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Angle-dependent SIBC model of metamaterial in conformal FDTD method

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***Abstract*—To control the diffraction of a target illuminated by a radar wave, one technique is to consider metamaterials. Simulating their behaviour can be complex especially when they are applied as thin heterogeneous layers on the surface of the target. This can be achieved, by first determining an angle-dependent surface impedance model, that is after implemented in a 3D conformal FDTD solver.**

***Index Terms*—conformal FDTD, metamaterial, SIBC.**

I. INTRODUCTION

The interest of using a surface impedance model (SIBC) is multiple. First, it avoids meshing a complex geometry covering some parts of the target. Then, the spatial mesh can be released. Indeed, it is supposed to be small enough to capture the field variations inside the thin layer of metamaterials. Since the latter is replaced by a SIBC model, the chosen spatial mesh can be larger because it is not governed anymore by the thin layer thickness. As a result, the computational volume is reduced as α^3 and the computational time by α^4 where α is the factor of relaxed meshing.

For this purpose, both the wideband and efficiency finite-difference time-domain (FDTD) method is used to compute the electromagnetic fields. In a first step, the surface impedances are calculated with the Spectral FDTD (SFDTD) scheme [1] for all incidence angles and for the TE and TM modes. SFDTD method is a good candidate because no additional constraint is needed on the CFL criterion. Thus, periodic Floquet boundary conditions (PBC) are applied around the elementary pattern of the periodic metamaterial. In a second step, the frequency-angle-polarization-dependent SIBC model is decomposed by the vector fitting (VF) technique [2] and the Leontovich relation is used to introduce the metamaterial on the target surface [3]. This approach allows a simple and efficient calculation of the tangential electric field at the metamaterial surface. Morevover, the VF decomposition avoids the processing of a convolution product in the time domain.

II. SFDTD CALCULATION OF SURFACE IMPEDANCES

Metamaterial is simulated with the SFDTD method [1] by introducing periodic boundary conditions around an elementary pattern of the periodic structure. The surface impedance is deduced for all incident elevation θ and azimuth φ angles and for the TE and TM polarisations of an incident plane wave. Surface impedances Z are then decomposed by the VF technique [2] to facilitate processing in the time domain

$$Z^{\mathrm{TE,TM}}(\omega,\theta,\varphi) = r_0 + \sum_{n=1}^{N} \frac{k_n}{j\omega - \omega_n}, \tag{1}$$

where r_0 is the resistance, k_n the residus et ω_n the poles.

III. OBLIQUE SIBC IN FDTD METHOD

Let k be the unit vector along the incident axis. For each cell containing an interface with a metamaterial, we identify the local basis (u, v, n) where n is the normal outgoing unit vector and (u, v) are the unit tangential vectors of the metamaterial. After determining the local elevation angle θ_n and azimuth $\varphi_{u,v}$, the electric field components in the cylindrical basis (ρ, φ) are then calculated by the Leontovich relation

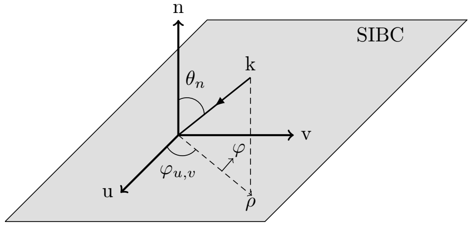

Fig. 1. Local basis (u, v, n) at an interface between air and a metamaterial.

$$\begin{bmatrix} E_\rho \\ E_\varphi \end{bmatrix} = \begin{bmatrix} 0 & -Z_\rho(\omega,\theta_n,\varphi_{u,v}) \\ Z_\varphi(\omega,\theta_n,\varphi_{u,v}) & 0 \end{bmatrix} \begin{bmatrix} H_\rho \\ H_\varphi \end{bmatrix}. \tag{2}$$

Note that the metamaterial surface impedances Z_ρ and Z_φ in (2) are known as they have been previously computed by the SFDTD method for all incident angles in section II. The conformal FDTD resolution will be described in the final paper and numerical examples will be illustrated.

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