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Design of Miniaturized Printed Spiral Monopole Antenna

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ABSTRACT

This paper introduces the design, simulation and implementation of miniaturized printed monopole antenna for medical application. FR-4 substrate with dielectric constant 4.3, and thickness 0.8 mm has been used. The proposed antenna operates in Medical Implant Communication System (MICS) band. It has a spiral shape with an overall dimension of (9x9x0.8) mm³. The proposed antenna was simulated and evaluated using CST microwave studio package. The simulation results show that the designed antenna operates at a frequency of 401.3MHz with return loss of (-10.904dB) and band width (3.9 MHz). The proposed antenna structure was fabricated and experimentally tested. Results of simulation and implementation show that the proposed antenna possesses a miniaturized dimensions and acceptable performances, enabling their use in medical applications.

1. Introduction

The development of health care is due to the prosperity of Wireless Body Area Networks (WBAN), and this development in turn provides ubiquitous health monitoring by virtue of wearable or implantable sensor nodes that commonly monitor biological signals. Medical applications are of great importance today as they provide continuous monitoring of the patient with the help of sensor nodes that can be warbled or implanted [1].

Many frequencies have been developed for the purpose of exploring and marketing communication systems(WBAN) such as Scientific and Medical (ISM) band(433MHz,915MHz,2.4GHz,...etc) Ultra-wideband (UWB) 3.1-10.76GHz, the Medical Implant Communication Services (MICS) band (402-405)MHz, and others [2-4].

The antennas are the most important part of these systems that must have special characteristics in order to capture the electromagnetic waves, these characteristics or features involve Omni-directional radiation, moderate gain, high radiation efficiency, and ultra-wide bandwidth.

Omni-directional radiation lets the antenna to accept electromagnetic waves from all directions, which is active parameter in the monitoring system. Moderate gain and high radiation efficiency are necessary for the receiving of high-quality signals that help the accurate detections of the electromagnetic waves. Ultra wide bandwidth antennas help the system to monitor a large range of the spectrum with minimum equipment by using fewer antennas leading to less complex portable stations that are capable of monitoring the usage of a large range of the spectrum.

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Antennas in medical devices (wearable and implantable) Characterized by its small size, therefore designer must be focus on how to miniaturize it with maintaining its good performance.

There are several methods used to reduce the antenna size, and each method has advantages and disadvantages, which we will obtain at later chapter. However, the antenna design is very challenging due to several constraints; the antenna should be small enough to be inserted into the human body and have broadband characteristics to operate in the various tissue layers. Occasionally, the antenna may be required for multiband operation. One of the most space-taking antennas in the design of the implantable antenna is the, planar patch where it took great care due to the ease of design, conformity, and flat shape that makes it suitable for most implanted and wearable devices [5-7].

In 2008, Karacolak et al. [8] proposed small size implantable meander line antenna for continuous glucose-monitoring needs, antenna dimension are $(22.5 \times 22.5 \times 2.5 \text{ mm}^3)$ operating in dual band frequency MICS (402–405 MHz) and ISM (2.4–2.48 GHz) bands. In 2011, Huang et al. [9] proposed an antenna design operating on three bands (MICS) band at 402 MHz, and (ISM) band at 433 MHz and 2.45 GHz) antenna has a small size of $(10 \text{ mm} \times 10 \text{ mm} \times 2.54 \text{ mm}^3)$. In 2013, Alrawashdeh, et al. [10] introduced a flexible meandered loop antenna covered the (MedRadio) and (ISM 433–434 MHz), with dimensions of $(180 \times 100 \times 50) \text{ mm}^3$. In 2013 SONDAS et al. [11] introduce an implantable microstrip antenna operating in MICS (402–405 MHz) band for biomedical telemetry applications. In 2015, Muhammad, et al. [12] proposed the Design of Miniaturized Implantable Antenna operating in dual band (MICS,403MHz) and (ISM,2.45GHz) Bands with overall dimension

of the purpose antenna are $(15 \times 18 \times 1.97) \text{ mm}^3$. In 2018 Kumar, et al. [13] introduce the design of CPW-fed monopole antenna for diagnosis applications covers almost all bands used in (WBAN) applications ,such as (ISM, 2.4–2.485 GHz) ,(MICS,402_405MHz) and (WMTS, 420–1430MHz) with dimensions of $(24 \times 18 \times 1.6 \text{ mm}^3)$. In 2019 KETAVATH, et al. [14] introduced monopole rectangular implanted antenna with three (SSR) and a rectangular slot with CPW feeding operating at ISM band (2.45GHz) with dimensions of $(24 \times 22 \times 0.07) \text{ mm}^3$. In 2019 Li , et al. [15] introduce the design of Miniature patch implanted antenna operates on frequency (MedRadio) band (401–406 MHz) with dimensions of $(23 \times 16.4 \times 1.27) \text{ mm}^3$. In 2020 SMIDA, et al. [16] introduced a Wideband Wearable Antenna of rectangular shape with modified patch and ground. The antenna operates at frequency 2.4 GHz with dimensions of $(17 \times 25 \times 0.787 \text{ mm}^3)$. Most of the antennas proposed in literature have large dimension and complex shape. Therefore, the main purpose of this study is to reduce the size of antenna as much as possible at suitable operating frequency band.

2. ANTENNA DESIGN

2.1. Primary Antenna Structure

The Printed Spiral Monopole Antenna (PSMA) was used as primary antenna structure consists of spiral patch with space between each slot (0.11mm), while the ground is rectangular shape with dimensions $(W_{\text{sub}} \times L_g)$, and feed line dimension is $(L_f \times W_f)$ printed on FR-4 substrate with a dielectric constant of $(\epsilon_r=4.3)$, and a thickness of (0.8 mm). The dimensions of the radiator were chosen using the parametric study to

achieve lower resonance frequency around (MICS, 405MHz).

The geometry of the antenna is illustrated in Figure -1 and the dimensions in Table1.

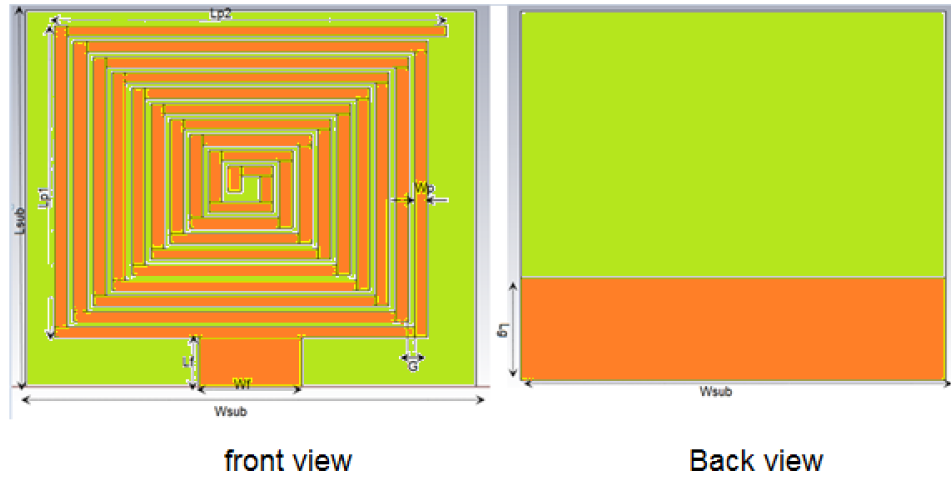


Figure -1: primary design of printed spiral monopole antenna.

Table -1: Dimensions of primary design of PSMA.

Dimension	Description	Value (mm)
Lsub	The length of the substrate	7
Wsub	The width of the substrate	7.25
h	Thickness of substrate	0.8
t	Thickness of patch	0.035
Lg	Length of ground plane	2
Lf	Length of the feed line	0.95
Wf	The width of the feed line	1.6
Lp1	Length of patch slot	6
G	Width of gap between slot	0.2
Lp2	Length of patch slot	6.1

The return loss response of primary design shown in Figure -2 illustrate that the antenna operate on single band (576 MHz) with return loss around -10 dB. The operating frequency of

this structure is far from the required, so that some changes were applied in order to obtain the required results.

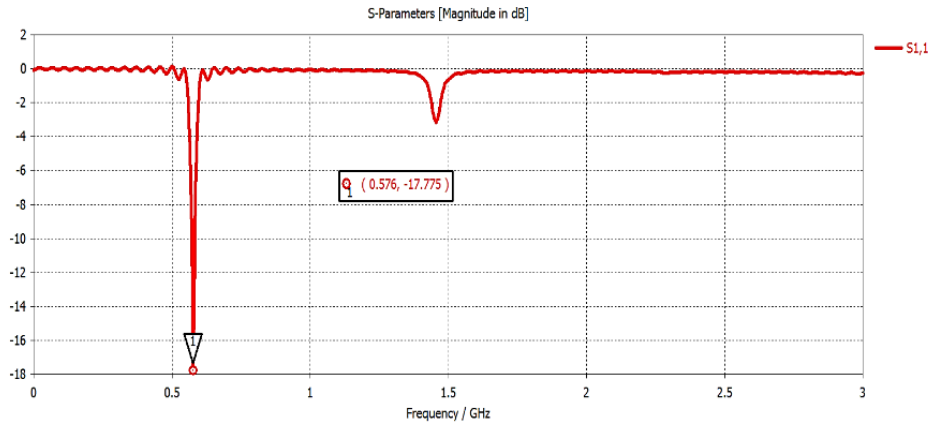


Figure -2: primary antennas return loss.

2.2. Proposed Antenna Structure.

There are several modifications that are made to the antenna, such as ground plane, overall dimension, and radioactive patch in

order to obtain the required results and the required performance.

The final geometry of the proposed antenna geometry and dimensions are shown in Figure 3 and Table -2 respectively.

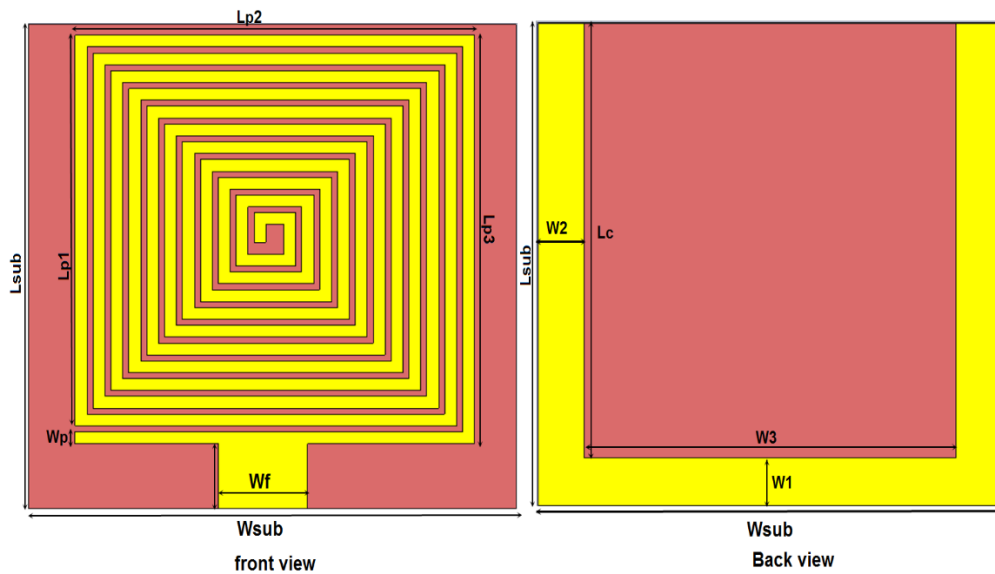


Figure -3: Final geometry of the proposed PSMA.

Table -2: Dimensions of the proposed PSMA.

Dimension	Description	Value (mm)
Lsub	The length of the substrate	9
Wsub	The width of the substrate	9
H	Thickness of substrate	0.8
T	Thickness of patch	0.035
Lf	Length of the feed line	1.21
Wf	The width of the feed line	1.65
S	Width of gap between slot	0.11

WP	Width of patch slot	0.22
Lp1	Length of left outer patch slot	7.26
Lp2	Length of top outer patch slot	7.37
Lp3	Length of right outer patch slot	7.59
W1	Width of lower ground slot	0.9
W2	Width of left ground slot	0.9
W3	Width of cutting ground	7.2
Lc	Length of cutting ground	8.1

Table -2 shows the optimum dimension of proposed antenna. This antenna operates on (MICS) band. The overall dimensions of the antenna are $(9 \times 9 \times 0.8) \text{ mm}^3$.

2.3. Simulation Result

Figure -4, shows the return loss of the optimum dimension of proposed antenna. The proposed antenna operating in MICS band (405MHz) with return loss less than -10dB (-10.904) with band width of 3.9MHz which is an acceptable result.

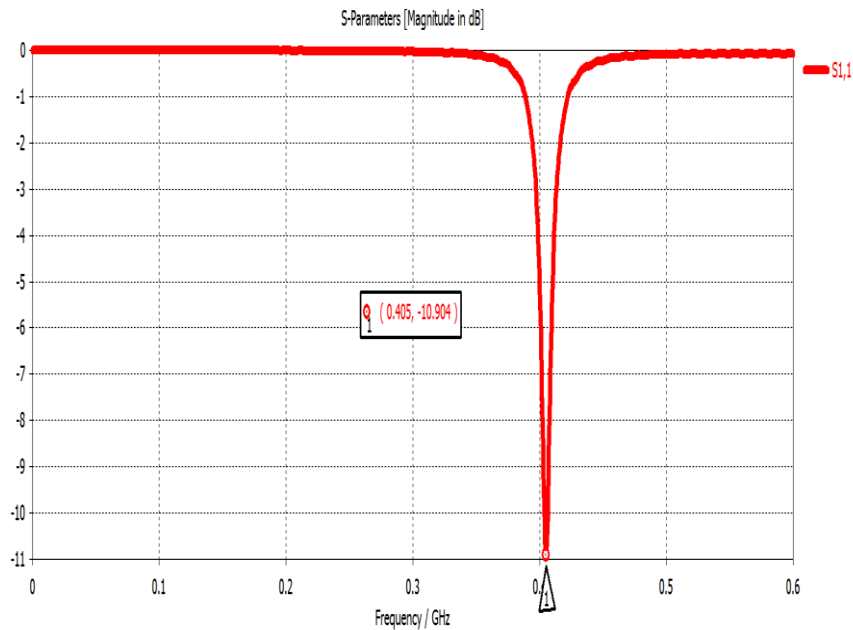


Figure -4: return losses after modifies radiator patch and ground.

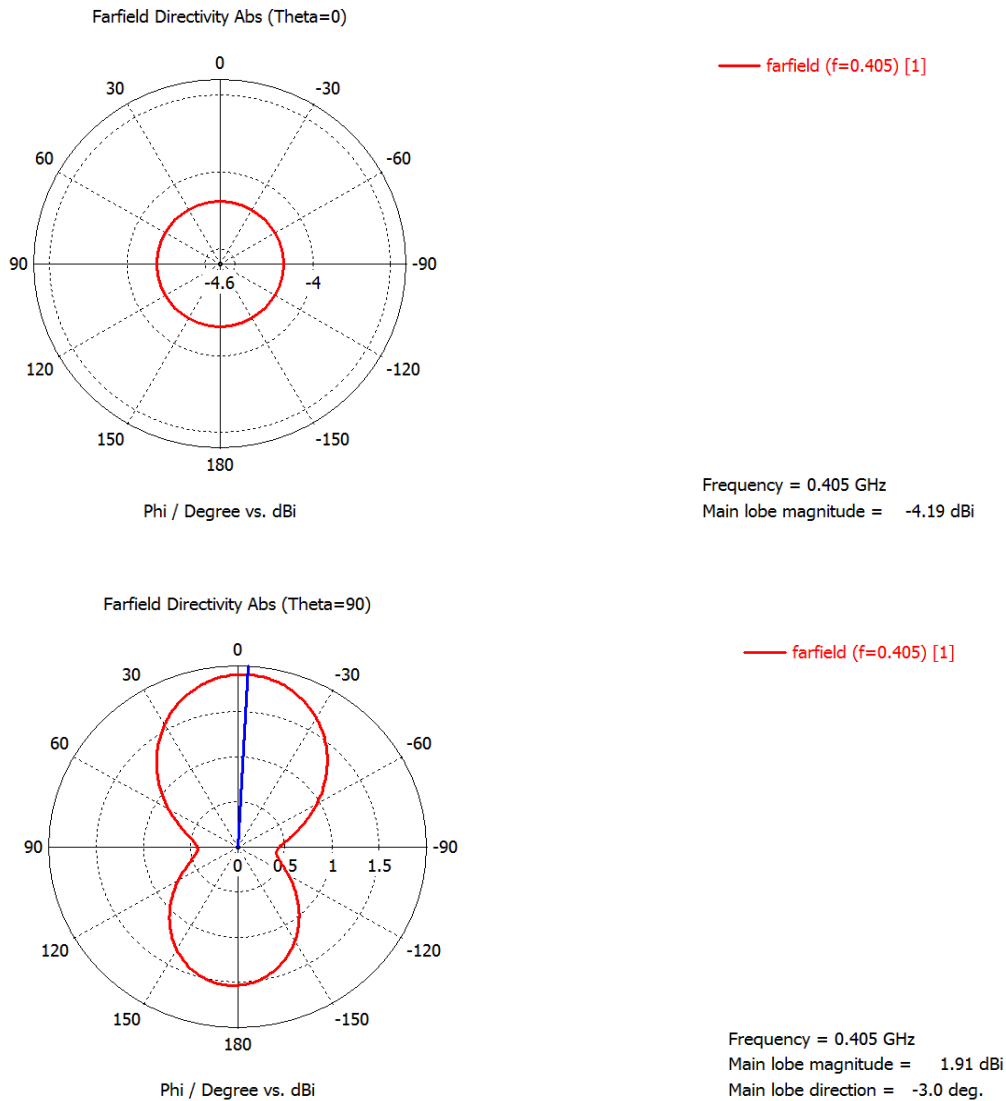


Figure -5: 2-D radiation pattern of the far field directivity for the proposed PSMA (Phi, theta = 90).

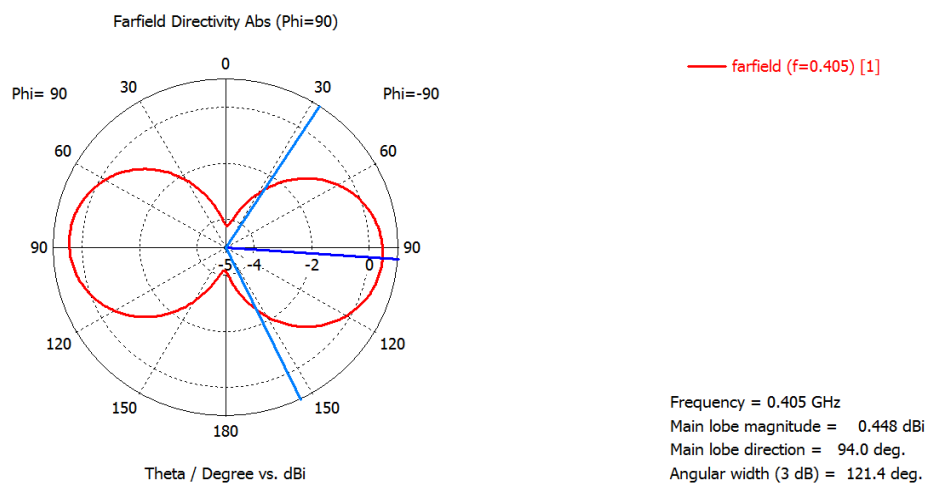


Figure -6: 2-D radiation pattern of the far field directivity for the proposed PSMA (Phi, theta = 0).

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The 3-D radiation pattern of the far field directivity and the surface current distribution for the suggested PSMA are illustrated in Figures 7 and 8 respectively.

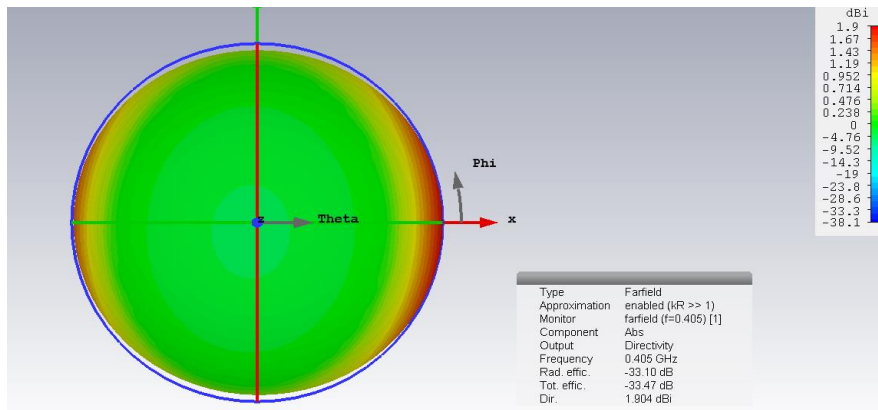


Figure -7: 3-D pattern of the far field directivity for the proposed PSMA.

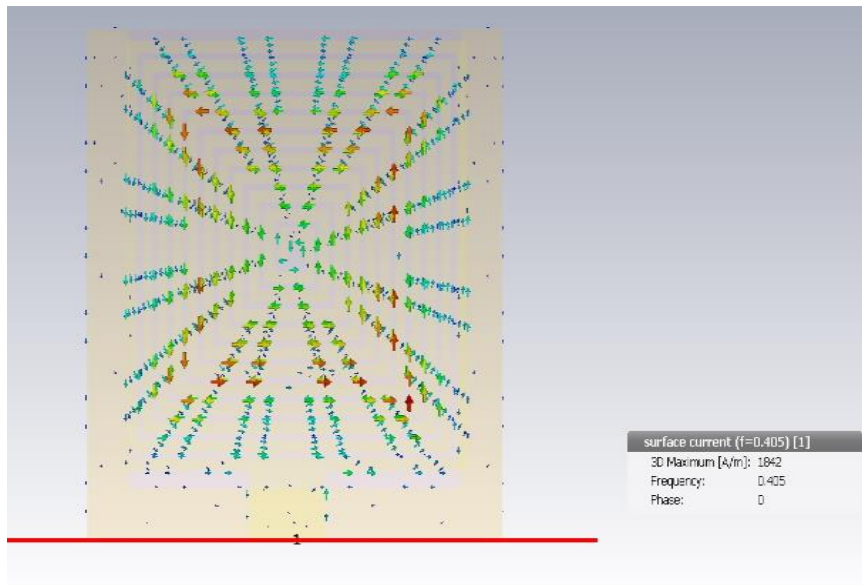


Figure -8: The surface currents for the fundamental frequency and the higher order harmonics of the proposed PSMA.

3.MEASUREMENT RESULT

The PSMA design shown in Figure -3 with the dimensions in Table -2 was fabricated using FR4 substrate of 0.8 mm thickness as shown in Figure -9.

The measurement results of the tested prototype show that the antennas resonate at (401.3MHz) with return loss of (-11.838dB) as shown in Figure -10. There is an acceptable slight difference between the simulation and practical results due to the manufacturing process.

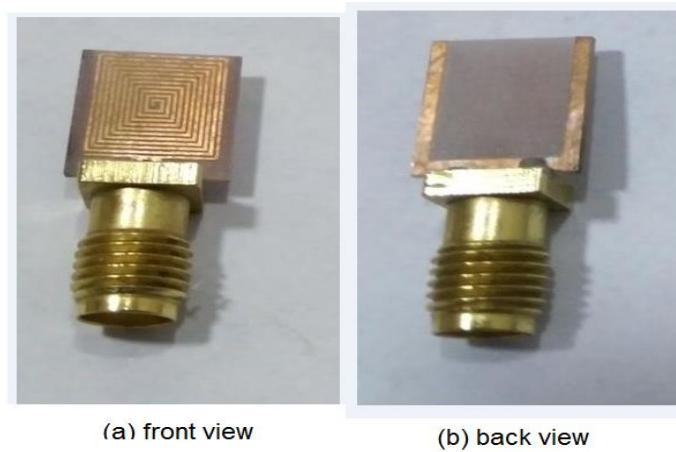


Figure -9: Fabricated PSMA.

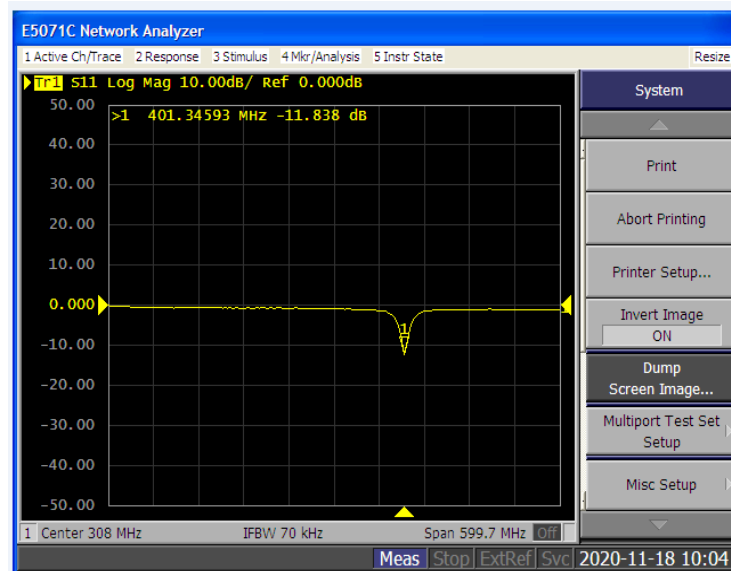
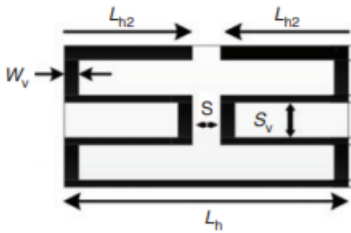
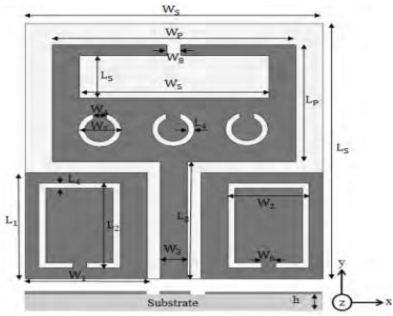
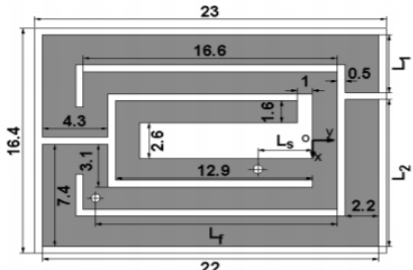
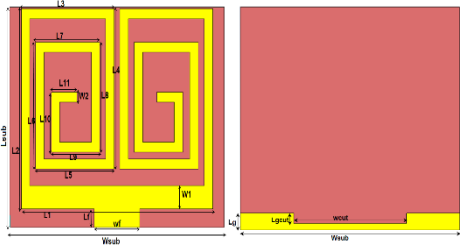
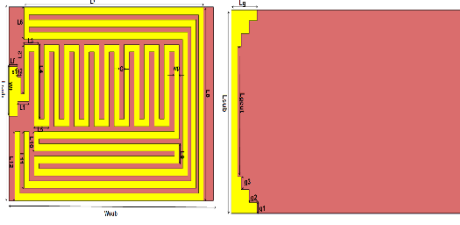


Figure -10: results of the fabricated PSMA.

4. COMPARISON WITH OTHER WORKS

Many antennas have been designed for medical applications. These antennas differ from each other in terms of size, shape, and frequency band and bandwidth. Table - 3 will provide a comparison between these antennas and the antennas designed in this work.

Table - 3 Comparison between the designed antenna and other works

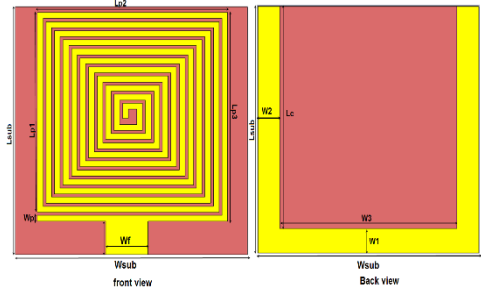
Ref.	Freq. & BW	size	S11	gain	Figure
[10]	433–434 MHz	$(180 \times 100 \times 50) \text{ mm}^3$	-28 dB	-28.4 dB	
[14]	2.4GHz BW = 400 MHz	24 x 22 mm^2	-27.5 dB	-19.6	
[15]	401–406 MHz BW = 52 MHz	$(23 \times 16.4 \times 1.27) \text{ mm}^3$	-25 dB	-34.9 dB	
[17]	2.406GHz BW = 44.021 MHz	$7.5 \times 6.6 \times 0.8$ mm^3	-14.7 dB	-13.92 dB	
[18]	915MHz BW = 20.377 MHz	$12.25 \times 7.81 \times 0.8$ mm^3	-11.71 dB	-18.1dB	

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In this work	405 MHz BW = 3.9 MHz	9×9×0.8 mm ³	-10.9 dB	-31.21 dB	
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The comparison shows that the proposed antenna has the minimum size compared with others in the lower band (405 MHz), where the size is an important parameter.

5. Conclusions

A miniaturized printed monopole antenna has been proposed in this paper. This antenna operates at the Medical Implant Communication System (MICS) band (401.3MHz) and bandwidth (3.9 MHz) with dimensions (9×9×0.8) mm³. Due to the small size, light weight, simple configuration and acceptable performance of the proposed antenna can be used for medical applications in either in wearable or implantable medical applications.

References

- [1] R. Punj et al., Technological aspects of WBANs for health monitoring: a comprehensive review” Wireless Networks, Issue 3/2019, springer, 2018.
- [2] International Telecommunications Union - Radio communications (ITU-R), radio regulations, section 5.138 and 5.150, ITU. Geneva, Switzerland.
- [3] S. Bakogianni et al. “An implantable planar dipole antenna for wireless med. radio-band biotelemetry devices”. IEEE Antennas and Wireless Propagation Letters 15, 234–237, 2016.
- [4] M. N. Islama et al., Review of Medical Implant Communication System (MICS) band and network, ICT Express, Volume 2, Issue 4, December 2016, Pages 188-194.
- [5] Z. Duan et al., Design and in Vitro Test of a Differentially Fed Dual-Band Implantable Antenna Operating at MICS and ISM Bands” IEEE Transactions on Antennas and Propagation, Vol. 62, No. 5, pp 2430- 2439, 2014.
- [6] A. Basir et al., A dual-band implantable antenna with wide-band characteristics at MICS and ISM bands” Microw. Opt. Technol. Lett., Vol. 60, pp 2944–2949, 2018.
- [7] A. EM. Mohammad et al., Implanted dual-band circular antenna for biomedical applications” Microw. Opt. Technol. Lett., vol. 60, pp1125–1132, 2018;.
- [8] T. Karacolak et al., Design of a Dual-Band Implantable Antenna and Development of Skin Mimicking Gels for Continuous Glucose Monitoring” IEEE Transaction on Microwave Theory and Techniques, Vol. 56, No. 4, pp1001-1008, 2008.
- [9] Fu-J. Huang et al., Rectenna Application of Miniaturized Implantable Antenna Design for Triple-Band Biotelemetry Communication” IEEE Transactions on Antennas and Propagation, Vol. 59, No. 7, pp 2646-2653, 2011.
- [10] R. Alrawashdeh et al., Flexible meandered loop antenna for implants in MedRadio and ISM bands Electronics Letters, Vol. 49, No. 24, pp. 1515–1517, 2013.
- [11] A. Sondas et al., An implantable microstrip antenna design for MICS-band biomedical applications, Turk J Elec Eng & Comp Sci, pp 2267- 2273, 2013.
- [12] M. A. Babar Abbasi et al., Design and Optimization of Miniaturized Dual-band Implantable Antenna for MICS and ISM Bands” PIERS Proceedings, pp 738-741, 2015.
- [13] A. Kumar et al., Design of a printed symmetrical CPW-fed monopole antenna for on-body medical diagnosis applications, Journal of Computational Electronics, 2018.
- [14] K.N. Ketavath et al., In-Vitro Test of Miniaturized CPW-Fed Implantable Conformal Patch Antenna at ISM Band for Biomedical Applications, IEEE, Vol.7, pp 43547-43554,2019.
- [15] R. Li, B. Li, G.Du, X. Sun and H. Sun” A Compact Broadband Antenna with Dual-Resonance for

- Implantable Devices” *Micromachines* 2019, Vol. 10, No. 59, 2019.
- [16] A. Smida et al., Wideband Wearable Antenna for Biomedical Telemetry Applications, *IEEE Access* · January 2020, Vol. 8, pp15687-15694.
- [17] A. R. Kamel et al., Design of Miniaturized Implantable Printed Spiral Antenna for Medical Application, Middle Eastern Simulation and Modeling (MESM) Conference, 2022.
- [18]] A. R. Kamel et al., Design of Miniaturized Printed Antenna for Medical Applications, *International Journal of Current Engineering and Technology*, Vol. 10, No. 6, 2020.