Modelling - based methodology for downscaling dielectric resonator material measurements of material surfaces

Malgorzata Celuch#1, Wojciech Gwarek#2, Andrzej Wieckowski#3
#QWED Sp. z o.o., Poland
[1]mceluch@qwed.eu, [2]wgwarek@qwed.eu, [3]awieckowski@qwed.eu

Our original report on this work has been submitted to the IEEE IMS2019. We use the format of 1-page abstract for an initial submission to NEMO to avoid potential conflicts, which later (by Final Paper Deadline: Mar. 18, 2019) can be expanded to a full-paper to be included in IEEE Xplore or kept as a 1-page abstract for presentation only, upon acceptance of NEMO.

***Keywords*—material measurements, non-destructive testing, dielectric resonators, spatial resolution, FDTD.**

ABSTRACT

Dielectric resonator (DR) methods based on split-post (SPDR) and single-post (SiPDR) configurations are **well established and accurate** for material measurements at microwave frequencies. **What restricts the application of DRs to inhomogeneous samples is their limited resolution**. Each DR provides complex permittivity of the material averaged under the DR's "head", ca. 16 mm in diameter at a nominal frequency of 10 GHz. Resolution improvement by frequency increase is impractical, due to high complexity (and hence prohibitive costs) of manufacturing and calibrating the DR.

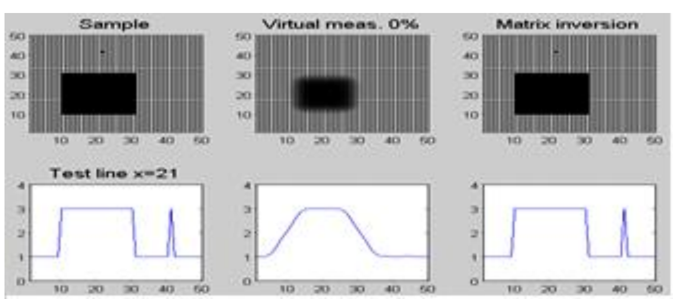
In this work, we discuss the modelling-based methodology to downscale the DR measurements without reducing the geometrical size of the DR's "head" or increasing the measurement frequency. We note that the measured microwave signal is due to the spatially-dependent material parameters weighted with the squared electric field, further referred to as the DR's *template*.

Our state-of-the-practice is as follows. We generate each DR's *template* by **BOR FDTD simulations** with QuickWave software. We have designed and manufactured a 2D scanner, where a sample of up to 80 mm x 80 mm size is initially imaged in 1 mm steps. Then the matrix of raw coarse measurements is transformed into the refined image, using the *template* matrix.

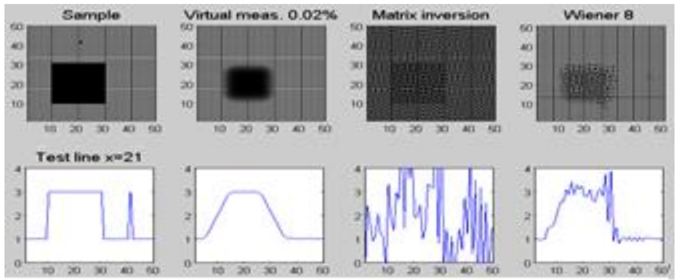
Our **downscaling methodology** resides in formulating an **implicit problem**, that relates the matrix of direct SPDR measurements to the matrix of permittivity distribution. While the system matrix to be inverted is ill-conditioned, we solve the implicit problem by **Singular Value Decomposition** (SVD) technique.

At the NEMO Conference we shall present practical results obtained by our downscaling technique in application to real-life samples. Herein, we demonstrate its validity with 3 virtual experiments in MATLAB environment. Our sample under test (SUT) consists of a dielectric rectangle and dot.

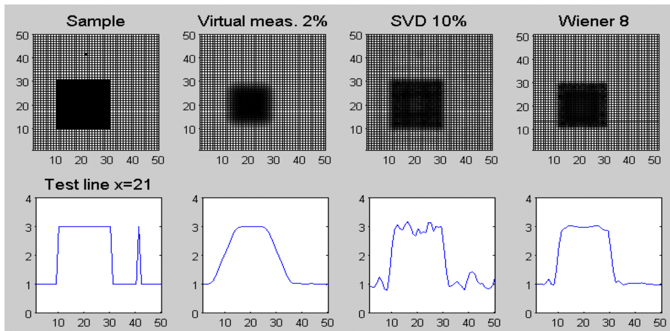
In the 1st experiment, we emulate a noiseless SPDR measurement (diluted, 2nd column), formulate our implicit problem and solve it by matrix inversion. The image reconstruction is perfect, despite matrix ill-conditioning:



In the 2nd experiment we add 0.02% noise. The matrix inversion amplifies the noise and leads to an unacceptable image, that cannot be effectively cured with standard Wiener filters:



In the 3rd experiment, we add an even high noise (2% as in real-life SPDR measurements). We solve the implicit problem by SVD and suppress 90% eigenvalues:



We confirm that the implicit method using SVD followed by standard Wiener filter reconstructs the SUT.