Inexpensive Terahertz Technologies for Moisture Sensing

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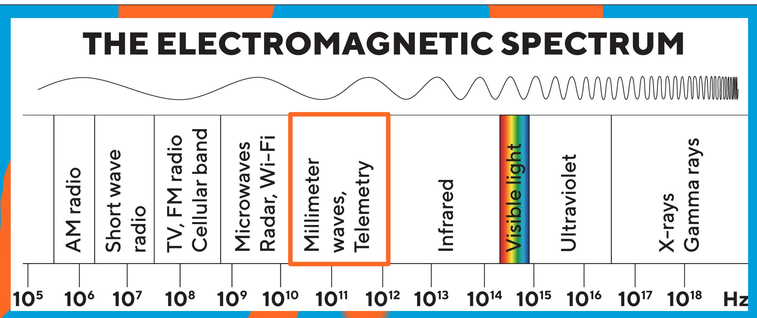
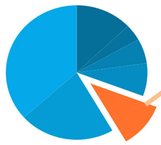


Energy Inefficacy in Paper Industry

One of the US Department of Energy (DOE) priorities is to reduce energy use. The paper industry, especially the drying stage of the manufacturing process, is highly inefficient and energy intensive. Monitoring the moisture content during the drying process can lead to intelligent dryers that minimize energy consumption while maintaining product quality.

During our research, we investigated contactless and relatively inexpensive methods of moisture sensing using a terahertz frequency radar sensor.



In 2018, the paper industry accounted for **11%** of total US manufacturing energy consumption[1]

Moisture Detection with Terahertz Set Ups

Below are three experiments to determine an inexpensive (<$500) radar unit's effectiveness at moisture detection. High-frequency radar systems (77 GHz) are sensitive to a content's moisture level since water strongly absorbs radiation at this frequency.

To calculate the optimal distance at which to place the lens to capture the complete signal:

Lens radius r: 50 mm

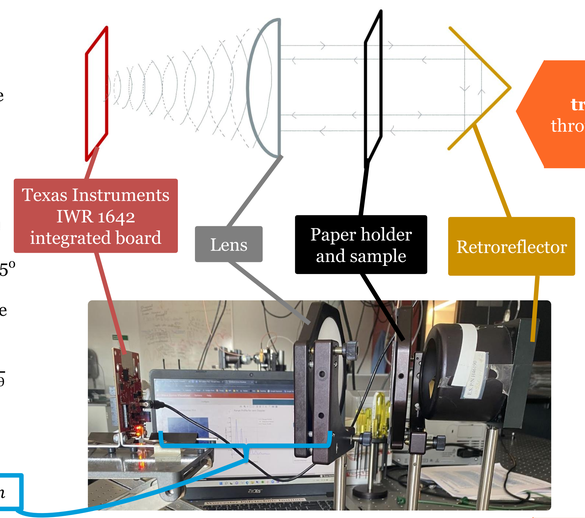
Beam azimuth resolution angle (from IWR1642 specifications sheet) θ : 15°

Distance at which to place lens: d

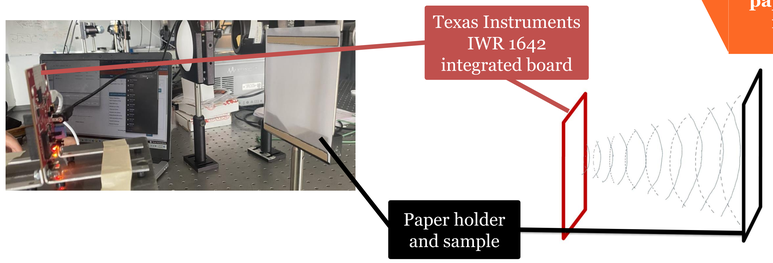
$$\tan\theta = \frac{r}{d} \implies d = \frac{r}{\tan\theta}$$

$$d = \frac{50}{\tan 15}$$

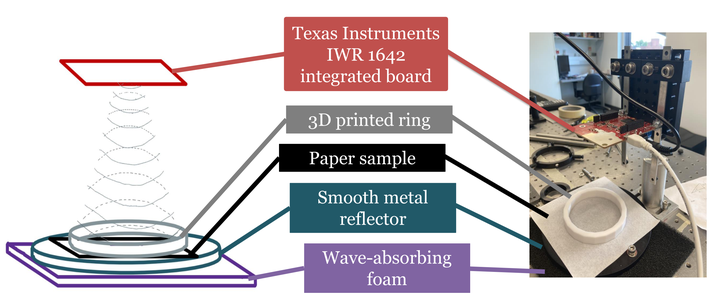
$$d = 186\ mm = 18.6\ cm$$



Two-way transmission through paper aided by a lens

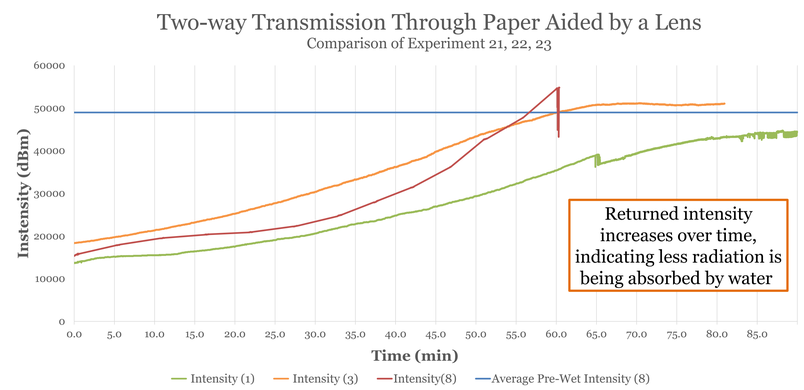


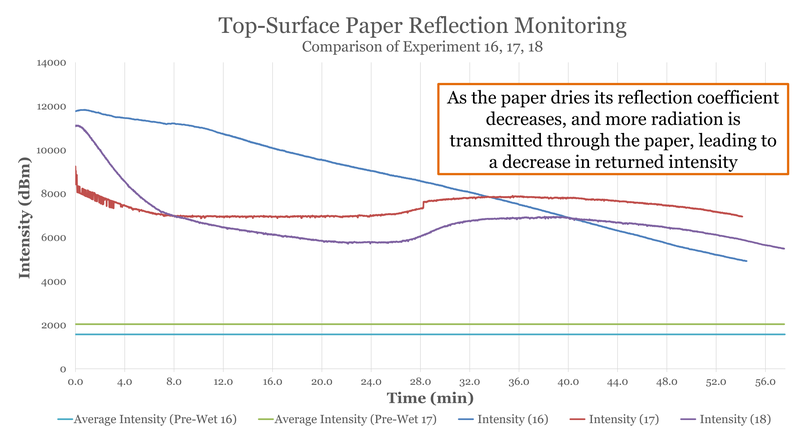
Top-surface paper reflection monitoring

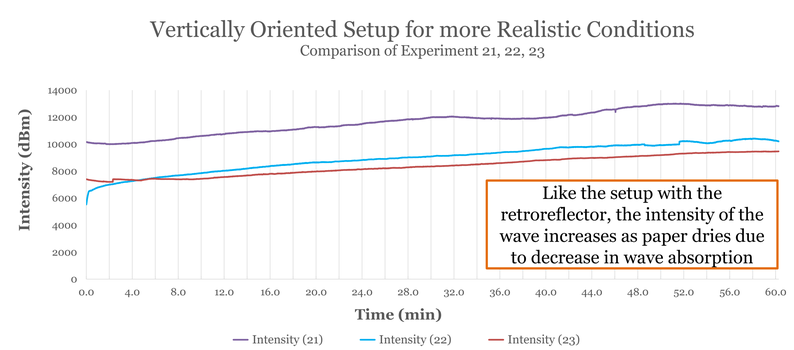


Vertically oriented setup for more realistic conditions

Results of Detecting Changes with Terahertz







Conclusion

The **IWR1642 radar sensor can detect small changes** in the intensity of return signals as the **moisture content of a piece of paper changes**. This is true for two-way transmission through paper, as well as top surface reflections from the paper itself. With further refinement, including dedicated software and supplementary optical setups, the sensor shows promise of accurately measuring paper moisture content for use in further research or industry.

Future Research and Applications

- Implementing terahertz sensors in a model intelligent drying system
- Soil moisture mapping for agricultural purposes
- Conduct experiments measuring moisture content vs. Intensity of waves

Lesson Plan

Middle School

6th grade STEM class activities

Project based learning creating noise canceling headphones for citizens with hearing sensitivity and creating device with color sensors to improve efficiency in agriculture.

Projects combines 21st century skills and collaboration skills.

High School

High School Physics activities

Physics in everyday technology is misunderstood and taken for granted. Students will make a creative visual about a technology that uses the properties of waves to present to their personal community.

Acknowledgments & References

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1. "Use of Energy Explained." *Energy Use in Industry*, U.S. Energy Information Administration (EIA), 13 June 2021, https://www.eia.gov/energyexplained/use-of-energy/industry.php.
2. "Communications Materials." *United Nations Sustainable Development*, United Nations, https://www.un.org/sustainabledevelopment/news/communications-material/
3. *Flinn Electromagnetic Spectrum Chart*. Flinn Scientific, https://www.flinnsci.com/flinn-electromagnetic-spectrum-chart/ap7148/.

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