Study of a Wide-band Strip Line Couplers' Susceptibility Based on the Number of Transmission Lines with Non-uniform Impedances

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Abstract— Hybrids and couplers are commonly used for the microwave applications as very important elements. These elements are made from various forms and used at the specific applications. The strip line structure is one of the cheap structures for couplers and hybrid's design due to their less radiation loss and interference on the micro strip. Presented is a wideband stripline directional coupler which is of interest in any measurement application. The susceptibility parameter of this coupler at 2–6 GHz band, have been reported based on the number of transmission line with non-uniform impedances.

1. INTRODUCTION

Directional couplers are essential components in various microwave applications for sampling from a signal or measure its power or to inject it into other parts of the system. The directivity parameter of a directional coupler is important in case of power measurement [1–5]. Accuracy of the coupling factors depends on the dimensional tolerances for the spacing of the two coupled lines. The $\lambda/4$ coupled line design is valid for coaxial and stripline implementations due to their homogeneous medium. A single 4 coupled section is good for bandwidths of less than an octave. To achieve greater bandwidth multiple $\lambda/4$ coupling sections are used. The design of such a couplers proceeds in much the same way as the design of distributed element filters.

In this paper, we present a directional coupler in 2–6 GHz band based on non-uniform transmission line design method. The sensitivity of the results due to variance of the number of sections has been reported. In order to carry out the boundary lines for this coupler, we are in need to solve an integral representing the coupling factor numerically. This integral has been solved for a 20-dB coupling factor in 2–6 GHz band.

2. COUPLER DESIGN

Figure 1 illustrates an N-section schema for an integrated non-uniform coupler. As we can see at the Fig. 1 coupler is made of the number of N transmission lines with unequal impedances. A numeric integration is performed to calculate even mode impedances namely Z_{oe}. The design procedure is carried out by means of equally ripple transmission and proper impedance bandwidth. Fig. 2, shown the steps to generate symmetrical coupler formulas with cascading ABCD matrices. The main purpose of these steps is to find out the polynomial function namely $P_{\mathrm{N}}(\sin\theta)$ with equally rippled response in the frequency band of the coupler. Here, θ is the electrical length of each section. The $P_{\mathrm{N}}(x)$ response has been shown in Fig. 3.

In this figure, P^+ and P represent for maximum and minimum value of $P_{\mathrm{N}}(x)$ function. Details are reported in [6]. In order to find out the even mode impedances which use in boundary line

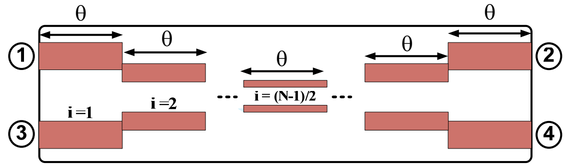

Figure 1: Internal structure of an N-section non-uniform coupler.

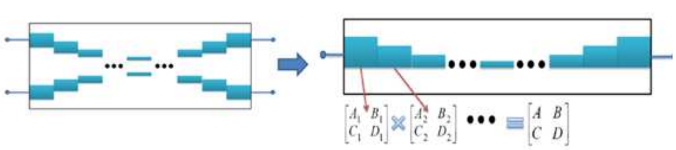

Figure 2: Steps to obtain symmetrical coupler formulas.

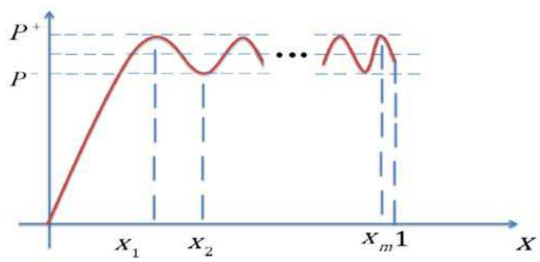

Figure 3: Ideal $P_{\mathrm{N}}(x)$ response.

calculation of the coupler, one need to solve a numeric integration reported in [7]:

$$\frac{1}{2}\ln\frac{Z_{0e}(u)}{Z_0} = \int_{\frac{-d}{2}}^{u} P(u)du = \frac{-R}{\pi}\int_{\frac{-d}{2}}^{u} wi\cdot\frac{\sin^2(\frac{u}{2})}{\frac{u}{2}}du \tag{1}$$

In which, R is the coupling coefficient and d is the length of the coupler and w_i represents the weighted parameters for i-th section.

Figure 4 illustrates the even-mode impedances versus the coupler length.

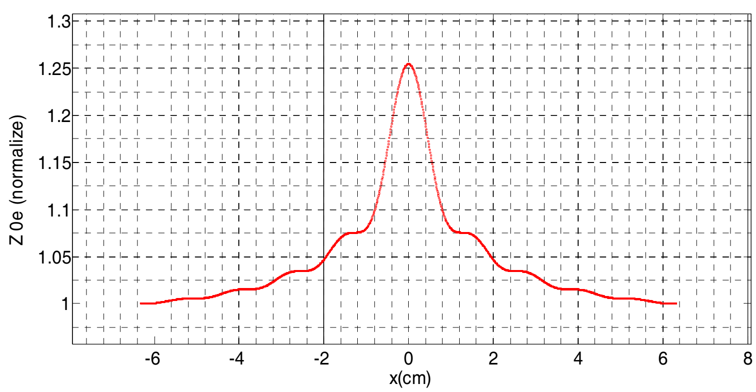

Figure 4: Even-mode impedances of nonuniform coupler.

The boundary lines of the coupler for a 20-dB coupling factor have been shown in Fig. 5

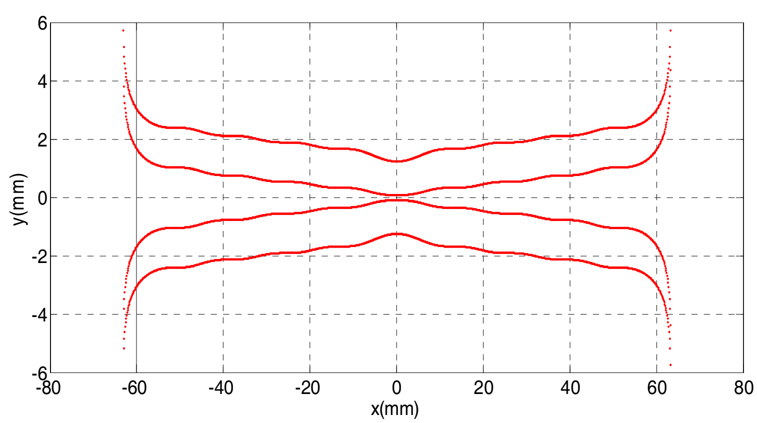

Figure 5: The boundary lines of the designed 20-dB coupler.

Presented focuses of the impact factor of this numerically integration namely L factor.

3. SIMULATION RESULTS

The aforementioned coupler has been simulated with CST microwave studio software [8]. An RT-Druid 5880 material is used for substrate with 31 mil thickness. Simulations have been done with variable $L = 40$, 50, 60 depicted in Fig. 6.

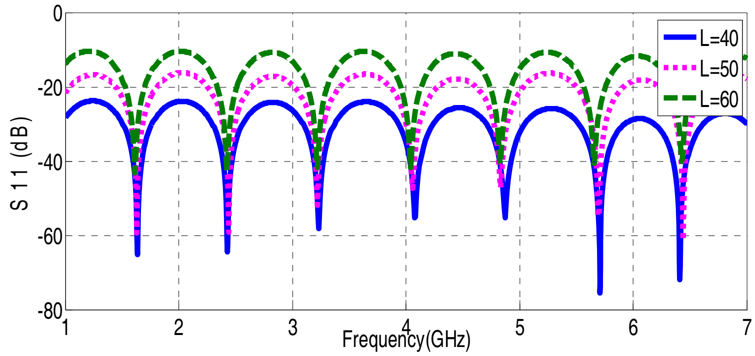

Figure 6: S_{11} parameters of the coupler with variable L parameter.

As shown in Fig. 6, choosing $L = 40$ yields to a better response of the coupler. The optimum design is shown in Fig. 7 in the CST microwave studio.

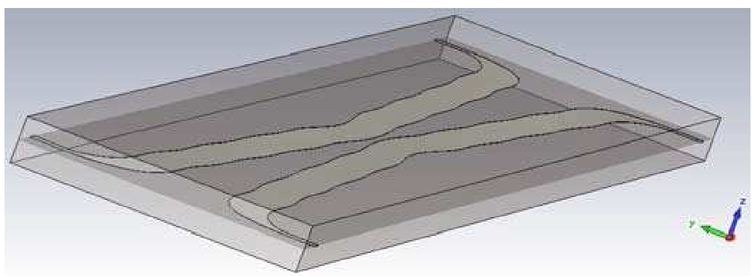

Figure 7: The coupler structure.

Coupling coefficient and return loss of the coupler are shown in Fig. 8.

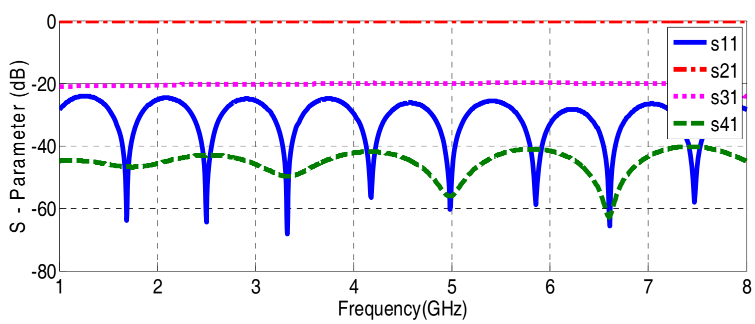

Figure 8: The scattering parameters of the designed coupler.

4. CONCLUSION

In this paper, we design a stripline coupler based on nonuniform transmission line impedances. We observe that the best value of the design can be obtained by changing the number of transmission lines. For a 20-dB coupler, $L = 40$ gives better responses rather than other parameters of L.

ACKNOWLEDGMENT

The authors would like to thank Semnan University for its support.

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