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Wideband Characterization of Micro strip Technologywith Boro float 33 and Some Classic Transparent Glasses

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Abstract: In this study, we used a broadband characterization approach of microstrip technology based on the S-parameters to determine the technical quality of borofloat 33 glass and other considerably cheaper conventional glasses, coupled with solid metallization. This allowed for the extraction of electromagnetic properties (dielectric permittivity, tangent loss) critical to the development of low-profile antennas. Then, using a vector network analyzer (VNA), the values of nodes S11, S33, S12, and S34 are retrieved. ADS software is used to analyze the measurement data and calculate the loss tangent and dielectric constant. We found r = 6.5 and tan = 0.0206 for the classical glass, r = 6.15 and tan = 0.021 for the microscope glass, and r = 4.5 and tan = 0.012 for the borofloat 33 glass.

Keywords: *glass, dielectric permittivity, tangent loss, S parameters, transparent antenna*

1. Introduction

The proliferation of wirelessly linked things has resulted in an increase in the frequency with which antennas are encountered. Among the many obstacles that must be overcome, the most significant are the minimization of antennas' aesthetic effect and their incorporation into communication equipment. This is why there is a pressing need for affordable, low-profile, or even completely invisible antennas to be mass-produced. Whiches will enable the adoption of antennas on glass surfaces (buildings, automobiles, cellphones, etc.) and their placement on historic places and retail centers to not only increase network coverage but also for more discretion to the public owing to their looks. Because of their size, weight, and other physical characteristics, planar antennas may be thought of as separate entities [1]. and they make it possible to use miniaturization strategies. Planar antennas need the use of both dielectric and conductive components in their construction. Glasses and so-called "plastic" materials are the two major groups to look at if dielectric properties are of primary importance.

IoT, or the Internet of Things, is driving the need for novel materials in a wide variety of areas and daily uses (health, industry of the future, automotive, etc.). These interconnected items may be built on any media, but they all need to be able to exchange data with the outside world. Therefore, we need to be able to create antennas on a wide range of substrates. First, we'll look at materials like borofloat 33, whose guaranteed properties can be verified through this work, and then we'll move on to slightly more "low cost" solutions, whose transparency properties are also guaranteed but for which no estimate has been made of the value of fundamental electromagnetic parameters for the design of antennas, such as the relative permittivity and the loss tangent of the dielectric substrate.

Because it allows for accurate sizing of antennas and, hence, exact prediction of their frequency characteristics prior to manufacture, electromagnetic characterisation of materials has become more significant, if not crucial [2]. Although there are a lot of different ways to measure materials, they may be broken down into two categories: broad-band (transmission lines) and narrow-band (resonant cavity, waveguide, free space).

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The material may be characterized at a single frequency or at a range of discrete frequencies using narrowband techniques that use a cavity resonator. They may be broken down into two categories: - The first is the dielectric resonance method, which uses the dielectric material itself as a resonant element, but is only applicable to low loss samples.

In the second method, known as the perturbation technique, a tiny sample is placed within a resonant cavity to generate a field disturbance, and therefore, a resonant frequency.

range of frequencies of the transmission and reflection coefficients resulting from characteristic changes in impedance and wave speed. The classification of materials is then done by determining the electromagnetic parameters of the substrate under test from these coefficients.

$\gamma = j$

2. Presentation of the Technology Used

The electromagnetic characterization method used is abroadband measurement method. In this method, only thefundamental waveguide mode (TEM mode in the coaxiallines, quasi-TEM mode in transmission lines and TE_{10}mode in the waveguides) is assumed to propagate. Thistechnique takes into account the fact that the dielectricsubstrate will be used in microstrip technology for thedesign of the antenna, ie with metallization above / below.A measurement using this method involves placing a sample in a section of waveguide line or coaxial line and measuring the diffusion parameters of the two-port complex with a vector network analyzer (VNA) (Figure 1).

The method comprises measuring the reflected (S_{11} or diffusion parameters are closely related to the complex permittivity and the permeability of the material by equations. For an accurate dielectric measurement, the maximum electric field is required in the sample. Figure 1 illustrates the typical measurement setup with a coaxial cable. This technique is relatively easy to be implemented both in measurement and in the process of extracting parameters.

For TEM mode, the complex relative permeability andpermittivity can be found as [6]:

shift [3]. This method may be used with both low- and medium-loss samples.

Attenuation coefficient and phase constant may be calculated from the propagation constant using the relation

Transmission lines are used in wideband techniques, allowing measurements to be taken across a broad frequency range.

$\gamma = \alpha + j\beta.$

(1)

For a dielectric material, the propagation coefficient of a wave in a transmission line is related to the complex permittivity of the filler material through the relation [4]:

(2) $$\sqrt{\frac{\omega^2\mu_r\varepsilon_r}{c^2} - \left(\frac{2\pi}{\lambda_c}\right)^2}$$

Where ω is the angular frequency, μ_r is the permeabilityof the material which is equal to 1, c is the speed of light and, λc is the cutoff wavelength of the transmission line.In case of a coaxial transmission line supporting TEM propagation the cutoff wavelength is taken to be equal to infinity. $\varepsilon_r = \varepsilon'_r + j\varepsilon''_r$; is the complex permittivity of the material filling the line where, ε' is the dielectric constant and ε'' is the dielectric loss of the medium. From equation 1 it becomes possible to extract the complex permittivity of the material filling the transmission line.

(2)

S_{22})and transmitted (S_{21} or S_{12}) parameters. The relevant

(3) —

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The advantages of using the transmission / reflectionline include:

- Coaxial lines and waveguides are commonly usedto measure samples with medium or high loss;
- They make it possible to more easily determine thepermittivity, the permeability and the loss tangent

of the material tested.

However, this broadband measurement technique alsopresents some constraints:

- The precision of the measurements is limited by theeffects of the air gap.
- It is limited to low precision when the length of thesample is the multiple of half the wavelength of the

Where Zs is the characteristic impedance of the sample, Z0 is the characteristic impedance of air for the same dimensions, λ is the wavelength of free space, and γ is the propagation constant which is determined by function of the S parameters as follows:

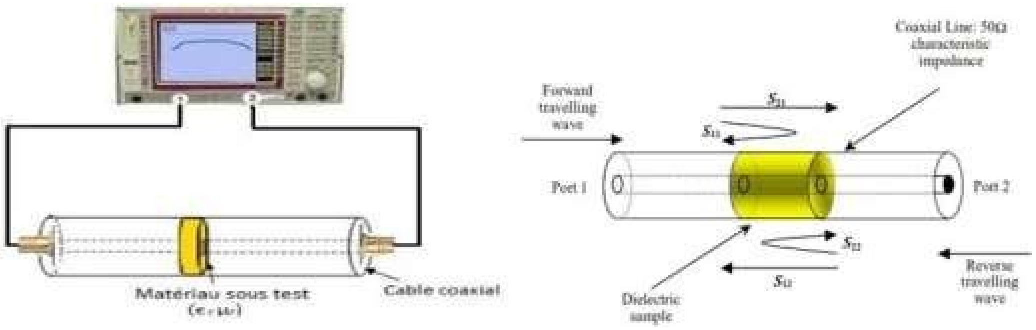

Figure 1. Measurement technique of a dielectric substrate taking into account the application to which it is intended i.e. antenna design [5]

3. Materials and Methods

This broadband microstrip characterization techniquewas first applied to two conventional glasses (typically microscope glass and classic glass) and whose transparency is around 90% in the visible range, then to borofloat 33 which has 92% transparency (supplier data). The idea is to work with transmission lines of clearly different impedance than 50 Ohms in order to generate sufficiently clear mismatches to be able then to associate a model with the measurement and to identify the values of the parameters ε_r and tan_δ which allow to fit the model to measure. On each glass, we put two metallizations with copper 35um thick. The upper metallization comprisestwo lines and the lower metallization constitutes the ground plane. On each line we have two 50 Ohm ports.

One of the 0.4 mm wide lines has an impedance greater than 50 Ohms and the second, 8 mm wide, has an impedance less than 50 Ohms (Figure 2).

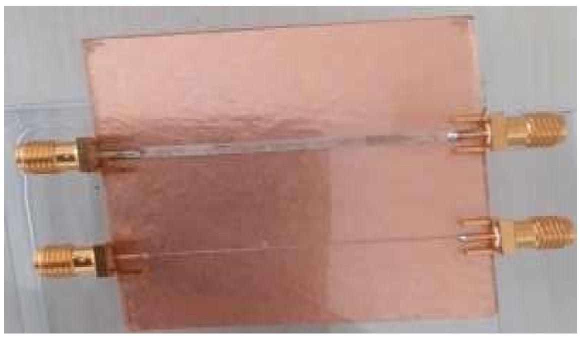

Figure 2. Realization of lines

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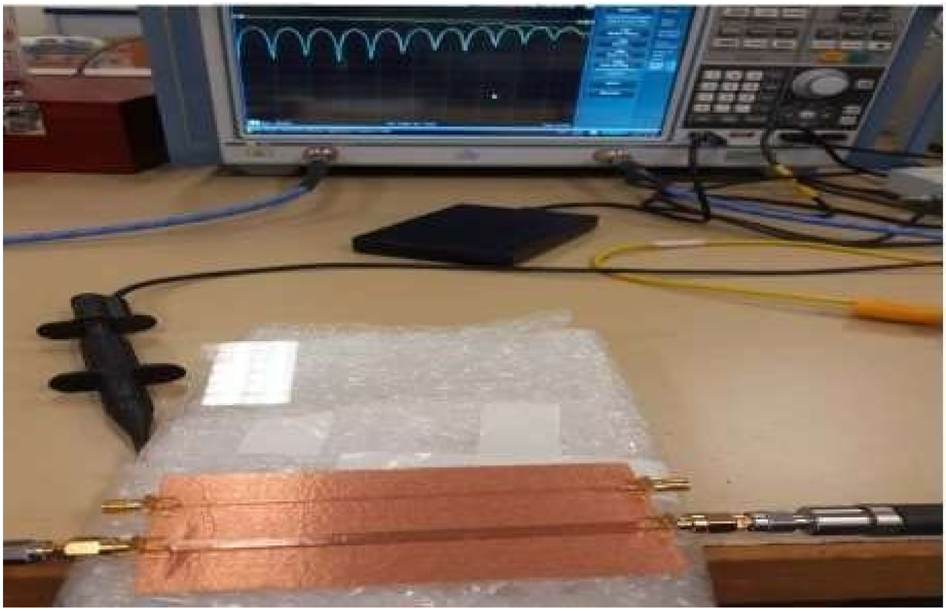

Figure 3. a) measurement configuration on VNA

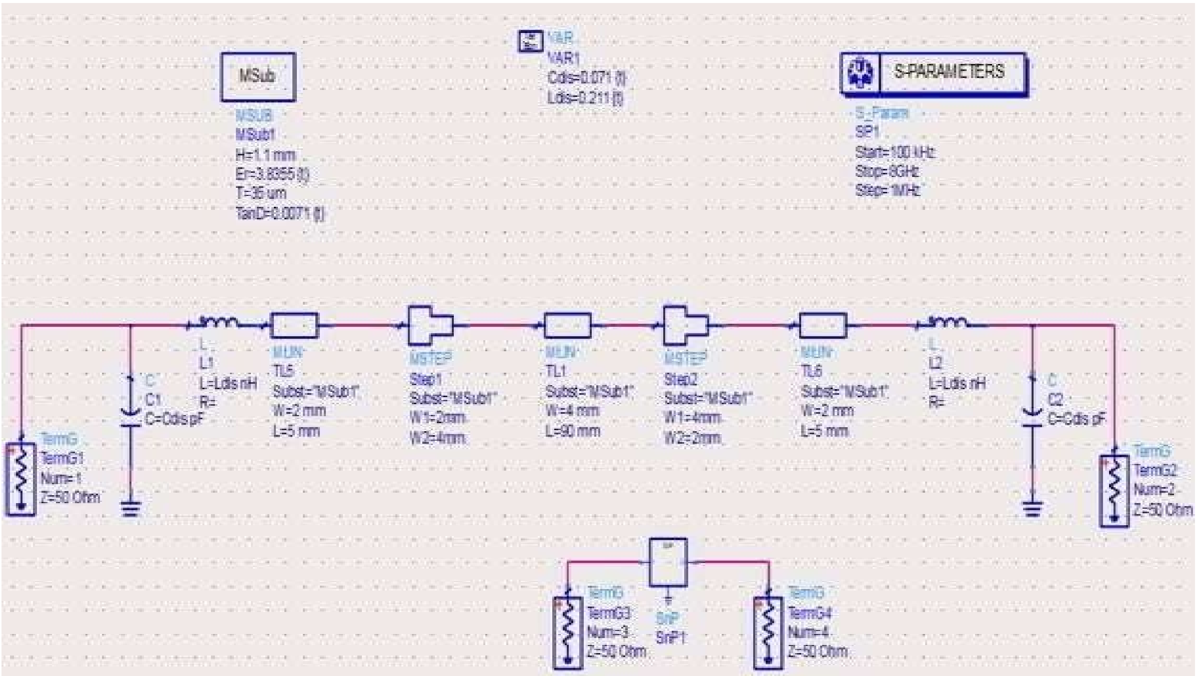

Figure 3.b) Modeling on ADS

After calibrating a network analyzer (VNA), reflection and transmission coefficients or parameters S were measured. Different but common terminations (such an open load, short circuit, or 50 ohm load, for example) need a primary calibration step. Thus, for each line linked to the VNA, we get its realistic values of the parameters S (Figure 3a). The created lines are then simulated in a one-dimensional environment using the ADS (Advanced Design System) program. The form and size of the resulting lines inform the development of the comparable model. Each line has two 50-Ohm ports at its ends, which are represented in Figure 3b by a pair of 50-Ohm generators series-connected to a capacitor C and an inductor L. A 50 Ohm wire is linked to each of the ports. The two ports' 50 Ohm lines are then joined by a third, separate line with the same impedance. To achieve this agreement between the theoretical (on ADS) and actual (on VNA) response curves, the values of the electromagnetic parameters (r and tan) and the values (C and L) of the components used in the port models are tweaked. This allows one to calculate the loss tangent and the dielectric constant of the material.

Simulation and measurement Results

Classic Glass

A classic glass is a common and affordable drinking vessel. The results of the measurements used to describe it are shown in Figure 4. The blue lines show experimental findings obtained with the VNA, whereas the red lines indicate ADS modeling results.

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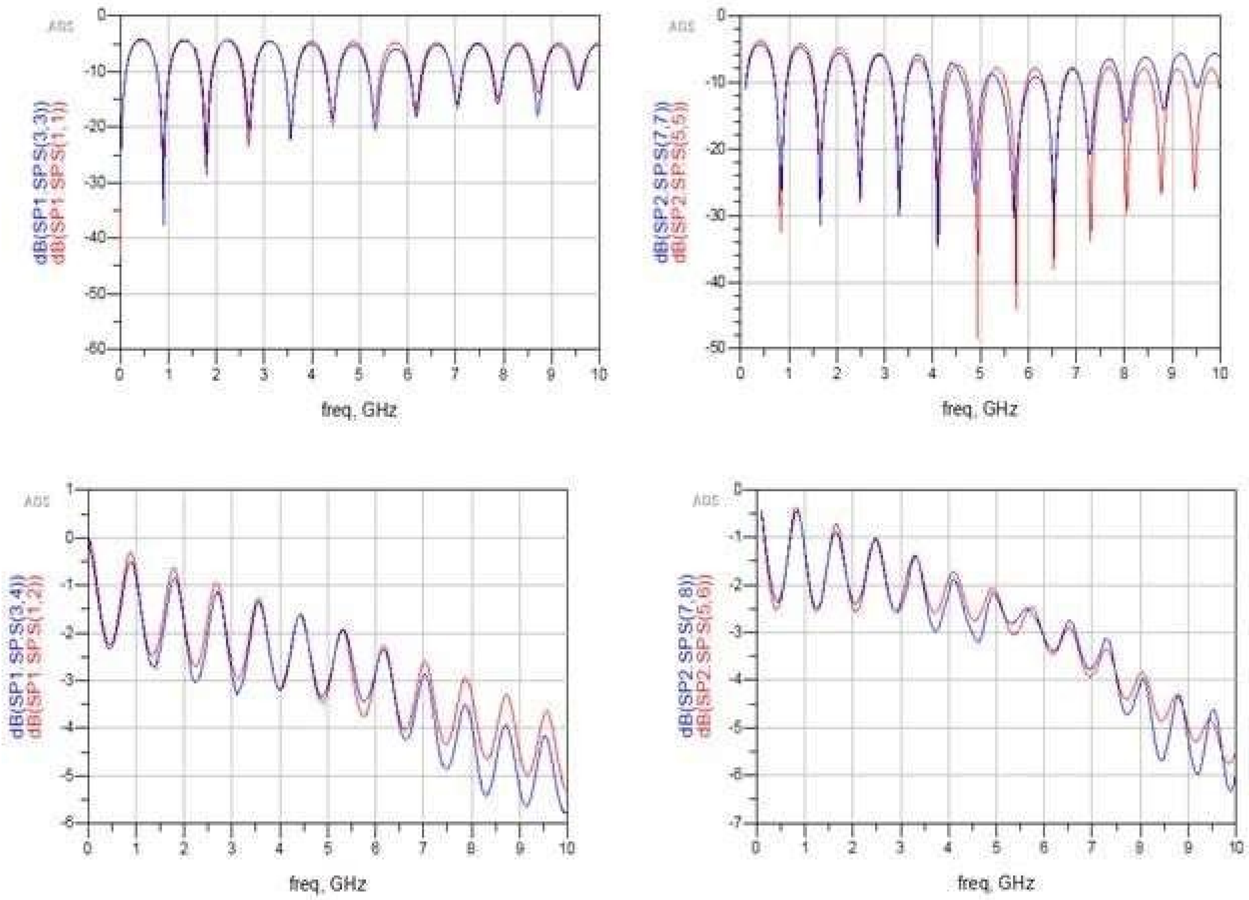

a) b)

Figure 4. Frequency responses of conventional glass. a) the impedance line Z <50 Ohm (8mm); b) the line of impedance Z> 50 Ohm (0.4mm)

Since it may be well correlated with the experiment, the model works well up to 8 GHz. The relative permittivity and loss tangent may be extracted with sufficient accuracy to enable a high-quality antenna design in this frequency range. We measured a loss tangent of 2.06102 and a dielectric permittivity of 6.5. For the antenna's layout, these parameters, especially tan, remain large.

Miniaturization is helped by a high dielectric permittivity value, however this reduces the radiation available.

Microscope Glass

As with conventional glass, we made the same measurements with a glass used in microscopy. We obtained a relative dielectric constant $\varepsilon_r = 6.15$, which is relatively smaller than that of conventional glass and a loss tangent $\tan\delta = 2.1\ 10^{-2}$. The resonance curves of the S parameters are shown in Figure 5.

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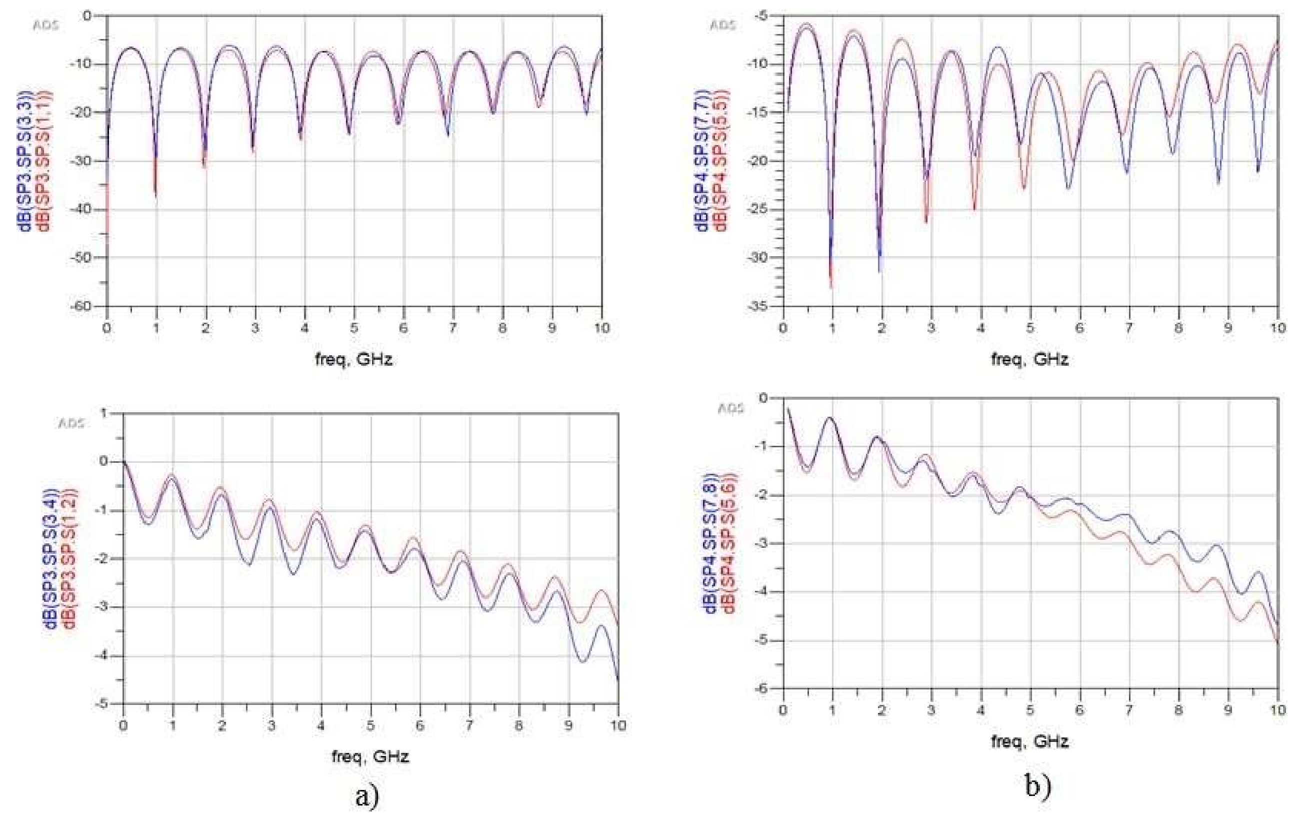

Figure 5. Frequency responses of the microscope glass a) the impedance line Z <50 Ohm (8mm) b) the impedance line Z> 50 Ohm (0.4mm)

The electromagnetic parameters of this type of glass are close to those of conventional glass in terms of loss, as are the resonance curves of the S parameters. The microscope glass can therefore be used in the same devices as conventional glass.

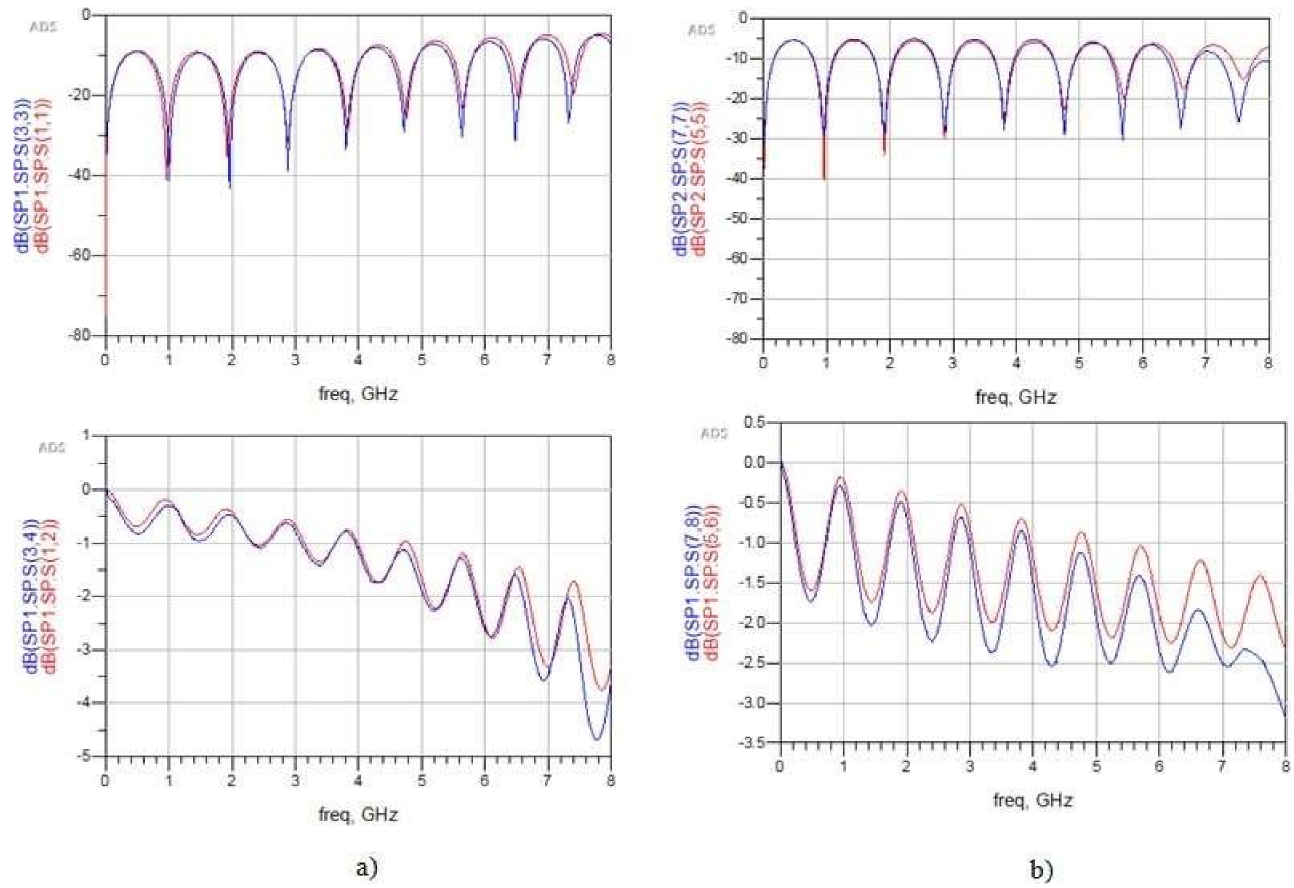

Figure 6. Frequency responses of borofloat 33 glass. a) the impedance line Z<50 Ohm (8mm), b) the impedance line Z> 50 Ohm (0.4mm)

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Borofloat 33 Glass

By the same method as above, Figure 6 shows us the reflection and transmission coefficient resonance curves ofborofloat 33. These resonance curves of the S parameters offer good performance in the 0.1 GHz - 8 GHz band. We obtained εr = 4.5 as the value of the dielectric permittivity and tanδ = 0.012 as the value of the loss tangent. Boroflaot 33 has a dielectric permittivity and a loss tangent lower than those of the first two glasses (Table 1).

Table 1. Comparison between the values of the electronic parameters of some glasses

Glasses	Frequency band (GHz)	s_r	*tantt*
Classic glass	0 à 8	6.5	$2.06.10^{-2}$
Microscope glass	0 à 8	6.15	$2.1\ 10^{-2}$
Borofloat 33 glass	0 à 8	3.9	$1.2\ 10^{-2}$

4. Conclusion

To construct antennas with minimal aesthetic effect and manufacturing expense, we were able to identify their corresponding dielectric characteristics in this article. It first describes the electromagnetic characterisation technique that was used to study the glass substrates in the development of see-through antennas. There are several benefits to using this approach. Broadband in nature, it may be used to determine the loss tangent and relative dielectric permittivity of a dielectric substrate across a range of several gigahertz. Depending on how precise the model is, this extraction may be performed on a very unimportant frequency spectrum. In addition, the configuration/technology that will be used for the design of the antennas is used for the extraction of the substrate's properties. Instead of focusing just on the substrate, as is the case with certain characterisation methods, this approach characterizes the technology used in the design of the antennas. In contrast, the relative values of permittivity and loss tangent that may be predicted from this sort of material on relatively conventional glasses or on glasses suited for RF applications are shown in this article. With its low dielectric permittivity and appropriate loss tangent, borofloat 33 is the ideal candidate for realizing an antenna with little aesthetic effect and minimal expense.

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