Dual Band Branch-Line Coupler using Novel CRLH Transmission Lines

Iulia A. Mocanu[1], Gh. Sajin[2]

[1]Department of Microwave,University Politehnica of Bucharest
P.O. Box 061071, B-dul Iuliu Maniu 1-3,Bucharest, Romania,
email: mihai.iulia83@yahoo.com
[2] National Institute for Research and Development in Microtechnologies, IMT Bucharest
P.O. Box 077190, Str. Erou Iancu Nicolae 126A, Bucharest, Romania
email: gheorghe.sajin@imt.ro

Abstract

In this paper is presented the design, simulation and electric characterization of a new CRLH dual band branch-line coupler. The novelty of this coupler is that it uses Composite Right / Left-Handed (CRLH) transmission lines with only one unit cell designed to act as a quarter wave-lengths. The design relations for this quarter wavelengths CRLH transmission lines are deduced analytically and validated accordingly to simulation and measurement of the coupler's perform-ances. The unit cells have been implemented using lumped components and the impact of the parasitic effects of the capsules has been analyzed and discussed.

1. Introduction

The artificial transmission lines are very important when designing dual band devices. The most commonly used are the CRLH transmission lines. In order to introduce a phase of $\pm 90^{o}$ at two different frequencies, the CRLH transmission lines were designed with more than one unit cell [1]. The impact of losses is very high when these unit cells were implemented with lumped elements. This is the main reason for which it is necessary to design transmission lines with only one unit cell whilst maintaining the main advantages of a quarter wavelength CRLH transmission line: the dual band be-haviour and the two phases introduced at the two different working frequencies. The cells may be de-signed having a "T" shape or a "Π" one, as shown in Fig.1 and Fig. 2.

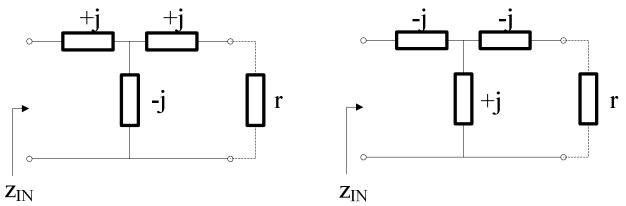

Fig.1: "T" shape unit cell for quarter wavelengths transmission lines.

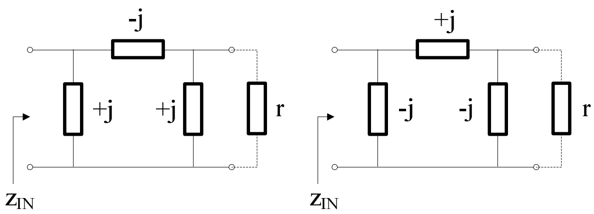

Fig.2: "Π" shape unit cell for quarter wavelengths transmission lines

ISBN 978-952-67611-2-1

It can be easily demonstrate that these unit cells have a behaviour of quarter wavelength transmission line [2]. A very important aspect of these unit cells is that they were designed using normalized immittances. This fact allows one to choose any value for the characteristic impedance that is needed.

Next, the analytical expressions for the lumped elements that form the transmission line will be obtained. In order to have a CRLH unit cell, in the longitudinal branches there was placed a capacitor in series with an inductor and in the transversal branch there was placed a capacitor in parallel with an inductor. Considering Z_c the characteristic impedance of the transmission line and $k = \omega_2 / \omega_1$ the ratio between the two working frequencies, one can get after some manipulations [2]:

$$\begin{aligned} L_R &= \frac{1}{k-1} \cdot \frac{Z_c}{\omega_1}; C_L = \frac{k-1}{k} \cdot \frac{1}{\omega_1 \cdot Z_c}; \\ C_R &= \frac{1}{k-1} \cdot \frac{1}{\omega_1 . Z_c}; L_L = \frac{k-1}{k} \cdot \frac{Z_c}{\omega_1}. \end{aligned} \tag{1}$$

where C_L, L_L, C_R and L_R, are, respectively, the capacitive and inductive series and parallel components of the CRLH cell.

2. Design and measurement of the novel dual band CRLH branch-line coupler

The new CRLH branch-line coupler was designed using unit cells like the ones presented in Fig. 1 and Fig. 2. The two working frequencies are: f_1 = 930 MHz, respectively f_2 = 1780 MHz. The first frequency is base stations transmit frequency band in the global system for mobile communication (GSM) 900 and the second frequency is the GSM 1800 mobile phone transmit frequency band [1]. The ratio between these two frequencies is $k = 930/1780$.

In order to obtain a greater bandwidth, there has been used a three branches branch-line coupler. The lumped elements used were SMD0603 ones. For this kind of components each capacitor had a series inductance of Lp = 0.7 nH, meanwhile each inductor had a parallel capacitance Cp =0.15pF. The layout of the coupler is presented in Fig. 3 and its total size is 1.5×0.75 mm^2. The “TL” abbreviation in Fig.3 stands for “Transmission Line”.

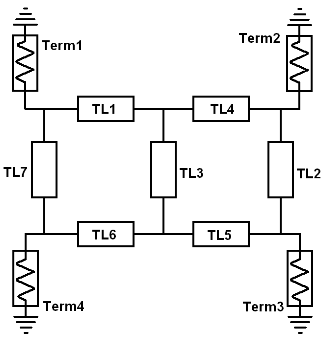

Fig.3: The layout of the three branches branch line coupler

After a process of optimisation and taking into account the effects of the parasitic elements [3], there have been obtained the numerical values for the characteristic impedances for each transmission line: Z_L = 40.749Ω for the transmission lines : TL1, TL4, TL5, TL6; Z_{TL} = 121.599Ω for the transmission lines TL7, TL8 and Z_{TC} = 51,583Ω for the transmission line TL3. One can now get the values for the capacitances and inductances using relations (1).

The coupler was implemented using lumped elements with values chosen to be as close as possible as the ones obtained analytical. The results obtained after measurements are presented in Fig.4.

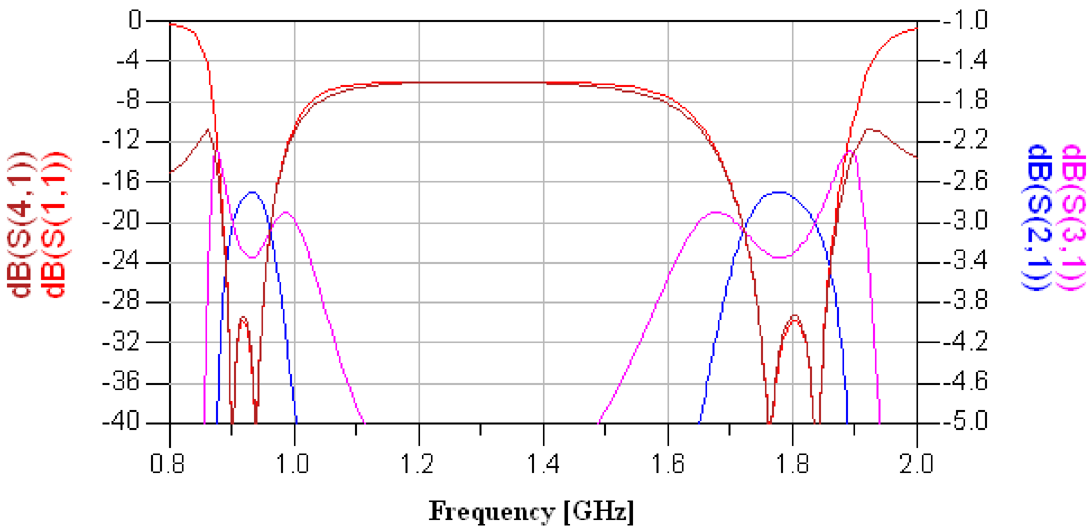

Fig.4: The performances of the novel CRLH three branches branch line coupler

For the first working frequency the fractional bandwidth is of 10%, meanwhile for the second working frequency the fractional bandwidth is of 16%. For both bandwidths the isolation and return loss are around 30dB. It is clear that the impact of parasitic effects and the values of the used lumped elements are very important in the performances of the coupler. Even though, the results obtained after measurements confirm the validity of design introduced in this paper.

4. Conclusion

In this paper was presented the design, optimization, simulation and electrical characterization of a CRLH branch line coupler using a new type of CRLH unit cell. The advantage of this type of cells is that they are designed to be symmetrical and to act as a quarter wavelength transmission line. In this case, the number of lumped elements used in creating the devices is reduced and so are the parasitic effects. The novel CRLH branch line coupler exhibits a dual band frequency behaviour and the performances are very good considering the type of lumped elements that were used. In order to improve the characteristics of the device, it is recommended to use other types of lumped elements, such as SMD 0201 which implies having small losses and tighter tolerances. The only inconvenience of using these elements is that an adequate technique is required which implies using automatic positioning of the components. This is one way of avoid the large errors that occur when SMD 0603 components are used.

References

[1] C. Caloz, T. Itoh, *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2006

[2] I.A.Mocanu, T. Petrescu, Novel Dual Band Hybrid Rat-Race Coupler with CRLH and D-CRLH Transmission Lines, Proceedings of *25th The Asia Pacific Microwave Conference, APMC 2011*, pp. 888-891, Melbourne, Australia, 5 – 8 December 2011.

[3] ***, Ansoft Designer, SV 2006.