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Closed-form formulas for the electromagnetic parameters of inverted microstrip line

Yamina Bekri[1], Nasreddine Benahmed[1], Nadia Benabdallah[2], Kamila Aliane[1] and Fethi Tarik Bendimerad[1]

[1]*Department of Telecommunications, University Abou Bekr Belkaid-Tlemcen,*
[2]*Department of Physics, Preparatory School of Sciences and Technology (EPST-Tlemcen), Tlemcen, Algeria.*

Abstract—This article presents simple analytical expressions for the electromagnetic parameters (characteristic impedance (Z_c), effective dielectric constant (ε_{eff}), inductance (L) and capacitance (C)) of inverted microstrip line (IML). Under quasi-TEM approximation, the analytical expressions can be deduced from rigorous analyses using finite element method (FEM) analysis and curve-fitting techniques. An analysis can be readily implemented in modern CAE software tools for the design of microwave and wireless components. For a dielectric material of ε_r=2.22, this study presents rigorous and suitable general expressions for all inverted microstrip lines with a wide range of (w/h_1) and (h_2/h_1) ratios varying respectively between 0.01-9.5 and 0.01-1. An inverted microstrip branch line coupler operating at 3 GHz will be designed to demonstrate the usefulness of these design equations.

Keywords— Analytical expressions, EM parameters, FEM Results, frequency response, inverted microstrip line (IML), inverted microstrip branch line coupler, S-parameters.

I. INTRODUCTION

Inverted substrate microstrip line (IML) is a very popular transmission media for millimeter and microwave applications. It has low attenuation, small effective dielectric constant, low propagation loss, and low insertion loss. This type of microstrip line is known to offer less stringent dimensional tolerances and provides less dispersion compared with the conventional microstrip lines [1-3]. The inhomogeneous structures may be used advantageously for the development of filters and couplers as compared to those using homogenous structures [4-5].

This article is a continuation of our previous paper that appeared in Computing Science and Technology International Journal [6]. In support of the analysis using FEM method, we developed rigorous and suitable general expressions for IML lines using duroïd substrate (ε_r=2.22) with a wide range of (w/h_1) and (h_2/h_1) ratios varying respectively between 0.01-9.5 and 0.01-1.

Figure 1 shows the cross section of the shielded inverted microstrip line (IML). The electrical properties of lossless IML lines can be described in terms of the characteristic impedance (Z_c), the effective dielectric constant (ε_{eff}) and the primary (L and C) parameters [7].