# DIRECTLY-CONNECTED IMAGE GUIDE 3dB COUPLER WITH VERY FLAT COUPLING

Dong Il Kim, Daisuke Kawabe, Kiyomichi Araki, and Yoshiyuki Naito

Dept. of Electrical and Electronic Engineering,
Tokyo Institute of Technology
Meguro-ku, Tokyo 152, Japan

SUMMARY

Design method of the broadband, compact, and mechanically stable 3dB coupler with very flat coupling are demonstrated using a directly-connected image guide. The experimental results agree reasonably well with the theoretical ones by forming appropriate tapers even at frequencies where higher modes could be excited.

## INTRODUCTION

The dielectric image guide 3dB 90 hybrid couplers in millimeter-wave range are of specific interest for balanced mixers, balanced amplifiers, and so on. The conventional parallel directional coupler with dielectric image lines[1],[2], [3] has the following drawbacks; (1) The size is very large in comparison with the wavelength in millimeter-wave range. (2) Since controlling the spacing of the coupled section of two guides is very difficult, it is very difficult to reproduce the coupler performances. Though the above problems have been somewhat overcome in [4],[5], the broadening of bandwidth was not considered in them.

Here, we proposed a directly-connected image guide 3dB coupler with high performance, which can be constructed with very good repeatability and broadbanded easily. After calculating the dispersion curves and coupling characteristics using the effective dielectric constant method, the directly-connected image guide 3dB couplers were designed and constructed, and their frequency characteristics were measured and compared to those of conventional distributed couplers.

## HIGH PERFORMANCE COUPLER DESIGN

In order to make the design process more flexible than that of other couplers, we consider the directly-connected image guide as shown in Fig.1. Figure 2 shows the dispersion curves for the directly-connected image guides, which are calculated by the effective dielectric constant method, when a, b, and c are 3, 1.5, and 1

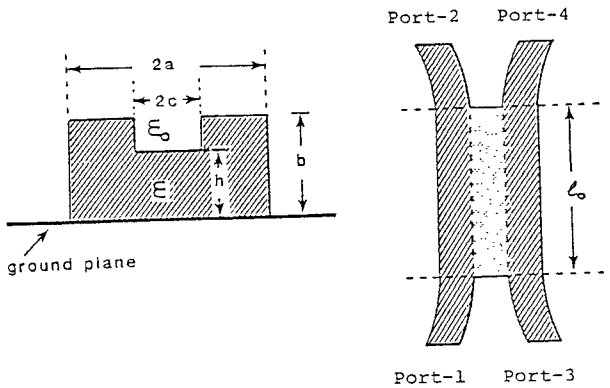


Fig.1 Directly-connected Image Guide

mm respectively, and h takes the values of 0 or 1.25 mm. The structure with h=0 corresponds to a coupling structure of a conventional distributed directional coupler. The coupling lengths for 3dB couplers calculated were also shown in Fig.2. Figure 3 shows the calculated frequency characteristics for the couplers at the center frequency of 50 GHz with the same dimensions as those in Fig.2. The coupling characteristics become broader and flatter as h becomes higher as shown in Fig.3. But, for single mode operation, the optimum values of h is about 1.25 mm because higher modes can be excited in certain frequency range when h is greater than 1.25 mm. Therefore, there is an optimum value of h for broadband design of a directly-connected image guide coupler. It is seen in Fig.3 that the coupler with a nearly optimum value of h has a extremely broad bandwidth of 28.1% whereas the conventional one has a bandwidth of 10.2% in the tolerance limit of ±0.25dB of the deviation in coupling from 3dB.

## EXPERIMENTAL RESULTS

In order to confirm the above design theory, we performed experiments for some



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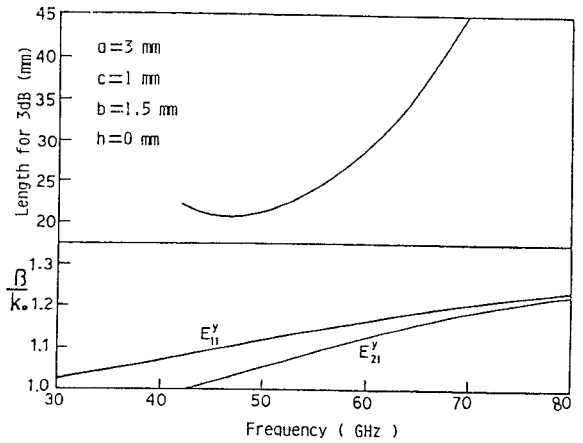
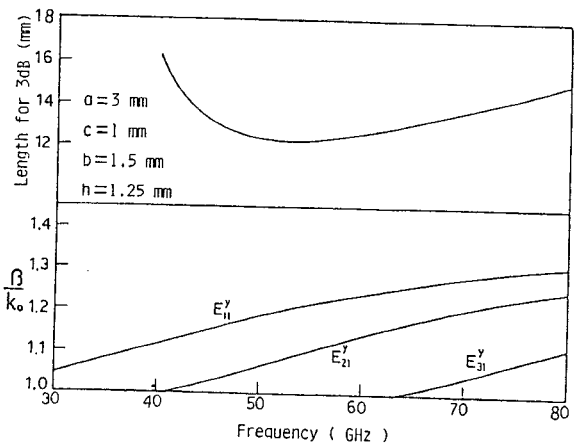



(a) with h=0 mm (Conventional Distributedly Coupled Image Guide)

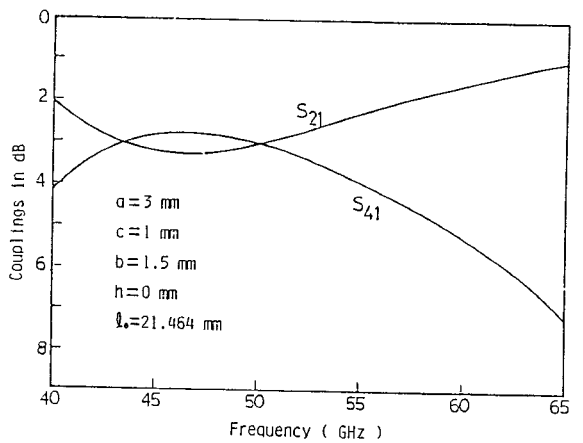



(b) with h=1.25 mm

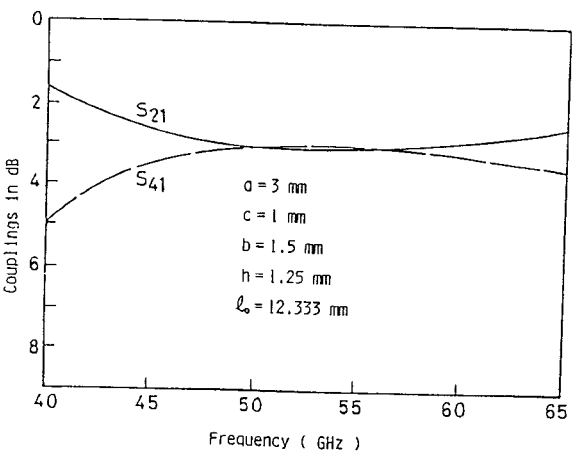
Fig.2 Dispersion Curves and Coupling Length for 3dB Directional Couplers for the Directly-Connected Image Guide (a=3, c=1, b=1.5 mm)

cases. All the guiding media were fabricated from Teflon with dielectric constant $\varepsilon_r$ of 2.1. Firstly, since the optimum value of h is 1.25 mm under the condition of single mode operation as stated above, the coupler with a=3, b=1.5, and c=1 mm for the both couplers. Figure 4 shows the experimental results which agree well with the theoretical ones.

Secondly, though there exists a possibility that higher modes coupled be excited in the directly-connected image guide, it is expected that the effect of higher modes in the coupling section can be removed by appropriately tapering the junctions between arms and coupling section. The measured frequency characteristics for the coupler with the dimension of a=4, b=2, c=1.5, and h=2.5 mm also agreed well with theoretical predictions in spite of the possibility of higher modes excitation, and the bandwidth extends to 24% in the tolerance limit of ±0.43 dB of coupling deviation from 3dB, while the bandwidth of the conventional one with same dimension is only 3%. Thus, it is confirmed by experiments that the higher mode is rarely excited if we adopt an appropriate taper in the section between the main arms and coupling section.




(a) with h=0 mm (Conventional Distributed Coupler)




(b) with h=1.25 mm (Nearly Optimized Value of h)

Fig.3 Calculated Frequency Characteristics for the Directly-Connected Directional Couplers (a=3, c=1, b=1.5 mm)

## CONCLUSION

Directly-connected image guide couplers have been proposed and studied theoretically and experimentally, and the comparison with the conventional distributed image guide couplers have been made in propagation constant and coupling characteristics. As a conclusion, the directly-connected image guide coupler is of extremely broad bandwidth, of very flat couplings, and a useful component for millimeter-wave integrated circuits. Furthermore, it is confirmed experimentally that the directly-connected image guide coupler has high performance by adopting appropriate tapered sections, even at frequencies where higher modes could be excited.

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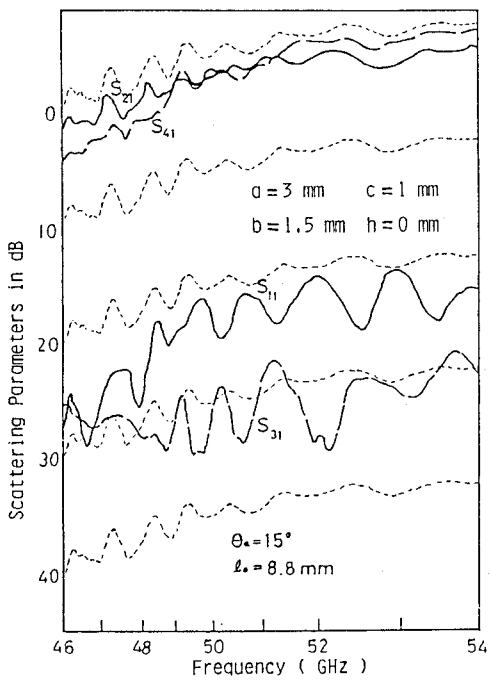
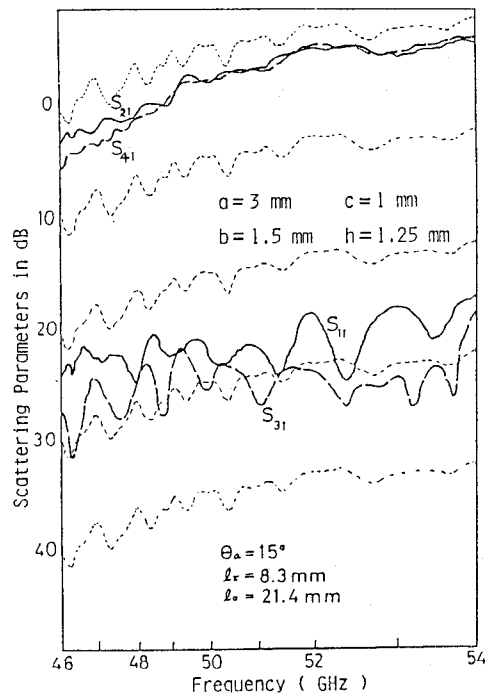



(a) with h=0 mm (Conventional Distributed Coupler)




(b) with h=1.25 mm (Nearly Optimized Value of h)

Fig.4 Measured Frequency Characteristics for the Directly-Connected Directional Couplers (a=3, c=1, b=1.5 mm)