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Research paper

Performance Comparison of S-Band Antenna with Series Fed and Corporate Fed Microstrip Array

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Abstract

Present wireless communication system needs the development of cost-effective, less weight and low profile antennas to show a high performance over different frequency spectrum. In this paper, we have designed a simple, economical and optimal gain rectangular microstrip patch antenna array capable of operating in S-band (2 to 4 GHz) frequency. The analysis is made for 2x1 patch antenna array connected in both series fed and corporate fed type. We carried out our simulation using High Frequency Structure Simulator (HFSS) and based on the results obtained; it helps us to identify the effective type of an antenna array. The antennas were designed using Flame Retardant 4 (FR4) epoxy substrate material with εr=4.4 and the thickness of the substrate (h) were kept at 1.6mm with a loss tangent value of 0.02. We considered return loss, gain, radiation pattern and bandwidth as our performance parameters for both series fed and corporate fed type microstrip antenna array. We finally achieved a higher gain value of about 5.47dB for the microstrip patch antenna array connected using corporate fed type.

Keywords: *Corporate fed antenna array, FR4-epoxy, Rectangular patch, Series fed antenna array, S-band.*

1. Introduction

Most of the wireless communication systems operating in L, S, C, X and Ku band needs suitable antenna array with optimum characteristics so as to meet the demand of far away communication. The microstrip patch antennas are found to be the best choice for such high frequencies due to their characteristics and several benefits when compared to other type of antennas [1]-[3]. Nowadays microstrip patch antenna is being used for different applications with enhanced value of gain and bandwidth [4]-[5]. Recently, wide economical designs of microstrip patch antennas were fabricated [6]-[7] in the market on an inexpensive FR4 substrate material having a loss tangent value of 0.02.

The word "Microstrip" means the thickness of the metallic strip is in the range of micro-meter. A microstrip patch antenna contains four parts namely: Patch, Ground plane, Substrate and the Feeding element. Among different shapes of patch, rectangular and circular shaped configurations are widely used [8]. Depending on the type of model, the ground plane can either be finite or infinite. The core features of the substrate are dielectric constant and height. The antenna feeding element can be of several types like coaxial probe, microstrip line, proximity coupled and aperture coupled feed [9].

In this paper we have designed a compact rectangular microstrip patch antenna of length L and width W with an effective dielectric constant "ε" _"r" . Here the main radiating element is the patch which is connected using microstrip line feed. To improve the gain and efficiency of an antenna, single microstrip patch element might not be the suitable solution and hence we have configured patch elements additionally in an array, called as patch antenna array [10]-[12].

Initially, we started our design with the construction of single microstrip patch antenna and further expanded the design by connecting two microstrip patch elements in both series and in corporate (parallel) fed type. The ultimate aim of the radiator array is to increase the gain value. The microstrip patch antenna elements were designed using High Frequency Structure Simulator software. It is a full wave electromagnetic field (EM) simulator that uses Finite Element Method (FEM) for solving all 3D EM issues [13]. Using this software, different antenna parameters like gain, return loss, directivity and radiation pattern can be accurately computed.

works. In section 6 results are performed and finally concluding remarks.in section 7.

2. Specifications of Single Microstrip Patch Antenna

The layout of single microstrip patch antenna is shown in the Figure 1. The patch dimensions were designed for the resonant frequency (f_r) 2.4GHz using the equations [14] represented below. Assume W as the width of the patch, $\varepsilon_{r(effective)}$ as the effective relative permittivity and length of the patch antenna denoted as L.

$$W=\frac{V_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

$$\varepsilon_{r(effective)}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+\frac{12*h}{W}\right]^{-\left(\frac{1}{2}\right)} \tag{2}$$

$$L=\frac{V_0}{2f_r}\frac{1}{\sqrt{\varepsilon_{r(\text{effective})}}}-2(\Delta L) \quad (3)$$

where the parameters ΔL and V_0 is the incremental length and velocity of light ($3\text{x}10^8$ m/sec).

$$\frac{\Delta L}{h}=0.412\left[\frac{\left(\varepsilon_{r(\text{effective})}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{r(\text{effective})}-0.258\right)\left(\frac{W}{h}+0.8\right)}\right] \quad (4)$$

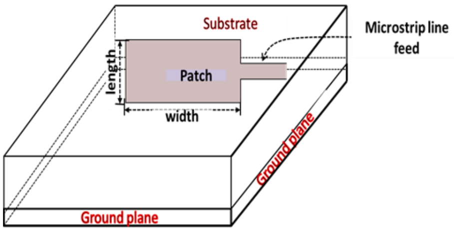

Fig. 1: Schematic diagram of Single Microstrip Patch Antenna

Based on the above formula, different antenna parameters [Table 1] are tabulated.

Table 1: Specifications of microstrip patch antenna array

Symbol	Quantity	Values (mm)
Substrate Material: FR4_Epoxy		
ε_r	Dielectric constant	4.4
W	Width of the patch antenna	38.04
L	Length of the patch antenna	29.44
h	Thickness of the substrate	1.6
g	Gap between the feed line and patch	0.3
b	Length of the feed	20.93
c	Inset depth_50Ohms	10.82
w_f	Width of the main feed	2.57
W_{if}	Width of the feed	0.44
y	Depth_100Ohms	9.04
d (λ/2)	Distance between the patch elements	62.5
a,e	Effective length and width	5,5

3. Design of microstrip patch antenna array usin series fed and corporate fed type

Microstrip patch antennas not only find its popularity with single element but also popular in arrays. To increase the gain and efficiency of the antenna system, single patch element might not be efficient and hence we go for antenna arrays. Hence, in the feed network arrangement of the microstrip array, we can either feed the elements using single line or with the help of multiple lines. Depending on their way of feeding, the array can be classified as: series fed and corporate fed [9].

In series type feed, the input signal which is fed from one end of the feed network is coupled in sequence to all the antenna elements. The series fed arrangement is compact and therefore the line losses related with this type of array is less compared to the corporate fed array. The corporate fed type microstrip antenna array contains multiple feed lines which helps to controls the feed of every element. The layout of series fed and corporate fed antenna array with a distance d is shown in Figure 2&3. An optimum value of distance (λ/2) is maintained between the two patch elements.

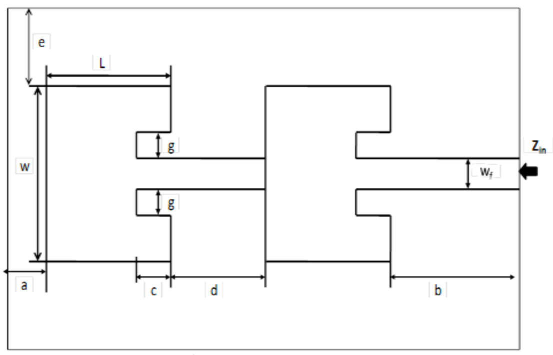

Fig. 2: Series fed microstrip patch antenna array

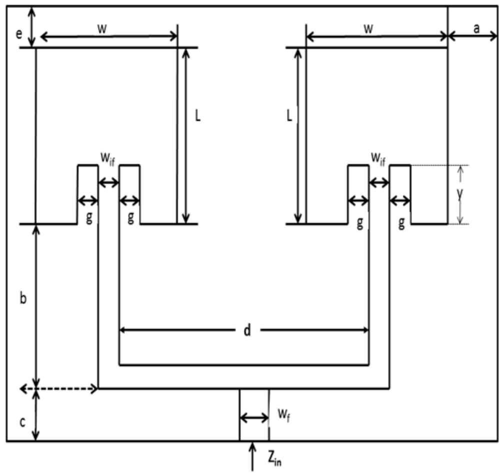

Fig. 3: Corporate fed microstrip patch antenna array

A suitable value for the length of the feed is maintained because any minor alterations in the value might affect the result. In series fed microstrip patch antenna array [Figure 2], the input impedance of the patch element is maintained as 50 Ohms and to match the impedance value of 50Ω, the width of the feed is considered to be 2.57mm and the characteristic impedance as 10.82mm. To achieve enhanced results, the gap g between the inset feed line and the patch antenna is considered as 0.3mm. In corporate fed type patch antenna array [Figure 3], to match the input impedance of the radiating element, a 50Ω microstrip line is connected to 100Ω microstrip line according to the logic of network theory [15].

4. Simulation and Analysis

We used HFSS as our simulation software and analyzed different antenna parameters like return loss, gain and radiation pattern. It is observed that [Figure 4&5], the single microstrip patch antenna resonating at a frequency 2.38GHz has a return loss value of -22.89dB and the gain value of about 3.29dB. The value of gain for single microstrip patch antenna is less compared to the antenna array. The microstrip patch antenna array connected in series fed type is resonating at a frequency of 2.5GHz [Figure 6] with a return loss value of -11.5dB. The gain value of the series fed microstrip antenna array [Figure 7] is increased further when compared to the single microstrip patch antenna.

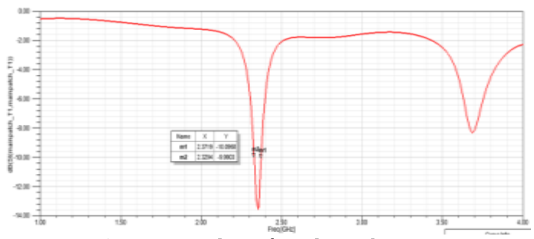
Fig. 4: Return loss of single patch antenna

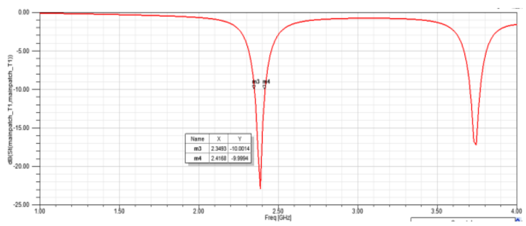
Fig. 5: Gain of single patch antenna

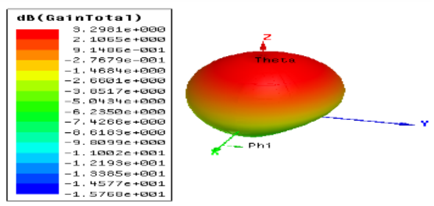

Fig. 6: Return loss of series fed patch antenna array

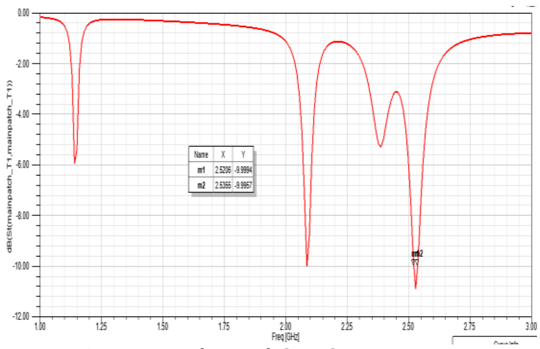

Fig. 7: Gain of series fed patch antenna array

The antenna connected in corporate fed manner is resonating at a frequency of 2.36GHz [Figure 8] with a return loss of -13.55dB. The gain value of corporate fed type microstrip antenna array [Figure 9] is 1.75 times more compared to the single microstrip patch antenna. Further, an optimum bandwidth value of 50 MHz is achieved when the microstrip patch antenna array is connected using corporate fed type.

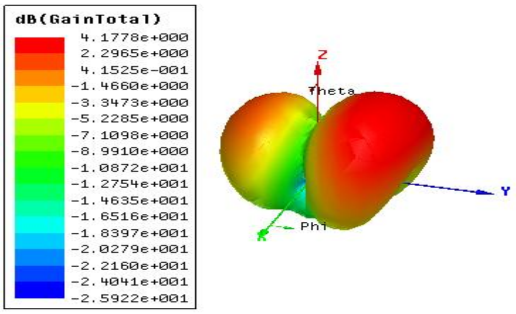

Fig. 8: Return loss of corporate fed patch antenna array

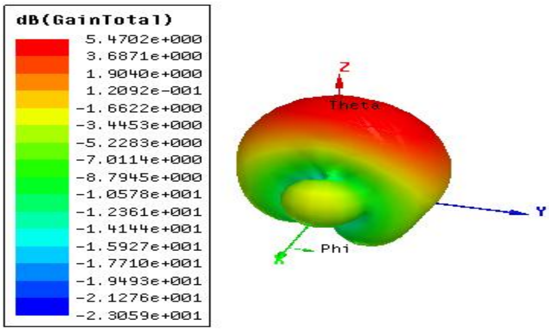

Fig. 9: Gain of corporate fed patch antenna array

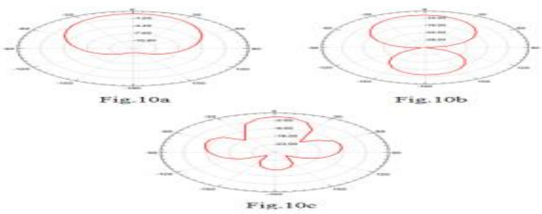

Fig. 10: Radiation pattern of single patch, series fed and corporate fed microstrip antenna array

The far field 2D radiation pattern of single microstrip patch antenna [Figure 10a], series fed patch antenna array [Figure 10b] and corporate fed patch antenna array [Figure 10c] in E-plane is shown below. The pattern analysis explains about the amount of energy radiated by array elements into free space. The single patch antenna possesses a unidirectional radiation pattern and the series fed patch antenna array possess bidirectional radiation pattern. We obtained a directional radiation pattern for the corporate fed type antenna array. The antenna array connected using series fed and corporate fed type radiates maximum power in the desired direction.

Different antenna parameter values are compared for single patch, series fed and corporate fed antenna array and summarized below [Table 2].

Table 2: Comparison between single microstrip patch, series fed and corporate fed type patch antenna array

Types	Gain (dB)	Return loss	Bandwidth
Single microstrip patch antenna	3.29	-22.89dB at 2.38GHz	70 MHz
Antenna array-Series fed	4.17	-11.5dB at 2.5GHz	15 MHz
Antenna array- Corporate fed	5.47	-13.55dB at 2.36GHz	50 MHz

The comparison table shows that the bandwidth value for single microstrip patch antenna is more but the gain value is considerably decreased when compared to the antenna array. The series fed type microstrip patch antenna array shows improved gain value compared to the single microstrip patch antenna but the value of bandwidth is considerably reduced. Through corporate fed antenna array we achieved higher gain value and optimum value of bandwidth and therefore we proceeded with it further and analyzed different values of gain for varied distance [Table 3]. From the result analyzed, we observed that the value of gain is nearly equal and high at multiple distance values λ/2 (d=62.5mm) and at λ/4 (d=31.25mm). Variation of gain against distance plot is shown in Figure 11.

Table 3: Distance (d) Vs Gain and Return loss (dB)

Distance (mm)	Gain (dB)	Return loss (dB) at frequency 2.36GHz
0.5	3.48	-14.9
1	2.23	-20.25
2.5	3.09	-15.7
5	3.96	-13.5
9.5	3.67	-18.4
12.5	4.65	-13.3
14	3.48	-15.7
18	4.79	-13.4
20.5	4.93	-12.8
21.5	4.89	-13.8
25	5.02	-13
30.5	3.18	-14.8
31.25	**5.17**	**-13.1**
40	2.53	-14.2
45	5.25	-13.1
62.5	**5.47**	**-13.5**

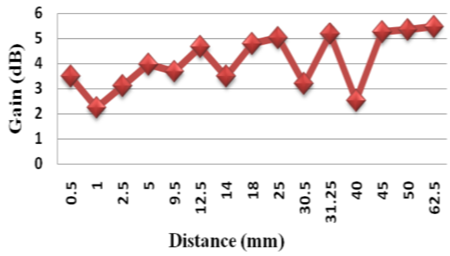

Fig. 11: Distance Vs Gain Plot

5. Conclusion

The proposed paper clearly explains about the design the performance analysis of single microstrip patch antenna and the 2x1 microstrip patch antenna array on an FR4 epoxy substrate material. Based on the performance analysis of different antenna parameters, it helps us to identify the effective type of patch antenna array which is mostly suitable for S-band frequency applications. We finally achieved optimum gain and bandwidth value of about

5.47dB and 50 MHz when the microstrip patch element connected using corporate fed type. In future, we plan to incorporate more patch elements in the array so as to achieve higher gain, bandwidth and high radiation efficiency.

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