Design of Wirelessly-powered Battery-less Remote Control Systems

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Abstract — This report summarizes the main outcomes of the work proposal presented to the MTT-S Graduate Student Fellowship program 2013, under the topic "Battery-less Remote Control Systems". In the scope of this project, a battery-free remote control system has been successfully prototyped and integrated in a TV equipment. The remote control unit relies on a multiplicity of passive RFID chips, sharing a common antenna, and the device to control incorporates an RFID reader. The design of a passive network to interconnect the several RFID chips was a major challenge in this implementation. Such network allows the individual control of the chips and ensures that only one chip is readable, while all other remain in idle mode.

Tangible outcomes include a four-key remote control prototype that interacts with a TV through an RFID reader. The work results have been disseminated through conference and journal papers [2-5].

***Index Terms*—Remote Control Systems, Battery-less Systems, Wireless Power Transmission, Passive UHF RFID, Eco-friendly.**

I. INTRODUCTION

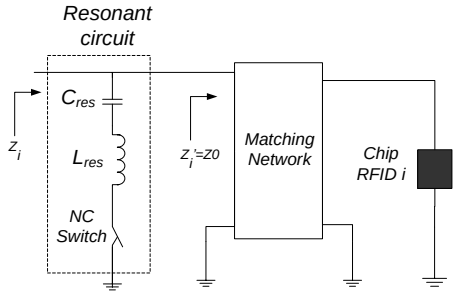
Conventionally, remote controls are based on infrared (IR) technology. IR communication requires direct line-of-sight to function, and most important in the perspective of this project, they use disposable batteries as power source. Several drawbacks can be identified: battery maintenance cost, limited lifetime of batteries. Moreover, chemical batteries generate toxic waste at the end of their lifecycle, which must be properly treated, otherwise can put in risk the public health and the environment. Here is where wireless power transfer can make difference.

Although the idea of transferring electricity without using wires has been there for more than one century, mainly with the work of Nikola Tesla [1], more recently this theme has been greatly revisited by researchers, becoming a very hot research topic, several practical applications have been proposed and WPT has became attractive also to the industry.

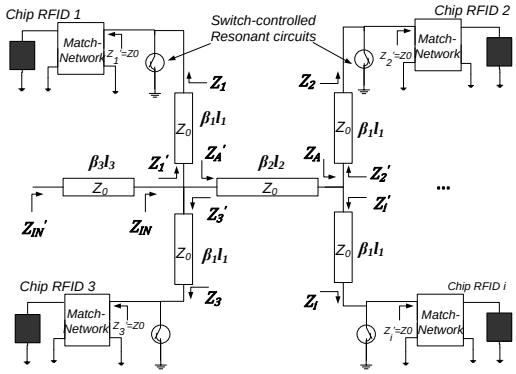
This project aims at the demonstration of a practical application of wireless power transfer to home automation. For this purpose, a battery-less remote control system has been developed and incorporated in a TV. The proposed remote control device does not require the use of batteries or other installed power source. Instead, it relies on passive RFID chips that are remotely powered by an RFID reader incorporated in the device to control. The proposed battery-less remote control is composed of an antenna, a plurality of N passive RFID chips and N switches, and a multi-port microstrip network that interconnects the various RFID chips, allowing them to share a common antenna. Each key of the remote control is associated to an RFID with an Unique IDentifier (UID), which allows the device to be control (TV) to identify the key pressed by the user. The proposed arrangement ensures that only the chip associated to the pressed key is read by the RFID reader, while the other chips remain in idle mode.

II. DESCRIPTION OF THE SYSTEM

The proposed remote control requires no battery to operate and it is based on passive RFID. To energize and to communicate with the battery-free remote control, the device to control (TV), uses an RFID reader. In order to allow the device to control to recognize the key pressed by the user in each moment, a multi-RFID arrangement is used, in which each chip is uniquely associated to a key. By default all the RFID chips are forced to be in idle mode so that they are unreadable. Once a switch is pressed by the user the respective chip is activated and the reader is allowed to read the chip ID and identify the key. The multi-chip operation imposes two challenges: first, control function is required to allow the user to activate and deactivate the chips. This is achieved by using the circuit depicted in Fig. 1a. Additionally, antenna sharing and proper interconnection of the various chips is needed. For this purpose a N-port microstrip network has been designed (Fig. 1b) to guarantee that: 1) Only the active chip is connected to the antenna; 2) The inactive chips do not interfere with the active one; 3)The structure dynamically re-arranges as the user presses different keys.



(a)



(b)

Fig. 1 a) Chip activation/deactivation mechanism; b) proposed multi-RFID arrangement using a specially-designed N-port microstrip network.

The RFID chips are controlled by switched-controlled resonant circuits as shown in Fig.1a. The input impedance of this circuit is given by (1). Details can be found in [2-4].

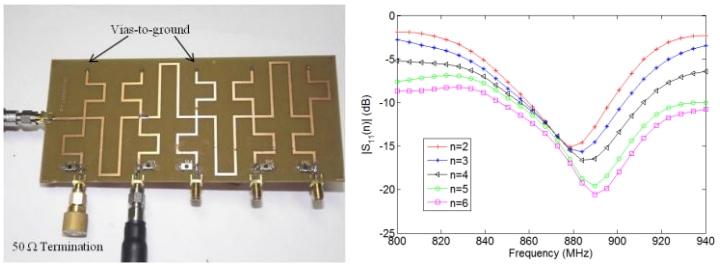
$$Z_i = \begin{cases} Z_n = Z_{TAG\_MATCHED} = Z_0, & \textit{if the key (n) is pressed} \\ 0, & \textit{by default, if no action is performed} \end{cases} \quad (1)$$

By imposing appropriate phase shits at central and lateral branches of the network in Fig.1b, the antenna port will be routed only to the active RFID chip. The input impedance of the multi-port network is given by (2). Details can be found in [2-4]

$$Z_{IN} = \left[\frac{Z_0 + jZ_1 \tan(90^o)}{Z_0(Z_1 + jZ_0 \tan(90^o))} + \frac{Z_0 + jZ_2 \tan(90^o)}{Z_0(Z_2 + jZ_0 \tan(90^o))} \right. \\ \left. \ldots + \frac{Z_0 + jZ_n \tan(90^o)}{Z_0(Z_n + jZ_0 \tan(90^o))} \ldots + \frac{Z_0 + jZ_N \tan(90^o)}{Z_0(Z_N + jZ_0 \tan(90^o))} \right]^{-1} \\ = Z_n = Z_0 \quad (2)$$

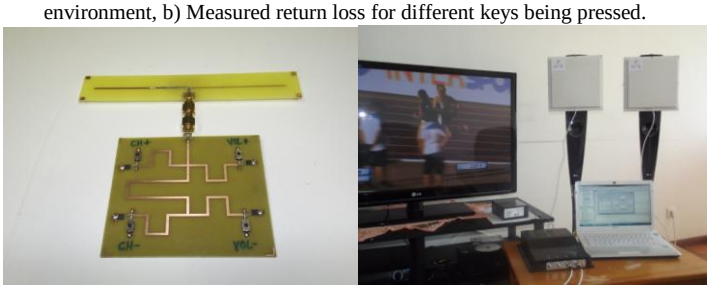
III. Prototypes and Measurements

First, a multi-port network has been simulated, prototyped and measured. In order to evaluate the performance of the fabricated N-port network (Fig.2a) with respect to parameters as number of ports and distance between antenna port and active port, the following quantities are measured: return loss of the antenna port (S_{11}) and return loss of the active port n (S_{nn}), insertion loss between the antenna port and the active port (S_{1n}), isolation between the active port and an adjacent inactive port ($S_{n,n+1}$) and isolation between the antenna and an inactive port adjacent to the active one ($S_{1,n+1}$). All these measurements are a function of the active port number or distance from the antenna (n). Both in the simulation and measurement scenarios it is considered that only one of the keys is pressed by the user. For this purpose, the active port is terminated with 50Ω both in simulations and measurements and the remaining ports are terminated with a short circuit to ground by using a via-to-ground. This represents the ideal case in which the series circuit exhibit infinite impedance when the switch is open, and zero impedance when the switch is closed. Measured results for the return loss are depicted in Fig. 2b. Good impedance matching is achieved for any key being pressed. Additional sets of measurement can be found in [3]. The prototype of a four-key remote control and the demonstration prototype including a TV are depicted in Fig.3.



(a) (b)

Fig. 2 a) Multi-port network, fabricated in low cost FR4 substrate in a 50Ω environment, b) Measured return loss for different keys being pressed.



(a) (b)

Fig. 3a) Fist prototype of a four-key remote control unit, b) Demonstration prototype including a TV, an RFID reader and antennas and an IR-RFID interface.

IV. Next Career Plans and Impact of the Fellowship Program

I am honoured and grateful to receive the award. The MTT-S Graduate Fellowship Program has been a great incentive to pursue R&D in RF and microwave filed. Our project in particular has received a lot of attention of the media in Portugal, mainly due its ability to illustrate to a broad audience a practical application of wireless power transfer. The program has contributed in part to my decision on conducting further research and development in low cost RFID readers, an so, entrepreneurship/industry is included in the next career plans.

References

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