



Exploiting symmetries in woodpile leaky-wave antennas

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A significant interest has been devoted in the last years towards 3-D periodic lattices. In particular, the woodpile crystal is a promising candidate for applications relative to waveguiding, sensing and antennas [1]: when proper geometrical and physical parameters are chosen, a large band gap is found. In our previous work [2], a Body Centered Tetragonal type 2 woodpile has been synthesized with two purposes: the presence of a total band gap (from 10.60 GHz to 10.98 GHz) and its upper edge fixed at the Irreducible Brillouin Zone Z point ($k_x = k_y = 0$ and $k_z \neq 0$). Conveniently, around 10.98 GHz the 3-D periodic crystal only allows for Bloch modes to propagate in a small cone in the vertical z-direction.

An Open Woodpile Waveguide (OWW) has been formed by considering a finite number N_z of vertical periods and its capability to radiate a broadside radiated pencil beam has been investigated. First, its bound modes are studied with CST Microwave Studio, whereas leaky modes have been analyzed using the formalism developed in [3]. Then, the directive radiation of a simple source embedded into the lattice has been explained in terms of the relevant 2-D leaky modes of the OWW and an accurate modeling of the radiation features has been accomplished. Finally, a laterally truncated OWW has been designed and two radiated directive pencil beams at broadside around 10.98 GHz have been observed in two hemispheres, with the relevant forward frequency scanning feature obtained at higher frequencies. It should be noted that no additional bound and leaky modes have been excited, resulting in a very high efficient leaky-wave radiation [3].

In this contribution, the introduction of a bisection to the OWW is investigated, in order to facilitate a practical realization of a 2-D Leaky-Wave Antenna (LWA) [4]. Since the OWW itself and the 3-D periodic crystal have no horizontal symmetry plane, a defect is created by properly mirroring the OWW. By means of a suitable tuning of the defect's physical and geometrical parameters, defect modes have not been included within the total stopband of the lattice. Moreover, the mirroring operation straightforwardly leads to the bisection of the lattice, and the latter can be performed with a PEC or a PMC plane, resulting, respectively, into odd and even modes of the lattice. Brillouin diagrams for propagation along x- and y-axes and along the diagonal direction in the 2-D periodic environment are evaluated using CST Microwave Studio. A parametric analysis of the modal dispersion is carried out by varying the bisection plane. Also, an influence of the parity on the modes through PEC- and PMC-bisected lattice is considered. This evaluation leads to an optimal choice of the mirror plane for a practical Grounded Woodpile Waveguide (GWW), for which the persistence of the stopband is assessed.

At the conference, the leaky modes dispersion of the metal bisected woodpile lattice will be described. The radiative properties of the relevant GWW, when a matched rectangular waveguide on the metal plate is used as a feeder, will be shown and the properties of the designed 2-D LWA, also in presence of dielectric losses, will be discussed.

1. Joannopoulos, J. D., Johnson, S. G., Winn, J. N., & Meade, R. D. (2008). *Photonic Crystals: Molding the Flow of Light*. 2nd Edition. Princeton University Press.

2. A. Romano, V. Jandieri, L. Tognolatti, G. Valerio, and P. Baccarelli, "2-D leaky-wave radiation from 3-D dielectric woodpile electromagnetic band-gap lattices," *IEEE Open J. Antennas and Propag.*, early access, 2026

3. V. Jandieri, G. Valerio, L. Tognolatti, and P. Baccarelli, "Semi-analytical method for the analysis of bound and leaky modes in woodpile dielectric structures," *IEEE Trans. Antennas Propag.*, vol. 73, no. 11, pp. 8779–8789, Nov. 2025.

4. D. R. Jackson and A. A. Oliner, *Modern Antenna Handbook*, C. A. Balanis, Ed. New York, NY, USA: Wiley-Interscience, 2008.