Design and simulation of Pyramidal Horn Antenna for NDT Applications

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***Abstract*— This paper describes a pyramidal horn antenna design which it works in a microwave domain. His operating frequency is 4.7 GHz. The parameters of the antenna were measured through its numerical modeling using *HFSS* (High Frequency Structure Simulator) electromagnetic simulation software. HFSS has the capability to calculate and plot a 3D image depicting the real beam of the gain. The obtained results show that an antenna gain of 12.90 dB was obtained at the frequency of 4.7 GHz, which means that the antenna is properly adapted to the transmission systems. This antenna will be used for non destructive testing (NDT) application, such as detection of cracks in different materials, materials characterization.**

***Keywords*— *pyramidal horn antenna, finite element method, HFSS, Radiation pattern, gain,* non destructive testing (NDT).**

I. Introduction

For several years, the domain of evaluation and non destructive testing has been developing and its fields of application are varied. Antenna is the basic element of these devices, it has different specificities according to each application. Those characteristics are defined using descriptors such as gain, efficiency, radiation pattern…etc. With the increase in bandwidth, the amount of information needed to characterize an antenna becomes very important. Solutions are being studied to compact this information, including the use of resonance poles [1].

The microwave horn antenna is widely used for many microwave applications as wireless communications, electromagnetic sensing, radio frequency heating, biomedicine and recently evaluation and non destructive testing…etc, where reasonable levels of directivity are needed. There are several types including, the pyramid horn antenna, conical horn and the corrugated horn antenna [2],

Pyramidal horn antenna is one of the most important parts of a transmission chain, it widely uses in various applications in the Microwave range [3], due to their advantages: high gain, moderate bandwidth and low voltage standing wave ratio VSWR [4]. It's construction is relatively simple, they are often used in applications where wide bandwidth is needed, such as WiMAX [5].

A widely used device for the propagation of guided waves is the rectangular waveguide. Its transmission quality is excellent. Its uses are very widespread in microwaves. The electromagnetic power transformer guided in radiated power is the horn antenna (Fig 1). Its shape makes it possible to gradually pass from the dimensions of the waveguide to the free space. The wave is thus naturally projected into the free space. This is the same principle as the acoustic horn. The transitions have varied forms: linear, exponential ...etc. The horn serves as a device of adaptation between the impedance of the horn and that of the vacuum. In a very natural way, the radiation takes place in the axis of the waveguide. This antenna is more directive than the previous antenna, since the power is emitted only in a region of limited space [1].

The waveguide is a very used microwave device because of his low losses caused by the propagation in the latter, even at high frequencies and, his ability to withstand the power. The horn antennas associated with it are therefore also widely used as a means of transformation of the guided wave in a radiated wave. They are found in all frequency bands in many systems such as radars, satellite antennas [6]....

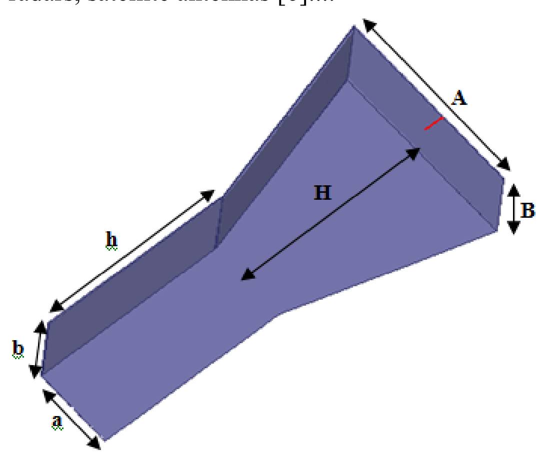

Fig. 1. Structure of Pyramidal Horn Antenna

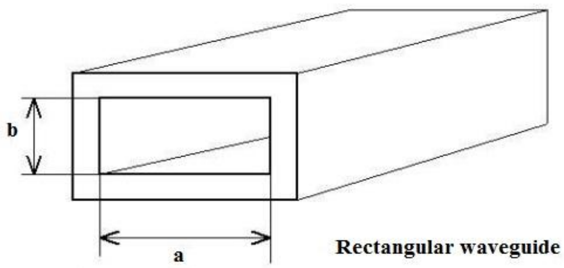

Fig. 2. Rectangular waveguide of horn pyramidal antenna

TABLE I. Antenna dimensions

F_0 (GHz)	A (mm)	B (mm)	a (mm)	b (mm)	h (mm)	H (mm)
4.7	20	17.2	8.6	4.3	20	40

II. Results and Discussion

The numerical results are obtained by using the HFSS microwave simulation software, is a software which performs the electromagnetic modeling of a structure by solving the Maxwell equations using the finite element method, this software sacrificed generally to the simulation High frequency microwave circuits, which is considered an asset for the simulation of horn antennas. It allows to visualize all the parameters that are needed to characterize, model or optimize pyramidal horn antennas, namely: the reflection coefficient as a function of frequency, the standing wave ratio, the radiation diagram in 2D or in 3D , The distribution of the electric and magnetic field in the antenna ... etc. The model of our simulated antenna is given in the following figure:

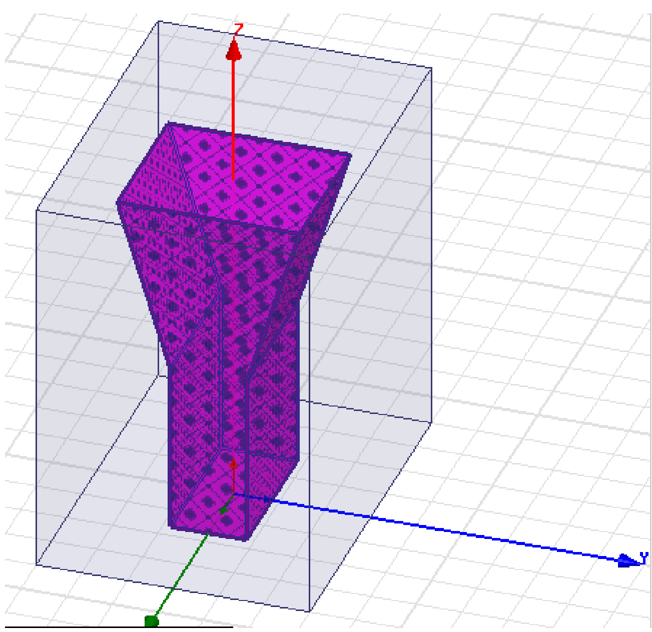

Fig. 3. 3D view of Pyramidal Horn in HFSS

A. Return Loss S11

It is a parameter that indicates the amount of energy lost during antenna radiation. It expresses to what extent the transmitter and the antenna are matched. The S_{11} parameter graph of an antenna as a function of frequency is called its loss-yield curve. A minimum value in dB at the resonant frequency must be present. The curves shown in the following figure represent the result of the return loss.

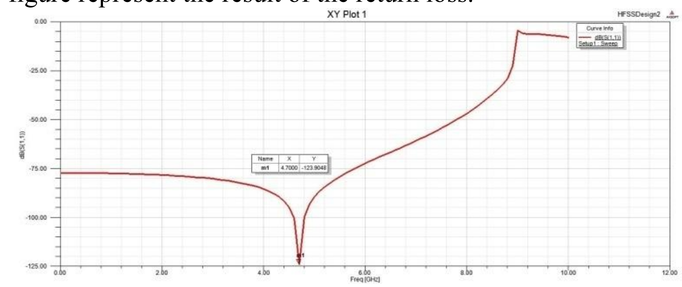

Fig. 4. Return loss of pyramidal horn antenna

It can be seen that the return loss attained -123.90 dB at the operating frequency 4.7 GHz, which represented the smallest reflection coefficient.

B. Voltage Standing Wave Ratio (VSWR)

It confirms the degree of adaptation or mismatch of the antenna with respect to the transmission and / or reception system. An antenna is perfectly adapted would have an VSWR close to 1, which means the amount of energy reflected or transferred into the cable. The following figure shows the VSWR of the antenna.

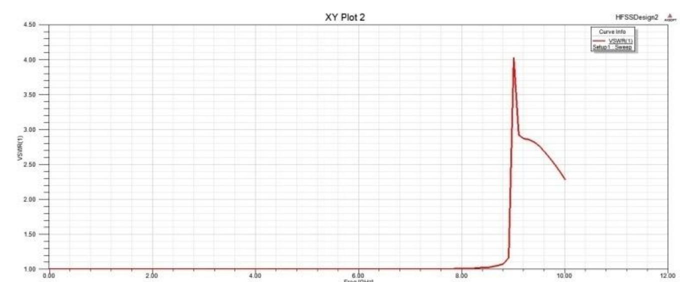

Fig 3 .Voltage standing wave ratio of the pyramidal horn antenna

Fig. 5. shows that the VSWR round about 1 over the entire frequency range swept by the antenna, which confirms the good adaptation of the antenna to the power supply system.

C. Directivity and Radiation pattern of the antenna

a) Directivity: is defined as the ratio of an antenna's radiation intensity in a given direction to the radiation intensity averaged over all directions. Peak directivity, in turn, is the maximum directivity over all the user-specified directions of the far-field infinite sphere.

b) Radiation Pattern: represents the geometric distribution of the radiation powers in the different directions of the space. The following figure shows the radiation pattern in 2D of the pyramidal horn antenna.

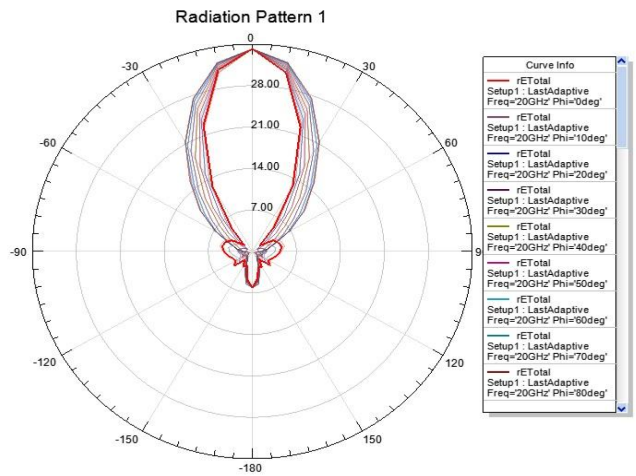

Fig. 6. Radiation pattern in 2D

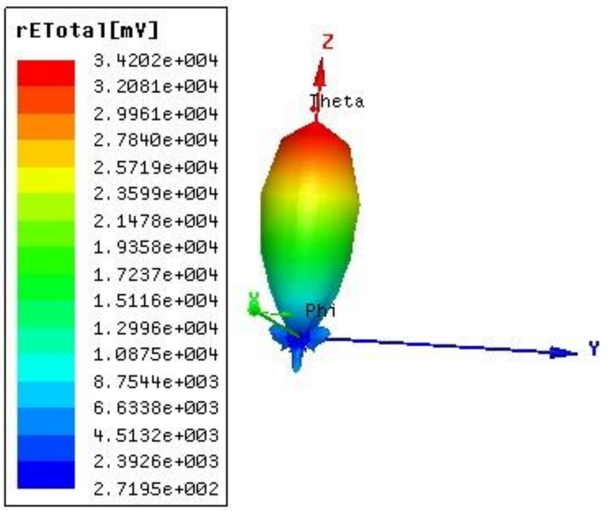

Fig. 4. Radiation pattern in 3D

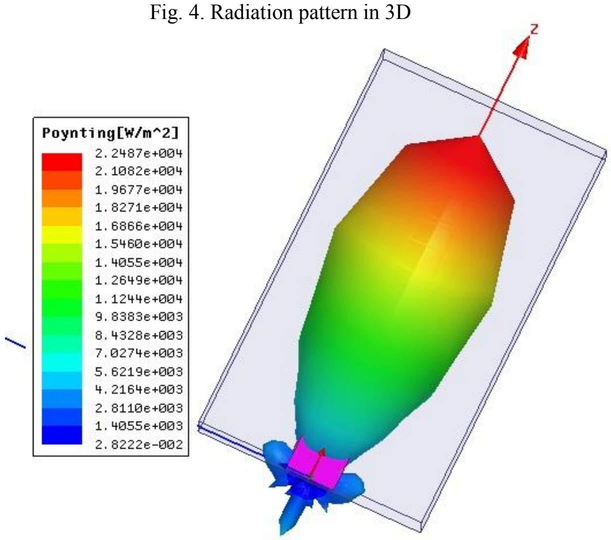

Fig. 5. Pointing vector

It can be seen from these radiation patterns that the pyramidal horn antenna has a stable radiation pattern with a resonant frequency of 4.7 GHz, this antenna is Omni-directional and it directs all his energy in only one direction which is called the main lobe.

D. Gain in 2D and 3D

Antenna gain describes the ability of this antenna to radiate in a certain direction when it is connected to an excitation source. Usually, we calculate the Gain in the direction of the maximum radiation (main lobe).

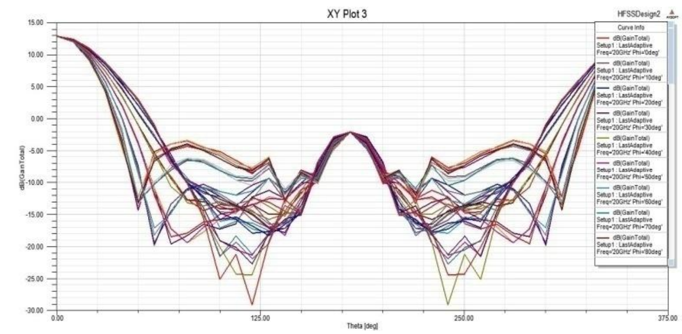

Fig. 9. Gain of antenna in 2D

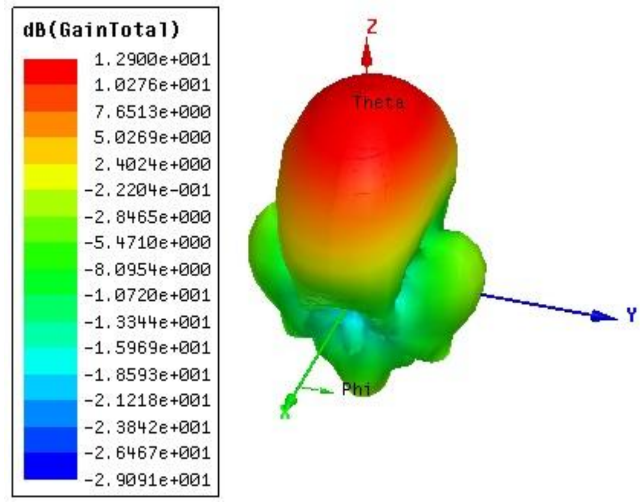

Fig . 10. Gain of antenna in 3D

E. Application to the non-destructive testing

The designed pyramidal horn antenna is used for detection of defects in dielectric and metallic materials. This antenna is placed facing the material at a distance of a few millimeters. Two samples, one without defect and the other with a defect, will be chosen for the purpose of comparing the microwave characteristics of the antenna. The following block diagram shows the method used for this material in relation to the antenna.

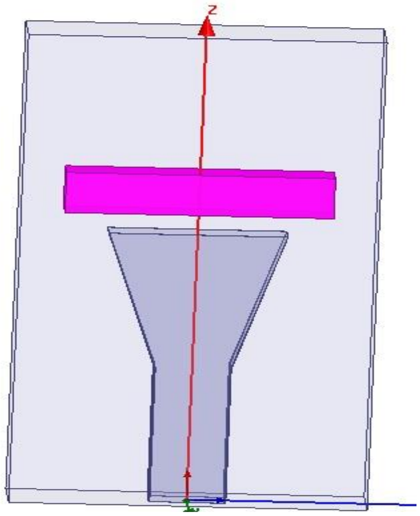

Fig. 11 . 3D view of the NDT system with HFSS

Fig12 and Fig13 show the obtained results of the simulation for the four specimens: dielectric material (fr4-epoxy), dielectric material with defect (1×5×1mm^3), conductive material (Aluminum) and Aluminum with defect (1×5×1mm^3).

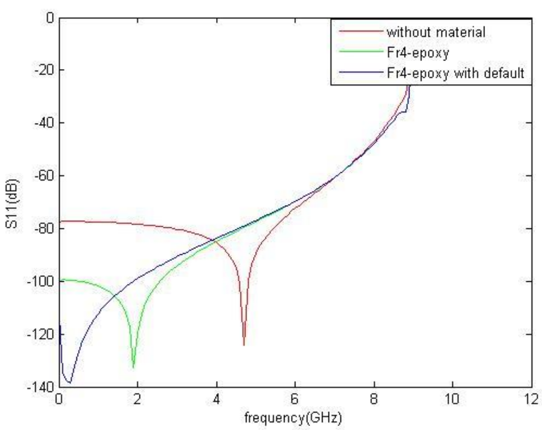

Fig. 12. S_{11} for different cases, dielectric material

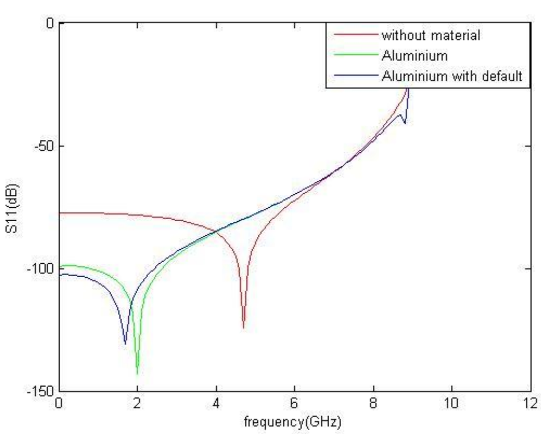

Fig. 13. S_{11} for different cases, conductive material

The simulation results in the four cases show that the default lowers the resonant frequency.

III. CONCLUSION

The main objective of this work was to give the characteristics of a waveguide fed, pyramidal horn antenna in the microwave range. The parameters of the antenna measured have made it possible to characterize this antenna. The results obtained show that at the operating frequency of 20 GHz a very low reflection coefficient is obtained which reaches -34.80 dB, a standing wave ratio very close to 1 and a higher gain reaches 12.80 dB. This confirms the adaptation of the pyramidal horn antenna to the transmission system. The simulated results verifying that the electrical properties of the pyramidal horn antenna yielded excellent impedance matching, and conformed to the design requirements.

The result obtained show that the default affects the resonance frequency and the bandwidth of the microwave system, for this purpose, the pyramidal horn antenna can be used for many applications in the field of evaluation and non destructive testing.

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