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Demo: Taking Advantage of the Shock Hazard: How to Use an Electric Fence for Data Transfers

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***Abstract*—The deployment of embedded sensing devices on croplands and pastures is an enabling element for precision agriculture applications. Changing conditions (e.g., different crops being grown), however, may require the occasional reconfiguration of the resulting networks of wireless sensors, e.g., to modify data reporting rates or synchronize internal clocks. In this demo we showcase an opportunistic broadcast channel to forward such configuration messages to embedded systems. The transmitting station is realized by means of an electric fence energizer, a device frequently utilized in agricultural settings. On the receiver side, only little hardware efforts are required to capture the high-voltage pulses and decode transmitted configuration messages.**

I. Introduction

The steady technological evolution has led to the availability of embedded wireless sensing systems for *smart farming* applications. By providing real-time updates on crop health and environmental conditions, such systems effectively support agriculturists in decision-making and have consequently established themselves as indispensable tools on many farms.

From a technological perspective, the employed sensor devices mostly rely on a low-power hardware design to ensure their long-lasting operation even when their energy budget is restricted (e.g., when they are battery-operated). Reducing a platform's demand for power is only possible to a certain extent, however. In particular, the on-board wireless transceiver often dominates the platform power consumption. To minimize its negative impact on the platform longevity, energy-efficient medium access control protocols have been proposed [1]. While their application often leads to a reduction of the energetic overhead for the collection of data from many sensor devices, they seldom provide a way to efficiently transfer control commands from a control center to sensor devices.

The use of secondary "wake-up" receivers, which activate the primary wireless transceiver only when it is needed [2], is one approach to maximize energy efficiency. However, it introduces an energy burden for the operation of the additional components, and still requires the primary radio device to be used for data communications. The alternative, and the option chosen in this work, is the use of a secondary radio channel to transmit control messages. In particular, we exploit the almost ubiquitous presence of electric fences in farming scenarios to this end. In the demonstration, we showcase how their periodic emission of high voltage pulses can be effectively used to transfer data, with no impact on their regular operation.

II. Data Transmission Via High Voltage Pulses

Electric fences are widely used in agriculture and farming. Placed around croplands, they prevent wild animals from trespassing onto arable land. Likewise, electric fences can be used to keep cattle within their pasturelands. Their operation is simple: Electric fence energizers periodically emit high voltage pulses onto fences made of electrically conductive material. Once an animal touches the fence, the resulting current flow is sufficiently painful to make the animal retreat.

The fact that fences usually fully encircle agricultural land combined with their high electrical conductivity makes them highly suitable candidates as transmission antennas for broadcasting configuration messages. Kulau et al. have demonstrated in [3] that the pulses emitted by electric fences can be detected by wireless sensor nodes. Building on this idea, we have conducted an in-depth study to find reliable ways to modulate data, devise antenna design considerations, and explore throughput limits in [4], which we showcase in this demo to confirm its practical viability.

During our applicability assessment of modulation schemes, we found the design choices to be limited. Regulations exist for electric fence energizers, such as IEC 60335-2-76 [5], which defines the maximum length of a pulse (10 ms), as well as the minimal time between two consecutive pulses (1 s). Pulses need to be applied to the electric fence frequent enough to avoid animals trespassing it. We have consequently chosen to apply a pulse position modulation (PPM) to encode data within the intervals between emitted pulses. We have made the pulse gap durations variable through a minor modification of the electric fence energizer's timing circuit. The fence energizer used in our experiments (model Kemo FG025, specification available at https://www.kemo-electronic.de/datasheets/fg025.pdf) internally relies on a NE555 timer, which determines its timings through two external resistors and one

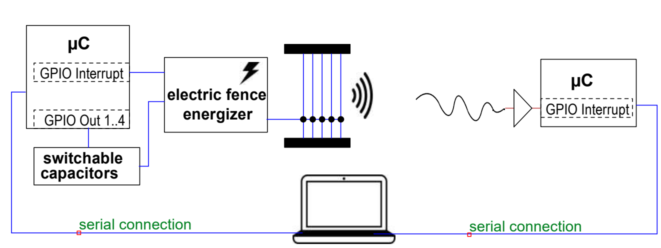
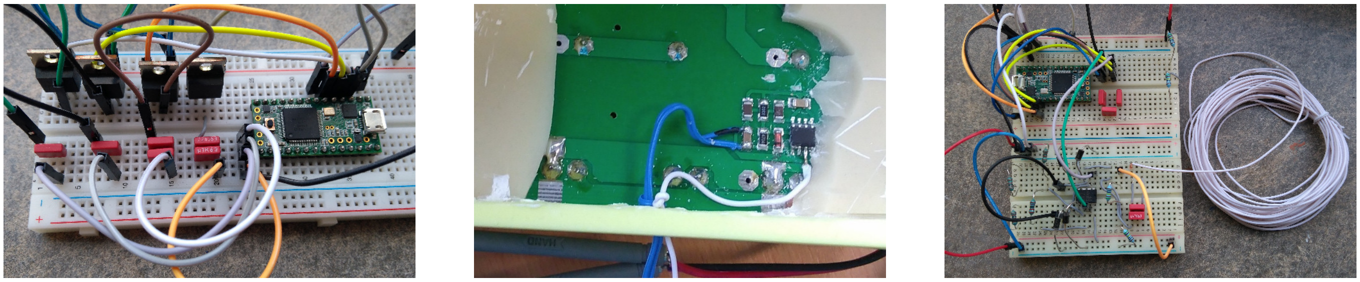


Figure 1. Schematic drawing of the demonstration setup.



(a) Sender-side implementation, with four switchable capacitances to alter the rate of emitted pulses.

(b) Fence energizer connections to external capacitors (blue) and a pin that signals whenever a high voltage pulse has just been emitted (white).

(c) Receiver setup with simple wire antenna (right) and operational amplifier (bottom) to buffer the received signal.

Figure 2. Photographs of the demonstration system setup; both microcontrollers will be connected to a computer.

capacitor. Without modification, the fence energizer sends a pulse every $1.256\,\mathrm{s}$. By integrating four switchable additional capacitors into its circuit, 16 timing configurations for inter-pulse gaps can be selected between $1.256\,\mathrm{s}$ and 1.726s. Thus, 4 bits can be transferred in each pulse gap at an average transmission rate of $2.7\,\frac{\mathrm{bit}}{\mathrm{s}}$. No further modifications to the electric fence energizer are necessary; only a microcontroller is needed to convert incoming data into 4 bit words and configure the capacitors accordingly.

III. Demonstration Setup

The demonstration setup is primarily composed of two microcontroller devices, both of which will be interfaced to a computer for visualization purposes. Moreover, an electric fence energizer and corresponding antenna circuitry for the receiver device will be set up in order to demonstrate practical data transmissions over this wireless channel. These components and their interconnections are visualized in Fig. 1.

A. Sender

The sender is designed using a Kemo FG025 electric fence energizer and a Teensy 3.2 microcontroller board[1]. The microcontroller offers serial connectivity to a personal computer via a built-in USB port, such that messages to be transmitted over the wireless channel can be input easily. The main task of the microcontroller is to selectively switch the additional capacitors on/off in order to modulate binary data into the durations of the inter-pulse intervals.

B. Receiver

The receiving device is also based on a microcontroller, in conjunction with an antenna design well suited to detect the electrical field emitted by the fence: A length of wire. The received signal is fed into an operational amplifier with high input impedance to avoid its distortion before being forwarded to one of the microcontroller's interrupt pins. Through the Teensy's internal timers, an accurate timestamping of the pulse intervals, and thus the detection of the transmitted signal, becomes possible. Received signals are checked for plausibility; all signals beyond the practically determined boundaries (cf. Sec. II) are ignored. Once a valid signal is detected, the receiver decodes it back into the corresponding binary representations and outputs this data via USB to be displayed for visualization.

IV. Conclusions

This demonstration shows a novel way for data transmissions in smart farming scenarios. It relies on electric fence energizers, systems that are ubiquitously present in agricultural settings. Only minimal modifications to their hardware are required to encode data in the intervals between emitted pulses, while accomplishing a transfer rate of 20 bytes per minute. Equally minor hardware modifications are needed to convert embedded sensing systems into receiving terminals. Through the simple addition of an antenna and an operational amplifier, reliable communications can be accomplished at an additional power consumption well below $300\,\mu\mathrm{A}$. Thus, its viability in smart farming scenarios based on energy-constrained sensing devices is implicitly given.

Acknowledgments

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