

S. Toyoda

Department of Electrical Engineering

Osaka Institute of Technology, 5-16-1 Omiya, Asahi-Ku, Osaka 535 Japan

## Abstract

A microstrip variable coupling directional couplers for 4 GHz band have been proposed and tested. By changing the junction capacitances of the varactor diodes, the coupling varies from 4 dB to 20 dB, and the directivity varies from 16 dB to 29 dB. Available frequency range is from 2.7 GHz to 5.3 GHz.

## Introduction

Many studies of directional couplers using rectangular waveguide, coaxial line or stripline have been reported so far. When the power and frequency are measured by using these directional couplers, the optimum coupling which depends on the situation they are used is required. Therefore, it is very convenient to have a directional coupler with variable coupling.

The papers concerning variable coupling directional couplers have already been reported [1], [2]. In this paper, the author proposed new microstrip variable coupling directional couplers using varactor diodes.

These couplers consist of several kinds of T-type circuits, and each of them is composed of two diodes and fixed capacitance which are connected in series between two microstrip lines. By changing the junction capacitance of the varactor diodes, the coupling and directivity of the directional coupler is varied. For the coupler with four T-type circuits, the coupling was varied from 4 dB to 20 dB, and the directivity was varied from 16 dB to 29 dB. Available frequency range is from 2.7 GHz to 5.3 GHz. The experimental results on the variable coupling directional couplers agree well with the theoretical results.

## Variable coupling directional coupler with two T-type circuits

The structure of the coupler is shown in Fig. 1(a). Two T-type circuits between microstrip lines I and II are composed of

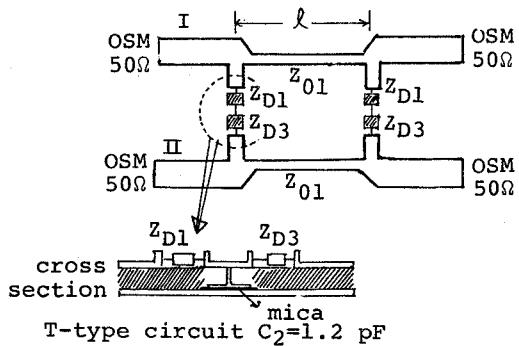


Fig. 1 Variable coupling directional coupler using varactor diodes with two T-type circuits

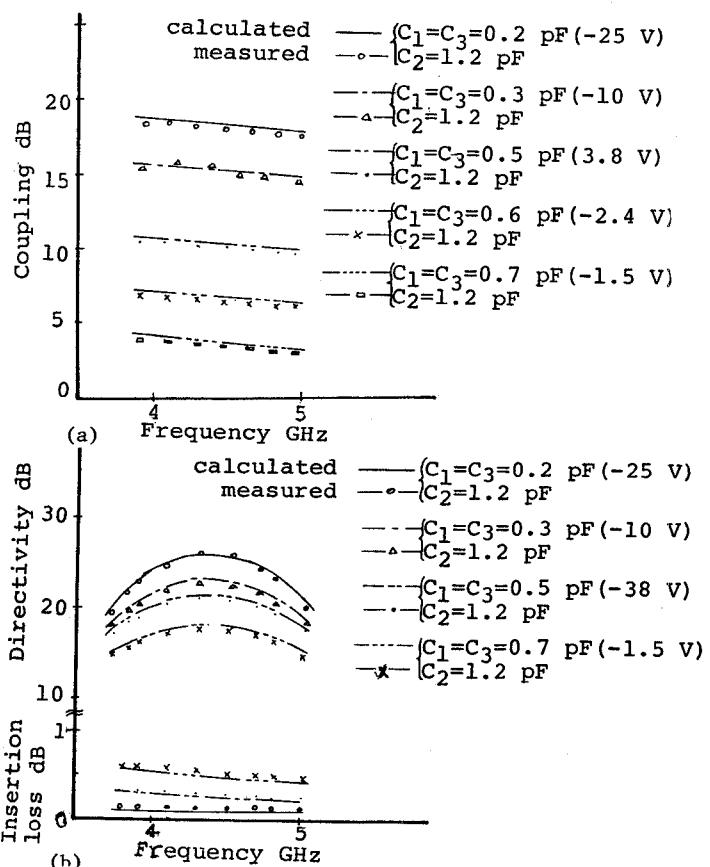


Fig. 2. Characteristics of variable directional coupler with two T-type circuits

varactor diodes  $Z_{D1}$ ,  $Z_{D3}$  and fixed capacitance  $C_2=1.2$  pF. These T-type circuits are separated by  $l$  in the  $z$ -direction. Detailed structure of the circuit is shown in Fig. 1(b). Capacitance  $C_2$  is formed by sandwiching a mica plate between upper and lower plates of the microstrip.

The experiments were carried out at the 4 GHz band. The coupling, directivity and an insertion loss are shown in Fig. 2. The junction capacitances of the varactor diodes  $Z_{D1}$  and  $Z_{D3}$  in Fig. 1 are denoted simply as  $C_1$  and  $C_3$  in Fig. 2.

The coupling varied from 4.1 dB to 19 dB when the bias voltage of the diodes  $Z_{D1}$  and  $Z_{D3}$  was changed from -1.5 V to -25 V. Available frequency range is from 3.9 GHz to 5 GHz. As the frequency increases from 3.9 GHz to 5 GHz, the coupling decreases about 1.5 dB.

The directivity and an insertion loss are shown in Fig. 2(b). Fig. 2(b) indicates that the directivity varied from 18 dB to 26 dB when the bias voltage of the varactor diodes was changed from -1.5 V to -25 V. An insertion loss is between 0.1 dB and 0.5 dB. VSWR was between 1.35 and 1.5 for 4 dB coupling, while it was between 1.1 and 1.25 for 19 dB coupling.

When the bias voltage of the diodes is zero, the coupling is so large that the impedance matching at the input and output terminal of the transmission line I and II is not achieved. At the same time, VSWR is high and directivity is not so good. More than 4 dB coupling is desirable for good operation of the coupler.

#### Variable coupling directional coupler with three T-type circuits

The structure of the coupler is shown in Fig. 3. The T-type circuits shown in Fig. 1(b) are connected between microstrip lines I and II. Varactor diodes MA45056 are used in the T-type circuits at both ends and, in the circuit at the center, a varactor diode D5047 with large junction capacitance is used in order to have twice the coupling in the circuits at both ends.

The coupling, directivity and an insertion loss are shown in Fig. 4. The junction capacitance of the varactor diodes  $Z_{D1}$ ,  $Z_{D3}$  and  $Z_{D4}$ ,  $Z_{D5}$  in Fig. 3 are denoted simply as  $C_1$ ,  $C_3$  and  $C_4$ ,  $C_5$  in Fig. 4. The coupling varied from 4.5 dB to 19.2 dB when the bias voltage of the varactor diodes was changed from -1.5 V to -25 V. Available frequency range is from 3.2 GHz to 5 GHz.

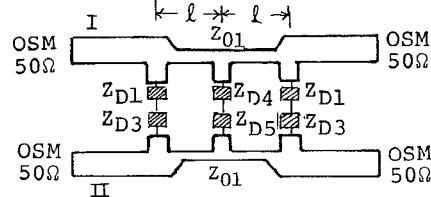


Fig. 3. Variable coupling directional coupler using varactor diodes with three T-type

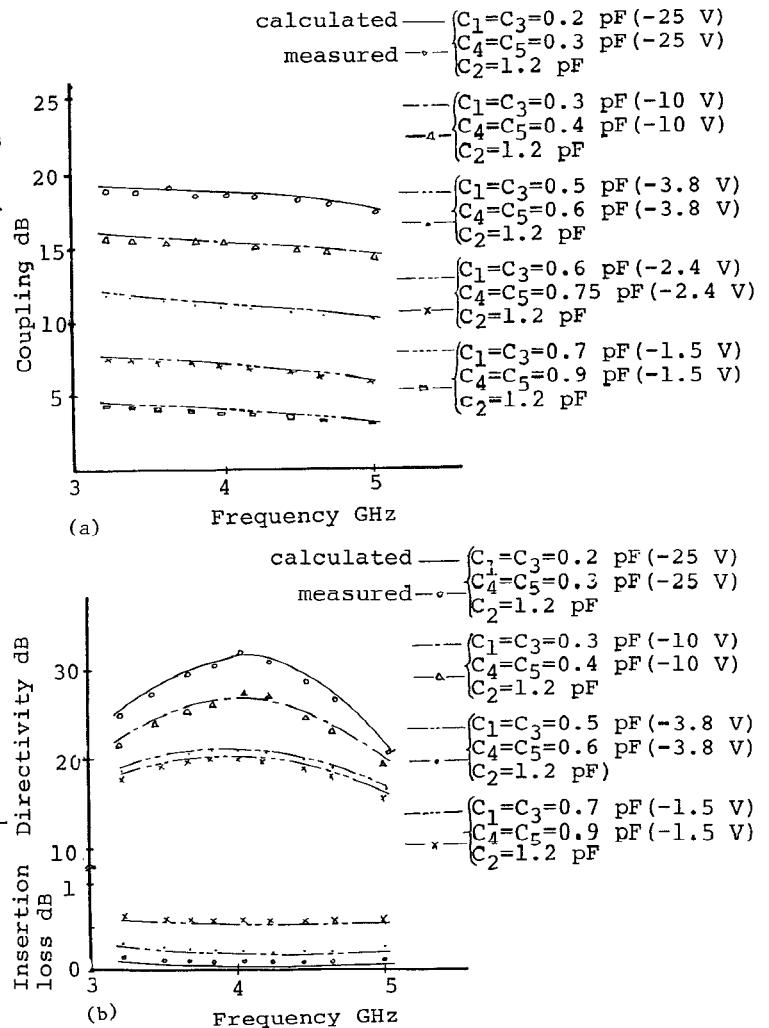


Fig. 4. Characteristics of variable coupling directional coupler with three T-type circuits

As the frequency increases from 3.2 GHz to 5 GHz, the coupling decreases about 1.5 dB.

The directivity and an insertion loss are shown in Fig. 4(b). The directivity is varied from 16 dB to 32 dB when the bias voltage of the varactor diodes was changed from -1.5 V to -25 V.

An insertion loss is between 0.1 dB and 0.6 dB. VSWR was between 1.35 and 1.5 for 4 dB coupling, while it was between 1.1 and 1.2 for 19 dB coupling.

#### Variable coupling directional coupler with four T-type circuits

The structure of the coupler is shown in Fig. 5. The T-type circuits shown in Fig. 1(b) are connected between two microstrip lines. varactor diodes MA45056 are used in the T-type circuits at both ends and, in the central two circuits, varactor diodes D5047 are used.

The coupling, directivity and an insertion loss are shown in Fig. 6. It is seen that the coupling varied from 4 dB to 20 dB when the bias voltage of the varactor diodes  $Z_{D1}$  and  $Z_{D3}$  was changed from -1.5 V to -25 V, that of the diodes  $Z_{D4}$  and  $Z_{D5}$  was changed from 0 V to -7.6 V. Available frequency range is 2.7 GHz to 5.3 GHz.

The directivity and an insertion loss are shown in Fig. 6(b). By changing the junction capacitance of the varactor diodes, the directivity is varied from 15 dB to 29 dB. An insertion loss is between 0.15 dB and 0.5 dB. VSWR was between 1.4 and 1.55 for 4 dB coupling, while it was between 1.1 and 1.25 for 20 dB coupling.

The experimental results are compared with the theoretical results, and good agreement between them is observed. By

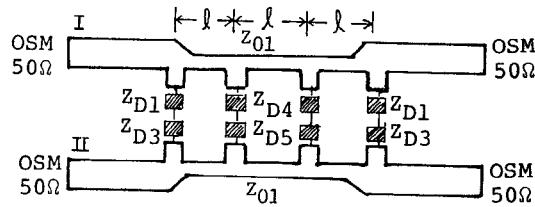


Fig. 5 Variable coupling directional coupler using varactor diodes with four T-type circuits

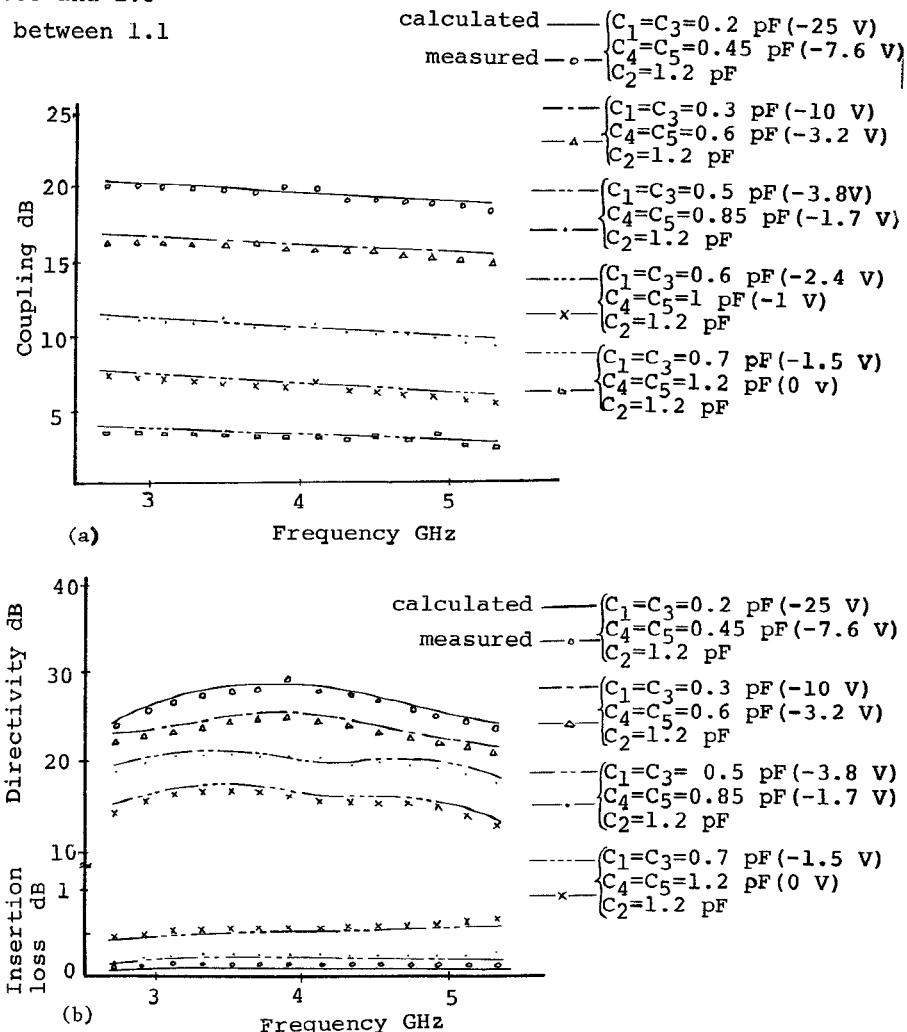


Fig. 6 Characteristics of variable coupling directional coupler with four T-type circuits

increasing the number of T-type circuits, the wide-band characteristics are obtained.

#### References

- 1) M.E. Brodin and V.Ramaswamy "Continuously variable directional couplers in rectangular waveguide" IEEE. Trans., Microwave Theory and Tech., MTT-11, 3, pp 137-142. March 1963.
- 2) I. Tanaka and M. Isai "A New variable directional coupler using n-InSb Thin Films" Trans. IECE Japan J 63-C No 11 pp 759-765 November 1980.