Comparison between effective medium theory models for the dielectric response of biological tissues to terahertz radiation

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***Abstract*—In this work, we empirically compare three effective medium theory models for the dielectric response of biological tissue in the terahertz range.**

I. Introduction and Background

EFFECTIVE MEDIUM THEORY (EMT) models are often used to determine the dielectric function of biological tissues in order to study their response to terahertz waves. The most used models to describe such heterogeneous dielectrics are the Maxwell-Garnett (MG), the Bruggeman (BM) and the Landau-Lifshitz-Looyenga (LLL). These three models are constructed on the grounds of some assumptions about the components of the mixture. The MG model assumes spherical inclusions in a material with relatively small dielectric function contrast; BM's model also restricts the inclusions to be spherical but allows a great contrast in the dielectric function of the components; the LLL model allows irregularly shaped inclusions but restricts the dielectric function contrast to be small [1]. In the terahertz regime, particularly in medical and biological applications, EMT is used to quantify hydration in biological tissues. However, owing to the inconsistencies between the biological tissue's components and the assumptions of the models, it is not clear which one is the most appropriate. It must be taken into account that the biological tissue is composed, to a large extent, of water whose dielectric function is much larger than that of any other component of the tissue; in addition, the shape of the components is not spherical. In this work, we obtained the dielectric function of mixtures composed of biological dry tissue and water using THz-TDS. We compare the measurements with the dielectric functions that result from the MG, BM and LLL models.

II. Results

Basil leaves were dehydrated and ground to powder. Pellets were formed to determine the dielectric function of the dry tissue component. Basil-water mixtures were prepared varying the components' volumetric fractions from 0 to 1.0 in steps of 0.1. Each mixture was measured with THz-TDS in reflection geometry and its complex dielectric function was obtained. Moreover, knowing the dielectric function of dry tissue and water [2], the theoretical dielectric function of the mixtures was obtained for the three models. The experimental data was compared with the theoretical curves.

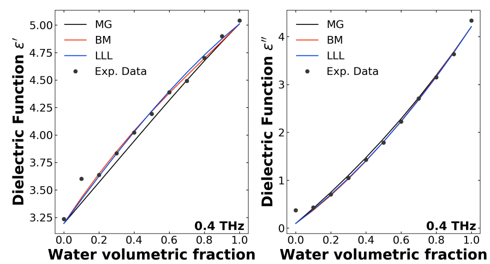

Fig. 1. Real and imaginary part of the complex dielectric function of basil-water mixture as a function of the water volumetric fraction at 0.4 THz. The solid black, red and blue lines represent the theoretical dielectric function given by the MG, BM and LLL models, respectively. The grey dots show the experimental data.

As we can see in Figure 1, the dielectric function of the experimental data coincides with the theoretical curves of the EMT models. Although, we can not see a significant difference between the three models that tell us which of them best fits the experimental data, it is possible to observe that the BM and LLL models behave in a similar way, differentiating more from the MG model. In these two models we see a greater coincidence between theoretical and experimental data. This can be due to the construction conditions. LLL does not limit the shape of the inclusions and BM allows great contrast in the dielectric function.

III. Conclusion

The results obtained in this work show that, although water and basil have a large contrast of dielectric functions, and the shape of the components is not spherical, the LLL and BM models can be properly used to determine the dielectric function of biological tissue [3].

References

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