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A Compact Dual Band Elliptical Microstrip Antenna for Ku/K Band Satellite Applications

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ABSTRACT

This paper presents an original elliptical microstrip patch antenna is proposed for Ku/K band satellite applications. The proposed antenna has a simple structure, small size with dimensions of about 10×12×1.58 mm^3. The antenna has been designed and simulated on an FR4 substrate with dielectric constant 4.4 and thickness of 1.58 mm. The design is simulated by two different electromagnetic solvers. The results from the measured data show that the antenna has two resonant frequencies that define 2 bandwidths, defined by a return loss of less than -10 dB, and are: (14.44 GHz, 829 MHz) and (21.05 GHz, 5126 MHz),with the gain 5.59 dB and 5.048 dB respectively. The proposed antenna can be used in many applications such as in satellite, and wireless communications.

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1. INTRODUCTION

The satellite communications are in perpetual evolution, the antennas are the essential components in the chain of emission/reception of this field, and the dynamics of this development requires a smaller size, less weight, low profile, performance and ease of installation, to ensure the reliability and the mobility of the antenna. Therefore the antenna must answer the constraints of the multiplication of the integration and frequency bands in the architecture of the terminals [1]-[4].

During modern day sophisticated communication systems operate at multiple frequencies at the same time and these results in having multiple antennas for different operating frequency on the same chip. This creates a space limiting problem and increases the device size, which invariably results in increased manufacturing cost. To overcome this problem, we use a multiband antenna where the same antenna can be used to operate at multiple frequencies [4], [5]. In a dual-band patch antenna, the same antenna operates at two different resonant frequencies and thus reduces the size of the antenna [6]-[9].

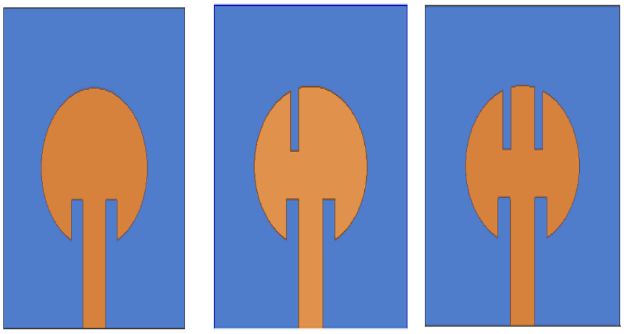
The microstrip antenna is one of the ideal choices for wireless/satellite communication to accommodate dual frequency bands [10], [11], consists of conducting patch, dielectric substrate and ground plane. The patch has different geometric shapes such as rectangular, square, dipole, triangular, circular, elliptical or possible shape. Furthermore, it constructs from conductive material such as copper or gold, the substrate dielectric constant ϵ_r is generally in the range $2.2 \leq \epsilon_r \leq 12$ and the height h usually in the range $0.003\lambda_0 \leq h \leq 0.05\lambda_0$, where λ_0 is the free space wavelength $\lambda_0 = 0.125$ [10]-[13].

In this paper, a new Dual Band Elliptical Microstrip Patch Antenna which can be integrated in the Satellite Communication devices for wireless communications based on Ku and K band. The antenna design and simulation was performed using two different electromagnetic solvers. The first solver is based on the finite element method (FEM) for solving electromagnetic structures and the second on the finite integration technique (FIT), to compare the results of the proposed antenna.

When compared with other microstrip dual band antenna our antenna possesses the advantage of not only having a broad bandwidth, high gain but also a smaller size [5]-[9].

2. ANTENNA DESIGN

The elliptical patch antenna proposed is applied on the dielectric material FR4 substrate with a thickness h=1.58 mm, relative permittivity $\epsilon_r = 4.4$ and Tangent loss $\delta = 0.02$. Initially an elliptical patch antenna is considered with inset-feed and the different design stage is shown in Figure 1.



Figures 1. Design stages of proposed antenna

The final geometry of the proposed antenna is shown in Figure 2, consists of two rectangular slots in the radiation patch that plays a significant role in determining the resonating frequency because they can control the electromagnetic coupling effects between the patch and the ground plane.

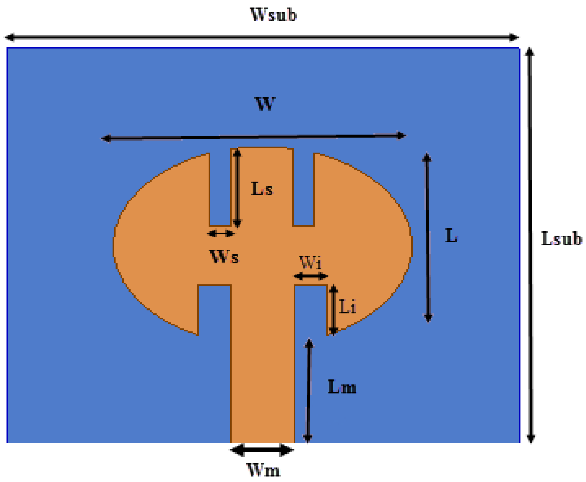


Figure 2. Geometry of the proposed antenna

The parameters calculated and optimized of the proposed antenna for 14 GHz operating frequency are shown in Table 1.

Table 1. Design Parameters of the Proposed Antenna

Parameter	Description	Values (mm)
W	Width of Patch	7
L	Length of Patch	5
Wsub	Width of Substrate	12
Lsub	Length of Substrate	10
h	Height of Substrate	1.58
Wm	Microstrip Feed Width	1.5
Lm	Microstrip Feed Length	4
Wi	Inset Width	0.75
Li	Inset Length	1.5
Ws	Width of therectangular slot	0.5
Ls	Length of the rectangular slot	2

3. SIMULATION RESULTS AND DISCUSSION

The proposed antenna is designed and simulated using an electromagnetic solver based on the finite element method (FEM) and another solver based on the finite integration technique (FIT), to compare the results of the proposed antenna. In this design, we simulate and measure many parameters, because the S Parameter (S_{11}), antenna gain, bandwidth, VSWR, and Radiation Pattern need to be evaluated at different resonant frequencies before one can conclude the proposed antennas to be practical. The frequency range is from 10 GHz to 25 GHz.

From the S Parameter of the proposed antenna with the finite element method (FEM) solver as in Figure 3, it is seen that the return loss of less than -10 dB occurs at two different resonant frequencies, the first occurring at 14.44 GHz, the second at 21.005 GHz. The bandwidth of this antenna at the first resonant frequency is 829 MHz where it can operate as an Ku-band antenna. And at the second resonant frequency is 5126 MHz where it can be used as an K-band antenna for satellite applications.

Figure 4 presents the reflection coefficient S_{11} of this antenna with an electromagnetics solvers based on the finite integration technique (FIT).

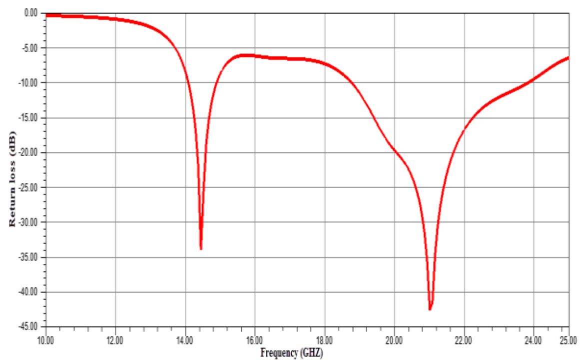


Figure 3. The proposed antenna return loss in dB

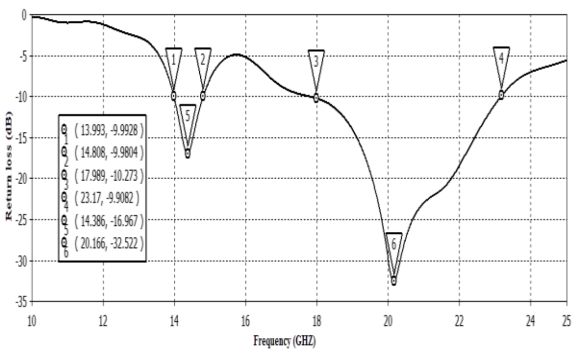


Figure 4. The proposed antenna return loss in dB with FIT solver

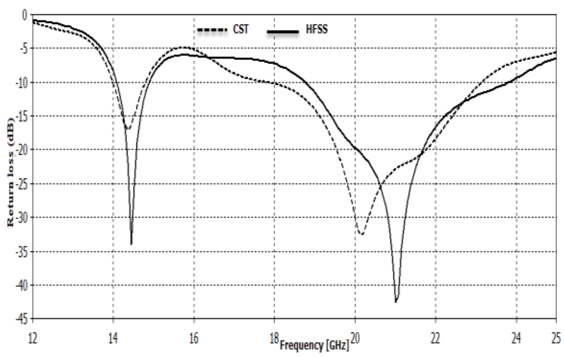


Figure 5. Comparison between the S parameter measured of the proposed antenna

The comparison between the S parameter measured with two electromagnetic solvers is shown in Figure 5. This comparison shows that we have almost the same frequency bands, with the high frequency resonance is slightly shifted.

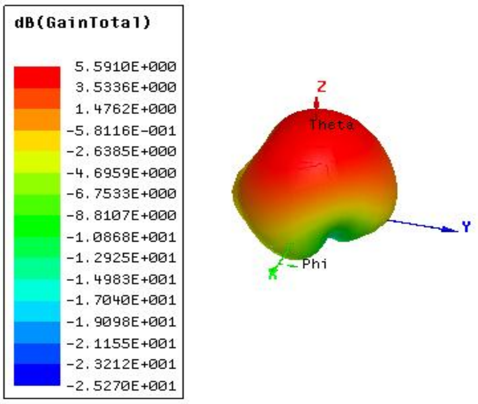


Figure 6. Gain at a resonant frequency of 14.44 GHz

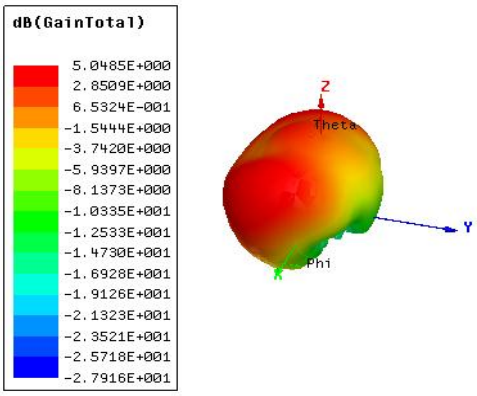


Figure 7. Gain at a resonant frequency of 21.005 GHz

From Figure 6 and Figure 7, the antenna gain at the first resonant frequency is 5.59 dB while that at second resonant frequency is 5.048 dB.

The gains at all the resonant frequency were found to be acceptable and stable, and they can be used as a receiving antenna for satellite application.

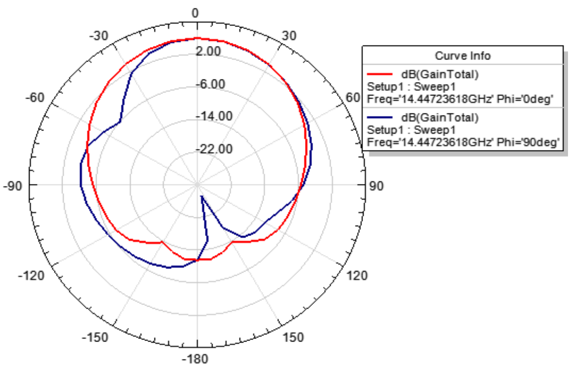


Figure 8. E-Plane and H-Plane Radiation patterns at a resonant frequency of 14.44 GHz

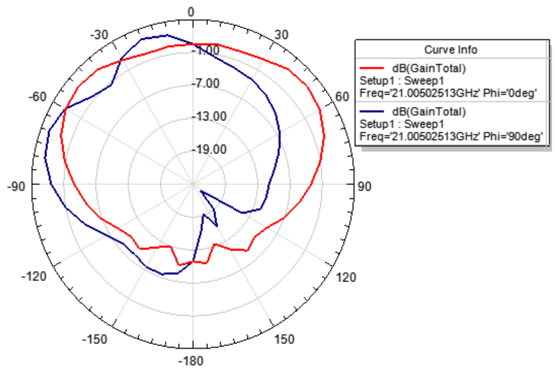


Figure 9. E-Plane and H-Plane Radiation patterns at a resonant frequency of 21.005 GHz

The proposed antenna radiation patterns (E-Plane and H-Plane) at different resonant frequencies are shown in the Figure 8 and Figure 9 The corresponding radiation efficiencies are practically acceptable and the antenna is nearly omnidirectional. From this it is observed that the antenna is well appropriate for the wireless communication applications.

The gain has certain stability over the operating frequency bands, and has a maximum value of 7.4 dB at 18.89 GHz. The gain is relatively good, but for really reaching the applications asked, it can be improved while inserting the antenna in an array.

The Voltage Standing Wave Ratio (VSWR) is used to measure the mismatch between feeding system and antenna. Mismatch will be high if VSWR will be high. Minimum value of VSWR could be unity and it shows the perfect match. For practical application, value of VSWR should be in between 1 and 2.

From Figure 11, the VSWR of the proposed antenna at the resonant frequencies 14.44 GHz and 20.005 GHz is 1.31 and 1.03 respectively which represents that a good impedance matching is achieved.

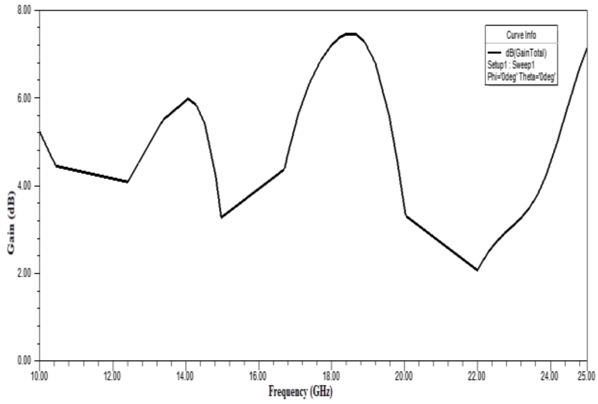


Figure 10. Gain of the antenna at different frequencies

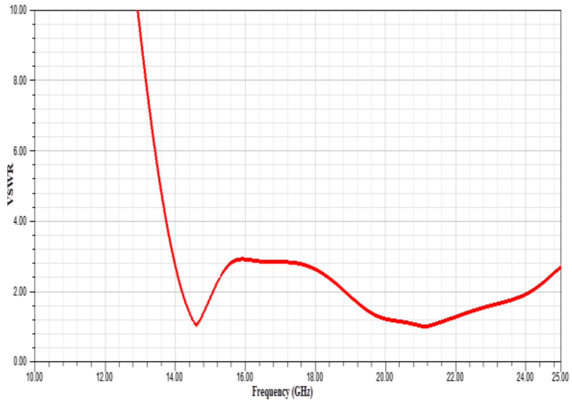


Figure 11. VSWR of the proposed antenna

Table 2. Characteristics of the Proposed Antenna

Solvers Method	Resonant Frequency (GHz)	Return Loss (dB)	VSWR	Bandwidth (MHz)	Bandwidth Percentage (%)
FEM	14.44	-33.98	1.31	829.1	5.74
	21.005	-42.59	1.03	5126	25.56
FIT	14.386	-16.967	1.33	815	5.67
	20.166	-32.522	1.04	5181	25.69

The proposed antenna has an ultrawide band effect on the second band (high frequency) with a bandwidth percentage of 25% and a bandwidth of 5.126 GHz. Table 2 show the characteristics of the proposed antenna.

Table 3. Comparison Between the Proposed Antenna and other Dual Band Antenna

Ref.	Substrat (ε_r)	Antenna Area(mm^2)	Resonant Frequency (GHz)	Bandwidth (GHz)	Gain (dB)
[6]	10.0	17x17	12.94	2.38	3.1
			19.04	1.56	4.13
[7]	10.2	8.5x7.96	13.62	0.576	3.53
			16.33	0.54	5.56
[8]	2.2	9x7.96	12.54	0.09	5
			14.15	0.06	4.6
[9]	4.6	20x15	15.15	1.9	5.9
			18.2	1.5	3.37
This Work	4.4	10x12	14.44	0.829	5.59
			21.005	5.126	5.048

The performance comparison between the proposed antenna and some of the presented antennas are shown in Table 3. Reviewing the optimized parameters, the proposed antenna offer much wider bandwidth with adequate gain and small size compared to reported antennas.

4. CONCLUSION

A compact dual band elliptical patch antenna is presented in this paper. This antenna has a simple structure and compact size of 10×12×1.58 mm^3, on FR4 substrate, which easy to be combined in small devices. The design and analysis of the characteristics of the proposed antenna have been through and verified by using two different electromagnetics solvers. Result show that the frequency bandwidth covers Ku-band (14.07-14.89) GHz and k-band (18.74-23.74) GHz at 14.44 GHz and 21.005 GHz witch return loss of -33.98 dB and -42.59 dB respectively.

The antenna characteristics from the simulated data show that the proposed dual-band elliptical antenna can be a promising candidate to cater many services required for Ku /K band satellite applications.

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Mohamed Mahfoudh Harane was born on June 22, 1991 in Rosso (Mauritania). After a bachelor's degree in mathematics in 2011, he gets a scholarship to complete his higher education in Algeria. He received the B.S. degrees from the Faculty of Science and Technology at Ferhat Abbas University Setif-1, Algeria, in 2014 and a Master's Degree in Science and Technology at Ferhat Abbas University Setif-1 (Algeria), Specialty: Network and telecommunication system, in July 2011. January 2017, PhD student in Smart Communications Research Team at Engineering 3S Research Center, Mohammadia School of Engineering, Mohammed V University in Rabat (Morocco).His research interests include RF/microwave techniques, antenna design, microstrip antennas for satellite communications, for wireless and telecommunication applications, miniaturization techniques and analysis of antenna with equivalent circuits.

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