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Low Bitrate Ambient FM Backscattering for Low Cost and Low Power Sensing

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Abstract

Backscatter radio communication (RFIDs) offers low cost and low power wireless sensors. Ambient backscatter is the new next novel approach for extremely low power communication. Using existing ambient signals for communication, the communication scheme is simplified only to a sensor-node and a receiver circuit. In this work is presented a wireless tag using FM signals for backscatter communication. The receiver consists of a commercial low-cost RTL SDR connected to a computer and a algorithm from signal processing. The tag has been demonstrated in an indoor laboratory setup using the most powerfull FM station.

1 Introduction

In the last decade, Internet-of-Things (IoT) technology has become a promising way for connecting our everyday devices. The most important challenge for IoT applications is the minimization of the cost and energy dissipation of the sensor-nodes. Backscatter radio communication is a technology that used in radio frequency identification (RFID) applications and offers this preferred standpoint [1]. Ambient backscattering is a novel approach of RFID [2], taking advantage of ambient signals to simplify the wireless topology to just a sensor-node/tag and a receiver, eliminating the need for a dedicated carrier emitter. In this work of a novel wireless tag is demonstrated using broadcast FM signals for backscatter communication. In [3] a prototype platform of a low cost ambient backscatter communication system was presented (Fig. 1). In this paper we present recent developments which lead to a better communication range and power efficiency of the system. The proposed proof of concept tag prototype, comprises of the new ultra-low power micro-controller (MCU) and an RF front-end for wireless communication. The MCU is the 8-bit PIC16LF1459 (25 μA/MHz @1.8 V) from Microchip and accumulates the data from two sensors through a 10-bit analog-to-digital converter (ADC). The tag transmits the information back to the receiver wirelessly. The transmit part of the tag exploits backscatter radio standards with Amplitude-shift keying (ASK) modulation and FM0 encoding on ambient FM music station signals. The receiver consists of a commercial low-cost TV-USB receiver (RTL SDR) with a monopole antenna connected to a computer

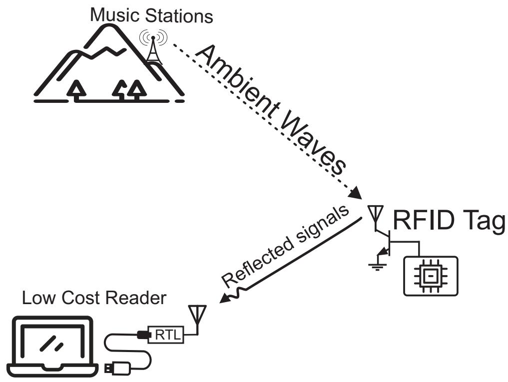

Figure 1. Ambient FM backscatter setup. Backscatter communication is utilized using ambient Frequency Modulated (FM) signals.

and an algorithm for signal processing. The tag was demonstrated live in an indoor laboratory deployment using the reflected signals of the most powerful FM station. Operation over a 5-meter tag-reader and a 34 Km tag-FM transmitter distance have been accomplished by backscattering information at 147 bps and power consumption only 3.6 μA.

2 Tag Design

The tag was programmed to read data for two ADC channels and send a packet (“bit-stream”) to the reader with the measured information. An analog sensor could be connected with each ADC channel; thus, this work does not focus on sensing aspect of the system. Each packet consists of four different “bit” sections: the preamble (10 bits), the tag-ID (2 bits), the sensor-ID (1 bit) and the sensor-data (10 bits). The last three sections are encoded into a 19-bit word using an (13,19) Hamming code, which provides single error correction and double error detection (SECDED), providing a more reliable transmission through the noisy FM ambient signals. After the Hamming encoding the hole packet is encoded again with FM0 encoding (Biphase space encoding). In FM0 encoding the bit “0” has a transition in the middle of a symbol, whereas a bit “1” does not and thus at the receiver, the detection of an FM0 bit depends on the number of its edges (transitions) reducing the likelihood of the bit error. Afterwards, the FM0 encoded signal was modulated with ASK binary modulation on noisy FM

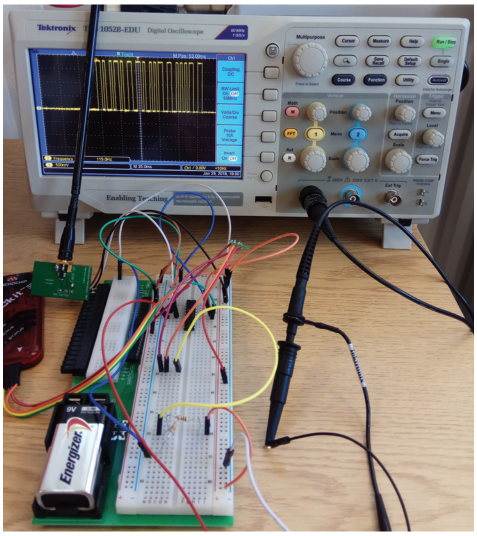

Figure 2. Tag and RF front-end part in breadboard deployment. In the oscilloscope is depicted the produced waveform of the tag. This pulses are used to control the RF switch.

signals using only one RF switch located on the RF front-end part. The minimum T_{symbol} achieved with this MCU was 3.4 ms for a bit rate of 147 bps. The internal 31 kHz low-power internal oscillator of MCU was utilized as clock source for ultra-low-power consumption. The bit rate could be increased by increasing the clock frequency resulting to a higher current consumption. A new improved RF front-end have been designed in a separate board. It consists of the RF switch ADG919 and a telescopic monopole antenna for reception/reflection in FM band (87.5-108 MHz). In this work the tag was supplied by a battery at 1.8 V through the external voltage regulator XC6504. The dissipated current of the tag (MCU & RF switch) was measured at 3.6 μA when the ADC was off and 220 μA when the ADC was activated. The tag developed in a breadboard and the RF front-end board are depicted in Fig. 2. The FM0 pulses of the packet that are used for the switch control, are also shown in oscilloscope. The backscattered information sent from the tag, can be detected as an OOK modulated signal in the receiver.

3 Reader

The low cost RTL SDR "Nooelec NESDR SMArt" (Fig. 3) was used for the receiver of our system,. It is an improved version of classic RTL SDR dongle based on the same RTL2832U Demodulator/USB interface IC and R820T2 tuner. It comes with ultra-low phase noise 0.5 (Phase noise @100 kHz: -152 dBc/Hz) PPM temperature compensated crystal oscillator (TCXO) with cooling via thermal pads and with an SMA connector. The tuning frequency range is from 24 MHz to 1850 MHz with sampling rate up to 2.8 MS/s and noise figure about 3.5 dB. Gain control is also provided, through the embedded low noise amplifier (LNA) at the input of R820T2 and at the output via a variable gain

Figure 3. USB Software Defined Radio Receiver and telescopic monopole antenna for FM signals reception.

amplifier (VGA). The SDR down-converts the received RF signal to baseband and sends real/inphase (I) and imaginary/quadrature (Q) signal samples to the PC through the USB interface. Is costs only 18$ and was connected with a telescopic antenna in order to receive the scattered FM Signals. The only limitation of the dongle is the 7 bit resolution of ADC but for our low-bit rate application, it does not affect the communication efficiency. In order to detect the reflected signals, a "real-time" algorithm were implemented in MATLAB. The receiver algorithm was described in [3] and have been improved for better communication range results. The algorithm reads the data through a FIFO file from GNU radio framework and presents the sensor data on the computer screen. New range measurements and implementation of an energy harvester (solar/electromagnetic & boost converter) represents the object of future work.

4 Conclusion

In this work, an ambient FM backscatter tag is presented. It exploits data acquisition from sensors with low power operation and communication ranges up to 5 meters. It seems that the use of ambient FM signals as the only source of both the carrier and "maybe" the tag power is an extremely high energy-efficient communication technique compared to the general RFID technique.

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