Wide-Band Transitions for Applications in MMIC's and OEIC's

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***Abstract*—Three different coplanar waveguide-to-slotline transitions on InP for operation around 30 GHz were designed. The performances of these transitions in back-to-back configuration were simulated and measured over 1–50 GHz. They were found to possess wideband characteristics. In particular, two of them had bandwidths as large as 35 GHz. The design of these transitions were carried out with the view to monolithically integrating tapered slot antennas with coplanar waveguide circuits on InP substrates.**

I. Introduction

Interest in the development of optoelectronic integrated circuits (OEIC's) on InP for high-speed communications is rapidly growing. One possible application area of OEIC's is in radio-fiber systems where the wireless distribution of broadband services to homes, offices, and mobiles is envisaged [1]. In such application, it is desirable to have optical receivers/transmitters, radio frequency circuits, and antennas monolithically fabricated on one InP-based chip.

For its various advantages [2], the coplanar waveguide (CPW) is a highly suitable transmission medium for the development of radio circuits on InP and GaAs. Such lines can be used from low frequencies up to W-band.

This paper focuses on three transitions on InP, designed to interface a 50 Ω CPW to an 80 Ω. Unlike the transitions analized in [3], the presented structures have no ground plane at the backside of the substrate and in fact, the slotline is the feeder to a tapered slot antenna on InP with the input impedance of about 80 Ω. In this paper, the simulation results for the three transitions are given and discussed. Since no suitable slotline probe is available with the conventional network analysers, the back-to back forms of the transitions were fabricated and measured over 1–50 GHz band using CPW probes. The measured results are presented and compared against those predicted by an electromagnetic simulator. Finally, reasons for any discrepancies between the measurements and simulations are addressed.

II. Transitions

The metallization patterns for the three CPW-slotline transitions are shown in Fig. 1(a)–(c). These transitions have been designed for fabrication on InP substrate with 200 μm thickness. They have nominal characteristic impedances of 50 Ω at the CPW port and 80 Ω at the slotline port and should have a return loss of about −10 dB around the frequency of 30 GHz. The first two transitions, Fig. 1(a) and (b), are a direct connection of the CPW to the slotline with some modification to the metallization around the connecting area in order to improve performance. The second transition, Fig. 1(b), allows the CPW to be connected to the antenna at right angle. The third transition, Fig. 1(c), is a new form of the balun in [4].

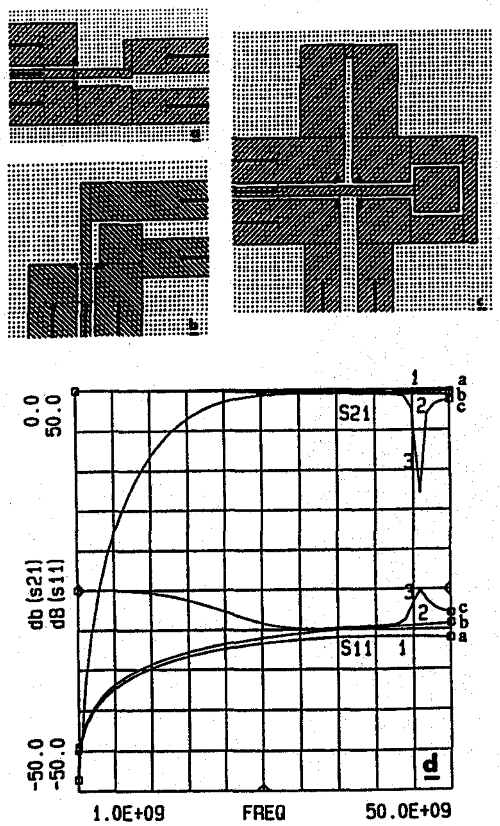

Fig. 1. (a)–(c) Three CPW-slotline transitions on 200-μm InP. Grid cell is 20 μm × 20 μm. Tips of arrows show the reference planes. (d) Simulation results for the magnitudes of scattering parameters of the three transitions when the input and output ports are terminated in 50 Ω.

The design of the transitions was optimised using an electromagnetic (EM) simulator [5]. However, the third transition can be designed using the simulator and expressions in [4]. The simulation results for the magnitude of the reflection and transmission coefficients ($|S_{11}|$ and $|S_{21}|$) are shown in Fig. 1(d). No losses were considered in the simulations. From Fig. 1(d), it is clear that transitions 1 and 2 are extremely broadband and can operate down to dc level. It was found that the performances of these transitions depend on the structure of the discontinuity between the CPW and the slotline. Therefore,

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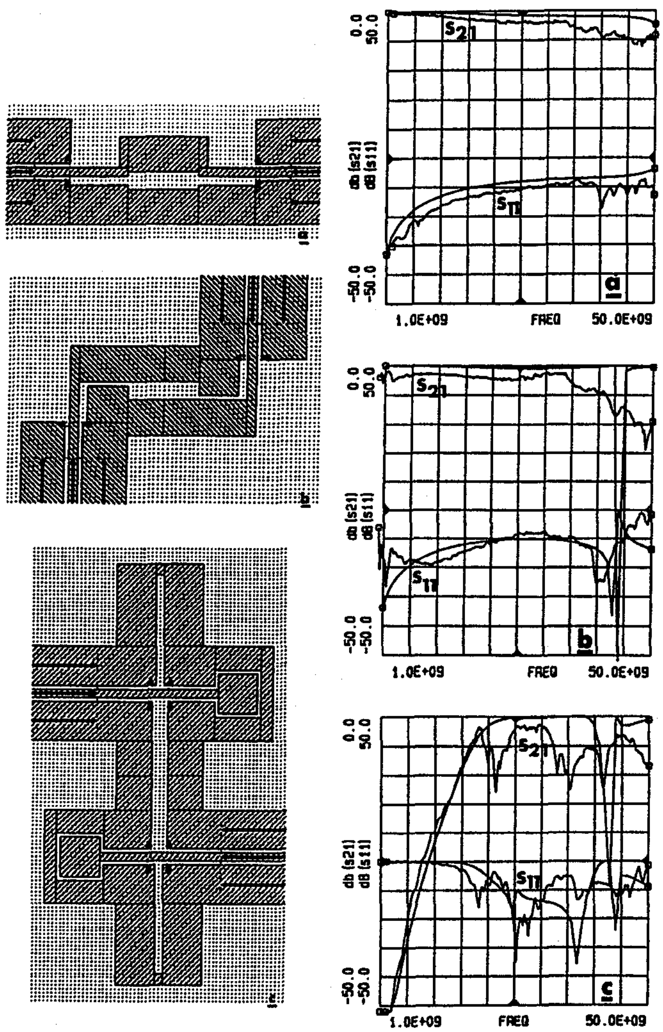

Fig. 2. (a)–(c) (at left) Back-to-back configurations of transitions shown in Fig. 1. Tips of arrows show the reference planes. (a)–(c) (at right) Simulated and measured results for the magnitudes of scattering parameters of the three back-to-back transitions.

for an optimum design, an optimization procedure involving dimensions of the structure of concern may be set up using an EM simulator to compute the scattering parameters.

The bandwidth of transition 3 is not as wide as those of transitions 1 and 2. If required, the bandwidth can be substantially increased by choosing appropriate quarter-wavelength CPW and slotline stubs [6] instead of the stubs used in the present transition. However, extending the bandwidth to cover dc is not possible, since the input and the output ports of transition 3 are electromagnetically coupled (i.e., not dc coupled). In the present design, the stubs are much shorter than quarter wavelength in order to save chip area. This is achieved by capacitively loading the CPW stub. Transitions in Fig. 1 can be scaled to operate within a required frequency band.

Since with a network analizer equipped with CPW probes, the direct measurement of the transitions was not possible, back-to-back versions of the transitions, Fig. 2(a)–(c), were fabricated and measured using HP8510C network analyser and Cascade Microtech CPW probes. The measurement and simulation results over 1–50 GHz are shown in Fig. 2, revealing that transitions 1 and 2 are indeed extremely broadband. Although difficult to compare, these transitions have performances similar to those of transitions reported in [3] and [7]. Alternative transitions with broadband characteristics are also reported in [8] for low-frequency applications. The experimental results for transitions 1 and 2 show some radiation above 40 GHz. This radiation can be attributed to the slotline resonators created by the back-to-back connection of the transitions, Fig. 2(a) and (b), and to the leakage of energy from the CPW end. The radiation due to the resonators is basically associated with the measurement method, since a direct measurement of the transitions was not possible. Unfortunately, the radiation from the transitions cannot be easily quantified theoretically because of the finite dimensions of samples, thus leading to discrepancies between simulation and measurement. Transition 3 (Fig. 2(c)) does not seem to greatly suffer from the radiation problem and has the best return loss (−15 dB) around the desired frequency (30 GHz). However, for this transition, the measurement does not support the simulation over a wide range of frequencies. The cause of the error could lie with the propagation of slot mode in the capacitively loaded CPW stub, in spite of the use of wire-bonds to suppress this mode.

III. Conclusion

Three different coplanar-waveguide-slotline transitions on InP for operation around 30 GHz were designed. Two of these transitions are direct connections of the CPW and the slotline. They are extremely broadband and dc coupled. The third transition is electromagnetically coupled and over its bandwidth has a return loss better than the other two. The performances of these transitions in back-to-back configuration were simulated and measured over 1–50 GHz. It is believed that energy leakage from resonators created as a result of the back-to-back connection of the transitions, affects the accuracy of the measurement at frequencies above 35 GHz. Also, in one of the transitions, the propagation of the slot mode in parts of the circuit is believed to be responsible for the discrepancy between the simulation and measurement over some bands of frequencies.

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