2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

Energy Harvesting for Hands-Free Operation of Soldier Equipment

H. Visser [(1)*], P. Colditz [(2)], T. Bertuch [(2)], J. Conradi [(2)], B. Nord [(2)], and G. Pognon [(3)]
(1) Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands, e-mail: h.j.visser@tue.nl
(2) Fraunhofer, Fraunhoferstrasse 20, 53343 Wachtberg, Germany, e-mail: paul.colditz@fhr.fraunhofer.de, thomas.bertuch@fhr.fraunhofer.de, jessica.conradi@fkie.fraunhofer.de, bjoern.thorsten.nord@fkie.fraunhofer.de
(3) Thales TRT, 1 av. Augustin Fresnel, Campus Polyt., 91767 Palaiseau, France, e-mail: gregory.pognon@thalesgroup.com

Abstract

In this paper we present a Remote Control Unit (RCU) that can be attached to any location on a rifle, binoculars, etc., and be operated by a single finger of a soldier without removing his hand from the device. Even for a gloved hand a haptic feedback from the RCU will be realized. A RCU prototype, equipped with a single button, is used as a remote Push-to-Talk (PTT) device for the radio being carried by the soldier. The RCU is powered by the radio waves emitted by this radio. The RCU - being attached to the device - works with a receive unit (RXU) that is attached to and operates the radio. The RCU consists of a RF harvester, energy storage device, a button and a transmitter. Laboratory prototypes are demonstrated.

1. Introduction

Future combat soldiers will be supplied with new devices and equipment making use of modern high-technology. Miniaturized components for the dismounted soldier must be lightweight and crafted to withstand the severities of a harsh combat environment [1]. One important piece of equipment that could support dismounted soldiers is a wireless control which allows for the remote operation of equipment while at the same time allowing to hold another instrument without disruption. An application example of such a system is the remote "push-to-talk" (PTT) button which a soldier can attach to devices such as his weapon, a pair of binoculars, etc. and use it to operate a communication radio while keeping his target in view. Such a device may find a wider application also for civilian use. Figure 1 shows the schematic representation of the RCU system.

The Remote Control Unit – that is attached to the hand-hold equipment – is driven by a RF energy harvesting system, harvesting from the radio waves emitted by the soldier's radio. An energy storage device, in the form of a (super) capacitor is used to store the harvested energy. The stored energy is then used to power the keyboard/button and RF transmitter. The radio is equipped with a Receive Unit (RXU) that receives PTT signals and requests for radio transmission to recharge the energy storage device if necessary.

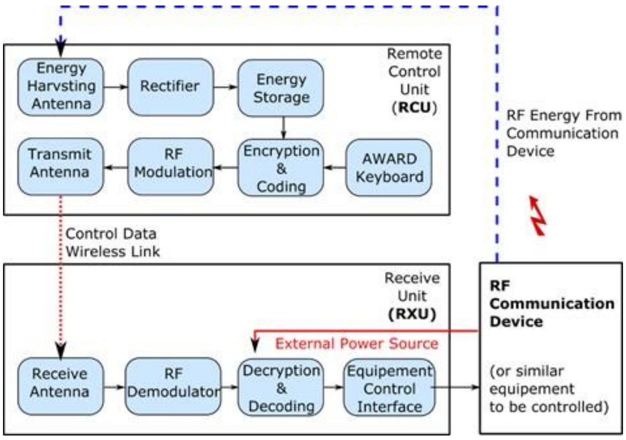

Figure 1. Schematic of the remote control system.

2. RCU

The core of the RF harvester is the rectifying circuit. This circuit consists of a cascade of four Schottky diodes in a Dickson charge pump configuration, optimized for 0 dBm RF input power in the frequency range 1.75 – 1.85 GHz. The diode selection (Skyworks SMS 7630) is based on the highest available saturation current [2]. Through Harmonic Balance simulations (using Keysight ADS), including the Printed Circuit Board (PCB) and a 10 kΩ load, the optimum number of diodes has been found. A prototype has been realized and characterized. Figure 2, left shows the simulated and measured input reflection coefficient as a function of frequency. Figure 2, right shows the measured DC output voltage as a function of frequency for different RF input power levels. The RF-to-DC Power Conversion Efficiency (PCE) is well above 40% for all power levels in the chosen frequency band.

The receiving antenna consists of a rectangular strip loop on a grounded dielectric slab, see Figure 3, left. This allows the antenna to be placed on any (metallic) carrier without the functioning being deteriorated. Inside the loop electronics can be housed. The antenna is excited through a small loop. The circumference of the large loop determines the resonance frequency, the dimensions of the small loop are used for impedance tuning.

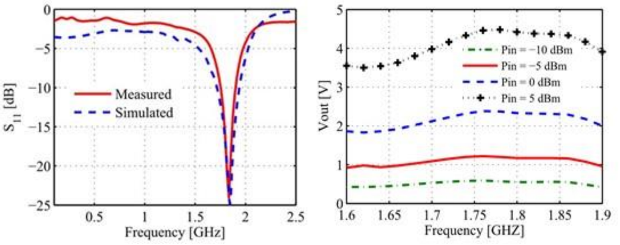

Figure 2 Left: Simulated and measured input reflection coefficient vs. frequency for the four-diodes rectifyer. **Right:** Simulated DC output voltage (over a 10 kΩ load resistor, emulating the power management circuit) as a function of frequency for diffferent RF input power levels.

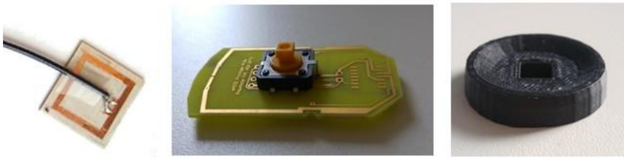

Figure 3 Left: Antenna prototype, resonant at 1.84 GHz. **Right:** RCU transmitter prototype with mounted push button (B3F-4155). **Right:** push button housing.

The DC output voltage is stabilized and boost converted to 2.75 V with a circuit using a Texas Instruments BQ25570 Ultra Low Power Harvester Power management IC. This voltage is used to charge a 2.4 F super capacitor and this capacitor is used to feed the RCU transmitter.

The RCU transmitter uses a Silicon Labs Si4010 transmitter with an integrated 8051 microcontroller, transmitting at 434 MHz. This device uses a 700 nA sleep mode current. The transmitter antenna is printed on the PCB, see Figure 3, middle. The button-down and -up actions are transmitted directly. The capacitor charge status is transmitted periodically. Therefore the transmitter is kept in sleep mode (and not in < 10 nA stand-by mode). A push button has been integrated on the PCB. We compared different strengths of button feedback for use with and without combat and/or winter gloves, using different test persons. As a result of the study we choose for a button with 2.55N force feedback for the RCU, placed in an indentation as shown in Figure 3, right.

3. Demonstration

For demonstration, a laboratory set-up as shown in Figure 4 is used. The radio is emulated using a Keysight E8267D vector signal generator, an amplifier and a horn antenna. The RXU uses a Silicon Labs Si4355 low-current, sub-GHz receiver, powered (by wire) by the radio. Using an UART-to-USB bridge, the received frames are evaluated on a PC and appropriate actions are taken based on the results, see Figure 5. After a successful demonstration, the RF harvester, power management, energy storage, push button and 434 MHz transmitter have been further miniaturized and integrated into a single device.

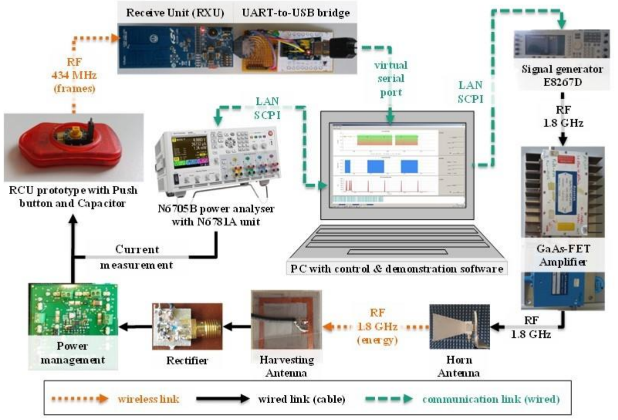

Figure 4 test and demonstration setup showing the different pieces of hardware used.

Figure 5 Data View of the control and demonstration software. **Top:** received RCU frames and capacitor charge state vs. time. **Middle:** Signal generator output vs. time. **Bottom:** Power analyzer measurement readings vs. time.

4. Conclusion

We have shown that it is feasible, with off the shelf components, to create a remote control unit, powered by a body worn radio. The power requirements are thus that civilian use, based on a cell phone, is feasible as well.

5. Acknowledgements

This work was supported by the e-Hose project A-1341-RT-GP that is coordinated by the European Defense Agency (EDA) and funded by contributing members (Austria, Germany, France, Italy, Luxemburg, The Netherlands, Poland and Sweden) in the framework of the Joint Investment Programme on Innovative Concepts and Emerging Technologies (JIP-ICET2).

6. References

1. S. Weinberger, “Soldier of the Future”, *New York Post*, NY, USA, May 2009.

2. S. Keyrouz, *Practical rectennas, RF Power Harvesting and Transport*, PhD Thesis Eindhoven University of technology, 2014.