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Highly Directive Rectangular Patch Antenna Arrays

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***Abstract*-This paper presents various designs of microstrip arrays antennas, suitable for wireless communication applications. Particularly, 4x1 2x1, and single element of rectangular geometry is designed and simulated. Gain and directivity can be enhanced by increasing the number of array elements but at the cost of side lobe level. Enhancement in gain and better return loss performance can be obtained by the use of Teflon substrate. Quarter wave transformer is used to feed the elements. This solution is investigated numerically, and simulated by using ADS 2011 software. Experimental testing on fabricated prototypes are presented and consent well with the theoretical predictions. The results demonstrated a good agreement between simulated return loss, directivity, gain for several design of microstrip arrays antennas. The antenna array designed best suits ISM band and WLAN applications.**

***Index Terms*-**Microstrip antennas array, rectangular microstrip antennas, resonant frequency of patch antenna

1. INTRODUCTION

A microstrip patch antenna in its simplest configuration consists of radiating patch on one of the dielectric substrate, which has ground plane on the other side [1]. The radiating elements and the feed line are usually photo etched on the dielectric substrate. A microstrip patch antenna is very simple in construction using a conventional microstrip fabrication technique [2].Patch arrays are extensively used in phased array radar application and in applications requiring high directivity and narrow beam width. A microstrip antenna element can be used alone or in combination with other like elements as part of an array. In this paper, several elements of rectangular patch antennas are presented [7]. Specifically, 4by1, 2by1, and single element, are designed and simulated using ADS 2011.

II. SINGLE ELEMENT DESIGN

A rectangular microstrip patch antenna of length L, width W resting on a substrate of height h.
The design value for L,

$$\mathrm{L} = \left(\frac{\mathrm{c}}{2\,fr\sqrt{\varepsilon_{reff}}}\right) - 2\Delta L$$

The effective patch length Le is written as, $Le = L + \Delta\mathrm{L}$

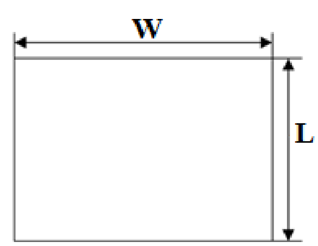

Figure.1. Geometry of a rectangular patch

Figure 1, shows the geometry of single element of rectangular patch antenna. Based on the cavity model, the resonant frequency of the rectangular patch antenna, of length L, can be calculated using the following formula [3],[6]:

$$\mathrm{f}(1,0) = \left(\frac{\mathrm{c}}{2\mathrm{L}\sqrt{\varepsilon_{reff}}}\right)$$

Where, c is the speed of light in free space,

ϵ_r is the dielectric constant of the substrate.

II a) *Substrate selection*

One of important steps in designing a patch antenna is to choose a suitable dielectric substrate of peculiar thickness h and loss tangent.
and thus the electromagnetic wave sees an effective permittivity ε_{reff},

$$\varepsilon_{reff} = \frac{(\varepsilon_{reff} + 1)}{\in \varepsilon 2} + \frac{(\varepsilon_{reff} - 1)}{2}\left(1 + 12\frac{h}{w}\right)^{\frac{1}{2}}$$

Where,

ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

A Substrate with ϵ_r = 2.0 and thickness h=1.6 mm is used in this design.

A thicker substrate, besides being mechanically strong, will increase the radiation power, reduce conductor loss, and improve impedance bandwidth. The substrate dielectric constant ϵ_r plays a role similar to that of substrate thickness. A low value of ϵ_r for the substrate, will increase the fringing field at the patch periphery, and thus, radiated power.

II b) *Design*

Figure.2 shows the design of a rectangular antenna and its dimension. As shown in the Figure, patch is fed by microstrip line inset feed. Figure 3 shows the radiation pattern for the design shown in Figure 2. It can be seen that the radiation pattern is in broadside direction [5].

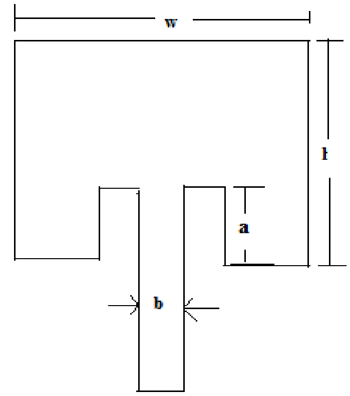

Figure 2. Geometry of single Rectangular patch antenna (in mm): l=42.0, w=42.4, a=13.5, b=4.82

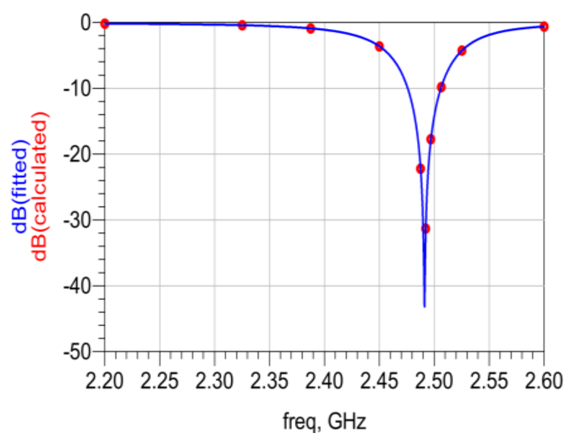

Figure 3. Simulated reflection coefficient

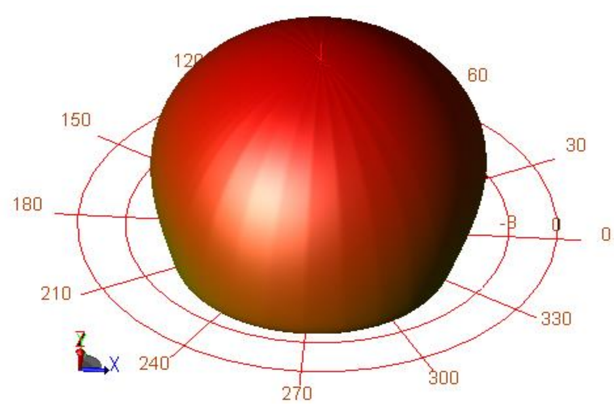

Figure 4. The radiation pattern for single rectangular element at 2.45 GHz

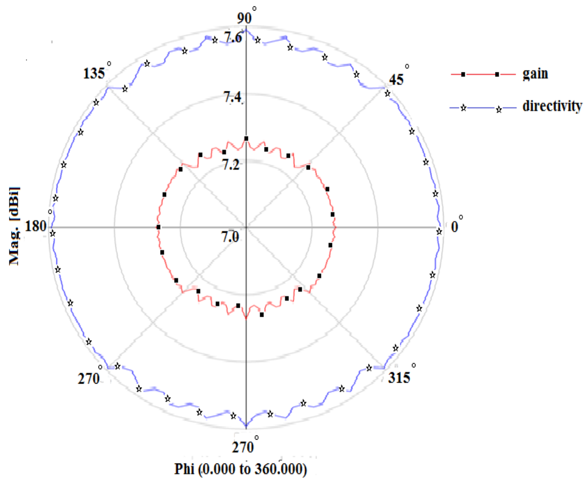

Figure 5.Gain and directivity of single element

III.ARRAY DESIGN

Array have relatively simple structure, light weight, small lateral dimensions, wideband, high efficiency, and high gain characteristics, they are excellent candidates for array applications. The elements of an array may be spatially distributed to form a linear, planar, or volume array. Feeding methods, that are employed to feed microstrip array in this paper, are parallel and quarter-wave-transformer methods [9].

III. a) *Design of Linear 2x1 Array*

In order to design an effective 2 element in phase radiator, the distance between patch elements needed to be optimized to yield a peak gain. The text identifies a separation distance λ/2 as providing the optimal gain.

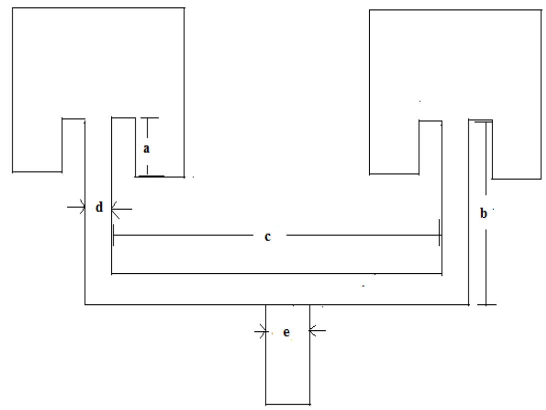

Figure 6. Configuration of 2x1 linear rectangular patch antenna array with a=10.5, b=30, d=1.41, c=96, e=4.89 (in mm)

Figure 6. Shows the configuration of 2x1 linear rectangular patch antenna array. To obtain 50 Ohms input impedance, feeding line with width W1=4.85 mm is used. This line is split into two 100 Ohms lines, with width Wo=1.41 mm for each as shown in Figure 6. It can be seen that the radiation patterns in design is in broadside direction. But, small side lobes appear in patterns.

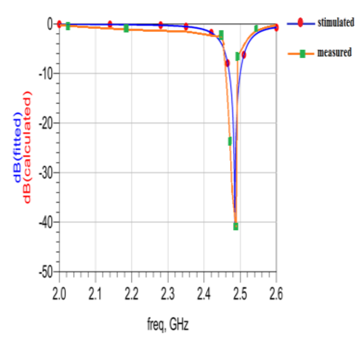

Figure 7. S_{11} of 2x1 arrays shown in fig.6

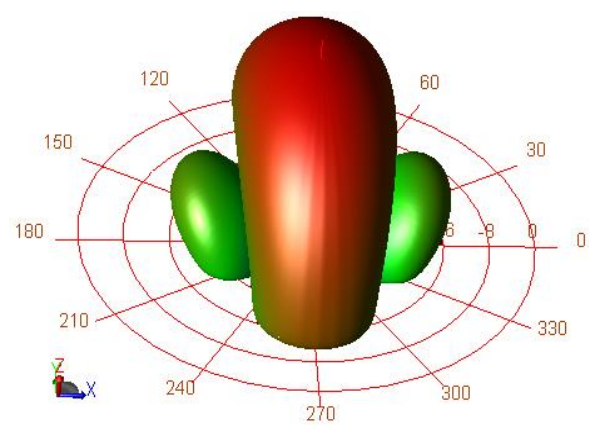

Figure 8. The radiation pattern for 2x1 Rectangular arrays at 2.48 GHz

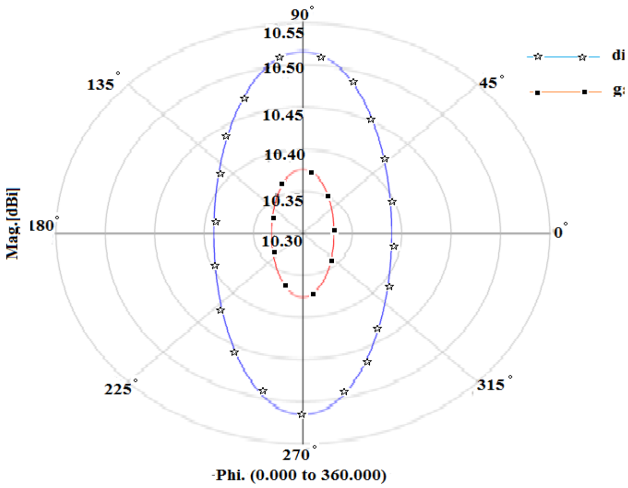

Figure 9. Gain and directivity of 2x1 rectangular array

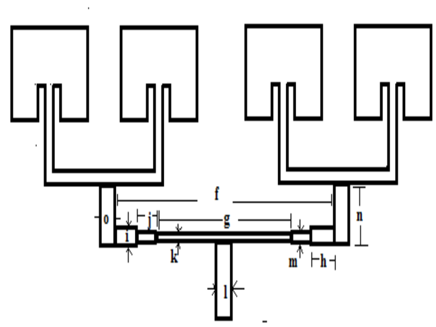

Figure 10. Configuration of 4x1 rectangular patch antenna array; with f=201.2, g=150, j=23.1, i=4.89, n=30, o=4.89, m=2.82, k=1.41, h=2.5, l=4.89 (in mm)

III. *b) Design of 4x1 Array*

The microstrip-to-parallel strip line transition presented. It is a simple design and easy to manufacture. Figure.10 shows the configuration of 4x1 rectangular patch antenna arrays. All dimensions are shown in the figure. It can be seen that the radiation patterns in the design is in broadside direction. The side lobes appear clearer in the design. Antennas, if not fed properly, do not work as predicted by the design.

Many antennas require balanced-line feeding, while power/signal transmission is mostly carried out by unbalanced line. Therefore, a balanced-to-unbalanced transformer, a balun, is a key issue in antenna design. Balun feeding has been made in order to improve the reflection coefficient. Broadband matching techniques were used to improve the matching between the balance port and antenna terminal.

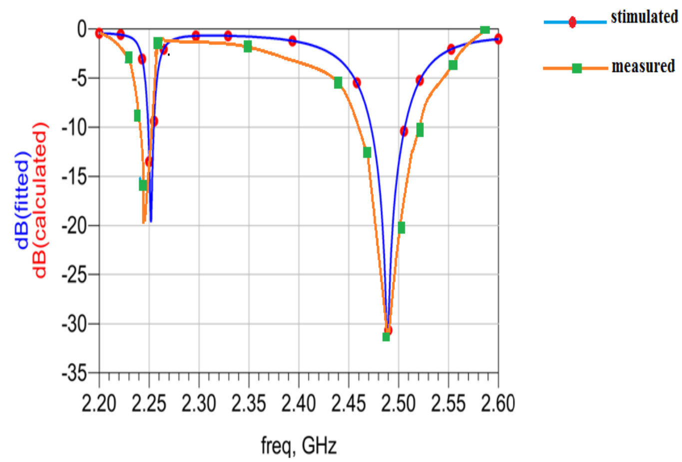

Figure 11. Simulated reflection coefficient for 4×1 rectangular array

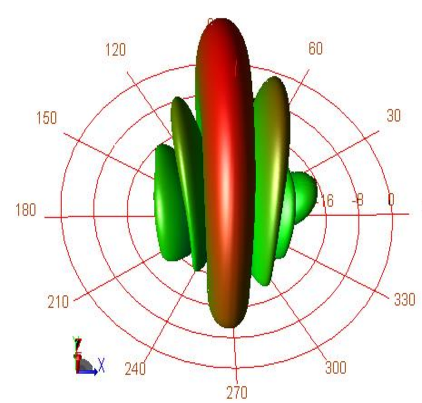

Figure 12. The radiation pattern for 4x1 array at 2.48 GHz

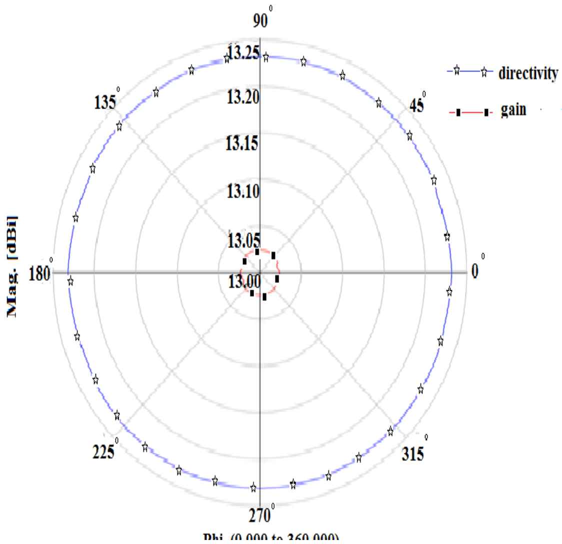

Figure 13. Gain and directivity of 4x1 array patch antenna

The result shows that S_{11} is now improved well below -10 dB for the dual band of frequencies 2.25 GHz and 2.48 GHz.

IV.COMPARISON

Table.1 shows the obtained simulated results with the measured ones. The reflection coefficient is best in single and 2x1 array. It could be because good matching is obtained in those cases. Both gain and directivity for the rectangular shape are increasing as the number of elements is increased, which is expected. Finally, the side lobe level is increasing as the number of elements is increased as shown in radiation pattern Figures (Figures 3, 8 and 12) with the advantage for over the rectangular patch antenna. Moreover, using Teflon substrate for antenna array, we could obtain better suppression for side lobe.

Table 1. Comparison between arrays & single element of rectangular patch in terms of directivity and gain under Teflon substrate.

Parameters	Simulated Result			Measured Result	
	Single	2×1	4×1	2×1	4×1
S_{11} (dB)	-44	-42	-20 &-31	-41	-20 &-31
Gain(dBi)	7.27	10.36	13.04	10.38	13.08
Directivity(dBi)	7.62	10.52	13.24	10.50	13.23
Frequency(GHz)	2.48	2.48	2.25, 2.48	2.48	2.24,2.48

V. CONCLUSION

In this paper, rectangular patch antenna arrays with integrated balun have designed and simulated using ADS 2011 software. 4x1, 2x1 and single element arrays are taken into consideration. The simulated result shows the return loss of -44dB,-42dB and -31 dB at 2.48GHz, 2.48GHz and 2.48GHz GHz respectively. The field gain of the antenna for single to 4 element ranges from 7.27 dBi to 13.24 dBi. Teflon substrate is used for the array with better performance of design in terms of suppression for side lobe level than that obtained using rectangular patch antenna array, especially in 2x1 arrays. All designs are compatible for ISM band and WLAN applications.

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