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Mono band Ka Antenna Design for Space Applications

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Abstract

In this paper, a new mono-band flexible antenna design for satellite internet services operating at the Ka-band applications is proposed. It consists of a flexible Roger's substrate with a dielectric constant equal to $\varepsilon r = 2.2$, Loss tangent of $\tan \partial = 0.009$, and thickness h=1.575mm. The all-oversize of the patch on the flexible Ka antenna is $7.75 \times 9.5 \times 0.035$ mm ^{3}. The microstrip line has adapted to 50 Ω and the ground plane was designed with perfect electrical conductor material. Using HFSS software, good simulation results of our proposed antenna were obtained in the terms of bandwidth ranging equal to 1150 MHz and a return loss equal to -17.25 dB at 22.19 GHz.
Keywords: Microstrip antenna, 3D design, flexible substrate, satellite application, Ka band.

1. Introduction

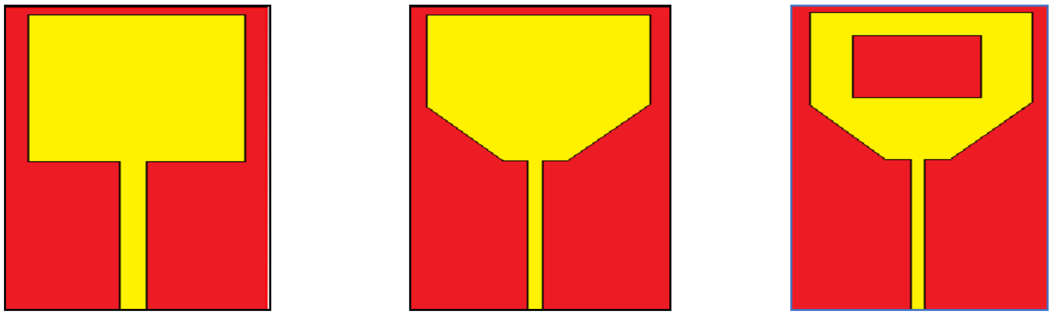
Systems satellite technology has progressed considerably in terms of its capacity, payload, and lifetime. It's developing very quickly meaning, and their applications has continuously improved all the time [1-19]. Currently, many researchers are working on developing the Rf components in the payload of satellites that contains Ku, C, Ka antennas, and repeaters [19-21], and several applications use the Ka band is making it possible to multiply the capacity offered, and to offer services at lower prices than those of the Ku band [21-23]. The Ka-band has been proposed for high-speed satellites, offering satellite internet services at prices comparable to those of ADSL [23-25].

In this context many related works refers to design the miniaturized antenna operating at Ka band. For example, a new approach presents of ultra-wideband MIMO Antenna Realization for Indoor Ka-band Applications was published in 2022 consists of using two port multi-input multi-output (MIMO) antenna is presented for Ka-band 5G communication system. The proposed design is embedded over substrate material Roger RT/duroid 5870 with unit element size of 8 mm × 8 mm ×0.79 mm. Furthermore, various performance parameters of the proposed MIMO antenna were analysed by using EM simulation tool Ansoft HFSS (High Frequency Solution Simulator) [26]. Therefore, Ka band high gain microstrip antenna array with four-element is proposed. In addition, an L-shaped matching branch is used to offer good impedance matching and spatial flexibility for positioning patch elements. Both simulation and measurement results are presented [28].

flexible substrates are attracting increasing interest for many components designs in space applications, such as small antenna, sensors for tracking, robotics and environmental control applications. The flexible substrates are used ever-increasingly important roles in electronic advanced. In this paper, the proposed microstrip antenna design consists of flexible Roger's substrate will reduce the weight of antenna and provide the ability to conform. Moreover, it will open up the possibility of fabricating the antenna with a cost-effective production, the truncated patch graved on the roger's substrate over size is $7.75 \times 9.5 \times 0.035$ mm^3.The dimension of microstrip line has optimized and adapted to (50 Ω).

2. Antenna design

The design of the proposed flexible Ka antenna is presented in three steps. First, the design begins with a basic rectangular flexible microstrip Ka antenna that provides mono-band characters (ANT_1). Then, the corners of the proposed patch (ANT_2) are truncated for adapting the resonance of the antenna at the range of Ka-band. Finally, the (ANT_2) antenna is connected with a new rectangular slot in the middle of a radiating patch and the dimension of the transmission line is optimized in the (Ant_3) prototype. The miniaturization technics are used for small antenna sizes, and then to improve the return loss adaptation at the Ka-band application (from 20 at 30 GHz). The proposed Ka antenna design is given in figure (1).



(ANT$_1$) (ANT$_2$) (ANT$_3$)

Fig. 1. Design procedure of proposed Ka antenna.

3. Theory and calculation

Microstrip antennas consist of a conductive strip, a dielectric substrate, and a conductive ground plane. The underside of the dielectric blade is metallized and constitutes the ground plane. The supply of this type of structure takes place from different ways: by coaxial probe, by microstrip line. The procedure of the design based on the analytics formula for calculating the parameters of the rectangular microstrip patch antenna depending on the dielectric constant (ε_r), resonant frequency f_r, and height of the substrate (h) should be considered for calculating the length and the width of the patch [6].

Width of patch (w):

$$w = \frac{1}{2f_r\sqrt{\varepsilon_0\mu_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

And the length of the antenna becomes

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta l \qquad (2)$$

Where,

$$\Delta l = 0.41\,h\,\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\,\frac{\frac{w}{h}+0.264}{\frac{w}{h}+0.8} \qquad (3)$$

Then;

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+10\frac{h}{w}\right)^{-B} \qquad (4)$$

The dimensions parameters of the proposed Ka antenna are optimized with HFSS software and the miniaturization technical are used to smaller the size of prototype proposed in figure (2).

The proposed antenna is designed using flexible Rogers's substrate, microstrip patch overall size of 9.5 x 7.75 mm^2, it is miniaturized using a rectangular slot in the middle of patch and the corners is truncated, the micro strip transmission line is adapted to 50 Ω band and the ground plane overall size of 20x10x0.035 mm^3.

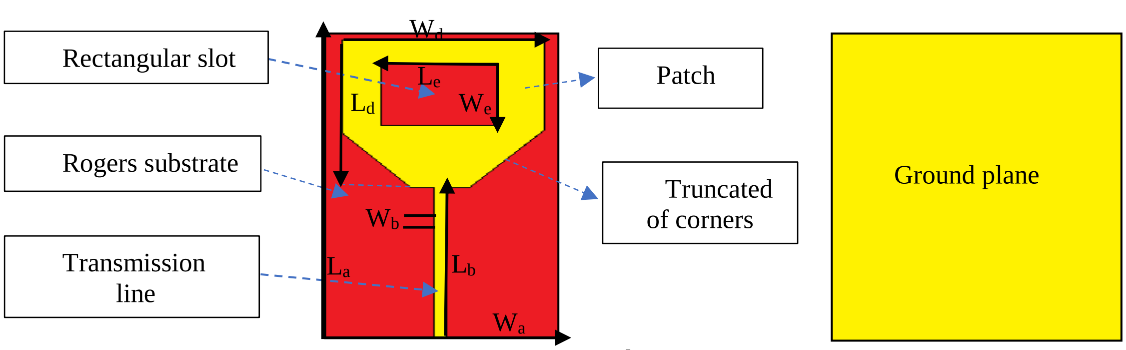


Fig. 2. Geometry proposed Ka antenna.

The parameters of antenna are calculated according to the formulas and optimized with a good software. The antenna dimensions are shown in table 1.

Table 1. Design Parameters of the Proposed Ka Antenna

Dimensions	Unit: mm
L_a	20
W_a	10
L_b	10
W_b	1
L_d	9.5
L_e	4.5
W_e	4
W_d	7.75

4. Simulation and Results

The simulation results are obtained using HFSS software based on finite element method, the simulation results optimise the performance of the proposed antenna in the term of return loss, VSWR, Radiation pattern, and Gain.

4.1 Return loss

Figure (3) presents the return loss of the proposed microstrip antenna operating at 22.19 GHz. The return loss improved is -17.25 dB at 22.19 GHz, the simulated bandwidth (return loss < -10 dB) of the proposed antenna equal to 1150 MHz.

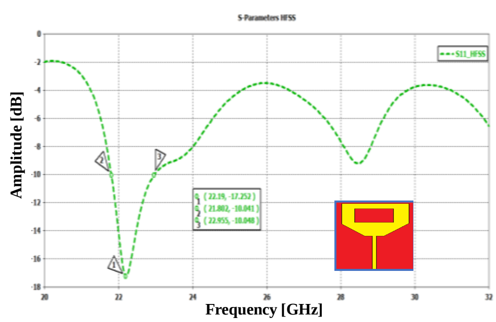


Fig.3. Simulated return loss of the proposed flexible Ka antenna.

4.2. Voltage Standing Wave Ratio (VSWR)

Figure (4) shows the VSWR < 2 for the Ka band (21.77~23.10 GHz) is presented.

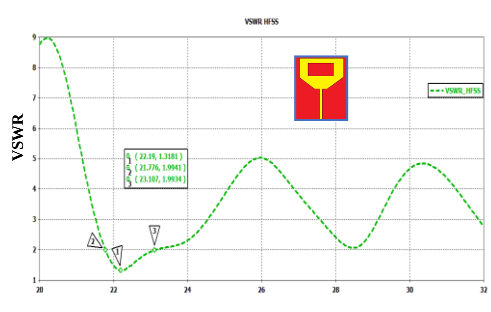


Fig.4. VSWR of the proposed multi-band antenna.

VSWR report indicates a good transmission-line efficiency and reflected energy, and the results obtained is very well established in Ka band are improved and the reflection is very lower.

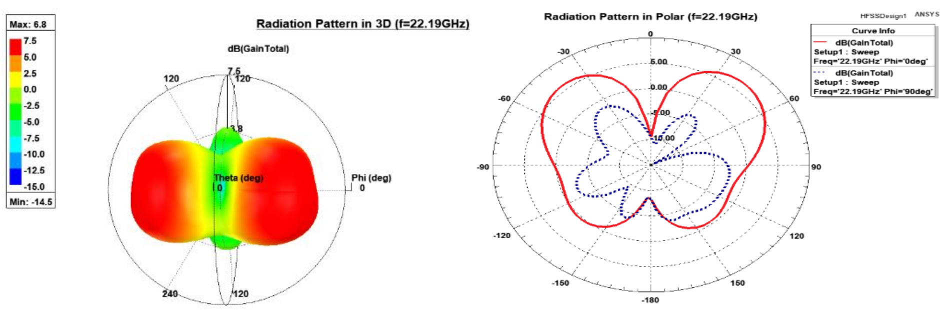
Table 2, shows the simulation results of VSWR in desired frequency range from [21.77 to 23.10GHz].

Table 2. VSWR vs variation of the desired frequency range from [21.77 to 23.10GHz].

Frequency	VSWR
22.19	1.31
21.77	1.99
23.10	1.993

4.3. Radiation pattern

The 3D radiation pattern presents a high gain obtained with one element is equal to 6.8 dBi at 22.19 GHz.The 2D radiation pattern in E and H plane is presented in figure (5). The gain concentrated in (xy) plane witch the pattern is omni-directional at 22.19 GHz, and a good characteristic of the main lobe magnitude is recorded from 22.19 GHz the desired frequency range.



(a) (b)

f=22.19 GHz.

Fig. 5. Simulated radiation pattern (in dB) at 22.19 GHz.

4.4. Gain

Antenna gain is the passive amplifying power of an antenna. It is the ratio between the power radiated in the main lobe and the power radiated by a reference. The gain of an antenna depends mainly on its effective area, its directivity and the frequency. Furthermore, Figure (6) depicts the variation of the antenna gain as a function of the frequency, the gain value is equal to 6.8 dB for 22.19 GHz, and the gain reached the maximum value of 8.5 dBi in the range of Ka band.

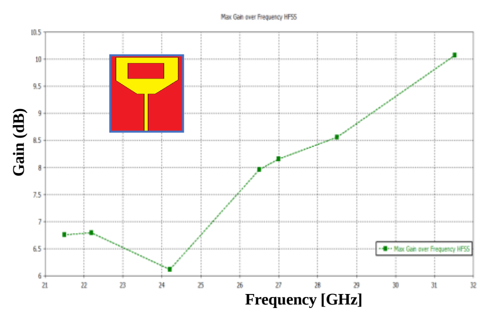


Fig. 6. Simulated gain of the proposed antenna.

5.Performance comparison with previous published literature

The proposed microstrip antenna has a good size, acceptable return loss, high gain compared with some other recent published Ka Mimo antennas presented in table 3.

Table 3. Performance comparison of our proposed Ka antenna with some other recent published antennas.

Ref.	Size(mm)	Gain(dBi)	Return loss [dB]	Frequency band
[26]	16 x 16	6.5	-15 to -20	Ka
[27]	30 × 28	6.22	-18	Ka
OUR WORK	10 x20	6.8	-17.25	Ka

From the table 3 we concluded that, a good simulation results were obtained by the finite element method relative to the return loss (S11) is equal to -17.25 dB, 1150 MHz acceptable bandwidth and 6.8 dBi for 22.19 GHz.

6. Conclusions

In this paper, a small size microstrip antenna design is proposed for satellite internet application operating at 22.19 GHz. The simulated results of the proposed microstrip antenna were obtained by the finite element method using HFSS software. The characteristics of antenna presents a good adaptation of return loss, omnidirectional radiation pattern and a positive gain. Based on the above findings, the proposed antenna can be suggested to create a new array antenna design with a new relatively Rogers material.

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