All-Pass Slot-Based Artificial Transmission Line Unit-Cell

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Abstract

In this contribution a novel artificial TL unit-cell implementation is presented, which uses superimposed slot and stub fed by a microstrip TL. The equivalent circuit of the resultant structure is a lattice network and, therefore, can be designed for all-pass behaviour. Simulated results of the proposed unit-cell compared to those of the unit-cell with alternate stub and slot highlight the improvement achieved through the superposition of the stub and slot.

1. Introduction

After the introduction of the CRLH TL, artificial TLs with different topologies were proposed. Even a derivation of artificial TLs of arbitrary order was presented in [1]. This way, a specific dispersion diagram can be synthesized by simply cascading the necessary unit-cells. Several realizations of artificial TLs with high order in planar technology can be found in the literature, like in [2], where the series and shunt immittances are implemented with DGSs and stubs, respectively. An alternative for this structure was presented by the authors in [3], which makes use of alternate dumbbell-shaped DGSs and stubs for building a tri-band artificial TL and has the advantage of simple design for the balanced case. However, its important stop band and its lack of matching over the rest of the studied bandwidth have limited its possible applications. In [4] a variant of the mentioned structure, which used alternate rectangular stubs and slots for providing the required shunt and series immittances, respectively, was introduced by the authors. However, since it is based on a ladder network, it yields to the appearance of unavoidable stop-bands in the frequency response. In 2008 Bongard *et al.* proposed a CRLH unit-cell using a lattice network [5]. This novel unit-cell does not suffer from stop-bands as the T- , Π- or ladder-networks, thus presenting an all-pass behaviour when properly designed.

This contribution presents a modification of the structure presented in [4]. The equivalent circuit of the proposed unit-cell is a lattice network, thus theoretically being able to present an all-pass behaviour.

2. Unit-Cell Geometry

Fig. 1a shows the layout of the unit-cell presented in [4]. It consisted of alternate rectangular microstrip-fed stub and slot, which provided the required shunt and series immittances for the corresponding artificial TL. The proposed unit-cell is depicted in Fig. 1b, which is similar to the one in [4], with the particular modification of the superposition of the stub and slot, which affects significantly the behaviour of the structure, as will be shown. The reason behind is that the superimposed stub-slot results in a lattice network [6] and, therefore, can be designed to theoretically achieve an all-pass behaviour [4]. This

ISBN 978-952-67611-2-1

cannot be accomplished with alternate stub and slot, since the appearance of stop-bands at the poles of the phase factor is unavoidable in the ladder-network topology.

For low coupling in the superimposed structure (that is, small widths of the stub and slot), it can be assumed that the immittances of the resultant networks in both cases of Fig. 1 are provided by the same elements (the slot provides the series immittance and the stub, the parallel/cross one). Therefore, the design methodology for balance condition would be the same: the immittances in each branch must present exactly the same critical frequencies (poles and zeros).

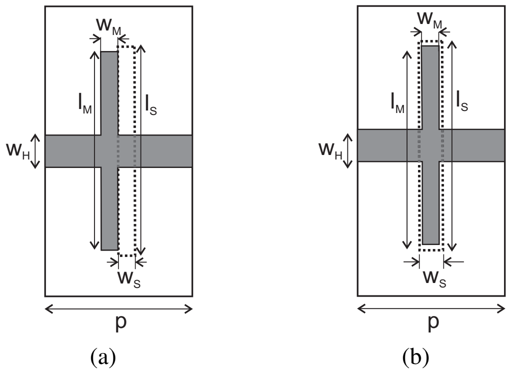


Fig. 1: Geometry of the unit-cell, where w_M, l_M, w_S and l_S stand for the widths and lengths of the stub and slot, respectively, p is the cell size and w_H the width of the host TL. (a) corresponds to the unit-cell presented in [4] and (b) to the proposed unit-cell.

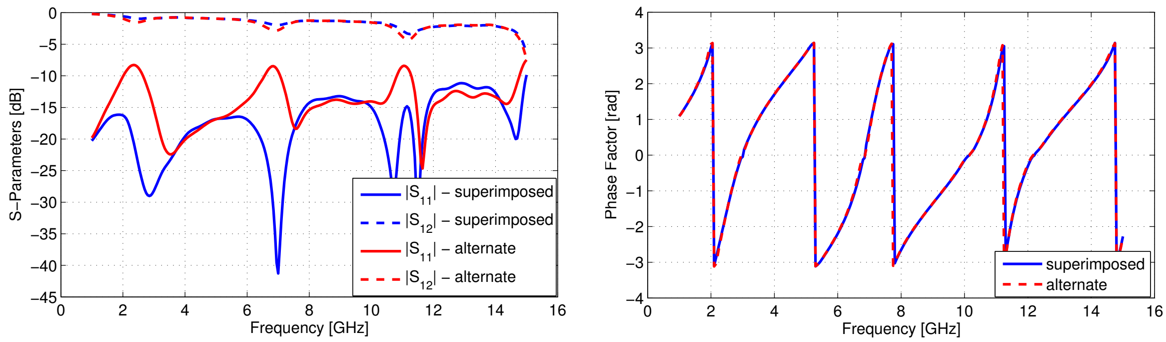
3. Simulated Results

Since the conditions for balance behaviour of both structures of Fig. 1 are the same, the results shown in this section correspond to the electromagnetic full-wave simulation of the structure with the dimensions of the design that was carried out in [4], for the sake of comparison with the unit-cell with alternate stub and slot. Then, the simulated structure is on ARLON 1000 substrate with ϵ_r=10 and h=50 mil, with $w_S = w_M$ =0.3 mm, l_S =30 mm, l_M =27.25 mm and w_H =1.95 mm (the characteristic impedance of the host TL is 39 Ω). Therefore, we compare the unit-cell presented in [4] with the one with superimposed stub and slot, without any further modification. Then, it is worth noting that design optimization will improve the obtained results. Fig. 2a and 2b show a comparison of the S-parameters and the phase factor, respectively, of both unit-cells for a cell-size p=10 mm. It can be observed, that the superimposed structure does not present any stop-bands at the poles of the phase factor, achieving good matching over the whole band. The phase factor remains practically the same in both cases, with alternate RH and LH bands. The first resonance frequency of the stub/slot was set to 2.4 GHz, which corresponds to the first pole of the phase factor.

Finally, Fig. 3 shows a comparison of the resultant S-parameters of a three-cells structure with the proposed unit-cell and the one presented in [4]. It is highlighted that the only fact of superimposing the stub and slot improves significantly the behaviour of the TL.

4. Conclusion

A novel unit-cell structure has been proposed, which is implemented on planar technology and uses superimposed stub and slot fed by a microstrip TL. A significant improvement is achieved through the superposition of both the stub and the slot instead of using alternate stub and slot, since the fact of superimposing both elements makes the resultant equivalent circuit change significantly: the structure behaves as a lattice network, which means that stop bands that are unavoidable in T- or $\Pi-$topologies



(a) (b)

Fig. 2: (a) S-parameters and (b) phase factor for the proposed unit-cell compared the unit-cell in [4].

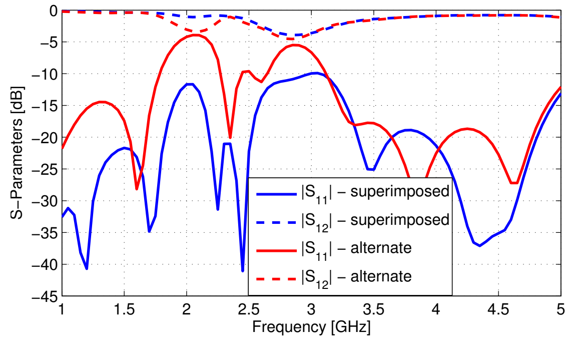


Fig. 3: S-Parameters comparison for a three-cells structure with the proposed unit-cell and with the unit-cell of [4].

can now be supressed. Besides its all-pass behaviour, advantages of the proposed unit-cell are its easy fabrication, single layer and the no need of via-holes or air bridges.

Acknowledgement

This work was supported by the Spanish Ministerio de Ciencia e Innovación (Programa Consolider-Ingenio 2010) under Grants CSD2008-00066, EMET, and CSD2008-00068, Terasense, and by the Junta de Andalucía (Spain) under Grant P10-TIC-6883.

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