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Topological realizability conditions and their interpretation for admittance matrices of an MTL system with mode delays

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Abstract

In a previous study by the authors regarding passive multiconductor transmission line (MTL) system quasi-TEM mode delay, we encounter longitudinal immittance matrix functions (LIMFs) whose behavior initially appears problematic, yet they are shown to be passive. This paper addresses the constraints on the realization of the admittance matrix and the physical interpretation of the realized circuits in the passive, common-ground microstrip system.

Keywords: Multiconductor transmission lines; Network synthesis; Modal analysis; Mode delays

1. Introduction

In multiconductor transmission line applications where quasi-TEM mode delay is present such as matching networks [1], filters, and amplifiers in coupled microstrip technology, the longitudinal immittance matrix functions (LIMFs) exhibit interesting behavior in the state (conductor) domain which was thoroughly examined in [2]. Among the most interesting manifestations of the mode delay were deviations from two common (but not necessary) properties of the input admittance matrix, namely its dominance and negative real off-diagonal terms. As its passivity was readily demonstrated, this letter concerns the topological realizability conditions on the admittance matrix in synthesizing

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equivalent circuits which model linear, passively terminated lengths a of coupled lines, and the interpretation of such models.

2. Admittance matrix realizability conditions

Physically, we considered a passive, generally lossy MTL system (n lines) terminated with linear, passive networks. The longitudinal conductor input admittance matrix $\boldsymbol{Y}_{\text{in}}^{\text{c}}$ $(z=-a)$ relates the conductor voltage and current vectors on the conductors at $z=-a$. It models the length a of coupled lines between the point $z=-a$ and the prescribed termination at the output $z=0$. This is shown in Fig. 1 (For a three-line case).

Coupling between the lines results in longitudinal conductor power oscillation along each conductor. The unequal z-varying amplitude envelopes of each conductor power oscillation (see [2, Fig. 11]) is perhaps the most significant consequence of the mode delays and provides the clearest physical insight to their presence. These fluctuations, directed related to the state voltage and current magnitude variations, effectively require compensation in the immittance parameters, including the admittance matrix. Though the admittance matrix accounts for these power oscillations, two of its properties superficially appear problematic: its lack of dominance,

$$\left|\left[\boldsymbol{Y}_{\text{in}}^{\text{c}}(z)\right]_{kk}\right| \ngeq \sum_{m=1,m\neq k}^{n}\left|\left[\boldsymbol{Y}_{\text{in}}^{\text{c}}(z)\right]_{km}\right|, \quad k=1,2,\ldots,n, \tag{1}$$

and the positiveness of the off-diagonal real terms for various distances $z=-a$

$$\text{Re}\left\{\left[\boldsymbol{Y}_{\text{in}}^{\text{c}}(z)\right]_{ij}\right\} > 0, \quad i\neq j. \tag{2}$$

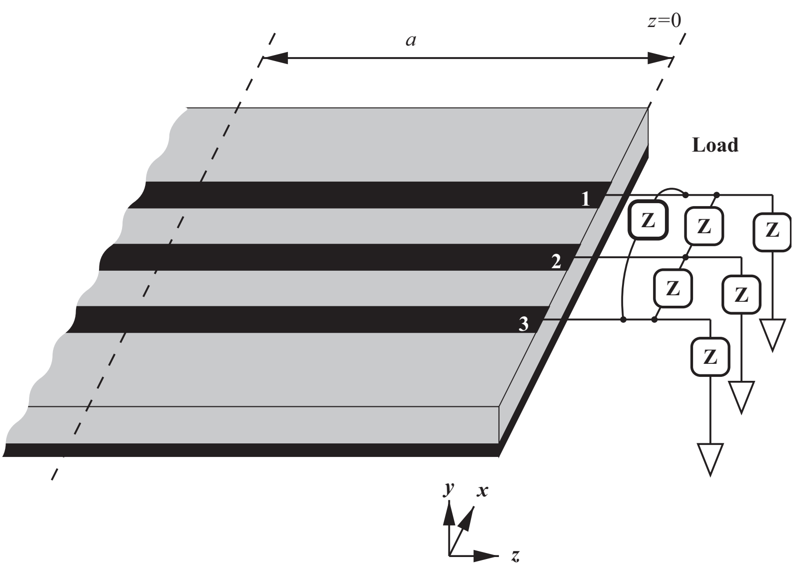

Fig. 1. Coupled transmission line section with load terminations and immittance matrices at $z=-a$.