ISSN 22773061

BACK RADIATION SUPPRESSION IN MODIFIED APERTURE COUPLED MICROSTRIP ANTENNA BY USING PATCHES UNDER THE SUBSTRATE

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ABSTRACT

A microstrip slot antenna for C Band has been proposed with compact structure and suppressed back radiation. In this paper, the feeding technique used is aperture coupling with a modification that patches and the feed line are positioned below the substrate and the slot is etched above the substrate. The position of the patches along the slot axis is kept at the negative peak of the standing wave distributions to generate the voltage null on the slot line so as to have a 180º phase shift in the centre of the patch hence achieving better front to back ratio. Also the gain of 6.774dB is achieved in this design. The results are validated by simulation measurements.

Keywords

Back radiation, directivity, gain, microstrip slot antenna , patch.

Academic Discipline And Sub-Disciplines

Engineering, Antenna Designs, Wireless Communication.

SUBJECT CLASSIFICATION

Antenna and Wave Propagation, Microstrip Antennas.

TYPE (METHOD/APPROACH)

Computer Simulation Technology (CST) 2010 Version.

Council for Innovative Research
Peer Review Research Publishing System
Journal: INTERNATIONAL JOURNAL OF COMPUTERS & TECHNOLOGY
Vol 6, No 3
editor@cirworld.com
www.cirworld.com, member.cirworld.com

1 INTRODUCTION

Microwave slot antennas have broad interest in military and commercial applications mainly due to the low profile, low cost as well as being simple to manufacture. Moreover, the slot antennas are quite easily incorporated with planar and non planar surfaces and have more degrees of freedom than a conventional design[1]-[3]. In spite of these advantages, it has the main disadvantage of back radiation, which limits its use in mobile communication. This back lobe is undesired because it shows power loss. It increases SAR (Specific Absorption Rate) for the mobile users [4].

Several methods have been proposed to suppress the back lobe, such as by using array topology [5], a tapered-loaded antenna [6] and a 2 wavelength Microwave Leaky Wave Antenna with coaxial probe coupled patch antenna arrays [7]. In addition, these methods also supported parallel plate modes, thus producing undesired radiation.

To solve such problems, a slot antenna with new aperture coupling design is proposed in this paper. The proposed design includes the slot etched on the substrate and the patches and the feed line are employed on the opposite side of the substrate. The purpose of employing the patches beneath the substrate layer is to reduce the radiation into the half space that they occupy and to increase the radiation in the other half space. Also, this design is compact, since it includes a single substrate layer as compared to conventional aperture coupled antennas.

The design is simulated using CST (Computer Simulation Technology) and the return loss, radiation pattern, gain and directivity are measured. In this paper, we will first study a simple slot antenna without patches under the substrate. This simple slot antenna shows the bidirectional nature of the antenna in the absence of the patch. Next, we will study the design, operation mechanism and simulation results of our proposed antenna.

2 ANTENNA DESIGN AND OPERATION MECHANISM

2.1 Antenna Structure Without Patch

The figure below shows the Fig. 1 (top view) and Fig. 2 (bottom view) view of the cell structure of a simple aperture coupled microstrip slot antenna. The design is a simple slot antenna with 125X130 mm^2 substrate layer with of Rogers RO4232 dielectric material with dielectric constant 3.2 and a slot is cut into the ground of this design which rests on the substrate layer. The microstrip feed line is on the opposite side of the slot and its width is set for 50Ω characteristic impedance.

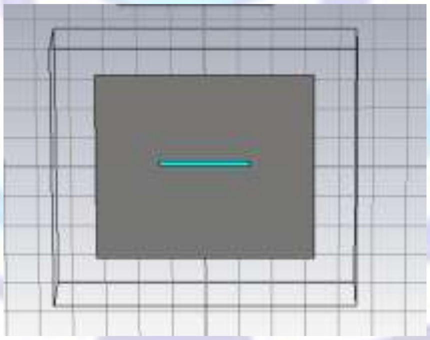

Figure 1Top view geometry of the slot antenna

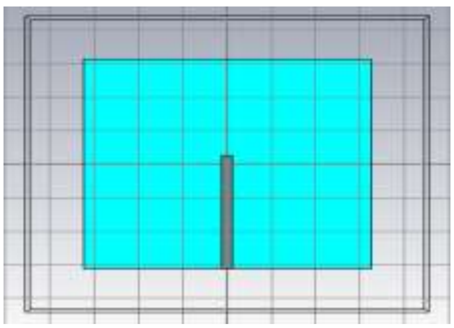

Figure 2 Bottom view geometry of the slot antenna

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The slot in the above design is incorporated to radiate bidirectionally. The S11 parameter and the E field pattern are shown in Fig. 3 and Fig. 4 below

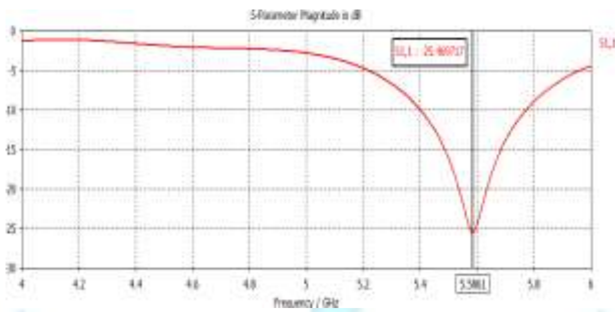

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Figure 3 S11 parameter of the slot antenna

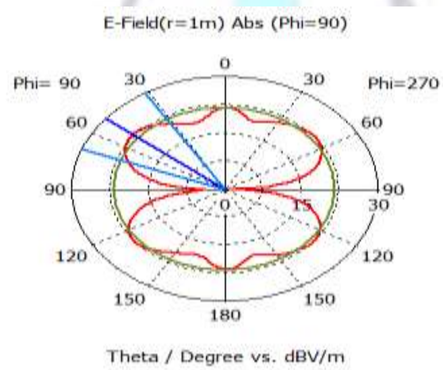


Figure 4 E Field pattern

The S11 parameter is -25.469dB and the antenna resonates at 5.57GHz.The E field pattern shows the bidirectional radiation distribution which is due to the alternating standing wave distribution along the slot axis which reverses over a half wavelength[8]. Since the field is distributed towards both sides, the power density of the antenna hence becomes low.

2.2 Antenna Structure With Patch

This is the proposed slot antenna in which there are two slots above the substrate and the patches are under the substrate. The idea of placing patches under the substrate is that the slot electric field perpendicular to the slot length appears to have a standing wave distribution with positive and negative nodes along its axis. The direction of this electric field is reversed after propagating over a half wavelength. Hence, by sliding the patch toward or away from the center of the slot, we can adjust the phase of the patch 180º by coupling it to the negative voltage node or the positive voltage node on the slot line [9]. The proposed antenna is simulated for different displacements of the patch position and their corresponding field patterns are also studied for better front to back ratio. The geometry of the proposed structure is as follows.

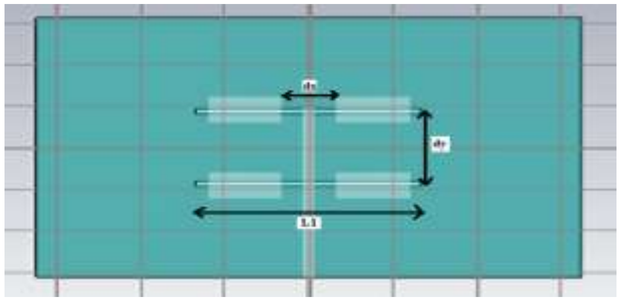


Fig5. Geometry of the proposed antenna

2.2.1 Design And Simulation Results

The configuration of the antenna is shown in the figure below. In this paper the antenna is expected to operate in 4.0 Ghz to 5.0 Ghz band. The slots are cut on the ground plane of 125X130 mm^2. The effective dielectric constant of the substrate is calculated by using equation (1). After calculating effective dielectric constant, the guided wavelength (λ_g) is calculated by using equation (2) and the length and width of slot is given by L_1 and W_1 in the Table. The thickness of substrate layer is h mm. The distance dy = 29mm. The length of the slot is calculated by using equation (3). The remaining dimensions of the antenna are calculated using [10] and are given in the Table 1.

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \quad (1)$$

$$\lambda_g = \lambda / \sqrt{\varepsilon reff} \quad (2)$$

$$L_1 = \frac{c}{2fo\sqrt{(\varepsilon reff)}} \quad (3)$$

Where c = $3X10^8$ m/sec

Table 1 Dimensions of antenna:

Dimensions	Value
Substrate height (h)	1mm
Dielectric constant of substrate ε_r	3.2
Length of slot (L_1)	54mm
Width of slot (W_1)	2mm
Length of patch (L)	17.5mm
Width of patch (W)	17.5mm

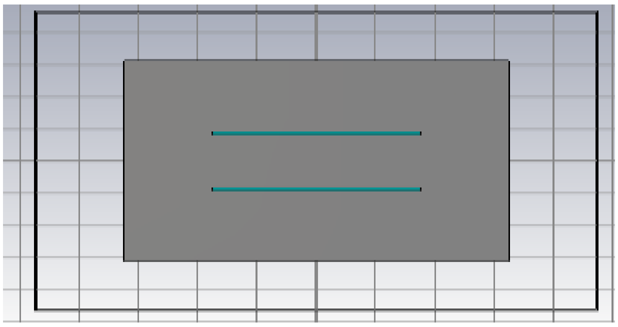


Figure 6 Top View of the proposed antenna

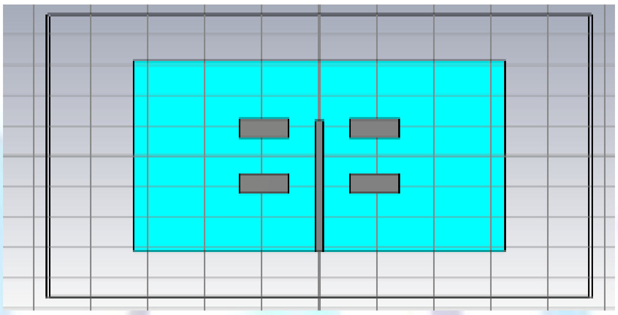
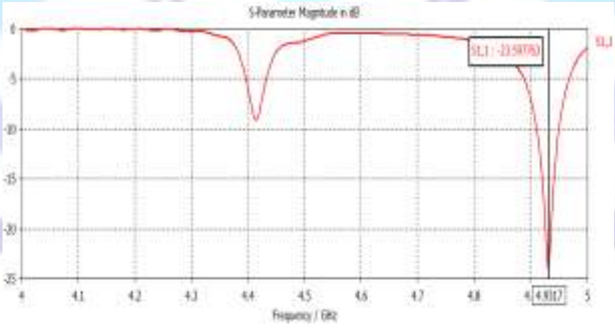


Figure 7 Bottom view of the proposed antenna

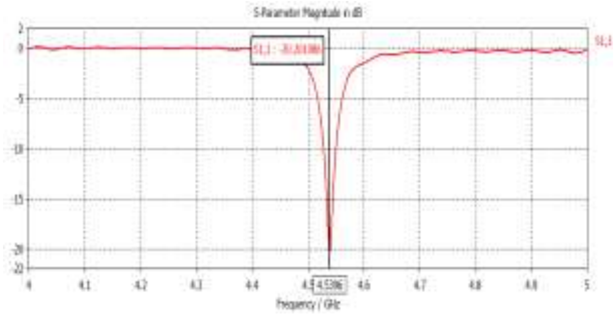
According to the operating mechanism described above, the spacing 'dx' between the two patches is very significant in affecting the antenna performance. Therefore, the antenna structure is simulated for different values of dx and at those values of dx the return loss, gain, E field pattern and directivity are compared.

2.2.2 Effect of Spacing (dx)

Since the effective length of the slot with the partly covered patches will be different from that without patches, the distance of the patches from the center of the slot is chosen to be 1/8 to 1/2 wavelength in the substrate [11]. This range allows the patches to cover the positive or the negative standing wave nodes when they move toward or away from the center of the slot. The antenna is simulated for four values of the dx spacing: 9, 13, 17 and 21.



(a)



(b)

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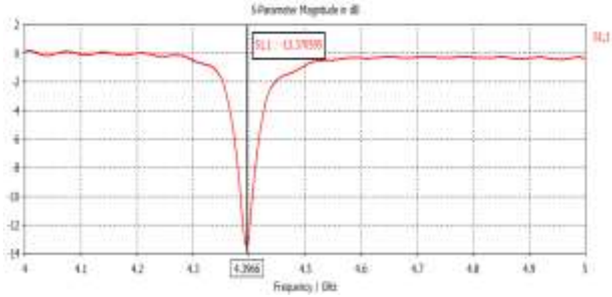
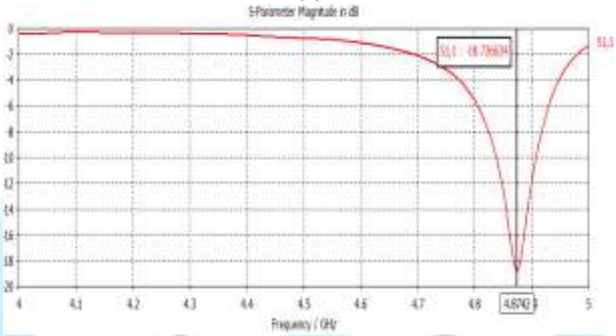


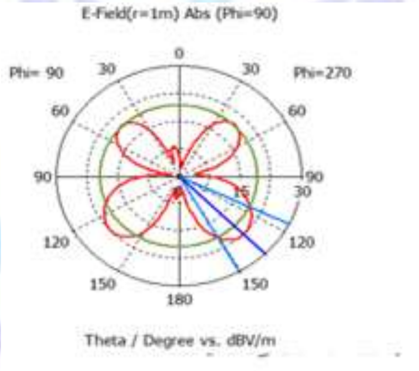
(c)



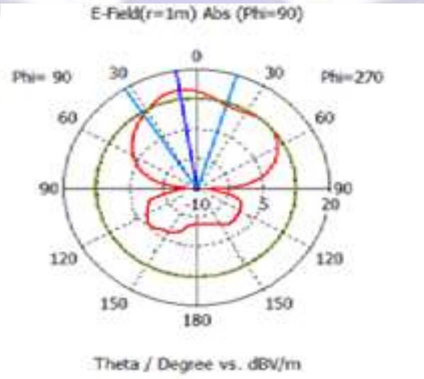
(d)

Figure 8 S11 parameter for dx =9,13,17 and 21mm in (a),(b),(c),(d) respectively

The S11 parameter for the different spacing between the patch has been simulated. The resonant frequency for dx =9mm is 4.93GHz, for dx = 13mm is 4.53GHz , for dx = 17mm is 4.39GHz and for dx = 21mm is 4.87GHz The resonant frequency is shifted to the left as the distance between the patches increases except for dx=19mm where the frequency starts shifting to the right. Thus, the resonant frequency decreases with increase in the distance between the patches up to a particular displacement of the patch. Beyond that displacement, it again increases. The E field patterns for different patch spacings are as follows.



(a)



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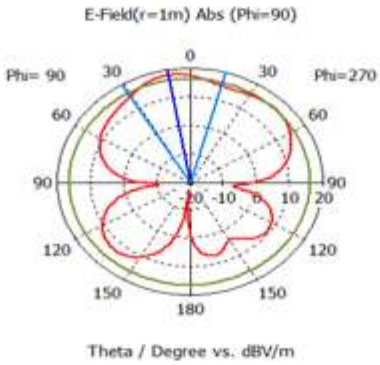
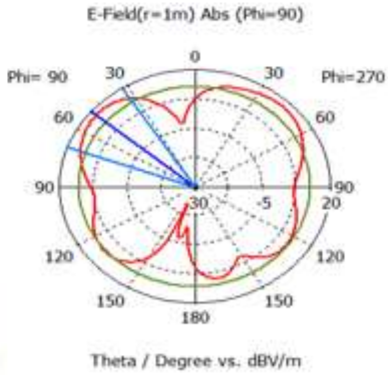


(c)



(d)

Figure 9 E field pattern for dx=9,13,17 and 21mm in (a),(b),(c),(d) respectively

The electric field pattern for the different displacements of the patch shows a better front radiation at dx = 13mm as shown in (b) in fig. 9. The back radiation is suppressed due to the reason that the effective length of the patch is about half wavelength, it causes voltage null movement in the slot as it moves along the axis of the slot as compared to (a), (c) and (d) in fig. 9 where there are significant side lobes and the back lobe.

Table 2 Comparison of result parameters at different patch displacements

dx ⟶	9mm	13mm	17mm	21mm
Return Loss	-23.59	-20.20	-13.37	-18.72
Gain	5.693dB	6.774dB	6.107dB	6.526dB
Directivity	5.816dBi	6.255dBi	5.568dBi	5.896dBi

Table 2 shows the comparison of various result parameters for the different patch displacements.The gain is 6.774 dB and the directivity is 6.255 dBi for dx = 12mm whereas it is less for the other three cases. Also, the coupling is also better at dx = 13mm as compared to dx = 17 and 21mm. Thus, dx =12 mm is the point of voltage null in the slot where the back lobe suppresses to a significant point, hence giving good simulation results.

CONCLUSION

The back radiation is successfully suppressed in a microstrip slot antenna with modified aperture coupling by varying the patch distance within 1/8 to 1/2 of the wavelength from the centre of the slot. The design of this work has given good results in term of return loss, gain and directivity. This design is very useful for the mobile communication where the back radiation from the cell phone is not desired. This design is also compact in size. However, the proposed design has the simple structure and it can be constructed with a lower cost.

ACKNOWLEDGMENTS

We are grateful to the referees for their valuable comments. We also acknowledge the CST software with the help of which we have deduced all the required results and the Thapar University for providing all the resourses for the study and research work.

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