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Design of 14GHz 4x4 Patch Antenna Array

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Abstract: The modern wireless communication demands high gain, wide bandwidth and reduced size antennas that are efficient to provide improved performance over a wide range of frequency spectrum, which can be easily obtained using microstrip patch antenna arrays. This paper presents the design of compact 4x4 microstrip patch antenna array. Corporate feeding technique is used for excitation. The proposed antenna array is designed on Rogers RT5880 substrate with dielectric constant (εr) of 2.2 and thickness (h) 0.762mm. The simulation is carried using CST Microwave Studio. The antenna has been designed at 14 GHz and is therefore suitable for Ku-band applications like in satellite communication .

Keywords: Microstrip patch antenna, corporate feed, microstrip patch antenna array, Ku-band

1. INTRODUCTION

Antenna is an integral part of any wireless communication system. The demand for lightweight communication devices and the emergence of modern systems, it is getting imperative to design compact and high gain antennas. [1]. The need for more compact antennas for communication devices is growing day by day. As communication devices are become smaller due to greater integration of electronics, the antenna becomes a bottleneck for size miniaturization as it occupies a significantly larger space of the real estate available in modern devices. In order to overcome such limitations, microstrip patch antennas are the favorable choices for wireless applications. Microstrip patch antennas are light in weight, conformal, simple planar structure. They can be easily fabricated using printed-circuit technology [2]. The main advantages of a microstrip antenna are ease of construction, light weight, low cost [2-7]. In single patch antenna element antenna, the main lobe of the radiation pattern is very broad and the gain is therefore relatively low. This problem can be overcome by increasing the physical dimensions of the antenna element. Alternatively an array can be made by assembling number of elements for enhancing the gain. The performance of a microstrip patch antenna and array depends on several factors such as type of substrate, feeding mechanism, the thickness of dielectric and dielectric constant of substrate respectively.

For increasing the bandwidth, directivity and gain, the most common method is to use an array [6, 7]. The efficiency of microstrip antenna arrays can be significantly increased by reducing losses in the feeding network. The choice of dielectric substrate used and its thickness are the main parameters in terms of size and compactness of the patch antenna. The array has an improved gain, band width and radiation pattern in comparison to that of a single patch antenna element [6]. In the present paper a microstrip patch antenna array suitable for Ku-band applications is designed. Ku-band is used in satellite applications including continuous-wave, pulsed, single polarization, dual-polarization, synthetic aperture radar, and phased arrays. The proposed antenna array is designed on the substrate with dielectric constant (εr) of 2.2 and height 0.762 mm.

2. CORPORATE FEEDING NETWORK

The feeding network used for exciting the Patch antenna array is corporate feed. In this configuration, the antenna elements are fed by 1: n power divider network with equal and identical path lengths from the feed point to each individual element. The corporate-feed network is used to maintain power splits of 2n (i.e. n = 2; 4; 8; 16; etc.). This method has more control of the feed of each element and is commonly used for antenna arrays. This feeding mechanism provides better directivity as well as radiation efficiency and minimizes the beam fluctuations over a band of frequencies. The phase of each element can be controlled by using phase shifters while amplitude can be adjusted using either amplifiers or attenuators [8-10].

3. DESIGN OF PATCH ANTENNA ARRAY

The main parameters for the design of a Microstrip Patch Antenna are [11-13]:

- Frequency of Operation: The resonant frequency of the antenna must be selected appropriately. The resonant frequency selected for the present design is 14GHz.
- Dielectric constant of the substrate (εr): The dielectric material selected for design has a dielectric constant of 2.2.

- Height of dielectric substrate): The height (h) of the dielectric substrate used is 0.762 mm.

4. DESIGN PROCEDURE

Step1

Calculate the width of the patch as

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

Step2

Calculate the effective dielectric constant for (W/h >1)

$$\epsilon_{\text{reff}} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$$

Step3

Calculate the length correction due to fringing

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

Step 4

The length of the patch can now be calculated as

Step 5

$$L = \frac{1}{2f_r\sqrt{\epsilon_{\text{reff}}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L$$

The feed point position for 50 Ohms can be calculated using the following expression

$$R_{in}(y=y_0) = R_{in}(y=0)\cos^2\left(\frac{\pi}{L}y_0\right)$$

Where Rin(y=y_0) is 50 Ohms and Rin(y=0)is roughly given as (Neglecting the mutual coupling of the slots)

$$Z_{in} = \frac{1}{Y_{in}} = R_{in} = \frac{1}{2G_1}$$

$$G_1 = \begin{cases} \frac{1}{90}\left(\frac{W}{\lambda_0}\right)^2 & W \ll \lambda_0 \\ \frac{1}{120}\left(\frac{W}{\lambda_0}\right) & W \gg \lambda_0 \end{cases}$$

The optimal dimensions of the designed antenna shown in Figures 1 (a), 1 (b) are as follows: W1= 8.47mm, L1= 6.75mm, W2=18mm L2= 16mm.On the back of the substrate, complete ground plane is used. The dimension of ground plane which is printed in the back side of the substrate is chosen to be W × L, where W=62 mm and L=64 mm.

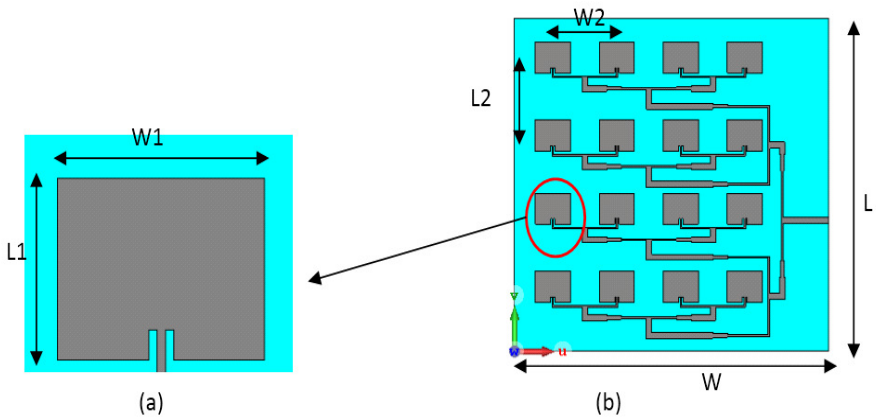

Fig. 1. (a) Single Element Patch Antenna (b) Sixteen element patch antenna array

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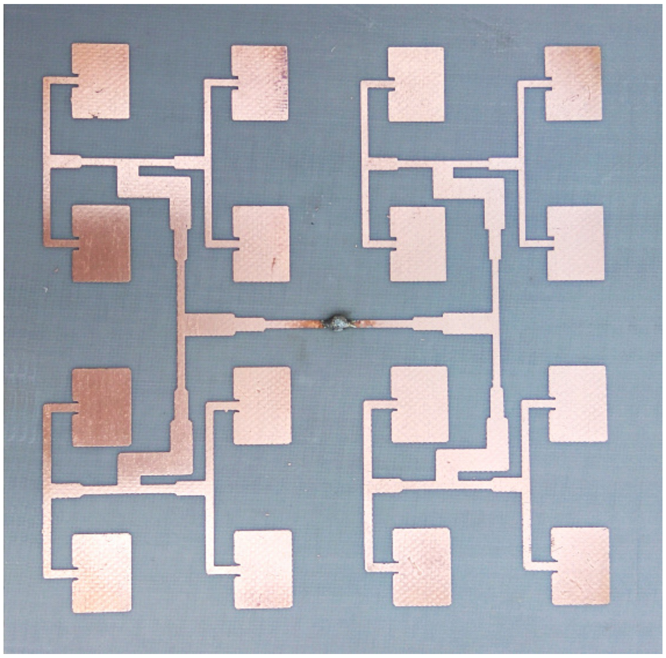

Fig. 1.(c) Photograph of Fabricated Patch Antenna Array

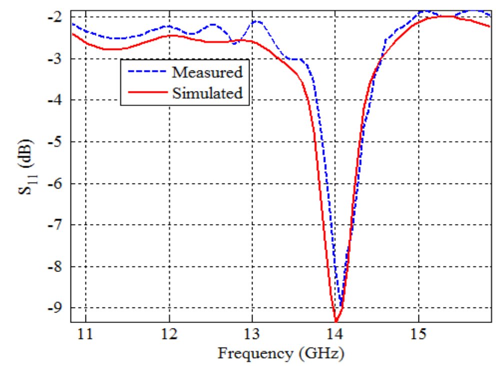

Fig. 2. Return Loss plot of the Single Antenna Element

5. SIMULATION RESULTS

The simulated results obtained using CST Microwave Studio are shown in Figures 2-4. Figure 2 shows the return loss plot of the single antenna element. Figure 3 shows the return loss plot of the proposed antenna array. Figures 4 and 5 show the three dimensional and polar radiation patterns respectively of the proposed antenna array. The gain for the array is 23 dB.

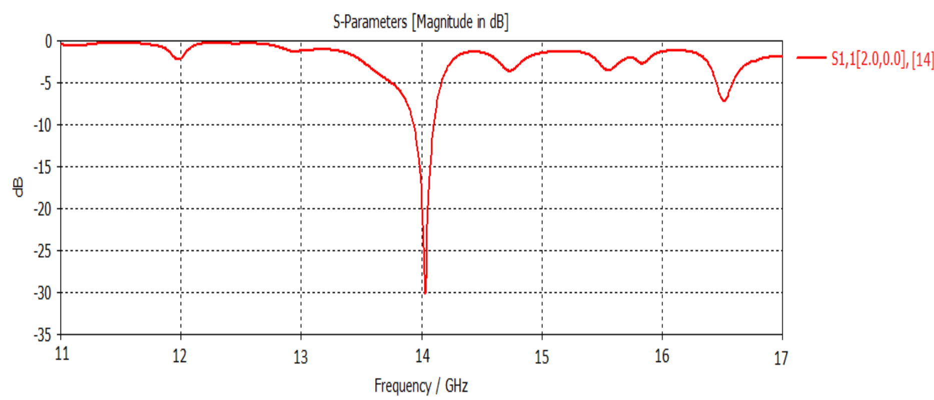

Fig. 3. Return Loss plot of the Array

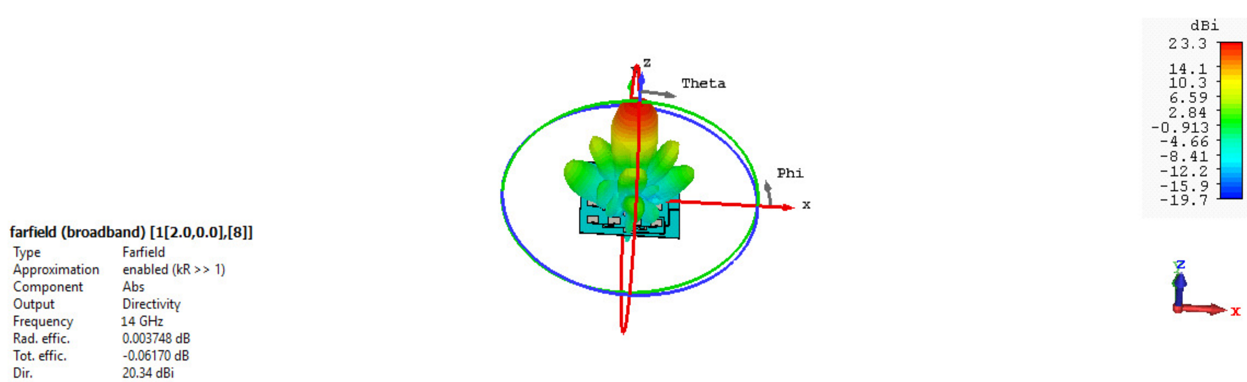

Fig. 4. Three Dimensional Radiation Pattern of the Antenna array

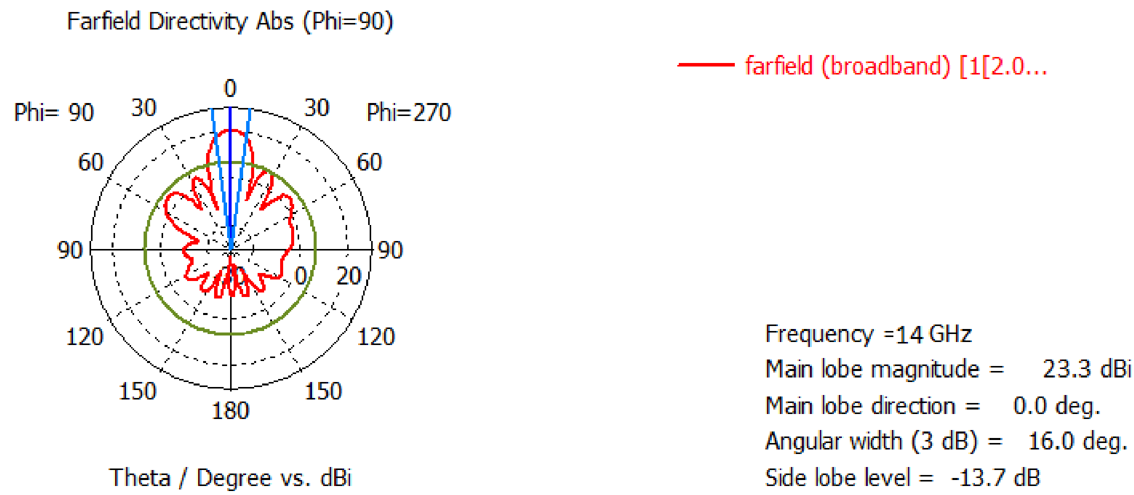

Fig. 5. Polar plot of the radiation pattern of the Antenna Array

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