Chip Reference Antennas: Improving Millimeter-Wave On-Chip Antenna Measurements

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***Abstract* – The adoption of millimeter wave phased arrays for a variety of applications, have led to an increased need for on-chip antenna measurements. The antenna elements are tested via micro-probe connections due to their tiny dimensions. For typical wireless applications (e.g. 5G/NR or IEEE 802.11.ad) these phased arrays, are expected to provide near omni-directional coverage. Even with carefully designed spherical antenna measurement system, the micro-probe and its positioner provide blockage and errors due to scattering. Judicious design of reference antennas can significantly improve the quality of the overall measurement. Consequently, the authors have led the development of a new set of reference antennas specifically designed to aid in calibration and verification of micro-probed antenna measurements [1]. The goal is not only to have a gold standard to monitor the consistent performance of an antenna test range, but to enable accurate on-chip antenna gain calibration using the substitution method [2]. The performance of the reference antennas are directly evaluated based on comparison between measurements and simulations and also via analysis of equivalent source currents using an inverse source technique shown to be effective in identifying and removing effects from feeding and support structures for general antenna measurements.[3,4,5] This paper will elaborate on the effectiveness of the inverse source technique in evaluating scattering for both the single patch and four (2x2) patch geometries shown in Fig 1. And Fig 2. , respectively.**

***Index Terms* — Measurement, Millimeter wave measurements, Chip Antennas, On-chip antenna testing.**

I. Introduction

Antenna Measurement systems for on-chip antennas test require a coplanar micro-probe to provide the connection to the Antenna Under Test (AUT). The micro-probe is attached to a probe positioner for landing on-the chip and provide electrical contact as is shown in Fig 1.

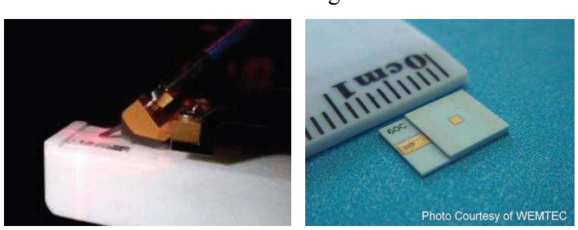


Fig 1. Chuck holder and landed air coplanar probe (ACP) (left), and, 60GHz (60-C) LTCC single patch antenna.

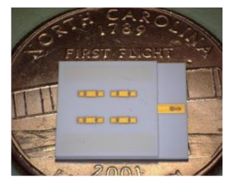


Fig 2. 60 GHz 2x2 array chip antenna (60-U-E) including parasitic elements and EBG structures on a US Quarter

When designing LTCC chip antennas, it is critical to reduce surface waves that can radiate from the chip substrate. The designed chip antennas incorporate Sievenpiper EBG structures for this purpose. This serves to minimize interaction with both the measurement setup and with the surrounding components in the final package. Despite design optimization, some residual currents and reflections still cause interference with the AUT in the test configuration [6]. In this paper, we examine how such effects can be evaluated by post-processing the measured data using the inverse source technique.

II. Equivalent currents diagnostics and filtering

The LTCC 60GHz chip antennas have been measured in the Orbit/FR μLab measurement system shown in Fig 4. using spherical Near Field techniques [2]. Equivalent sources on a conformal geometry has been determined by the INSIGHT software processing of the measured data. The conformal geometry represents the AUT, micro-probe and probe positioner as shown in Fig 3.

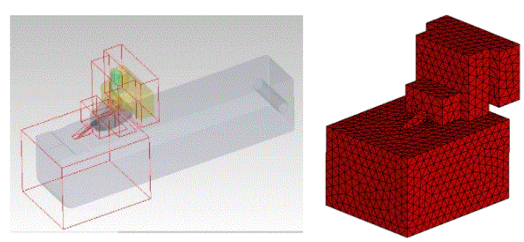
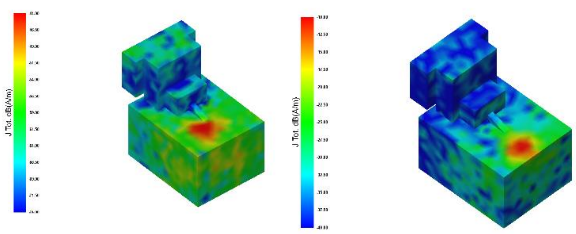


Fig 3. AUT and the measurement set-up, showing reconstruction geometry (left); meshed reconstruction geometry (right).

Fig 4. Orbit/FR μLab on-chip measurement setup

The measurement scenario consists of the probe, part of both the dielectric chuck and the probe support. The reconstruction surface represents these objects to detect all details needed for accurate diagnostics. Computations results are shown in Fig 5.



a) Single Patch Model 60-C b) 2x2 Array Model 60-U-E

Fig 5. Total equivalent electric current obtained with the two different chip reference antennas

As expected, the currents associated with the AUT as the intended radiator, is the "hot" portion of the equivalent sources. Examining the surface currents more closely, it can be observed that the single patch element couple with both the chuck and the micro-probe structure at a levelof approximately 15dB below peak levels. The more directive 2x2 array antenna, on the other hand, show a lower coupling to the microprobe at a level of approximately 25-30 dB below the peak. This interaction can be removed from the measured antenna pattern by spatial filtering of the currents in which the far field pattern is calculated only from the currents associated to the antennas as shown in Fig. 6.

The measured and simulated far field pattern of the LTCC chip antenna are reported in Fig. 6 and Fig 7 and confirms that the more directive 2x2 array exhibits much less ripple on the radiation pattern consistent with less scattering from the micro-probe assembly.

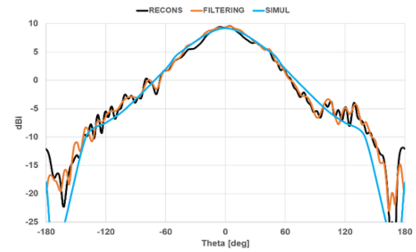


Fig 6. 60C (single patch) H-Plane Gain vs Angle

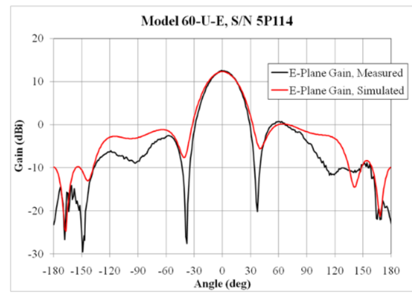


Fig 7. 60-U-E (2x2) E-Plane Gain vs. Angle (60GHz)

III. Conclusion

The interaction between the test setup and two different LTCC chip antennas have been evaluated using a spherical near-field antenna measurement system. The four element array predictably shows a clear reduction in scattering from the micro-probe both in the far-field pattern and via the maps of equivalent currents using the inverse source technique. Ongoing work will include more accurate physical model for the micro-probe and other measurement improvements to improve the resolution between desired and interfering fields.

Acknowledgment

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