VOL. 10, NO 22, DECEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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ANALYSIS OF SLOTTED MICROSTRIP ANTENNA WITH PARTIAL SUBSTRATE REMOVAL AND DEFECTED GROUND STRUCTURE

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ABSTRACT

This article presents the design and analysis of a slotted microstrip antenna on defected ground structure. The proposed antenna consisting of defected ground structure at lower part and defected substrate on the upper part of the design. Parametric analysis with change in dimensional characteristics of the antenna is done using HFSS tool to optimize the antenna model for prototyping. The antenna performance is analyzed with respect to the reflection coefficient, bandwidth, radiation pattern and current distribution and presented in this work. The proposed antenna is resonating at dual band and meeting the requirements of the communication systems with considerable gain in L, S and C-Band.

Keywords: slotted antenna, defected ground structure (DGS), high frequency structure simulator (HFSS), communication systems.

1. INTRODUCTION

A microstrip patch antenna is widely used in compact and portable communication devices due to its small size, thin profile configurations, conformity and low cost. In spite of these remark-able advantages, the patch suffers some serious drawbacks like low bandwidth (due to small size). Bandwidth can be increased but at the cost of size of the patch, making it large and bulky. There are different types of losses in antenna, one of which is surface wave loss due to the permittivity of the material and thickness of the substrate [1-2]. Due to excitation of surface waves, patch antenna also suffers from reduced gain and efficiency as well as unacceptably high levels of cross-polarization and mutual coupling within an array environment at high frequencies. In this paper, parts of the substrate surrounding the patch have been strategically removed to suppress surface wave losses, and thereby increase gain [3-4].

The method to improve the gain is to reduce the loss of the microstrip antenna. The gain of the antenna can be increased by reducing the loss due to surface wave propagation [5-6]. One method to do so is by replacing the substrate of patch with low dielectric values or with air (ε_r = 1). Periodic structures of electromagnetic band-gap (EBG) can be used to block the surface waves from propagating in a certain band of frequency. A common method to generate EBG structures is to drill holes in substrate to synthesize a lower dielectric constant substrate [7-8]. However, in this paper, a rather simpler version of EBG structure approach has been used by partially removing the substrate surrounding the patch instead of drilling periodic holes. Removing the substrate partially stops the propagation of surface wave in the substrate, which reduces the power coupled in backward direction and enhances the forward coupled power [9-10]. As a result the gain increases.

2. ANTENNA DIMENSIONS

It is known that for a particular resonant frequency, the bandwidth increases with increase in size of patch antenna for a high dielectric [11-14]. The patch antenna of low dielectric has a moderate band-width but large size. Bandwidth decreases with increase in the dielectric value of the substrate [15-18]. By considering all these points, designed the proposed antenna on FR4 substrate with dielectric constant 4.4 and loss tangent 0.02. Figure 1(a) shows the slotted microstrip antenna model 1 and Figure-1(b) shows the partial substrate removed slotted antenna model 2. The dimension of the antenna with partial substrate removal is presented in Figure-2. Defected ground structure is taken in Figure 1(c) with model 3 and modified ground structure is shown in Figure-1(d) with model 4. Finally proposed defected ground structure with partial substrate removed model 5 is shown in Figure-1(e).

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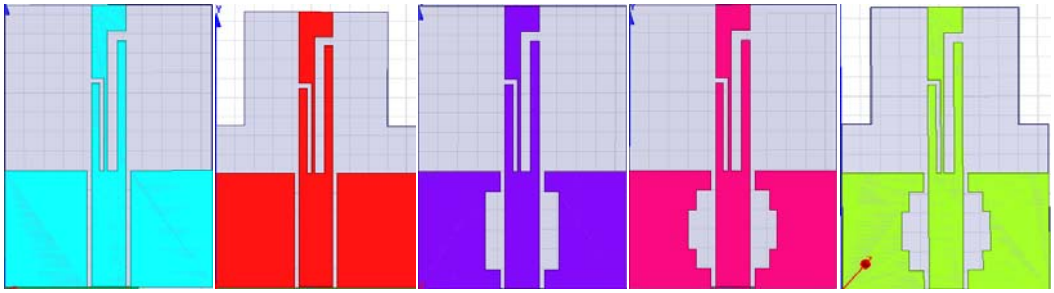

(a) (b) (c) (d) (e)

Figure-1. Slotted Microstrip antenna, (a) Slot Antenna with full substrate, (b) Slot antenna with partial substrate, (c) slot antenna with defected ground, (d) Slot antenna with modifie defected ground, (e) slot antenna with modified ground on partial substrate.

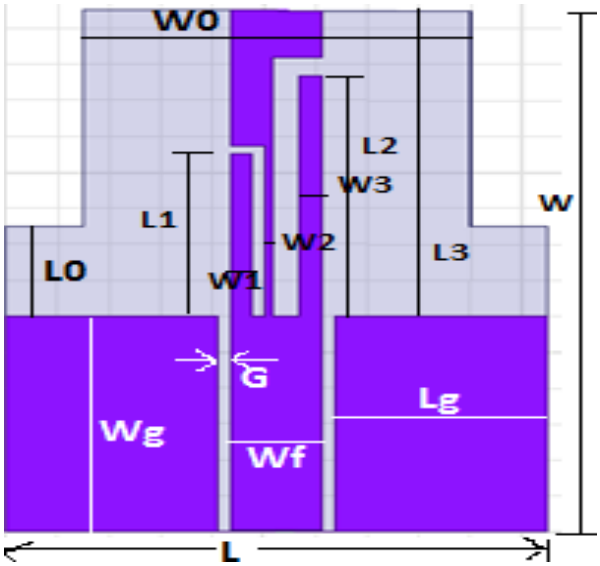

Figure-2. Slot Antenna Dimensions with partial substrate. L = 21 mm, W = 29 mm, L0 = 5 mm, W0 = 15 mm, L1 = 9 mm, W1 = 0.8 mm,
L2 = 13.4 mm, W2 = 0.3 mm, L3 = 17 mm, W3 = 0.9 mm, Lg = 12 mm, Wg = 8.25 mm, Wf = 3.5 mm, G = 0.5 mm

The dimensions of the antenna are calculated from the resonant frequency and wavelength. The dielectric constant value ε_r is used to calculate the effective dielectric constant value from the equation $\varepsilon_{reff} = ((\varepsilon_{r+1})/2)$. The dimensions of the antenna is taken in the form of wavelength

$\lambda c = c/f\sqrt{(\varepsilon_{reff})}$
L= 4.75 λc, W=3.44 λc, L0 = 19.9 λc,
W0 = 6.66 λc, L1 = 11.10 λc, W1 = 124.9 λc,
L2 = 7.45 λc, W2 = 333.1 λc, L3 = 5.87 λc, W3 = 111 λc,
Lg = 8.32 λc, Wg =12.1 λc, Wf =29.8 λc, G = 199 λc

The total dimension of the antenna models are around 21x29x1.6 mm. Figure-2 shows the dimensional characteristics of the antenna model in mm. A small portion of the substrate is removed on the either side of the patch as shown in the Figure-2.

3. RESULTS AND DISCUSSIONS

A good antenna might have a return loss value of -10dB as 90% of the signal is absorbed and 10% is reflected back. The proposed antenna is giving the excellent return loss curve in the specified frequency range. Five iterations are taken in this case and the models are simulated using HFSS tool. The simulated return loss curve for the five models are shown in Figure-3. Model 1 is resonating at triple band with high bandwidth between 4.5 to 5.5 GHz. Model 5 is giving superior result with high bandwidth in the wireless communication system operating band. If the antenna is not matched to the interconnecting transmission line, a standing wave is induced along the transmission line. The ratio of the maximum voltage to the minimum voltage along the line is called the Voltage Standing Wave Ratio. The VSWR obtained for this antenna is maintaining the ratio of 2:1 at the resonating frequencies.

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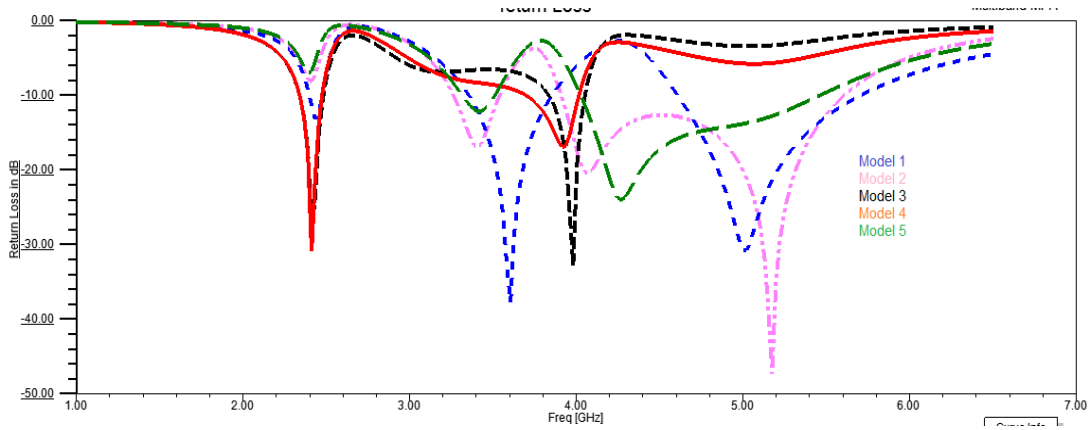

Figure-3. Return loss vs frequency.

The bandwidth of an antenna refers to "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard". The most common usage of bandwidth is in the sense of impedance bandwidth, which refers to those frequencies over which an antenna may operate. The impedance bandwidth of these models is giving average of 44% for all the iterations.

The radiation pattern of the antenna can be defined as the spatial distribution of a quantity that characterizes the electromagnetic field generated by an antenna. The polar plots represent the radiation pattern in elevation and azimuthal angles. The radiation pattern represents the energy radiated from the antenna in each direction, often pictorially at their corresponding resonant frequencies. From three dimensional radiation pattern curves we can observe the omni directional radiation pattern in H-field and dipole like radiation in E-field. The proposed slot antenna with modified defected ground structure with partial substrate removal model is showing superior results in the gain from polar coordinates curve.

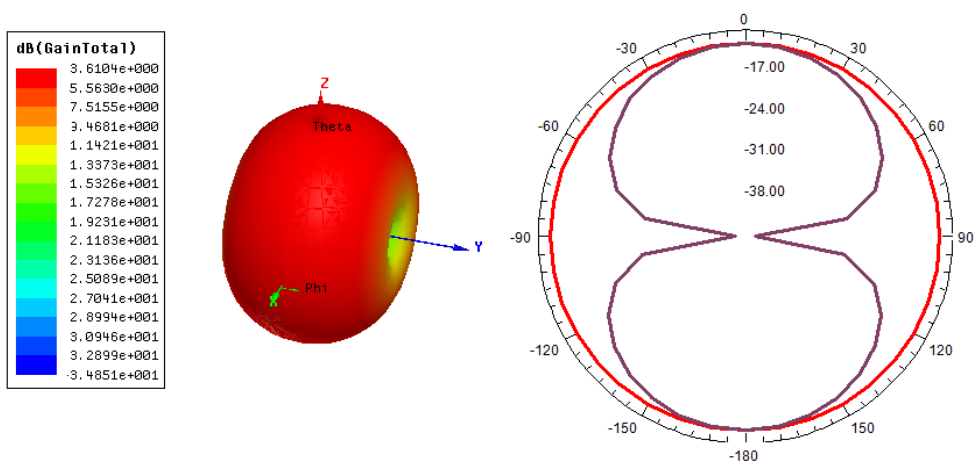

Figure-4. Radiation in 3D and in Polar coordinates for slotted microstrip antenna with full substrate at 2.4 GHz.

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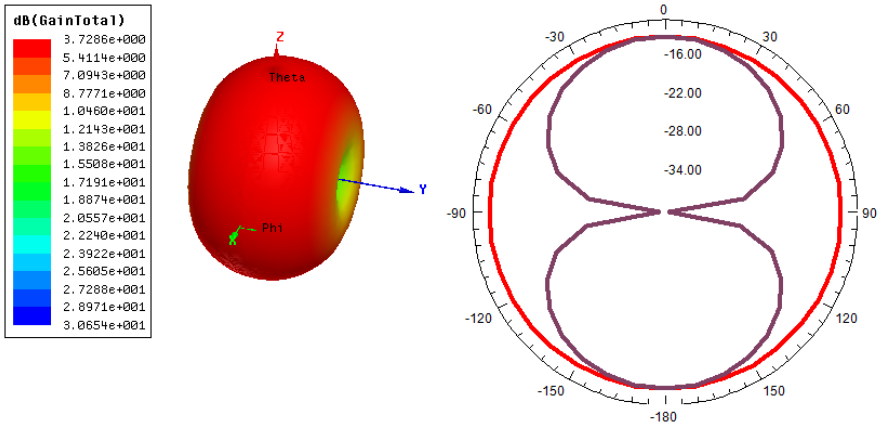

Figure-5. Radiation in 3D and in Polar coordinates for slotted microstrip antenna with partial substrate at 3.2 GH .

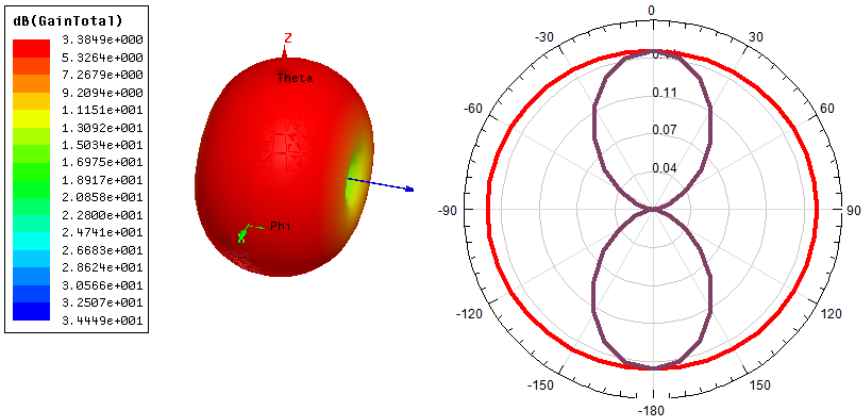

Figure-6. Radiation in 3D and in Polar coordinates for slot antenna with defected ground at 2.4 GHz.

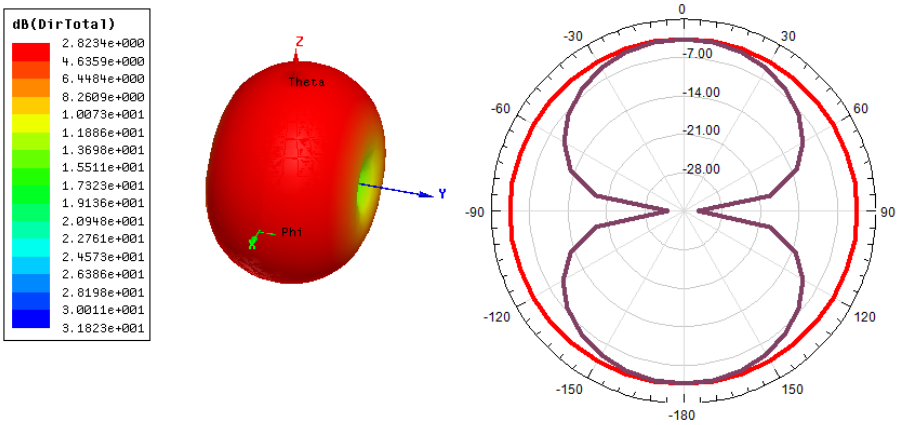

Figure-7. Radiation in 3D and in Polar coordinates for slot antenna with modifie defected ground at 2.4 GHz.

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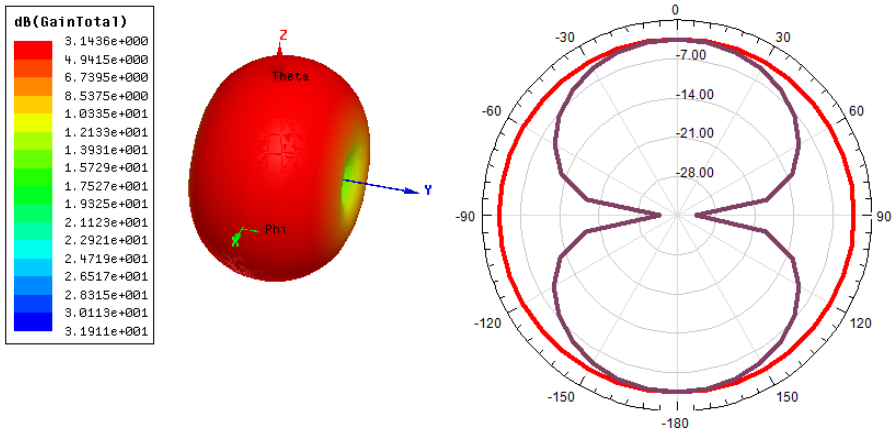

Figure-8. Radiation in 3D and in Polar coordinates for slot antenna with modified ground on partial substrate at 3.2 Ghz

Antenna gain is often related to the gain of an isotropic radiator, resulting in units dBi. Antenna gain may be viewed with the aid of a radiation pattern. A gain of 3.8 dB is obtained in this case.

$$G(\theta,\phi)=\eta D(\theta,\phi)=\frac{P_{rad}}{P_{input}}=4\pi\frac{I^{rad}(\theta,\phi)}{P_{input}}=\frac{P_{rad}}{P_{rad}^{avg}}$$

Where $\eta=\frac{P_{rad}^{avg}}{P_{input}}$ is Antenna Efficiency and $I_{rad}(\theta,\phi)$ is the radiation intensity. Gain can be given as $20\log(v/v_{dipole})$ where V is induced voltage at the input of antenna.

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain to the highest possible degree of accuracy. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis or computational fluid dynamics. Current distribution of the antenna models at their resonant frequencies are presented in the Figure-9. It is been observed that the maximum intensity is focused on the feed line and nearer ground plane for the antenna models rather than on patch surface. This gives clear evidence that the contribution of the patch is less and the surface nearer to the excitation is more for the radiation.

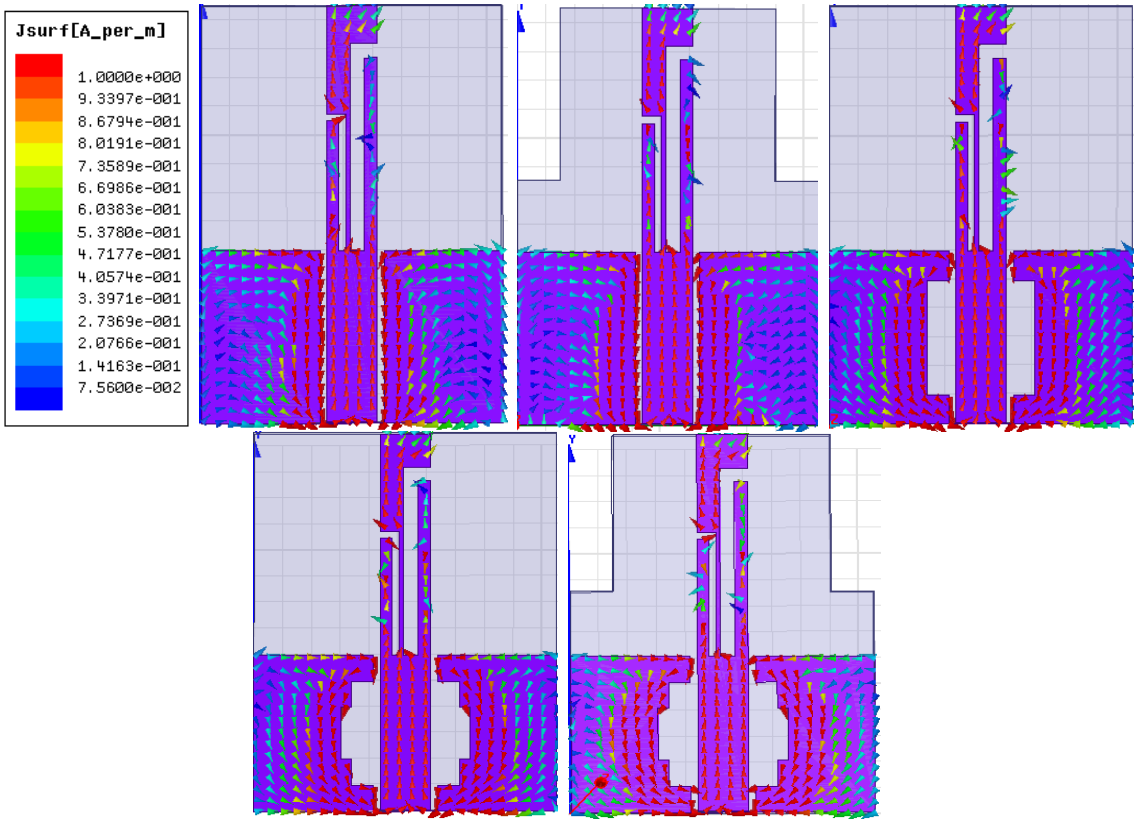

Figure-9. Surface current distribution for the antenna models at their fundamental resonant frequencies.

CONCLUSIONS

The proposed models are giving excellent results in the wireless communication bands with their stable gain and considerable bandwidth. All the models are resonating at dual and triple bands; model 5 is giving excellent radiation characteristics and 88% radiation efficiency at their resonant frequencies. By employing partial substrate removal technique, the performance characteristics of the antenna models are improved and the analysis is presented in this work. Partial substrate removal technique giving low cross polarization with omni directional pattern in H-field and dipole like radiation in E-field and bandwidth enhancement of 12% with suppression of surface wave loss related issues in the proposed design. The results giving strong motivation towards the applicability of the partial substrate removal slot antenna with defected ground structure design in the desired communication operation bands.

ACKNOWLEDGEMENTS

Authors like to express their gratitude towards the department of ECE and management of Andhra University and K L University for their support and encouragement during this work.

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