Application Note

Example for Moisture Detection using Terahertz Imaging

1. Introduction to Terahertz imaging

Terahertz or millimeter-wave imaging (THz imaging) is a novel measurement technique for non-destructive testing applications with the need for millimeter or even sub-millimeter resolution. Terahertz-waves are safe electro-magnetic waves in the frequency range from 100 GHz to 10 THz. Dielectric or non-conducting materials, like most plastics, cloth, ceramics, papers and similar materials are transparent for this radiation, while metallic and conducting surfaces act as mirrors. These properties allow the image reconstruction of density interfaces and distributions in non-conducting materials.

For the application discussed here, the high sensitivity towards conducting materials, i.e. water, has the potential for a precise evaluation of the gradient of water / moisture content.

However, in the past THz imaging technology was not mature enough to fulfill the numerous industrial and commercial requirements. The main limitations were an insufficient image quality or an unacceptably large image acquisition time. These limitations have been overcome with the SynView imaging technology and products, so that a table-top turn-key measurement system like the SynViewScan is now commercially available and ready for the use in industrial testing environments. For many different applications the feasibility has been proven.

Figure 1: **Photograph of the SynViewScan 3D imaging system (left), which includes the Terahertz range profilometer SynViewHead (middle). An example of a SynViewEdge end-of-line testing system is shown on the right. (Copyright by SynView GmbH)**

The SynViewScan system, as shown in Figure 1, performs a full 3D tomographic scan of a surface area of 650 mm by 650 mm in approximately 15 minutes. A dynamic range of 50-70 dB is typically achieved with the current imaging system. The SynViewScan 300 system with an operating frequency of 230-320 GHz achieves a **spatial resolution of 1 mm**, while the SynViewScan 100 with an operating frequency of 60-110 GHz achieves a spatial resolution of 3 mm.

A core advantage of the SynView all-electronic technology is the high measurement speed combined with an unprecedented dynamic range for Terahertz Imaging systems. The SynViewHead measures a full depth profile (range pixel) in less than 250 µs, leading to a potential sample rate of more than 4000 range pixels per second. Depending on the system configuration and the sample size, even video rate imaging of larger structures is possible.

For the industrial environment, especially for the use in a production line, a customized SynViewEdge system will be build. An example drawing is shown in Figure 1 (right). Such a SynViewEdge system typically consists of several SynViewHeads and includes customized image analysis software. The achievable image quality of a SynViewEdge system is identical to the one of the SynViewScan.

2. Short study on water content: Terahertz imaging of wet pasta

For the measurements we placed a pasta plate (Lasagne) on top of a metal reflector, such that an air gap of approximately 5 mm lies between the pasta and the metal. This geometry allows us to measure both, the reflectivity and the transmission of the pasta plate with a single measurement. In Figure 2 the sample and the setup can be seen as well as a photograph of the wet sample. The wet sample was created by putting water on the dry pasta plate, leading to a round wet spot in the middle of the plate.

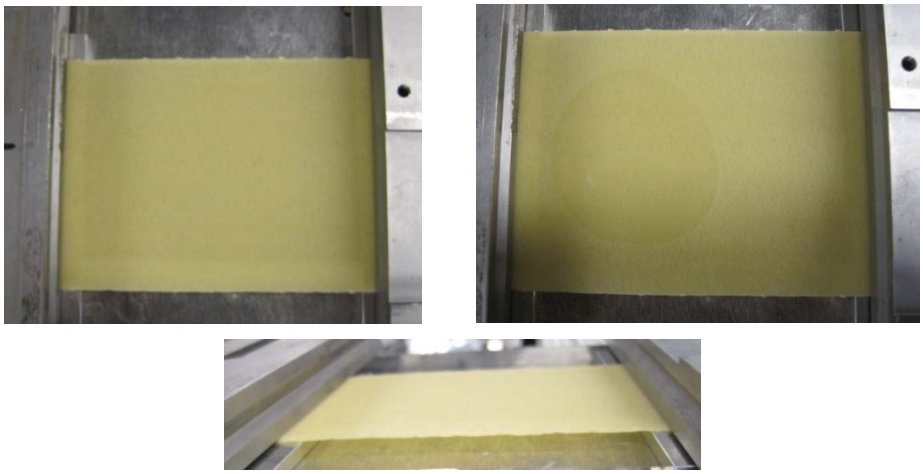

Figure 2: **Top left: photograph of the dry sample (top view); Top right: photograph of the wet sample (top view), the round darker spot of is the wet area. Bottom: Side view of sample, showing the gap between pasta and metal reflector.**

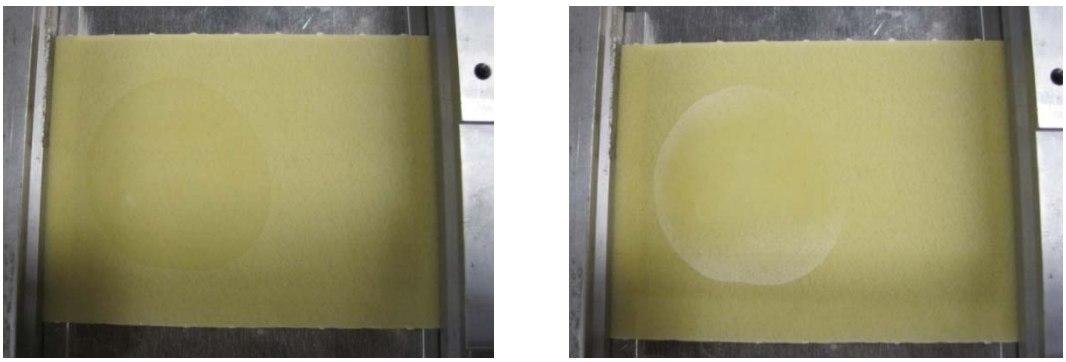

Figure 3: **Left: photograph of the wet sample (top view); Right: photograph of the wet sample after 20 minutes of drying (top view).**

Using the SynViewScan 300 system we automatically measure a full 3D image of the experimental area (volume). In this case this gives us the option to visualize the relevant 2D planes, i.e. the plane layer of the pasta as well as the plane layer of the metal reflector.

In order to obtain the transmission values of the pasta plate, we look at the reflectivity values of the metal layer. Its reflectivity values depend on the transmission values of the pasta plate.

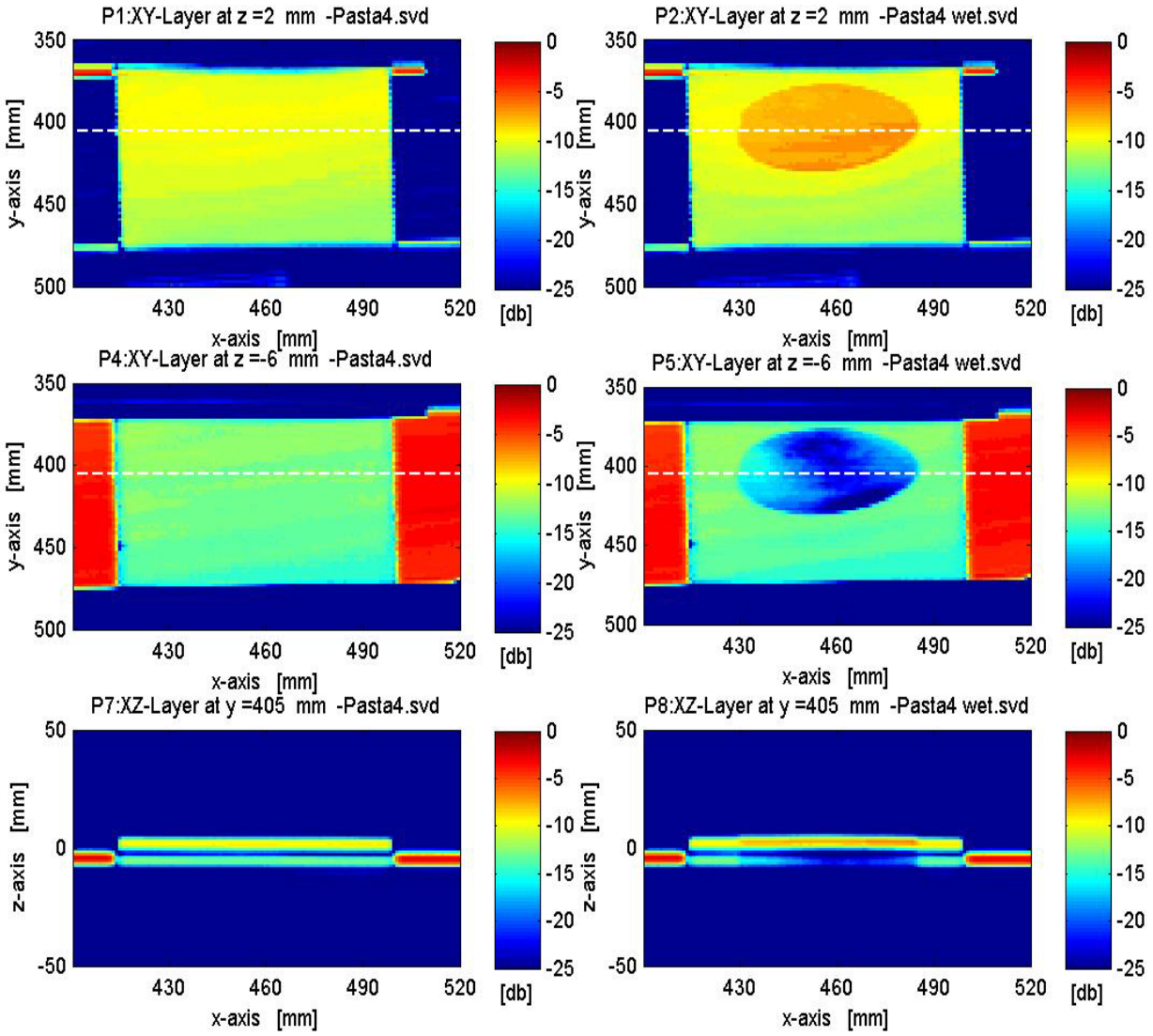

Figure 4: **Terahertz measurement results: Left: dry sample, Right: wet sample; Top row: Reflectivity of the pasta layer, Middle row: Transmission of the pasta layer; Bottom row: cross section image. The wet spot can clearly be identified. Also, the transition area from wet to dry can be recognized. (Copyright by SynView GmbH)**

In Figure 4, the measured data, i.e. the Terahertz image plotting reflectivity and transmission of the pasta plate, is shown. **The wet area of the pasta can easily be identified.** The measured data shows that the transmission of the pasta plate changes from -5 dB for a dry sample to about -10 dB for a wet sample. Our measurement system can easily resolve changes in the transmission of less than 1 dB, a further enhancement of the resolution might be possible if required.

To obtain the full 3D image of the pasta plate, the measurement time using the SynViewScan 300 was about 2 minutes. **A single one millimeter wide line with a length of 650 mm is measured in about 3 seconds.**

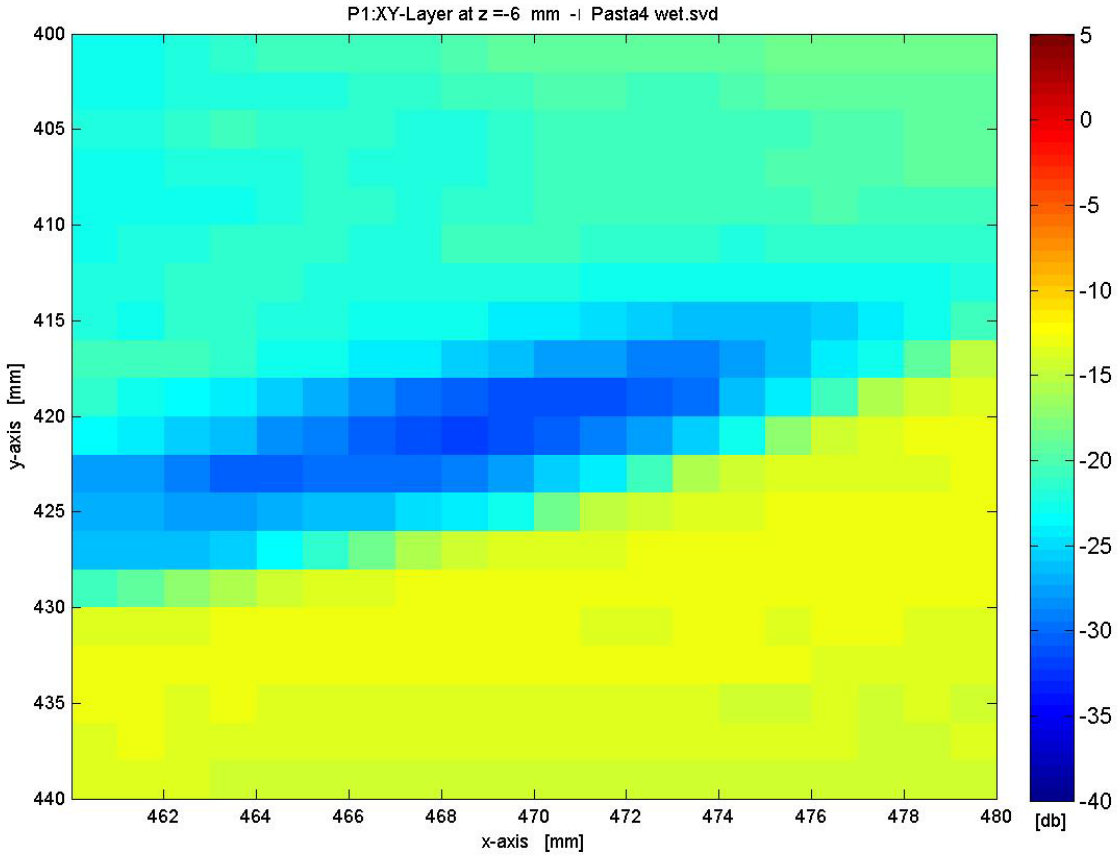

Figure 5: **Terahertz measurement result: zoom of a part of the transition area from wet to dry. The resolution of one millimeter allows a precise measurement of the gradient of the water content. The dB scale on the right shows the absorption in transmission mode. (Copyright by SynView GmbH)**

The transition area from wet to dry, i.e. the gradient of the water content can be well characterized, as is shown in Figure 5. In contrast to a microwave system, the Millimeter/Terahertz wave system used here has a resolution of 1 mm.

Furthermore, as shown in Figure 6, the drying process over time can be analyzed. Please note that after the sample seems to be dry based on visible inspection, the “dry” area has still larger water content than when taken out of the package. This is clearly visible in Figure 6 d), where the Terahertz image still reveals an area with more water in it.

In summary, the shown preliminary results clearly proof that Terahertz imaging is suitable for the detection of the gradient of water content in non-conducting structures. The results are valid for other materials like cork, wood, paper, etc.

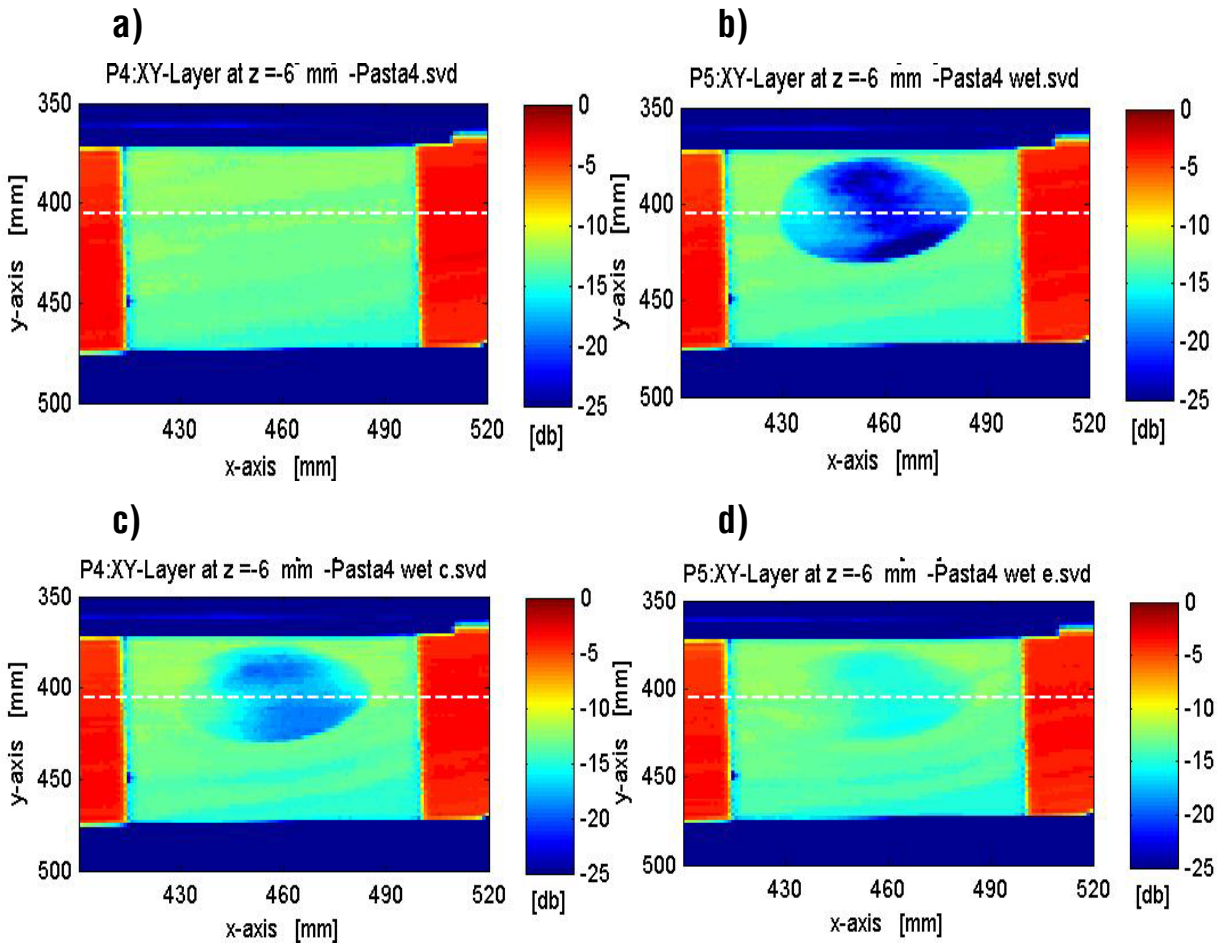

Figure 6: **Series of Terahertz measurements at different points in time: a) dry sample, b) wet sample, c) wet sample after 10 minutes of drying, d) wet sample after 20 minutes of drying.**

Please contact us now for more information or to discuss your application:

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