Development of a Vertical Method for Dielectric Measurement of Powders and Liquids

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ABSTRACT

Two free-space broadband measurement techniques to determine the dielectrics properties of powders and liquids are presented based on horizontal and vertical propagation paths, both of which allow for a series of measurements to be taken where the varying parameter is thickness of material under test (to overcome the challenge of the unknown electrical length).

MEASUREMENT BACKGROUND

The basis for microwave dielectric measurement is that propagating microwaves will change due to the presence of the dielectric material in the propagation path and this change can be used to extract the material's permittivity (and permeability) values. This work starts by using two test setups, using horizontal and vertical propagation paths, and measuring the S-parameters over a wide range of frequencies (here 800 to 6000MHz), with the horizontal set-up previously described in [1]. The dielectric materials being targeted were powders and liquids, so material containment was a big issue, especially so given that the proposed measurements included a requirement to vary the material's thickness, in order to reduce the impact of the unknown electrical length. Glass was used to contain the material in part so that visual inspection of powders for air-pockets could be facilitated.

HORIZONTAL TECHNIQUE

In the horizontal test structure, the combined requirements of container rigidity and ability to vary thickness were very difficult to meet. For example, to measure materials at several thicknesses also presented challenges with container wall alignment, as shown in Figures 1(b) and (c). In terms of the rigidity issues, Figure 1 (a) shows bulging in the centre of the containment structure. One consequence of this is a lens-like concentration in the propagation path leading to large S_{21} values at some frequencies as shown, for example, in Figure 2, where the blue baseline is established as part of a free space calibration technique.

(a) (b) (c)

Figure 1: Issues with container rigidity and misalignment

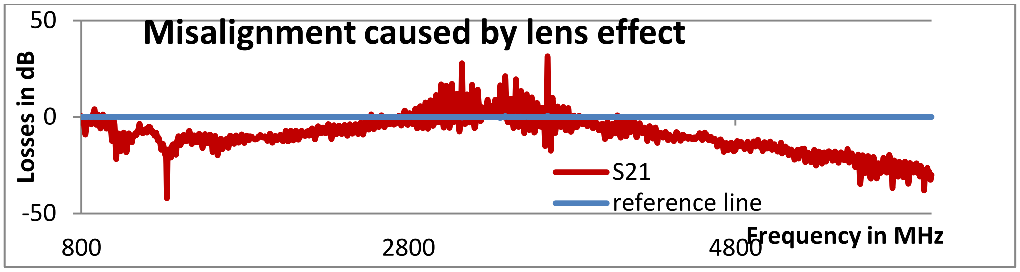

Figure2: Misalignment of a salt measurement result caused by lens effect

In the early tests, the horizontal propagation technique was used exclusively. When compared with a vertical propagation arrangement, this technique also requires an extra containment layer for powders and liquids, which has consequent mechanical and also computational difficulties. In terms of the latter, the removal of the containment walls' influence required conversion of the S-parameters to the ABCD-matrix equivalent [2].

VERTICAL MEASUREMENT PROPOSAL

Although a vertically aligned test infrastructure presents particular structural challenges in terms of stability, normal incidence and alignment, some benefits are immediately apparent compared with the horizontal structure. Immediately, the containment requirement is simpler and the ability to control material thickness by adding and, in the case of powders, levelling material, [3].
Moreover, the vertical propagation measurements also show more promise, in the inversion of the measured S-parameters to arrive at the complex electric permittivity, as the single containment wall in the propagation path can be either calculated out as before using an ABCD matrix or calibrated out using a free-space calibration and a VNA.

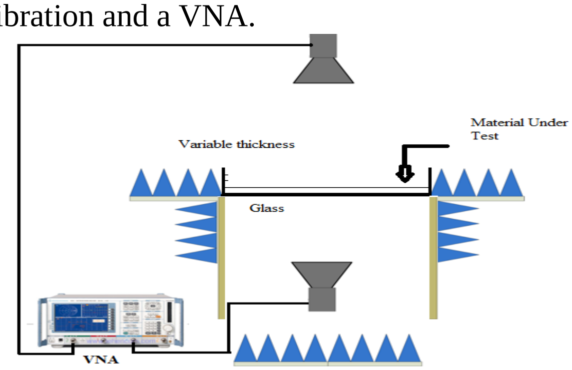

Figure 3 Candidate vertical measurement systems, in WIT anechoic chamber

Figure 3 illustrates the actual structure to implement a vertically aligned measurement in an anechoic chamber. This structure consists of one layer of glass beneath the material, which as just mentioned, also allows an easier inversion (no ABCD matrix requirements) in the permittivity calculations. Once fixed correctly in place, it also permits normal incidence of the waves with more accuracy. It is excellent for high permittivity values (short electrical length), as it is easy to start measurements at thin material thicknesses, that were impractical with the horizontal measurements. It is also easy to control uniform MUT thickness and is particularly easy to test liquids and provides good results than probe techniques based on the measurement of only S11 which is limited because it gives us an idea about the surrounding of the probe not about all the target in case of a bunch of material. However, powders are always tested using glue to get a solid target in deferent thicknesses which present an issue of non-homogeneity and the density of the material (composite material).

REFERENCES

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