An Efficient Forward Scattering Model for Through-the-Wall Imaging of an Arbitrary 2D Object

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Detection of objects behind walls has become an emerging area of interest in search and rescue operations, law enforcement, and military surveillance. Through-the-wall imaging ideally involves the retrieval of the dielectric contrasts and geometric parameters of the wall and the target behind the wall. Human body, for example, has a very high dielectric constant and therefore can potentially become a good target for detection. The penetration capabilities of the low frequency radiation make it a good candidate for this type of application if sufficient resolution can be achieved. To solve the inverse problem of imaging a target behind a wall, first a fast and efficient forward problem is required that can realistically represent both the wall and the possibly complex targets. Currently, such models are largely lacking.

In this paper, an efficient algorithm to obtain the forward model for through-the-wall imaging of an object is presented. In particular, a solution to scattering from a dielectric cylinder with an arbitrary cross section behind a non-conducting, possibly rough, and possibly periodic wall is developed. The approach of the algorithm is based on the extended boundary condition method (EBCM) and scattering matrix technique. The reflection and transmission matrices of an arbitrary periodic interface as well as an arbitrarily shaped dielectric cylinder are constructed using EBCM and Method of Moments (MoM), respectively. The cylinder/wall interactions are fully accounted for by applying the generalized scattering matrix technique. The scattering matrix technique is used to cascade reflection and transmission matrices from individual components (i.e., periodic surfaces or cylinders) in order to obtain the scattering pattern from the overall system. Bistatic scattering coefficients are then obtained by incoherently averaging the power computed from the resulting Floquet modes of the overall system. One of the major advantages of the proposed method is maintaining the constant matrix size even with an increasing number of targets in the problem scenario, which significantly improves the speed of the determination of forward models. The scattered field properties and sensitivities to object and wall parameters are investigated to assess feasible ranges of parameters for retrieval, which is the ultimate goal of this work in the future. This method can also be extended to handle scattering from a cluster of arbitrarily placed dielectric cylinders behind a periodic wall. In the numerical simulations, scattering from an arbitrary 2D dielectric object behind a periodic brick wall is investigated.