Using a Via-Less Composite Right/Left Handed Transmission Line to Design a High Compact Wilkinson Power Divider

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Abstract

The design and implementation method of a new via less CRLH transmission line is presented. The CRLH transmission line characteristics are explained versus the variation of parameters. The CRLH unit cell is optimized to reach the characteristic impedances as low as 30 Ohms. Finally a very compact 1-4 Wilkinson power divider is designed and fabricated.

1. Introduction

Since the introduction of materials supporting backward wave propagation, different realization of these materials has been reported. A transmission line (TL) with a series capacitance and shunt inductance can be used as a left handed TL. Unfortunately, due to the parasitic series inductor and shunt capacitor, it's impossible to have a pure left handed TL. Therefore, by modelling these parasitic elements, a model of TL called composite right/left-handed (CRLH) transmission line has been introduced. This line acts as a left-handed line at high frequencies while it is a conventional transmission line at low frequencies[1,2]. In this paper, a new via less CRLH TL have been modelled. The effect of all the parameters variations is derived and four more important parameters are selected to use in optimization. The results show that by using this new CRLH, any characteristic impedance can be achieved as low as 30 Ohms. Although, small electrical length can't be realized with small characteristic impedances. Finally, a 1-4 Wilkinson divider is designed and fabricated to show the capability of the method.

2. CRLH Transmission Line Model

A CRLH TL is composed of series capacitance, shunt inductor, series inductor and shunt capacitance. The model of this via less CRLH TL is shown in Fig.1. The series capacitor (C_{se}) is a metal-insulator-metal (MIM) capacitor. The series capacitor, C_{se}, is a function of the distance between the metal plates, substrate height and their area. The parameters *lcap* and *wcap* which are the dimension of C_{se} area plates, are used to change the value of the series capacitor. The shunt inductor (L_{sh}) is a meander inductor located at the ground plate of the substrate. The length of each meander is equals to *lcap* and the width and space between meanders is *wmndr* and *smndr*, respectively. Parasitic capacitors between top and bottom metals are modelled by shunt capacitor, C_{sh}. Also, the effective inductance of the defected ground structure are modelled by the series inductor, L_{se}, which can been controlled by s_x.

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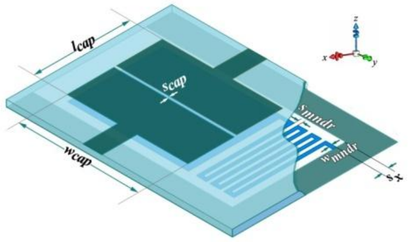

Fig. 1: 3D structure of composite right/left-handed transmission line

As it is proved in [1], when $C_{sh}L_{sh}=C_{se}L_{se}$, a balanced CRLH TL is achieved. The characteristic impedance of this CRLH TL (Z_0) doesn't change versus frequency. One the other hand, we don't have a complete control on L_{se} and C_{sh}. Therefore it's hard to achieve this condition and design a balanced CRLH TL.

To design this TL, we added a parameter called *scale* to scale all the parameters, (*lcap, wcap, scap, lmndr, wmndr, smndr,* and *sx*) identically. Therefore, we can change the operation frequency by tuning this parameter. Simulation results show that increasing *wmndr* and *smndr*, decreases the CRLH TL characteristic impedance while it's electrical length is increased. In summary, increasing of *wcap* and *lcap* increases the characteristic impedance and decreases electrical length of CRLH TL. Fig. 2 shows the effect of *wmndr* and *wcap* on the characteristic impedance and electrical length of CRLH TL separately.

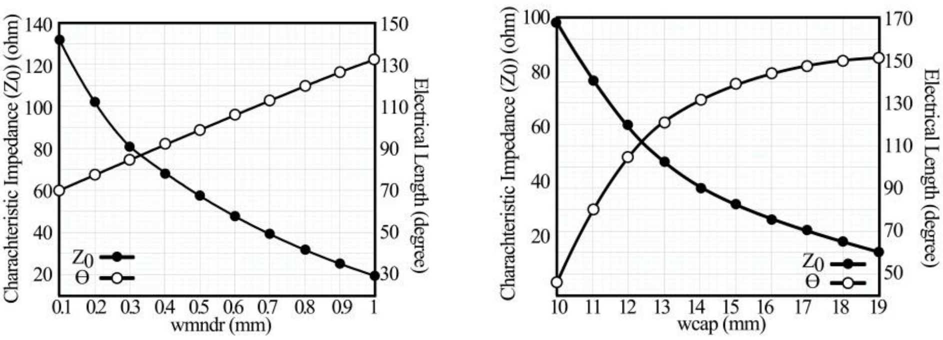

Fig. 2: Effect of *wmndr* and *wcap* on CRLH TL characteristic impedance and electrical length

The effect of *lcap* and *wcap* in electrical length is similar, while *lcap* has a more effect on characteristic impedance. Moreover, *wmndr* has the most effect on electrical length.

Also, the location effect of two 50 Ohm lines is studied. It has a small effect on characteristic impedance and electrical length, but the best condition will be achieved when the right line is far from the meander inductor and the left line is near to it.

Now we are ready to design a transmission line based on 70.7 ohm characteristic impedance for a Wilkinson power divider. Our reference impedance(Z_r) is 50 Ohm. The relation between characteristic impedance and S parameters is[3]

$$Z_0 = Z_r\sqrt{\frac{(1+S_{11})^2 - S_{21}^2}{(1-S_{11})^2 - S_{21}^2}}\,. \quad (1)$$

This approximation well describes the proposed CRLH TL. Notice the Electrical length of the CRLH is equals to the argument of S_{12}. By optimization of the design parameters described before, a CRLH TL with real characteristic impedance of 72.2Ω and small imaginary part of 0.2 Ω and an electrical length of 90 degrees has been designed at 460 MHz on a TLX-8 substrate with a dielectric constant of 2.55, a tangent loss of 0.0019 and a thickness of 0.8 mm. The value of the parameters is shown in Table 1.

Table 1. The design parameters value for a CRLH with Z0=72.2Ω and 90 degrees electrical length

Parameters	Value	Parameters	Value
Wmndr	0.45 mm	*wcap*	16.5 mm
Smndr	0.4 mm	*lcap*	12 mm
Sx	1 mm	*scap*	0.2 mm

3. Wilkinson Implementation

According to the designed CRLH TL, a 1 to 4 Wilkinson power divider is designed at 460 MHz. The designed power divider shown in Fig. 3 has about 80% compactness compared with the traditional one.

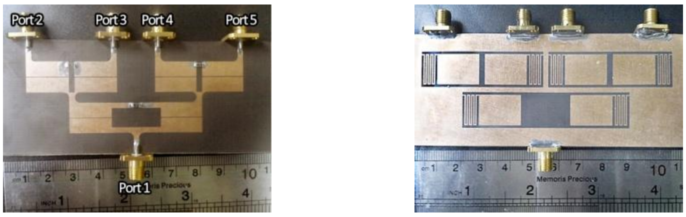

Fig. 3 The fabricated 1 to 4 Wilkinson power divider

The electrical performance of the divider has been measured by using Agilent E5071C network analyser. To measure S parameters, 3 ports terminated with a 50 Ohm loads while two other ports connected to network analyser. The simulated and measured return losses, insertion losses and isolations are shown in Fig. 5. Due to the symmetry of the structure, other ports have the same results. The plots show a good agreement between the measurement and simulation results. The fabricated Wilkinson divider has a return loss better that 30 dB, an insertion loss better than 6.4 dB, and an isolation better than 15dB for near ports and better than 25dB for far ports.

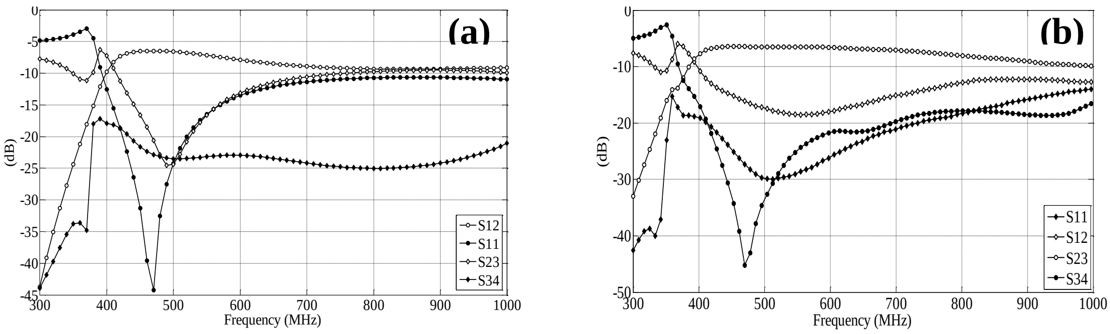

Fig. 5: S parameters of 1 to 4 Wilkinson power divider a) Simulation and b) measurement

4. Conclusion

An improved method to design a via-less CRLH TL were developed. The effect of the proposed CRLH TL parameters were completely discussed. A CRLH TL with a real characteristic impedance of 72.2 Ohm and electrical length of 90 degrees were designed and used to implement a 1 to 4 Wilkinson power divider. The divider has about 80% compactness compared with the traditional one.

References

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