Microstrip/CPW differential lines for common-mode suppression

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Abstract

This paper reports on differential printed transmission lines which yield a very good matching for differential-mode and strong rejection for the common-mode. The new differential lines are inspired on the concept of metamaterial transmission lines. Circuit model predictions, electromagnetic simulations and experimental results are quite satisfactory.

1. Introduction

Differential signal paths are commonly used in high-speed digital electronics as a means to reduce undesired EMI and crosstalk problems. Noise preferentially couples to common-mode and this is ideally suppressed. However discontinuities, fabrication uncertainties and other issues yield some level of common-mode signal that should be strongly attenuated while keeping differential-signal unchanged. A number of approaches are available for common-mode noise suppression in differential transmission lines over the gigahertz frequency range. Metamaterial inspired coupled transmission line systems have been proposed in the recent literature. Thus, mushroom based structures [1] or periodic defected ground structures (DGS) [2, 3] have been proposed to achieve a negative-permittivity rejection band for common-mode while only slightly affecting to the differential-mode. Those solutions are based on relatively complex geometries involving via holes and multilayered structures [1] or significantly affect the behavior of the differential-mode [2, 3]. In this contribution a relatively simple configuration that makes use of double-side MIC technology [4, 5] is proposed. In this structure the ground plane below the area occupied by a pair of conventional coupled microstrip lines is substituted with a quasi–periodic structure consisting of a number of metallic patches connected to ground through high impedance transmission line sections. The patches in the bottom plane are capacitively coupled to the pair of transmission lines printed in the upper side of the substrate. The differential-mode characteristic impedance and propagation constants are almost the same of the structure with a continuous ground plane (no patterned ground plane). However the common-mode is strongly rejected above a certain thresold frequency. This is because the structure behaves as a evanescent artificial transmission line for common-mode operation above a certain frequency value (low-pass filter behavior). The dimensions of the different sections of

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the structure are obtained by using the fast quasi-TEM solver reported in [6]. Some fine tuning based on the use of a full-wave solver for planar structures is required (ADS Momentum has been used in our case). The analytical results obtained with a circuit-like model satisfactorily account for the qualitative behavior of the structure. Numerical and experimental results demonstrate the usefulness in practical applications.

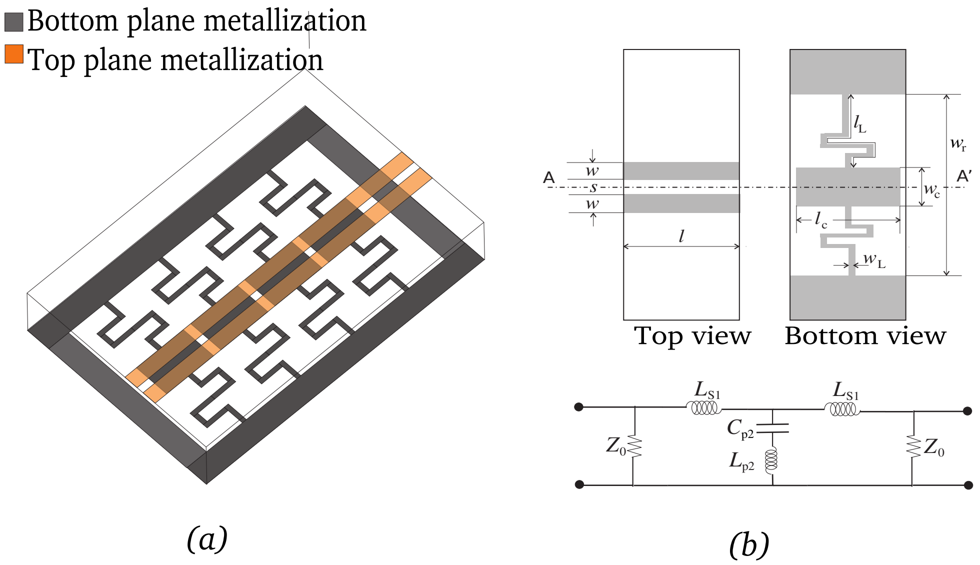

Fig. 1: (a) Differential transmission line proposed in this paper (four unit cell sections are shown). (b) Top and bottom views of a single unit cell and its elementary equivalent circuit.

2. Proposed differential transmission line

Fig. 1(a) shows the proposed structure for common-mode suppression. A number of LC resonators are etched in a slotted ground plane below a pair of coupled identical microstrip transmission lines. The basic unit cell is depicted in Fig. 1(b) together with the equivalent circuit for common mode operation. This equivalent circuit is obtained taking into account that the AA' central plane is a magnetic wall. An additional capacitance accounting for capacitive coupling between adjacent cells can be added to improve the quality of the model. Note that for the differential-mode the plane AA' is an electric wall, in such a way that patches in the ground plane side are virtually grounded. This means that the structure under differential mode operation does not meaningfully differ from a similar structure with a continuous ground plane (i.e., without the slotted and patterned region below the coupled strips). This would explain a very good matching of the structure to the nominal characteristic impedance (100 Ω in a typical case). However, it is obvious that the equivalent circuit in Fig. 1(b) gives place to a low–pass filter behavior. An artificial transmission line having as unit cell the one depicted in Fig. 1(b) has real characteristic impedance and propagation constant for frequencies below the resonance frequency of the shunt branch. Above that resonance frequency the transmission line exhibits an evanescent behavior, thus rejecting high frequencies. If a finite number of cells are considered, we could explain the same behavior in terms of the electrical response of a non-optimized quasi-elliptic low–pass filter. Therefore, we expect that the proposed structure prevents common-mode propagation above a certain frequency (the resonance frequency of the series LC branch) while differential–mode is not affected.

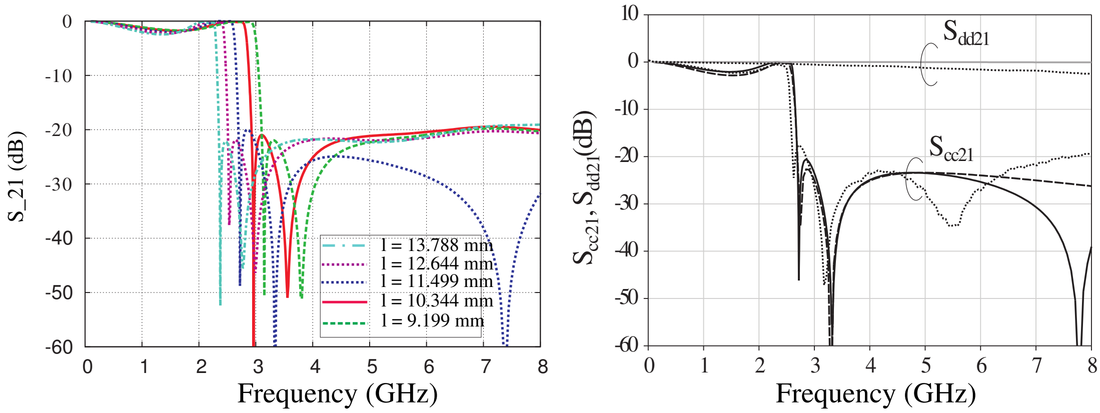

Fig. 2: (a) Common-mode filtering behavior for a pair of coupled strips having 100 Ω characteristic impedance for differential-mode operation; different curves correspond to different values of the shunt inductance. (b) Comparison between full-wave simulation (solid lines), measures (dot lines) for the insertion losses of both common and differential mode obtained by cascading two unit cells. Common-mode insertion losses from the equivalent circuit in Fig. 1(b) incorporating a coupling capacitance (dashed lines) are shown.

3. Numerical and experimental results

The behavior of the common-mode of a pair of coupled strips having the appropriate characteristic impedance under differential-mode operation is shown in Fig. 2(a). The variable parameter is the length of the high impedance meander line printed in the back-side of the substrate. This parameter controls the cutoff frequency of the low-pass filter. Simulated and measured results for one of those cases are shown in Fig. 2(b). Experimental data show a good rejection level (above 20 dB) along a wide frequency band (2.7 to 7.8 GHz). Differential-mode losses are rather small. The rejection level can be improved adding cells, although a higher level of losses for the differential mode should be then expected. Results including a pass-band balanced filter will be reported in the presentation.

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