Poster: Thaw: A UWB-based Ice-Water State Detector

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ABSTRACT

This work explores the use of wireless signals to distinguish between solid and liquid states of water inside enclosed spaces such as freezers and microwave ovens. This proof-of-concept system, utilizes ultra-wideband (UWB) technology, demonstrating how changes in wireless reflection patterns can indicate transition between ice and water states.

CCS CONCEPTS

• **Hardware** → **Sensor devices and platforms**; **Sensor applications and deployments**.

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1 INTRODUCTION

Wireless signals can be used to differentiate between materials based on their different complex permittivities. This idea has been explored in several previous works [2–4]. However, the prior art has missed out on a particularly interesting aspect of material identification—solid-liquid state transition. It can indicate when a frozen food item has thawed and is ready to be cooked, or in reverse can indicate when ice-cream is fully formed in the freezer. It can provide finer control over cooling and heating cycles at home, in grocery stores, as well as during transportation. While existing techniques such as an RFID tag on packaging [3] or passing UWB signals through a thin column of liquid [2] work in theory, a more practical and potentially simpler solution is needed for the thawing detection problem, since food could be unpackaged, or piled up.

One might wonder *isn't measuring temperature a sufficient indicator of thawing or freezing?* Unfortunately, due to latent heat of fusion, the temperature remains constant throughout the process of melting or freezing. In a microwave oven, the temperature of the surrounding air can be significantly higher than the frozen food kept in the oven. Therefore, monitoring the extent of thawing is non-trivial. Using the drastic difference in the complex permittivity of the two states of water is a novel approach to this problem. In this work, our approach is only exploratory and, in fact, we hope to bring together this research community for solving an important problem—detection of liquid-solid state transition.

We propose a wireless reflections based system, called Thaw, that can be installed inside a storage system and starting from a known reflection pattern, alert the user when the reflection pattern changes. We benefit from two physical attributes: (1) storage systems are essentially closed metal boxes, meaning, wireless signals remain isolated from the outside world, and (2) ice and water have drastically different complex permittivities [1], meaning, the thawed and frozen foods have markedly different reflection patterns.

2 THAW SYSTEM DESIGN

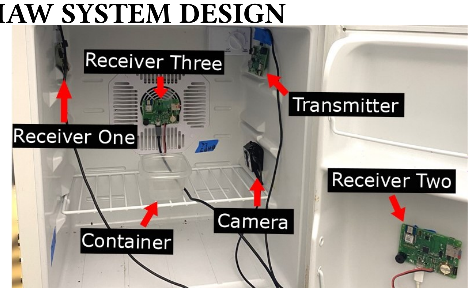

Figure 1: Thaw platform with three UWB receivers, one transmitter, and a camera with light inside a small freezer.

The core idea in Thaw is to observe the change in the wireless reflection pattern as seen inside an enclosure due to ice-water state transition. Since ultra-wideband (UWB) radios provide a detailed channel impulse response (CIR), and ice and water have vastly different complex permittivities at the UWB center frequencies of 4GHz, UWB proves to be an effective platform. Our test setup with three UWB receivers and one transmitter is shown in Figure 1. It can easily detect ice-water state transitions indicated by a *change* in the CIR as shown in Figure 2, while the CIR remains stable when no state change occurs. Using multiple UWB receivers allows capturing reflections despite *ad hoc* placement of food inside the enclosure causing signal blockages. Work partially supported by the NSF under grant 2145278.

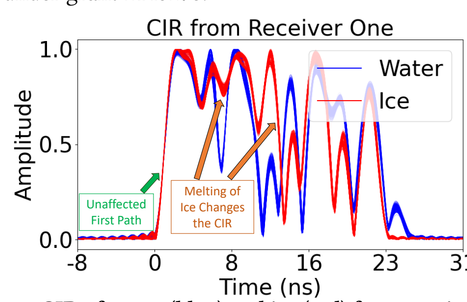

Figure 2: CIR of water (blue) and ice (red) from receiver one.

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