2.4/5.2 GHz Dual Band Rectangular Microstrip Antenna with Orthogonal Polarization for Bluetooth and WLAN Applications

Kanchan D. Katore, M. B. Kadu, R. P. Labade and S. S. Dongare

***Abstract*—This article presents design and evolution of dual band RMSA (rectangular microstrip antenna) with orthogonal polarization. First we have designed a single band RMSA which operates at Bluetooth band then it is modified into a dual band RMSA. The dual band RMSA has return loss ≤ -10 dB from 2.41 GHz to 2.47 GHz (i.e. Bluetooth Band) as well as from 5.05 GHz to 5.45 GHz (i.e. lower WLAN band). It shows orthogonal polarization at these two operating frequency bands. It exhibits horizontal linear polarization at Bluetooth band and vertical linear polarization at WLAN band. The proposed antenna has its radiation pattern in broadside direction. It has acceptable gain and efficiency within operating frequency range. It is designed over a low cost FR4 substrate having relative permittivity equal to 4.4 and height equal to 1.6 mm. It is fed with a microstrip line of 50 Ω. Parametric analysis is carried out on different dimensions of antenna in CAD FEKO simulation software to obtain desired results.**

***Index Terms*—Bluetooth band, dual band, orthogonal polarization, rectangular microstrip antenna, WLAN band**

I. Introduction

TODAY a number of wireless communication technologies are incorporated into a single system to save its space and cost. The basic element of any wireless communication system is an antenna. This antenna should be small in size, light weight and planar to save the space. It should have uniform gain and sufficiently high efficiency over its operating frequency range. All these requirements are satisfied by microstrip antenna [1]. Hence it is widely used in a number of wireless communication systems like RADAR, satellite, pager, hand telephones, etc. The microstrip antenna consists of radiating patch on one side of substrate and ground plane on other side. The patch can be rectangular, square, circular, elliptical, triangular, etc. Different substrates are used to manufacture microstrip antenna like Teflon, FR4, Alumina, Ferrite, Silicon, etc. Out of all these substrates, FR4 is having low cost and it is easily available [2].

The microstrip antenna should operate at dual bands or multiple bands to save space and cost of the system. Also it should exhibit proper isolation between these different operating frequency bands. Many microstrip antennas are available which show dual band operation. They are designed using C shaped notch at the edge of patch [2], angular bent slots in the patch [2], rectangular slot in the patch [3], [4], pair of slots near radiating edge or nonradiating edge [5], and many more [6]-[8]. Almost all of these dual band microstrip antennas have same polarization at both operating frequency bands. Very few microstrip antennas are reported which exhibit orthogonal polarization at two operating frequency bands [1], [2].

This paper explains the design and evolution of dual band orthogonally polarized RMSA (rectangular microstrip antenna). It operates at Bluetooth band and lower WLAN band. Today Bluetooth and WLAN are the most widely used wireless technologies. These are short range communication technologies and can be used everywhere. They are widely used in number of devices like mobile phones, computers, printers, medical devices, home entertainment products, etc. Bluetooth band frequency range is from 2.4 GHz to 2.484 GHz as per the specification of IEEE 802.11b/g. WLAN band frequency range is from 5.15 GHz to 5.35 GHz and from 5.725 GHz to 5.825 GHz as per the specification of IEEE 802.11a [8].

The rest of the paper is mentioned as below. Section II describes about the antenna design and results. At last, section III concludes the paper.

II. Antenna Designs and Results

A. Design Steps

First we have designed a single band RMSA which operates at Bluetooth band.

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Then it is modified into a dual band RMSA which operates at Bluetooth band and lower WLAN band. Both antennas are fed by 50 Ω microstrip lines. They are designed using FR4 substrate having relative permittivity 4.4, loss tangent 0.02 and height 1.6 mm. The antenna designs are simulated and optimized using CAD FEKO software.

TM10 is the fundamental mode of RMSA. It implies that there is one half wavelength variation of field along the length of patch while there is no variation of field along the width. The dimensions of rectangular patch are slightly less than a half of wavelength (λ/2) of field in substrate material. Reference [9] as well as [10] gives formulae to calculate dimensions of RMSA. They are explained below. The width of rectangular patch for efficient radiation is given by (1).

$$Wp = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Where 'c' is free space velocity of light, 'f_r' is the resonant frequency and 'ε_r' is the relative permittivity.

We have to consider effective dielectric constant of the substrate material because the field is not only confined within the substrate material but also spreads in the air in the form of fringing. This effective dielectric constant (ε_{reff}) is always less than relative dielectric constant (ε_r) of the substrate material. The effective dielectric constant (ε_{reff}) is given by (2).

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{Hs}{Wp}\right]^{-\frac{1}{2}} \tag{2}$$

Where 'Hs' is height of the substrate.

The dimensions of the patch extend along its length on each end by a distance ΔL due to fringing field. This incremental length (ΔL) is a function of the effective dielectric constant (ε_{reff}) and the width to height ratio (Wp/Hs). This ΔL is given by (3) and the effective length is given by (4).

$$\Delta L = 0.412 * Hs \frac{(\varepsilon_{reff}+0.3)\left(\frac{Wp}{Hs}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{Wp}{Hs}+0.8\right)} \tag{3}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{4}$$

The actual physical length of the patch (Lp) can be calculated by (5).

$$Lp = L_{eff} - 2\Delta L \tag{5}$$

B. *Proposed Single Band RMSA*

Proposed single band RMSA has a rectangular patch on one side of substrate and full ground plane on other side. Fig. 1 shows geometry of proposed single band RMSA. We have simulated the antenna design for different values of width of patch (Wp) to obtain resonant frequency at 2.44 GHz. The comparative results for different values of 'Wp' are shown in Fig. 2. The resonant frequency is 2.52 GHz for Wp = 26.4 mm and it is 2.37 GHz for Wp = 28.4 mm. Whereas the resonant frequency is 2.44 GHz at Wp = 27.4 mm and it is desired one. Hence we have selected the width (Wp) of patch equal to 27.4 mm. The optimized dimensions of single band RMSA are summarized in Table I.

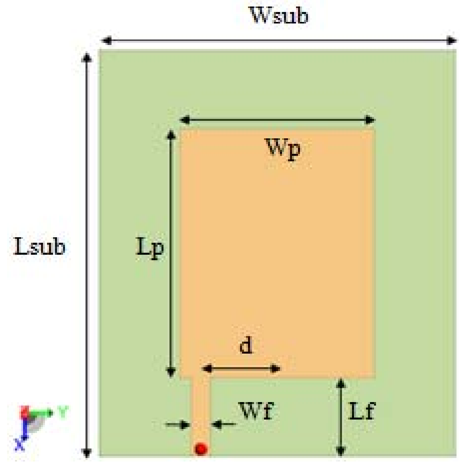

Fig. 1. Geometry of proposed single band RMSA.

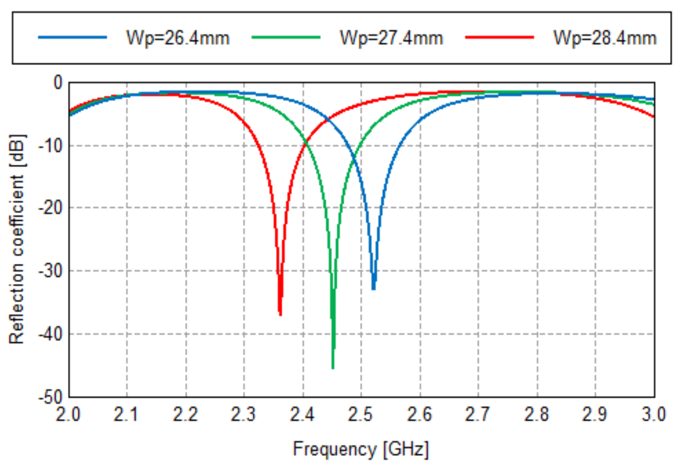

Fig. 2. Effect of width of patch (Wp) on return loss of proposed single band RMSA.

TABLE I
OPTIMIZED DIMENSIONS OF PROPOSED SINGLE BAND RMSA

Parameter	Value
Wsub	50.1 mm
Lsub	58.6 mm
Wp	27.4 mm
Lp	36.1 mm
Wf	2.6 mm
Lf	11.3 mm
d	10.7 mm

Fig. 3 shows variation of return loss of proposed single band RMSA with frequency. It has return loss equal to -45 dB at 2.44 GHz. It shows operating frequency band from 2.41 GHz to 2.49 GHz for return loss ≤ -10 dB. This frequency band is Bluetooth band.

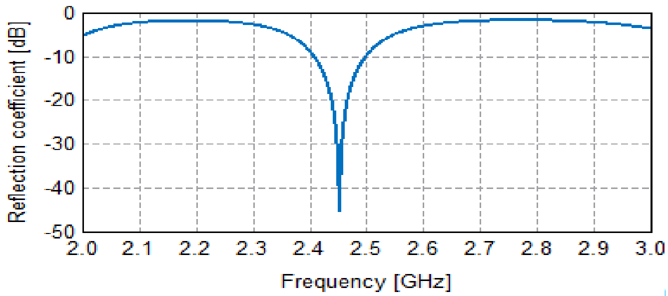

Fig. 3. Return loss vs. frequency graph of proposed single band RMSA.

C. *Proposed Dual Band RMSA*

The single band RMSA modified into a dual band RMSA with orthogonal polarization. This RMSA is designed to operate in TM10 and TM01 modes which show orthogonal polarization at its two operating frequency bands. These two operating frequency bands are Bluetooth band (2.4 GHz) and lower WLAN band (5.2 GHz). TM10 mode implies that there is one half wavelength variation of field along the length of patch. Whereas TM01 mode implies that there is one half wavelength variation of the field along the width of patch. The resonant frequency 5.25 GHz is considered to calculate the length of patch while 2.44 GHz is considered to calculate the width of patch. Fig. 4 shows geometry of proposed dual band RMSA with orthogonal polarization.

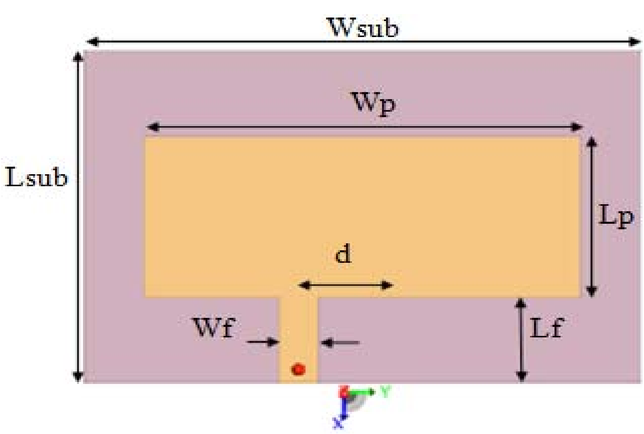

Fig. 4. Geometry of proposed dual band RMSA.

We have simulated the dual band antenna design for different values of length of patch (Lp) to obtain first resonant frequency at 5.25 GHz. The comparative results for different values of 'Lp' are shown in Fig. 5. The resonant frequency is 5.7 GHz for Lp = 11 mm and it is 4.9 GHz for Lp = 13 mm. Whereas the resonant frequency is 5.25 GHz at Lp = 12 mm and it is desired one. Hence we have selected the length (Lp) of patch equal to 12 mm.

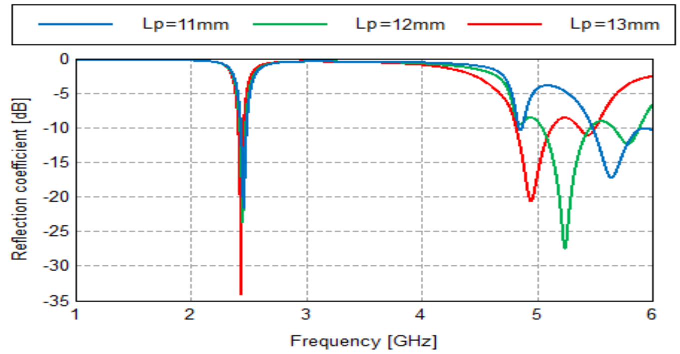

Fig. 5. Effect of length of patch (Lp) on return loss of proposed dual band RMSA.

We have simulated the antenna design for different values of width of patch (Wp) to obtain second resonant frequency at 2.44 GHz. The comparative results for different values of 'Wp' are shown in Fig. 6. The resonant frequency is 2.55 GHz for Wp = 28 mm and it is 2.3 GHz for Wp = 29.5 mm. Whereas the resonant frequency is 2.44 GHz at Wp = 28.7 mm and it is desired one. Hence we have selected the length (Wp) of patch equal to 28.7 mm.

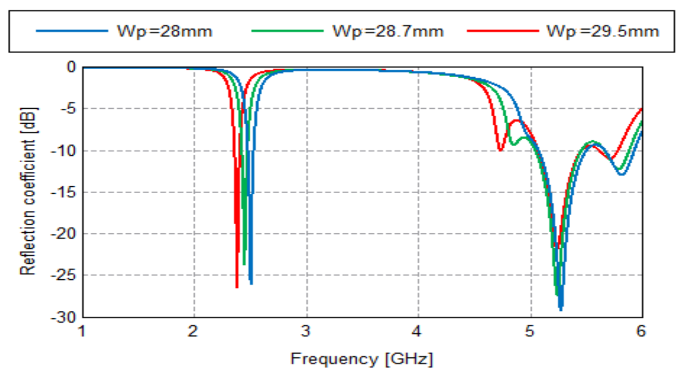

Fig. 6. Effect of width of patch (Wp) on return loss of proposed dual band RMSA.

The location (d) of microstrip feedline and its width (Wf) are important parameters which control the impedance matching. We have simulated the antenna design for different values of 'd' and 'Wf'. Fig. 7 shows effect of 'd' and Fig. 8 shows effect of 'Wf' on impedance matching. We have obtained best impedance matching and desired operating frequency bands for d = 4.2 mm and Wf = 2.6 mm. The optimized dimensions of dual band RMSA with orthogonal polarization are summarized in Table II.

TABLE II
OPTIMIZED DIMENSIONS OF PROPOSED DUAL BAND RMSA

Parameter	Value
Wsub	36.7 mm
Lsub	24.7 mm
Wp	28.7 mm
Lp	12 mm
Wf	2.6 mm
Lf	6.3 mm
d	4.2 mm

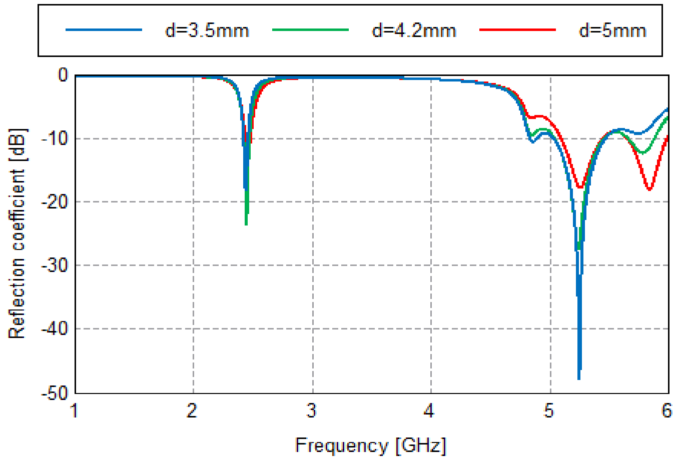

Fig. 7. Effect of microstrip feedline location (d) on return loss of proposed dual band RMSA.

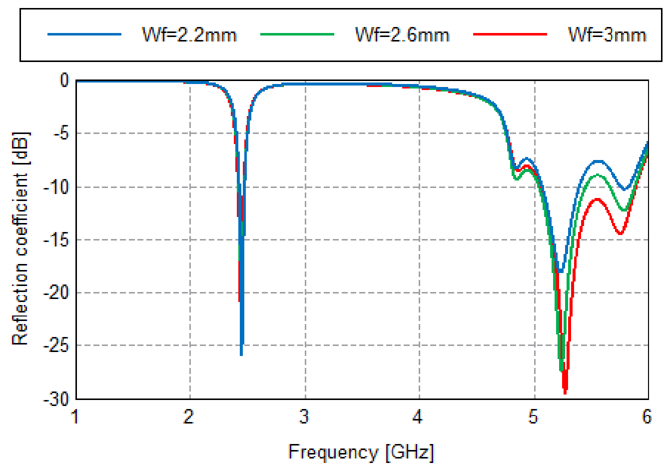

Fig. 8. Effect of microstrip feedline width (Wf) on return loss of proposed dual band RMSA.

Fig. 9 shows variation of return loss of proposed dual band RMSA with frequency. It has return loss equal to -24 dB at 2.44 GHz and -27 dB at 5.25 GHz. It shows first operating frequency band from 2.41 GHz to 2.47 GHz and second operating frequency band from 5.05 GHz to 5.45 GHz for return loss ≤ -10 dB. These are Bluetooth and lower WLAN frequency bands respectively.

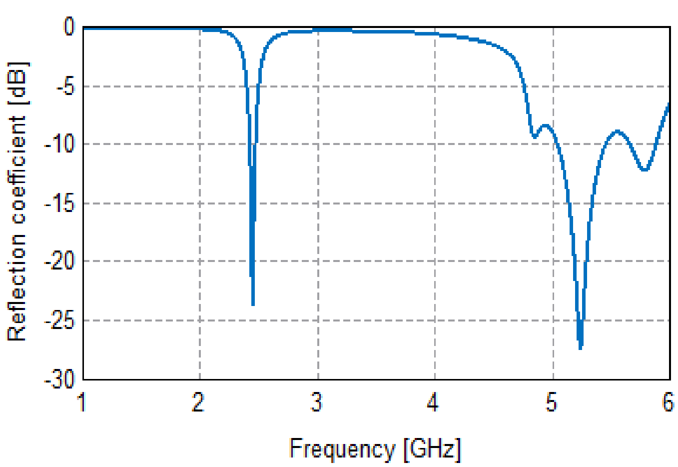

Fig. 9. Return loss vs. frequency graph of proposed dual band RMSA.

Fig. 10 represents variation of gain of proposed dual band RMSA with frequency. It has gain equal to 0.5 dB at 2.44 GHz and 5 dB at 5.25 GHz. Fig. 11 shows variation of efficiency of proposed dual band RMSA with frequency. It has efficiency equal to 25% at 2.44 GHz and 58% at 5.25 GHz.

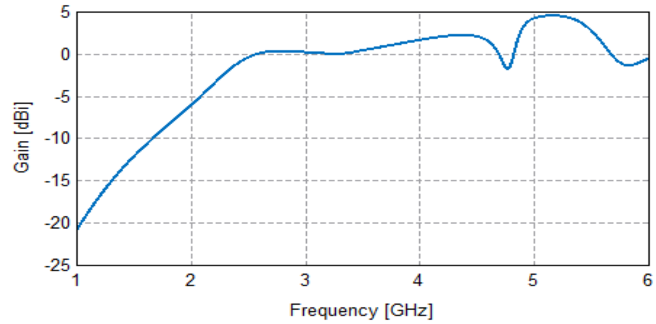

Fig. 10. Gain vs. frequency graph of proposed dual band RMSA.

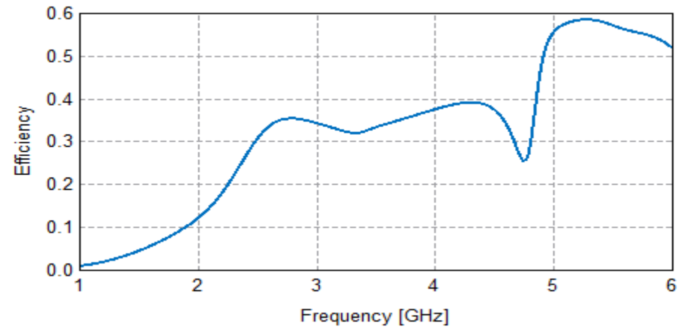

Fig. 11. Efficiency vs. frequency graph of proposed dual band RMSA.

Fig. 12 represents variation of axial ratio of proposed dual band RMSA with frequency. It has axial ratio equal to 40 dB at 2.44 GHz and 28 dB at 5.25 GHz. It indicates that the proposed dual band RMSA has linear polarization at both of its operating frequency bands. Fig. 13 shows the surface current distribution of proposed dual band RMSA at 2.44 GHz. The current vectors are along the width of patch at 2.44 GHz and there is one half wavelength variation of current along the width. Fig. 14 shows the surface current distribution of proposed dual band RMSA at 5.25 GHz. The current vectors are along the length of patch at 5.25 GHz and there is one half wavelength variation of current along the length. The current vectors are orthogonal at two operating frequency bands. It proves that the proposed dual band RMSA has orthogonal polarization at its two operating frequency bands.

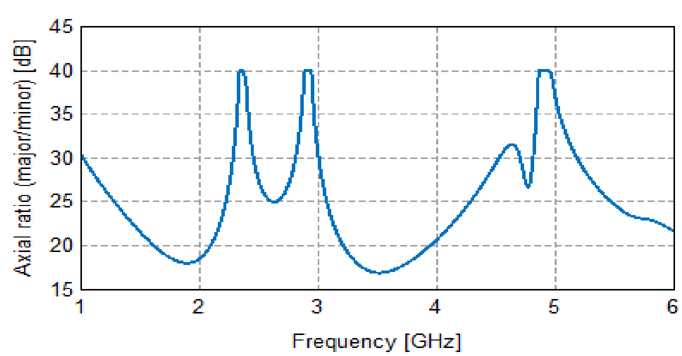

Fig. 12. Axial ratio vs. frequency graph of proposed dual band RMSA.

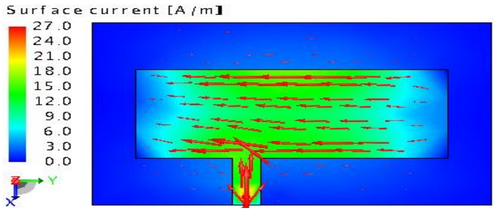

Fig. 13. Surface current of proposed dual band RMSA at 2.44 GHz.

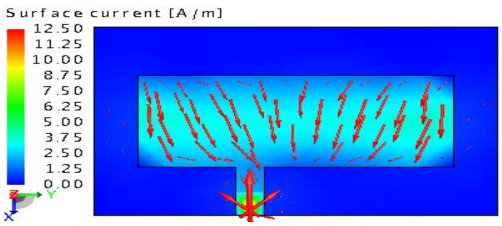

Fig. 14. Surface current of proposed dual band RMSA at 5.25 GHz.

Fig. 15 shows radiation patterns of proposed dual band RMSA at 2.44 GHz while Fig. 16 shows its radiation patterns at 5.25 GHz. The radiation patterns are directional in XZ plane while they are nearly omnidirectional in XY plane at both operating frequencies.

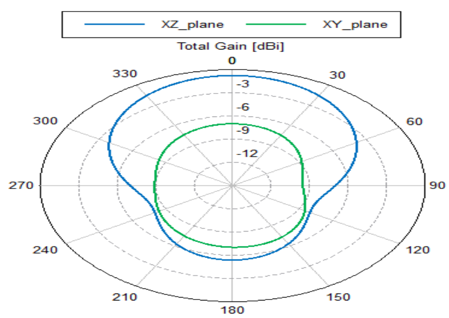

Fig. 15. Radiation patterns of proposed dual band RMSA at 2.44 GHz.

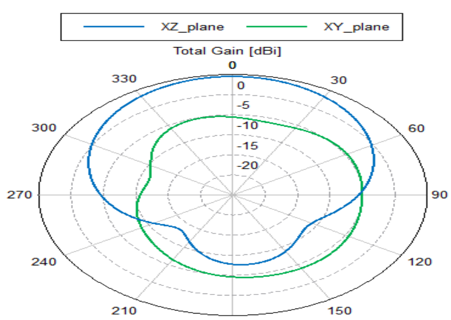

Fig. 16. Radiation patterns of proposed dual band RMSA at 5.25 GHz.

III. CONCLUSION

The proposed dual band rectangular microstrip antenna is fully planar, low cost and small in size. It can be easily fabricated using simple PCB etching technique. It operates at Bluetooth band and lower WLAN band. It has return loss ≤ -10 dB from 2.41 GHz to 2.47 GHz (i.e. Bluetooth Band) as well as from 5.05 GHz to 5.45 GHz (i.e. lower WLAN band). It has gain equal to 0.5 dB at 2.44 GHz and 5 dB at 5.25 GHz. It has efficiency equal to 25% at 2.44 GHz and 58% at 5.25 GHz. The radiation of proposed antenna is in broadside direction. It has directional radiation pattern in XZ plane while nearly omnidirectional radiation pattern in XY plane. The proposed antenna has axial ratio equal to 40 dB at 2.44 GHz and 28 dB at 5.25 GHz. It exhibits orthogonal polarization at its two operating frequency bands. Hence it is the best choice for MIMO (Multiple Input, Multiple Output) systems.

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