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A Numerical Study of Moving Reference Planes Associated with Unit Cells of Reciprocal Lossy Periodic Transmission-Line Structures by Using the Equivalent BCITL Model

Suthasinee Lamultree[a,]*, Prayoot Akkaraekthalin[b]

and Danai Torrungrueng[a]

[a]Asian University, 89 Moo 12 Highway 331, Banglamung, Chon Buri, 20260, Thailand
[b]Faculty of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, 10800, Thailand

Abstract

A moving reference plane of unit cell of reciprocal lossy periodic transmission-line (TL) structures (RLSPTLSs) by using the equivalent bi- characteristic-impedance transmission line (BCITL) model is studied numerically in this paper. Applying the BCITL theory, only the equivalent BCITL parameters, characteristic impedances for wave propagating in forward and reverse directions and associated complex propagation constant, are of interest. In this study, a unit cell of an infinite RLSPTLSs is obtained by shifting a reference position of unit cells along TLs of interest. For illustration, an example of symmetrical RLSPTLSs is initially considered. Then, unsymmetrical structures are subsequently investigated by shifting a reference position of unit cells. It is found that the equivalent BCITL complex propagation constant remains unchanged as expected, while the equivalent BCITL characteristic impedances are generally different, depending on the reference position of unit cells. Numerical results will be provided and discussed in this paper.

Keywords: Unit cell; periodic transmission-line structure; bi-characteristic-impedance transmission line (BCITL).

1. Introduction

Periodic structures of transmission lines (TLs) have several practical applications in microwave technology; e.g., microwave filters, slow wave components, traveling-wave amplifiers, phase shifters, antennas and metamaterials[1-4]. They are composed of identical cascaded two-port networks, referred to as unit cells. To analyze and design associated problems of periodically loaded TL structures, there are several methods having been used in the literature. Recently,

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the theory based on bi-characteristic-impedance TLs (BCITLs) has been successfully employed to terminated finite reciprocal lossy periodic TL structures (RLSPTLSs)[5]. To apply the equivalent BCITL model, only the equivalent quantities associated with each unit cell of RLSPTLSs are employed instead; i.e., the characteristic impedances for waves propagating in forward and reverse directions, defined as Z_0^+ and Z_0^- respectively, and the corresponding complex propagation constants for waves propagating in the forward (γ^+) and reverse (γ^-) reverse directions, respectively. It should be pointed out that conjugately characteristic-impedance TLs (CCITLs)[6] are the special case of BCITLs when Z_0^+ and Z_0^- are conjugated of each other.

2. Theory

A finite RLSPTLS of M unit cells at each unit-cell terminal in [5] can be effectively modeled as a BCITL of length $l=Md$, as shown in Fig. 1(a), where d is the length of each unit cell. Note that V_m and I_m are the phasor voltage and the phasor current at the terminal of the m^{th} unit cell (where m = 1, 2, …, M), respectively. Generally, reciprocal BCITLs possess the complex propagation constant γ with the characteristic impedances Z_0^+ and Z_0^-. Note that both forward and reverse complex propagation constants are identical ($\gamma^+ = \gamma^- = \gamma$) for *reciprocal* lossy periodic TL structures. In this paper, an infinite RLSPTLS is considered, which can be obtained from Fig.1 by letting both ends approach infinity.

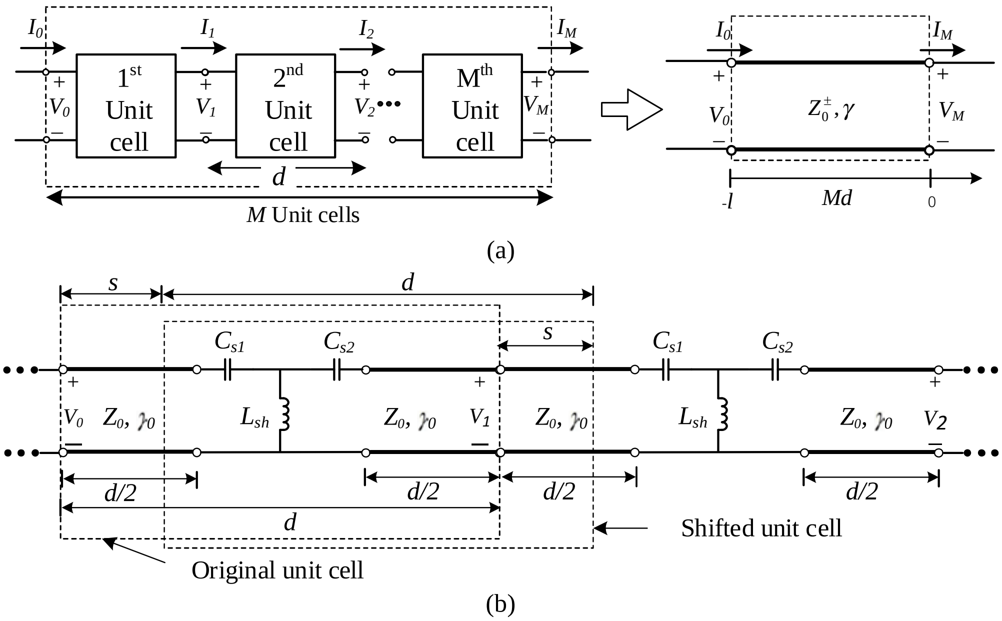

Fig. 1. A finite RLSPTLS of: (a) M unit cells and its equivalent BCITL model; (b) a single unit cell obtained by shifting a reference position s along TLs of interest.

Using the *ABCD* matrix technique[1,5], $Z_0^\pm$ can be expressed in terms of the total *ABCD* parameters of the unit cell of interest as

$$Z_0^\pm = \frac{\mp 2B}{A - D \mp j\sqrt{4-(A+D)^2}}, \tag{1}$$

In addition, γ can be determined from the following dispersion relation:

$$\cosh \gamma d = \frac{A+D}{2}. \tag{2}$$