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# Effect of Substrate parameters on Mutual Coupling between Microstrip Antennas

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**Abstract**: For any wireless application, microstrip patch antenna has to meet the contrasting requirement of high gain and low return loss. The gain of microstrip patch antenna can be improved by increasing the number of antenna elements forming a linear or planar array. Mutual coupling between microstrip antennas becomes an important factor to consider when designing an antenna array. A mutual coupling reduction method is introduced here for closely placed two element microstrip antennas positioned in E-plane, H-plane and for diagonal orientations. The microstrip patch array antennas are designed, simulated and optimized using HFSS software. To achieve the compactness of an antenna array, antennas are placed at distance of less than half wavelength. To reduce the coupling effect, rectangular slots are introduced between the patch antenna elements.

**Keywords**: Mutual coupling, Microstrip Array Antenna, HFSS, Simulation, RT Duroid.

## I. INTRODUCTION

The microstrip patch antennas are well known for their performance, robust design, fabrication and their extent usage. The applications are in the various fields such as medical, satellites, military systems, aircrafts, missiles etc. The usages of the microstrip antennas are spreading widely in all the fields and now they are booming in the commercial aspects due to their low cost of the substrate material and fabrication. In some applications where high gain is required and area is a constraint, the dimensions of antenna and the number of antennas used play a crucial role. When more than one antenna is used, each radiating element will affect the gain of other antenna because of mutual coupling. The effect increases as the distance between the radiating elements is reduced. This reduces the overall gain of the system.

The mathematical equations in [1] [2] are used to understand the variation of mutual coupling with respect to distance in E and H planes and with respect to angle variations. In order to reduce the mutual coupling between the antennas [3], the radiating elements have to be placed far greater than half wavelength. The structure that comprises of a slit pattern etched onto a single ground plane to decrease the mutual coupling between antenna elements which are placed closer [4].One technique to reduce mutual coupling is by introducing (cutting) a slot on the ground plane, referred to as defected ground structure (DGS) [5], [6]. This solution is not useful in our case, because the aim here is to compact the array antenna. In order to achieve the compactness of the array, as well as to reduce the mutual coupling, the slots were introduced between the radiating elements. The technique, which effectively suppresses mutual coupling of closely placed microstrip antennas than any other traditional methods, makes use of a simple slot. The slots were introduced in E-pane, H-plane, Right diagonal plane and Left diagonal planes. The air gap in the slots helped to reduce the mutual coupling between the antennas to some extent. The slot dimension is optimized to get better $S_{11}$, $S_{12}$,VSWR and gain. The antennas are simulated in HFSS software at 1.575GHz for GPS application with RT Duriod substrate. Antenna array is also simulated with FR4 and TMM10i substrates to compare the performance of antenna characteristics on substrate parameters.

The maximum additional gain achieved by introducing a slot is 0.5dB. The mutual coupling reduction of -2dB is achieved. In Section II, we describe the proposed slot structure and demonstrate its effectiveness when configured with two closely placed microstrip antennas.

In Section III, S-parameters and radiation patterns of the antennas are given. Finally, in Section IV, a conclusion of the work is presented.

## II. ANTENNA GEOMETRY AND DESIGN

### A. *Antenna Geometry*

The geometry of the designed two-element microstrip antennas is shown in Fig. 1. This array consists of two microstrip antennas operating at 1.575 GHz. RT Duroid with dielectric permittivity of 2.2 and loss tangent of 0.0009 is used for simulation.

The microstrip antennas on a common ground plane have centre to centre spacing of less than $\lambda/2$. The two microstrip antennas use two symmetrical co-axial feed points and are fed with a 50Ω SMA coaxial probe.

L and W denote the length and width of the slot structure, respectively. Parameter feed denote the offset of the feed point from the antenna edge.

AL is the width of each microstrip antenna. The ground size is denoted by GW X GL. Slot dimensions are optimized for better antenna performance.

Antenna substrate specification details and frequency of operation are shown in table I.

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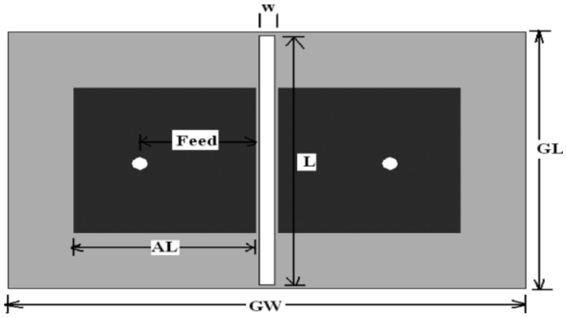

Fig.1 Microstrip slot array antenna model

TABLE I
ANTENNA DESIGN PARAMETERS

| Parameters | Specification | | |
|---|---|---|---|
| Resonant Frequency ($f_r$) | 1.575GHz | | |
| Substrate | RT-Duroid | FR4 | TMM10i |
| Dielectric constant ($\varepsilon_r$) | 2.2 | 4.4 | 9.9 |
| Loss tangent ($\delta$) | 0.0009 | 0.02 | 0.002 |
| Thickness of substrate | 1.57 mm | 1.6mm | 1.6mm |
| Feeding method | Co-axial feed | | |

## III. SIMULATION RESULTS AND DISCUSSION

Simulation of designed antenna is carried out using HFSS electromagnetic software. The output results are described in this section.

*A.* Model of 1x2 array antenna in H-Plane without slot

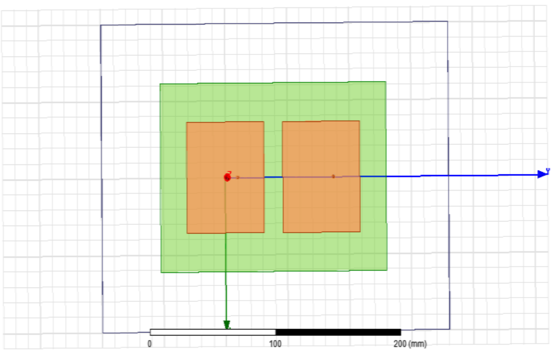
Fig.2 (a) simulated array antenna model for H-plane Without slot

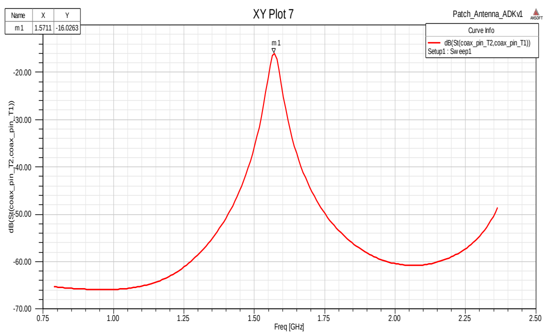

Fig.2 (b) $S_{12}$ (dB) v/s frequency (GHz)

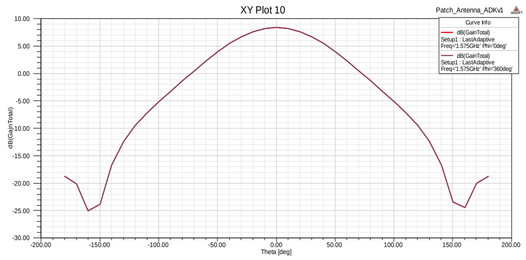

Fig.2 (c) Gain (dB) v/s Frequency (GHz)

*B.* Model of 1x2 array antenna in H-Plane with slot

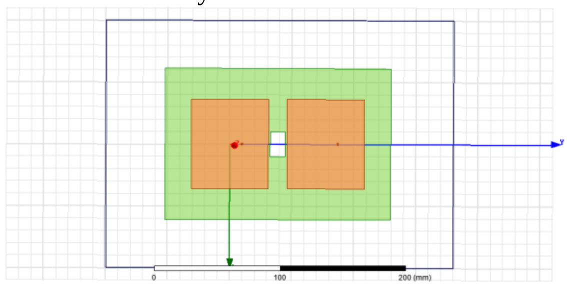
Fig.3 (a) simulated array antenna model for H-plane With slot

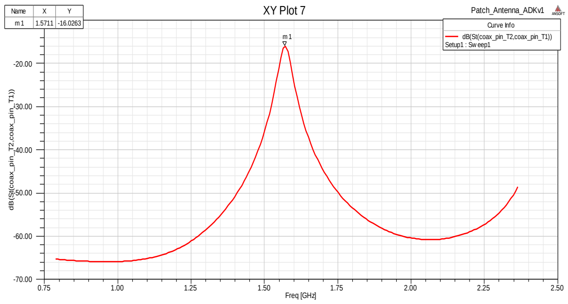

Fig.3 (b) $S_{12}$ (dB) v/s frequency (GHz)

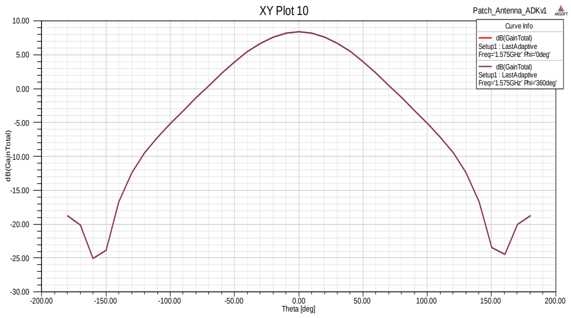

Fig.3 (c) Gain (dB) v/s Frequency (GHz)

*C.* Model of 1x2 array antenna in Angle Right without slot

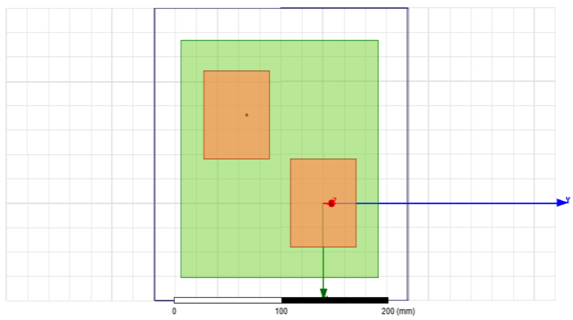
Fig.4 (a) simulated array antenna model for angle right Without slot

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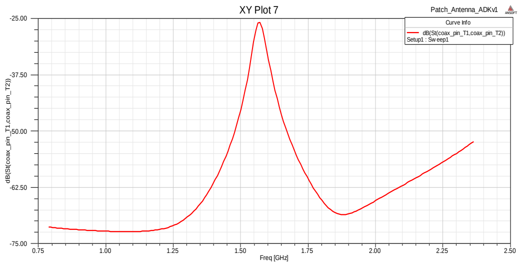


Fig.4 (b) $S_{12}$(dB) v/s frequency (GHz)

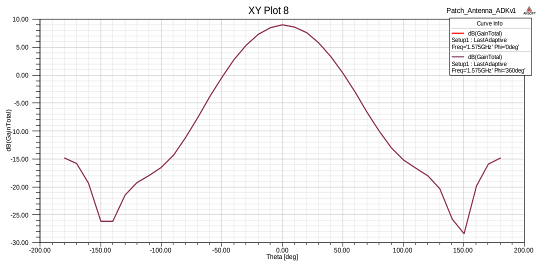


Fig.4 (c) Gain(dB) v/s Frequency (GHz)

*D.* Model of 1x2 array antenna in Angle Right with slot

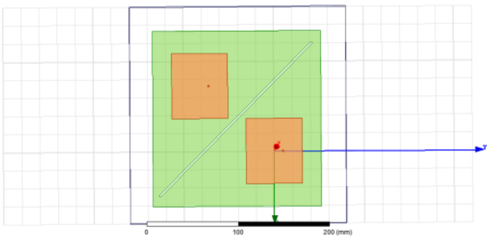

Fig.5 (a) simulated array antenna model for angle right With slot

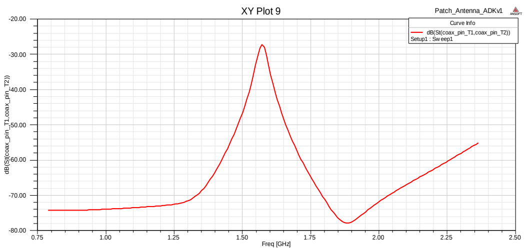


Fig.5 (b) $S_{12}$ (dB) v/s frequency (GHz)

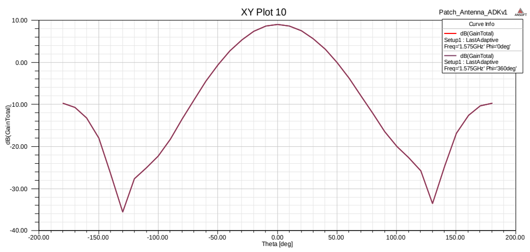


Fig.5 (c) Gain(dB) v/s Frequency (GHz)

Fig.2 (a), 3(a) ,4(a) and 5(a) shows the simulated models for array antenna in H-plane and right angle diagonal orientation for without slot and with slot. Fig 2 (b), 3(b), 4(b) and 5(b) represent $S_{12}$ (dB) obtained for antenna simulated in H-plane and right angle diagonal orientation for without slot and with slot. Fig. 2 (c), 3(c), 4(c) and 5(c) represent gain (dB) in H-plane and right angle diagonal orientation for without slot and with slot. The antenna is resonating at 1.575GHz frequency. For all resonating frequencies $S_{12}$ obtained is less than -10dB, VSWR of less than 2 is obtained and impedance is matched to 50Ω.

Similarly simulations are carried out for E-Plane and in left angle diagonal plane for without slot and with slot and simulation results are shown in TABLE II.

TABLE II
SIMULATION RESULTS OBTAINED FOR RT-DUROID SUBSTRATE

| Substrate | RT-Duroid | |
|---|---|---|
| **Antenna Structure** | **$S_{12}$(dB)** | **GAIN(dB)** |
| H-Plane without slot | -16.02 | 9.32 |
| H-Plane with slot | -16.51 | 9.38 |
| E-Plane without slot | -11.79 | 8.33 |
| E-Plane with slot | -12.35 | 8.38 |
| Angle Right without slot | -25.90 | 8.90 |
| Angle Right with slot | -27.27 | 8.94 |
| Angle Left without slot | -24.20 | 9.46 |
| Angle Left with slot | -24.78 | 9.56 |

Similarly simulation are carried out for FR4 and TMM10i substrates to compare the dependence of substrate parameters on antenna performance. Simulation results are shown in TABLE III and TABLE IV.

TABLE III
SIMULATION RESULTS OBTAINED FOR TMM10I SUBSTRATE

| Substrate | TMM10i | |
|---|---|---|
| **Antenna Structure** | **$S_{12}$(dB)** | **GAIN(dB)** |
| H-Plane without slot | -8.92 | 5.79 |
| H-Plane with slot | -9.06 | 5.87 |
| E-Plane without slot | -14.33 | 4.56 |
| E-Plane with slot | -14.75 | 4.65 |
| Angle Right without slot | -25.65 | 3.91 |
| Angle Right with slot | -30.05 | 3.91 |
| Angle Left without slot | -25.65 | 3.89 |
| Angle Left with slot | -34.07 | 3.92 |

TABLE IV
SIMULATION RESULTS OBTAINED FOR FR4 SUBSTRATE

| Substrate | FR4 | |
|---|---|---|
| **Antenna Structure** | **$S_{12}$(dB)** | **GAIN(dB)** |
| H-Plane without slot | -21.22 | 3.37 |
| H-Plane with slot | -21.42 | 3.45 |
| E-Plane without slot | -16.22 | 4.44 |
| E-Plane with slot | -16.77 | 4.51 |
| Angle Right without slot | -27.38 | 4.37 |
| Angle Right with slot | -29.66 | 4.42 |
| Angle Left without slot | -27.29 | 4.36 |
| Angle Left with slot | -28.93 | 4.42 |

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## IV. CONCLUSION

The technique for reducing mutual coupling between closely spaced antennas is proposed in E-plane, H-plane and Diagonal planes with three substrates. The antenna array is designed for frequency of 1.575GHz for GPS application. Antennas in all the planes are spaced at less than half wavelength between the feed points. Rectangular slots were cut between the patch elements to suppress the mutual coupling effect. Among all the substrates considered, RT Duroid gives better antenna performance, but the dimension of the array is higher. TMM10i substrate reduces the overall dimension of the antenna array at the same resonant frequency.

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