Higher Symmetries in Periodic Surfaces for Graded-Index and Band-Gap Components

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Electromagnetic periodic structures are arrangements of scatterers (metallic or dielectric objects, corrugations or holes in a metal, etc.) whose *lattice is invariant with respect to a translation operator T*. These structures have recently received a renewed interest in the context of metamaterials and metasurfaces for a very large spectrum of applications.

In this context, the presence of higher symmetries, in addition to periodicity, has recently been proven to be a very promising condition to obtain desired propagation features by means of low-cost implementations. Strictly speaking, a higher symmetry occurs in *a periodic system which is invariant under a geometrical transformation H* "simpler" than the translation T defining the periodicity. Simpler here means that T can be obtained as a composition of an integer number of H: $H^n = T$. The pioneering work by Hessel and Oliner (A. Hessel *et al.*, Proceedings of the IEEE, 61, 183-195, 1973) showed that exceptional properties can be obtained with specific higher symmetries which are beneficial for microwave components such as filters, traveling-wave tubes, and waveguides. Namely, the glide-symmetric operator G, is composed of a translation along a direction (x) and a mirror reflection along an orthogonal direction (z), i.e.,

$$G = \begin{cases} x \rightarrow x + p/2 \\ z \rightarrow -z \end{cases} \tag{1}$$

defines a periodic structure such that $T=G^2$, with period p. In glide-symmetric geometries, the stop-band at the X edge of the fundamental Brillouin zone is suppressed. As a consequence, smart arrangements of glide-symmetric objects can lead to severely reduced frequency dependence in their first passband.

Very recent researches in the context of metasurfaces have in fact confirmed this prediction, and have finally demonstrated that glide-symmetric metasurfaces can produce ultrawideband (UWB) response (O. Quevedo-Teruel *et al.*, IEEE Antennas Wireless Propag. Lett., 15, 484-487 2016). This first demonstration showed the potential of high symmetries for creating ultrawideband graded-index antennas. Additionally, glide-symmetric configurations can be also employed to produce Electromagnetic Band Gap (EBG) surfaces with a potential use for gap-waveguide technology (M. Ebrahimpouri *et al.*, EuCAP, 2016). The main advantage of glide-symmetric EBGs is their low cost of implementation for high frequency devices, when compared with other proposed EBGs, such as the bed of nails or mushroom structures.

These interesting features subsequently stimulated research on analytical and numerical analyses in order to accurately compute the propagation constant of supported modes (G. Valerio *et al.*, submitted to IEEE Trans. Antennas. Prop.). This is not an easy task, since strong interactions between opposite layers are required to achieve UWB or EBG behaviors, which prevent from the use of common homogenized formulas or simplified circuit approach. The presence of details at different scales (within and among unit cells) further motivates the need for new efficient numerical tools to support the design of these novel structures.