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Single Antenna Changeover Switch for UHF RFID Communications and RF Energy Harvesting

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Abstract—With the increasing development of low power technologies, particularly wireless, RF energy harvesting to power such devices has become possible. UHF RFID is a versatile platform offering both an RF signal to harvest and a data communications link. A challenge is to efficiently share a single tag antenna for both harvesting and data communication duties. This paper demonstrates a practical design for efficiently switching and sharing a single UHF RFID tag antenna.

Keywords—antenna; antenna switching; RF energy harvesting; RFID;

I. INTRODUCTION

Since the early developments of radio there has been great interest in remotely powering devices utilizing electromagnetic waves, even more so now with developments in low power electronics making battery free low powered sensors a reality. There are typically two approaches to RF energy harvesting (scavenging). Firstly, where the system designer has no control over the RF source, the harvesting device (sensor) is totally reliant upon a source of energy from such as a local TV/Radio broadcast transmitter or GSM cell-site. This has obvious limitations, both in terms of the power received, depending upon the distance from the transmitter and the possibility of it becoming non-operational. This could be either temporarily in the case of a power outage, or permanently and leaving any harvesting sensors reliant upon this source non-functioning. A more reliable and robust method is to have control over the harvesting source, particularly in terms of its location and timings. A technology that has received interest in this area is UHF RFID, with the advantages that a quantifiable amount of RF energy can be available locally, and data can be transferred through its back-scattered signal. An issue arises in efficiently sharing a single antenna on the tag for both RFID communications and RF energy harvesting. Previous designs have either used a dual antenna approach [1] where one antenna provides RFID communication and the second harvests energy, or simply a tap off from a single harvesting antenna to the RFID port [2]. Presented here is an efficient low power switching technique that achieves both RFID communications and RF energy harvesting from a single antenna.

II. THEORY OF OPERATION

A. Switching Technique

Single antenna transmit/receive switching (Time Switched Duplexing) is an established technique for transceiver design commonly using PIN diodes or relay switching. Although relatively RF efficient, these technologies are not really suitable

for low power operation. Effective switching of PIN diodes can still be in the region of tens of milliamps and far more for relays. A proposed alternative is the ADG902 SPST CMOS switch from Analog Devices [3]. This device has a -3 dB frequency range of 0 Hz to 4.5 GHz, where at 1 GHz it has an insertion loss of 0.8 dB, an off isolation of 40 dB and a 17 dBm P1dBm. It is specified to operate at 1.65 V to 2.75 V with a power consumption of $< 1 \mu\text{A}$.

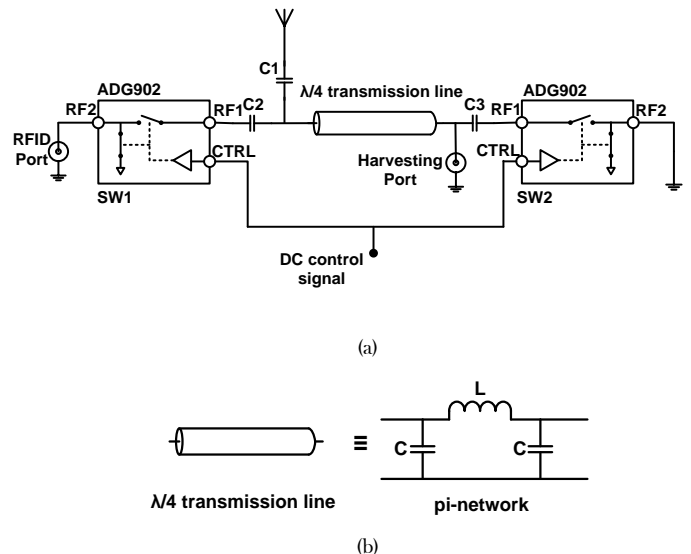


Fig. 1. (a) prototype switching circuit. (b) $\lambda/4$ transmission line and its pi-network equivalent circuit.

B. Circuit Description

Shown in Fig. 1(a) is a basic block diagram of the prototype antenna switch employing two ADG902 devices. In the state shown the switch is in harvesting mode, where the signal present on the antenna port is routed via the $\lambda/4$ transmission line to the harvesting port. The RFID port is isolated from the antenna by SW1. Applying a DC control signal, thus closing both SW1 and SW2 the switch is in RFID communication mode, where the antenna routes to the RFID port via SW1, secondly SW2 shorts the far end of the $\lambda/4$ transmission line and results in an open-circuit (high impedance) at the open end of the $\lambda/4$ line. This effectively isolates the harvesting and antenna ports. Capacitors C1, C2 and C3 function as DC blocks. The $\lambda/4$ transmission line is replaced by an equivalent lumped element pi-network as shown in Fig. 1(b) and where the reactances of the lumped elements are equivalent to the characteristic impedance of the transmission line, in this case 50Ω . From calculation this gives

values of $C = 3.7$ pF and $L = 9.2$ nH for a design frequency of 866 MHz.

III. CONSTRUCTION AND PRACTICAL MEASUREMENTS

A. Circuit Construction

Fig. 2 shows a prototype test circuit designed and constructed on FR-4 PCB material 0.8 mm thick with $\epsilon_r = 4.4$ and $\tan \delta = 0.018$. All transmission lines were designed for an impedance of 50Ω . Nearest preferred values (NPV) of 3.9 pF and 10 nH were used for the pi-network. The three DC blocking capacitors were 47 pF. Additional supply line decoupling of 1 nF was added to each of the ADG902 devices.

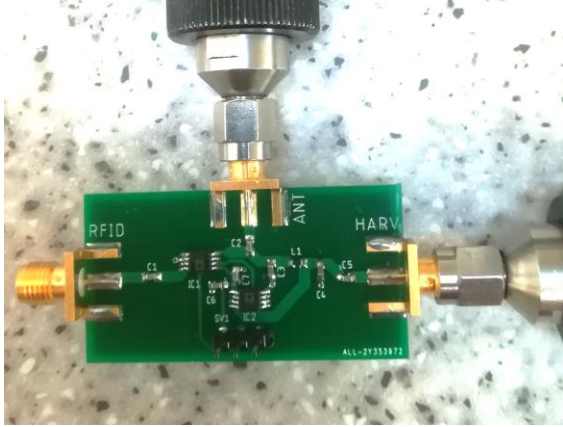


Fig. 2. Constructed prototype time switch duplexer circuit under test.

B. Practical Measurements

Port-to-port transmission and isolation measurements for the two control statuses of the switch were carried out using a vector network analyser (VNA). The measurements are shown in Fig. 3, and spot frequency measurements at 866 MHz are tabulated in Table I. All tests were carried out with supply and control voltages of 1.8V, which is compatible with microcontrollers typically used in RF energy harvesting applications.

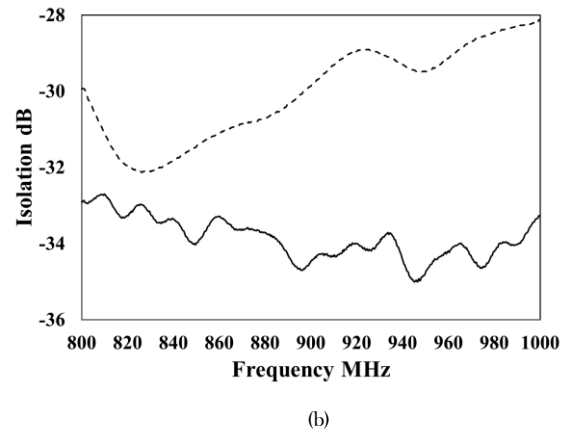
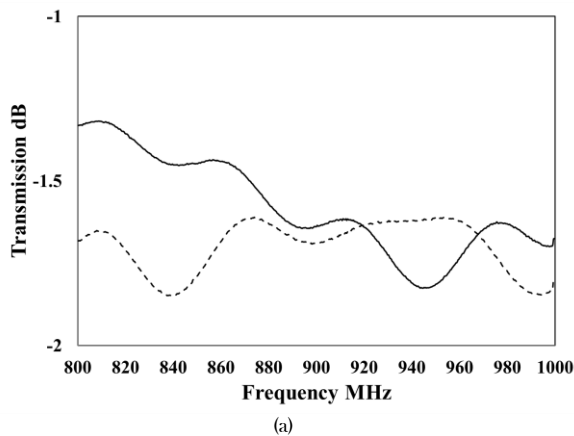


Fig. 3. (a) Measured insertion loss for the test circuit and (b) port-to-port isolation, where — antenna to RFID port, --- antenna to harvesting port.

TABLE I.

Switched Path	Insertion Loss (dB)	Isolation (dB)
Antenna → Harvester	-1.53	-31.8
Antenna → RFID	-1.5	-33.9

IV. CONCLUSIONS

This paper has demonstrated a technique for efficient switching of a single antenna between two ports, in this case RF harvesting and RFID communication ports. A design targeted at the European UHF RFID band of 866 MHz was prototyped and measured and gave good performance both in terms of port isolation and insertion loss. An overall insertion loss of ~ 1.5 dB is considered good when compared to the 3 dB loss of conventional RF splitter designs, or the potential greater losses an un-tuned tapped design can introduce. It should be noted that the maximum port-to-port isolation for the antenna to harvesting port is low in frequency at ~ 820 MHz, this is due to using NPVs for the $\lambda/4$ transmission line and the resultant shift in frequency. The design exhibited very low power dc performance with a current consumption of $< 1\mu\text{A}$ for all switching states when powered from a 1.8V supply.

ACKNOWLEDGMENT

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