A New W–Band Coplanar Waveguide Test Fixture

PP-22

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Abstract—A new type of coplanar waveguide (CPW) test fixture suitable for transistor measurements in the 75–110 GHz band will be presented. The fixture employs finline tapers to transition from waveguide to CPW, and air–bridges to tie the opposing ground planes to the same potential. A simple computer model has been developed to aid in the design of the waveguide to CPW transitions. A prototype fabricated on low dielectric substrate has 4 dB loss from 85–95 GHz.

Introduction

Recent breakthroughs in high performance HEMTs has stimulated the need for waveguide test fixtures to characterize these devices at millimeter–wave frequencies. Fixtures that transition from waveguide into microstrip require grounding of the transistor source leads either with via holes or bonding wires. At W-band frequencies, this generates undesirable parasitic effects that can degrade device performance. By using coplanar waveguide, source parasitics can be minimized. We have developed a coplanar waveguide test fixture suitable for characterizing devices at millimeter-wave frequencies. The fixture includes back–to–back low–loss transitions, a monolithic compatible geometry, and the ability to easily apply DC bias.

Test Fixture Circuit

Figure 1(a) is a schematic illustration of the E–plane circuit metalization employed by the test fixture. Unilateral finline is used to transition from waveguide to a short length of asymmetrical double–strip coplanar waveguide. The finline contour is obtained using previously developed theories of nonuniform waveguides[1]. An air–bridge placed directly after the asymmetrical coplanar waveguide converts the line into standard coplanar waveguide. A two port test fixture is formed by interconnecting a pair of back–to–back finline air–bridge transitions with a length of 50 Ω coplanar waveguide. A diagram of how the circuit sits in a waveguide housing is shown in Fig. 2.

Operation of the transition is best understood by examining the finline air–bridge structure when excited by a waveguide mode. Currents flowing along the waveguide walls are first concentrated by the finline taper. The current in the lower section of finline then continues down the center conductor of the coplanar line, while the current in the upper finline is split by the air–bridge. As a result of distributed effects associated with the air–bridge, the signal arriving at the lower coplanar waveguide ground plane experiences attenuation and a phase shift relative to the upper ground plane. Balancing the amplitude of the ground plane signals can be accomplished by tuning the air–bridge structure to a Tchebyscheff filter response. Because the wavelength in the air–bridge is longer than in the CPW, the length and angle of the air–bridge can be set to compensate for small differences in path lengths along the opposing ground planes.

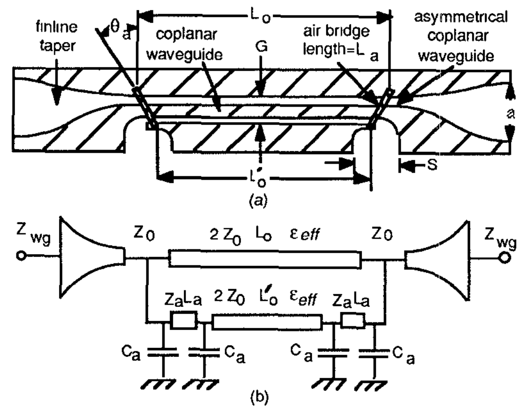

Figure 1. (a) Schematic layout, and (b) computer model of the W-band E–plane test fixture circuit.

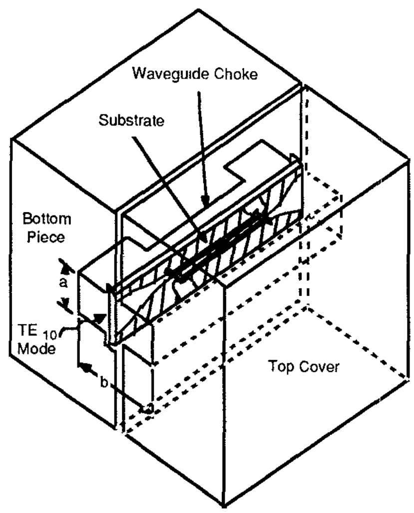

Figure 2. Diagram of the split block waveguide housing showing the finline orientated in the E–plane.

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Equal path lengths in the two ground planes require, Fig. 1

$$\frac{L_o}{\sqrt{\epsilon_{eff}}} = 2L_a + \frac{L_o'}{\sqrt{\epsilon_{eff}}} \quad (1)$$

where ϵ_{eff} is the effective dielectric constant of the slot line, and L_a is the electrical length of the air–bridge. The required angle of the air–bridge can be optimized using

$$L_o' = L_o - 2G\tan\theta_a \quad \text{and} \quad L_a = G/\cos\theta_a \quad (2)$$

The computer model in Fig. 1(b) has proven useful for predicting the circuit response. Analysis is simplified by viewing the CPW section as two parallel slot lines with characteristic impedance Z_0, length L_o and L_o', and attenuation α. The loose coupling along the length of the slot lines is assumed to be negligible for wide center conductors. Segmenting the finline taper into 40 two–port sections allows analysis to be performed with commercially available CAD programs.

Predictions from the computer model using typical values for the CPW gap G, show that ϵ_{eff} of the substrate must be large enough that the angle of the air–bridge required to equalize the phase is held to less than 60°. Otherwise, the increase in air–bridge parasitics associated with long bridges results in degraded performance. This criteria can be satisfied on high dielectric substrates such as GaAs or Alumina, but not on low dielectric substrates.

Prototype test fixture

For ease of fabrication, a soft substrate of low dielectric constant was used to evaluate the test fixture circuit. Because of the low dielectric constant ($\epsilon_r = 2.22$), an alternative design was developed to match the path lengths. The circuit design in Fig. 3 balances the path lengths, although the phases on the opposing ground planes signals are not necessarily identical.

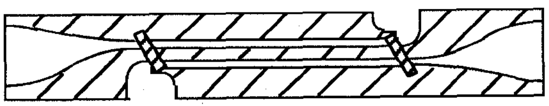

Figure 3. Prototype fixture circuit on low dielectric substrate ($\epsilon_r = 2.22$). Total circuit length = 600 mils.

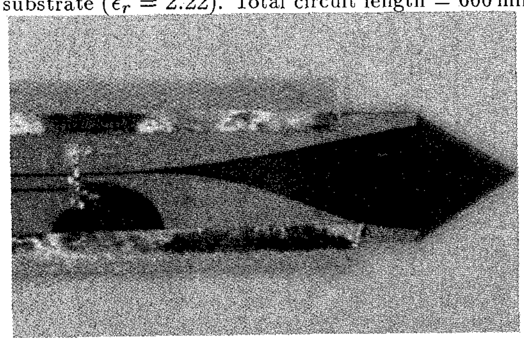

Figure 4. Photograph of test fixture circuit showing finline taper and gold ribbon air–bridge. The width of the ribbon is 1.8 mils and the CPW gaps are 1 mil.

Experimental Results

Reflection and transmission measurements were made by simplifying a previously built 6-port into a 4-port scalar analyzer[2] and controlling it with an IBM personal computer. Measurement accuracy of this system was verified by comparing its results with measurements made on an HP 8510 network analyzer equipped with the W-band extender. Typical results for one of the transitions is graphed in Fig. 5. The minimum insertion loss was 2 dB. A 4.5 dB per inch attenuation factor was used in the computer model. There are four dips in s_{21}. Two of the dips are due to an estimated 2 mil difference between the two gold ribbon air-bridges. The frequency spacing between these dips is inversely proportional to L_o. The other two dips are above 100 GHz. One has been determined, using a tapered finline circuit, to be related to the choke in the waveguide housing. The other is believed to be due to a resonance in the cavity located near the air-bridge.

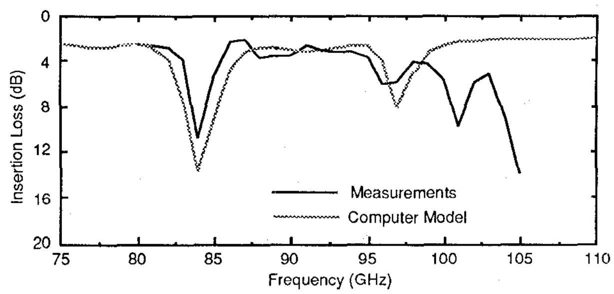

Figure 5. Insertion loss (s_{21}) of the low dielectric constant prototype test fixture.

Conclusion

We have developed a W-band test fixture that provides good RF characteristics and can be integrated monolithically with a GaAs device. A computer model has been used to accurately predict performance of the E-plane circuit employed in the fixture. Based on knowledge gained from the prototype circuit, a 3 dB improvement is predicted by going to a shorter CPW line, and using a lower loss substrate.

Acknowledgements

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