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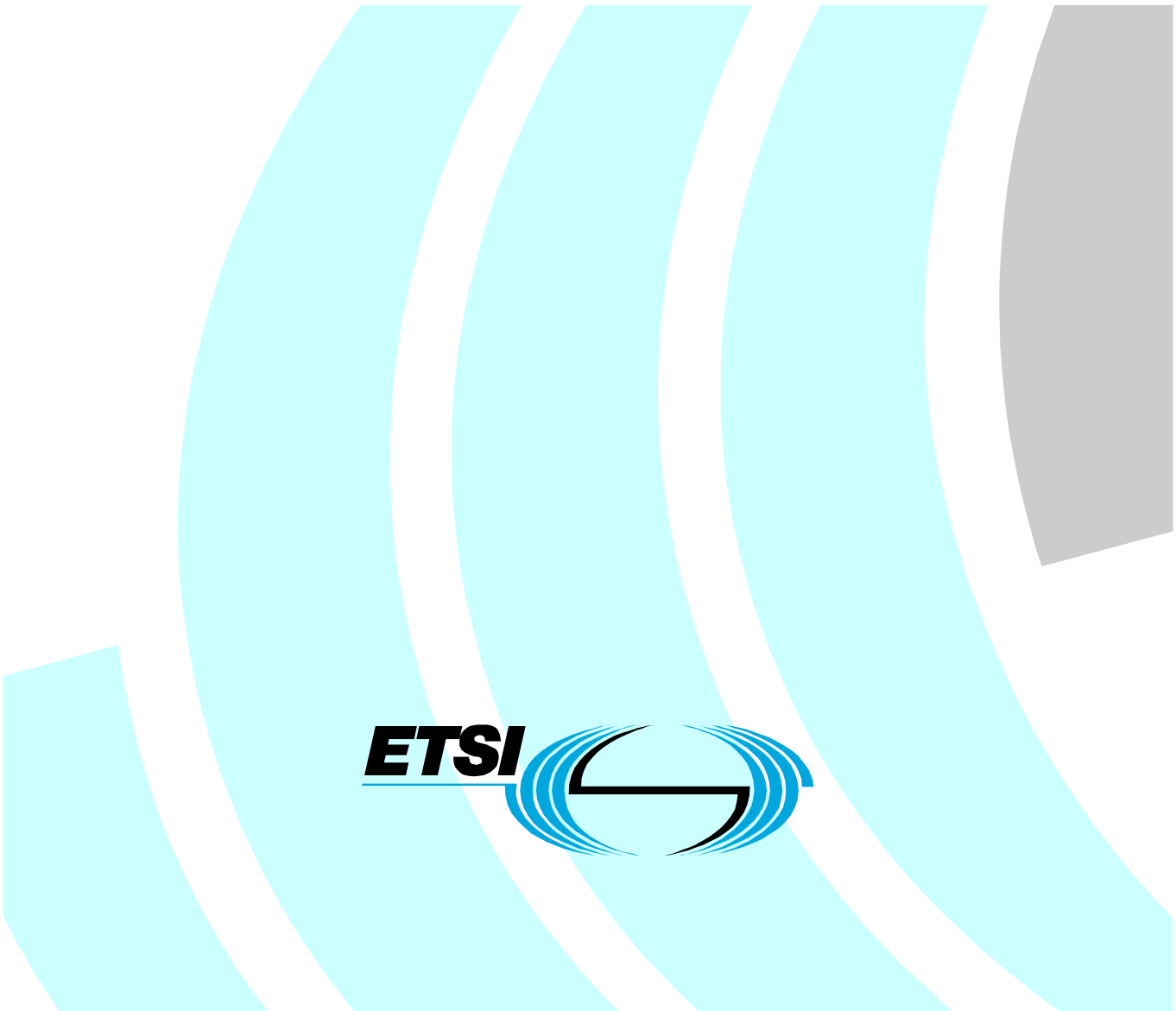
Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for identification and location systems; System Reference Document for inductive systems for industrial applications operating in the frequency range from 400 kHz to 600 kHz



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Contents

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Foreword

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

Introduction

RFID for item management is an emerging technology applicable in all areas of daily life, business, industry, and manufacturing.

The inductive, industrial RFID applications are mainly found in assembly and manufacturing lines; warehouses; chemical, automotive, semiconductor and chip manufacturing areas; machine tooling; construction; transport; medical; and in a variety of other applications.

Nearly all applications in this field use passive tags. In some applications, tags use a battery for power supply back-up in case the powering field strength is too low for excitation by the interrogator field strength. Because of cost reasons, such battery tag applications are often limited to reusable tags which also have to be more robust. This means that the tag size is considerably larger.

The passive tags as well as reader antennas are normally restricted to very small sizes. In conjunction with special small-size, read-heads, the system does not only provide the read/write function of determining the code of the object and retrieving data content, but very often allows for the position-sensing and tracing of the objects. The read-write function allows for information, such as date of handling or the treatment of a certain process, or the required next process steps, etc. to be written onto the tag.

The choice of the frequency is vital to meet the performance and market requirements. Industrial RFID systems for various applications are limited by many restrictions related to the physical size requirements, hence component restrictions, and also environmental and longevity requirements for the needed application.

One of the constraints is the in-plant or cross-applicational pollution, which may occur, for instance, if several different RFID systems would operate on the same frequency in the LF or HF ranges (as defined by the ITU Radio Regulations [3]) in close vicinity at one production site. They would interfere especially in view of the high field strength levels at which these systems operate.

DC or LBT [8] techniques in industrial systems (needed for operation in the LF or HF band), would not work because of the high speed of object movement on conveyor belts and the required continuous high speed data tran [3] smission. LBT would interrupt the process flow unacceptably.

For industrial RFIDs, technology using the MF frequency range (as defined by the ITU [3]) has proven to yield adequate performance with high data rates, efficient powering with small antennas or read-heads and tags, low field strength levels, and the functionality in all critical applications and environmental conditions. They have been in use globally for some time without record of interference problems. Countries where systems are in wide use include: the Americas, Japan, and other Far East countries, as well as a number of European countries, such as Germany, Finland, UK, Sweden, and many others based on individual approvals.

The frequency range and bandwidth requirement is around 550 kHz with bandwidths from 50 kHz up to 200 kHz.

1 Scope

The present document provides information on RFID systems including applications, technical parameters, and radio spectrum requirements for RFID equipment operating in the MF frequency band from 400 kHz to 600 kHz.

The scope is limited to RFID systems for industrial applications. Most of the applications are in indoor installations.

The RFID systems use inductive SRD technology covered by the harmonized standard, EN 300 330-2 [2].

Additional information is given in the following annexes:

- annex A: detailed market and application information;
- annex B: technical information;
- annex C: expected compatibility issues.

2 References

For the purposes of this Technical Report (TR), the following references apply:

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

[2] ETSI EN 300 330-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz; Part 2: Harmonized EN under article 3.2 of the R&TTE Directive".

[3] ITU Radio Regulations; Article 2: "Nomenclature, Section I: Frequency and wavelength bands". http://www.itu.int/publications/pdfcatalogue/CatalogE.PDF, (Section 3.2 Radio regulations).

[4] 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. (R&TTE Directive).

[5] ECC Report 001: "Compatibility between inductive LF and HF RFID transponder and other radio communications systems in the frequency ranges 135-148.5 kHz, 4.78-8.78 MHz and 11.56-15.56 MHz".

[6] ECC Report 007: "Compatibility between inductive LF RFID systems and radio communications systems in the frequency range 135 - 148.5 kHz".

[7] ETSI TR 102 313: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Frequency-agile Generic Short Range Devices using Listen-Before-Transmit (LBT) Technical Report".

[8] FCC CFR 47: Part 15, Section 15.209
http://www.access.gpo.gov/nara/cfr/waisidx-03/47cfr15-03.html.

[9] Japan: Regulation for "extremely low power radio station".

[10] ETSI EN 300 330-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment in the frequency range 9 kHz to 25 MHz and inductive loop systems in the frequency range 9 kHz to 30 MHz; Part 1: Technical characteristics and test methods".

[11] ITU-R Recommendation SM 1538: "Technical and operating parameters and spectrum requirements for short-range radio communication devices".

[12] CEPT/ECC/FM(04)179, 26 August 2004: "Results of the Public Consultation on Annexes to ERC/REC 70-03".

[13] ITU Radio Regulations, edition 2004.

[14] Klaus Finkenzeller, RFID handbook: (the book will give further RFID references and RFID internet pages.) http://rfid-handbook.com.

[15] OMRON, RFID Sensors http://www.europe.omron.com/Images/en/165_23073.pdf

3 Definitions, symbols and abbreviations

3.1 Definitions

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

duty cycle: ratio, expressed as a percentage, of the maximum total transmitter "on" time, relative to a one hour period

transponder: device that responds to an interrogation signal

3.2 Symbols

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

f	Frequency
H	Magnetic field strength
P	Power

3.3 Abbreviations

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

ASK	Amplitude Shift Keying
BC	BroadCast
BW	BandWidth
dB	Decibel
dBc	Attenuation in dB relative to the carrier
DC	Duty Cycle
ECC	Electronic Communications Committee
ERC	European Radiocommunications Committee
FPD	Flat Panel Display
LBT	Listen Before Talk
LW	Long Wave
MF	Medium wave Frequency range
RFID	Radio Frequency IDentification
SRD	Short Range Device

4 Executive summary

The present document provides insight into the applications, functionality, and basic requirement for a regulation for industrial RFID systems in the frequency range 400 kHz to 600 kHz, especially in view of the large market impact. The proposed regulation would provide an indispensable solution for all areas of the industry, as described in annex A.

ETSI expects the proposed regulations in table 6.1 to be compatible with the services operating in the frequency range of 400 kHz to 600 kHz without causing harmful interference. This is supported by:

a) the preliminary compatibility studies show for the MF frequency range under discussion calculated protection distances in the order of 25 m or lower;

b) the absence of interference in a large number of installations in many countries which operate virtually continuously over a number of years and which confirms the theoretical calculations by ECC-SE24;

c) the location of the described MF RFID installations in non-public, industrial sites and primarily indoor installations, which are considered as additional mitigation factors.

The ECC-WGFM is already considering a generic level of -5dBµA/m in the LF and MF range up to 1 600 kHz in an amendment of an draft annex 9 of CEPT/ERC Recommendation 70-03 [1]. This was reviewed by WGFM and sent to SRDMG for revision of the levels in the LW BC bands of 148,5 kHz to 285 kHz.

The technical characteristics of the MF RFID systems will not require new ETSI standards since the systems are compatible with the EN 300 330-2 [2] as well as the recently proposed amendments to it.

4.1 Status of the present document

ERM-TG28 approved V1.1.1_1.1.1. The version V1.1.1_1.1.2 incorporates minor editorials and was circulated for approval by correspondence within ERM-RM. Version V1.1.1_2.1.1 has been approved by ERM-RM, submitted to ECC-WGFM and SRD-MG for consideration, and submitted to ERM#25 for approval for publication.

4.2 Market information

For detailed market information, see annex A.

4.3 Technical system description

For detailed technical information, see annex B.

5 Current regulations

CEPT/ERC Recommendation 70-03 [1] covers LF frequency regulations in the range up to 148,5 kHz and HF regulations for 6,78 MHz and 13,56 MHz for RFID for inductive technologies.

For the applications of the present document, the ERC/Rec 70-03 were recently amended.

CEPT WGSE is currently studying a generic limit for short range devices up to 30 MHz. A revision of annex 9 of ERC/Recommendation 70-03 [1] has been published for the level of -5dBµA/m at 10 m for the range of 148,5 to 1 600 kHz.

Table 5.1: Proposed amendment to annex 9 of CEPT/ERC Recommendation 70-03 [1]

Frequency band	Maximum Magnetic field (see note)	Duty cycle	Channel spacing	ERC/ECC Decision	Notes
148,5 to 1 600 kHz	-5dBµA/m at 10 m	No restriction	No spacing		none

OTHERS

Several CEPT counties, including Germany, Finland, and the U.K., have national regulation in place for industrial RFID in the frequency range 400 kHz to 600 kHz. Many other countries allow these systems individually. The regulations of the U.S.A. and Japan also have regulations in place, these can be found in:

- U.S.A.: FCC: CFR 47, Part 15, Section 15.209 [7].
- Japan: Regulation for "extremely low power radio station" [9] (500 µV/m@3m < 322 MHz) and ITU-Recommendation SM. 1538 [11].

6 Main conclusions

- The industrial RFID systems present a basic requirement for society and the functioning of the industrial infrastructure.
- Industrial RFID systems have been deployed for a number of years and in many highly industrialized countries with no interference problems on record.
- Calculated protection distances of the preliminary draft report for the MF range are in the order of 23 m to 11 m - depending on the degradation level - which should suffice for compatibility in the scenarios for industrial and mostly indoor applications.

7 Expected ETSI and ECC actions

ECC- WGSE to complete the compatibility report in stating that the min. bandwidth of 30 kHz for the range of 300 to 1 600 kHz is allowed at a level of -5 dBµA/m at 10 m.

Annex A:
Detailed market information

A.1 Range of applications

There is a rapidly expanding market for industrial RFID technology automation in the examples of the application areas listed below:

- automotive manufacturing;
- industrial machinery and tooling;
- in factory logistics;
- semiconductor processing and packaging;
- chemicals handling, dangerous goods processing, waste management;
- construction, steel-making;
- paper making, printing industry;
- medical supply handling;
- processing and control of food items;
- transport, loading control, vehicle entry / exit control.

The benefits are:

- cost saving through a higher degree of automation;
- reduction of labour;
- enhanced safety for critical environmental goods processing;
- enhanced quality, reduced failure rates, higher process yields;
- higher competitiveness and uniform products.

A.2 Market size and value

Figure A.2.1 shows the typical structure of the industrial MF RFID market segments and the total market.

It is to be noted that the figures for the year 2004 include the systems installed up to date as well as installations planned for the rest of the year 2004 and which have been certified under present national regulations.

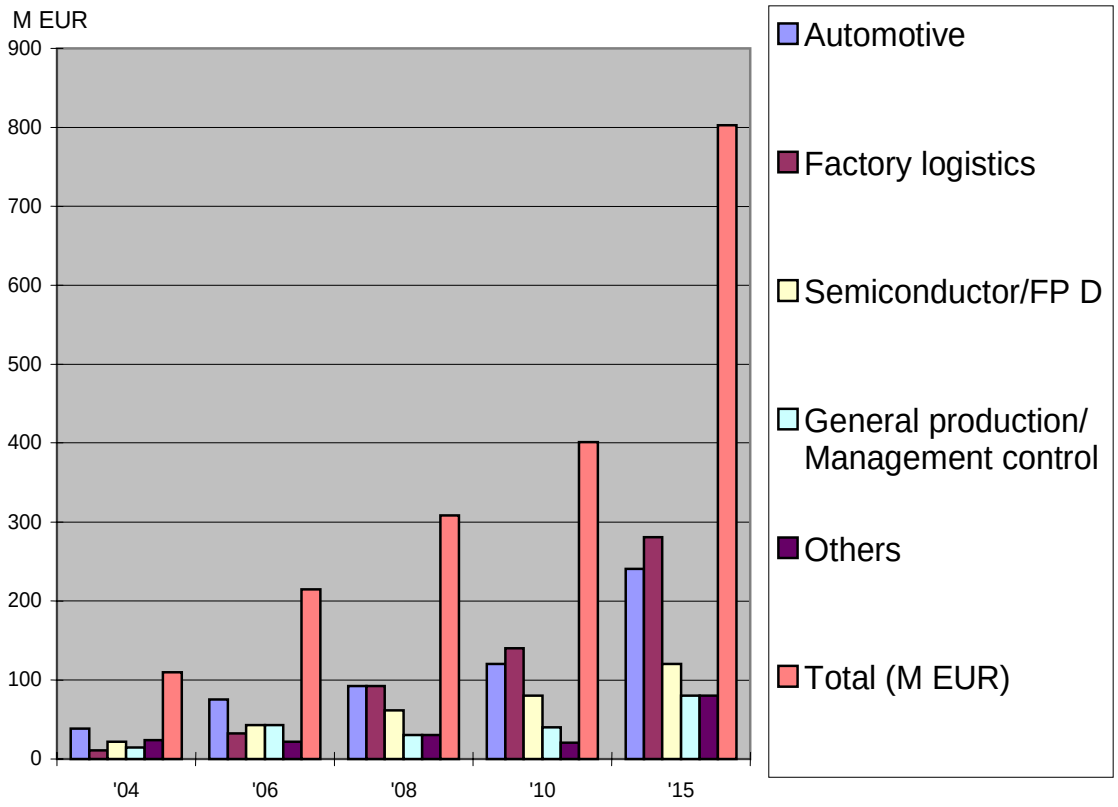

Figure A.2.1: Market size of industrial RFIDs (in millions of Euros per year)

NOTE: Figure A.2.1 is according to OMRON, a major supplier of MF RFID equipment in a number of CEPT and other countries.

Annex B:
Technical information

B.1 Detailed technical description

Industrial RFID systems operating in the MF range function similar to RFID systems in the LF and HF range.

The difference between the MF systems and the LF and HF systems is that for the MF systems, the reader antenna as well as the tags are both smaller in size and operate over much shorter distance. In many applications, there is a need to combine the data read-write function with the position sensing of the data carrier or tags for tracing purposes.

The MF RFIDs allow the design of robust miniature tags with enhanced reliability because, compared to LF tags, the inductances become much smaller. Physically compact, LF tags are more complex and difficult to manufacture. For example, for small tag dimensions with ferrite coils with some 400 windings with diameters of some 50 microns to 100 microns, handling and reliability of such components is difficult to manage especially in difficult environmental conditions.

For some applications such as tooling or metal materials, the tag has to be placed into the metal object. MF frequencies present the optimal solutions since LF tags would have to be placed in open (half) pot ferrite cores, while HF tags would suffer radiation efficiency problems if embedded in metal.

For similar performance and relative size, the MF tags operate with much lower field strength. The industrial MF tags require a maximum magnetic field strength of -5 dBµA/m at 10 m for satisfactory operation, while LF tags need a field strength of +42 to + 60 dBµA/m at 10 m for satisfactory operation CEPT/ERC Recommendation 70-03 [1], EN 300 330-2 [2], ECC Report 007 [6] and TR 102 313 [7].

The MF frequency operation also provides high data speed. Systems typically operate at shorter distance between reader and tags, which also contributes to the low field strength requirement emitted by the reader antenna.

Figure B.1.1 explains the interaction of the data carrier with or without back-up battery (bottom left) with the reader unit (bottom right). The upper section of figure B.1.1 displays the different tags and sizes and dedicated antenna or read/write heads fitted to the application or objects. The low field strength of -5 dBµA/m at 10 m powers the tag. The incident signal is fed to the power supply circuitry and to the signal detector to write information to the tag, simultaneously the tag transmits data back to the reader.

As in other LF and HF RFID systems, ASK modulation is mostly used because the tag's complexity and power consumption is limited; therefore damping or load switching modulation of the received carrier is applied.

The small physical sizes of both the reader heads as well as the tags allow a position detection function of the tag in the process flow.

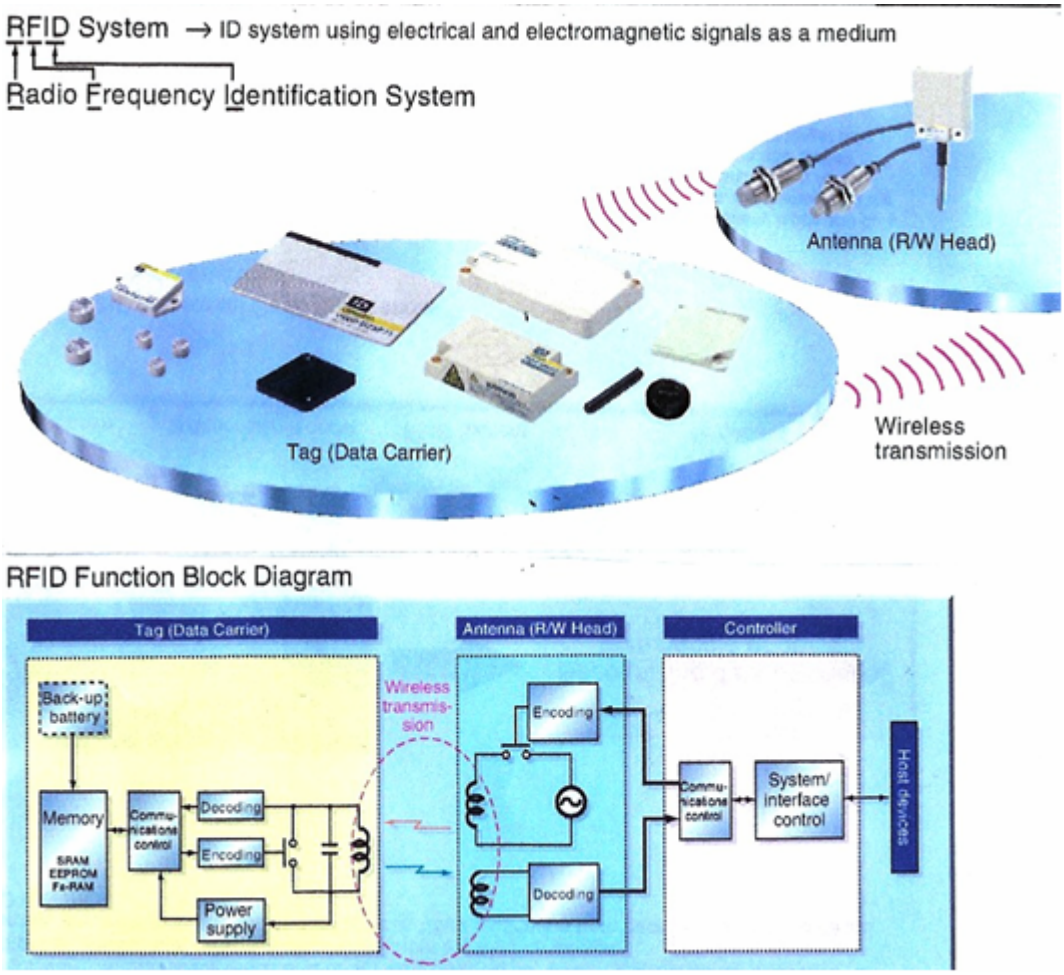

Figure B.1.1: Interaction of RFID tag and antenna

Figure B.1.2 displays an application of a typical manufacturing process during which all process steps, from receiving parts for a car assembly line to the finishing of a car, are managed by an RFID system.

The high degree of automation in present manufacturing lines is only feasible with such MF RFID type of systems.

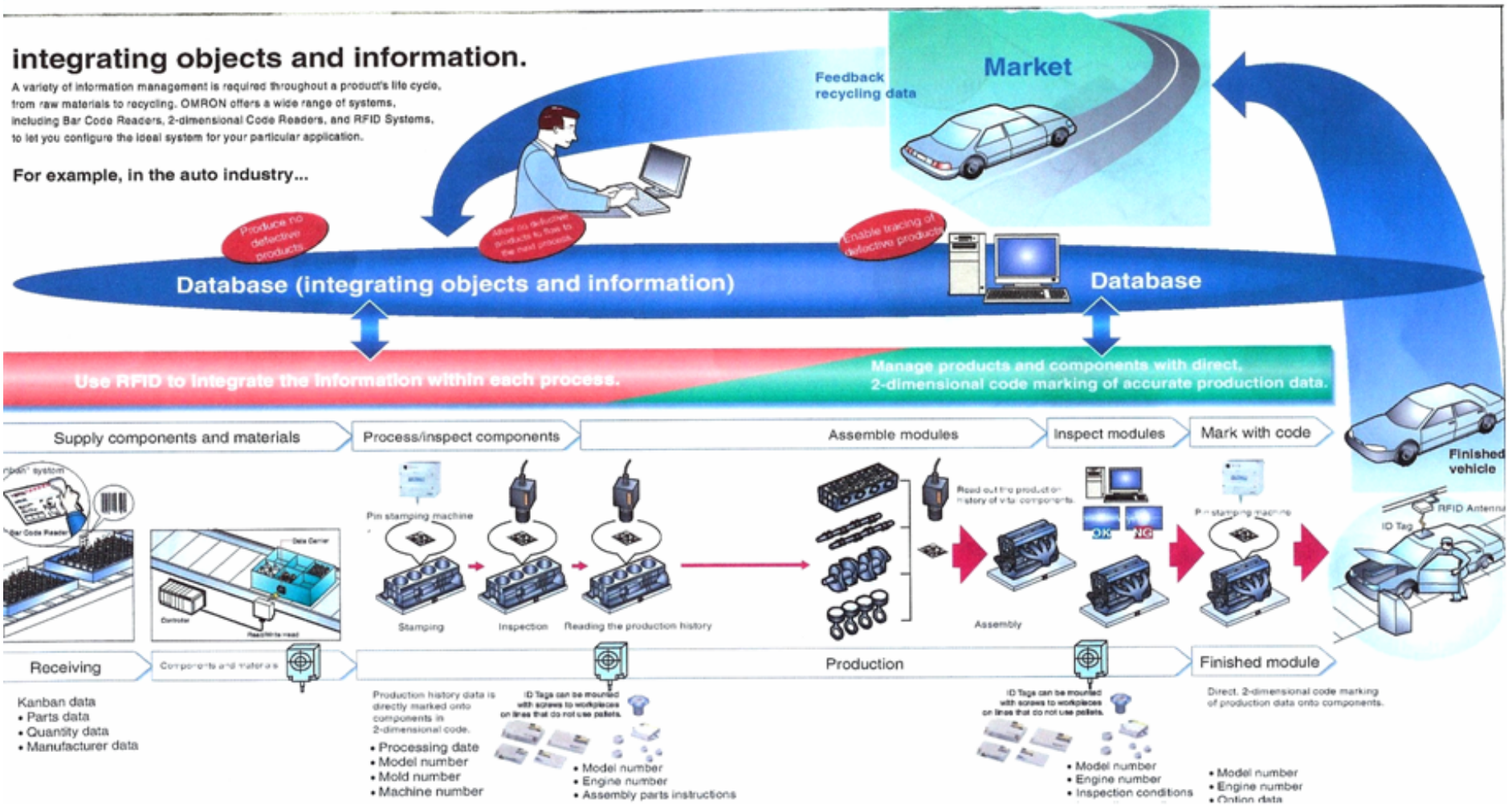

Figure B.1.2: Typical manufacturing process managed by an RFID system

B.2 Technical justification for spectrum

For basic considerations, please see the clause B.1.

The ASK modulation for the required data rates will result in a bandwidth of 200 kHz to 300 kHz at -20 dBc.

B.3 Radiation limits

Table B.3.1: Recent amendment to Annex 9 of CEPT/ERC Recommendation 70-03 [1]

Frequency band	Maximum Magnetic field (see note)	Duty cycle	Channel spacing	ERC/ECC Decision	Notes
148,5 to 1 600 kHz	-5dBµA/m at 10 m	No restriction	No spacing		none

Annex C:
Expected compatibility issues

C.1 Coexistence issues

There are studies ongoing in ECC-SE24 to define the coexistence and permissible field strength levels between SRDs and the various services in the frequency range between 9 kHz and 30 MHz. The draft compatibility report produced by ECC-SE24 has so far considered field strength of -5 dBµA/m which is related to an emission bandwidth of 100 kHz and a further derating for larger BWs is foreseen.

Based on the first results of the protection distances in the range of 9 kHz to 1 600 kHz, in April 2004 the ECC-WGFM has approved the amendment for Annex 9 of the ERC/Recommendation 70-03 [1] with a generic level of -5 dBµA/m in the range from 148,5 kHz up to 1 600 kHz.

The industrial applications are situated in non-public areas, and the systems are dominantly used indoors in warehouses, automotive plants, manufacturing buildings. Secondly, attenuation of buildings - mostly steel or concrete steel reinforced – are taken into account,

For this scenario and considering that the actual deployment which is in continuous operation in a number of countries, no interference was reported, ETSI anticipates the compatibility of industrial RFID"s to the services operating in this range.

C.2 Current ITU-R allocations [15]

<table>
<tr><th colspan="3">kHz
315 – 495</th></tr>
<tr><th>Region 1</th><th>Region 2</th><th>Region 3</th></tr>
<tr><td rowspan="2">325 – 405
AERONAUTICAL
RADIONAVIGATION

5.72</td><td>325 – 335
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile
Maritime radionavigation
(radiobeacons)</td><td rowspan="2">325 – 405
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>335 – 405
AERONAUTICAL
RADIONAVIGATION
Aeronautical mobile</td></tr>
<tr><td>405 – 415
RADIONAVIGATION 5.76
5.72</td><td colspan="2">405 – 415
RADIONAVIGATION 5.76
Aeronautical mobile</td></tr>
<tr><td>415 – 435
MARITIME MOBILE 5.79
AERONAUTICAL
RADIONAVIGATION
5.72</td><td colspan="2">415 – 495
MARITIME MOBILE 5.79 5.79A
Aeronautical radionavigation 5.80</td></tr>
<tr><td>435 – 495
MARITIME MOBILE 5.79 5.79A
Aeronautical Radionavigation
5.72 5.82</td><td colspan="2">5.77 5.78 5.82</td></tr>
<tr><td colspan="3">495 – 505 MOBILE (distress and calling)
5.83</td></tr>
<tr><td>505 – 526.5
MARITIME MOBILE 5.79 5.79A
5.84</td><td>505 – 510
MARITIME MOBILE 5.79</td><td rowspan="3">505 – 526.5
MARITIME MOBILE 5.79 5.79A
5.84
AERONAUTICAL
RADIONAVIGATION
Aeronautical Mobile
Land Mobile</td></tr>
<tr><td rowspan="2">AERONAUTICAL
RADIONAVIGATION

5.72</td><td>510 – 525
MOBILE 5.79A 5.84</td></tr>
<tr><td>AERONAUTICAL
RADIONAVIGATION</td></tr>
<tr><td rowspan="2">526.5 – 1 606.5
BROADCASTING</td><td rowspan="2">525 – 535
BROADCASTING 5.86
AERONAUTICAL
RADIONAVIGATION</td><td>526.5 – 535
BROADCASTING
Mobile
5.88</td></tr>
<tr><td>5.87 5.87A</td><td>535 – 1 605
BROADCASTING</td><td>535 – 1 606.5
BROADCASTING</td></tr>
<tr><td colspan="3">NOTE 5.72: Norwegian stations of the fixed service situated in northern areas (north of 60° N) subject to auroral disturbances are allowed to continue operation on four frequencies in the bands 283,5 to 490 kHz and 510 to 526,5 kHz.</td></tr>
<tr><td colspan="3">NOTE 5.76: The frequency 410 kHz is designated for radio direction-finding in the maritime radionavigation service. The other radionavigation services to which the band 405 to 415 kHz is allocated shall not cause harmful interference to radio direction-finding in the band 406,5 to 413,5 kHz.</td></tr>
<tr><td colspan="3">NOTE 5.77: Different category of service: in Australia, China, the French Overseas Territories of Region 3, India, Indonesia (until 1 January 2005), Iran (Islamic Republic of), Japan, Pakistan, Papua New Guinea and Sri Lanka, the allocation of the band 415 to 495 kHz to the aeronautical radionavigation service is on a primary basis. Administrations in these countries shall take all practical steps necessary to ensure that aeronautical radionavigation stations in the band 435 to 495 kHz do not cause interference to reception by coast stations of ship stations transmitting on frequencies designated for ship stations on a worldwide basis (see No. 52.39). (WRC-2000).</td></tr>
<tr><td colspan="3">NOTE 5.78: Different category of service: in Cuba, the United States of America and Mexico, the allocation of the band 415 to 435 kHz to the aeronautical radionavigation service is on a primary basis.</td></tr>
<tr><td colspan="3">NOTE 5.79: The use of the bands 415 to 495 kHz and 505 to 526,5 kHz (505 to 510 kHz in Region 2) by the maritime mobile service is limited to radiotelegraphy.</td></tr>
<tr><td colspan="3">NOTE 5.79A: When establishing coast stations in the NAVTEX service on the frequencies 490 kHz, 518 kHz and 4 209,5 kHz, administrations are strongly recommended to coordinate the operating characteristics in accordance with the procedures of the International Maritime Organization (IMO) (see Resolution 339 (Rev.WRC-97)). (WRC-97).</td></tr>
</table>

NOTE 5.80:	In Region 2, the use of the band 435 to 495 kHz by the aeronautical radionavigation service is limited to non-directional beacons not employing voice transmission.
NOTE 5.82:	In the maritime mobile service, the frequency 490 kHz is, from the date of full implementation of the GMDSS (see Resolution 331 (Rev.WRC-97)), to be used exclusively for the transmission by coast stations of navigational and meteorological warnings and urgent information to ships, by means of narrow-band direct-printing telegraphy. The conditions for use of the frequency 490 kHz are prescribed in articles 31 and 52. In using the band 415 to 495 kHz for the aeronautical radionavigation service, administrations are requested to ensure that no harmful interference is caused to the frequency 490 kHz. (WRC-97).
NOTE 5.83:	The frequency 500 kHz is an international distress and calling frequency for Morse radiotelegraphy. The conditions for its use are prescribed in articles 31 and 52, and in appendix 13.
NOTE 5.84:	The conditions for the use of the frequency 518 kHz by the maritime mobile service are prescribed in articles 31 and 52 and in appendix 13. (WRC-97).
NOTE 5.86:	In Region 2, in the band 525 to 535 kHz the carrier power of broadcasting stations shall not exceed 1 kW during the day and 250 W at night.
NOTE 5.87:	Additional allocation: in Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland and Zimbabwe, the band 526,5 to 535 kHz is also allocated to the mobile service on a secondary basis. (WRC-03).
NOTE 5.87A:	Additional allocation: in Uzbekistan, the band 526,5 to 1 606.5 kHz is also allocated to the radionavigation service on a primary basis. Such use is subject to agreement obtained under No. 9.21 with administrations concerned and limited to ground-based radiobeacons in operation on 27 October 1997 until the end of their lifetime. (WRC-97).
NOTE 5.88:	Additional allocation: in China, the band 526,5 to 535 kHz is also allocated to the aeronautical radionavigation service on a secondary basis.

C.3 Sharing issues

Because of the low emission level, the operation in industrial and non-public sites, as well as the low calculated protection distances and the absence of interference in large deployment in many countries, no sharing issues are expected.

History

Document history		
V1.1.1	April 2005	Publication