Design of directional planar antennas with circular polarizations for space applications

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Abstract

In this project, we propose a new patch antenna structure to establish an uplink with geostationary satellites operating in Ka band. The goal is to design this type of more directive antennas that work for this kind of applications while ensuring very high gain and good directivity with an acceptable reflection coefficient.

Keywords and phrases: Planar antenna, patch, circular polarization, high frequency 28GHz, Ka band, S-parameters, radiation pattern, CST WMS.

1 Introduction

The phased array antennas have, in recent years, been the subject of several researches, particularly in the field of applications such as satellite communication, which has enabled the discovery of many advantages of this type of antenna such as its beam capacity. Microstrip antennas [1] are widely used in array antennas due to their low cost and weight. They can also be easily printed on a dielectric substrate with photolithography techniques.[2]

The democratization of terrestrial satellite reception systems [3],[4] has also led to the proliferation of reception systems on the ground which have clearly contributed to the visual pollution caused particularly by antennas placed on roofs or in gardens and in balconies of buildings [5]. Beyond cost control, the notion of discretion and therefore integration into the urban landscape is becoming more and more essential. In recent years, the discretion criterion has taken on an importance rivaling the cost criterion in the direction of avoiding any public nuisance and to do this, new antenna solutions [6] with low visual impact have gradually emerged in recent years. This work is part of the research on miniature sub-array antennas. Our goal is to design and simulate a small array of antennas working in the ka frequency band at the 28Ghz resonant frequency for a space application. To do this, we rely on antenna theory to determine the geometric parameters of our proposed antenna using the CST MWS software as a simulation tool.

2 Characteristics and dimensions of the patch antenna

The different characteristics of the patch antenna are given by:

- Rectangular patch.
- Substrate: FR4 Lossy ($h = 1.6mm$, $\varepsilon r = 4.3$) with dielectric loss tangent, tan $\delta = 0.025$
- Resonance frequency: $fr = 28GHz$ (27.50GHz to 31GHz: band ka rising frequency).

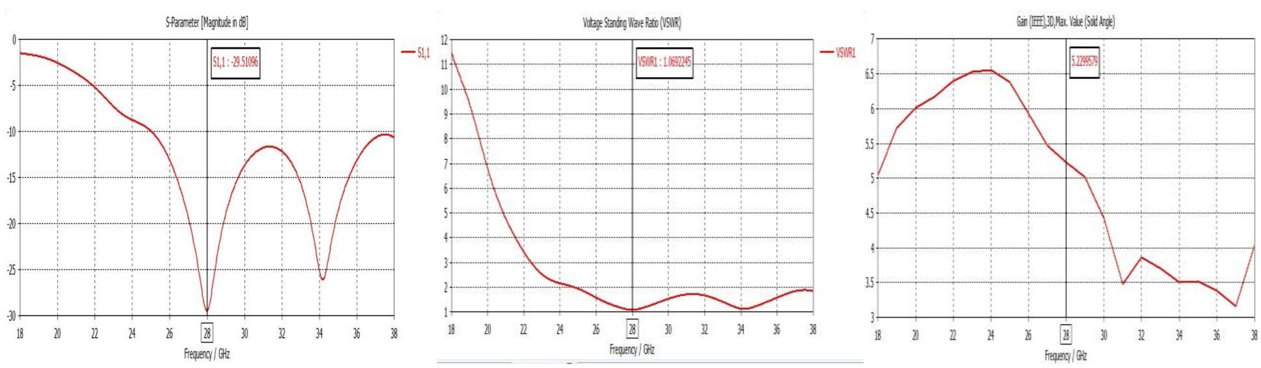
Table 1 gives the dimensions of the patch antenna studied, (Sub: Substrate and PM: ground plane).

Table 1: Dimensions of the patch antenna.

Parameters	Description	Values (mm)
L	Longueur Sub et PM	11.29
W	Largeur Sub et PM	12.89
Hp	Epaisseur PM et patch	0.035
Lp	Longueur Patch	1.638
Wp	Largeur Patch	3.29
Hs	Epaisseur Sub	1.6
Lf	Longueur deligne	2.84
Wf	Largeur de ligne	1

3 Design and simulation of the patch antenna

Figure 3. ((a), (b), (c)), respectively represent the reflection coefficient, the standing wave ratio SWR and the gain of the initial antenna.

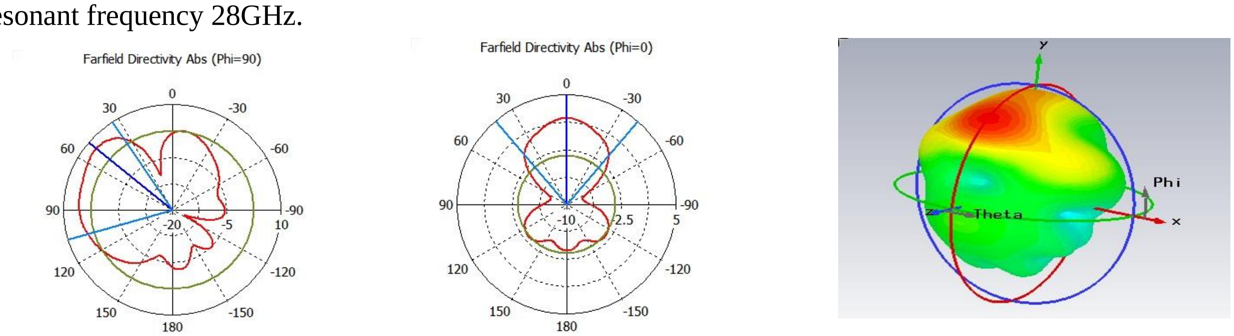


(a) (b) (c)

Figure 3: (a): Reflection coefficient. (b): Standing wave rate TOS. (c): Antenna gain.

A good adaptation is observed, since the reflection coefficient S11 is -29.51dB at the resonant frequency 28 GHz, with a maximum bandwidth of 1.795GHz (figure3.a). The standing wave ratio SWR <2 (figure3.b). The gain obtained from the antenna is 5.22dB at 28GHz.

Figures 4. ((a), (b), (c)) represent respectively the 2D and 3D polar radiation patterns of the antenna at the resonant frequency 28GHz.



(a) (b) (c)

Figure 4 : (a) : 2D radiation pattern, plane H. (b) : 2D radiation pattern, E plane (c) : 3D radiation pattern**.**

We notice that the antenna presents an almost quasi-directional radiation in the plane E (φ= 0 °) and in the plane H (φ = 90 °), the latter are verified by the tracing of the radiation diagram in 3D.

4 Structure of a new design of the patch antenna

The proposed antenna structure as shown in figure 5, presents a star inserted in the middle of the triangular patch (an equilateral triangle), its three sides have the same length a = 1.305 mm, its three internal angles are 60 degrees, knowing that all the other parameters are the same as the initial antenna.

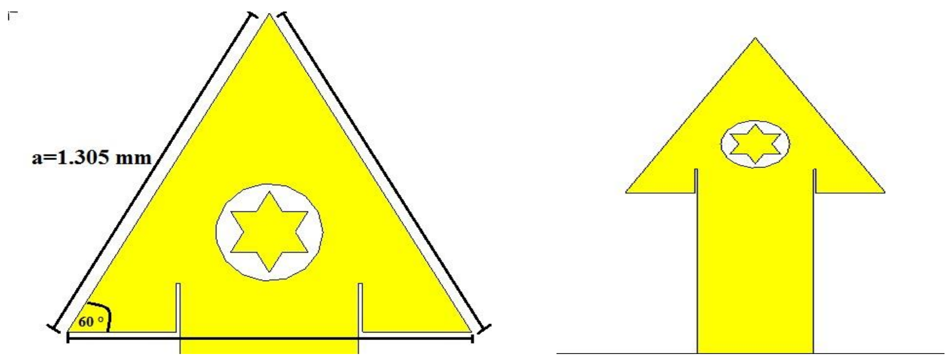


Figure 5: Geometry of triangular antenna.

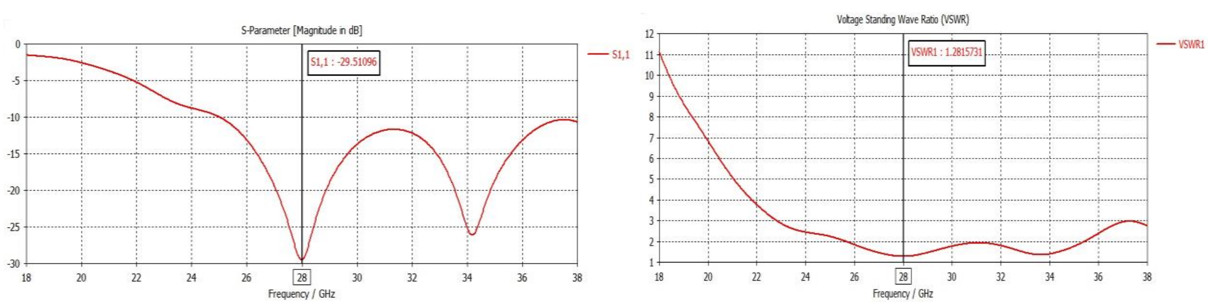


Figure 6: (a). Variation of coefficient S11 (dB) and (b): VSWR as a function of frequency (GHz).

The antenna has a maximum bandwidth of 5.246GHz with an S11 equal to -30dB at the resonant frequency (28GHz) in the interval (31.057-25.811) GHz, shown in (Figure 6.a). The standing wave ratio SWR <2 in the same bandwidth which gives a good adaptation of the patch antenna to the desired frequency as shown in (figure 6.b).

Figures 7 and 8 show the radiation pattern in 2D and 3D polar presentations, respectively. We notice that the antenna has directional radiation.

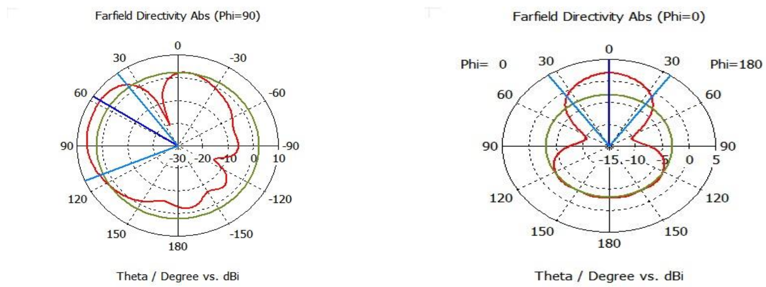


Figure 7: Radiation diagram in polar presentation phi = 0 and phi = 90.

The radiation pattern is concentrated in the upper part of the antenna (between the Y and Z plane), the gain value is 4.606dB and the maximum directivity is 6.562dB.

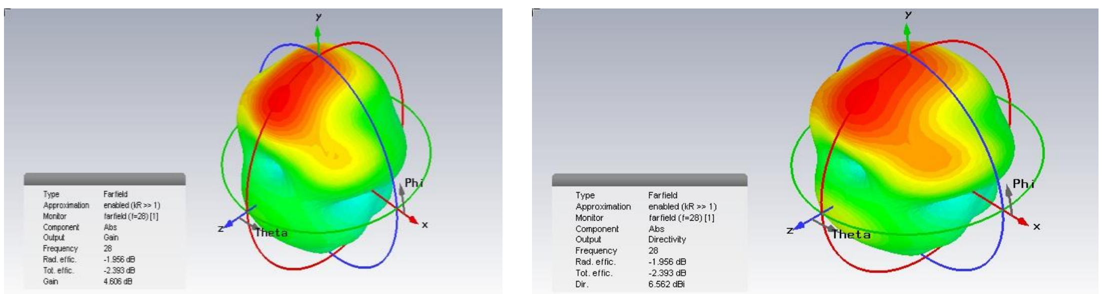


Figure 8: Patch antenna gain radiation and patch antenna directivity diagram.

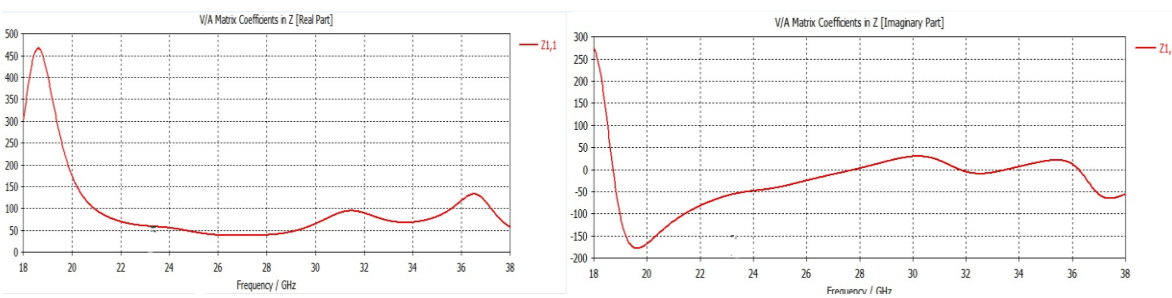


Figure 9: Antenna input impedance (real part) on the left, (imaginary part) on the right.

The efficiency of this antenna is given by the relation: $\boldsymbol{\varepsilon_R} = \frac{G}{D} = \frac{4.606}{6.562} = 0.701 = 70\%.$

Table 2 shows the patch antenna parameters with a single element.

PARAMETRES	VALEURS
Return losses (S_{11})	$S_{11mín}$ = -18.17dB
Directivity	D = 6.562 dB
Gain	G = 4.606 dB
Radiation efficiency (ηrad)	ηrad = -1.956 dB

Total efficiency (ηT)	ηT = -2.393dB
Passe Band (BW)	BW = 5.246 GHz et S11 = -10 dB
Beam width (AW)	AW = 71.3°

Table 2: Basic parameters of the patch antenna at the 28GHz frequency.

6 Antenna arrays with 2 elements at the resonant frequency 28GHz

In our work, we choose the power divider as a T junction, because it is easy to model and compatible with the structure of 2 element antenna arrays as shown in figure 10.

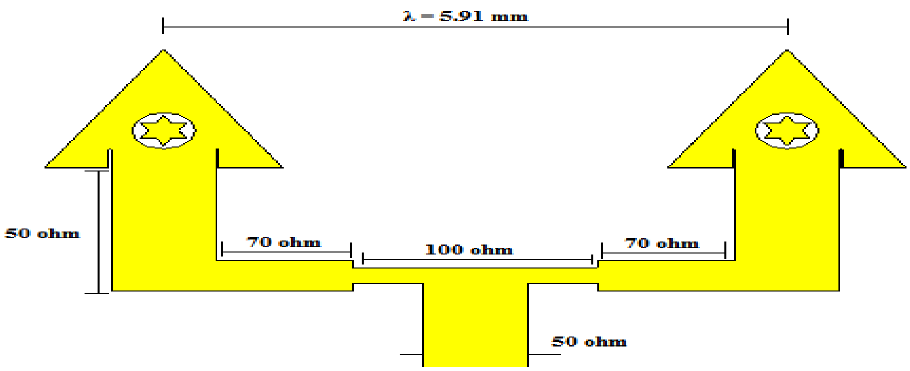


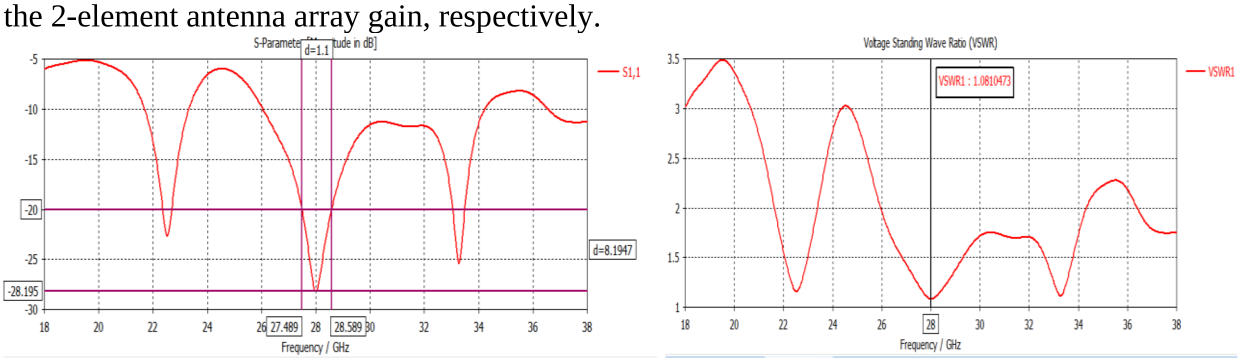
Figure 10: Network of antennas with 2 elements.

Table (3.3) shows the parameters of the T junction and their values.

Parameters	Larger (mm)	length (mm)
50 Ohm	1	2.84
70 Ohm	0.5	1.30
100 Ohm	0.255	2.31

Table 3: Parameters of the T junction.

Figure 14 ((a) and (b)) and (c)) shows the reflection coefficient, the standing wave ratio SWR and the 2-element antenna array gain, respectively.



(a) **(b)**

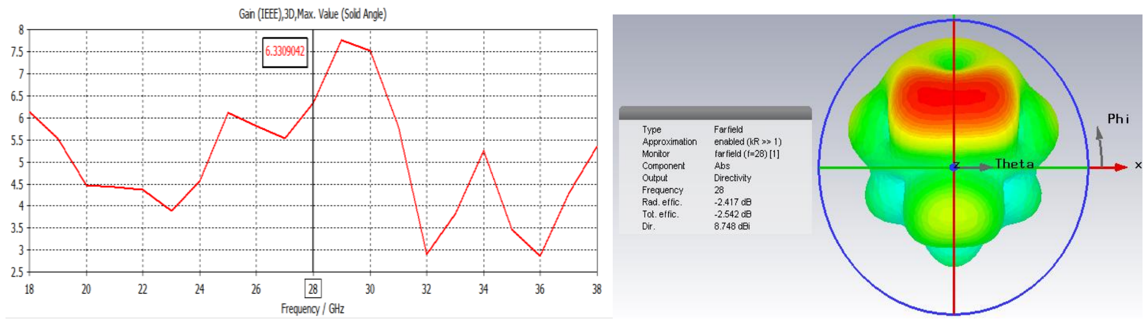


Figure 11: (a): Reflection coefficient. (b): Standing wave rate. (c): Gain. (d): Directivity radiation pattern. (2-element network).

Figure (11.a) shows a good match with a reflection coefficient S11 = -28.19dB at the resonant frequency 28GHz, with a bandwidth of 1.1GHz. We noted a TOS <2 (figure 19.b). The gain of the antenna obtained is 6.33dB (figure 19.b). The radiation pattern is concentrated in the upper part of the antenna (between the Y and Z plane), the maximum value of the directivity is 8.748dB (figure 19.d). Table (3.3) shows the parameters of the two-element antenna network.

Parameters	Values
Return loss (S11)	S11mín = -28.19 dB
Directivity	D = 8.748 dB
Gain	G = 6.33 dB
Radiation efficiency (ηrad)	ηrad = -2.417dB
Total Efficacity (ηT)	ηT = -2.542 dB
Passe Band (BW)	BW = 1100 MHz à S11 = -20 dB
Beam width (AW)	AW = 28.1°

Table 3: Basic parameters of a 2-element antenna network.

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