High Resolution Terahertz Volume Inspection Using a Rectangular Dielectric Rod Antenna in Transceiver Configuration

B. Baccouche, N. Baktash, J. Clemens, A. Natale, J. Jonuscheit and F. Friederich
Fraunhofer Institute for Physical Measurement Techniques IPM, 67663 Kaiserslautern, Germany

***Abstract*—Ultra wide-band frequency-modulated continuous-wave imaging systems operating in the lower terahertz regime have proven to be highly desirable for non-destructive testing applications. However, either quasi-optical configurations or the characteristics of typically used antennas as well as temperature-dependent nonlinear frequency sweeps restrict the achievable spatial resolution and reliability of these systems. In this contribution we report on the implementation of a dielectric rectangular rod antenna and a software-assisted feedback control loop to overcome these limitations.**

I. INTRODUCTION

WHILE there have been impressive developments towards terahertz imaging systems with real-time capabilities in the last years [1, 2], the performance of single terahertz sensor systems, in regard of integration time and dynamic range, remains superior. Despite the need for fast active terahertz imaging systems, as for instance in the industrial process control, more flexible single sensor systems ultimately provide advantages in less time critical applications.

Due to their volume inspection capabilities, frequency-modulated continuous-wave (FMCW) terahertz systems operating in the lower terahertz regime are of high interest for non-destructive testing applications [3, 4]. Besides a large frequency modulation bandwidth, a stable and linear frequency sweep is required for an accurate depth resolution.

In our setup a wide-band voltage-controlled oscillator (VCO) in combination with a frequency multiplier-chain is used to generate a terahertz signal with high modulation bandwidth and short frequency sweeping time. The temperature-dependent non-linearity of the VCO is compensated by an implemented software-assisted feedback control loop. Since the lateral resolution of quasi-optical systems is varying with the distance to the focal plane, we are using a synthetic aperture approach to obtain a constant level of detail throughout the sample volume. Hereby the smallest detail which can be resolved is defined by half the antenna aperture. In order to achieve a high lateral resolution a rectangular dielectric rod antenna [5] has been implemented, which provides an aperture in the size of the typical waveguide dimensions of the respective frequency band. The radiation pattern of the tapered antenna is suitable to obtain depth images with a high dynamic range in the antenna's far-field.

II. RESULTS

The imaging system has been setup in reflection geometry, using a single W-band (75 GHz to 110 GHz) transceiver unit in combination with an x-y-translation stage to raster-scan the object. The sensor unit comprises a single rectangular dielectric rod antenna to send and receive the generated terahertz radiation. In order to compensate for VCO non-linearities an integrated delay line is used as part of a feedback control loop. In this way a linear frequency sweep of 35 GHz within 200 µs for FMCW operation can be achieved, which allows to separate signal reflections from the measurement object with a depth resolution better than 4.3 mm. Due to the small aperture of the dielectric rod antenna, the application of synthetic aperture focusing methods allows to reconstruct depth cross-sections of a volume with a lateral resolution of 1.5 mm with a system operating at 100 GHz center frequency, as shown in Fig. 1.

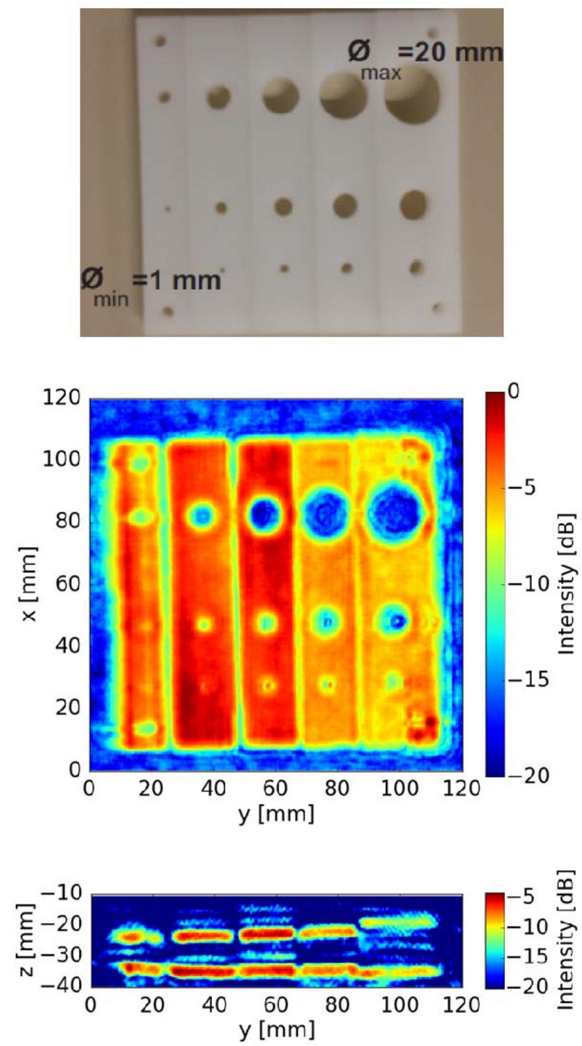

Fig. 1 *Top*: Photograph of a step wedge (10 cm x 10 cm) with holes of different size. *Middle*: FMCW-Terahertz image of the step wedge at 100 GHz center frequency using a dielectric rod antenna. *Bottom*: Depth image of the step wedge.

III. SUMMARY

The implementation of a dielectric rod antenna in combination with a FMCW terahertz synthetic aperture focusing setup has led to a new flexible imaging solution, which provides constant high resolution image cross sections throughout the recorded sample volume. In addition, the integrated VCO feedback control loop ensures stable FMCW operation, even in harsh environments.

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