

Microstrip Patch Antenna Array with Discontinuities for Wireless Applications

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Abstract

Dual band 1x4 rectangular-shaped microstrip Patch Antenna array with discontinuity has been designed for high-speed wireless local area networks (IEEE 802.11a standard) and other wireless communication systems covering this frequency band like WiMax and C-Band with the mounted on a low-cost FR-4 substrate. FR-4 whose relative permeability is 4.4 and a loss tangent of 0.02 is used for proposed design. A simulation tool, CST studio a planar 3D electromagnetic simulator is used in this work.

Keywords: *Microstrip patch, Array antenna, Wi-Max, FR-4, Dielectric Substrate, WLAN, C-band, Microwave Integrated Circuits.*

Introduction

The microstrip antenna have a number of useful properties such as small size, low cost fabrication, low profile, light weight, ease of installation and integration with feed networks. Microstrip antenna in its simplest form consists of a radiating patch, which made up of a conducting material like Copper or Gold on one side of a dielectric substrate and a ground plane on the other side [1].

Different array configurations of microstrip antenna can give high gain, wide bandwidth and improved efficiency. The distribution of voltages among the elements of an array depends on feeding network. Suitable feeding network accumulates all of the induced voltages to feed into one point [2]. The proper impedance matching throughout the corporate and series feeding array configurations provides high efficiency microstrip antenna [3].

Dielectric Substrate: FR-4 is a grade designation assigned to glass reinforced epoxy laminate sheets, tubes, rods and printed circuit boards (PCB). With dielectric constant $\epsilon_r = 4.4$, FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant. FR-4 most commonly used as an electrical insulator possessing considerable mechanical strength [4].

Wireless communication is among technology's biggest contributions to humanity. Wireless communication involves the transmission of information over a distance without help of wires, cables or any other forms of electrical conductors [5].

Some of the devices used for wireless communication are cordless telephones, mobiles, GPS units, wireless computer parts, and satellite television.

Wireless local area networks (WLAN) are widely used worldwide. The IEEE 802.11b and 802.11g standards utilize the 2.4-GHz ISM band. The frequency band is license free, hence the WLAN equipment will suffer interference from microwave ovens, cordless phone, Bluetooth devices and other appliances that use this same band. The 802.11a standard uses the 5-GHz band, which is cleaner to support high-speed WLAN [6]. However, the segment of frequency band used varies from one region of the world to another.

Wi-Max (Worldwide Interoperability for Microwave Access) is a family of wireless communication standard based on the IEEE 802.16 and provides multiple physical layer and media access control option. In January 2003 IEEE approved the 802.16a standard which covers frequency band between 2GHz-11GHz [7].

The IEEE C-Band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4.0 to 8.0 GHz, which is followed by radar manufacturers and users. The C-Band and its slight variations contain frequency ranges that are used for many satellite communication transmissions, some Wi-Fi devices, cordless telephones and weather radar systems [8].

The proposed antenna parameters like return loss, gain, and radiation pattern in 2D & 3D dimension, current density are simulated using CST software. CST employs the Finite Element Method (FEM), brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. CST can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields.

Fundamental Parameters to Design a Patch Antenna

The three essential parameters for the design of a rectangular microstrip patch antenna are [9], [10]:

- I. Frequency of operation (f_r): The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for design is at Wi-Fi that is at 0.6 and 4.8 GHz.
- II. Dielectric constant of the substrate (ϵ_r): The dielectric material selected for the design is FR-4 epoxy which has a dielectric constant of 4.4. A substrate with a high dielectric constant reduces the dimensions of the antenna.
- III. Height of dielectric substrate (h): For the microstrip patch antenna it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6mm.

Formulation

Theoretical analysis and calculation of microstrip patch is calculated with following equations:

- I. For the designing of the antenna, the width (w) is calculated by

$$w = \frac{c}{2f_r \sqrt{\frac{\epsilon_r + 1}{2}}}$$

Where, ϵ_r = relative permittivity of the substrate, c = speed of the light in free space and f_r = resonant frequency

II. Length (L) of the patch antenna is calculated by

$$L = \frac{c}{2 f_r \sqrt{\epsilon_{eff}}}$$

Where, ϵ_{eff} = effective dielectric constant of the substrate. Actual length is given by

$$L = L_{eff} - 2\Delta$$

III. The effective dielectric constant (ϵ_{eff}) is an important parameter which arises because part of the fields from the microstrip conductor, exist in air.

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-\frac{1}{2}}$$

Where, h = height of the dielectric substrate

IV. Calculation of the ground plane L_g and W_g : Usually the size of the ground plane is greater than the patch dimension by approximately six times the substrate thickness all around the periphery.

Hence, $L_g = 6h + L$ & $W_g = 6h + W$

Geometry of Patch Antenna Array

The structure of the antenna is shown in Fig. 1. The antenna is simulated on an CST substrate with a dielectric constant = 4.4 and a loss tangent = 0.02. The thickness of the substrate = 1.6mm. The size of Patch Length (L) = 13.4mm, and Patch Width (W) = 6mm which is suitable for most wireless communication.

The patch can also be fed with a probe through ground plane. The probe position can be inset for matching the patch impedance with the input impedance. This inseting minimizes probe radiation. The ease of inseting and low radiations is advantages of probe feeding as compared to microstrip line feeding. Dimensions of double rectangular shaped patch shown in Fig - 1. These are designed at operating frequency 4.8 GHz.

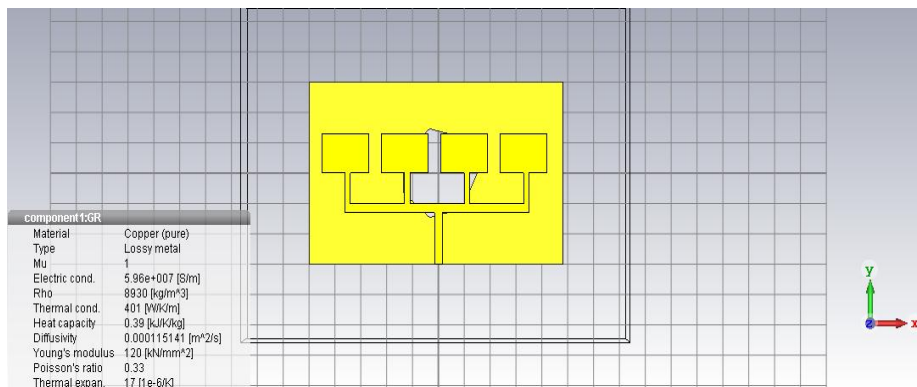


Fig. 1: Structure of star shaped DGS

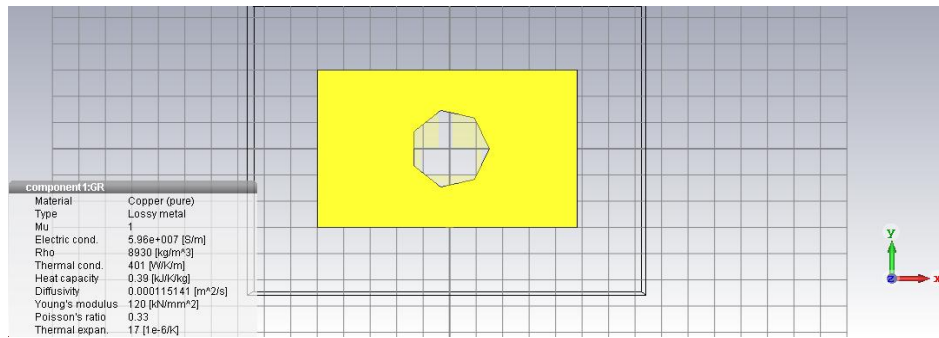


Fig - 2: Ground Structure of star shaped DGS

Results and Discussion

To examine the performance of the designed 1x4 patch antenna array with ground hexagonal-shaped discontinuity, the radiating components are designed, analyzed and simulated employing CST software.

Proposed rectangular shape Patch Antenna Array: The results are explained in terms of three dimensional, the current density, the return loss, gain and the VSWR on the antenna is also showed.

Return Loss [S_{11}] & VSWR

Fig.3 shows the return loss and gain of Rectangular-Shaped patch antenna array. It is clear from the Fig.3 that at the resonant frequency, the return loss is -29.5dB. Return loss is a measure of the reflected energy from a transmitted signal. Result is suitable for WLAN, Wi-Max and C-band applications. Antenna work as dual band antenna at frequency 0.67 and 4.85GHz. Return loss of the antenna is -21.9 & -29.5, VSWR is 1.17 & 1.06 are shown in fig.4 at frequency 0.67 and 4.85. Efficiency is 4.85, reference impedance of antenna is 49.27, while gain is 3.027 are shown in fig. 5, 6 and 7 simultaneously at the centre frequency 4.85GHz.

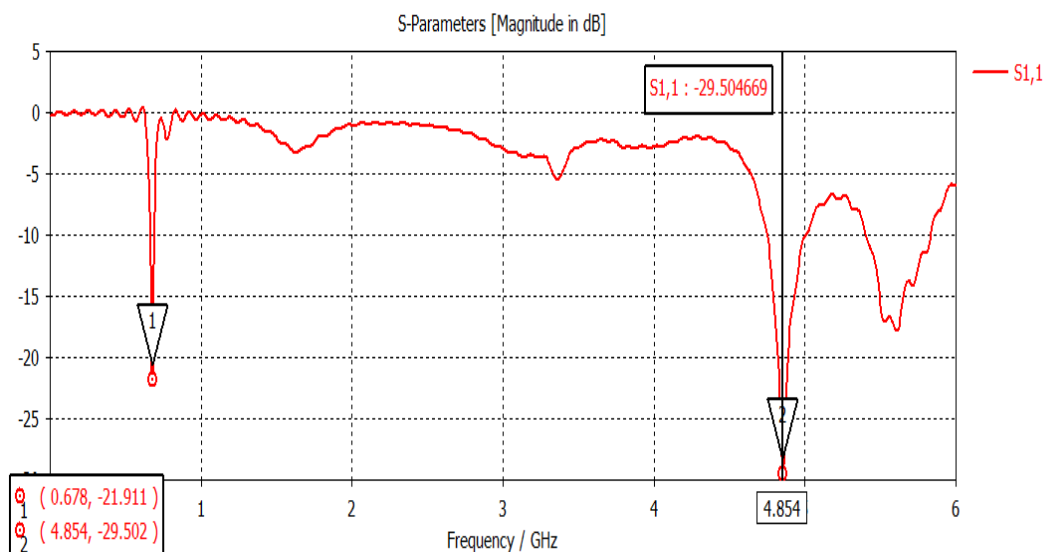


Fig - 3. Return Loss of Hexagonal shaped DGS

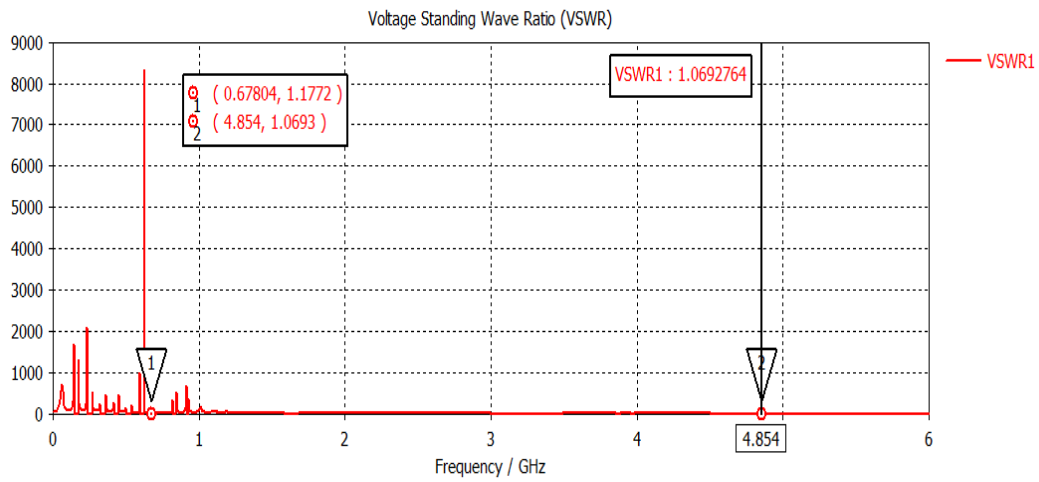


Fig - 4: VSWR of Hexagonal shaped DGS

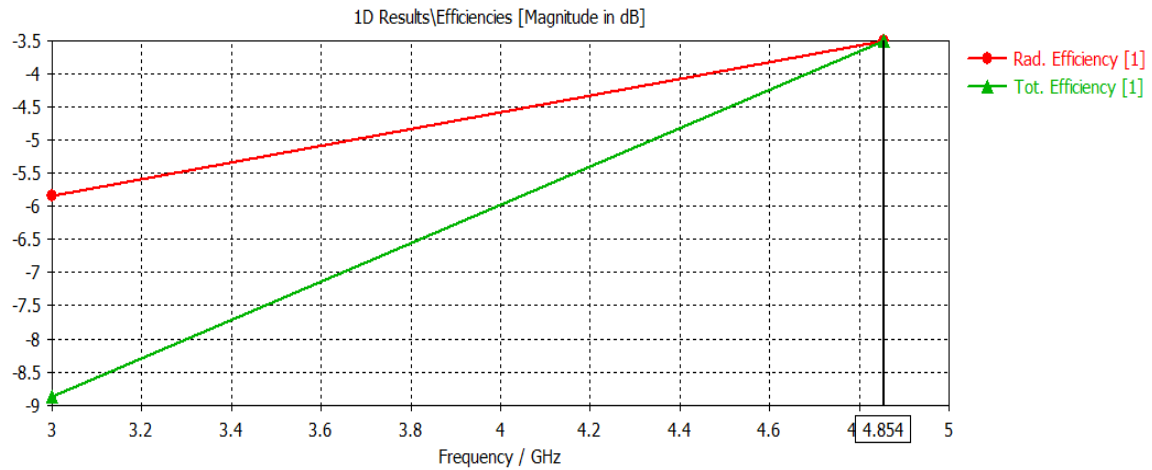


Fig - 5: Efficiencies of star shaped DGS

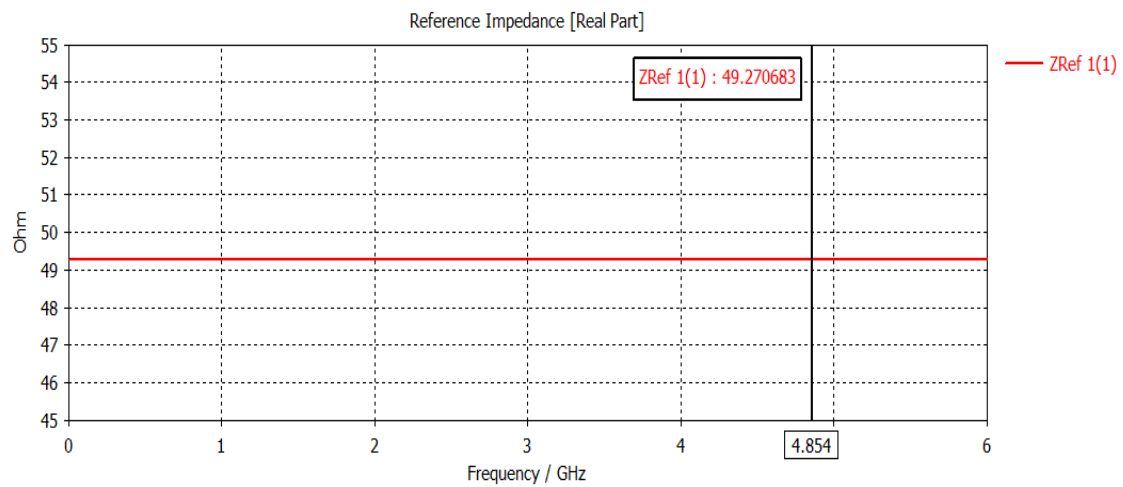


Fig - 6: Reference Impedance of star shaped DGS

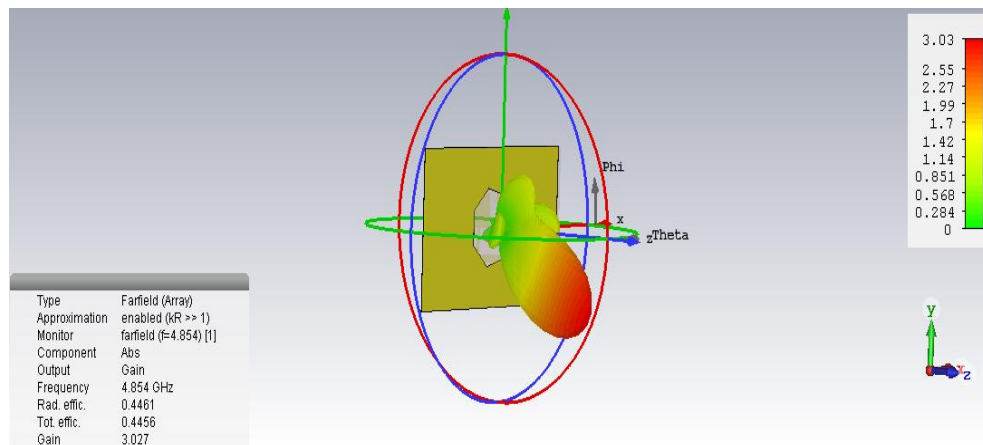


Fig - 7: Gain of star shaped DGS

Conclusion

Finally, 1x4 patch antenna array with hexagonal discontinuity on FR-4 dielectric substrate for Wireless applications has been investigated. The return loss of 1x4 Rectangular-Shaped microstrip patch antenna array = -29.5dB and the VSWR = 1.06 at resonant frequency 5GHz (Approx.). The performance properties are analysed for the optimized dimensions and the proposed antenna works well at the required 5 GHz (Approx) frequency band.

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