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Optimizing the Size of A Multi-Layered Patch Antenna for K-Band Applications

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Abstract**—***In this work, the size of the antenna has been optimized by introducing an air-filled cavity into the lower substrate of the antenna with two layers. Analysis and modeling were performed using the HFSS (High Frequency Structure Simulator) simulator based on the finite element method. The simulation results obtained for the reflection coefficient, bandwidth, and gain were compared with those published. This comparison showed a good satisfaction*

Keywords**— *Multilayer patch antenna, K band, air-filled cavity, S11, gain, bandwidth, HFSS*.**

I. INTRODUCTION

Microstrip antennas play a very important role in the development of wireless communication technologies. Indeed, these patch antennas, despite their relatively narrow bandwidth[1], are among the devices that most respond to the miniaturization requirements imposed by new telecommunication devices. Compatible with Monolithic Microwave Integrated Circuit (MMIC) designs, such as Cell phones[2], [3]

The simplest typical structure of a patch antenna consists of a radiating element printed on a dielectric substrate disposed on a ground plane[4].

At present, satellite communication in the K-band is of major interest for the development of telecommunication systems such as satellite television channels [5],because this band has a large number of unused bandwidth [2]

One of the effective techniques for the miniaturization of this type of antenna is the use of a dielectric substrate having a high dielectric constant [6].Indeed, the ceramic materials provide adequate dielectric permittivity; in addition they possess very useful physical properties [7] [8].Several works have been published to increase the bandwidth[9], [10], but they have a relatively large antenna size[11] however we find other works that proposed a miniaturized size but with A very narrow bandwidth[12].

This work presents a miniaturized antenna with a wider bandwidth by using a second layer of the dielectric substrate while introducing an air-filled cavity into the lower substrate of the microstrip antenna.

II. PRESENTATION OF THE MICROSTRIP ANTENNA

fig. 1 shows the diagram of a microstrip antenna formed by a radiating structure (patch), two dielectric substrates of the same electrical permittivity separated by a rectangular probe and a ground plane.

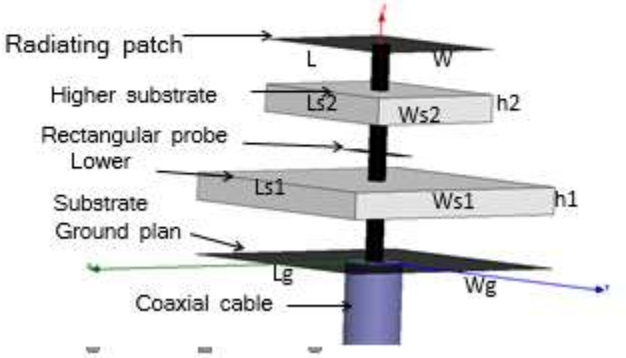

Fig.1: Structure of the studied antenna.

The microstrip antenna is fed by a coaxial cable to ensure the excitation of the probe in order to have an almost omnidirectional radiation pattern. The introduction of a second dietetic substrate increases the performance of the microstrip antenna, namely the bandwidth and the gain [7]

III. RESULTS AND DISCUSSIONS

a. Without air-filled cavity

Using the following parameters: L = 10mmn, W = 8mm, h1 = 1.5mm and ε_r = 9.8 given by[2], and after a certain number of simulations with the HFSS software concerning the physical parameters of the microstrip antenna, The appropriate values are described in the following table

Table.1: Physical Parameters of the Microstrip Antenna

paramètre	description	Valeur (mm)
L	Length of the patch	8
W	Width of the patch	10
Lg	Length of the ground plane	14
Wg	Width of the ground plane	14
Ls1	Length of the first layer	14
Ws1	Width of the first layer	14
h1	Thickness of the first layer	1.5

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Ls2	Length of the second layer	8
Ws2	Length of the second layer	10
h2	Thickness of the second layer	1.5

In fig. 2, the simulation result obtained for the reflection coefficient is presented. This curve shows that the microstrip antenna resonates at a frequency of 20 GHz antenna with a coefficient of reflection equal to -32.5 dB and a bandwidth of 0.2 GHz. The results obtained are unsatisfactory in particular the bandwidth which is relatively narrow compared with the results given in references [2],[13] .

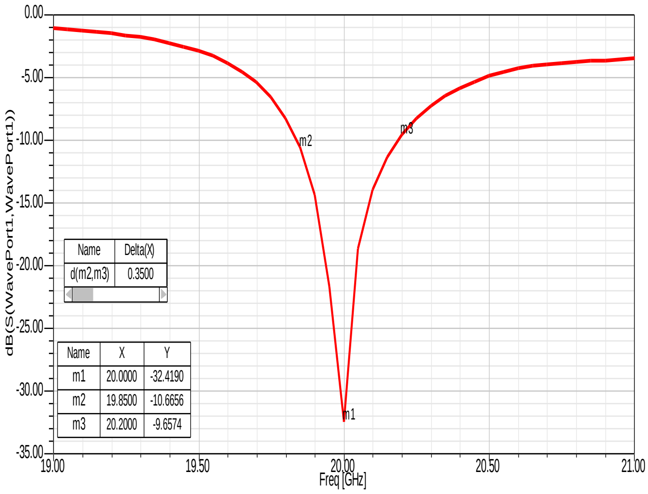

Fig.2: Reflection coefficient as a function of the frequency of the antenna without air-filled cavity forL=8 mm, W=10 mm andεr=9.8 [2]

b. Insertion of anair-filled cavity

To remedy this problem due to the excitation of the surface waves and the bad adaptation between the coaxial cable and the patch [14], we chose to introduce an air-filled cavity at the lower substrate [15] (Figure 3), which will reduce the effect of the dielectric permittivity on the bandwidth and increase considerably the gain of the antenna.

The dimensions of the air-filled cavity with (3x3x1.5mm3) are obtained, after a certain number of tests, equal to those of the radial connector SMA.

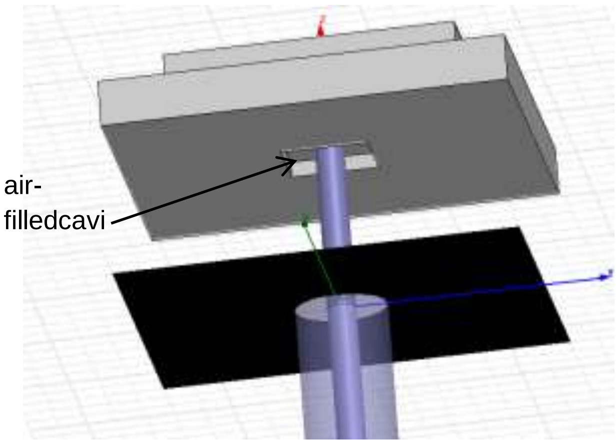

Fig.3: antenna in two layers after the insertion of an air-filled cavity in the lower substrate

Figs. 4a and 4b illustrate the distribution of the surface current at the patch of the antenna without air-filled cavity (Fig. a) and with air-filled cavity (Fig. b). These graphs show that the density of the current is greater in the second configuration at the center of the patch, which allows a greater radiation

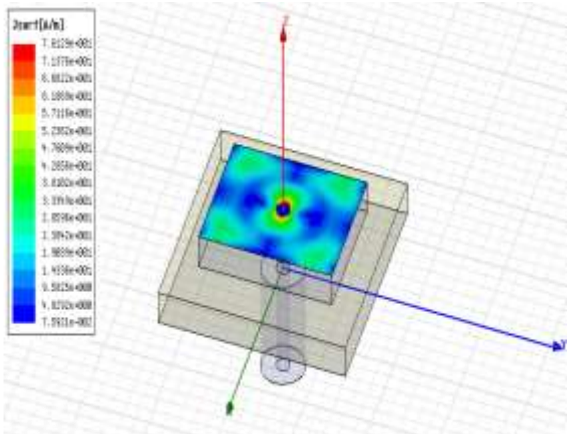

Fig. 4a : without air-filled cavity

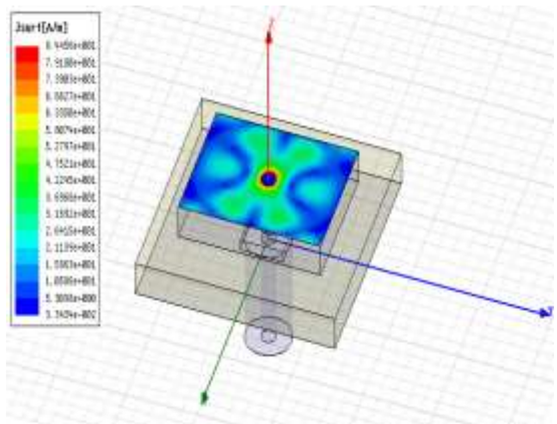

Fig. 4b : with air-filled cavity

Fig.4: Illustrates the distribution of the surface current at the patch of the antenna without cavity FIG. A and with cavity Fig. B for L = 8 mm, W = 10 mm and εr = 9.8

Figs. 5 and 6 show the results obtained of the reflection coefficient S_{11} of the microstrip antenna in the K band for the two configurations of the antenna.

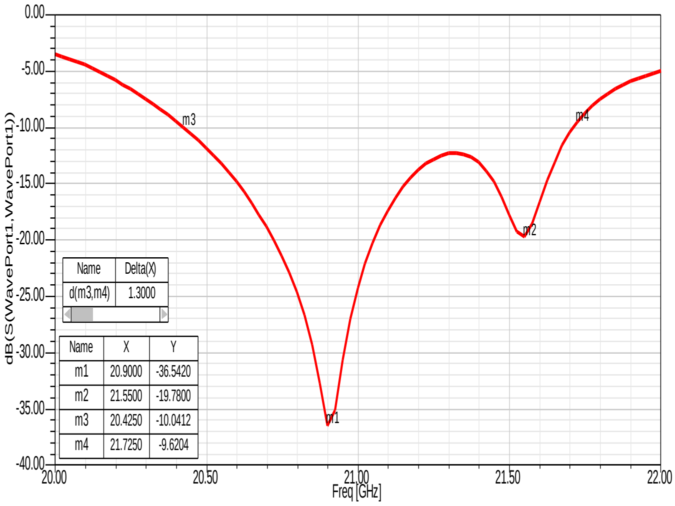

*Fig.5: Reflection coefficient as a function of the frequency of the antenna with **air-filled cavity for** L=8 mm, W=10 mm and εr=9.8*

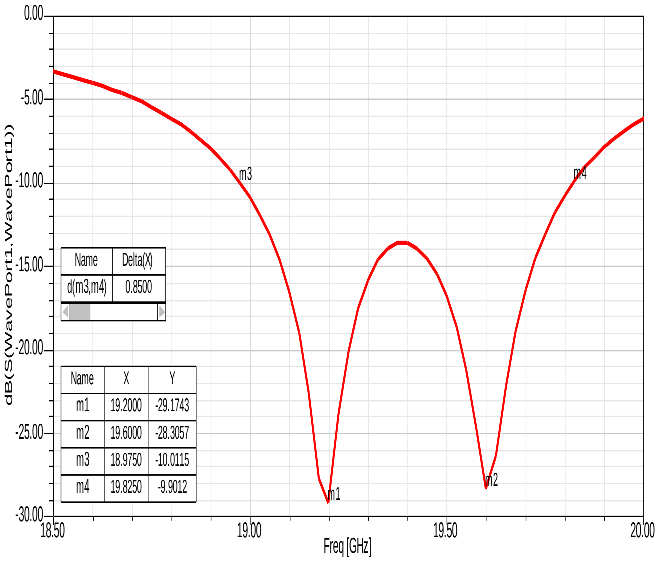

*Fig.6: Reflection coefficient as a function of the frequency of the antenna with **air-filled cavity for** L=8 mm, W=8 mm and εr=11*

Figs. 7 and 8 show the gains of the microstrip antenna for L = 8 mm, W = 10 mm, εr = 9.8 and for L = 8 mm, W = 8 mm, εr = 9.8 respectively.

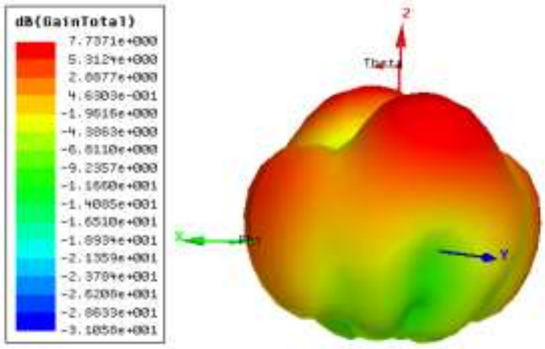

Fig.7: Gain of the microstrip antenna, for L=8 mm, W=10 mm etεr=9.8

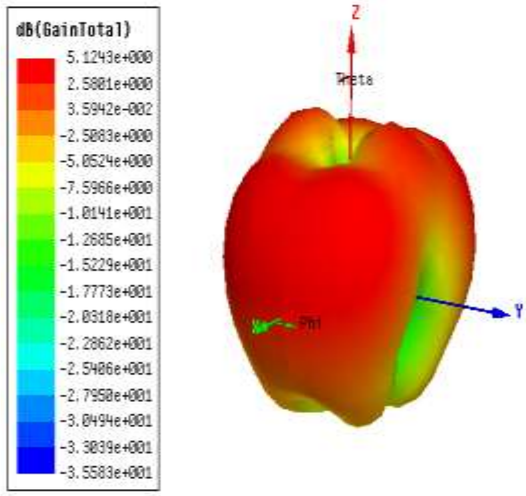

Fig.8: Gain of the microstrip antenna, for L=8 mm, W=8 mm etεr=11.0

Table 2 summarizes the results obtained from the simulation and those published for different dimensions of the microstrip antenna.

Table.2: Comparison between the published results of the characteristics of the antenna and those obtained

Physical Parameters	**References**	**Resonant Frequency (GHz)**	**S_{11}(dB)**	**Bandwidth (MHz)**	**Gain Max(dB)**
L x W= 8x10mm^2 εr=9.8	[2]	fr1=20.13	-26.00	830	3.50
		fr2=20.53	-29.00		
	Our work	fr1=20.85	-36.60	1300	7.73
		fr2=21.55	-19.80		
L x W= 8x8mm^2 ε_r=11.0	[13]	19.75	-18.75	250	2.80
	Our work	19.6	-28.30	900	5.12

The results obtained show that the resonant frequencies are included in the K band, as well as a clear improvement in the reflection coefficient, the bandwidth and the maximum gain.

II. CONCLUSION

In this paper, research has been presented on the miniaturization of the dimensions of the microstrip antenna, operating in the K band while improving these characteristics, namely the reflection coefficient S_{11}, bandwidth and gain. This improvement is due to the use of a second layer of the substrate and to the introduction of a cavity filled with air at the level of the lower substrate. The comparison of the results obtained with those published showed a great satisfaction, which will make it possible to encourage more the use of this type of antennas in the field of wireless telecommunications.

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