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Electromagnetic multi-simulation method for determining dielectric permittivity spectrum

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Dielectric permittivity spectrum is closely related to the moisture of porous materials such as soil, moreover, it can be used as a reference for the calibration of GPR and microwave remote sensing techniques.
Dielectric permittivity sensors are usually built in the form of open (antenna or multi-rod probe) or closed (cell) electrode systems. Depending on the frequency, electromagnetic waves can propagate in waveguides or transmission lines, or can radiate into a dielectric medium. Mathematical description of the phenomenon of electromagnetic waves propagation in such complicated systems is very difficult. EM simulations allow to study the influence of known geometry of the electrode system and known dielectric parameters of surrounding materials on the scattering parameters of the electrical port defined in the simulation. However, to measure the dielectric parameters of an unknown material, the reverse problem needs to be solved. It requires the determination of dielectric parameters of unknown material on the basis of the known measured scattering parameter. To solve this problem, it is necessary for the EM simulator to work in feedback by selecting the dielectric permittivity spectrum parameters so that the response obtained from the simulation fits the measured scattering parameter.
The aim of this work was to demonstrate the possibility of using a limited number of simulations without feedback to determine the dielectric permittivity spectrum. This method is based on the use of a finite number of simulations to create a fixed map that is used to convert the scattering parameters to the dielectric permittivity. The calculation of the sought value is based on a bilinear transformation. The obtained results indicated that the proposed method can be used in low-computing-power data processing to obtain the dielectric permittivity spectrum from dielectric sensors.
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