Conference Paper

A High Gain Flexible Antenna for Biomedical Applications

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***Abstract* — In this paper, a miniaturized antenna is presented for biomedical applications due to its flexibility. The proposed antenna operates in the Industrial, Medical, and Scientific (ISM) 24.00 GHz to 24.25 GHz band. This antenna consists of a radiating element with circular and rectangular slots and the ground with cross plus four square slots. The dielectric material Rogers RO3003 with permittivity of 3, is used for substrate and superstrate. The miniaturization of the antenna is achieved by shorting pin and some other techniques. The total volume of the designed antenna is (6.8×6.8×0.26) mm^3. The maximum gain achieved by the simulation of the proposed antenna is 5.44 dB at 24.25 GHz, and at the start of the band, the gain is 4.9 dB at 23.98 GHz, and at the end of the band, the gain is 5.1 dB at 24.47 GHz. The designed antenna has better results than the antennas discussed in the literature in terms of size, gain, and efficiency.**

Keywords: **Biomedical applications, ISM band, high gain, Compact antenna, flexible**

I. Introduction

From the past few years, biomedical devices are very much in demand from all the other instruments, and the implantable medical devices (IMD's) are on the top of the list. With the help of these devices, the treatment becomes more efficient, fast, and precise. The IMD's also help us to diagnose the disease, the information can be collected through antennas used in the IMD, but apart from this, it is not easy to design miniaturized antenna; the IMDs face many challenges such as miniaturization, gain, and patient safety. We need many techniques to minimize the size of an antenna, e.g., use of shorting pin between the ground surface and radiating surface and by doing several changes in ground and radiating surface.

A novel differentially fed compact dual-band implantable antenna is discussed in [1], for biotelemetry applications. Still, the size of the differentially fed compact antenna is 642.62 mm^3. And, it is large for implantation purposes so that the gain achieved by the compact antenna is -36.7 dB at medical implant communication service (MICS) band 402-405 MHz and -27.1 dB at Industrial, scientific and medical (ISM) band 2.4 GHz. An implantable planar dipole antenna is designed for bio-telemetry devices. The planar dipole antenna has a maximum volume of 18.1 mm^3, and the highest achieved gain is -29.4 dB in [2]. A single fed wide beamwidth circularly polarized antenna has been proposed for subcutaneous real-time glucose monitoring applications in [3]. The wide beamwidth circularly polarized antenna has a maximum volume of (8.5×8.5×1.27) mm^3 and having the peak gain of -17 dBi with a covered bandwidth of 300 MHz. A miniaturized novel-shape dual-band antenna for implantable applications having a volume of (7×7.2×0.2) mm^3 is discussed in [4]. The maximum gain achieved by dual-band antenna is -28.44 dB for 928 MHz and -25.65 dB for 2.45 GHz band.

The high gain antenna is designed for biomedical applications for 2.4 GHz ISM band, with -12.98 dB gain and 660 MHz bandwidth in [5], and a wideband implantable antenna has also been discussed in [6] for telemetry applications with 156 MHz bandwidth and -24.9 dB gain. A miniaturized wideband implantable antenna with -12 dB gain and 483 MHz bandwidth is considered for biomedical applications in [7]. A compact wideband antenna having a bandwidth of 420 MHz and a gain of -15 dB is intended in [8] for biotelemetry. The total volume of all the implantable antennas discussed in [5] - [8] is 9.8 mm^3.

The proposed antenna is novel due to its flexibility, size and bio compatibility, it has a dimension of (6.8×6.8×0.26) mm^3, and this proposed antenna operates in the industrial, scientific, and medical band (24.00 - 24.25) GHz, which gives the highest gain of 5.44 dB at 24.25 GHz. The paper is divided into the following sections. Section-I consists of the literature review. In section-II, the antenna design procedure will be discussed. In section-III and section-IV, results and conclusion will be elaborated respectively.

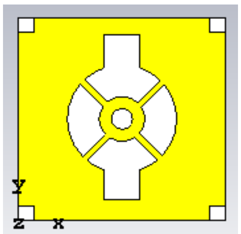
II. Antenna Design

Fig. 1 shows the proposed antenna ((a) front, (b) back, and (c) side view), and the proposed antenna has attained high gain with the small volume of (6.8 × 6.8 × 0.26) mm^3. Fig. 1 (c) shows the side view of stacked four layers, from top to bottom, first and third layers are of dielectric material for superstrate and substrate. The second and fourth layers are of conducting material for radiator and ground, respectively. The dimensions of the proposed antenna with radiator and ground plane are presented in Fig. 2. In Fig. 3, the desired bandwidth is achieved by cutting the radiating body in different shapes; moreover, shorting the ground plane with the radiating plane is the best technique to achieve high gain, and we use this too. More techniques are discussed in [5] -

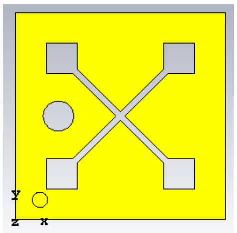
[8] for fast and accurate gain in miniaturized antenna. Rogers RO3003 with a thickness of 0.13 *mm* is used as a dielectric in the substrate, as its thickness is minimal, the antenna gives us maximum flexibility. The height width ratio equation is used to design the antenna.

$$\left(\frac{\Delta L}{h}\right) = 0.412 \times \frac{(\varepsilon_r + 0.3) \times \left(\frac{W}{h} + 0.264\right)}{(\varepsilon_r - 0.258) \times \left(\frac{W}{h} + 0.8\right)}$$

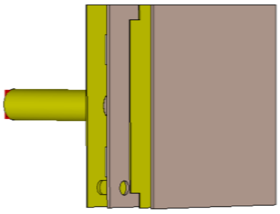
The above equation shows the height-width ratio, where ΔL is the increment of patch length due to the fringing effect, h is the height of a substrate, ε_r is the relative permittivity of the dielectric material used, and W is the width of the patch/radiator.



(a) Front view

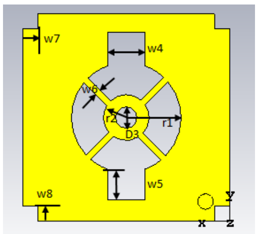


(b) Back view

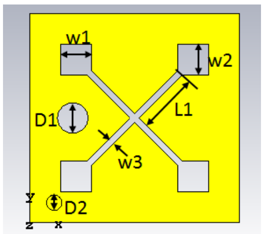


(c) Side view

Fig. 1. Proposed antenna with front, back, and side view



(a) Front view



(b) Back view

Fig. 2. The dimensions of the proposed antenna

This proposed antenna is fed by 50Ω coaxial feed at the most left corner of the circular slot with a diameter of coaxial cable is 1 *mm*. The dimensions of the proposed antenna, as mentioned in Fig. 2, are given in Table I.

TABLE I. ANTENNA PARAMETERS

Parameter	Value (*mm*)	Parameter	Value (*mm*)
w_1	1	w_2	1
w_3	0.2	D_1	1
w_4	1.2	D_2	0.5
w_5	1.0	D_3	0.7
w_6	0.2	r_1	1.8
w_7	0.5	r_2	0.75
w_8	0.5	L_1	1.98

III. Parametric Analysis

In this section, the proposed antenna is discussed by stepwise terminology. In the first step, the antenna is designed for the said ISM band, which has to be more compact than in literature, but in this step, we got the 13 GHz band (12.75 GHz – 13.25 GHz), which does not lie in our requirement. So, we move to the next step of introducing the shorting pin, which connects the radiator and ground plane directly, and this technique is used for the miniaturization of the antenna. In Fig. 3, the blue curve has a resonance frequency of 24.6 GHz, we have to move this to 24 GHz. In the final step, we placed a superstrate exact on the radiator to enhance the gain of the antenna and the shifting of resonance band to the desired range.

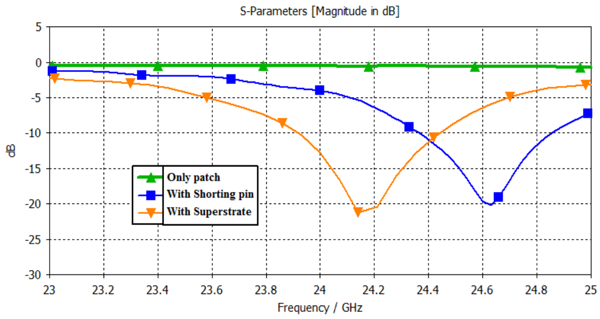


Fig. 3. Reflection coefficients of stepwise antenna

IV. Results

This section discusses the results achieved by the proposed design. Different parameters, such as reflection coefficient, far-field radiation pattern at the resonance frequency, gain, and surface current, are discussed. The reflection coefficient is given in Fig. 4, which shows a wideband of 488 MHz, also covers the desired bandwidth of 24 GHz to 24.25 GHz ISM band. The radiation pattern of this proposed antenna is directional, and it is shown in Fig. 5, and the highest gain achieved by this proposed design, which is 5.44 dB at the resonance frequency. The graph of maximum to minimum realized gain of the proposed antenna throughout the covered bandwidth is shown in Fig. 6.

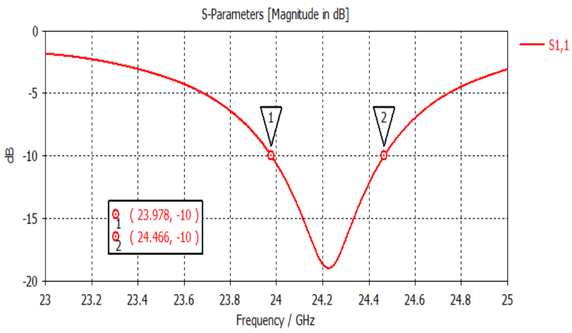


Fig. 4. The reflection coefficient of the proposed antenna

TABLE II. Comparison of Proposed Antenna with Previously Published Work

Ref.	Frequency (MHz)	Bandwidth (MHz)	Gain (dBi)	Dielectric Material	Volume(mm^3)
[1]	402-405, 2400-2480	30, 168	-36.7, -27.1	Rogers 3010	642.62
[2]	401-406	~90	-29.4	Rogers RT 6010	18.1
[3]	2400-2480	300	-17	Rogers 3210	91.76
[4]	902-928, 2400-2484	197.6, 245.3	-28.44, -25.65	Rogers ULTRALAM	10.08
[5]	2450	660	-12.98	Rogers ULTRALAM	9.8
[6]	928	156	-24.9	Rogers ULTRALAM	9.8
[7]	2450	483	-12	Rogers ULTRALAM	9.8
[8]	2450	420	-15	Rogers ULTRALAM	9.8
This work	24000-24500	488	5.44	Rogers RO3003	12.02

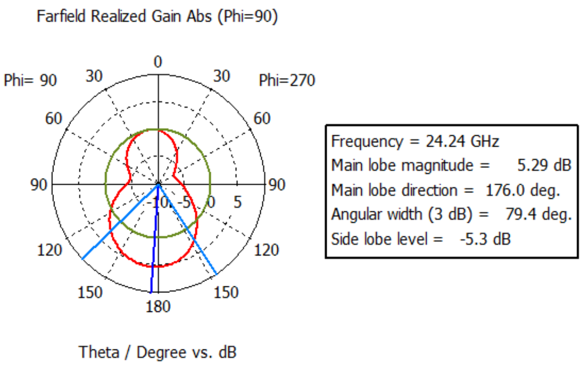


Fig. 5. The radiation pattern of the proposed antenna

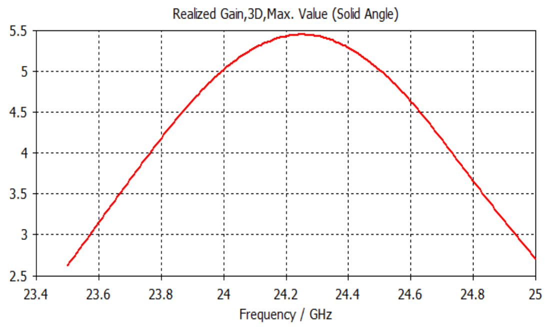


Fig. 6. The realized gain of the proposed antenna throughout the band

Another fundamental characteristic of the antenna is the surface current of radiating material, surface current of the proposed antenna design is shown in Fig. 6, and the current distribution is more excellent at the right side of the circular slot. This antenna is wideband and covers almost 489 MHz from (23.978 to 24.466) GHz. This advanced design is suitable in size, bandwidth, and the gain than the antennas discussed in the literature. The comparison of the proposed antenna with previously published antennas is elaborated in Table II, which shows the highest gain than already published antennas. Still, this antenna is operated at a higher frequency than previous work performed at a lower ISM band. The designed purpose of this antenna is to communicate only on the body area network; this will give us the minimum distance as we need for in body to on-body communication with low power and higher data rate.

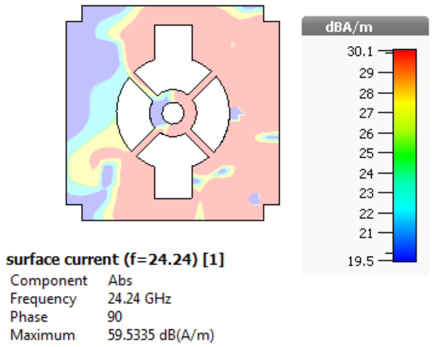


Fig. 7. Surface current at the resonance frequency of 24.24 GHz

V. Conclusion

The proposed antenna consists of ground with rectangular slots, substrate, superstrate, and patch with circular, rectangular slots and shorting pin. Cutting slots and the pin is used to minimize the size of the antenna for the better placement within and outside the human body. It is obvious that when we insert the antenna within the human body size must be minimized so that there will be no difficulty. At such a small size achieving high gain is a big challenge; this is done by cutting the plane and shorting pin. The total volume of the proposed antenna is $(6.8 \times 6.8 \times 0.26)$ mm^3, and the maximum gain achieved by the proposed antenna design is 5.44 dB. The proposed antenna is operating at the ISM band. This antenna is used for implantation in the human body and also in other biomedical applications to monitor human health.

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