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Abstract.

An annular structure 2× 2 MIMO antenna with low mutual coupling is proposed to operate at 2.4 GHz WLAN band applications. This paper presents a multiple input multiple out antenna design with an overall size of 40x75x1.5mm^{3}. for WLAN applications. The proposed MIMO antenna is printed on a thin 1.5 mm FR4 substrate with the dielectric constant of 4.4 and loss tangent of 0.02.

It is found that the newly designed MIMO antenna which combines the annular slot radiation patch and slotted ground plane with vertical strip has the widest bandwidth and the best matching characteristic. The results indicate that the proposed receiving antenna performs well at LTE band with a wide bandwidth from 2.25 GHz to 3. GHz. The maximum efficiency of the proposed rectenna reaches 69% at 2.4 GHz. An implanted I-shaped ground stub is placed between a pair of radiating element to achieve improved impedance bandwidth and isolation. The proposed antenna covers a −10 dB operating band of 2.25 to 3 GHz with more than 30 dB isolation between a pair of elements. The value of ECC < 0.0004, DG > 10.1, and current distribution 74.96%.

Keywords: ECC, DIVERSITY GAIN, ISOLATTION AND SURFACE CURRENT DISTRIBUTION

1. Introduction

The ultra-wide band (UWB) technology with several advantages has attracted so much attention [16] since the Federal Communication Commission (FCC) assigned an authorized and unlicensed frequency range from 3.1 to 10.6 GHz [16], such as high data rate transmission, high precision range, low power spectrum density, etc.

The desire for high data rates and spatial diversity encourages a high degree of data diversity. Compared to an antenna system with a signal-input signal output (SISO), The MIMO antenna system is more immune to noise. High separation between MIMO antenna system elements makes it more suitable for a multi path feeding and helps to achieve a low coefficient of correlation. A MIMO electronics device leads to enhanced gain, bandwidth, channel output of capacity and diversity compared to a SISO system [1]. A MIMO device requires less data repetition, so the data throughput is high. Another benefit of a MIMO system in a rich scattering area is less channel capacity loss that results in greater data rate without losing additional spectrum and transmitted strength [1]. Many MIMO antennas have been proposed in the last-few years. and designed for multi-band operations, especially working in the ISM bands. There is more emphasis on achieving the isotropic pattern in a MIMO system, leading to an increase in channel power, because it is beneficial to have the same radiation and isotropic pattern in all the elements of a MIMO system. Multiple antenna elements are mounted near each other in the MIMO system to transmit or receive replicas of the same signal. By suppressing fading effects, MIMO technology is used to boost the efficiency of communication network. Many compact MIMO antenna designs have been reported with wide bandwidth, high isolation, stable radiation patterns, polarization purity, and band-notched characteristics. [3].

The MIMO antenna has been widely used in WLAN applications to enhance the channel capacity and data rate without sacrificing additional spectrum or transmitted power in rich scattering . The MIMO antenna needs numerous transmitter and receiver antennas that function concurrently. In this paper, a two-port printed MIMO/diversity antenna is presented for Bluetooth / Wi-Fi / ISM / and WLAN AP applications. The elements of the MIMO/diversity antenna configuration resonate at 2.4 GHz.

$$C_{MIMO} = log\left[det\left(I_{M_R} + \frac{SINR}{M_T}\right)HH^H\right] \quad 1$$

Where, M_T and $M_R$are the numbers of transmitters and receivers, respectively. While I_{MR} is the identity matrix, M_R x M_R, and H is a M_T & M_T matrix. [2].

Several lengths of antenna element have a substantial role in pivotal the value of the gain, efficiency, size and for field radiation characteristics. [11] . To enhance the insulation with faulty ground structure (DGCs), This is responsible for poor front to back lobe radiation between antenna components, and thus affects the efficiency of antenna radiation.

MIMO technology is considered as one of the new architypes in fourth generation wireless communication standard that leads to enhance the capacity and increase in data rate by use of MIMO antenna array at both the terminals of receiver and transmitter. [12] The radiation pattern is reduced to the effect of reciprocal coupling and therefore the co-channel interference is enhanced and the characteristics of the antenna change the input. The technique pertaining to isolation enhancement and integrated to overcome the strong mutual coupling.[12]

A common view is that, for the most part, the required data rate increase can be achieved by combined gains in three categories [7]: 1) extreme network densification to boost spectral area efficiency (more node per unit area and Hz);2) increased bandwidth, mainly by switching to the mm- wave spectrum and allowing better use of unlicensed spectrum in the 5GHz (more Hz) band;3) increased spectral efficiency, chiefly through advances in multiple input multiple output (MIMO) technique [4]. To increase the frequency of the signal, multipath propagation is used in MIMO techniques. compared with single element antenna, the MIMO antenna also help to decrease the signal fading effect. To improve the isolation between two elements of a MIMO antenna, different techniques are introduced like F shaped stubs [6], defected ground structure [7], metamaterial-based approaches [8], SIW technology [9], symmetrical and asymmetrical ML stubs [10]. In [8], a metamaterial inspired dual-band MIMO antenna for LTE and WiMAX application is presented. [5]. By using neutralization line techniques, the port isolation of the MIMO antenna is enhanced by changing the distance between two elements of the antenna.[5]. Wireless 5G access networks can support sub-6 GHz (spectrum below 6 GHz) and millimetre-wave spectrum bands (spectrum above 24 GHz). Recently, in many nations, the broadband wireless industry is Based predominantly on the sub-6 GHz (3.4-3.8 GHz)2 and millimetre-wave frequency bands (24.25-27.5 GHz). For researchers, the antenna size is the main constraints because the area available is limited for the placement of multiple antenna elements in portable/compact devices. It can be mitigated by designing compact elements of the antenna which are closely spaced.[13]. Various methods have been published in the literature to improve the isolation between a pair of antennas elements of the MIMO systems, A vertical slit created on the between two mutual coupling antenna which is used for isolation.

In this paper, a two-port printed, “Wideband MIMO antenna for ISM/Bluetooth/Wi-Fi/WLAN applications. “the proposed MIMO antenna design consist of the microstrip patch loaded with annular slots and rectangular slots which is non radiating edge of the patch. The isolation enhancements are achieved by providing vertical strip between two MIMO antenna, loaded on the ground plane radiating elements. The performance of this antenna, both by simulation and experiment, suggests that the proposed MIMO antenna has good matching of impedance, low mutual coupling and low envelope correlation coefficient (ECC) good performance of diversity gain, all the way through the WLAN (2.4-3 GHz). this MIMO antenna provide impedance bandwidth ($S_{11} \leq -10dB$) of 29 %(2.25 to 3 GHz) [14]. The results are verified by the mutual coupling parameters like envelope corelation coefficients (ECC) and channel capacity loss (CCL) at desire frequency.

2. Design of Wide-band MIMO Antenna System:

In this section, the design evolution of the single microstrip annular slot, L-shape slot, circular strip patch, and also used slotted ground with vertical strip for isolation in between MIMO antenna. The experimental and simulated results are compared with resonant frequencies.[15]

The proposed MIMO antenna geometry, as shown in Fig. 1, with a common ground plane, has two identical radiating elements. The overall dimension of the proposed MIMO antenna is only 40mm× 75mm=3000mm^2 is presented based on a slotted radiation patch and a new ground plane. With the creation of the rectangular and annular slots, the surface current direction of the antenna is altered, which is advantageous for broadband operation and miniaturization. A conventional rectangular radiation patch is chosen as the initial design. The width of the antenna W is calculated as:

$$W=\frac{c}{2f_0}\left(\frac{\epsilon_r+1}{2}\right)^{-1/2}$$

where c is the speed of light, f_0 is the resonance frequency of antenna and ϵ_r is the relative permittivity of substrate.

The length of the antenna L can be described as:

$$L=\frac{c}{2f_0\sqrt{\epsilon_{reff}}}-2\Delta L$$

Where

$$\epsilon_{reff}=\frac{\epsilon_r+1}{2}+\frac{\epsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-1/2}$$

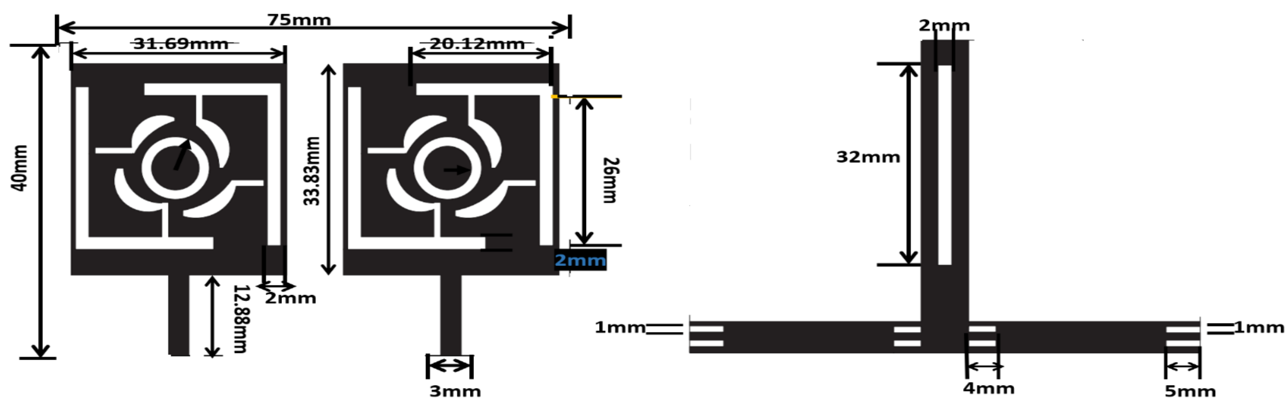
And

$$\Delta L=0.412h\frac{(\mathcal{E}_{reff}+0.3)(W/h+0.264)}{(\mathcal{E}_{reff}-0.258)(W/h+0.8)}$$

where $\mathcal{E}_{reff}$ is the effective permittivity of substrate, h is the thickness of substrate which is taken as 1.6 mm.

The proposed antenna has a dielectric constant of 4.4 and a tangent loss of 0.02 on a thickness 1.6 mm FR4 substrate. Via the HFSS software, the performance of the antenna is investigated. For a broader bandwidth, a 50 Ω microstrip line is selected to feed the antenna with the optimal dimension of 3×12.88 mm^2. The efficiency of the antenna varies significantly due to heterogeneity of the surface current direction when cutting slots on the radiation patch of the antenna.

The dimension of the antenna shows in the fig.1, there are two views (a) top view and (b) bottom view represents the total dimension of the antenna which is 40mm × 75mm $\times 1.6mm$ and there is two L- shape which is symmetrical, width of the L-shape is 2mm, vertical Hight is 26mm, and horizontal length is 20.12mm. In fig.1 (a) there are two circles, the radius of small circle is 3.5mm and the radius of the big circle is 5mm. And the fig.1(b) shows the bottom views, there are shows one vertical strip which have Hight 32mm and width is 2mm, it is used for isolation. and in the bottom views shows the ground with the newly slotted plane, the dimension shows in the fig.1



Top view(a) Bottom view(b)

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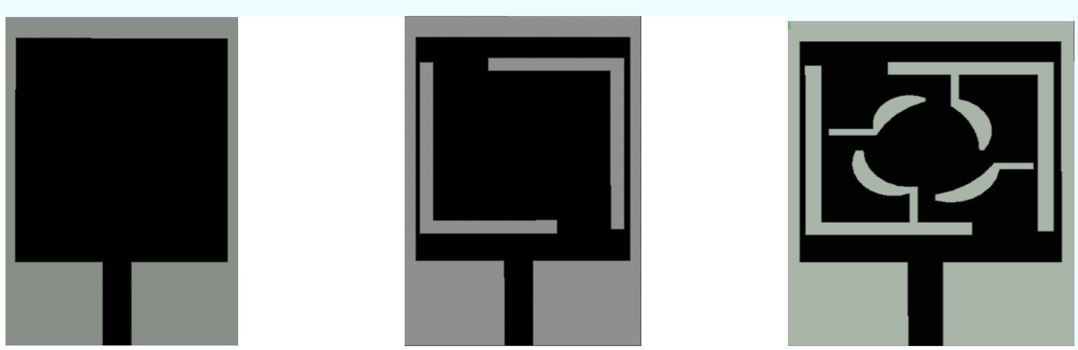
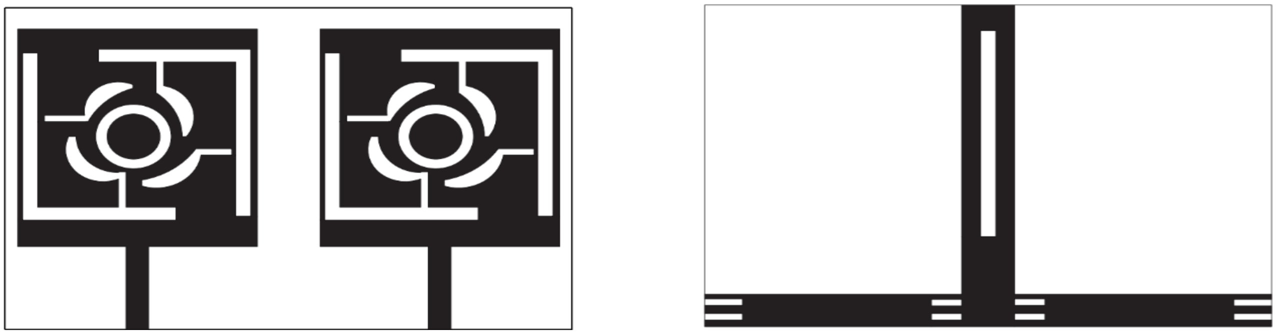
Fig. 1. Configuration of the proposed annular-slot antenna. (a) Top view. (b) Bottom view.

2.2 Antenna Design Procedure:

Figure 2. displays four distinct antenna patch geometries, including the conventional geometry patch (Patch with CG) (ant-1), Rectangular (Patch with RS) (ant-2), annular slots (Patch with AS) (ant-3), and circular (Patch with CS) slots respectively and also used vertical strip line for isolations (ant-4). In terms of matching and resonance characteristics, the simulated performance of the antenna is investigated and compared, as shown in Figure 3.



Ant (1) Ant (2) Ant (3)



Top View **Ant- (4)** **Bottom View**

Fig. 2. Antenna with four different patches. (1) Patch with CG. (ant-1) (2) Patch with RS. (ant-2) (3) Patch with AS (ant-3) (4) patch with circular slots and vertical slots. With slotted ground (ant-4). The above fig. 2 shows the step-by-step evolution of the proposed wide-band antenna for the desired frequency of MIMO system. fig 2 (ant-1 to ant-4) shows the design of the simple microstrip patch antenna fed with 50 Ω feed line through quarter wave transformer Zin.

3.Results and discussions:

The comparison between the simulated S-parameters for different evolutionary design stages illustrated in Fig. 3.[16]

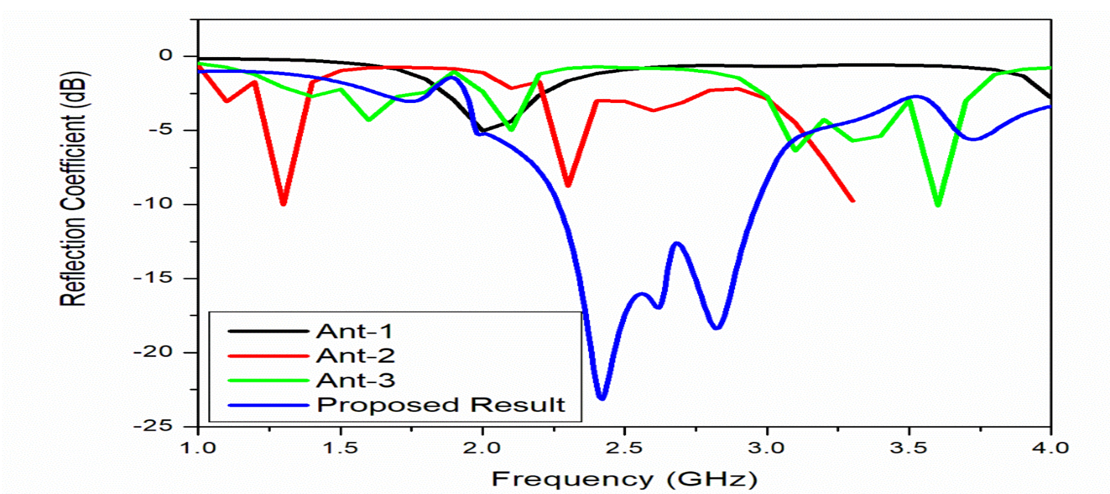


fig.3Simulated reflection coefficients S_{11} for the different antenna configurations.

It is observed from fig.3 that the ant.1 with the conventional patch (with CG) which is shows in fig.2 (1), has the minimum reflection coefficient of -5.0 dB at 2.87 GHz with the -10 dB bandwidth ranging from 2.15 GHz to 3.8 GHz. By etching rectangular slots (RS), which is represents in the fig.2 (2), the reflection coefficient is decreased to -10.2

dB at 1.6 GHz and the bandwidth is very less However, the antenna with annular slots (AS), which is represents in fig.2(3), has the reflection coefficient of -10 dB at 3.87 GHz and the bandwidth of less than 1 GHz. And the antenna with MIMO, fig.2 (4) enhances the reflection coefficients -23.87 dB at 2.3 GHz. the MIMO antenna has offers better isolation in comperation antenna -1, antenna-2 and antenna-3 .and the MIMO antenna -4 also enhance the bandwidth which is 2.3 GHz to 2.96 GHz. The input impedance of the antenna is required to match with 50 Ω. The ground plane also has a great influence on the efficiency of the antenna, aside from the geometry of the antenna patches. In this MIMO antenna illustrates two different ground planes, which a

re the conventional ground plane (Conventional GP), and newly slotted ground plane (Newly slotted GP). It is noted that with the evolution of the ground plane with the reduction of VSWR, impedance and improvement of radiation efficiency and also isolation of the MIMO antenna performance is gradually enhanced. Therefore, by combining the annular-slot radiation patch, the newly slotted GP, and also vertical strip slot is used to obtained the appropriate MIMO wide band antenna.

The comparison result of with vertical strip and without strip of fig.4 shown below the table-1 As we can see in Fig. 2, the design steps of the isolation structure from ant-1 to ant-4. [1] . We start with the no isolation structure in ant-1 to ant -3 for the reference where the minimum isolation is only 12dB. As shown in fig.2 ant-4 there are two views (a) Top views, top view represents without vertical strip patch, which is provide > -41.1 dB, isolation at the frequency 1.8 GHz. and (b) bottom view represents with vertical strip patch, which is provide > -45.2 dB, at the resonate frequency is 2.4 GHz.

For better understanding the function of the two half-wavelengths annular shaped single complementary split-circle resonators, surface current distributions at two central frequencies are depicted in Fig. 5 (a) and (b) when port 1 is excited and port 2 is matched by 50 Ω load.[16] The current distribution at 2.4 GHz is shown in Fig 5 (a) and (b) As it is clear in this figure, the main concentration of surface current is around the larger annular shaped single complementary split circle resonators rather than elsewhere thus WiMAX / WLAN / Bluetooth band is achieved. This would cancel the antenna's outside radiation. Similarly, surface current is more prevalent in the single complementary split circle resonator in the inner annular form and near the port rather than elsewhere. In general, it can be interpreted that in the vicinity of the slots and antenna, a large amount of electromagnetic energy is concentrated without radiation in the bands described. Also, current distribution on the element that matched by 50 Ω is very small thanks to the vertical strip -shape stub which high mutual coupling between two monopoles.

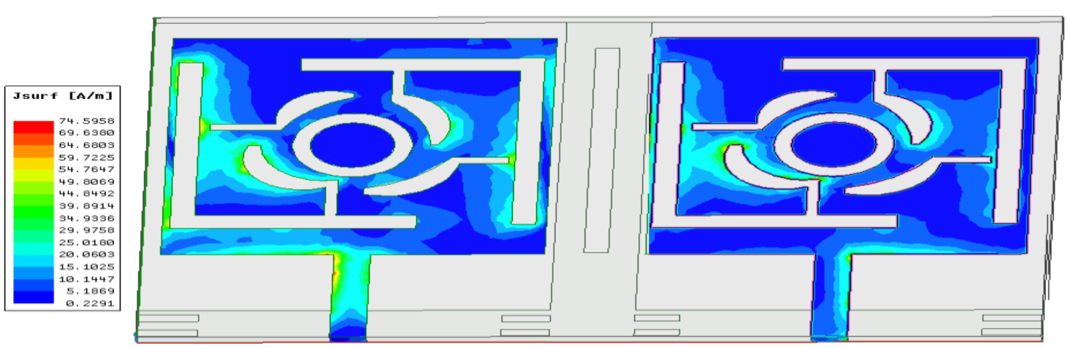


fig.5 (a)surface current distribution of port - 1 and port - 2 at 2.4GHz

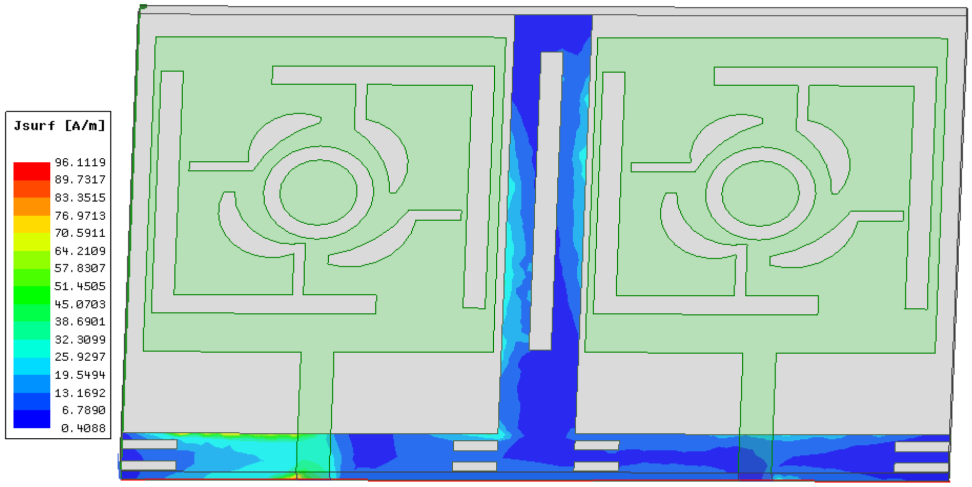


Fig.5(b) surface current distribution of ground at 2.4GHz

4.Conclusion

The proposed compact slotted receiving MIMO antenna has an excellent matching performance at 2.4 GHz. The rectangular and annular slots on the radiation patch has significantly reduced the antenna dimension and improved its performance in terms of the bandwidth and reflection coefficient. The effect of the geometry and dimension of the slotted ground plane and vertical strip on the matching performance, enhance isolation, realized gain of the antenna is investigated. The MIMO antenna features the maximum RF to DC conversion efficiency of 69% at 2.4 GHz when the input power is 5 dBm. The designed antenna has a −10 dB impedance bandwidth of 2.4 GHz covering the entire band of (2.25-3. GHz) with a minimum isolation value of 30 dB between antenna ports with impedance matching of −45.2 dB the value of ECC < 0.0004, and DG > 10.1. These characteristics make the antenna a good candidate for handheld and portable UWB systems.

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