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RESEARCH ARTICLE

SRR Loaded Dual Band MIMO Antenna with Enhanced Isolation

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Abstract

An antenna is a device or a transducer that converts an RF signal into electromagnetic waves and serves as a means of transmitting and receiving radio waves. A novel dual-band Multiple Input and Multiple Output (MIMO) antenna for Wireless Local Area Network (WLAN) applications is presented in this paper. Each dual-band antenna element in the MIMO antenna is made up of a T-shaped monopole and a Split Ring Resonator (SRR). The antenna operates at frequencies ranging from 2.1 GHz to 5.6 GHz in the centre. Furthermore, the isolation at the dual band is improved by inserting a meta material-based spilt ring resonator, which can reduce the original mutual coupling. The MIMO antenna has a dimension of $50 \times 110 \times 1.6\,\mathrm{mm}^3$ and the dimension of single patch antenna is $50 \times 70 \times 1.6\,\mathrm{mm}^3$. This designed partial ground antenna resonates at 2.1 GHz and 5.6 GHz frequencies, with return losses of -24.67 dB and -15 dB, respectively, and good isolation of less than -10 dB in the 2.1 GHz to 5.6 GHz band. The MIMO antenna has a far field gain of 2.44 dB at 2.1 GHz and 4.22 dB at 5.6 GHz.

Keywords: *Antenna, Dual-Band, Monopole, MIMO, SRR, WLAN*

1. Introduction

Wireless Communication Systems (WCS) have witnessed rapid development and are becoming more popular among the users because of their affordable cost. However, to further reduce service charge of WCS there is opportunity for research on high data rate and miniaturing the size of the antenna. Low cost and ease of fabrication has made the printed monopole antenna become very popular among the antenna designers. Printed monopole antennas can be fabricated on printed circuit boards and can easily be integrated into communication systems, such as laptops and similar electronics devices for WLAN applications. To meet the growing demand for various applications, future communication systems will require multi-band or wide-band antenna designs. Due to the demand for higher transmission rates and more reliable links in wireless communications, MIMO technology has attracted attention of researchers. MIMO is a complicated and difficult technology that employs multiple antennas to increase channel capacity and eliminate multipath fading propagation(1; 2). However, as wireless devices are made smaller and portable, the amount of space available for antennas becomes limited. As a result, designing a compact MIMO antenna is of importance. Printing MIMO antennas is an attractive option for adapting to commonly used wireless devices. There is strong mutual coupling when the separation between antenna elements is very close. As a result, the most critical issue in a MIMO antenna design is to reduce mutual coupling between the closely packed antenna elements. Several innovations have been incorporated to increase isolation among antennas in order to reduce mutual coupling, a popular one among them is the Electromagnetic Band Gap (EBG) structure(3; 4). To improve isolation between the elements of a MIMO antenna system, F-shaped stubs have also been incorporated into the ground plane5. A defected ground plane structure (DGS) has also been proposed to reduce mutual coupling(6). Use of meta material effectively reduces mutual coupling among radiating components, which is presented in this work. A two-element MIMO antenna is presented in the work that operates at 2.1 GHz and 5.6 GHz and has SRR units integrated between the two radiating antenna elements is proposed with an aim to improve the isolation between the array's monopole antenna elements in order to reduce the effect of mutual coupling.

The SRR meta material resonator is designed to improve isolation between antenna elements in an array. This meta material resonator has negative permeability at its resonant frequency and is made of FR-4 epoxy with a thickness of about 1.6mm and a relative permittivity of about 4.4. This proposed dual band MIMO antenna is found to have good isolation of -17.46 dB for 2.1 GHz and -14.68 dB for 5.6 GHz. Dual band antennas are available for wireless applications. In the year 2003, Yen-Liang Kuo and Kin-Lu Wong reported a printed double T-monopole antenna operating at 2.4 and 5.2 GHz dual band WLAN frequencies(7). This antenna is made up of two stacked T-shaped monopoles of varying sizes, which generate two distinct resonant modes for the desired dual-band operation. The proposed monopole can be easily fed by a 50 Ωmicrostrip line.

2. Antenna Design Procedure

2.1 Design of Dual Band Monopole Antenna

The double T-monopole antenna developed by Yen-Liang Kuo and Kin-Lu Wong(7) to operate at 2.4 and 5.2 GHz dual band WLAN operation is comprised of two stacked T-shaped monopoles of different sizes that produce two separates resonant mode for dual band operation. Low profile printed monopole antennas have been developed in the last few years for WLAN applications which include double L-shaped slots(8), U-shaped slots(9), and straight radiating strip(10; 11; 12). In order to comply with IEEE 802.11 WLAN standards at 2.4GHz (2400-2484 MHz) and 5.2GHz (5150-5350MHz), printed monopole antennas must be operated in dual bands with50 Ω microstrip lines. A simple dual band printed monopole antenna for wireless communication applications is reported in this work. Slots with specific dimensions were included to make a dual band monopole antenna. Each T-shaped monopole element is stacked on top of one another and the entire substrate is equipped with a ground plane as shown in Figure1. The design has been adopted from(7)with certain dimensional modifications. Slits are introduced to optimize the S parameters and impedance bandwidth. The length, width and other parameters of the designed antenna were calculated using standard formulae for a specific frequency. The proposed patch antenna has the dimension of $55\times70\times1.6\,\text{mm}^3$ designed over FR-4 epoxy substrate with dielectric constant of 4.4. The antenna is excited with a single lumped portfeed with a 50 Ω transmission line. On the bottom side of the dielectric substrate, a partial ground plane of length 'l'and width 'w' is printed beneath the microstrip feed line. Ansys High Frequency Structure Simulator (HFSS) software was used to design and simulate the proposed antenna. The substrate in this design has a length Ls = 50 mm and a width Ws = 70 mm. The dimensional area of the partial base is 29 x 70 mm2. Excitation is done through a 50 Ωmicrostrip feeder with a length (L + h2) = 37 mm and a width wf = 1.5 mm. Here, h2 is the feeding point and the floor height of the first arm radiator. The radiator element of Section 2 is located at a distance of h1= 9.5 mm from the partial tread. A vertical strip with a width of b = 1.6 mm connects the two arms. The sections of the first two arms are not the same (L31 = 4.5 mm and L32 = 5 mm), but the second arm is symmetrical (L1 = 4.7 mm). The width of the two arms is equal to W1= W2 = 1.62mm.

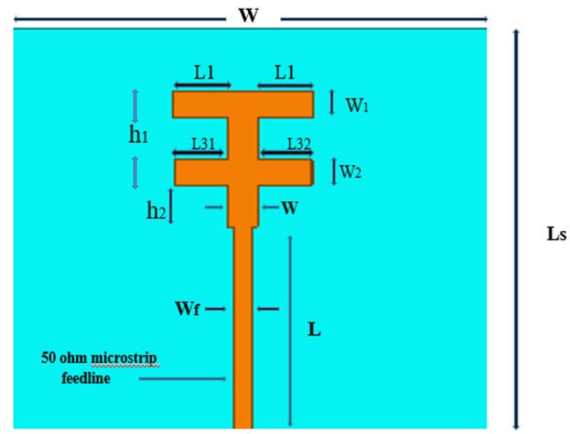

Figure 1: Dual band dual T-shaped monopole antenna fed with a 50 Ω microstrip line over a FR-4 epoxy substrate

2.2 Design of 2 ×1 MIMO antenna

The 2x1 monopole antenna shown in Figure 2 which is designed by placing two identical antenna elements as shown in Figure 1. The 2×1 MIMO antenna is designed with different slots in T-shape with different dimensions. The copper material is used to design the radiating patch, with a partial ground plane. The patch antenna has dimensions of 12 × 16 × 0.05 mm3, and the height of the substrate is about 1.6 mm. The antenna is designed and simulated using ANSYS HFSS®. To achieve a compact MIMO array, the distance between the antenna elements in the array should be minimum. However, it should be noted that the small distance between the two microstrip monopole antenna elements results in high mutual coupling. To reduce this mutual coupling effect, meta material SRR elements are placed in between the antenna elements to increase the isolation between the antenna elements.

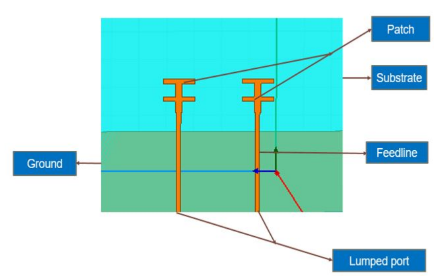

Figure 2: Geometry of the proposed MIMO antenna with two T-shaped antenna elements

2.3 Design of SRR unit Cell Design for Coupling Suppression

meta material based SRR exhibit negative permeability near to its resonating frequency. It is made up of a pair of enclosed conducting loops of copper and slots cut at opposite ends. SRR is designed over FR-4 epoxy substrate. SRR

Table 1: DesignParameters of SRR Unit Cell

Sl. No.	Physical parameter	Dimension (mm)
1	Length of the SRR, a	10
2	Width of the SRR, b	10
3	Gap between the rings, c	1
4	Gap within the rings, w	1
5	Width of the strip, d	1

is employed for the enhancement of the isolation between the two antenna elements within the array. Compared to other meta material structures,SRR structure is found to be suitable for enhancing the isolation between the closely spaced MIMO antenna elements. Figure3 illustrates the geometry of the SRR building block, which is fabricated over FR-4 epoxy substrate with thickness around1.6mm and relative permittivity around 4.4. The dimension of SRR is 10x10 m^2. The dimensional parameter of the SRR unit is tabulated in Table 1.

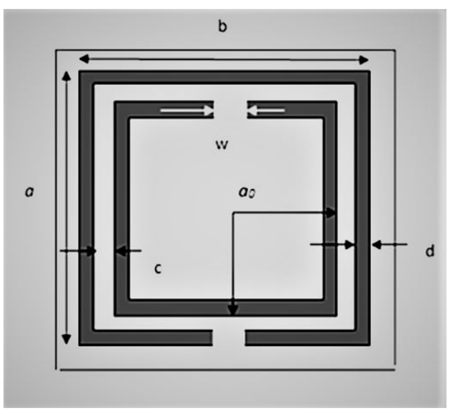

Figure 3: 2D view of the SRR with two conducting loops with opposite cut slots

2.4 Design of compact 2×1 MIMO array loaded with SRR unit cell

In this design, 2×1 MIMO antenna is intended with three meta material based SRR as shown in Figure 4. Here, three SRR unit cells were placed in between two monopole antennas to achieve better radiation isolations between the closely spaced antenna elements. The patch antenna includes a dimension of $12 \times 16 \times 0.05\,m^3$designed over the FR-4 substrate of height 1.6 mm.

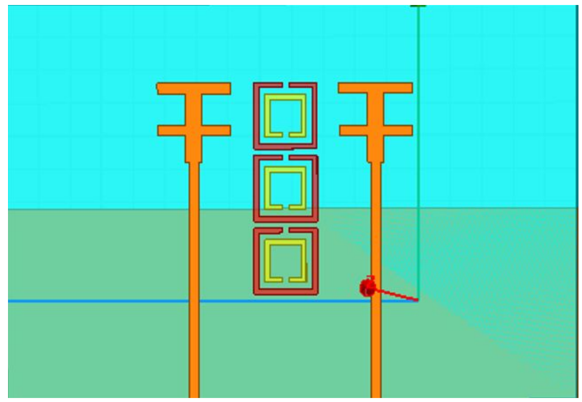

Figure 4: Geometry of the proposed 2×1 MIMO antenna array

3. Experimental Results

3.1 Performance of the Single Monopole Antenna

Figure 5 illustrates the S-Parameter of single monopole antenna. The simulation results show that the proposed antenna is dual band and resonating at 2.3 GHz (S11= -34.77 dB) and 5.6 GHz (S11=-23.16 dB). Thus, the proposed dual band antenna shows good impedance matching below (-10 dB) at its resonating frequencies. Moreover, the S11 plot of the dual band antenna shows around 200 MHz (-10 dB) bandwidth of at its resonating frequencies. Figure 6 shows the radiation E-field and H-field pattern of the proposed antenna. The radiation pattern of the monopole antenna shows around 2 dB gain along the major lobe.

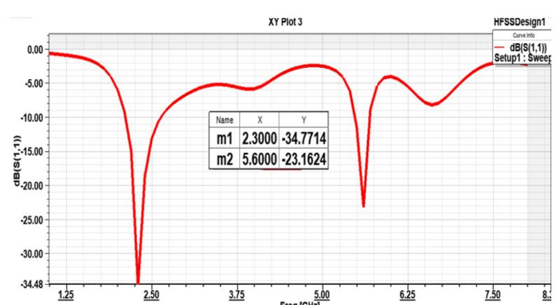

Figure 5: S-parameter of the T-Shaped Dual band of monopole antenna

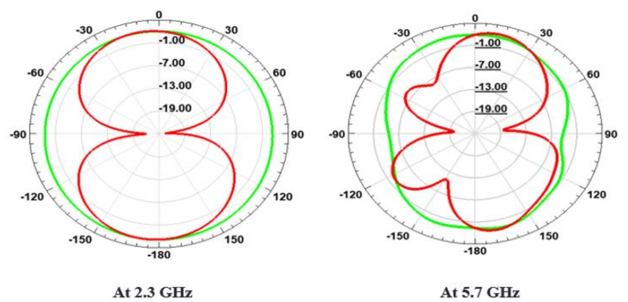

Figure 6: Radiation patterns of the dual band monopole antenna at 2.3 GHz and 5.6 GHz

3.2 Performance of Proposed 2 X 1 MIMO Antenna Array

The S-parameter vs frequency plot for the MIMO antenna array without inserting the meta material unit cell is shown in Figure 7. The first resonating frequency of MIMO array was observed to have shifted from 2.3 GHz to 2.1 GHz and the second resonating frequency of 5.6 GHz remained unchanged.

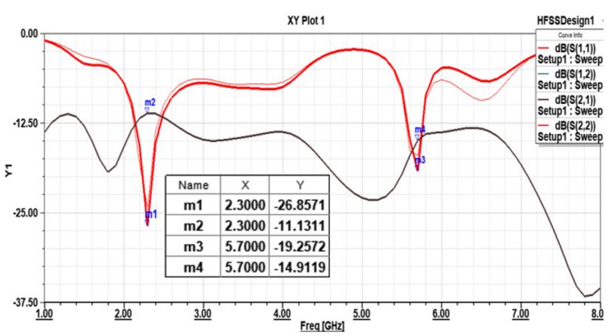

Figure 7: S parameter vs frequency plot of the 2×1 MIMO array showing the resonating frequency and mutual coupling at 2.1 GHz and 5.6 GHz

This can be attributed to the mutual coupling effect between the antenna elements of the array and the change in the overall dimension of the array. The S11 at the first resonating frequency of 2.1 GHz is -26.85 dB and at 5.6 GHz it is -19.24 dB. The mutual coupling effect between the antenna elements of the array can be measured from the S12 and S21 parameters. The S12 and S21 of the MIMO array are measured as -14.91dB at 2.1 GHz and -11.13 dB at 5.6 GHz. This shows appreciable isolation between the antenna elements. Figure 8 shows the radiation pattern of the array antenna at 2.1 GHz and 5.6 GHz. The gain of the antenna is around 1.8 dB at both the resonating frequency. The overall gain of the array antenna is also decreased due to mutual coupling between the antenna elements.

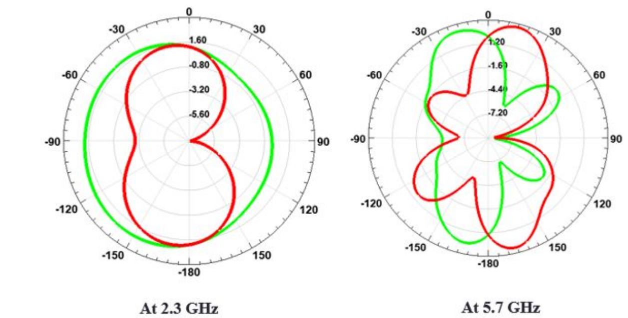

Figure 8: E and H plane radiation patterns of the 2×1 MIMO antenna at 2.3 GHz and 5.7 GHz

3.3 Analysis of the Proposed 2 X 1 MIMO Antenna Array Loaded With SRR Unit Cell

It can be observed from Figure 8 that the gain of the antenna array at its resonating frequency is affected due to the closely spaced antenna elements. To overcome the effect of mutual coupling within the antenna array, three SRR unit cells are etched between the gap of the antenna elements. The results after the insertion of the meta material resonator within the array are shown in Figure 8 as aS-parameter vs frequency plot of the MIMO array. The S11 values observed from the plot are -22 dB and – 24.67 dB at its resonating frequency 2.3 and 5.6 GHz. The MIMO array shows a satisfactory impedance matching at both resonating frequencies. However, the S12 and S21 parameter of the MIMO array is significantly improved to -11.5 dB and -17.46 dB respectively at its resonating frequency. The improvement in the transmission parameters of the array antenna is due to abortion of electromagnetic radiation by the three SRR unit cell at its resonating frequency. This improvement in the isolation between the antenna elements will lead to better radiation performance of the dual band MIMO antenna at its resonating frequency. Figure 10 shows the E-field and H-field radiation pattern for the dual band MIMO array. The radiation pattern shows a significant gain enhancement of the antenna array by about 2.1 dB at its resonating frequency.

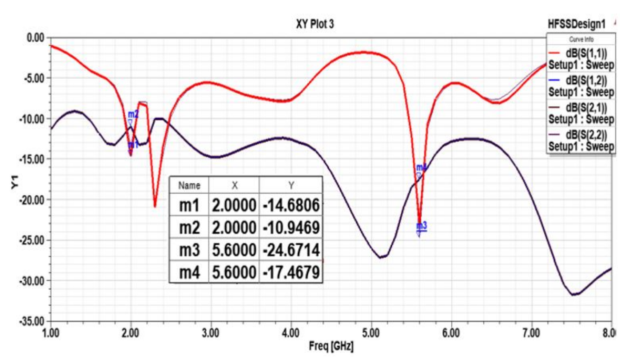

Figure 9: S-Parameter vs frequency plot of the 2×1 MIMO array with three SRR unit cell between the antenna elements

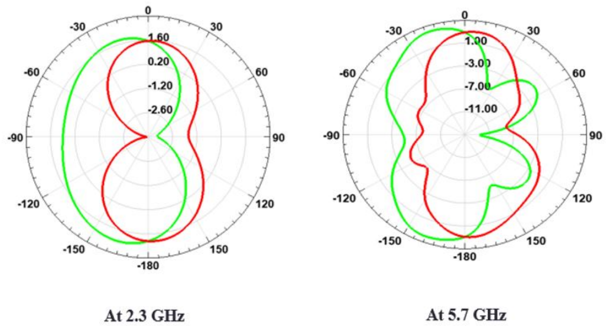

Figure 10: Radiation patterns of the 2×1 MIMO antenna with three SRR unit cell at 2.3 GHz and 5.7 GHz

4. Conclusion

In this work, a meta material loaded 2 × 1 MIMO antenna array is presented. The proposed antenna system is a dual band MIMO array resonating at 2.3 GHz and 5.6 GHz which is suitable for use in WLAN frequency band. The initial design included a single element dual band T-shaped monopole antenna. The monopole antenna showed around 200 MHz operating bandwidth at its resonating frequencies of 2.3 and 5.6 GHz. The mutual coupling between the antenna elements was improved by insetting three elements of meta material SSR unit cells. The isolation achieved by the MIMO array is around -11.5 dB and -17.46 dB at its operating frequencies. The overall gain of the antenna array at is resonating frequency is also well above 2 dB. The proposed MIMO array can be considered for a potential application in a multiband WLAN communication system.

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