RFEnvelope: Long distance mailbox notification through radio signals

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Abstract*— Mailboxes are required to be checked regularly, regardless of accessibility, to ensure no important mails have been missed. In this work, I introduce RFEnvelope, a system running on two ESP32s communicating through 433MHz radio signals where one serves as a detection module to recognize mailboxes opening (potentially through light sensor integration) and where the other serves as a hub to connect the home network for push notification and smart home integration. Through this work, it becomes possible to alert users of mail potentially having entered into their mailbox to ensure duties are fulfilled in timely manners.

I. Introduction

In daily life, we receive notifications from all sorts of services including messages, software updates and email notifications. These notifications are often entirely in digital space, sent from one device or server to another, ensuring the recipient has received information in a timely manner when required. However, in our physical world we are often not aware of changes or occurrences that happened until we actively check for these changes. One such occurrence is receiving mail in the mailbox, where not knowing that you have received mail can lead to problematic scenarios if found too late (e.g., works in the street, fines to be paid, documents to sign). It is often left to the individuals themselves to remember to check the mailbox regularly to avoid missing these important documents. However, depending on your living environment, mailboxes can also be limited in accessibility (e.g., far away from your home entrance) or inflexible to customization (e.g., apartment complexes with communal mailbox spaces).

In recent years, there have been trends related to making homes more "smart" where we introduce physical changes in home environments based on digital detections (e.g., close window blinds automatically when sun is out) or detect physical changes to bring digital notifications (e.g., intruder detection in security cameras). These smart home tools are often integrated with systems such as *Home Assistant*[1] to link events together and define behavior that should occur as a result of them. Events linked to sensors such as touch, temperature, humidity, sunrise/sunset time, and camera detections are commonplace in these smart home systems. and camera detections are commonplace in these smart home systems.

To bridge the gap in mailbox responsibility and smart home integrations, I introduce a system called "RFEnvelope" (RF standing for "radio frequency"), aimed towards notifying users of their mailbox having been opened to alert them to check the contents whenever possible. The system makes use of radio modules to send low frequency signals (433 MHz) to traverse further distances and better handle occlusions such as concrete, while retaining power for longer durations even with limited power availability. This system can also be integrated further with systems such as *Home Assistant* to give reminders, log events or record camera footage on event detection (e.g., to record cases of privacy intrusion).

II. Related Work

My concept builds further upon past works, specifically related to radio signal integration and mailbox opening notification. A prior system created by Subramaniam et al. (2007) called "MASYS" handled the detection of mailbox mail entering through integration of an infrared (IR) sensor for detection, a Zelio Logic Smart Relay PLC for logic handling, and a GSM modem to connect to a cellular network and send SMS messages/emails whenever post has arrived [1]. While their system will work for most cases to create a mailbox notification system, it uses more costly hardware rather than cheap components, requires SIM card integration (resulting in telecom costs), and will be hard to power and maintain continuously (most likely powered through 24V DC power supply due to PLC demands). In comparison, my system provides low power integration, together with cheap components and does not require any cellular reach, but instead an active home network connection.

Another work, introduced by Vanjavakam and Kottedu (2021) discussed the integration of a smart mailbox notification system utilizing a microcontroller (Arduino MKR1000) connected to home Wi-Fi for notification and an Inertial Measurement Unit (IMU) to detect the mailbox

[1]Home Assistant: https://home-assistant.io/ (Last Accessed 12/05/2026)

opening [2]. Similarly, Kapoor et al. (2018) also created the concept for two Arduino based systems to detect mailbox opening using light sensors and communicate the signal across 433MHz to inform the user of mail being present in their mailbox [3]. While Kapoor et al. has discussed potential for giving mobile notifications, no system was presented yet that actively implemented this behavior. Within my system, I propose a similar solution to that of Kapoor et al. to send signals across the 433MHz network, where the indoor microcontroller connects to the Wi-Fi network of the owner and sends an event through smart home integration or as a notification to the owner through push notifications (e.g., through Ntfy)[2].

III. Prototype

In this section, I start with introducing the concept of what the *RFEnvelope* will entail towards the end. Afterwards, I present the current state of the implementation since the implementation of the *RFEnvelope* system is currently still ongoing, . I also discuss a feasibility test at the current state to ensure the concept can work for the intended scenarios.

A. Concept

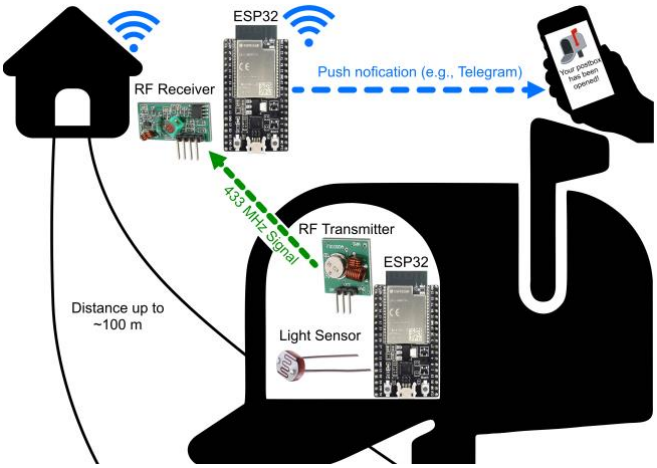

Figure 1: General concept of RfEnvelope with two modules, one in the mailbox, the other in the house.

The concept consists of two primary systems, a mailbox system and a system inside the owners house (see Figure 1):

Mailbox system: An ESP32-WROOM-32 connected to a 433MHz RF Transmitter FS1000A and a GL5516 Light Dependent Resistor (LDR) or a standard photodiode. For power a simple battery pack with voltage regulator setup suffices. The ESP32 is intended to go into deep sleep until the LDR receives a bright enough light signal where a voltage comparator (such as LM311) is used to awake the ESP32 to send the signal through the RF transmitter.

House system: An ESP32-WROOM-32 connected to a 433MHz RF Receiver XY-MK-5V. For power the ESP32 can be connected directly through micro-USB and either permanently connected to the home Wi-Fi network or only upon receiving an RF signal. The ESP32 performs a web API request upon receival of an agreed upon RF signal to notify users of mail.

B. Current state of the implementation

At the time of writing this short paper, a working prototype of the RF sending and receiving modules has been implemented. Every RF module has its own ESP32 to power and control it with the default wiring of the RF module. The simplified setup is showcased on Figure 2. The receiver module is powered through the 5V pin of the ESP32 to support the full 433MHz RF range, the transmitter module is also powered through the 5V pin, but this voltage could still be increased up to 10V for more transmission power. Both modules have an antenna of around 17.3 centimeters. Since most mailboxes in Belgium are metallic, one of the primary concerns was that the mailbox will act as a Faraday cage[3] to block the radio signals. This behavior had to be tested before moving on with the prototype. The hypothesis is that the radio signals are reflected inside the metallic box, but can potentially release some waves through the crevices or small openings in the mailbox. In particular, when the mailbox lid is opened, part of the reflecting radio signals can be released and might give out some of the signals. To test this hypothesis, I set up some tests of distance coverage and material interference to perform the validation.

C. Validation of the mailbox RF modules

For the test setup, I placed the transmitter module into the metallic mailbox of the Digital Future Lab of Hasselt University in Belgium (right of Figure 2), where a signal is transmitted every second. During the test, I would stand still while holding the receiver module for 10 seconds, at distances of intervals 20 meters (starting from 10 meters from the mailbox) and measure the amount of signals that was received on the receiver module (verified with the timestamp). The final location is inside the building on the ground floor of the lab (left of Figure 2), around 50 meters away from the mailbox with still a line of sight to the mailbox but with double glass windows in between.

The results are presented in the following table:

TABLE 1. SIGNALS RECEIVED ACROSS 10 SECONDS FOR DISTANCES AWAY FROM THE MAILBOX

Distance in meters (m)	Signals received across 10 seconds (out of 10)		
	Mailbox open	***Mailbox lid open***	***Mailbox closed***
~10 m	10	8	4
~30 m	6	3	0
~50 m	3	1	0

While these test results are only preliminary and likely inconsistent, they do indicate potential for longer range

[2]Ntfy Push Notifications: https://ntfy.sh/ (Last Accessed 12/05/2026)

[3]Faraday cage: https://en.wikipedia.org/wiki/Faraday_cage#cite_note-Encarta-1 (Last Accessed 12/05/2026)

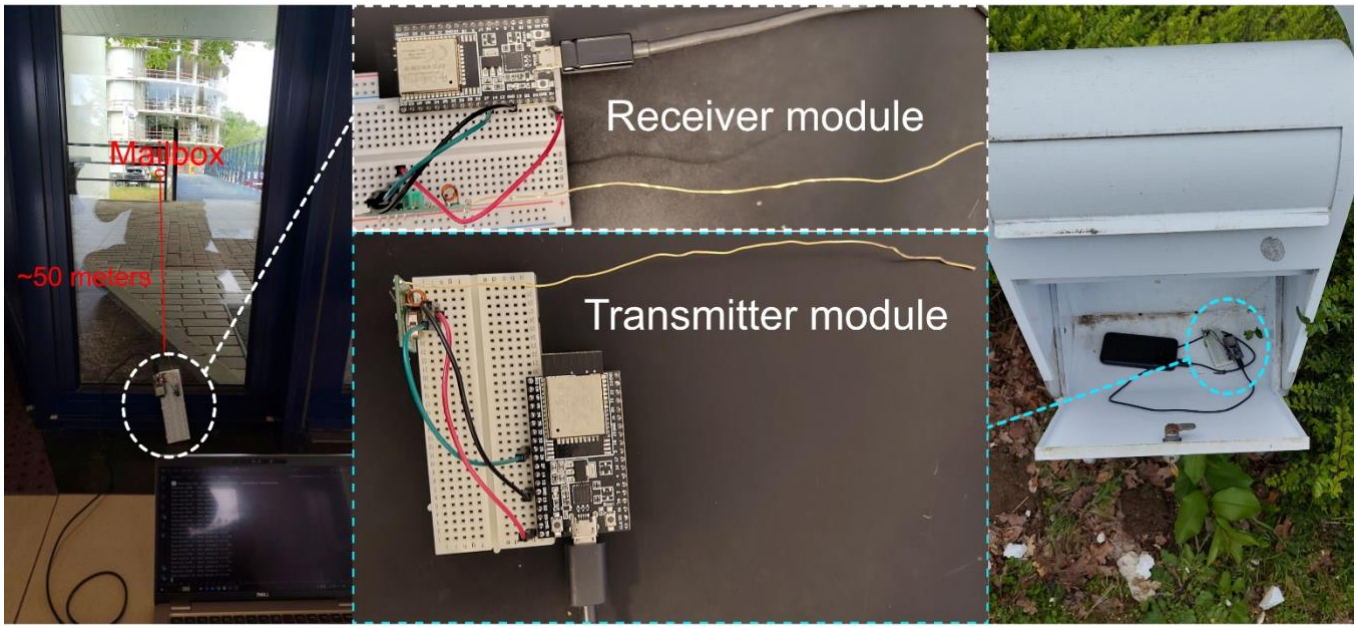

Figure 2: The middle depicts the test setup with the RF transmitter and receiver connected to an ESP32 each, left is the receiver around 60 meters away from the mailbox, on the right is the mailbox with the transmitter inside.

communication during the time that the lid of the mailbox is open (even if very limited). When the mailbox is closed, some residual signals travel out a short range which will be most likely insufficient for reliable communication. However, when testing the solution indoor, the signal does seem to easily travel throughout the concrete walls of the lab. For a working, consistent mailbox system, it might be more feasible to make the transmission antenna external to the mailbox. Additional tests at higher transmission voltage or by utilizing other radio technologies such as LoRa[4] which are aimed at increasing the range through modulation.

What further remains is to integrate the battery pack and light sensor to power the transmitter module without power bank and detect the opening of the mailbox lid with the light sensor. In case the light sensor does not achieve the desired result, it might be required to use other technologies such as IR, similar to works such as Subramaniam et al. [1].

IV. Responsible Innovation

For this project, I wanted to create a modular, easy to build system that any hobbyist can pick up to build for themselves to monitor their mailing traffic. The system is intentionally based on widely available and inexpensive components such as ESP32 microcontrollers and simple 433 MHz RF modules to lower the barrier for hobbyists, researchers, and individuals to replicate, repair, or further adapt the system for their own needs. The prototype also avoids dependence on subscription-based services such as GSM connectivity or any cloud infrastructures.

From an environmental sustainability perspective, the prototype has been designed around low-power operation principles. The mailbox-side ESP32 is intended to remain in deep-sleep mode for the majority of its lifetime and only awaken briefly when mailbox activity is detected through the light sensor trigger. By minimizing active power consumption, the system can operate for extended periods using small battery packs, reducing the frequency of battery replacements and associated electronic waste. Additionally, the use of low-frequency 433 MHz communication allows long-distance signal transmission without requiring energy-intensive Wi-Fi connectivity at the mailbox location itself (while incorporating more practical scenarios). In the future it would be possible to further improve sustainability by integrating rechargeable battery systems combined with small solar charging modules or maybe by exploring ultra-low-power microcontrollers specifically optimized for long-term sensor deployments.

V. Author Bio(s) / Experiences

I am a postdoctoral researcher from Digital Future Lab, Hasselt University specifically focused in the field of Spatial Computing and Extended Reality (XR). In the context of my PhD, I have studied how XR can contribute to humans being able to perform motions that are difficult to perform correctly. Aside from my work as a researcher, I like to spend my free time making hobby projects related to functional 3D prints, electronic prototypes, and digital simulations. In both my research and hobby projects, I specifically like to focus on fulfilling certain needs to assist people in their daily life. This project is also a spin-off from a past project where I utilized the ESP32s with radio modules to assist an elderly neighbor that wanted to inform other neighbors that she is having difficulty opening the heavy front door of the apartment building we lived in. Here the button was 3D printed, which when pushed, sent a signal to the receiver which then sent a message to a *Telegram* group chat of neighbors in the apartment. The components for this new use case were recycled from this project since the door has been replaced

[4] LoRa: https://en.wikipedia.org/wiki/LoRa (Last Accessed 12/05/2026)

by something lighter (two months after finishing the button). Most of my knowledge related to soldering and hardware has been completely self-taught, aside from basic knowledge on electronics which was taught in high school. I would to love to be able to learn more about the possibilities of prototyping, wiring techniques, soldering, and electronics, as I often run into problems with my lacking knowledge on them. Hence I would love to be able to participate in the workshops to learn more about what is possible.

VI. References

[1] Subramaniam, S. K., Husin, S. H., Yusop, Y. & Hamidon, A. H. (2007). Real time mailbox alert system via SMS or email. 2007 Asia-Pacific Conference on Applied Electromagnetics. https://doi.org/10.1109/APACE.2007.4603963

[2] Vanjavakam, S., & Kottedu, C. S. A. (2021). Notification alert system in postbox (Bachelor's thesis, Blekinge Institute of Technology)

[3] Kapoor, A., Rajawat, R.S., Sutradhar, K., & Sharma, P. (2018). Arduino Based Mail Notifier System. International Journal of Advance Research and Innovative Ideas in Education, 4, 2492-2499.