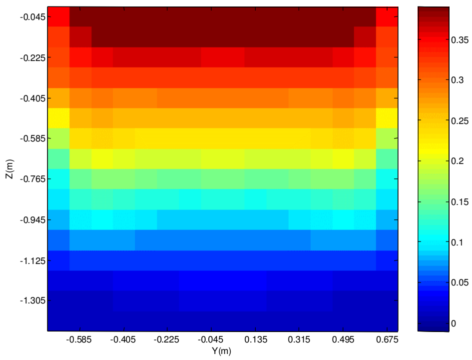
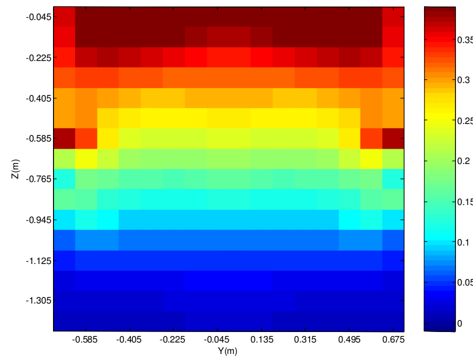
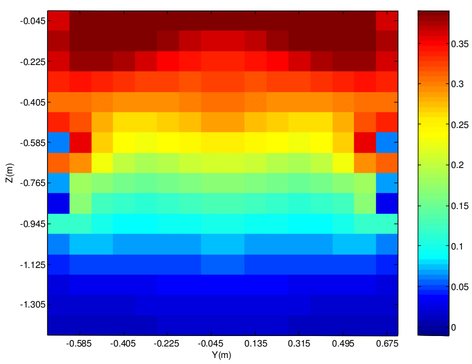


slice5



slice6



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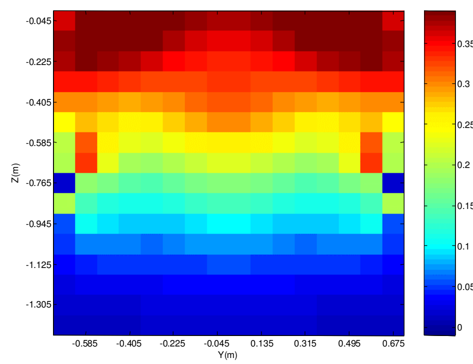
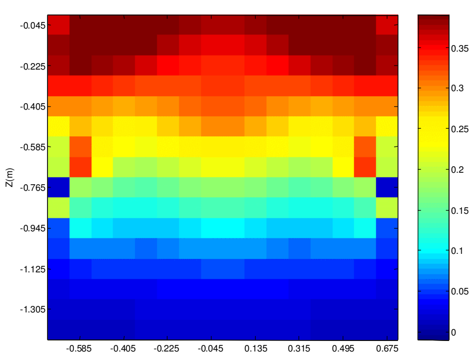
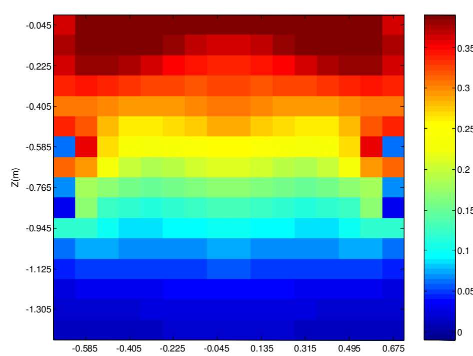


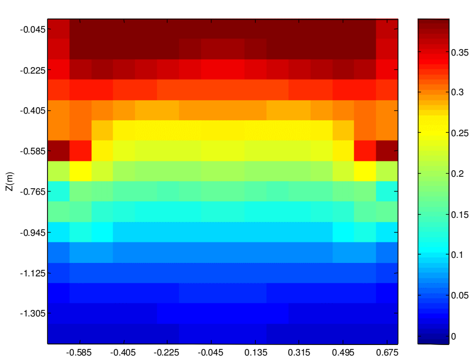
slice8



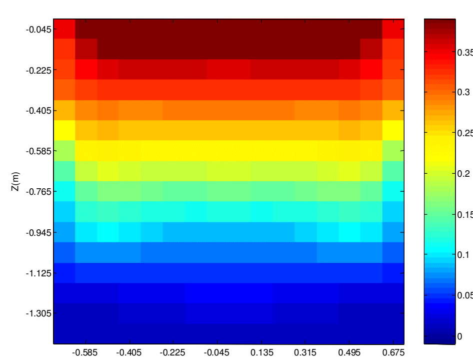
slice9



slice10



slice11



slice12

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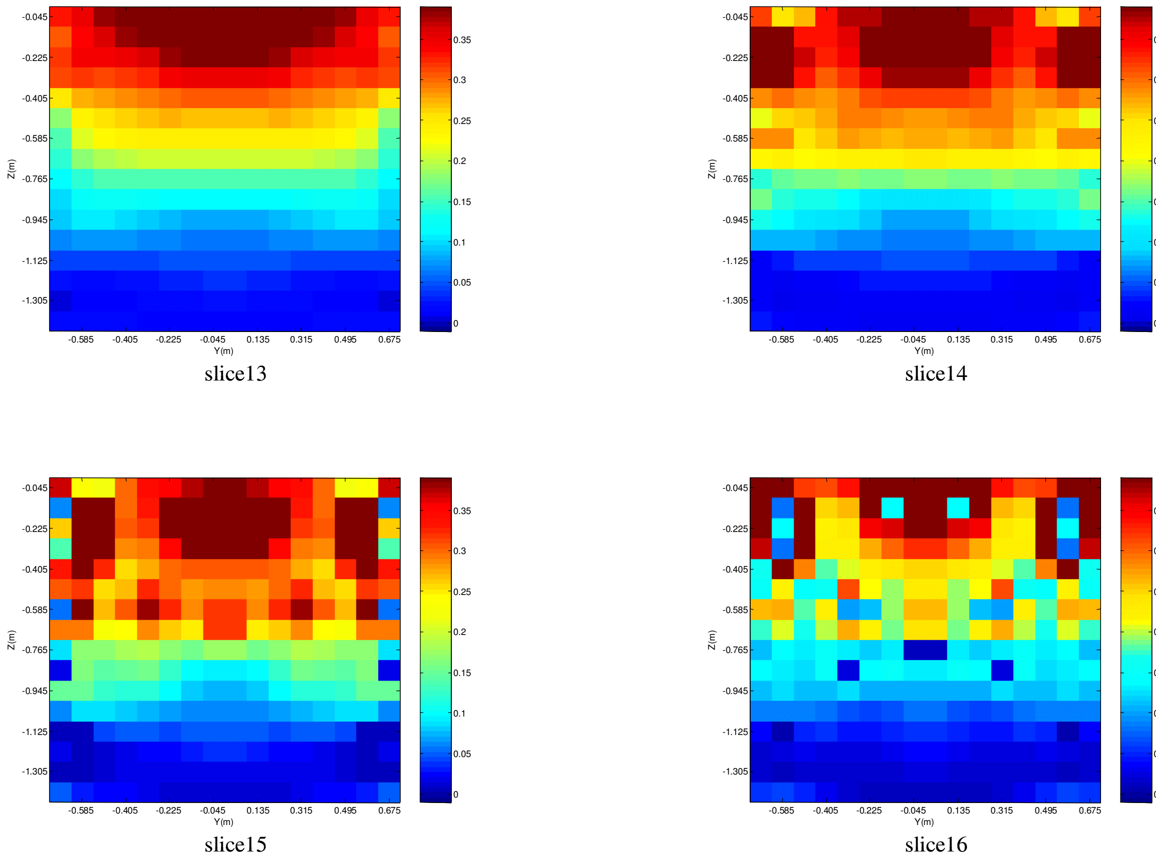

Figure 4: Inversion results, vertical slices 1-16, for a layered medium, using the antenna design reflected in Fig. 3.

We attribute the relatively poor inversion results near the antennas to two phenomena. First, the fields vary quickly in the vicinity of the antennas, with this complexity possibly undermining inversion quality. In addition, there is an abrupt discontinuity between the half-space background and the layered media characteristic of the heterogeneity, and the antennas reside right at this discontinuity. This latter phenomenon is expected to diminish of the antennas are placed further inside the domain to be imaged.

To make the inversion quality quantitative, in Fig. 5 we plot the relative error between the true and estimated profile, defined as

$$E = \frac{\sum_{i=1}^{N} \left| a_t(\boldsymbol{r}_i) - a_{ivt}(\boldsymbol{r}_i) \right|}{\sum_{i=1}^{N} \left| a_t(\boldsymbol{r}_i) \right|}$$

where $a_t(\boldsymbol{r}_i)$ represents the true contrast at position $\boldsymbol{r}_i$ and $a_{ivt}(\boldsymbol{r}_i)$ represents the associated inverted profile. The results in Fig. 5 are plotted as a function of percentage of additive noise, as defined above, with actual data computed in increments of 5% noise levels.

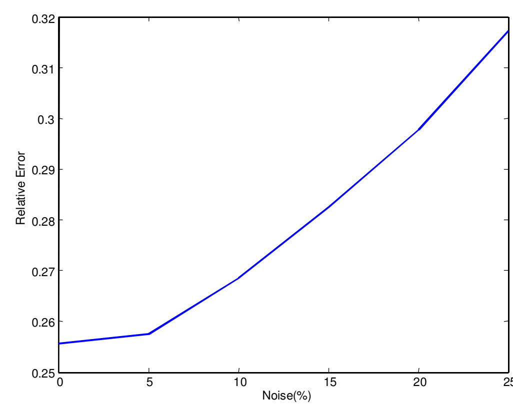

Figure 5: Relative error between the true and estimated heterogeneity profile, as a function of percentage additive white Gaussian noise.

5. DISCUSSION AND CONCLUSIONS

An algorithm has been developed based on the theory of optimal experiments [16], with the goal of defining the optimal antenna positions for performing an inversion based on measured fields. We have considered low-frequency (100 MHz) electromagnetic fields, but the same framework is applicable as well to acoustic scattering data. We have demonstrated that by employing the Born approximation, the optimal design of antennas may be determined prior to collecting any

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data. We have considered this case in our example results. However, the basic design framework may be extended beyond the Born approximation, but in this case the design must be performed iteratively as new data are collected (i.e., measured data are required and determined adaptively). We note that after the experimental setup has been constituted, any (e.g., non-Born) inversion method may be employed. Consequently, the use of the Born approximation within the design does not imply that the actual contrast/size of the problem has to be weak/small (as required for the Born approximation [4]), but the final design may not be rigorously optimal if this is not the case.

Example results have been presented for the problem of monitoring the near-surface electrical properties of soils, with this problem motivating the design framework presented here. Results of the antenna design have been presented, in addition to corresponding results based on an iterative Born inversion [8]. In future work one may consider other parameters to vary when performing the experimental design. For example, one may also consider investigating the optimal choice of sensor frequencies. Moreover, one may wish to choose between multiple antenna types.

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