EVALUATION OF RFID LOCATION SYSTEMS

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Abstract: *In this paper we present an evaluation of location systems available commercially on the world market as full working systems or as prototype and evaluation versions. We made tests for both location precision and electromagnetic field emissions in order to find out the possible influences of this kind of systems on human safety. The performances of RFID location systems are affected by many factors. We identified here that for a system working in the band near 900 MHz, the objects interposed between the antenna system and the tags to be located may have a great influence in terms of accuracy of the measurement. In closed areas multiple reflection paths may disturb the measurement systems, a percent of only 40 to 60 of total measurements are enough accurate to locate an objects. Regarding the EMC aspects of this RFID location system, we may say, based on measurements presented here, that the electric field are high enough not to use this system indoors at distances less than 5 meters, if humans are present on a regular basis in that area. For applications in open areas, like access control for auto vehicles and many similar others, this kind of systems are very good.*
Keywords: *location system, RFID, electromagnetic compatibility, emission, spectrum*

Introduction

Radio Frequency Identification (RFID) Systems are based on radio frequency (RF) tags and RF readers. Tags are made up around a microchip containing a small memory. Modern tags have memory capacities of several tens of kilobits or more. RF readers are microprocessor based systems. RFID systems may be divided in two main categories: passive and active. In passive systems the power supply needed by the tags is assured by a small antenna, located near the chip. This antenna captures the RF energy from the reader and uses it to power the logic circuits. Active systems use tags with on-board batteries power sources and can support more sophisticated electronics with more data storage capacity, data processing capabilities and / or interfaces to external sensors. Many applications require precise location information for objects or persons.

Location systems

Location of mobile objects becomes of great interest in the last years and will be in the period to come. There are many applications where precise positioning information is desired: goods and assets management, supply chain management, point of interest (POIs), proximity services, navigation and routing inside buildings, emergency services as defined by the E911 recommendations in North America and EU countries, etc.

There are numerous outdoor solutions, based mainly on GPS but there are also so-called inertial systems (INS). Solution based on cellular phone networks signals are another good example of outdoor positioning service. For GPS based solution the precision of location is dictated by a sum of factors, almost all of them out of user control. Inertial systems can provide continuous position, velocity and orientation data that are accurate for short time intervals but are affected by drift due to sensors noise [1], [2]. For indoor environments the outdoor solutions are, in most of the practical situations, not applicable. The main reason is that the received signal, affected by multiple path reflections, absorptions and diffusion, is too weak to provide accurate location information. This introduces difficulties to use positioning techniques applied in cellular networks (time of arrival, angle of arrival, observed time reference, etc.) in order to provide accurate location information inside buildings or isolate areas.

Indoor positioning systems should provide the accuracy desired by the context-aware applications that will be installed in that area. There are three main techniques used to provide location information: triangulation, scene analysis and proximity [3, 4, 5, and 6]. These three techniques may be used separately or jointly.

Indoor positioning systems may be divided into three main categories. First of all there are systems using specialized infrastructure, different from other wireless data communication networks. Second, there are systems based on wireless communication networks, using the same infrastructure and signals in order to obtain the location information. Third, there are mixed system, that use both wireless networks signals and another sources to achieve the goal.

There are many implementations, we mention here several of them having something new in technology and / or the implementation comparing with previous systems [6, 7, 8, 9, 10, 11, 12, 13, 14, and 15]:

- Active Badge is a proximity system that uses infrared emission of small badges mounted on the moving objects. A central server receives the signals and provides location information as the positions of the receivers are known;
- Cricket system from MIT which is based on "beacons" transmitting an RF signal and an ultrasound wave to a receiver attached to the moving object. The receiver estimates the it's position by listening to the emissions of the beacons based on the difference of arrival time between the RF signal and the ultrasound wave;
- MotionStar is a magnetic tracker system which use electromagnetic sensors to provide position information;
- MSR Easy Living uses computer vision techniques to recognize and locate objects in 3D;
- MSR Radar uses both triangulation based on the attenuation of the RF signal received and scene analysis;
- Pinpoint 3D-iD which uses the time-of-flight techniques for RF emitted and received signals to provide position information;
- Pseudolites are devices emulating the GPS satellite signals for indoor positioning;
- RFID Radar which used RF signals
- SmartFloor utilizes pressure sensors integrated in the floor. The difference of pressure created by a person movement in the room is analyzed and transmitted to a server which provides the position of that person;
- SpotON is a location technology based on RF signals. The idea is to measure on the fixed receivers the strength of the RF signals emitted by the tags mounted on moving objects to be located.

RFID Radar positioning system

The RFID Radar system used for the tests and evaluation was made by Trolley Scan [24], the version we had was the "Development version". The main unit is built around a development board from Microchip. The antenna system is composed by three patch panel antennas, one for signal generation and two for receiving the signals from the transponders. As stated in the RFID Radar handbook, the processor inside the system is able to make calculation to determine the positions of up to 50 tags in a range of 50 meters. Both RFID Radar and RFID system functions are available to the user, only one of the two selectable by software. The RFID radar measures the path length for the signals traveling from the transponder to the reader to determine the distance. By comparing the two signals the reader is able to determine the angle of arrival of the signals from the transponder. Transponders are either passive (Ecochiptag 500 µWatts transponders) or active. We used for the tests two types of active transponders Claymore long-range Ecotag and Stick long-range Ecotag and one type of passive transponder. All long-range active transponders use a Lithium battery to supply the chip.

We made a series of test during several days, in different environment conditions and using different positions for the tags. Before starting the measurement session the receiver itself must be calibrated using, as recommended by the producer, an active tag. The tag was positioned in the center in front of the antenna system at 9 m distance. The operation is mandatory as the cables length introduces delays in the signal path from the antenna to the receiver. We made a calibration for every site we made the measurements, in order to compensate the influence of antenna, cables and receiver positions.

For the tests we used all three types of tags provided (two type active and one passive). The batteries voltages where checked to be at the nominal value before and after every individual test in order to be sure the results where not affected by the low supply voltage. During all the tests we used a spectrum analyzer to measure the electric field strength in the test area, in a frequency interval from 75 MHz up to 3 GHz. The screen captures saved on the spectrum analyzer internal memory where downloaded in a computer after each set of tests.

For the first set of tests we used a real laboratory room, with a surface of about 165 square meters (7.5 meters x 22 meters). There where several wooden tables and chairs inside, but we did not changed their positions during the experiment. The antenna system was mounted about 1.4 meters height above the ground on a polystyrene stand, with no objects in front. All tags where placed at the same height, but their position where changed in front of the antenna. We used a notebook PC to run the control and command software.

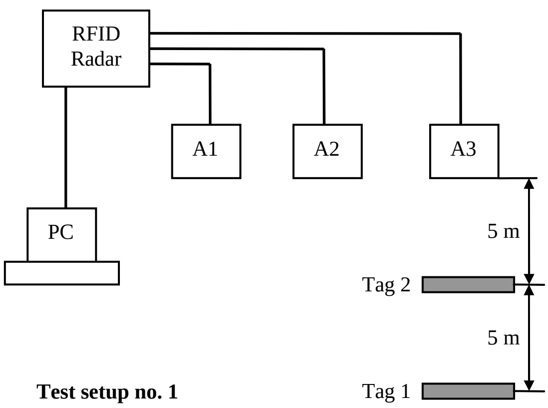

Figure 1. Test setup for distance measurement fro two tags - one at 5 m and the second at 10 m in front of the antenna

We present only the relevant results of the tests and conclusions, very useful for future developments of this kind of location systems. For the first result presented we used two long range tags, one Claymore (at 10 meters in front of the antenna) and one Stick type (at 5 meters) - Figure 1.

We made these measurements for several times using the same spatial configuration for all elements. The test presented here was made for duration of 4 hours. Analyzing the numerical results, we find out the for 65 % of cases for the tag located at 5 meters the position was reported with an error less than 10 % and for 47 % of cases the results where affected by the same error for the tag located 10 meters in front of the antenna.

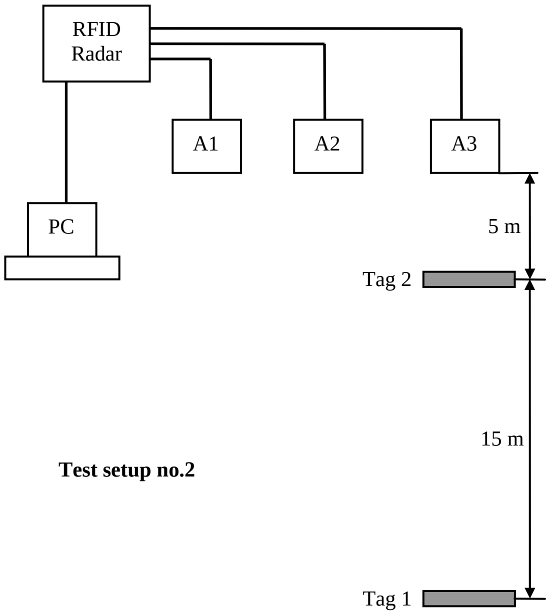

Figure 2. Test setup for distance measurement fro two tags - one at 5 m and the second at 20 m in front of the antenna

The second setup was the same in respect of location of the measurement, but one tag was moved more in front of the antenna system, at a distance of 20 meters. The results are practically the same regarding the position dispersion. Only in about 35 % of all measurements for the tag situated at 20 meters the results where with an error less than 10 %.

EMC Measurements

The RFID location system is supposed to use a central frequency of 870.00 MHz with a bandwidth of 10 kHz. The frequency was chosen in order to be outside the GSM 900 band used in Europe (880.0 MHz - 915.0 MHz / 925.0 MHz - 960.0 MHz). As we might see in the capture from the spectrum analyzer (see Figure 3), the electric field strength, at distance of 20 m in front of the reader antenna, is about 1.2 V/m, a value sufficiently low to be in accordance with the EMC safety levels in Europe and in the US.

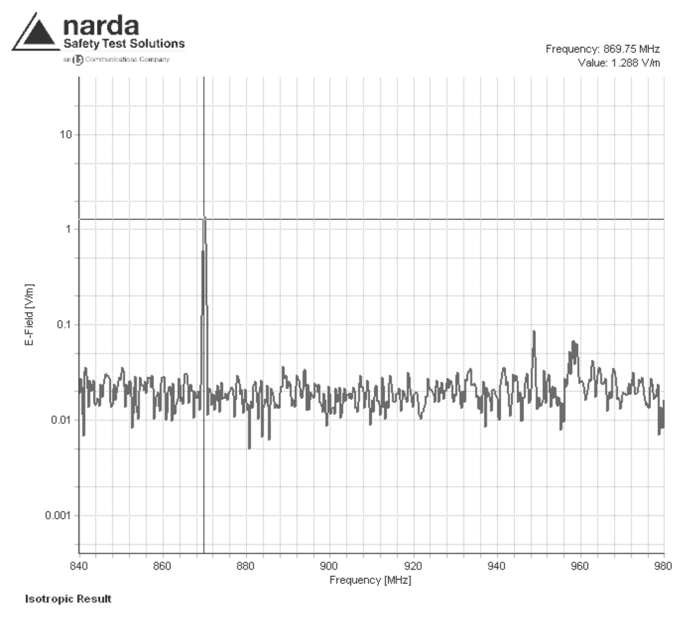

Figure 3. Electric field magnitude at 20m distance in front of the antenna

There are also visible, above the RF noise floor, the emissions from the GSM base stations, located at about 600 meters from the laboratory the tests where made.

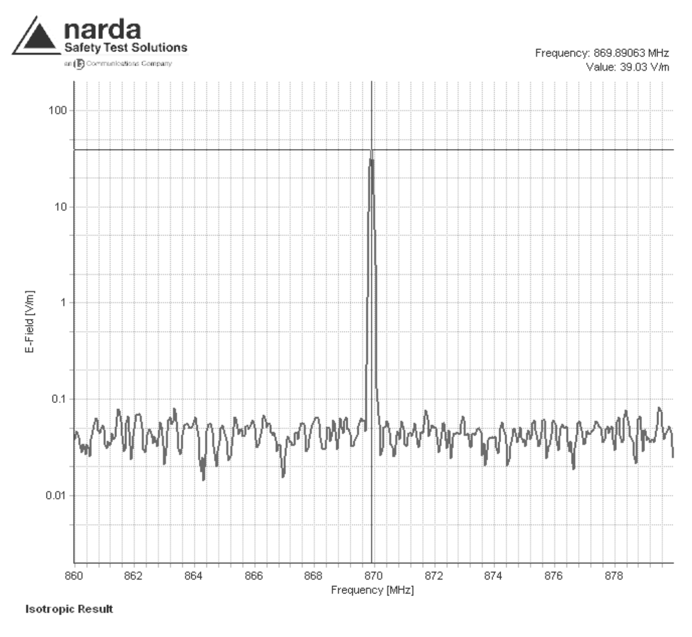

Figure 4. Electric field magnitude at 3m distance in front of the antenna

Problems appear right in front and very close to the antenna system. In Figure 4 we show the field strength at a distance of 3 meters in front of the antenna. At this distance the emission level is about 39 V/m, a value high enough to worry. At about 30 cm near the emission antenna the filed was about 200 V/m, the maximum value the spectrum analyzer could measure.

Regarding the bandwidth of the signal, we observe to be in the range of 10 to 25 kHz, small enough not to produce interference with other radio spectrum users. If many such devices are to be used simultaneously, on different central frequencies, there will be no problem if the spacing between to channel will be as low as 30 kHz.

Conclusions

RFID location systems for indoor and outdoor positioning are a promise for the future [16, 17, 18, 19 and 20]. The performances of these systems are affected by many factors. We identified here that for a system working in the band near 900 MHz, the objects interposed between the antenna system and the tags to be located may have a great influence in terms of accuracy of the measurement.
In closed areas multiple reflection paths may disturb the measurement systems, a percent of only 40 to 60 of total measurements are enough accurate to locate an objects. In such conditions, there are small chances for this kind of systems to be used for high precision applications.
The results obtained in open area test sites are more promising, more than 93 percent of total result where not affected by big errors. Regarding the EMC aspects of this RFID location system, we may say, based on measurements presented here, that the electric field are high enough not to use this system indoors at distances less than 5 meters, if humans are present on a regular basis in that area. For applications in open areas, like access control for auto vehicles and many similar others, this kind of systems are very good.

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