NEW BROAD-BAND 5-SECTION MICROSTRIP-LINE DIRECTIONAL COUPLER

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ABSTRACT

A new 2 to 18 GHz 6dB microstrip-line directional coupler has been realized using 3 semi-re-entrant tight-coupling sections implemented into 5 coupling sections formed on Teflon substrate. The measured coupling coefficient of this coupler is in good agreement with theoretical values.

I INTRODUCTION

Coupled transmission lines constructed with microstrip lines have become very important from the viewpoint of microwave integrated circuit structures. The design of multi-section couplers is one approach for obtaining broad-band characteristics. Tight-coupling sections in the multi-section couplers are required in order to have sufficient coupling strength. However, appropriate tight-coupling structures have not been available.

An interdigitated coupled line structure[1] has been proposed by Lange for tightly coupling microstrip lines, but it is not well suited to interconnections within multi-section couplers because of its structural complexity. A 3-section 3dB hybrid coupler, on the other hand, has been proposed by Izadian with the use of broadside coupled microstrip lines[2]. Again, the design of this coupler is not simple because we can no longer apply the analysis concept based on the even- and odd-mode field to such broadside coupled microstrip lines.

We describe, in this paper, a broad-band 6dB microstrip-line directional coupler which consists of 5 cascaded quarter-wavelength coupling sections with identical characteristic impedance. The feature of this coupler is the use of semi-re-entrant coupling sections for the first time. This is a tight-coupling structure which can be well connected to microstrip lines. It has not been employed in multi-section directional couplers in the past because any good analysis method has not been established. The authors have devised such a method for the quasi-TEM wave analysis of the semi-re-entrant tight-coupling sections[3]. A theoretically designed directional coupler based on this analysis method was experimentally fabricated on Teflon substrate. Some measured values of coupling characteristics are compared with theoretical values.

II DESIGN OF SEMI-RE-ENTRANT TIGHT-COUPLING SECTIONS

The plan schematic and cross-sectional view of a semi-re-entrant tight-coupling section are shown in Fig.1 and Fig.2, respectively. The strip conductors, 2 and 3, are coupled each other with an ordinary edge-coupling mechanism. The overlay strip conductor, 1, is electrically floating. Coupling strength between the two strip conductors, 2 and 3, is enhanced with the existence of such overlay strip conductor,1. This coupling section can be characterized with the use of the rectangular boundary division method[3]. Since the analysis procedure of this method was detailed in a previous paper[4], it is not repeated here. Such a quasi-TEM wave analysis gives the capacitance matrix per unit length of the three strip conductor system defined as

$$\begin{bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{12} & C_{22} & C_{23} \\ C_{13} & C_{23} & C_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} \quad (1)$$

where Q_1, Q_2, and Q_3 denote the line charge per unit length of each strip conductor,

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and V_1, V_2, and V_3 the line potential of each strip conductor. By using the electrically floating condition, the symmetrical structure as shown in Fig.2 is treated based on the method of the even- and odd-mode field. Then, the mode capacitances, C_{odd} and C_{even}, are derived from the capacitance matrix as

$$C_{odd} = C_{22} - C_{23}$$

$$C_{even} = C_{22} + C_{23} - \frac{2C_{12}^2}{C_{11}} \quad (2)$$

The impedance for each mode and the coupling coefficient are obtained with the above mode capacitances.

A 5-section microstrip-line directional coupler with the frequency band of 2 to 18GHz and the coupling of -6dB was designed. Its plan schematic view is shown in Fig.3. The coupling parameters for each section are obtained from the tables proposed by Levy[5] as summarized in Table 1. Three out of the five sections were made with the use of semi-re-entrant tight-coupling sections and the other two sections are composed of edge-coupled sections.

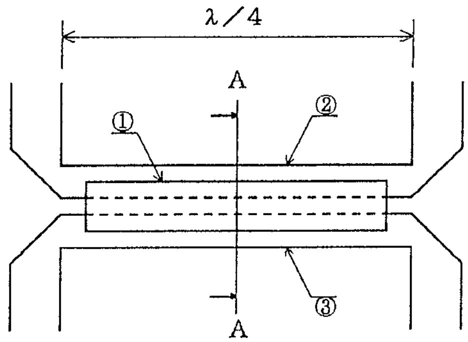

Fig.1 A plan schematic view of a single section semi-re-entrant coupler.

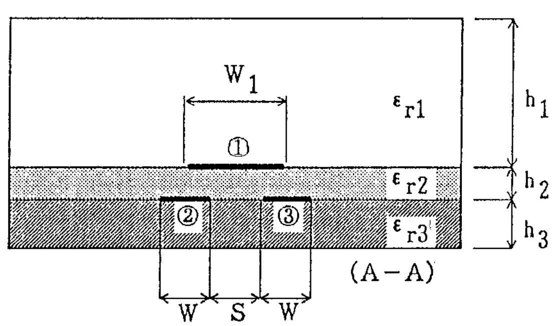

Fig.2 A cross-sectional view of a semi-re-entrant coupled section.

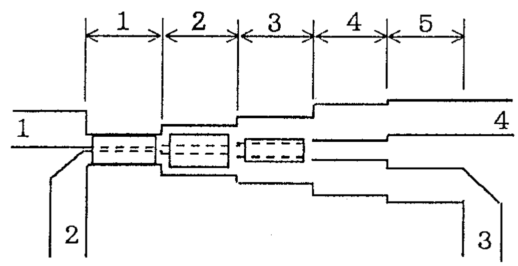

Fig.3 The plan schematic view of the designed 5-section directional coupler.

	semi-re-entrant coupled sections			edge-coupled sections	
Section No.	1	2	3	4	5
k	0.730	0.551	0.367	0.212	0.111
Zoe(Ω)	126.63	92.96	73.51	62.00	55.275
Zoo(Ω)	19.74	26.89	34.01	40.32	44.23
ε_{re}	1.85	1.93	1.95	1.97	1.97
ε_{ro}	2.11	1.97	1.90	1.83	1.84
W_1 (mm)	0.98	0.46	0.23	—	—
S (mm)	0.08	0.10	0.14	0.20	0.63
W (mm)	0.45	0.79	1.10	1.37	1.40

ε_{rm} : mode dielectric constant
Zom : mode impedance
m : e(even) or o(odd)

W_1, S, W } structural dimensions

Table 1 Parameters of the designed directional coupler.

III EXPERIMENTAL RESULTS

Experimentally, coupled strip conductors and an overlay strip conductor were deposited on the both sides of Teflon substrate(Duroid 5890) with the thickness of 0.051mm, which was adhered to Teflon glass substrate(Duroid 5880) with the thickness of 0.508mm.

Fig.4 and 5 show comparison of measured and calculated characteristics of the experimental 5-section coupler. Dotted lines and solid lines indicate the measured and the calculated S-parameters, respectively. The coupling coefficient, $|S_{21}|$, of -6.5+0.5dB in the frequency band, 2 to 18 GHz, has been obtained against the designed value of -6+0.36dB.

In the theory, the impedance matrix and admittance matrix are obtained with the capacitance matrix elements of each coupled-line section given by the analysis and with the use of the method introduced by Tripathi[6]. The characteristics of the multi-section coupler are obtained by connecting T-matrix for each section derived from the impedance matrix elements. The coupled-line sections are all assumed as lossless coupled transmission lines having symmetrical cross-sectional dimension in the inhomogeneous medium.

The characteristics of $|S_{31}|$ as shown in Fig.5 seem to have been affected by the phase velocity difference between the even- and odd-mode field, and by the discontinuities between sections. However, it should be possible to improve the characteristics of $|S_{31}|$ by equalizing the phase velocity with the wiggly line technique[7], and by eliminating these discontinuities in the microwave circuit[8].

IV CONCLUSION

A new broad-band microstrip-line coupler structure was proposed. The advantages of the newly utilized semi-re-entrant tight-coupling section in this coupler are as follows:

1) Tight-coupling is possible which is necessary for making broad-band couplers.
2) There is no necessity of bonding wires or air bridges.
3) The structure is convenient for connecting themselves or connecting them to ordinary edge coupling sections.
4) Conventional synthesis techniques based on the concept of the even-mode and odd-mode field and of multi-section couplers are applicable.

ACKNOWLEDGMENT

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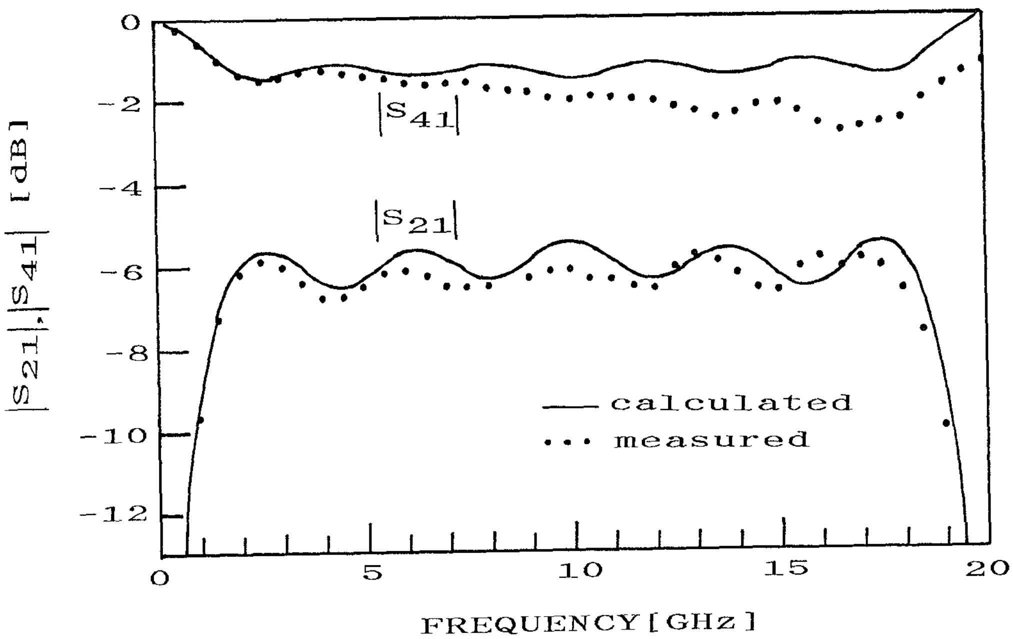

Fig.4 Comparison of measured and calculated coupling characteristics, $|S_{21}|$ and $|S_{41}|$, of the designed directional coupler.

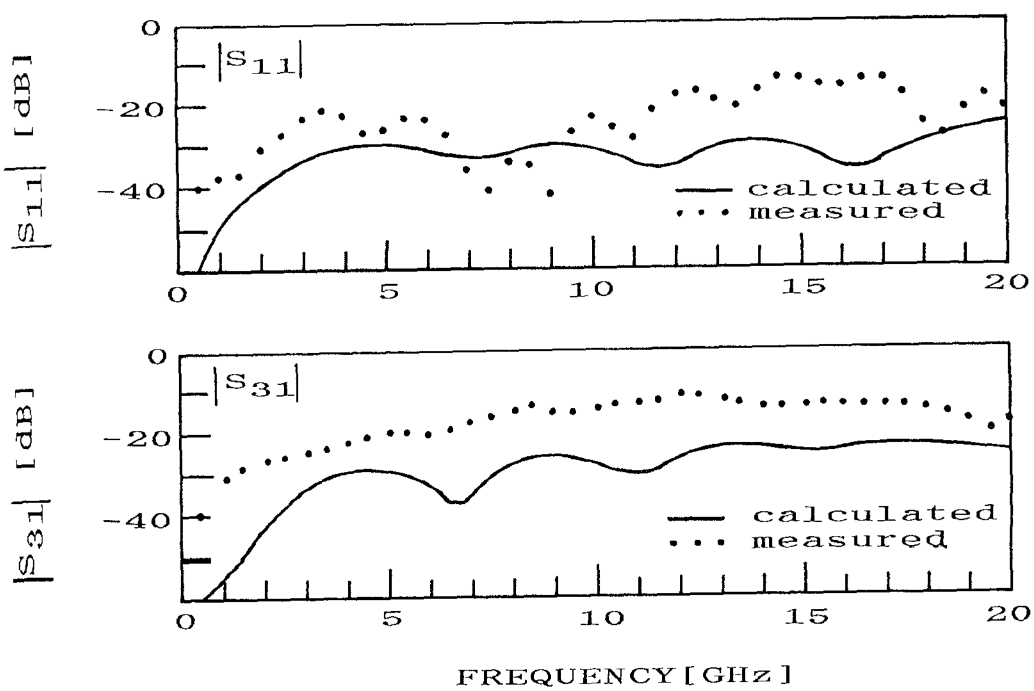

Fig.5 Comparison of measured and calculated coupling characteristics, $|S_{11}|$ and $|S_{31}|$, of the designed directional coupler.