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A Semi-Analytical Method for the Study and Characterization of 3-D Periodic Woodpile Lattices

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3-D dielectric woodpile structures can be effectively used in wireless technology for applications at microwave and mm-Wave frequencies, such as in the design of highly directive lattice and cavity antennas [1]. Furthermore, the adoption of low-index dielectrics makes these structures promising for low-cost additive manufacturing technologies. In this contribution, we propose a semi-analytical method to efficiently study the dispersion properties of 3-D periodic woodpiles, made by cylindrical dielectric rods in free space or holes in dielectric hosting media, with different lattice arrangements and geometrical and physical parameters. Applying a Fourier modal analysis over a unit cell, an expression of the transfer matrix is rigorously derived, relating the up-going and down-going field amplitudes at the upper and lower ends of the unit cell. The elements of the transfer matrix are expressed through the reflection and transmission matrices of the woodpiles, calculated using the lattice sums technique [2]. The proposed method is especially efficient to determine location of complete bandgaps by simply calculating the eigenvalues of the transfer matrix. Just a few seconds are needed to determine the location of the bandgap. The relevant results are compared with those obtained by using commercial EM simulators and adopting specific post-processing procedures [3]. The Wigner-Seitz (WS) unit cell of a 3-D periodic woodpile lattice consists in a body-centered cubic (BCC) or body-centered tetragonal (BCT) cell, depending on the chosen geometrical parameters. Unfortunately, the WS unit-cell boundaries are made by nonorthogonal faces or sides, which neither eigenmode solvers of commercial software nor the "ad hoc" approach presented here can directly consider. Hence, a simple cubic (or tetragonal) supercell of the periodic structure is conveniently simulated. In this case, however, additional modes of the supercell need to be carefully individuated and considered [4]. In Fig. 1(a) the dispersion diagram in the irreducible Brillouin zone of the first three modes of the structure in Fig. 1(b) is reported, which shows a perfect agreement between results from the two independent methods. A total bandgap is observed in $0.5 < a/\lambda_0 < 0.535$, in gray in the figure. The characterization of different dielectric and holey woodpile lattices and the relevant application to the design of highly directive leaky-wave antennas will be discussed at the conference.

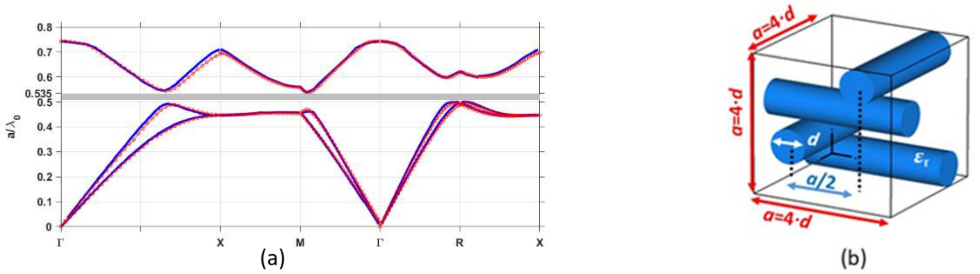

Figure 1. (a) The band diagram of the BCC lattice: semi-analytical approach (blue lines), CST Microwave Studio (red dots). (b) The analyzed cubic supercell with details on the dimensions: $d = 2.5$ mm, $\varepsilon_r = 10.37$.

References

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