

RFID BASED LOCATION IN CLOSED ROOMS

Implementation of a Location Algorithm using a Passive UHF-RFID System

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Abstract: This paper presents a new concept for determining the location of an RFID-tag without any additional hardware. For this positioning system standard RFID components with passive RFID-tags within the UHF range are used. The measurement is based on a location algorithm which makes use of the RSSI value of the UHF reader. The RSSI value is the return signal strength indicator and, as it is shown in the paper in hand, this signal correlates to the distance between the RFID tag and the antenna of the reader. This positioning system is especially useful indoors, where other positioning systems may not work. For this reason it could prove very useful in various logistics applications. The maximum distance from antenna to the tag is approximately between 0.5 m and 3 m. To this end a special algorithm is used to obtain stable calculation results. A minimum of two antennas is needed to get a two-dimensional location.

1 INTRODUCTION

Identification using RFID (radio frequency identification device) is more or less standard in many industrial applications and in many logistics processes. There are a variety of applications where the combination of identification and location is very useful.

This paper presents a solution for the location of UHF-RFID tags within the range of a reader antenna. For this positioning system only standard RFID equipment is used. The concept, the algorithm, and known limitations of the system are presented.

2 THE BASIC IDEA

The basic concept of the positioning system is to measure the distance between an RFID antenna and the RFID tag using only standard RFID equipment. The measurement of the distance is done by interpreting the signal strength of the UHF signal.

The proposed system is especially useful for indoor use.

2.1 Location Algorithms

There are a variety of different location methods proposed in literature and in practical use nowadays. Examples with RFID or WLAN can be found in (bekkali 2007, chon 2004, ekahau 2007, geroldt 2007, ibach 2005, lionel 2004, tomberge 2004, tsukiyama 2007). This chapter provides a comparison between these methods. The main focus is on determining location within buildings. This ability could be very useful for numerous applications in logistics.

2.1.1 Cell-of-Origin Concept

This type of positioning system makes use of an algorithm using a mobile tag and a fixed reader. Upon detecting a nearby reader, the tag determines its position to be nearly equal to that of the reader. For this the tag must be within the range of the corresponding reader.

This type of positioning system is frequently used with RFID systems in the 125 kHz and the 13.56 MHz range. Practical applications of this type can be found on AGV systems (autonomous guided vehicles) or mobile robots.

A commercially available example of this type of positioning system which uses WLAN or Bluetooth technology is the Ekahau Positioning Engine (ekahau 2007).

An “inverse cell-of-origin concept” is used if the RFID reader is on the mobile unit and different tags have a fixed position. If the reader can communicate with a specific tag, then the position of the mobile unit can be determined in relation to the position of the fixed tag. An example for this concept can be found in (tsukiyama 2007).

2.1.2 Triangulation Method

The location of a tag can be calculated by triangulation if the distance between the tag and several known reference stations can be determined. The measurement of the distance can be achieved by detecting the runtime of the radio signal or laser or by measuring the signal strength of the radio signal.

The best known positioning system of this type is the global positioning system (GPS). This method also finds use in RFID systems which use active tags and operate in the 2.45 GHz range.

2.2 RFID

An RFID system consists of two components which communicate via radio:

- a device called a “tag” or “transponder” which is capable of storing data
- a so called “reader” (providing read and write functionality) communicates with the tags using an appropriate antenna-system, controller and amplifier.

Nowadays tags are very cheap as they are produced in large numbers. Therefore they are widely used in many goods and logistics devices.

One reader can be equipped with several antennas. Within the range of one antenna multiple tags can be detected and communication is organised into a sequence of the different tags.

2.2.1 Types of RFID Systems

There are various types of RFID systems available. Different types operate at different frequencies, have different couplings and differ as well in the energy supply of the transponders.

The different frequencies are

- “low frequency” (119 ... 148.5 kHz)
- “high frequency” (13.56 MHz)
- “ultra high frequency” (865 ... 955 MHz)
- “microwave” (2.4 ... 2.5 GHz)

The different coupling technologies are inductive coupling and modulated backscatter coupling.

Both the coupling method and the operating frequency influence the range of operation

- “close-coupling” – distance < 1 cm
- “remote-coupling” – distance < 1 m
- “long-range” – distance > 1 m

Tags can operate as passive tags, which get their power from the reader via the electromagnetic field of the antenna, or as active tags, which are powered by a remote battery or some other power supply.

2.2.2 Applications

As mentioned above logistics applications need a location algorithm to find a specific tag. Location, used in combination with RFID, has the advantage of combining identification and location using the same hardware.

One typical example is the localisation of parcels on a conveyor belt, persons walking through an RFID gate carrying a transponder or the localisation of a palette carried by a forklift. All these applications have the need for optimised performance, better process control and supervision. For proper use it is important to heed the basic limitations of this concept.

2.3 The RSSI-Value

The RSSI value (received signal strength indicator) is a commonly used value within radio communication systems. Modern RFID readers within the UHF frequency range have the ability to determine this value as a measure of the reflected UHF signal from the tag. That is where RSSI value gets its name “reflected signal strength indicator”. one must consider that up to now this RSSI value has not been standardised and is therefore manufacturer dependent.

2.4 Used Technology

To achieve the goal of this location procedure, RFID technology is used which has a long distance range and is widely used in logistic systems. According to VDI 4472 the recommended frequency for logistics applications is 868 MHz (UHF range), which is indeed very commonly used. UHF systems have

long-range readability with passive tags and the reader normally has an output for the RSSI value.

Therefore a passive RFID system with a frequency of 868 MHz was chosen for this particular location system.

3 MEASURING DISTANCE USING THE RSSI VALUE

During the project a theoretical and practical analysis was undertaken to determine if the RSSI value is a well-working solution for measuring distance. Figure 1 shows the schematic design of the lab equipment for the practical investigations.

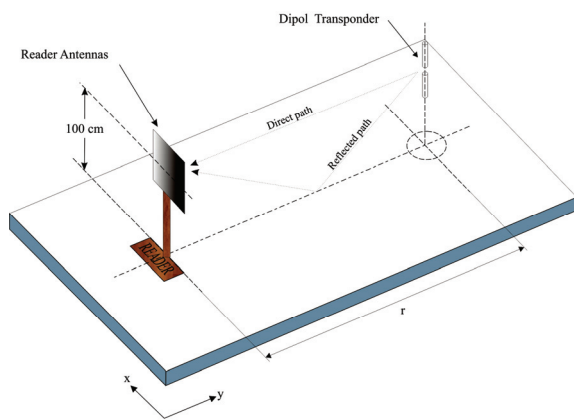


Figure 1: Schematic view of the lab equipment used for distance measuring.

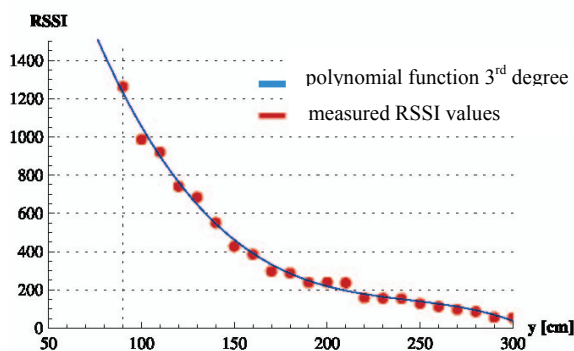


Figure 2: Measured RSSI-values varying only the y-coordinate of the tag-position.

For the practical measurements three different antennas and two different kinds of tags were used. Figure 2 and Figure 3 depict the mean value of the RSSI value of a 10dBi antenna. Figure 2 shows the variation of one coordinate and figure 3 the variation

of two coordinates which leads to a three-dimensional radio-map. Each measured value is a mean value of 1000 datasets.

If the distance between the antenna of the reader and the tag is too low, the RSSI value may not be obtained due to saturation, which causes a heavy non-linear behaviour.

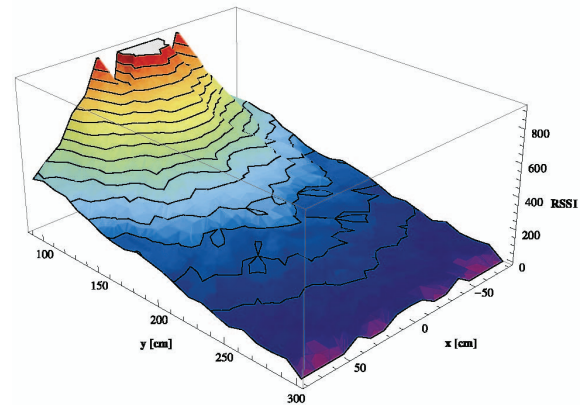


Figure 3: Three-dimensional radio map of the RSSI values, varying the x and the y coordinates of the tag position.

Three different types of antennas and two different types of tags were investigated (see Table 1 for the tags and Table 2 for the antennas of the reader). All antennas used have a circular right polarisation.

Table 1: Comparison of different types of tags.

	Philips	TI
Chip	Philips U-Code HSL	RI-UHF-00C02-04
Protocol	ISO 18000-6B	EPCUHF Gen 2
Antenna	Dipole $\lambda/2$	“dog bone”

Table 2: Comparison of different antennas of the reader.

	GP-ANTU	RH-ANTU	RH-ANTU
VSWR	< 1.3 : 1	< 1.5 : 1	< 1.5 : 1
Gain [dBi]	6	> 8.5	> 10
3 dB beamwidth horizontal	70°	63°	55°
Max. input power [W]	10	6	6

Due to the characteristics of the antenna on the tag, the best result was achieved using the combination of a $\lambda/2$ -Dipole tag and the 10dBi antenna on the reader side.

Furthermore the influences of temperature were also investigated. This influence must be

compensated by adequate correction algorithms according to the measured temperature.

Additional influences are electromagnetic disturbances caused by fluorescent lamps and, of course, atmospheric humidity. As this system is proposed for indoor use humidity will not influence the system dramatically.

4 CALCULATION OF POSITION

In chapter 3 the strong correlation between the RSSI value and the distance between antenna and tag has been presented. To obtain the location of the tag, the results of more than one antenna have to be combined. During experiments in the project a two-dimensional location was tested. To determine this location at least two antennas are necessary which have contact to the same tag simultaneously. Knowing the RSSI value, it is possible to calculate a set of positions relative to the antenna where the tag might be based on the radio map.

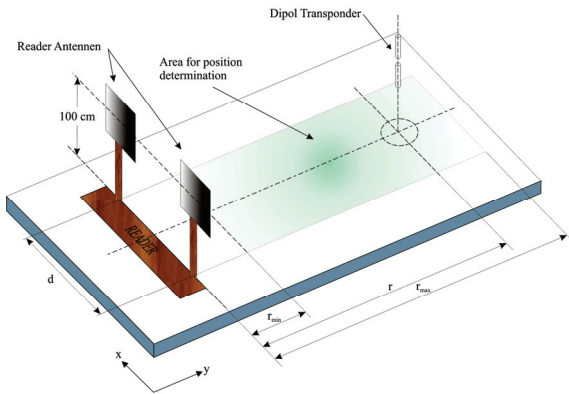


Figure 4: Schematic view of the enhanced lab equipment for location using two antennas.

Three different calculation algorithms have been investigated:

- Numeric iteration with finite differences
- Geometric intersection of polynomial approximations
- Weighted position determination

4.1 Numeric Iteration

This situation, where two antennas which communicate with the same tag is depicted in Figure 5. Antenna A has an RSSI value which can be located at the positions marked by red points (left curve in figure 5), antenna B has an RSSI value

which can be located at the positions marked by blue points (right curve).

A scenic analysis (see also bahl 2000) yields the possible tag positions represented as a set of discrete points from each antenna in accordance with the measured RSSI value. The most probable tag position is the minimum distance between the possible locations of the two antennas within the overlapping area. If there is only a non-zero solution, the most probable position of the tag can be calculated by calculating the mean value. The Accuracy of this algorithm is, however, low.

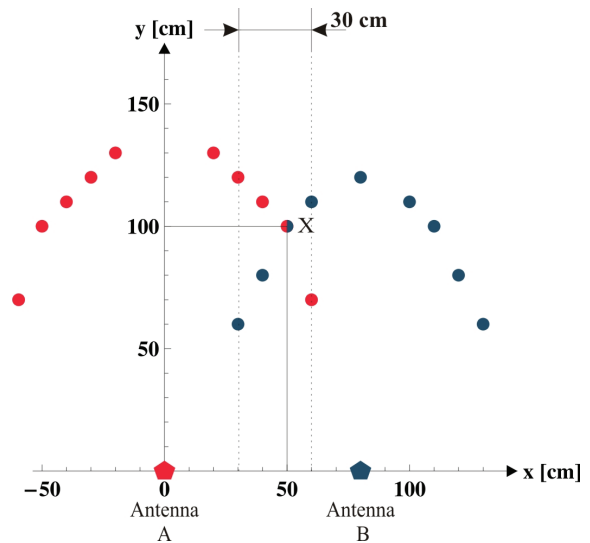


Figure 5: Scenario of two antennas for the algorithm "Numeric iteration".

4.2 Polynomial Approximation

This algorithm is based on a polynomial approximation of the line of constant RSSI value using a least square algorithm. For each antenna one polynomial exists for the measured RSSI value. Figure 6 depicts the appropriate situation.

The position of the tag is the intersection of the two polynomial functions. If this polynomial function is of second order the error of the calculated position is rather high. If the polynomial function is of 5th order the error is very low but the calculation effort is very high.

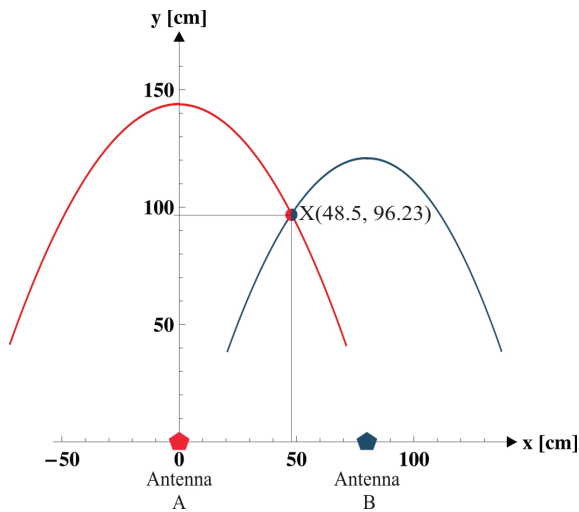


Figure 6: Scenario of two antennas for the algorithm “polynomial approximation”.

4.3 Weighted Position Determination

Based on the same possible tag position as in chapter 4.1 the position of the tag is calculated with a “centre of gravity calculation”. A similar algorithm is presented in (bulusu 2000).

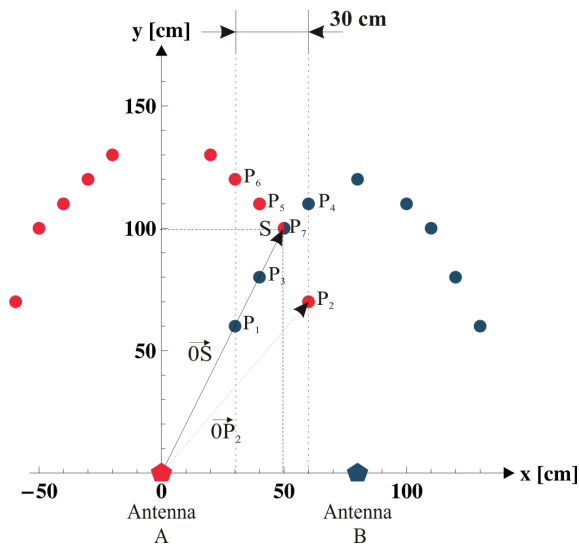


Figure 7: Scenario of two antennas for the algorithm “weighted position determination”.

The position of the tag S is calculated by the following equation:

$$\vec{OS} = \frac{1}{\sum_i m_i} (\sum_i m_i \cdot \vec{OP}_i) \quad (1)$$

Hereby i are all points within the overlapping area and m_i are the appropriate weighting factors.

This algorithm requires fewer computing resources and achieves a higher level of accuracy. It combines easy computing and the possibility of adapting the radio map, allowing for the compensation of atmospheric humidity or other influences.

4.4 Recommendations

Due to the previously mentioned advantages and disadvantages the “weighted position determination” algorithm can be considered best.

This algorithm is very stable and returns a calculated position of the tag with respect to the available discrete relations between RSSI value and possible positions relative to the two antennas.

Accuracy has been checked too. In a wide part of the space it is quite good (less than 5%) but there are single points of rather high inaccuracy. Further investigations have to be carried out to determine their cause and improve this situation. Further details can be found in (schoenegger 2007).

5 CONCLUSIONS

The paper presents the results of having investigated an RFID based location system. Only standard RFID equipment with passive tags operating within the UHF range was used. Determination of location works within a range of approximately 3 meters and is based on the use of the reader’s RSSI value. A tag can be located two dimensionally if it is situated within the range of at least two readers. This location algorithm might be used, for example, in combination with a fork-lift, whereby the forks are equipped with antennas. The algorithm is capable of providing a good notion where a specific tag is located relative to the fork.

In addition to logistics application this algorithm may be useful for positioning of mobile robots within production automation.

As the presented location system uses only standard hardware and is based on a simple calculation algorithm, it might be considered as “a new concept”. No similar solution is known to the authors.

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