A LOW-LOSS SERIAL POWER COMBINER USING NOVEL SUSPENDED STRIPLINE COUPLERS

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Abstract

This paper describes a serial power combiner which consists of novel suspended stripline couplers. The suspended stripline couplers have additional parallel capacitances to improve their directivities. The fabricated three-way power combiner has realized the good performance in insertion loss which is less than 0.23 dB over a bandwidth of 10 % in the S-band.

Introduction

Power amplifiers for base-station applications have required high power level, good linearity, and high efficiency. In order to meet these requirements, the amplifiers combine output powers of multiple transistors.

The Wilkinson network[1] is a quite simple combining technique. A problem with the Wilkinson network is the power-handling-capability of the internal isolation resistors for the combiner on the output side of the amplifier. Another solution is the corporate coupler network. It has a disadvantage that long interconnect lines increase the insertion loss. The serial coupler network is more suitable for the amplifier applications[2][3]. It is a compact and low-loss combiner because it can minimize the interconnection length of the components in the combiner. Termination resistors with high power handling are employed instead of the isolation resistors. This type of combiner using coupled lines has adopted the triplate line structure to realize broadside-coupled lines with high coupling levels[2][3]. However, the above combiner has a problem that the propagation loss in the triplate line is large.

This paper presents a serial power combiner with the suspended stripline structure. The power combiner is comprised of coupled-suspended-stripline couplers. For conventional suspended stripline couplers, the different phase velocities between the even mode and the odd mode cause poor performances of the couplers in directivities and return losses[4]. We propose a novel suspended stripline coupler with parallel capacitances. The additional capacitances reduce the difference of the phase velocities between the two modes in the coupled suspended stripline. The three-way power combiner designed in the S-band are simulated and measured. The experimental result shows the good performance in insertion loss.

Configuration

Figure 1 shows a circuit schematic of the three-way serial power combiner. The power combiner is a series of couplers which have coupling coefficients of 3 dB and 4.8 dB, respectively. It differs from the more conventional corporate combiner in that nonbinary combining can be realized straightforwardly. This provides a high degree of flexibility in the number of com-

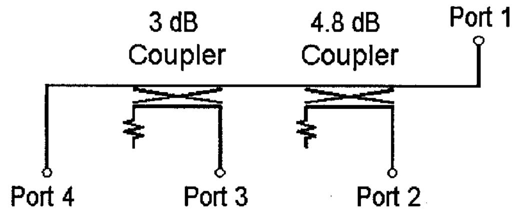

Figure 1: Circuit schematic of the three-way serial power combiner.

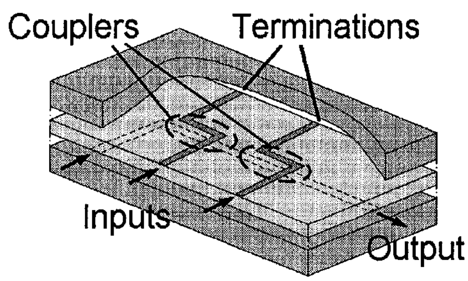

Figure 2: Configuration of the serial power combiner with the suspended stripline technology.

bining. The layout of the serial power combiner also has the shortest interconnect lines, which reduces the insertion loss.

The serial power combiner has been implemented in suspended striplines. Figure 2 shows a configuration of the serial power combiner with the suspended stripline technology.

Suspended stripline coupler

A typical cross section for the suspended stripline coupler is shown in Figure 3. In the suspended stripline coupler, a coupled line consists of two strip conductors formed on upper and lower sides of a dielectric substrate. The electric field distributions for the even and odd modes are shown in Figures 3(a) and (b), respectively. For the even mode, the electric fields are distributed mainly in the air. On the other hand, the electric fields concentrate in the dielectric substrate for the odd mode. It makes the odd-mode wavelength shorter than

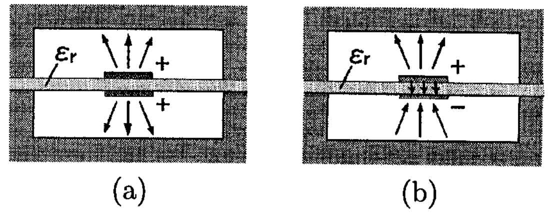

Figure 3: Cross section of suspended stripline coupler: (a) even mode. (b) odd mode.

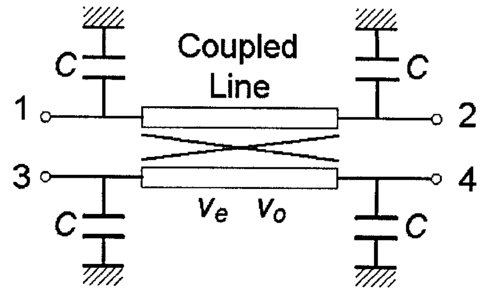

Figure 4: Circuit model of the coupler with parallel capacitances

the even-mode wavelength. In other words, the even-mode phase velocity v_e is larger than the odd-mode phase velocity v_o, that is,

$$v_e > v_o. \tag{1}$$

This difference of phase velocities degrades the directivity of the coupler.

To improve the directivity, a novel suspended stripline coupler is presented. Figure 4 illustrates a circuit model of the proposed suspended stripline coupler. Parallel capacitance is added to each ports of the coupled line. These capacitances reduce the difference of the phase velocities between the even mode and the odd mode.

The phase velocities v_e and v_o in the coupled line for the two modes are given by

$$v_e = \frac{1}{\sqrt{L_e C_e}} \tag{2}$$

$$v_o = \frac{1}{\sqrt{L_o C_o}}, \tag{3}$$

where L_e, L_o and C_e, C_o are distributed series inductances and shunt capacitances per unit length in the coupled line, respectively. For suspended stripline couplers, it is considered that C_o is larger than C_e owing to the cross section shown in Figure 3:

$$C_e < C_o. \tag{4}$$

We assume that the additional capacitances C shown in Figure 4 increase C_e and C_o. Differentiating the equations (2) and (3) in terms of C, we obtain

$$\frac{\partial v_e}{\partial C} = -\frac{1}{2} \cdot \frac{v_e}{C_e} \cdot \frac{\partial C_e}{\partial C} \tag{5}$$

$$\frac{\partial v_o}{\partial C} = -\frac{1}{2} \cdot \frac{v_o}{C_o} \cdot \frac{\partial C_o}{\partial C}. \tag{6}$$

Applying the equations (1) and (4) to the above equations, we obtain

$$\frac{\partial v_e}{\partial C} < \frac{\partial v_o}{\partial C} < 0, \tag{7}$$

where $\partial C_e/\partial C = \partial C_o/\partial C > 0$ is assumed. This means that the additional capacitances C decrease the phase velocity v_e more than v_o. Consequently, it reduces the difference of the phase velocities.

To verify the effect of the additional parallel capacitances, we have calculated the performance of the couplers on a circuit simulator. The parameters of the simulated coupled line are shown in Table 1. Figure 5 shows the calculated performances of the couplers. The conventional suspended stripline coupler ($C = 0$) shows poor performances in return loss and isolation, while the proposed coupler ($C = 0.25$ pF) shows good performances.

Table 1: Parameters of the coupled line

parameters	values
Z_e	120 [Ω]
Z_o	21 [Ω]
v_e/v_0	0.94
v_o/v_0	0.67

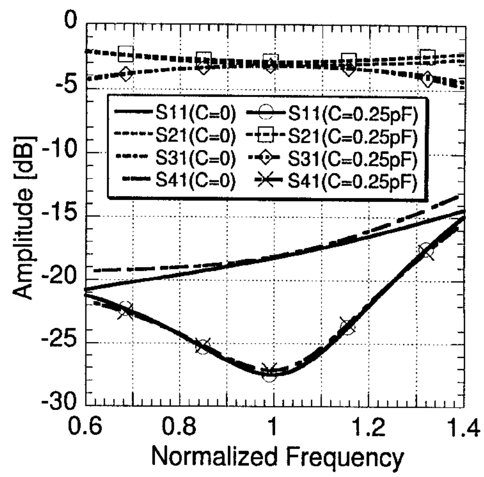

Figure 5: Performances of the coupler with parallel capacitances

Experimental results

The 3-dB suspended stripline coupler has been fabricated in the S-band. Figure 6 illustrates the equivalent circuit of the fabricated coupler. A low-impedance line is inserted to each port of the coupled line as the parallel capacitance. Figure 7 shows simulated and measured performances of the coupler. The simulations have been carried out on an electromagnetic simulator (Agilent/Momentum). It is noted that the measured results include the characteristics of the input and output connectors. The experimental results generally agree with the simulated results.

The three-way power combiner designed in

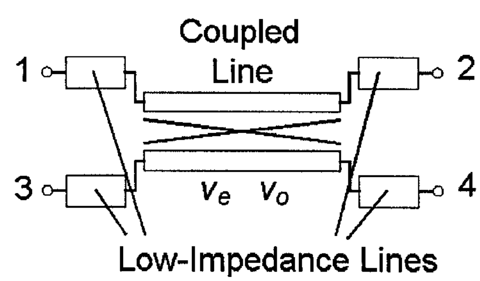

Figure 6: Equivalent circuit of the fabricated suspended stripline coupler.

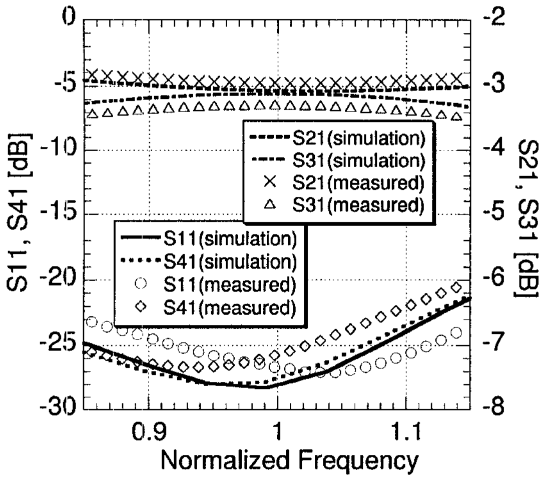

Figure 7: Performances of the 3-dB coupler.

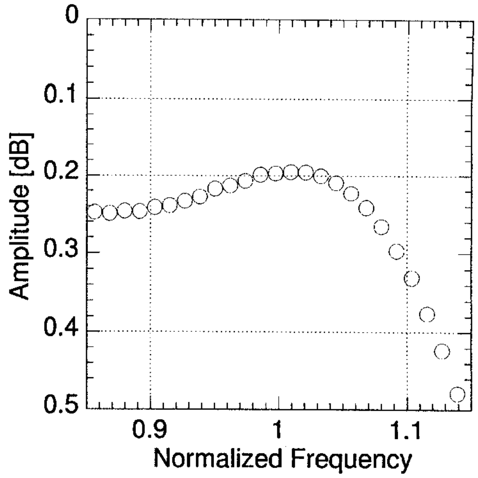

Figure 9: Insertion loss of the three-way power combiner.

the S-band has been also fabricated. Simulated results are compared with experimental results in Figure 8. Figure 9 shows the measured insertion loss of the combiner. It is noted that this measured result shows half of the insertion loss of the two combiners connected back-to-back each other. The result indicates that the insertion loss is less than 0.23 dB over a bandwidth of 10 % in the S-band.

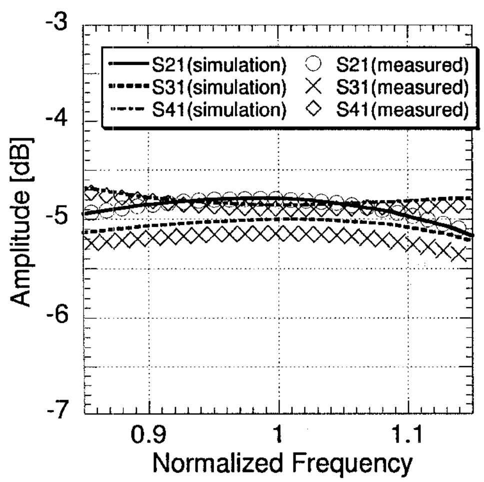

Figure 8: Performances of the three-way power combiner.

Conclusions

This paper has presented a low-loss serial power combiner with the suspended stripline structure. A novel suspended stripline coupler with parallel capacitances has been proposed to improve the directivity. The effect of the additional capacitances has been verified by the simulations and the experiments. The three-way serial power combiner with the insertion loss less than 0.23 dB has been realized.

References

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