

NRD GUIDE COUPLERS COMBINED WITH MICROWAVE INTEGRATED CIRCUITS IN SIDE-BY-SIDE ALIGNMENT

Tomoyuki Goi, Shigeo Kawasaki, Tatsuo Itoh* and Tsukasa Yoneyama**

*Tokai University,
Department of Communication Engineering
1117 Kita-Kaname, Hiratsuka, Kanagawa 259-1292 Japan*

**UCLA
Department of Electrical Engineering
405 Hilgard Ave., Los Angeles, California 90095 USA*

***Tohoku University
Institute of Electrical and Communication
2-1-1 Katahira Aoba-ku, Sendai, Miyagi 980-77 Japan*

Abstract

This paper describes one of hybrid integration technologies with an NRD guide and planar circuits. The proposed circuit is a coupler which consists of two NRD guide dielectric rods attached a microstrip line planar circuit in the rod side wall. A leakage signal from one NRD guide can travel to the other NRD guide through a surface wave propagating in the coupler planar circuit. The coupling at 9.86 GHz was improved with 20.1 dB using a tapered microstrip line and amplified with 27.2 dB by the FET planar circuit, compared with the NRD coupler with a simple planar dielectric slab.

1. INTRODUCTION

Recent development of millimeter-wave technologies has been remarkable to various applications. In many countries, the 60 GHz band and the 77 GHz band are focused as the

frequency bands opened for a high speed communication and a precision sensor. At these frequencies, the applications for the communication and the sensor request the millimeter-wave technology to realize a small size, right weight and multi-function electronic circuit subsystem[1].

Among the various technologies, the MMIC is one of the most promising one to cope with the requirement mentioned above. However, it is hard to say that the MMIC is suitable for easy fabrication. Meanwhile, a millimeter-wave subsystem using NRD guide has good features of simplicity, easy fabrication and adjustment, low propagation loss etc.[2],[3]. Therefore, the work on the NRD guide technology has extensively been carried out and published for the development purpose of the millimeter-wave applications[4].

In this paper, one of the hybrid integration technologies was demonstrated with NRD guide

dielectric rods attached a microstrip line planar circuit in the rod side wall. A leakage signal from one NRD guide can travel to the other NRD guide through a surface wave propagating in the coupler planar circuit[5],[6]. Coupling between the NRD guide and the planar circuit using the microstrip line were carefully investigated, and improvement of the coupling and incorporation of an amplifier circuit with the NRD guide were achieved.

2. CONFIGURATION

The basic coupler circuit configuration is indicated in Fig. 1, which consists of the two separated NRD guide rods and the planar microwave circuit by a soft dielectric substrate. Since the NRD guide and the dielectric substrate are set in side-by-side alignment, the coupling between the NRD guide and the substrate microwave circuit by a soft dielectric substrate. Since the NRD guide and the dielectric substrate are set in side-by-side alignment, the coupling between the NRD guide and the substrate occurs due to the leakage (a surface wave in a dielectric slab) of a propagation mode in NRD guide such as LSM01 mode.

If the transmission line such as a microstrip line is etched out in the substrate as shown in Fig. 2, wave propagation in the substrate can be controlled in accordance with the propagation mode in the microstrip line. Using this concept, a signal in the planar circuit can be controlled, switched, mixed, amplified and radiated by integrating an active circuit or an antenna. For instance, patch antennas can be incorporated with the microstrip-line active circuit in the NRD guide coupler by electromagnetically coupling through slot apertures on the top of the metal .

Design and analysis for the NRD guide and the planar circuit with a operation frequency of 10 GHz were carried out by a circuit and a

electromagnetic simulators. Further, in order to improve the coupling, a tapered transition between the NRD guide and the microstrip line shown in Fig. 3 was introduced. Using the simulator, it is analyzed that improvement of coupling is achieved. In addition to this idea, as an example of combination of the NRD guide with the microwave planar active circuits, a trial to involve the amplifier circuit in the coupling microstrip line has been done as shown in Fig. 4.

3. EXPERIMENTAL RESULTS

The NRD guide was made by a Teflon dielectric rod 13.5 mm by 15 mm and 150 mm long. The planar circuit was made by the dielectric substrate (ARLON DICLAD880), and a package type FET (Mitsubishi MGF4314D) was used for the microwave amplifier which circuit is indicated in Fig. 5. In addition, Figure 6 shows a photograph of the NRD coupler with the tapered microstrip coupling line and the FET amplifier.

Five types of the NRD coupler were fabricated: (1) an NRD guide circuit with two separated rods, (2) the NRD coupler by the rods and the slab in side-by-side alignment, (3) the NRD coupler with the microstrip coupling line circuit, (4) the NRD coupler with the tapered microstrip coupling line circuit, and (5) the NRD coupler with the FET amplifier circuit. In order to compare matching and coupling characteristics of the NRD coupler proposed here, S parameters of the four types of NRD couplers as well as the NRD guide circuit with the two separated rods were measured. In Fig. 7, the measured S-parameters in the cases of (2), (4), and (5) were shown as Fig. 7 (a), (b) and (c), respectively.

From observation of the experimental data, followings were found that the microstrip line can guide the wave from the NRD guide, the taper is effective to enhance the coupling, and the guided wave by the microstrip line can be

amplified by the planar active circuit. Improvement of coupling at 9.86 GHz was observed in the cases from (3), (4), and (5) as 4.4 dB, 20.1 dB and 27.2 dB, respectively, with respect to the case of (2) using the simple dielectric slab.

4. CONCLUSIONS

A novel hybrid integration of the NRD guide and the planar microwave circuits were reported in this paper. Using the tapered microstrip line, the coupling at 9.86 GHz was improved with 20.1 dB and amplified with 27.2 dB compared with the NRD coupler with the simple dielectric slab. It is believed that the microwave planar circuit used here can be replaced by the MMIC.

Acknowledgement

This work was partially supported by the grant of Electric Telecommunication Frontier Project by Ministry of Post and Telecommunication Japan.

Reference

- [1] T. Yoneyama and S. Nishida, "Nonradiative Dielectric Waveguide for Millimeter-Wave Integrated Circuits", 1981 IEEE Trans. Microwave Theory Tech., 29, 11, pp. 1188-1192, Nov. 1981.
- [2] A. A. Oliner, S. T. Peng, T. Hsu and A. Sanchez, "Guidance and Leakage Properties of a class of Open Dielectric Waveguides: Part II - New Physical Effects", 1981 IEEE Trans. Microwave Theory Tech., 29, 9, pp. 855-869, Sep. 1981.
- [3] K. Wu, "A Combined Efficient Approach for Analysis of Nonradiative Dielectric (NRD) Waveguide Components", 1994 IEEE Trans. Microwave Theory Tech., 42, 4, pp. 672-677, Apr. 1994.
- [4] Ke Wu, L. Han, "Hybrid Integration Technology of Planar Circuits and NRD-Guide for Cost-Effective Microwave and Millimeter-Wave Applications", IEEE Trans. Microwave Theory Tech., Vol. 45, No. 6, pp. 946-953, Jun. 1997.
- [5] T. Yoneyama and S. Nishida, "Dielectric Waveguide Coupling by Leaky Wave", Int'l Symp. on Microwave and Communication, India, pp. 185-190, Dec. 1981.
- [6] D. Niu, T. Itoh, T. Yoneyama, "Measurement of NRD-guide leaky wave coupler in Ka band", 1993 MTT-S Int'l Microwave Symp., Atlanta, pp. 1207-1210, June 1993.

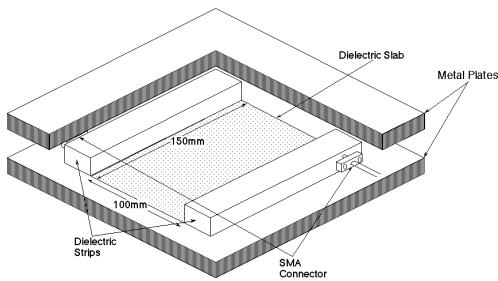


Fig. 1 Configuration of the NRD coupler by the rods and the slab

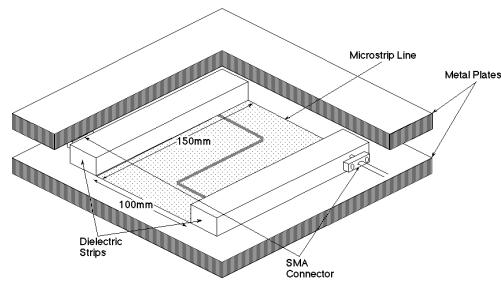


Fig. 2 Configuration of the NRD coupler with the microstrip coupling line circuit

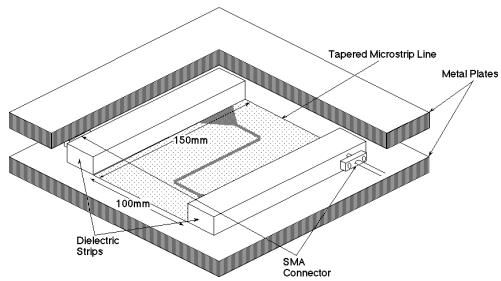


Fig. 3 Configuration of the NRD coupler with the tapered microstrip coupling line circuit

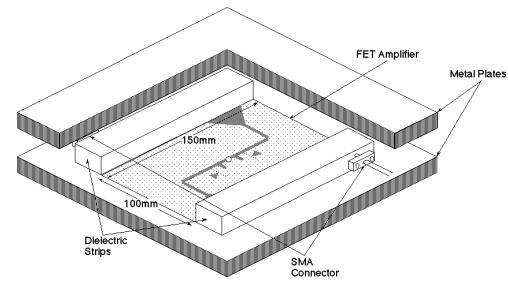


Fig. 4 Configuration of the NRD coupler with the FET amplifier circuit

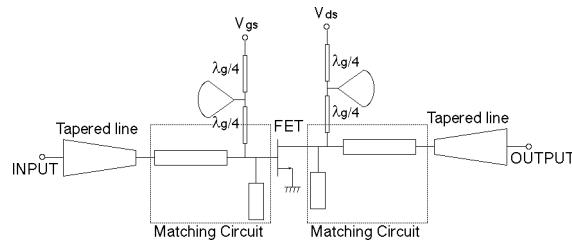


Fig. 5 Circuit schematic of the FET amplifier

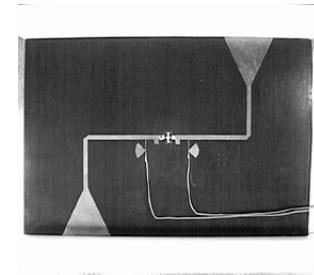
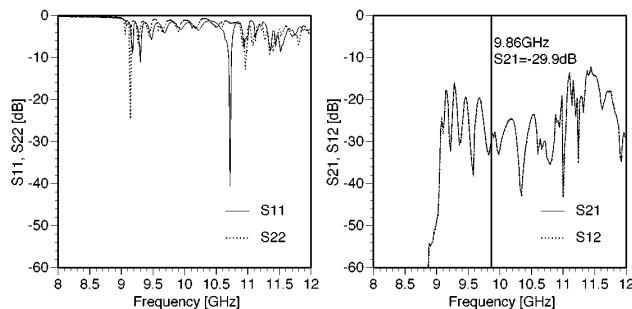
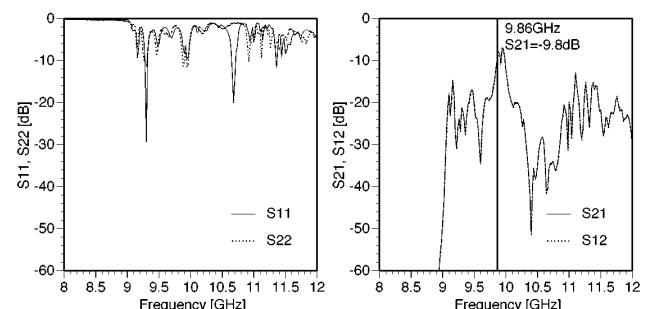


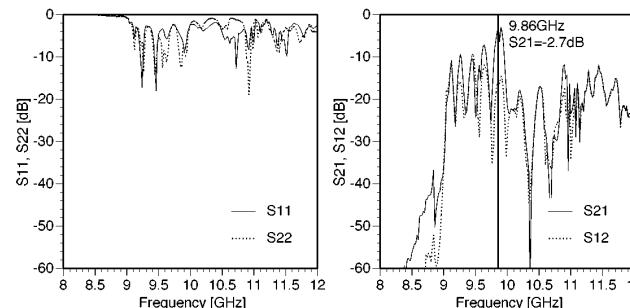
Fig. 6 Photograph of the NRD coupler with the tapered microstrip coupling line and the FET amplifier



(a) the NRD coupler by the rods and the slab



(b) the NRD coupler with the tapered microstrip coupling line circuit



(c) the NRD coupler with the FET amplifier circuit

Fig. 7 Comparison with the measured S parameters of the three types of NRD couplers