A METHOD OF IDENTIFYING A PLURALITY OF TRANSPONDERS, ANALYSIS APPARATUS, AND A TRANSPONDER FOR IMPLEMENTING SUCH A METHOD

The present invention relates to a method enabling a plurality of transponders present simultaneously in the field of analysis apparatus to be identified, and also to analysis apparatus and to a set of transponders for implementing such a method.

Numerous analysis apparatuses are known that enable a transponder to be identified, for example to control access to a building.

Most such analysis apparatuses are adapted to identify only a small number of transponders at a time, which is not a problem when controlling access to a building since the number of people, and thus the number of transponders, capable of arriving simultaneously in the field of the analysis apparatus is no more than about ten.

By way of example, mention can be made of European patent application EP 0 285 419 which describes analysis apparatus for requiring n successive interrogations to determine an n-bit identity code.

Such analysis apparatus is unsuitable for the case where the identity code of each transponder is encoded on a large number of bits, e.g. 32 bits, and where a large number of transponders, e.g. more than 50, are present simultaneously in the field of the analysis apparatus.

Unfortunately, this situation arises when transponders are used for remote identification of articles present in a container and for providing information concerning their origins, for example.

A particular object of the present invention is to enable a plurality of transponders to be identified in a relatively short length of time, for example to be able to determine how many of them there are, and to be able to address each of them separately to interrogate them.

The invention achieves this by a novel method of identifying a set of transponders situated in the field of analysis apparatus, each transponder having a different identity code in memory, the method being characterized by the fact that it comprises the steps consisting in:

a) causing the analysis apparatus to transmit data for comparison with a portion of the identity code as selected by the analysis apparatus;

b) causing each as-yet unidentified transponder to compare the received data and the portion of its identity code as selected by the analysis apparatus;

c) causing each as-yet unidentified transponder to transmit in at least one time window selected from a set of time windows common to the set of transponders as a function of the result of said comparison; and

d) causing the analysis apparatus to analyze the data transmitted by the transponders in said set of time windows, and when the data transmitted by the transponders does not enable a transponder identity code to be determined, at least in part, causing the apparatus to start again with data that has been modified in such a manner that, within a finite number of iterations, the transponders are caused to transmit data enabling the identity code of at least one of the transponders to be determined, at least in part.

In a preferred implementation of the method, each transponder includes a comparison register in which the data for comparison is stored.

This comparison register is preferably organized to store a plurality of binary words, and the identity code is likewise made up of binary words.

In a preferred implementation of the invention, the analysis apparatus modifies, one at a time, a binary word of given significance in the comparison register, and each as-yet unidentified transponder compares the most-

recently modified word with the binary word of corresponding significance of the identity code.

The portion of the identity code that is to be subjected to comparison is selected by selecting the significance of each new binary word that is to be stored in the comparison register.

Preferably, the method of the invention further comprises the step consisting in:

· causing the analysis apparatus, whenever the data previously received thereby makes this possible, to determine at least a portion of the identity code of one or more transponders, to send an order causing said transponder(s) to transmit its/their identity code(s); and

· analyzing said identity code(s) as received to determine whether only one identity code was transmitted or whether there has been interference associated with a plurality of different codes being transmitted simultaneously, and in the event of only one identity code being received, storing said code.

Results that are particularly satisfying in terms of the time required to identify all of the transponders have been obtained when the identification method comprises the steps consisting in:

a) using the analysis apparatus to transmit data to be compared with a portion of the identity code selected by the analysis apparatus;

b) within each unidentified transponder, comparing the received data and a corresponding portion of the transponder's identity code;

c) causing each unidentified transponder to transmit in at least one time window selected from a set of time windows common to the set of transponders;

d) using the analysis apparatus to analyze the data transmitted by the transponders in said set of time windows, and when the data transmitted by the transponders does not enable at least part of the

identity code of at least one of the transponders to be identified, beginning again with data modified in such a manner that, after a finite number of iterations, the transponders transmit data making it possible to determine at least a part of the identity code of at least one of the transponders;

e) causing the analysis apparatus, when the data previously received thereby makes it possible to determine at least a portion of the identity code of one or more transponders, to transmit an order causing every such transponder to transmit its own identity code; and

f) analyzing reception of the identity code to determine whether a single identity code has been transmitted or whether interference has occurred associated with simultaneous transmission of a plurality of different codes, and when only one identity code is received, storing said code.

Preferably, when a plurality of transponders transmit a plurality of different identity codes simultaneously and they interfere with one another, the method of the invention further includes the step consisting in sending new data to be compared with a new portion of the identity code in said transponders, other than the portion already determined by the analysis apparatus, optionally in modifying said new data until said new identity code portion has been determined, and thereafter in causing the transponder(s) for which the new identity code portion has been determined to transmit its/their identity code(s), and in the event of interference restarting the process for determining the identity code again by causing the comparison to be performed on an as-yet undetermined portion of the identity code, until only one identity code is received from the transponders.

In a preferred implementation of the method of the invention, each identified transponder is put into a standby mode in which it ceases to transmit the result of

comparing its own identity code with the data transmitted by the analysis apparatus.

Preferably, each transponder that has been identified is put into said standby mode by using the analysis apparatus to transmit its identity code. The identity code is advantageously transmitted by loading said identity code into the comparison register, with the transponder whose comparison register matches its identity code then putting itself into a standby mode.

The invention also provides a transponder of the type comprising an identification code such as a serial number stored in a memory and means for remote communication with analysis apparatus, the transponder being characterized by the fact that it includes a comparison register in which data from the analysis apparatus can be stored, calculation means for comparing at least a portion of the identity code with at least a portion of the comparison register, and means for transmitting the result of the comparison in at least one time window selected from a set of time windows, the particular time window depending on the result of the comparison.

The invention also provides analysis apparatus for a plurality of transponders having different identity codes, the apparatus being characterized by the fact that it includes processor means organized to determine the identity codes of a plurality of transponders placed in the field of the analysis apparatus, said analysis apparatus being suitable for:

- transmitting a write order associated with identity data, said order causing said identity data to be stored in the transponders at a particular address selected by the analysis apparatus;
- analyzing the response from as-yet unidentified transponders in a set of time windows after said identity data has been transmitted;

· transmitting a read order to cause the transponders whose identity codes have been determined in part to send their identity codes in full;

· transmitting a new write order associated with new identity data in the event of interference between the data transmitted by the transponders, so as to end up by causing only one transponder at a time to send its identity code, and storing said code; and

· repeating the above steps so as to identity all of the transponders in turn.

The invention also provides analysis apparatus and a set of transponders for implementing a method as defined above.

By means of the invention, it is possible to identify a large number of transponders in a relatively short length of time, and to do so even if the identity code of each transponder is encoded on a large number of bits, e.g. 32 bits.

Other characteristics and advantages of the present invention appear on reading the following detailed description of a non-limiting implementations of the invention, and on examining the accompanying drawings, in which:

· Figure 1 is a diagrammatic view showing a set of transponders placed simultaneously in the field of analysis apparatus;

· Figure 2 is a diagram of a transponder in isolation;

· Figure 3 is a flow chart showing the steps of a first implementation of the method enabling the transponders to be identified;

· Figure 4 shows how the information stored in the comparison register is made up of 8-bit bytes;

· Figure 5 is a timing diagram showing the various time windows in which the transponders can transmit the results of comparison between their comparison registers and their serial numbers;

· Figure 6 shows how an identification process takes place in the presence of four transponders when performing the first implementation of the invention; and

· Figure 7 shows how an identification process takes place in the presence of four transponders when performing a second implementation of the invention.

Figure 1 shows a plurality of transponders 1 placed in the magnetic field of an antenna 2 of analysis apparatus 3, which apparatus includes a transmitter-receiver connected to the antenna 2 and processor means 5 such as a microcomputer for processing information received by the transmitter-receiver 4 and for controlling transmission thereby.

The antenna 2 is constituted by a solenoid within which the field is substantially constant.

The analysis apparatus 3 is organized to identify transponders 1 that are located inside the antenna 2, with the field being strong enough to deliver sufficient energy to the transponders to enable them to be activated.

By way of example, the transponders 1 are in the form of labels and they are all contained in a common enclosure inside the antenna 2, which enclosure is represented by dashed lines.

In the example described, information is interchanged by amplitude modulation of a signal at a frequency of 125 kHz.

Figure 2 shows a transponder 1.

The transponder has an internal antenna 6 coupled to a tuning capacitor 7, a rectifier circuit 8 to rectify the current induced in the antenna 6, a capacitor 9 for smoothing the current rectified in this way, and a circuit 10 which is programmed to perform certain functions in response to orders received from the analysis apparatus 3, in particular to cause data to be transmitted by the transponder, which functions are described in greater detail below.

The circuit 10 is coupled to a transmitter 11 to modulate and transmit data to the analysis apparatus 3, via the antenna 6, and a receiver 12 to demodulate and receive data transmitted by the analysis apparatus 3, in conventional manner.

The transponder 1 also has a memory 13 of the EEPROM type, associated with the circuit 10.

In the memory 13, a serial number S is written in non-erasable manner, which number is encoded on four bytes S_3, S_2, S_1, S_0 giving a total of 32 bits.

The circuit 10 has a buffer memory referred to below as the comparison register H, and capable of storing four respective addresses H_3, H_2, H_1, and H_0, as shown in Figure 4.

It is assumed below that all of the transponders placed in the field of the antenna 2 have different serial numbers.

Figure 3 shows a first implementation of the method of the invention.

In the example described, when the magnetic field of the antenna 2 is established, all of the transponders start continuous transmission of preprogrammed information.

That is why the method begins in step 20 by silencing the transponders 1. To do this, the analysis apparatus 3 sends a specific instruction to the transponders 1 to place all of them in a "listen" mode, in which they do not transmit unless instructed to do so, i.e. they transmit only in response to particular instructions transmitted by the analysis apparatus 3.

In following step 21, it is assumed that all of the transponders are in listen mode.

In step 22, the analysis apparatus 3 transmits an order to write the value m at address H_n, where the value of the index n generally lies in the range 0 to 3, and is equal to 0 at the beginning of the identification process.

The value m is encoded on 8 bits, and it lies in general in the hexadecimal range 00 to FF. m is initially given the hexadecimal value 80.

At step 23, all of the transponders 1 store the value m at address H_n, i.e. the value 80 at address H_0 at the beginning of the identification process.

Thereafter, in step 24, the transponders 1 compare the contents of address H_n with the corresponding byte S_n of their respective serial numbers.

At the beginning of the identification process, n is equal to 0 and the transponders 1 therefore compare the least significant byte H_0 in their comparison registers 8 with the least significant bytes S_0 of their serial numbers.

The comparison in question consists in determining whether the value m stored at address H_n is greater than, equal to, or less than S_n.

When the comparison does not apply to the least significant byte S_0, then the transponder 1 also checks in the presently-described implementation for a match between the contents of each address of lower significance and each corresponding address of its serial number.

In other words, if a comparison is being made, for example, on byte S_2 of the serial number, then the transponder 1 also checks for a match between bytes S_1 and S_0 and the contents of address H_1 and H_0 respectively.

As a function of the result of the comparison, and as explained possibly also providing that the contents of the less significant addresses and the corresponding bytes of the serial number match, each transponder 1 responds in a step 25 by transmitting during a predetermined time window, unless the analysis apparatus has already put the transponder into a standby mode, as described below.

Transmission from the transponders 1 takes place in the presently-described implementation in one of four

groups G_3, G_2, G_1, and G_0, each of three time windows, with each group G_n being associated with a different value for the index n.

The three successive time windows of each group G_n correspond respectively to the case where S_n is less than the contents of the address H_n which is written $S_n < H_n$ in Figure 5, to the case where they are equal which is written $S_n = H_n$, and to the case where S_n is greater than the contents of the comparison register at address H_n which is written $S_n > H_n$.

As shown in Figure 5, the first group G_3 of time windows extends between instants t_1 and t_4, the second group G_2 between instants t_4 and t_7, the third group G_1 between instants t_7 and t_{10}, and the fourth group G_0 between instants t_{10} and t_{13}.

All of the time windows are of the same duration. Instant t_1 is situated at a predetermined time interval from the end of data transmission by the analysis apparatus.

At step 26, the analysis apparatus 3 analyzes the responses coming from the transponders 1.

For each group G_n of three time windows, eight situations can arise:

· the first situation corresponds to the analysis apparatus 3 receiving a signal 111, i.e. receiving binary value 1 in each of the three time windows of a single group G_n allocated to the result of the comparison between the contents of address H_n in the comparison registers and the bytes S_n of the serial numbers; this means that there is at least one transponder 1 whose byte S_n is less than the contents of address H_n, at least one transponder 1 whose byte S_n is equal to the contents of address H_n, and at least one transponder 1 whose byte S_n is greater than the contents of address H_n;

· the second situation corresponds to the analysis apparatus 3 receiving the signal 100, i.e. binary value 1 in the first time window only of the group G_n under

consideration; this means that all of the transponders 1 have their bytes S_n less than the value $\mathfrak{m}$ stored at address H_n of their respective comparison registers H;

· the third situation corresponds to the analysis apparatus receiving the signal 110, i.e. binary value 1 in each of the first two time windows of the group under consideration; this means that the byte S_n in each transponder 1 is either less than or equal to the value $\mathfrak{m}$, and that there is no transponder 1 whose byte S_n is greater than the contents of the address H_n in the comparison register;

· the fourth situation corresponds to receiving the signal 011, i.e. binary value 1 in each of the last two time windows; this means that the byte S_n in each transponder 1 is either equal to or greater than the contents of the address H_n of its comparison register H;

· the fifth situation corresponds to receiving the signal 001, i.e. binary value 1 in the last time window only of the group G_n under consideration; this means that all of the transponders have a byte S_n greater than the contents of the address H_n of their comparison registers;

· the sixth case corresponds to receiving the signal 101, i.e. binary value 1 in the first and the last time windows only of the group G_n; this means that some transponders have a byte S_n less than the contents of the address H_n and others have the byte S_n greater than the contents of the address H_n;

· the seventh situation corresponds to receiving the signal 010, i.e. the binary value 1 in the second time window only of group G_n; this means that all of the transponders have their respective bytes S_n equal to the contents of the address H_n; and finally

· the eighth and last situation corresponds to receiving the signal 000, i.e. no binary value 1 in any of the three time windows of group G_n; this means either that all of the transponders have been identified, or that the group under consideration is the group G_q where q

= 1, 2, or 3, and there is no equality between any of the bytes S_w and H_w where w is an integer in the range 0 to q-1.

In the following step 27, if no transponder has byte S_n of its serial number equal to the value m stored at address H_n of its comparison register H, then the value of m is changed and the method returns to step 22, as represented by arrow 28.

The particular new value that is selected for m depends on the current situation: if all of the transponders have their respective bytes S_n greater than the value m, then it is increased; in contrast, if all of the transponders have their respective bytes S_n less than the value of m, then, on the contrary, it is decreased.

The value of m is modified without changing the value of n so that by interval halving a value is obtained as quickly as possible for which equality is obtained between the byte S_n and the contents of the register H_n of at least one transponder, giving a maximum of eight iterations; if transponders 1 having their byte S_n greater than the value m are present simultaneously with transponders having their byte S_n less than the value m, then attention is paid initially only to those transponders for which the byte S_n is greater than the value m, for example, with the other transponders being dealt with subsequently.

When the analysis apparatus 3 receives binary value 1 in the second time window of the group G_n under consideration, that means that there is at least one transponder 1 for which S_n is equal to the value m; under such circumstances, in a step 30, a read order is sent to read the serial number of said transponder(s).

This read order is given and index value p which is taken to be equal to the current value of n.

If p = 0, then only those transponders for which there is an 8-bit match between the comparison register H and the serial number S reply, i.e. only those for which

there is a match between S_0 and the contents of address H_0.

If p = 1, only those transponders for which there is a 16-bit match between the comparison register H and the serial number S reply, i.e. only those for which there is a match between both S_1 and S_0 and the contents of addresses H_1 and H_0 respectively.

If p = 2, only those transponders for which there is a 24-bit match between the comparison register H and the serial number S reply, i.e. only those for which there is a match between S_2, S_1, and S_0 and the contents of addresses H_2, H_1, and H_0, respectively.

In step 31, every transponder concerned simultaneously transmits the four bytes S_2, S_1, and S_0 constituting its serial number S.

If only one transponder 1 is responding, then in step 33 the analysis apparatus 3 is capable of analyzing and reading the serial number so as to store it in step 34 and then return to the method to identify the remaining transponders.

However, if a plurality of transponders 1 reply, given that their serial numbers are different, then there is mutual interference which is detected by the analysis apparatus 3.

Another term is "collision", and in any event it is necessary to perform comparison on a larger number of bits and to determine the value of at least one byte of greater significance in the serial number.

When a plurality of transponders share the same byte S_0, the value of the byte S_1 is determined, and where necessary, i.e. when a plurality of transponders share serial numbers that match on 16 bits, then the value of the byte S_3 is determined likewise, but that is exceptional.

To determine the value of byte S_{n+1}, the method returns to step 22 after incrementing the value of n by unity.

Each identified transponder is placed in a listen mode in which it ceases to transmit the results of comparisons between its own serial number and the comparison register H, by loading its register H with its own serial number.

With reference to Figure 6, there follows a description of an implementation of the method to identifying four transponders having the following serial numbers: 12345678, 12345680, 65432178, 55555578.

The comparison registers of the four transponders are initially at 00000000, and the method begins by loading hexadecimal 80 in the least significant byte S_0 by the analysis apparatus 3 transmitting the order to write the value 80 at address H_0 (the contents of the comparison register is shown on the right of Figure 6).

In response to this write order, the analysis apparatus receives the signal 110 in group G_0 of time windows associated with byte S_0, i.e. at least one of the four transponders transmits binary value 1 in the time window extending between instants t_{11} and t_{12}, which means that the least significant byte S_0 of the serial number of at least one of the transponders is equal to 80.

The analysis apparatus 3 then transmits a read order with p = 0, which causes the, or each, transponder whose least significant byte S_0 is equal to the contents of address H_0 of the comparison register to read its own serial number.

Since only one of the four transponders in the example described has a serial number that terminates in hexadecimal value 80, the analysis apparatus 3 can read the serial number 12345680 transmitted by that transponder and can store it.

Thereafter, to put that transponder into standby mode, the analysis apparatus 3 sends in succession orders to write the value 56 at address H_1 of the comparison register, the value 34 at address H_2 of the comparison

register, and the value 12 in the most significant byte H_3 of the comparison register.

Once this transponder has been put on standby, there still remain three transponders to be identified, i.e. the transponders having the following serial numbers: 12345678, 65432178, and 55555578.

Because it has received binary value 1 in the time window extending between instants t_{12} and t_{13}, the analysis apparatus 3 knows that all of the remaining transponders have byte S_0 less than the hexadecimal value 80 contained at address H_0 of the comparison register.

Consequently, it decreases the contents at address H_0, and takes 40 as the new value for comparison purposes, i.e. it takes half the hexadecimal value 80.

The analysis apparatus 3 then sends the order to write hexadecimal value 40 at address H_0, to which the transponders respond by transmitting the signal 001 in time window group G_0, i.e. binary value 1 in the time window that extends between instants t_{12} and t_{13}, since every one of them has a byte S_0 that is greater than 40.

The analysis apparatus 3 then again changes the contents of address H_0 of the comparison register, each time to a value that is halfway along a range whose end values are respectively greater than and less than the value to be determined.

The analysis apparatus 3 thus sends in succession orders to write the following hexadecimal values in address H_0 of the comparison register: 60, then 70, and finally 78.

The analysis apparatus 3 then receives from all three transponders binary value 1 in the time window which extends between instants t_{11} and t_{12}.

It can happen, exceptionally, as illustrated in the example under consideration, that the comparison register of a transponder finds itself loaded by chance with the full value of its own serial number during the successive iterations for identifying the transponders.

Under such circumstances, the transponder in question transmits binary value 1 in the second time window of each of the four groups G_3, G_2, G_1, and G_0 of the time windows in order to inform the analysis apparatus 3 that it has a match between each of the bytes of its comparison register and each of the bytes of its serial number.

Thereafter, this identified transponder switches to standby, however the analysis apparatus has been able to store its serial number which is equal to 12345678 in this case.

The analysis apparatus 3 sends a read order requesting transmission from the, or each, transponder which has hexadecimal value 78 for the last byte S_0 of its serial number.

In the example described, the two transponders that have not been identified both reply simultaneously, and since their serial numbers are different, there is interference between the information they transmit.

The analysis apparatus 3 is therefore incapable of reading the serial numbers and it deduces that there must be at least two transponders having a serial number that terminates in hexadecimal value 78.

In order to identify those transponders it is necessary to perform comparison on the next most significant byte S_1 of the serial numbers.

The analysis apparatus 3 thus begins a new identification process, modifying on each occasion the contents of address H_1 while leaving the contents of address H_0 unchanged.

Hexadecimal value 80 is initially loaded into address H_1.

The transponders reply in groups G_1 and G_0 of time windows, with the signal received in group G_1 being 100 since both remaining transponders have respective bytes S_1 that are less than hexadecimal value 80.

Thereafter, the analysis apparatus 3 halves the contents of address H_1 of the comparison register, thereby causing binary value 1 to be sent in each of the time windows that extend between instants t_7 and t_8, and t_9 and t_{10}, since of the two remaining transponders, one has its byte S_1 less than hexadecimal value 40, and the other has its byte S_1 greater than hexadecimal value 40.

Initially, analysis apparatus 3 searches only for the transponder whose byte S_1 is greater than hexadecimal value 40, and this value is changed by successive range halving until hexadecimal value 55 is reached, thereby causing binary value 1 to be transmitted in the time window that extends between instants t_8 and t_9.

The analysis apparatus 3 then sends a read order with p = 1 for the attention of the transponder for which there is a 16-bit match between the contents of the comparison register and its serial number, i.e. the transponder whose serial number is 55555578.

The analysis apparatus 3 receives this serial number and thereafter loads hexadecimal value 55 at addresses H_2 and H_3 of the comparison register so as to put this transponder into standby mode.

The analysis apparatus 3 has stored the fact that there exists a plurality of transponders having a serial number in which the least significant byte has hexadecimal value 78, and it has also identified one of them by making comparisons on the byte S_1 of the next higher significance, so it now sends a new read order to cause the remaining transponder(s) having byte S_0 equal to hexadecimal value 78 to transmit its or their serial number(s).

In the example under consideration, there is only one remaining transponder, the transponder whose serial number is 65432178.

The analysis apparatus 3 thereafter loads this serial number into the comparison register, thereby putting that transponder on standby.

The person skilled in the art will have observed on reading the above that each transponder is identified while using a relatively small number of iterations, thus making it possible to identify a large number of transponders quickly, with each transponder being identified in 250 ms on average, for example.

In the example described with reference to Figure 6, the contents of the comparison register is never reinitialized to 00000000.

In a variant that is not shown, each transponder transmits only in the time window G_n corresponding to the significance n of the byte most recently loaded into the comparison register, and the comparison register is reinitialized to 00000000 each time the serial number of a transponder has been determined.

There follows a description, with reference to Figure 7 of a second implementation of the invention.

It is assumed that four transponders 1a, 1b, 1c, and 1d having respective identity codes 12345678, 12345680, 65432178, and 10345680 are placed in the field of an analysis apparatus 3.

The transponders 1a to 1d have a comparison register H identical to that of the transponders described above.

The transponders 1a to 1d are organized to transmit the result of a comparison between the binary word H_n placed most recently in the comparison register H and the word S_n of corresponding weight in the serial number S, in one of three time windows of a group Gc of three time windows corresponding respectively to the cases where the result of the comparison is less than, equal to, or greater than, said time windows extending respectively between instants t_1 and t_2, t_2 and t_3, and t_3 and t_4. Each transponder 1a to 1d transmits the result of a comparison relating to a byte S_n of its serial number only if all the bytes S_m of smaller weight in the serial number for m lying in the range 0 to n-1 are respectively equal to the corresponding bytes H_m of the comparison register.

The transponders 1a to 1d are also organized to transmit in a fourth time window Ge extending between instants t_4 and t_5 when the serial number is equal to the contents of the comparison register. In the event of such a match, the transponder that has just transmitted in this fourth time window puts itself into a standby mode for the remainder of the identification method.

In this case, the analysis apparatus 3 is suitable for analyzing the responses of as-yet unidentified transponders in the four above-mentioned time windows, i.e. the three time windows of the set Gc corresponding to the results of the comparisons performed by the as-yet unidentified transponders between the identity data most recently stored in their transponders and the corresponding portions of their respective identity codes as determined by the address selected by the analysis apparatus; and in the fourth time window Ge corresponding to the fact that the identity code of a transponder matches the entire identity data stored by said transponder in the various selected addresses.

In the method described with reference to Figure 7, in general:

a) a byte of given significance H_n of the comparison register H of every unidentified transponder is loaded with a value $\underline{m}$ by the analysis apparatus 3 transmitting an order to write said value $\underline{m}$ in said byte H_n;

b) said byte of given significance H_n is compared within each unidentified transponder with the byte S_n of corresponding significance in its serial number S;

c) depending on the result of the comparison, greater than, equal to, or less than, each unidentified transponder transmits a response respectively in the above-mentioned first, second, or third time window, providing the serial number bytes of significance smaller than the byte on which a comparison is actually being performed are all equal to the corresponding bytes of the comparison register;

d) within each unidentified transponder, the comparison register is compared with the serial number and if they match, the transponder transmits in said fourth time window and then after transmitting in said fourth time window, the transponder is put into a standby mode;

e) the analysis apparatus 3 analyzes the responses; and

f) in the event of a transmitter transmitting in said fourth time window, its serial number is determined as a function of the data that has been stored in the comparison register of that transponder;

g) in the event of none of the responses corresponding to a match between the byte of the most-recently given significance loaded into the comparison register and the byte of corresponding significance of the serial number, the method starts again at above step a) after modifying the value m previously loaded into the comparison register at the same address H_n so as to reach, by a range-halving technique, the situation in which the analysis apparatus 3 detects a response corresponding to the fact that the value of the byte H_n of given weight in the comparison register matches the byte S_n of corresponding weight in the serial number of at least one transponder;

h) if there is a response corresponding to the fact that there is a match between the byte H_n of given weight in the comparison register H and the byte S_n of corresponding weight of the serial number, the analysis apparatus 3 sends a read order causing every transponder in which said match has occurred to transmit its serial number;

i) in the event of it being impossible to read the serial numbers transmitted by the transponders in step h) because of interference, the byte H_{n+1} of the comparison register having the next greater significance is loaded with a given value m, and said value is modified, where

necessary, by a range-halving technique so as to obtain, on analyzing the responses delivered by the transponders, a response corresponding to the fact that there is a match between the value of the byte of given significance most recently loaded into the comparison register and the corresponding portion of the serial number in at least one transponder, in which case a read order is transmitted causing every transponder for which said match occurs to transmit its serial number;

j) when it is possible to read a serial number because only one transponder is responding, said serial number is stored and then the comparison registers of said transponder is loaded with this serial number so as to put it in standby mode; and

k) in the event of it being impossible to read the serial numbers transmitted by the transponders because of interference, the method starts again at step i).

More particularly, the method begins by loading byte H_0 of the comparison registers of all four transponders in Figure 7 with hexadecimal value 80.

The transponders 1a and 1c whose corresponding serial number byte is 78 transmit in the time window lying between instants t_1 and t_2 to inform the analysis apparatus that the value of the corresponding byte S_0 of their serial numbers is less than 80.

The transponders 1b and 1d transmit in the time window that extends between instants t_2 and t_3 to inform the analysis apparatus 3 that the value of the corresponding byte in their serial numbers is 80.

Thereafter the analysis apparatus asks the transponders that have replied in the second time window to transmit their serial numbers. Specifically, the transponders 1b and 1d transmit simultaneously so there is a collision, and the analysis apparatus 3 detects the collision.

The analysis apparatus 3 then loads hexadecimal value 80 into the byte having the next greater significance of the comparison register, i.e. byte H_1.

The transponders 1b and 1d then reply in the first time window.

The analysis apparatus 3 then transmits again so as to modify the value of byte H_1 in the comparison register, changing it to 40.

This time, the transponders 1b and 1d transmit in the third time window since the values of the corresponding bytes S_1 of their respective serial numbers are all greater than 40.

The analysis device 3 proceeds by a range-halving technique and after a few iterations loads hexadecimal value 56 into byte H_1.

The transponders 1b and 1d then reply in the second time window.

The analysis apparatus 3 again requests all of the transponders that have replied in the second time window to transmit their respective serial numbers.

The transponders 1b and 1d still reply simultaneously, thereby giving rise to a collision which is detected by the analysis apparatus 3.

The analysis apparatus then loads hexadecimal value 80 into the next most significant byte of the comparison register, i.e. H_2.

The transponders 1b and 1d respond in the first time window. The analysis apparatus 3 then halves the value in byte H_2, so that it becomes 40. The transponders 1b and 1d respond again in the first time window.

After a few iterations, not shown, the value of the byte H_2 is hexadecimal 34, and the transponders 1b and 1d reply in the second time window.

The analysis apparatus 3 again requests the transponders that have responded in the second time window to transmit their identity codes. The transponders 1b and 1d respond simultaneously, giving

rise yet again to a collision which is detected by the analysis apparatus 3. This apparatus then loads the value 80 into byte H_3 of the comparison register and after a certain number of iterations, as shown in Figure 7, the value of register H_3 becomes, equal to 10. Only the transponder 1d then transmits in the second time window, and since the contents of its comparison register then is equal to its serial number, this transponder 1d also transmits in the fourth time window. The analysis apparatus detects this transmission and stores the content of the comparison register. The transponder 1d which has just transmitted in the fourth time window puts itself into standby mode.

The analysis apparatus 3 then requests the other transponders that have previously responded to the order to transmit their respective serial numbers to transmit again. This request is made by sending an order to the transponders requiring them to transmit their serial numbers if the value of byte H_3 (i.e. the byte of significance next smaller than that which the most recent comparison register modifications applied) is equal to the corresponding byte S_2 of their serial numbers.

In this case, only transponder 1b transmits its serial number, having its byte S_3 equal to 12.

The analysis apparatus then loads the value 12 into byte H_3 of the comparison register to put transponder 1b into standby mode.

Thereafter, the analysis apparatus 3 takes up the identification method by modifying the value of byte H_0 in the comparison register and by range halving this value ends up by being equal to 78.

The transponder 1c then responds in the second and fourth time windows and then puts itself into standby mode.

The analysis apparatus 3 then requests all of the other transponders that responded in the second time window to send their identity numbers.

Only the transponder 1c responds, thereby enabling it to be identified. Thereafter, the analysis apparatus loads the comparison register with the serial number of said transponder so as to put it into standby mode as well.

Finally, when the analysis apparatus seeks to continue the identification method and loads a new value, specifically 22 into byte H_0, no transponder responds, meaning that all of the transponders have been identified, and have been put into standby mode.

The data transmitted by the transponders is preferably preceded and followed by a synchronization signal.

It is possible initially, before the identification method has been implemented, that not all of the transponders are reached simultaneously by the field of the antenna 2 when the apparatus 3 is activated, or that the smoothing capacitors they contain do not all have the same charging time, in which case they will not all be activated simultaneously.

This means that the transponders will not all respond synchronously, such that the signals transmitted by the transponders interfere so that the analysis apparatus cannot read them.

That is why, in the event of interference, transmission from the analysis apparatus is interrupted for a given length of time, and then transmission is restarted, so that all of the transponders are synchronized when transmission is restarted.

If in spite of that there continues to be interference, then there is an anomaly, and the analysis apparatus 3 gives a warning.

Naturally, the invention is not restricted to the implementations described above.

In particular, in the implementations described, the comparison register has four bytes, but in a variant that is not shown, it could have a greater or smaller number

of binary words each of which could have a greater or smaller number of bits.

Once the serial numbers are known, the number of transponders present in the field of the antenna 2 is also known, and it is possible to address each of them individually.

To address a transponder individually, it suffices to load the comparison register with its serial number and then send a special instruction instructing the transponder whose serial number is equal to the contents of the comparison register to enter into communication with the analysis apparatus 3 for the purpose of reading or writing information in its own memory 13.

Although the invention has been described by making comparisons initially on the least significant byte S_0 of the serial number, and subsequently making comparisons where necessary on the more significant bytes S_1, S_2, S_3, it would not go beyond the ambit of the present invention to start by making comparisons on the most significant byte S_3, and subsequently, and where necessary, making comparisons on the less significant bytes S_2, S_1, and S_0.

CLAIMS

1/ A method of identifying a set of transponders situated in the field of analysis apparatus, each transponder having a different identity code (S) in memory, the method being characterized by the fact that it comprises the steps consisting in:

a) causing the analysis apparatus (3) to transmit data (H_n, m) for comparison with a portion (S_n) of the identity code (S) as selected by the analysis apparatus;

b) causing each as-yet unidentified transponder (1; 1a, 1b, 1c, 1d) to compare the received data (H_n, m) and the portion of its identity code (S) as selected by the analysis apparatus;

c) causing each as-yet unidentified transponder to transmit in at least one time window selected from a set (G_3, G_2, G_1, G_0; Gc, Ge) of time windows common to the set of transponders as a function of the result of said comparison; and

d) causing the analysis apparatus (3) to analyze the data transmitted by the transponders (1; 1a, 1b, 1c, 1d) in said set (G_3, G_2, G_1, G_0; Gc, Ge) of time windows, and when the data transmitted by the transponders (1) does not enable a transponder identity code to be determined, at least in part, causing the apparatus to start again with data (H_n, m) that has been modified in such a manner that, within a finite number of iterations, the transponders are caused to transmit data enabling the identity code of at least one of the transponders to be determined, at least in part.

2/ A method according to claim 1, characterized by the fact that each transponder (1; 1a, 1b, 1c, 1d) includes a comparison register (H) in which the data for comparison is stored.

3/ A method according to claim 2, characterized by the fact that said comparison register (H) is organized to

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store a plurality of binary words (H_3, H_2, H_1, H_0), by the fact that the identity code is constituted by binary words (S_3, S_2, S_1, S_0), by the fact that the analysis apparatus (3) modifies, one at a time, a binary word (H_n) of given significance (n) in the comparison register, and by the fact that each as-yet unidentified transponder (1) compares the most-recently modified binary word and the binary word of corresponding significance in its identity code, the portion of the identity code on which comparison is to be performed being selected by selecting the significance of each new binary word that is to be stored in the comparison register.

4/ A method according to claim 3, characterized by the fact that each transponder (1a, 1b, 1c, 1d) transmits in a first set (Gc) of time windows the result of comparing the most-recently modified binary word and the portion of its identity code that has been selected by the analysis apparatus, providing the bytes of its identity code already determined by the analysis apparatus are respectively equal to the corresponding bytes of the comparison register, and transmits in a second set of time windows (Ge) the result of comparing the entire comparison register with the entire identity code.

5/ A method according to claim 4, characterized by the fact that said second set of time windows is reduced to a single time window in which each transponder transmits in the event of a match between its comparison register and its identity code.

6/ A method according to any preceding claim, characterized by the fact that it further comprises the step constituting in:

· causing the analysis apparatus (3), whenever the data previously received thereby makes this possible, to determine at least a portion of the identity code of one

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or more transponders, to send an order causing said transponder(s) to transmit its/their identity code(s); and

· analyzing said identity code(s) as received to determine whether only one identity code was transmitted or whether there has been interference associated with a plurality of different codes being transmitted, and in the event of only one identity code being received, storing said code.

7/ A method according to the preceding claim, characterized by the fact that, when a plurality of transponders transmit a plurality of different identity codes simultaneously and they interfere with one another, the method further includes the step consisting in sending new data to be compared with a new portion of the identity code in said transponders, other than the portion (S_0) already determined by the analysis apparatus, optionally in modifying said new data until said new identity code portion (S_1) has been determined, and thereafter in causing the transponder(s) for which the new identity code portion has been determined to transmit its/their identity code(s), and in the event of interference restarting the process for determining the identity code again by causing the comparison to be performed on an as-yet undetermined portion of the identity code, until only one identity code is received from the transponders.

8/ A method according to any preceding claim, characterized by the fact that each identified transponder is put into a standby mode in which it ceases to transmit the result of comparing its own identity code (S) with the data (H_n, m) transmitted by the analysis apparatus.

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9/ A method according to the preceding claim, characterized by the fact that each transponder that has been identified is put into said standby mode by using the analysis apparatus to transmit the identity code of the transponder.

10/ A method according to claim 2, characterized by the fact that each transponder whose comparison register is equal to its identity code puts itself into a standby mode.

11/ A method of identifying the serial number (S) of all the transponders (1) in a plurality of transponders (1) located simultaneously in the field of an analysis apparatus (3), each transponder (1) having a comparison register (H) capable of storing a plurality of bytes, preferably four bytes, in which method:

a) a byte (H_n) of given significance of the comparison register (H) in all of the unidentified transponders is loaded with a value (m) by causing the analysis apparatus (3) to send an order to write said value (m) in said byte (H_n):

b) within each transponder (1) said byte of given significance (H_n) is compared with the byte (S_n) of corresponding significance in its serial number (S);

c) for this byte of given significance (H_n) of the comparison register, and depending on the result of the comparison, greater than, or equal to, or less than, every as-yet unidentified transponder transmits a response respectively in a first, a second, or a third time window of a group (G_n) of three time windows associated with the significance (n) of the byte on which the comparison has been performed, said group being selected from a plurality of time window groups (G_3, G_2, G_1, G_0) respectively associated with bytes of different significance (n) of the comparison register, each as-yet unidentified transponder transmitting the result of

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comparing the byte of given significance (H_n) most recently loaded into the comparison register with the corresponding byte of its serial number, with the proviso, when the byte of given significance on which comparison is being performed is not the least significant byte, respectively the most significant, that there is a match between the less significant bytes, respectively the more significant, of the comparison register and the corresponding bytes of the serial number;

d) the analysis apparatus (3) is caused to analyze the responses, and:

· when none of the responses corresponds to a match between the byte of given significance most recently loaded into the comparison register and the byte of corresponding significance in the serial number, the method begins again at above step a) by modifying the value (n) previously loaded into the comparison register at the same address (H_n) by a range-halving technique so as to reach a situation in which the analysis apparatus (3) detects a response corresponding to the fact that the value of the byte (H_n) of given significance in the comparison register matches the byte (S_n) of corresponding significance in the serial number;

· if one of the responses corresponds to the fact that there is a match between the byte (H_n) of given significance in the comparison register (H) and the byte (S_n) of corresponding significance in the serial number, the analysis apparatus (3) is caused to send a read order causing every transponder for which a match has occurred to send its serial number (S);

· in the event of it being impossible to read the serial numbers transmitted by the transponders (1) because of mutual interference, a given value (m) is loaded into the next most, respectively least, significant byte (H_{n+1}) of the comparison register, and said value is modified by a range-halving technique until

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analysis of the responses from the transponders indicates a match with the corresponding byte (S_{n+1}) of the serial number; and

· when a serial number can be read because only one transponder is responding, said serial number is stored.

12/ A method of identifying the serial number (S) of each transponder (1) in a plurality of transponders (1) placed simultaneously in the field of an analysis apparatus (3), each transponder (1) having a comparison register (H) capable of storing a plurality of bytes, preferably four bytes, in which method:

a) a byte of given significance (H_n) of the comparison register (H) of every unidentified transponder is loaded with a value (m) by the analysis apparatus (3) transmitting an order to write said value (m) in said byte (H_n);

b) said byte of given significance (H_n) is compared within each transponder (1) with the byte (S_n) of corresponding significance in its own serial number (S);

c) depending on the result of the comparison, greater than, equal to, or less than, each unidentified transponder transmits a response respectively in a first, a second, or a third time window, providing the serial number bytes of significance smaller, respectively higher, than the byte on which a comparison is actually being performed are all equal to the corresponding bytes of the comparison register;

d) within each unidentified transponder, the comparison register is compared with the serial number and if they match, the transponder transmits in a fourth time window and then after transmitting in said fourth time window, the transponder is put into a standby mode;

e) the analysis apparatus (3) analyzes the responses; and

f) in the event of a transmitter transmitting in said fourth time window, its serial number is determined

as a function of the data that has been stored in the comparison register of that transponder;

g) in the event of none of the responses corresponding to a match between the byte of the most-recently given significance loaded into the comparison register and the byte of corresponding significance of the serial number, the method starts again at above step a) after modifying the value (m) previously loaded into the comparison register at the same address (H_n) so as to reach, by a range-halving technique, the situation in which the analysis apparatus (3) detects a response corresponding to the fact that the value of the byte (H_n) of given weight in the comparison register matches the byte (S_n) of corresponding weight in the serial number of at least one transponder;

h) if there is a response corresponding to the fact that there is a match between the byte (H_n) of given weight in the comparison register (H) and the byte (S_n) of corresponding weight of the serial number, the analysis apparatus (3) sends a read order causing every transponder in which said match has occurred to transmit its serial number;

i) in the event of it being impossible to read the serial numbers transmitted by the transponders (1) in step h) because of interference, the byte (H_{n+1}) of the comparison register having the next greater, respectively smaller, significance is loaded with a given value (m), and said value is modified, where necessary, by a range-halving technique so as to obtain, on analyzing the responses delivered by the transponders, a response corresponding to the fact that there is a match between the value of the byte of given significance most recently loaded into the comparison register and the corresponding portion of the serial number in at least one transponder, in which case a read order is transmitted causing every transponder for which there is a match to transmit its serial number;



j) when it is possible to read a serial number because only one transponder is responding, said serial number is stored and then the comparison registers of all the transponders are loaded with this serial number so as to put the transponder which responded in standby mode; and

k) in the event of it being impossible to read the serial numbers transmitted by the transponders because of interference, the method starts again at step i).

13/ A transponder of the type comprising an identification code such as a serial number stored in a memory (13) and means for remote communication with analysis apparatus (3), the transponder being characterized by the fact that it includes a comparison register (H) in which data from the analysis apparatus (3) can be stored, calculation means (10) for comparing at least a portion of the identity code (5) with at least a portion of the comparison register (H), and means for transmitting the result of the comparison in at least one time window selected from a set of time windows, the particular time window depending on the result of the comparison.

14/ A transponder according to claim 13, characterized by the fact that the comparison register (H) is constituted by a plurality of binary words (H_3, H_2, H_1, H_0) of different significance, and by the fact that said calculation means (10) are organized to compare the binary word (H_n, m) most recently stored in the register with a binary word of corresponding significance (S_n) of the identity code.

15/ A transponder according to claim 14, characterized by the fact that the transponder is organized to transmit the result of the comparison between the binary word most recently stored in the register and the binary word of

corresponding significance of the serial number, except in the event of the comparison being performed on a word other than the least, respectively most, significant binary word and there is no match between the binary word(s) of significance less, respectively higher, than that of the word most recently stored in the register and the corresponding binary word(s) of the identity code.

16/ A transponder according to any one of claims 13 to 15, characterized by the fact that the comparison register has four bytes.

17/ A transponder according to any one of claims 13 to 16, characterized by the fact that it is organized to transmit the result of the comparison only once when the contents of the comparison register matches the identity code.

18/ A transponder according to claim 14, characterized by the fact that it is organized to transmit the result of comparing the binary word most recently stored in its comparison register and the word of corresponding significance of its serial number in one of three time windows corresponding respectively to the case where the result of the comparison is less than, equal to, and greater than.

19/ A transponder according to claim 18, characterized by the fact that it is organized also to transmit in a fourth time window when its serial number matches the comparison register.

20/ Analysis apparatus for a plurality of transponders having different identity codes, the apparatus being characterized by the fact that it includes processor means (5) organized to determine the identity codes of a plurality of transponders placed in the field of the



analysis apparatus, said analysis apparatus (3) being suitable for:

· transmitting a write order associated with identity data, said order causing said identity data (m) to be stored in the transponders at a particular address (H_n) selected by the analysis apparatus;

· analyzing the response from as-yet unidentified transponders in a set of time windows (G_3, G_2, G_1, G_0) after said identity data has been transmitted;

· transmitting a read order to cause the transponders whose identity codes have been determined in part to send their identity codes in full;

· transmitting a new write order associated with new identity data (H_{n+1}, m) in the event of interference between the data transmitted by the transponders, so as to end up by causing only one transponder at a time to send its identity code, and storing said code; and

· repeating the above steps so as to identity all of the transponders in turn.

21/ Apparatus according to claim 20, characterized by the fact that the analysis apparatus is suitable for:

· analyzing the responses of as-yet unidentified transponders in four time windows, three of the time windows corresponding to the results of comparisons performed by the as-yet unidentified transponders between the identity data most recently stored in the transponders and a portion of their respective identity codes as determined by the address selected by the analysis apparatus, transmission by a transponder in the fourth time window corresponding to the fact that the identity code of the transponder matches the entire identity data stored by said transponder in the various selected addresses.

22/ Apparatus according to claim 20 or 21, characterized by the fact that it includes an antenna (2) constituted by a solenoid in which the transponders are placed.

23/ A method of enabling transponders situated in the field of an analysis apparatus to be identified, each transponder having a different identity code (S), the method being characterized by the fact that it comprises the steps consisting in:

a) using the analysis apparatus (3) to transmit data (H_n, m) to be compared with a portion (S_n) of the identity code (S) selected by the analysis apparatus;

b) within each unidentified transponder (1; 1a, 1b, 1c, 1d), comparing the received data (H_n, m) and a corresponding portion of the transponder's identity code (H);

c) causing each unidentified transponder to transmit in at least one time window selected from a set (G_3, G_2, G_1, G_0; Gc, Ge) of time windows common to the set of transponders;

d) using the analysis apparatus (3) to analyze the data transmitted by the transponders (1; 1a, 1b, 1c, 1d) in said set (G_3, G_2, G_1, G_0; Gc, Ge) of time windows, and when the data transmitted by the transponders (1) does not enable at least part of the identity code of at least one of the transponders to be identified, beginning again with data (H_n, m) modified in such a manner that, after a finite number of iterations, the transponders transmit data making it possible to determine at least a part of the identity code of at least one of the transponders;

e) causing the analysis apparatus, when the data previously received thereby makes it possible to determine at least a portion of the identity code of one or more transponders, to transmit an order causing every such transponder to transmit its own identity code; and

f) analyzing reception of the identity code (S) to determine whether a single identity code has been

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transmitted or whether interference has occurred associated with simultaneous transmission of a plurality of different codes, and when only one identity code is received, storing said code.

24/ Analysis apparatus and a set of transponders for implementing the method defined in the preceding claim.

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