LOW COST MICROSTRIP PATCH ANTENNA ARRAY FOR WIRELESS COMMUNICATIONS

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***Abstract*-Single band E-shaped microstrip Patch Antenna array 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, Sonnet Suites, a planar 3D electromagnetic simulator is used in this work.**

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

I. 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 is 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 = 4.4, FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant. FR-4 is most commonly used as an electrical insulator possessing considerable mechanical strength [4]
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 [5]. 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 [6].

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 [7].

The proposed antenna parameters like return loss, gain, and radiation pattern in 2D & 3D dimension, current density are simulated using Sonnet 13.0. Sonnet employs the Method of Moment (MOM), brilliant graphics to give you unparalleled performance and insight to all of your 3D EM problems. Sonnet can be used to calculate parameters such as S-Parameters, Resonant Frequency, and Fields [8].

II. FUNDAMENTAL PARAMETERS TO DESIGN A PATCH ANTENNA

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

1. 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 5 GHz.

2. 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.

3. 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 1.5mm.

III. *FORMULATIONS*

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

1. For the designing of the antenna, the width (w) is calculated by
   a. $$w = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}}$$
   b. Where, ε_r = relative permittivity of the substrate,
      1. c = speed of the light in free space and
      2. f_r = resonant frequency
2. Length (L) of the patch antenna is calculated by
3. $$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$$
   i. Where, ε_{eff} = effective dielectric constant of the substrate. Actual length is given by

4. $L = L_{eff} - 2\Delta$
5. The effective dielectric constant (ε_{eff}) is an important parameter which arises because part of the fields from the microstrip conductor, exist in air.
    1. $\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$
    ii. Where, h = height of the dielectric substrate
6. 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.
    i. Hence, $L_g = 6h + L$ & $W_g = 6h + W$

IV. GEOMETRY OF PATCH ANTENNA ARRAY

The structure of the antenna is shown in Fig. (1).The antenna is simulated on an FR-4 substrate with a dielectric constant = 4.4 and a loss tangent = 0.02. The thickness of the substrate = 1.5mm. 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 insetting minimizes probe radiation. The ease of insetting and low radiations is advantages of probe feeding as compared to microstrip line feeding. The dimensions of double E-shaped patch shown in Fig. (1) These are designed at operating frequency 5 GHz.

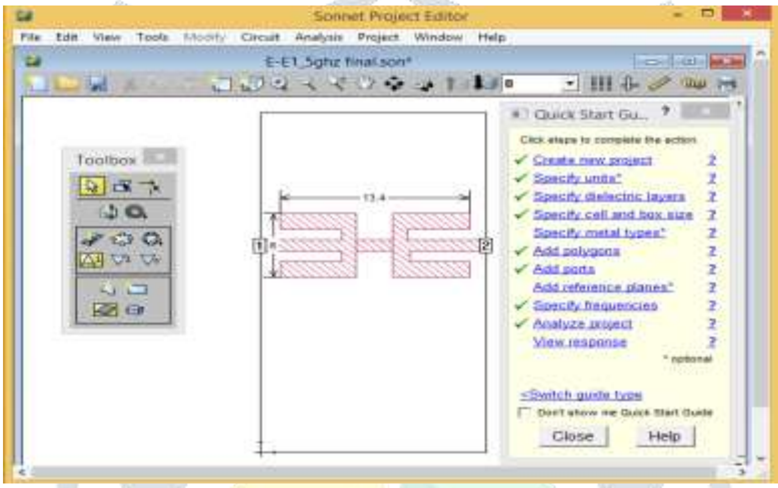

Figure.1. Geometry of E-Shaped Patch Antenna Array

V. RESULTS AND DISCUSSION

To examine the performance of the designed monopole antenna, the radiating components are designed, analyzed and simulated employing Sonnet 13.

Proposed E-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.

Three dimensional & Current Density: Fig.1 shows the front view geometry and Fig.2 shows the three dimensional structure and Current density designed on Sonnet software of the single band operation for wireless communication, the physical meaning of current density distribution is that it is a measure how the antenna is producing a beam.

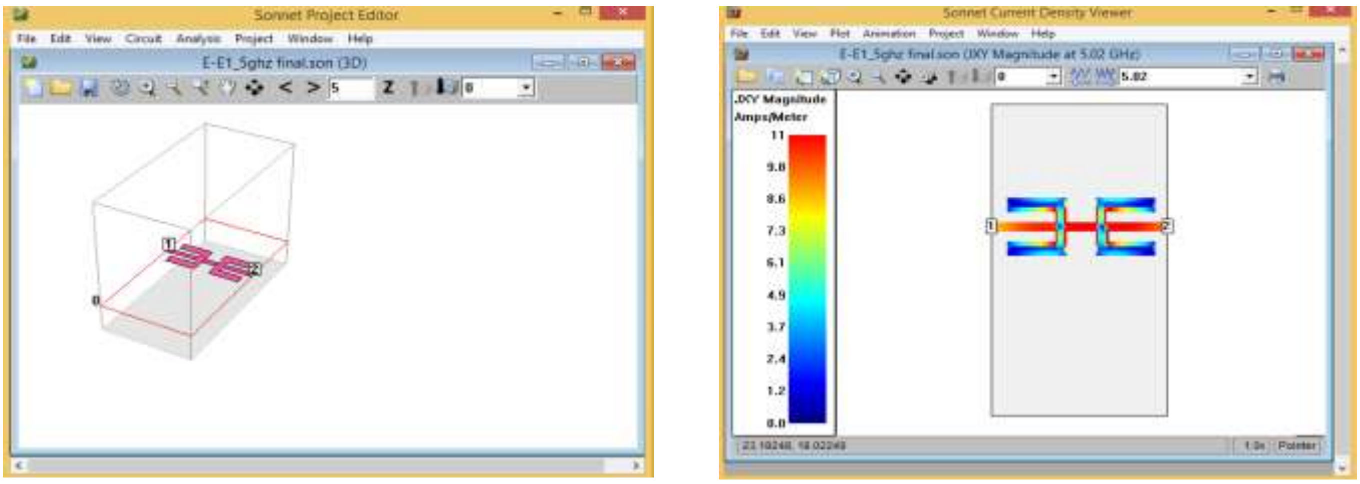

Fig.2.Three Dimension of Patch Antenna Array & its Current Density of Patch Antenna Array

Return Loss [S11] & Gain: Fig.3 shows the return loss and gain of E-Shaped patch antenna array. It is clear from the fig.3 that at the resonant frequency, the return loss
is -18.4dB.Return loss is a measure of the reflected energy from a transmitted signal. Result is suitable for WLAN, Wi-Max and C-band applications.

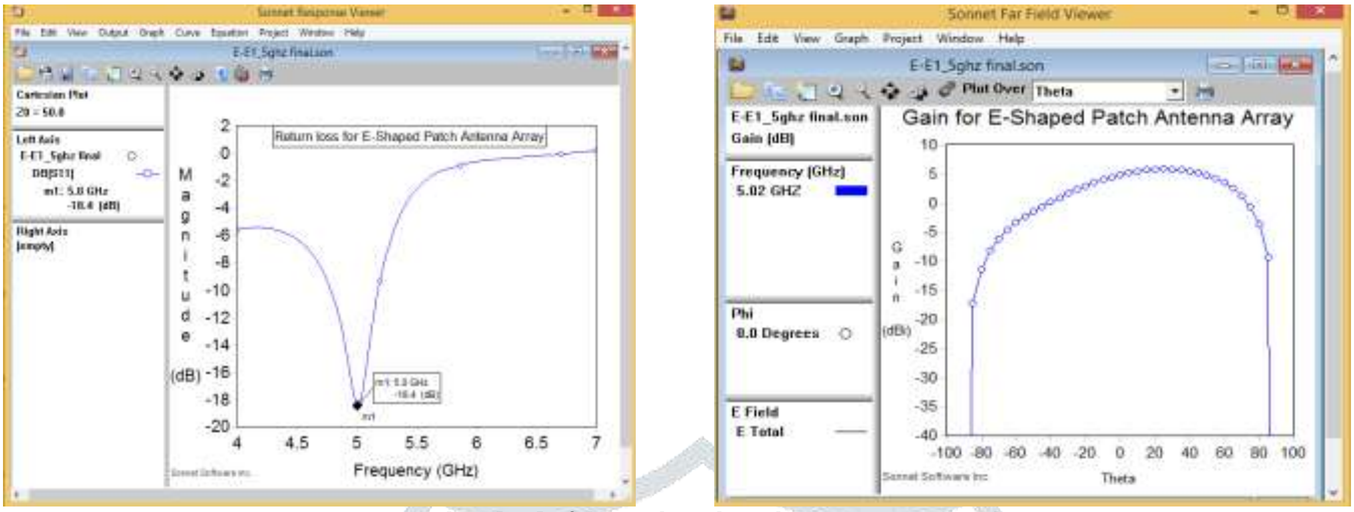

Fig.3.Return loss [S_{11}] of the E-Shaped Patch Antenna Array and its Gain

Fig.4 show the VSWR of the patch antenna array, the VSWR circle is indicated by red circle where VSWR =1.6. VSWR input impedance of the antenna at the resonant frequency are found at VSWR = 1.27.

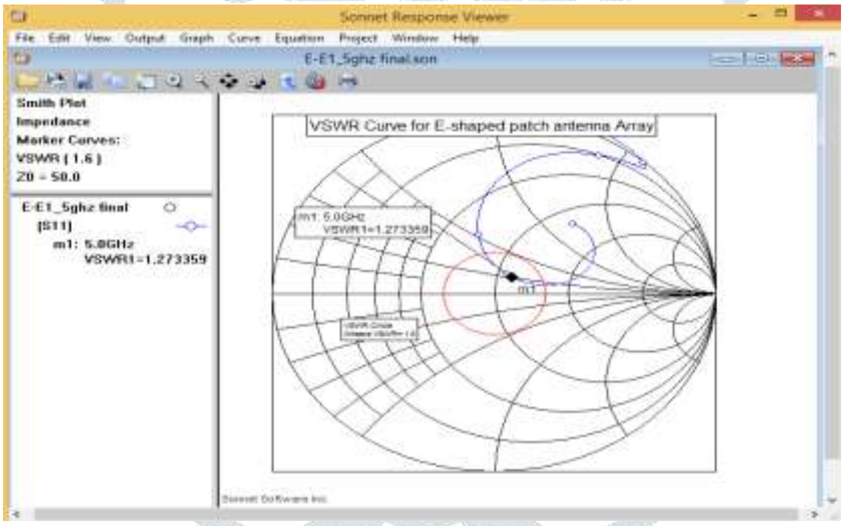

Fig.4, VSWR of the Patch Antenna Array at resonant frequency (5 GHz)

CONCLUSION

Finally, the optimum dimension of patch antenna on FR-4 dielectric substrate for Wi-Fi applications has been investigated. The return loss of E-Shaped microstrip patch antenna array = -18.4dB and the VSWR = 1.27 at resonant frequency. The performance properties are analyzed for the optimized dimensions and the proposed antenna works well at the required 5 GHz frequency band.

ACKNOWLEDGMENT

Authors would like to thank Maulana Azad National Fellowship (UGC) for financial support.

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