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Method for Characterizing Laminar Tissues via Surface Reflectometry

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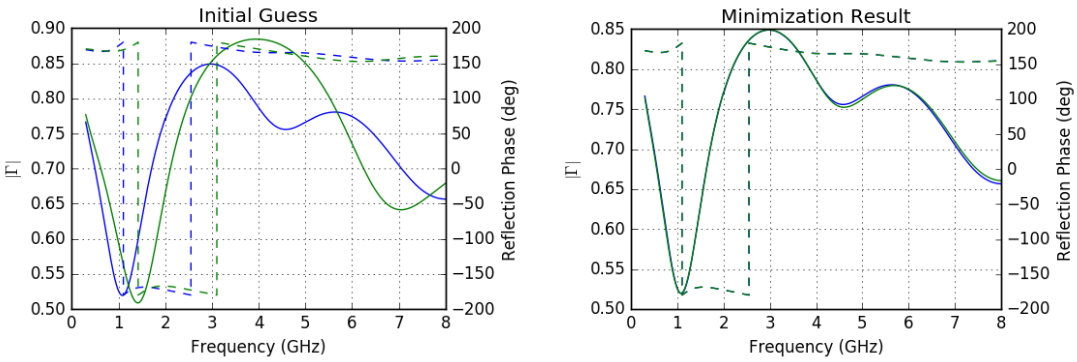
1 Extended Abstract

A variety of applications require specific knowledge of thickness and electromagnetic properties of individual tissue layers. One example is non-invasive internal body temperature measurement based on microwave radiometry [1] or SAR calculations for estimating electromagnetic exposure safety. This work describes a technique for fully characterizing a coplanar stack of homogeneous tissues based on a single set of broad-band reflection data from the surface/skin. It is assumed that the tissues have unknown dispersive electrical material properties and thicknesses.

Because solving for tissue thicknesses and dispersive properties from reflection data is an inverse problem, a bounded least-squares optimizer is used along with an efficient forward model that computes expected reflection spectra from a proposed stack of tissues. This forward model uses a matrix formulation originating from transmission-line theory to solve for (multiple) reflections at all interfaces simultaneously.

For validation, a stack of skin, fat, and muscle (with dispersive behavior according to the Cole-Cole models from [2]) is simulated in Sim4Life (an FDTD solver from Zurich Med Tech, Zurich, Switzerland). The spectrum of the reflected plane-wave at the surface of the skin is extracted and used as a virtual measurement for a configuration with known layer thicknesses and properties. The optimizer starts with an estimate that is close to the initial stack, but substituting wet skin for dry and estimating a fat thickness of 5 mm, rather than the 10 mm that was originally simulated. In less than a minute, running on a mobile i5-3317U processor, the optimizer is able to correct the fat thickness and Cole-Cole terms of the skin to match the original simulation very closely.



(a) **(b)**

Figure 1. Reflection from tissue stack consisting of skin (3 mm), fat (10 mm), and muscle (half-space), with dispersive permittivities and conductivities from [2]. The magnitude and phase are shown in solid and dashed lines, respectively. The blue trace is from the reference Sim4Life result. The green line shows results computed with our forward-model for the initial guess (a) and after using the optimizer to solve the inverse problem and recover the parameters (b).

References

[1] Z. Popovic, P. Momenroodaki and R. Scheeler, "Toward wearable wireless thermometers for internal body temperature measurements," in *IEEE Communications Magazine*, vol. 52, no. 10, pp. 118-125, October 2014.

[2] S Gabriel, R W Lau and C Gabriel, "The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues," in *Physics in Medicine and Biology*, vol. 41, no. 11, April 1996.