(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
30 November 2006 (30.11.2006)

PCT

(10) International Publication Number
WO 2006/126007 A1

(51) International Patent Classification:
G06K 7/00 (2006.01)

(21) International Application Number: PCT/GB2006/001943

(22) International Filing Date: 26 May 2006 (26.05.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0510783.4 26 May 2005 (26.05.2005) GB

(71) Applicant *(for all designated States except US)*: **SHEARWELL DATA LIMITED** [GB/GB]; Putham Farm, Wheddon Cross, Minehead Somerset TA24 7AS (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **TERESZCZAK, Mark** [GB/GB]; 60 Bampton Street, Minehead Somerset TA24 5TU (GB). **POWELL, George** [GB/AU]; 21 Sedges Grove, Canning Vale, Melbourne, Victoria WA 6155 (AU).

(74) Agents: **STONER, Patrick** et al.; Mewburn Ellis LLP, York House, 23 Kingsway, London Greater London WC2B 6HP (GB).

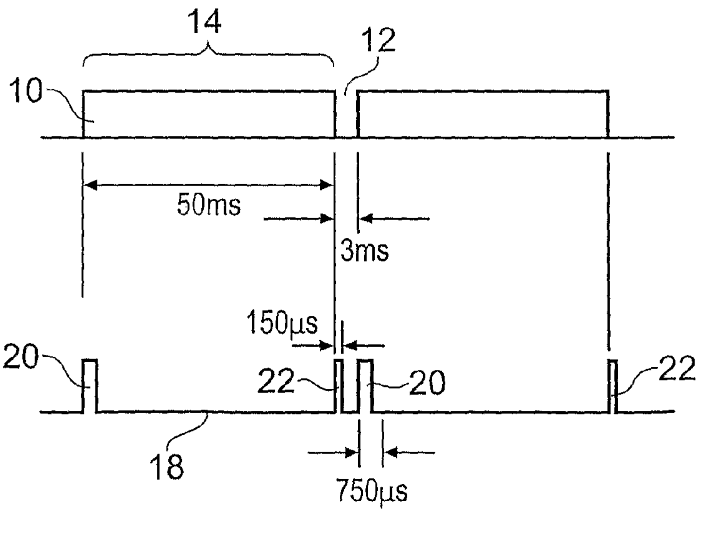
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: RFID DETECTION APPARATUS, SYNCHRONISATION AND OPERATION THEREOF



(57) Abstract: Apparatus and methods are disclosed for detecting RFID devices, such as when detecting livestock. Transmitters generate cyclic patterns of RF electric field to energise RFID devices for detection. The cyclic patterns include transmitting phases to energise and silent phases to allow half-duplex (HDX) RFID devices to respond. These phases can be individually extended by the control processor when the system detects an RFID device, to give time for reading to be completed. Multiple transmitters have their phases synchronised, so that HDX devices continue to be readable, by means of a shared synchronisation signal which may - characterise every transmitting phase and/or every silent phase, so that plural transmitters quickly fall into synchronicity, and/or - characterise a fixed-duration pulse pattern, used for synchronisation, at its onset rather than in its silent phase.

WO 2006/126007 A1

RFID DETECTION APPARATUS, SYNCHRONISATION AND OPERATION THEREOF

This invention relates to radio frequency identification (RFID) apparatus, to elements thereof, and methods of operation. For example, it is applicable to a system for energising and reading information contained in RFID tags (e.g. used in animal ear tags or boluses). RFID tag are also called RFID transponders. These names can be used interchangeably.

A radio frequency identification tag is a device that stores unique identification information. When exposed to an interrogating electric field e.g. a radio frequency (RF) electric field, the tag is energised, i.e. it is "powered up", and is arranged to respond by sending the identification information to a reader (which may be incorporated into the interrogator). For convenience, the following background description assumes that the reader and interrogator are included in the same device, and refers to that device hereinafter as a "reader", since this is common practice in the art.

RFID devices (henceforth "tags") and their readers operate at a number of different frequencies and protocols. One example is the low frequency (LF) type RFID devices which are used in the identification of animals. The frequency band of operation is based around 134.2 kHz. It is possible to write over the information stored in some tags; read-only tags, e.g. with non-modifiable code to ensure security, are typically used as standard at the present time.

Two transmission protocols are presently used: full duplex (FDX) and half duplex (HDX). In the FDX protocol, the response from the tag is sent whilst continuously receiving the interrogating RF energy. The reply transmission from the FDX tag occurs at a different frequency from the interrogating energy so that the reader can recognise that a response is being sent. In the HDX protocol, the response from the tag is sent in a window where no interrogating RF field is present, and the reader is listening for a response. The interrogating field pattern for a HDX tag is therefore necessarily intermittent; the periods where the field is present energise the tag, which then waits for a silent period to send its response. A reader can be constructed to interrogate and read both HDX and FDX tags.

Two types of reader are generally known; stationary (fixed) readers and mobile (e.g. portable) readers. A stationary reader can be linked to a fixed installation e.g. to identify cattle flowing through a cattle yard.

International standard ISO 11785:1996(E) describes one example of the technical attributes of detection apparatus - tags and tag readers of the above type - used for the radio-frequency identification of animals. Figs. 1 and 2 show relative timing of the transmit and silent (listening) periods for a reader that can identify both HDX and FDX tags.

Fig. 1 shows a standard format of a cyclic electric field emitted by a transmitter arranged to energise a RFID tag so that it may be detected. Fig. 1 shows a plurality of cycles 14, each of which has a transmitting phase 10, where an electric field is generated by the transmitter, and a silent phase 12, where no electric field is generated. The standard format shown in Fig. 1 occurs when no transponders are detected by the reader: the transmitting phase 10 lasts for 50ms, and the silent phase lasts for 3ms.

FDX transponders may be detected in the transmitting phase 10. Sometimes, all the information from the FDX tag cannot be completely sent within the 50ms period, e.g. because the tag only started transmitting late in the period or because it only entered the field late in the period. In this case, i.e. when the reader has not validated a FDX response, the transmitter's control processor is programmed to extend the transmitting phase 10. The phase is extended for long enough to allow the information from the FDX tag to be completely read or to a maximum of 100ms, to avoid a damaged tag from blocking the system. This extension is illustrated in Fig. 3.

The presence of a HDX tag in the field can be detected within the 3ms silent phase 12. If a HDX tag is present, the duration of the silent phase is then extended to 20ms to allow the information from the HDX tag to be read. When no HDX tag is detected, the silent phase 12 lasts for only 3ms. This maximises the fraction of time that the field is transmitted, which maximises the time for detecting FDX tags and for energising HDX tags.

Fig. 4 shows a cycle where both phases are extended because an FDX tag and a HDX tag are detected. The maximum cycle duration is 120ms because the phase extensions are limited so that the transmitting phase is not longer than 100ms and the silent phase is not longer than 20ms in operation.

In many applications more than one tag reader will operate in the local vicinity. When more than one transmitter is used to generate the electric field, e.g. to provide the field over a larger area, it is necessary to synchronise generation of the electric fields of each transmitter so that there is some guaranteed silent time, where none of the transmitters generate a field, so that HDX transponders will be detected. Without synchronisation, the transmitting phase of one transmitter may overlap with the silent phase of another transmitter and prevent any listening silence from occurring.

Synchronisation may be achieved by instructing all the transmitters simultaneously to produce a cycle (a synchronisation cycle) having a fixed structure (pattern), i.e. not subject to the detection-dependent phase extensions referred to above. The fixed duration of the silent phase of the synchronisation cycle can also be long enough for HDX tags to be detected, e.g. 20ms. As it is not efficient to have too many silent periods, the synchronisation cycle is arranged to occur once every predetermined plural number of cycles, e.g. as every tenth cycle.

Fig. 2 shows a synchronisation cycle 16 at the tenth cycle of a transmit format shown in Fig. 1.

A further reason for including a synchronisation cycle is to permit mobile readers, i.e. readers that are not connected to a local network of transmitters, to read HDX responses. By having a definite fixed period of 20ms silence, the mobile reader need not communicate with the transmitters to find out what stage of the cycle is occurring; the mobile reader can simply wait for the silent phase of the synchronisation cycle to occur.

One way of ensuring a network of stationary transmitting readers operate correctly and efficiently is to distribute a synchronisation signal to each reader via a wired connection. An example of a scheme to synchronise readers is presented in the ISO 11785: 1996(E), known to the skilled person. This relies on all readers in the vicinity being synchronised and at every tenth transmit/receive cycle all readers transmit for a fixed period of 50ms and receive for a fixed period of 20ms as shown in figure 2.

The synchronisation signal proposed in ISO 11785: 1996(E) is a two state (high/low) signal which is generated as output from a 'master' reader and received as input by the remaining 'slave' readers. The signal is usually in the low state. In the absence of any action on the synchronisation signal line, i.e. while it stays in a low state, the readers will transmit cycles having the standard format (50ms transmit followed by 3ms silence). Each reader also counts the number of cycles transmitted, and when that counter reaches ten, the reader transmits for a fixed time of 50ms, and then generates a 20ms high pulse on the synchronisation signal line. The reader that generates this pulse is the master reader. Any high pulse on the synchronisation signal line automatically prevents the slave readers from transmitting. Thus, all the readers will be silent for 20ms at this point. The slave readers reset their cycle counters so that all readers begin counting up following the synchronisation cycle.

In fact, all the readers' processors are programmed to attempt to generate a 20ms high pulse and apply it to the synchronisation signal line when their counters indicate that it should be generated, but only the first to do so will succeed and become the master reader *pro tempore*.

The pulse or phase extensions to read late FDX and HDX tags also use the synchronisation signal line. For example, when a reader registers a late FDX and determines that it requires a phase extension, it generates a high pulse on the synchronisation signal line within the 50ms transmit phase, thereby becoming master reader and indicating to the slave readers that transmission should continue until the synchronisation signal is brought low again (which happens automatically at the 100ms limit or can be done by the master reader when the FDX tag is validated). However, it is necessary to program the system processor so that the extension signal on the synchronisation line is not exactly 20ms because this may be interpreted as a synchronisation cycle by slave readers, which will cause them to reset their counters and therefore disturb synchronisation. Likewise, when a HDX tag is detected by a reader in the 3ms silent phase, that reader generates a high pulse on the synchronisation signal line at the end of the 3ms phase, thereby becoming master reader and indicating to the slave readers that silence should continue until the synchronisation signal is brought low again. To ensure the total silence period is 20ms, the high pulse on the synchronisation signal line generated by the master reader in this case lasts for 17ms.

Figs. 7, 8, 9, 10 show the electric field produced by a transmitter as shown in Figs. 1, 2, 3, 4 and additionally show the output on the synchronisation signal line from a 'master' transmitter. In Fig. 7, the synchronisation signal line is low because no transponders have been detected and it is not the tenth (i.e. synchronisation) cycle. In Fig. 8, the synchronisation signal line is high during the fixed 20ms silent phase of the synchronisation cycle. Any 'slave' transmitters present will reset their counters at the end of this 20ms synchronisation signal. In Fig. 9, a transmitter which has detected a transponder, but has not succeeded in reading the information from that transponder after 48ms of a transmitting phase 10, extends the transmitting phase 10 by setting the synchronisation signal line to high until it has read the transponder, or, as in this case, until it has extended the transmitting phase to a maximum of 100ms. The transmitter is not allowed to extend the transmitting phase by exactly 20ms to avoid confusion with the synchronisation cycle. In Fig. 10, a transmitter has detected an FDX transponder and so the signal line is high after 48ms of the transmitting phase and lasts for 52ms to extend the transmitting phase to its maximum of 100ms. A transmitter also detects a HDX transponder in the next silent phase. To inform any other transmitters which are present that the silent phase should be extended to 20ms, the transmitter holds the synchronisation signal line high after 2-3ms of the silent phase until the 20ms (extended) silent phase has finished.

Synchronisation schemes heretofore proposed, including the scheme set out in ISO 11785:1996(E) present certain practical problems, or leave scope for improvement.

Firstly, existing schemes make no provision for one or more of the readers to tune their antenna (known as auto-tune). Tuning may occur either when a transmitting reader initially enters a network (one or more other readers), or periodically during operation. Tuning the antenna means selecting an internal configuration which provides optimal performance in a particular network, and involves testing each possible configuration (e.g. combinations of capacitors etc). Whilst this testing is being carried out, the reader may transmit signals that cause other readers on the network to lose synchronisation. For example, one form of tuning requires the reader to transmit a RF signal for a specific period of time. The network may be down during tuning because no silent periods occur. The network may be brought back up again after tuning has finished. If synchronisation is lost, it will take longer to bring the network back up because of the need to resynchronise.

Secondly, it may be difficult to identify the synchronisation signal which corresponds to the pre-set and fixed synchronisation cycle, so that either the slave readers miss the fact that a synchronisation signal has (or should have) occurred, or they misinterpret an extension signal as a synchronisation signal. The synchronisation scheme described above suggests pulling the synchronisation signal line high whenever a HDX or FDX tag is detected, and to signal the silent phase of the tenth cycle with a high of fixed duration. However, the extension signal for HDX tags is 17ms, and for FDX tags is up to 50ms (but not 20ms). The extension signal is not held for 20ms, to ensure that it is not confused with the 20ms synchronisation signal. Thus, for a slave to ensure that a signal on the synchronisation line is a synchronisation signal and not a extension signal, it must time it. This means that the slave reader must be configured to check very accurately for a drop on the synchronisation line around 17ms to distinguish between a HDX extension signal and a synchronisation signal. Such checking requires accurate timing. Moreover, slight phase drift between readers during each ten cycle period can make it difficult to ascertain when a pulse on the synchronisation line actually starts, thereby causing further confusion and greater likelihood of error. Previous proposals have tried to avoid this problem by programming extra rules into the synchronisation protocol of the control processor. For example, the variable FDX extension may be forbidden from being a length that will cause an 20ms pulse to appear on the synchronisation signal line. Extra programming of this kind may contribute to a more complex system, more prone to error.

The present invention aims to ameliorate at least some of these problems by providing apparatus and methods with a robust synchronisation scheme. One aspect of the present proposals is to allow tuning to occur without disturbing the synchronisation of the readers connected to the network and therefore to minimise the reader down-time. Another aim is to reduce errors in the identification of the synchronisation signal.

The present invention therefore proposes various techniques to improve synchronisation of a network of transmitters.

Various aspects of the invention are set out in the claims. These are freely combinable with one another.

In a first aspect, the invention provides systems and methods with identifying means for a phase of the generated electric field. The identified phase may be the transmitting phase of the synchronisation cycle.

Thus, in this aspect the invention provides apparatus and methods deploying a synchronisation signal for use with a network (or set) of electric field transmitters arranged to emit an electric field cycle which includes a variable-duration transmitting phase, where an electric field is generated by the transmitters for an extendible duration, and a variable-duration silent phase, where no electric field is generated by the transmitters for an extendible duration, the synchronisation signal being arranged to cause the transmitters simultaneously to emit a synchronisation cycle which has a fixed transmitting phase, where an electric field is generated by the transmitters for a fixed duration, and a fixed silent phase, where no electric field is generated by the transmitters for a fixed duration, wherein the synchronisation signal includes a unique marker to indicate the start of the synchronisation cycle. Thus, a transmitter new to the network or an existing slave transmitter can recognise a synchronisation cycle immediately. This avoids the need to distinguish a signal indicating a synchronisation cycle from a signal indicating that either the variable transmitting phase or the variable silent phase should be extended.

Preferably, the marker is arranged to indicate the start of the fixed transmitting phase. This gives the transmitter network time to prepare for the simultaneous fixed silent phase. In particular, it allows a transmitter new to the network to know that a synchronisation cycle is occurring, in time for that transmitter to join in e.g. with the fixed silent phase.

This is in contrast to previous proposals, where a new transmitter may only know that a synchronisation cycle has occurred after the fixed silent phase has finished.

Preferably, the synchronisation signal is arranged to be constantly supplied at the control processors of the transmitters of the operational set. The signal desirably has a first state and a second state, and the unique marker preferably includes a transition between the first and second states.

In use, the signal may be usually maintained in the first state, the marker preferably including a pulse to the second state and back to the first state. The marker may have one or more pulses in a characteristic pattern. In a preferred embodiment, the marker is a double pulse. The states may be respectively characterised by low and high impedance detectable by the transmitters. Thus, the signal may be pulled low by a master transmitter, and the marker may include a high pulse on the signal line.

Preferably, a transition between the first and second states coincides with the start of the fixed transmitting phase. The duration of the fixed transmitting phase may be timed from this transition.

The duration of the fixed transmitting phase may be 50ms. The duration of the fixed silent phase may be 20ms. The duration of the marker is preferably much less, e.g. less than a tenth, preferably less than a twentieth, of the duration of the synchronisation cycle. The marker duration may be less than 1ms, preferably around 750μs. There may be more than one pulse within that duration, as mentioned above. For example, the marker may be a double pulse. Each pulse may have a different duration, e.g. a longer pulse followed by a shorter pulse or vice versa. The separation between the pulses is preferably very short, e.g. shorter than either pulse. In a preferred embodiment, the marker includes a 600μs pulse separated from a 100μs by a gap of 50μs.

Preferably, there is also a marker at the beginning of the silent phase of the synchronisation cycle. This marker is preferably different from (e.g. of shorter duration than) a marker signalling the beginning of the transmitting phase of the synchronisation cycle. Its duration may be less than 500μs, preferably around 150μs.

Alternatively, apparatus and methods in the first aspect of the present invention may provide a synchronisation signal for controlling a network of electric field transmitters which are arranged to emit a cyclic electric field, each cycle including a transmitting phase, where an electric field is generated by the transmitters, and a silent phase, where no electric field is generated by the transmitters, wherein the synchronisation signal includes a first unique marker to indicate the start of each transmitting phase and/or a second unique marker to indicate the start of each silent phase. Here each type of phase is immediately identifiable, which allows a transmitter to join the network more efficiently.

Preferably, the signal is arranged to be constantly supplied to the transmitters, wherein the signal has a first state and a second state, and each marker includes a transition between the first and second states. The signal may usually be maintained in the first state, and each marker may be a pulse to the second state and back to the first state.

Preferably, the first unique marker pulse has a different duration from the second unique marker pulse. In other words, it is the duration of the marker pulses which may allow the transmitters to distinguish between them and decide what type of phase is occurring. Preferably, the duration of each marker pulse is small, e.g. less than a tenth, preferably less than a twentieth, of the duration of the phase that it characterises or indicates. For example, the first marker pulse duration may be less than 1ms, preferably around 750μs. The second marker pulse duration is preferably less than the first marker pulse duration, more preferably less than 500μs, most preferably around 150μs.

The transmitting and silent phases may have variable e.g. extendible duration. Their duration may be varied e.g. extended by delaying the generation of the first or second marker pulse respectively. Extendible duration means that a transmitter output state (emitting or silent, corresponding to the transmitting and silent phases respectively) is maintained for longer than a notional or set minimum or standard duration. The duration may be extended upon receiving an indication e.g. notification or determination that more time is needed in that particular output state e.g. to enable a detected tag to be fully identified. The indication to extend may be the detection of the presence of a tag. Alternatively or additionally, the indication may result from a determination e.g. calculation that a detected tag will not be fully identified within the notional or set duration. These are of course programmed functions of the control processor(s) for the transmitter(s) concerned.

The first and second markers may be used in addition to the synchronisation cycle marker described above. Thus, the signal may be further arranged to cause the transmitters simultaneously to emit a synchronisation cycle which has a fixed duration transmitting phase and a fixed duration silent phase, wherein the synchronisation signal includes a third unique marker arranged to indicate the start of the synchronisation cycle. The third marker may have the double pulse structure described above.

The first and second markers may be used independently. Thus, the first aspect of the invention may be expressed as a synchronisation signal for controlling a network of electric field transmitters which are arranged to emit a cyclic electric field, each cycle including a transmitting phase, where an electric field is generated by the transmitters, and a silent phase, where no electric field is generated by the transmitters, wherein the synchronisation signal includes a unique marker arranged to indicate the start of each transmitting phase. Alternatively, the first aspect may be expressed as a synchronisation signal for controlling a network of electric field transmitters which are arranged to emit a cyclic electric field, each cycle including a transmitting phase, where an electric field is generated by the transmitters, and a silent phase, where no electric field is generated by the transmitters, wherein the synchronisation signal includes a unique marker arranged to indicate the start of each silent phase.

The synchronisation signal may be supplied to the network of transmitters via a physical, e.g. wired, connection or via a wireless connection using conventional technology, e.g. infrared communication or the like.

The synchronisation signal may be supplied to the network of transmitters by one of the transmitters, more then one of the transmitters or by a separate apparatus.

The first aspect may alternatively be expressed as a method of synchronising a network of transmitters arranged to emit an electric field cycle which includes a variable transmitting phase, where an electric field is generated by the transmitters for an extendible duration, and a variable silent phase, where no electric field is generated by the transmitters for an extendible duration, the method including: supplying a synchronisation signal to the transmitters; generating a unique marker on the synchronisation signal to indicate the start of a synchronisation cycle; simultaneously emitting a synchronisation cycle from the transmitters in response to the unique marker on the synchronisation signal, the synchronisation cycle having a fixed transmitting phase, where an electric field is generated by the transmitters for a fixed duration, and a fixed silent phase, where no electric field is generated by the transmitters for a fixed duration.

Other aspects related to the first aspect include the following.

A network of transmitters arranged to emit an electric field cycle which includes a variable transmitting phase, where an electric field is generated by the transmitters for an extendible duration, and a variable silent phase, where no electric field is generated by the transmitters for an extendible duration, the network being adapted to receive a synchronisation signal which is arranged to cause the transmitters simultaneously to emit a synchronisation cycle which has a fixed transmitting phase, where an electric field is generated by the transmitters for a fixed duration, and a fixed silent phase, where no electric field is generated by the transmitters for a fixed duration, wherein the network is arranged to detect a unique marker on the synchronisation signal, the unique marker being arranged to indicate the start of the synchronisation cycle.

A transmitter adapted for connection to or use in an above-described network or apparatus.

Synchronisation apparatus programmed to emit a synchronisation signal for controlling a network of transmitters, the synchronisation apparatus including marker generation means for producing a unique marker (e.g. a pulse as described above) on the synchronisation signal, wherein the unique marker is arranged to cause the transmitters simultaneously to emit a synchronisation cycle, e.g. as described above.

A method of detecting RFID devices, e.g. carried by animals such as livestock. The method may include energising tags (e.g. RFID tags) carried by the animals by providing a network of electric field transmitters which emit an electric field cycle which includes a variable transmitting phase (e.g. for detecting full duplex [FDX] tags), where an electric field is generated by the transmitters for an extendible duration, and a variable silent phase (e.g. for detecting half duplex [HDX] tags), where no electric field is generated by the transmitters for an extendible duration, wherein the method includes: supplying a synchronisation signal to the transmitters; generating a unique marker on the synchronisation signal to indicate the start of a synchronisation cycle; simultaneously emitting a synchronisation cycle from the transmitters in response to the unique marker on the synchronisation signal, the synchronisation cycle having a fixed transmitting phase, where an electric field is generated by the transmitters for a fixed duration, and a fixed silent phase, where no electric field is generated by the transmitters for a fixed duration.

A livestock detection system including a network of electric field transmitters arranged to emit an electric field to energise tags (e.g. RFID tags) carried by the livestock, wherein the network of transmitters is arranged to operate with a synchronisation signal as described above.

The transmitters may also be adapted to detect the presence of the livestock tags.

The technique described in the first aspect of the invention can be used to overcome the above-identified problems by generating a marker at the commencement of both transmit and receive periods. As a result all transmitters (which are preferably also readers) connected to the network know the status of the network within the duration of one phase (e.g. transmitting or silent), i.e. as soon as the transmitters receive a marker on the synchronisation signal line, they know the status of the network. This minimises reader down time due to events such as an auto-tune.

In a second aspect, the invention provides a network where the transmitters synchronise with each other at every transmitting phase or silent phase (or both). For example, the transmitters may synchronise at the beginning of each phase. This improves the accuracy of the network without requiring more accurate timing apparatus and reduces the effect of phase drift. According to the second aspect of the invention, there may therefore be provided a network of transmitters arranged to emit a cyclic electric field, each cycle including a transmitting phase, where an electric field is generated by the transmitters, and a silent phase, where no electric field is generated by the transmitters, wherein each transmitter is connected to a common input arranged to trigger the transmitting and silent phases. The network may include timing apparatus arranged to monitor the duration of the transmitting phase and silent phase of each cycle, the timing apparatus being arranged to begin timing each phase from the common input trigger.

Preferably, the common input supplies a synchronisation signal to trigger the transmitting and silent phases in the transmitters. The synchronisation signal may have markers according to the first aspect of the invention. For example, the synchronisation signal may include a first unique marker arranged to indicate the start of each transmitting phase and a second unique marker arranged to indicate the start of each silent phase, the timing apparatus being arranged to begin timing each phase upon detection of its respective unique marker.

Each transmitter may include its own timing apparatus for timing the transmitting and silent phases. The timing apparatus may include separate timers for the transmitting and silent phases. The timers preferably start on detection of the common signal trigger, i.e. they have a common source. This improves synchronicity.

Of course this could be varied by marking only some phases of either or each type, speeding synchronisation but not optimally, and introducing needless complication.

In a third aspect, the operation of a network of transmitters is controlled by a common signal. Each transmitter on the network is arranged to interpret instructions supplied by the common signal to determine how it should act. Thus, according to the third aspect of the invention, there may be provided a network of transmitters arranged to emit a cyclic electric field, each cycle including a transmitting phase, where an electric field is generated by the transmitters, and a silent phase, where no electric field is generated by the transmitters, wherein a common input is supplied to the transmitters, the common input being arranged to provide operation instructions for the transmitters.

Preferably, the operation instructions include one or more of: a transmit instruction to cause the transmitter to emit an electric field; a silence instruction to cause the transmitter to remain silent; a synchronisation instruction to cause the transmitter to emit a synchronisation cycle.

Preferably, the common input is a synchronisation signal. The synchronisation signal may have the form described in the first aspect of the invention. The unique markers may be used as operating instructions. Preferably, the signal is constantly supplied to the transmitters and has a first state and a second state, and wherein each instruction includes a transition between the first and second states.

Preferably, each transmitter is arranged to obey each operation instruction until it receives another instruction. This is in contrast to known proposals in that action is required on the synchronisation signal line for any change of state in the transmitters to occur, whereas the known proposals will change state according to a programmed schedule (see e.g. Fig. 1) if there is no action on the synchronisation signal line. By providing a common source of instructions rather than relying on the synchronicity of individual timers associated with each transmitter, this aspect of the present invention provides tighter, i.e. more accurate, synchronisation.

Preferably, the transmitters include a master transmitter arranged to generate the synchronisation signal, and one or more slave transmitters arranged to receive the synchronisation signal. The network is preferably arranged so that any transmitter can be the master transmitter, but only one master transmitter can exist at any point in time. In other words, each transmitter on the network is capable of taking control of the synchronisation signal line.

Alternatively, the synchronisation signal can be supplied by a separate apparatus.

Preferably, the duration of the transmitting phase or silent phase of each cycle is extendible by delaying the supply of an operation instruction via the synchronisation signal. Thus, each transmitter can communicate to the others by delaying an instruction. Using the two state signal line described above, this may mean holding the signal line in the first state (e.g. low state) to prevent a instruction (e.g. pulse) from being generated. Only when the master transmitter allows it will an instruction changing the state of the network be generated. This may be used to tell the network to remain silent because of the presence of a HDX tag.

Preferably, the synchronisation signal is arranged to cause the transmitters simultaneously to emit a synchronisation cycle which has a fixed duration transmitting phase and a fixed duration silent phase.

Preferably, the synchronisation signal is arranged to cause the synchronisation cycle to be emitted after a predetermined number of electric field cycles, e.g. as every tenth cycle.

Preferably, the transmitters of all three aspects are arranged also to read (i.e. pick up) signals generated by transponders (e.g. RFID tags) energised by the emitted electric field. The transmitters may read both FDX and HDX response signals.

An embodiment of the invention is described below with reference to the accompanying drawings, in which:

Fig. 1 shows the standard format of a cyclic electric field emitted by a transmitter and has been described above;

Fig. 2 shows a synchronisation cycle as the tenth cycle of the electric field shown in Fig. 1, and is also described above;

Fig. 3 shows an extended transmitting phase of the electric field shown in Fig. 1, and is also described above;

Fig. 4 shows an extended transmitting phase and an extended silent phase of the electric field shown in Fig. 1, and is also described above;

Fig. 5 shows the standard format of a cyclic electric field and its associated synchronisation signal line according to an embodiment of the present invention;

Fig. 6 shows a synchronisation cycle of the electric field shown in Fig. 5 together with its associated synchronisation signal line;

Fig. 7 shows the electric field emitted by a transmitter as shown in Fig. 1 and also shows the output on the synchronisation signal line from a 'master' transmitter; and

Figs. 8, 9 and 10 supplement the data of Figs. 2, 3 and 4 in the same way.

The embodiment described below is implemented on a network of fixed (stationary) tags readers (i.e. electric field transceivers arranged to emit an energising electric field and pick up responses). The readers can detect both FDX and HDX tags. The readers are interconnected to receive a synchronisation signal. The connection is usually physical, i.e. wired, but wireless arrangements are feasible, e.g. using conventional wireless (e.g. infrared) technology such as Bluetooth® or the like. Each reader has the same synchronisation signal interface; the interface can operate as either an output, i.e. controlling the synchronisation signal line, or input, i.e. responding to signals on the line. In practice, the interface port is pulled to logic high by a high impedance. When the synchronisation interface is configured as an output, the reader will determine the 'normal' level of the line as "high" e.g. logic 1. To control the line, the interface causes the line to be pulled "low", detected as logic 0. Signals (e.g. pulses) are therefore created on the line when no reader is acting to pull the line low, hence it is free to occupy its default "high" position.

Considering initially a single reader, the synchronisation interface is configured as an output. It is configured to produce the signal line 18 shown in Fig. 5. That is, it pulls line 18 low except for a first pulse 20 lasting 750µs which coincides with the start of each transmitting phase 10 and a second pulse 22 lasting 150µs which coincides with the start of the silent phase 12. Between the first and second pulses 20, 22 the synchronisation signal line 18 is held low.

As with known systems, it is sometimes necessary to extend the duration of a transmitting phase if a FDX tag is detected but not validated during that phase. Extension is allowed to a maximum total duration of 100ms. The extension is achieved by holding the synchronisation line low until the FDX tag is validated or the transmitting phase duration reaches 100ms. Then the line is released for 150µs to provide the second pulse 22. In other words, the second pulse 22 is delayed. The transmitter does not become silent until the second pulse 22 is produced.

Similarly, if a HDX tag is detected during a silent phase 12, the synchronisation line is held low to extend the silent period (e.g. to its fixed length of 20ms) before releasing the synchronisation line for 750µs to provide the first pulse 20. The transmitter does not begin the next transmitting phase until the first pulse 20 is produced.

In both the above cases, it is the pulse on the synchronisation line that triggers the change of state of the reader. A reader that is transmitting will therefore continue to do so until it detects a signal on the synchronisation signal; it knows this signal will mean it has to change state, so it will become silent.

Considering now a network of readers interconnected on a common synchronisation signal line 18, it becomes clear that each reader is capable of extending the transmitting or silent phases 10, 12 of all the readers by holding down the synchronisation signal line 18. The first and second pulses 20, 22 are only produced when all the readers agree that the signal line 18 should be released. In practice, only one reader is in control of the signal line 18 at any one time. This reader is the master reader, whereas the others are slave readers who listen to the signal line and have no effect on it. Of course, the control of the signal line 18 may pass from reader to reader in the course of a number of cycles; a slave reader that requires an extension will become the master reader by taking control of the signal line 18. The previous master reader reverts to being a slave.

To allow a reader not connected to the network (e.g. a mobile reader) to detect an HDX tag, the network is synchronised so that every tenth cycle is a synchronisation cycle 16 with a fixed format: 50ms transmitting phase followed by 20ms silent phase. In Fig. 6, the start of the synchronisation cycle 16 is identified by a double pulse 24, which coincides with the start of the tenth transmitting phase. Another pulse 25 (having the same format as the second pulse 22 mentioned above) is produced at the start of the fixed silent period, i.e. exactly 50ms after the start of the double pulse 24. Each reader has a cycle counter running to detect where to insert the synchronisation cycle 16 in the correct position. That is, each reader counts from the previous double pulse 24. When the counter reaches ten, that reader attempts to generate the double pulse. Detection of another double pulse in the meantime will reset the counters of the other readers, thereby synchronising the network.

As shown in the magnified part of Fig. 6, the format of the double pulse 24 is an initial pulse 26 lasting

600μs followed by a gap 28 lasting 50μs and then a final pulse 30 lasting 100μs. Overall, the double pulse 24 lasts the same length of time as the first pulse 20, i.e. 750μs.

A reader joining the existing network typically needs to tune before it can operate; the tuning procedure is described below. However, if the new reader is already tuned, it may obey the following joining procedure:

1. It initially sets its synchronisation interface as an input, i.e. it listens for pulses on the signal line 18; then
2. If it detects that the signal line remains high for a predetermined period (i.e. it detects no markers), the new reader assumes no other reader is connected and therefore takes control of the synchronisation signal line (by pulling it low as described above); or
3. If it detects that the signal line is low, the reader knows it is joining an existing network; then
4. By measuring the width of any high pulses on the signal line 18, the reader can synchronise with the existing network - e.g. on detecting a 750μs pulse, the reader knows that a transmitting phase is occurring, so it may begin transmitting; on detecting a 150μs pulse, the reader knows that a silent phase is occurring, so it will keep silent until a transmit pulse occurs;
5. On detecting its first 750μs pulse, the reader resets its ten cycle counter, and starts counting cycles - it will attempt to produce the double pulse if it reaches ten;

6. On detecting a double pulse 24 indicating the tenth cycle, the new reader resets its ten cycle counter thereby synchronising to the existing network.

As all readers have their own ten-cycle counters which automatically reset upon detecting a double pulse issued by another reader, the network will maintain synchronisation of the ten cycle period even if the initial master reader is turned off.

The cycle counters operate by counting the number of completed cycles, i.e. transmitting phase followed by silent phase. The length of each phase is immaterial as far as the counters are concerned. Thus, even if a phase extends beyond its notional maximum duration, e.g. due to an auto-tune event (see below), the established synchronisation of the counters will not be disturbed; they will count up regardless of the unusual nature of any phase when the synchronisation signal line provides the expected markers.

All readers in the network have their own timers. These timers include a silent period timer triggered by the 150μs pulse and a transmit period timer triggered by the 750μs pulse. These timers time default periods (50ms and 3ms respectively) which are extendible to maxima (100ms and 20ms) if certain conditions (detection of FDX of HDX tags respectively) occur. There are also fixed period timers for timing the phases of the synchronisation cycle 16 (50ms and 20ms respectively).

A new reader will set its silent period timer upon detection of the 150μs pulse and its transmit timer upon detection of the 750μs pulse. If the new reader then detects a FDX transponder it will configure its synchronisation interface as an output (i.e. take control of the synchronisation signal line 18) and maintain the line low to prevent a 150μs pulse from occurring, thereby causing the remaining readers to carry on transmitting so that the FDX tag may be detected. If or when the transmit timer reaches 100ms, the reader causes the 750μs pulse to be produced by releasing the synchronisation signal line 18 to allow it to return to a high. The remaining readers will have set their synchronisation ports as inputs, so will detect the 750μs signal, and begin transmitting again.

The same procedure is repeated on the detection of a HDX tag except that the silent period timer is used to extend the silent phase 12 to a maximum duration of 20ms.

Only a reader detecting the transponder can increase either the silent or transmit phases by becoming the master in the network, whereby the remaining readers obey the status of the synchronisation line.

Should the network contain a number of readers, any of the readers can hold the synchronisation low on detection of a transponder. Each reader may detect a transponder at different times during transmit or silent periods. It will be the last reader to complete the transponder interrogation that will allow the synchronisation signal line 18 to return to a high. Once synchronised, each reader is timing its own transmit periods and silent periods from the common synchronisation signal pulses thus preventing periods extending beyond 100ms for transmit and 20ms for the listening periods.

A new reader joining the network (or an established reader, upon request) may need to perform an auto-tune. Throughout its auto-tune, the reader holds the synchronisation line low, thereby maintaining the network in the current phase (the phase taking place when the auto-tune began) until the auto-tune is completed. This occurs because the transmitters only change phase when a marker is detected on the synchronisation line. If no markers are produced, no change of phase occurs. When the auto-tune is complete, the synchronisation line is released by the tuned reader, which allows the pulse indicating the next phase to be produced on the synchronisation line. Established readers on the network resume the usual cycle sequence immediately after receiving that identifying pulse (e.g. transmit (750μs) or silent (150μs)) without resetting their cycle counters.

It may be desirable for auto-tune to take place during a silent phase. The reader requiring auto-tune may therefore listen to the synchronisation line for a marker pulse which indicates a silent phase before starting the auto-tune operation.

CLAIMS:

1. RFID device detection apparatus, comprising:

a transmitter programmed to generate a cyclic interrogation signal pattern for energising a corresponding antenna to produce a corresponding cyclic electric field pattern which energises RFID devices in use, the interrogation signal pattern including one or more transmitting phases and one or more silent phases to enable reading of RFID device responses; and

synchronisation means to generate a corresponding synchronisation signal pattern enabling said transmitter to cooperate with one or more further such transmitters by synchronising the phases of their respective interrogation signal patterns;

wherein the synchronisation signal pattern includes first markers characteristic for the starts of transmitting phases, e.g. each transmitting phase, and/or second markers characteristic for the starts of silent phases, e.g. each silent phase.

2. RFID apparatus according to claim 1 in which the synchronisation signal pattern has a first state and a second state, and the characteristic markers include a transition between the first and second states.

3. RFID apparatus according to claim 2 in which the synchronisation signal pattern is usually maintained in the first state, and the characteristic markers comprise a pulse to the second state and back to the first state.

4. RFID apparatus according to claim 3 wherein the synchronisation signal pattern has both said first and second characteristic markers, the first marker pulses having a different duration from the second marker pulses.

5. RFID apparatus according to any one of claims 2 to 4 wherein the first and second states are respectively characterised by low and high impedance detectable by a control processor for the transmitter.

6. RFID apparatus according to any of the preceding claim, wherein the interrogation signal pattern comprises a synchronisation cycle which has a fixed duration transmitting phase and a fixed duration silent phase, other phases in the pattern being variable in duration if an RFID device is detected.

7. RFID apparatus according to claim 6, wherein the synchronisation signal pattern includes a marker characteristic of the start of the synchronisation cycle.

8. RFID apparatus according to claim 7 wherein the third characteristic marker is at the start of the fixed duration transmitting phase of the synchronisation cycle.

9. RFID apparatus according to any one of the preceding claims in which a control processor for the transmitter is operable to extend the duration of a said transmitting phase or of a said silent phase of the interrogation signal pattern, in dependence on detection of an RFID device, to facilitate completing the reading of the detected device.

10. RFID device detection apparatus, comprising:

a transmitter programmed to generate a cyclic interrogation signal pattern for energising a corresponding antenna to produce a corresponding cyclic electric field pattern which energises RFID devices in use, the interrogation signal pattern including one or more transmitting phases, and one or more silent phases to enable reading of RFID device responses, said transmitting and silent phases including phases which are length-variable in the event of an RFID device detection; and

means for generating a corresponding synchronisation signal pattern enabling said transmitter to cooperate with one or more further such transmitters by synchronising the phases of their respective interrogation signal patterns;

the interrogation signal pattern comprising a fixed synchronisation cycle which has a fixed-duration transmitting phase and a fixed-duration silent phase;

wherein the synchronisation signal pattern includes a characteristic marker to indicate the start of the synchronisation cycle.

11. RFID device detection apparatus, comprising:

a transmitter programmed to generate a cyclic interrogation signal pattern for energising a corresponding antenna to produce a corresponding cyclic electric field pattern which energises RFID devices in use, the interrogation signal pattern including one or more transmitting phases, and one or more silent phases to enable reading of RFID device responses; and

means for generating a corresponding synchronisation signal pattern enabling said transmitter to cooperate with one or more further such transmitters by synchronising the phases of their respective interrogation signal patterns;

wherein the transmitter includes timing apparatus arranged to monitor the duration of the transmitting phases and silent phases of each cycle, the timing apparatus being arranged to begin timing each phase from the start of that phase.

12. RFID apparatus according to any one of the preceding claims comprising further said transmitters.

13. RFID aparatus according to claim 12 with a wired link between at least two of said transmitters to communicate the synchronisation signal.

14. RFID apparatus according to claim 12 in which at least one said transmitter is a fixed installation and at least one is mobile.

15. RFID apparatus according to any one of the preceding claims in which each transmitter is accompanied by a reader as a transceiver, to read detected RFID devices.

16. A detection method for detecting and reading RFID devices, using detection apparatus according to any one of claims 1 to 15.

17. A detection method according to claim 16 which is to identify animals carrying the RFID devices.

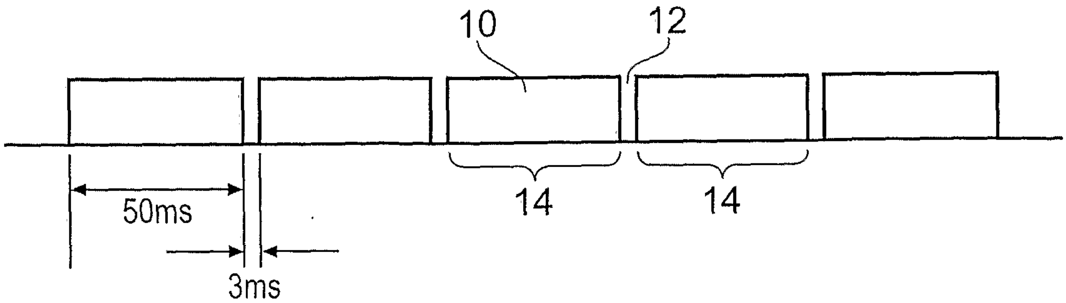


Fig. 1 (PRIOR ART)

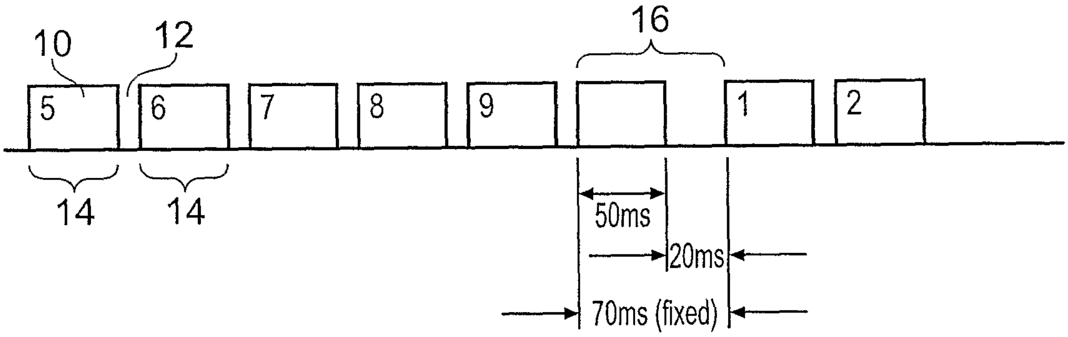


Fig. 2 (PRIOR ART)

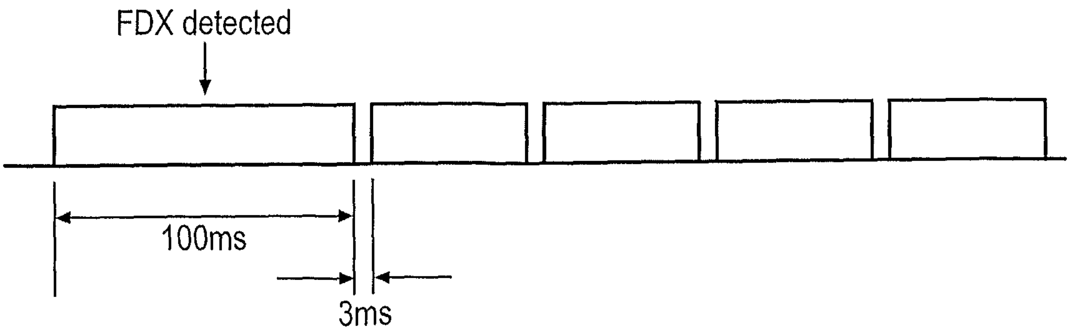


Fig. 3 (PRIOR ART)

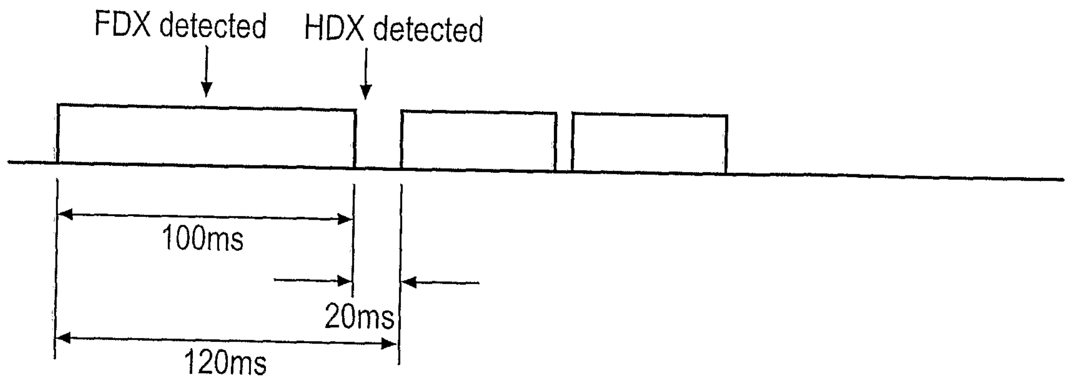


Fig. 4 (PRIOR ART)

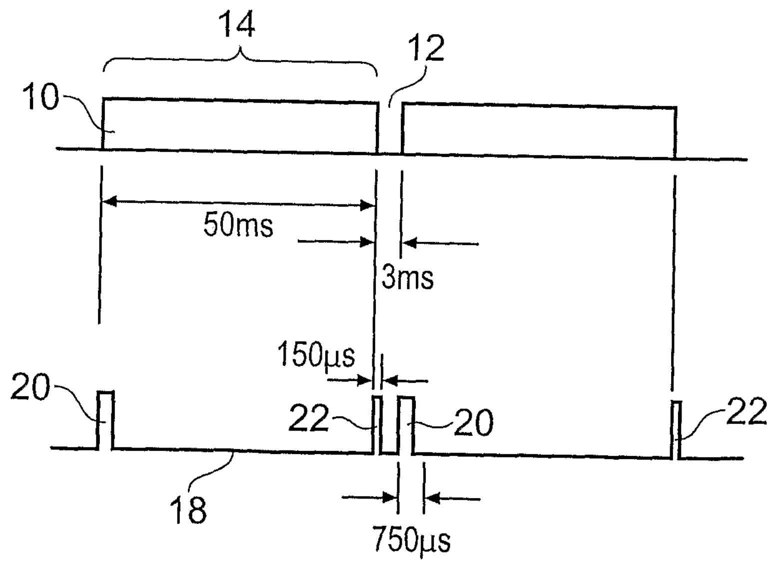


Fig. 5 (EMBODIMENT OF INVENTION)

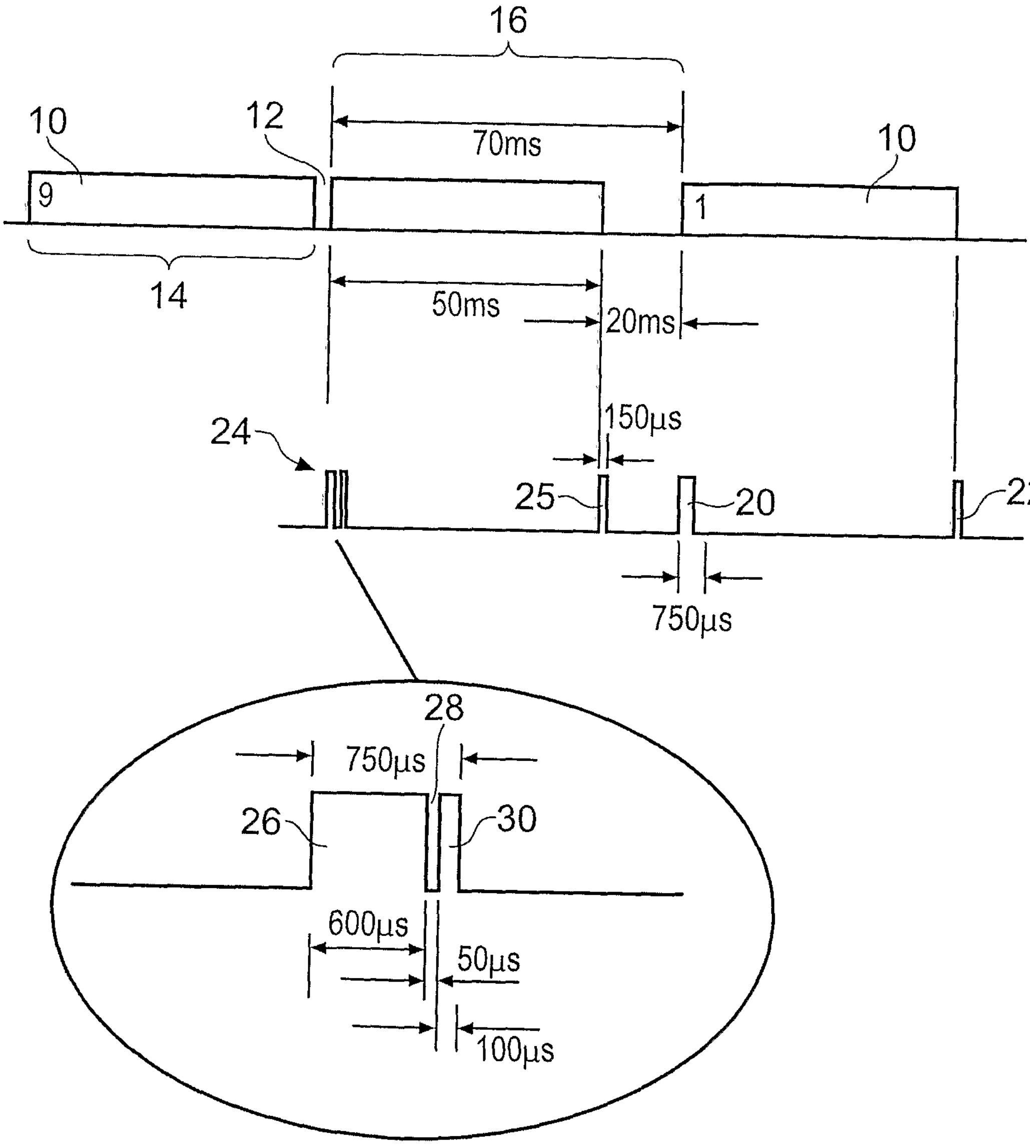

16
70ms
10
12
9
10
1
14
50ms
20ms
150µs
24
25
20
22
750µs
28
750µs
26
30
600µs
50µs
100µs

Fig. 6

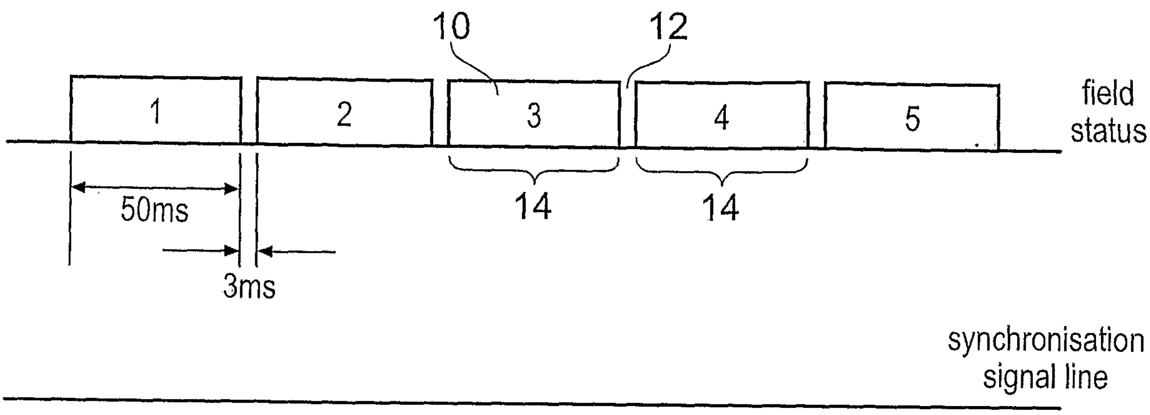


Fig. 7 (PRIOR ART)

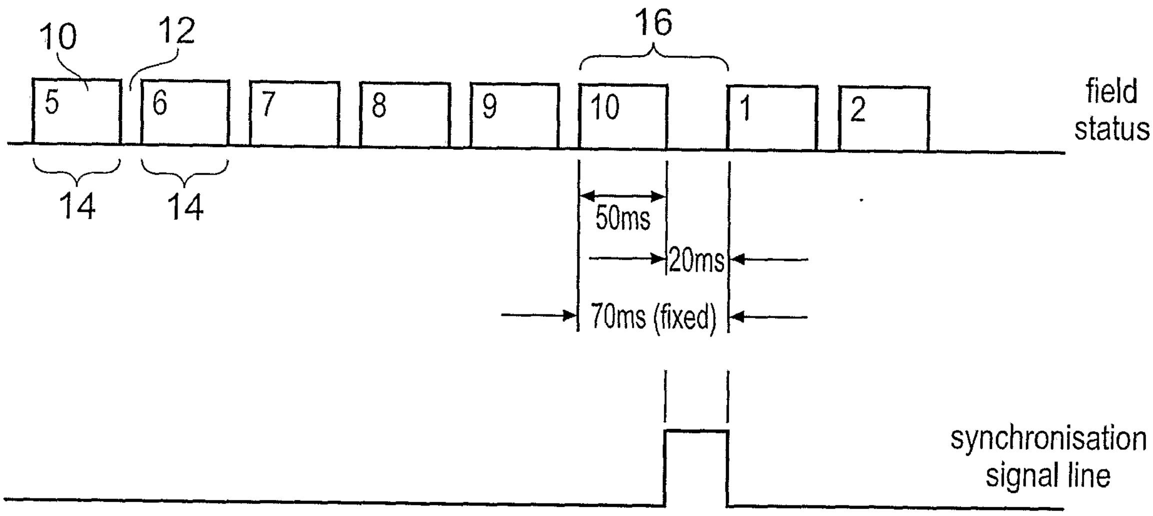


Fig. 8 (PRIOR ART)

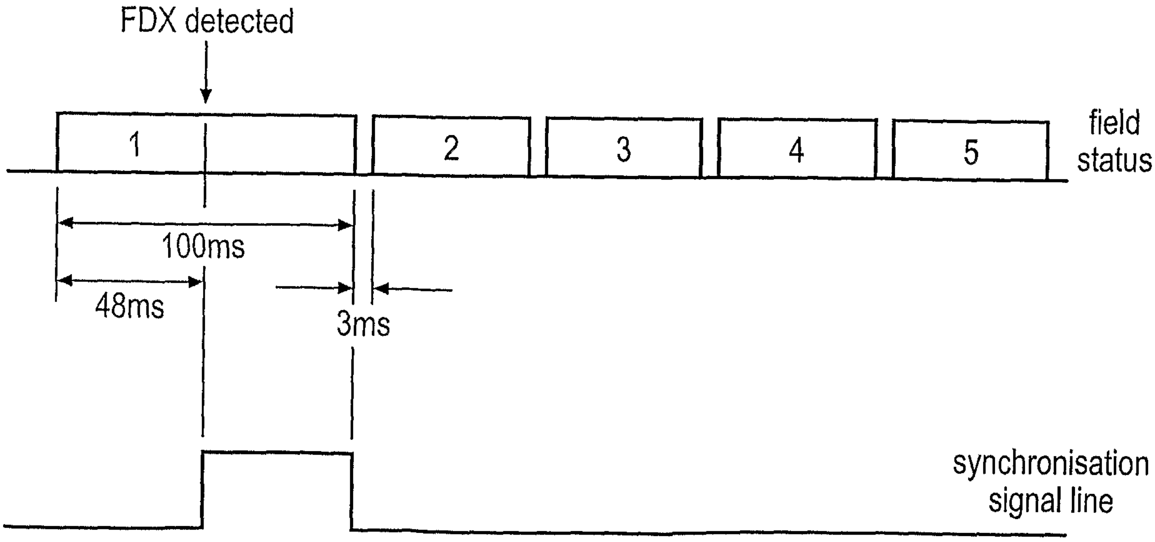


Fig. 9 (PRIOR ART)

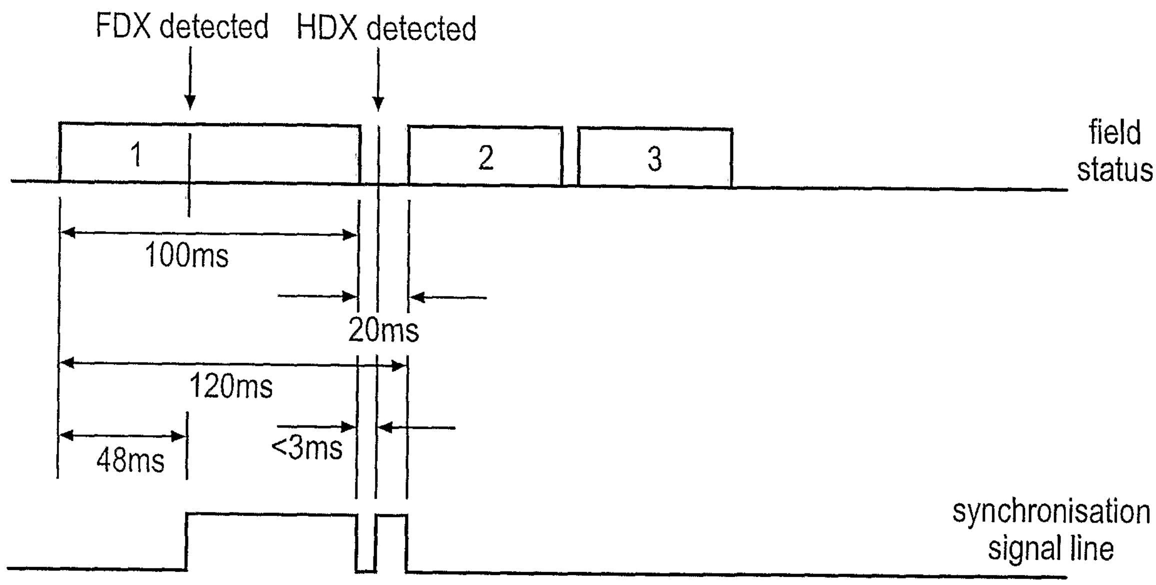


Fig. 10 (PRIOR ART)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2006/001943

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06K7/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01/09814 A (N.V. NEDERLANDSCHE APPARATENFABRIEK NEDAP; POSTMA, EBELE, MARTEN; ROOS) 8 February 2001 (2001-02-08) the whole document	1-17
X	US 5 646 607 A (SCHUERMANN ET AL) 8 July 1997 (1997-07-08) column 3, line 22 - column 4, line 64	1,10,11, 16
X	US 5 748 137 A (D'HONT ET AL) 5 May 1998 (1998-05-05) column 3, line 44 - column 4, line 9	1,10,11, 16

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 August 2006	11/08/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Schauler, M

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2006/001943

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
WO 0109814	A	08-02-2001	AT	269561	T	15-07-2004
			AU	6482500	A	19-02-2001
			CA	2388302	A1	08-02-2001
			DE	60011627	D1	22-07-2004
			DE	60011627	T2	07-07-2005
			EP	1204943	A1	15-05-2002
			ES	2222916	T3	16-02-2005
			NL	1012760	C2	05-02-2001
US 5646607	A	08-07-1997	NONE			
US 5748137	A	05-05-1998	NONE			