W-Band Finite Ground Coplanar Waveguide (FGCPW) to Microstrip Line Transition

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Abstract

A uniplanar transition from finite ground coplanar waveguide (FGCPW) to microstrip line operating at W-Band has been developped. The design is uniplanar and does not require viaholes or wirebonds. The transition, centered at 94 GHz, results in 0.2 dB insertion loss with a bandwidth of 20 %. The return loss is better than -17 dB from 85 GHz to 100 GHz. To our knowledge, this simple transition shows state-of-the-art performance, and can be very useful for CPW-probe to microstrip circuit measurements.

I. INTRODUCTION

At millimeter- and sub-millimeterwave frequencies, coplanar waveguides (CPW) and finite ground coplanar waveguides (FGCPW) provide many solutions to the design of low-loss, uniplanar, low-cost and compact integrated circuits.

However, many applications such as vertically integrated circuits require the flexibility to use a combination of planar technologies (microstrip, coplanar strips and waveguides...). Low-loss, wideband and small transitions are therefore necessary to ensure the compatibility of CPW and microstrip technologies. The CPW to microstrip transition based on electromagnetic coupling was first described in 1976 and demonstrated from 5-11 GHz and from 11-18 GHz [1]. In this paper we present the extension of this transition to 94 GHz, and present a new wideband version of the transition.

II. TRANSITION DESIGN

The transition has been designed following the procedure described by Pavlidis *et al.* [2], which considers the coupling region as a six-port network with a ground plane, or as three coupled microstrip lines (Fig. 1). In this configuration, as seen in Fig. 1, ports 2 and 5 are the input/output ports, respectively. The transition is $\lambda_g/4$ long at the center frequency of operation ($f_0 = 94$ GHz), where λ_g is the guided wavelength of the three-conductor line. Ports 4 and 6 are terminated by an open circuit, which results in ports

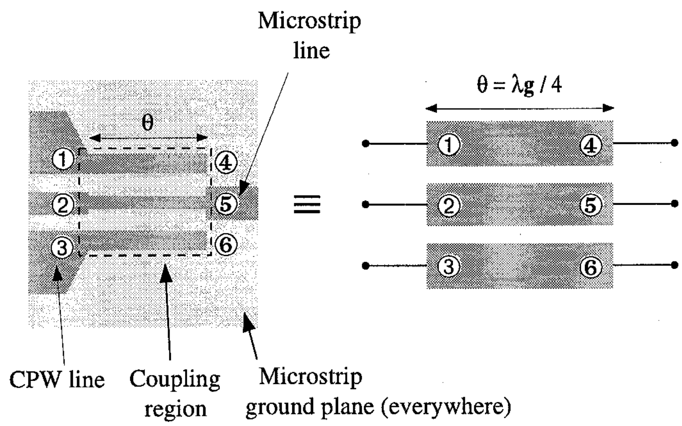


Fig. 1. CPW-to-microstrip transition and the equivalent three-line microstrip coupler used to analyze and design the transition.

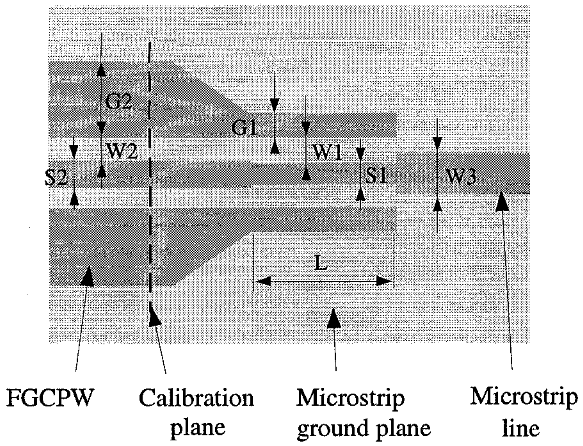
1 and 3 being short-circuited at f_0. The system is characterized by three mode impedances, which depend only on the geometry of the multi-wire network: width and spacing of the microstrip lines, height and dielectric constant of the substrate [2]. These mode impedances, (Z_{oo}, Z_{oe} and Z_{ee}), are calculated from the 2-D quasi-static capacitances. The dimensions of each coupled line are then calculated to optimize the insertion and return losses of the transition, referenced to 50 Ω. The input line is a 50 Ω finite ground coplanar waveguide (FGCPW), The output line is a 50 Ω microstrip line. In this design, the lower ground plane extends everywhere. However, since the ground plane of the FGCPW line is finite, no unwanted parallel-plate modes are triggered in the substrate between the coplanar lines and the ground plane.

In the second design, the straight coupling stubs are replaced by wideband radial stubs to increase the bandwidth of the transition. As will be shown later, this results in 25 % more bandwidth than the straight stubs.

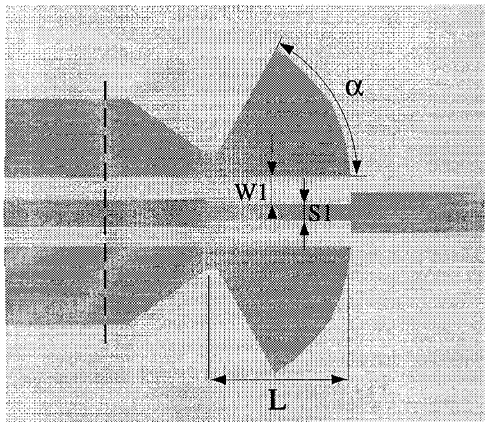
II. W-BAND MEASUREMENTS

A/ DESIGN

Two FGCPW-to-microstrip transitions have been de-



(a)

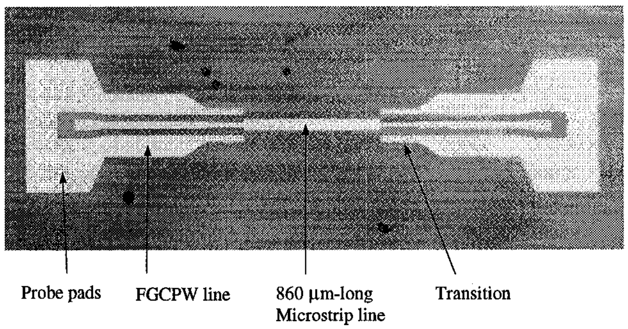


(b)

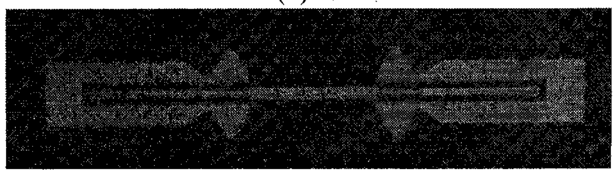
Fig. 2. CPW-to-microstrip transition with straight coupling stubs (a) and with radial coupling stubs (b).

signed, fabricated and tested in the W-band region (75-110 GHz): a straight stub design (transition A) and a radial stub design (transition B). The transitions are built on a 120 μm thick high-resistivity Silicon substrate ($\epsilon_r = 11.7$). The circuit is mounted on a metallized Silicon wafer to provide the ground plane. The evaporated gold is 9000 $\mathring{A}$ (more than 3 skin-depths at 94 GHz). The FGCPW input line dimensions are $S2 = 50$ μm, $W2 = 45$ μm and $G2 = 145$ μm (Fig. 2a) corresponding to a characteristic impedance of $Z_c = 47$ Ω [3]. The microstrip line is 70 μm wide, corresponding to a characteristic impedance of $Z_m = 50$ Ω.

The coupling region is chosen to be $L = 280$ μm long ($\lambda_g/4$ at 94 GHz). For transition A, the dimensions are $S1 = 30$ μm, $W1 = 55$ μm, and the straight stubs are $G1 = 45$ μm wide (see Fig. 2a), corresponding to fundamental mode impedances of $Z_{oo} = 13$ Ω, $Z_{oe} = 130$ Ω and $Z_{ee} = 50$ Ω. For transition B, the dimensions are also $S1 = 30$ μm, $W1 = 55$ μm, and the angle of the radial stubs is 60^o (Fig. 2b).



(a)



(b)

Fig. 3. Pictures of the two back-to-back FGCPW-to-microstrip transitions: straight -stub design (a) and radial-stub design (b).

B/ MEASUREMENTS

The S-parameters of two back-to-back transitions, separated by a 860 μm-long microstrip line, as shown in Fig. 3, are measured with W-band picoprobes on a HP8510 network analyzer. The VNA is calibrated before the transition region using TRL calibration techniques and the calibration plane is shown in Fig. 2. The measured performances of the transitions are compared with IE3D Method-of-Moment simulations and are shown in Fig. 4a (straight stubs) and Fig. 4b (radial stubs).

The measured total insertion loss is 0.4 dB from 85 GHz to 95 GHz for the straight-stub transition and includes two transitions and the microstrip line, and the 3-dB bandwidth is 20 %. The loss of the microstrip line (w=70 μm, h=120 μm) is calculated to be 0.04 dB. The deduced insertion loss for a single transition is 0.18 dB. The measured return loss is better than -17 dB from 83 GHz to 100 GHz providing a bandwidth of 20 %. However, the IE3D simulations give a wider bandwidth as shown in Fig. 4a and Fig. 4b. The differences in frequencies between the measurements and the IE3D simulations are not well explained. We believe they are due, partly to a meshing problem in the transition region that does not predict the currents with accuracy along the strips, partly to the definition of the ports of the FGCPW lines.

The radial-stub transition shows very similar performances but is more wideband: 0.18 dB insertion loss, 3-dB bandwidth of 25 %, and a return loss better than -17 dB from 85 GHz to 110 GHz. This bandwidth covers nearly the

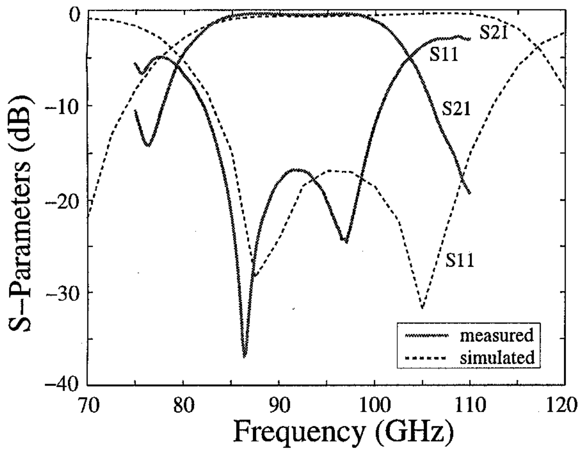


Fig. 4a. CPW-to-microstrip straight-stub transition S-parameters (-) vs. Method-of-Moment simulation (- -).

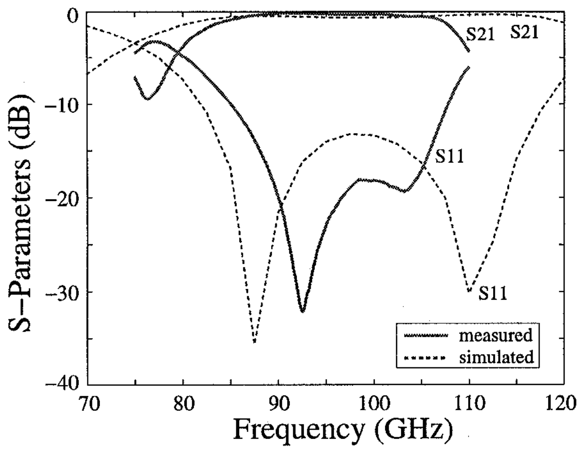


Fig. 4b. CPW-to-microstrip radial-stub transition S-parameters (-) vs. Method-of-Moment simulation (- -).

entire W-band region and the radial-stub transition can be used in CPW-microstrip circuits VNA on-wafer measurements. However, the straight-stub transition is more compact and might be prefered when space is the main issue on the wafer.

ACKNOWLEDGEMENTS

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REFERENCES

[1] M. Houdart and C. Aury, "Various excitation of coplanar waveguide," *IEEE-MTT Int. Microwave Symp. Digest,* pp. 116-118, 1979.

[2] D. Pavlidis and H.L. Hartnagel, "The design and performance of three-line microstrip couplers," *IEEE Trans. on Microwave Theory and Tech.*, Vol. 24, No. 10, pp. 631-640, Oct. 1976.

[3] F. Brauchler, S.V. Robertson, J. East and L.P.B. Katehi, "W-Band finite ground coplanar (FGC) line circuit elements", *IEEE-MTT Int. Microwave Symp. Digest,* pp. 1845-1848, 1996.

[4] IE3D Version 4, Zeland Software, Inc., 39120 Argonaut Way, Suite 499, Fermont, CA 94538.

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