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DESIGN AND DEVELOPMENT OF AN ULTRA-WIDEBAND VIVALDI ANTENNA FOR MEDICAL IMAGING APPLICATIONS

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ABSTRACT

This comparative research seeks to highlight the differences in the stimulation efficiency of two software in order to ensure a higher level of accuracy in the design of an ultra-wideband Vivaldi antenna and maintain a precision development regarding its operation for an improved medical application purpose.

Keywords: Vivaldi antenna, ultra-wideband, conical slot antenna, microwave imaging, biomedical imaging, medical imaging, federal communications commission (FCC), bandwidth, medical applications.

1. INTRODUCTION

Biomedical imaging, one of the main pillars of comprehensive cancer management, has many advantages, including real-time monitoring, accessibility without tissue destruction, minimal or no invasiveness, and can operate over long periods of time. Wide ranges of time and sizes are involved in biological and pathological processes [1].

The goal of medical imaging is to create an intelligible visual representation of medical information. This problem is more generally within the framework of the scientific and technical image: the objective is indeed to be able to represent in a relatively simple format a large quantity of information resulting from a multitude of measurements acquired according to a good mode defined [2].

Since the Federal Communications Commission (FCC) allocated the frequency band 3.1-10.6 GHz for commercial applications, Ultra-Wide Band (UWB) systems have been widely used around the world, especially for imaging systems [3].

Ultra-Wideband (or technology without carrier or baseband signal) is defined more generally as any communication technology which occupies more than 500 MHz of bandwidth, i.e. more than 25% of the central frequency of the band. [4] Ultra-Wideband communications have many advantages and are used in a large number of civil, military, and medical applications [5].

Indeed, UWB systems use very short pulses (normally a few nanoseconds) which results in an ultra-wideband spectrum [6]. The use of UWB offers several advantages, such as a high capacity of high precision positioning, low power transmission, and high-reliability thanks to the fineness of the pulses, which facilitates localization [7]. The use of UWB antennas helps to provide high resolution in the resulting images due to the wide bandwidth spectrum [8]. The UWB spectrum contains both low and high-frequency components: the low-frequency components offer a high penetrating capacity to detect relatively deeply buried tumors while the high-frequency components do not have the same penetrating capacity but offer a high penetration capacity. resolution to detect relatively small tumors [9, 10].

In our work, we are interested in the design and optimization of a VIVALDI ULB antenna in direct contact with the body to study the possibility of detecting cancerous tumors in the breast; with this, in mind, we implement the wear of two different software to validate the operations of improvement at the antenna.

2. ANTENNA DESIGN

The proposed design below in Figure-2 represents a Vivaldi conical slot antenna composed of an FR4 type substrate with a dielectric constant of 4.3, a thickness h = 1.5748 mm and a loss tangent of 0.025.

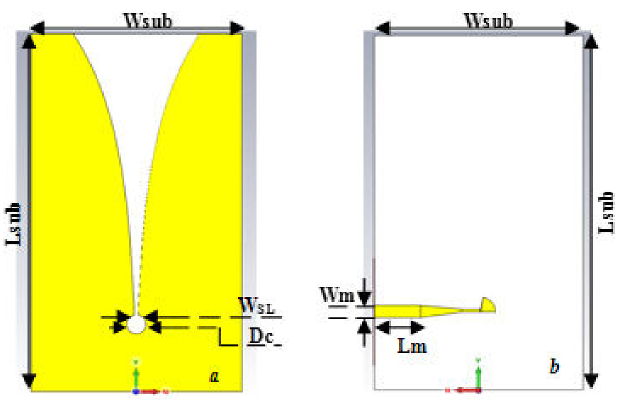

Figure-1. Vivaldi antenna with conical slot: (a) Front view & (b) Back view.

The final parameters calculated and optimized of the Vivaldi antenna through EM simulations for 3, 5 GHz operating frequency are shown in Table-1.

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Table-1. Design parameters of the proposed antenna.

Parameter	Description	Values (mm)
W_{sub}	Width of Substrate	53.00
L_{sub}	Length of Substrate	90.00
W_m	Width of Microstrip	3.04
L_m	Lengthof Microstrip	11.76
W_{SL}	Width of slot line	0.99
Dc	Diameter of cercl	4.913

3. SIMULATION RESULTS AND DISCUSSIONS

The performance of the proposed Vivaldi antenna was studied using an electromagnetic solver based on the finite integration technique (FIT), which is CST™.

To validate the design of our proposed antenna, we designed and simulated the same structure using another solver based on the finite element method (FEM), which is HFSS™.

A. S Parameter (S_{11})

Figure-2 presents the S-parameter (S11) obtained from the two different simulation tools.

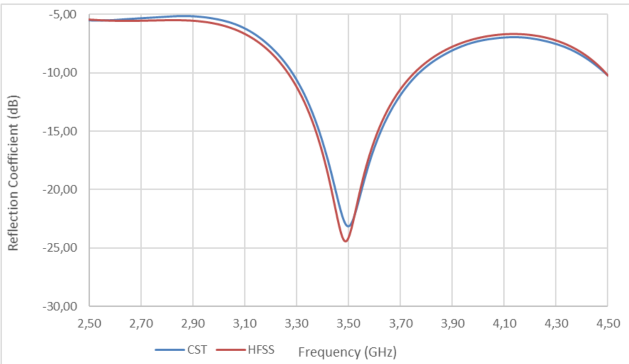

Figure-2. Comparison between the S parameter measured of the proposed antenna.

The graph obtained by the two software represents the curves of the parameters S (S_{11}) highlights the resonance of the antenna proposed at 3.5 GHz having a bandwidth of 450 MHz, as well as its medical application as an antenna in the S-band. The graph also shows that the maximum adaptation attenuation of - 23 dB is achieved at a resonance frequency of 3.5 GHz.

B. Antenna Gain and Radiation Pattern

As an evaluation of the completed design, we simulated and measured the antenna gain as well as the radiation pattern and bandwidth at the 3.5GHz resonance frequency.

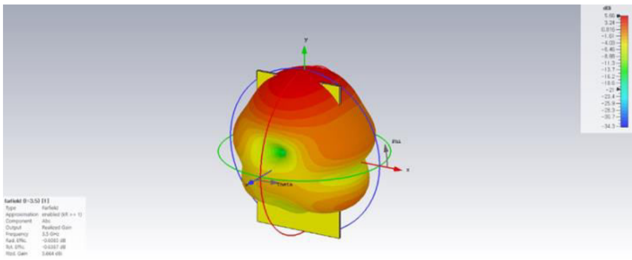

Figure-3. 3D radiation pattern at 3.5 GHz.

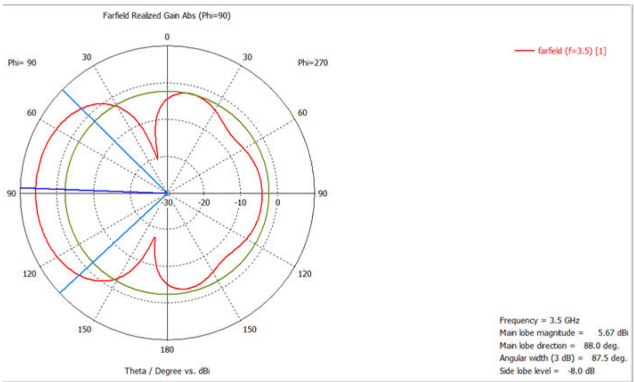

Figure-4. Antenna gain polar at 3.5 GHz.

Figures-3 shows the 3D radiation diagram and Figure-4 shows the polar radiation diagram at the resonance frequency. As mentioned in the previous figures, they also show an acceptable gain value that can be considered stable and adequate for our antenna. This antenna can therefore be used as a basic element of an antenna array for a medical application.

C. Voltage Standing Wave Ratio (VSWR)

To study the offset between the power system and the antenna, the wear of the VSWR is used so that the level of incompatibility is proportional to its value. Following this, we deduce that the minimization of the VSWR indicates the perfect match. More concretely, the value of the VSWR is assumed to be between the values 1 and 2.

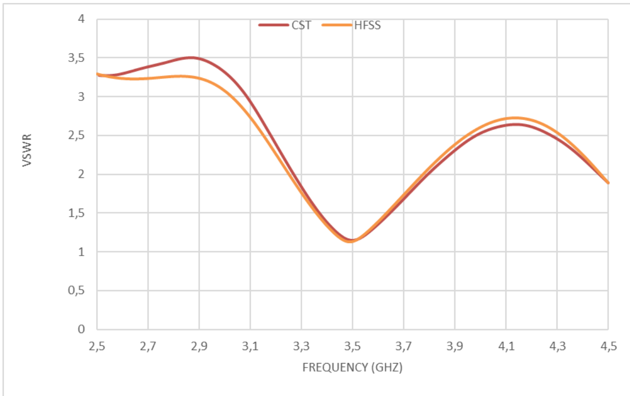

Figure-5. Voltage standing wave ratio (VSWR).

From Figure-5, it is noted that the proposed antenna gives a VSWR of 1.1 at the resonance frequency of 3.5 GHz, which means that a good adaptation of the impedance is obtained.

D. Impedance

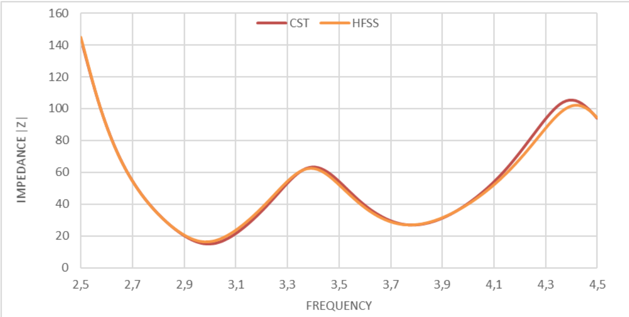

Figure-6. Impedance |Z|.

The measurement of the input impedance and the reflection coefficient has a good adequacy with the simulations with regard to the values of the frequency 3.5 GHz. It should be noted that there is a perfect correlation between the resonance frequency of 3.5 GHz with the characteristic impedance of 50 Ohm, which will allow a good adaptation of the antenna as shown in Figure X.

4. CONCLUSIONS

The objective of this study was to verify the accuracy of tumor detection for a Vivaldi ULB antenna using two different software, so the comparison focused on the S parameter, the radiation pattern, and the VSWR. Following the analysis of the results collected by these three studies, we obtained confirmation of the validity of this antenna in the detection of tumors since the results of the two software were convergent and at the limit of superposition.

The prospects due to this research are linked to the adaptation of this antenna in medical equipment in such a way as to elucidate the detection of tumors more accurately for the medical profession and achieve a better quality of care in oncology departments.

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