Non-Contact Probes for Characterization of THz Devices and Components

Matthieu Martin, Prasanna Kumar Daram, Elliott R. Brown
Department of Physics, Wright State University, Dayton, OH, 45435, USA

Abstract—We investigate through numerical simulation the coupling properties of a novel, AC-coupled, contact-free probe. The new probe couples radiation from a CPW-embedded device-under-test via polarization current, which is then transformed to conduction current in the probe and down-converted in frequency to baseband by an optically-pumped photomixer. Numerous simulations have been realized in order to understand and improve the behavior of the probe. Here, we present the most interesting results: the use of a symmetric side coupled coplanar waveguide and a broadband design showing promising performance up to 1300 GHz with an operating range of 1 THz.

I. INTRODUCTION AND BACKGROUND

Measurement and characterization of new devices and components is always a necessary step in their development. A few methods have already been developed. The first easy technique consists of adding microwaves designs on a wafer along with the device-under-test (DUT) to allow on-chip testing [1]. Then, techniques have been developed in order to avoid the waste of wafer space, major drawback of this solution. Probes, relying on DC-coupled contacts, were developed and are commercially available up to 1.1 THz [2]. However, these probes have a limited lifetime due to the necessity of a contact. In addition, they can damage the DUT. Contactless techniques like micro-machined photomixer probes [3] or electro-optic time-domain sampling system [4] have been developed to overcome the disadvantages of contact testing. Nevertheless, the first technique cannot be applied to an integrated circuit and the second one cannot typically provide as high as a spectral resolution.

Here, we examine a novel contact-free optoelectronic probe that should operate up to 1 THz and beyond. Our probes are designed to transmit and receive THz waves along a coplanar waveguide (CPW) containing a DUT. A conceptual view of the approach is shown in Fig. 1. The coupling to the CPW occurs through a dielectric probe acting similar to a near-field antenna. A fraction of the THz radiation travelling along the CPW is collected by the probe via polarization current:

$$\frac{\partial \tilde{P}}{\partial t} = \epsilon_0 \chi_e \frac{\partial \tilde{E}}{\partial t}$$

where $\frac{\partial \tilde{P}}{\partial t}$ is the polarization current, $\chi_e$ is the electric susceptibility given by $\chi_e = \epsilon_r - 1$, $\epsilon_r$ is the dielectric constant, $\epsilon_0$ is the vacuum permittivity, and $\frac{\partial \tilde{E}}{\partial t}$ is the rate of change of the total electrical field. Once collected, the polarization current is converted to conduction current by a modal transformation from dielectric waveguide to CPW. The signal in the CPW is then down-converted to baseband by a monolithically integrated, fiber-coupled THz photomixer. The transmitting and receiving probes have the same physical structure and behave the same way. The transmit photomixer is dc biased, but the receive photomixer is not, so the pair together act in the same way as the coherent (homodyne) photomixing transceiver now used in frequency-domain THz spectrometers world-wide [5].

II. RESULTS

Numerical simulations of the probe performance have been carried out with High Frequency Structure Simulator (HFSS). In order to reduce the computational time, only one probe is simulated at a time since it is reciprocal. It is a three-port model; the probe itself containing lumped Port#3 located in the gap of the photomixer, and a CPW section “under-test” containing lumped Ports #1 and #2 as shown on Fig. 2.
Various parameters (dimensions, backshort design, CPW designs…) have been tested, compared and optimized in order to improve the coupling. Fig. 3 shows the simulated coupling for two different designs, both aimed at achieving the highest possible coupling over a moderate bandwidth. Fig. 4 shows the coupling of a probe having lower coupling but over a bandwidth of ~1 THz with a CPW design.

**Fig. 3.** Simulated coupling between the DUT-CPW and the Rx probe obtained with two different CPW designs. The coupling is maintained above -17 dB over a range of 350 GHz with the side coupled CPW design.

**Fig. 4.** Simulated coupling between the DUT-CPW and the Rx probe obtained with a regular CPW design. The coupling is maintained above -27 dB over a range of 1 THz.

**REFERENCES**


[3] M. Nagel, C. Matheisen, A. Deninger, and H. Kurz, “Continuous-wave terahertz near-field spectroscopy and imaging with a micro-
