Material test: RF Permittivity and Permeability

Measuring Using Waveguide ASTM D7449 14

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Complex Permittivity and Permeability

The complex permittivity ϵ_r^* represent the proportionality factor of electric displacement field and electric field [2]. It depends on the characteristinc of the meterials, i.e. polarizabiliy, charge mobility and so on. So:

$$\epsilon_r^* = \epsilon_r^{'} - j\epsilon_r^{''} = \frac{\vec{D}}{\epsilon_0 \vec{E}} \tag{1}$$

where: ϵ_0 = the permittivity of free space, equal to $8.854 * 10^{-12} F/m$, $\vec{D}$ = the electric displacement field vector, $\vec{E}$ = the electric field vector.

Definition

The complex permeability μ_r^* represent the proportionality factor of magnetic field and magnetic field intensity [2]. It depends on the characteristinc of the meterials, i.e. magnetic moment, magnetization and so on. So:

$$\mu_r^* = \mu_r^{'} - j\mu_r^{''} = \frac{\vec{B}}{\mu_0 \vec{H}} \tag{2}$$

where: μ_0 = the permeability of free space, equal to $4\pi 10^{-7} H/m$, $\vec{B}$ = the magnetic field vector, $\vec{H}$ = the magnetic field intensity vector.

The importance of knowing of ϵ_r and μ_r

It is known that permeability and permittivity change as a function of frequency. For example, a plastic material such as theflon maintains its properties up to a few GHz but then changes. The increase in RF frequencies used in devices makes it increasingly important to know the permeability and permittivity values of the materials used. The high-frequency insulating materials are not transparent and therefore it can happen to encounter problems related to radio transparency that can significantly reduce the performance of the devices. There are also many new materials made with nanotechnologies that require a correct knowledge of the permittivity and permeability values [1].

The EMC and radio test requires the knowledge of these values. Alot of standards indicate to use for the test supports with $\epsilon_r < 1.2$, however very often the laboratories use supports found on the market of which they do not know the value of this parameter at all. Anyone with experience in radio testing will have noticed that if the radio source is too close to a plastic support, the measured values can change by more than $6dB$ even at relatively low frequencies (above 2GHz). Furthermore, the aging of the insulating supports and humidity modify the value of ϵ_r with strong impacts on the uncertainty of the measurements.

Simulation

Electromagnetic simulation has become and will become increasingly important in device development. To obtain results close to the real values it is very important to use accurate models of the components and materials. From the above considerations, it is evident that the knowledge of the parameters ϵ_r and μ_r in frequency is of fundamental importance for a quality simulation.

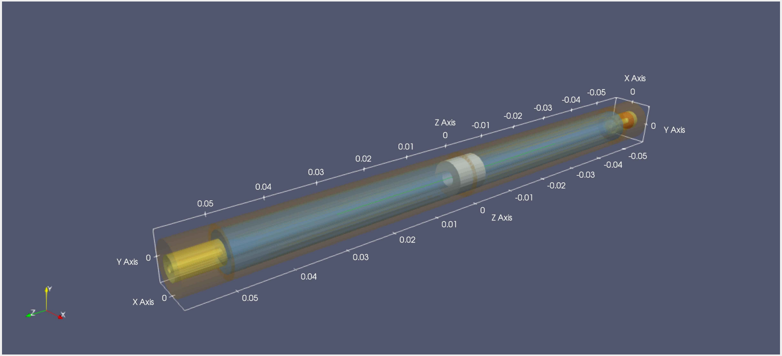
EXONX SERVICE FOR THE ϵ_r AND μ_r MEASUREMENT

Coaxial Line Method

In the literature there are alot of methods for the determination of permeability and penetivity. EXONX offer services to the industry and therefore we have preferred standard methods. These methods are well defined and allow to obtain homogeneous results between workshops. The other solutions available on the market are essentially internal methods that bring with them all the problems related to the validation of the method in accordance with ISO 17025. The standards available are:
ASTM D7449 14: use the coaxial air line
ASTM D5568 14: use a weaveguide
The advantage of the coaxial air line method is that it allows you to make a broadband measures from DC up to 18GHz, for this reason it has been selected.

Preparation of the sample: the test fixture

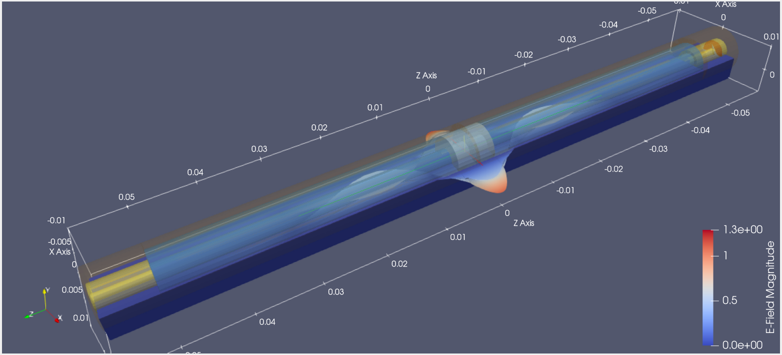
The sample is inserted in a 7mm coaxial line made very accurately. The airline used is the Agilent Technologies 85051B 7 mm Verification Kit. This is the 3d model of the line:



The material under test (MUT) was placed in the center.

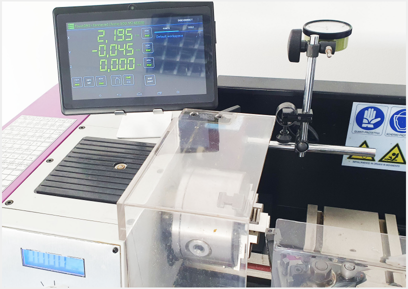
Preparation of the sample: the test signal

The terminals of the line only connected through APC 7mm connector to Port 1 and Port 2 of the VNA. A large bandwidth sign is launched on the port1 and the S11 and S12 parameters from which it will be calculated ϵ_r and μ_r. Below is the simulation of what is happening



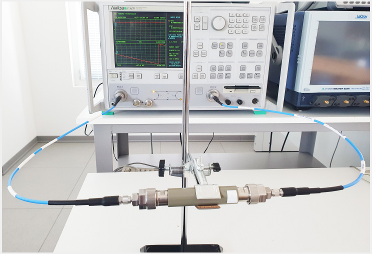
The MUT modify the signal that acording to ϵ_r and μ_r.

The size of the material must be chosen according to the type of material and the processing must be very accurate. In Exonx we use a precision lathe.

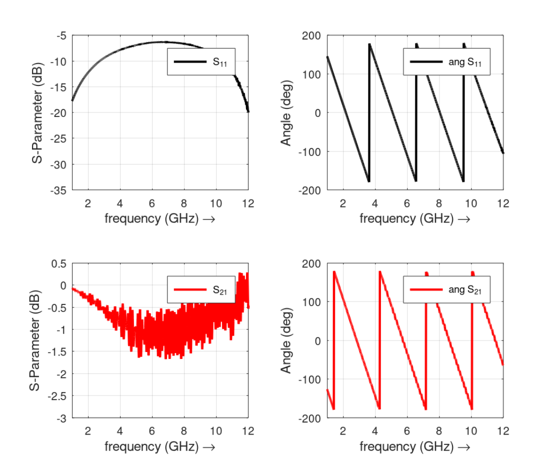


Preparation of the sample: measurement

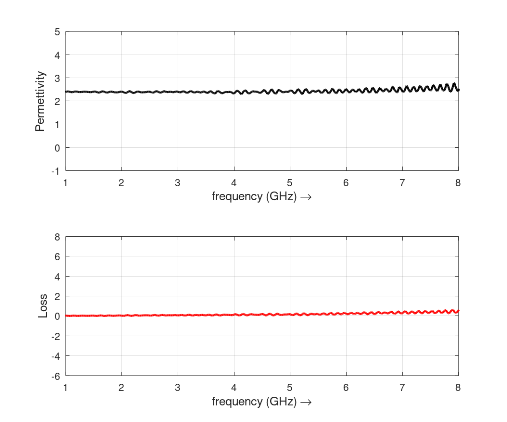
When the sample is ready, it is inserted in the fixth and therefore the size is made with the newly calibrated VNA in a very accurate way



The result of the measurement of the scattering parameters that is obtained for a cynindro of Tefon measured from 1 to 12GHz is as follows:



The calculation of ϵ_r and μ_r can be performed essentially using two methods: *NRW algorithm* or *Iterative Four-parameter Algorithm*. The second is better because it depends less on the positioning of the MUT. In this example $\mu_r = 1$



Thanks for youe attention.
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Notes