Rigorous analysis of a reciprocal PTD-symmetric structure supporting a back-scattering protected edge mode

E. Martini[1], M: G. Silveirinha [2], and S. Maci[1]
(1) University of Siena, Siena, Italy
(2) University of Lisbon, Lisbon, Portugal

In the last years, there has been great interest towards structures supporting edge modes characterized by robust directional propagation, *i.e.* immunity to backscattering from discontinuities. This phenomenon is usually associated with non-reciprocity. Recently, however, it has been shown that also reciprocal structure satisfying a condition of parity-time reversal-duality (PTD) symmetry can support modes protected from back-scattering (M. G. Silveirinha, "PTD Symmetry protected scattering anomaly in optics," *Phys. Rev. B*, vol. 95, 035153, 2017).

A particular implementation of this concept is analyzed in this contribution. It consists in the combination of two dual semi-infinite parallel-plate waveguides (PPWs) of thickness d, each consisting of a perfect electric conductor (PEC) and a perfect magnetic conductor (PMC) walls (see Fig. 1). This structure supports a TEM mode, whose field is confined at the junction between the two semi-infinite PPWs. This is the unique supported mode in the frequency range from zero frequency to the frequency where the PPW thickness d is equal to $\lambda/4$ (E. Martini, M. G. Silveirinha and S. Maci, "Exact Solution for the Protected TEM edge mode in a PTD-Symmetric Parallel-Plate Waveguide," early access in *IEEE Transactions on Antennas and Propagation, 2018*.).

The electromagnetic field distribution of this mode, which is equal to the static electric and magnetic field distributions, is derived in closed form by applying different approaches. The first one is a conformal mapping applied to a square waveguide with PEC/PMC walls. The second approach is based on mode matching between the two semi-infinite PPWs. Finally, the third approach uses the Fourier-transform method. The derived analytical expression show that the TEM mode has characteristic and wave impedance equal to the free space impedance. The PTD-symmetric edge waveguide structure is actually matched to free space, i.e. it can be terminated with ideally zero reflections. Other discontinuities characterized by PTD-symmetry (e.g. bends) are also reflectionless.

For practical realizations, the PMC condition can be emulated (in a given frequency range) by high impedance surfaces based on patch-type metasurfaces, mushroom structures or pins, as verified through numerical simulations. Possible generalizations and applications of this structure will be discussed at the conference.

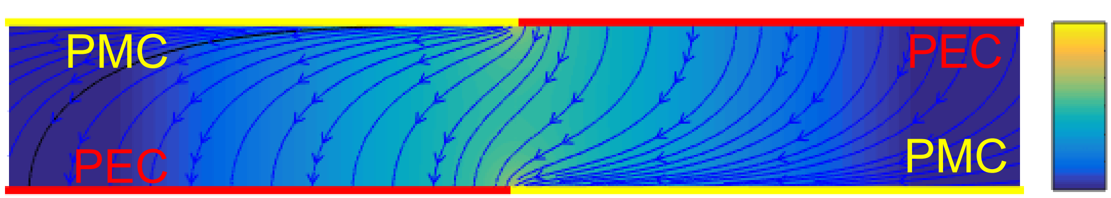

Figure 1. Electric field distribution inside the PTD-symmetric PPW.