THE THz SOLUTION

The Prospects for Terahertz Imaging Technology in the Wood Products Industry

by Dennis Callaghan and Matt Reid

Many parts of the electromagnetic spectrum have been tapped to provide sensing and imaging capabilities for applications in the forest industry. Microwave kiln drying, infrared moisture sensors, visible light profilers, and X-ray density scanning machines are examples that span the electromagnetic spectrum.

Terahertz (THz) radiation, which falls between microwave and infrared frequencies, is noticeably absent from this list. This is not because THz radiation is not useful to the wood products industry, but rather because the technology to produce and detect THz radiation for industrial sensing has not been available.

Every new development in THz technology brings us closer to realizing it's potential for imaging and sensing in industry. It is not every day that a part of the electromagnetic spectrum becomes available for use in new applications.

What Is THz Radiation?

Long wavelength radio-waves to very short wavelength X-rays span the electromagnetic spectrum. The terahertz part of the spectrum lies between microwave and infrared, having shorter wavelengths than microwaves but longer wavelengths than infrared waves. To date, this part of the spectrum has remained relatively unexploited for industrial applications. However, new developments in technology are opening the door to new and exciting applications that are taking advantage of the unique characteristics of radiation in the THz part of the spectrum.

The characteristics that are driving significant interest in this emerging technology include transparency, resolution and safety. THz waves can penetrate most non-metallic dry materials in a similar fashion to X-rays. Having much longer wavelengths than X-rays, the radiation is non-ionizing and therefore much safer than X-ray technologies. This has generated significant interest in security applications where clothing can be penetrated on a human body without health risk.

There is also increasing interest in pharmaceutical and biomedical applications because packaging materials can be transparent at THz frequencies, and the radiation can detect unique spectral signatures of pharmaceutical and biological compounds.

Why is there interest in this technology for the wood products industry? Consider the characteristics that one would like to have for imaging wood products. It is desirable to be able to look "through" the wood for imperfections and defects, so *transparency* is an important characteristic. It is also important to be able to see the features that are of interest. That is, the *resolution* of the imaging technique is important to resolve the features of interest. It is convenient to have no regulatory restrictions in implementing the technology, and therefore *safety* also is a plus factor.

In addition to the properties listed above, the strength properties of wood products are strongly tied to the internal fibre structure of the materials. The ability to *probe gross fibre structure* makes THz very attractive to wood product manufacturers. These four characteristics—transparency, resolution, safety and probing ability—are summarized with the different portions of the electromagnetic spectrum that can access them in the table below. As noted, Terahertz waves are the only part of the spectrum that can access all four characteristics, and that is why we expect this technology to play a significant role in the wood products industry moving forward.

	Transparency	Resolution	Safety	Probes Fibre
X-Ray	Yes	Yes	No	No
Visible	No	Yes	Yes	Yes
Infrared	No	Yes	Yes	Yes
Terahertz	Yes	Yes	Yes	Yes
Microwave	Yes	No	Yes	Yes

Moving the Technology into the Wood Products Industry

Researchers at the University of Northern British Columbia working with local industry have been looking at applications of terahertz technology to the forest products industry. This research has attracted a lot of attention, and has recently received funding from both Western Economic Diversification and the Northern Development Initiative Trust. The current terahertz project is a partnership between:

- Deltech Manufacturing Inc.
- The University of Northern British Columbia
- The College of New Caledonia
- A&D Integrations
- Western Economic Diversification Canada
- The Northern Development Initiatives Trust
- Natural Sciences and Engineering Council of Canada

The first phase of the initiative was to identify potential value of the technology in the wood products industry. Several viable applications were found in engineered wood products, dimensional lumber and in the pulp and paper industries. The second phase of the project was a technical feasibility study, which determined that the unique characteristics of terahertz technology would be best suited to a first application study in the oriented strand board industry.

Terahertz Technology in the OSB Manufacturing Process

The production of OSB involves converting a log into dried wafers, or “flakes”. Flakes are aligned on a forming line to generate a mat, which is pressed at high temperature with adhesives and pressure to form the boards themselves. Each OSB panel consists of four separate layers; a top and bottom in which the flakes are aligned and face forwards, and two core layers where the flake are aligned and face sideways. The structural strength properties are derived from the overall density of the board (the amount of flake used) and the orientation of the flakes in the two directions.

Because raw materials, including the wood used, form a large percentage of total production costs in the OSB process, it is desirable to minimize the amount of raw materials used. The reduction of materials is limited by the need for the finished OSB panels to meet performance standards, which provide a baseline of performance in regulated markets. These standards are met in part by statistical sampling of the product (after production), usually in off-line quality control tests involving the manual testing of board strength.

It is both the overall density and fibre orientation of the strands imparted by the formers that lead to the strength of the finished product. It is therefore desirable to OSB manufacturers to have the capability of to measure and control these two parameters on the mat before the press. Technologies have been developed to measure density, including X-Ray and mechanical measurement techniques, but these measurement tools do not have the capability to measure the fibre orientation (or direction of the strands).

Attempts have been made to measure fibre orientation using visible profiling and other techniques that are restricted to examining the surface of the mat. Since the mat has a large thickness, this lack of transparency has to a large degree limited these types of fibre orientation measurement techniques.

The transparency of the mat at THz frequencies allows an average measurement of density as the radiation is transmitted through an OSB board. The characteristics of the THz radiation transmitted through the board can be used to produce an image of the density profile of the boards. For example, the difference between a struc-1 grade and regular grade board is clearly visible in the picture below, which shows up as an increased amount of red (higher transmission of the THz radiation through the lower density regular grade board).

The ability to measure density alone is only part of the key to minimizing materials costs in the OSB process. Sensing of the fibre orientation is also required. This is what we believe is the most powerful measurement capability that THz technology has to offer. It is possible to examine the average fibre orientation through the board *at the same time* as measuring the density of the boards. An image similar to that used for density can be produced, but showing the deviation from the theoretical target values for the orientation of the wood flake.

Next Steps

A proof-of-concept device is being developed through the collaboration of the partners mentioned above. An alpha prototype is expected to be operational in the summer of 2009 to demonstrate that density and fibre orientation can be measured on the mat before the press. The current stage in research is to characterize the measurements on an OSB mat, as opposed to the boards themselves, in a manner that is easily integrated by the controls system at an OSB plant.

The key to the success of this project will be that the target variables can actually be measured in real-time so that cost-savings for the OSB plant can be realized. There is also strong potential in other engineered wood product manufacturing processes that display similar issues to those outlined in the OSB process currently under investigation, such as in log profiling and moisture content measurement.

THz imaging is an emerging technology, and it is expected that more work will need to be done to mature the technology to a point where a robust, commercial system can be produced for sale. However, once a viable and working prototype is in use significant changes to wood products scanning and imaging may be on the way.

Conclusion

New and powerful Terahertz technology is expected to play an important role in sensing and imaging within the forest products industry as a result of its inherent safety, the transparency of wood at these frequencies, the resolution that is possible with the technology, and its sensitivity to internal fibre structure.

While there are many applications in the industry that could ultimately benefit from these capabilities, the OSB industry applications are the first target of research efforts presently under way. Proof-of-concept equipment is under development to tackle the problem of measuring fibre orientation and density on the OSB mat before the press, which is expected to produce significant cost savings to the average OSB plant.

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