Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

COMPATIBILITY BETWEEN INDUCTIVE LF RFID SYSTEMS AND RADIO COMMUNICATION SYSTEMS IN THE FREQUENCY RANGE 135–148.5 kHz

Beaune, February 2002

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1 INTRODUCTION

Inductive RFID systems[1] with passive transponders (also called tags) have been in use since 1980 or earlier. In 1990, RFID applications started in the animal ID tagging business which is one of the major applications.

Other major inductive RFID applications are found in automotive and general industrial and commercial applications. Inductive systems below 135 kHz represent the largest portion of the RFID business with nearly 200 Mio tags shipped in 1999 and growing.

ISO has published the RFID Standards ISO 11785, ISO 14223 which operate at 134.2 kHz to provide globally interoperable systems. Other inductive RFID standards below 135 kHz, such as ISO 18000-2 for Item Management, are in process.

Recently the RFID industry has improved systems from “read-only” to “read-write” technology. New and efficient anticollision protocols were introduced in order to manage bulk reading of a large number of tags within the antenna field to avoid RFID tag pollution effects.

These “smart” RFID technologies require bi-directional communication of the reader with the tag and therefore the modulation of the RFID carrier. RFID systems operating to ISO standards and in other major applications therefore require a transmitter mask to accommodate the emitted modulation spectrum. The carriers of all inductive LF RFID systems operate below 135 kHz. Their modulation spectrum cover emissions according to the transmitter mask as specified in this report.

The report investigates sharing of RFID systems with primary and secondary services operating in the frequency range between 135 and 148.5 kHz.

The LF band in generally suffers high atmospheric (and in many areas terrestrial) noise which can vary from –10 dBµV/m to +20 dBµV/m or more. This can reduce functionality of systems and communication links which are relying on far-field propagation severely in cases especially where the service has to be guaranteed on a business level. Systems operating in the nearfield mode are less susceptible to this variation in noise levels.

The objective of this report is to show compatibility of RFID systems with other services operating in the frequency range 135–148.5 kHz.

2 BACKGROUND

2.1 ETSI Standards and ERC SRD Recommendation

Early 1990, ETSI has started to develop the first generic Standards for SRD’s which included inductive devices and published the I-ETS 300 330 in 1994. The Standard covers the frequency range of 9 kHz to 30 MHz. The LF range for inductive devices was limited to below 135 kHz. Thereafter ERC has developed the SRD Recommendation 70-03 beginning 1995 (in FM/PT26) and has issued the first version by 1997.

The operating frequency range and levels for inductive RFID systems are in agreement with the ERC Rec70-03.

2.2 Industry Requirements

LF RFID systems present the largest and stable base of the RFID market and the technology can meet most of the requirements with some exceptions. These are higher data speeds and there are also formfactor limitations due to the large inductances of the transponder antenna coils.

Distinct advantages of inductive LF systems are the low absorption of materials in the line of sight between the reader and tags. Operation of inductive RFID systems provide a larger range under adverse material absorption conditions as

[1] Inductive RFID systems and a propagation model for frequencies below 30 MHz are described in ERC reports 044, 069 and 074. Inductive RFID systems operate in the nearfield with H-field roll-off of 60dB/decade.

compared to higher frequencies. The choice of the frequency close to the upper band limit of 135 kHz was chosen because of higher efficiency, small component, tag size and cost.

The inductive RFID technology uses tuned circuits with high Q and L/C ratio in the tags in order to maximize operating range. The tuning capacitor ot the tag antenna circuit is integrated in the silicon chip and presents a significant part of the chip size. Since the size of the tuning capacitor reduces with the square of the frequency, a high operating frequency reduces chip size and cost.

3 INDUCTIVE RFID TECHNOLOGY IN THE LF RANGE

3.1 RFID Reader Technology, Emitted Spectrum and Transmitter Mask Requirements

An RFID system comprises the interrogator or reader and one or several tags as data carriers. The tags are attached to objects like industrial, warehouse goods or animals. RFID systems are used in logistics for manufacturing or in automotive applications, e.g. immobilisers or radio keys (car entry) systems, in animal identifications and in transportation applications.

Smart RFID systems use bi-directional communication between reader and tags. They can differentiate between tags used for different applications as well as to read a large number of tags within the interrogation field. Another important requirement in critical applications is the ability to provide encryption.

Tags are normally dormant and only activated into a receive mode when interrogated or activated by the reader.

Once activated, tags wait for their “family” or AI (Application Identifier) code and the specific command for instance to run an “anticollision” protocol. This protocol normally first inventory the number of tags in a given read zone prior to start with the main read and/or write function. This minimizes air-time and “tag pollution” effects of Read-Only tags. Figure 1 shows a basic reader configuration.

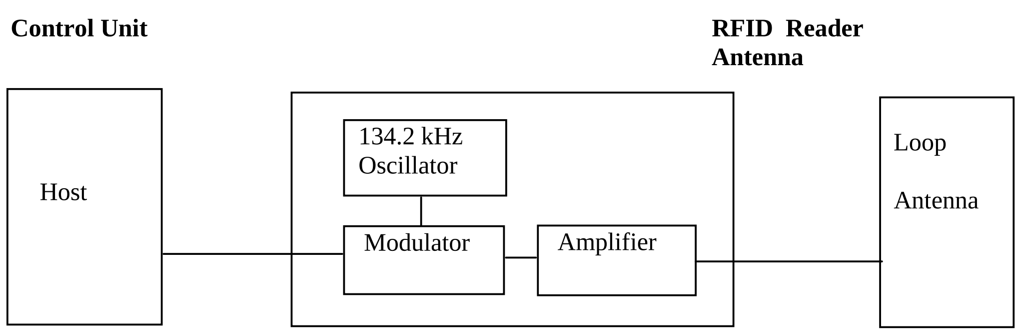

Figure 1 : RFID Reader Configuration

The reader spectrum of a 134.2 kHz carrier signal is shown in Figure 2. It should be noted that this reader signal spectrum was operating about 4 dB below the maximum level of 65.5 dBµA/m.

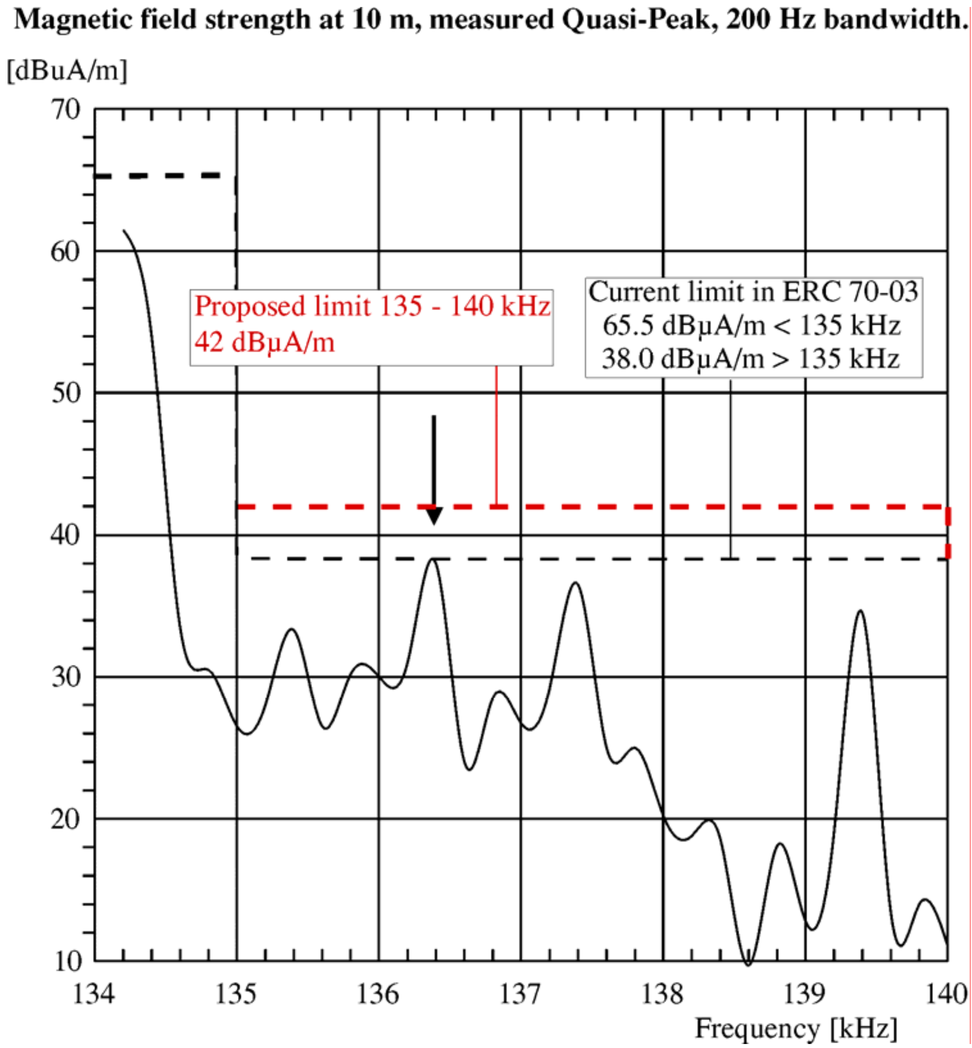

Figure 2 : Transmitter mask and measured magnetic field strength of a bi-directional RFID reader system operating according to the ISO Standards

4 LF BAND STUDY BELOW 148.5 kHz

4.1 Overview of the LF Band from 119–148.5 kHz

Current radio services share with inductive SRD's the range from 119 kHz up to 135 kHz as defined in the SRD REC 70-03 Annex 9.

The ITU regulations list for the LF range services FIXED, MARITIME MOBILE and RADIO NAVIGATION. The ERC Report 044 has dealt with the requirements of these services up to 135 kHz.

In the range of 135 to 148,5 kHz, fixed, Maritime mobile and Amateur radio services are allocated and considered in this report

The Figure 3 shows the present scenario of inductive applications.

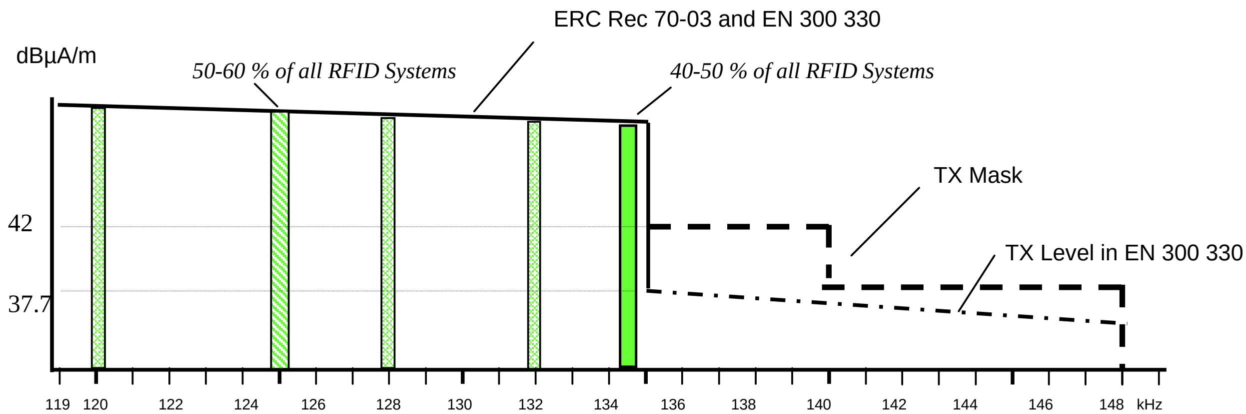

Figure 3 : Primary and Secondary Services in the LF Range Inductive SRD Applications

A number of primary stations are allocated in the frquency range 119 – 135 kHz, one is located at 125 kHz which is the RFID frequency with the highest usage and density (some 50 – 100 millions Transponders are deployed).

The amateur radio has a secondary service assignment as per the ERC Recommendation 62-01 in the frequency range 135.7 – 137.8 kHz. Two field tests were conducted to support the interference study as given in Item 5.

4.2 Primary and Secondary Services Data

Service:	**Fixed**	**Maritime Mobile**,	**Amateur Radio**	
Victim rx bandwidth	1100	200	200 / 0.5	Hz
Protected signal level	63	32	0	dBµV/m
Minimal SNR	12	12	0	dB
Permissible interference level (in rx bandwidth)	51	20	0	dBµV/m
Permissible I L in 200 Hz QP	46			dBµV/m
Atmospheric noise level in rx bandwidth		20 (80%, 200 Hz)	0 (20%, 200 Hz)	dBµV/m

Table 1 : Primary Radio Services in the Band 119 – 148 kHz and Protection data

The noise levels for the band 119 – 148.5 kHz are:

Bandwidth	2.7	1.1	0.5	0.2	kHz
Atmospheric noise level: 80 %	31	28	24	20	dBµV/m
20 %	11	8	4	0	dBµV/m
Manmade noise level: Quiet Rural	0				dBµV/m
Rural	13				dBµV/m
Business	22				dBµV/m

Table 2 : Noise Levels

5 CONSIDERATION OF ATMOSPHERIC CONDITIONS AND S/N

5.1 ITU Noise Definition in the LF range

The ITU-R has defined the atmospheric noise field strength according to Figure 4.

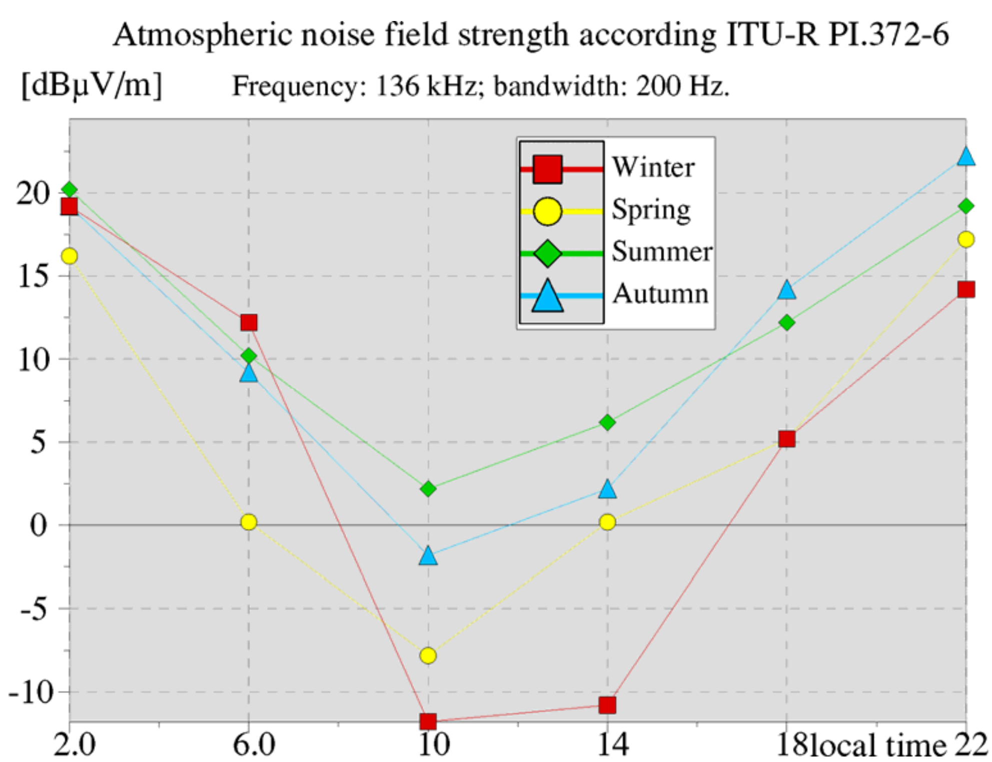

Figure 4 : Atmospheric Noise versus Time and Seasons

5.2 Actual Noise Measurements

The actual background noise level was recently monitored d during 4 full days in the week before the measurements (of June 12th, 2001). An active loop antenna (H-field), as well as the L-type wire antenna (E-field) was used. For this purpose the ESH2 measurement receiver (Rhode & Schwarz) was connected to a Tie Pie Handyscope, which was connected to a notebook PC, running a transient recorder program.
Every three seconds a sample was taken.
Receiver settings: centre frequency 136.5 kHz, 500 Hz bandwidth, average mode.

(The peak was due to a regional thunderstorm.)

The Figure 5 shows the result of this noise recording.

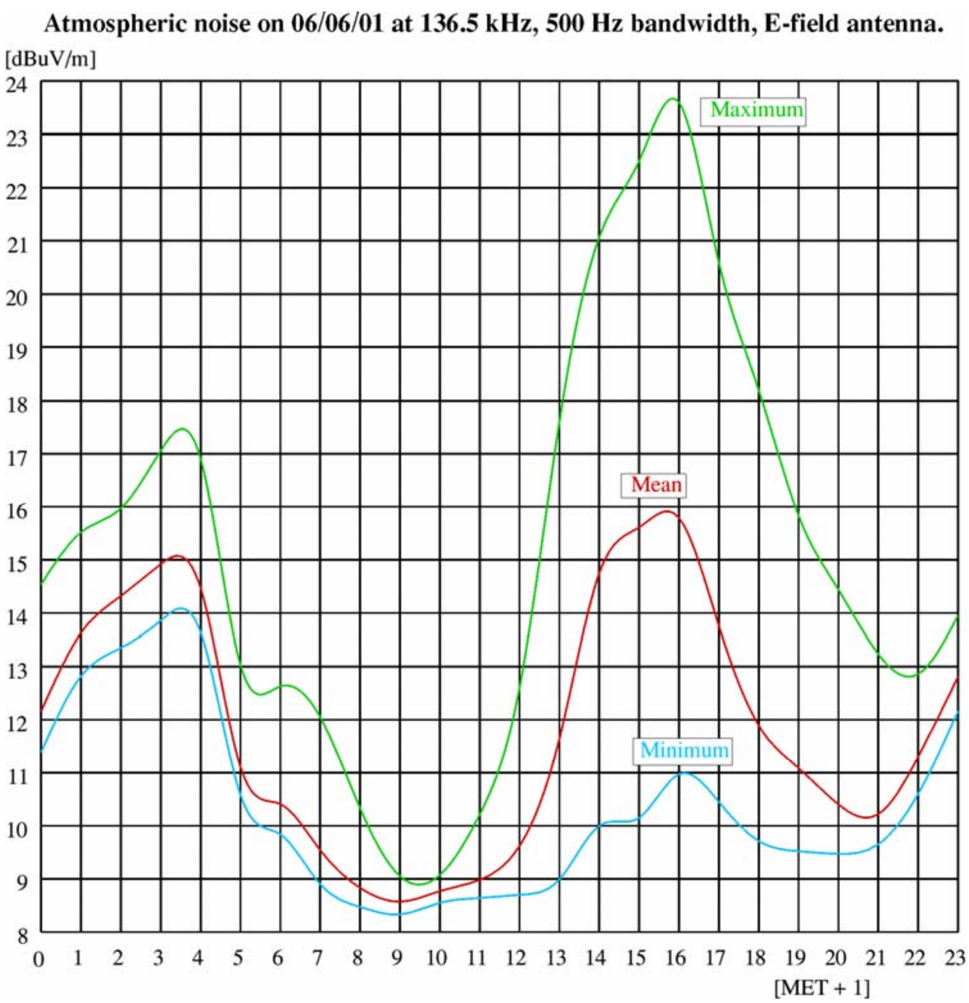

Figure 5 : Observation of Atmospheric Noise Measurement over 24 Hours on June 6th 2001

6 RISK OF INTERFERENCE TO PRIMARY AND SECONDARY SERVICES

6.1 RFID Market and installed Equipment

The RFID readers are potentially producing interference to other services while the transponders signal levels are typically operating below the spurious levels and will not contribute to any additional risk of interference.
Secondly the number of readers relative to the tags per system varies considerably but in significant and major applications the ratio of tags to reader can exceed 5.000 - 10.000 for instance in large warehouses, libraries etc.

The amount of RFID Readers can be assessed from the following data given in **Table 3**:

The total market volume of tags shipped in 1999 (per the year 2000, DATAQUEST Market study) is 200 Million units. This study covers all LF tags operating worldwide below 135 kHz.

YEAR	**2000**	**2005**	**2010**	**Units**
Total Market of LF Tags (WW)	~200	~ 300	~ 500	Mio Tags/Y
Average number of tags per reader	2000	3000	4000	
ISO 18000-2, 14223 and other industry 134.2 kHz type systems of total RFID	-	20	30	%
Deployed Reader Systems (WW)	-	20	38	k Units
Deployed Reader Systems In ERC countries	-	8	15	k Units

Table 3 : Calculation of LF RFID Readers

The risk of interference from an inductive system to a user in the primary or secondary radio service is determined by factors related to the inductive systems in a specific application, as well as related to the service.

Per application these factors are:

- Total number of the relevant installed and projected equipment
- Actual field strength,- generated by the inductive system in the specific application, relative to maximum allowed transmitter field strength
- Duty Cycle.

The data of **Table 6**, *Calculation of the risk of interference,* have been supplied by the industry and RFID work groups of organisations as ISO. Only those applications and equipment are given which use the carrier frequency of 134.2 kHz.

For equipment and application that does not generate a modulation sideband above 135 kHz, relative field strength of 0 % has been substituted.

For the Duty Cycle factor, the ON time of the carrier has been taken, multiplied by a mean modulation factor, which is 1 for the high speed mode causing the modulation sidebands of Fig. 2 and 0.3 for the low speed mode with lower modulation levels.

6.2 Interference Factors and Data for Primary and Secondary Services

For a radio service, the relevant factors are:

- Number of users and density of users related to colocation with inductive systems,
- Interference range and interference area, derived from a maximum permissable interference level, the receiver victim bandwidth and the sensitivity of that service for interference.

For the Fixed Service, the only available data is the number of receivers in one country: 10000.

For the Amateur Service the number of users of the 135.7 - 137.8 kHz band is derived from the total number of Amateur Radio stations in the CEPT countries in the year 2000: 436.243 (IARU).
At the time of writing only 15 countries have implemented ERC/REC 62-01, or have planned to. The total of Amateur Radio stations for these countries is 201.235. From current experience about 1 % of these stations is using the 135.7 - 137.8 kHz band, actively or passively. This results in a number of 2012 users.

Some amateur radio stations *(estimated to be in the order of 1%)* use very narrowband receivers of 0.5 Hz bandwidth.

Table 4, *Data on population and Amateur Radio user Density in Europe*, gives information about the population and geographical area of the CEPT countries, source: http://www.gazetteer.de/, the number of Amateur Radio stations, source: IARU, the implementation of ERC/REC 62-01 (the allocation of the 135.7 - 137.8 kHz band to the Amateur Service) and the reduction of the numbers to the 15 CEPT countries which have implemented ERC/REC 62-01, or have planned to do so (source: ERO).

	A	B	C	D	E	F	G	H	I	J	K
1	Country	Population	Area Size	Density	RA stations	RA/1000	ERC/REC 62-01?	Population	Area Size	RA stations	RA/1000
2	Albania	3608.4	28748	126	16	0.00	1	3608.4	28748	16	
3	Andorra	68.6	464	148	94	1.37	0	0	0	0	
4	Austria	8119.1	83858	97	6542	0.81	0	0	0	0	
5	Belgium	10255.6	30518	336	5444	0.53	0	0	0	0	
6	Bosnia-Hercegovina	4340	51129	85	1758	0.41	0	0	0	0	
7	Bulgaria	8240.8	110994	74	3994	0.48	1	8240.8	110994	3994	
8	Croatia	4688.1	56610	83	1837	0.39	1	4688.1	56610	1837	
9	Cyprus	804.5	9251	87	581	0.72	0	0	0	0	
10	Czech Republic	10325.1	78866	131	7147	0.69	1	10325.1	78866	7147	
11	Denmark	5392.7	43093	125	10060	1.87	0	0	0	0	
12	Estonia	1429.1	45226	32	634	0.44	1	1429.1	45226	634	
13	Finland	5194.2	338145	15	6100	1.17	1	5194.2	338145	6100	
14	France	58882.3	547030	108	19110	0.32	0	0	0	0	
15	Germany	81981.9	357021	230	82151	1.00	0	0	0	0	
16	Great Britain	59730.3	244910	244	58426	0.98	1	59730.3	244910	58426	
17	Greece	10965.7	131957	83	2959	0.27	0	0	0	0	
18	Hungary	10154.7	93030	109	8620	0.85	1	10154.7	93030	8620	
19	Iceland	284.3	102819	3	146	0.51	1	284.3	102819	146	
20	Ireland	3755.3	70273	53	1708	0.45	0	0	0	0	
21	Italy	57989.9	301323	192	30000	0.52	1	57989.9	301323	30000	
22	Latvia	2407.2	64598	37	215	0.09	0	0	0	0	
23	Liechtenstein	33.6	160	210	15	0.45	0	0	0	0	
24	Lithuania	3695.8	65300	57	871	0.24	1	3695.8	65300	871	
25	Luxembourg	440.4	2586	170	582	1.32	0	0	0	0	
26	Macedonia	2101.5	25333	83	200	0.10	0	0	0	0	
27	Malta	384.3	315	1220	473	1.23	0	0	0	0	
28	Moldova	4461.4	33700	132	217	0.05	0	0	0	0	
29	Monaco	33.1	2	16550	65	1.96	0	0	0	0	
30	Netherlands	16074.1	41526	387	14720	0.92	1	16074.1	41526	14720	
31	Norway	4463.2	323759	14	5512	1.23	1	4463.2	323759	5512	
32	Poland	38622.9	312685	124	16000	0.41	0	0	0	0	
33	Portugal	10008.8	92391	108	4212	0.42	1	10008.8	92391	4212	
34	Romania	22287.4	238391	93	3850	0.17	0	0	0	0	
35	Russian Federation	145532.5	17031900	9	38000	0.26	0	0	0	0	
36	San Marino	27.5	61	451	31	1.13	0	0	0	0	
37	Slovakia	5428.6	49034	111	1030	0.19	0	0	0	0	
38	Slovenia	1863.2	20256	92	6765	3.63	0	0	0	0	
39	Spain	40117.1	504842	79	59000	1.47	1	40117.1	504842	59000	
40	Sweden	8826.1	449965	20	11516	1.30	0	0	0	0	
41	Switzerland	7407.7	41285	179	5500	0.74	0	0	0	0	
42	Turkey	68634.8	779452	88	3000	0.04	0	0	0	0	
43	Ukraine	50222.4	603700	83	18488	0.37	0	0	0	0	
44	Vatican	0.85	0.44	1932	4	4.71	0	0	0	0	
45	Yugoslavia	10211.5	102350	100	425	0.04	0	0	0	0	
46											
47	Totals	789496.6	23508856	33.58	438018	0.55	15				
48	136 kHz only							236003.9	2428489	201235	0.85

Table 4 : Data on Population and Amateur Radio user Density in Europe

Amateur Service
Permissible interference level: 0 dBµV/m as derived from the 20 % curve in the ERC Report 069 which gives a level of 11 dBµV/m for a bandwidth of 2.7 kHz. This level is derived from ITU atmospheric noise data and gives an accumulated chance of occurrence of 20 %. This level is only achievable in wintertime.

The corresponding interference range according the measurements and using a limit of 42 dBµA/m @ 10m is 374 m and is 592 m @ 50 dBuA/m.

Some amateur radio stations *(estimated to be in the order of 1%)* use very narrowband receivers of 0.5 Hz bandwidth. Considering a narrowband interferer *(carrier only)* and a 0.5 Hz victim receiver, the anticipated field strength level would increase the interference range considerably. However when the interferer is a broadband signal, no increase in interference distance occurs.

The **Table 5** indicates the interference distance of broadband versus single carrier interference for 200 Hz and 0.5 Hz receiver bandwidth.

Bandwidth victim receiver	Broadband interferer	Single Carrier interferer	
200 Hz	374	374	m
0.5 Hz	374	5609	m

Table 5 : Interference Distances of Broadband versus Single Carrier Interferers

Fixed Service
Permissible interference level: 51 dBµV/m as derived from earlier measurements and related to the ERC Report 44.
The corresponding interference range using a limit of 42 dBuA/m@ 10 m is 62 m and is 84 m for a limit of 50 dBµA/m.

Maritime Service
Permissible interference level: 20 dBµV/m, derived from ITU atmospheric noise data.
The corresponding interference range using a limit of 42 dBµA/m @ 10m is 168 m and 228 m @ 50 dBuA/m. Number of users, N_user = 0. The receiving sites are at sea.

The summary of the interference ranges for the different services is given in **Table 6**

Service	**Permissible Interference level**	**Interference range [1)] 42 dBµA/m @ 10m**	***Interference range 50 dBµA/m @ 10 m***
Amateur 200 Hz	0 dBµV/m(200 Hz BW)	374m	*592 m*
Amateur, 0.5 Hz/NBI	-26 dBµV/m (0.5 Hz BW)	5609 m	*14090 m*
Fixed	51 dBµV/m	62 m	*84 m*
Maritime	*20 dBµV/m*	*(168 m)*	*(228 m)*

[1)] The level of 42 dBµA/m is selected

Table 6 : Summary of Interference Ranges

7 INTERFERENCE CALCULATION

The Interference range of an inductive system in a specific application and for a given service, using maximum permitted power, is R. The interfered area is $A_{int} = N_{app} * \pi * R^2$, N_{app} is number of inductive systems in that application.

The statistical number of interference cases, p_{int}, is set by the ratio of interfered area, A_{int}, and the populated area, A_{pop}, multiplied by the number of users. Assumed is that the total of the interfered area, multiplied by the number of users, is much smaller then the populated area:

$$A_{int} * N_{users} \ll A_{pop}$$

The populated area is smaller than the total geographical area, as given by **Table 5**, because of excluding scarcely populated areas as mountain sites, natural parks, etc. Neither RFID systems, nor radio users will be there.
Also to be taken into account is that even in rural areas the population is not distributed equally, but more or less is concentrated in groups of farms and family houses, leaving open space between them.

To take this into account a populated area, A_{pop}, is defined as the product of the numbers of inhabitants, N_{pop}, and a population density factor, d. Giving a basis for an estimated value of d, the average population density of a dense populated country such as The Netherlands is 387.

This leads to estimation: $d = 400.$
The number of inductive systems in a specific application, N_{app}, is derived from the total number of relevant inductive systems, N_{rfid}, multiplied by the market share of that application, ms.

Further, the effect on the number of interference cases for a specific application, p_{app}, is the duty cycle in that application, dc, and the reduction in interference area caused by the reduced field strength in that application, fr.
So:

$$N_{app} = N_{rfid} * ms$$

and:

$$p_{app} = N_{app} * dc * fr^{2/3}$$

The total number of interference cases is given by:

$$p_{int} = \Sigma p_{app}$$

So:

$$p_{\text{int}} = \sum \frac{N_{rfid}.ms.dc.fr^{\frac{2}{3}}.\pi.R^2.N_{users}}{\frac{N_{pop}}{d}}$$

For the ease of the calculation, service specific factors are put together in the service specific factor, $K_{service}$:

$$p_{int} = N_{rfid} * \Sigma(ms * dc * fr^{2/3}) * K_{service}$$

with:

$$K_{service} := \frac{\pi \cdot R^2 \cdot N_{users}}{\frac{N_{pop}}{d}}$$

From these data it is also possible to derive the probability of interference to a single station (fixed or amateur), in an average populated area (400 hab/km²), using a simplified model, valid for low probability of interference :

$$p_{\text{int}} = \sum \frac{N_{rfid}.ms.dc.fr^{\frac{2}{3}}.\pi.R^2}{\frac{N_{pop}}{400}}$$

or in a densely populated area (10000 hab/km2):

$$p_{\text{int}} = \sum \frac{N_{rfid}.ms.dc.fr^{\frac{2}{3}}.\pi.R^2}{\frac{N_{pop}}{10000}}$$

The result of the risk of interference calculations is given in **Table 7** below**.**

	A	B	C	D	E	F	G	H	I	J	K
3	Interference range@42dBµA/m (R_42)	374	62	5609							
4	Interference range@50dBµA/m (R_50)	592	84	14090							
5				REC 62-01							
6	Population CEPT (N_pop)	283741824		236003900							
7	Average density populated area (d)	400									
8	Populated area [km²] (A_pop)	709355		590010							
9	Number RA stations	436243		201235							
10	Percentage RA active on 136 kHz	1%		1%							
11	Number potential victims AR Service (N_users)	4362		2012							
12	Pi	3.1415926									
13	Number potential victims Fixed Service (N_users)	10000									
14											
15	Application	Marketshare	Relative	Duty cycle	134.2 kHz?	Fixed	Service	Amateur	Service	Am. Serv.	0.5 Hz
16			field strength			42 dBµA/m	50 dBµA/m	42 dBµA/m	50 dBµA/m	42 dBµA/m	50 dBµA/m
17	K_Service					0.0001691	0.0003125	0.0014988	0.0037552	0.3371049	2.1272385
18	Automotive, Immobilizer	25.00%	0.00%	10.00%	0.5	0	0	0	0	0	0
19	Automotive, other (Passive Intry)	2.00%	50.00%	10.00%	0.5	0.003196	0.0059057	0.0141626	0.0354848	3.1854418	20.101144
20	Animal tagging, Read Only	15.00%	0.00%	100.00%	1	0	0	0	0	0	0
21	Animal tagging, Read/Write	2.00%	50.00%	100.00%	1	0.03196	0.0590572	0.2832514	0.7096957	63.708835	201.01144
22	Other Agricult. Application	3.00%	40.00%	100.00%	1	0.0413134	0.0763409	0.3661479	0.9173959	82.353915	207.87169
23	Cargo handling	4.00%	50.00%	100.00%	0.5	0.0639199	0.1181144	0.2832514	0.7096957	63.708835	402.02288
24	Access, Personal control, ID	4.00%	100.00%	100.00%	0.5	0.1014665	0.1874949	0.4496335	1.1265718	101.13147	638.17154
25	Item Managment, General	12.00%	60.00%	50.00%	0.5	0.1082717	0.2000698	0.4797895	1.2021287	107.91416	680.97243
26	Vehicle ID, Parking access	2.00%	100.00%	100.00%	0.5	0.0507333	0.0937475	0.2248167	0.5632859	50.565736	319.08577
27	Industrial Process control	4.00%	30.00%	100.00%	0.5	0.0454713	0.0840241	0.201499	0.5048624	45.321106	285.9905
28	Logistics, general	2.00%	50.00%	80.00%	0.5	0.025568	0.0472458	0.1133005	0.2838783	25.483534	160.80915
29	Warehouse shipping, receiving	5.00%	80.00%	80.00%	0.5	0.0874412	0.1615782	0.3874824	0.9708501	87.152461	549.95957
30	Warehouse control, (Handheld reader)	6.00%	10.00%	5.00%	0.5	0.0016395	0.0030296	0.0072653	0.0182034	1.6341086	10.311742
31	Vehicle Detection, Monitoring	2.00%	80.00%	100.00%	0.5	0.0437206	0.0807891	0.1937412	0.4854251	43.57623	274.97978
32	Waste Control	7.00%	90.00%	100.00%	0.5	0.1655221	0.3058599	0.7334858	1.8377732	164.97547	1041.0474
33	Other	5.00%	20.00%	40.00%	0.5	0.0173505	0.0320612	0.0768862	0.1926411	17.293238	109.1258
34											
35	**Total of number of cases of interference**	**100%**				**0.79**	**1.46**	**3.81**	**9.56**	**858.00**	**4901.46**
36											
37	**Probability of interference (average)**					**7.876E-05**	**0.0001455**	**0.0008744**	**0.002191**	***0.426369***	***2.43569***
38											
39	**Probability of interference (dense areas)**					**0.0019689**	**0.0036383**	**0.0218612**	**0.0547739**	***10.65924***	***60.89225***
40											
41											
42											

Table 7 : Calculation of the Risk of Interference

Discussion of the effect of very narrow victim receiver bandwidths on the risk of interference

In the case of a narrowband interferer (constant carrier) the interference range increases very much, and is equal to 5.6 km for a 0.5 Hz receiver bandwidth. Consequently the calculation of the probability of interference is approaching or exceeding 1, i.e. the simple formula is no more valid. But at the same time the risk of co-channel is reduced by a factor $p_{co-channel} = B_{rx} / B_{band}$, wherein B_{rx} is the victim receiver bandwidth, and B_{band} (= 2.1 kHz) is the bandwidth of the Amateur service allocation.

So for an estimation of the interference probability to the Amateur Service this co-channel factor $p_{co-channel}$ has to be included. From **Table 7** for an interference range of 5609 m, a limit of 42 dBµA/m@10m, 20 %, wintertime, noise level) we arrive to a number of cases of 858. This number must be multiplied by $p_{co-channel}$, so we arrive at 858*0.5/2100=0.20 cases, which gives a probability of interference of 0.20/2012 = **0.01%** in average populated area and 0.25% in densely populated area. We assumed here that all users of the LF amateur band are (potential) users of these very low speed techniques.

For the cases of a broadband interferer, the distance of interference to narrow victim receiver is the same as the distance of interference to 200 Hz victim receiver bandwidth and the co-channel factor does not apply. The probability of interference will therefore be be 3.81/2012= **0.16%**.

Remark :
In the case of a victim receiver bandwidth of 200 Hz, and a narrowband interferer, a Pco-channel of 200/2100 = 0.095 also applies, causing a probability of interference of 3.81*0.095/2012= **0.018%** in average populated area (the value of p=3.81 is calculated assuming a density of d = 400 hab/km2, see **Table 7**) and 3.81*0.095/2012*10000/400= **0.45%** in a densely populated area (d = 10000 hab/km2).

8 CONCLUSION

From **Table 7** and the discussion above, a few conclusions can be drawn:

- The statistical number of expected interference cases for the CEPT area is given as 0.28 for the fixed and 3.81 for the Amateur service (for the limit of 42 dBµA/m @ 10m in 135–140 kHz and 37.7 dBµA/m @ 10m in 140–148.5 kHz). This corresponds to a probability of interference of 0.2% for Amateur Service and 0.003% for Fixed Service, includes narrowband receiver systems and is valid in the case that all RFID equipment is installed at once.

- Although the absolute values have a large uncertainty due the great number of estimations in the input numbers, the relative difference between expected interference cases for both limits is stable: 8 dB increase in limit level gives a 85 % increase in the expected number of interference cases, therefore the level of 42 dBµA/m was chosen.

- Due to the combination of duty cycle and readers operating at average field strength, resulting in a low probability of interference, the level of 42 dBµA/m @ 10 m can be justified.

9 REFERENCES

M05_12r0_SE24	System Reference Document for RFID Systems operating under ISO14223-1 11785 and 11784
ERC Report 69	Propagation Model and Interference Range Calculation. For Inductive Systems 10 kHz-30 MHz
ERC Rec 70-03	Relating to the Use of Short Range Devices
ERC Rec 62-01	Use of the Band 135.7-137.8 KHz by the Amateur Service
ISO 11785	Radio Frequency Identification of Animals, Technical concept
ISO 14223-1	Radio Frequency Identification of Animals, Advanced Transponders
EN 300 330-1	Short Range Devices, 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.
M13_39R0_SE24	Addition to the draft Report Compatibility between Inductive LF RFID Systems an Radio Communication Systems in the Frequency range 135-148.5 kHz

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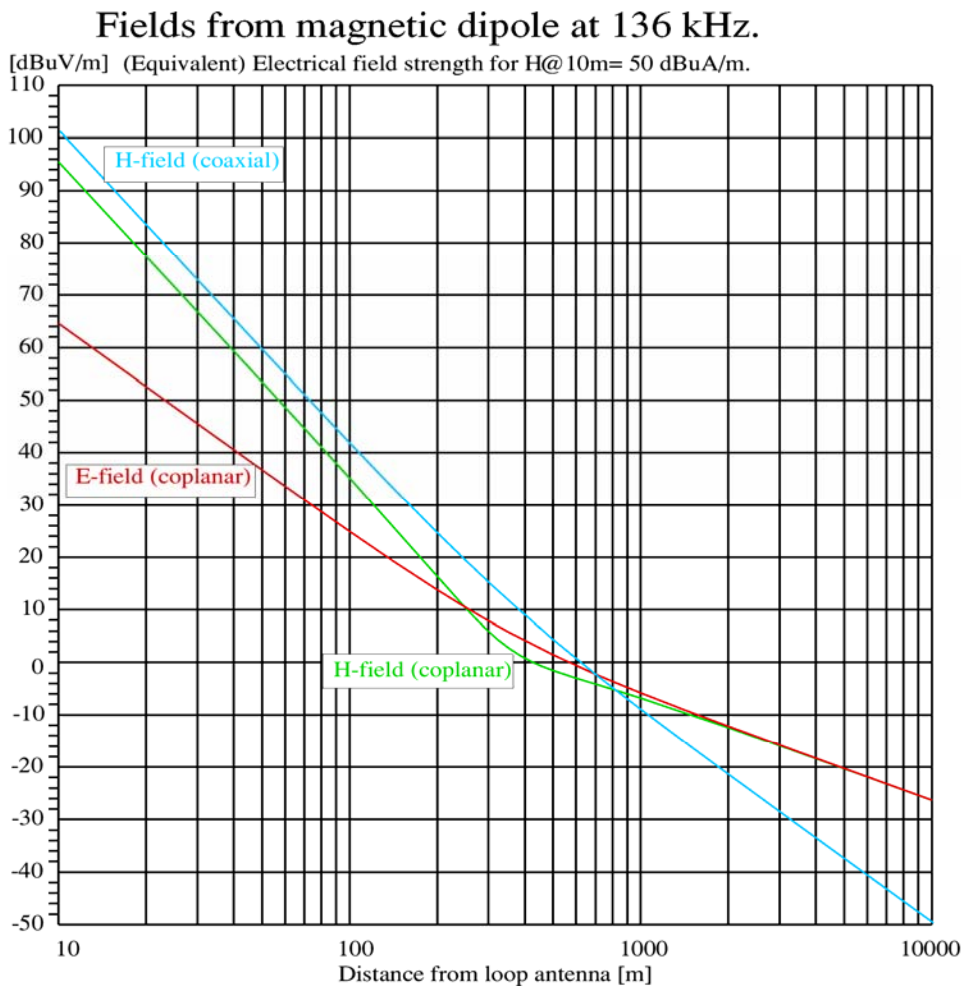
ANNEX 1


Fields from magnetic dipole at 136 kHz.
[dBuV/m] (Equivalent) Electrical field strength for H@10m= 50 dBuA/m.
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
H-field (coaxial)
E-field (coplanar)
H-field (coplanar)
10
100
1000
10000
Distance from loop antenna [m]