Design and Simulation of 4×1 Corporate Feed Circular Microstrip Patch Array Antennas for Wireless Communication

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Abstract. The purpose of this paper is to analysis the results obtained from the design and simulation of an array of circular microstrip patch elements. 4×1 corporate feed circular microstrip patch array antennas have been designed for three different dielectric constants of substrate with fixed substrate height. The proposed antenna is simulated using commercial General Electromagnetic Solver (GEMS) software version 7 and all the output parameters are presented in this paper. The effect of bandwidth due to change of dielectric constants have been investigated and bandwidth of each case is measured. The designed antennas are operated at the frequency range of 9.5 to 10 GHz and applicable for broadband wireless access, Wimax and radar applications.

Keywords: surface waves, return loss, radiation pattern, s-parameter, dielectric constant.

1. INTRODUCTION

Antenna is a vital component in wireless application systems. With the rapid growth of the wireless mobile communication technology, the future technologies need a very small antenna and also the need of wide band antenna is increased to avoid using two antennas and to allow video, voice and data information to be transmitted (Stutzman 1989). Microstrip patch antenna is promising to be a good candidate for the future technology. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low weight (H. F. AbuTarboush 2008), low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology (Nashaat DM 2006), the microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems (H. F. AbuTarboush 2008).
Although patch antenna has numerous advantages, it has also some drawbacks such as restricted bandwidth, low gain, excitation of surface waves and a potential decrease in radiation pattern (Mst. Nargis Aktar 2011). Various techniques like using Frequency Selective Surface, Employing stacked configuration(Mst. Nargis Aktar 2011), using thicker profile for folded shorted patch antennas, slot antennas like U-slot patch antennas together with shorted patch, double U-slot patch antenna(Mst. Nargis Aktar 2011), L-slot patch antenna (Kazi Tofayel Ahmed 2011), annular slot antenna, double C patch antenna, E-shaped

patch antenna(H. F. AbuTarboush 2008), and feeding techniques like L-probe feed (Shackelford, A.K 2003), circular coaxial probe feed , proximity coupled feed (Guo, Y.X., Luk, K.M 1999) are used to enhance bandwidth of microstrip patch antenna.

The main goal of this paper is to design and performance analysis of a corporate microstrip line feed 4 array circular microstrip patch antennas and as well as improvement of bandwidth. The operating frequency of the antenna is 9.5 to 10 GHz which is used for wireless applications such as mobile and radar communication (G. Kumar 2003). Performances of the antennas are evaluated for the different values of dielectric constant of the substrate. For each design all performance parameters are presented in this paper. Finally, the bandwidth of the designed antennas is measured manually from the return loss curve.

In this paper, we proposed corporate feed circular patch array antennas with three different dielectric constants. Polypropylene with dielectric constant 2.2, plamitic acid with dielectric constant is 2.3 and polystyrene with dielectric constant is 2.4 are used to investigate the effect of bandwidth. Incident and accepted power, gain and efficiency variation are presented graphically.

2. ANTENNA DESIGN AND CONFIGURATION

In this paper, a 4 element corporate feed circular patch antennas are designed. By using different design parameter equations the appropriate values are selected. The equations are used to select the design parameters are given below.

The radius of the patch is given by (Constantine A. Balanis 2009)

$$a=\frac{F}{\sqrt{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]}} \quad (1)$$

where,

a= radius of the patch (mm)

$F=\frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$

h= height of the substrate (mm)

ε_r = dielectric constant of the substrate

f_r = operating frequency of the antenna

The effective radius of the patch is given by (Constantine A. Balanis 2009)

$$a_e= a\sqrt{1+\frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{\pi a}{2h}\right)+1.7726\right]} \quad (2)$$

where,

a= actual radius of the circular patch (mm)

h= height of the substrate (mm).

ε_r = dielectric constant of the substrate

The conductance due to the radiated power of the circular microstrip patch antenna can be computed based on the radiated power expressed as (Constantine A. Balanis 2009)

$$P_{rad} = |V_0|\frac{(k_0a_e)^2}{960}\int_0^{\frac{\pi}{2}}[J'^{\,2}_{02} + \cos^2\theta\, J_{02}^{\,2}]\sin\theta d\theta \quad (3)$$

The various conductance's across the gap between the patch and the ground plane at $\varphi = 0$ is given by (Constantine A. Balanis 2009)

$$G_{rad} = \frac{(k_0a_e)^2}{480}\int_0^{\frac{\pi}{2}}[J'^{\,2}_{02} + \cos^2\theta\, J_{02}^{\,2}]\sin\theta d\theta \quad (4)$$

$$G_c = \frac{\varepsilon_{m0}\pi\{\pi\mu_0(f_r)_{10}\}^{-\frac{3}{2}}}{4h^2\sqrt{\sigma}}[(ka_e)^2 - m^2] \; (5)$$

$$G_d = \frac{\varepsilon_{m0}\tan\delta}{4\mu_0 h(f_r)_{10}}[(ka_e)^2 - m^2] \; (6)$$

Where,

G_c is the conductance due to conduction losses

G_d is the conductance due to dielectric losses

f_r is the frequency of the dominant mode.

Input impedance of the antenna is given (Constantine A. Balanis 2009)

$$R_{in}(\rho' = \rho_0) = R_{in}(\rho' = a_e)\,\frac{J^2{}_m(k\rho_0)}{J^2{}_m(ka_e)} \quad (8)$$

The operational mode was TM_{110}. The antenna was excited by a microstrip transmission line feed. Figure 1 shows two dimensional view of proposed circular array of patch antenna.

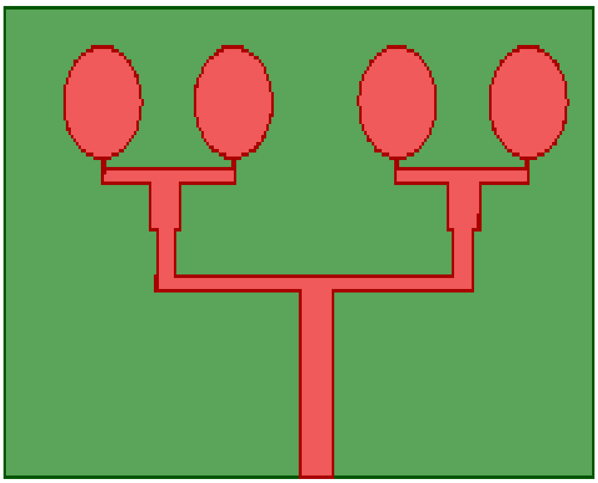

Fig 1: two dimensional view of proposed patch antenna

The width, depth and height for ground plane are 50mm, 90mm and 0.2mm respectively. The substrate height is 0.2mm with dielectric constants of substrate are 2.2, 2.3 and 2.4 are taken to design the antennas. The operating frequency is 10GHz. With these values different design parameters are calculated by using MATLAB command .Table 1 shows different design parameters.

Table 1: Design parameters calculated by MATLAB program

Design Parameters (Units)	ε_r=2.2	ε_r=2.3	ε_r=2.4
a (mm)	0.5771	0.5648	0.5532
a_e (mm)	0.5930	0.5800	0.5678

G_{rad} (S)	0.0022	0.0022	0.0022
G_c (S)	1.716e-08	1.70e-08	1.70e-08
G_d (S)	5.99e-12	5.96e-12	5.94e-12
R_{in} (Ω)	214.6406	226.8933	238.112

3. SIMULATION RESULT

Now a day, it is a common practice to evaluate the system performances through computer simulation before the real time implementation. A simulator "GEMS" based on finite element method (FEM) has been used to calculate return loss, impedance bandwidth, radiation pattern. This simulator also helps to reduce the fabrication cost because only the antenna with the best performance would be fabricated. Figure 2 shows the simulated results of the return loss of the proposed antenna for three different dielectric constants values.

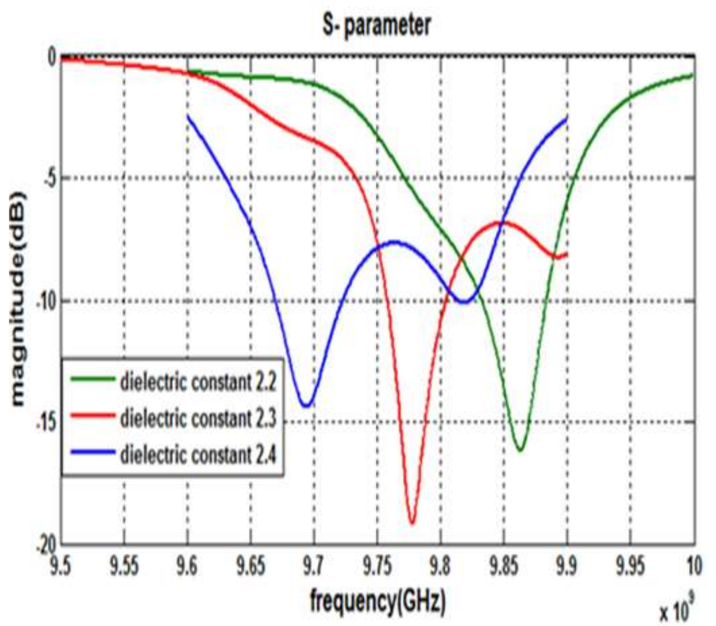

Fig 2: Return loss curves for different dielectric constants

It is seen from the figure 2, with substrate height 0.2mm and dielectric constant 2.2 return loss is -16dB at resonance frequency of 9.872 GHz, with substrate height 0. 2mm and dielectric constant 2.3 return loss is -19dB at resonance frequency of 9.772 GHz and with substrate height 0.2mm and dielectric constant 2.4 return loss is -14.9dB at resonance frequency of 9.692 GHz. A negative value for return loss shows that this antenna had not many losses while transmitting the signals. The return losses are changed due to the change of substrate heights. The bandwidth of the each designed antenna is measured from the return loss curve. Theoretically bandwidth is measured from the -3dB point of the return loss. Due to various antenna losses we have chosen the reference point of return loss is -5dB. According to this method the measured bandwidth of the antennas are given in the following table.

Table 2: Bandwidth variation with dielectric constants

Substrate height(mm)	Dielectric constant	Bandwidth (MHz)
0.2	2.2	60
0.2	2.3	49
0.2	2.4	44

Figure 3, 4 and 5 shows three dimensional radiation patterns for three different values of dielectric constants.

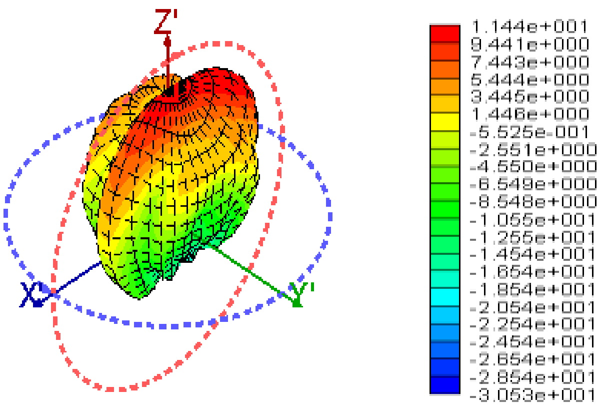

Fig 3: Radiation pattern at 9.872 GHz

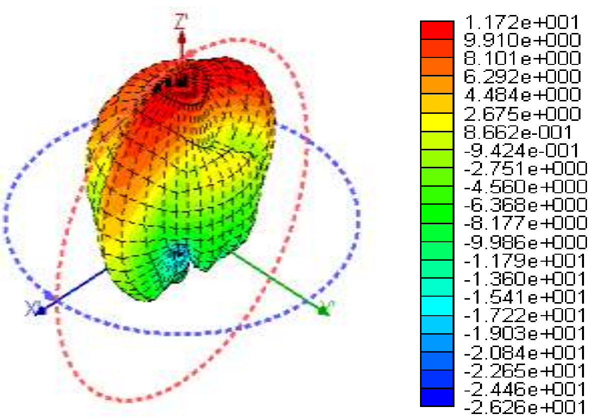

Fig 4: Radiation pattern at 9.772 GHz

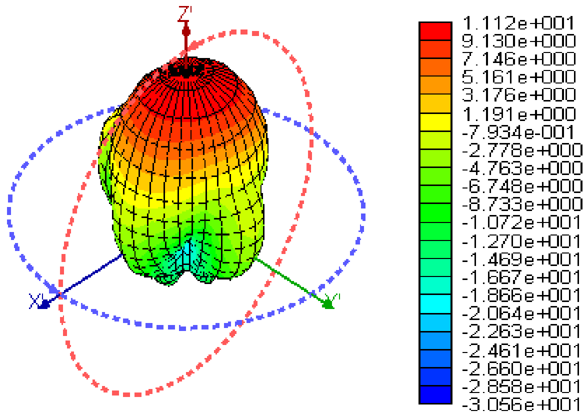

Fig 5: Radiation pattern at 9.692 GHz

Figure 6, 7 and 8 shows E-plane and H-plane views for three different values of dielectric constants.

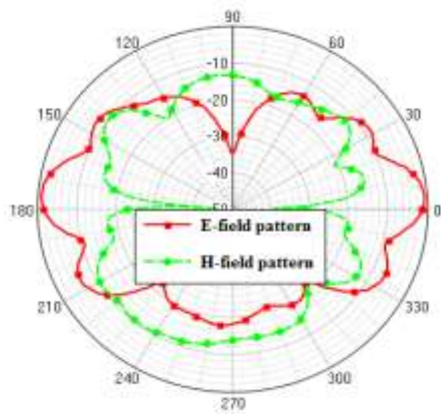

Fig 6: E-plane and H-plane view at 9.872 GHz

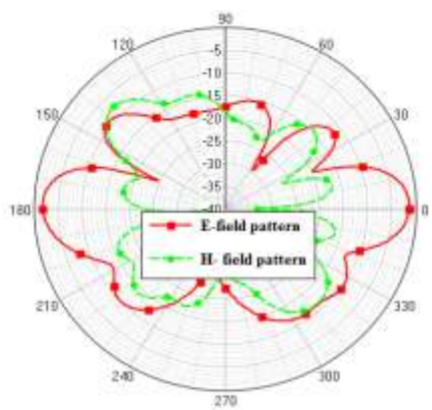

Fig 7: E-plane and H-plane view at 9.772 GHz

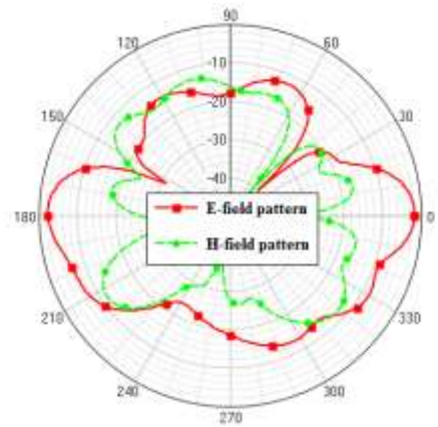

Fig 8: E-plane and H-plane view at 9.692 GHz

Figure 9 shows the comparisons of different far field powers such as radiated power, accepted power, forward power and incident power.

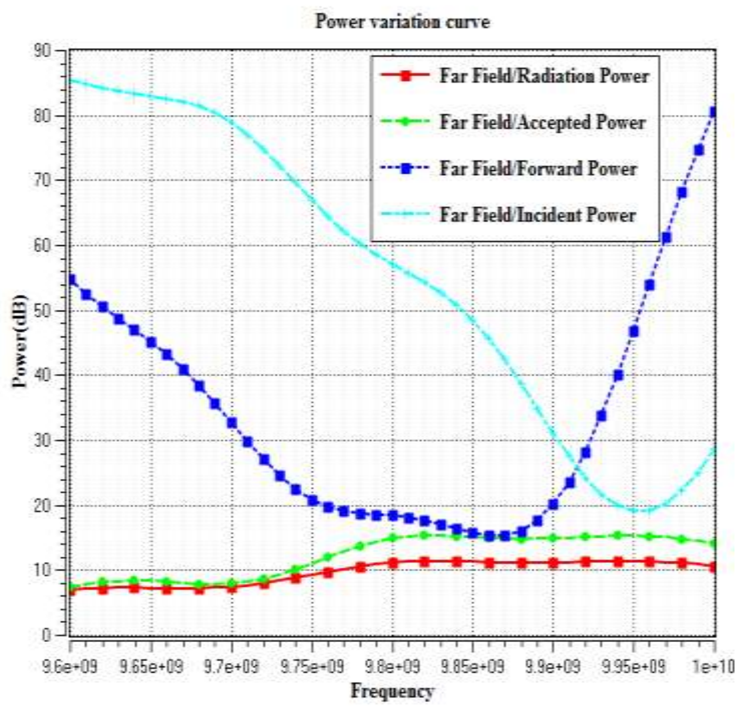

Fig 9: power variation at different stages

4. CONCLUSION

We designed 4 array circular microstrip antennas with the variation of dielectric constants at frequency of 10GHz. The observation shows the antenna bandwidth decreases with the increase of dielectric constants. It also shows that the designed antennas are well situated for narrowband application as bandwidth is too low. We got the return losses in the range -14.9dB to -19dB at resonance frequency.

5. FUTURE SCOPE

Higher order array antenna having higher directivity and radiation efficiency can be used to implement the smart antenna in the application of the Space Division Multiple Access (SDMA) technique. We would like to reduce surface waves for further increase of bandwidth in our future works.

6. ACKNOELEDGEMENT

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