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**Electromagnetic compatibility
and Radio spectrum Matters (ERM);
Short-Range Devices (SRD) for operation
in the 13,56 MHz band;
System Reference Document for Radio Frequency
Identification (RFID) equipment**

Reference
DTR/ERM-TG28-046

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Foreword

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

Executive summary

The present document analyses the potential and status of 13,56 MHz RF Identification Systems and the need for regulatory and standard improvements as:

- 13 MHz RFID systems cover the widest range of markets and applications of among the RFID families, this detailed in clause 6.1 and annex A.
- The prospects for the next decade for the 13,56 MHz RFID technology is that these RFIDs have the highest turnover and increase rate compared to other frequencies. The rate is estimated for about 50 % or higher. This is based on:
    - the mature and versatile 13,56 MHz technology is providing either large reading range with high datarates and bulk reading capabilitiy as well as very high data rates for the required safety and security features as requested by the recent EC mandate M436 for private/public and commercial use;
    - 13,56 MHz systems have the high level of installed systems covering various markets and applications;
    - the inductive near-field reader-tag communication system feature unique properties as highest spectrum efficiency because of the frequent re-use of the frequency band allowing dense reader operation (see clause 5.2).
- 13,56 MHz frequency band is harmonized in all three ITU regions which assures coverage of all markets.

Secondly recent developments in the evolution of the technology and ISO standards as well as developments/requirements in social, public, commercial and industrial areas have dictated the need for amending the spectrum mask in the ERC/REC 70-03, annex 9 as well as amending the EN 300 330-1 [i.2] for:

- higher operating ranges as well as higher data rates by
- improvement of the modulation level and spectrum width to meet the market needs. The modifications can be made by keeping the 13,56 MHz carrier to the present level of 60 dBµA/m as specified in the ERC/REC 70-03 [i.10] and modifying the transmitter mask.

Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT) for internal reference within ETSI [i.1].

RFIDs have been in use for almost all areas of the industrial-commercial, the public and private sector.

Especially the 13,56 MHz RFID technology is matured and has achieved tag deployment rates in the several billion unit range. This frequency is highly attractive because of the global harmonization of this frequency band since it is an ISM band in all 3 ITU regions.

The 13,56 MHz RFIDs use the inductive near field propagation mode which has the unique advantage of allowing a high reader fieldstrength without disturbing the in-band or adjacent band radio services because of the fast fieldstrength roll-off of 60 dB/Decade [i.2] and [i.5].

This means that the reading range is controlled or limited while far-field operation can suffer from reflections and diffractions.

The two most limiting factors for 13,56 MHz RFIDs are regulatory constraints with regard to the modulation allowance level which is addressed in the present document.

Status of the pre-approval draft

Final approval for publication as ETSI Technical Report is expected after ERM #42.

Target version	**Pre-approval date version (see note)**				
V1.1.1	**A**	**s**	**m**	**Date**	**Description**
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V1.0.3r1				October 2011	Final draft approved in TG 28 for ERM release for publication
V1.0.3r2				October 2011	Final draft for remote consultation

1 Scope

The present document provides information on short range device equipment for RFIDs operating in the 13,56 MHz frequency range from 13,553 MHz to 13,567 MHz and covering the requirements for carrier and the associated modulation emissions.

The present document includes the necessary information to support the co-operation between ETSI and the ECC including:

- market information;
- technical information;
- regulatory issues.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) 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.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ECC-ETSI MoU (version of April 2004).

[i.2] 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".

[i.3] ERC Report 69 (February 1999): "Propagation model and interference range calculations for inductive systems 10 kHz - 30 MHz".

NOTE: Available at: http://www.satoworldwide.com/news_releases_02062008_DIP.htm

[i.4] Wired Science: "New RFID Tag could mean the end of Bar Codes".

NOTE: Available at: http://www.satoworldwide.com/news_releases_02062008_DIP.htm

[i.5] ERC Report 44 (January 1997): "Sharing between inductive systems and radiocommunication systems in the band 9 - 135 kHz".

[i.6] ECC Report 74: "Compatibility between radio frequency identification devices (rfid), and the radioastronomy service at 13 MHz".

[i.7] Poly IC printed electronics.

NOTE: Available at: http://www.polyic.de/upload/PolyIC200709-001_de.PDF .

[i.8] ISO/IEC 14443-2 Amd. 3: "Identification cards - Contactless integrated circuit(s) cards - Proximity cards - Part 2: Radio frequency power and signal interface - Amd. 3: Bits rates of fc/8, fc/4 and fc/2".

[i.9] ISO/IEC 15693-1:2010: "Identification cards - Contactless integrated circuit cards - Vicinity cards - Part 1: Physical characteristics".

[i.10] ERC Recommendation 70-03: "Relating to the use of short range devices (srd)".

[i.11] ISO/DIS 17367: "Supply chain applications of RFID - Product tagging".

[i.12] CEN EN 14803: "Identification and/or determination of the quantity of waste".

[i.13] FM(10)092 Annex 24: "Dynamic Evolution of RFID Market".

[i.14] Klaus Finkenzeller: "RFID Handbook", Chapter 5.1.11: "Selection of frequency for inductive coupled RFID systems", issue 2008, ISBN 978-3-446-41200-2.

[i.15] VDC Market Report: "RFID and related solutions".

NOTE: Available at: http://www.vdcresearch.com/market_research/autoid/research_reports.aspx

[i.16] EETimes publishes an article about PolyIC: "Organic RFID breakthroughs detailed".

NOTE: Available at: http://www.polyic.com/read.php?page=359&l1=5&l2=4

[i.17] ISO/IEC 18000-3: " Information technology - Radio frequency identification for item management - Part 3: Parameters for air interface communications at 13,56 MHz".

[i.18] ISO/IEC 10536: "Identification cards -- Contactless integrated circuit(s) cards".

[i.19] ISO/IEC TR 18047-3: "Information technology - Radio frequency identification device conformance test methods - Part 3: Test methods for air interface communications at 13,56 MHz".

[i.20] ISO/IEC 15693-3: "Identification cards - Contactless integrated circuit cards - Vicinity cards - Part 3: Anticollision and transmission protocol".

[i.21] ISO/IEC 10373-4: "Identification cards -- Test methods -- Part 4: Contactless integrated circuit cards".

[i.22] ISO/IEC 10373-6: "Identification cards - Test methods - Part 6: Proximity cards".

[i.23] ISO/IEC 10373-7: "Identification cards -- Test methods -- Part 7: Vicinity cards".

[i.24] ETSI EN 302 291: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Close Range Inductive Data Communication equipment operating at 13,56 MHz".

[i.25] ISO/IEC 18092: "Information technology -- Telecommunications and information exchange between systems -- Near Field Communication -- Interface and Protocol (NFCIP-1)".

[i.26] ECMA 340: "Near Field Communication Interface and Protocol (NFCIP-1)".

[i.27] ISO/IEC TR 18001: "Information technology - Radio frequency identification for item management - Application requirements profiles".

[i.28] ISO/IEC 18046 (parts 1 to 3): "Information technology - Radio frequency identification device performance test methods".

[i.29] ISO/IEC18000-1: "Information technology - Radio frequency identification for item management - Part 1: Reference architecture and definition of parameters to be standardized".

[i.30] ITU Radio Regulations.

[i.31] http://www.efis.dk/views2/search-allocations.jsp.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

bulk reading: extension of single reading to a set of tags within the illumination field

identification system: equipment consisting of a transmitter(s), receiver(s) (or a combination of the two) and an antenna(s) to identify objects by means of a transponder

Short Range Devices (SRDs): radio devices which provide either unidirectional or bi-directional communication and which have low capability of causing interference to other radio equipment

tag: device that responds to an interrogation signal

3.2 Symbols

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

P	Power
R	Distance
f	frequency
f_C	carrier frequency in Hz
H	magnetic field strength
kB/s	Data transmission speed
λ	Wave length

3.3 Abbreviations

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

AIDC	Automatic Identification and Data Capture
ANFR	Agence Nationale des Fréquences
ASK	Amplitude Shift Keying
EAS	Electronic Article Surveillance
ECA	European Common Allocation
ECC	Electronic Communications Committee
EM	ElectroMagnetic
EPC	Electronic Product Code
HF	High Frequency
ISM	Industrial Scientific Medical
ISO	International Standards Organisation
LF	Low Fequency
NFC	Near Field Communication
NRZ	Non Return Zero
RX	Radio Receiver
SRD	Short Range Device
TG	Task Group
TX	Transmitter
UHF	Ultra High Frequency

4 Comments on the System Reference Document

No comments are received to date.

5 Background information

5.1 The current situation

RFIDs operating at 13,56 MHz meet a number of different market requirements and has reached the highest market acceptance and penetration among all other RFID technologies operating at other frequency ranges.

The increase rate over the next decade is about 50 % or higher. This is based on an already high level of installed systems and particularly the number of tags. This high level of acceptance is due to the versatile yet simple 13,56 MHz inductive technology.

13,56 MHz benefits are:

- Frequency band is harmonized ➔ in ITU regions 1, 2 and 3
- Near field properties RFIDs have distinct features ➔ well defined and limited operating range
- Very high spectrum efficient technology ➔ 13,56 MHz ±7 kHz is sufficient
- High coverage of Standards ➔ by global standards (ISO) and regional as well as different application specific standards
- Highest data rate and bidirectional communications ➔ up to 423 kB/s for sophisticated, secure data transmission and anti-collision and up to 30 MB/s for short distance systems
- Low cost structure ➔ using mature and high volume technologies
- Choice of technology for long or short operating ranges ➔ with controlled and short range at high data rate or high range with medium data rates

The regulation for the carrier field strength level was increased from 42 dBμA/m to 60 dBμA/m a few years ago in order to provide higher reading ranges and to meet the market demands. At the time, the market primarily required read-only tags and the enhanced reading range was effectively enabled by the 60 dBμA/m limit.

The increased complexity of RFID systems, the level of sophistication of the various applications, last not least the need for data protection and enhanced capability for data security have dictated the shift from read-only and unidirectional data communication to bidirectional communication between reader and the tag.

Bidirectional communication to the tags is essential for present RFID systems with sophisticated protocols e.g. for addressing individual tags, and also enabling data security functions. For bulk reading environments fast protocols for tag serialization is required, which is only feasible with bidirectional communication.

The large majority of the RFID systems respectively the tags are passive, this is a precondition for high market penetration and reliable operation at low cost. Passive tags face a number of limitations for realizing the chip technology, especially if bidirectional communication between reader and tag is required.

The bidirectional communication requires that the tag activation signal is to be ASK modulated. The modulation level has to be minimum ~10 % (respectively a modulation index of 18 %) in order to be reliably detected by the passive tags.

The present modulation mask, initially defined for operation at a carrier level of 42 dBμA/m, works satisfactorily with the present modulation mask level of 9 dBμA/m. However using the increased carrier level of 60 dBμA/m the modulation level of 9 dBμA/m is too low.

The present document supports the need for amending the modulation emission levels and defines the required modulation mask to allow reliable bidirectional communication at the carrier operation level of 60 dBμA/m.

The present modulation mask, initially defined for operation at a carrier level of 42 dBμA/m, works satisfactorily with the present modulation mask level of 9 dB/μA/m but with the increased carrier level the modulation level is too low and no longer functional to support bidirectional communication at 60 dBμA/m.

The present document supports the need for amending the modulation emission levels and defines the required modulation mask to support bidirectional communication at the operation level of 60 dBµA/m.

5.2 The 13,56 MHz inductive RFID technology

- RFID systems at 13,56 MHz basically operates as magnetically coupled and tuned circuits.
- Systems can use the trade-off potential to either make use of high quality factors (Q) for the antenna circuits in order to provide the highest efficiency to power the tags over the maximum required reading distance at moderate data rates, - or using a lower Q and broadband tuned circuits supporting high data rates up to 100 kBit/s resulting in lower ranges.
- A distinct advantage of the 13,56 MHz technology is the fact that below 30 MHz RFID systems operate in the near field propagation domain which features:
    - high field strength roll-off of ~60 dB/decade [i.2] and [i.5];
    - lower interference potential to other services operating in the same or nearby frequency bands [i.3] and [i.6];
    - the re-use of the frequency band allowing high spectrum efficiency and dense operation of 13,56 MHz RFID systems in a given area;
    - controlled and limited operating range and free from reflections and diffraction.

Inductive technology RFIDs therefore have favourable propagation properties and ideally suited for Short Range Device (SRD) operation which are not present with other RFIDs operating in higher frequency ranges and at EM fields.

Another aspect for future high market growth and significantly lower cost is that the printed chip and technology for RFIDs is opening significantly larger markets as compared to the present RFID forecasts because of the much lower cost [i.4] and [i.7].

The most limiting factor for 13,56 MHz RFID's is the regulatory constraint for the modulation emission level such as addressed in the present document.

5.3 The socio-economic benefits

The RFIDs are an established technology in the industry, known as "Automatic Identification and Data Capture (AIDC) technology" and have developed nowadays as an active and indispensable part in all areas of daily life.

AIDC technologies primarily known as Bar Codes. The next generation and successor or complementary technology to Bar Codes is the RFID technology which is more versatile and essential for applications such as e. g. logistics, apparel and textiles, industrial installations, payment, access control, ecology savings, libraries, medical and many other applications [i.4].

There are a number of new applications and markets which are imperative for the public and by a number of states already regulated because of the saving cost, allowing international control/security functions, such as e-Pass and the ID card, driver licenses or similar applications. These are all using 13 MHz RFID according to ISO standards.

Therefore 13 MHz tags presenting high volumes and provide fast growing markets over the next decade and beyond.

The enabler for the various applications is on one hand a transmitter mask to cope with wide modulation range and high data speed as defined in ISO/IEC 14443-2 Amd. 3 [i.8] and on the other hand high reading ranges to allow a sufficiently high modulation level as required by ISO/IEC 15693-1 [i.9].

As example of the socio-economic benefits in the various applications in the industrial area where RFIDs can be used is shown in table 1 identifying savings and performance improvements using RFID in a manufacturing environment.

This is typical for ISO/IEC 18000-3 [i.17] for 13,56 MHz in industrial applications.

Table 1: Savings of Radio Frequency Identification (RFID) technology

Parameter	Benefit
Productivity	Increased between 10 % and 100 %
Throughput times	Decreased between 40 % and 90 %
Inventories	Decreased between 40 % and 90 %
Scrap	Reduced between 10 % and 50 %
Space savings	Between 30 % and 60 %
Overtime	Decreased up to 90 %
Safety-related injuries	Decreased up to 50 %
Product development time	Decreased up to 30 %

Other high volume applications examples are ticketing and payment and access control e.g. ski pass, parking, tracking and tracing, libraries, etc.

Numerous ISO and other technical standards are available for the various applications and markets which are given in clause 7.4.

6 Market information

6.1 General

Besides the Low Frequency (LF) RFID systems, the 13,56 MHz technology is one of the first RFID technology brought to the market back in 1995 or earlier in the form of the first smartcard applications. Presently the market covers a variety of applications.

The market for 13,56 MHz applications is established in the following areas *(the list may not be complete)*:

1) Logistics and materials handling, where goods and mobile assets are tagged for their use along the supply chain [i.11].

2) Ticketing and Payment systems to secure transactions (i.e. smart cards, e-Passport, mass transportation tickets).

3) Libraries, books handling.

4) Ecology related applications such as waste management.

5) Item level tagging - especially efficient if combined with an Electronic Article Surveillance (EAS) function which can be performed in the same chip.

NOTE: The 60 dBµA/m emission level according to ERC/REC 70-03 [i.10], Annex 9 provided the needed reading ranges of RFIDs to cover combine the EAS function with RFIDs. These EAS devices are extremely range critical and the needed EAS ranges were previously only achieved at different frequencies with very simple EAS technologies (capable of handling more than 1 bit).

6) Automatic display of information where items are tagged to provide additional information to consumers on products and services.

7) Medical applications in identifying equipment, medical process steps, monitoring etc.

8) Inventory audit, for example in warehouses where boxes or pallets are tagged to improve the speed, accuracy and efficiency of stock taking.

9) Asset monitoring and maintenance, where mostly fixed and high value assets are tagged to store information, e.g. for maintenance purposes.

10) Tagging in the apparel manufacturing and laundry services for industrial and private use.

11) Item flow control in processes, where RFID tags are attached to items which are moving along a production line.

12) Authentication to provide secure identification mechanisms for persons and objects.

The range of applications is still increasing.

6.2 History, technology and systems

The first developments of RFIDs wireless cards were based on the *"Close Coupling (smart) Cards"* which had to be positioned rather precisely to match the position of the coils of the card with the position of the reader coils in order to have a functioning inductive coupled link for power and data.

Therefore these close coupling cards were slot operated (these close coupling cards were operated at 4,9 MHz and presented the forerunner of the 13,56 MHz system).

The 13,56 MHz RFID Systems for proximity cards were first developed by Mikron in the early 90's as Fare Collection systems and deployed in volume as MIFARE system from 1996 onwards. The first major application was a 13,56 MHz RFID card (U-pass) deployed for instance in Seoul for ticketing/payment systems. The MIFARE card was only for short distance operation. In 1998 Mikron was acquired by Philips® and later transferred to NXP® which continued the success story of this ISO/IEC 14443-2 Amd. 3 [i.8] smartcard technology with about 1 Billion cards sold.

While the ISO/IEC 14443-2 Amd. 3 [i.8] card was designed for proximity operation (5 cm to 10 cm) and with inherent safety functionality, the ISO/IEC 15693-1 [i.9] followed from 1999 onwards and was called the vicinity card. This card allowed reading ranges up to 1,5 m, initially for access control but also successful in many different applications which similarly also required large reading ranges.

This is one example for the unique 13,56 MHz technology providing either long range enabled by high Q Tag antenna circuits or short range combined with high data speed with larger modulation bandwidth.

6.3 Overview of 13,56 MHz RFID family and standards

There are more than five 5 different standards available for the RFID frequency band of 13,56 MHz, they differ in different reading ranges, modes, modulation rates and data speed according to the different applications, see figure 1.

Table 2 provides an overview of the different 13,56 MHz RFID technologies, applications and the corresponding reading ranges as one of the key parameters for RFID systems.

Table 2: 13,56 MHz RFID reading range overview

Application / technology	Standard	Reading range
Close coupling Card (initially for 4,9 MHz)	ISO/IEC 10536 [i.18]	<1 cm
IC Cards (smart cards), e-Pass	ISO/IEC 14443-2 Amd. 3 [i.8]	~10 cm
Vicinity cards, for access control, etc.	ISO/IEC 15693-1 [i.9]	~150 cm
NFC / mobile RFID applications, data streaming, ect.	ECMA 340 [i.26]	~10 cm
Logistics, manufacturing, item tagging, asset control, etc.	ISO/IEC 18000-3 [i.17]	~150 cm

13,56 MHz RFID standards are handled in several Standardization Groups, ISO/IEC JTC1/SC17 (cards), ISO/IEC JTC1/SC31 (logistics), CEN, CENELEC and NFC/ECMA (mobile phone) in cooperation with ETSI ERM TG23.

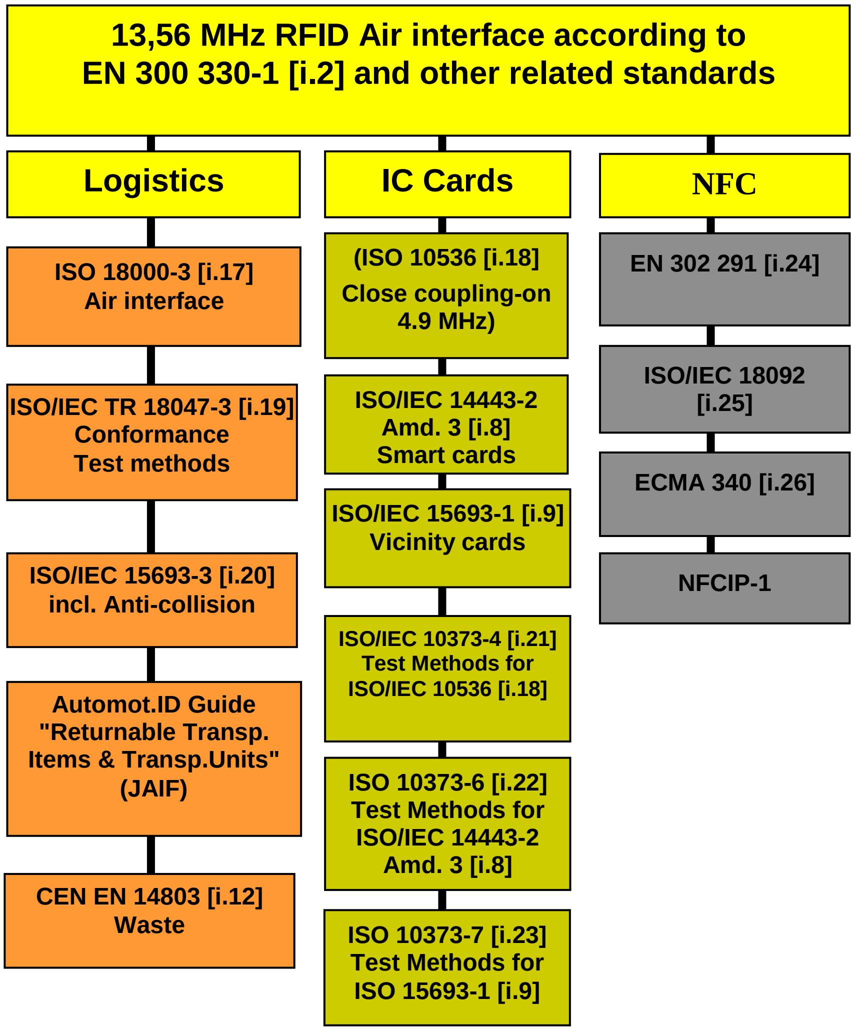


Figure 1: Overview of the 13,56 MHz RFID standard family

The 13,56 MHz RFID standard for logistics (ISO/IEC 18000-3 [i.17]) operates with different modes, recently a mode M3 was added which resembles the Gen2 EPC protocol to provide compatibility on the data protocol level as used in UHF RFID tags.

The ISO standards for logistics and also provides bulk reading of many tags in a given or defined area. This is also inherent to ISO/IEC 15693-1 [i.9]. Bulk reading *(also referred to as anti-collision mechanism)* is not needed for RFID systems operating at low ranges for instance for ISO/IEC 14443-2 Amd. 3 [i.8] smart cards because the low reading distance of a few centimetres provide physical tag differentiation in order to provide privacy.

The NFC family is a data communication device used as high speed data transmission media between different cards, card and terminals, mobile phones i.e. as mobile ticketing, access card, credit cards and other applications requiring very high data speed.

The NFC devices are very flexible; they can function as contactless chip card as well as a reader device for reading other cards.

Another functionality of NFC is a card to card communication to operate as data link. Depending on the function, NFC cards can have a battery or operate as passive or active RFID devices.

7 Technical information

7.1 Detailed technical description

7.1.1 13,56 MHz Receiver-Reader restrictions due to present regulations

High volume applications predominantly use the passive tags for low cost, small size, no environmental problems and simple design reasons.

The regulation for the modulation emissions (mask) is too restrictive and the emitted spectrum width and the modulation level have to be increased as proposed in the present document.

Presently these passive RFID systems are unable to use the maximum carrier allowance of 60 dBμA/m for bidirectional passive RFIDs because of modulation sideband restrictions.

In technically optimized "classic" communication type systems with e.g. battery power supply can live with the low transmitter modulation levels as defined in ERC/REC 70-03 [i.10], Annex 9 because the tag receiver can be more sophisticated.

The receiver of passive tags suffers restrictions for the chip design and results in the limited readers receiver sensitivity in presence of the very signal required to power the tag.

The limitations are due to physically collocated receiver operating from the simultaneous operating transmitter and using the same antenna for receive and transmit. Therefore the tag suffers from e.g. carrier phase noise, blocking effects RX-TX signal separation.

Therefore the reliable detection of the low modulation signal from transmitter by the tag is to be provided by an enhanced modulation level of the reader.

In practice the difference between the powering signal and the received tag signal should be below 90 dB to 100 dB for a reliable communication link (see also figure 7).

7.1.2 Detailed technical description of 13,56 MHz systems

In figure 2 a basic RFID Full Duplex (FD) system *(with regard to Power and Read function)* is explained. The reader signal powers and activates the tag. At the same time the powering signal is ASK modulated to instruct the tag for certain functions like listen for following commands, to receive data to update the tags memory with newer information, or request the tags ID number e.g. for bulk reading situations to receive a serial number of a certain tag in order to be able to call up individual tags.

The binary data as read out from the memory can be transmitted directly or is often encoded for synchronism between TX and RX. The synchronism between the transmitter and the receiver is provided if the receiver clock is derived from the transmitted signal either from the RF signal directly as NRZ (Non-Return-to-Zero) or from an encoded modulation signal as e.g. Manchester or Miller encoding (called self-clocking).

Mostly at LF and HF the clock signal is derived from the carrier frequency. The clock as time base is provided by dividing the frequency by an integer number to provide the synchronism between the transmitted data signal and a clock. In this case the binary signal can be transmitted directly without further encoding. This is called the NRZ which saves transmission bandwidth as compared to e.g. Manchester or MILLER. NRZ encoded signal transmission can speed up the data rate up to a factor 2 or vice versa for a given data rate cut the transmission bandwidth is accordingly lower.

The modulation on the tag and reader side is in most cases ASK or a phase encoded ASK. In absence of own power supply and on board oscillators, tags can only use absorption or damping modulation imposed onto the received (powering) signal thus the tuned circuit.

In this case the received carrier signal is periodically damped according to the encoded modulation. Since periodically damping absorbs energy from the tag, the Manchester encoding can be made more spectrum efficient if e.g. a Miller pulse-pause coding scheme is used where the pauses are made very short compared to the pause or the clock durations.

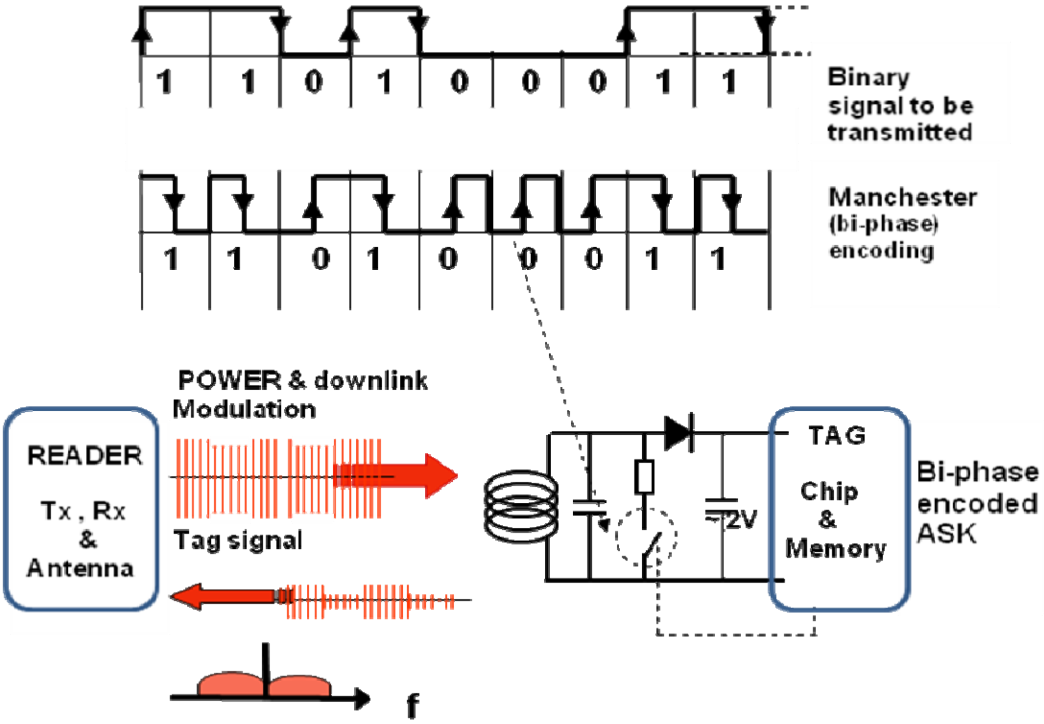


Figure 2: 13,56 MHz RFID system

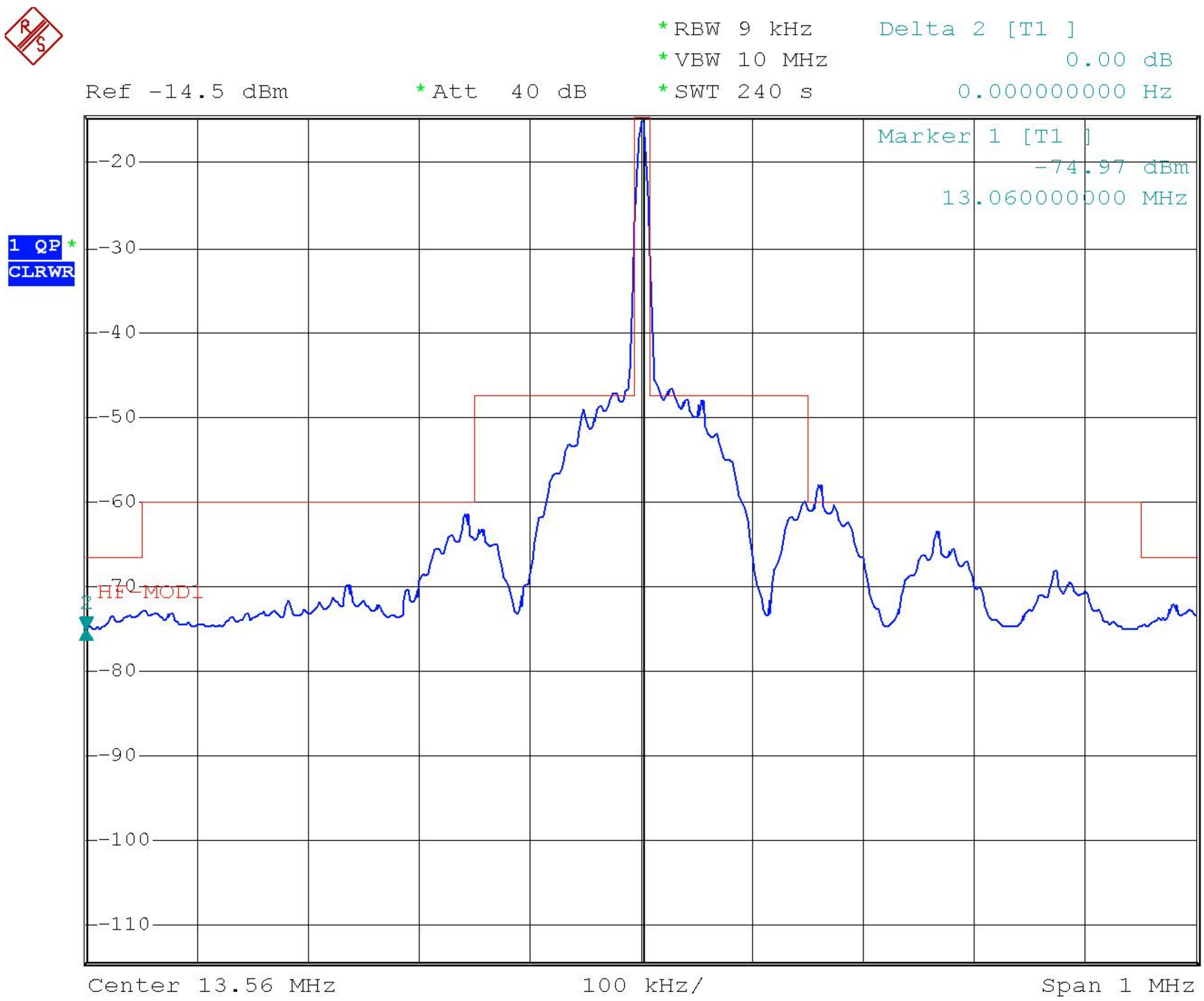
The basic problem addressed in the present document is that the ISO standards ISO/EC 18000-3 [i.17] and ISO/IEC 15693-1 [i.9] must use a very low modulation index or modulation depth because of regularly constraints in that the level of the allowed modulation sidebands in relation to the carrier is very low.

The ratio of the modulation to the carrier for reliable bidirectional communication must be in the order of 33 dB as it is defined in the ERC/REC 70-03 [i.10], Annex 9 considering the carrier level of 42 dBµA/m measured at d = 10 meter and the associated sideband allowance of 9 dBµA/m.

For the maximum allowed carrier level of 60 dBµA/m the modulation index with the present carrier - sideband emission allowance at a 51 dB lower level is too low and no reliable data transmission from reader to tag is possible.

Therefore 13,56 MHz RFID bidirectional systems and downlink modulation cannot use the 60 dBµA/m level and are restricted to carrier levels in the order of 42 dBµA/m.

Figure 3 displays from a practical measurement a modulated transmitter signal according to the maximum allowed modulation mask just designed to reach the maximum sideband limit of 9 dBµA/m.



ISO Readers are presently limited by the spectrum mask and they cannot use the maximum allowed carrier field strength of 60 dBµA/m.

Figure 3: 13,56 MHz spectrum measurement showing the maximum modulation level according to ERC/REC 70-03 [i.10]

7.2 Status of technical parameters

7.2.1 Current ITU and European Common Allocations

Table 3: ITU Allocations (excerpt from ITU Radio Regulations [i.30])

Allocation to services		
Region 1	**Region 2**	**Region 3**
13 360-13 410	FIXED RADIO ASTRONOMY 5.149	
13 410-13 570	FIXED Mobile except aeronautical mobile I 5.150	
13 570-13 600	BROADCASTING 5.134 5.151	
13 600-13 800	BROADCASTING	
13 800-13 870	BROADCASTING 5.134 5.151	
13 870-14 000	FIXED Mobile except aeronautical mobile I	

Table 4: ECA Allocations Table (excerpt from http://www.efis.dk/views2/search-allocations.jsp [i.31])

12.23 MHz - 13.2 MHz Maritime Mobile

13.2 MHz - 13.26 MHz Aeronautical Mobile (OR)

13.26 MHz - 13.36 MHz Aeronautical Mobile I

13.36 MHz - 13.41 MHz Fixed

13.36 MHz - 13.41 MHz Radio Astronomy

13.41 MHz - 13.57 MHz Fixed

13.41 MHz - 13.57 MHz Mobile except aeronautical mobile I

13.57 MHz - 13.6 MHz Broadcasting by 2007 (WARC-92)

13.6 MHz - 13.8 MHz Broadcasting

13.8 MHz - 13.87 MHz Broadcasting by 2007 (WARC-92)

13.87 MHz - 14 MHz Fixed

13.87 MHz - 14 MHz Mobile except aeronautical mobile I

14 MHz - 14.25 MHz Amateur

14 MHz - 14.25 MHz Amateur-Satellite

7.2.2 Sharing and compatibility studies (if any) already available

ERC Report 74 [i.6] addresses the compatibility of 13,56 MHz RFID systems to radio astronomy receiving stations which operate in the same band. The report was issued in May 1999 after extensive Field tests and studies involving several representative RFID systems from RFID systems suppliers in cooperation with Radio Astronomy experts. The tests were arranged and conducted under the supervision of the French administration ANFR.

Extensive field tests were done in the Nancay, where decametric observations are done with an antenna array with a maximum effective aperture of 2 x 4 000 m^2 and is one of the largest astronomy site worldwide for decametric observations in the 13 MHz band [i.6].

For the compatibility measurements the astronomy receiver at the Nancay site was configured to observe the frequency range from 13 MHz to 14 MHz which covered the carrier frequency as well as the modulation spectrum of the RFID systems which overlaps the astronomy allocation.

The report reveals that no disturbance was recorded and the fact was that if RFID system is placed inside the astronomy site e.g. on the visitors parking site, and no interference signal from the RFID systems could be detected. This included the emission of the RFID carrier at a level of +42 dBµA/m [i.6].

7.3 RFID system parameters

An RFID system consists of an interrogator or a reader and one or several tags as data carriers.

The reader emits a carrier signal to power the tags. The induced field strength to power the tag s threshold is in the order of 70 dBµA/m to 80 dBµA/m to just activate the tag. Starting for instance at a field strength limit of 42 dBµA/m at d= 10 m the operating range is about 1,50 m form the antenna position. If the system meets the ISO/IEC 15693-1 [i.9] standard and has a typical antenna size to fit in a standard card (85,6 mm to 54 mm = tag size). The derating of the field strength in the near field is given in figure 4. For a reader emitted maximum field strength of 60 dBµA/m (measured at d= 10) meter, the maximum RFID system operating range is about 2 m.

The maximum range depends primarily on the efficiency of the tuned circuit (Q) and the size of the antenna coil of the tag for a given field strength level under the ETSI test conditions (EN 300 330-1 [i.2]).

Figure 4 displays the roll-off of the field strength from the reader antenna creating the interrogation field. The intersection of the individual tag threshold level with the roll-of curve determines the maximum reading or powering range of a system.

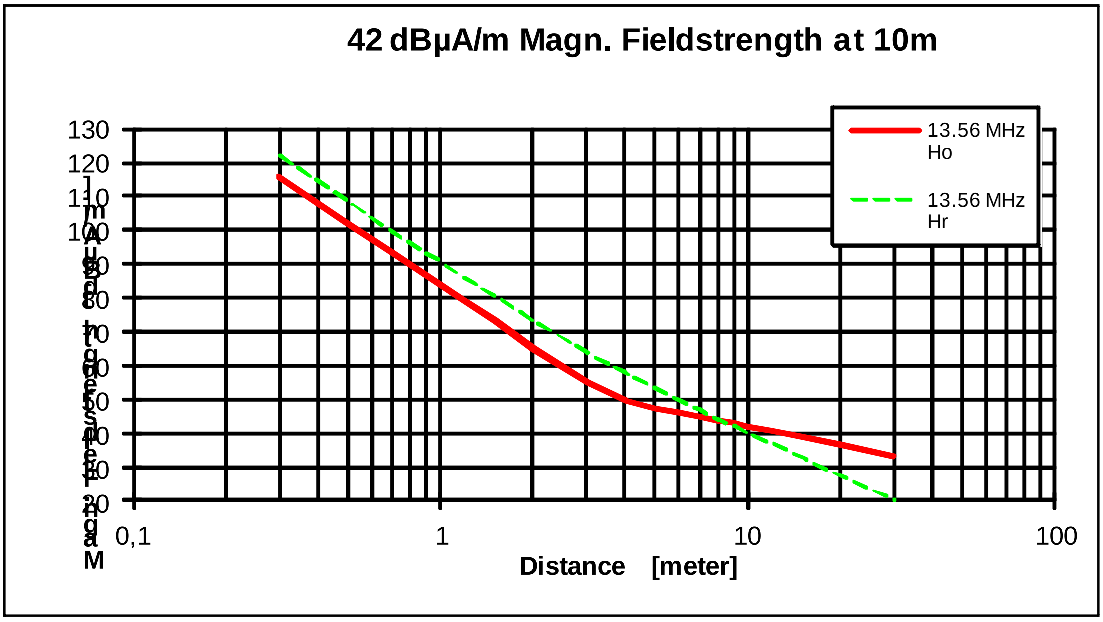


Figure 4: 13,56 MHz field strength derating in the nearfield for coaxial and coplanar position of reader and tag

The downlink transmitter signal is shown in figure 5. A too deep modulation would reduce the reading range because the powering capability is reduced.

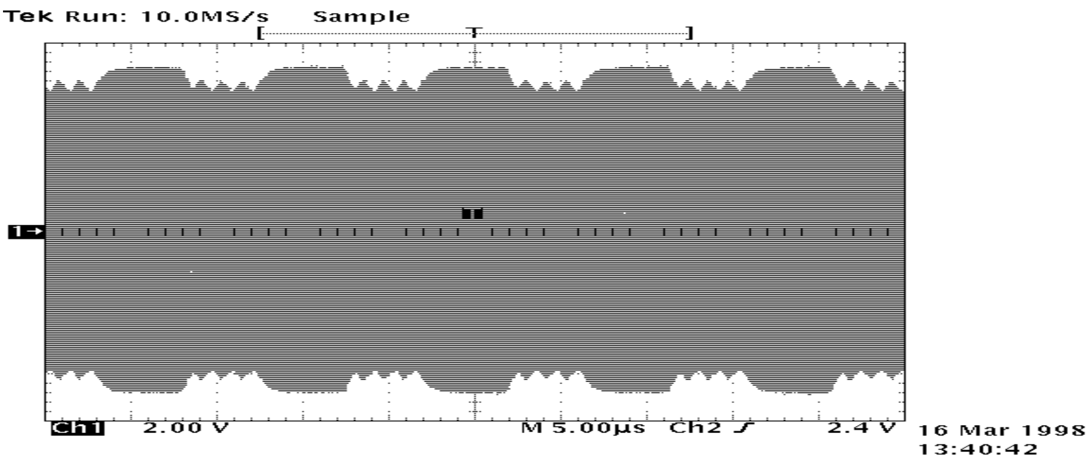


Figure 5: Typical downlink modulation signal (reader to tag)

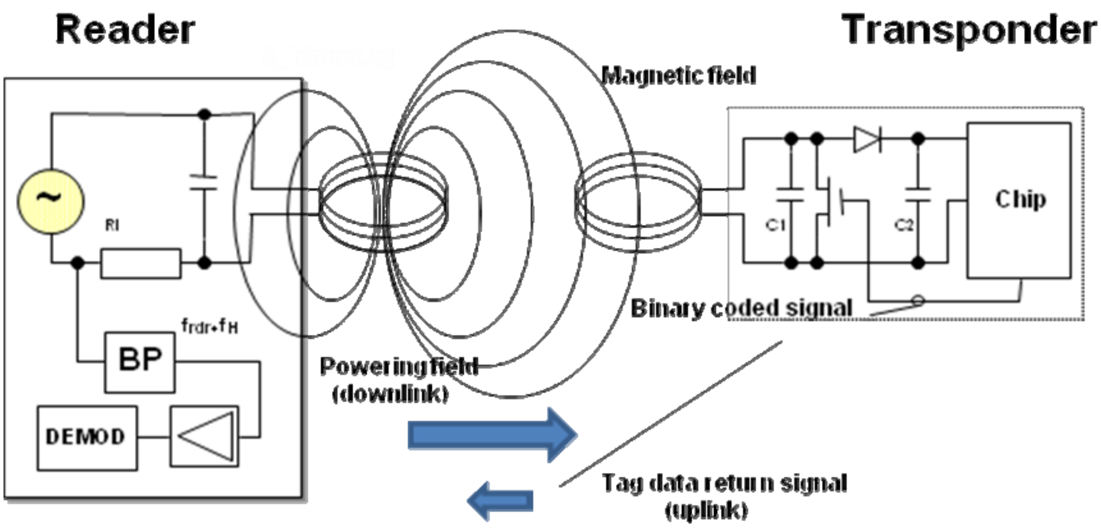


Figure 6: Typical 13,56 MHz RFID system

The receiver input of the reader has to handle a weak transponder or tag return signal with a very low degree of modulation while at the same time the own emitted high carrier level to power the tag is present at the same antenna causing desensitation or blocking effects.

The tag return signal modulation depth is also compromised because a higher (damping) modulation reduces the power for activation of the chip.

These are very demanding conditions for the tags receiver/transmitter so that the chip designers have to deal with several compromises to provide a reliable function for the RFID function.

The figure 7 displays the signal levels at the receiver input.

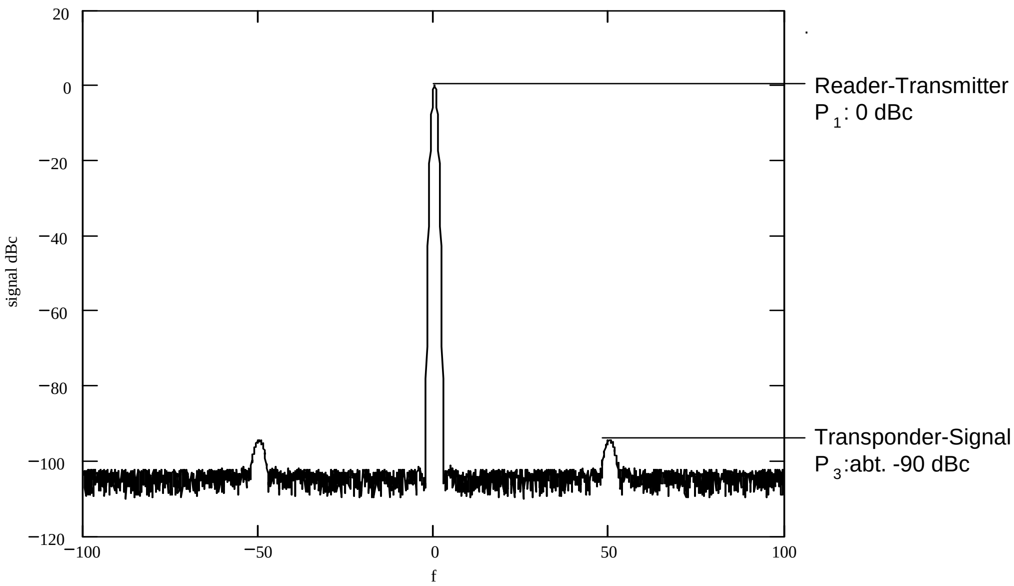


Figure 7: Signal levels at the input of the receiver of the reader

8 Radio spectrum request and justification

The present mask for the allowance level of the modulation spectrum (see figure 9) is presently insufficient to provide a reliable bidirectional data link for high speed as well as for very high datarates as it is required for the majority of the 13,56 MHz applications. The effective modulation level close to the carrier must be increased from 9 dBµA/m to 27 dBµA/m and the modulation width defined for ±7 MHz and at the level of -5 dBµA/m in agreement with the ERC/REC 70-03 [i.10], annex 9 which defines the generic level from 5 MHz to 30 MHz also to -5 dBµA/m.

Additional information for the justification of the radio spectrum request is given in more detail in clauses 5.1 and in 7.1.1. Figure 8 displays the proposed mask.

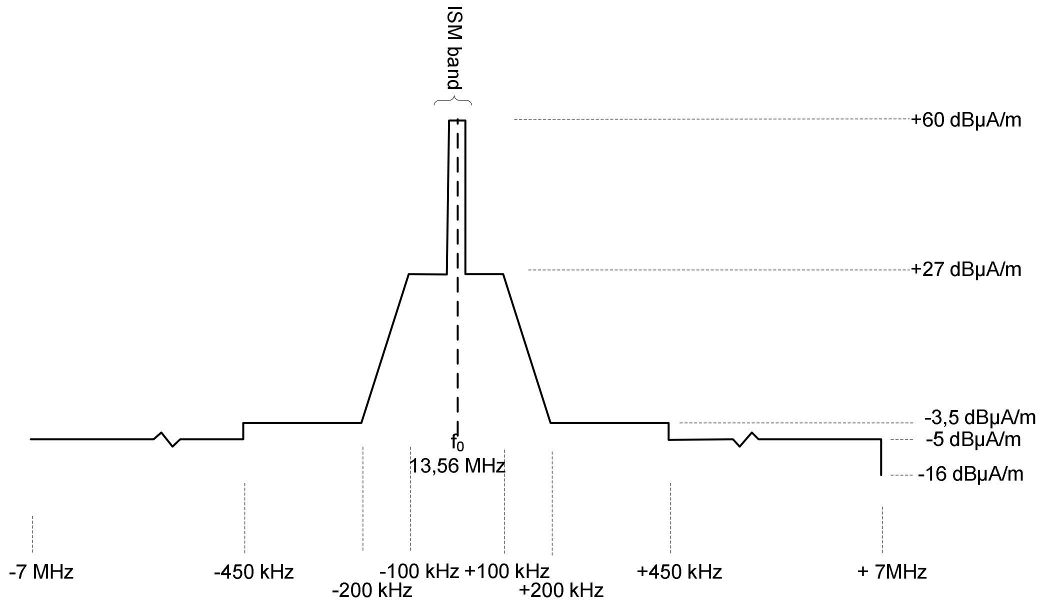


Figure 8: Emitted spectrum of a 13,56 MHz reader

The first level of the modulation near the carrier needs 27 dBµA/m for ±100 kHz and rolls-off to -3,5 dBµA/m at f= 200 kHz while the 3rd level starts at 450 kHz and is attenuated to -5 dBµA/m.

The proposed mask solves two basic problems (1) the downlink data speed for long range systems as ISO/IEC 15693-1 [i.9] and (2) the significantly enhanced data speed for ISO/IEC 14443-2 Amd. 3 [i.8] type systems (see clause 6).

For (1) the downlink data speed for systems with high read ranges of >1,5 m. These systems have to operate at a high datarate to provide efficient bulk read capability in order to deal with a number of tags in range e.g. to identify and read hundreds of tags per seconds. In this case the system first has to inventory and identify all tags in the shortest time possible (called serialization where only the tags unique number is recorded by the reader). After this inventory process, the reader can address and read one tag after the other by addressing them individually. This is a key requirement for most applications.

As practical example, using the mask of the present EN 300 330-1 [i.2], the maximum number of tags that can be read within 1 s is only 30. The new mask can increase the read speed from 30 to 800 tags per second.

For (2) a much higher data speed is needed which is enabled by the spectrum extension up to ±7 MHz. The new amended ISO/IEC 14443-2 Amd. 3 [i.8] require data rates of up to 30 Mbit/s and must cope with high security protocols as well as to deal with inherently high up- and downlink data transmission speeds.

This high speed is realized by providing a high clock frequency hence data rates where the carrier of 13,56 MHz is divided by 2 to create the clock of 6,8 MHz.

The present mask as per figure 9 does not allow the introduction of the required safety and security features as requested by the recent EC mandate M436 (see also clause 5.1 Current situation). These authentication and crypto functions are presently not feasible with bidirectional communication at reading ranges above 10 cm. The proposed mask provides the required data speed for 100 kBit/s transmissions.

9 Regulations

9.1 Current regulations

The present regulation is given in the ERC/REC 70-03 [i.10], annex 9 is presented in table 5 and by the figure 9.

Table 5: Current regulation (as given in the ERC/REC 70-03 [i.10], annex 9)

f	13.553 - 13,567 MHz	42 dBµA/m at 10m	No requirement	No spacing		
f1	13.553 - 13,567 MHz	60 dBµA/m at 10m	No requirement	No spacing		For RFID and EAS only.

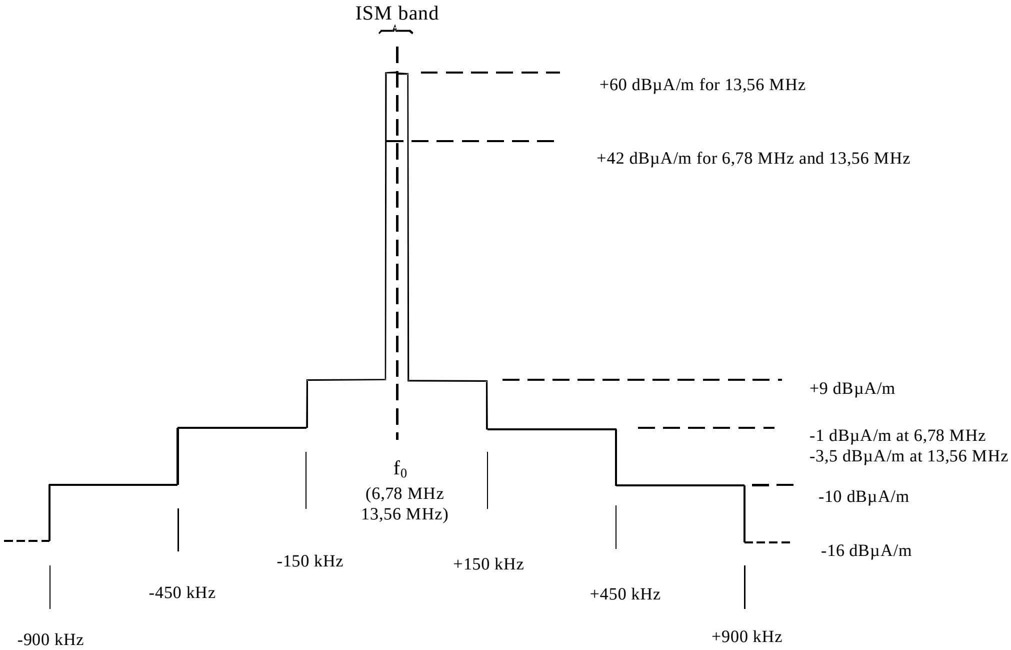


Figure 9: Current regulation
(as given in the ERC/REC 70-03 [i.10], annex 9 and EN 300 330-1 [i.2])

Annex A: Detailed market information

A.1 Applications

The list of applications covers a wide range of markets ranging from logistics and materials handling, Ticketing in mass transportation, payment systems, smart cards, e-Passport, mass transportation tickets, libraries and books, books handling, ecology related applications/, waste management; item level tagging, manufacturing control, automatic display of information to purchase items in warehouses, medical applications in identifying equipment, medical/hospital process steps, monitoring, inventory audit, asset monitoring and maintenance, where mostly fixed and high value assets are tagged to store information, tagging in the apparel manufacturing and laundry services for industrial and private use, item flow control in processes, authentication to provide secure identification mechanisms for persons and objects; access control.

The 13,56 MHz applications have been proven and are used in established markets, running in high volume.

A.2 Evolution and outlook of the 13,56 MHz RFID market

The HF RFIDs are predominantly are using 13,56 MHz. Some applications in the early days of RFID were using systems at 27 MHz or 6,78 MHz. These as well as the first 13,56 MHz systems were found in standalone or closed systems for specific application.

With the proliferation of systems and the logistics and interfacing and penetration of global markets only 13,56 MHz systems are deployed. The 13,56 MHz RFID technology is covered by various standards and global and regional standards are the basis for worldwide acceptance of the 13,56 MHz RFIDs.

13,56 MHz is presently most important frequency band for RFID in terms of value as well as in volume shipments of tags and systems.

Many new markets for passive RFID, from RFID enabled phones to financial cards, national ID cards, passports and tickets in addition a significant number of the new smart active labels are operating at HF. Many applications, typically met with LF RFID such as secure access and tagging metallic items, are moving to 13,56 MHz.

The market prediction from market researchers assess the global market for 13,56 MHz RFID will triple from $2,9 billion in 2008 to $8,6 billion in 2018. [i.13], notably exceeding UHF passive RFID for some time to come.

In 2007, 50 % of the global RFID market value was on 13,56 MHz established and from an earlier forecast [i.14] the figure A.1 provides a former market assessment, evolution or trend and the ratio of tags shipped for the years 2000 to 2005. Considering the present situation, this volume has been exceeded by factors.

Considering the figure A.1, -although showing past years- the ratio of tags by frequency is still representing the current distribution of RFID systems per frequency range and secondly the much steeper trend of the 13,56 MHz penetration is still valid.

Especially in view of the actual and forecasts of new technologies, some estimations expect x-times the volume and expenditures spent on 13,56 MHz as compared to any other frequency.

The 13,56 MHz dominance has been retained as RFID entered a phase of rapid growth in the last two years mainly because of the e-passport, now issued by over 70 countries, and financial cards such as the MasterCard Paypass®, e-Pass®, driver licences. Further on the printed electronic technology is progressing and expectations are that it can be made available within the next 5 + years. This is feasible at 13,56 MHz but printed technology is not likely to occur at UHF so that the HF tags will be significantly lower in cost and multiplying the market figures [i.7], [i.15] and [i.16].

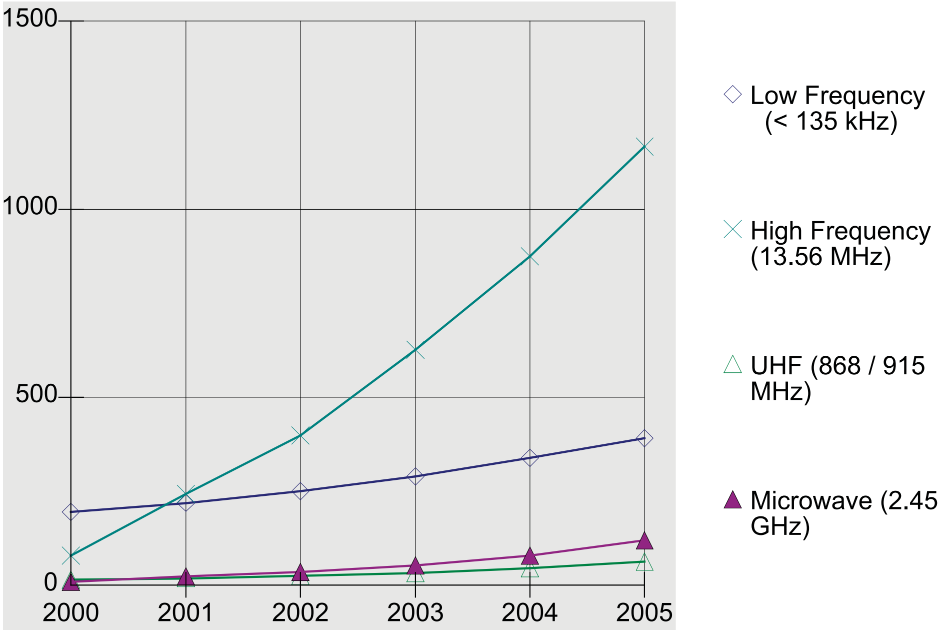


Figure A.1: Distribution and evolution of RFID systems

Annex B: Technical information

B.1 Technical description

B.1.1 Rationale and design considerations and for 13,56 MHz systems

Considering inductive RFID systems below 30 MHz, the only options considering the radio regulations for SRDs are at LF, 6,78 MHz, 13,56 MHz and 27 MHz bands. The powering efficiency is the highest at 6,78 MHz to 13,56 MHz considering normalized conditions for the test such as constant excitation fieldstrength for all frequencies and effective sizes of the tag antennas

Since 6.78 MHz is an ISM band in but requires special authorization by individual national administrations therefore it is not harmonized, while 13,56 MHz is an ISM band and available for SRDs therefore is a globally harmonized band. Consequently the industry has favoured the 13,56 MHz band for RFIDs and the international RFID standards.

Considering a constant fieldstrength of e.g. 105 dBµA/m the operating range of comparable reader and tag antenna sizes has its maximum around f = 10 MHz e.g. ISO/IEC 15693-1 [i.9] which assures the highest powering efficiency for 13,56 MHz systems. Figure B.1 shows the powering efficiency as a function of frequency highlighting the potential ISM/SRD bands.

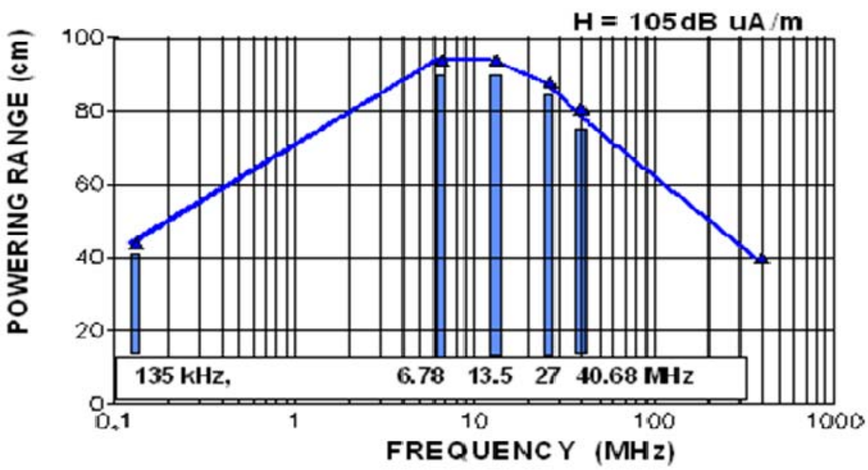


Figure B.1: Comparison of powering efficiency for RFID systems at available LF and RF frequencies for SRDs

B.1.2 System functions

Clauses 7.1.2, 7.3 and figures 5, 6 and 7 are describing the basic system functions and the main system relevant issues.

B.2 Technical justifications for spectrum

B.2.1 Power and frequency issues

As noted in clause 7.1.1 the powering level of 60 dBµA/m is required for more sophisticated bidirectional RFID systems to meet the market demands. However for the allowed carrier the level of 60 dBµA/m, the present modulation regulation with 9 dBµA/m is too low because the modulation sideband are not allowing downlink function because such a low level of modulation relative to the high carrier cannot be detected by the tags.

The passive tags have a number of restrictions to reliably detect such low modulation levels (see also clause 7.1.1).

Regarding the frequency issue, the required RFID mask for proper system functioning is explained and defined in clause 8.

B.3 Technical standards for RFID

ISO technical standards are application oriented and ISO has different sections which engage in the creation of RFID standards for global use.

At present 3 sections under the ISO, IEC and the Joint Technical Committee (JTC1) are active in the standardization of RFID systems and in the definition of measurement parameters as well as the definition of performance and conformance of RFID systems.

The ISO/IEC JTC1 with its SC31 Committees SC31 and SC17 defines the 13,56 MHz RFID relevant are RFID standards.

Figure B.2 shows the standardization bodies relating to RFID functions within ISO/IEC.

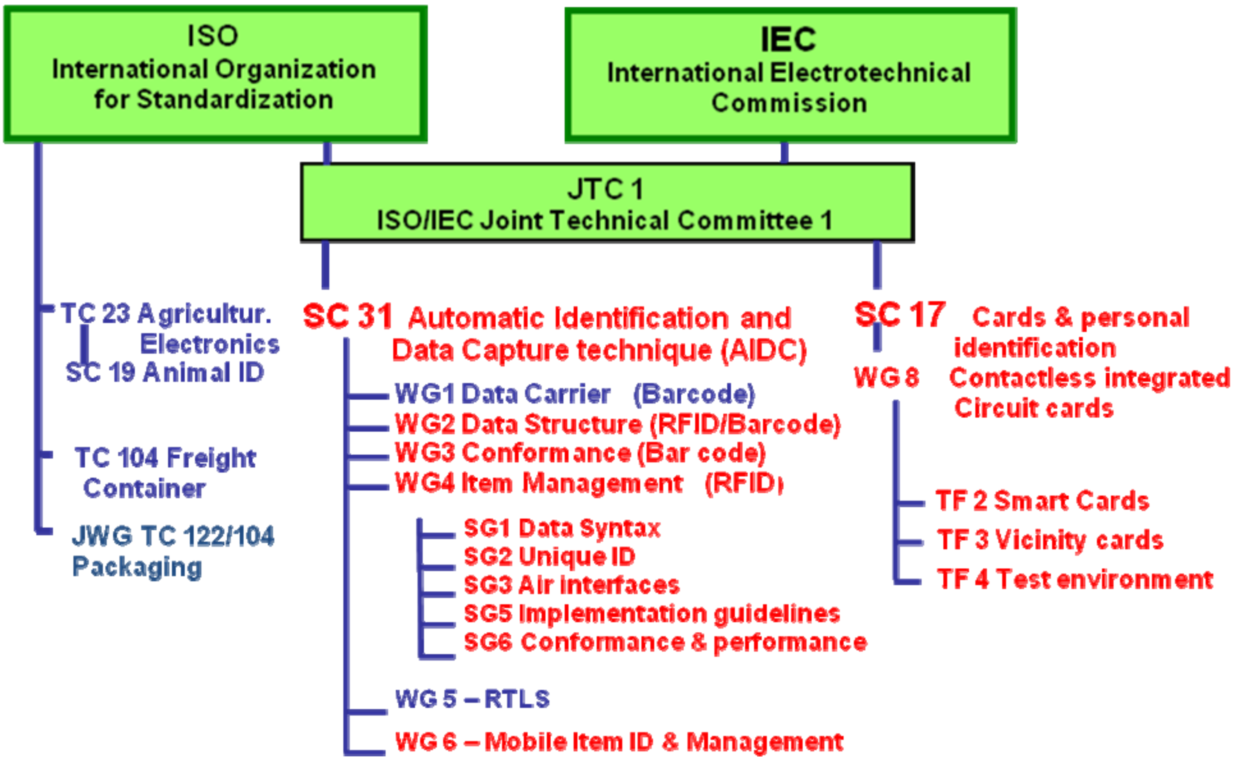


Figure B.2: overview over 13,56 MHz RFID standardisation activities in ISO/IEC highlighting bodies engaged with 13.56 MHz RFID systems in red

Table B.1 lists the relevant ISO standards for air interface RFID related standards for the 13 MHz frequency band.

Table B.1: ISO RFID relevant ISO standards for the 13,56 MHz band

18000	**Air Interface**
ISO/IEC18000-1 [i.29]	Reference architecture and definition of parameters to be standardized
18000-1 R1	Reference architecture and definition of parameters to be standardized - Revision
ISO/IEC 18000-3 [i.17]	**Air interface at 13,56 MHz** - Mode 1 based on ISO/IEC 15693-1 [i.9], 2 speeds 26 kB & 52 kB - Mode 2 high speed interface, 424 kB, 8 return channels! Both modes are **not** interoperable (Magellan technology)
18000-3 R1	Revision 1 (Batteries & sensors)
18000-3 R2	Revision 2 (Mode 3) - *Rev to meet EPC global, Gen 2 Protocol*
ISOIEC TR 18001 [i.27]	**Application Requirements Profiles**
ISO/IEC 18046 [i.28]	Radio frequency identification device performance test methods
ISO/IEC 18046-1 [i.28]	Radio frequency identification device performance test methods - Part 1: Test methods for system performance
ISO/IEC 18046-2 [i.28]	Radio frequency identification device performance test methods - Part 2: Test methods for interrogator performance
ISO/IEC 18046-3 [i.28]	Radio frequency identification device performance test methods - Part 3: Test methods for tag performance
ISO/IEC 14443-2 Amd. 3 [i.8]	Identification cards - Contactless integrated circuit(s) cards - Proximity cards Part 1: Physical characteristics
ISO/IEC 15693-1 [i.9]	Information technology - Radio frequency identification for item management - Unique identification for RF tags

Annex C: Bibliography

A breakthrough RFID printing technology that enables direct encoding to and printing of small RFID tags.

"Measuring Lean benefits using Radio Frequency Identification (RFID) technology".

NOTE: Available at: http://www.rfidinfo.jp/whitepaper/381.pdf

RFI Mitigation workshop, Bonn, March 28. 30 2001: "New generation of robust receivers at Nançay Radioastronomy Observatory".

History

Document history		
V1.1.1	March 2012	Publication