DIRECT CALIBRATION AND MEASUREMENT OF MICROSTRIP STRUCTURES ON GALLIUM ARSENIDE

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ABSTRACT

Measurements on coupled microstrip line structures on gallium arsenide are described which use a direct launch and calibration standards in the same microstrip medium. Novel techniques are adopted to ensure repeatability and overcome problems of fragility of the substrates. Measured results show good agreement with theoretical analysis.

INTRODUCTION

With increasing interest in microwave integrated circuits (MICs) on GaAs, as well as other new ceramic and plastic substrates, there is a need for accurate measurement techniques in order to characterize both the materials and circuits. The most popular and useful transmission line medium on these circuits is microstrip, so it is necessary for the circuit designer to have good models for this transmission medium and its associated structures. Such models are often derived empirically from measurements performed on test structures and it follows that measurement techniques are required which are capable of accurate characterization in the microstrip medium. Microwave characterization of circuits and devices is most often performed using a vector network analyzer, but to obtain accurate results this equipment must be calibrated using "standards", i.e. devices with known response. To avoid the additional uncertainty due to the use of adaptors it is necessary that such calibration standards be fabricated in the same transmission line medium as the circuit to be measured. For characterization of MICs on GaAs, an "on-circuit" probing system has been demonstrated [1] which utilises calibration standards in coplanar waveguide (CPW). CPW has the advantages that the test signals can be launched easily from the source onto the circuit and good calibration standards can be fabricated readily. However, most MICs necessarily employ microstrip as their transmission line medium and it is preferable to have a measurement system in this medium. The development of such a system is the basic objective of this work.

Of specific interest is the coupling between microstrip lines, and a problem in GaAs in particular is that of spurious coupling between different parts of a circuit which may cause unexpected degradation of the circuit performance. It is necessary that these effects be well understood in order to reduce the spurious coupling or to be able to design around its effects. It was these types of structures therefore that were examined in the experimental part of this work.

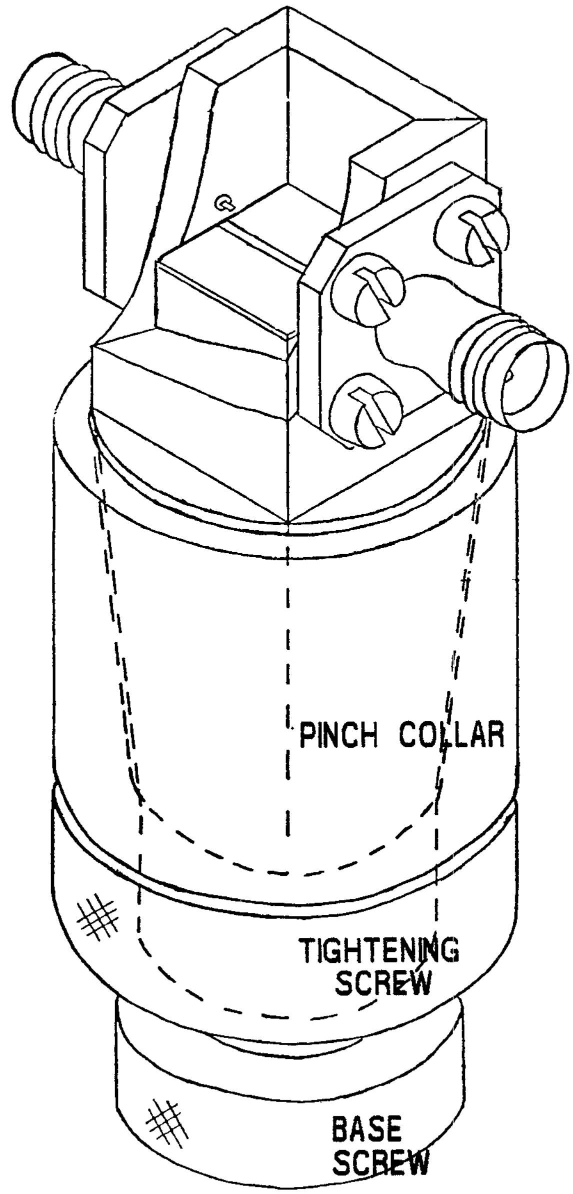

Figure 1. Measurement Fixture

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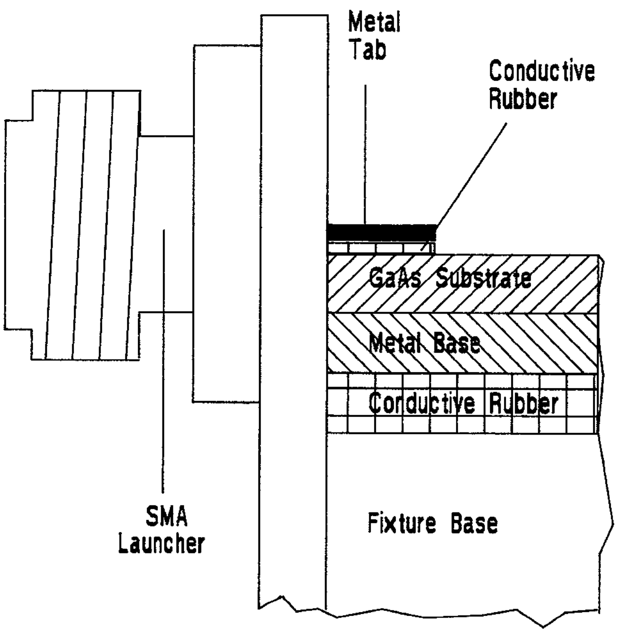
MEASUREMENT TECHNIQUES

A measurement fixture has been developed (Figure 1) for direct calibration and measurement of microstrip structures. The fixture has provision for up to four measurement ports, one on each side, and the transition from coaxial line to microstrip being achieved with SMA tab-type launchers. The fixture has an adjustable ground plane, which serves two purposes. Firstly, the fixture is capable of accommodating substrates of arbitrary thickness and, secondly, a good short circuit can be created in the absence of a substrate by bringing the ground plane into contact with the launching tabs. It is this short circuit which is used to define accurately the reference plane for the measurement. The problem with an adjustable ground plane is that of achieving a good electrical contact between that ground plane and the side walls of the fixture; this can cause problems of spurious resonances which were evident in earlier versions. The solution is to have slits at the corners of the fixture and a beveled pinch collar to grip the four walls together once the circuit substrate is in position and the tightening screw adjusted.

Figure 2. Direct Launching onto GaAs



The calibration standards used are open circuits at the end of microstrip lines of known length and a microstrip through line. The reflection coefficient due to the end-effect of the open circuits is not assumed and is eliminated by using a semi-redundant calibration procedure involving one additional calibration standard. This measurement technique has been used successfully on alumina substrates [2] but the important step here has been its application to GaAs. The overwhelming problem is the fragility of the GaAs substrates since considerable contact pressure is required to obtain a good and, more importantly, repeatable contact between the tab and the circuit. This pressure will invariably fracture normal unmounted GaAs substrates. The solution adopted here is to cement the substrates down onto metal shims using a conductive adhesive to make the structure sufficiently robust. There remains the problem of the actual launching point, and here it is found that the metal tabs tend to crush the substrate which disintegrates with the repeated pressure, resulting in a poor, unrepeatable contact as well as limited life for the calibration standards. The problem has been overcome by cementing a thin sliver of conductive rubber onto the underside of the tab to spread the pressure of the contact. A thin layer of this rubber is also placed between the substrate and the ground plane of the fixture to counteract variations in flatness of these and to ensure good electrical contact over the whole area of the ground plane. The cross section of the overall launching structure is shown in Figure 2.

RESULTS

A series of test structures were fabricated on semi-insulating GaAs substrates. The relevant dimensions of the microstrip lines are shown in Figure 3. The coupling and isolation of the structures were measured over the frequency range 2 to 10 GHz and the results of the coupling measurements are shown in Figure 4. They are compared with the theoretical S-parameters derived from an analysis of the microstrip structure. The S-parameters are derived from the voltages and currents at the four ports of the structure, which are in turn obtained from a superposition of the even and odd modes of propagation. The characteristic impedances and effective dielectric constants of these two modes are calculated using the routine of Bryant & Weiss [3].

There is good agreement between theory and measurements, particularly in the lower part of the frequency range. There is an apparent resonance at 8.5 GHz for the 1.0 mm spaced structure which is not predicted by the theory. To investigate this further, more coupled structures were fabricated with the same 1.0 mm spacing, but with coupled lengths of 3 mm and 5 mm. These also exhibited the discrepancy at 8.5 GHz, indicating that the effect is not a longitudinal one, but must be a transverse effect dependent on the spacing between the lines and probably the distance of the structure from the side walls.

CONCLUSIONS

A measurement technique has been presented for the direct calibration and measurement of microstrip structures which has been applied to GaAs circuits. Results have been presented for coupled line structures and the authors believe that these represent the first published results of a calibration and measurement performed *directly in microstrip on GaAs*. The technique provides a basis for improved characterization, not only of GaAs structures and active device circuits but also in the broader field of a wide range of microwave ceramic and plastic substrates which are becoming available and which could achieve widespread use if their properties were well characterized and reliable techniques available for measurements of circuits employing these materials.

Acknowledgements

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Fig. 3 Dimensions of Coupled Line Structures

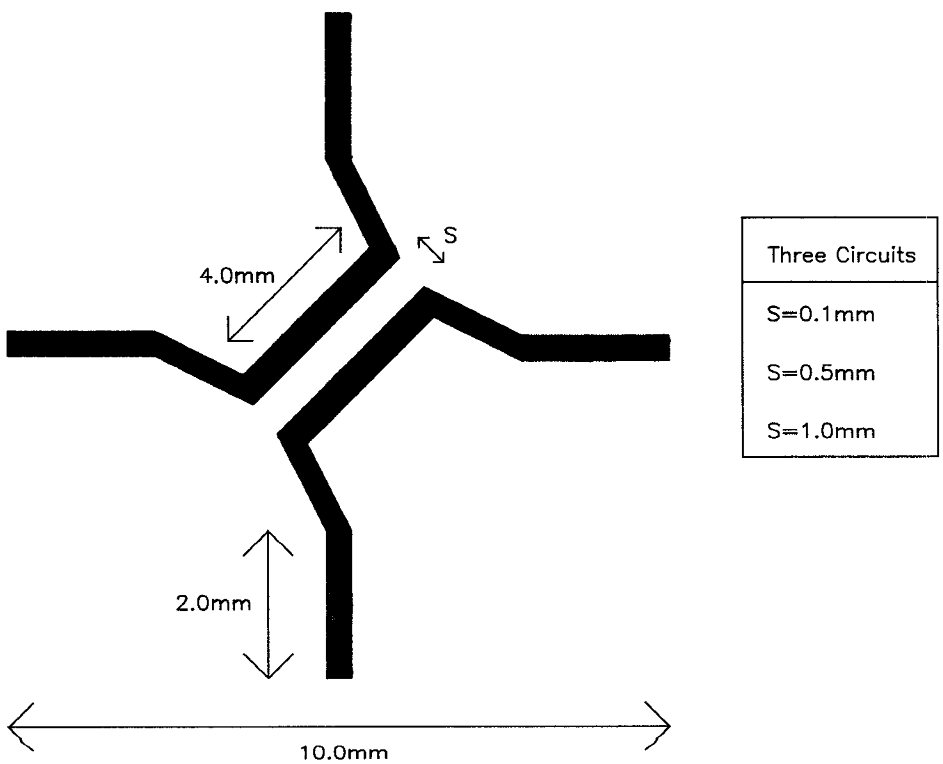

Figure 4. Theoretical and Measured Coupling of Coupled Lines on GaAs