Enhancement of Inset Feed Microstrip Semicircular Patch Antenna Directivity using Dielectric Superstrate

Hayat Errifi
PhD student, EEA & TI Laboratory
Faculty of Science and Technology
Mohammedia, Morocco
Email: errifi.haya [AT] live.fr

Abdennaceur Baghdad, Abdelmajid Badri, Aicha Sahel
Professors, EEA & TI Laboratory
Faculty of Science and Technology
Mohammedia, Morocco

Abstract—**The subject of enhancing microstrip patch antennas directivity, using either a frequency selective surface (FSS) or a double-negative (DNG) metamaterial slab, has been investigated by a number of researchers in recent years. The purpose of this paper is to show that we can also achieve the same goal by using a much simpler design for the superstrate, namely a dielectric slab, whose performance can be comparable to those of the other two typical choices for the superstrate. In this paper, we study the influence of dielectric superstrate on the performances of inset feed semicircular patch antenna. This dielectric layer is disposed above the patch and both are separated by the air. The return loss, radiation pattern, and directivity are studied using HFSS software. The simulation results show that the gain, directivity and S11 parameter of the antenna with dielectric superstrate are increased significantly at X band (8-12GHz). Compared with the conventional patch antenna with the same size but without superstrate, the performance of the proposed antenna is improved obviously.**

***Keywords**—patch antenna; HFSS; dielectric slab; return Loss; gain; directivity.*

I. Introduction

The rapid and explosive growth in wireless communication technology and communication systems is prompting the extensive use of low profile, low cost, less weight and easy to manufacture antennas. All these requirements are efficiently realized by microstrip patch antennas (MPAs). The applications of microstrip antennas are wide spread because of their advantages due to their conformal and simple planar structure. In spite of its several advantages, they suffer from drawbacks such as narrow bandwidth, low gain and excitation of surface waves [1]. So to overcome these limitations, several authors have proposed the use of superstrate to improve the performance of microstrip patch antennas that are used to excite the Fabry-Perot resonators [2]. Different types of superstrates have been proposed to obtain gain enhancement, including DNGs, EBGs, FSSs, and plain dielectric slabs. Other researchers working independently, suggested that directivity enhancement of MPAs can also be obtained by using either a plain dielectric slab, or a thin FSS [3, 4].The dielectric slab is a simple form of Electromagnetic Band Gap structure (EBG); it is typically low loss and is relatively easy to procure.

In this paper, we consider the problem of enhancing the directivity of inset feed semicircular microstrip patch antenna using dielectric superstrate. The paper is organized as follows: Section II explains the design procedure of an inset feed semicircular microstrip patch antenna covered by dielectric superstrate (DS) and section III is about the simulation results and discussion in addition to the analysis of a comparative performance between the conventional patch antenna and the patch antenna loaded with dielectric superstare for better understanding. Section IV gives conclusion and anticipated future works.

II. DESIGN OF PATCH ANTENNA WITH DIELECTRIC SUPERSTRATE

The microstrip patch antenna consists of a metallic conductor called radiating element and deposited on a dielectric substrate. The lower face is completely metalized to provide a ground plane. Microstrip patch antennas can be fed in a variety of ways, Contacting or Non-Contacting.

In contacting method the RF power is fed directly to the radiating patch using a connected element, they are microstrip feed and coaxial feed [5]. In Non-Contacting method, electromagnetic coupling is done to transfer the power between the feed line and the radiating patch, they are Aperture coupled feed and Proximity coupled feed [6].

Inset feeding is a variation of the edge feeding where the fed line is in direct contact with one of the radiating edges of the patch. Impedance control is achieved by cutting out a notch from the radiating edge and extending the feed line into the notch. This scheme has the advantage that the feed line and the radiating patch can be etched on the same substrate making design and realization easier and highly suited for array design [5-7]. The design can be well explained with the figure.

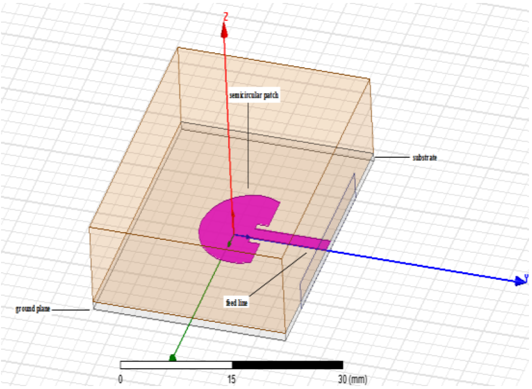

Fig. 1. Inset feeding semicircular microstrip patch antenna

Figure 1 represents conventional inset feed semicircular microstrip patch antenna. The proposed patch antenna is realized on the Roger RT/duroid substrate with permittivity εr=2.2 and thickness (h) of substrate is 0.79 mm, the ground plane and radiating patch is made of copper. The operating frequency of antenna (fr), at which we wish to achieve the maximum directivity, is 11 GHz. The radius of the semicircular patch is given by [1]:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \qquad (1)$$

Where

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}} \qquad (2)$$

The patch radius (r) has been calculated as (5 mm) and for ground plane dimension has been calculated as (35 mm×27 mm).

One layer dielectric superstrate places above the patch of antenna for concentrating of radiation energy normal to itself. The dielectric constant of the superstrate is 9.2, which corresponds to the dielectric constant of the "Rogers TMM 10 (tm)" in the microwave frequency range. Adjustment of the superstrate layer is the most important stage in antenna design and it is about one third of operation wavelength (λ/3) above ground plane which cause to gain increase in addition to improving beam shaping and directivity. Figure 2 shows configuration of semicircular patch antenna with dielectric superstrate.

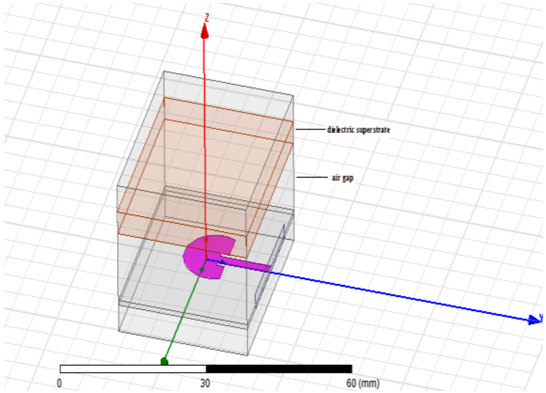

Fig. 2. Geometry of the semicircular patch antenna with dielectric superstrate

Below, we will present the simulation results in terms of the computed radiation patterns, return loss, gain and directivity of the proposed antenna. We use

HFSS, which is 3D High Frequency Structure Simulator software [8].

III. SIMULATION RESULTS AND DISCUSSION

Now-a-days, it is a common practice to evaluate the system performances through computer simulation before the real time implementation. A simulator *"Ansoft HFSS"* based on finite element method (FEM) has been used to calculate return loss, gain, directivity and radiation pattern. This simulator also helps to reduce the fabrication cost because only the antenna with the best performance would be fabricated.

A. Reflection characteristics

The reflection characteristic of the antenna design for high directivity operation is shown in Figure 3. For comparison the results are also presented for the inset feeding patch antenna without the dielectric superstrate.

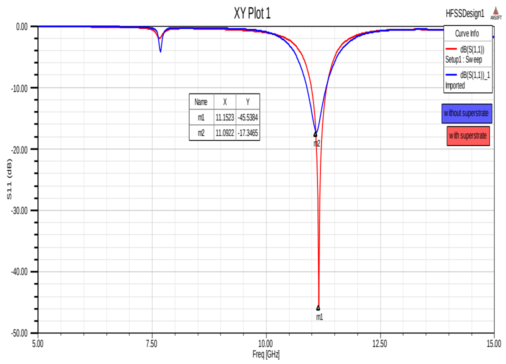

Fig. 3. Reflection coefficients of the semicircular patch antenna with and without dielectric superstrate

The return loss should be minimal at resonance frequency for better performance; it can be seen that the reflection behavior of the antenna without dielectric superstrate shows low resonance over the X band (-17.34 dB at 11.09 GHz). After the patch antenna is loaded with dielectric superstrate, it can be seen that the reflection losses were minimized significantly (-45.53 dB at 11.15 GH). Adding this layer provides a good impedance matching with the source antenna that was initially designed with an air medium above it at a frequency of 11 GHz nearly.

B. Gain

Figure 4 shows the results of gain as a function of frequency for the patch antenna without superstrate and the patch antenna with dielectric superstrate. It is observed that maximum Gain is obtained for the antenna loaded with dielectric superstrate, it is about 11.33 dB. The adjustment of the thickness layer has an important role in this enhancement.

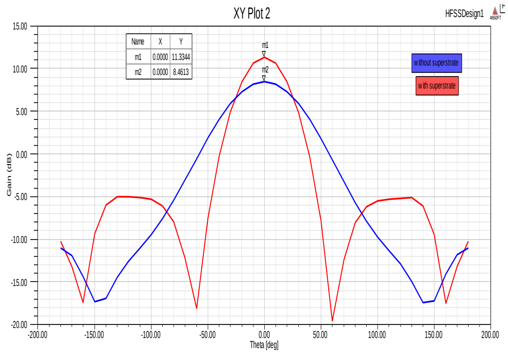

Fig. 4. Results of gain of semicircular patch antenna without superstrate and semicircular patch antenna with superstrate

C. Directivity

Figure 5 shows the results of directivity as a function of frequency for the patch antenna without superstrate and the patch antenna with dielectric superstrate. It can be seen that the antenna loaded with dielectric superstrate provides much better performance than that of the antenna without superstrate in term of directivity. The adjustments of the distance layer has an important role in this enhancement [9-10].

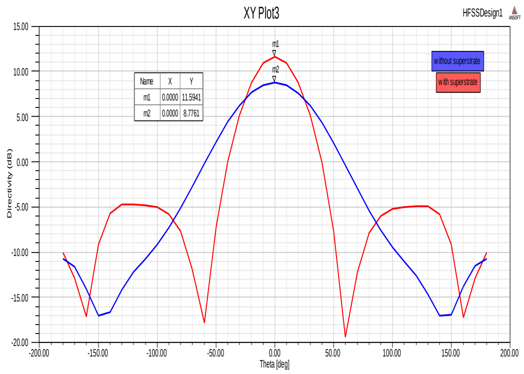

Fig. 5. Directivity results of semicircular patch antenna without superstrate and semicircular patch antenna with superstrate

To obtain an optimum response for directivity the distance between the layer and the patch was varied to produce the final characteristic of directivity as shown in Figure 5. The corresponding value is 10 mm. A maximum directivity of 11.59 dB is obtained at the frequency of 11 GHz. Therefore it is important to control the layer thickness in order to obtain a better performance from the antenna, the corresponding value is 3 mm.

D. Radiation pattern and 3dB beam-width

In figures (6 and 7) 3-D radiation pattern of the antenna without superstrate and antenna with dielectric superstrate is shown. It is clear from these figures that directivity has been improved by 2.82 dB by adding dielectric cover, therefore the total efficiency of proposed antenna has been also increased.

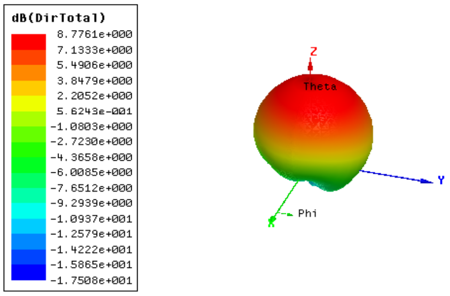

Fig. 6. 3D-Radiation pattern of semicircular patch antenna without dielectric superstrate

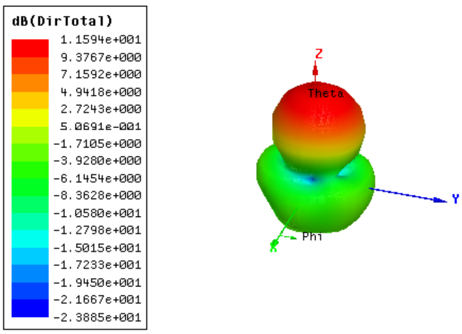

Fig. 7. 3D-Radiation pattern of semicircular patch antenna with dielectric superstrate

Figure 8 and 9 display Radiation pattern for the antenna without superstrate and antenna with dielectric superstrate. It is clear from the graphs that the radiation is not distributed but directed along a single direction.

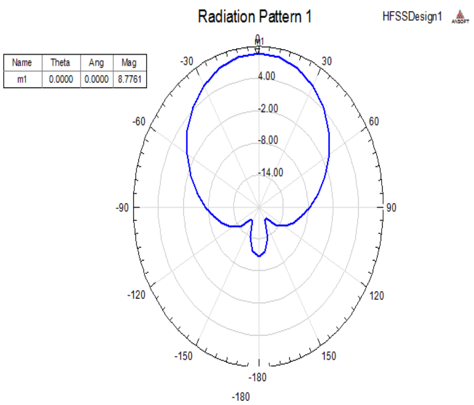

Fig. 8. 2D-Radiation pattern of semicircular patch antenna without dielectric superstrate

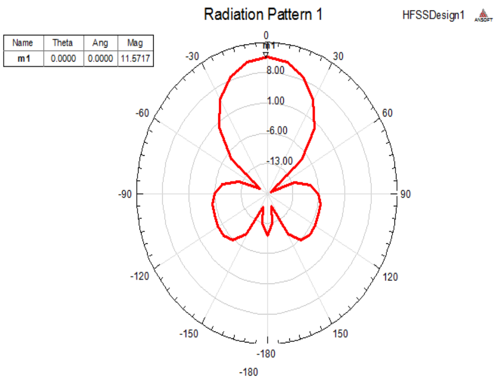

Fig. 9. 2D-Radiation pattern of semicircular patch antenna with dielectric superstrate

The results for the beam-width are 65°and 40° at the frequency of 11.09 GHz and 11.15 GHz for the simple antenna and antenna with one layer dielectric superstrate respectively.

It is obvious the use of the dielectric superstrate, cause the increase of directivity of the antenna, the new antenna provides a narrower beam-width (40° at E-plane) along the forward direction

E. VSWR

Figure 10 shows the results of VSWR as a function of frequency for the patch antenna without superstrate and the patch antenna with dielectric superstrate. It is shown that at the resonant frequency the patch antenna with dielectric superstrate has a better VSWR value of 1.03 than that of the patch antenna without superstrate with VSWR 1.31 as the VSWR of the patch antenna loaded with dielectric superstrate is more closer to the ideal value of VSWR=1 for an antenna.

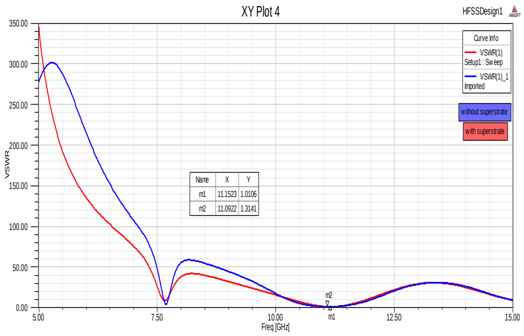

Fig. 10. VSWR results of semicircular patch antenna without superstrate and semicircular patch antenna with superstrate

F. Comparative analysis

A summary of the designed antennas is given in Table I. The table reveals that the designed antenna with dielectric superstrate had the best results in terms of return loss, directivity, gain and beam-width as those of antenna without superstrate.

TABLE I. COMPARISON FOR RETURN LOSS, DIRECTIVITY, GAIN AND BEAM-WIDTH

Antenna	Freq	Return loss	Directivity	Gain	Beam-width
Without DS	11.09 GHz	-17.34 dB	8.77 dB	8.46 dB	65°
With DS	11.15 GHz	-45.53 dB	11.59 dB	11.33 dB	40°

II. CONCLUSION AND FUTURE WORKS

In this paper, inset feed semicircular patch antenna with dielectric superstrate have been studied. The main impetus for studying this antenna structure was the desire to realize increased directivity without using complex structures such as DNG or FSS superstrate. The radiation characteristics of the composite structure have been investigated by using HFSS software, which has been found to be a useful tool for designing antennas of this type. Finally, it was found that the directivity level, beam-with as well as reflection coefficient and gain could be further enhanced by using one layer dielectric superstrate. In future work, a very important need is to apply this dielectric superstrate on semicircular patch array antenna and see its effect on radiation characteristics, then make a comparative study between patch antenna and array antenna loaded with dielectric superstrate.

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