BROADBAND DIRECTIONAL COUPLER USING DIELECTRIC LOADED SLIT

Hideyuki Oh-hashi, Hideki Asao, and Osami Ishida

Electro-Optics & Microwave Systems Laboratory,
Mitsubishi Electric Corporation,
5-1-1 Ofuna, Kamakura-city, Kanagawa-prefecture, 247, JAPAN

ABSTRACT

A broadband 40dB directional coupler using coupling-slits opened in common ground conductors between parallel coaxial lines has been fabricated. Dielectric plates are loaded in the slits in order to compensate the directivity degradation due to ground conductor discontinuities at the slit ends. The directivity is greater than 24dB.

INTRODUCTION

Multi-octave broadband directional couplers can be realized by using nonuniform-coupled transmission lines [1]. Slit coupled directional coupler has a feature of simple configuration, because the nonuniform coupling can be obtained by tapering the slit width [2]. But in this configuration, abrupt openings of ground conductor exist at the ends of the slit, and such discontinuities cause a degradation of the directivity. To compensate the discontinuity effect, trimming of inner and ground conductors were needed in conventional couplers [3].

In this paper, a slit coupled directional coupler loading a dielectric plate in the slit is proposed. It is theoretically and experimentally presented that the effect of even and odd mode phase velocity difference caused by the dielectric plate contributes to the compensation of the directivity degradation due to the discontinuities.

BASIC CONFIGURATION AND EQUIVALENT CIRCUITS

Figure 1 shows the structure of a slit coupled directional coupler. Two lines are coupled through a slit opened on the ground conductor between two inner conductors. The discontinuities of the ground conductor excite higher order evanescent modes. The effect of these modes is expressed by parasitic susceptances connected to the dominant mode transmission line [4]. Figure 2 shows the even and odd mode equivalent circuits of the coupler. Ye and Yo are the parasitic susceptances for even and odd modes, respectively.

GROUND CONDUCTOR DISCONTINUITY EFFECT

The degradation of directivity is regarded as an increase of the signal coupling to port4 (S_{41}). S_{41} is expressed by a superposition of even and odd mode transmitted waves in Figure 2, and given by

$$S_{41} = (Te - To)/2 \quad , \qquad (1)$$

OF2

where Te and To are even and odd mode transmission coefficient derived from F matrices of the equivalent circuits.

In the case of loose coupling, the influence of nonuniform coupling is negligible on S_{41}, because the even and odd mode impedances $Ze(x)$, $Zo(x)$ should be almost uniform along the coupling lines. Assuming that the coupler satisfies the impedance matching condition and has equal even and odd mode phase velocities, S_{41} is given by

$$S_{41} \approx \frac{Yo - Ye}{2} e^{-j\beta l} \quad , \qquad (2)$$

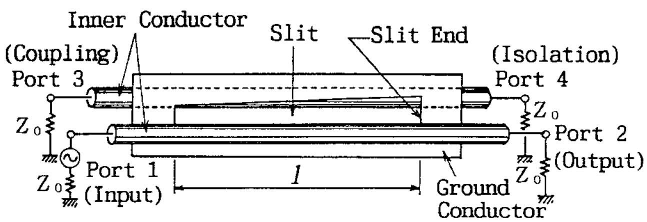


Fig.1 Structure of slit coupled directional coupler.

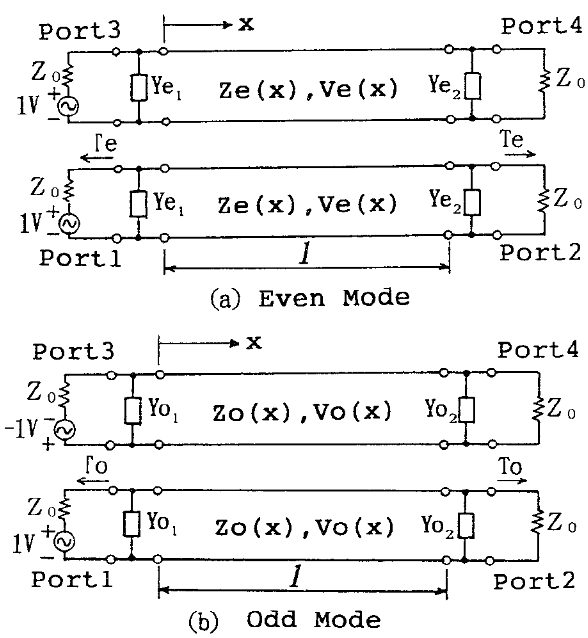


Fig.2 Equivalent circuits of slit coupled directional coupler.

where $Ye = (Ye_1 + Ye_2)/2$, $Yo = (Yo_1 + Yo_2)/2$, β is the phase constant, and l is the coupling length. Since even and odd mode electromagnetic fields are different, the parasitic susceptance for each mode is supposed to have different values.

Assuming that the parasitic susceptances are capacitive and are expressed by

$$Ye = j\omega Ce = j2\pi Ce \cdot f \; , \qquad Yo = j\omega Co = j2\pi Co \cdot f \; , \qquad (3)$$

S_{41} is given by

$$S_{41} \approx j\pi(Co - Ce)f \cdot e^{-j\beta l} . \qquad (4)$$

Calculated S_{41} from equation (4) and measured S_{41} of a slit coupled directional coupler without any compensation for discontinuity effect are compared in Figure 3. The Co-Ce value in equation (4) was determined to agree the calculated S_{41} with measured S_{41} at the frequency fo. The calculated S_{41} shows the same frequency response as the measured S_{41}.

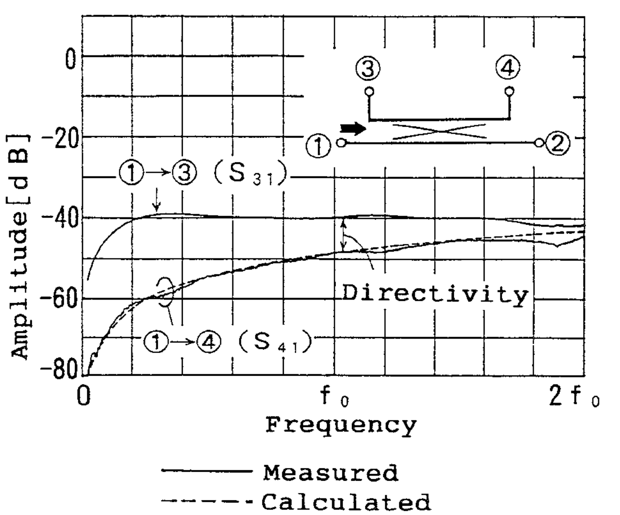


Fig.3 Comparision of measured and calculated S41.

COMPENSATION USING PHASE VELOCITY DIFFERENCE

The effect of even and odd mode phase velocity difference on a directional coupler without parasitic susceptances can be also obtained by neglecting Ye and Yo in the equivalent circuits. In the case of small phase velocity difference, the signal coupling to port4 (S^v_{41}) is given by

$$S^v_{41} \approx j\pi l \cdot \left(\frac{1}{Vo} - \frac{1}{Ve}\right) \cdot f \cdot e^{-j\beta l}, \tag{5}$$

where Ve and Vo are phase velocities for even and odd modes, respectively. Similar to equation (4), the amplitude of S^v_{41} is proportional to frequency f.

If a phase velocity difference is provided for the slit coupled directional coupler, the resultant S_{41} can be expressed as the summation of equations (4) and (5), approximatively. Therefore, the discontinuity effect can be compensated by providing the phase velocity difference which satisfies the following condition,

$$-(Co - Ce) = l \cdot \left(\frac{1}{Vo} - \frac{1}{Ve}\right). \tag{6}$$

EXPERIMENTAL RESULT

Figures 4 and 5 show the structure and the photograph of the broadband 40dB dual directional coupler, respectively. Two coupling sections are arranged in parallel to shorten the coupler length. Tapered slits are opened on both sides of the main line. Dielectric plates are loaded in the slits to provide the even and odd mode phase velocity difference. The dielectric plate dimension is designed using the finite element method to obtain the desired phase velocity difference determined by the measured amplitude of S_{41} .

Figure 6 shows the measured performance of the coupler. The directivity is greater than 24dB and the deviation of coupling is within 1.5dB over 0.2fo to 1.8fo frequency range.

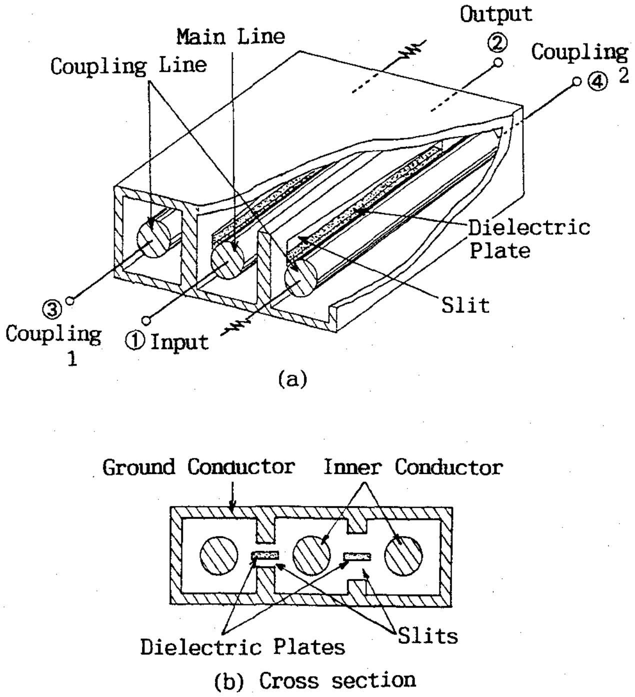


Fig.4 Structure of dual directional coupler.

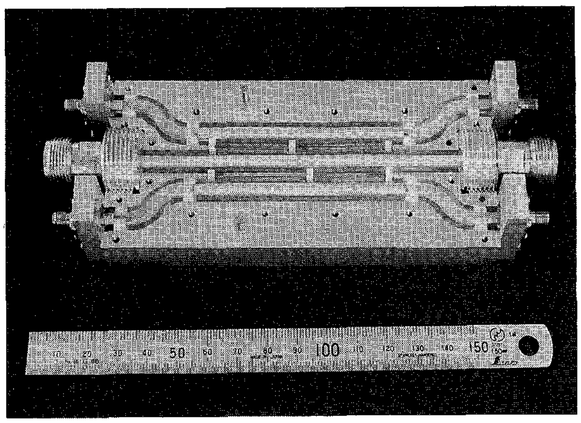
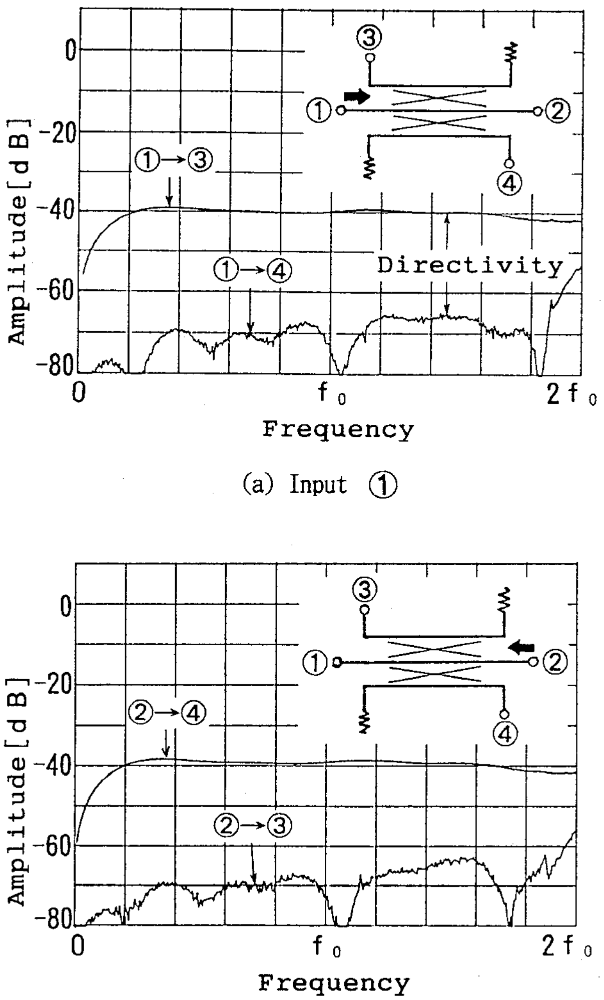


Fig.5 Photograph of fabricated dual directional coupler.



(a) Input ①

(b) Input ②

Fig.6 Measured performance of dual directional coupler.

CONCLUSION

A broadband slit coupled 40dB directional coupler has been fabricated. Dielectric plates are loaded in the slits in order to compensate the directivity degradation due to the ground conductor discontinuities at the slit ends. The directivity is greater than 24dB.

REFERENCES

[1] B. M. Oliver, "Directional Electromagnetic Couplers," Proc. IRE, vol.42, pp.1686-1692, Nov., 1954.

[2] S. Yamamoto et al., "Coupled Non-uniform Transmission Line and Its Aplications," IEEE Trans. vol.MTT-15, pp.220-231, Apr., 1967.

[3] J. D. Bickford et al., "Ultla-Broadband High-Directivity Directional Coupler Design," 1988 IEEE MTT-S Digest, pp.595-598, 1988.

[4] N. Marcuvitz, "Waveguide Handbook," McGRAW-HILL BOOK COMPANY, INC., 1951.