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A Calculation Method for Frequency Dependent Characteristic Impedance and Slow-wave Factor of Microwave Transmission Lines with a Perturbation

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Abstract— A frequency-dependent slow-wave factor (SWF) and equivalent circuit model of transmission lines with a perturbation such as photonic band-gaps (PBGs), defected ground structures (DGSs), and so on, is proposed in this work. DGS is adopted as an example of the perturbation structure imposed on the ground plane of transmission lines (Fig. 1). Once S-parameters of the transmission line with DGS are given, the conventional equivalent circuit elements are extracted using 3 dB cutoff and resonant frequencies ($F_{c.3\,\mathrm{dB}}$ and F_o) as the first step. Using these initial equivalent circuit elements and simple transmission line theories, a frequency-dependent equivalent transmission line model is established through an analytical method. In the proposed method, the equivalent characteristic impedance (Z) of the transmission line with a perturbation depends on frequency (Fig. 2), while it has been known to be a fixed value. Finally the frequency-dependent SWF is calculated (Fig. 3). The proposed equivalent circuit of the transmission line with a perturbation element is composed of frequency dependent series resistance (R_s) and characteristic impedance (Z). The obtained equivalent circuit and SWF are frequency-dependent and more reliable than the conventional result because even small insertion loss within the available pass band is considered in calculating characteristic impedance (Z) and SWF, while they have been ignored in the conventional way. The S-parameters calculated using the obtained frequency-dependent equivalent circuit elements and frequency-dependent characteristic impedance (Z) are in an excellent agreement with the original S-parameters of the transmission line with the perturbation. The proposed method is well applicable to find the more reliable equivalent characteristic impedance and SWF of all transmission lines having PBGs, DGSs, and other periodical perturbation patterns on the ground plane.

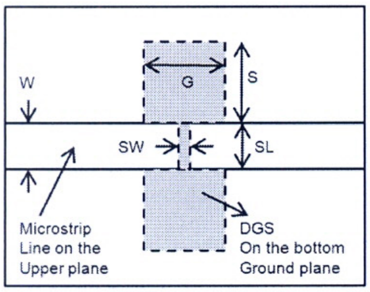

Figure 1.

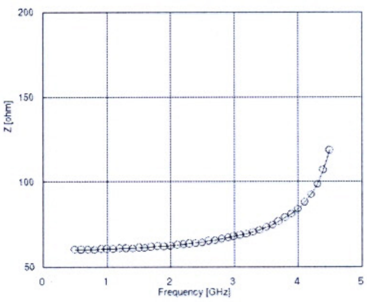

Figure 2.

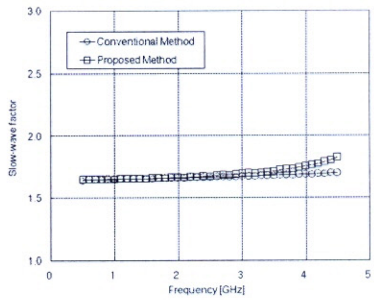

Figure 3.