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Research paper

Design and Analysis of Rectangular Microstrip Array Antenna at Ka Band Becon Frequency 20.2GHz

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Abstract

The design and analysis of single double (1×2) and four (1×4) element linear rectangular micro strip array antennas is done to achieve high gain and directivity. The operating frequency of the proposed array antenna is Ka-band, 20.2GHz which is a Beacon frequency of GSAT-14 launched by ISRO.
The substrate material used is common for the single, double (1×2) and four (1×4) i.e. FR4 with a thickness of 0.8mm and the dielectric constant is 4.4. The antenna elements are placed uniform at a same distance. The feeding network used here is a parallel or corporate feed network. The power splitting and impedance matching is done using RF Wilkinson power divider. The entire proposed micro strip phased array antenna is evaluated using HFSS software tool.

Keywords: *Single, double (1×2) and four (1 × 4) elements, micro strip array antenna, Ka- Band, rectangular micro strip array antenna.*

1. Introduction

Now a day the requirement for the wide band width is increasing for long distance communications, high-speed data transmission, audio & video distribution and for many other applications, so we must go with mill metric waves for the wide bandwidth, where high gain is mandatory to overcome the attenuation problems and for long distance applications [1][2]. Here the suitable antenna is micro strip patch antenna because of its lite weight, planar and conformal nature [3]. The operating frequency of this micro strip patch antenna is 20.2GHz which is a Ka-Band Beacon frequency [4][5].
In the year 2014 ISRO have launched GSAT-14, for providing a platform for new experiments with two beacons operating at 20.2GHz and 30.5GHz [6][7].
A micro strip array antenna at Ka-band consisting of 4×1 and 4×2 elements with a gain of 12.43 dB and 13.72dB at 35GHz with return loss of -19.20dB and -40.01dB has been reported in [8]. In [9] the phased patch array antenna at Ka-band with single element gain of 6.3 dB and 4×4 elements have gain of 15.6dB with a beam steering implementation is observed.
This paper is organized in the following manner- firstly, the designs of single, double (1×2) and four (1 × 4) elements with a parallel feed technique is presented in section 2. In section 3, the proposed design simulation results are displayed and compared. And in section 4, the conclusion is drawn.

2. Construction and Design of Antennas

2.1Construction of Single Patch

This patch antenna is designed and simulated using HFSS software tool. The fig.1 shows the single element rectangular micro strip patch antenna geometry which operates at 20.2 GHz frequency.

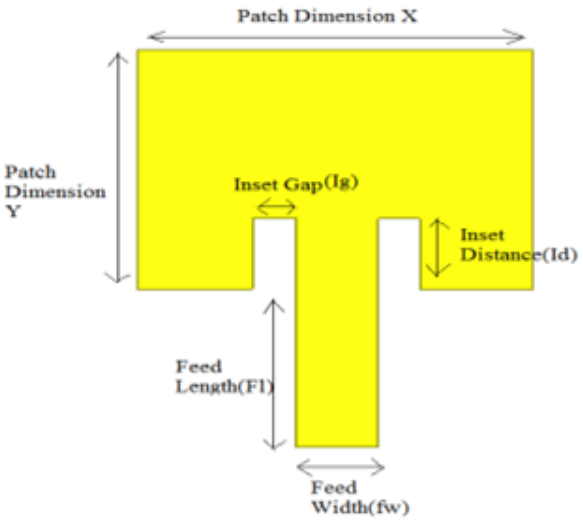

Fig. 1: Single (1×1) element rectangular micro strip patch antenna

The material used for design is Epoxy FR4 with a substrate thickness of 0.8mm, dielectric constant ε_r=4.4 and loss tangent is 0.02, from the above specifications the parameters of antenna design are calculated using standard equations [10] [11]. The calculated parameters are in table 1.

Table 1: Single Element Patch Parameters

Parameter	Value	parameter	value
patch Dimension X	5.05mm	Inset Gap(Ig)	0.37mm
patch Dimension y	3.2mm	Feed Width(Fw)	1.5mm
Inset Distance (Id)	1.05mm	Feed Length(Fl)	3.2mm

The standard equations for patch design are

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$w = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$ (1) where $c = 3 \times 10^8 m/s$ is for width of the patch

Length $L = l_{eff} - 2\Delta l$ (2) where $l_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}}$

$$\Delta l = 0.412hr\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.8\right)}$$

2.2 Construction of 1×2 And 2×2 Rectangular Micro Strip Array Antenna

Fig-2 and Fig-3 shows the proposed 1×2 and 1×4 rectangular micro strip antenna array. These two antenna elements are having the same dielectric substrate and patch dimensions as the single element antenna. The spacing between the rectangular patch array elements is equal.

Parameter(P)	Value(V)	P	V	P	V
Patch Dimension (X)	5.05mm	W1	0.8mm	L1	4.0mm
Patch Dimension (Y)	3.2mm	W2	0.3mm	L2	2.1mm
Inset Distance (Id)	1.05mm	W3	1.5mm	L3	2.0mm
Inset Gap(Ig)	0.37mm	W4	0.8mm	L4	4.0mm
Feed Width(Fw)	1.5mm	W5	0.3mm	L5	2.0mm
Feed Length(Fl)	3.2mm	W6	0.8mm	L6	3.6mm
Substrate dimension (S_x)	2*X	W7	0.3mm	L7	4.0mm
Substrate dimension (S_Y)	2*Y	W8	1.5mm	L8	6.5mm

Corporate feeding network is used for the proposed rectangular micro strip array antenna elements to feed in parallel from single source. Here for feeding network, three different feed lines of 50Ω,70.7Ω and 100Ω are used.

The required equation to obtain the feed widths of different impedances is as follows [12]

$$\frac{w_f}{h} = \begin{cases} \frac{8e^A}{e^{2A}-2} & , \frac{w_0}{h} \le 2 \\ \frac{2}{\mu}\left\{B-1-\ln(2B-1)+\frac{\epsilon_r-1}{2\epsilon_r}\left[\ln(B-1)+0.39-\frac{0.61}{\epsilon_r}\right]\right\} & , \frac{w_0}{h} \ge 2 \end{cases}$$

(3)

Where

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r+1}{\varepsilon_r-1}\left(0.23+\frac{0.11}{\varepsilon_r}\right)$$

$$B = \frac{377\pi}{2z_0\sqrt{\varepsilon_r}}$$

Here in the array design the RF power divider is Wilkinson power divider which divides the power in to equal amount.

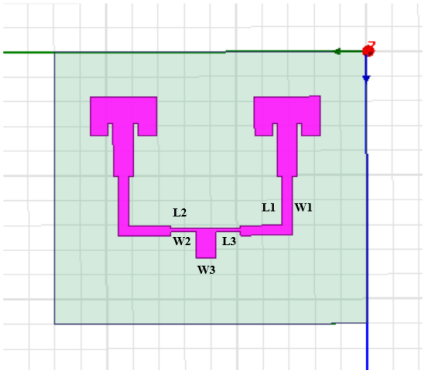


Fig. 2: Two (1×2) element patch antenna

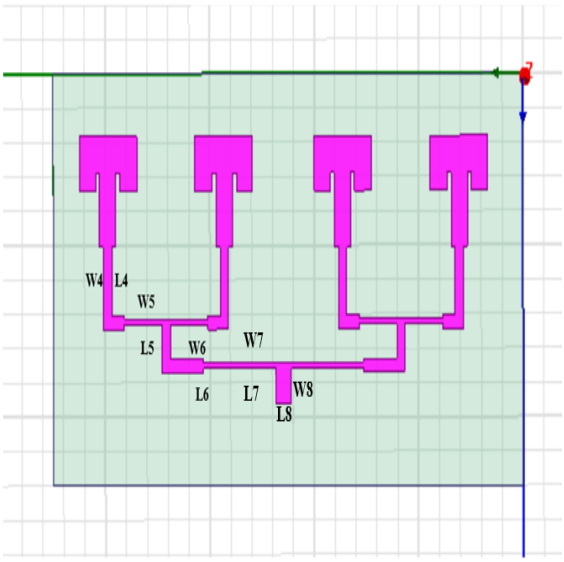


Fig. 3: Four (1×4) element rectangular micro strip patch antenna

3. Simulated Results

The simulation and optimization of proposed designs with An soft designer and HFSS software tool is done. The single element, two elements (1×2) and four elements (1×4) microstrip array antenna with a parallel or corporate feed network are analyzed. The simulated results of Return loss, Gain, Radiation pattern, VSWR and Axial Ratio are compared and shown in figures.

As seen from the figure 5, the simulated return loss of single element patch antenna is -15.77dB, two element (1×2) array as -39.31dB and the four element (1×4) array is -35.77dB and at 20.2GHz.

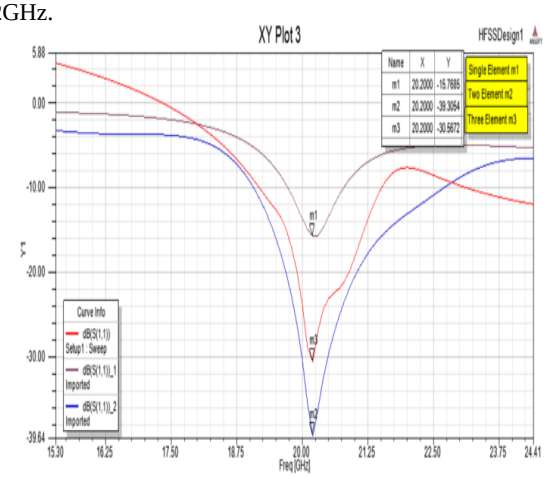


Fig. 5: Return Loss of Single, Two (1×2) and Four (1×4) element rectangular micro strip patch antenna

The gain and directivity of antenna is related to each other, gain shows the efficiency of antenna and directivity represents the directional capabilities of antenna. The gain of the single, 1×2 and 1×4 elements are 5.8dB, 8.7dB and 10.3dB as shown in fig.6 respectively.

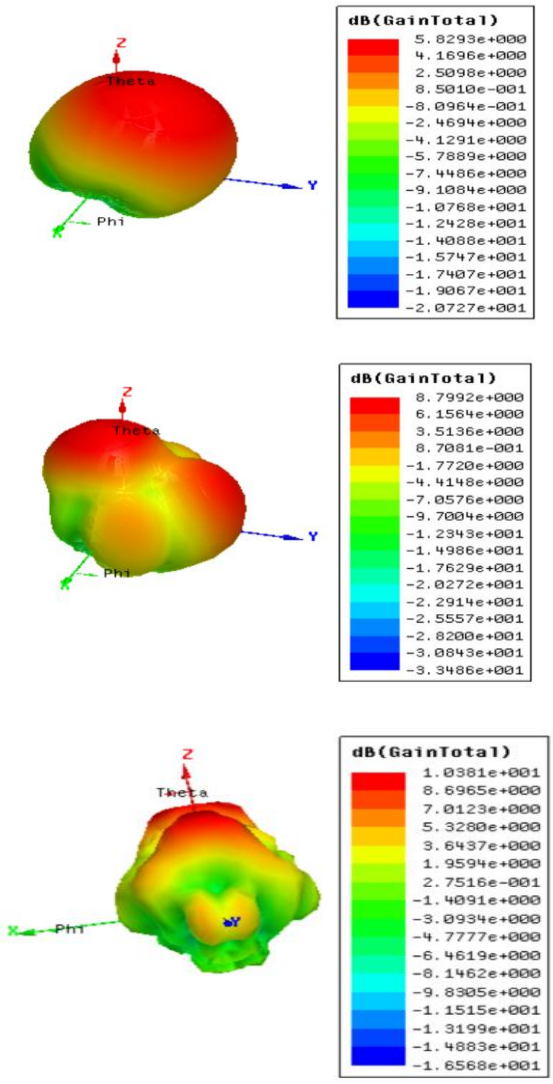
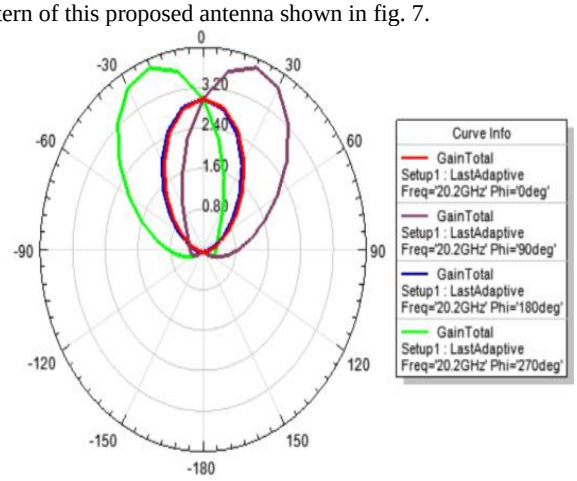


Fig. 6: Gain of Single, Two (1×2) element and Four (1×4) element rectangular micro strip patch antenna.

Radiation pattern represent the property of far field radiation in the form of azimuthal angle(φ) and elevation angle(ɵ). Radiation pattern of this proposed antenna shown in fig. 7.



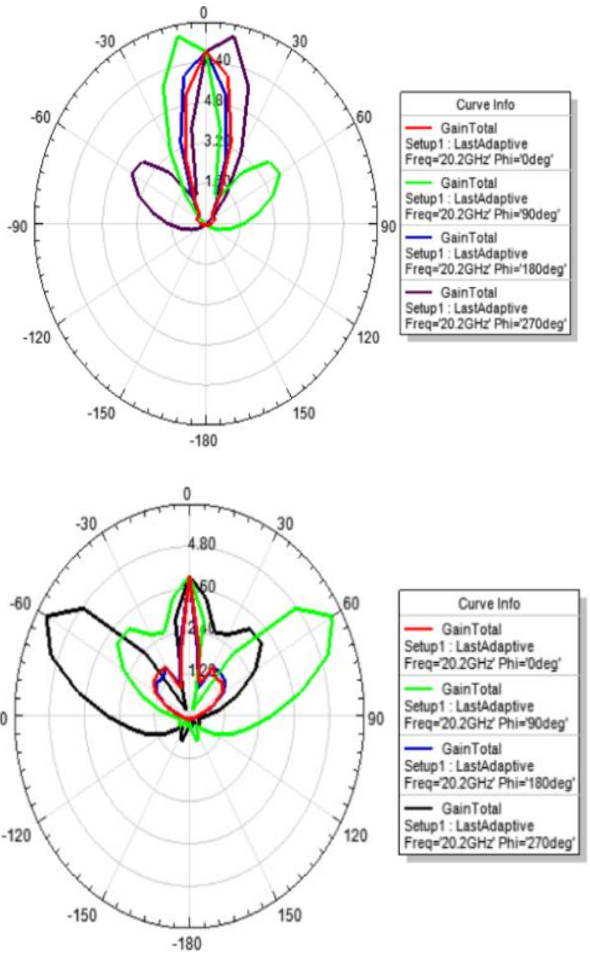


Fig. 7: Radiation Pattern of Single, Two (1 × 2) elements and Four (1×4) element rectangular micro strip patch antenna

At the operating frequency 20.2 GHz the value of VSWR should be less than 2 fig. 8 shows the values of minimum VSWR as 1.81,1.02 and 1.42 respectively for Single, Two (1×2) element and Four (1×4) element rectangular micro strip patch antenna.

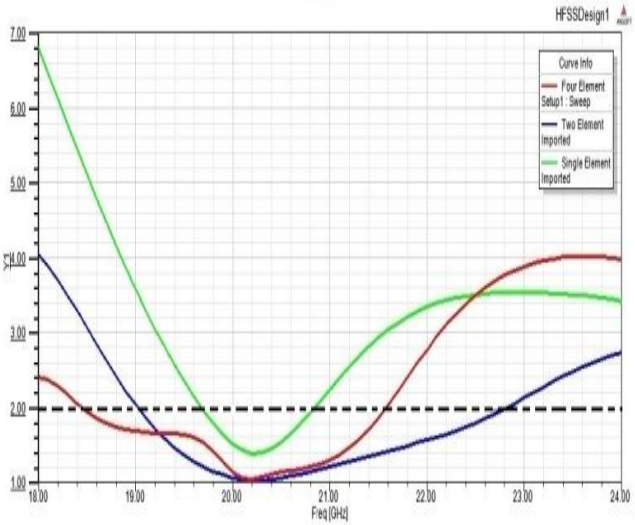


Fig. 8: VSWR of Proposed Antennas

The term Axial Ratio is defined as the ratio of orthogonal components of Electric field. From the fig-9 as the Axial Ratio is infinite but not zero or one, we can say that the polarization is linear.

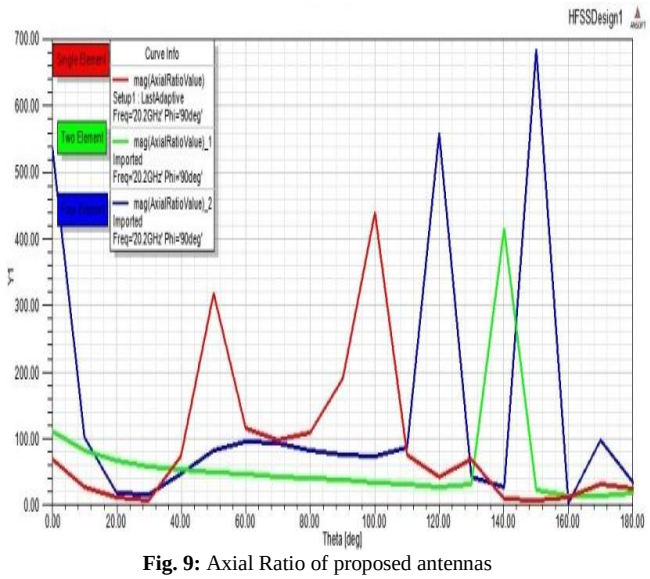


Fig. 9: Axial Ratio of proposed antennas

4. Ccomparison of Results

The table II compares the simulated results

Table 2: Comparison of Simulated Results

Parameters	Single element	Two Element (1×2)	Four Element (1×4)
Physical dimensions(mm)	10×7	24×22	50×30
Return loss(dB)	-15.7	-39.3	-30.5
Gain (dB)	5.8	8.7	10.3
Directivity (dB)	6.4	9.2	11.0
VSWR	1.81	1.02	1.42
Efficiency (%)	99%	98.1%	99.4%

5. Result

Three proposed designs single element, 1×2 and 1×4 element array with inset corporate feed are designed and simulated at a Ka band Beacon frequency 20.2GHz. The designed models are simulated and various parameters like Return loss, Gain, Directivity, Radiation pattern, VSWR and Axial Ratio parameters are plotted. By comparing all parameters, a result comes out i.e. with the increase in antenna elements the enhancement of return loss, gain, directivity and VSWR performance is done.

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