A Domain Decomposition FDTD Method for Scattering from Very Large Rough Surfaces

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The FDTD method has been previously used to investigate the problem of scattering from rough surfaces, with sizes whose maximum area was $51.2\lambda \times 51.2\lambda$ at 0.3 GHz. Domain decomposition (DD) methods have been proposed in the past to improve the computational efficiency of techniques dealing with large scatterers or with a complex structure. In this work, a DD-FDTD method is proposed to simulate the scattering phenomenon from very large rough surfaces. The size of the subdomains can be chosen to be within the memory limit. The coupling between adjacent subdomains is evaluated to account for mutual interaction effects between the subdomains by using a reaction integral based on the reciprocity theorem.

The far-field properties of the rough surface are calculated by applying the near-to-far-field transformation. The frequency-domain fields are derived by Fourier transforming the time-domain fields derived by the FDTD. The coupling between adjacent subdomains must be included to accurately calculate the scattering fields such that the results have the same accuracy levels as those of the fields derived by using the entire computational domain.

The coupling effects are evaluated by using the reciprocity theorem. The Huygens current sources and fields satisfy the reaction integral

$$\iint_{S_h} \left(\bar{E}_s \cdot \bar{J}_h - \bar{H}_s \cdot \bar{M}_h\right) ds = \iint_{S} \left(\bar{E}_h \cdot \bar{J}_s - \bar{H}_h \cdot \bar{M}_s\right) ds \tag{1}$$

where the artificial current sources $(\bar{J}_h, \bar{M}_h)$ are placed on the Huygens' surface (S_h) in the target subdomain, which radiate fields $(\bar{E}_h, \bar{H}_h)$ to the rough surface (S) in an adjacent subdomain. The equivalent current sources $(\bar{J}_s, \bar{M}_s)$ on S in the adjacent subdomain radiate fields $(\bar{E}_s, \bar{H}_s)$ onto S_h in the target subdomain. In (1), $\bar{J}_s = \hat{n} \times \bar{H}_t$ and $\bar{M}_s = \bar{E}_t \times \hat{n}$, and $\hat{n}$ is the normal vector of S.

The normalized radar cross section (NRCS) of a Gaussian rough surface is calculated, which has $\epsilon_r = 4 - j$, an area of $32\lambda \times 32\lambda$ and roughness parameters of $(h_{\rm rms}, \ell_c) = (0.16\lambda, 0.95\lambda)$. The NRCS obtained with the proposed DD-FDTD method matches well with those obtained from the conventional FDTD and other methods available in the literatures.

To demonstrate the capabilities of the proposed DD-FDTD algorithm, we also calculate the NRCS of Gaussian rough surfaces with areas of $100\lambda \times 100\lambda$, which is decomposed into 5×5 subdomains. The main advantage of the proposed DD-FDTD technique is that it can handle surface areas may be too large for the conventional FDTD methods. We mention, before closing, that the DD-FDTD approach can be extended to even larger areas without encountering any difficulties.