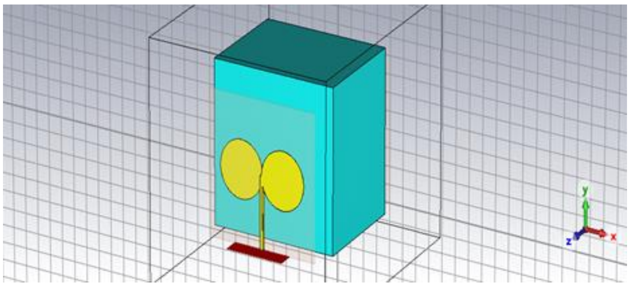

Figure 4 **Circular Bow-Tie Antenna with Biological Tissue**

The structure is realized on an FR4 dielectric substrate, selected for its affordability, mechanical strength, and ease of fabrication. With a dielectric constant of $\varepsilon r = 4.3$, the substrate characteristics are carefully integrated into the design equations to achieve accurate resonance prediction. A continuous ground plane is placed on the underside of the substrate, serving as the current return path while contributing to improved radiation efficiency and overall operational stability. Together, these elements establish a compact, reliable antenna architecture suitable for biomedical wireless communication and sensing applications.

3.3. Design Metrics

The circular patch antenna is a microstrip configuration in which the radiating element adopts a circular geometry instead of the conventional rectangular form. Its inherent rotational symmetry yields more stable radiation patterns and allows for simpler control over polarization characteristics. When operating in the dominant TM_{11} mode, the resonant frequency of a circular patch can be estimated using the standard resonance equation:

Where:

- **fr** = resonant frequency (Hz),
- **c** = speed of light in free space (m/s),
- **a** = effective radius of the patch (m),
- εr = relative permittivity of the substrate.

In the dual circular patch configuration, each patch is dimensioned to resonate at a specific frequency, and their joint optimization enables effective coverage of the GPS, ISM, and WLAN bands. Excitation is

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

achieved using a stripline feed, selected over the conventional microstrip line for its superior confinement of electromagnetic fields within the substrate, reduced radiation leakage, and higher port-to-port isolation—critical advantages for biomedical systems requiring reliable, interference-free communication. By carefully positioning and optimizing the stripline feed, the resonant modes of the circular patches are simultaneously excited, ensuring proper impedance matching, low VSWR, and stable broadband performance across the targeted frequency range.

3.4. Material Selection

The proposed antenna is implemented on an FR4 substrate, chosen for its wide availability, low cost, mechanical robustness, and ease of fabrication, which make it suitable for prototyping biomedical communication systems. With a relative permittivity of εr = 4.3 and a loss tangent of tanδ = 0.02, FR4 provides predictable dielectric behaviour that is incorporated into the resonance calculations to ensure accurate frequency alignment of the circular patches. Although higher-performance substrates with lower dielectric losses exist, FR4 offers a practical trade-off between performance and manufacturability, particularly when aiming for compact, low-cost biomedical devices. The conducting layers are realized using 35 µm copper cladding, providing adequate conductivity and mechanical stability for the stripline-fed dual patch design. Additionally, the use of a continuous ground plane on the underside of the substrate enhances radiation efficiency and stabilizes antenna performance, ensuring reliable operation in lossy biological environments.

3.5. Dimensions for Design of Circular Bow-Tie Antenna

The antenna was designed and optimized in CST Microwave Studio with the objectives of compactness, wideband operation, and fabrication simplicity. It is implemented on an 80 mm × 80 mm FR4 substrate with a 1.6 mm thickness, providing mechanical stability, cost efficiency, and suitable dielectric performance. The radiating element is a 16 mm radius circular patch, selected for its ability to support stable resonant modes, suppress cross-polarization, and achieve a more compact footprint than rectangular counterparts. By fine-tuning the patch radius and feed configuration, the antenna effectively covers the target frequency bands while maintaining a wide impedance bandwidth.

Table 1 Dimensions of design of Circular Bow-Tie Antenna

Name(Description)	Value (mm)	Material
t(Copper Thickness)	0.035	Copper (standard PCB thickness)
h(Substrate Thickness)	1.6	FR-4 (εr ≈ 4.3, tanδ = 0.02)
wf(Feed Width)	2	Copper (conductive strip)
lf(Feed Length)	40	Copper (conductive strip)
sw(Substrate Width)	80	FR-4 (εr ≈ 4.3, tanδ = 0.02)
Sl(Substrate Length)	80	FR-4 (εr ≈ 4.3, tanδ = 0.02)
R1(Circular Radius)	16	Copper (on FR-4 substrate)
pw(Phantom Width)	90	Brain Tissue(εr ≈ 43, tanδ = 0.25)
Pl(Phantom Length)	90	Brain Tissue(εr ≈ 43, tanδ = 0.25)

3.6. Advantages

- The compact circular geometry minimizes the antenna footprint, enabling seamless integration into portable and biomedical devices while maintaining stable radiation patterns and gain for continuous data transfer.
- Efficient power transfer with low reflection losses enhances signal strength and focused radiation, improving both transmission efficiency and target detection.
- The dual circular patch design supports multiple resonant modes, ensuring simultaneous operation across the GPS, ISM, and WLAN frequency bands.
- Implementation on a cost-effective FR4 substrate offers a practical balance of performance, affordability, and scalability for large-scale biomedical applications.

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

3.7. Applications

- Circular patch antennas play a vital role in microwave imaging applications, including breast cancer detection, brain imaging, and other diagnostic systems by exploiting dielectric contrasts in biological tissues.
- They can be effectively integrated into implantable and wearable medical devices, such as pacemakers and glucose monitoring systems, enabling reliable wireless communication.
- Their ability to characterize the dielectric properties of tissues supports accurate diagnosis in non-invasive and minimally invasive biomedical systems, including neural activity monitoring.
- Multi-band circular patch designs enhance microwave imaging resolution and sensitivity, thereby improving the early detection of tumors and other abnormalities in complex biological environments.

4. Results

4.1. S-Parameter

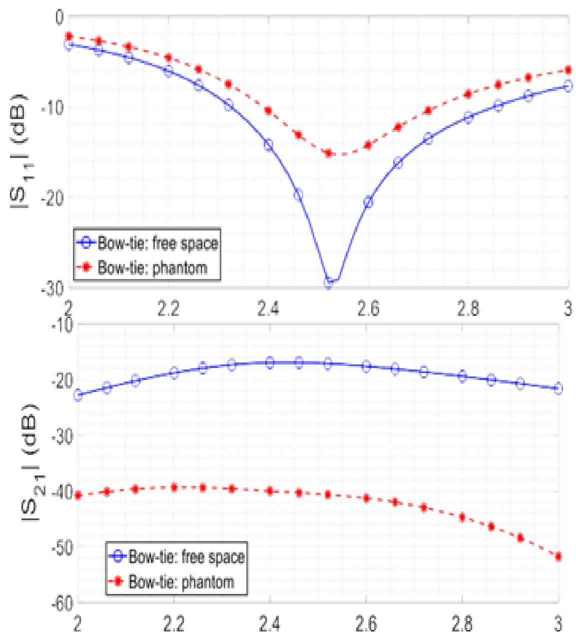

Figure 5 S-Parameter Coeffiecients S11 and S21

The S_{11} parameter, or reflection coefficient, characterizes the impedance matching between the antenna and the feed line. For the proposed stripline-fed dual circular patch antenna, the S_{11} response exhibits distinct resonances around 2.4 GHz, with transmission coefficients ranging from –38 dB to –52 dB, well below the –10 dB benchmark. These results confirm highly efficient power transfer with minimal reflections, ensuring reliable operation across the GPS, ISM, and WLAN frequency bands.

4.2. Directivity

The three-dimensional gain patterns demonstrate the spatial radiation characteristics of the proposed antenna across its operating frequencies. A peak gain of approximately 1.9 dBi is achieved at 1.59 GHz, which increases to about 3.4 dBi at 2.25 GHz and nearly 3.68 dBi at 2.4 GHz. These results confirm that the antenna satisfies the targeted performance requirements, ensuring reliable signal strength and stable operation for biomedical communication and diagnostic applications.

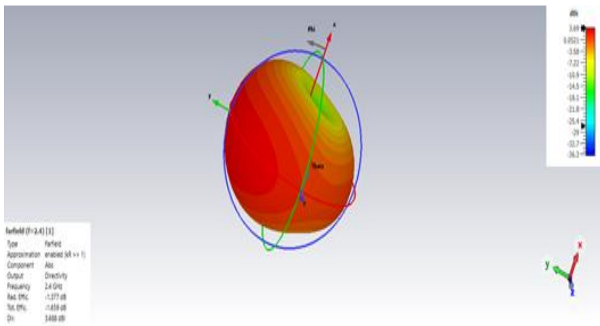

Figure 6 Directivity

Table 2 Design Aspects of Circular Bow-Tie Antenna

Aspects	Implemented Method
Geometry Shape	Circular Bow-Tie Antenna
Impedance Matching	Excellent (S_{11} <-10dB) at multiple distinct bands
Transmission	Very high isolation (S_{21}= –38 to –52 dB)
Directivity	3-4 dBi
Substrate Material	FR-4(εr =4.3, tanδ = 0.02)
Dimensions	Radius = 16mm Thickness = 1.6mm
Feed Mechanism	Microstrip Line
Bandwidth	Narrow Bandwidth
Radiation Pattern	Omni-directional

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 03 Issue: 10 October 2025
Page No: 3845-3853
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2025.0558

Conclusion

This work presents the simulation and design of a stripline-fed dual circular patch antenna was designed and optimized to operate across the GPS, ISM, and WLAN bands. The antenna demonstrates excellent impedance matching (S_{11} < –10 dB), high port isolation (–38 dB to –52 dB), and stable radiation with moderate gain, surpassing the performance of a conventional bow-tie configuration. Its compact geometry, cost-effective FR4 implementation, and reliable multi-band operation make it well-suited for portable, IoT, and biomedical applications, including wearable health monitoring and wireless body area networks.

References

[1]. E.Razzicchia, I.Sotiriou, H. Cano-Garcia, E. Kallos "Feasibility study of enhancing microwave brain imaging using metamaterials, IEEE Trans. 2019".
[2]. A.S.M.Alqadami, N.Nguyen-Trong, A.E.Stancombe "Compact flexible wideband antenna for on-body electromagnetic medical diagnostic systems, IEEE Trans.2020".
[3]. F. Costa et al., "Wireless detection of water level by using spiral resonators operating in sub-GHz range," in Proc. IEEE Int. Conf. RFID Technol. Appl. (RFID-TA), Sep. 2019.
[4]. X. Li, M. Jalilvand, Y. L. Sit, and T. Zwick, "A compact double-layer on-body matched Bowtie antenna for medical diagnosis," IEEE Trans. Antennas Propag., vol. 62, no. 4, pp. 1808–1816, Apr. 2014.
[5]. Amjad Iqbal, Muath Al-Hasan, Ismail Ben, Mabrouk, "Biotelemetry and Wireless Powering of Biomedical Implants Using a Rectifier Integrated Self-Duplexing Implantable Antenna".
[6]. A. S. M. Alqadami, K. S. Bialkowski, A. T. Mobashsher, and A. M. Abbosh, "Wearable electromagnetic head imaging system using flexible wideband antenna array based on polymer technology for brain stroke diagnosis," IEEE Trans. Biomed. Circuits Syst., vol. 13, no. 1, pp. 124–134, Feb. 2018.
[7]. A. Yadav, V. K. Singh, A. K. Bhoi, G. Marques, B. Garcia-Zapirain, and I. de la Torre Díez, "Wireless body area networks: UWB wearable textile antenna for telemedicine and mobile health systems," Microma chines, vol. 11, no. 6, p. 558, May 2020.
[8]. S.Diana, D.Brizi, C.Ciampalini, G.Nenna, "A compact double-ridged horn antenna for ultra-wide band microwave imaging, IEEE Trans.2021".
[9]. E.Razzicchia, Pan Lu,Wei Guo, "Metasurface Enhanced Antennas for Microwave Brain Imaging".
[10]. M. Grimm and D. Manteuffel, "On-body antenna parameters," IEEE Trans. Antennas Propag., vol. 63, no. 12, pp. 5812–5821, Dec. 2015.
[11]. R. Chandra, H. Zhou, I. Balasingham, and R. M. Narayanan, "On the opportunities and challenges in microwave medical sensing and imaging," IEEE Trans. Biomed. Eng., vol. 62, no. 7, pp. 1667–1682, Jul. 2015.
[12]. S. Hall and Y. Hao, Antennas and Propagation for Body-Centric Wireless Communications. Norwood, MA, USA: Artech House, 2012.
[13]. M.Berg, T. Tuovinen, and E. T. Salonen, "Low-profile antenna with opti mal polarization for 2.45 GHz on-body sensor nodes," in Proc. Lough borough Antennas Propag. Conf. (LAPC), Nov. 2014, pp. 641–643.
[14]. A. Lea, P. Hui, J. Ollikainen, and R. G. Vaughan, "Propagation between on-body antennas," IEEE Trans. Antennas Propag., vol. 57, no. 11, pp. 3619–3627, Nov. 2009.