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Miniaturized Wideband Branch-Line Hybrid Coupler with Capacitive Effect and Defected Ground Structure (DGS)

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Abstract

Background/Objectives: Branch-line hybrid couplers are used as components, in almost every Radio Frequency (RF) system, including power combiners and dividers**.** In this paper a 3dB miniaturized broadband branch-line coupler is designed and experimentally verified. **Methods/Statistical Analysis**: The new distributed capacitors which are placed within the empty space of the hybrid, minimize the size of the coupler. The ground of the structure is also defected by dumbbell shape parts to increase the impedance bandwidth. **Findings:** A prototype at 2.5GHz was designed and fabricated. The measurement results show that the bandwidth and isolation of the modified version are superior to the conventional 3dB hybrid coupler, also the measurement results confirmed that there is 270^0 phase difference between output ports. The size of the fabricated structure shows 62% size reduction and also the measured bandwidth is 0.82GHz. **Conclusion/ Improvements:** Miniaturized wideband branch-line hybrid coupler is a good candidate for development of a compact size and integrated microwave systems.

Keywords: Bandwidth, Branch-Line Hybrid Coupler, Miniaturized Hybrid, Size Reduction

1. Introduction

Quadrature hybrids are realized with four quadrature-wave $\frac{\lambda}{4}$ transmission lines, as shown in Figure 1. There are many techniques for size reduction of the structure[26]. In most cases the empty space between $\frac{\lambda}{4}$ transmission lines is occupied with special parts. This space in conventional 3dB hybrid is impractical. However, the available miniaturized structures have narrow bandwidth.

These capacitors have been placed in empty space between transmission lines.The ground of the structure is also defected in order to increase the bandwidth.

1.1 Analysis and Design

The proposed conventional coupler for 2.5 GHz is composed of two pairs of $\frac{\lambda}{4}$ transmission lines with characteristic impedances of 50Ω and 35.5Ω as shown in Figure 2 (a). The size reduction approach is realized by considering the following formulas:

$$vp = \frac{1}{\sqrt{LC}} \tag{1}$$

$$\lambda_g = \frac{Vp}{f} \tag{2}$$

$$z_0 = \sqrt{\frac{L}{C}} \tag{3}$$

Where,

Vp, λ_g and z_0 are the phase velocity, guided wavelength and characteristic impedance respectively. According to the formula 1 if L (inductance) or C (capacitance) is increased, the phase velocity will be decreased. Guided wavelength also decreases owing to 2. Since the size of the coupler is related to λ_g, therefore it will be com-

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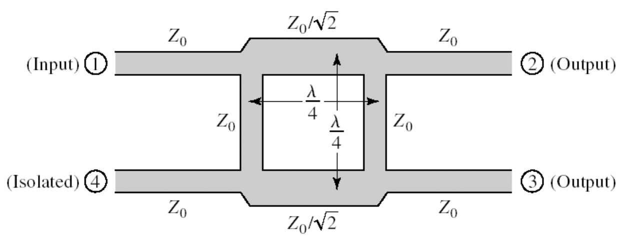


Figure 1. Geometry of a branch –line hybrid coupler.

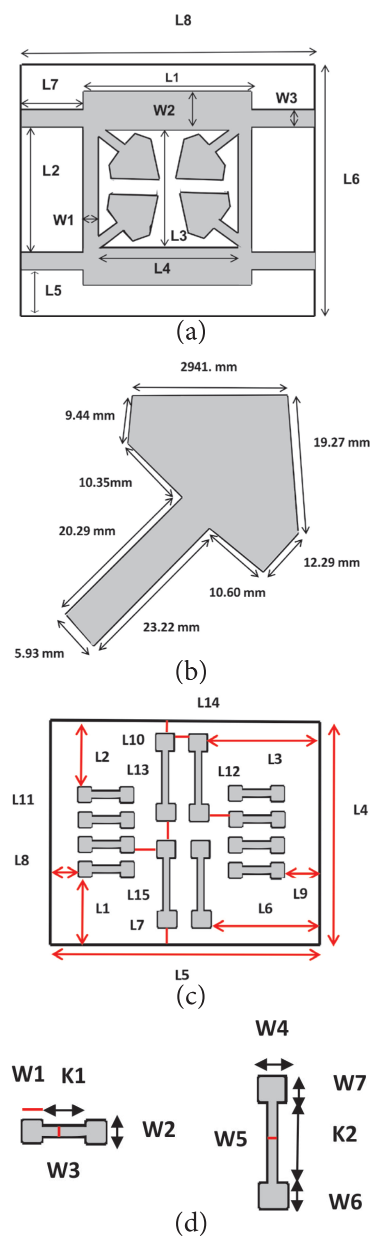


Figure 2. Geometry of the branch line coupler **(a)** conventional **(b)** modified **(c)** Geometry of the shape added into inner area of the 3dB coupler **(d)** The ground of the modified branch – line coupler.

pacted in comparison to the conventional coupler. The formula 3 shows that L and C should increase simultaneously in order to leave z_0 unchanged.

Following the above theory four similar structures have been added to the empty space. Edge-coupling capacitors and inductors are added to the structure in order to increase the conducting parts in mentioned space. Thus, the reduction of size condition can be satisfied. The geometry of the conventional and modified 3dB coupler are shown in Figure 2 (a, b). The ground of the hybrid also changes with dumbbell shapes shown in Figure 2 (d). One of the shapes, which is added into inner area is shown in Figure 2 (c). The DGS (Defected Ground Structure) technique is used to overcome the narrow bandwidth problem of the conventional 3dB coupler.

The designed coupler was etched onto a piece of Rogers 4003 with$\varepsilon_r = 3.55$, $\tan\delta = 0.0027$ and thickness of substrate layer is 0.508.

The dimensions of the conventional and modified 3dB couplers are shown in Table 1 and Table 2 respectively. In Table 3 and Table 4 the ground structure parameters of the modified branch – line coupler are demonstrated. Comparison between the size of the conventional and modified 3dB coupler is shown in Table 4. According to the Table 4, 62% size reduction can be obtained. All simulations were performed using HFSS software.

2. Mesurement Results

Figure 3 (a) shows the top view of conventional and modified version of the branch line coupler operating at the frequency of 2.5 GHz. Bottom views of the modified and conventional versions are shown in Figure 3 (b) . The miniaturization of the 3dB coupler leads to 62% size reduction compared to the conventional 3dB hybrid coupler at the same operation frequency. Furthermore, the bandwidth can be increased using DGS. The measurement results at Figure 4 (a, b) show that for the modified

Table 1. Dimensions of conventional branch – line coupler

Parameter	mm	Parameter	mm
L1	19.1	L2	5
L3	16.9	L4	16.2
L5	17	L6	29.1
L7	31	W1	3
W2	3	W3	3

Table 2. Dimensions of modified branch – line coupler

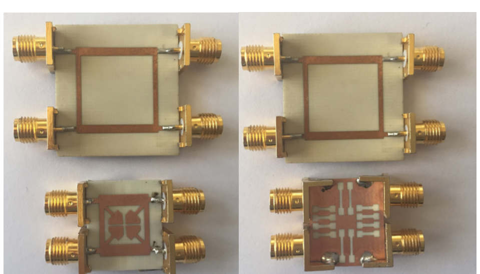
Parameter	mm	Parameter	mm
L1	11.46	L2	10.2
L3	8.8	L4	9.26
L5	4	L6	19.9
L7	3	L8	17.46
W1	1.1	W2	2.5
W3	1.1		

Table 3. Dimensions of DGS structure of modified branch – line coupler

Parameter	mm	Parameter	mm
L1	6.382	L2	5.882
L3	7.06	L4	19.9
L5	17.46	L6	7.06
L7	0.8	L8	0.8
L9	1.06	L10	0.3
L11	0.8	L12	0.6
L13	3.2	L14	0.8
L15	0.6	K1	2.6
K2	4.2	W1	1.4
W2	1.6	W3	0.8
W4	1.4	W5	1.8
W6	0.6	W7	0.6

Table 4. Comparison of the conventional and modified 3dB branch line coupler's size

	Substrate area(mm)^2	Relative size
Propose soupler	347.454	38%
Base shape	902.1	100%

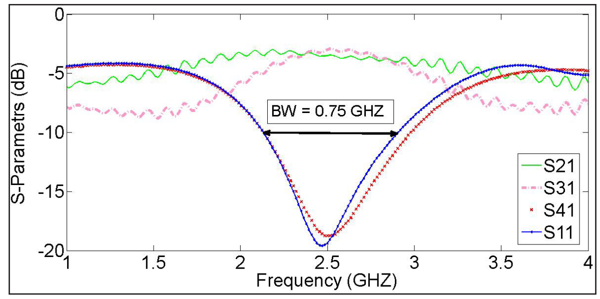


(a) (b)

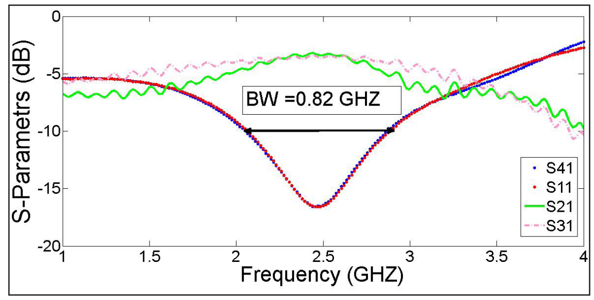
Figure 3. Branch line coupler **(a)** standard and modified top view **(b)** standard and modified bottom view.

version, the bandwidth is around 0.07GHz wider than the conventional 3dB coupler.

The simulation and measurement results for modified 3dB coupler is illustrated in Figure 5. The simulation

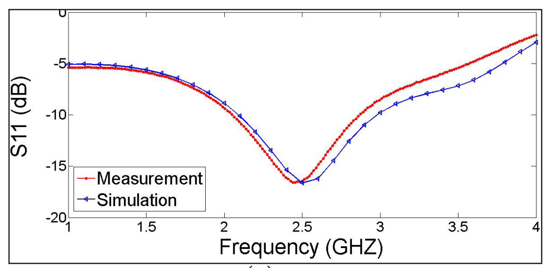


(a)

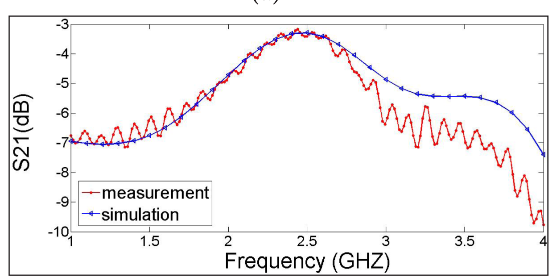


(b)

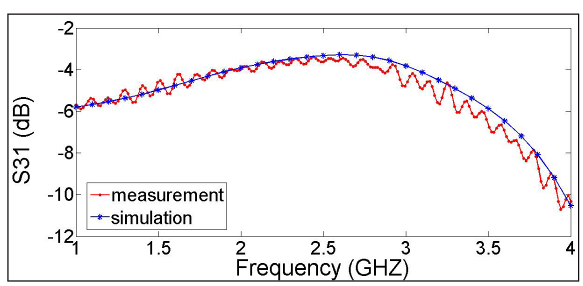
Figure 4. The measured S-parameters for **(a)** standard coupler **(b)** modified coupler.



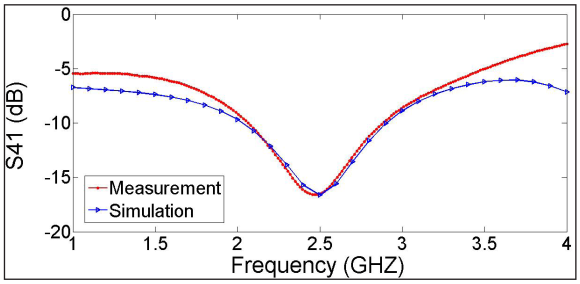
(a)



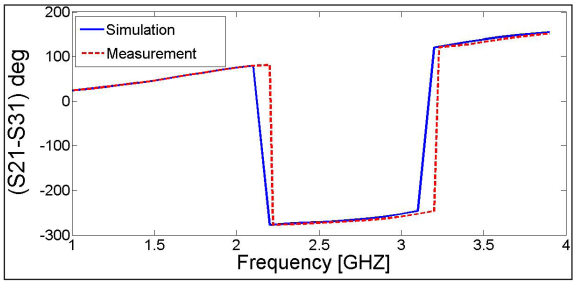
(b)



(c)



(d)



(e)

Figure 5. The simulation and measurement results for modified 3dB coupler.

Table 5. Compression between this work and other works

Res	Freq.	Reduction ratio comparer	Input bandwidth(GHz)	Isolation bandwidth(GHz)
1	0.836	70%	0.120	0.2
2	3.45	62%	0.6	0.6
4	1.8	36.8 %	0.6	0.6
6	2.4	63.9 %	0.6	0.6
7	0.9	95%	0.5	0’.SS
7	0.9	87.76 %	0.34	0.4
This work	2.5%	62%	0.82	0.82

and measurement results for input return loss (S_{11}), transmission coefficients (S_{21} and S_{31}), isolation (S_{41}) and phase difference between output ports are in good agreement with each other. There is a -270 ^{0} phase difference between output ports (port 2 and port3) as shown in Figure 5 (e).The comparison between the measurement results of this work and some references are given in Table 5. Size reduction, bandwidth and isolation of the modified coupler is much superior to the reported couplers.

3. Conclusion

The new edge-coupling capacitors with inductance effects due to are added to empty space of a conventional 3dB hybrid coupler in order to increase metallic area. The ground of the structure is also defected with dumbbell shape parts. The modified 3dB hybrid coupler has small size and large bandwidth. Realization of the techniques explained above for 2.5GHz branch line hybrid coupler shows 62% reduction in the size of coupler with approximately 0.82 GHZ bandwidth.

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