

ENHANCED DETECTION OF MULTIPLE DATA TRANSMISSIONS

BACKGROUND OF THE INVENTION

THIS invention relates to a method of identifying a plurality of transmitters, each of which transmits data at intervals to a receiver. The invention also relates to an identification
5 system comprising a plurality of transmitters and a receiver, and to the transmitters themselves. The invention further relates to method and apparatus for improving the identification systems disclosed in EP 494,114 A and, in particular, EP 585,132 A.

Identification systems are known in which a plurality of transmitters, typically transponders, are activated by an interrogation signal and then transmit reply signals,
10 usually containing identification data, to a receiver, which typically forms part of the interrogator. The signals may be transmitted in many ways, including electromagnetic energy, e.g. radio frequency (RF), infra red (IR), and coherent light, and sound, e.g. ultrasound. For example, the transmission may be achieved by actual emission of RF energy by the transmitters, or by the modulation of the reflectivity of an antenna of the
15 transmitter, resulting in varying amounts of RF energy in the interrogation signal being reflected or back-scattered from the transmitter antenna.

In general, if the transmissions of two transmitters overlap or clash, the transmissions are lost, since the receiver cannot distinguish the separate transmissions. Thus, the system must provide for each transmitter to transmit repeatedly until its transmission takes place
20 in a "quiet" time and is successfully received by the interrogator. GB 2,116,808 A discloses an identification system in which the individual transponders are programmed to retransmit data in a pseudo-random manner. Timing signals for the transponders in this identification system are derived from a crystal oscillator, thereby making the transponders more expensive to manufacture.

25 EP 467.036 A describes another identification system which uses a pseudo-random delay between transponder data transmissions. In this example, a linear recursive sequence

generator is seeded by the transponder identification address to make the pseudo-random delay as random as possible.

It is an object of the invention to provide an alternative system for enhancing the detection of multiple transmissions in a system of this kind.

- 5 EP 494,114 A and EP 585,132 A disclose identifications systems in which the transponders may be programmed with the same data. It is an object of this invention to provide an improved system for generating the pseudo-random delays between transponder transmissions.

SUMMARY OF THE INVENTION

- 10 According to a first aspect of the invention there is provided a method of identifying a plurality of transmitters, each transmitting at intervals to a receiver, comprising varying the duration of the intervals between successive transmissions from each transmitter by enabling each transmitter at intervals which are calculated randomly or pseudo-randomly and are related to an operating frequency of local timing means associated with that
15 transmitter.

The intervals are preferably varied between a maximum duration which is related to a predetermined number of cycles of the local timing means, and a minimum interval.

- In the above method, the duration of the intervals between transmissions may be calculated by periodically generating pseudo-random numbers, comparing the pseudo-random number
20 with an output of counter means clocked by the local timing means, and enabling the transmitter when the pseudo-random number and the output of the counter means correspond.

According to a second aspect of the invention there is provided an identification system comprising a plurality of transmitters each adapted to transmit at intervals and at least one

receiver for receiving transmissions from the transmitters, each transmitter including means for generating transmissions, means for calculating the duration of the intervals between successive transmissions and means for enabling the transmitter at random or pseudo-random intervals related to an operating frequency of local timing means.

- 5 According to third aspect of the invention there is provided a transmitter adapted to transmit at intervals comprising means for generating transmissions, means for calculating the duration of the intervals between successive transmissions and means for enabling the transmitter at random or pseudo-random intervals related to an operating frequency of local timing means.
- 10 The local timing means is preferably an oscillator of the transmitter, with an unspecified clock frequency which is subject to a relatively large tolerance, so that the oscillators of different transmitters tend to run at different frequencies.

- The enabling means may include a pseudo-random number generator arranged to generate pseudo-random numbers, counter means arranged to count at a rate related to the oscillator
- 15 frequency, and comparator means arranged to compare the outputs of the pseudo-random number generator and the counter means and to enable the transmitter only when the outputs correspond.

- The transmitters may be radio frequency identification (RF/ID) transponders. In transponders which embody the "anti-clash protocol" described in EP 494,114 A and EP
- 20 585,132 A, it is not necessary for the identification code of each transponder to be different; the transponders can be identical, allowing them to be manufactured in large quantities, very cheaply. It is an advantage of this invention that when such an anti-clash protocol is used there is better immunity against clashes. However, reading a plurality of transponders may be completed more rapidly if unique seeds are used in the pseudo-random number
- 25 generator.

The invention extends to a method of operating a transmitter and the integrated circuits from which the transmitters of the invention are customarily constructed.

BRIEF DESCRIPTION OF THE DRAWINGS

- Figure 1 is a block schematic diagram of a radio frequency transponder according to the invention;
- Figure 2 is a block schematic diagram of the transmit controller block in Figure 1; and
- Figure 3 is a schematic diagram showing the timing of the transmissions of two transponders or tags.

10 DESCRIPTION OF AN EMBODIMENT

The purpose of the present invention is to provide a method and a system which enhances the probability of identification of a number of transmitters, typically transponders, which are all transmitting data to a receiver. Although the embodiment described below refers to passive radio-frequency transponders which are activated and powered by an interrogation signal received from an interrogator, the invention is also applicable to other systems. For example, the invention may be employed in systems in which a number of self-powered transmitters must be identified by a receiver, or systems in which a number of transmitters broadcast using a randomly delayed "back-off and retry" algorithm.

The invention addresses this requirement by having the transmitters, or transponders, transmit at different times, at random or pseudo-random intervals, rather than at regular intervals. In addition, the degree of randomness of successive transmissions from each transponder is enhanced by deriving the random or pseudo-random timing from local timing means, typically an oscillator, of each transponder. The transponders may be of the type described in EP 494,114 A and EP 585,132 A, the entire contents of these documents being incorporated herein by reference. The relatively large tolerance in the operating

frequency of the oscillators of nominally identical transponders increases the randomness of their transmissions.

Referring now to Figure 1, a passive RF transponder is shown schematically. The transponder has an antenna 10 which receives energy from an RF interrogation signal transmitted by an interrogator, and a portion of this energy is diverted to charge a capacitor C which acts as a power supply for the transponder. The transponder has an on-board oscillator 12 which operates at the same nominal frequency as other nominally identical transponders. However, due to manufacturing tolerances in the preferred low cost integrated circuit transponders, the output frequency of the oscillator 12 typically has a manufacturing tolerance of $\pm 25\%$. The output frequency is also affected by the supply voltage VDD from the capacitor C, which is in turn affected by the strength of the received energy from the interrogation signal due to proximity to the interrogator, antenna orientation and other factors. Thus each tag has an oscillator whose frequency is subject to significant uncertainty, being dependent on both manufacturing tolerances and supply voltage, which is itself dependent on received RF field strength. The frequency of each oscillator is therefore indeterminate, being unspecified until the tag is in operation.

The heavy black line 1 indicates the components of the transponder which may be integrated into a monolithic integrated circuit.

The transponder includes a non-volatile memory element 14, typically an EEPROM, which stores the transponder's identification code and configuration information which programs the transponder for different code data transmission frequencies (bit rates), maximum delay time ($N_{max} \cdot T$), and seeds for a pseudo-random time delay circuit. The transponder further includes an output driver 16 which in the described embodiment modulates the load applied to the antenna 10, thus modulating its reflectivity, but which could also be an active transmitter. A control logic circuit 18 controls the operation of the output driver 16 and reads data from the memory element 14 in response to signals from a transmit controller circuit 20 which is shown in greater detail in Figure 2. A power on reset circuit 22

initialises the control logic circuit 18 into a predetermined start-up state when a voltage is applied to the circuit.

In Figure 2, the transmit controller circuit 20 is shown in greater detail. This circuit includes a sequencer 24 which receives the clock signal from the oscillator 12 and derives
5 from it a frequency, which may be lower, to generate a "memory read" signal which is applied to the control logic circuit 18, together with the clock signal. The "memory read" signal is a continuous sequence of pulses at a constant frequency and with a period T. Each of these pulses causes the control logic block 18 to instruct the memory element 14, via a
10 "read out command" signal, to output the identification code stored therein sequentially into the control logic circuit. However, the code is not passed to the output driver 16 by the control logic circuit for transmission unless the transmit controller 20 also outputs a
"transmit enable" signal to the control logic circuit 18 simultaneously with the respective "memory read" pulse. This occurs only occasionally, at pseudo-random time intervals, as described below.

15 The output of the sequencer circuit 24 is also fed to a code cycle counter 26 which is therefore incremented each time the identification code output sequence from the memory element 14 is started. The code cycle counter is never reset, but counts up to its maximum count, after which it returns to zero and counts up again. A pseudo-random number
20 generator circuit 28 generates a pseudo-random number from time to time, and both the output of the pseudo-random number generator 28 and the current output of the code cycle counter 26 are fed to a comparator 30. The comparator 30 gives an output whenever the two numbers being compared are equal, which output is the "transmit enable" signal referred to above. The transmit enable signal also triggers the pseudo-random number
25 generator to generate a new pseudo-random number. When the "transmit enable" signal goes high at the same time as the "memory read" signal, the code which has been read from the memory element 14 by the control logic circuit 18 is output to the output driver 16 and transmitted.

Referring to Figure 3, the transmissions of two transponders or tags, Tag 1 and Tag 2 are compared. Tag 1 has an oscillator running somewhat faster than Tag 2. Both have the same N_{max} programmed into them, but at the particular time shown in the diagram, Tag 1 will remain in a passive (non-transmitting) mode for a period of $N_1.T$, where N_1 varies with
5 each transmission/quiet cycle, ($0 \leq N \leq N_{max}$), while Tag 2 remains passive for $N_2.T$. Note that T for Tag 1 is not the same as for T for Tag 2, but subject to the same variations as the frequency referred to above. Furthermore, $T_1, T_2, T_3, \dots, T_N$ for any tag are not exactly equal owing to variations with time in the supply voltage for the particular tag. There are therefore frequency variations between tags, and between different times with the
10 same tag. The anti-clash system used in this invention achieves a considerably better immunity against clashes than if the tag clock signals were derived from the RF carrier frequency (by frequency division, for example), as is the case in some other RF identification systems, and is relatively inexpensive to implement.

The value of N_{max} is determined by the number of bits being compared by the comparator
15 30. In the case of an 8 bit comparison, $N_{max}=255$. N_{max} is configured at the time of programming or manufacture of the transponders. It has been experimentally determined that for a particular figure of N_{max} there is a practical limit to the number of transponders or tags which can be read simultaneously, in the same RF interrogation field. If the number of transponders in the same interrogation field is compared with the time taken for all
20 transponders to be identified successfully, that time is roughly proportional to the number of transponders, due to clashes between transponder transmissions, until the number of transponders approaches $N_{max}/2$. If the number of transponders is increased beyond this point, the time taken to identify the tags increases rapidly towards a condition where no transponders are identified at all, as all transmissions result in clashes.

25 Because of the various advantageous aspects of the design of the above described transponders, a large degree of randomness is obtained in the transmission of data from each transponder, notwithstanding that the transponders are programmed with the same value of N_{max} and are essentially identical. This means that the only value which may need to be adjusted from one transponder to the next is the transponder identification code.

It will be appreciated by those skilled in the art that the invention may be put into effect in a number of different systems. In systems in which the variation of local timing means is not an inherent feature, such a variation may be included into the system design. For example, a number of different crystal oscillator circuits which run at a various speeds may
5 be used. Each transmitter may be provided with a different oscillator circuit although the provision of unique frequencies for a set transmitters is not essential. Alternatively, transmitters may be able to dynamically alter the frequency of the local timing means, by e.g. switching between oscillator circuits. In the same spirit, local timing means in which the frequency is dependent on external factors e.g. temperature, incident light, may provide
10 the necessary variation in frequency.



Claims

1. A method of identifying a plurality of transmitters, each transmitting at intervals to a receiver, comprising varying the duration of the intervals between successive transmissions from each transmitter by enabling each transmitter at intervals which are
5 calculated randomly or pseudo-randomly and are related to an operating frequency of local timing means associated with that transmitter.
2. A method as claimed in claim 1 in which the intervals are varied between a maximum duration which is related to a predetermined number of cycles of the local timing means, and a minimum interval.
- 10 3. A method as claimed in claim 1 in which the operating frequency of the local timing means is indeterminate.
4. A method as claimed in claim 1 in which the duration of the intervals between transmissions may be calculated by generating pseudo-random numbers, comparing the pseudo-random number with an output of counter means clocked by the local timing
15 means, and enabling the transmitter only when the pseudo-random number and the output of the counter means correspond.
5. A method as claimed in claim 4 in which the pseudo-random numbers are generated periodically.
6. An identification system comprising a plurality of transmitters each adapted to
20 transmit at intervals and at least one receiver for receiving transmissions from the transmitters, each transmitter including means for generating transmissions, means for calculating the duration of the intervals between successive transmissions and means for enabling the transmitter at random or pseudo-random intervals related to an operating frequency of local timing means.
- 25 7. An identification system as claimed in claim 6 in which the calculating means varies the intervals between a maximum duration which is related to a predetermined number of cycles of the local timing means, and a minimum interval.
8. An identification system as claimed in claim 6 in which the local timing means is an oscillator.
- 30 9. An identification system as claimed in claim 8 in which the clock frequency of each oscillator is subject to a relatively large tolerance.



10. An identification system as claimed in claim 8 in which the oscillators of different transmitters tend to run at different frequencies.
11. An identification system as claimed in claim 8 in which the operating frequency of the transmitter is indeterminate.
- 5 12. An identification system as claimed in claim 6 in which the calculating means includes a pseudo-random number generator arranged to generate pseudo-random numbers and counter means arranged to count at a rate related to the frequency of the local timing means
13. An identification system as claimed in claim 12 in which the enabling means
10 compares the output of the pseudo-random number generator with the output of the counter and enables the transmitter only when the pseudo-random number and the output of the counter means correspond.
- 14 An identification system as claimed in claim 13 in which the pseudo-random numbers are generated periodically.
- 15 15. A transmitter adapted to transmit at intervals comprising means for generating transmissions, means for calculating the duration of the intervals between successive transmissions and means for enabling the transmitter at random or pseudo-random intervals related to an operating frequency of local timing means.
16. A transmitter as claimed in claim 15 in which the calculating means varies the
20 intervals between a maximum duration which is related to a predetermined number of cycles of the local timing means, and a minimum interval.
17. A transmitter as claimed in claim 15 in which the local timing means is an oscillator.
18. A transmitter as claimed in claim 17 in which the clock frequency of the oscillator
25 is subject to a relatively large tolerance.
19. A transmitter as claimed in claim 15 in which the calculating means includes a pseudo-random number generator arranged to generate pseudo-random numbers and counter means arranged to count at a rate related to the frequency of the local timing means
20. A transmitter as claimed in claim 19 in which the enabling means compares the
30 output of the pseudo-random number generator with the output of the counter and enables



the transmitter only when the pseudo-random number and the output of the counter means correspond.

21 A transmitter as claimed in claim 20 in which the pseudo-random numbers are generated periodically.

5 22. A method of generating transmissions from a transmitter at random intervals comprising, varying the duration of the intervals between successive transmissions from each transmitter by enabling the transmitter at intervals which are calculated randomly or pseudo-randomly and are related to an operating frequency of local timing means associated with the transmitter

10 23. A method as claimed in claim 22 in which the intervals are varied between a maximum duration which is related to a predetermined number of cycles of the local timing means, and a minimum interval.

24. A method as claimed in claim 22 in which the duration of the intervals between transmissions may be calculated by generating pseudo-random numbers, comparing the
15 pseudo-random number with an output of counter means clocked by the local timing means, and enabling the transmitter only when the pseudo-random number and the output of the counter means correspond.

25. A method as claimed in claim 24 in which the pseudo-random numbers are generated periodically.

20 26. An integrated circuit for use in a transmitter comprising local timing means, means for calculating the duration of the intervals between successive transmissions and means for enabling the transmitter at random or pseudo-random intervals related to an operating frequency of the local timing means.

27. An integrated circuit as claimed in claim 25 in which the local timing means is an
25 oscillator.

28. An integrated circuit as claimed in claim 27 in which the clock frequency of the oscillator is subject to a relatively large tolerance.

29. An integrated circuit as claimed in claim 25 in which the calculating means includes a pseudo-random number generator arranged to generate pseudo-random numbers and
30 counter means arranged to count at a rate related to the frequency of the local timing means



30. An integrated circuit as claimed in claim 29 in which the enabling means compares the output of the pseudo-random number generator with the output of the counter and enables the transmitter only when the pseudo-random number and the output of the counter means correspond.