The Adjoint-field Method for Reconstructing Breast Cancer Tumors of Irregular Shape

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In this work we combine the method of moments for 3D electromagnetic propagation and the adjoint field method for shape reconstruction for the problem of breast tumor detection using microwaves. The method of moments forward solver is used to calculate the scattered fields at several receivers surrounding the tumor. Moreover, the total fields are calculated everywhere in the considered domain including the interface of the tumor. The mismatch between calculated and synthetically measured fields is then used as new sources at all receiver locations and is back-propagated towards the tumor by just solving another forward problem with the method of moments code. The gradient is calculated as the product of the forward and adjoint fields at the best guess of the tumor interface in order to extract a new search direction. The location of each surface node is then updated individually based on these new gradient values in the normal direction of the surface. Using this technique, the forward solver will be used only twice, regardless of the shape of the tumor; once for solving the forward problem and once for the adjoint problem. This process is repeated iteratively until the mismatch in the data is minimized according to some criterion.

In our previous work, the irregular shape of a malignant tumor was modeled using a spherical harmonics representation, which leads to smooth reconstructions. However, sometimes it is desirable to be able to recover more irregular shapes, which cannot be achieved efficiently by the spherical harmonics method. Therefore, we will use in this work a more general representation directly given by the discretization mesh of the method of moments. Doing so, we need to find an efficient way for calculating shape gradients. Instead of using the often employed perturbative method for this purpose, we will use an adjoint field method which is more efficient in this situation.

In our numerical experiments, the background medium is assumed to be homogeneous and lossy. The embedded tumors are assumed to be shape-like with constant dielectric parameters inside. The contrast in these dielectric parameters between tumors and background medium is assumed to be high, which is typical for breast tumors. We will present several numerical results in 3D based on the proposed technique using multiple transmitting sources/receivers at multiple microwave frequencies.