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Speed Measurement of a Moving Object by using a RFID Location System and Active Transponders

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Introduction

RFID systems are still developing, despite the problems and discussions generated by privacy issues. Many commercially available systems using passive or active transponders provide only information regarding the identity (ID), memory content and in very few cases, the position of the transponders relative to a fixed point, usually the main antenna system. Very few progresses were made in the direction of using these systems for real-time speed measurements. One system delivering accurate positioning information for active transponders is the RFID Radar from Trolley Scan [1]. We have developed a software program to compute the speed based on the location information provided by the reader and have made various performance tests using a RFID Radar.

RFID Radar location system description

The location system we used to perform the speed measurement tests is a mixed one, based on ToA - Time of Arrival and AoA - Angle of Arrival methods [2]. It uses a system based on one emitting antenna and two receiving ones. The working principle, mainly based on a tag-talks-first protocol [3] is as follows: when a transponder enters the area covered by the emitting antenna, it will send its ID and memory content. The signal transmitted by the transponder is received by two receiving antennas. Based on the time difference between the two signals and the range data, it computes the angle and the distance information.

We used for our tests active long-range transponders of Claymore type [4]. The system uses a central frequency of 870.00 MHz with a bandwidth of 10 kHz chosen outside the GSM 900 bands used in Europe (880.0 MHz - 915.0 MHz / 925.0 MHz - 960.0 MHz).

Calculating the speed using distance and angle information

In order to calculate the speed of the moving transponder we need to know the distances and the angles for two consecutive points P_1 and P_2. Our system provides distance and angle information for transponders in range. We assume the movement between these points is linear, which is a reasonable assumption for small distances.

The equipment computes the distance between the reference point "0" (located in the middle of the antenna system) and the transponder, as well as the angle between the reference axis and the line connecting "0" to the transponder. Let us consider that the moving object is located at points P_1 and, respectively, P_2, at two consecutive readings. Since the RFID radar provides the values of d_1, d_2, α_1 and α_2, one can determine the distance between the two points as it follows.

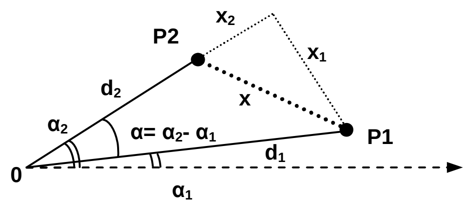

Fig. 1. Calculating the speed from two distances and two angles of two consecutive positions

By taking into account the diagram presented in Fig. 1, one can derive the following expressions:

$$\cos\alpha = \frac{d}{d_1}, \quad (1)$$

$$\sin\alpha = \frac{x_1}{d_1}, \quad (2)$$

where: $\alpha = \alpha_2 - \alpha_1$, $d = d_2 + x_2$.

By replacing the values of the known variables in the equations, we obtain:

$$x_2 = d - d_2 = d_1.\cos\alpha - d_2 \quad (3)$$

$$x_1 = d_1.\sin\alpha . \quad (4)$$

We may now calculate the value of the distance between the two points as:

$$x = \sqrt{x_1^2 + x_2^2} = \sqrt{d_1^2 . \sin^2 \alpha + (d_1 . \cos \alpha - d_2)^2} \quad (5)$$

so

$$x = \sqrt{d_1^2 + d_2^2 - 2.d_1.d_2.\cos \alpha} \; . \qquad (6)$$

For the variables in these equations, we have the values determined at two time moments t_1 and t_2, so computing the speed of the object having attached the tag is obvious:

$$v = \frac{x}{\Delta t} = \frac{\sqrt{d_1^2 + d_2^2 - 2.d_1.d_2.\cos\alpha}}{t_2 - t_1} \; . \qquad (7)$$

Software diagram of the speed computing program

The program was developed on a platform running Windows XP as an operating system. We used Power Basic for writing and compiling the program, with very good results regarding the processing speed. Data was exchanged with the RFID system by using the RS232C serial interface. Results where delivered in a text box and were written in a text file on the local disk.

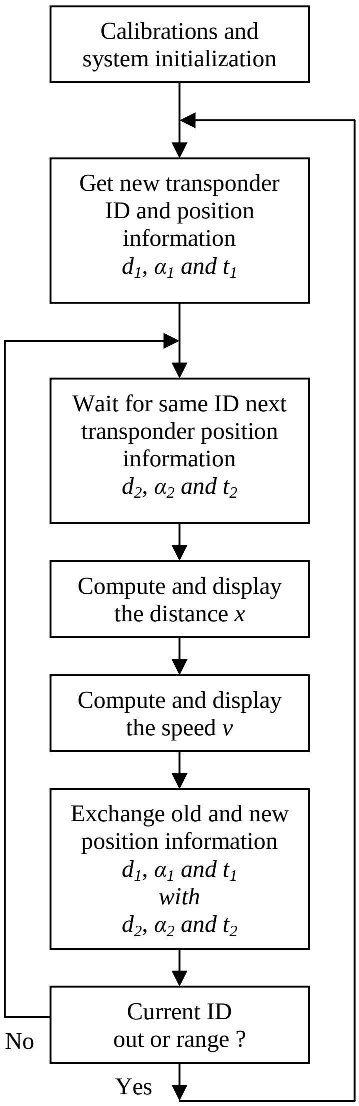

Fig. 2. Software diagram to calculate the transponder speed

Fig. 2 presents the software diagram for calculating the speed. The process begins with a system initialization procedure, followed by a calibration routine. After these operations, we wait for a transponder to come in the active range of the antennas. When the transponder enters the range, we get the current information, such as the unique ID, the location and time information. We do not need, and consequently, do not process any information stored in the transponder internal memory. After a delay of about 100 ms, the program enters a routine expecting the next reading. When receiving the same ID, the program gets the new values for location and time information, and then, it computes and displays the distance traveled by the transponder, and its speed.

When the current transponder ID is out of range, the program will acquire a new unique ID to calculate the new speed. If another transponder comes into the active range of the reader while the software is acquiring the speed for one transponder, the last one will not be read.

Measurements

The diagrams shown bellow are obtained from the signal transmitted between the receiving antennas preprocessor (and demodulation block) and the digital processing board located inside the reader. The board is made using a Microchip Explorer 16 development board. We used for measurements a LeCroy 104Xi scope and 1/10 passive probes.

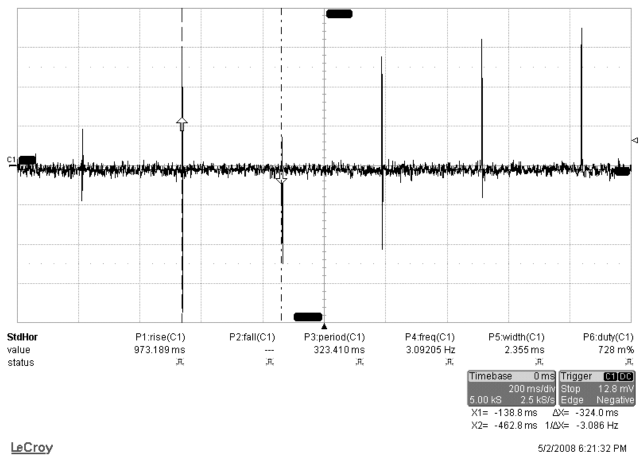

Fig. 3. Reading one transponder every 333 ms

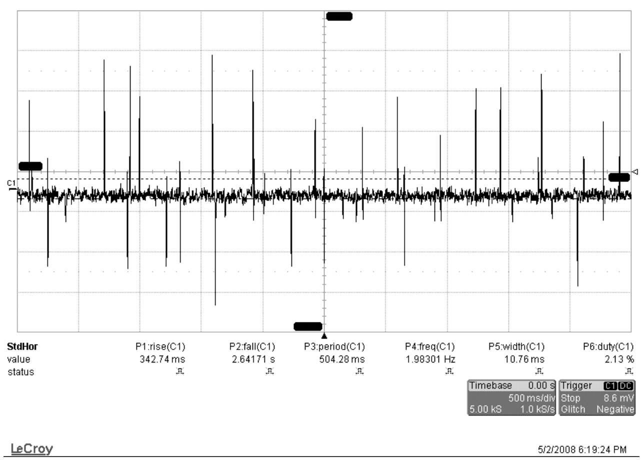

Fig. 4. Three transponders located in reader's range

A typical signal received by the processing board, when only one active transponder is in the active area of the reader, is represented in Fig. 3. When multiple transponders are located in the Radar range, the received signal contains multiple data streams. See, for example, Fig. 4, which presents the signal received in the presence of four transponders. The information transmitted by the reader system to the processing board inside the reader is plotted in Fig. 5.

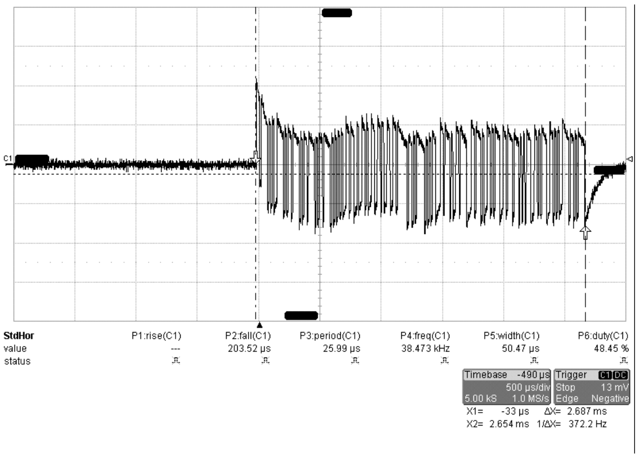

Fig. 5. Reading 1024 bits from one transponder takes 2.66 ms

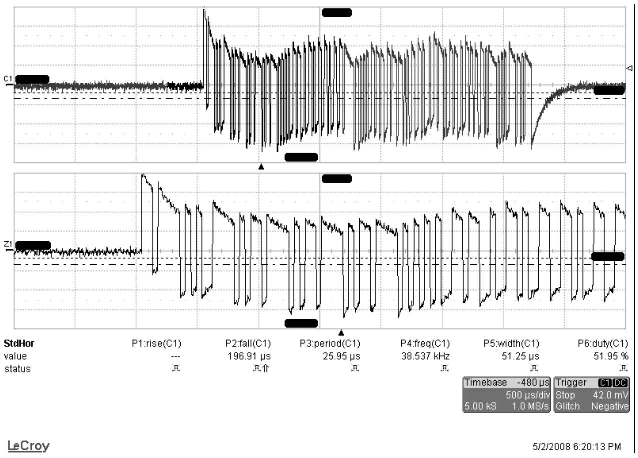

Fig. 6. Header data in one active transponder

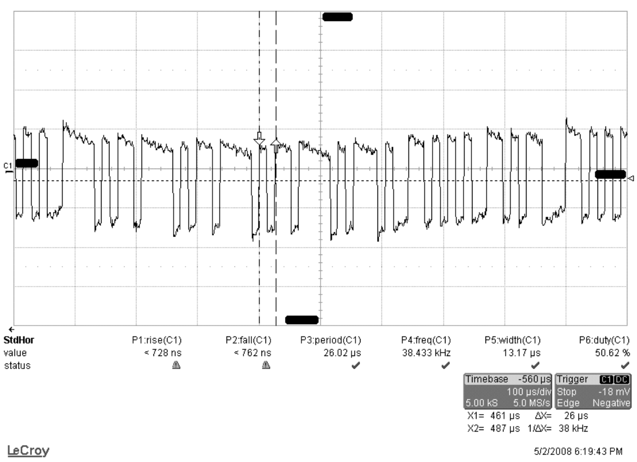

Fig. 7. Every bit takes about 26 μs to be transmitted

The transmission duration for one transponder takes approximately 2.66 milliseconds for 1024 bits. The ID bits from the first part of the transmission, the so-called header, which is shown in the zoomed part at the bottom of Fig. 6. The last part of the transmission contains the information regarding the angle and time relative to the receiving antennas.

As one can see in Fig. 7, a bit is transmitted every 26 microseconds.

Theoretical and practical limitations

Considering the distance between the two receiving antennas of 31 cm (factory default), the system is able to solve angles between -30 and +30 degrees. The time spacing between two transponder transmissions is, as in Fig. 2, about 333 milliseconds (three transmissions per second). Assuming that a transponder is moving such that the distance to the antenna system is constant, one can calculate the maximum theoretical speed that may be measured by using only the angle of arrival information.

We also assume that we read two times the transponder in the whole working range of 60 degrees, the minimum information needed to compute the speed. If the reader does not receive the second transmitted signal, due to propagation issues, the speed can not be computed. The software will initiate a new measurement sequence by acquiring a new transponder ID. Table 1 presents a summary of the maximum detected speed as a function of the distance from the transponder to the antennas.

In practical cases, more than two transmissions will be necessary in order to compute and have trusted information regarding the speed. Moreover, by reducing the angle between two transmission points, let us say the system is not able to process the information in a timely manner or the radio signal is disturbed/attenuated due to propagation, the maximum measurable speed is much lower.

Table 1. The theoretical maximum speed as a function of the distance between the transponder and the antenna system

Distance to the antenna system (meters)	10	20	30	40	50
Distance traveled by the transponder (meters)	5.8	11	17	23	28
Speed (km/h)	62	124	187	249	311

For the tests we made in a laboratory-controlled environment, with very low noise floor, we obtained the results presented in Table 2.

Table 2. The maximum measured speed as a function of the distance between the transponder and the antenna system

Distance to the antenna system (meters)	10	20	30	40	50
Speed (km/h)	6	24	32	36	n/a

Due to propagation issues generated by multiple reflections, we where not able to measure transponder speeds for distances over 40 meters.

Conclusions

The Radar RFID location system is very good as an identification and location system. Based on time of arrival and angle of arrival methods, the location precision for both passive and active transponders is in the range of 10-30 centimeters. The performances obtained for speed measurements are good enough for a single transponder or a reduced number of transponders and small speeds, bellow 40 km/h. For better speed measurement results, we may combine the use of a RFID system for reading IDs and transponder internal memory contents with a classical radar system and process the results in a software interface.

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Many commercial RFID available systems provide accurate information regarding the identity, memory content and, in a few cases, the position of the transponders. Very few progresses were made in the direction of using these systems for real-time speed measurements. One system delivering accurate positioning information for transponders is the RFID Radar system from Trolley Scan. For this system, we developed a software program to compute the speed from the location information provided by the reader and made several performance tests and measurements in various working conditions. The performances obtained for speed measurements are satisfactory for a single transponder or a reduced number of transponders and small speeds, usually bellow 40 km/h. Ill. 7, bibl. 6 (in English; summaries in English, Russian and Lithuanian).

Е. Цока, В. Попа, В. Г. Гайтан, Ц. О. Турцу, Цр. Турцу. Измерение скорости перемещающегося объекта при использовании системы определения местоположения RFID и активных приемоответчиков // Электроника и электротехника – Каунас: Технология, 2008. – № 8(88). – С. 63–66.

Многие коммерческие системы RFID обеспечивают точную информацию идентичности, содержания памяти и в нескольких случаях положение приемоответчиков. И только очень немного исследований проведено в направлении использования этих систем для измерения скорости в реальном времени. Одна из систем, позволяющих установить точную информацию расположения приемоответчиков, – радарная система RFID компании «Trolley Scan». Для этой системы была разработана программа для вычисления скорости по информации местоположения, полученой читательным устройством и сделали несколько тестов и измерений эффективности в различных условиях работы. Показатели эффективности, получены при измерении скорости, удовлетворительны, когда используется единственный приемоответчик или уменьшенное число приемоответчиков при малых скоростях, обычно менее чем 40 км/ч. Ил. 7, библ. 6 (на английском языке; рефераты на литовском, английском и русском яз.).

E. Coca, V. Popa, V. G. Găitan, C. O. Turcu, Cr. Turcu. Judančio objekto greičio matavimai naudojant RFID vietos nustatymo sistemą ir aktyvius retransliatorius // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 8(88). – P. 63–66.

Dauguma komercinių RFID sistemų pateikia tikslią asmens ir kitą atmintyje įrašytą informaciją. Retesniais atvejais jie gali retransliatoriams pateikti informaciją apie objekto padėtį. Kol kas šios sistemos labai retai naudojamos matavimams atlikti realiu laiku. Kompanijos „Trolley Scan“ sistema „RFID Radar“ yra vienas gaminių, galinčių retransliatoriams pateikti tikslią padėties informaciją. Šiai sistemai sukurta programa, leidžianti apskaičiuoti objekto greitį pagal specialiu skaitytuvu nuskaitytą padėties informaciją. Atlikti keli sistemos bandymai esant įvairioms darbo sąlygoms. Gauti našumo rezultatai tenkina keliamus reikalavimus, kai naudojamas vienas retransliatorius arba kai naudojam nedaug retransliatorių, o objektas juda nedideliu greičiu, paprastai mažesniu nei 40 km/h. Il. 7, bibl. 6 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).