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Technical Specification

Electromagnetic compatibility and Radio spectrum Matters (ERM); Improved spectrum efficiency for RFID in the UHF Band

Reference

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

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1 Scope

The present document has been written in response to a market requirement to operate many interrogators simultaneously in close proximity with each other. At the time that the standard EN 302 208 [1] was written it was believed that the provision of 10 channels at 2 W e.r.p. would be sufficient. With the adoption of RFID for large logistic applications it is apparent that the original estimate of usage was too low. An alternative method of operation has been devised in which multiple interrogators can share the same channels. This technique is very spectrum efficient and relies on a process called synchronization. The same technique may be extended to permit synchronization between RFID systems in adjacent sites. This process will enable the market requirement to be satisfied while ensuring compliance with regulatory requirements.

The present document provides guidance on recommended methods for the implementation of synchronization to ensure that RFID equipment will satisfy the requirements of EN 302 208 [1]. In order to satisfy the requirements of the R&TTE Directive [7] providers should use this document in conjunction with the standard EN 302 208 v1.1.2 [1] as a means to seek an opinion from a notified body.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

[1] ETSI EN 302 208: (V1.1.2) "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W; Part 1: Technical requirements and methods of measurement".

[2] ETSI EN 300 220-1: (V2.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods".

[3] ERC/REC 70-03: "Relating to the use of Short Range Devices (SRD)".

[4] ISO/IEC 18000-6: "Information technology - Radio frequency identification for item management, Part 6: Parameters for air interface communications at 860 MHz to 960 MHz", 1st edition.

[5] ISO/IEC 18000-6:2004/Amd.1:2006(E): "Information Technology - Radio frequency identification for item management - Part 6: Parameters for air interface communications at 860 MHz to 960 MHz, AMENDMENT 1: Extension with Type C and update of Types A and B".

[6] Commission Decision of 23 November 2006 on harmonization of the radio spectrum for radio frequency identification (RFID) devices operating in the ultra high frequency (UHF) band; (2006/804/EC).

NOTE: See Official Journal of the European Union, L 329/64.

[7] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity; Official Journal of the European Communities.

NOTE: See Official Journal of the European Union, L 91/10, 07.04.1999.

[8] EPCglobal Low Level Reader Protocol (LLRP), Version 1.0.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

assigned frequency band: frequency band within which the device is authorized to operate

battery assisted tag: transponder that includes a battery to enhance its receive performance and power its internal circuitry

batteryless tag: transponder that derives all of the power necessary for its operation from the field generated by an interrogator

battery powered tag: transponder that uses the power from its battery to perform all of its operational functions

channel: frequency range within a designated frequency band in which an equipment may operate

cluster: collection of interrogators that form a system or sub-system within a geographical area

dedicated antenna: removable antenna supplied and type tested with the radio equipment, designed as an indispensable part of the equipment

frequency agile technique: the technique used to determine an unoccupied sub-band in order to minimize interference with other users of the same band

link frequency: frequency offset of the tag backscatter with respect to the centre frequency of the interrogating signal

in-band radio: means of communicating between interrogators using a radio signal at a frequency that lies within the band designated for use by RFID

integral antenna: permanent fixed antenna, which may be built-in, designed as an indispensable part of the equipment

interrogator: equipment that will activate an adjacent tag and read its data. It may also enter or modify the information in a tag

load: collection of tagged objects that are carried on a transportable device such as a pallet or dolly

network approach: techniques used to interconnect interrogators such as Ethernet, WLAN etc but excluding in-band radio

preferred channel: channel assigned to an interrogator which, provided it is available, shall be selected automatically as the channel of first choice

presence sensing routine: routine that allows an interrogator to transmit for the shortest possible period necessary to detect the presence of a tag

provider: manufacturer, or his authorized representative or the person responsible for placing on the market

listen before talk: action taken by an interrogator to detect an unoccupied channel prior to transmitting

NOTE: also known as "listen before transmit".

radiated measurements: measurements which involve the absolute measurement of a radiated field

scan mode: specific test mode of an interrogator that detects a signal on a pre-selected channel and transmits automatically on another channel

NOTE: See clause 4.2.4, clause 5 of EN 302 208 [1].

secondary channel: channels assigned to an interrogator, which shall be selected in the event that use of the preferred channel is not possible

site: geographical area of limited size that might incorporate one or more systems

synchronization: technique that permits multiple interrogators to share the same channels while observing the rules for LBT

system: set of interrogators operating in synchronization with regard to their timing and frequency of transmission

tag: transponder that holds data and responds to an interrogation signal

talk mode: transmission of intentional radiation by an interrogator

3.2 Symbols

For the purposes of the present document, the following symbols apply:

dB	decibel
dBm	power in decibels relative to 1 mW
d	distance
f_c	centre frequency
λ	wavelength

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

CW	Continuous Wave
ECC	Electronic Communications Committee
e.r.p.	effective radiated power
ERC	European Radiocommunications Committee
Fc	Centre Frequency
LAN	Local Area Network
LBT	Listen Before Talk
NTP	Network Timing Protocol
R&TTE	Radio and Telecommunications Terminal Equipment
RF	Radio Frequency
RFID	Radio Frequency IDentification
SID	System IDentifier
SRD	Short Range Device
WLAN	Wireless LAN
XOR	eXclusive OR function

4 Channel sharing

4.1 General concept

Increasingly end users have a need to operate multiple interrogators simultaneously. EN 302 208 [1] describes a configuration in which only one interrogator may occupy a channel at a time. Since the number of designated high power channels is 10, this defines the maximum number of nearby interrogators that may be operated simultaneously. For many applications end users regard this restriction as unacceptable.

To overcome this limitation RFID manufacturers have introduced a technique called synchronization. This permits multiple interrogators to transmit on the same channel while conforming to the requirements of EN 302 208 [1].

In order to understand synchronization it is first necessary to understand a new feature that has been introduced in the Gen 2 chip, which is embedded in every tag. This feature is called the dense interrogator mode. It enables the backscatter response from the tag to be offset from the carrier frequency of the interrogator. The amount by which the backscatter is offset is called the link frequency.

4.2 Dense interrogator mode

The principle of the dense interrogator mode is shown in the diagram at Figure 1 and is illustrative only.

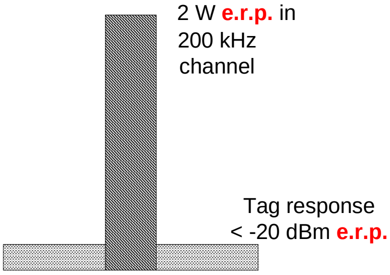


Figure 1: Principle of dense interrogator mode

The transmit signal from an interrogator may be at a power level of up to 2 W e.r.p. and is shown in Figure 1 as occupying the centre channel of 200 kHz. The two channels on each side of the transmit channel are reserved for the backscatter response from the tag. Typically tags will respond at link frequencies of approximately 200 kHz or 300 kHz, which is set by the configuration of the interrogator. The power level of the response from a tag will be -20 dBm e.r.p. or less depending on its distance from the interrogator and the nature of the material to which it is attached. The dense interrogator mode separates the high power transmission of the interrogator from the low power signals of the tags, which improves system performance. It also permits transmissions from multiple interrogators on the same channel. In fact provided that an adequate minimum working distance is maintained between adjacent interrogators, there is no upper limit to the number of interrogators that may simultaneously occupy the same channel.

In practice sites may require the simultaneous use of more than one channel. For example where two or more interrogators are operated in close proximity to each other, it may be beneficial for them to occupy separate channels. Tests have shown that for interference free operation between two adjacent interrogators, the separation between their respective transmit frequencies preferably should be at least 1,0 MHz. This has led to the development of a four channel plan, which is recommended for use in all European RFID installations. A diagram of the four channel plan is shown in Figure 2.

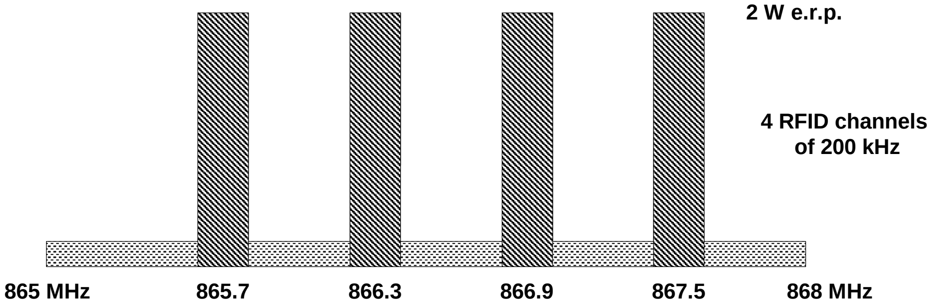


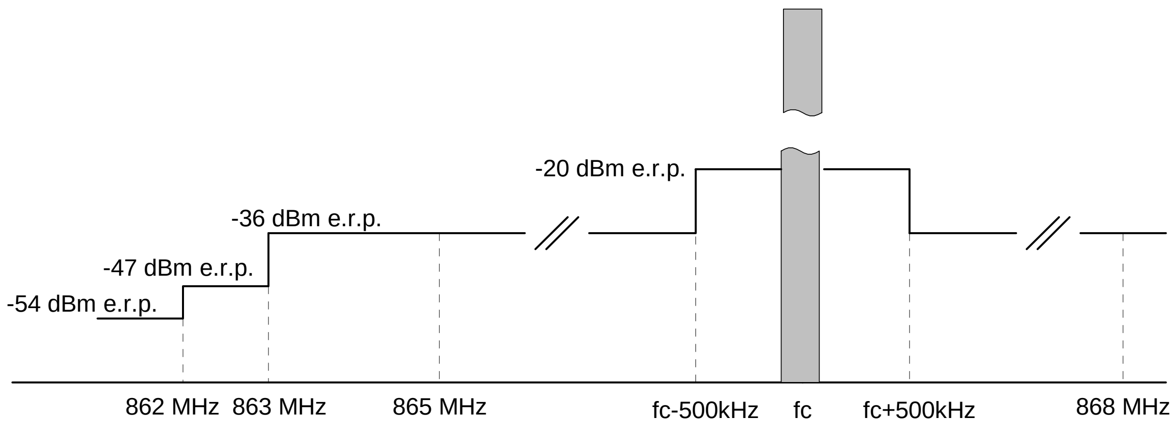
Figure 2: Diagram of four channel plan

The diagram at Figure 2 shows the band 865 MHz to 868 MHz, which has been designated by the ECC for the non-exclusive use by RFID in accordance with [5]. Under ERC/REC 70-03 Annex 11 [3] the operation of RFID at power levels up to 2 W e.r.p. is permitted in the ten channels, each of 200 kHz, from centre frequencies of 865,7 MHz to 867,5 MHz. These equate to channels 4 to 13. Many RFID manufacturers have voluntarily agreed to adopt a common four channel plan and to restrict their high power transmissions to channels 4, 7, 10 and 13. The remaining channels in the band are used to carry the back scatter response from the tags. It should be noted that all channels within the band 865,0 MHz to 868,0 MHz may also be used by SRDs (for details see EN 300 220-1 [2]).

As an example of one use of the four channel plan, distribution centres with dock doors typically will select two channels that are at least 1,2 MHz apart as its preferred channels. The other two channels will be designated as secondary channels and may be used in the event that a preferred channel is not available. It will be normal practice to assign each interrogator with one preferred channel and one or more secondary channels.

4.2.1 Spectrum mask for tag

The present version of the standard EN 302 208 [1] does not include emissions from the tag when operating in the dense interrogator mode. It is important therefore that this topic is addressed in the present document. All tags operating in the dense interrogator mode shall comply with the spectrum mask shown in Figure 3.



NOTE 1: Figure 3 shows the spectrum mask, out of band emissions and emissions in the spurious domain for the tag.
NOTE 2: Fc is the centre frequency of the carrier transmitted by the interrogator.
NOTE 3: The transmit channel occupied by the interrogator is shown in grey.

Figure 3: Spectrum mask for tag operating in the dense interrogator mode

4.3 Principles of synchronization

4.3.1 Basic principles

Synchronization is a technique that co-ordinates the operation of multiple interrogators so that they may carry out their LBT function as a single system. This means that, following a successful LBT operation, multiple interrogators may simultaneously occupy the same high power channel within a common 4 s transmit window. Any tags that are within reading range of these interrogators will respond in the adjacent low power channels. A number of different techniques have been developed to implement synchronization. However they all have certain common features. For example synchronized systems all make use of interrogators that operate in the dense interrogator mode.

EN 302 208 [1] imposes certain rules that shall be observed before an interrogator may occupy a channel. In particular an interrogator shall first listen for a specific period to ensure that the channel is available. If the channel is clear, the interrogator may transmit continuously on that channel for a period not exceeding 4 s. The process of checking that a channel is available is called "listen before talk" (LBT) and the full requirements for its operation are described in clause 4.1 of EN 302 208 [1].

The principle behind synchronization is described by way of the following example. Consider a situation in which two or more interrogators are linked together by some means to form a system. If at a certain instant one interrogator is triggered, it shall first perform LBT. If it locates a channel that is available and is compliant with clause 9.2 of EN 302 208 [1], it shall start to transmit on that channel. At the same time details of the acquired channel may be passed to the other interrogators which, subject to the conditions described in the clauses below, may also share the same channel. However all interrogators must stop transmitting on the channel within the same 4 s window. The interrogator that acquires an unoccupied channel is called the master while the other interrogators that subsequently share the same channel are referred to as slaves.

In many cases interrogators that have been triggered will transmit for an indeterminate period. However in some applications it may be possible to predict the required transmission time of the interrogators in advance. In such circumstances it is permitted to pre-define their transmit times. For both cases slaves that have synchronized to a master must complete their transmission within the permitted 4 s transmit window. Furthermore in order to comply with the standard EN 302 208 [1], slaves shall only transmit on channel if they know that the channel is already occupied by another interrogator. To satisfy these requirements slaves shall meet one of the following three conditions:

1) A master may transmit for an unspecified time. In this case slaves must continuously monitor the channel before transmitting to ensure that it remains occupied.

2) A master may be pre-configured to transmit for a known period of 4 s. In this case there is no need for slaves to monitor the channel during the 4 s transmit window to determine that it is occupied.

3) A master may be pre-configured to transmit for a known time of less then 4 s. Slaves shall start to transmit within this known time and stop within the 4 s transmit window. There is no need for slaves to monitor the channel during the transmit period to determine that it is occupied.

It is not permitted for a master to transmit for a limited period of time and for a slave to transmit later in the transmit window when the channel is unoccupied. For example if a master is pre-configured to transmit for 1 s, a slave shall not start its transmission 2 s later when the channel is no longer occupied.

Two possible approaches are described in the present document for linking interrogators together in a synchronized system. One approach is to connect all of the interrogators in the system together by means of a network. Typically this may take the form of an Ethernet drop, although equally the connection might be implemented by a radio LAN or some other equivalent means. The network is used to pass information between interrogators about channel availability and timing. There are two alternative techniques available for synchronizing networked systems. One of these makes use of a centralized controller. The other technique is called floating masters where the first interrogator to transmit at the start of a 4 s window assumes the role of master.

The second approach is called in-band radio. Conceptually the in-band radio technique is very similar to the floating master technique except that the synchronization information is contained within the transmit signal sent by the master interrogator.

A distinctly different approach for implementing synchronization uses a master time source as a reference. If all interrogators are connected to the same time source, it can be arranged that all interrogators perform their LBT operation over exactly the same period. If each interrogator determines that the channel is available, they may all share the same channel.

Each of these techniques is described in greater detail in the following clauses.

4.4 Networked approach

4.4.1 Centralized systems

4.4.1.1 Outline description

In the centralized technique all of the interrogators in a system are connected to a network controller. The network controller is also connected to a LBT transceiver. The network controller may manage the tag reads from each of the interrogators and pass this data to the host system A diagram of such a system is shown in Figure 4.

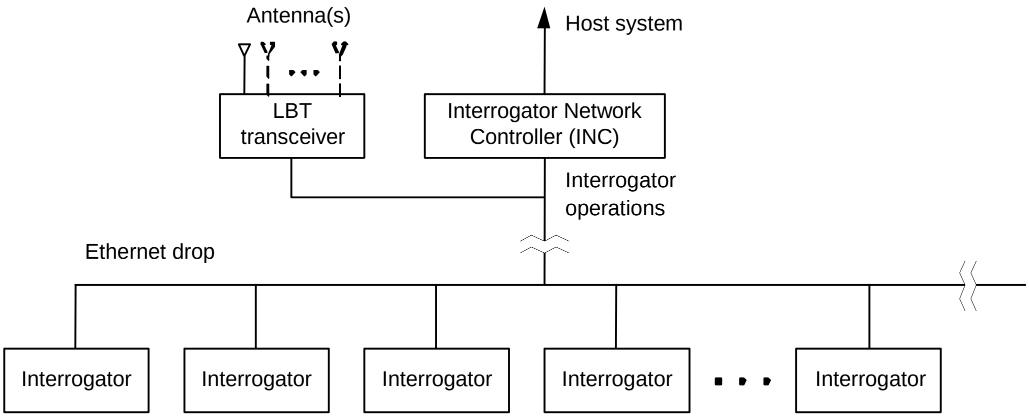


Figure 4: Block diagram of a centralized system

In the initial rest condition all of the interrogators are in standby mode and the LBT transceiver will scan the four high power channels to determine whether they are available for use. At a particular instant one of the interrogators in the system may be triggered by a sensor device. The interrogator will immediately report this event (in essence a request to transmit) to the network controller, which will obtain a channel allocation through the LBT transceiver. The network controller will convey the allocated channel number via the Ethernet to the interrogator and instruct it to interrogate any passing tags. If any other interrogators in the system are triggered, the network controller may also command them to transmit on the same channel. Interrogators may continue to transmit on this channel until the maximum permitted transmit time of 4 s is reached at which point the network controller shall command them to stop. The network controller will then verify the availability of other channels through the LBT transceiver and allocate these channels for a further 4 s to those interrogators in the system that still wish to transmit. This process may continue indefinitely.

In densely populated sites the management of the channel plan may become more complex. For example a line of interrogators may be alternately allocated to channels 4 and 10 respectively as preferred channels. Note that it is important to maintain a frequency separation between high power channels of 1,2 MHz. For interrogators to continue transmitting without any perceptible interruption, the network controller must allocate the secondary channels 7 and 13. Alternatively the central controller may introduce a mandatory rest period of 100 ms before performing LBT operations on the primary channels.

Where a site is subject to interference from other devices, the central controller must optimize the way in which it allocates channels to its interrogators. This is particularly important in situations where channels may be blocked by SRDs. For example if two channels are blocked, the central controller should allocate the two remaining channels to its interrogators. If three channels are blocked, it should assign the one available channel to all interrogators.

It is appropriate to limit the geographical size of a system that uses a single LBT transceiver. Without any limit interrogators that are a long way from the LBT transceiver could cause unacceptable interference to SRDs and other RFID systems. A rule is therefore imposed that the distance from the LBT transceiver to any interrogator in the system shall not exceed 200 m.

In addition to arranging the allocation of channels to its interrogators, the network controller also serves as a concentrator for all of the data generated by interrogators when reading tags. Interrogators have the ability to produce very large quantities of data. It is important therefore that the network controller is fully capable of handling this load.

4.4.1.2 Interface requirements for interrogators

A characteristic of centralized systems is that a number of operations, normally performed within interrogators, are handled by the network controller. Interrogators used in centralized systems must therefore have the necessary functionality to support certain additional commands in the network protocol. The main areas where this is necessary are summarized below:

1) In a centralized system the LBT function is managed centrally by the LBT transceiver. This means that it must be possible for the network controller to disable the LBT feature in each interrogator in the system.

2) In many applications interrogators will receive a trigger, which will initiate a transaction. For a centralized system, the interrogator shall react to the trigger only by sending a message to the network controller saying that a trigger event has occurred.

3) On receiving a trigger message from an interrogator, the network controller must allocate an available channel. It will pass this information to the interrogator. The interrogator must be capable of accepting this message from the network controller and of setting the allocated channel for its next transmission.

4) The network controller will then instruct the interrogator to transmit either for a specified time or until it commands the interrogator to cease. The interrogator must be capable of responding to these commands. The interrogator is only permitted to transmit when commanded to do so by the network controller.

RFID manufacturers may specify their own protocol to support all of these additional functions. However they should be aware that EPCglobal Reader Operations Working Group is currently developing the Low Level Reader Protocol (LLRP) [8] interface.

4.4.1.3 LBT transceiver in centralized systems

The LBT transceiver in Figure 3 shows the use of a single channel device. In practice an LBT transceiver may be capable of listening to all four high power channels simultaneously. This enables the system to pass channel allocations quickly to its interrogators once they have been triggered. In addition by separating the listen and interrogation functions within the system, it is possible for the LBT transceiver to check on the availability of other channels during interrogations. If for any reason it is necessary to extend transactions beyond a single 4 s transmit window, the network controller will know which channels are available. It is thus able to send new channel allocations to interrogators enabling them to switch seamlessly from one channel to another.

The use of a centralized receiver raises a practical problem of timing. EN 302 208 [1] requires that transmission of the interrogation signal occurs within 1 ms of completion of LBT. Due to the cumulative propagation delays from the LBT transceiver via the network controller to the interrogator, it is not possible for an interrogator to start transmitting within the 1 ms limit. To overcome this difficulty the LBT transceiver also includes transmitters capable of transmitting on each of the four high power channels. Every time that the LBT transceiver acquires a channel, its transmitter section sends a transmit pulse on the same channel. This transmit signal shall include the pre-pulse described in clause 4.5.2.

The pre-pulse also permits any portable devices within range of the master to synchronize to it. It also provides a means by which adjacent clusters may synchronize with each other. For further details refer to clause 4.5.2, clause 5 and clause 6.

Although it would be possible to integrate the LBT transceiver within another device, such as the network controller, there are some benefits in keeping it as a separate unit. For example in some sites there may be localized areas of high noise or restrictions to the radio path. Keeping the LBT transceiver as a separate unit provides greater freedom to position it in the most beneficial location.

4.4.2 Floating masters

4.4.2.1 Outline description

An alternative technique used to implement the networked approach is called floating masters. All interrogators in the system are connected to the network, which in turn is connected to the host system. Additional functionality in the interrogators enables them to manage the synchronization process. A block diagram of such an arrangement is shown in Figure 5.

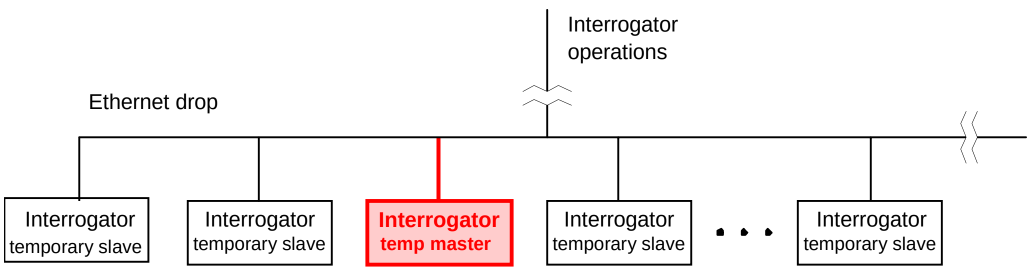


Figure 5: Block diagram of a floating masters system

The system operates as follows. Assume a start condition in which no interrogator is transmitting. At a particular instant one of the interrogators will be triggered. The interrogator first checks its preferred channel to confirm that it is unoccupied. If available it will immediately transmit on that channel for as long as is necessary, but within the 4 s transmit limit, to read all of the tags. At the same time it will assume the role of master and send a message to all of the other interrogators in the system informing them that the preferred channel is available for their use. These "slave" interrogators will note the availability of the channel and start their own 4 s timers. In the event that any of the other "slave" interrogators are triggered during the 4 s period and the channel is still occupied, they may also transmit on the preferred channel.

At the end of the 4 s period any interrogator that is still transmitting must cease using the preferred channel. Instead it must wait for 100 ms before performing its own LBT on the preferred channel. Alternatively it may check if its secondary channel is unoccupied. Once the interrogator has secured an available channel, it is free to transmit. At the same time the interrogator will become the new master and shall send a message to all of the other interrogators in the system informing them that the channel is available for their use. Once again the new "slave" interrogators will note the availability of the channel and start their 4 s timers. Depending on the throughput of tags, this process can continue indefinitely. The management of the system becomes more complex if multiple interrogators are close together. If for example the system comprises a line of interrogators it may be necessary to allocate channels 4 and 10 (or 13) respectively to alternate interrogators as preferred channels. In such a situation channels 7 and 13 (or 10) would most probably be assigned as secondary channels.

As in the case of centralized systems it is necessary to restrict the geographical size of floating master systems. However in this situation, since the position of the master is indeterminate, it is necessary to adopt a rule that assumes worst case. Thus for any floating master system the maximum distance from a master to any other interrogators forming part of the same system shall not exceed 200 m.

4.4.2.2 Detailed operation

In many situations interrogators will be configured in a series of clusters. All interrogators forming part of a cluster shall be connected to each other over a network connection. Interrogators belonging to different clusters are assumed to have no direct connections but shall be capable of seeing each other by means of RF activity. An example of such an arrangement is shown in Figure 6 which, for illustrative purposes, shows only two clusters.

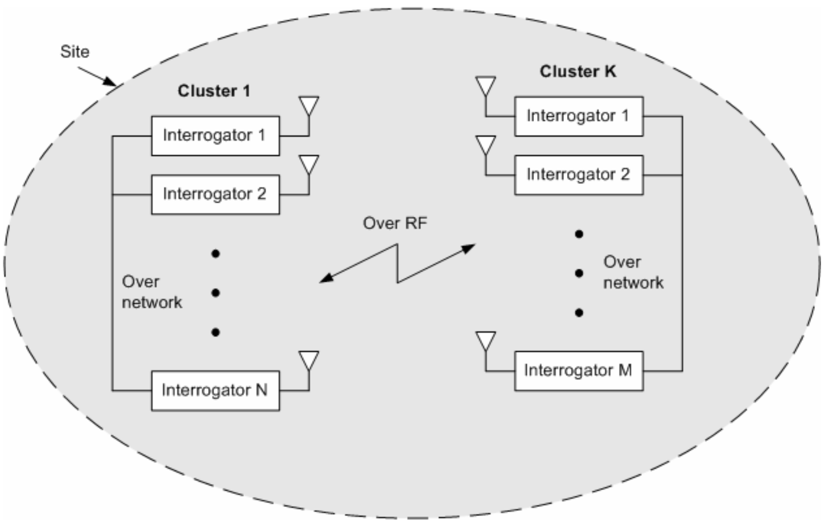


Figure 6: Two clusters of interrogators with floating masters

Each interrogator in a cluster shall be assigned a preferred channel and one or more secondary channels. Whenever an interrogator is triggered it will always attempt first to transmit on its preferred channel. It will only select a secondary channel if the preferred channel is unavailable.

Any interrogator in a cluster may act as a master or operate as a slave. Where an interrogator wishes to transmit and the channel is unoccupied, it shall automatically assume the role of master. Once this interrogator successfully completes an LBT cycle and acquires a channel, it will send a message over the network to all of the other interrogators in the cluster. The message will include details of the available channel and define the instant when the 4 s transmit window started. The master interrogator will then commence immediately its transaction. If any of these interrogators subsequently wish to transmit within the transmit window, they may operate as slaves on the same channel. The transaction will cease when either the channel is no longer occupied or the 4 s transmit window has elapsed.

At all times each interrogator will continuously monitor the network to check the status of all other interrogators in the cluster. This is achieved by incorporating three different modes of operation within the interrogators. Operation in each of these three modes is described below.

Standby mode: When not transmitting, interrogators should continuously monitor their assigned channels to determine whether they are available in accordance with the following rules.

- If the preferred channel is not occupied the interrogator shall continue to monitor it for activity. If the preferred channel is occupied by non-RFID devices (see clause 4.5.1), the interrogator shall check for activity on its secondary channels before returning to monitor its preferred channel.

- If the assigned channels are occupied by RFID activity from another cluster, (see clause 6) the interrogator detecting this activity shall send a message over the network. This message shall indicate which channel is occupied by RFID activity and how much time is left for the transaction.

- If the assigned channels are occupied by non-RFID activity, the interrogator shall continue monitoring to determine when a channel becomes available.

Read mode: An interrogation shall be initiated either as the result of a trigger from an external source or by the interrogator detecting a tag using its presence sensing routine. On receiving a command to interrogate, the interrogator shall first check the status of its assigned channels.

- If no assigned channels are occupied, the interrogator shall select its preferred channel and send a message over the network to the other interrogators in the cluster declaring itself as the master for the selected channel. The interrogator shall then transmit in order to read any tags that are within range.

- If one or more assigned channels are already occupied by other interrogators, and if there is adequate time left in the 4 s transmit window, the interrogator will operate as a slave on the channel with most time remaining. If the interrogator completes its transaction within the 4 s transmit window it will return to the Standby mode.

- If all assigned channels are occupied, the interrogator will continue to monitor all channels until one of them becomes available.

- If a transaction is incomplete at the end of a 4 s transmit window, the interrogator shall go into the Pause mode.

Pause mode: Where an interrogator is unable to complete its transaction within the 4 s transmit window, it is required to cease transmitting on its selected channel. As soon as the transmission has stopped, the interrogator shall monitor all of its assigned channels to determine whether any are available.

- If the interrogator chooses to remain on the same channel, a minimum period of 100 ms shall elapse before it is permitted to return to the Read mode.

- If other assigned channels are available, the interrogator is permitted to occupy any one of them immediately by returning to the Read mode.

- If all assigned channels are occupied, the interrogator shall continue to monitor all of its channels until one of them becomes available. It will then return to the Read mode.

Whenever an interrogator, which is acting as a master, starts to transmit, it shall precede its interrogation of tags with a pre-pulse and optionally a site identifier (for example see clause 4.7) and/or other data. The pre-pulse and optionally a site identifier and/or other data permits any portable devices within range of the master to synchronize to it. It also provides a means by which adjacent clusters may synchronize with each other. For further details refer to clause 4.5.2, clause 5 and clause 6.

4.5 In-band radio approach

4.5.1 Outline summary

The in-band radio approach makes use of a preamble, which consists of a pre-pulse (see clause 4.5.2.1) followed by an optional site identifier (see clause 6). It is similar to the floating master approach except that the synchronization information is contained within the transmit signal sent by the master interrogator. The method of operation is best illustrated by means of an example.

Consider a system comprising three interrogators labelled A, B and C that are all initially in their standby mode. Assume at a particular moment that interrogator A is triggered. Since no other interrogators are transmitting, interrogator A will become the master. Having successfully performed its LBT operation and acquired an available channel, interrogator A will start its 4 s internal timer. It will then transmit a pre-pulse followed by its optional data and its interrogation signal. The parameters of the pre-pulse are unique to RFID systems, thus any other nearby interrogators will identify that the transmission has originated from a RFID master.

Interrogators B and C will have been in standby mode during which time they will have been monitoring the same preferred channel as A. They will both have verified that the channel was clear up to the instant when they detected the pre-pulse. Once interrogators B and C have validated the pre-pulse and/or optional the site identifier transmitted by A, they will start their internal timers. During the following 4 s interrogators A, B and C may all share the same channel. Note that the 4 s transmit window should commence from the first rising edge of the pre-pulse, which in this example was generated by interrogator A. A possible timing diagram using the pre-pulse is shown in Figure 7.

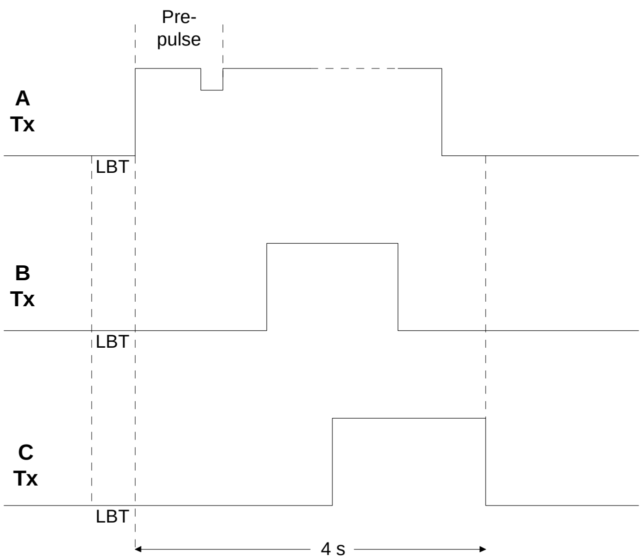


Figure 7: Tx waveforms of interrogators A, B and C

From the diagram it will be seen that all three interrogators perform their LBT function at the same time. However only interrogator A, as the master, transmits a pre-pulse. Provided that the channel remains occupied, slave interrogators B and C may transmit at any time within the 4 s transmit window.

In the example interrogator C is still in the process of reading tags when the 4 s window expires so it must therefore cease transmitting on the preferred channel. Under the LBT rules interrogator C must wait for 100 ms and then check if the preferred channel is available before continuing to transmit. Alternatively it is permitted immediately to acquire another unused channel. Once interrogator C has acquired a channel, it becomes the new master and transmits a pre-pulse followed by an optional site identifier and its main transmission.

With in band radio systems, since each interrogator is able to perform its own LBT, there is no requirement to impose any geographical restriction on the system size.

To ensure interoperability between equipment supplied by different vendors, it is important that the essential parameters of the pre-pulse are adequately specified. A full specification of the pre-pulse together with the provision for optional additional data is covered in greater detail in clauses 4.5.2.1 and 4.5.2.2.

4.5.2 Detailed operation

4.5.2.1 Definition of pre-pulse

The in-band radio technique is based on a unique pattern transmitted by a master interrogator following a successful LBT operation. This pattern comprises an initial period t_{SPON} during which the master interrogator transmits at high power followed by a period t_{SPOFF} during which the power level is significantly reduced by at least P_{MOD}. It is a mandatory requirement that a master shall transmit a pre-pulse prior to each interrogation. The waveform of the signal from a master interrogator showing the pre-pulse followed by its optional data and interrogation signal is shown in Figure 8.

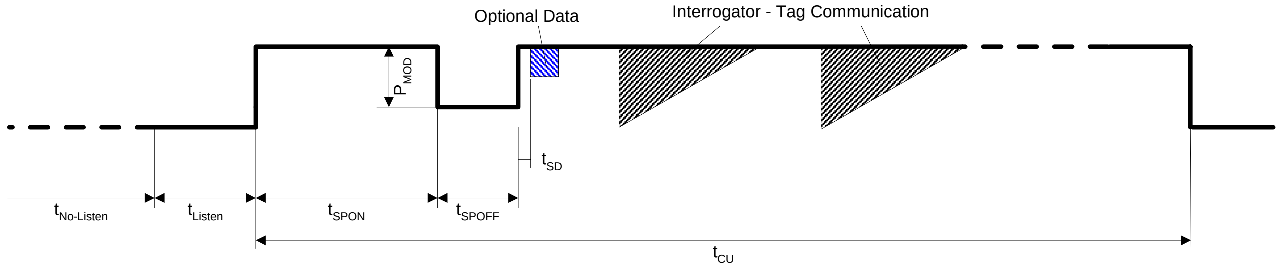


Figure 8: Signal transmitted by a master interrogator

A short period is provided following the pre-pulse for the transmission of optional data. The content of the optional data is not defined and may be proprietary to individual manufacturers. Manufacturers may also interleave the transmission of the optional data with the interrogation of tags. As will be seen below the optional data provides a number of useful benefits during system operation.

To ensure that the pre-pulse is inter-operable between equipment provided by different manufacturers, it is important that it is precisely defined. The RF envelope for the pre-pulse is specified in Figure 9 below, supported by the table of parameter values in Table 1.

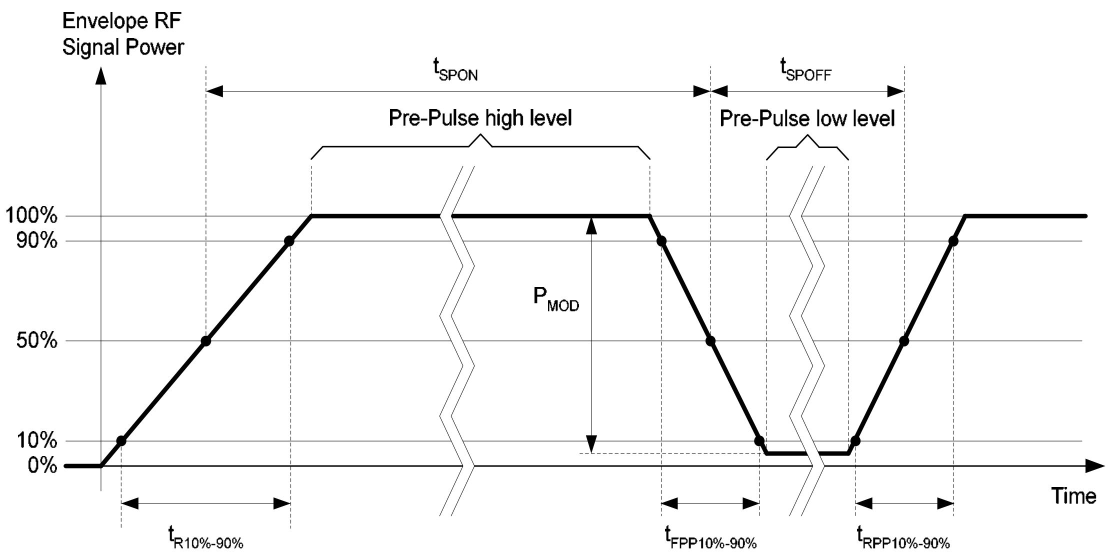


Figure 9: RF envelope of pre-pulse

Table 1: Specification of timing parameters

PARAMETER	SYMBOL	VALUE	UNIT	COMMENT
No-Listen Time	$t_{No\text{-}Listen}$	≥ 0 or ≥ 100	Ms	See Note 1
Listen Time	t_{Listen}	5 to 10	Ms	See Note 2
Synchronization signal ON time	t_{SPON}	16 ± 0,5	Ms	
Synchronization signal OFF time	t_{SPOFF}	4 ± 0,10	Ms	
Synchronization Data delay time	t_{SD}	0,5 ± 0,05	Ms	
Channel Utilization Time	t_{CU}	≤ 4	s	
Rise time	$t_{R10\%\text{-}90\%}$	≤ 500	µs	Parameters are aligned with ISO/IEC 18000-6 [4]; See Note 3
Rise time pre-pulse	$t_{RPP10\%\text{-}90\%}$	≤ 25	µs	Parameters are aligned with ISO/IEC 18000-6 [4]; See Note 3
Fall time pre-pulse	$t_{FPP10\%\text{-}90\%}$	≤ 25	µs	Parameters are aligned with ISO/IEC 18000-6 [4]; See Note 3
Modulation depth for low phase	P_{MOD}	≥ 14	DB	Parameters are aligned with ISO/IEC 18000-6 [4]; See Note 3
NOTE 1: At the end of a 4 s transmit window, if an interrogator wishes to remain on the same channel, it must wait for 100 ms then perform LBT before continuing to transmit. The 100 ms wait period does not apply if the interrogator switches to a different channel. NOTE 2: The Listen Time may vary and is dependent on the conditions described in clause 9.2 of EN 302 208 [1]. NOTE 3: The times specified must be long enough to fulfil the requirements of the spectrum mask in EN 302 208 [1].				

4.5.2.2 Slave interrogators

A slave interrogator shall be capable of reliably identifying a transmission from a master interrogator. It may do this either by detecting the pre-pulse from the master or by demodulation of the optional data such that the slave clearly identifies the master interrogator.

A slave may share the same channel as the master provided it satisfies one of the following two sets of conditions:

Condition A:

1) The slave interrogator has detected a difference of at least 6 dB between the pre-pulse high and pre-pulse low levels.

2) The slave has either completed a successful LBT or the signal level received by the slave during t_{SPON} was more than -40 dBm. (A signal level of greater than -40 dBm indicates that the slave is less than 200 m from the master).

Condition B:

1) The slave identifies that the site identifier has been transmitted by an interrogator from the same cluster or system.

2) The deployment of the slave is arranged such that its distance to a master with matching site identifier is less than 200 m. In these circumstances it is not necessary for the slave to perform its own LBT operation.

In either case, provided the channel remains occupied, the slave may start to transmit at any time between the identification of the master and the end of the transmit window t_{CU}. If any interrogator subsequently wishes to interrogate, it is necessary for a new master to acquire a channel.

Under condition B above, slave interrogators may share a channel without performing LBT when located within 200 m of the master interrogator. This is conditional on the ability of the slave to detect the presence of the master with a confidence level of at least 98 %.

Since it is difficult to measure confidence levels in a reasonable time period, interrogator vendors shall provide either data or analysis to prove that their systems meet this requirement.

4.6 Autonomous NTP approach

4.6.1 Outline summary

The autonomous NTP approach makes use of a single timing source within the system as a reference. Typically this timing source is derived from the Network Timing Protocol (NTP), although it may also be taken from other accurate sources such as GPS. All interrogators in the system complying with this approach are synchronized to the timing source so that they each perform their LBT function during the same window of time. Those interrogators that perform a successful LBT operation may then transmit for a pre-defined transmit period. At the end of the transmit period the process is repeated.

Each interrogator will normally be assigned a preferred channel and one or more secondary channels. In order to minimize the off time, interrogators will normally switch immediately from one channel to another. To ensure that this operation works satisfactorily, it is necessary for all interrogators in a cluster to select the same channel at the same time. Performance is improved by the use of a pre-screening process, which is carried out by each interrogator immediately prior to its LBT. This process increases the probability that each interrogator will find an available channel.

It is important that the transmit window of all interrogators in the system is fixed to the same value otherwise synchronization between these interrogators will be lost. For optimum operation of the system it has been determined that the transmit time should be set at 0,5 s or 1 s. It should also be noted that, in normal operation of a system, all triggered interrogators will commence transmission at the same time but will cease transmission on completion of their respective transactions. An interrogator that has not received a trigger will take part in the periodically recurring LBT cycles but will not transmit.

A more detailed description of the NTP approach is provided in clause 4.6.2.

4.6.2 Detailed operation

The autonomous NTP based method is based on the concept of a shared listen period by all interrogators. This shared listen period occurs once every shared listen cycle. The cycle time (T_{CYCLE}) for a shared listen period is constant and must be set to a common value within each particular geographic area so that all interrogators cease talking by a known time. Because all interrogators listen simultaneously, each interrogator is now able to listen autonomously on the channel or channels it wishes to occupy. There are various schemes that maximize the interrogators' chances of occupying the correct channel. A concept of preferred channel is one such scheme and is described in some detail in clause 4.6.3.

The interrogator's ability to switch to alternative channels, when its preferred channel is blocked, requires consideration of the channel selection process. Since the standard ([1]) restricts continuous transmission on a channel to less than 4 s, repetition of the shared listen period is set typically to 1 or 0,5 s. The process also further employs the concept of a preferred channel with channel switching to avoid the 100 ms off period. A second process uses the concept of pre-screening, which is necessary to allow interrogators to migrate to secondary channels when their preferred channel is occupied. A more detailed description of pre-screening and the use of preferred channels is given below.

In summary, the autonomous NTP approach requires the following basic timing characteristics:

1) Shared channel cycle time.

2) Shared channel listen time.

3) Pre-screen time.

An illustration of the autonomous NTP process is illustrated in Figures 10 and 11.

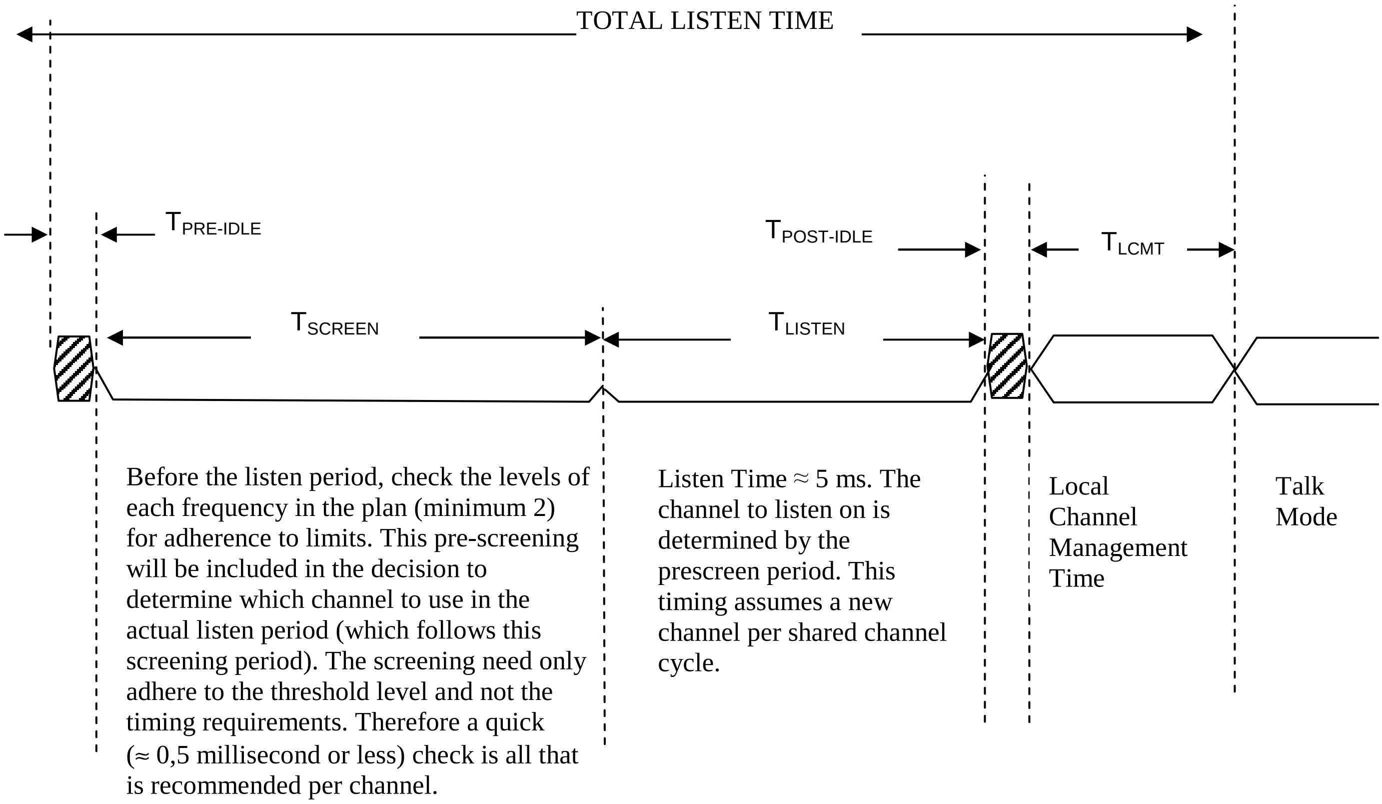


Figure 10: Shared Channel Implementation method

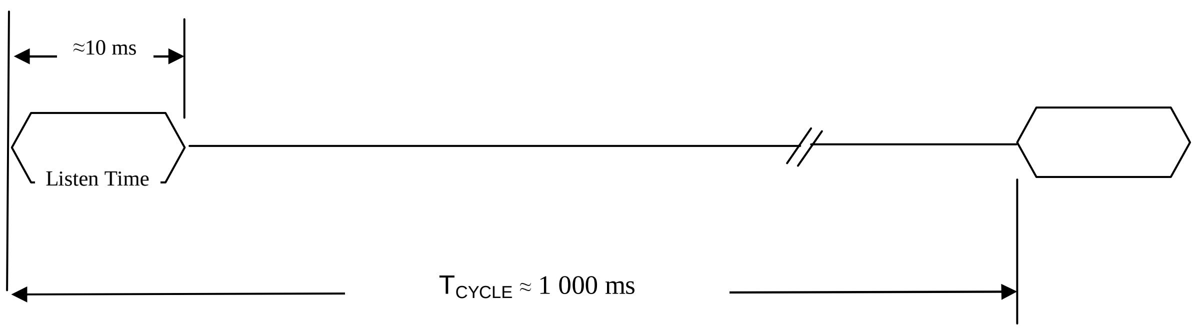


Figure 11: Shared Channel Cycle timing

4.6.3 Preferred channel switching

In one implementation of the preferred channel method, the interrogator is assigned four channels. For each transaction the interrogator shall, where possible, use its preferred channel. If extended transactions are required, the 100 ms off period may be avoided by switching channels. If, due to unavailability, it is not possible to switch channels, the 100 ms mandatory off period shall be invoked. In such circumstances, to remain in synchronization with the system, an interrogator that is blocked from all but one channel will have to skip one shared channel cycle time. However, an interrogator that is equipped with a pre-pulse detector may, on detection of the pre-pulse, occupy the channel in accordance with the guidelines in clause 4.5. However this interrogator shall respect the channel cycle time to remain synchronized with the time frame of the other interrogators within the site.

4.6.4 Channel acquisition

Since there is only one opportunity per shared channel cycle time to perform LBT, all interrogators using the NTP approach must listen for their channel during the same shared listen period. In practice, any interrogator that fails to obtain a channel during this time usually has to wait until the next listen period. Also, it is important that all interrogators migrate to their correct preferred channel at all times; otherwise interrogators will be out of synchronization with their channel selection plan.

To improve the probability of acquiring a channel, the concept of pre-screening is introduced with the following criteria:

1) Pre-screen a minimum of two channels.

2) One of the pre-screened channels must be the preferred channel.

Pre-screening involves testing two or more channels to determine if they are unoccupied and occurs immediately prior to the listen time. The pre-screening process increases the probability that an interrogator will acquire a channel.

4.6.5 Interfacing with in-band radio approach

The Local Channel Management Time T_{LCMT} is reserved for managing mobile interrogators rather than those that are networked. The use of this period may be proprietary to the manufacturer. This period shall also be used for the transmission of a pre-pulse and may include optional data in order to synchronize interrogators using the in-band radio approach described in clause 4.5. In such an arrangement certain interrogators may be designated to act as masters. However, in an effort to minimize interference of the pre-pulse signal, only one interrogator in a given geographic area may transmit a pre-pulse signal on a channel at any given time. Nevertheless this does not preclude the transmission of pre-pulse signals on a number of different channels.

In summary, the autonomous method requires the following parameters for implementation:

Table 2: Example Parameters for NTP approach

PARAMETER		SYMBOL	LIMITS	Tolerance	UNITS	DESCRIPTION
1	Shared channel Cycle time	T_{CYCLE}	1 000	+/- 0,5	ms	The accuracy of this time is governed by NTP accuracy and operating system jitter. Where insufficient NTP accuracy is achieved, an interrogator might interfere with the rest of the system. In such cases the interrogator has the ability to inhibit its operation.
2	Pre-Listen Idle time	$T_{PRE-IDLE}$	1 000	+/- 5,0	µs	Idle time padding to prevent late arrivals from interfering with early arriving interrogators.
3	Post-Listen Idle time	$T_{POST-IDLE}$	500	+/- 5,0	µs	Idle time padding to prevent early arrivals from interfering with late arriving interrogators that might still be listening.
4	Pre-Screen Time	T_{SCREEN}	1 500	+/- 5,0	µs	This time is used to pre-screen as many channels as warranted by the manufacturer. The information gained will be included in the channel assignment used in the listen period.

PARAMETER		SYMBOL	LIMITS	Tolerance	UNITS	DESCRIPTION
5	ETSI listen time	T_{LISTEN}	5 000	+ 10,0 - 0,0	µs	Listen period as per EN 302 208 [1] guidelines. Note that because this method requires changing channels on each cycle, the random time is always set to zero only if that the channel is unoccupied.
6	Local Channel Management Time	T_{LCMT}	≥ 20	± 0,6	ms	Minimum duration given by timing specification of pre-pulse (see Table 1).

4.7 Multi-channel synchronization incorporating a System IDentifier (SID)

The present clause describes a different technique in which a System Identifier (SID) is used to provide multi-channel wireless synchronization. In a similar way to the pre-pulse synchronization technique (see clause 4.5), the interrogators operate in a master-slave configuration. However, the master transmits an SID pattern that is unique to the system. The slaves can recognize this pattern. This means that the slaves do not need to perform LBT prior to transmitting provided that they are within 200 m of the master.

Using this method the interrogators can synchronize in all 4 channels simultaneously. In this respect the channel utilization is similar to the networked approach (see clause 4.4).

A unique System Identifier (SID) code is assigned to interrogators that form part of a cluster or system. There is no need for any wired connections as the SID is broadcasted using in-band radio. The SID comprises a 255 bit gold code, transmitted for a duration of 40 ms at 40kbits/s. The synchronized system may operate on one or more of the four high power channels at the same time using the same SID.

Initially, when the system is inactive, the interrogators in the system sample all four channels and correlate their local SID code with any incoming signal. The duration of the SID (6,375 ms) and the scanning rate (i.e. the aggregate time to transmit the SID on all 4 channels) are arranged so that the SID is always detected on any channel by any interrogator. This method is shown in Figure 12.

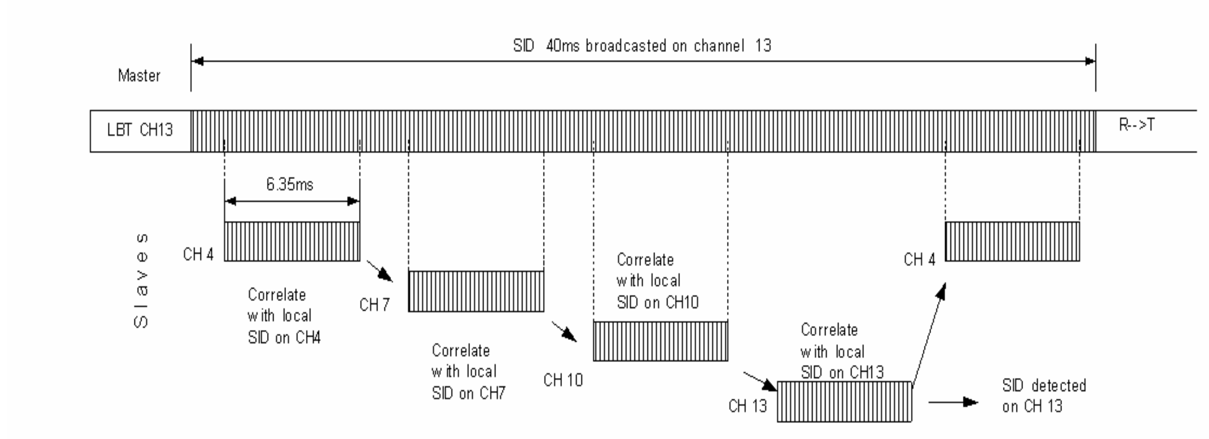


Figure 12: SID scanning and detection

The first interrogator to transmit on a channel becomes the master for that channel and has to perform LBT in accordance with the requirements of EN 302 208 [1]. If the channel is available, the master broadcasts the SID and then proceeds with the normal interrogation cycle.

The other interrogators in the synchronized system automatically become slaves to the master that has acquired the channel. The slaves recognize the broadcasted SID and start their internal timer to keep track of the remaining time on the selected channel. The maximum allowable period of continuous transmission on any channel is 4 s. In the event that the system requirements can be predicted, the duration of transmissions can be pre-programmed up to the 4 s time limit. Where slaves are at a distance of less than 200 m of the master, there is no requirement for them independently to perform LBT. However if slaves are at a distance of more than 200 m from the master they are required to carry out their own LBT.

The slaves continue to monitor the remaining channels for both SID and LBT and build up a map of channel occupancy. This means that they "know" which channels are used at any time by their "own" synchronized system and the remaining time on each channel. They also "know" which channels are free and/or which channels are occupied by other devices.

When slaves, that are known to be within 200 m of a master, are triggered, they may transmit without prior LBT on any synchronized channel, providing that a matching SID has been detected. Alternatively, the interrogators may choose a new (unused) channel on which to transmit the SID and to become the master for that channel. The choice of whether to use a new or the existing channel for transmission, is determined by the remaining time and/or the system configuration. The behaviour of a system comprising 3 interrogators is illustrated in Figure 13.

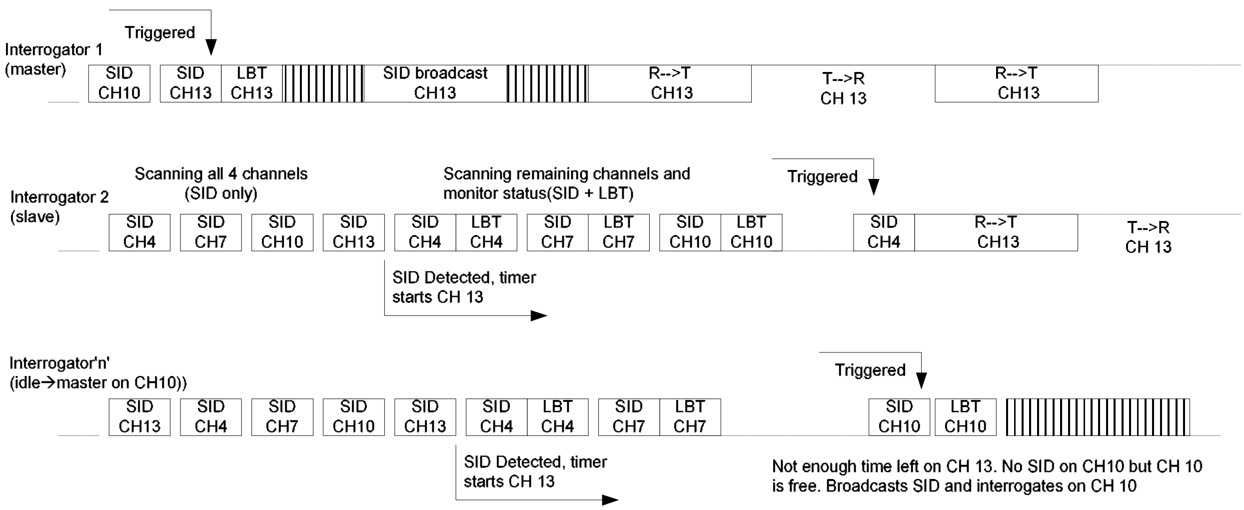


Figure 13: Master-Slave synchronization using SID

In this example, interrogator 1 is the master. There is no SID transmission prior to interrogator 1 being triggered, so it has to carry out an LBT cycle. In this example channel 13 is free and interrogator 1 transmits the SID then starts its interrogation. Interrogator 2 detects the SID on channel 13. It carries on scanning the remaining channels, and maps the channel status. (This may include a record of available channels, channels occupied by its own system and channels occupied by other systems) In this example when interrogator 2 is triggered it will transmit on channel 13 for a period not exceeding the remaining time in the 4 s transmit window. Interrogator "n" is also scanning the channels and receives the SID on channel 13. However, it is triggered much later when there is very little time remaining in the 4 s transmit window of interrogator 1. Rather than transmit on channel 13, interrogator n finds that channel 10 is available. Interrogator n transmits the SID as a master on channel 10 and proceeds with the interrogation.

Any interrogators that have been monitoring the system will have detected the SID broadcasted by interrogator n and will "know" that channel 10 has just become available. Any other interrogators that were operating on channel 13 and wish to continue transmitting may do so on channel 10 provided that they had detected the SID immediately after they had ceased transmitting. This demonstrates that, by switching channels, interrogators in the system may transmit continuously while meeting the requirements of the ETSI standard. It should be noted that this is only possible so long as other users do not block the channels.

The ability to distinguish between different systems that wish to occupy the same channels is due to the auto-correlation and the cross-correlation properties of the gold codes used for the SID broadcasts. Gold codes are frequently used in spread spectrum communication systems for similar purposes. The SID contains an N=8 bit gold code that consists of 255 binary symbols which is repeated 6 times. Table 3 shows the parameters of the SID transmission.

Table 3: System identifier properties

SID Parameter	Value	Unit
SID Pattern length	255	bits
Broadcasting time	40 nominal	ms
Bit rate	40 nominal	Kb/s
Bit period	25 +/- 10ppm	µs
Modulation	AM DSB or FM	
Modulation depth (AM)	80 to 100	%
Modulation index (FM)	1	
Rise /Fall time	max. 15	µs
Overshoot	max. 10	%
Shift register length	8	
Feedback positions for gold codes	8,4,3,2 8,5,3,1 8,5,3,2 8,6,3,2 8,6,4,3,2,1 8,6,5,1 8,6,5,2 8,6,5,3 8,6,5,4 8,7,2,1 8,7,3,2 8,7,5,3 8,7,6,1 8,7,6,3,2,1 8,7,6,5,2,1 8,7,6,5,4,2	

The gold code is the XOR product of two linear shift registers with feedback. There are 16 possible tap positions as shown in Table 1. Any pair of these can produce 257 gold codes; all of which have similar autocorrelation and cross-correlation properties. An example for generating gold code sets with 8 bit shift registers for feedback values of 8, 4, 3, 2 and 8, 5, 3, 1 is illustrated in Figure 14. This generator can start up at 255 different seed values and hence can produce 255 + 2 = 257 gold codes.

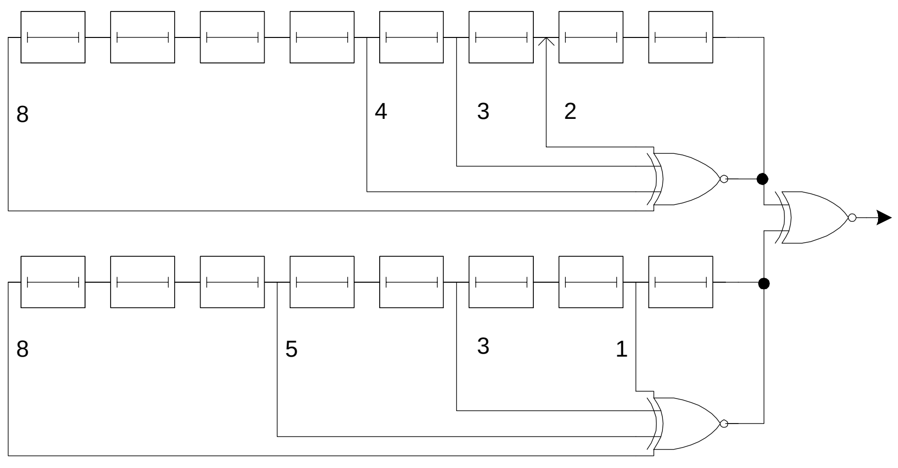


Figure 14: Gold code generation example N = 8

For the purposes of interoperability, a pre-pulse shall be included with an SID transmission (see clause 6).

5 Mixed Systems

In large systems with many interrogators there may be benefits in using networked systems. This is because the communication system frequently is hard-wired and is likely to be more reliable.

There is one specific application area where the use of a networked system alone may be unsuitable. This is where interrogators are mobile as, for example, in the case of forklift trucks and hand held interrogators. In systems that require both fixed and mobile interrogators, it is necessary to combine the networked and in-band radio techniques. These are referred to as mixed systems.

One synchronization method used with a combination of networked and in-band radio interrogators is described in clause 4.5.2. and clause 4.7. Any fixed interrogator that initiates a transaction becomes a master and shall first transmit a pre-pulse. Mobile devices may synchronize to the pre-pulse, and optionally the site, provided that they satisfy the conditions described in clause 4.5.2.3. The adoption of a common specification for the pre-pulse ensures interoperability between interrogators produced by different RFID manufacturers.

There may be some applications where it is beneficial to inhibit the ability of a mobile interrogators to act as a master. To cater for this requirement it is recommended that mobile interrogators have the capability to behave either as a master or for this feature to be inhibited.

6 Combining in-band systems with a site identifier

It may be possible to improve the integrity of system operation by combining the in-band approach described in clause 4.5 with a site identifier such as the technique described in clause 4.7. In this case the System Identifier SID is included as part of the optional data following transmission of the pre-pulse. An illustration of the transmitted waveform is given in Figure 15. This shows the pattern that is transmitted before the interrogation cycle comprising the pre-pulse followed by 6 SID patterns according to Table 3 and then a short transmission of CW.

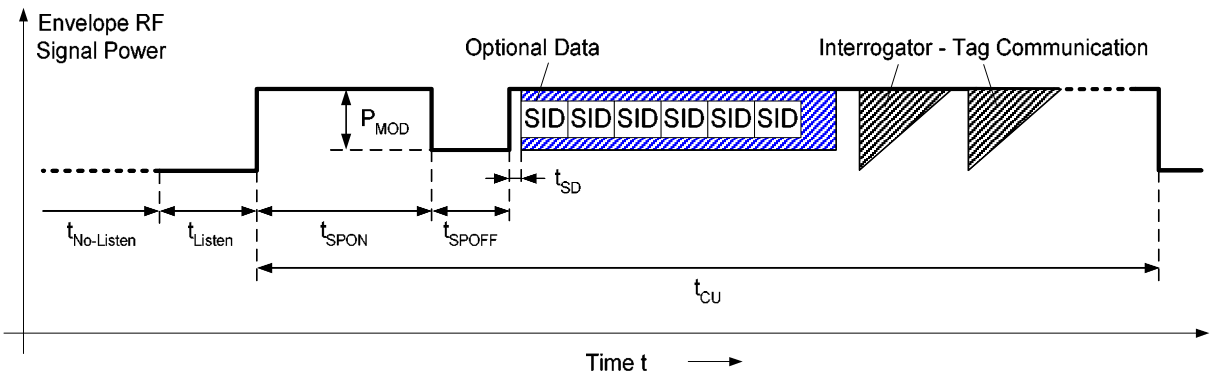


Figure 15: Transmission preceding interrogation cycle

Sites greater than 200 m apart, should be assigned different site identifiers, unless the distance between them is sufficient to ensure that they do not interact.

7 Synchronization between adjacent sites

Situations may arise where the signals from RFID systems at adjacent sites may cause interference with each other. This might occur for example where there are a number of warehouse co-located on the same industrial park. To minimize the effects of interference, steps should be taken to synchronize the different systems. The present clause describes one technique that allows a system to synchronize to other adjacent sites. The technique does not require any specific knowledge of the other sites operating in the same geographic area and avoids the need for any hard wired connection between sites.

In order for the technique to work it is advisable for the system to include at least one interrogator with a receiver that is able to operate at levels down to -96 dBm. The use of more than one interrogator listening on the same channel at a site should be avoided since this will prevent any possibility of interference between their pre-pulses.

For the technique to function effectively all of the interrogators at a site should use a common site identifier. This site identifier is transmitted by a master as part of the optional data immediately after a pre-pulse.

Operation of the technique is best illustrated by means of an example. Consider a situation in which 3 sites, A, B and C, are each assigned with their own unique site identifier and are separated by a distance d. The maximum value for d corresponds to the distance at which the field transmitted by an adjacent site has fallen to -96 dBm. Assume also that there is at least one receiver at each site that it is able to read signals at -96 dBm. In such a system B can just detect a pre-pulse from A and C can just detect a pre-pulse from B but not from A. A diagram of the configuration is illustrated in Figure 16.

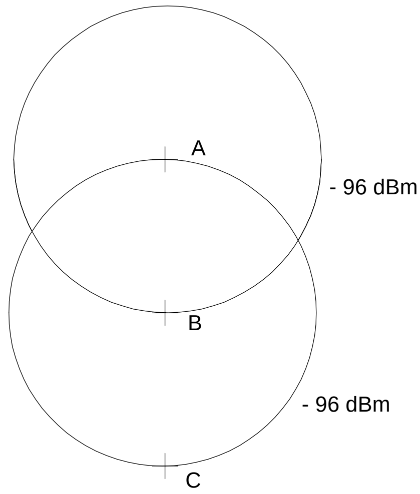


Figure 16: Relative locations of sites A, B and C

All interrogators using in-band radio synchronization should adopt the rule that, where they receive a pre-pulse accompanied by their own site identifier, they will act as slaves. This means that they may transmit within the 4 s transmit window while within 200 m of the master. In the case of interrogators that are at distances greater than 200 m from the master, they must in addition perform LBT. Networked systems should continue to operate as described in clause 4.4 except that they should have the ability both to detect a pre-pulse and decode a site identifier.

If an interrogator at B successfully detects the site identifier from A, it will know that the signal has originated from another site. Provided that the LBT requirement has been satisfied, this interrogator may transmit a pre-pulse together with the site identifier for site B. All other interrogators using in-band radio synchronization at site B shall detect this pre-pulse and/or the matching site identifier and respond as slaves. Similarly if the system at site B is networked, the interrogator that transmits a pre-pulse followed by its site identifier shall become the master for the network.

Similarly if an interrogator at site C successfully detects the site identifier from B, it will know that the signal has originated from another site. Again provided that the LBT requirement has been satisfied, this interrogator will transmit a pre-pulse accompanied by the site identifier for site C. All other interrogators using in-band radio synchronization at site C shall detect this pre-pulse and/or the matching site identifier and respond as slaves. Similarly if the system at site C is networked, the interrogator that transmits its site identifier shall become the master for the network.

The waveform of the transmissions from the master interrogator at each of the three sites is shown.

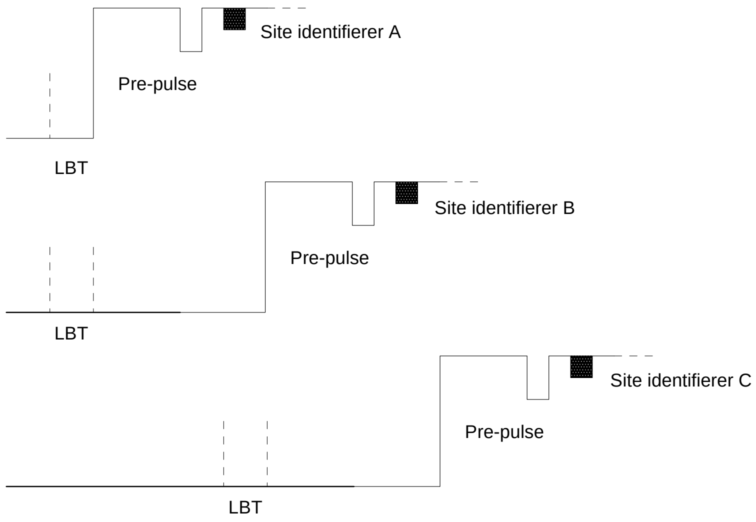


Figure 17: Waveforms of masters at sites A, B and C

It will be seen that the LBT process for sites B and C takes place during the 5 ms period immediately prior to the instant when the pre-pulse from another site was first successfully detected. For each site the 4 s transmit window commences at the instant that its master interrogator commences transmission of a pre-pulse. This means that the 4 s transmit windows at each of the three sites will be slightly displaced in time. In practice this will have no adverse effect on the operation at any of the sites. For example in Figure 17 site B will start transmission of its pre-pulse approximately 65 ms after site A. Assuming both sites occupy the channel over their full permitted 4 s transmit window, site A will stop transmitting 65 ms before site B. If site A wishes to continue transmitting, it must either switch to another channel or wait for 100 ms before continuing on the same channel. The fact that site B is transmitting for part of the 100 ms period will not effect either of the options available to site A.

A comparison between the timing diagrams at Figures 7 and 17 shows that the process for synchronization between sites is merely an extension of the principle of synchronization between interrogators within a single site as described in clause 4.5.1 of the present document.

A generalized flow diagram describing synchronization both within a system and between different systems is provided in Annex A.

Where adjacent sites are synchronized using the NTP method, it is unnecessary to sense pre-pulses or SIDs. There is also no restriction on the separation between interrogators as they each perform their own LBT. Pre-pulses or optional site identifiers are only required when NTP masters are used to synchronize with systems or interrogators that use the in-band radio approach. In such circumstances the limitations on distance or signal level shall apply.

Annex A (informative): Flow diagram of synchronized systems when using site identifier

A.1 General Principles

The flow diagram in Figure A.1 describes the synchronization process for both a single RFID system and for multiple RFID systems. It assumes that all of the systems make use of a site identifier.

Local synchronization. Occurs when interrogators in a single system detect a pre-pulse followed by the local site identifier. In this event interrogators that are known to be within 200 m of the master do not have to perform LBT and may synchronize to the pre-pulse. Any interrogator that synchronizes to the master becomes a slave and does not generate a pre-pulse.

Inter-system synchronization. Occurs when an interrogator in a system detects a pre-pulse which includes a site identifier that is different to the local site identifier. In this case the interrogator must have determined that the LBT requirement was satisfied prior to receiving the pre-pulse. If this condition is met the interrogator will transmit a pre-pulse that will include its own local site identifier. Other interrogators in the same system may synchronize to this pre-pulse and behave as slaves.

Where a slave detects a pre-pulse at a level in excess of -40 dBm, it need not perform LBT. At levels below -40 dBm slaves that do not support a site identifier must perform LBT before they may synchronize to a master.

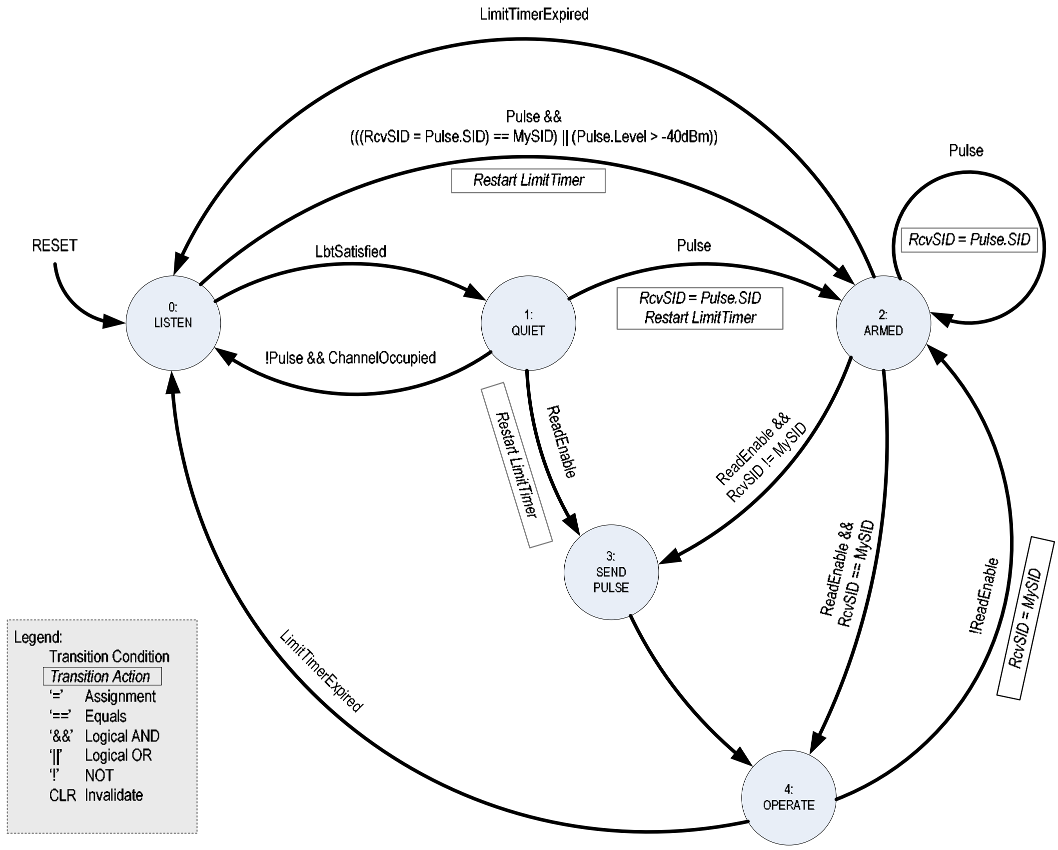


Figure A.1: Flow diagram of synchronization process

A.2 Explanation of variables, timers and signals

LbtSatisfied signal that is asserted when an interrogator has determined that the LBT requirements for a channel are satisfied. The means by which this is achieved is implementation-specific.

ChannelOccupied flag that is asserted when the interrogator detects that a channel is occupied (by measuring received signal strength on that channel).

Pulse signal that is asserted when an interrogator detects a pre-pulse on a channel. The pulse may be accompanied by additional data including an site identifier.

LimitTimer timer used to limit the maximum period of transmission on a channel by an interrogator.

LimitTimerExpired signal that is asserted when the LimitTimer has reached the maximum period of transmission on a channel.

ReadEnable flag that is asserted when the interrogator is instructed to perform a transaction (this may include reading, writing, or tag-killing operations). The state of this flag may be independent of the LBT feature.

RcvSID variable that stores the value of the received site identifier (if any) following a pre-pulse. RcvSID may be cleared by CLR, in which case, when tested against MySID, it will give an invalid value.

MySID variable that stores the local value of site identifier configured for this interrogator. If the interrogator has no site identifier, it is invalid and will not match RcvSID.

A.3 State Description

State0: LISTEN. In this state the interrogator monitors one or more channels in accordance with the LBT criteria specified in EN 302 208 [1]. The means by which multiple channels are monitored is defined by individual manufacturers.

State1: QUIET. In this state, the interrogator has determined that a channel meets the LBT requirements and waits for either a command to transmit (via ReadEnable) or the detection of a pre-pulse.

State2: ARMED. In this state, the interrogator has received a valid pre-pulse (inter-system or local system), and awaits either a command to transmit (via ReadEnable), or a command that the channel is no longer available. (This may be because the time limit has expired).

State3: SEND PULSE. In this state, the interrogator transmits a pre-pulse and any optional data. If a site identifier is included in the optional data, the value of MySID is used.

State4: OPERATE. In this state the interrogator performs a transaction. Note that while a channel remains available an interrogator may carry out multiple transactions (via ReadEnable).

Annex B (informative):
Bibliography

ECC Report 037: "Compatibility of planned SRD applications with currently existing Radiocommunication applications in the frequency band 863 MHz - 870 MHz" Granada.

History

Document history		
V1.1.1	March 2007	Publication