Design and Implementation of Slotted Circular Patch Antenna for MIMO Applications

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Abstract **-** This paper includes a design of a four-port patch antenna with bandwidth enhancement for MIMO application. The proposed antenna consists of two micro-strip patches printed on the substrate. The two patches are inner patch and the outer ring. We have obtained four different radiation patterns when the outer ring is excited by the resonant modes with the help of coaxial feeds. The proposed antenna is operating at 5.8 GHz frequency band with at least 10.7% in measurement impedance bandwidth for each port with low profile. By taking all the four ports into consideration the bandwidth of the proposed antenna is enhanced. Numerical and experimental results illustrate the validity of the design. In this project we are designing and analyzing antenna using HFSS tool of version 15.0

Key words: MIMO antenna, Radiation pattern, four port patch antenna.

I. INTRODUCTION

Multiple-input and multiple-output (MIMO) is a method for multiplying the capacity using multiple transmission and receiving antennas to exploit multipath propagation. In modern usage, MIMO specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same band by exploiting multipath propagation. It improves wireless communication capacity and robustness by exploiting multipath effects. Performances of these multiple antenna systems largely depend on the correlation between received signals [1]. To maximize the capacity, this correlation must be as low as possible. Spatial diversity is commonly used to reduce it. This is not always compatible with the limited volume available on a wireless terminal [1]. By using antennas with different radiation patterns, it is possible to reduce the size of the multiple antenna system while keeping a low correlation between received signals. To achieve this pattern diversity, the concept of co-located antennas has been introduced [6]. Nowadays, with the rapid development of microwave technology, there is a growing demand on the bandwidth [1]. Instead of using different antennas for different applications, we are going use the MIMO antenna for different applications. In order to achieve that, we try to enhance the bandwidth such that the four ports resonant at nearby frequencies [1].

There are many antenna designs for MIMO application based upon the multi-mode concepts, including slot antenna, spiral antenna, and dielectric resonator antenna. Microstrip antenna has also been widely investigated for MIMO application due to its low profile. Low profile means less complexity i.e, small height and width, ease of integration and fabrication. To enhance the bandwidth we have different options like increasing the height of the substrate, increasing the number of slots, including the partial grounds, choosing circular shapes. We have opted for circular shapes as other choices have their own disadvantages.

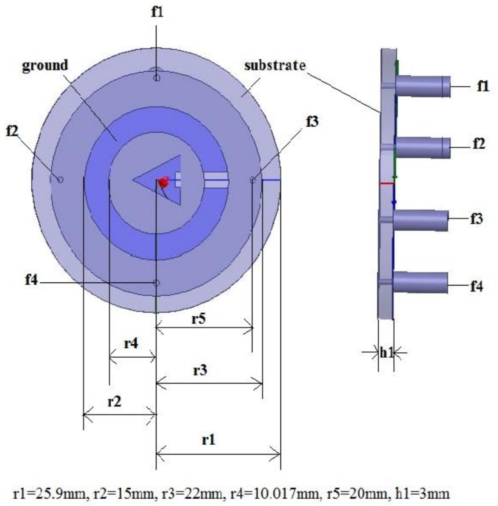

Figure1: Proposed model

In a rectangular patch antenna which consists of rectangular slots is considered which is used for MIMO applications. It is resonated at 2.45GHz and has impedance bandwidth of only 0.13%-0.25% .Here frequency convergence concept is used but it has the drawback of providing low bandwidth and introduction of slots result in overlapping. Hence the antenna cannot be used for many applications at the same time.

II. LITERATURE SURVEY

Four Port Disk Shaped Compact Mimo Antenna - The structure is composed of a circle patch with cross slot combined to an annular ring patch. This antenna is proposed for vehicular applications. In vehicular applications the large ground plane is necessary and the bandwidth of the antenna must be wide enough to cover the interested band. When the antenna is operated we get four different radiation patterns. When the antenna is simulated we get -16db in simulation and -18db in measurement in the frequency band. In this design a conventional ring and disc are used[2].

Dual-Band Multi-Port Mimo Slot Antenna - A compact dual-band multi-mode multiple input multiple output antenna design can be used for IEEE 802.11 applications. The antenna operates at 4.9-5.725GHz with 4-ports and at 2.4-2.5 GHz with 2 ports and utilizes a dual-port MIMO antenna to cover the 2.4/5GHz bands alongside two single band antennas to cover the 5GHz band. The overall antenna size is compact and is printed on an FR-4 printed –circuit-board. To achieve good performance in MIMO systems, the antenna ports should be uncorrelated and in most scenarios, this can be shown to be equivalent to good isolation or sufficiently low isolation between radiators. A major advantage of this design is that it does not require reconfiguration and the same or higher total efficiency and gain is achieved [3].

III. PROPOSED MODEL

The circular patch MIMO antenna is designed using EM simulator software Ansoft's HFSS v15, which works on the principle of Finite Element Method (FEM). The proposed model consists of substrate, ground and two patches. Substrate is made of material FR_4 epoxy of permittivity 4.4 and height 3mm.It uses FR4 epoxy substrate which has good fabrication characteristics and for a wide variety of applications, which offer significant cost savings. Ground plane and other two patches are perfectly conducting material. Ground is of radius 20.7mm and it consists of a rectangular slot of length 16.7mm and breadth 3mm. There are two patches in which, one is of outer annular ring and other is of inner circular patch. The inner circular patch consists of triangular slot. The triangular slot is introduced in order to the decrease the area of the circular patch. This circular patch's area is to be decreased in order to obtain unified bandwidth and identical resonant frequency. The triangular sides of length 5mm is introduced in inner patch, with median of (0,0,0) and area of 10.18mm^2

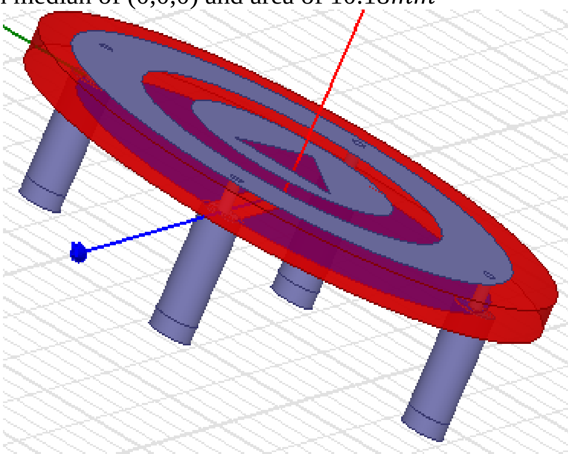

Figure 2: Four feed antenna designed in HFSS

The antenna is excited with coaxial feeds as it has its own advantages over other types of feeds. The outer patch is excited by the coaxial feeds symmetrically by assigning the wave port to it whose impedance is of 50Ω. The four feeds are given to the outer ring in order to distribute the field uniformly.

IV. SIMULATION RESULTS

In the context of S-parameters, scattering refers to the way in which the traveling currents and voltages in a transmission line are affected when they meet a discontinuity caused by the insertion of a network into the transmission line As there are 4 ports, we have to simulate the output i.e s-parameters of each port individually.

The s-parameters S_{11} of port 1 are simulated and it is resonated at 5.8GHz frequency and return loss of around -12.5db

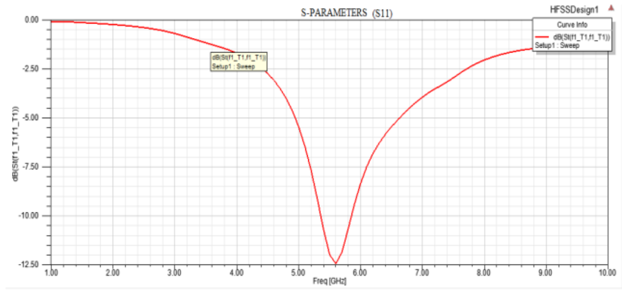

Figure 3: Frequency v/s Return loss for ant1

The s-parameters S_{22} of port 2 are simulated and it is resonated at 4.8GHz frequency and return loss of around -9.5db

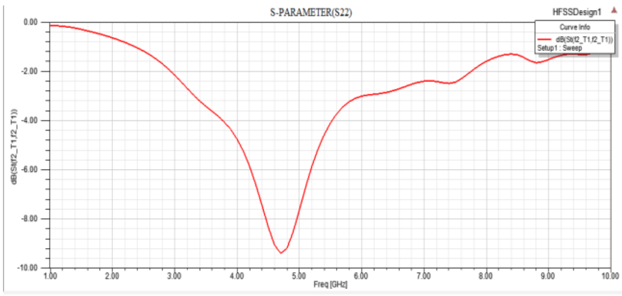

Figure 4: Frequency v/s Return loss for ant2

The s-parameters S_{33} of port 3 are simulated and it is resonated at 4.8GHz frequency and return loss of around -7.9db

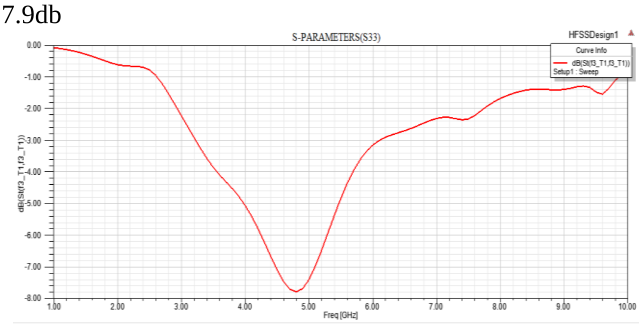

Figure 5: Frequency v/s Return loss for ant3

The s-parameters S_{44} of port 4 are simulated and it is resonated at 4.8GHz frequency and return loss of around -7.9db

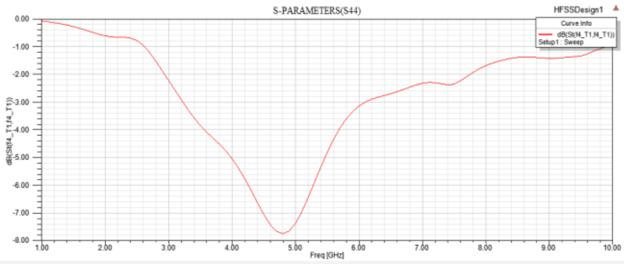

Figure 6: Frequency v/s Return loss for ant4

The 3D polar plot of the four port circular patch antenna is also observed

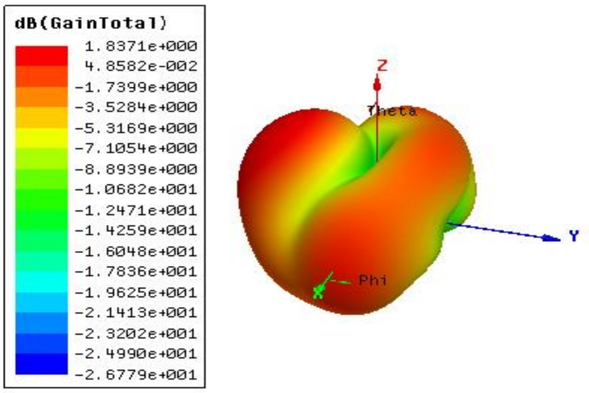

Figure 7: 3D polar plot

The radiation pattern of circular patch antenna is also observed from which gain is maximum at 90^0can be concluded. It a slice of 3D pattern of the antenna at a particular angle/ plane. From the plot below, it seems that there are four resonant frequencies for which Radiation pattern 2D is presented. The values on the perimeter of the circle is values for Theta while the values inside the circle such as -1 dB, -7 dB, -10 dB and -19 dB are the radiation intensity values.

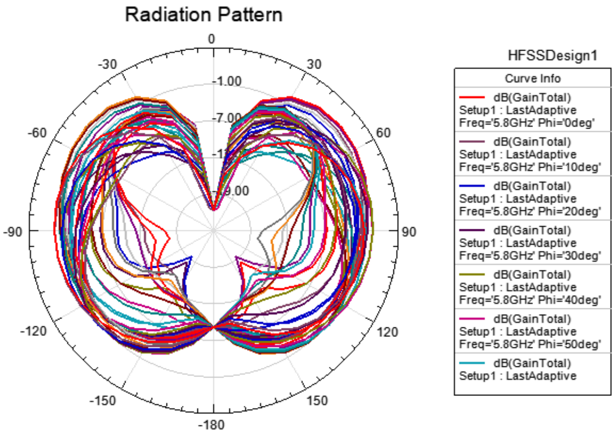

Figure 8: Gain of the antenna estimated from radiation pattern

The electric field distribution of the four port antenna is analyzed and observed.

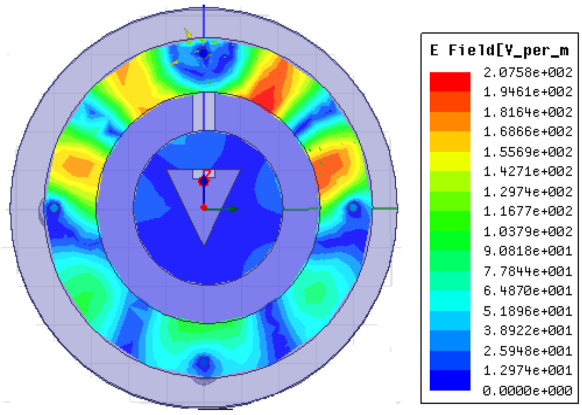

Figure 9: electric field pattern

The frequency bandwidth and percentage bandwidth can be obtained for circular Microstrip patch antenna as

$$frequency\ bandwidth = f_h - f_l \qquad (1)$$

And,

$$bandwidth\ percentage = \frac{f_h - f_l}{f_r} * 100 \qquad (2)$$

Where f_h and f_l are higher frequency and lower frequency, f_r is the resonant frequency

Hence from the four ports s-parameters graph we can infer that total bandwidth of the antenna is enhanced of about 10.7%

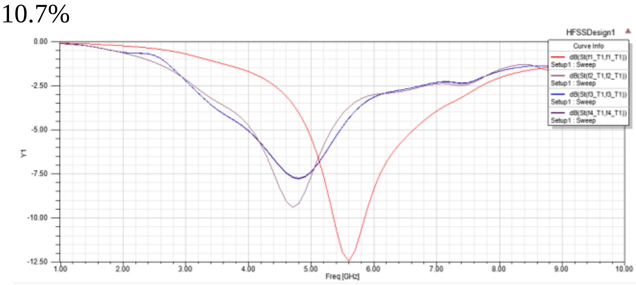

Figure 10: Combined bandwidth of the circular patch antenna

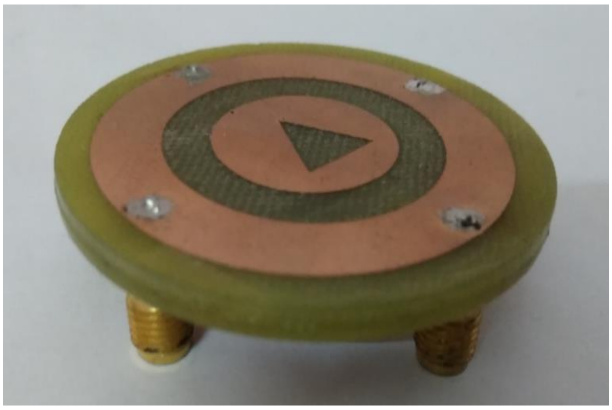

Figure 11: Prototype of proposed circular patch antenna

Figure 11 shows the prototype of circular patch antenna which is fabricated with four inputs for four ports. The patch design has been etched on a FR4 epoxy substrate of permittivity ε_r = 4.4 and thickness h = 3 mm. The feedings are given at the four sides welded via holes with coaxial feeding. The results obtained when we analyze the prototype may differ from simulation results due to antenna orientation and environmental changes.

The S_{11} graph for circular path antenna using prototype is shown in the figure12.The value is measured in the presence of noise absorbers. The S_{11} graph for prototype is shown in the figure for port1 is 4.9GHz.But, the simulated value is 5.8GHz .Due to the environmental changes and the orientation of the antenna, values may differ and return loss of -12.5db in simulated and -20db as in prototype.

Figure 12: S_{11} parameter measured in combinational analyzer

V. COMPARISION

Table1: Comparative results between antennas

Parameters	Ant1	Ant 2	Ant 3	Ant 4
Operating frequency	5.8GHz	4.7GHz	4.8GHz	4.8GHz
Return loss	-12.5db	-9.5db	-7.9db	-7.9db

VI. CONCLUSION

The designing of four port circular patch is done. We analyzed the circular patch antenna to observe the parameters like gain, bandwidth and s-parameters. When compared to the rectangular patch antenna the overall bandwidth is increased to 10.7%.Therefore the concept of circular antenna resulted in better performance.

VII. FUTURE SCOPE

The further extension for this design is to implement the concept of modal analysis.

An important characteristic of micro-strip patch antenna can be significantly improved by using multilayered dielectric configuration, bandwidth can be further enhanced.

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