MEASUREMENTS FOR THE VALIDATION OF AN ELECTROMAGNETIC SOLVER

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Abstract

A measurement campaign with a vector network analyzer has been conducted to validate the results obtained by a numerical simulation of electromagnetic scattering from a dielectric body. A previously adopted test procedure is reconsidered and modified in order to gain more reliable results to compare to simulated data. To this purpose, the size of the investigated object has been increased to better approximate the ideal condition of infinitely extended medium and the probing session has been performed in a more controlled environment.

1 Introduction

In [1], it is described a measurement setup and procedure used to validate an electromagnetic solver included in a backscattering-based procedure for the nondestructive estimation of the permittivity range profile of a layered dielectric object [2].

The results presented were highly questionable for the poor match between the ideal conditions and the actual measurement geometry, especially under the respects of the assumed plane-wave illumination and infinite extension of the body under test in all the direction orthogonal to the line of sight.

Here, I report the results of a new measurement campaign intended to gather a data set that is more comparable to the simulated one. Instead of the small, high-permittivity tiles used in [1], I used $1\times 1 \times 0.01$ m^3 plexiglas slabs, with a permittivity of about 2.5 at the relevant working frequency, and a styrofoam slab of the same size, with a permittivity of about 1. The measurements have been subtracted of the background radiation, measured separately in the absence of any target, and normalized against the response of a perfectly conducting surface (PEC), simulated by a thin copper plate of 1×1 m^2.

2 Measurements

In this section, I show the results of the new measurement campaign. For details on the measurement system refer to [1]. In this campaign, the object under test were single dielectric slabs or sandwiches placed at a distance of about 2 m from the phase center of the probing/sensing antenna. All the results shown, except for the environment case, are obtained by normalizing the measurements with respect to a thin copper plate of the same size as the dielectric test objects. For more details on this, please refer to [1].

Case #1: Environment & PEC
After the calibration, we have measured the scattering produced by the background environment in order to subtract its contribution to all the other measurements done by using the probed samples.
In order to properly normalize the collected data, we have measured the field scattered by a PEC plate of the same size of the other samples. Following this procedure we do not need to know the exact frequency behavior of the gain and the distance between the antenna and the sample to calculate the attenuation in free space. In Fig 1-2, the magnitude of the reflection coefficient of the environment and PEC plate measurements are reported and compared.
In Fig.3, the red line is the phase measured for the PEC case. After the application of a linear offset the phase lies close to the dashed gray line at -180°. This increment in the offset is due to the practical difficulties met during the port extension procedure which does not allow the exact location of the reference plane.

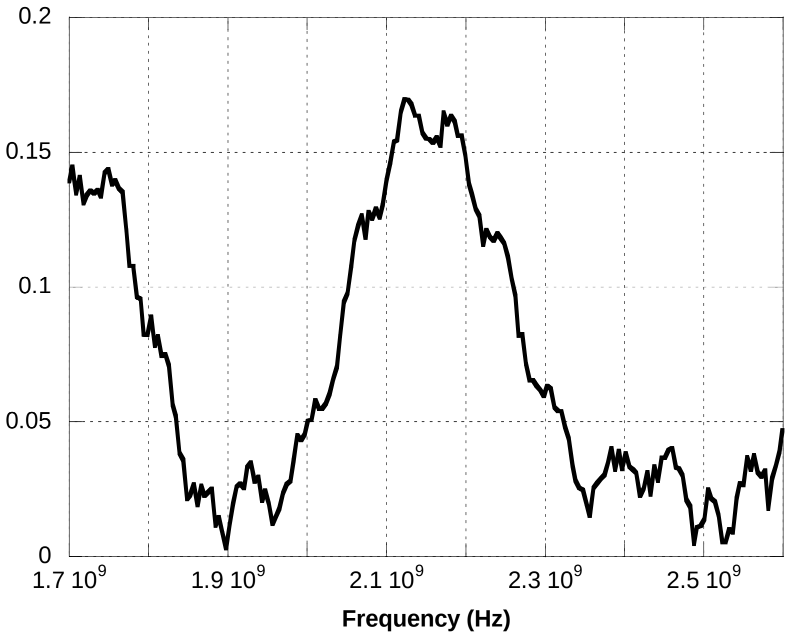


Fig. 1 – Average magnitude of the reflection coefficient measured after calibration and port extension.

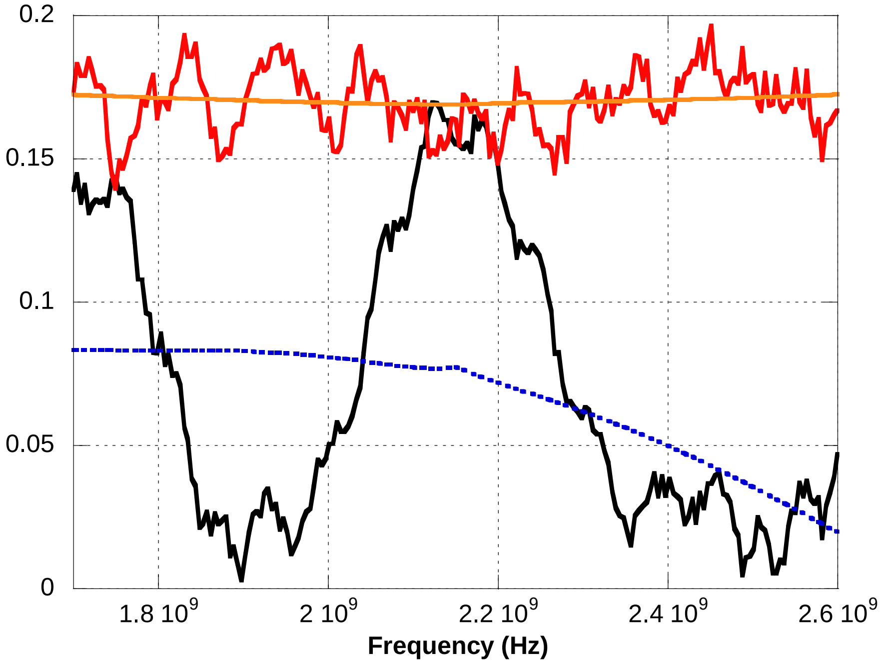


Fig. 2 – Comparison between the magnitude of the reflection coefficient of the environment (black line) and PEC sample (red line). The blue dotted line is the smoothed average of the environment while the continuous orange one regards the PEC plate.

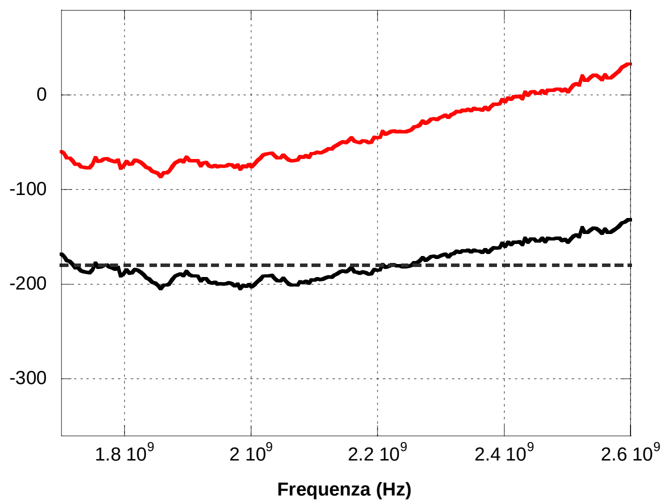


Fig. 3 – Phase of the reflection coefficient for the PEC case. The red line is the phase measured after the Port Extension, the black one is the shifted phase and the gray dashed line is -180°.

Case # 2: Single Plexiglass slab

For this analysis we have considered a single plexiglass slab (ε_r= 2.5) one centimeter thick. As previously said, we have subtracted from the measurements the contribution due to the background and normalized with respect to the PEC case. In Fig.4, it is possible to compare the magnitude of the reflection coefficient, while in Fig. 5 the polar plot allows us to have a simultaneous view of the magnitude and phase comparison.

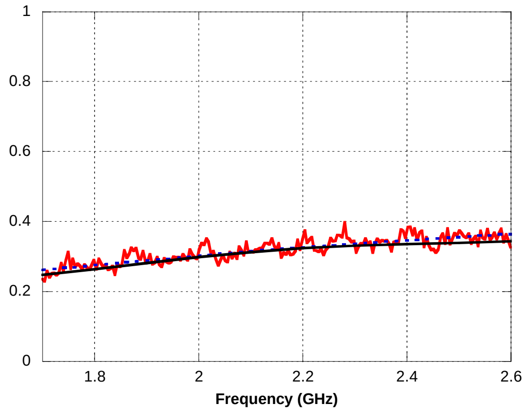
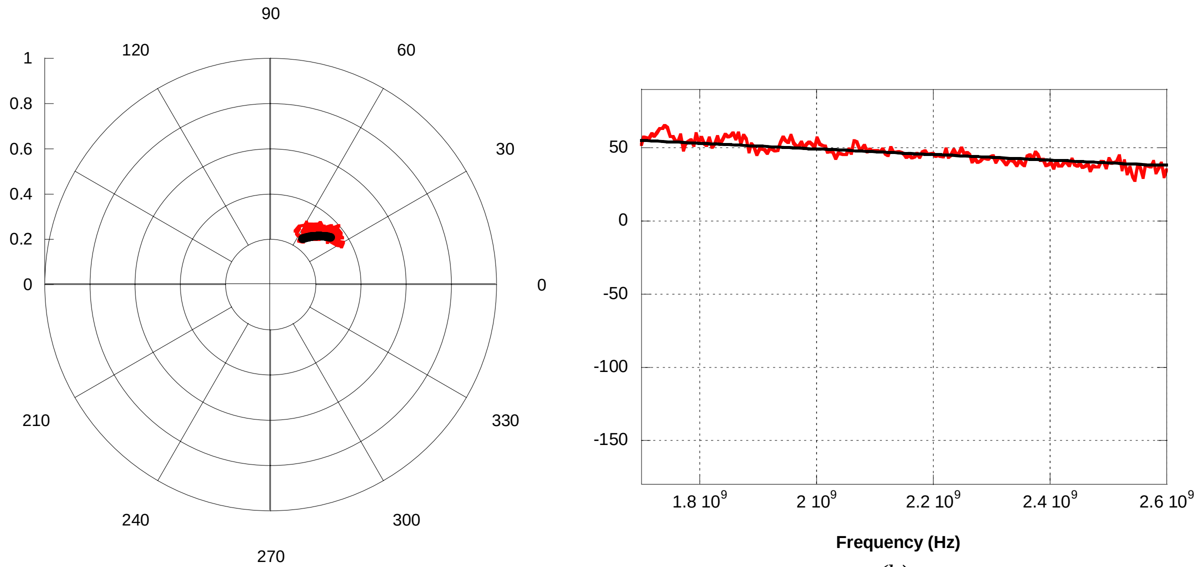


Fig.4 – Comparison between the magnitude of the simulated and measured reflection coefficient for the single slab of plexiglas. The black line is the simulated one while the red curve is the result of the probing session. The blue dashed line is the smoothed average of the measured data.



(a) *(b)*

Fig. 5 – (a) Polar plot of the simulated data (black line) and the measured values (red line); (b) Comparison between the phases of the simulated and measured reflection coefficients for the plaxiglas sample (black: simulated data, red: measured data).

Case #3: Plexiglas-Air-Plexiglas

The last case analyzed is a three-layer medium composed by two slabs of plexiglas containing a void layer. Both the slabs and the void are one centimeter thick. The void has been simulated by a styrofoam slab of the same size as the plexiglas slab. In Fig. 6, the simulated and measured magnitudes of the reflection coefficient are compared.

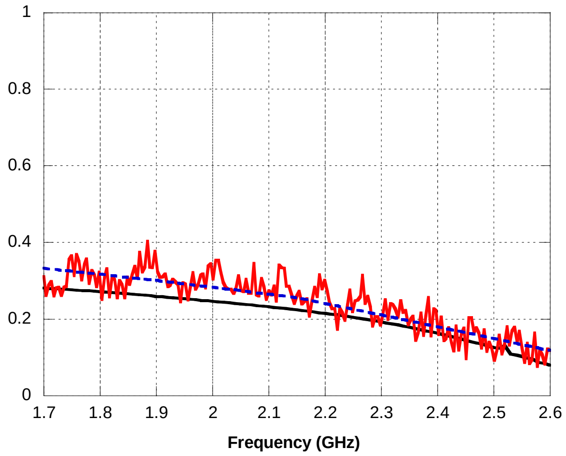


Fig. 6 – Comparison between the magnitudes of the simulated and measured reflection coefficients for the composite structure (plexiglas-void-plexiglas). Black: represents the simulated data. Red: measured data. Blue: measured data smoothed by moving average.

In Fig.7, the phase of the computed reflection coefficient is compared with the measured one.

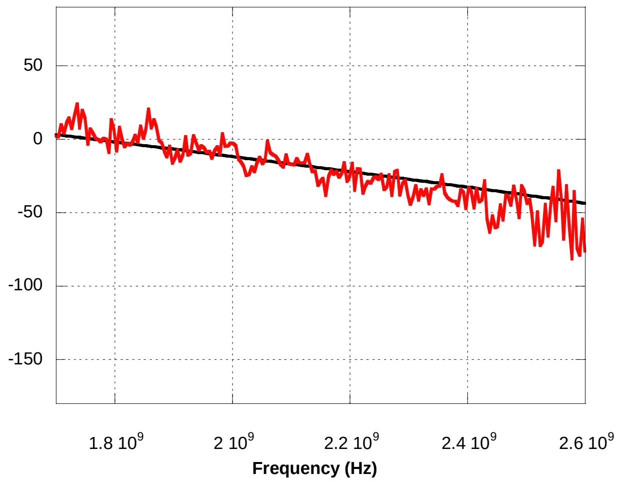


Fig.7 – Comparison between the phases of the simulated and measured reflection coefficients for the composite structure (plexiglas-void-plexiglas). Black: simulated data. Red: measured data.

3 Conclusion

The results obtained in this measurement campaign agree very well with the data predicted numerically. The reason of the improvement in the results of this new setting is certainly due to the increased size of the samples that have been used in the probing session and in the more controlled conditions of the test environment.

References

[1] Genovesi S., Evangelisti S., “Validation of an electromagnetic solver used for inverse scattering applications”, Nota interna ISTI-B4-03, 2006.

[2] S. Genovesi, E. Salerno, A. Monorchio, G. Manara, "A Permittivity Range Profile Reconstruction Technique for Multilayered Structures by a Line Process-Augmented Genetic Algorithm", *Proc. 2005 IEEE AP-S International Symposium*, Washington DC, 5-8 July 2005.