A MINIATURIZED BRANCH-LINE DIRECTIONAL COUPLER ON LOW TEMPERATURE COFIRED CERAMIC BOARD

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***Abstract*-This paper outlines the capability to develop a 3D compact-size branch-line directional coupler within the LTCC process. The substrate of Dupont Green Tape ™ ceramic has been successfully utilized to manufacture 3-dB 90° coupler assigned for a dualband phone DCS (1710-2000 MHz). The approach of modeling and creating lumped-distributed element directional couplers is presented here. The modeling results are in a good agreement with the experimental data.**

INTRODUCTION

In recent years, the wireless communication market has had an explosive growth. There is increasing demand to make communication systems lighter, more compact and portable, with better functionality and longer battery lifetime. Passive components play an important role to satisfy these requirements. Compared with active circuits, they typically consume less DC power and have lower noise figure.

Extremely important components in the realization are splitters and dividers. In addition to their application in radiating structures (automotive radars, microwave scanning radiometers, phased array systems) they have broad utility in numerous wireless communication systems. They are widely used in such microwave circuits as balanced mixers, image-rejection mixers, multipliers and balanced amplifiers.

Conventional directional couplers and baluns are realized with the use of transmission lines of different types. In MIC (Microwave Integrated Circuit) and MMIC (Monolithic Microwave Integrated Circuit) constructions, microstrip lines are the most popular. Microwave couplers and baluns can be realized either distributed or lumped circuits. But at the frequencies below 20 GHz distributed components occupy large areas. The lumped- and lumped-distributed-element approaches are the way to solve this problem. Especially the use of multilayer configuration (for example, on the base of the Low Temperature Cofired Ceramics technology) allows creating very compact and saving-cost components for wireless communication market.

COUPLER DESIGN

Design procedure of different types of directional couplers is described by Vogel in [1]. For 90° lumped co-directional coupler one can utilize a simplified technique. It is known that at a single frequency the symmetrical π- or T- LC section is equivalent to the transmission line section with the appropriate characteristic impedance and length [2]. For a quarter wavelength transmission line section, which is used in branch-line directional coupler, equivalent circuit element values of π-network are calculated as:

$$\begin{aligned} Z_a &= j \cdot Z_0 \quad \Rightarrow \quad L = Z_0/\omega_0 \quad \text{for a series element} \\ Z_b &= -j \cdot Z_0 \quad \Rightarrow \quad C = 1/\omega_0 \cdot Z_0 \quad \text{for a shunt element} \end{aligned} \tag{1}$$

where Z_0 is transmission line section impedance, ω_0 is operating frequency.

Applying this result to the branch line coupler (fig. 1) the following values of equivalent circuit elements are obtained using these equations:

$$\begin{gathered} L_1 = Z_{01}/\omega_0 \\ L_2 = Z_{02}/\omega_0 \\ C = (Z_{01} + Z_{02})/\omega_0 \cdot Z_{01} \cdot Z_{02} \\ Z_{01} = 50\ \Omega \\ Z_{01} = 35\ \Omega \end{gathered} \tag{2}$$

The directional coupler has been realized as microstrip configuration (fig. 2). Lumped inductors are realized using high impedance microstrip sections or spiral conductors. Due to the device is fabricated as a multilayer chip, lumped capacitors are realized as double stubs of strip line with low impedance. The overall dimension for the microstrip branch-line coupler is $13 \times 13\ mm^2$. The coupler layout occupies ten Dupont Green Tape™ ceramic layers of 112 μm thickness with dielectric constant of 7.5.

SIMULATION, MEASUREMENTS AND DISCUSSION

Several sets of tested couplers have been manufactured in the Microelectronic Laboratory of the University of Oulu. The simulation has been performed using Sonnet full-wave EM simulator. It includes both dielectric and metal losses of the silver-ink cofired with the Dupont system. The measurements have been carried out using a network analyser HP8719C and high frequency probes. Fig. 3 and 4 represent the confrontation of simulated and measured scattering parameters of the directional coupler for some chosen samples. Good agreement between the modeling and the experiment is obtained. The phase difference between the output ports is 90±2.5 degrees over the 10 percent bandwidth at central frequency 1.95Ghz for every sample. The maximum values of isolation and return losses at central frequency are between –26 dB (the best sample) and –23 dB (the worst sample), and they do not exceed –17 dB over the operating frequency range. From the theoretical investigation it was found that the characteristics of the branch-line coupler designed are slightly affected by the LTCC material dispersion over the bandwidth.

CONCLUSION

The 90° lumped element branch-line coupler implemented as microstrip layout was developed to be adopted to the multilayer LTCC process. Such realization allowed to get small overall dimensions. Wide experimental verification of the designed branch-line coupler was carried out to confront with simulated response and to test the performance repeatability. The predicted characteristics are very close to the measurement data and show high repeatability. Thus, the microstrip structure of directional coupler presented here is sufficient for many wireless applications.

ACKNOWLEDGEMENTS

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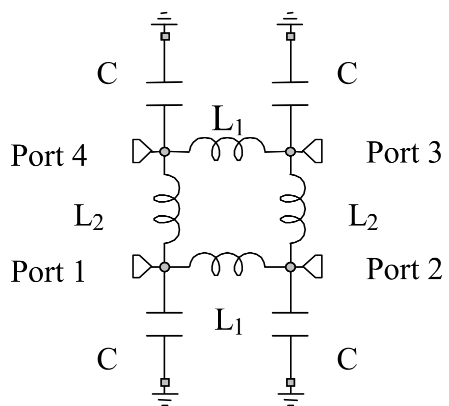


Fig. 1. Lumped element circuit presentation of the branch-line coupler.

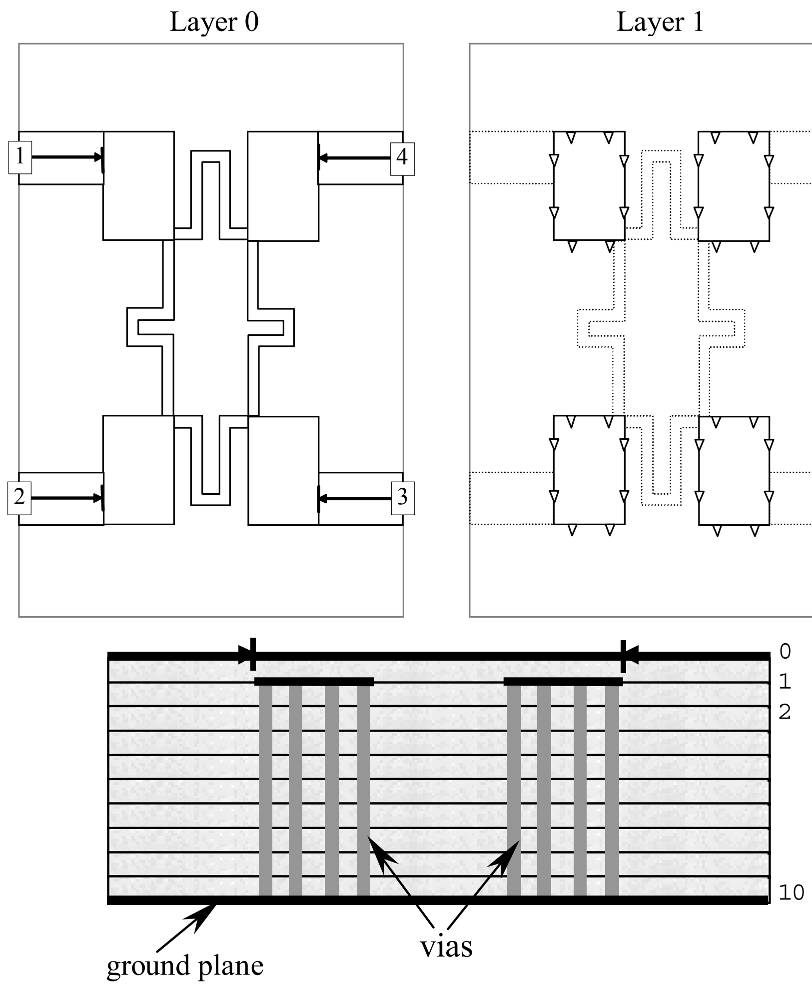


Fig. 2. The layout of the microstrip directional coupler designed.

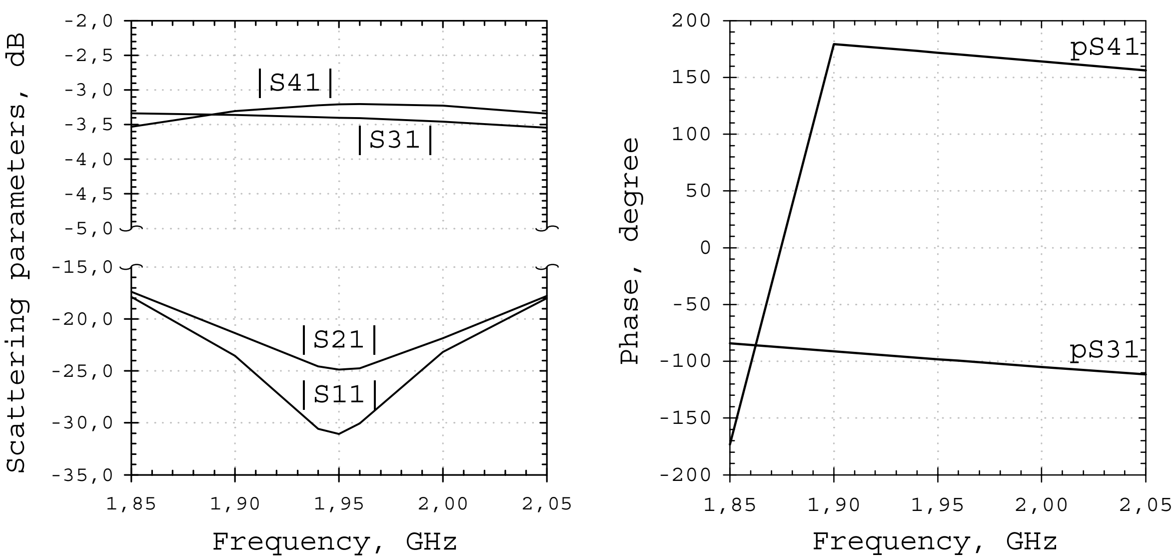
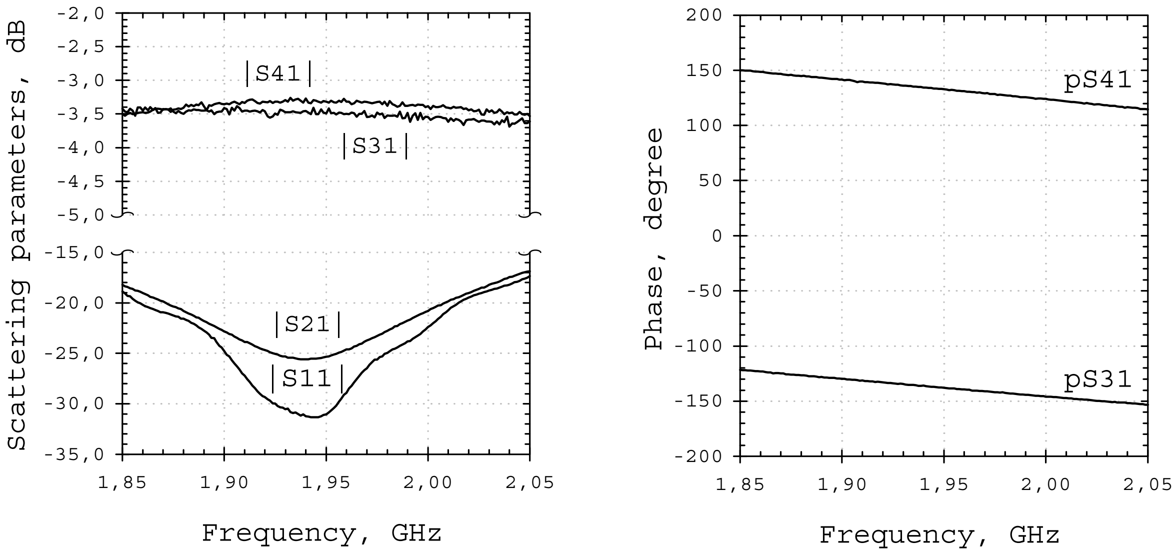
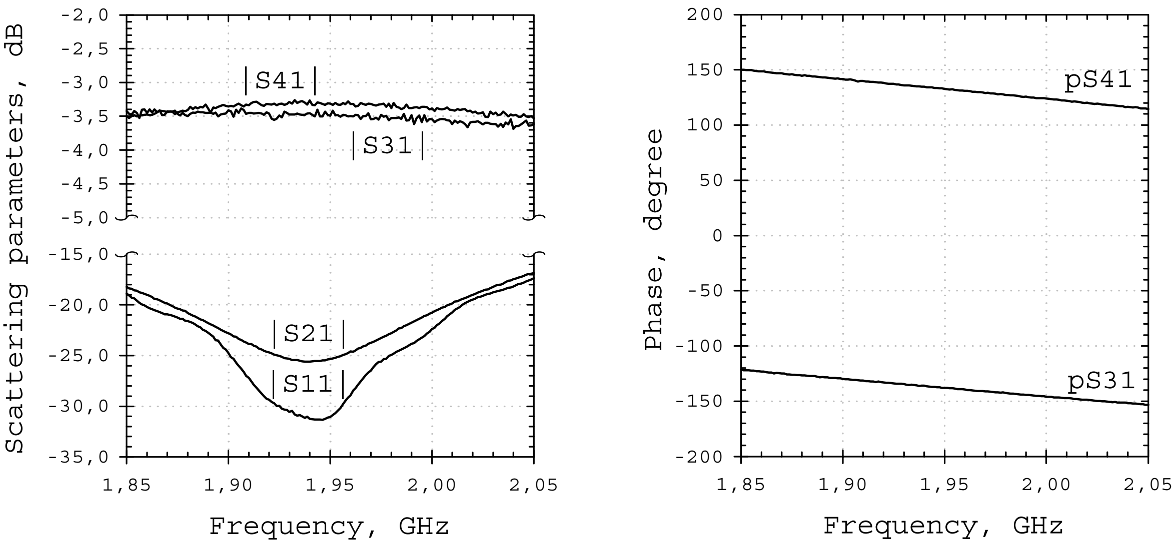


Fig. 3. Simulated performance of the microstrip coupler.

Sample LTO 1/a



Sample LTO 2/2 a



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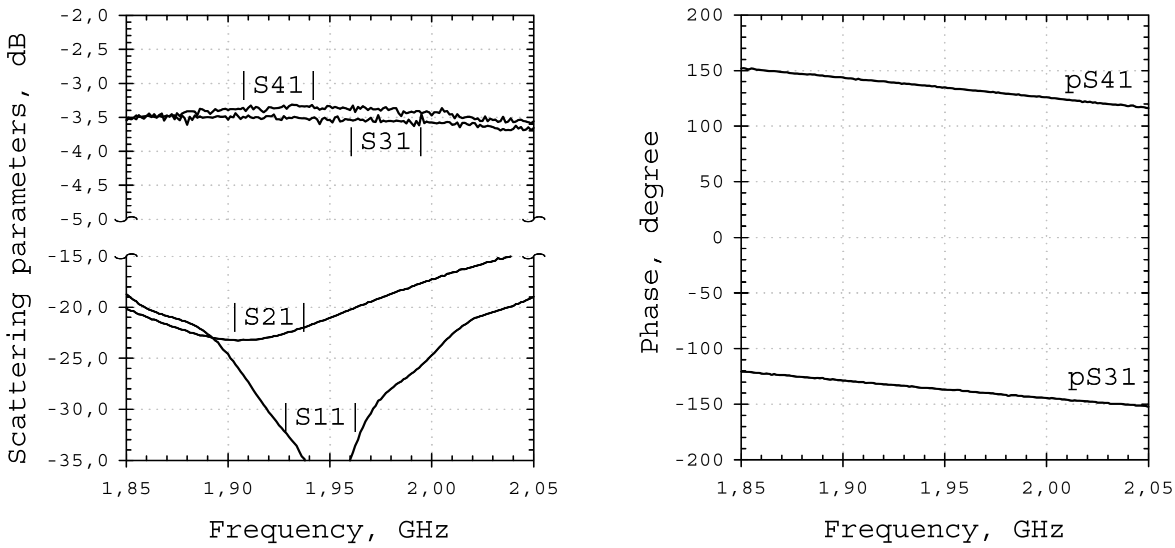

Fig. 4. Measured characteristics of the microstrip coupler.