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Article

Vivaldi antenna design and simulation with Bakelite substrate compared to RT duroid 5880 substrate

Diseño y simulación de antena vivaldi con sustrato de baquelita comparado con sustrato RT duroid 5880

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Abstract

The main objective of this paper is to show the difference between two vivaldi antennas simulated with two different substrates, the first one is bakelite, since it is very easy to find a phenolic plate for the simplest electronics projects, this type of plate consists of one or two copper plates on the outside and a bakelite plate that separates them, However, the intention of the article is to compare this type of material so commercial with a material that has gradually made its way into the field of communications in a wide bandwidth, called RT duroid 5880 from Rogers Corporation and show the differences in relation to the gain. It is worth mentioning that this work shows the development of the antenna design using simulation software and that the development of this antenna will be adapted to contribute to later projects.

Objectives	Methodology	Contribution
The main objective i s to show the differe nce between simulat ed vivaldi antennas with two di fferent substrates: bakelite and the RT duroid 5880	The methodology in cludes the use of Hig h Frequency Simulat ion Software (HFSS) belonging to Ansys.	The contribution shows a clear development of new construction elements of telecommunications devices.

Antenna, Vivaldi, Duroid 5880

Resumen

El objetivo principal del presente trabajo es mostrar la diferencia entre dos antenas vivaldi simuladas con dos diferentes substratos, el primero es la bakelita, ya que es muy fácil encontrar una placa fenólica para los proyectos más simples de electrónica, este tipo de placa se conforma de una o dos placas de cobre en el exterior y una placa de bakelita que las separa, sin embargo, la intención del artículo es comparar este tipo de material tan comercial con un material que poco a poco se ha abierto camino en el campo de las comunicaciones en un ancho de banda amplio, llamado RT duroid 5880 de la empresa Rogers Corporation y mostrar las diferencias en relación a la ganancia. Cabe mencionar que este trabajo muestra el desarrollo del diseño de las antenas utilizando software de simulación y que el desarrollo de esta antena se irá adaptando para contribuir a proyectos posteriores.

Objetivo	Metodología	Contribución
El objetivo principal del presente trabajo es mostrar la diferencia entre antenas vivaldi simuladas con dos diferentes substratos: bakelita y el RT duroid 5880	La metodología incluye el uso de software High Frequency Simulation Software (HFSS) perteneciente a Ansys.	La contrinución muestra un claro desarrollo de nuevos elementos de construcción de dispositivos de telecomunicaciones.

Antena, Vivaldi, Duroid 5880

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Introduction

The development of this research work is framed with the research projects that arise from academic bodies in which the participants of this article are integrated. It is very common in the area of electronics design to be able to use inexpensive instruments for the exercises and main topics of instrument design, such as phenolic plates that are used from the first semesters of the study of electronics to design electrical and electronic circuits and whose cost does not exceed twenty pesos (on a single-sided plate of 10 cm by 10 cm) [1] however, With FORME, the topics of the area are being specialized, different materials are being used not only as conductors but also for the development of more specific devices.

This type of phenolic plate that is mentioned in the previous paragraph has the main characteristic that its faces are made of copper (in the case of when it has both metal faces), since copper is the metal also most used by electrical and electronic devices due to its conductive properties, however, the subject of study of this article is Bakelite, The material that has the plate in the central part, since it is known that this material was the first plastic that was chemically synthesized, from 1907 to date it has been on the market [2] covering the necessary requirements of design and implementation in various electronic devices.

Over the years, electrical and electronic systems evolved to make improvements in life, for example, in the area of health it is very common to find different devices that serve as support to the medical staff to be able to clearly determine the condition of a patient, proof of this is shown in the article "the crucial importance of imaging in the diagnosis of cranial pathology" [3] where they make use of of different imaging techniques for the diagnosis of cranial pathologies such as radiography, ultrasound and scintigraphy, among others. We also use technology for media that are advancing by leaps and bounds, a clear example is the issue of the implementation of technology in education, as shown in the article "Evolution of Information and Communication Technologies in Education" [4] where it shows a clear comparison of the use of technologies in education from the 1970s to 2022, giving a guideline to the entry of social networks and even emphasizing the rise of artificial intelligence.

In the area of telecommunications, specifically in the area of antennas, there have also been different advances, each time the devices need less space or size, but greater advantages over the previous ones, wide bandwidth, adaptability to the operating systems and the requirements of the system for which they are designed, to mention a few cases. That is why this publication makes the comparison between two types of materials: the oldest and most commercial against one of the new ones on the market. In general, this article will address the design of the antenna with the two substrates separately within the Ansys HFSS simulator, then the results obtained will be shown and these will be discussed in its conclusions.

RT duroid 5880 in recent applications

In the article Development of Rogers RT/Duroid 5880 Substrate-Based MIMO Antenna Array for Automotive Radar Applications, the design of a patch antenna for the new smart cars is developed, using relatively low frequencies and relying on short-range radars, it is selected because it has a low Constant dielectric and low dielectric loss, making them suitable for high-frequency/broadband applications. [5] In the article Half mode rogers RT duroid 5880 substrate integrated waveguide cavity backed V-slot antenna for C-band applications it is mentioned that a patch antenna is used for applications in the C-band, it mentions that the antenna is designed using a Rogers RT Duroid 5880 substrate with permittivity $\varepsilon_r = 2.2$ and its thickness is h = 0.787 mm. The RT/duroid 5880 substrate has a low dielectric constant and low dielectric loss, making them suitable for wideband/high-frequency applications. [6].

In the article New Multiband E-Shape Microstrip Patch Antenna on RT DUROID 5880 Substrate and RO4003 Substrate for Pervasive Wireless Communication the use of RT duroid 5880 due to Rogers-Corp's RT DUROID 5880 Substrate is mentioned and compared with RO4003 with dielectric constant of 2.2 and tangent of loss of 0.004. In fact, the articles Gain improvement and return loss reduction of microstrip patch antenna at 12 GHz using rogers RT/Duroid (TM) substrate in comparison with FR-4 epoxy substrate [7].

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Analysis of Equivalent Antennas in RT Duroid 5880 and 5870 for GPS Operating Frequency [8] and Gain enhancement of rectangular microstrip patch antenna using Rt-Duroid 5880 substrate and comparison with Rogers 4350 substrate on S-band [9] make a very complete comparison of recent use of the RT duroid 5880 material compared to other materials.

Methodology

The methodology is not very complex because the intention of the article is to present the results of the simulation of the antennas. In support of this methodology, the following diagram (Figure 1) was established in which the development of the methodology is shown step by step as well as the scope of the article.

Box 1

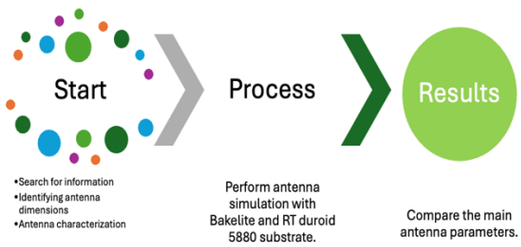

Figure 1
Methodology
Source: Own elaboration

The idea of the work is to be able to bring people closer to the use of the software, which is why each of the windows that arise when the characterization and simulation of the antenna is carried out is developed step by step. Nowadays, this type of description is important for the correct use of specialized software that allows the development of new technologies.

Vivaldi antenna design with Bakelite and RT duroid 5880 substrate

As specified in previous sections, this work is based on the simulation of antennas using Ansys' High Frequency Simulation Software (HFSS), which is one of the most complete software for the development of antennas and electromagnetic field for different frequencies. [10] It is worth mentioning that the vivaldi antenna has an exponential aperture, in addition to the following features:

- 0.035 mm thick copper top and bottom.
- 1.57 mm Bakelite core.
- Antenna Dimensions: 14mm by 19.5mm.
- Initial antenna aperture width of 0.12 mm.

Figure 2 shows the front side of the antenna while Figure 3 shows the back side.

Box 2

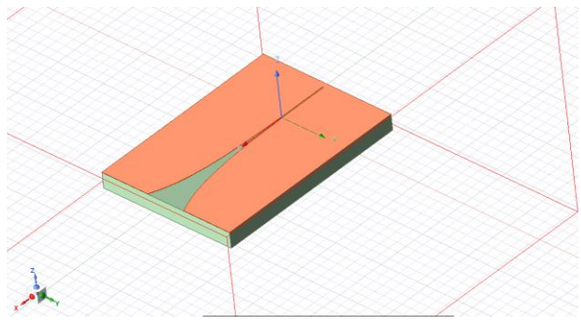

Figure 2
Front face of the antenna
Source: Own elaboration in the Ansys HFSS software

Box 3

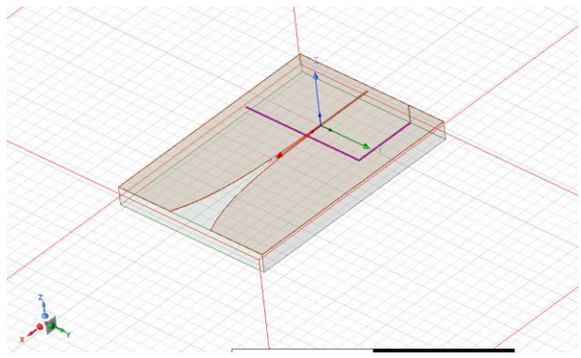

Figure 3
Back of the antenna
Source: Own elaboration in the Ansys HFSS software

These conditions follow the classical theories of Vivaldi antennas, where it is mentioned that for aperture lengths less than half the wavelength (λ), the wave is guided by the groove while for longer lengths, the wave propagates through the dielectric until it is radiated to the outside [11] [12] in the case of the design of this antenna it is worth mentioning that it seeks to develop the simulation at different frequencies of operation, mainly at 10 GHz, which corresponds to a wavelength of 30 millimeters, according to equation 1.

$$\lambda = \frac{c}{f_0} = \frac{3x10^8 m/s}{10x10^9\ Hz} = 3x10^{-2}m = 30\ mm \quad (1)$$

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Where λ is the wavelength, c is the speed of light in a vacuum, and f0 is the operating frequency. To get started, the software environment is shown in Figure 4.

Box 4

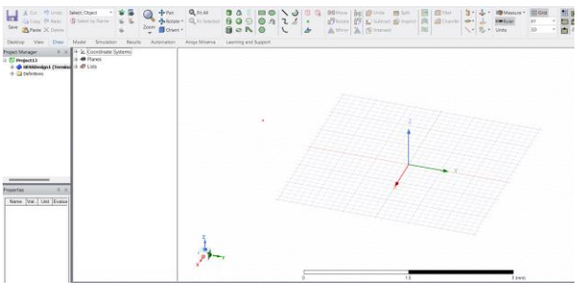

Figure 4
Software Environment
Source: Own elaboration in the Ansys HFSS software

At the top you can see the main icons for the design, this can be manually or by equation. In the case of using the equation shown in figure 5 in the icon marked with a red circumference in the "draw" tab, a window will automatically be displayed to write the equation of the surface you want to use.

Box 5

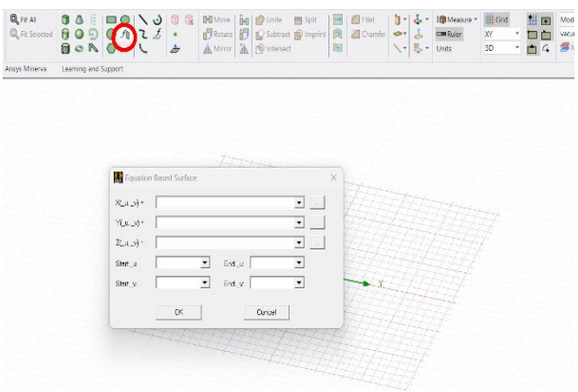

Figure 5
Window for writing equations for the surface
Source: Own elaboration in the Ansys HFSS software

Step by step and with the support of symbology to present figures in two or 3 dimensions, the conditions of the antenna are developed, for example, for the section of the bakelite substrate we select a cube and drag it to the workspace and although at first it is not in the position and size that is required, Double-clicking on the word "Create Box" (red circle in Figure 6) will bring up a window to place it in the desired position, as shown in Figure 6.

Box 6

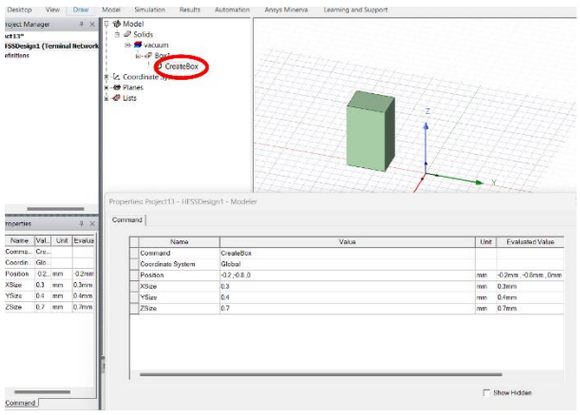

Figure 6
Window to describe substrate location and specifications
Source: Own elaboration in the Ansys HFSS software

To place the material to be simulated, you must right-click on the word "box" and then on the "assign material" section and a window like the one mentioned in figure 7 will be displayed where you simply select "bakelite" as the material to be used and it is automatically loaded to the surface that is being simulated.

Box 7

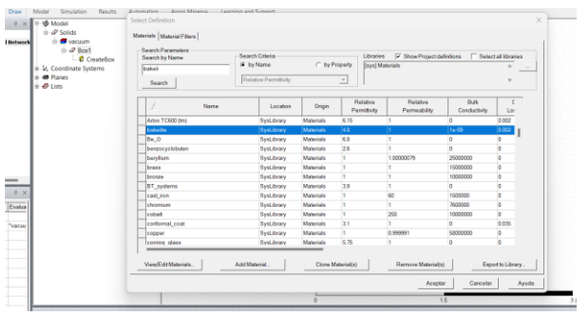

Figure 7
Selection of Bakelite as the material for the antenna substrate.
Source: Own elaboration in the Ansys HFSS software

In the case of the antenna design but with RT duroid 5880 substrate, the same procedure is carried out, but in the previous step the selection of the Rogers RT/duroid 5880 material is carried out, as shown in Figure 8.

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Box 8

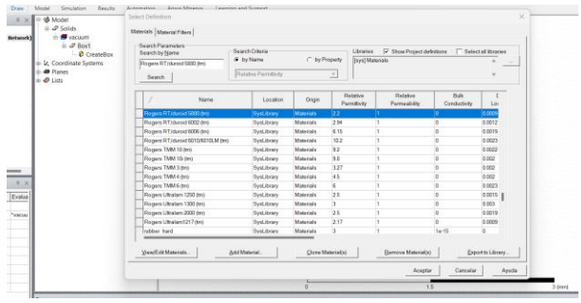

Figure 8

Selection of RT duroid 5880 as the material for the antenna substrate.

Own elaboration in the Ansys HFSS software

At the end of the antenna design with the main characteristics, you proceed to switch to the simulation tab and click on validate (icon marked in green at the top and on the analyze all icon indicated with two gears) as shown in Figure 9.

Box 9

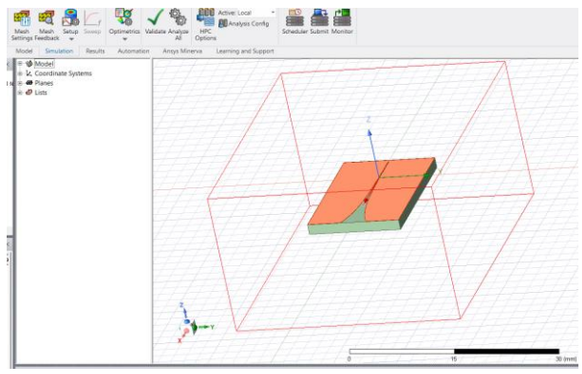

Figure 9

Software simulation window

Source: Own elaboration in the Ansys HFSS software

Depending on the characteristics of the antenna, it is the processing time of the simulation.

Results

Figure 10 shows the simulation result for the S11 parameter which is defined as the reflection coefficient between the port impedance and the network input impedance or simply the reflection coefficient. While Figure 11 shows the result for the VSWR (Voltage Standing Wave Ratio) parameter which refers to a measure of the efficiency of the transmission of a radio frequency (RF) signal.

While figures 12 and 13 refer to the results of the same parameters but for the simulated vivaldi antenna with RT duroid 5880 substrate.

Box 10

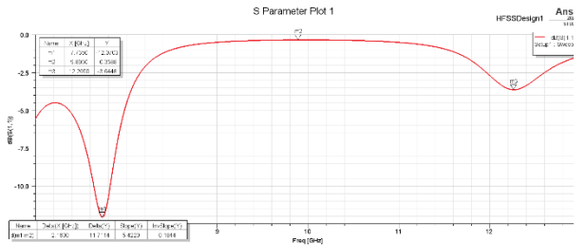

Figure 10

Result of the s11 parameter of the vivaldi antenna with Bakelite substrate

Source: Own elaboration in the Ansys HFSS software

Box 11

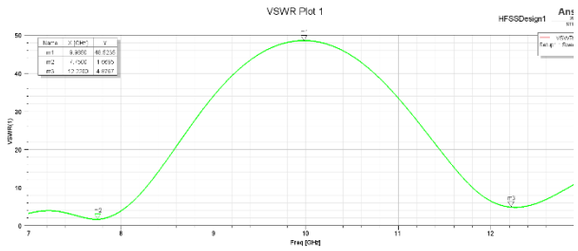

Figure 11

VSWR parameter result of vivaldi antenna with Bakelite substrate

Source: Own elaboration in the Ansys HFSS software

Box 12

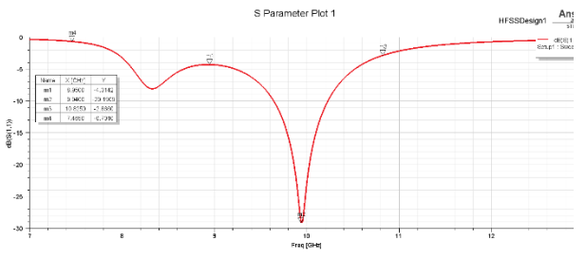

Figure 12

Result of the s11 parameter of the vivaldi antenna with RT duroid 5880 substrate.

Source: Own elaboration in the Ansys HFSS software

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Box 13

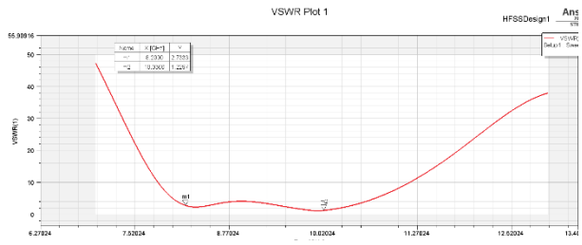

Figure 13
VSWR parameter result of Vivaldi antenna with RT duroid 5880 substrate
Source: Own elaboration in the Ansys HFSS software

Conclusions

The difference between the simulation of both antennas is remarkably large only with the response to the reflection coefficient (parameter s11), in the first case, in which the substrate is bakelite we can observe that the lowest value of the response signal is around 8 GHz while for the simulated antenna with RT duroid 5880 substrate it is very close to 10GHz. It should be remembered that these results are experimental and work continues with them in research projects.

It is important to mention that this work did not receive funding from any research program, however, it is part of a preamble for projects that will be carried out in the following months for the development of new technology.

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