Measurement and Modeling of CPW Transmission Lines and Power Dividers on Electrically Thick GaAs Substrate to 220GHz

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***Abstract*—In this paper, we describe the measurement and modeling of coplanar waveguide (CPW) transmission lines and power dividers on a 620µm thick GaAs substrate to 220GHz. It is shown that excellent agreement with measurements can be predicted using a commercial solver (HFSS™) by appropriate use of port stimuli and boundary conditions.**

***Index Terms*—Coplanar waveguides, *G*-band, couplers, power dividers**

I. Introduction

Accurate measurement and modeling of transmission lines, and passive circuits based upon them, is a big challenge at deep mm-wave frequencies [1]. This is especially true when the substrate is electrically thick [2]. In the present paper, we describe an electromagnetic modeling approach and compare with measurements of coplanar waveguide (CPW) transmission lines and passive power dividers up to 220GHz. The results will be useful for accurate design of monolithic circuits to these extremely high frequencies.

II. Experimental and Simulation Results

We have designed and fabricated a set of CPW transmission lines, branch-line couplers and Wilkinson dividers [3, 4] on 620µm thick GaAs substrate. A cross-section of the CPW geometry is shown in Fig. 1. The gold conductors are nominally 1.2µm thick. The airbridges are 2µm thick and separated from the substrate by 5µm. RF-on-wafer measurements were made with the substrate separated from the wafer chuck by a 1mm quartz spacer. Line-reflect-line (LRL) calibration was performed with WR5 100-µm pitch probes and an impedance standard substrate to place the measurement reference plane at the probe tips. Alignment markers on thin lower level metal were used in the probe pad areas to aid repeatable measurements and calibration. This is essential because the probe skate distance (25µm) is of a significant electrical length at such high frequency. The CPW probe pad dimensions are W/S=60µm/40µm that linearly tapers into the 50Ω CPW line of dimension W/S=20µm/15µm.

All the structures were modeled using the commercial HFSS™ 3D solver and meshed at 180GHz. The dielectric constant and loss tangent of GaAs were assumed to be frequency independent (ε_r=12.9 and tanδ=0.006) since CPW has low dispersion. For simplicity, the conductors were assumed to be perfectly smooth with bulk conductivity of 4.1×10^7 S/m. For each structure, the surrounding air-box was set as radiation boundaries while the bottom face was a perfect-E boundary to represent the metal chuck. The excitations were applied as lumped-ports. These are better suited for coplanar structures on thick substrates than wave ports [5]. In particular, at *G*-band frequencies, we found that the size of the lumped ports was very critical in order to model the phase response accurately. The best agreement was obtained using a 60µm×6µm size lumped port which approximates the probe tip area.

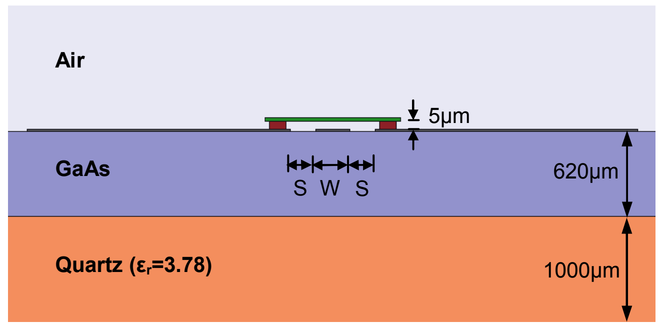

Fig. 1. Cross-section of the CPW geometry and substrate stack.

To verify our modeling approach, we firstly measured the transmission response of long CPW line test structures on the same wafer. Fig. 2 shows the excellent agreement obtained between simulation and measurement over wide bandwidth. The results up to 120GHz were measured with 100-µm pitch probes but using a different test set. Excellent continuity in measurements was achieved.

The *G*-band power dividers were measured as two ports, as shown in Fig. 3, with the remaining ports terminated with on-chip nichrome resistors. Deviations from the design center frequency of 180GHz are attributed to reduced resistivity of the nichrome layer in this sample run. In our modeling, we accounted for this process variation to obtain better agreement with measurements as given in Fig. 4. The insertion losses of the dividers were around 5dB at 170GHz. A summary of the measured output imbalances and isolation are given in Fig. 5 and Table 1. To the best of our knowledge, these are the highest frequency single-stage power dividers reported to date using standard CPW technology.

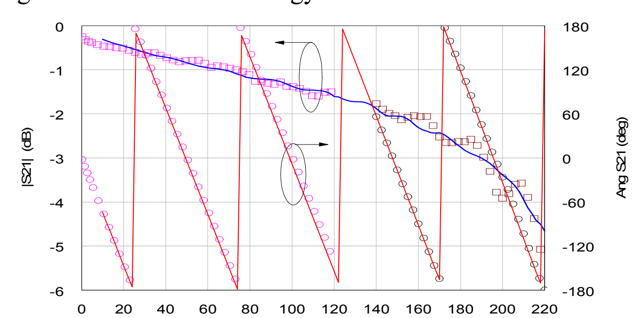

Fig. 2. Transmission response of 2mm long CPW transmission line: *measured (symbols) & modeled (solid line)*.

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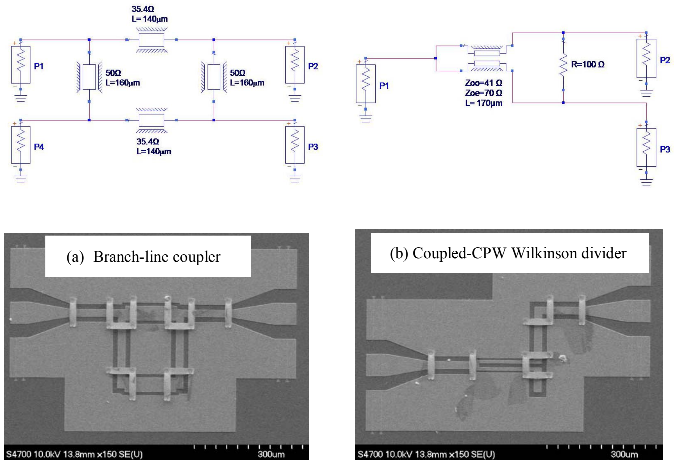
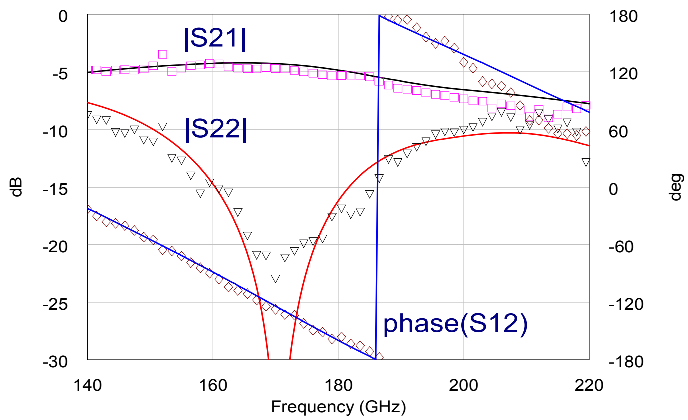
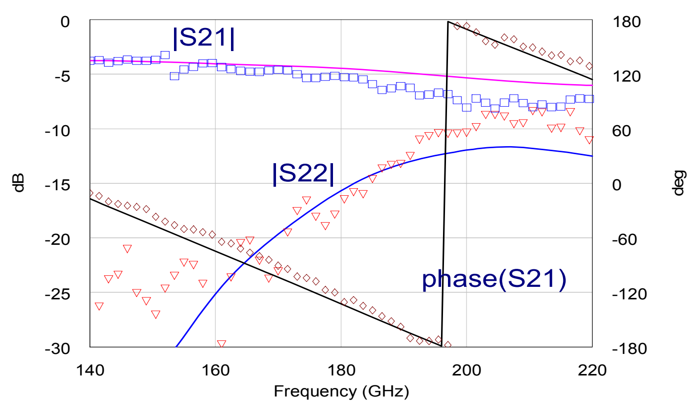


Fig. 3. Simplified schematics (top) and microphotographs (bottom) of the fabricated power dividers.



(a)

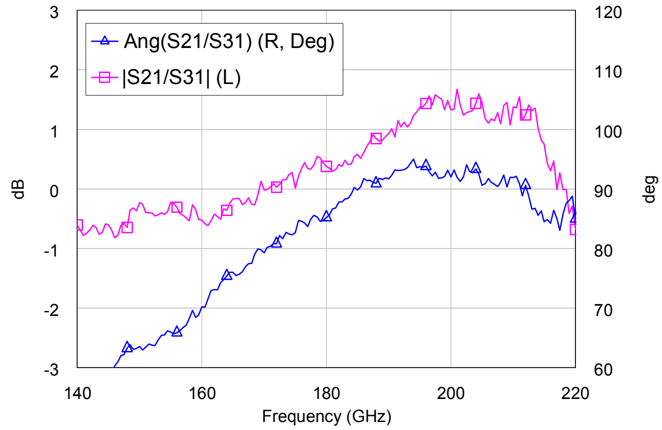


(b)

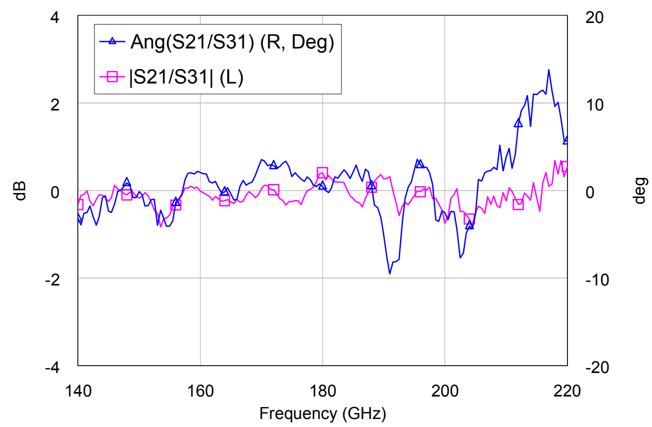
Fig. 4. Frequency response of the (a) branch-line coupler, and (b) coupled-CPW Wilkinson divider: *Solid lines = modeled, Symbols = measured.*

Freq.=170GHz	**Branch-Line coupler**	**Wilkinson divider**
Amplitude bal. (dB)	0.2	0.1
Phase bal. (deg)	9.6	3.0
Isolation (dB)	12.0	12.4

Table. 1. Measured output imbalances and isolation performance.



(a)



(b)

Fig. 5. Measured output amplitude and phase balance of the (a) branch-line coupler, and (b) coupled-CPW Wilkinson divider.

III. Conclusions

The measurement and electromagnetic modeling of coplanar structures on electrically thick substrates have been presented. Good agreement was obtained with proper use of port stimuli and boundary conditions. The results also support the viability of conventional CPW technology to *G*-band frequencies.

Acknowledgements

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