A Terahertz Planar Near-Field Measurement System

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***Abstract*-A THz planar near-field system is presented for antenna measurement based on software and hardware designs, and system integration. Software involving the use of motor control, near-field data acquisition, near-field to far-field transformation, and probe compensation has been implemented. In hardware design, a 3D printed absorber is incorporated in the THz probe to reduce wave reflection in the measured data. A phase detection technique is proposed for probe alignment as a part of system integration. In principle, the system can work up to 1.1 THz but is currently limited to 0.75 THz due to the availability of the required open-ended waveguide probe.**

I. Introduction

Terahertz (THz) technology has experienced a rapid surge since the seminal paper published by Peter Siegel [1]. One of the key reasons is the availability of precision measurement and testing equipment. Nevertheless, turnkey solutions may be either expensive or commercially inaccessible. The THz measurement equipment comprises an Agilent N5245A NPA-x network analyzer working from 10 MHz to 50 GHz, and frequency extension modules from OML and VDI up to 1.1 THz. Output power of these extension modules is typically around -35 dBm. For communications applications, high-gain antennas are required and far-field measurement may not be attainable due to the limitation of the dynamic range of the measurement system and length of the connecting cables. To alleviate these difficulties, we resort to building a near-field scanning system on which an open-ended waveguide (OEWG) probe captures the amplitude and phase data of the near-field radiation from the antenna under test (AUT). A near-field to far-field transformation is performed to compute the far-field radiation pattern of the AUT. Probe compensation is required as the radiation pattern of the measurement probe is not isotropic. In principle, the designed near-field scanning system can operate up to 1.1 THz but is currently limited to 0.75 THz as the OEWG probe is not available to operate beyond 0.75 THz.

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II. THz Near- Field Scanning System

Fig. 1 shows the practical THz near-field scanning system. The system is mounted on a vibration-free optical table. GUI of the system can display the amplitude and phase of near-field component on two measured orthogonal planes, the co- and cross polarization far-field radiation patterns with and without probe compensation, and the directivity of the AUT. A pair of OML frequency extension modules from 0.22 to 0.325 THz is employed here. These modules can be replaced with 0.325-0.5 THz and 0.5-0.75 THz modules from OML and VDI respectively for higher frequency bands measurement.

The extension module for the AUT on the right in Fig. 1 is mounded on an RM-8 motorized rotary stage, which can rotate the AUT by 90^{o} for cross-polarization measurement. Alternately, a 90^{0}-waveguide twist can be used. The extension module on the left connected to the measuring probe is mounted on a supporting bracket with a 3-axis motoring stage for 2D planar scanning and separation adjustment between the AUT and measuring probe. The motor has a full-step resolution of 2.5 μm and a 1/8-step resolution of 0.31 μm. Therefore, the system can be extended to 1.1 THz if a measuring probe working at 1.1 THz is available. Absorbers are placed on the front panels of the extension modules and on top of the optical table to reduced wave reflections.

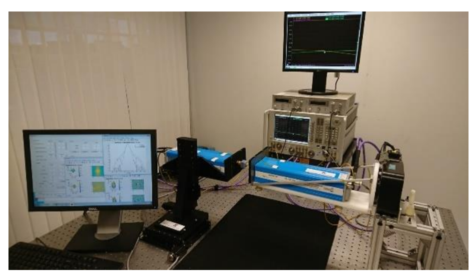


Fig. 1 THz near-field scanning system.

III. Probe Alignment

In typical commercial measurement systems, the center points of the AUT and the measuring probe are aligned using laser positioning. For a THz system, the laser spot size is relatively large for accurate alignment. A phase detection scheme is proposed in which the local critical point of the phase of S_{21} along the horizontal scan is detected and followed by the similar procedure in the vertical scan. The initial guess of the center position of the 2D scan is first estimated. By repeating the procedure of scanning horizontal and vertical axes continuously in the proximity region, the software can adjust the intersection point of the two scanning axes, and zoom in to the center point eventually. Reducing the scanning range, increasing the step size, and relaxing the acceptable error range can speed up the center alignment time. At 0.3 THz, the minimum phase error is only 0.108° due to the small step size of the motor. The measured phase of S_{21} along the vertical direction and a local phase minimum can be easily tracked as shown in Fig. 2.

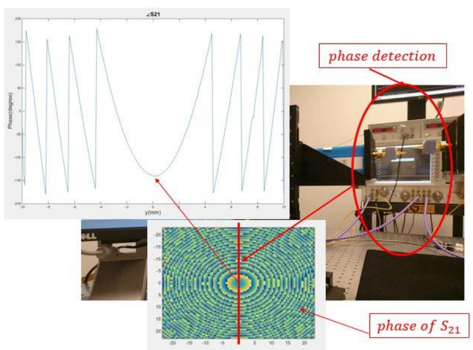


Fig. 2 Captured phase plot along the vertical axis.

IV. Probe Modification

Practically, the waveguide wall cannot be made very thin due to the fabrication process, hence, the OEWG probe is made in pyramidal shape. The wall thickness is around 0.3 mm or 0.3 $\lambda_{0.3THz}$. When the 0.3 THz probe is used as a radiating antenna, there are induced surface currents on the outer wall of the probe which will create ripples in its radiation pattern. Figs. 3(a) and (b) show the designed THz absorber using simple 3D printing to absorb the electromagnetic wave propagation down the length of the probe, and the simulation model using ANSYS HFSS. To speed up the modeling time, a 2-fold symmetry has been employed. Figs. 4(a) and (b) show the simulated radiation patterns in both E- and H-plane with and without the absorber. By using this simple 3D printing design, the ripples in the broadside direction have been successfully eliminated.

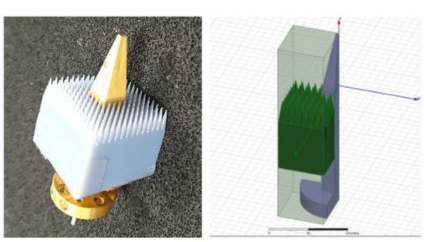

(a) (b)

Fig. 3 THz probe with 3D printed absorber. (a) Actual probe with absorber and (b) simulated model.

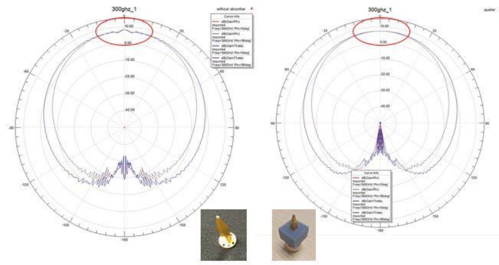
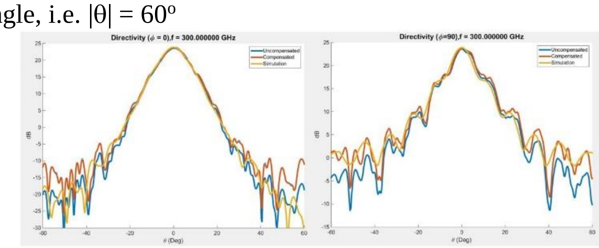

(a) (b)

Fig. 4 Radiation patterns of the 0.3 THz OEWG probe. (a) without absorber and (b) with absorber.

Results

A horn antenna is measured for testing the proposed near-field measurement system. Fig. 5 shows the comparison of measured uncompensated, measured compensated, and simulated results of the horn antenna. In the horizontal cut, i.e., $\phi = 0$, the simulated and compensated patterns are closed to each other within the range $-30° < \theta < 30°$. Out of this range, the compensated results of the sidelobes are higher than the simulated ones. When θ exceeds this range, the power is dropped by ~34 dB, it is reasonable to get an inaccurate result beyond this range. In the vertical cut, i.e., $\phi = 90°$, the approximation of the compensated result is close to the simulation in the entire range of the maximum far-field angle, i.e. $|\theta| = 60°$



(a) (b)

Fig. 5 Comparison of measured (uncompensated and compensated) and simulated directivities of the horn antenna for (a) horizontal plane, and (b) vertical plane

Conclusion

We have built a near-field planar system for THz antenna measurement. The probe alignment is done automatically by the phase detection technique. 3D-printed pyramidal shape absorber together with a purpose-built THz probe reduces the measurement error. Further improvement of the system should be done with more absorbers to minimize reflections from the surrounding.

Impact of the MTT-S Scholarship

It has been an honor to receive the MTT-S Scholarship. This award helps cut down the part-time jobs to concentrate the working in the laboratory. As my immediate career plan, it is hoped that I can pursue a doctoral degree in this field.

References

[1] P. H. Siegel, "Terahertz technology," IEEE Trans. Microw. Theory Tech., vol. 50, no. 3, pp. 910-928, Mar. 2002.