Ultra-wideband Non Reciprocal Devices in Space-Time Modulated Transmission Lines

Y. Hadad(1), A. Shlivinski* (2)
(1) Tel-Aviv University, Ramat-Aviv, Israel 69978
(2) Ben-Gurion University of the Negev, Beer Sheva, Israel 84105

A fundamental aspect of wave engineering deals with wave propagation in transmission line (TL) structures as they, generally, serve as the medium through which energy is delivered from "sources" to a "loads". As distributed structures, TLs are also used for wave-field manipulations as for example with TL filters and matching networks or as an integral part in nonreciprocal devices such as isolators or circulators. The traditional practice of TL's wave engineering uses *spatial-modulation* of the TL characteristic properties (wave propagation velocity and characteristic impedance or alternatively inductance and capacitance per unit length) for the wave-field manipulations. An alternative practice for the TL wave engineering may use *temporal-modulation* (i.e., rendering time-dependent TL characteristics), for the wave-field manipulations. In a recent publication [A. Shlivinski and Y Hadad, Phys. Rev. Lett. 121, 204301] we demonstrated a temporal-modulation in the form of abrupt temporal switching of the TL properties to provide an efficient ultra-wideband matching scheme for pulsed wave-fields.

Using either the spatial-modulation or the temporal-modulation provides only one set of "controls" on the TL structure degrees of freedom (characteristics), either space dependent or time dependent. A manipulation of the TL properties by a combination of *space-time modulation* where the TL's characteristics are changed in both space and time provides an alternative set of controls on the design degrees of freedom. There are many practices for the combination of the space and time into a space-time modulation paradigm. Here we focus on one such practice where the modulation seems to behave as a "material-wave" that propagates along the TL to make its characteristics space-time dependent. A fundamental property of such space-time dependent structure is its nonreciprocal behavior (without the use of magnetic external fields). Despite recent progress in this direction, the possibility to obtain wideband devices yet remain subtle. In this presentation we discuss novel modulation schemes that give rise to significant isolation, over, theoretically, infinite bandwidth that makes it particularly useful with pulsed wave-fields. In the presentation we discuss some space-time schemes, the corresponding TL characteristics and wave field properties and their use in devising desired nonreciprocal properties and devices.