Enhanced Gain Tapered Slot Vivaldi Antenna Using a Superstrate Layer for Ultra Wide Band Antenna Systems

S. Taleb, L. Merad and S.M. Meriah
Telecommunications Laboratory (LTT)
Department of Electrical and Electronics Engineering, Faculty of Technology
Abou bekr Belkaid University, Tlemcen, Algeria
email: sarah.ghizlene89@yahoo.fr
merad77@yahoo.fr
meriah_m@yahoo.com

Abstract— **One of the key issues in Ultra Wide Band systems (UWB) is to design appropriate antennas capable to operate in the desired frequency band [3.1-10.6] GHz. In the medical and military fields, and sensing applications, directional antennas which provide a high gain gives more advantages. In this paper, we will introduce a new technique to increase the performance of this antenna by adding a superstrate layer in the environment of the antenna.**

Keywords- Vivaldi antennas, ultra wideband (UWB) antenna, superstrate, gain.

I. INTRODUCTION

The advantage of broadband systems is confirmed every day. The Vivaldi antenna has been widely used in UWB systems, primarily in radar and medical imaging applications [1].

The slot antennas gradual transition (TSA) is based on the idea that an antenna can be seen as a transition region between a wave guide and free space, generally consist of a slot line expanding in a given profile, the profile of these aperture can be in different shapes according to the specifications of a desired radiation. Thus, Vivaldi antennas or ETSA have a exponential transition profile.

Compared to other types of antennas, the (TSA) are efficient in terms of bandwidth, moderate directivity, flat structure and the gains achieved by these antennas can be up to 10 dBi depending on the profile [2].

At this stage of discoveries, we can assume that the evolution of these antennas open further the scope of these types of antennas. In this paper, we will introduce a superstrate to the antenna environment in order to improve the gain and the directivity [3, 4, and 6]. Results regarding antenna parameters such as return loss, radiation pattern and gain will be presented.

II. ANTENNA DESIGN

A. Methodologie

We will discuss the study and design of a Vivaldi antenna.

We will show the importance of the apertures of the antennas for the enlargement of the bandwidth and also the variation of the radiation pattern for the tapered slot antenna (TSA).

We were inspired by the work of the article [5] to achieve this structure. This antenna consists of a single layer. The top layer is a copper layer having a thickness h1 = 0.035 mm.

The geometry of the proposed antenna is shown schematically in "Fig. 1". The antenna is arranged on a substrate εr equal to 3.38 and a thickness h = 1.524 mm, length and width of this design is 30 mm x 40 mm.

In this design, the microstrip line is used as a transmission line, in order to have characteristic impedance equal to 50Ω at the frequency band 3.1 to 10.6 Ghz. The structure is designed and dimensioned by the CST software.

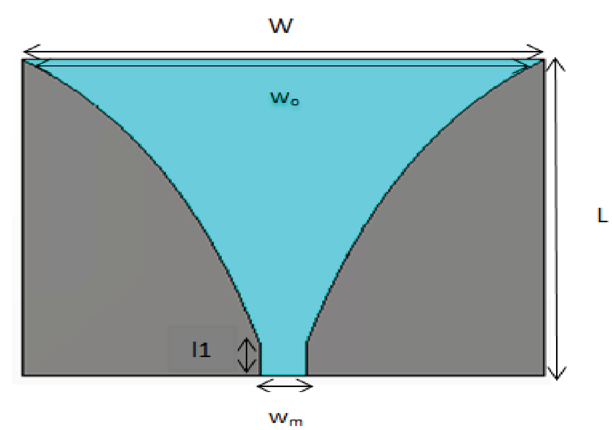


Figure 1. Vivaldi Antenna structure.

The following table defines the different dimensions of the structure:

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA.

Parameters type	Parameters		
	Variable	***Dimension***	***Unit***
width	w	40	mm
length	L	30	mm
aperure width	w_o	40	mm
slot width	wm	3.499511	mm
slot length	l1	3	mm

B. Calculation

In theory, the maximum aperture width is given by the following equation [5]:

$$\lambda g = \frac{c}{f_{min}\sqrt{\varepsilon r}} \quad (1)$$

Where,

c : speed of light ($3 \cdot 10^8$)
f_{min} : minimum frequency (2 GHz)
ε_r : dielectric constant (3.38)

Thus,

$$\lambda_g = 81.59 \ mm$$

So,

$$W_{max} = \lambda g / 2 \quad (2)$$
$$= 40.795 \ mm$$

Then, the minimum of aperture width is:

$$W_{min} = \frac{c}{f\sqrt{\varepsilon r}} \quad (3)$$

where,

f : center frequency (9 GHz)

$W_{min} = 18.13 \ mm$

Therefore, five different sizes of the aperture width were simulated.

III. SIMULATION RESULT

A. Parametric Study

We will vary the aperture width (w_o) of our structure, and we can thus show the influence of this parameter on the performance of the antenna.

The "Fig. 2" represents the variation of the coefficient S11 (return loss) versus the frequency for different sizes of the aperture width.

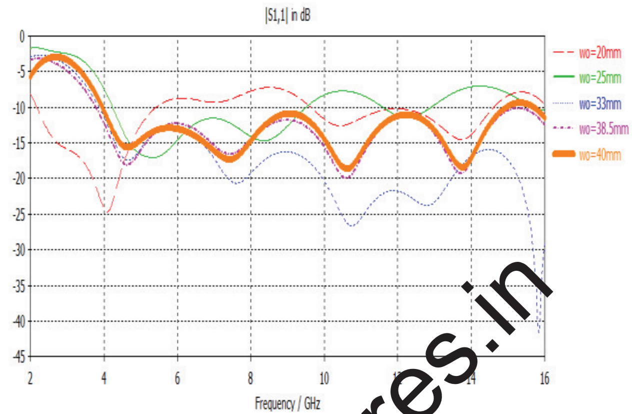


Figure 2. Variation of the parameter S_{11} versus frequency.

As we can seen the Vivaldi antenna has a better bandwidth for w_o = 40 mm. The antenna is adapted to a frequency band [3.95 - 14.97] Ghz.

B. Gain variation

"Fig. 3" illustrates the variation of antenna gain versus frequency.

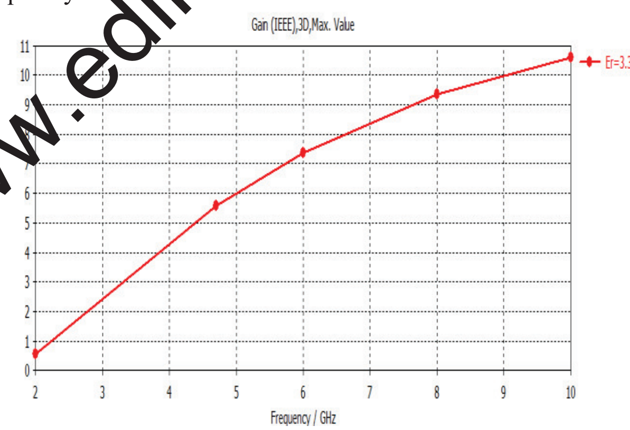


Figure 3. Variation of the gain of the antenna in selected frequencies.

Like all wave aerials, antenna Vivaldi TSA has the distinction of having an increasing gain [1] with frequency. Here the antenna has a maximum gain of 10.61 dB at 10 GHz.

IV. ANTENNA DESIGN WITH SUPERSTRATE

A. Methodology

In this part, we will used a superstrate which is a dielectric layer with high permittivity (εr = 10) or high permeability ($\mu >> 1$), in order to improve the gain and directivity of microstrip antennas "Fig. 4".

We have chosen the commercially dielectric with a permittivity equal to 10 like the AR® Arlon [3].

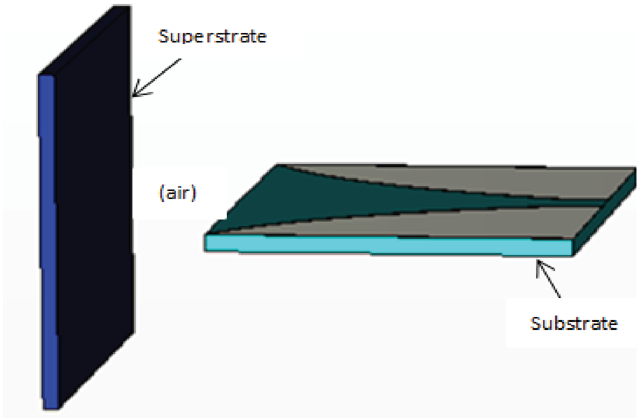


Figure 4. Structure of the device where the substrate is positioned perpendicular with the Vivaldi antenna.

Some conditions were taken into account the thicknesses of substrate and superstrate (equal to 1.27), and also on the relationship between the permittivities of the two materials. The study has been done for different distances between the antenna and the superstrate. A distance equal to 12.111 mm was chosen in order to get the maximum gain and directional radiation. “Fig. 5” represents the return loss for different distances.

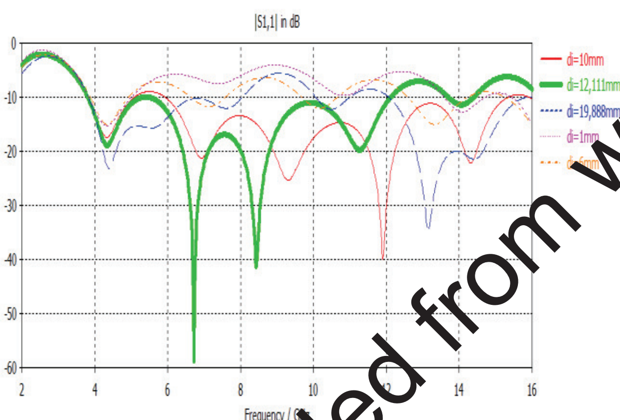


Figure 5. Variation of S_{11} according to the frequency parameter for different distances.

B. Comparative study

“Fig. 6 and 7” represents respectively the return loss and variation of the antenna gain with and without superstrate.

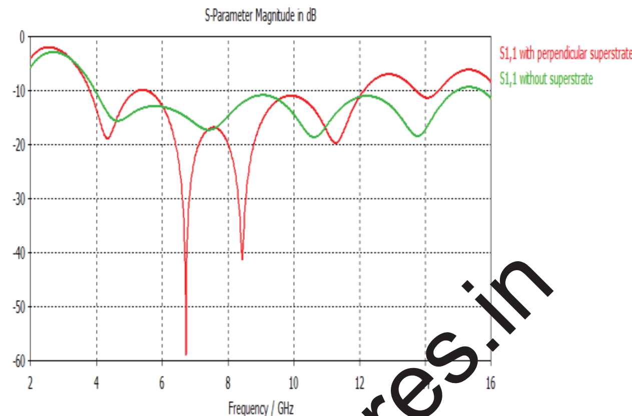


Figure 6. Variation of S_{11} with and without superstrate .

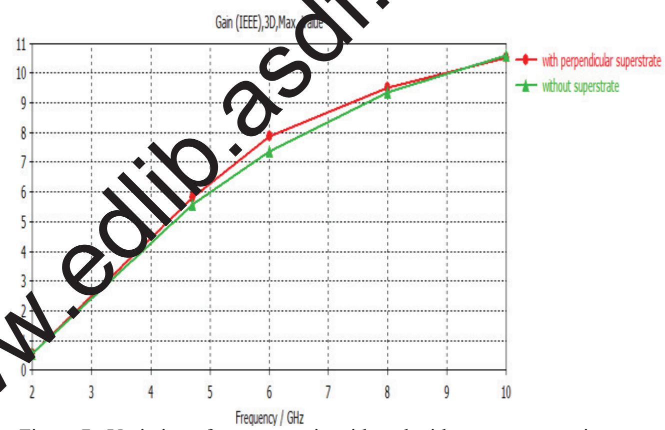


Figure 7. Variation of antenna gain with and without superstrate in selected frequencies.

We notice in “Fig. 7” that the gain of antenna with superstrate increase over the desired band [3.1-10.6] GHz

Furthermore, we have introduced another superstrate with permittivity equal to 6.15, and a thickness of 0.64mm. The study has been done for different distances between the antenna and the superstrate. A distance equal to 10 mm was chosen in order to get the maximum gain and directional radiation. “Fig. 8” represents the return loss for different distances.

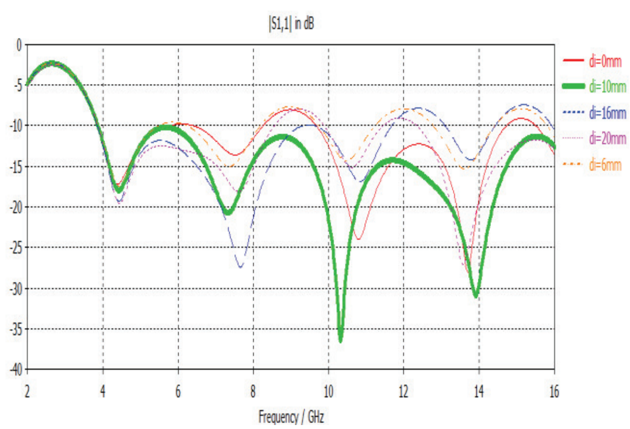


Figure 8. Variation of S_{11} according to the frequency parameter for different distances.

"Fig. 9, 10, 11 and 12" represents respectively the return loss, variation of the antenna gain, radiation pattern in 2D and 3D with and without superstrate.

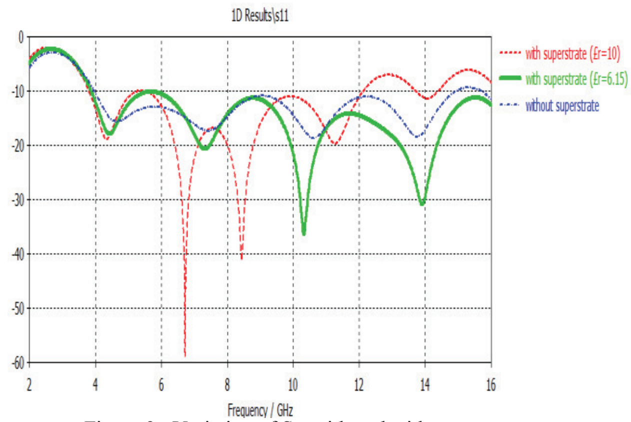


Figure 9. Variation of S_{11} with and without superstrate .

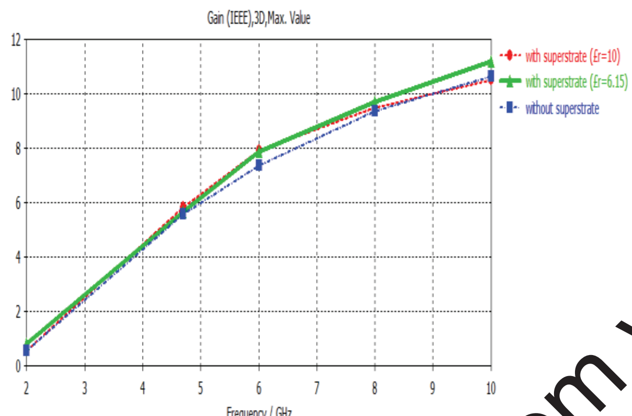
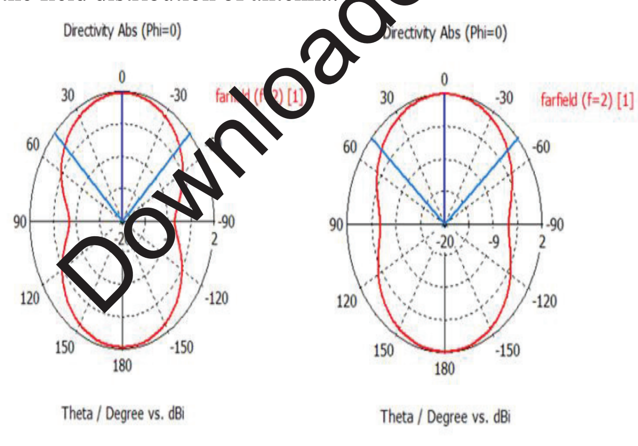
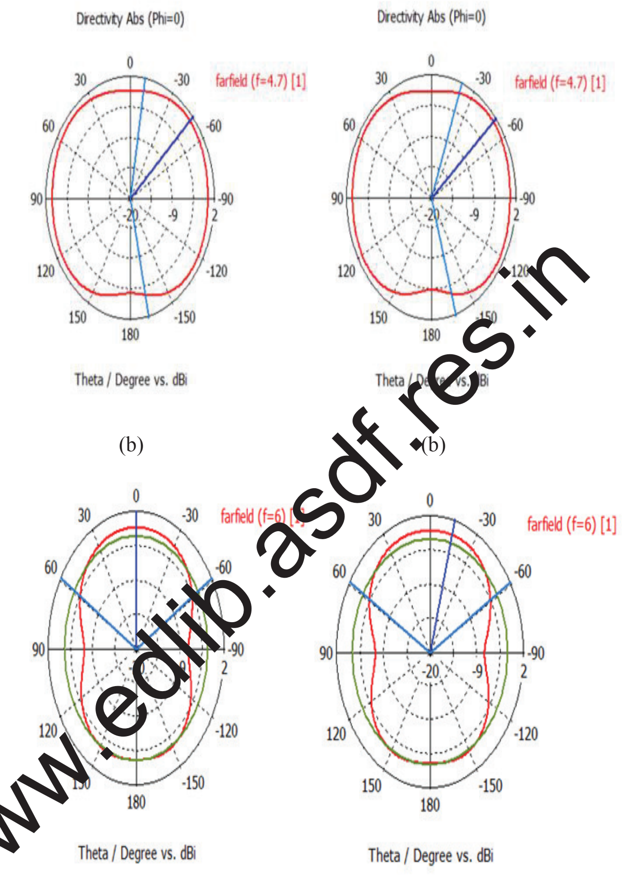


Figure 10. Variation of antenna gain with and without superstrate in selected frequencies.

We notice in "Fig. 10" that the gain increase over the desired band [3.1-10.6] GHz. Indeed, the improvement of the gain and directivity "Fig. 12" is due to the modification of the field distribution of antenna.



(a) (a)



(b) (b)

(c) (c)

Figure 11. Radiation pattern in the azimuth plane of the simulated directivity (dBi): (a) 2 GHz, (b) 6 GHz, and (c) 10 GHz Vivaldi antenna: left: without superstrate, right: with superstrate (ε_r =6.15).

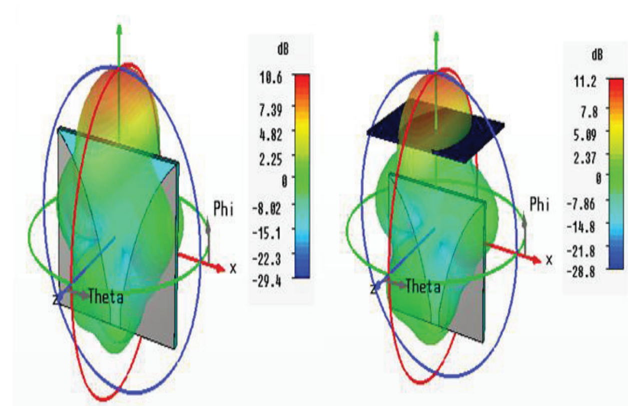


Figure 12. 3D radiation pattern of the antenna Vivaldi (F=10 GHz) left: without superstrate, right: with superstrate (ε_r =6.15).

From the obtained results, it is clear that the permittivity of the superstrate affect the antenna gain. Good performances were obtained for a permittivity equal to 6.15.

V. CONCLUSION

In this paper, we have designed and optimized a microstrip antenna with Vivaldi TSA conical transition shape feeded by microstrip line slot.

Regarding the influence of the superstrate on the antenna, Simulation results showed a good improvement in the directivity and gain of the Vivaldi antenna in the presence of the dielectric.

This work has shown that the performance of the antenna to meet the desired requirements in terms of adaptation, directivity and gain. The application of this antenna can be used in medical imaging.

REFERENCES

[1] P. Bucanayandi, W. Korti, "Study and Design of Vivaldi antenna UWB", master thesis, Dept.GEE, Tlemcen, Univ., Tlemcen, Algeria, 2012.

[2] L. BABOUR, "Study and Ultra wideband pulse miniaturized antenna design," PhD thesis, Polytechnic Institute of Grenoble, France, 2009.

[3] S. N. BUROKUR, "Implementation of metamaterials for application to microwave circuits and antennas," PhD thesis, Graduate School of Science and Technology Information and materials, Univ., Nantes, 2005.

[4] S. M. Meriah, E. Cambiaggio, R. Staraj and F. T. Bendimerad, "Gain enhancement for microstrip reflect array Using superstrate layer," Electronics, Antennae and Telecommunications Laboratory. University of Nice Sophia Antipolis, unpublished.

[5] H. Norhayati and O. Kama Azura, "Designing Vivaldi Antenna with Various Sizes using CST Software, " presented at the 2011 Vol II WCE. Congress. Engineering, London, U.K.

[6] Y. Shi and W. Zhang, "High gain stacked minkowski fractal patch antenna with superstrate for 60 GHz communications," Institute of Microelrctronics of Tsinghua University, 10084 Beijing. China Vol 135, 2012, pp. 53-59.

 ISBN : 978-81-925233-8-5