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# A Time-Reversal Cavity for Electromagnetic Waves in Transmission Line Networks with Arbitrary Topology

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***Abstract*—This paper describes the realization of a time-reversal cavity for electromagnetic waves in transmission line networks. A frequency-domain analysis of the two-stage wave processes that pertain to the time-reversal cavity is presented for a multi-terminal and multi-node transmission line network characterized by arbitrary topology.**

***Index Terms*—Electromagnetic waves; time reversal; time-reversal cavity; transmission lines**

## I. Introduction

Recently, it was demonstrated in [1] that a matched transmission line network composed of coaxial cables can be considered as an exact one-dimensional (1-D) time-reversal cavity [2]–[5]. Specifically, by back-injecting, at each line terminal, the time-reversed voltage or current measured as a response to an initial source excitation, a time-reversed copy of the voltage or current distribution in the forward-propagation stage can be reproduced [1].

In [1], the time-reversal cavity was explored in the time domain marking reference to a network of three transmission lines connected to a single node. Also, it is indicated in [1] that the realization of the time-reversal cavity remains established despite the increasing topological complexity of transmission line networks. In this regard, the present paper is focused on generalizing the concept and properties of the time-reversal cavity to a multi-terminal and multi-node transmission line network characterized by arbitrary topology.

## II. Frequency-Domain Analysis of a Time-Reversal Cavity in Transmission Line Networks with Arbitrary Topology

Consider the scenario of an inhomogeneous transmission-line network excited by a lumped series voltage source. The voltages and currents acquired in the forward- and backward-propagation stages are formulated analytically first using the frequency domain solutions. Furthermore, the converging and diverging components of the backward-propagating voltage are identified, and the time-reversed relation between the forward-propagating voltage and the converging component of the backward-propagating wave is inferred through a frequency spectral analysis. Then, the so-called interfering effect of the diverging component is comparatively investigated with respect to its counterpart in the time domain (e.g., [1]). Finally, the study discusses the implementation and effectiveness of an active time-reversal sink in the frequency domain to compensate for the effect of the diverging component.

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