Compact Dual-Mode Single-Band Microstrip Antenna for Body Area Network Applications

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***Abstract*— A dual mode microstrip patch antenna operating at 2.45 GHz is presented in this article. The design and analysis of the proposed antenna with two modes that is on-body and off-body is accomplished by ANSYS HFSS Electromagnetic software. The on-body mode is obtained with the help of square-ring patch, whereas the off-body is achieved with slotted circular patch placed inside the square-ring patch. Both the patch antennas are independently fed, but share a common ground plane among them. Radiation pattern, S-parameter, radiation efficiency of the proposed antenna have been presented here. The antenna can be suitable for body area network applications in the industrial, scientific, and medical band(ISM).**

Keywords—Dual mode, body area network (BAN), on-body, off-body.

I. Introduction

In recent years, there have been many breakthroughs in the field of wireless technology which has led to development of body area networks. There are wide ranging applications of BAN's, namely smart homes, navigation and identification systems [1]. But the medical field has the most potential applications of BAN's, where different kinds of network nodes are scattered along the human body to monitor various health parameters.

For this purpose, two different modes of communication are proposed [2]. First mode is the on-body mode where the antenna communicates with network nodes placed along the human body [3]. The second mode is off-body mode which is used to communicate with nearby external devices. In this mode the antenna is required to exchange data with the network nodes placed outside or away from the human body [2].

In this paper a dual mode antenna is designed, that can operate in either of the modes depending on the requirement. For the on-body mode, omnidirectional radiation pattern similar to a monopole antenna is preferred, whereas for off-body a bit more directive type or a broadside radiation pattern is required. Hence for different modes, a different type of radiation pattern is required. The proposed dual mode antenna can satisfy both of the radiation pattern requirement in the ISM band (2.45GHz). Few research articles of dual mode antenna have been presented in [4] and [5]. In the proposed structure square-ring patch and slotted circular patch has been used for on- and off-body modes respectively. The antenna can be suitable for applications in ISM band.

Antenna geometry and design of the proposed structure are presented in section II. Simulated results are shown in section III followed by the future work and conclusion in section IV, V respectively.

II. Antenna Geometry

The dual mode antenna design has been presented in Fig. 1, comprises of two different antennae: square-ring patch antenna and slotted circular patch antenna. The antenna structure comprises of substrate, ground plane and antenna patches which are fed with the help of coaxial feed lines.

Here, 1.6 mm thick high permittivity Rogers RT 6006 material with $\varepsilon_r = 6.15$ and $tan\,\delta = 0.0019$ is used as the substrate. The square-ring and slotted circular patch are placed on top of this substrate. The antennas were designed for 2.45 GHz and optimized subsequently. The slotted circular patch is placed inside the square-ring patch. The dimensions are adjusted in order to obtain less mutual coupling between the two patch antennas.

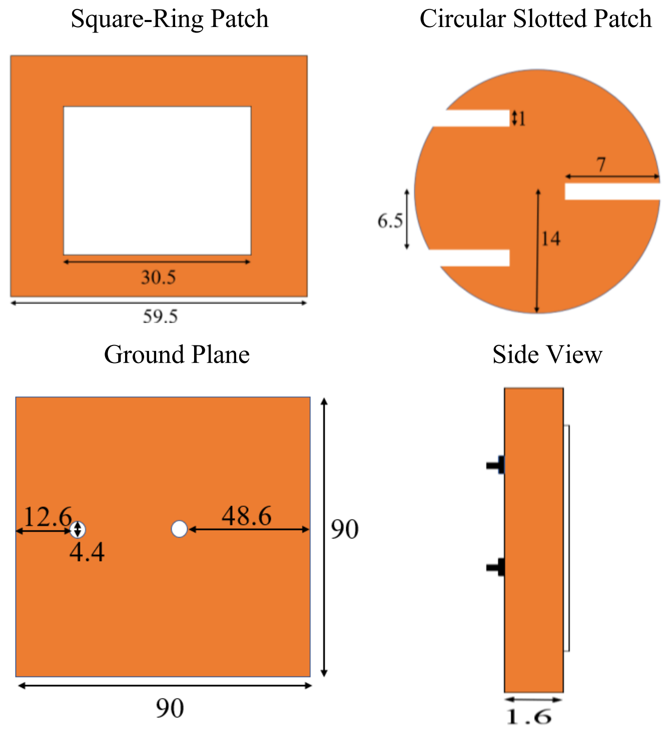


Fig. 1. Antenna Geometry (in mm)

The dimensions of the outer and inner boundary for the square ring are 59.5mm and 30.5mm respectively. The circular slotted patch has a radius of 14mm, with slot width 1mm and slot length of 7mm. One slot is placed at the centre, the other two slots are placed at a distance of half the radius from the center. The slots help to lower the resonant frequency of the patch for a given size. Both the radiating elements share a common ground plane which is placed at the bottom side of the substrate. The antennas are independently fed with the help of coaxial probes. The location of the feed point for the square ring patch is determined using [6]:

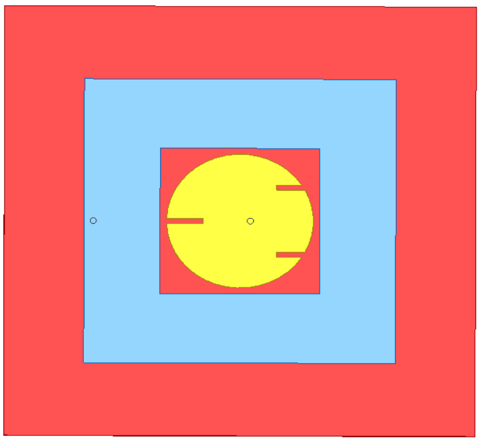
$$X_f = L/\sqrt{\epsilon_{reff}} \quad (1)$$

$$Y_f = W/2 \quad (2)$$

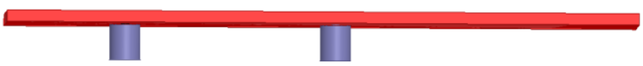
The proper impedance matching for the square ring is obtained at 28mm from the centre. And for slotted circular patch, the feed is initially placed at centre and then parameterized. Optimum impedance matching is obtained at a distance of 2mm from centre. The coaxial probe provides 50Ω matching to both the antenna patches. The outer probe is surrounded by Teflon ($\varepsilon_r = 2.1$). The outer and inner diameters of the probes are determined by [7]:

$$Z_0 = 138 \log_{10}\left(\frac{D}{d}\right)/\sqrt{\epsilon_r} \quad (3)$$

With the help of above design parameters, analysis of the patch antenna has been performed using ANSYS HFSS Version 15 software. The geometry of the proposed antenna designed in HFSS is shown in Fig. 2.



(a)



(b)

Fig. 2. Geometry of the designed antenna in HFSS (a) Top View (b) Side View

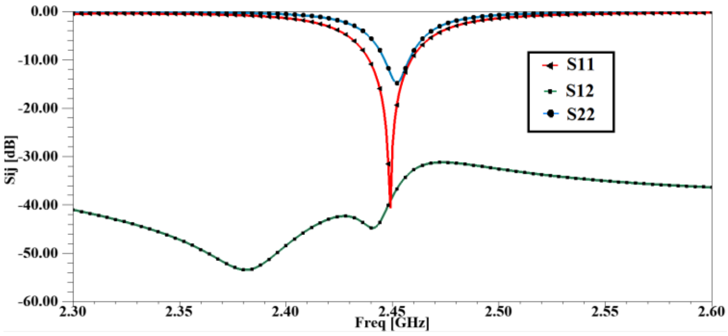


Fig. 3. Simulated S-Parameter of the Dual mode patch antenna in free space

III. Simulation Results

The analysis of various parameters of simulation results for the proposed antenna is described as below:

A. S-parameter

In Fig. 3, it is observed that $S_{11} > -25dB$, where S_{11} represents the S-parameter of square ring patch antenna. The S-parameter of slotted circular patch is approximately $-12dB$ where, $S_{22} > -10dB$. The simulation results show that the resonance occurs at 2.45 GHz. Fig. 3 also shows that the mutual coupling between the two antennas is low, that is $S_{12} > -30dB$ in the ISM band.

TABLE I

Comparision of Simulated Parameters of On-body and Off-body Mode (at 2.45 GHz)

Parameter	On-body	Off-body
S-Parameter	-27.6 dB	-13.9 dB
Realized Gain	1.2	3.2917
Efficiency	83.42	82.7

B. Radiation pattern

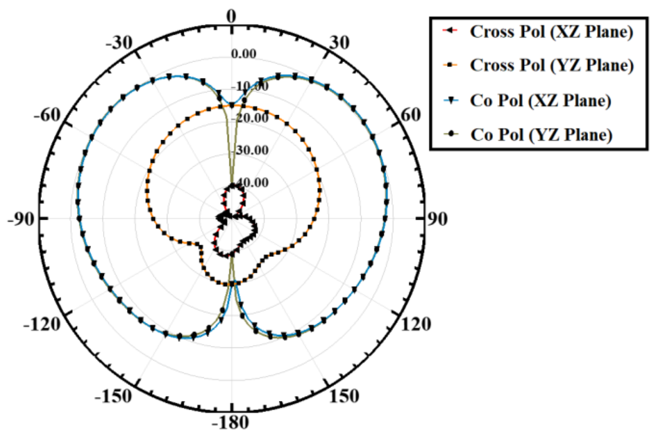


Fig. 4. Simulated radiation pattern for on-body mode in free space.

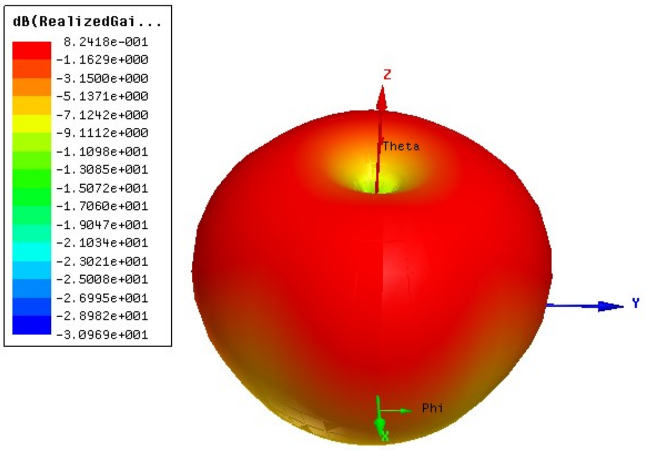


Fig. 5. Simulated 3D polar plot for on-body mode in free space.

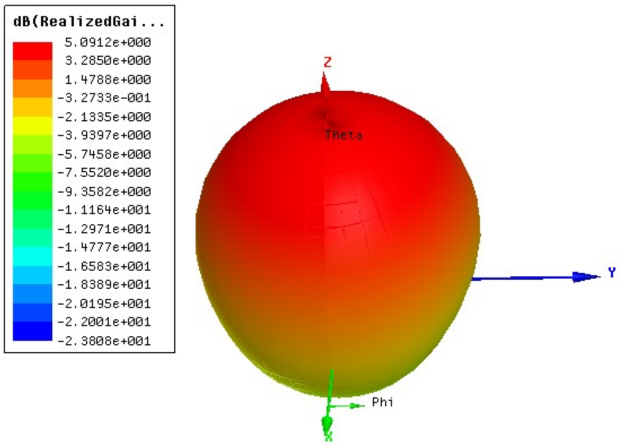


Fig. 7. Simulated 3D polar plot for off-body mode in free space.

Radiation pattern has been simulated for the two modes that is on-body mode and off-body mode respectively. Fig. 4 presents the radiation pattern for on-body mode. It shows the difference between co-polar and cross-polar radiation is more than 30dB, in all directions.

It also shows that the minima is in broadside direction and pattern obtained is similar to monopole antenna. The 3D polar plot for the above mode is shown in Fig. 5.

It is comparatively lower towards the broadside. In XY-plane the radiation is spread in all directions, and in YZ-plane notch is obtained in the broadside direction.

For off-body mode the radiation pattern is shown in Fig. 6. The radiation pattern is observed to be bit broadside (directional) as opposed to monopole like radiation for on-body mode.

It is also observed in Fig. 6 that the difference between co-pol and cross-pol components in broadside direction is more than $40dB$.

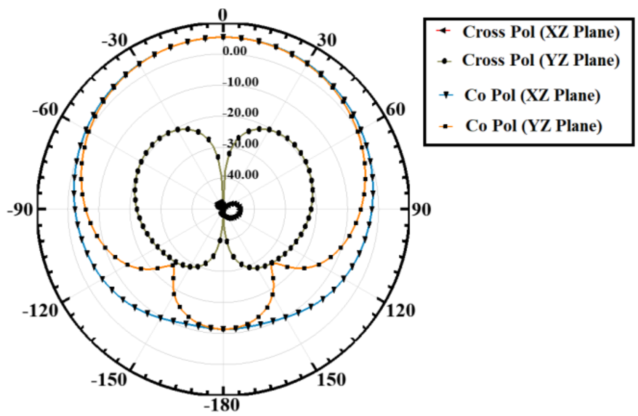


Fig. 6. Simulated radiation pattern for off-body mode in free space. (Both XZ and YZ planes)

The 3D polar plot for off-body mode is presented in Fig. 7. It can be clearly observed that the off-body mode is slightly directive in the broadside direction.

IV. Future Work

One of the main objectives for future work is to obtain a better broadside radiation pattern for off-body mode. To achieve this an annular ring patch can be used which gives better broadside radiation pattern as compared to the slotted circular patch. But the challenge is to optimize the size of the annular ring and to be able to fit it inside the square-ring patch [8]. Along with this slot can be incorporated in ground plane to improve the bandwidth of the antenna and well as for improvement in return loss [9]. As the above discussed antenna is for body area networks (BAN), a deformable antenna can be conceptualized with the help of fabrics. A prototype for the discussed antenna will be made to measure the values and compare with the simulated results.

V. Conclusion

A compact dual mode antenna is proposed consisting of square-ring and slotted circular antenna integrated together with separate feeding ports. The above discussed antenna operates in on-body mode with square ring antenna and in off-body mode with the slotted circular antenna respectively. The design and analysis of the structure makes it suitable to operate in the ISM band for body area network applications.

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