Investigation of Propagation in Screw-Symmetric Structures

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During recent years, the interest in metamaterials and metasurfaces has increased due their low cost and usefulness in different antenna and microwave components (S. Maci et al. , *IEEE Antennas Wireless Propag. Lett.*, vol. 10, 2011). Metamaterials in general, and metasurfaces in particular, are often based on periodic repetition of unit cells in one or more directions. These unit cells are designed to achieve desired propagation characteristics and can be tailored in different ways. Metasurfaces can be used to produce lenses that are employed to produce directive antennas, or imaging systems. Despite the possibilities of metamaterials, and specifically metasurfaces, they have limitations, e.g narrow bandwidth (K. Lekkas, et al., *IEEE APS*, 2016), which have motivated further investigations. Here, we propose the use of higher symmetries to reduce the frequency dependence of periodic structures, i.e. to increase their bandwidth of operation.

A structure possesses higher symmetries if it consists of a repetition of a unit cell in a more complex way than just simple translation or mirroring. The concept of higher symmetries was first introduced at the end of the 1960s', and explored for electromagnetic devices in the 1970s' (A. Hessel et al., *Proc. of IEEE*, vol 61, 1973). However, this topic has recently recovered the attention of scientists and engineers. For example, higher symmetry metasurfaces were demonstrated to provide wide stop-bands and low frequency dependence. In the first case, these metasurfaces can be used for low cost gap-waveguide technology. In the second case, they can be used to produce ultra wide band lenses (O. Quevedo-Teruel et al., *IEEE Antennas Wireless Propag. Lett.*, vol. 15, 2016).

There are mainly two types of higher symmetries considered in literature, glide- and screw-symmetries. A glide-symmetric structure is a structure where the repetition of the unit cell is made by a translation and mirroring. Screw symmetry can be seen as a special case of glide symmetry with one more degree of freedom. It is obtained by translating the unit cell and rotate it around its symmetry axis. (A. Hessel et al., Proc. of IEEE, vol 61, 1973). Previous works have been focused mainly on purely glide-symmetric structures.

Our proposed screw-symmetric configuration consists of a coaxial cable with orthogonal pins, uniformly placed, in both translation and rotation. Four different cases are considered where the angle of rotation between two adjacent pins is changed. For every pin in the unit cell, the mode makes a turn in the dispersion diagram, alternating forward and 'backward' propagation. The new medium becomes denser and flatter, specially at lower frequencies, resulting in a higher refractive index and a lower frequency dependence. These results are coherent with previous studies in glide-symmetric structures (O. Quevedo-Teruel, et at., *IEEE Antennas Wireless Propag. Lett.*, vol. 15, 2016).

These new studies in screw symmetries open new possibilities for leaky wave antennas.