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Circularly Polarized Antenna Array for L-band Applications

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***Abstract*—The design of antenna array in the wireless communication system can be used to achieve high gain, steering capability and also to reduce the effect of fading. These antenna array is suitable for L-band applications such as military, global positioning system, digital audio broadcasting and other telecommunication areas. This paper presents a simple, low cost, low profile triangular microstrip antenna array with circular polarization providing high gain by 4×1 array. The designed antenna array provide the return loss below -20 dB and the gain of this antenna array is found to be around 12 dB. The resonant frequency of this antenna array is 1.29 GHz. Single triangular microstrip patch is resonating at 1.29 GHz and quarter wave transformer with power division method is used for matching the loss due to reflection. Single patch is providing the gain of 6.31dB.**

***Index Terms*—2×1 Array Antenna, 4×1 Array Antenna, Circular Polarization, Gain, Microstrip Triangular Patch Antenna**

I. INTRODUCTION

The wireless communication system requires light weight, low profile and simple structure antenna to assure reliability and high efficiency. A microstrip antenna is of low cost, light weight and provides conformability for mounting planar and nonplanar surfaces. It is simple and also inexpensive to manufacture using modern printed-circuit technology in wireless communication. It is desired that microstrip antenna is to be used as circularly polarized antenna for receiving and transmitting signal in all directions. All these attractive features of microstrip antenna make them popular in many wireless communication applications such as spacecraft, satellite communication and radar etc [1]-[16]. The limitations of microstrip antenna are that they tend to radiate efficiently over a narrow frequency band only a few percent (2-5%) and not able to operate at high frequency level of waveguide, coaxial line or even stripline [2]. Therefore it becomes more important to develop broadband technique to increase the bandwidth and gain of microstrip antenna. In this paper, array technique is used to improve the performance of antenna that overcome the above problems.

Synthetic Aperture Radar (SAR) & Air Route Surveillance Radar (ARSR) operates in L-band. SAR antennas offer several advantages for spaceborn remote sensing satellite application. Microstrip antennas appear to be more suitable for such application due to its low cost, light weight & robustness [3]. L-band is also used for military satellites, low earth orbit satellites and terrestrial wireless connections like GSM mobile phones.

The equilateral triangular patch shape is chosen because of being physically smaller than other patch geometries like rectangular and circular patches and each patch is provided with equal input impedance using microstrip feed line and also to provide circular polarization [4]. In this paper, several designs of triangular patch antenna arrays are presented specifically, single element antenna, 2×1 antenna array, and 4×1 antenna array.

II. MICROSTRIP ANTENNA DESIGN TECHNIQUE

Single equilateral triangular patch antenna is designed and simulated for resonant frequency 1.29 GHz on a finite ground plane. The microstrip feed line technique has been used, as it is more reliable in many applications such as outer space and requires no transition. The geometry of an equilateral triangle microstrip antenna is shown in Fig. 1 [4]. The triangular patch has the side length ‘ ’ and the substrate has relative permittivity ‘ε_r’ and substrate height is ‘h’.

A. Resonant Frequency

The resonant frequency of triangular patch corresponding to various modes is given as [4- 6]

$$f_{mn} = \frac{cK_{mn}}{2\pi\sqrt{\varepsilon_r}} = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + mn + n^2} \quad (1)$$

where, c is the velocity of the light and K_{mn} is the wave number.

The expression for fundamental mode resonant frequency is given by

$$f_{10} = \frac{2c}{3a\sqrt{\varepsilon_r}} \quad (2)$$

In this relation, the effect of fringing field is not considered. In the above equation for better accuracy, ‘ ’ and ‘ε_r’ are replaced by effective dielectric constant and which is given by (3) and (4)

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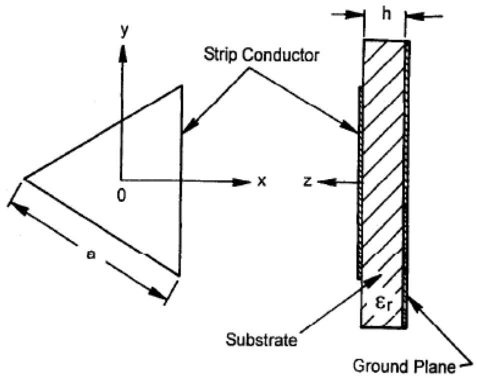

Fig. 1. Geometry of an equilateral triangle microstrip antenna

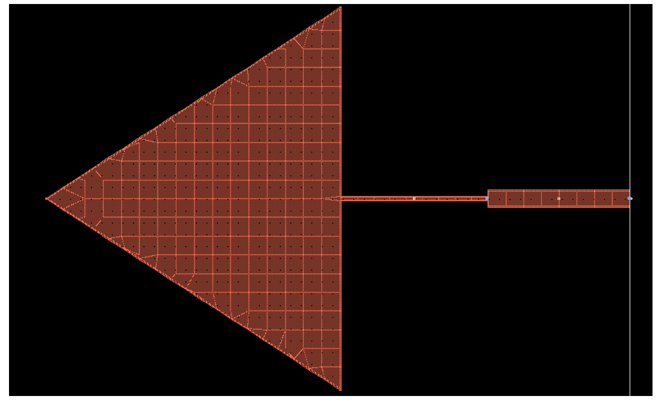

Fig. 2. Single element equilateral triangular patch antenna

$$\varepsilon_{eff} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{4}\frac{(\varepsilon_r - 1)}{\sqrt{1 + \frac{12h}{a}}} \quad (3)$$

And

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \quad (4)$$

Hence,

$$f_{10} = \frac{2c}{3a_{eff}\sqrt{\varepsilon_{eff}}} \quad (5)$$

B. *Antenna Parameters*

The equilateral triangular patch has side length = 100 mm which is fabricated on RT/Duroid substrate of height 1.59 mm with relative dielectric constant of 2.32 and loss tangent (tan δ) = 0.001. The calculated resonant frequency for the fundamental mode TM_{10} is 1.29 GHz. The quarter wavelength transformer method is used to match the impedance of the patch element with the transmission line of 50 Ω which is acting as feeder. The impedance of the patch is 180.5 Ω and the impedance of the line that is matched to the patch is 95 Ω. Fig. 2 shows the configuration of single element antenna. Designed single patch provides return loss of -34.63 dB and gain of 6.31 dB as shown in Fig. 5.

III. MICROSTRIP ARRAY ANTENNA DESIGN

An antenna array is a set of two or more antennas. Antenna arrays configuration are used to scan the beam of an antenna system, to increase the directivity, gain and enhance various other functions which would be difficult with single element antenna.

A. *2×1 Antenna Array Network*

In this paper corporate feed technique is used for designing microstrip antenna array. Corporate feed arrays are general and versatile. The feed is taken such that each element receives equal input impedance. The feed works as the 1:2 power divider, i.e. power is equally divided in both the arms from the common feed [8, 9]. To obtain 50 Ω input impedance, the line is split into two 100 Ω lines, which gives 3 dB output. The separation between the patch elements is optimized to be 0.75 λ and the electrical length used is 90^0. The same substrate used in single element (ε_r= 2.32 and thickness h=1.59 mm), is used in the 1x2 array. Fig. 3 shows the configuration of 1x2 linear triangular patch antenna array. The input impedance of the patch is 180.5 Ω which is matched to the 100 Ω line through quarter transformer. The two 100 Ω lines in parallel give the 50 Ω impedance which is matched to the 50 Ω port impedance through 50 Ω transmission line. Operating frequency that used to design the antenna array is 1.29 GHz.

B. *4×1 Antenna Array Network*

To design 4x1 array network quarter wave transformer is used to feed the elements. Fig. 4 shows the configuration of 4x1 patch antenna array. The same substrate RT/Duroid, is used in the 4x1 array. The design resonates at 1.29 GHz frequency. Setting 50 Ω feed line, which splits into two 100 Ω ones, and to match 100 Ω transmission line with 50 Ω line impedance of quarter-wave transformer is calculated which is 70 Ω. The calculated width of quarter- wave transformer at 70 Ω is 2.56745 mm. The separation between the patch elements is taken same as in 1×2 antenna array is 0.75 λ and the electrical length used is 90^0.

IV. SIMULATION RESULT & DISCUSSION

A. *Single Element Simulation*

In this design, it is considered that the substrate permittivity of the antenna is 2.32 (RT/Duriod), height is 1.59 mm and resonant frequency of the antenna is 1.29 GHz. From calculation resonant frequencies are found to be 1.29 GHz

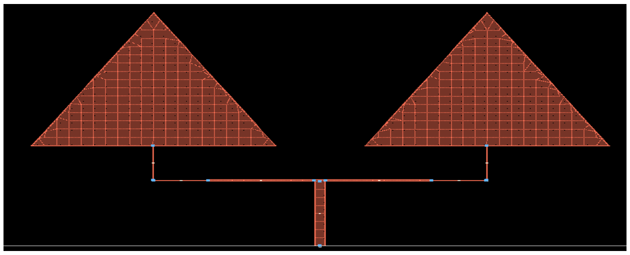

Fig. 3. 2×1 patch antenna array

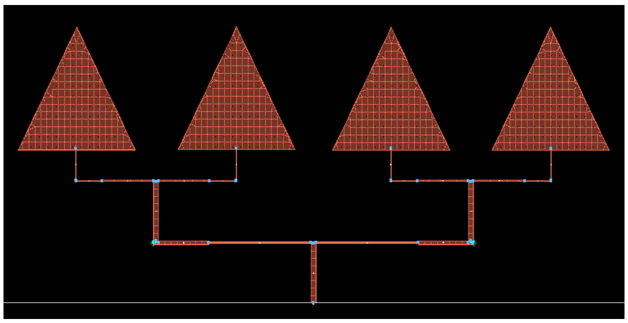

Fig. 4. 4×1 patch antenna array

for TM_{10} mode. From simulation resonant frequencies are found to be much closer to the calculated values, which are 1.286 GHz. Fig. 5 shows that the reflection coefficient is -34.63 dB at 1.29 GHz for single patch antenna. The three dimension radiation pattern of single patch antenna is shown in Fig. 6, which shows the circular polarization radiation pattern with maximum value of E_θ is 83.87 and $E_ø$ is 166.92. In the $\Phi = 0^\circ$ plane only the component E_θ is present. In the $\Phi = 90^\circ$ plane, however, both the E_θ and $E_ø$ components are present, except in the broadside direction ($\theta = 0^\circ$). This feature is different from the circular and the rectangular patches for which the principal plane patterns contain only either E_θ or $E_ø$ but not both [5]. Fig. 7 shows the simulated gain of 6 dB with beam width of 180^0 between first two nulls for single patch Antenna. The directivity of antenna is 7 dB and the radiated power is 2.03 mw.

B. 2×1 Array Simulation

In this array network, two successive patch elements as well as their corresponding transmission lines are matched by using quarter wavelength transformer method. Here, the permittivity of the substrate is 2.32 (RT/Duroid), height is 1.59 mm and resonance frequency of the antenna is 1.29 GHz. Fig 8 shows the reflection coefficient is -21.03 dB at 1.29 GHz for two element antenna array. Fig 9 shows the three dimension radiation pattern of two element antenna array with maximum value of E_θ and $E_ø$ is 151. Fig. 10 shows the simulated gain of antenna is 8.9 dB with beam width of 120^0 between first two nulls and the directivity of the antenna array is 9.7 dB which is greater than the single element antenna. This antenna array has high gain and side lobe lavel is -18 dB lower than main lobe.

C. 4×1 Array Simulation

Fig. 11 shows reflection coefficient is -20.37 dB at 1.29 GHz for 4 element antenna array. The same substrate as in single patch antenna of RT/Duroid is used. The resonance frequency of the designed antenna is 1.29 GHz. Fig. 12 shows the three dimension radiation pattern with maximum value of E_θ is -7 and $E_ø$ maximum is 141. This antenna array has side lobe label is -14 dB lower than main lobe so it can be used for 1.29 GHz The simulated gain and directive gain of the antenna, as shown in Fig. 13 are 11.84 dB and 12.83 dB respectively with beam width of 40^0 between first two nulls for the operating frequency of 1.29 GHz.

D. Comparison among three different configurations

Table 1 shows the comparison between three different antenna configurations, single element, two element array and four element antenna array. The reflection coefficient is less than -20 dB in all the cases. Both gain and the directivity, are increased as the number of elements is increased, as expected. Four element antenna array provides better directivity and gain as compared to single element antenna and two element antenna array.

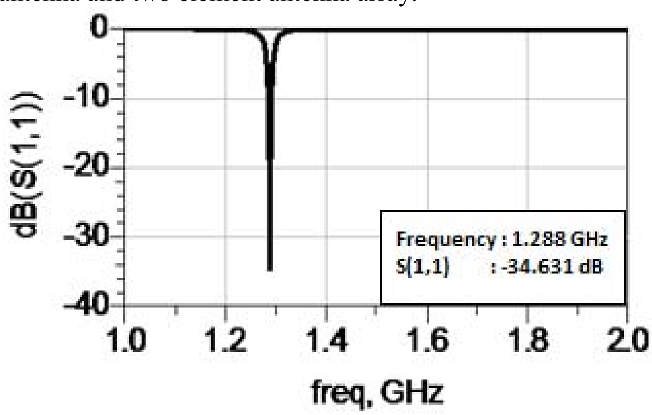

Fig. 5. Return loss of single element antenna

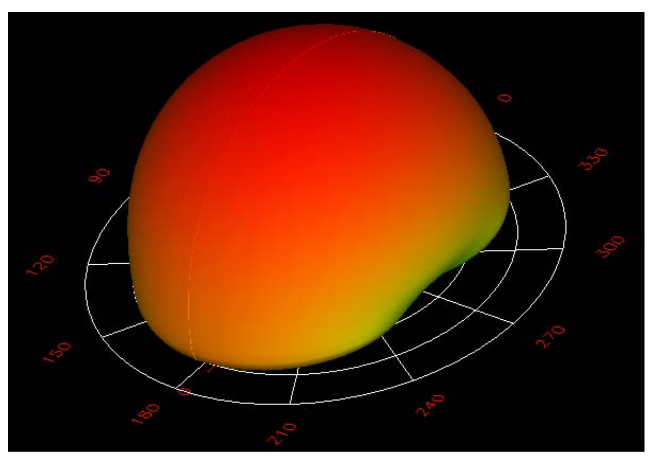

Fig. 6. 3D Radiation pattern of single element antenna

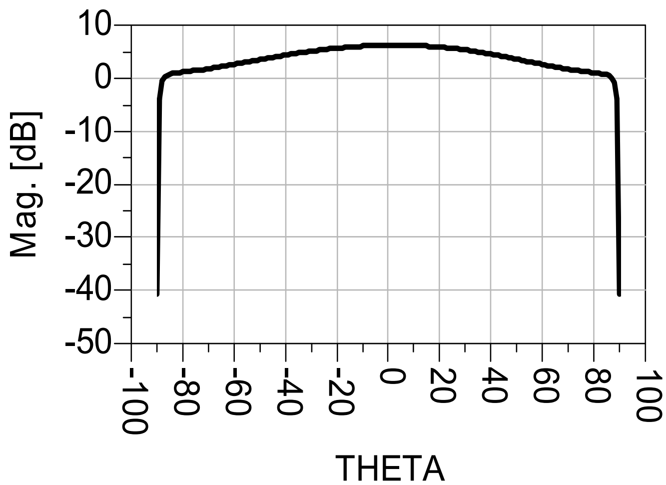

Fig. 7. Gain of single element antenna

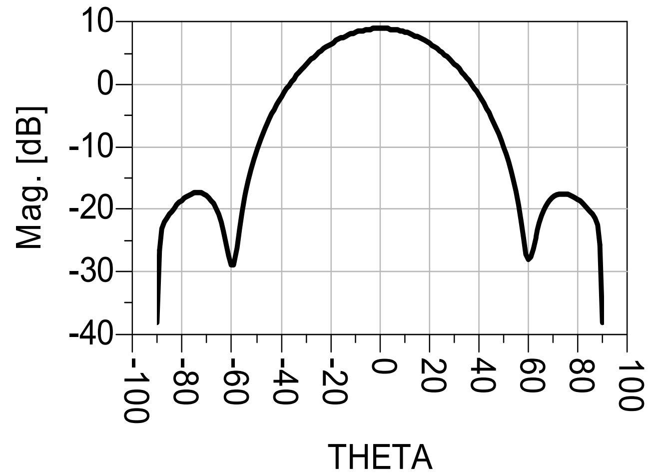

Fig. 10. Gain of 2×1 antenna array

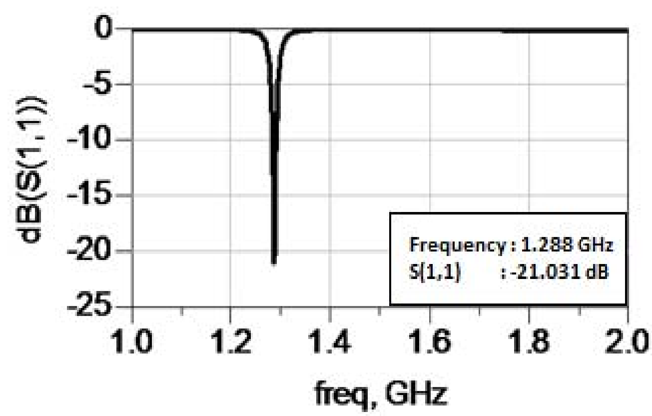

Fig. 8. Return loss of 2×1 antenna array

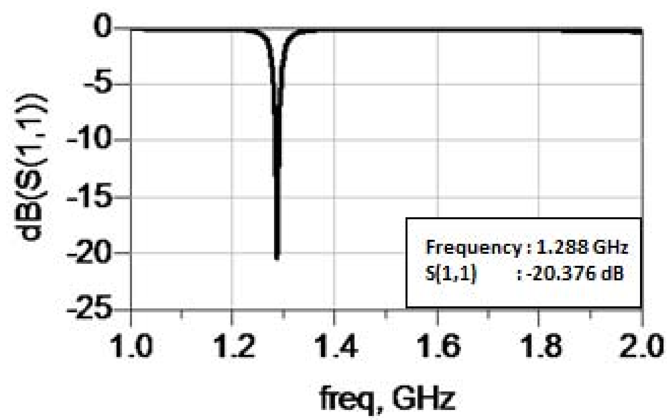

Fig. 11. Return loss of 4×1 antenna array

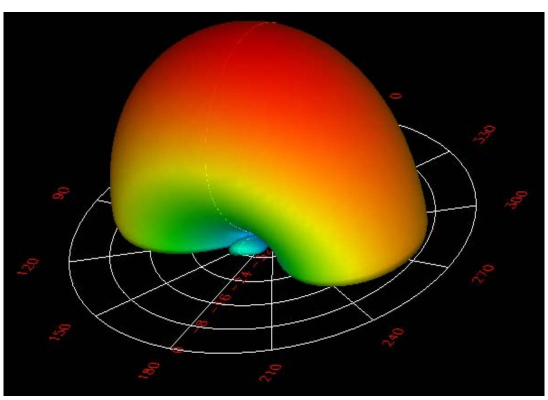

Fig. 9. 3D Radiation pattern of 2×1 antenna array

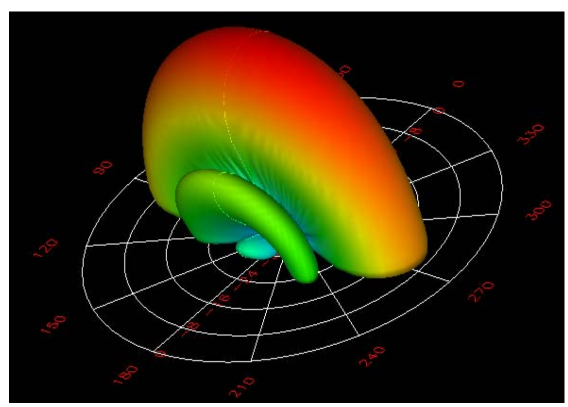

Fig. 12. 3D Radiation pattern of 4×1 antenna array

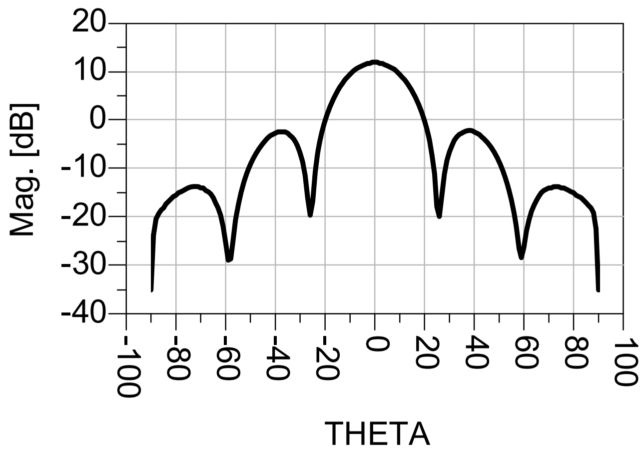

Fig. 13. Gain of 4×1 antenna array

TABLE I. COMPARISON AMONG THREE DIFFERENT CONFIGURATIONS

Antenna Parameters	Single Element Antenna	2×1 Antenna Array	4×1 Antenna Array
S11(dB)	-34.63	-21.03	-20.37
Simulated Gain (dB)	6.31	8.95	11.84
Directivity (dB)	7.03	9.64	12.43
Resonant Frequency	1.29 GHz	1.29GHz	1.29 GHz
Beam width between first nulls	180^0	120^0	40^0

V. CONCLUSION

In this paper, triangular patch antenna arrays with several elements, specifically, single element, 2x1 and 4x1 were designed. These designed antennas are very simple, suitable for L-band applications, thereby providing circular polarizations. The optimum design parameters (i.e. operating frequency, dielectric material, height of the substrate) are used to achieve the compact dimensions and high radiation efficiency. The operating frequency of all designed antenna is about 1.29 GHz which is suitable for L-band applications. Array technique provides good enhancement in both gain and directivity as summarized in Table 1. It would also be possible to design an antenna operating in any other frequency bands by changing the design parameters.

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