THE INFLUENCE OF CELL SYMMETRY IN THE PERFORMANCES OF D-CRLH BRANCH LINE COUPLERS

Iulia Andreea MOCANU[1]

În această lucrare este prezentată o nouă categorie de cuploare branch-line de tip bandă dublă, cuploarele D-CRLH (Dual-Composite Right/Left Handed). Noutatea acestui tip de cuploare este că ele sunt variantele duale ale cuploarelor CRLH branch-line, care au fost deja implementate. Avantajul acestor noi cuploare este că prezintă proprietatea de a lucra la două frecvențe de lucru, arbitrar alese cu performanțe similare. Aşadar ele pot fi folosite cu succes în aplicații de tip bandă dublă. Pentru realizarea acestor cuploare, se vor deduce relațiile de proiectare a liniilor de transmisiune D-CRLH care le alcătuiesc, urmând a se studia influența simetrizării celulelor ce compun liniile de transmisiune asupra performanțelor cuplorului D-CRLH branch-line propus.

In this paper, a new category of branch-line dual band couplers is presented, the D-CRLH (Dual-Composite Right/Left Handed) couplers. These novel couplers are the dual alternative for the already implemented CRLH branch-line couplers. The advantage of these couplers is that they posses the property of dual band behavior at two distinct frequencies. So, they are very good candidates for dual band applications. In order to create these couplers, there will be deduced the design relations for the D-CRLH transmission lines. Next, there will be studied the influence of the cells symmetry in the performances of these type of couplers.

Keywords: D-CRLH transmission lines, branch-line coupler, dual band, cell symmetry

1. Introduction

The first dual band LH branch-line couplers have been the CRLH (Composite Right/Left Handed) ones [1]. They were created using CRLH transmission lines and proved dual band behavior. Meanwhile, new transmission lines have been imaginated, such as the D-CRLH ones [2], which are the dual alternative to the well known CRLH transmission lines and have dual behavior.

In this paper, we will determine the analytical designing relations for the transmission lines that create the dual band D-CRLH coupler and we will study its performances reffered to the symmetry of the cells used in the designing process.

[1] Assistant, Depart. of Telecommunications, University POLITEHNICA of Bucharest, Romania, e-mail: mihai.iulia83@yahoo.com

2. Design of dual band D-CRLH transmission lines

In order to design a branch line coupler, one needs to first design the quarter-wavelengths transmission lines. First of all, the phases introduced by the transmission line at the two operating frequencies are considered: $\Phi_1 = -\beta_1 l$ and $\Phi_2 = -\beta_2 l$, where l is the physical lengths of the transmission lines, meanwhile $\beta_1 = \beta(\omega_1)$, respectively $\beta_2 = \beta(\omega_2)$ are the two phase constants evaluated at each frequency ω_1, respectively ω_2.

It has been demonstrated that the phase constant and the characteristic impedance for a balanced D-CRLH cell can be expressed using the per-unit-lengths lumped elements, as follows [2]:

$$\beta^{D-CRLH} = \frac{\omega\sqrt{L'_R C'_R}}{1-\omega^2\sqrt{L'_R C'_R L'_L C'_L}}, \quad (1)$$

$$Z_t^{D-CRLH} = \sqrt{\frac{L'_R}{C'_R}} = \sqrt{\frac{L'_L}{C'_L}}. \quad (2)$$

As relations (1) and (2) show, we can determine the lumped elements if we consider the two expressions for the characteristic impedance and if we have two different values for the phase constant at two different frequencies [3], [4]. So, it is obvious that this transmission line have a dual band behavior. After solving the system, we find the expressions for the per-unit-lengths inductances and capacities of the D-CRLH cell:

$$L'_R = \frac{Z_t\beta_1\beta_2\left[1-(\omega_1/\omega_2)^2\right]}{\omega_1\left[\beta_2-\beta_1(\omega_1/\omega_2)\right]}, \quad (3)$$

$$C'_R = \frac{\beta_1\beta_2\left[1-(\omega_1/\omega_2)^2\right]}{Z_t\omega_1\left[\beta_2-\beta_1(\omega_1/\omega_2)\right]}, \quad (4)$$

$$L'_L = \frac{Z_t\left[(\omega_1/\omega_2)\beta_2-\beta_1\right]}{\omega_2\beta_1\beta_2\left[1-(\omega_1/\omega_2)^2\right]}, \quad (5)$$

$$C'_L = \frac{\left[(\omega_1/\omega_2)\beta_2-\beta_1\right]}{Z_t\omega_2\beta_1\beta_2\left[1-(\omega_1/\omega_2)^2\right]}. \quad (6)$$

The transmission line implies having chained a number of N cells and each cell introduce a certain phase, so the total phase introduced by the transmission line is:

$$\Phi = N\Delta\Phi = \frac{l}{\mathrm{d}z}\Delta\Phi, \tag{7}$$

where dz is the length of the unit cell and $\Delta\Phi$ is the phase introduced by each cell. After taking into account relation (7) and the fact that:

$$L'_R = \frac{L_R}{\mathrm{d}z},\ C'_R = \frac{C_R}{\mathrm{d}z},\ L'_L = L_L \mathrm{d}z,\ C'_L = C_L \mathrm{d}z. \tag{8}$$

Relations (3)-(6) can be rewritten:

$$L_R = \frac{Z_t \Phi_1 \Phi_2 \left[1-(\omega_1/\omega_2)^2\right]}{N\omega_1\left[\Phi_2 - \Phi_1(\omega_1/\omega_2)\right]}, \tag{9}$$

$$C_R = \frac{\Phi_1 \Phi_2 \left[1-(\omega_1/\omega_2)^2\right]}{NZ_t\omega_1\left[\Phi_2 - \Phi_1(\omega_1/\omega_2)\right]}, \tag{10}$$

$$L_L = \frac{NZ_t\left[(\omega_1/\omega_2)\Phi_2 - \Phi_1\right]}{\omega_2\Phi_1\Phi_2\left[1-(\omega_1/\omega_2)^2\right]}, \tag{11}$$

$$C_L = \frac{N\left[(\omega_1/\omega_2)\Phi_2 - \Phi_1\right]}{Z_t\omega_2\Phi_1\Phi_2\left[1-(\omega_1/\omega_2)^2\right]}. \tag{12}$$

3. Dual band D-CRLH branch-line coupler with asymmetric unit cells

A branch-line coupler is created using two types of transmission lines with characteristic impedance of 50Ω, respectively of 35.35Ω [5]. Also, in order to design the transmission lines, it is needed to set the two operating frequencies for the coupler: $f_1 = 930\text{MHz}$, respectively $f_2 = 1780\text{MHz}$ [6]. These two frequencies are chosen so that the first frequency is in the global system for mobile communication (GSM) 900 base station transmit frequency band, and the second frequency is the GSM 1800 mobile phone transmit frequency band [7], [8].

Also, the number of unit cells that will create each transmission line will be N=2 and the two phases that they will introduce at the operating frequencies, will be $\Phi_1 = \frac{\pi}{2}$, respectively $\Phi_2 = -\frac{\pi}{2}$. So, the first frequency will be found in the RH frequency range, meanwhile the second one will be found in the LH frequency range. Using the relations demonstrated above, (9)-(12), there can be determined the values for the lumped elements for each transmission line:

- For the transmission line with the characteristic impedance of $Z_t = 35.35\Omega$:

  $L_R = 2.269nH$, $C_R = 1.816pF$, $L_L = 8.428nH$, $C_L = 6.744pF$;

- For the transmission line with the characteristic impedance of $Z_t = 50\Omega$:

  $L_R = 3.209nH$, $C_R = 1.284\,pF$, $L_L = 11.92nH$, $C_L = 4.768\,pF$.

In Fig. 1, it is presented the D-CRLH branch-line coupler using transmission lines with asymmetric cells [3].

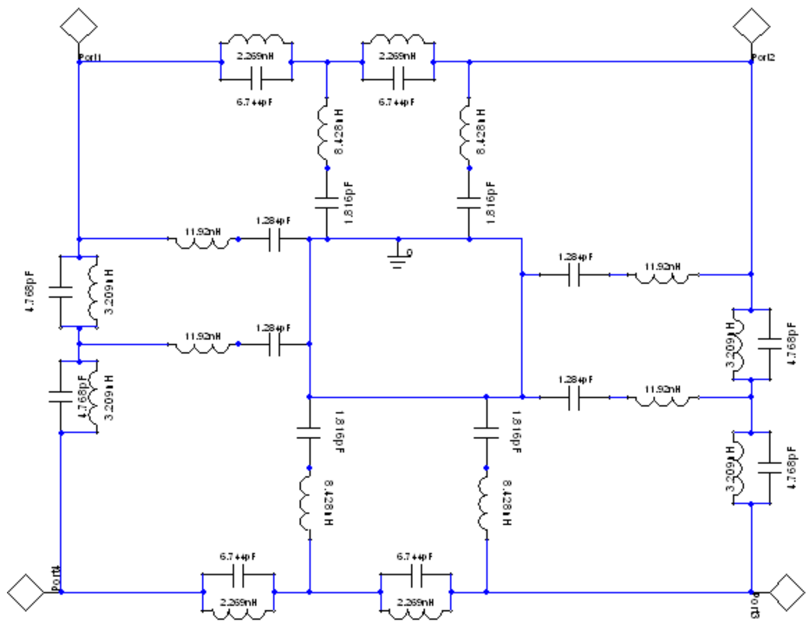

Fig. 1. D-CRLH branch-line coupler using asymmetric unit cells

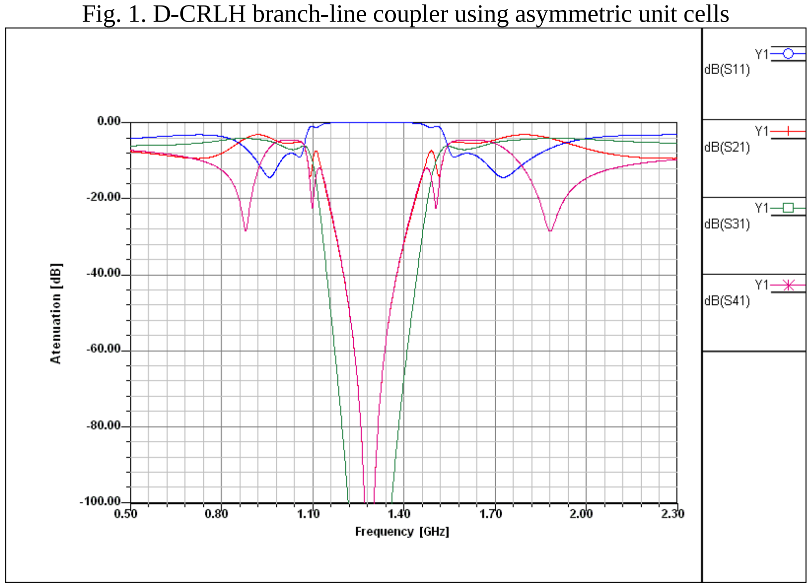

Fig. 2. Simulated S-parameters for D-CRLH branch-line coupler using asymmetric unit cells

The results for the simulated S-parameters are represented in Fig. 2, meanwhile the phase difference at the two output ports is represented in Fig. 3. The values for the most important parameters at the two operating frequencies are shown in Tabel 1.

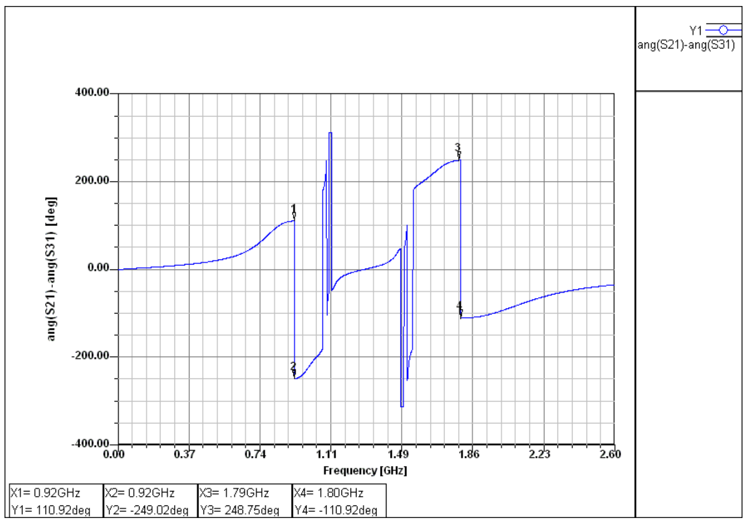

Fig. 3. Simulated phase difference for D-CRLH branch-line coupler using asymmetric unit cells

Table 1

The parameters of the D-CRLH branch-line coupler using asymmetric unit cells

Parameters	f_1=920MHz	f_2=1790MHz
Return loss (s_{11})	10.84 dB	10.79 dB
Output 1 (s_{21})	3.11 dB	3.10 dB
Output 2 (s_{31})	4.39 dB	4.39 dB
Isolation (s_{41})	11.89 dB	11.98 dB
Phase difference	$110.92^{o}/-249.02^{o}$	$248.75^{o}/-110.92^{o}$

As shown in Table 1, the performances for this type of coupler are very poor and the main reason is the fact that there are used asymmetric unit cells for the transmission lines, which determine different values for the input impedances of the transmission lines.

4. Dual band D-CRLH branch-line coupler with symmetric unit cells

As it was previously shown, a symmetric unit cell is needed in order to improve the performances of the proposed coupler. There will be analyzed two cases for the symmetry: after a transversal plane and a longitudinal one. In Fig. 4, it is shown the coupler using transversal plane symmetric unit cells.

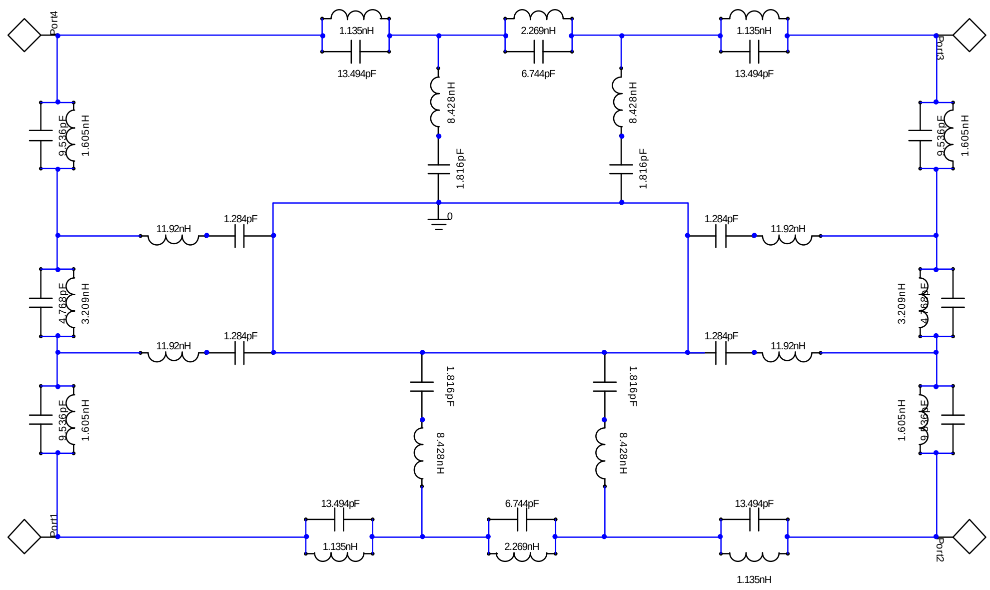

Fig. 4. D-CRLH branch-line coupler using transversal plane symmetric unit cells

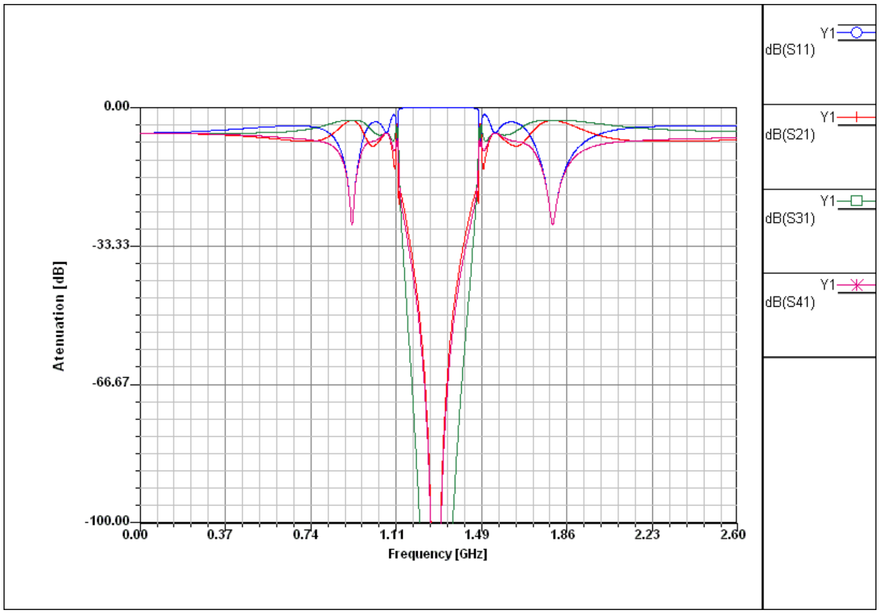

Fig. 5. Simulated S-parameters for D-CRLH branch-line coupler using transversal plane symmetric unit cells

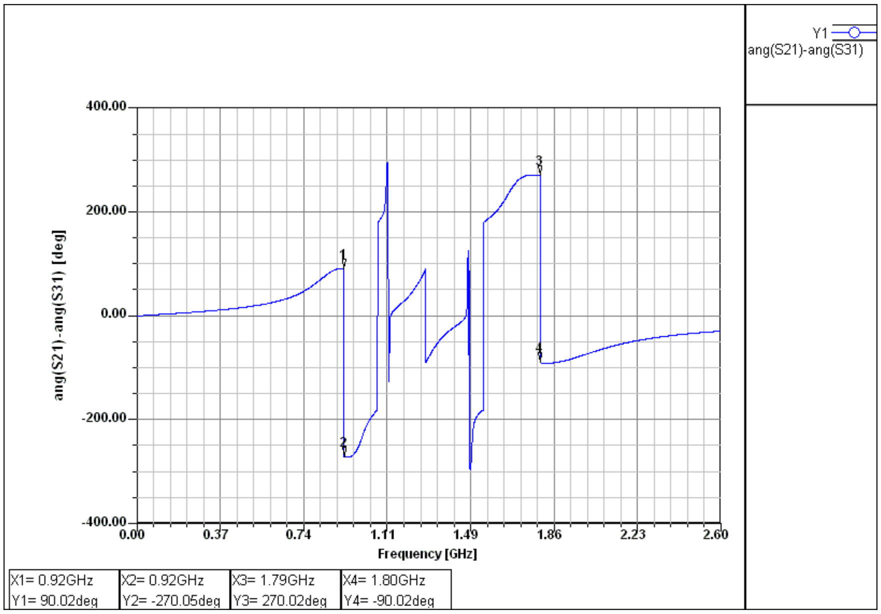

Fig. 6. Simulated phase difference for D-CRLH branch-line coupler using transversal plane symmetric unit cells

The results from simulation at the two operating frequencies are synthesised in Table 2.

Table 2

The parameters of the D-CRLH branch-line coupler using transversal plane symmetric unit cells

Parameters	f_1=920MHz	f_2=1790MHz
Return loss (s_{11})	27,89	28,02
Output 1 (s_{21})	3,01	3,01
Output 2 (s_{31})	3,04	3,04
Isolation (s_{41})	28,04	28,05
Phase difference	90,02/-270,05	270,02/-90,02

As table 2 shows the results are improved due to symmetry of the cells, because in this case the input impedances at each port of the transmission lines are equal. This helps having a good return loss at the two operating frequencies. The fact that the two frequencies are easily shifted is due to the fact that when symmetry is realized the values for the lumped components are slightly different from the original, calculated ones. But, even though, the performances are much better in this case than in the previous one, when asymmetric unit cells were used. Next, there will be analyzed the coupler using longitudinal plane symmetric unit cells, Fig. 7. The simulated S-parameters and the phase difference are represented in Fig. 8and Fig. 9, respectively.

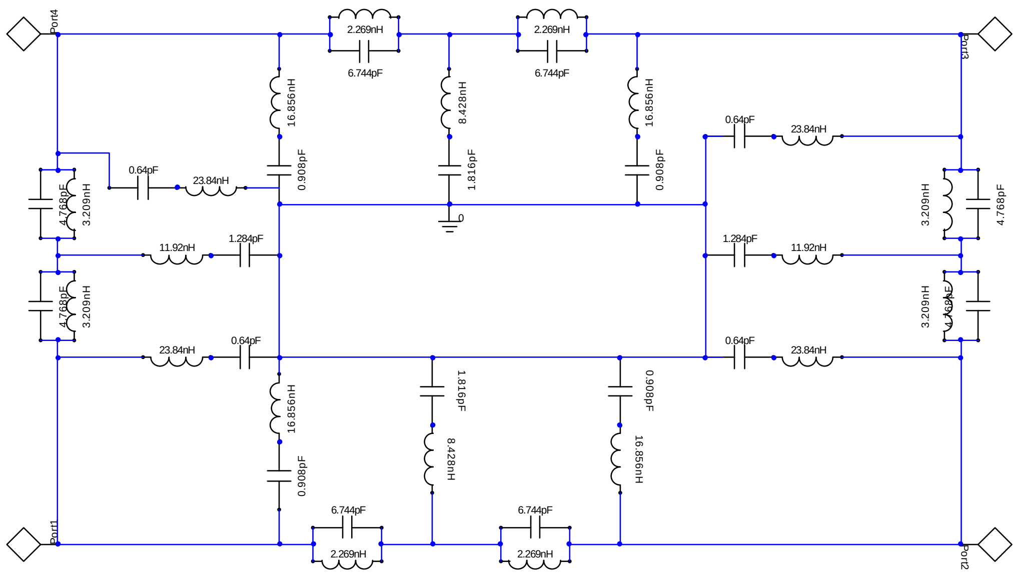

Fig. 7. D-CRLH branch-line coupler using longitudinal plane symmetric unit cells

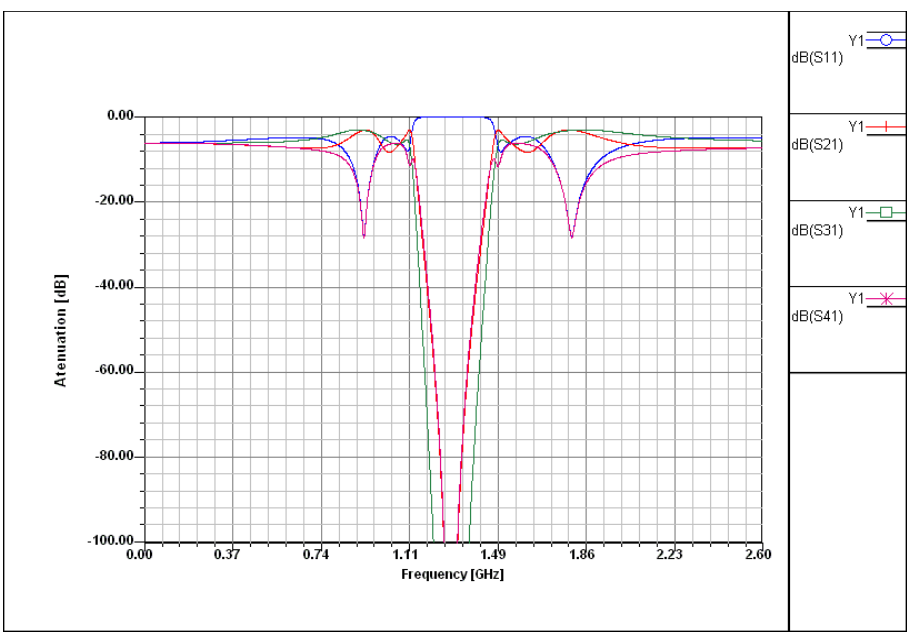

Fig. 8. Simulated S-parameters for D-CRLH branch-line coupler using longitudinal plane symmetric unit cells

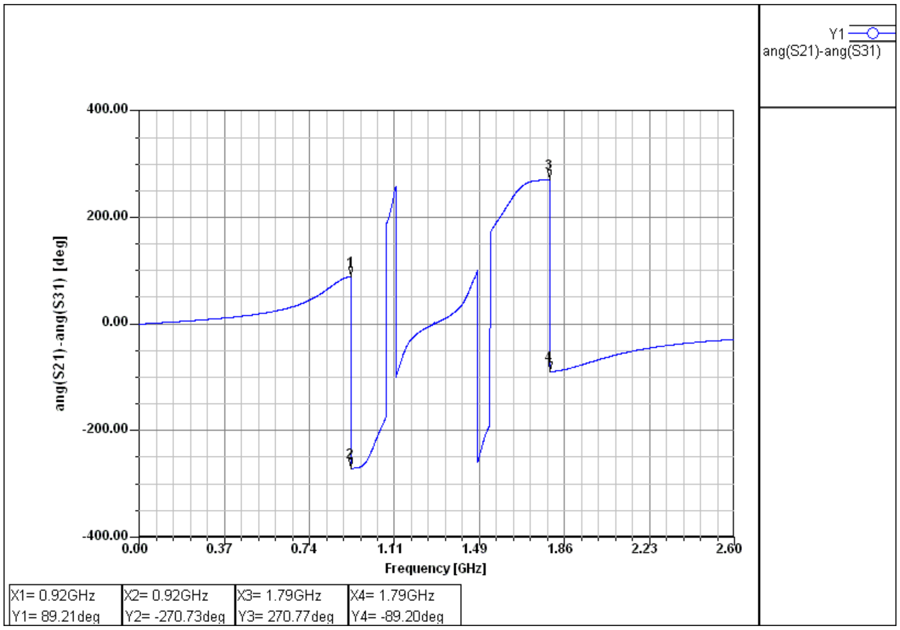

Fig. 9. Simulated phase difference for D-CRLH branch-line coupler using longitudinal plane symmetric unit cells

The values for the most important parameters of the coupler are shown in Table 3.

Table 3

The parameters of the D-CRLH branch-line coupler using longitudinal plane symmetric unit cells

Parameters	f_1=920MHz	f_2=1790MHz
Return loss (s_{11})	28.07	28.07
Output 1 (s_{21})	3.00	3.00
Output 2 (s_{31})	3.04	3.05
Isolation (s_{41})	28.26	28.27
Phase difference	89.21°/-270,73°	270.77°/-89,20°

Comparing the results from the two tables, Table 2 and Table 3, one can notice that there are no major differences between the two analyzed cases. This means that the type of symmetry for the unit cells is not that important as long as it is done. Even though, some small differences can be seen. For example, the phase imbalance is slightly smaller in the case of the transversal plane symmetric unit cells than in the case of the longitudinal plane symmetric unit cells. But, the coupler using longitudinal plane symmetric unit cells has the return loss and the isolation better than the case of the transversal plane symmetric unit cells [9].

6. Conclusions

The differences between the two types of symmetry: over a transversal plane and the longitudinal plane, will be neglected when a real implementation will be made. Choosing a certain type of symmetry for the unit cells is restrained by the available components and the technological possibilities to realize parallel groups.

The most important aspect that must be considered is the fact symmetric unit cells are needed in order to improve the performances of the coupler.

Also, the D-CRLH branch-line coupler exhibits dual band behaviour, so it can be used successfully in dual band applications [10].

R E F E R E N C E S

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