Highly Isolated Dual-Polarized Microstrip Patch Antenna Using Defected Microstrip Structure

Arabinda Roy, Chandan Ghosh, Susanta Kumar Parui

***Abstract*: A two-port rectangular microstrip patch antenna for dual frequency operation is investigated in this paper. Simple microstrip line feed has been used to feed the antenna. Quarter wavelength transformer is used for impedance matching. For the conventional dual feed dual frequency antenna the isolation between the two ports is obtained as 30 dB. An Improvement in isolation performance has been achieved by the introduction of defected microstrip structure which acts as band stop filters and thereby increases isolation between the two ports..**

***Index Terms*: Dual-Polarized, Patch Antenna, port isolation, Defected Microstrip Structure.**

I. INTRODUCTION

It has been only very recent in human history that the electromagnetic spectrum, outside the visible region, has been employed for communication, through the use of radio. One of humankind's greatest natural resources is the electromagnetic spectrum and the antenna has been instrumental in harnessing this resource. There has been an increasing interest in design of the dual frequency dual-polarized patch antennas for satellite and wireless communication applications. Here, conventional rectangular patch antenna for dual frequency operation is simply fed by direct connection of two microstrip lines which are perpendicular to two corresponding adjacent sides of the microstrip patch at different operating frequencies. However, this type of antenna has poor isolation between exciting ports. To achieve better isolation Defected Microstrip Structure (DMS) is used. DMS has been successfully employed as a technique to reduce the size and tuning of rectangular patch antennas. It can be employed to add an extra attenuation in the stop-band, and to increase the selectivity of the resonator. In this paper, we design a dual-polarized rectangular patch antenna and its mistrip lin feeding technique using quarter wave transformer. Then use DMS to improve the isolation between the ports of the antenna and study the other parameters.

II. DESIGN OF DUAL POLIRIZED PATCH ANTENNA

A dual-polarized rectangular patch antenna as shown in Fig.1 is designed to operate at 2 GHz and 2.5 GHz. The feeding technique used here is Microstrip line feeding. To match the antenna impedance, two quarter-wave transformers are used. The width of patch is given by [1,2]

$$W=\frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Effective dielectric constant and Effective Length are given by the following equations [1,2].

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{W}\right)^{-\frac{1}{2}}$$

$$L_{eff}=\frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$$

Equation of Length Extension (ΔL) is given by:

$$\Delta L=0.412\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)}$$

So the equation for actual length of the patch $L=L_{eff}-2\Delta L$ Solving the above equation, patch dimensions for $f_{01}=2GHz$, are found to be, length L=36.8 mm., width W=45.6 mm. and patch dimensions for $f_{01}=2.5GHz$, are found to be, length L=28.2 mm., width W=36.5 mm. So, for our rectangular microstrip patch antenna using dual microstrip line feed for dual frequency operation, the patch dimensions are chosen to be the last one.

The 50Ω input ports need to be matched with the edge impedances of the main patch to decrease the return loss and so, quarter-wave transformer is used [3]. The edge impedance is found from the Smith Chart after feeding the main patch along its length and width. The values of the characteristic impedance (Z_0) of the $\lambda/4$ transformers are found to be $Z_0=120.6\Omega$ for the 2GHz port. $Z_0=93.6\Omega$ for the 2.5GHz port and hence length and width of the $\lambda/4$ Trans-former is calculated. So, the dimensions of the quarter-wave transformers for 2GHz port and for 2.5GHz port, are given by $l=18.8mm$, $w=0.2mm$ and $l=15mm$ and $w=0.6mm$ respectively.

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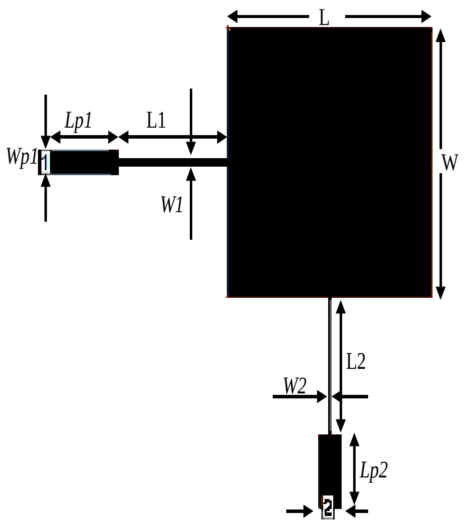

Fig.1: Schematic of rectangular patch antenna

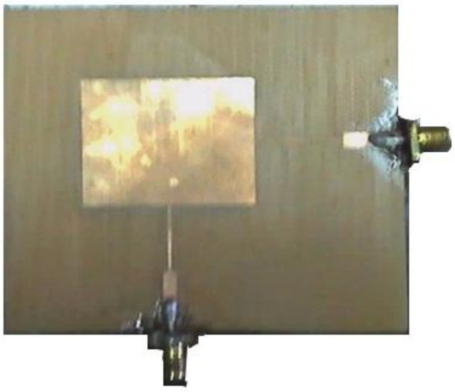

Fig.2: Pholograph of rectangular patch antenna

Method of moment based IE3D software is used for design and simulation. A PTFE substrate of dielectric constant of 4.4 and height of 1.59 mm is taken for both simulation and prototyping. The fabricated prototype is shown in Fig.2.

TABLE1: DIMENSIONS OF PROPOSED ANTENNA (IN MM)

L=28.2	l1=15	l2=18.8	Lp1=Lp2=10
W=36.8	w1=0.6	w2=0.2	Wp1=Wp2=3

The simulated and experimentally measured return loss characteristics are shown in Fig.3 and observed the resonant frequencies at 1.95 GHz and 2.45 GHz respectively.

Fig.4 shows the isolation between two ports of the rectangular patch antenna. The simulated isolation is about -32dB and measured isolation is about -28dB. So, the measured result differs from the predicted simulated result to some extent. This is due to fabrication tolerance of the prototype.

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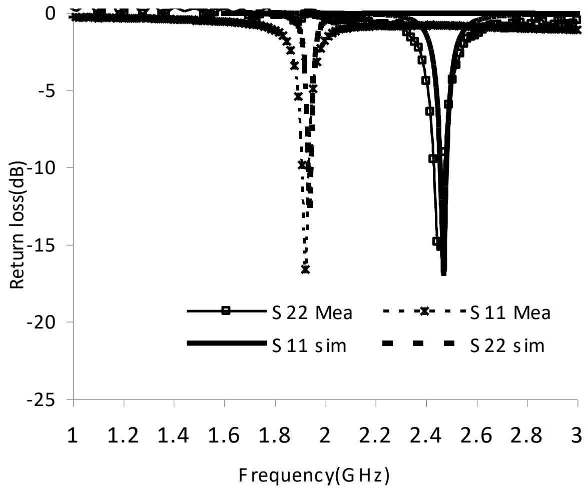

Fig.3: Simulated and measured S-parameter plot for the antenna

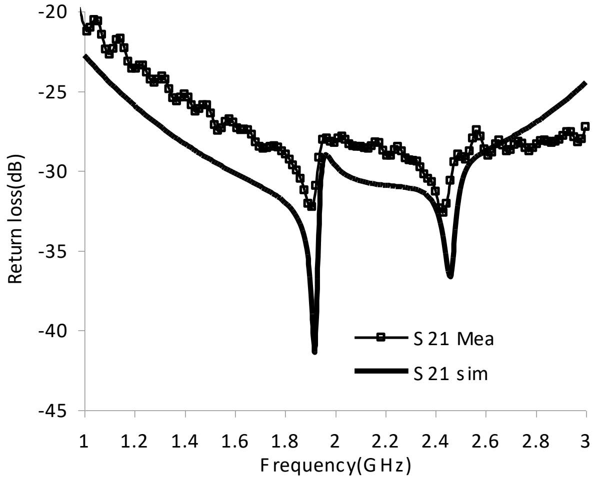

Fig. 4: simulated and measured S-parameter plot for isolation between ports

The EM-simulated and measured E-plane radiation pattern for the antenna in the resonant frequency at 1.95GHz is shown in Fig.5 and the resonant frequency at 2.45GHz is shown in Fig.6. For both the frequencies the E-field cross polarization level is below 20dB.

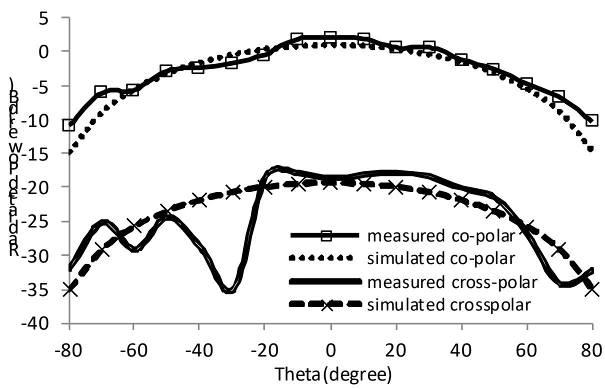

Fig.: 5 E-plane radiation pattern at 1.95 GHz

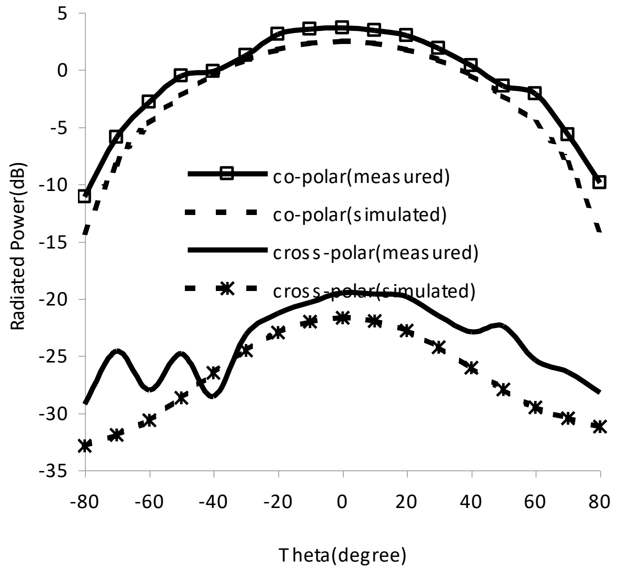

Fig.: 6 E-plane radiation pattern at 2.45 GHz

III. DEFECTED MICROSTRIP STRUCTURE

The microstrip line acts as a good transmission line. The performance of the microstrip line can be improved if we etch geometry on signal plane and such structures are known as Defected Microstrip Structure (DMS) [3,4]. The slowwave factor of a DMS microstrip line is raised as discontinuities is introduced in the path of EM waves, which increases the impedance of line. This phenomenon can be used to reduce the size of passive planar circuits like microstrip line length, coupling lines, and microstrip antennas. Its improved filtering characteristics can help to meet the emerging application challenges. The radiation from the ground plane is the major constrain to design a DGS based circuit. But DMS provides same slowwave characteristics, keeping ground plane intact [5].

A nnew DMS structure, is introduced here as Fig. 7 for isolation improvement application of patch antenna [6, 7]. DMS structure act as a Band Stop Filter and its resonant frequency depends upon the total length of the slot. The variation of resonant frequency with total length of the slot is shown in the Fig 8. It is observed that the resonant frequency decreases with increment of the slot length.

Fig.7: Schematic diagram of proposed spiral DMS

From the graph in Fig. 8, the slot length has been estimated as 21.5 mm for the resonant frequency of 2 GHz, and 17.8 mm for the resonant frequency of 2.5 GHz.

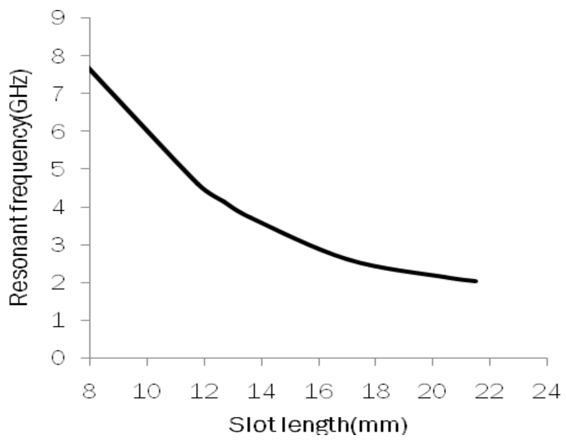

Fig.8: slot length vs Frequency graph for DMS

IV. ANTENNA WITH DMS AT FEED LINE

In the proposed structre, DMS units are incorporated into both the 50 Ohm feed line of the antenna. DMS having stopband with center frequency at 2 GHz is used in the feeding line of the port having resonant frequency 2.5 GHz and vice versa. The dimensions of DMSs are obtained as length of 17.9 mm (for port 1) and 21.5mm (for port 2) and with of the slot are taken same for both structures as 0.2 mm. The 50 Ohm feeding line have a length 10 mm and width 3 mm.This is for FR4 substrate of dielectric constant 4.4 and thickness 1.59 mm. A photograph of the fabricated antenna without DMS is illustrated in Fig 9.

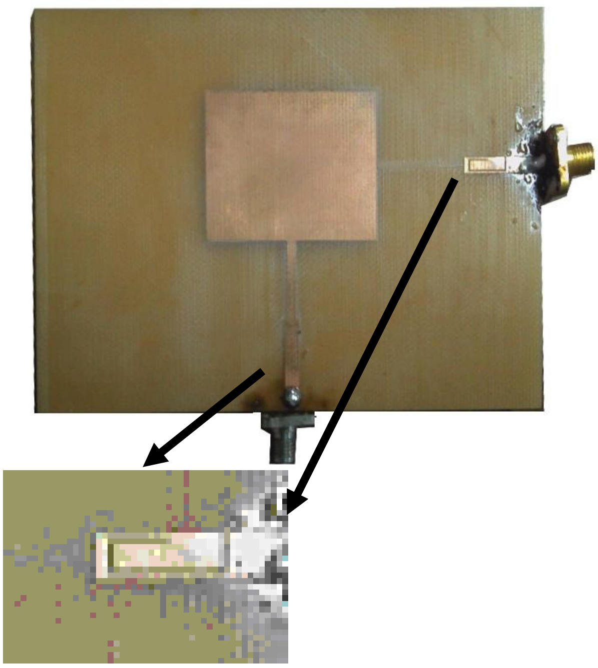

Fig.9: photograph of the fabricated antenna with DMS at both feed line

For the conventional microstrip patch antenna i.e. without any DMS structure, the isolation is about -30dB.But using DMS structure, the isolation is -46dB i.e. isolation is increased by 16dB.

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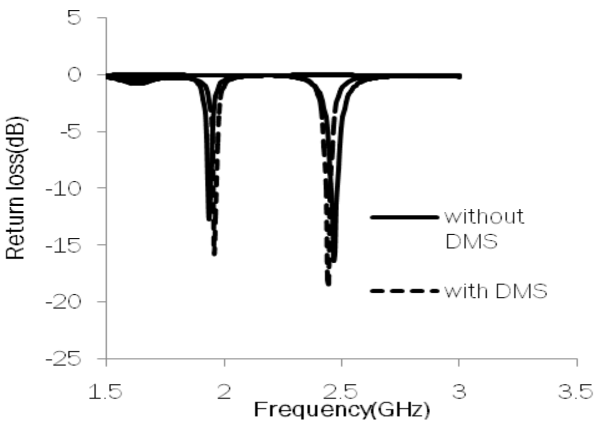
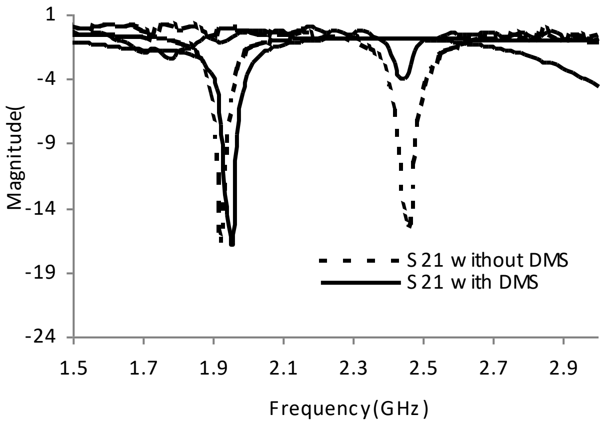
The return loss for DGS and without DGS structures are compared in Fig 10 and similarly isolations are shown in Fig 11. Using the DMS structure the isolation between the two ports has been increased.

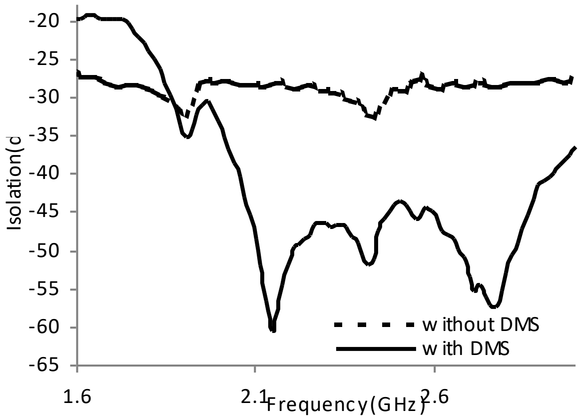


(a)

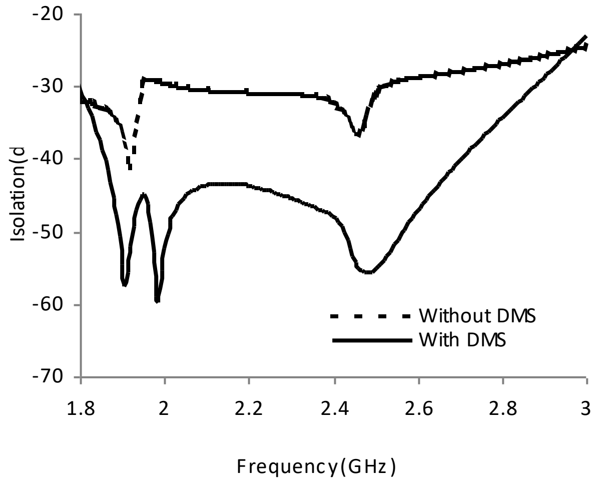


(b)

Fig 10: comparison of Return loss between conventional and DMS integrated antenna (a) Simulated, (b) Measured



(a)



(b)

Fig 11: comparison of Isolation between conventional and DMS integrated antenna (a) Simulated, (b) Measured

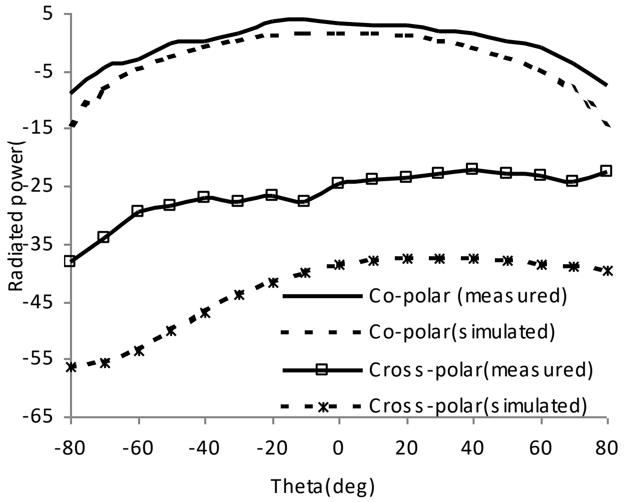


Fig 12: E-plane radiation pattern at 1.95GHz (with DMS)

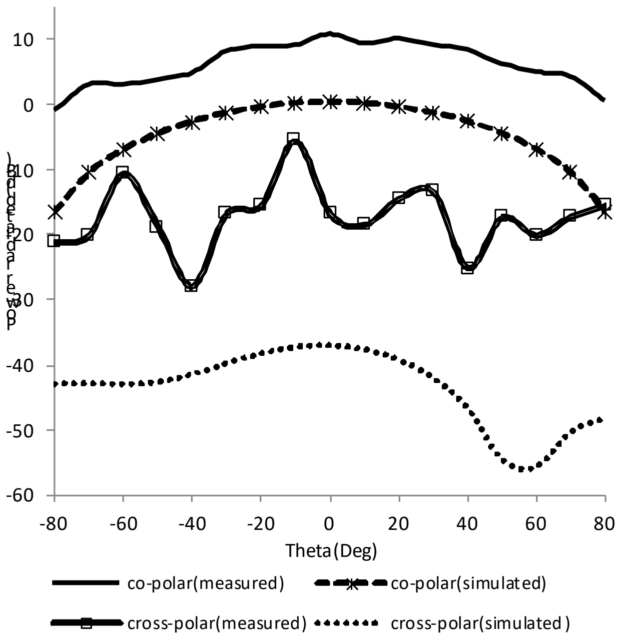


Fig.13: E-plane radiation pattern at 2.45GHz (with DMS)

Fig 12 and Fig 13 shows the E-field Radiation pattern where performances for integrating DGS are compared. From these, it is observed that the patch antenna provide low cross polarization level (<-20dB) at both frequency.

V. CONCLUSION

In this paper, a new microstrip DMS is proposed. The structure is more compact compared to conventional spurline. The structure is well suited for a dual-frequency antenna with two close bands. By inserting DMS in both the feeding lines of a dual-frequency patch antenna, more than 20 dB improvement in ports isolation relative to a conventional patch antenna has been achieved. Furthermore, return loss, and impedance bandwidth changes very small. The radiation patterns are not affected much by such inclusions.

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