

Frequency Dependent Parameters in EM Simulation – Changing Dielectric Constant and Loss Tangent with Operating Frequency

Introduction

Most materials used in fabrication of microwave circuits and antennas have parameters that are frequency dependent. Including the dependency of the relevant electrical parameters in the simulation is a prerequisite for the highly accurate prediction of the device performance. This application note will show how to set up and use **frequency dependent parameters in EM simulations**. The document will be focused on frequency dependent dielectric parameters: relative dielectric constant and loss tangent, but in principle frequency dependency can be attributed to any symbolically defined parameter such as length, radius, etc.

In the example highlighted in this note, full-wave 3D EM **WIPL-D Pro** software is used for modelling and simulations of a simple patch antenna. The numerical engine is based on **Method-of-Moments (MoM)**, applied to **Surface Integral Equations (SIEs)** with judicious utilization of **Higher Order Basis Functions (HOBFs)** resulting in high numerical efficiency. Accordingly, the selected example with frequency dependent dielectric parameters can be simulated in a very short time using ‘standard’ computer workstation even for the case where wide frequency band is of interest.

EM Models in WIPL-D Pro

Frequency dependent parameters in WIPL-D Pro will be demonstrated using example of a patch antenna presented in Figure 1. The size of the finite metallic ground plane is 40 mm x 40 mm, the radiating patch size is 30 mm x 30 mm, while the height of the substrate is 0.508 mm.

The model of the antenna is symmetrical, so a symmetry plane has been applied to reduce a number of unknowns, as indicated in Figure 1.

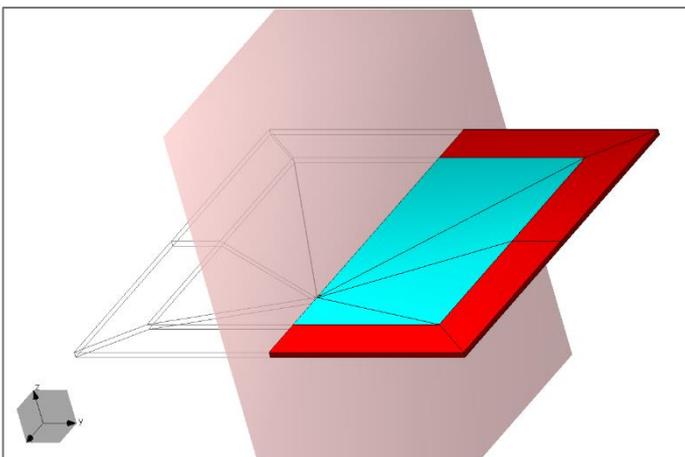


Figure 1. WIPL-D Pro model of the patch antenna.

WIPL-D has a **built-in function**, namely **freq()**, to perform EM simulations with frequency dependent parameters. Values of any parameter can be made dependent on an instantaneous simulation frequency as **the function freq() returns the required instantaneous frequency value**. However, in this particular case it is more appropriate to use another WIPL-D Pro built-in function, namely **freqtab()**, as **it reads frequency dependent data from a file**.

Regarding the varying dielectric parameters, two scenarios are investigated. The first scenario assumes that relative dielectric constant and loss tangent are frequency independent taking values 3.38 and 0.037 respectively. The second scenario is related to frequency dependent parameters with variations as presented in Figure 2.

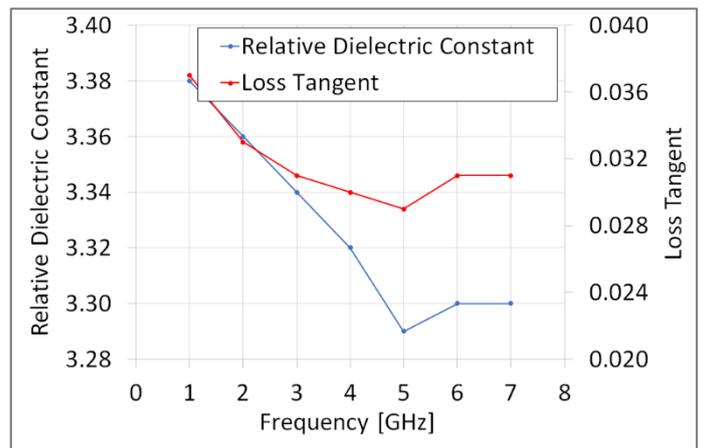


Figure 2. Variation of relative dielectric constant and loss tangent with frequency.

Results and Simulations

The patch antenna with dielectric properties as specified were simulated from 1 GHz to 7 GHz, so that the effects of dielectric parameters variation can be easily recognized at higher frequencies. The results of the simulations are presented in Figure 3 where S_{11} -parameters calculated at 25 discrete frequency points are fitted using WIPL-Graph **built-in fitter**.

All simulations are performed on the ‘affordable’ computer platform presented in the Table 1.

Table 1. Computer used in the simulations.

Hardware	Description
CPU	Intel® Core™ i7-7700 CPU @ 3.60 GHz
RAM	64 GB

The simulated EM models require **less than 650 unknown coefficients** while the **simulation per frequency point lasts less than 2.5 seconds**.

Conclusion

The application presented simulation scenarios considering dependency of EM simulation parameters on instantaneous simulation frequency. **WIPL-D Pro** software, a full wave 3D EM **Method-of-Moments (MoM)** based solver, applying **Surface Integral Equations (SIEs)** and **Higher Order Basis Functions (HOBFs)** is used for modelling and wideband EM simulations of a simple patch antenna with **frequency dependent** relative dielectric constant and loss tangent.

All simulations presented, although considered as wideband, are completed in around one minute even when an ‘everyday’

workstation is used for calculations, confirming once again that WIPL-D software is very efficient in performing EM simulations.

Furthermore, it has been demonstrated that WIPL-D software can **successfully handle multiparameter dependency on frequency** using tabulated data stored in a project file. This becomes extremely important **when simulations are expected to produce high fidelity results which should serve as a benchmark in validating simulations against the measurements.**

A built-in function can be used for introducing frequency dependent parameters can be used in several ways. For example, various dimensions can be defined using symbols dependent on a frequency. One, two or more dependent parameters can be read from a file.

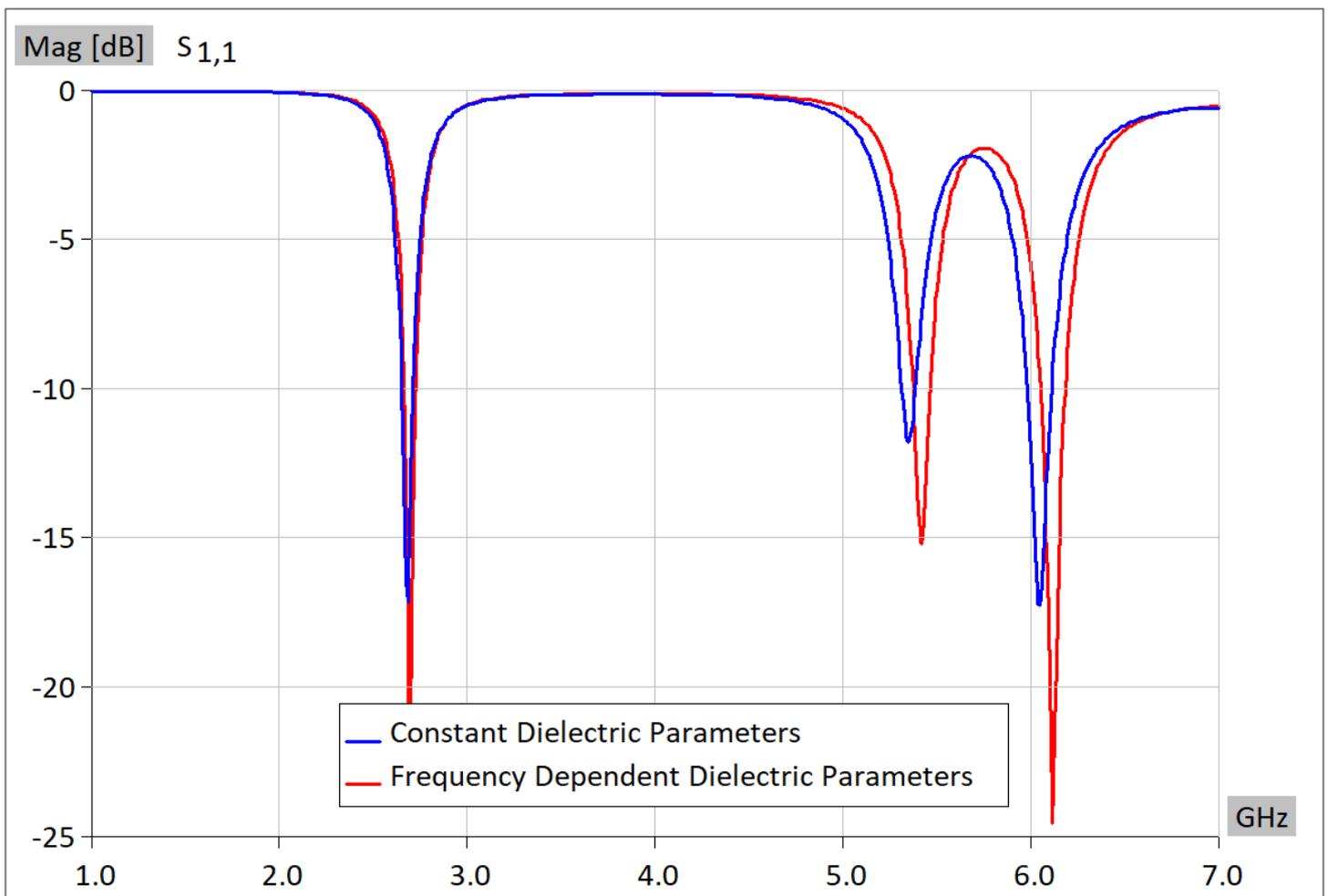


Figure 3. S_{11} -parameter variation with frequency for antenna with constant dielectric parameters and antenna with frequency dependent dielectric parameters.