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Design and Implementation of RFID Tag in 4G Mobile Network using Software Defined Radio Technology

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Abstract-*Radio Frequency identification (RFID) technology has become emerging technique for tracking and items identification. Depend upon the function; various RFID technologies could be used. Disadvantages of passive RFID technology, associated to the range of reading tags and assurance in difficult environmental condition, puts boundaries on performance in the real life situation. To improve the range of reading tags and assurance, we consider implementing active backscattering tag technology. For making mobiles of multiple radio standards in 4G network; the Software Defined Radio (SDR) technology is used. Restrictions in Existing RFID technologies and SDR technology, can be eliminated by the development and implementation of the Software Defined Radio (SDR) active backscattering tag compatible with the EPC global UHF Class 1 Generation 2 (Gen2) RFID standard. Such technology can be used for many of applications and services.*

The system is developed and tested on SDR platform. Power and performances of developed Gen2 SDR tag are shown through actual presented result.

Index Terms-Software Defined Radio (SDR), Active backscattering, Gen2RFID, Mobilephones RFID, 4th Generation Mobile Networks (4G)

1, INTRODUCTION

RFID technology based on wireless radio communication between the reader and tags is today applicable in many functions.

Depending upon the tag battery presence or absence, RFID comes under three types: full battery powered systems in active RFID, battery-assisted semi passive systems (BAP) and battery-free tags in passive RFID technology.

In low cost passive RFID tags, for backscatter communication and tag IC power supply, the energy from RFID reader antenna is used. To get proper result, passive tags have to be kept close and long to absorb enough energy, and Passive RFID relatively low reading range and not performance well in tag reading on metal or liquid surfaces.

BAP RFID technology additionally has battery for tag IC running, which makes BAP to respond back quickly to the reader. BAP tags are limited in the communication from tag to reader (i.e. backward-link), cannot process weak backscattered signal from larger distances**.**

Using BAP tags reading range can boost, up to 10-12 meters, that increases size, cost of about 10 USD per unit. but active RFID tags (transceivers) has reading range of up to 100 m , that make them more expensive solution depends on size. Today's research directions in RFID technology include improvements in the tag reading range with solutions which are of low complexity and thus low cost. We can use amplifiers for active backscattering to maximize reading range tags. Such move extends tag reading range, but it makes too expensive hardware device (tag).

To overcome this space, new technologies, like mobiles, can be used to accomplish radio frequency identification, due to their active technology and capacity to transmit higher power than all types of RFID tags. Such an approach can be used for objects and human identification, especially in difficult environmental conditions.

promise mobility for different applications and services. SDR Mobile phones in 4G networks are projected to be able to fill radio-applications and achieve functionalities of various protocols and services on a single chip such as WLAN, Bluetooth, and many RFID technologies, etc.

2, PROPOSAL SYSTEM

The projected solution, backscattered signal amplification has providing additional energy to charge the battery. The model shows that necessary energy for the signal amplification could be generate from the reader with appropriate energy scheduling method and that maximizes reading range. This method involves additional circuitry and logic that result in tag more robust and expensive.
Our proposal donates to the state of the art in the sense of the organized RFID technology practice with comprehensive tag reading range by means of SDR method.

3, GENERATION 2 PROTOCOL AND THE REQUIREMENT ANALYSIS

To understand tag functionalities it is required to go after Gen2protocol requirements.

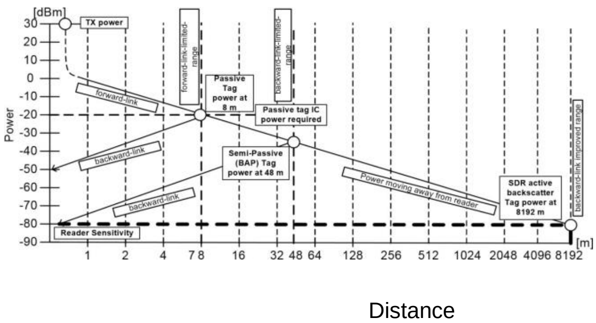

Fig. 1. Simplified description of different RFID reader-tag communication technologies, with its

limitations (omnidirectional TX antenna). Theoretically, SDR tag could response from approximately 8 km away from the reader if it has the same sensitivity and output power as the reader.

This method provides a single universal device for all radio-tasks. Figure1 shows restrictions on each tag type along with the projected SDR method. Moreover, with SDR mobile phones, all kind of RFID technologies can be employed on single device with different PHY/MAC layer programming and thus applied in variety of applications of authentication, tracking, person or object identification, etc.

In this paper we explain the prototype of the Gen2 RFID active backscattering tag created on SDR platform. This SDR RFID tag implementation to

To create the interrogation, first RFID reader sends *PowerUp* command, followed by *Select* command, where group of tags for interrogation can be selected. *Select* is an arbitrary command. After that *Select*, reader sends *Query* command, where the number of cycles in Miller modulated subcarrier for tag reaction, population of tags that contribute in an inventory round, and *Q* factor which specifies the length of interrogating structure separated into 2^Q timeslots. With *Query* command, tags slot counters are initialized to the random number in between 0 - 2^Q.

Afterwards tags can, respond with 16 bit random number *RN16* to the RFID reader, if their slot counter is set to zero. If tag reacts to the command, reader sends tag and *ACKRN16* acknowledgement, if it demodulates it correctly, sends its own 96 bit Electronic Product Code (EPC) value. Reader will send *QueryRepeat (QRep)* command to decrease slot counters by 1, when tags do not reacts to the *Query* command i.e. none of the slot counters is zero. After *QRep*, tag(s) take action with the random number, before sending EPC, which should be acknowledged. Number of *QRep* commands before sending new *PowerUp* and *Query* is specified with *Q* factor, so there will be 2^Q -1 *QRep* commands that decrease all potential slot counters. Time between two *Query* commands is specified as inventory (interrogation) round. For the duration of the inventory round, reader can alter the number of slots with adjustment of *Q*, e.g. using *QueryAdjust (QAdj)* command. Figure 2 shows an invento**ry** round with one tag reaction.

4, 4G MOBILE PHONE UHFGEN2TAG IMPLEMENTATION THROUGH SDR

In real state, passive Gen2RFID tags are backscattering the modulated subcarrier of the assigned reader carrier these transmitted at Ultra High frequency it is tuned. Since SDR is active transceiver and it does not backscatter signal by default, one has to deal with the problem of frequency organization between RFID reader and SDR tag (due to their oscillator offsets). The frequency offset which appears when RFID reader and SDR tag are not synchronized is shown in Figure 3, and it causes information from SDR tag not to be correctly decoded. Moreover, timing necessities are crucial for the protocol agreement. For the real implementation in the mobile phones, the system latency should be reduced to 1 *ms* in order to keep timing requirements specified in. In the SDR PC performance, buffer size should be set in order to receive and process the samples sooner.

In the same case, it is required to guarantee that the system is not under/overrunning samples and the processing capacity is less than 32 Mega Samples per second (MS/s) which is the maximum throughput of USB 2.0 protocol (if SDR to PC connection uses USB interface).

A. Some Issues in the development of SDR tag

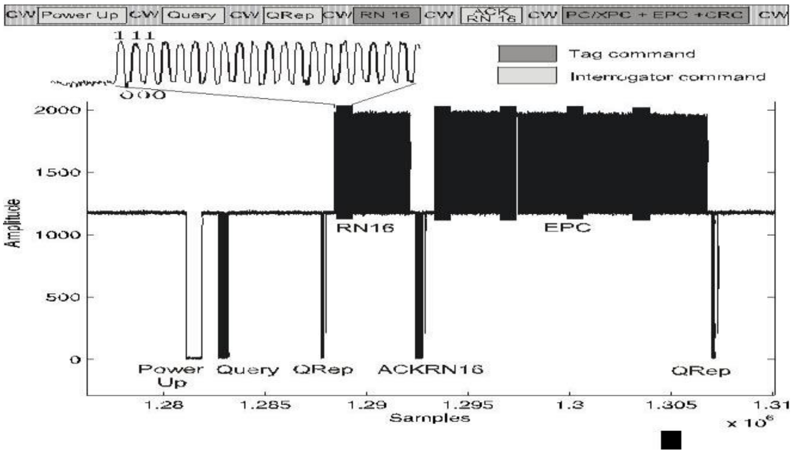

Fig. 2. Gen2 protocol interrogation round, where Q 1. SDR Tag respond 4 meters away from the reader, after first *QRep* command.

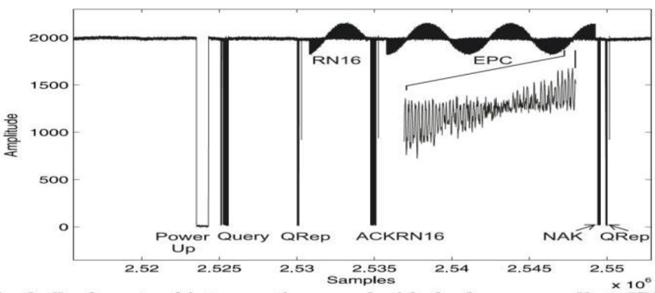

Fig. 3. Gen2 protocol interrogation round with the frequency offset. SDR

tag command was not decoded correctly, since zero crossings could not be successfully decoded. Afterwards, reader sends *NAK* command to tell the tag that *RN16* was not successfully decoded

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In order to assure that the computer processes the information in the time window proposed by the protocol.

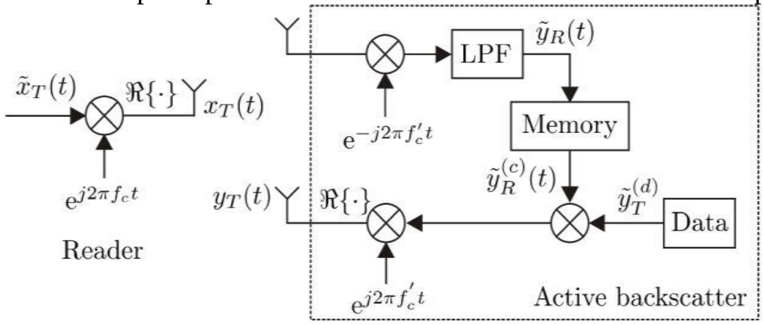

Fig. 4. Communication block scheme of the RFID reader-tag (active

backscattering).

B. SDR tag implementation

Developed application for SDR implements and provides functionalities of Gen2 tag PHY/MAC layer. The system was tested on Buettner's SDR
RFID UHF GEN2 Reader tool.

The start of an inventory round in the reader is marked with *PowerUp* command. SDR tag application uses *PowerUp* command to synchronize on, and sends information compliant with the protocol necessities. Its period counter always equals 1, which means that next first *QRep*, *RN16* is sent. After *PowerUp* detection, we count number of frames when to send the *RN16.*

Sampling frequency should be set properly in order to receive and decode complete information reader.
Afterwards, when signal is sampled, it is vital to define suitable bus block sizes

Communication between reader and tag is based on backscattering of the same carrier, where reader expects to receive the same carrier. Since SDR tag is not synchronized to the reader's carrier due to oscillator frequency offset, for data backscattering we use the same received carrier with the offset.

5, MEASUREMENT SETUP AND PERFORMANCE ANALYSIS

System tests were developed through SDR tag (Figure 5), which uses developed SDR application which implements fixed X10 amplification of the received signal. Figure 6 shows

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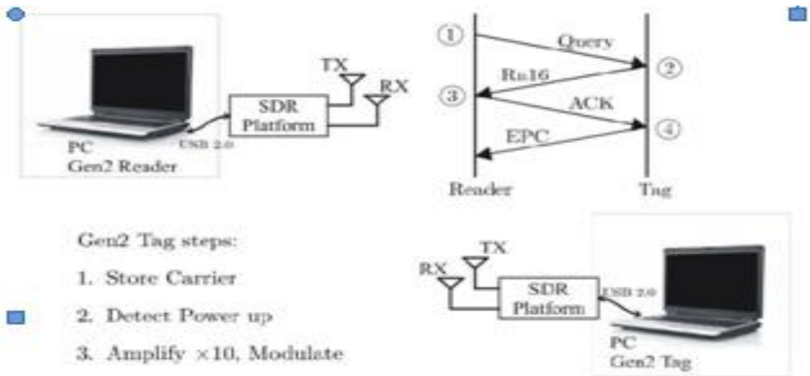

Fig. 5. Measurements setup, with the communication system block scheme. For performance measurements, SDR RFID reader [16] was used on one side and the developed SDR tag on another side.

The measurement lab environment as well as performance results computed from

$$\text{EPC Read Efficiency} = \frac{\text{Successful EPC Reading Rate}}{\text{Number of Inventory Rounds}} \quad \text{--- (1)}$$

Where number of inventory rounds always equals 1000. For comparison with standard tag measurements, reader could read tags only 30 cm away with [16] transmitting at 200 mW.

The performance of the developed system can be compared with results obtained from familiar Friis Equation [2]

$$FSL = -20\log(\lambda/4\pi d) - (G_{TX} + G_{RX}) \quad \text{- -- (2)}$$

With f_c = 915 MHz (λ= 0.33 m) and antennas gains $G_{TX} = G_{RX}$ = 6 dBi, we obtained from (2) that in a free space SDR tag could be detected in a range up to d=105 m.

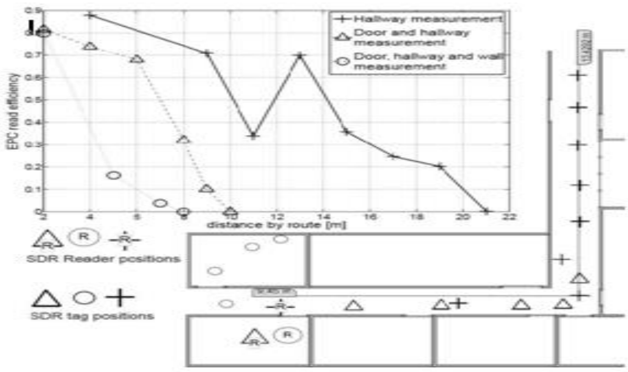

Fig. 6. Floor blueprint and the measurements plan. SDR tag reading performances are calculated from (1). Since the propagation after the Hallway corner is affected by diffraction at the edge and by reflected wave components, measurements at 11m and 13m are obviously affected by the two signal components. It is worth to mention that existing reader is reading regular tags only 30 cm away from reader antenna (200 mW of reader output power).

The measurement results we obtained on our test platform for SDR with CW sensitivity of -110dBm, and with RFID reader with sensitivity of -80dBm, are presented in Figure 6. In a case of SDR mobile phones, at the standard output power of 1W, it is reasonable to suppose that the system could respond from the distance of approximately 160 meters, even in a noisier environment. Given ranges are obtained for fixed X10 amplification, without automatic gain control (AGC).

6, CONCLUSION

The SDR technology allows greater flexibility in the implementation of standard protocols and technologies, especially in the next mobile phones scenario usage. For testing purposes active backscattering SDR tag application has been developed and the reading results are presented. For a comparison, SDR tag can report through 2 walls, while standard RFID tags (labels) performances are degraded, if tag is not in the reader's line of a sight.

Developed SDR tag application can be used in noisy environments where tag identification performances are crucial. Our intention in this paper is to provide the proof of concept of building PHY/MAC layer of Gen2 RFID tag using SDR.

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