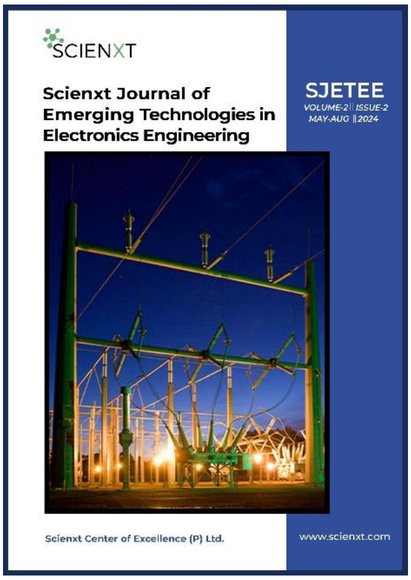

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A coplanar mimo antenna with reduced mutual coupling for ism band applications

Snehal Sanjay Patil
M.Tech (Electronics), Assistant Professor CSE Department
RIT Islampur

Priyanka Gajanan Bendre
M.E (Electronics), Assistant Professor CSE Department
RIT Islampur

**Corresponding Author: Sarika Rai*
Email: rai91sr09@gmail.com

Abstract:

This paper discuss about problems of mutual coupling and uses transmission coefficient S12 as means tocharacterize it. The lesser the value of S12 less amount of power is coupled between ports. This paper describes design and optimization of rectangular patch antenna in ISM band, operating at centre frequency of 2.45GHz. Such 4 elements are placed are placed in a matrix of 2X2 separated by distance of λ/2 and mutual coupling of -23dB is observed. Since ground plane is common and continuous between 4 elements amount of unwanted coupling is more 4 separate ground planes for 4 separate antennas is investigated. Mutual coupling for such antenna is reduced by almost 10Db. The simulated and fabricated results align with the conclusion that separate ground planes are better in performance for mutual coupling. Gain of MIMO antenna system is observed to be increased from 2.8dB to 3.7dB for modified MIMO antenna. Proposed MIMO antenna can be used in high efficiency ISM band applications**.**

Keywords:

MIMO Antenna, MSA, mutual coupling, gain, impedance matching.

1. Introduction:

Over the past few years, a remarkable development in indoor and outdoor wireless activities enhances the multiple input multiple output (MIMO) antenna technology. Most of the wireless work on MIMO antenna systems wasreported and investigated for wireless local area network (WLAN)/worldwide interoperability for microwave access (WiMAX)/long term evolution (LTE) and other required applications. MIMO technology is a good candidate in non-line of sight(NLOS) communication to provide better quality of services. The idea of MIMO was started with the capacity theorem [1] and its application on wireless communication with pulse amplitude modulation signals [2], multivariate analysis overthe Gaussian channel with memory [3], multi-channel digital transmission systems [4, 5], and directional digital transmission and reception using beam-forming signal-processingapplications [6, 7]. The idea of using an array at the base station to improve channelcharacteristics for transmission and reception with space division multiple access invoked in minds of Richard Roy and Bjorn Ottersten [8]

Multiple-input-multiple-output (MIMO) is an advanced technology for multiplying the Capacity of a radio link using multiple transmit and receive antennas to achieve multipath propagation. MIMO systems specifically refer to apractical technique for sending and receiving multiple independent channels simultaneously over the same radio channel using multiple antenna topologies without any extra radiation power loss in rich scattering environment. It is also featured as next generation wirelesscommunication technology due to its capability of improving system reliability and increasing channel capacity using multiple antennas. MIMO was initially proposed in the early 90’s as a feasible solution that can overcome the data rate limitation experienced by single-input-single-output (SISO) systems. Further, MIMO can be used in different networks to improve channel capacity, system reliability and transmission speed of data by utilizing the highest capacity of the wireless communication systems.

Mutual coupling in MIMO antennas arises dueto free space radiations, surface currents, and surface waves. The former two are general for alltypes of arrays, whereas the last one is more common for micro strip antennas. The mutual coupling can seriously degrade the signal- to interference-noise ratio (SINR) of an adaptive array and the convergence of array signal processing algorithms [5], [6]. It can degrade theestimations of carrier frequency offset [7], channel estimation [8], and angle of arrival [9]. Latest increase in a couple of in multiple (MIMO) structures for wireless verbal exchange Needs studies in efficient use of array antenna. Micro strip antenna array is likewise used in many

Needs studies in efficient use of array antenna. Micro strip antenna array is likewise used in many

Programs due to compatibility with RF circuits, smaller size, less weight and clean fabrication.

All array factors percentage substrate and floor. This results in troubles involving mutual coupling As a result of floor waves and unfastened area radiation by using floor. To be had literature categorize 3. Distinctive strategies for decreasing mutual coupling. First approach is based totally on innovative and Green arrangement of radiating elements. It's been located that intentionally designed Truncation and corrugations in edges of factors of Vivaldi antenna drastically reduces mutual Coupling [1]. Placing radiating patches close to to floor [2] or arranging patches at angular offset With respect to every different [3] also improves overall performance of array antenna. These nuance adjustments In positioning and orientation of radiating elements reduces mutual coupling in very small Quantity. A number of the researchers describe second method to resolve this problem with use of Decoupling networks like meander line in ground at the back of radiators [4]. Such decoupling networks May be lumped or disbursed in nature.[5]. This technique did not turn out to be very popular amongst Researches because of complex nature of decoupling network layout. Paper discusses design of Micro strip array with 4-element continuous ground and 4-element separated ground antenaa. Last Part of this paper describes simulation and fabrication results followed by conclusion. High frequency structure simulator (HFSS) by ANSYS is used for simulation purpose. Even though antenna is four ports, it maintains low profile and light weight, and the radiation properties remain unaltered.

2. MIMO Antenna Design:

Understanding of extent of mutual coupling between multiple ports is important to consider as a standard reference to which modified structures can be compared. Here comparison of 4 antennas has been considered

a) 4-element continuous ground array antenna

b) 4-element separated ground array antenna

2.1. Antenna structures:

Design of array antenna started with simple rectangular micro strip patch antenna element of size 37mm X 28mm. Four such elements symmetrically arranged in 2 rows and 2 columns such that their edges are 30mm apart from each other as shown in figure 3. Entire structure is designed over FR4 material as substrate which has relative Dielectric Constant of 4.4. Substrate used is 1.6mm thick with opposite side covered with copper plane acting as ground having dimensions as 164mm X 176mm.

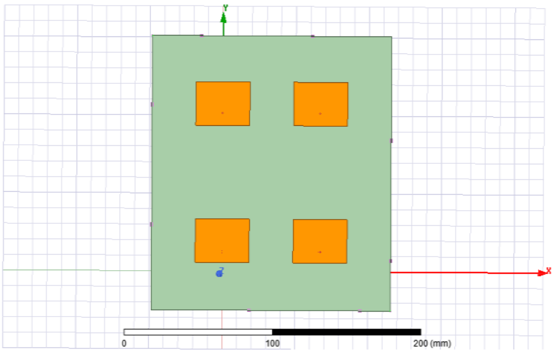


Figure. 3: 4-Element Continuous Ground ArrayAntenna

4-element separated ground arrayantenna

Design of array antenna started with simple rectangular micro strip patch antenna element of size 37mm X 28mm. Four such elements symmetrically arranged in 2rows and 2 columns such that their edges are 30mm and edges from separated part is 5mm apart from each other as shown in figure 4. Entire structure is designed over FR4 material as substrate which has relative Dielectric Constant if 4.4. Substrate used is 1.6mm thick with oppositeside covered with copper plane acting as groundhaving dimensions as 164mm X 176mm.

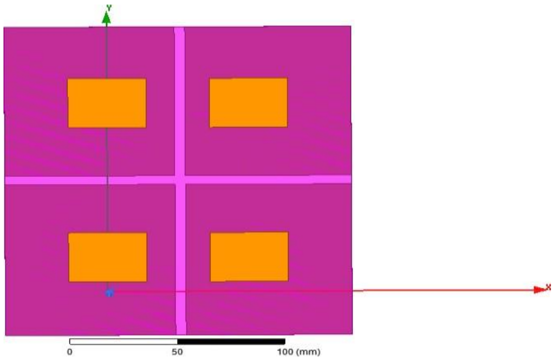


Figure. 4: 4-Element Separated Ground ArrayAntenna

3. Simulation results:

Results of all four antennas with respect toparameters: reflection coefficient,

3.1. Reflection coefficient S11:

Return Loss lessthan -10 dB indicates operating band of all antennas. Designed antennas like

1-element array antenna, 2-element array antenna, 4- element continuous ground array antenna and 4-element separated ground array antenna operates at resonating frequency of 2.4329 and 2.4458 GHz respectively with S11 as low as, - 27.8446 and -24.6661 dB respectively. Each antennas having narrow bandwidth of 60, 60 MHz with start band frequencies of 2.40, 2.41 GHz and end band frequencies of 2.46, 2.47 GHzrespectively as seen in Fig. 6.

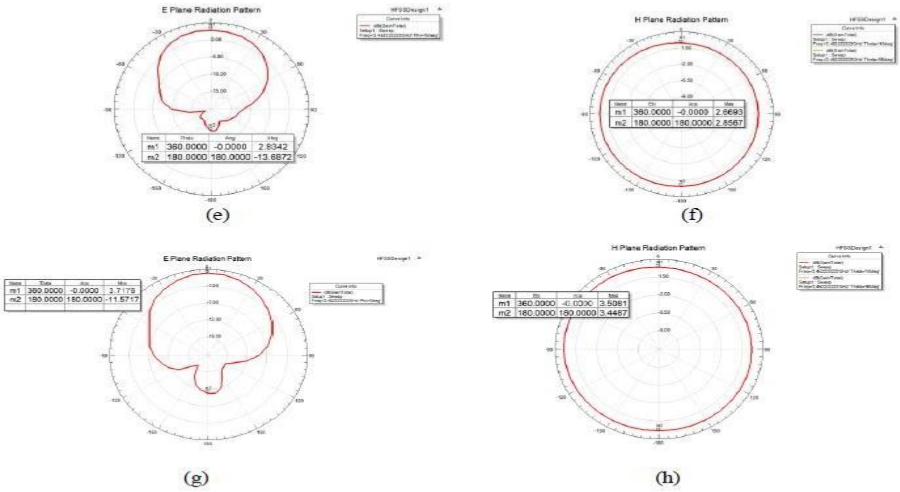
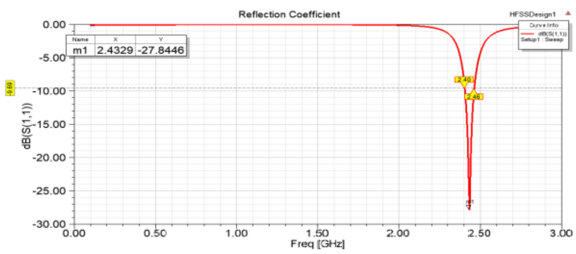
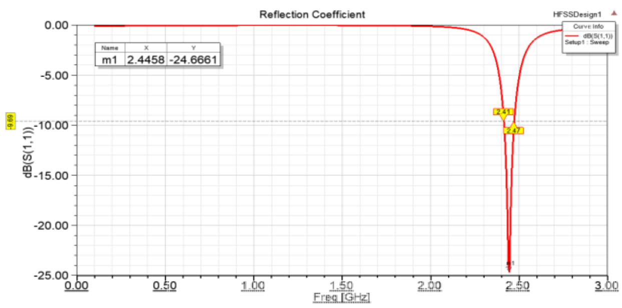


Figure. 7: E-plane and H-plane Radiation Pattern of of: (e, f) 4-element continuous ground array antenna (g, h) 4-element separated ground array antenna



(c)



(d)

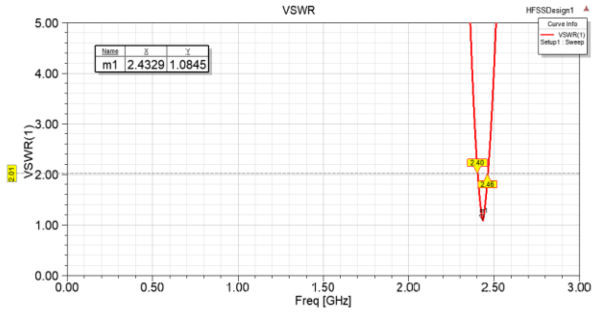
Figure. 6: Reflection Coefficient (S11) of: (a) 1- element array antenna (b) 2-element array antenna (c) 4-element continuous ground arrayantenna (d) 4-element separated ground array antenna

3.2. Radiation pattern:

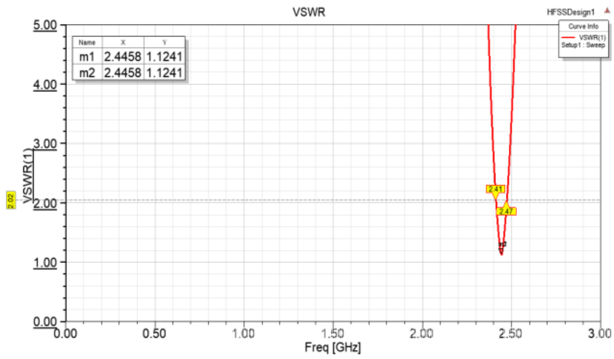
Radiation Pattern of 1-element arrayantenna, 2-element array antenna, 4-element continuous ground antenna and 4-element separated ground antenna shows unidirectionalradiation in E-Plane and omnidirectional radiation in H-Plane of antenna with maximum gain of 1.5526, 2.9659, 2.8342, 3.7176 dB along 0 degree (boresight) direction as shown in below figures.

3.3. VSWR:

The Voltage Standing Wave Ratio (VSWR) is an indication of the amount of mismatch between an antenna and the feed line connecting to it. This is also known as the Standing Wave Ratio (SWR). The range of values for VSWR is from 1 to ∞. A VSWR value under 2 is considered suitable for most antenna applications. As shown in Fig. 8, for designed antennas like 4-element continuous ground array antenna and 4-element separated ground array antenna the VSWR values are 1.0845 and 1.1241 respectively for frequencies 2.4329 and 2.4458 GHz.



(a)

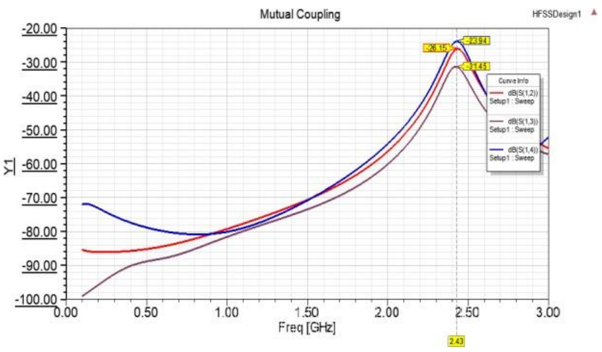


(b)

Figure. 8: VSWR of: a) 4-element continuousground (d) 4-element separated ground

3.4. Mutual coupling S:

Mutual coupling is unwarranted electromagnetic crosstalk between antenna units in an array. That is energy absorbed by one antenna's receiver when another antenna is operating. Total power supplied to each element in array depends on their own excitation and additional contributions from adjacent antenna units. Thisreduces the antenna efficiency and performance.



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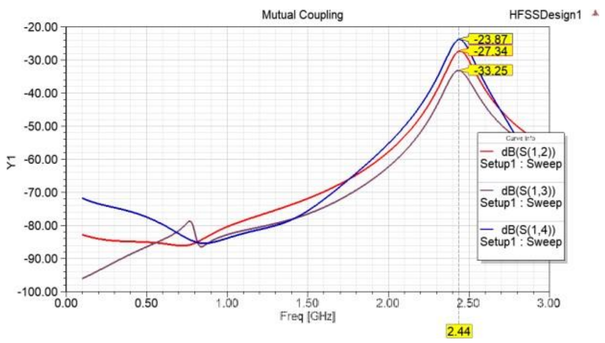


(d)

Figure. 8: Mutual coupling value of: (c) 4- element continuous ground array antenna (d)4-element separated ground array antenna

3.5. Mutual coupling:

Electromagnetic surface wave interaction between antenna units in an array is mutual coupling. Power supplied to each antenna element depends on their own excitation and also on the contributions from adjacent antenna units. Thus mutual coupling results in reduction of the antenna efficiency and performance. Coupling of micro strip antennas is studied using FDTD [2]. The Scattering matrix is defined as, Where a1, a2, b1, b2 normalized incoming and outgoing waves at ports. Voltages, impedances, currents and waves are related with each other as follows;

$V1 = \sqrt{Zc1}(a1+b1)$ (5)

$l1 = \frac{1}{\sqrt{zc1}}(a1-b1)$ (6)

$V2 = \sqrt{ZC2}(a2+b2)$ (7)

$l_2 = \frac{1}{\sqrt{Zc2}}(a_2 - b_2)$

Where, Z_{C1}, Z_{C2} are probe impedances used for feeding. If we put a2=0 i.e. no incident wave at second port since only first port is active and others are terminated in matched load. Thus, equation (4) will be modified as

$b_1 = S_{11} * a_1$ (9)

$b_2 = S_{21} * a_1$ (10)

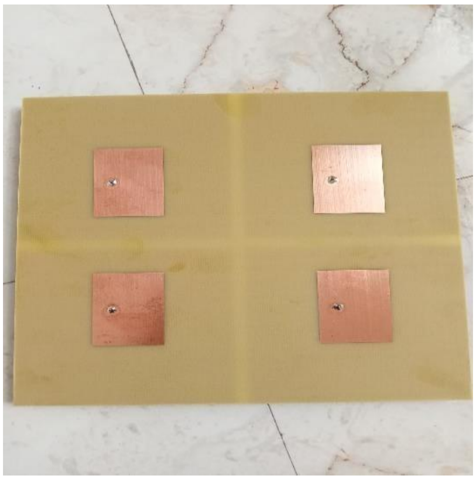
Input impedance and transfer impedances canbe calculated by substituting above equations:

$$\frac{V_1}{I_1} = Z_{c1}\frac{1+S_{11}}{1-S_{11}}$$

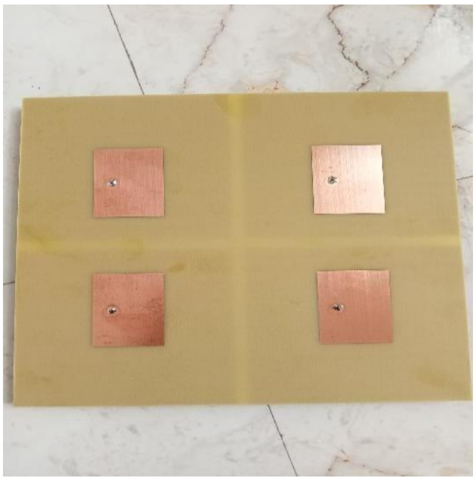
$$\frac{V_2}{I_1} = \sqrt{Z\ Z}\ S_{21} \quad (12)$$

Mutual coupling S21 and return loss S11 can be easily calculated by rearranging terms in equation (11) and (12) [9].

4. Fabrication:

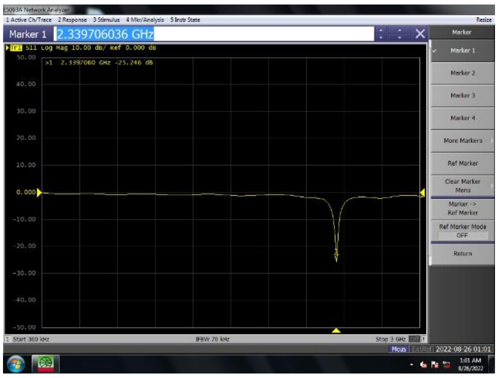


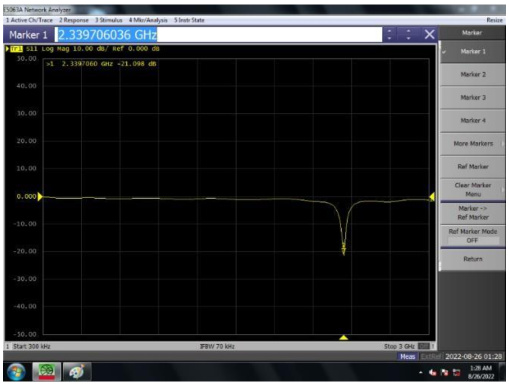
(a) Fabricated 4-element Continuous groundarray antenna (b) 4-element separate ground array antenna



b) 4-element separate ground array antenna

4.1. Simulated graph- S11 (Reflection coefficient):

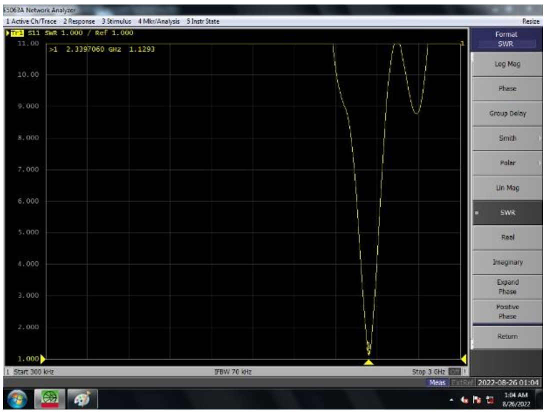


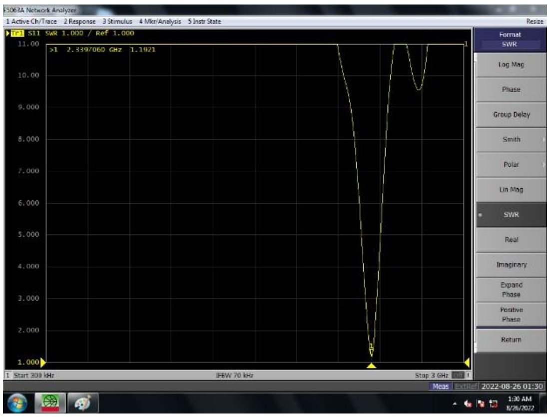


Continous ground Separated ground

Resonating frequency of 2.34 GHz indicated by lowest S11 is constant for continuous ground and separate ground. S11 have value of -25.246 dB and -21.098 dB respectively for both antennas. Acceptable values for S11 are below -10 dB. A shift of resonating frequency towards lower side of band is due to human errors in fabrication and testing.

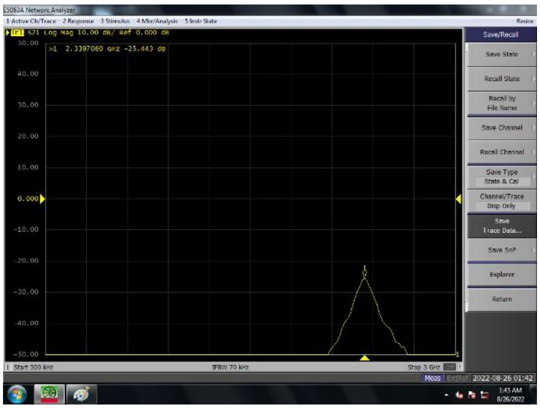
4.2. VSWR (Voltage standing wave ratio):

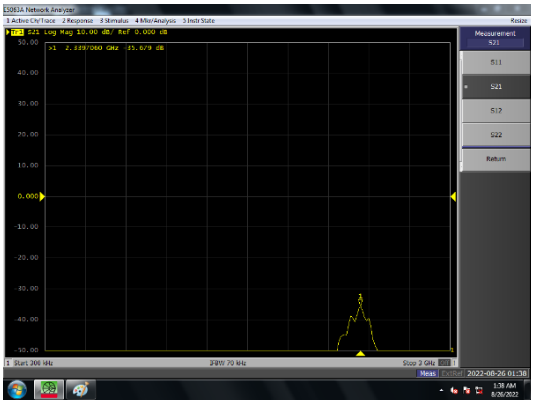




Resonating frequency of 2.34 GHz indicated by lowest VSWR is constant for continuous ground and separate ground. VSWR have value of 1.129 and 1.192 dB respectively for both antennas. Acceptable values for VSWR are between 1 & 2. Thus it is evident from S11 and VSWR graphs that antenna is functional in ISM band.

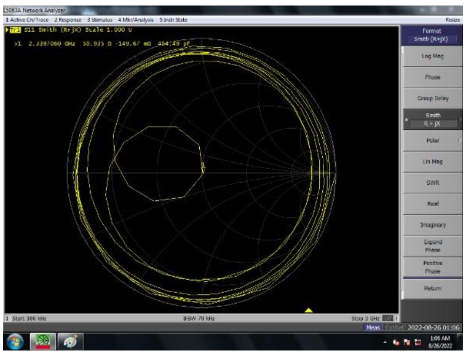
4.3. S12 (Mutual coupling):

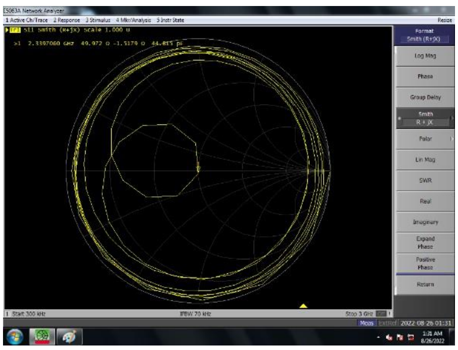




Resonating frequency of 2.34 GHz indicated by sudden peak in S12 is constant for continuous ground and separate ground. S12 have value of -25.443 dB and -35.679 dB respectively for both antennas. Themutual coupling is reduced by almost 10 dB, which is an useful characteristic for MIMO antenna.

4.4. Smith chart:





Smith chart graphs show a good impedance matching of both antennas at resonating frequency; indicated by closeness of marker to center of the smith chart. This means that both antennas have terminal port impedance very close to ideal impedance of 50 Ohm.

4.5. Comparative result:

Table. 1:

Sr.No	*Parameter*	*4-element continuous ground*		*4-element separated ground*	
		Simulated	***Measured***	***Simulated***	***Measured***
1	S11	-27.8446 dB	-25.246 dB	-24.6661dB	-21.098 dB
2	VSWR	1.0845	1.129	1.1241	1.192
3	S12	-26.15 dB	-25.443 dB	-33.25 dB	-35.679 dB
4	Bandwidth	60 MHz	70 MHz	60 MHz	78 MHz
5	Gain	2.8342	Not Measured	3.7176	Not Measured
6	Resonating Frequency	2.4329	2.34GHz	2.4458	2.34 GHz

5. Conclusion:

This paper only discusses about 1-element, 2- element, 4-element continuous ground and 4-element separated ground array. As mutual coupling reduces from -25.443 dB to -35.679 dB due to involvement of separate ground for individual elements. Radiation pattern of antenna array remains unaffected due to separate ground, while gain of antenna increases from 2.834 dB to 3.717 dB due to reduced mutual coupling. Simulated and fabricated antenna results are in good agreement with each other. Further investigations can be made with higher order arrays to verify proposed theory.

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