RESEAUX DU FUTUR : 5G ET AU-DELA

Caractérisation de matériaux diélectriques jusqu'à 330GHz : une technique de mesure en espace libre sans filtrage temporel

Dielectric material characterization up to 330 GHz : a free space S-parameter measurement technique without time domain gating

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Résumé/Abstract
This paper presents the implementation of free space S-parameter measurement setups in the Ka, W and J bands. The complex permittivity extraction is performed without any specific processing on the S-parameters from 26 up to 330 GHz. The comparison between the measured and simulated four S-parameters (magnitude and phase) shows very good agreement and validates the test benches as well as the calibration procedure.

1 Introduction

Millimeter waves up to THz are increasingly being used or foreseen in various applications such as 5G (backhaul), RFID tags to analyze the risks associated with aging structures, imaging (non-destructive control, security), automotive radars, radiometry, ... Regardless of the application, the complex dielectric permittivity of materials is a key parameter in the design and optimization of microwave devices and systems. Moreover, the study of the propagation and the interactions of waves with the environment also requires a precise knowledge of these characteristics.

This paper presents the implementation of tests benches from 26 GHz to 330 GHz in 3 normalized frequency bands: Ka, W and J. The measured S-parameter of a dielectric material slab are used to extract the complex permittivity and the validation of the extraction results is carried out by the comparison with the four S-parameter analytical model, in magnitude and phase.

2 Test bench description

The "quasi-optical" test benches allows us to measure the free space S-parameters of a dielectric slab placed between two GOLA (Gaussian Optic Lens Antenna), as shown in Fig. 1 and 2 [1] [2] [3] [4].

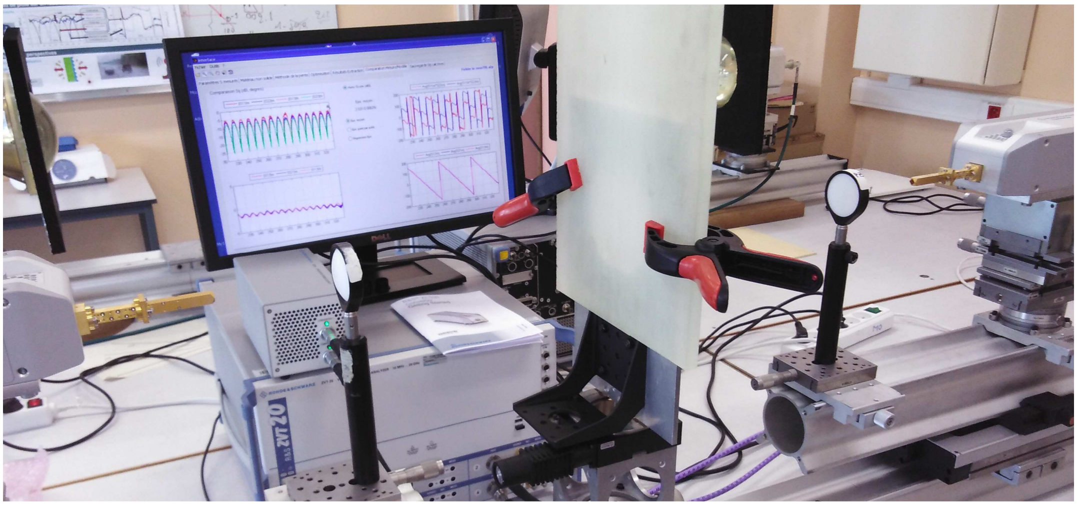

Fig. 1 : Quasi-optical test bench in the J band with a Rexolite slab under test

Such specific antennas are realized using a horn and a lens [1] [2] to obtain a focused or paraxial gaussian beam depending on the waist to wavelength ratio.

The higher the ratio, the more paraxial the beam. Therefore, the waist is the optimal position for the free space S-parameter measurement of a device under test (dielectric slab, frequencies selective surfaces, polarizer, etc.) without filtering and time gating [3] [4].

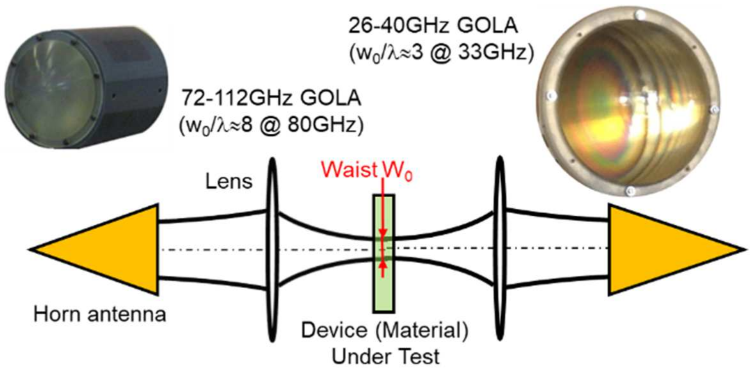

Fig. 2 : Gaussian beam focused to obtain the waist

3 Material characterization

The permittivity extraction is carried out using the analytical model of a dielectric slab whose parallel faces are under normal incidence of a plane wave (see Fig 3 : dielectric slab model). The free space Thru-Reflect-Line (TRL) technique is used for the setup calibration as described in [3] [4].

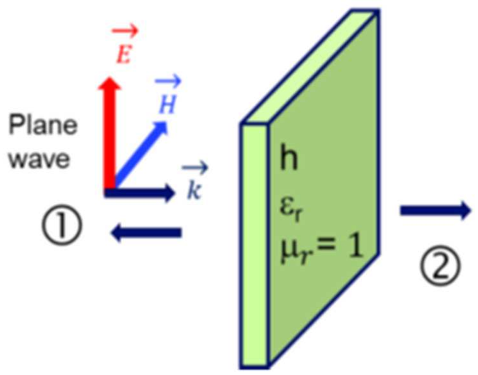

Fig 3 : dielectric slab model

As the slab thickness is measured with a caliper, the relative complex permittivity can be extracted at each frequency point only from the measured S_{12} and S_{21} parameters (magnitude and phase). The S_{11} and S_{22} coefficients are used to refine the slab thickness by comparing the measured and simulated S-parameters [3] [4]. The extraction result performed in the Ka, W and J bands for a 12.815 mm Rexolite slab is shown in Fig 4.

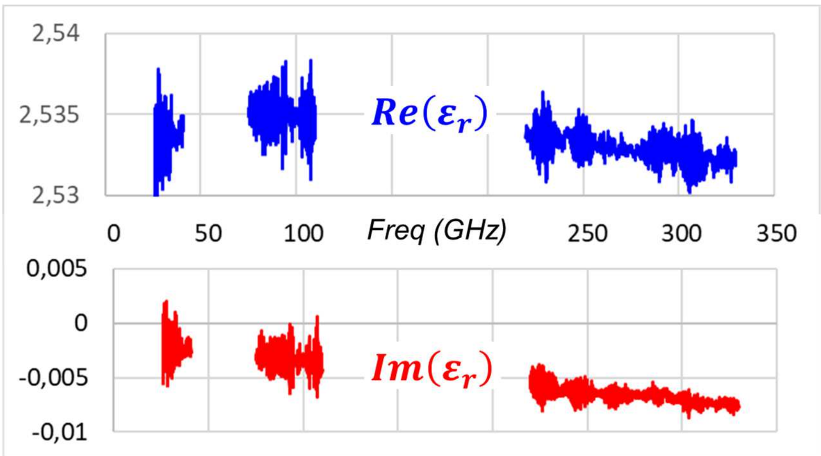

Fig 4 : Extracted permittivity (real and imaginary parts) of a Rexolite slab

Given the very small change of the permittivity over the frequency bands, the mean values with their standard deviations are calculated. Some materials have frequency-dependent complex permittivity. For such materials, a linear regression or a Debye model can be fitted [5].

4 Validation results

To validate the permittivity extraction, as well as the S-parameter measurement, we performed the comparison in magnitude and phase between the simulated and measured S-parameters. As an example, Fig 5 shows the results obtained using the mean values extracted in the J band. We also analyze the linear regression of the permittivity and if necessary we can extract a model (Debye, ...).

Very good agreement is demonstrate without any preliminary data processing of the calibrated S-parameters.

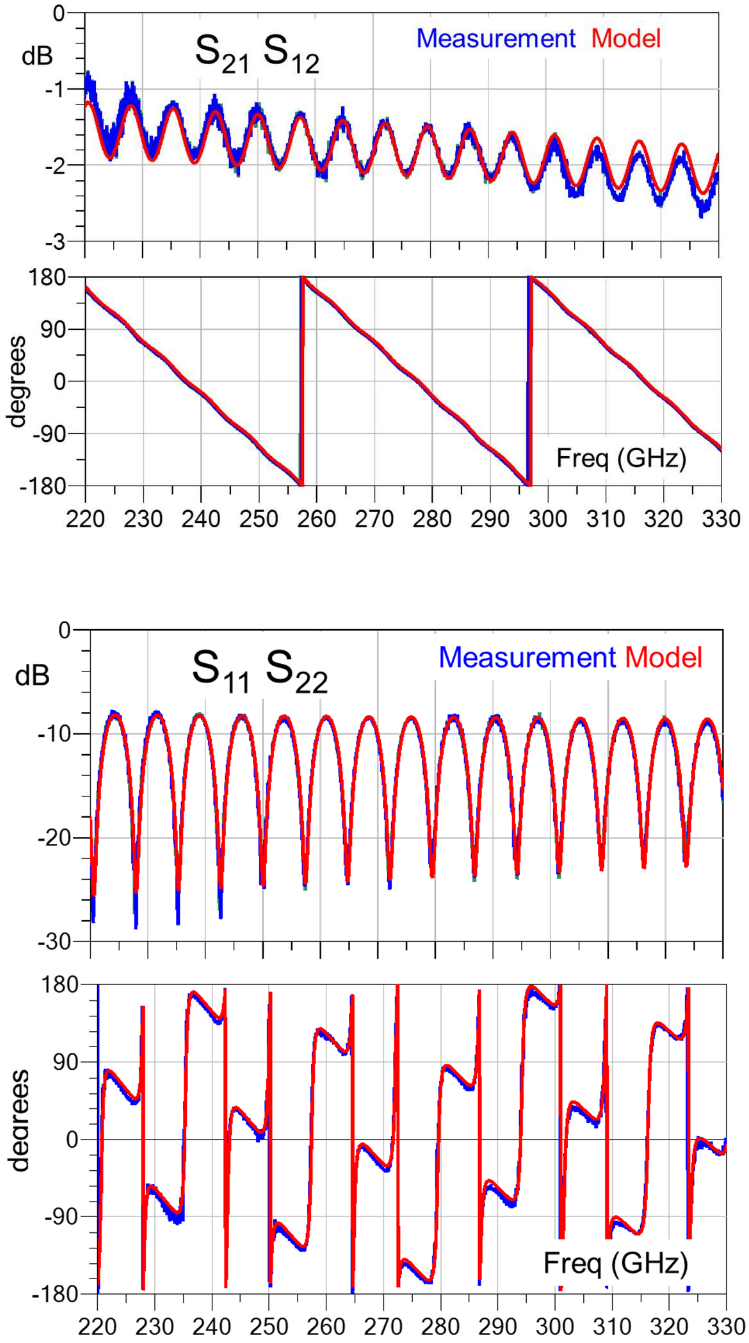

Fig 5 : Comparison between measured and simulated S parameters of the Rexolite slab in the J band

5 Current developments

Processes use powders and liquids to make a solid material. We could be use the same characterization method to extract the dielectric properties for non-solid materials (powder or liquids) [5]. It is then possible to define a database or a model to predict the desired property.

Multi-layers materials is be also tested but painted materials have very low thickness and the method is very sensitive. As well as S-parameter measurement under incidence angle of the beam, we investigated multilayer properties extraction.

The ACC radar operates around 77 GHz. In these frequency ranges, rain has high propagation losses which disturb the operation of the radar. In addition, the runoff of water on a bumper (radome) disrupts its transfer function. In our laboratory we have made such measurements that we will model in order to integrate this phenomenon in a radar simulator [6].

6 Conclusion and perspectives

We present a free space S-parameter measurement technique in the Ka, W and J bands. Very good results, repeatability and precision are demonstrate through the comparison with the theoretical model.

The D band setup (110-170 GHz) is also under progress. FSS (Frequency Selective Surfaces) and metamaterial can also be measured.

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