NOVEL FOUR- PORT MIMO ANTENNA WITH HALFGROUNDFOR MULTI-BAND APPLICATIONS

Ms.S.Padma Priya[1], Mrs.P.Palniladevi[2], Dr.T.Sabapathi[3], Ms.K.RedeemEmima[4], Ms.M.Swetha[5] and Ms.M.Sneha[6]

[1,4,5,6]UG Student (B.E) ,[2]Assistant professor and [3]Associate Professor (Sr.Grade), Department of Electronics and Communication Engineering, Mepco Schlenk Engineering College, Sivakasi, Tamilnadu, India

[1]padmapriya01022002_ec@mepcoeng.ac.in, [2]ppalniladevi@mepcoeng.ac.in, [3]sabapathi@mepcoeng.ac.in, [4]emima2001_ec@mepcoeng.ac.in, [5]swemohan2001_ec@mepcoeng.ac.in and [6]sneha632001_ec@mepcoeng.ac.in

ABSTRACT

In this paper, a four-port multiple input multiple output (MIMO) antenna with half ground for multiband application has been presented. The four antennas are planned to be assembled on a single FR4 substrate of thickness 1.57mm withadequate isolation between them to produce a four-port MIMO antenna that can operate for multiband applications. The proposed MIMO antenna is simulated in ANSYS HFSS software. In the proposed antenna, the ground has been modified to improve the antenna parameters. For the proposed four-port MIMO antenna with half ground for multiple band applications, the achieved return loss is -33.88dB, -28.31dB, -30.56 dB, -29.45dB and -26.05dB; Insertion loss are -26.12dB, -19.67 dB, -27.29dB, -23.53dB and -24.62 dB; VSWR are 1.05 mag, 1.08 mag, 1.06mag, 1.07mag and 1.10mag for corresponding frequencies of 1.50GHz, 3.62GHz, 5.59GHz, 6.75GHz and 7.47GHz and gain of the proposed antenna is 4.3dB.

Index Terms- Single port antenna, four-port MIMO antenna, multiple- input multiple- output, multi-band.

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INTRODUCTION

In today's telecommunication fields needs a single antenna system that supports for multiband applications. Multi-band antennas are designed; it has several advantages with the goal of maximizing energy gathering. The multiband antenna designed by A.D. Boursianisetal works well in L- band, C-band, WiMAX, X band applications [1]. However, now a day's 4G, 5G applications take a role in wireless communication. The study of 5G networks was prompted by the ever-increasing need for faster data speeds, increased coverage, improved signal efficiency, and reduced latency. The MIMO design meets all requirements of both 4G and 5G antennas using a single structure[2] [3]. MIMO antennas should be able to provide multiband operation across a wide bandwidth for a variety of broadband services. Several MIMO antenna designs with multiband operations have been published, including a dual-band 8 x 8 MIMO antenna that works in the sub-6 GHz region. The design uses a completely grounded plane with closely spaced orthogonal pairs of antennas for improved performance, although it is bigger in size and has a coupling effect [4]. Anpingzhao proposed that very good isolation and antenna efficiency for an 8-antenna MIMO system can be obtained without using any additional isolation elements or decoupling techniques [5]. Separation between the antenna elements is a key feature of MIMO design, since it is required to minimize mutual coupling and enable reliable transmission. Because isolation is a crucial aspect in MIMO, a parasitic strip and defective ground structure (DGS) technology are used in tandem to increase bandwidth and isolation. [6][7]. MIMO structure is designed using patch elements. A Micro Strip Antenna's simplest form consists of a radiating patch on one side of dielectric substrate and a ground plane on the other side. Patch elements are designed in square, elliptical, triangular, semicircular, and annular ring shapes are also used. They are lighter in weight, low volume, low cost, low profile, smaller in dimension, and ease of fabrication and conformity [8] [9]. By providing enough isolation between the antenna elements, the mutual coupling between the antenna elements is decreased. Without altering the ground plane, the patch antenna's bandwidth and gain are inadequate. The antenna area is decreased to half of the typical one by modifying the ground plane size of the patch antenna, while still maintaining excellent gain and directivity, and thebandwidth is also enhanced [10] [11]. In this paper, an elliptical four-element MIMO antenna with half ground for multiple band applications is presented.

II. DESIGN AND SPECIFICATIONS

The main aim of this paper is to create an MIMO antenna for multiband applications. In MIMO systems, the minimum number of MIMO antenna employed at both the transmitter and reception ends is four. Four- port MIMO antenna has been designed, with the required isolation between the antenna elements to develop a MIMOantenna for multiple band applications. Ground plane of the MIMO antenna is reduced to increase the antenna parameters. The substrate element used in the design of MIMO is FR4, because FR4 has good resistance and it keeps high mechanical strength and good insulating capacity. Substrate thickness is 1.57mm.

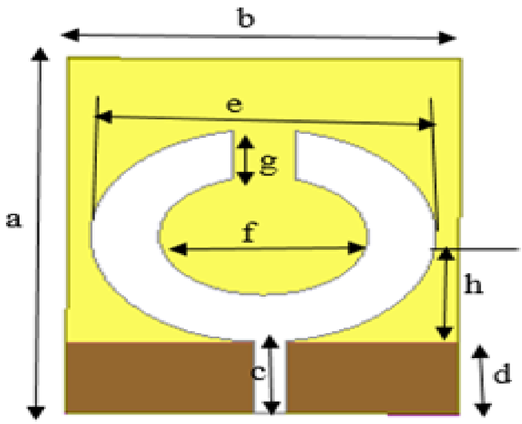

Fig.2.1: Single port design in HFSS

The dimensions shown in Figure.2.1 are a=60, b=50, c=22, d=18, e=36, f=20, g=8, h=10 all in mm. A single- port antenna has been designed in HFSS as shown in Figure .2.1. To create MIMO antennas for multiband, a minimum of four antenna elements must be employed. As a result, the single-port antenna has been extended to four ports. The design of four-port antenna is given in Figure.2.2.

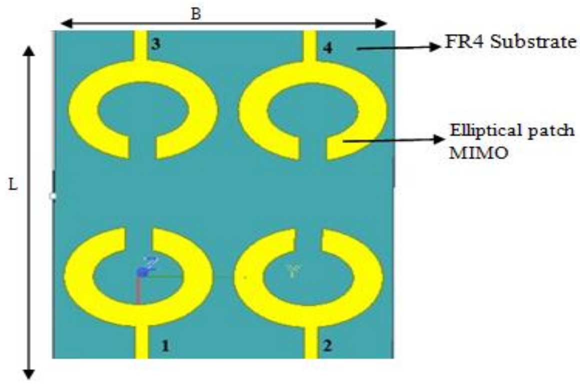

Fig.2.2: Four-port MIMO antenna design

The length (L) of the substrate is 120mm and the breadth (B) of the substrate is 100mm.A four-port MIMO antenna has been designed in HFSS as shown in Figure.2.2.

III. PROPOSED DESIGN IN HFSS

3.1 Design of Four Port Mimo Antenna with Half Ground

FR4 is used as a substrate with the thickness of 1.57mm to design a four-port MIMO antenna .The minimumnumber of ports for MIMO antenna is four used for multiband application. Here half ground structure is assignedfor MIMO antenna. To increase the antenna parameters such as return loss, gain, VSWR, the dimension of the ground plane is reduced to the dimension of strip line (18mm). Design of four-port MIMO antenna with half ground is given in Figure.3.1.1

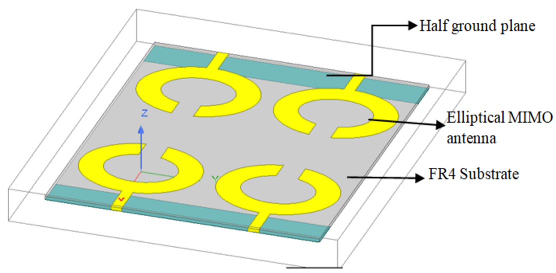

Fig.3.1.1: Four-port MIMO antenna with half ground

By reducing the dimension of the ground plane in using dimension of the strip line of the antenna, the antenna performance is increased. The four-port MIMO antenna gets S_{11} to S_{44} elements. For analyses return loss concentrate on S_{11}, S_{22}, S_{33} and S_{44}. To analyze the four-port MIMO antenna with half ground, the return loss S_{11} is obtained. The mutual coupling between the first and second antenna elements is identified by using S_{21}.

Generally, the mutual coupling between any two antenna elements should be less than −15dB.To analyze the power wastage between the antenna elements, S_{21} is obtained.

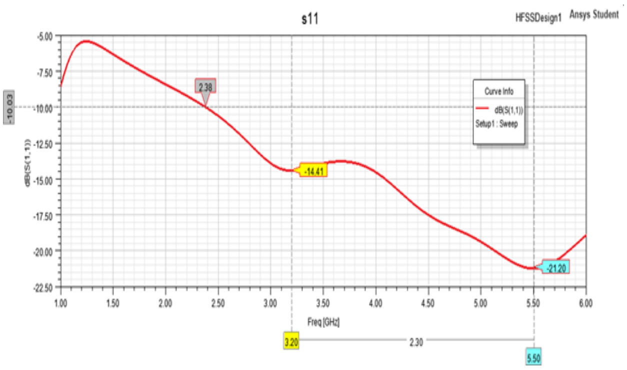

Fig.3.1.2: Return loss (S_{11}) for the four-port antenna with half ground.

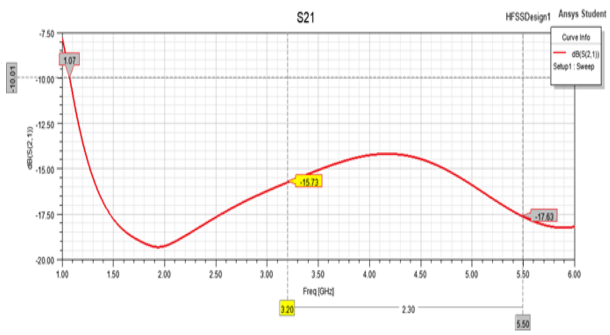

Fig.3.1.3: Isolation loss (S_{21}) for the four-port antenna with half ground.

In this plot, the obtained return losses are-14.40dB and -21.20dB for the corresponding frequency of 3.20GHz and 5.51GHz mentioned in Figure 3.1.2 it supports for multiband applications. Isolation losses (S_{21}) for the corresponding frequencies are -15.73dB and -17. 67dB mentioned in Figure 3.1.3. VSWR for the four-port MIMO antenna with half ground is given in Figure.3.1.4.

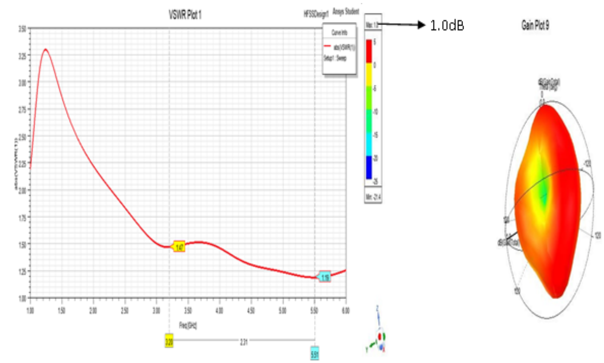

Fig.3.1.4. VSWR for the four-port antenna with half ground.

VSWR for the four-port MIMO antenna with half ground is 1.47mag and 1.19mag in 3.20GHz and 5.51GHz.Antenna gain is the ability of the antenna to radiate more or less in any direction compared to a theoretical antenna. It makes the antenna more directional at the transmitter, a good effect for reducing unwanted radio frequency (RF). Gain of the four-port MIMO antenna is measured in a 3D polar plot. Gain for the four-port MIMO antenna with half ground is given in Figure.3.1.5. The obtained gain for four-port MIMO antenna with half ground is 1.0dB.

3.2 Design of Direction Changed Four Port Mimo Antenna with Half Ground

Ground plane of the MIMO antenna is reduced to half of the dimension to increase the antenna parameters, and it also requires the correct orientation for optimal performance. Correct placement and orientation allow each antenna element to catch a different polarization and reduce the mutual coupling between the antenna elements. Antennaorientation technique is used to reduce the mutual coupling between the antenna elements.

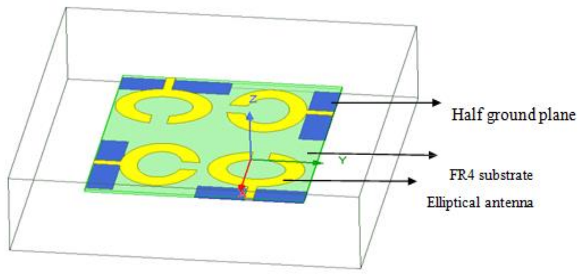

Fig.3.2.1. Four-port MIMO antenna with half ground after changing the orientation of antenna.

To enhance the antenna parameters and gain, the orientation of the antenna elements is changed and the dimensionof the ground plane is reduced to the dimension of strip line as shown in Figure 3.2.1. Return loss for the four- port MIMO antenna with half ground after changing the position of the antenna elements is obtained in Figure.3.2.2

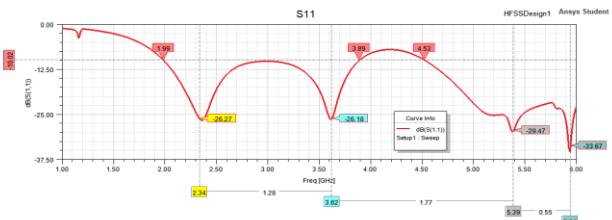

Fig.3.2.2. Return loss for the four-port antenna with half ground by changing position

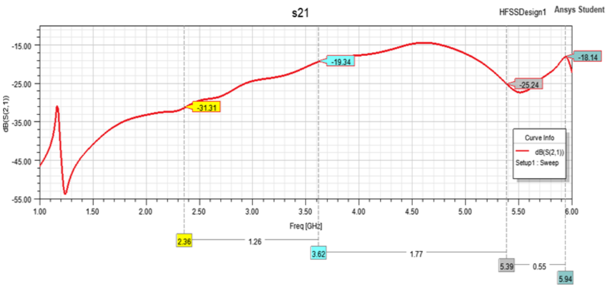

Fig.3.2.3. Isolation loss (S_{21}) for the four-port antenna with half ground by changing position.

In this plot, the obtained return losses are -26.64dB, -26.31dB, -29.54dBand-35.04dB for the corresponding frequency of 2.36GHz, 3.62GHz, 5.39GHz and 5.94GHz it operates at various band of frequencies. Isolation losses(S_{21}) for the corresponding frequencies are -31.31dB, -19.34dB, -25.24dB and -18. 14dB mentioned in Figure 3.2.3. VSWR for the four-port antenna with half ground after changing the position is given in Figure.3.2.4.

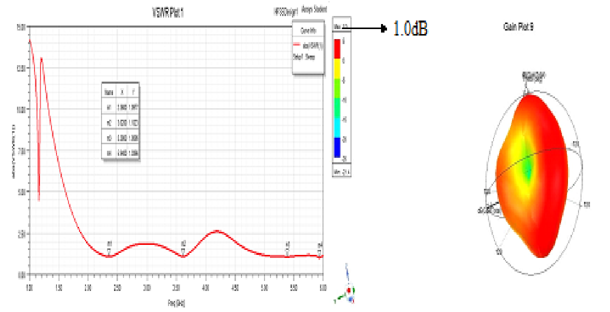

Fig.3.2.4. VSWR for the four-port antenna with half ground afterchanging the position.

Fig.3.2.5. Gain of the four-port antenna with half ground afterchanging the position.

VSWR for the four-port antenna with half ground after changing the position and direction of the antenna is 1.09 mag,1.10 mag,1.07 mag and 1.04 mag in 2.36GHz,3.62GHz,5.39GHz, and 5. 94GHz operates at various bands of frequencies is mentioned in Figure 3.2.4. Gain of the directional changed four-port MIMO antenna is increased compared to the other proposed designs. Gain for the four-port antenna with half ground after changing the position is given in Figure.3.2.5. The obtained gain for four-port MIMO antenna direction changed to half ground is 1.0dB. By changing the direction of the antenna and reducing the dimension of the ground plane, the overall antenna performance is increased and the gain is 1.0dB.

3.3 Design of Direction Changed Four-Port Mimo Antenna with Dgs

The Defective Ground Structure (DGS) has been used in the field of microstrip antennas for enhancing the bandwidth and gain of microstrip antenna and to reduce the mutual coupling between adjacent elements. The circular DGS is introduced in the ground plane of the four-port MIMO antenna as shown in Figure 3.3.1, to cover the lower frequency and to increase gain. The slot radius is 2mm.

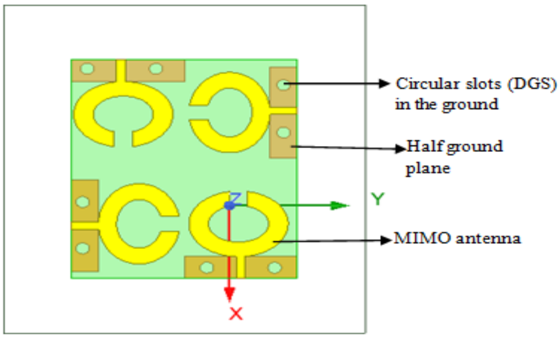

Fig.3.3.1. Direction changed MIMO antenna with DGS

To enhance the antenna parameters and to cover the lower frequencies, the circular slots are introduced in to the ground plane. To analyze the antenna parameters, return loss (S_{11}) is obtained in figure.3.3.2.To analyze the power wastage between the antennas elements isolation loss (S_{21}) is obtained in figure.3.3.3.

Fig.3.3.2. Return loss for the four-port antenna with slot in half ground.

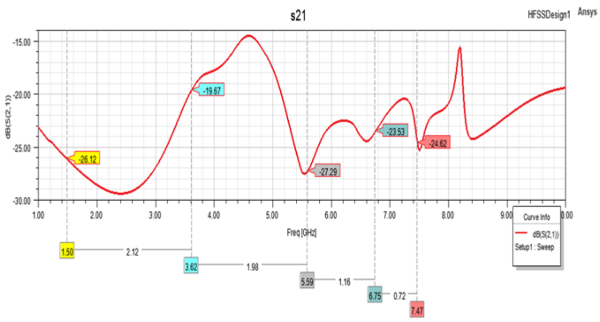

Fig.3.3.3.Isolation loss for the four-port antenna with a slot in the ground plane.

From the figure.3.3.2. the return losses are -33.88dB,-28.31dB,-30.56dB,-29.45dB,-26.05dB for the corresponding frequencies of 1.50GHz, 3.62GHz, 5.59GHz, 6.75GHz, 7.47GHz and it also covers the lower frequency that operates for multiband applications. To analyze the power wastage between the antenna elements, Isolation loss (S_{21}) is obtained. The power wastages, that is, the isolation loss between the antenna elements is always less than -15dB.From figure.3.3.3 isolation loss for the four port MIMO antenna with slot in ground are -26.12dB,-19.67dB,-27.29dB,-23.53dB,-24.62dB for the corresponding frequencies of 1.50GHz, 3.62GHz, 5.59GHz, 6.75GHz, 7.47GHz.VSWR for the four-port antenna with half ground after changing the position is given in Figure.3.3.4

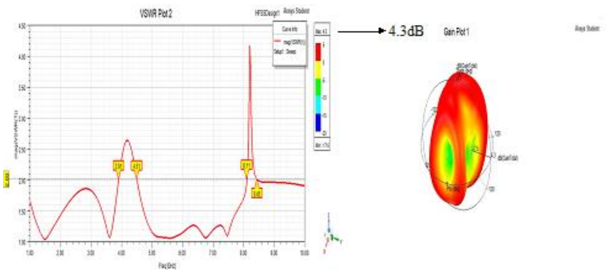

Fig.3.3.4. VSWR for the four-port antenna with slot in halfground.

Fig.3.5.5. Gain of the four-port antenna with slot in groundplane.

VSWR for the four-port MIMO antenna with a slot in the ground plane are 1.05mag, 1.08 mag, 1.06 mag, 1.07mag,

1.10 mag for the corresponding frequencies of 1.50GHz, 3.62GHz, 5.59GHz, 6.75GHz,7. 47GHz.Gain for the four-port MIMO antenna with a slot in the ground plane is measured in a 3D polar plot. Gain for the four-port MIMO antenna with a slot in the ground plane is obtained in Figure.3.3.5. The obtained gain for four-port MIMO antenna direction changed with a slot in the ground plane is 4.3dB. By changing the direction of the antenna and reducing the dimension of the ground plane and introducing the circular slot in the ground plane, the overall antenna performance and gain is increased.

IV. MEASUREMENT ANALYSIS

Table.4.1. Comparision Table

	Frequency (GHZ)	Return loss S_{11}(dB)	Isolation loss S_{21} (dB)	VSWR (mag)	Gain (dB)
Four-port MIMO antenna with full ground.	4.89	-14.75	-20.91	1.47	-1.35
Four-port MIMO antennawith half ground.	3.20	-14.40	-15.73	1.47	1.0
	5.51	-21.20	-17.67	1.19	
Directional changed four-port MIMO antenna withfull ground.	4.89	-12	-35.30	1.68	0.9
Directional changed four-port MIMO antenna with half ground.	2.36	-26.64	-31.31	1.09	1.0
	3.62	-26.31	-19.34	1.10	
	5.39	-29.54	`-25.24	1.07	
	5.94	-35.04	-18.14	1.04	
Directional changed four-port MIMO antenna with slot(DGS) **(proposed work)**	1.50	-33.88	-26.12	1.05	4.3
	3.62	-28.31	-19.67	1.08	
	5.59	-30.56	-27.29	1.06	
	6.75	-29.45	-23.53	1.07	
	7.47	-26.05	-24.62	1.10	

From the Table.4.1. By analyzing the antenna parameters of four-port MIMO antenna with different ground structure and by changing the direction of antenna, the half ground structure gives more gain and better performance than the full ground structure, and after changing the direction of the antenna elements and introducing a slot in the ground, it gives more gain in half ground structure. The four-port antenna with half ground gives 1.0dB gain and the four-port antenna with a slot in the ground after changing the position gives an increased gain of 4.3dB. Therefore, by changing the direction of the antenna elements and introducing the slot in the ground plane, the antenna performance is enhanced and there is good frequency coverage (1-8GHz).

VI. CONCLUSION

In this paper, four-port MIMO antenna with full and half ground and MIMO antenna direction shifted with full and half ground and MIMO antenna direction shifted with slots in the ground are designed and analyzed. The proposed direction shifted MIMO antenna with slots in the ground covermultiband L-band, WI-MAX band and X-band satellite communication. The four-port MIMO antenna direction changed with DGS based half ground gives the better antenna parameters and it also covers the frequency range (1-8GHz) usedfor multiband applications. The simulated and measured MIMO antenna provides better results useful for multiband applications.

VII. CONFLICTS OF INTEREST

The author(s) declare(s) that there are no conflicts of interest regarding the publication of this article.

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