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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Second co-existence test between ER-GSM with RFID

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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).

1 Scope

The present document describes a series of tests that were undertaken to determine the parameters necessary to permit RFID to share the band 918 MHz to 921 MHz with ER-GSM. The tests were undertaken at the BNetzA Test Laboratory at Kolberg. The main purpose of these tests was to find answers to a number of important questions that had been raised during some earlier tests and to gather additional information.

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.

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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] ETSI EN 302 208 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Radio Frequency Identification Equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Cognitive Radio System (CRS): Radio system (optionally including multiple entities and network elements), which has the following capabilities:

- to obtain the knowledge of radio operational environment and established policies and to monitor usage patterns and users' needs;
- to dynamically, autonomously and whenever possible adjust its operational parameters and protocols according to this knowledge in order to achieve predefined objectives, e.g. minimize a loss in performance or increase spectrum efficiency;

and to learn from the results of its actions in order to further improve its performance.

Detect And Avoid: (DAA): technology used to protect radio communication services by avoiding co-channel operation

NOTE: Before transmitting, a system should sense the channel within its operative bandwidth in order to detect the possible presence of other systems. If another system is detected, the first system should avoid transmission until the detected system disappears.

DownLink (DL): direction from a hierarchic higher network element to the one below, in the case of a typical RFID system direction from the interrogator to tag or from the (E)R-GSM Base Transceive Station (BTS) to the terminal

Dynamic Frequency Allocation (DFA): protocol that allows for changing transmit frequency during operation

Dynamic Power Control (DPC): capability that enables the transmitter output power of a device to be adjusted during operation in accordance with its link budget requirements or other conditions

fixed: physically fixed, non- moving device; includes temporary event installations as well

link adaptation: result of applying all of the control mechanisms used in Radio Resource Management to optimize the performance of the radio link

Listen before Talk (LBT): spectrum access protocol requiring a cognitive radio to perform spectrum sensing before transmitting

location awareness: capability that allows a device to determine its location to a defined level of precision

master: controls the radio resource changing actions

mobile: physically moving device

Radio Environment Map (REM): integrated multi-domain database that characterises the radio environment in which a cognitive radio system finds itself

NOTE: It may contain geographical information, available radio communication services, spectral regulations and policies, and the positions and activities of co-located radios.

Service Level Agreement (SLA): defined level of service agreed between the contractor and the service provider

slave: responds to the commands from the Master

UpLink (UL): Direction from Slave to Master

white space: label indicating a part of the spectrum, which is available for a radio communication application at a given time in a given geographical area on a non-interfering/non-protected basis with regard to other services with a higher priority on a national basis

3.2 Symbols

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

α	Pathloss Exponent in the Friis Equation
dB	decibel
d	distance
f	frequency measured under normal test conditions
fc	centre frequency of carrier transmitted by interrogator
λ	wavelength

3.3 Abbreviations

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

BCCH	Broadcast Control CHannel
BP	BandPass
BTS	Base Transceive Station
C/I	Carrier to Interference ratio
CMU	Central Management Unit

DAA	Detect And Avoid
DFA	Dynamic Frequency Allocation
DL	DownLink
DPC	Dynamic Power Control
ER-GSM	Extended R-GSM system
FFT	Fast Fourier Transform
GSM	Global System for Mobile communication
IM3	third order intermodulation
LBT	Listen before Talk
POS	Point Of Sale
R&S	Rohde&Schwarz
REM	Radio Environment Map
RF	Radio Frequency
RFID	Radio Frequency IDentification
R-GSM	Railway Global System for Mobile communications
Rx	Receiver
SLA	Service Level Agreement
Tx	Transmitter
UHF	Ultra High Frequency
UL	UpLink

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5 Background Information

In summer 2009 a first feasibility test between R-GSM and RFID was carried out. The results of this test showed that it is feasible for RFID Systems to co-exist in the band 918 MHz to 921 MHz with ER-GSM (i.e. ER-GSM BS transmit band) without causing unacceptable levels of interference.

ETSI ERM set up STF 397 to develop procedures, techniques and solutions to achieve co-existence of UHF RFID devices with the victim radio service ER-GSM.

In order to achieve more information on the parameters necessary to optimise co-existence, STF 397 performed a second test where they made some more detailed measurements. The results of the measurements should be used to define suitable mitigation strategies to ensure acceptable protection of ER-GSM. Furthermore the measurements should verify the initial assumptions of STF 397 and should form a basis for the definition of suitable test parameters for a test procedure for an RFID interrogator. This document describes the test methods and results of the second co-existence test performed at Kolberg, which should help the STF to define DAA or similar techniques, test procedures and test parameters.

6 Equipment under Test

In order to perform the tests the following equipment was used:

- R-GSM:
  - 1 × R-GSM base unit (R&S CMU 200 BS);
  - 1 × R-GSM terminal (Cab Radio, Funkwerke Hörmann with Sagem® radio module MRM R2);
  - 1 × R-GSM terminal (GPH, Sagem®).

- RFID:
  - 2 × RFID interrogators from FEIG (ID-ISC.LRU3500),
  - 1 × CISC RFID Tag Emulator R1.1.

The RFID interrogator was operated in accordance with the four channel plan described in EN 302 208 (V1.2.1) [i.1]. For the purpose of the tests the frequency range of the interrogator was shifted to the existing R-GSM frequencies 918 MHz to 924 MHz (3 MHz overlap with R-GSM). In some of the tests the channel width of the transmissions from the interrogator was increased to 400 kHz.

7 Tests with R-GSM as a victim

The purpose of these tests was to determine the conditions under which RFID can cause interference to the R-GSM receiver in a mobile unit. To verify the worst interference conditions for the R-GSM receiver in this part of the test session, the R-GSM receiver was tested with the interrogator operating in different modes. In this first set of measurements the behaviour of the R-GSM receiver was tested in its various operating modes and at different simulated distances from the Base station. This was done by increasing the attenuation that can be inserted until the Rx-Qual value reported by the mobile unit changed from 1 to 2. In the second part of the test session the behaviour of the R-GSM receiver was tested with different RFID bandwidths and modulation scenarios. It should be noted that some of the RFID modulation scenarios were not typical of those found in most RFID communication systems. These unusual modulation scenarios were tested in order to determine the worst case conditions for an R-GSM receiver. Conducted measurements were also performed to obtain protection distances for the various scenarios.

7.1 Measurement setup

The equipment was configured as shown in figure 1. This measurement setup was the same as that used in the first co-existence tests between ER-GSM and RFID.

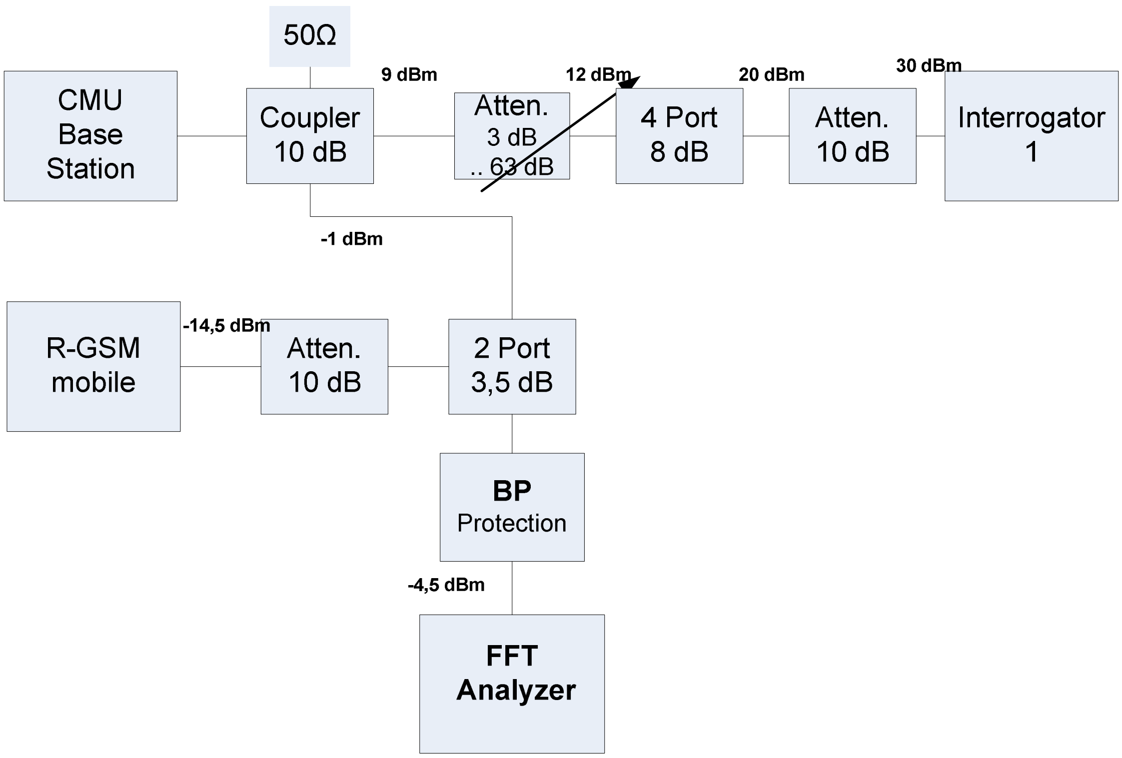


Figure 1: Setup for R-GSM as a victim

7.2 General Measurement procedure

The CMU behaved like a R-GSM Base Station transmitting the BCCH, i.e. all time slots on air with a constant Tx-level. The Tx-level of the CMU was adjusted to give different input levels at the Cab Radio. The Tx-levels were specified in the test sections below. The Rx-level of the R-GSM signal and the levels generated by the RFID interrogators were measured with a spectrum analyser. The downlink bandpass filter protected the analysers from the high uplink level of the Cab Radio.

During testing the interrogator was set to the nominal frequency of 921,4 MHz and shifted in 100 kHz steps towards 925 MHz. The output signal level from the interrogator was adjusted by its attenuator to give the specified conditions on the display of the cab receiver.

The CMU was initially set to transmit at a frequency of 921,4 MHz.

7.3 Measurement results

7.3.1 Measurement results with different Rx level at the Cab Radio

Figure 2 shows a comparison of the measurements made in 2009 and 2010. The figure shows the C/I for one RFID interrogator experienced by the Cab Radio, with the RFID Interrogator transmitting within a 400 kHz channel width. This comparison shows that the measurement setup in 2010 was the same as the setup in 2009. There were two minor differences. Firstly the slopes of the two C/I curves are not exactly the same. This may be due to the fact that the Cab Radios were not the same, so the filters in the Cab Radios may have slightly different characteristics. Secondly the frequency offset of 0 kHz was not tested in 2009. From the measurement of 2010 it can be seen that there is a 9 dB lower C/I between the point of 0 kHz offset and the point of 100 kHz offset. This means an offset of 100 kHz between the ER-GSM centre frequencies and the RFID centre frequencies improves the protection for ER-GSM terminals by 9 dB.

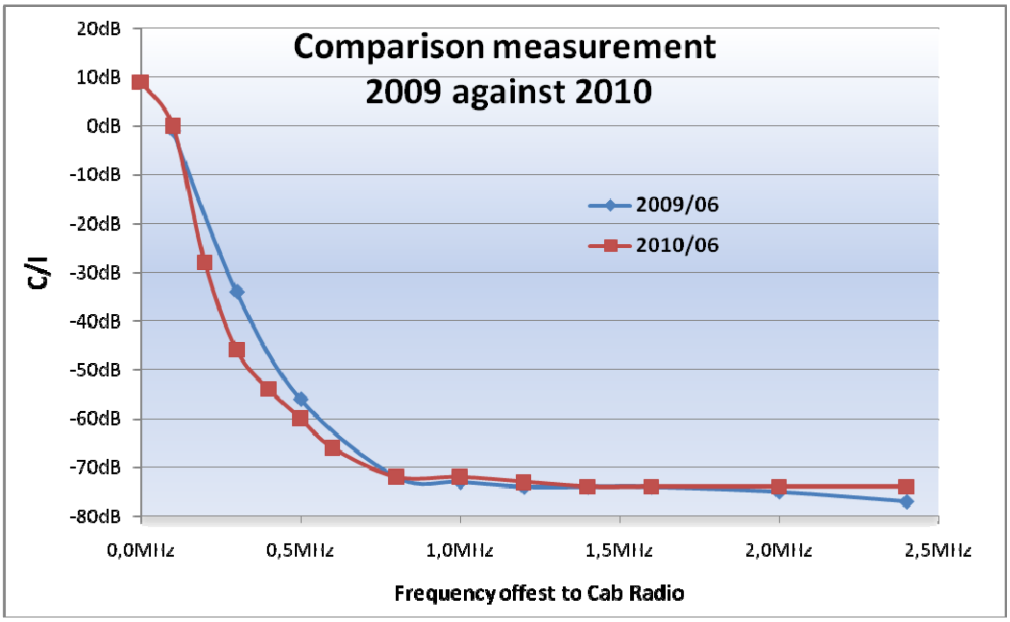


Figure 2: Comparison measurement 2009 / 2010 (R-GSM as a victim)

A further test was made to determine which of either the idle mode or active voice call needs the most protection against interference from RFID. The result of this measurement is shown in figure 3. In the frequency offset range from 0 kHz to 600 kHz, the R-GSM terminal needs about 10 dB less protection in idle mode than in an active voice call. This means that voice call is the worst case situation and therefore should be used for all further measurements of protection range. Since voice call is the worst case situation, no additional allowance in protection range is necessary for a terminal when in idle mode.

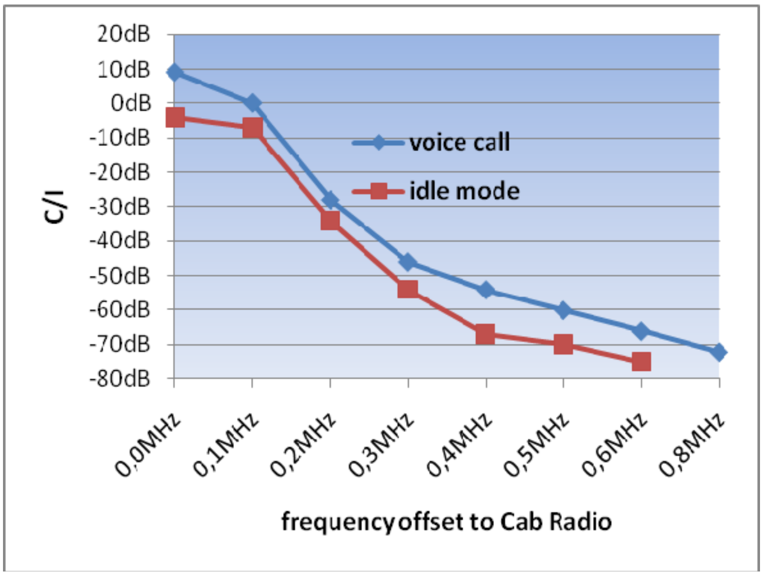


Figure 3: Comparison of protection distances for R-GSM terminal in idle mode and voice call

Figure 4 shows the absolute RF Power at the input of the Cab Radio at which its RxQual level drops to a value of 2. The three curves were measured at different R-GSM Rx power levels at the Cab Radio input. The power levels are representative of different communication scenarios of the R-GSM system and are specified below.

- Cab low power -96 dBm.
- Cell edge -86 dBm.
- Good link -76 dBm.

From the measurement it can be seen that a Cab Radio receiving a higher Rx signal from the R-GSM base station can operate with a higher interfering signal from an RFID Interrogator. This characteristic of the R-GSM terminal is true until the interfering RF power exceeds the in-band blocking level of -23 dBm. So when the interfering RF power at the receiver input of the Cab Radio exceeds about -23 dBm, it does not matter whether or not it is receiving a good R-GSM signal. The receiver of the Cab Radio is blocked.

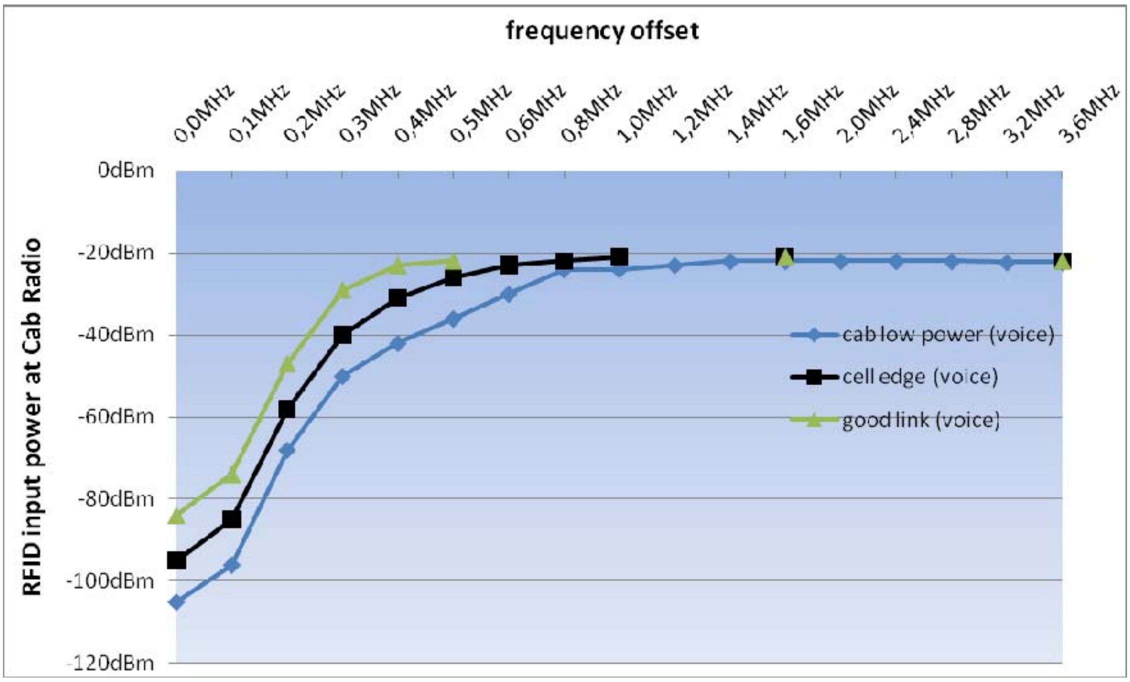


Figure 4: Protection Cab Radio in different RF link situations

Figure 5 shows a comparison of the protection ratio of R-GSM as a function of the RFID channel width. The measurement shows that it does not matter what channel width is used by the RFID system. Thus it is not possible to reduce the protection separation of 700 kHz for an RFID interrogator by reducing its channel width to 200 kHz.

The reason for this result is because the Tx Mask specified in EN 302 208 [i.1] for the interrogator requires a steeper slope than the Rx Filter in a R-GSM terminal. So the Rx Filter of the R-GSM terminal determines the protection separation.

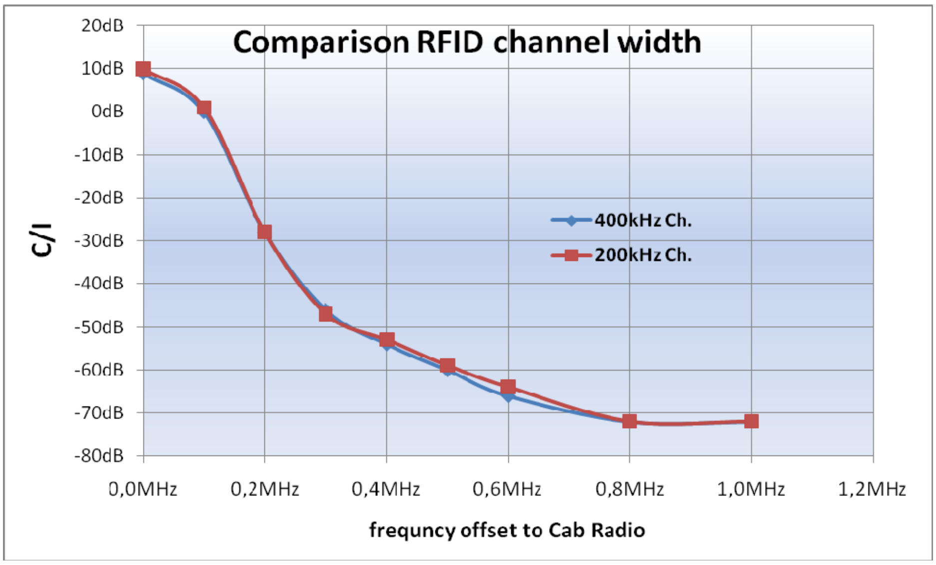


Figure 5: Comparison of R-GSM protection with different RFID channel widths

Figure 6 shows a comparison of different RFID modulation scenarios. From these measurements it can be seen that where the RFID signal is modulated, the R-GSM terminal requires a higher protection ratio. The worst case for the R-GSM terminal is the typical modulated RFID signal. This can be seen at offset frequencies between 400 kHz and 600 kHz. Within this range of offset frequencies, the R-GSM terminal needs between 6 dB to 9 dB better protection when an RFID interrogator is transmitting a modulated signal.

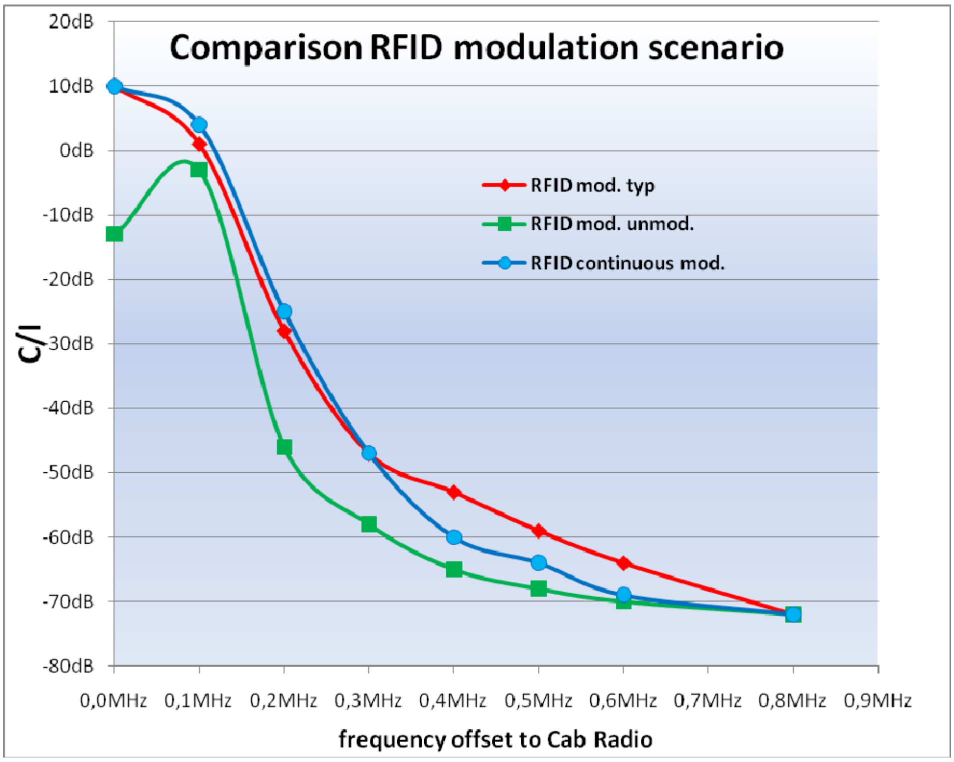


Figure 6: Comparison of R-GSM protection depending on RFID modulation scenarios

8 Tests concerning IM3 of RFID

The purpose of this test was to determine if the intermodulation observed in the co-existence test between ER-GSM and RFID in June 2009 was caused by RFID interrogators. A test was therefore undertaken to investigate which part of the system under test caused the intermodulation.

8.1 Measurement setup

The equipment was arranged as shown in figure 7. This measurement setup was very similar to the measurement setup used in the first co-existence test between ER-GSM and RFID in June 2009. The only difference to June 2009 was the use of an additional variable attenuator in front of interrogator 2.

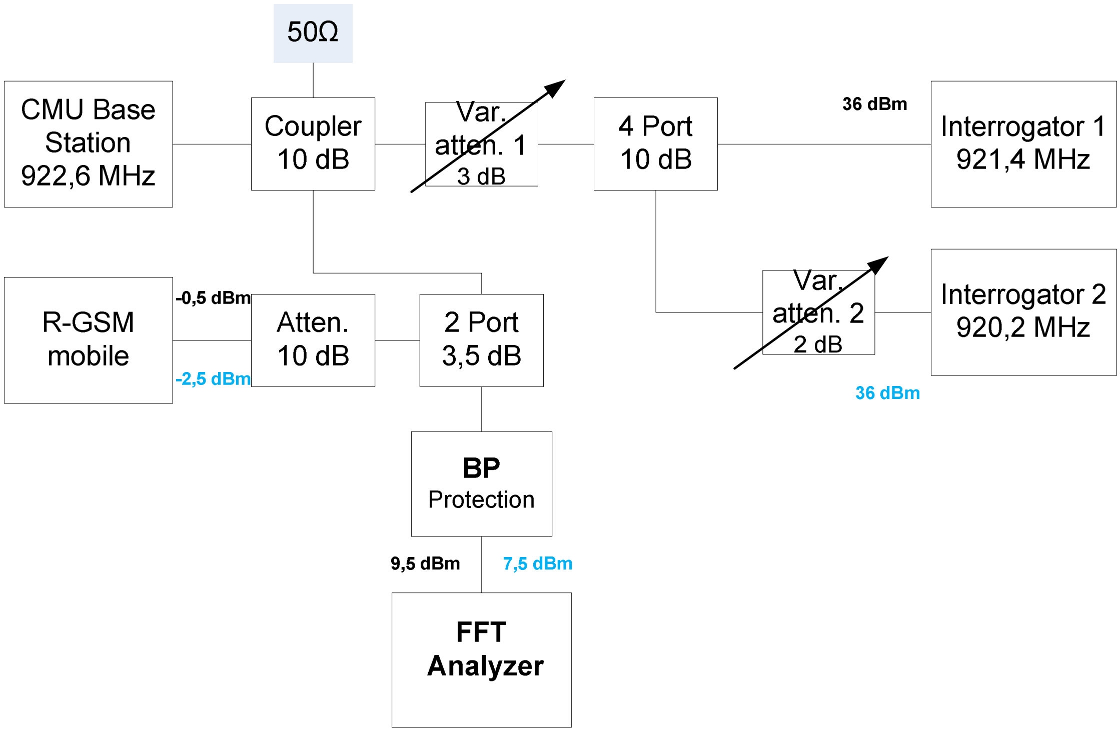


Figure 7: Setup for IM3 test

8.2 General Measurement procedure

The CMU behaves like a R-GSM Base Station transmitting the BCCH, (i.e. all time slots on air with constant Tx-level). The Tx-Level of the CMU was adjusted to -96 dBm input level at the Cab Radio. The frequency of the CMU was set to 922,6 MHz.

Interrogator 1 was set to 921,4 MHz and interrogator 2 was set to 920,2 MHz. Both interrogators occupied a Tx channel of 400 kHz. The difference between the two interrogator frequencies was 1,2 MHz. This meant that the IM3 frequency of interrogator 1 caused by interrogator 2 was 920,2 MHz and 922,6 MHz. A test was made in which the frequency of the R-GSM system was set to 922,6 MHz.

Variable attenuator 1 was used to adjust the path lost between the two interrogators and the R-GSM terminal. Variable attenuator 2 was used to adjust the path lost between interrogator 2 and interrogator 1. The variable attenuator 2 was used to set the IM3 level created by the RFID system.

In step 1 of the test, attenuator 1 was adjusted to a value at which the R-GSM system could operate a voice call without interference from interrogator 1. Interrogator 1 created a strong signal on the FFT analyser so that IM3 products from interrogator 1 could be displayed within the dynamic range of the FFT analyzer. Interrogator 2 was switched off for this adjustment. To adjust attenuator 2 Interrogator 2 was switched on and attenuator 2 was decreased from the maximum attenuation until the R-GSM system could just set up a voice call on the 922,6 MHz channel. The values of the variable attenuator settings were noted.

In step 2 the path loss between the two interrogators was increased by 20 dB by adjusting the variable attenuator 2 from its original value in step 1. After this the path loss between the RFID system and the R-GSM system was decreased in 1 dB steps until the R-GSM system could not set up the voice call. The values of the variable attenuator settings were noted.

8.3 Measurement results

The recorded attenuator settings at step 1 and step 2 can be seen in table 3. Table 3 shows in column "Step 1" the variable attenuator settings in step 1 and the calculated power levels at certain points in the measurement setup. The highlighted value is the calculated power level at the IM3 frequency of 922,6 MHz generated by interrogator 1 at the input of the Cab Radio. The calculated value -103,5 dB for IM3 in step 1 is the same as the value that can be seen in the screen shot of the FFT analyzer in annex B. So IM3 should really be the IM3 product created by interrogator 1.

In step 2 the attenuation between interrogator 1 and interrogator 2 was increased by 20 dB. That meant that the power levels of all intermodulation frequencies coming out of interrogator 1 were reduced by 20 dB. It was assumed that the attenuation between both interrogators and the R-GSM could now be reduced by 20 dB. However the test showed that by decreasing attenuator 1 by 7 dB the R-GSM system ceases to operate the voice call. This meanst that there had to be another source in the test system, which was also generating an IM3 product.

Comparing the calculated IM3 power level and the measured IM3 power level at the FFT analyser showed that the calculated power level of the IM3 product generated by interrogator 1 was about 5 dB lower than the measured IM3 level. This meant that not all of the measured power level of the IM3 was generated by interrogator 1. Furthermore the fact that the measured IM3 level decreased by 7 dB from test step 1 to test step 2 indicated that the IM3 component which interfered with the R-GSM voice call was generated from elsewhere. The source had to be to the left of attenuator 1 in figure 7 and had to originate from either the CMU or Cab Radio or FFT analyser.

It should be noted that during step 1 of the test, the path loss between interrogator 1 and interrogator 2 was lower than in practical use of an RFID system. For example the path loss between 2 adjacent dock doors in a distribution centre is always higher than 35 dB. This means that the IM3 products generated in step 1 of the test will not occur in the practical use of 4 W RFID systems. No further investigion of the source of the IM3 was carried out.

Table 1: Attenuation setup

Fixed attenuation of components in setup	Var Atten 2	4 Port	Var Atten 1	Coupler	2 Port
	2,0 dB	10,0 dB	3,0 dB	10,0 dB	3,5 dB

Table 2: Test settings

Test settings	
Interrogator output power	36 dBm
fixed attenuation: path R1 -> FFT analyser	26,5 dB
fixed attenuation: path R2 -> FFT analyser	28,5 dB
fixed path loss R1 - R2	21,0 dB
IM3 attenuation RFID Interrogator	50,0 dB

Table 3: Test results and calculated power levels

Test results and calculated power levels	Step 1	Step 2
Variable attenuation attenuator 1	**34,0 dB**	**27,0 dB**
Variable attenuation attenuator 2	**8,0 dB**	**28,0 dB**
Power R2 at R1	7,0 dBm	-13,0 dBm
IM3 out R1	-43,0 dBm	-63,0 dBm
IM3 of R1 at FFT analyzer	**-103,5 dBm**	**-116,5 dBm**
Measures IM3 in screen shot FFT analyzer	**-104,0 dBm**	**-111,0 dBm**
Power R1 at FFT analyzer	-24,5 dBm	-17,5 dBm
Power R2 at FFT analyzer	-34,5 dBm	-47,5 dBm
Power R1 at Cab Radio	-34,5 dBm	-27,5 dBm
Power R2 at Cab Radio	-44,5 dBm	-57,5 dBm

9 Test with RFID as a victim of R-GSM terminal

The purpose of this test was to determine the conditions under which GSM terminals can cause unacceptable interference to an RFID system. The results of the test should give an indication of the minimum frequency separation between the lowest RFID transmit channel and the GSM uplink band edge of 915 MHz. Instead of a GSM Cab Radio, the test used an R-GSM handheld. It was assumed that the R-GSM handheld had the same interference behaviour towards RFID as the other GSM terminals during the operation of voice calls. Since no GSM terminal test system was available, the band edge condition between GSM and RFID was emulated using an R-GSM test system. This made use of an R-GSM terminal operating on a single channel at a frequency of 921,1 MHz

The equipment was configured in accordance with figure 8.

9.1 Measurement setup

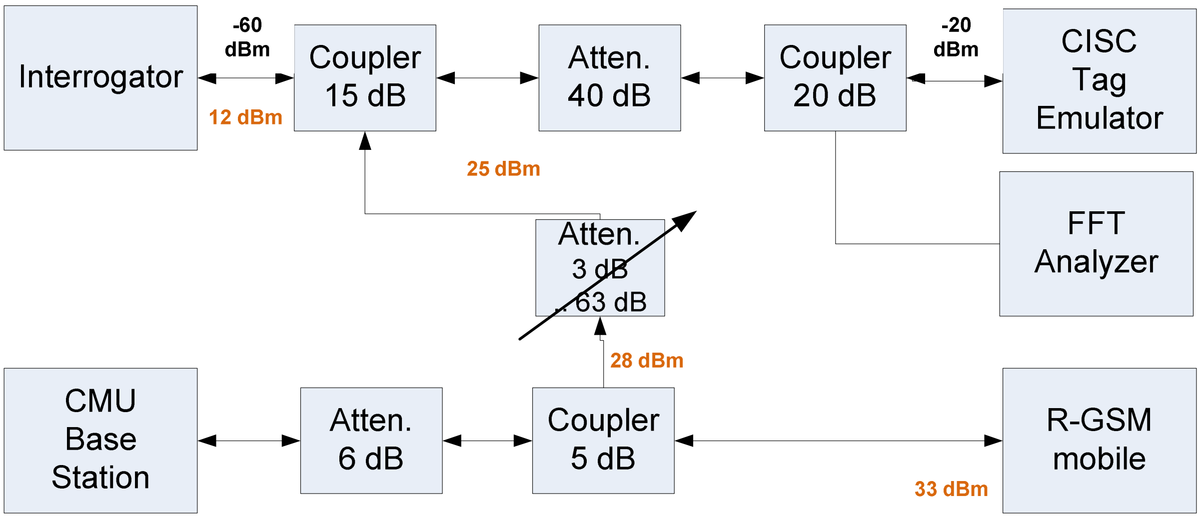


Figure 8: Setup for RFID as a victim

9.2 General Measurement procedure

The CMU behaves like a R-GSM Base Station transmitting the BCCH, i.e. all time slots on air at a constant Tx-Level. The Cab Radio transmits at a constant level of 2 W.

The Rx Level of the tag signal and the levels generated by the Cab Radio were measured with a spectrum analyser.

The CMU acting as a BTS was initially set up to transmit (normal voice call established) at a frequency of 921,1 MHz. The Cab Radio established the voice call on the corresponding uplink channel of 876,1 MHz.

For the test the interrogator was set to the nominal transmit frequency of 877,3 MHz using a 200 kHz channel bandwidth. During the test, the frequency of the interrogator was shifted in steps of 100 kHz from 877,3 MHz to 876,1 MHz.

The attenuation of the variable attenuator at which the read rate of the RFID system dropped below a specified percentage was recorded.

9.3 Measurement results

Figure 9 shows the input level at the RFID reader of the Cab Radio signal (a GSM terminal) for specified reductions in communication of the RFID system. This measurement showed that full RFID performance was achieved when the centre frequency of the terminal was separated by at least 800 kHz from the centre frequency of the RFID system. Another observation from the test was that some valid RFID protocol exchanges were possible when the frequency separation was less than 800 kHz. But the reliability of the RFID system dropped dramatically when the frequency separation was less than 800 kHz. This was because the probability of setting up a valid RFID command between two successive GSM bursts is very low. Even to operate the RFID system at a performance level of 50 %, the protection distance in space is about 3 dB lower than at 100 % performance. Measurement of the level which degrades RFID communication by 100 % shows that it is possible to set up valid RFID communication between two bursts of the R-GSM System, but the probability of achieving this is very low. The screen shot in annex C shows the operation of the R-GSM system during a voice call. The gaps between the R-GSM burst can be seen in this screen shot.

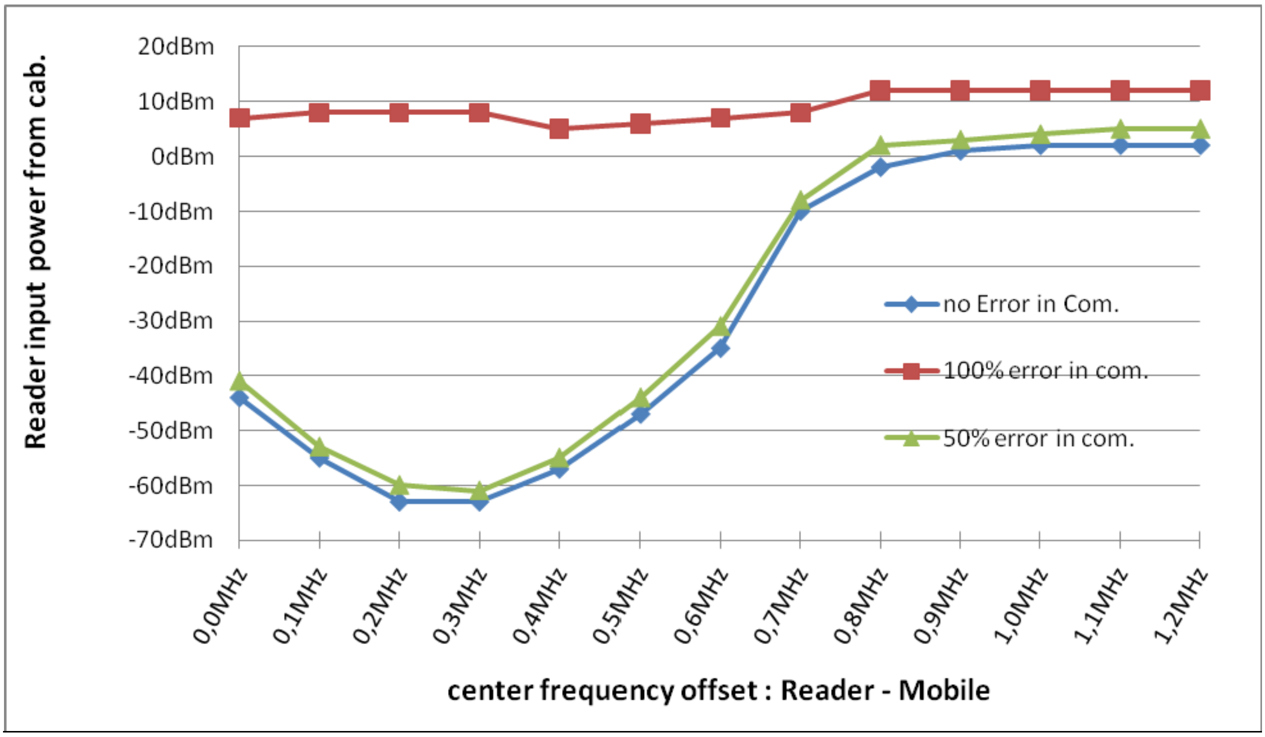


Figure 9: RFID as victim, centre frequency offset versus R-GSM interference input power at RFID reader input

10 Measurements with an RFID near-field antenna

10.1 Measurement setup

The near-field antenna measurements were performed in an anechoic chamber in the Kolberg Lab. The general setup is depicted in figure 10. The deployed equipment is listed in table 4.

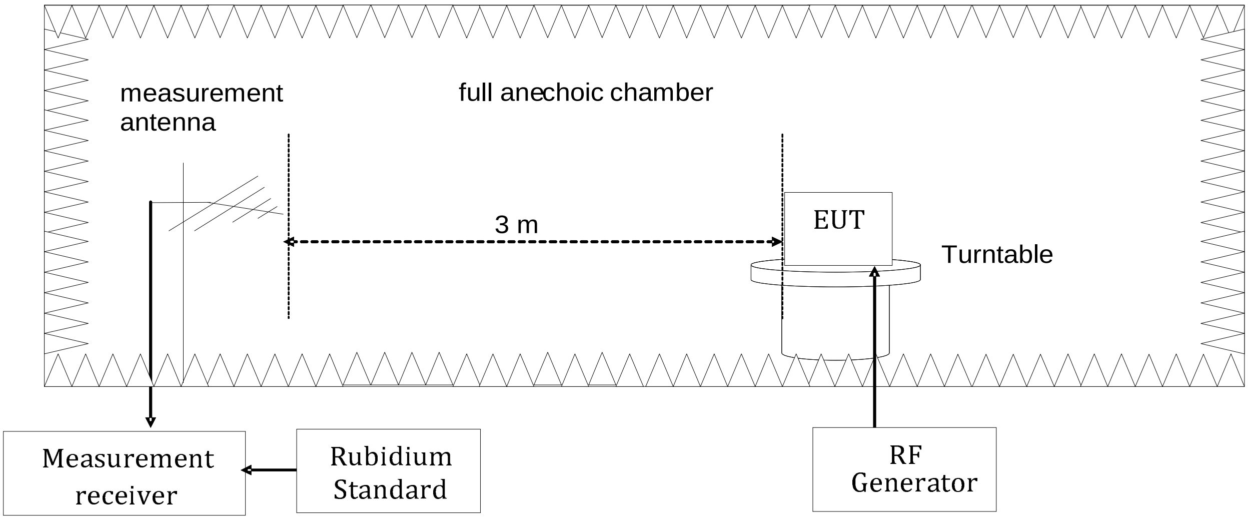


Figure 10: Setup for the measurement of antenna gain

Table 4: Near-field antenna measurements, used equipment

Ident-Nr.	Equipment	Manufacturer	Typ
11009400	EMI Test-Receiver	Rohde & Schwarz	ESU26
6042776	Relais Matrix	Rohde & Schwarz	RSU
16008510	Measurement Antenna	Schwarzbeck	VULB9160
11005470	Positioning-Controller	Inn-co	CO 2000
11005471	Turntable	Inn-co	DS 1200 HA
6042763	Antenna mast	Heinrich Deisel	AS620 P / TILT
6042767	HF Generator	Hewlett Packard	HP 83640 A
16008512	Telescope stand	Inn-co	RHC
11005584	10 MHz Standard	VAD GmbH	Rubidium/ GPS Ref
	Software EMC 32	Rohde & Schwarz	V.8.40

10.2 Measurement results

Figure 11 shows the results for the measurement of the antenna. The antenna was measured for both the vertical and the horizontal field component. Three different frequencies were used for the evaluation.

It can be seen that for both polarizations the highest gain was measured at a frequency of 915 MHz. The maximum gain in the vertical polarization is down by -12 dB to -15 dB while for horizontal polarization the range is down by -18 dB to -20 dB.

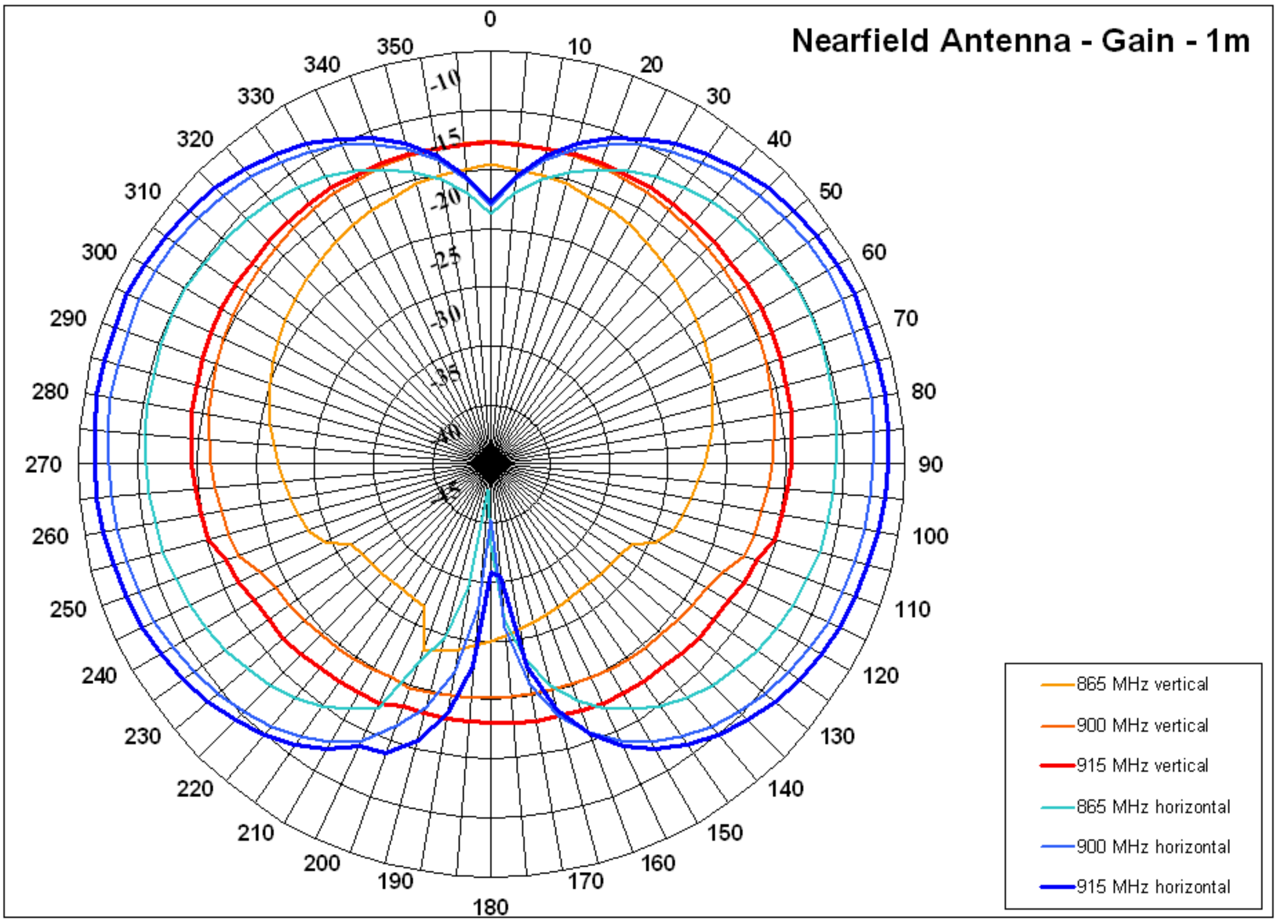


Figure 11: Antenna gain diagram for a near-field antenna for a POS application in the band 865 MHz to 915 MHz

11 Observations and conclusions

The second co-existence test between ER-GSM and RFID was performed under the same measurement conditions as the first. Thus the measurements can be compared directly and the results of the first co-existence test were confirmed by the second test.

These tests confirmed that the 700 kHz frequency offset between the centre of the R-GSM channel and the RFID channel, which had been measured in June 2009. This means that if an interrogator detects an ER-GSM channel with a power above a certain limit, the interrogator should use a channel with a centre frequency which is at least 700 kHz away from the detected ER-GSM channel. For RFID channel planning this means that the highest RFID channel can be positioned 700 kHz below the lowest existing R-GSM channel of 921,2 MHz. This equates to a centre frequency for the RFID system of 920,5 MHz.

The 700 kHz frequency offset was not affected by the RFID channel width or modulation scenarios. This means that an RFID Interrogator cannot influence the 700 kHz protection in frequency. A more stringent RFID spectrum mask will not improve the 700 kHz spacing of the channels, because the 700 kHz spacing is dependent on the filter width and filter steepness of the R-GSM receivers.

The test confirmed that RFID interrogators which maintain a 700 kHz frequency offset from an operational R-GSM cannot cause interference to it provided the RFID interrogator is more than 20 m away from the R-GSM terminal.

The second test in June 2010 showed that it is useful to implement a 100 kHz offset between the ER-GSM channels and the RFID channels because this adds an additional mitigation factor of around 9 dB independent of the deployed RFID channel bandwidth (200 kHz and 400 kHz). This result is important for the further discussion related to the channelization.

The measured protection levels in the tests in which R-GSM was the victim represents worst-case scenarios. R-GSM terminals in idle mode or in better RF link situations require lower protection levels. This should be considered in further discussion of the protection level for the different ER-GSM protection models.

In the second co-existence test it was possible to again generate IM3 products. One test shows that the interrogator did not generate IM3 products, which interfere with the R-GSM system. This means a stringent IM3 test in the relevant RFID standards will not improve the level of mitigation for the co-existence of R-GSM and RFID.

Assuming that the current GSM band below 915 MHz uses 200 kHz channels (centre frequency at 914,8 MHz) and based on the presented measurement results, RFID transmit channels can be placed at a minimum frequency separation between the GSM centre frequency and the RFID systems centre frequency of 800 kHz. This means that the first RFID channel could be placed at 915,6 MHz.

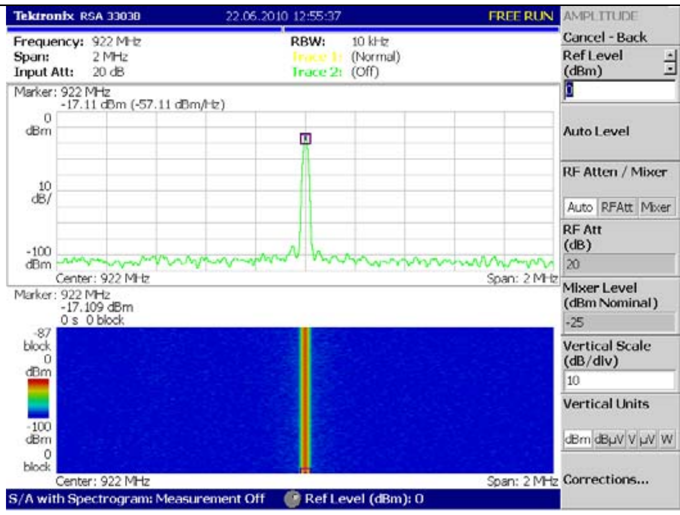
The future channel plan for RFID systems in the proposed band 915 MHz to 921 MHz should take into account the presented measurement results and considerations.

Based on the results presented in figure 11, the maximum gain of a specific near field antenna for use in POS (Point Of Sale) applications and packaging stations is down by -12 dB to -20 dB when operated within the frequency range around 915 MHz. This fact can be used as an additional mitigation factor for these kinds of applications.

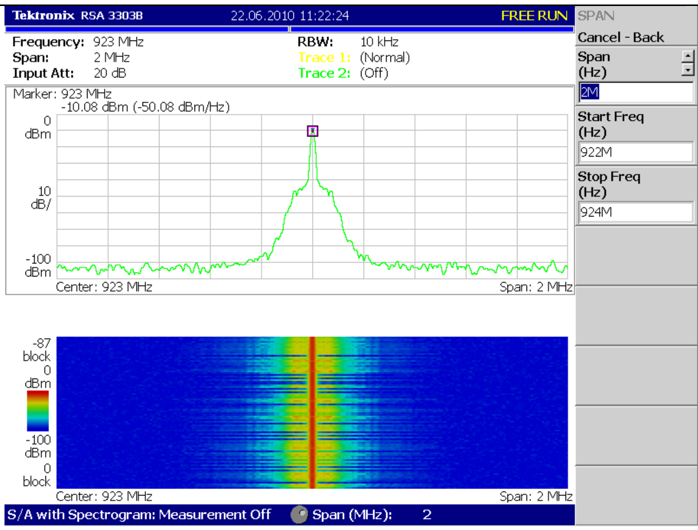
Annex A: Measurement values for R-GSM as a victim

Cab Level		-96 dBm	-96 dBm	-86 dBm	-76 dBm	-96 dBm	-96 dBm	-86 dBm	-76 dBm	-96 dBm	-96 dBm	-86 dBm	-76 dBm
		cab low power (voice)	cab low power (idle)	cell edge (voice)	good link (voice)	cab low power (voice)	cab low power (idle)	cell edge (voice)	good link (voice)	cab low power (voice)	cab low power (idle)	cell edge (voice)	good link (voice)
Cab mode		voice call	idle mode	voice call	voice call	voice call	idle mode	voice call	voice call	voice call	idle mode	voice call	voice call
RFID Interrogator freq.	**Offset**	**Attenuation**				**RFID Power at Cab Radio**				**C/I**			
921,4 MHz	0,0 MHz	90 dB	77 dB	80 dB	69 dB	-105 dBm	-92 dBm	-95 dBm	-84 dBm	9 dB	-4 dB	9 dB	8 dB
921,5 MHz	0,1 MHz	81 dB	74 dB	70 dB	59 dB	-96 dBm	-89 dBm	-85 dBm	-74 dBm	0 dB	-7 dB	-1 dB	-2 dB
921,6 MHz	0,2 MHz	53 dB	47 dB	43 dB	32 dB	-68 dBm	-62 dBm	-58 dBm	-47 dBm	-28 dB	-34 dB	-28 dB	-29 dB
921,7 MHz	0,3 MHz	35 dB	27 dB	25 dB	14 dB	-50 dBm	-42 dBm	-40 dBm	-29 dBm	-46 dB	-54 dB	-46 dB	-47 dB
921,8 MHz	0,4 MHz	27 dB	14 dB	16 dB	8 dB	-42 dBm	-29 dBm	-31 dBm	-23 dBm	-54 dB	-67 dB	-55 dB	-53 dB
921,9 MHz	0,5 MHz	21 dB	11 dB	11 dB	7 dB	-36 dBm	-26 dBm	-26 dBm	-22 dBm	-60 dB	-70 dB	-60 dB	-54 dB
922,0 MHz	0,6 MHz	15 dB	6 dB	8 dB		-30 dBm	-21 dBm	-23 dBm		-66 dB	-75 dB	-63 dB	
922,2 MHz	0,8 MHz	9 dB		7 dB		-24 dBm		-22 dBm		-72 dB		-64 dB	
922,4 MHz	1,0 MHz	9 dB		6 dB		-24 dBm		-21 dBm		-72 dB		-65 dB	
922,6 MHz	1,2 MHz	8 dB				-23 dBm				-73 dB			
922,8 MHz	1,4 MHz	7 dB				-22 dBm				-74 dB			
923,0 MHz	1,6 MHz	7 dB	6 dB	6 dB	6 dB	-22 dBm	-21 dBm	-21 dBm	-21 dBm	-74 dB	-75 dB	-65 dB	-55 dB
923,4 MHz	2,0 MHz	7 dB				-22 dBm				-74 dB			
923,8 MHz	2,4 MHz	7 dB				-22 dBm				-74 dB			
924,2 MHz	2,8 MHz	7 dB				-22 dBm				-74 dB			
924,6 MHz	3,2 MHz	7 dB				-22 dBm				-74 dB			
925,0 MHz	3,6 MHz	7 dB		7 dB	7 dB	-22 dBm		-22 dBm	-22 dBm	-74 dB		-64 dB	-54 dB

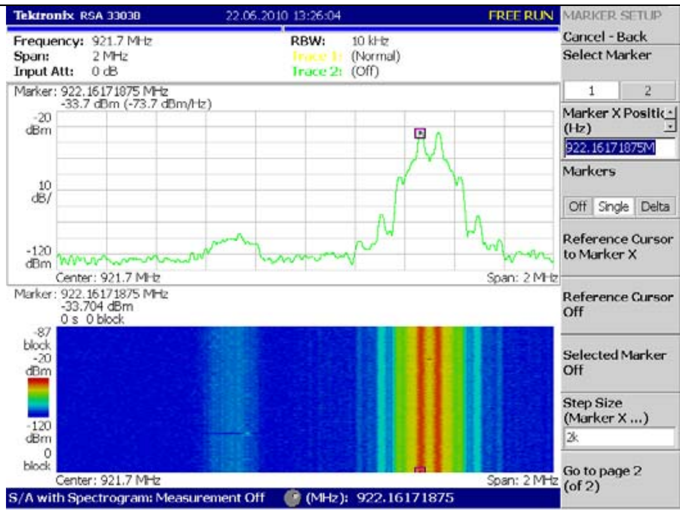
RFID modulation scenario ”unmodulated” (Powering Tag)



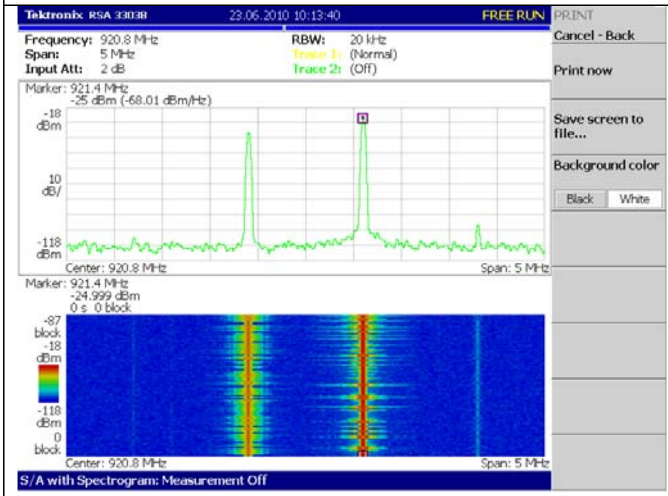
RFID modulation scenario ”typical”



RFID modulation scenario ”continuous modulation” with Cab Radio 800 kHz offset



Annex B: Screen shot of power levels of IM3 test

<table>
<tr><td>Screen shots of Step 1
TOP screen shot: R-GSM OFF
BOTTOM screen shot: R-GSM ON</td><td>Screen shots of Step 2
TOP screen shot: R-GSM OFF
BOTTOM screen shot: R-GSM ON</td></tr>
<tr><td>


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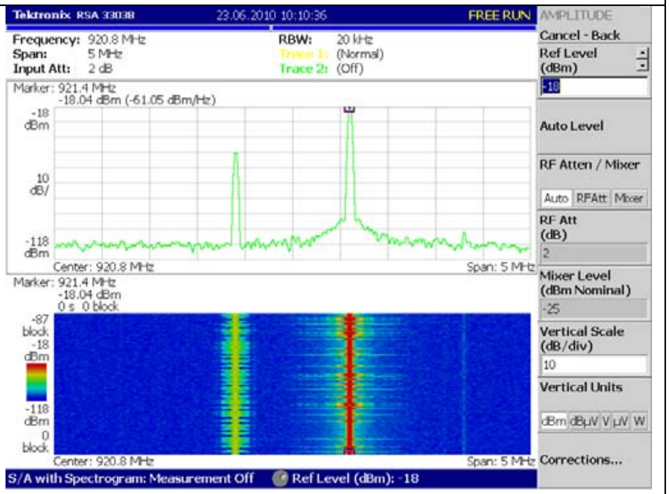

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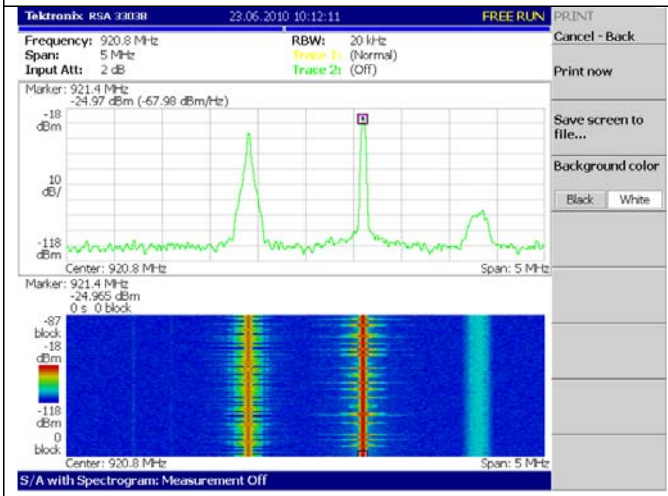

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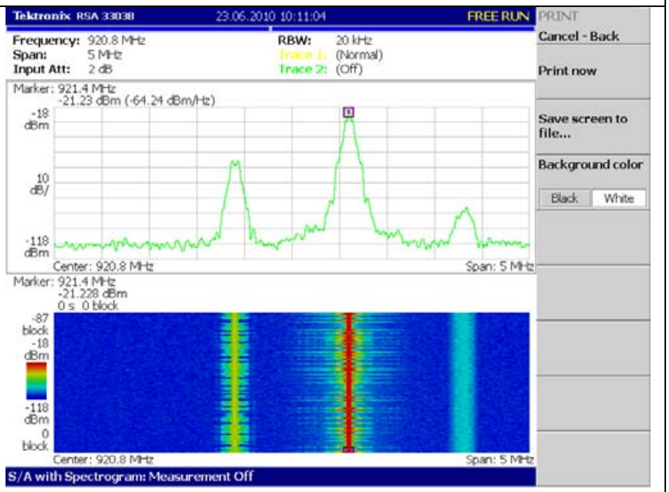
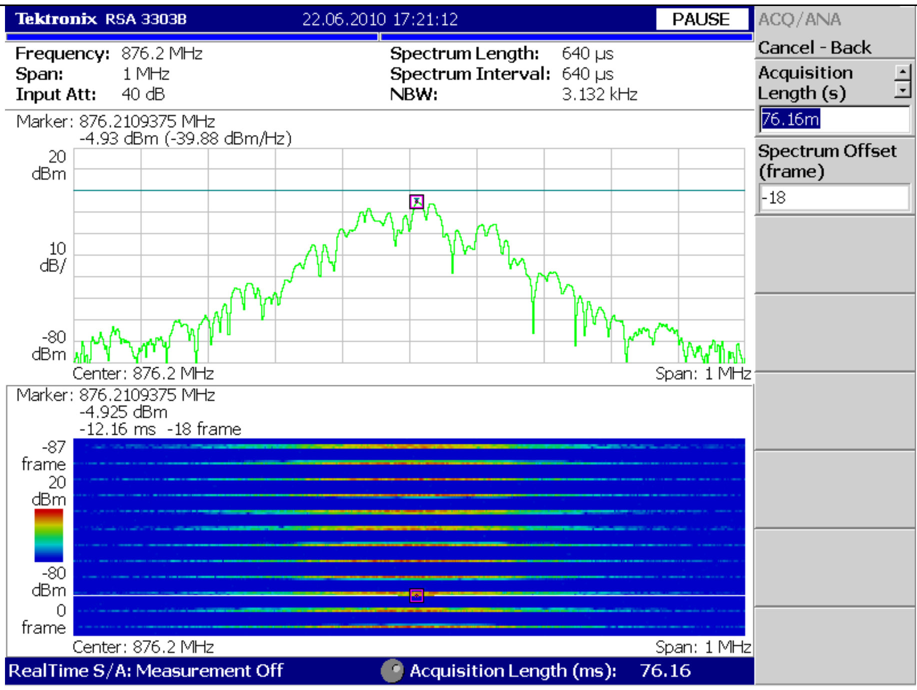


</td></tr>
</table>

Annex C: Measurements values for RFID as a victim

Measurement conditions							
CMU freq.	921,2 MHz			max. input power Interrogator from cab.			12 dB
Cab Radio f.	876,2 MHz			Attenuation path: terminal -> Interrogator			21 dB
Interrogator power	4 W	Cab power	2 W				
Interrogator freq.	Offset		Attenuation		Input power terminal at Interrogator		
		no Error in Com.	100 % error in com.	50 % error in com.	no Error in Com.	100 % error in com.	50 % error in com.
877,4 MHz	1,2 MHz	10 dB	0 dB	7 dB	2 dBm	12 dBm	5 dBm
877,3 MHz	1,1 MHz	10 dB	0 dB	7 dB	2 dBm	12 dBm	5 dBm
877,2 MHz	1,0 MHz	10 dB	0 dB	8 dB	2 dBm	12 dBm	4 dBm
877,1 MHz	0,9 MHz	11 dB	0 dB	9 dB	1 dBm	12 dBm	3 dBm
877,0 MHz	0,8 MHz	14 dB	0 dB	10 dB	-2 dBm	12 dBm	2 dBm
876,9 MHz	0,7 MHz	22 dB	4 dB	20 dB	-10 dBm	8 dBm	-8 dBm
876,8 MHz	0,6 MHz	47 dB	5 dB	43 dB	-35 dBm	7 dBm	-31 dBm
876,7 MHz	0,5 MHz	59 dB	6 dB	56 dB	-47 dBm	6 dBm	-44 dBm
876,6 MHz	0,4 MHz	69 dB	7 dB	67 dB	-57 dBm	5 dBm	-55 dBm
876,5 MHz	0,3 MHz	75 dB	4 dB	73 dB	-63 dBm	8 dBm	-61 dBm
876,4 MHz	0,2 MHz	75 dB	4 dB	72 dB	-63 dBm	8 dBm	-60 dBm
876,3 MHz	0,1 MHz	67 dB	4 dB	65 dB	-55 dBm	8 dBm	-53 dBm
876,2 MHz	0,0 MHz	56 dB	5 dB	53 dB	-44 dBm	7 dBm	-41 dBm

Cab Radio spectrum and Cab Radio burst



Annex D:
Picture gallery

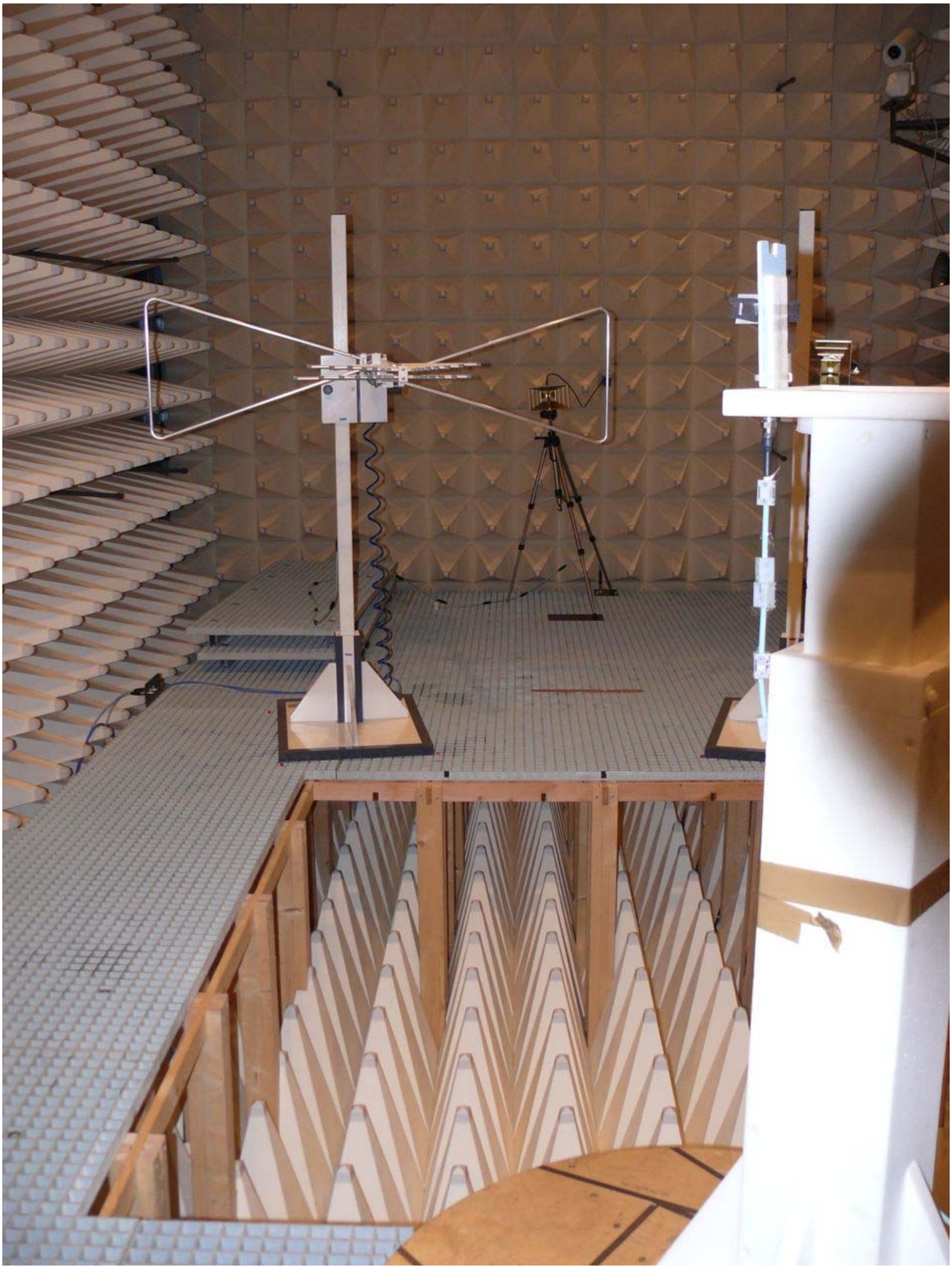


Figure D.1: Anechoic Chamber with Antenna measurement setup

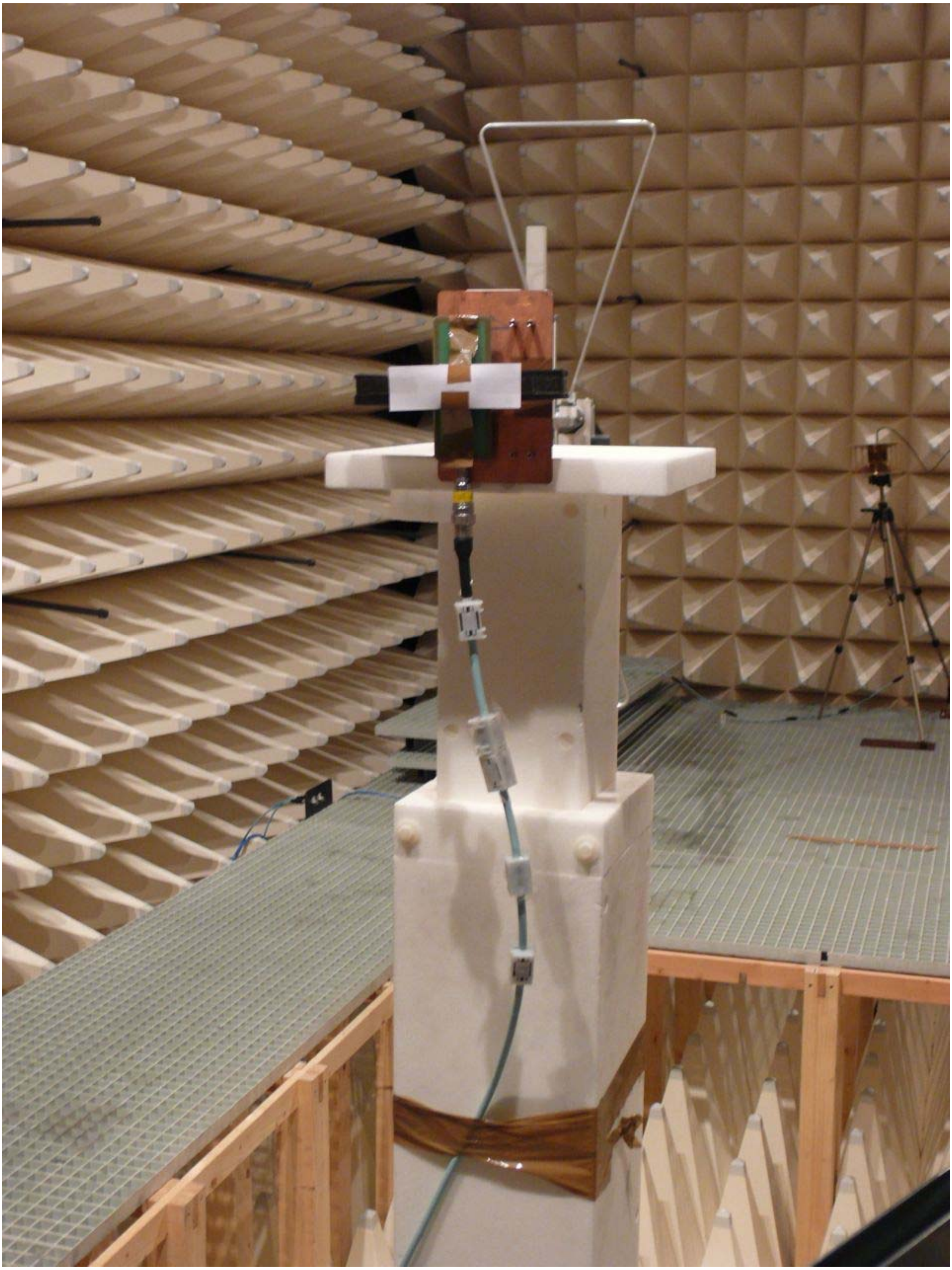


Figure D.2: Detailed picture of the near-field antenna positioning

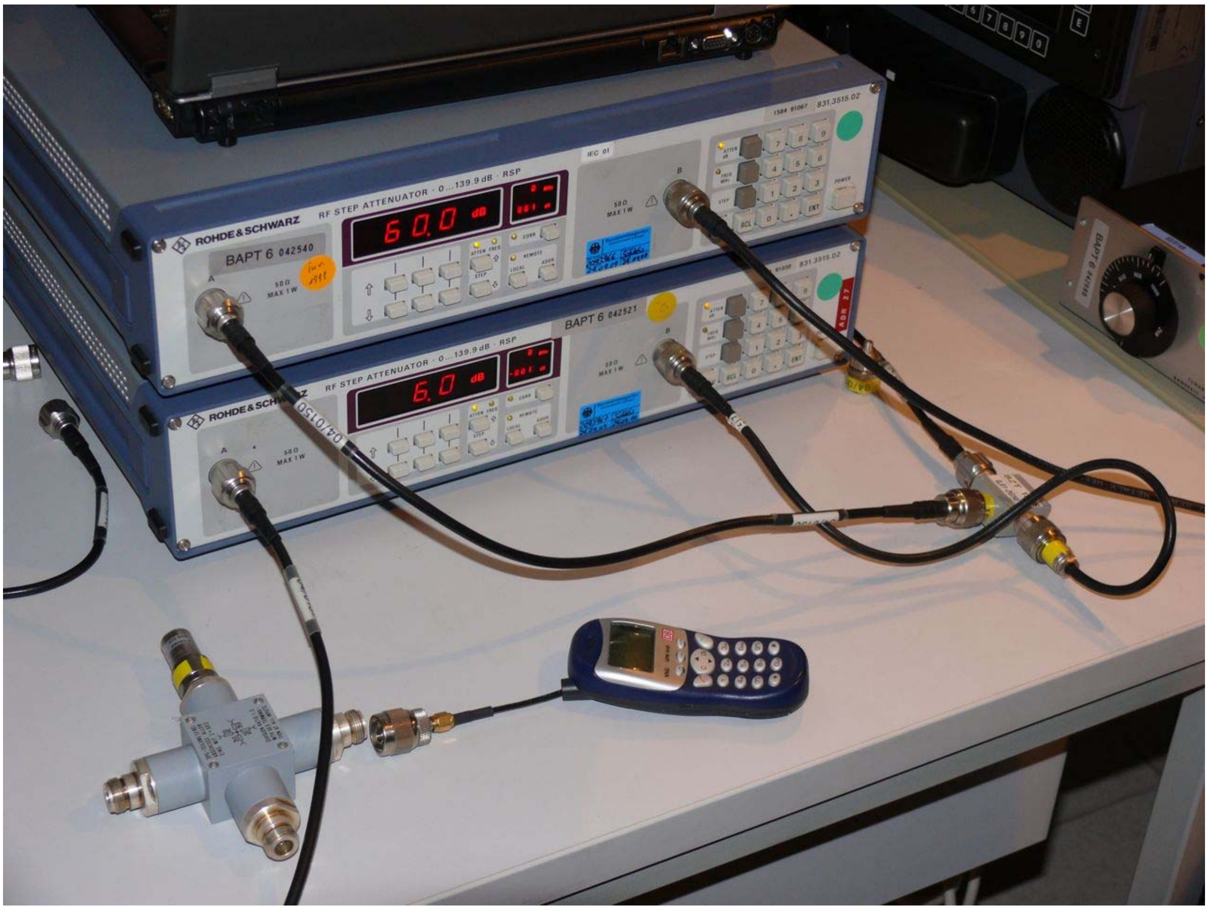


Figure D.3: Setup Attenuators and Cab Radio

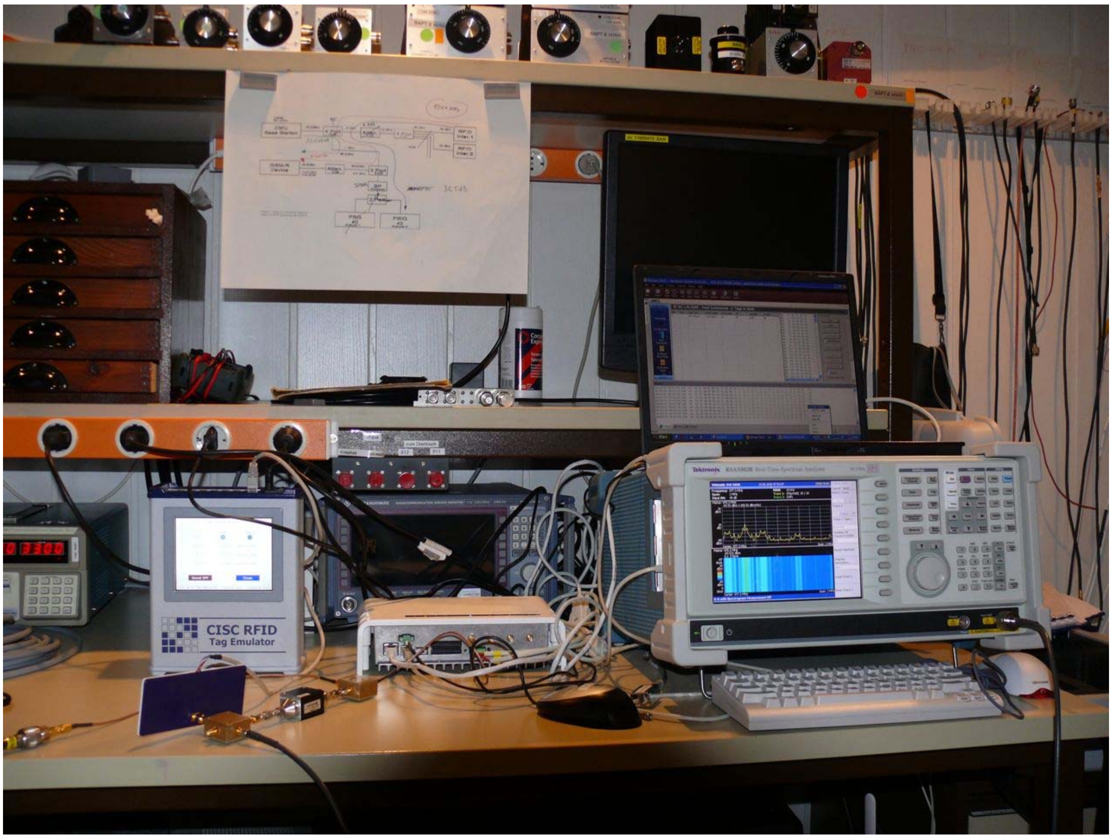


Figure D.4: Measurement setup with Tag Emulator system

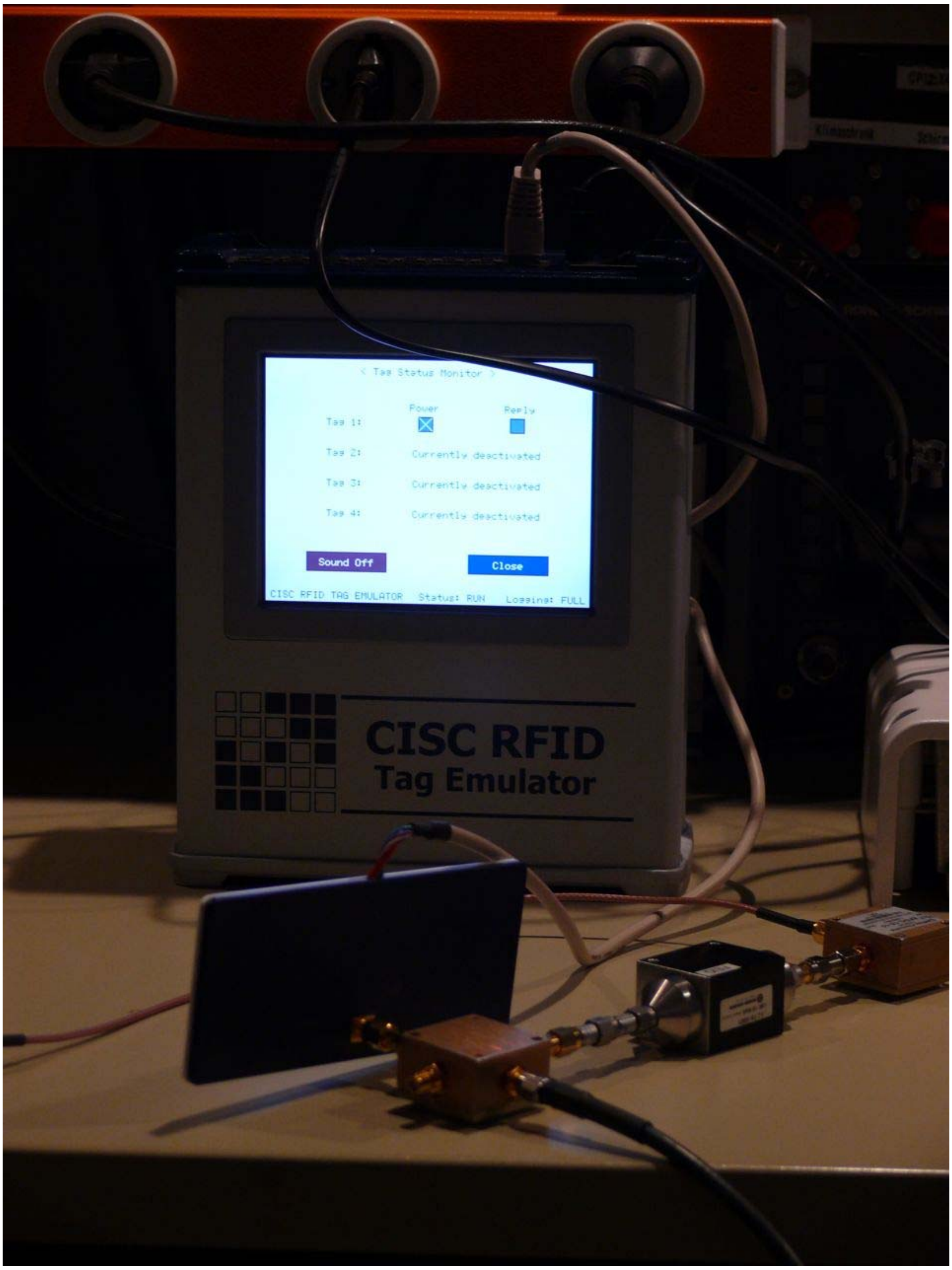


Figure D.5: Tag Emulator

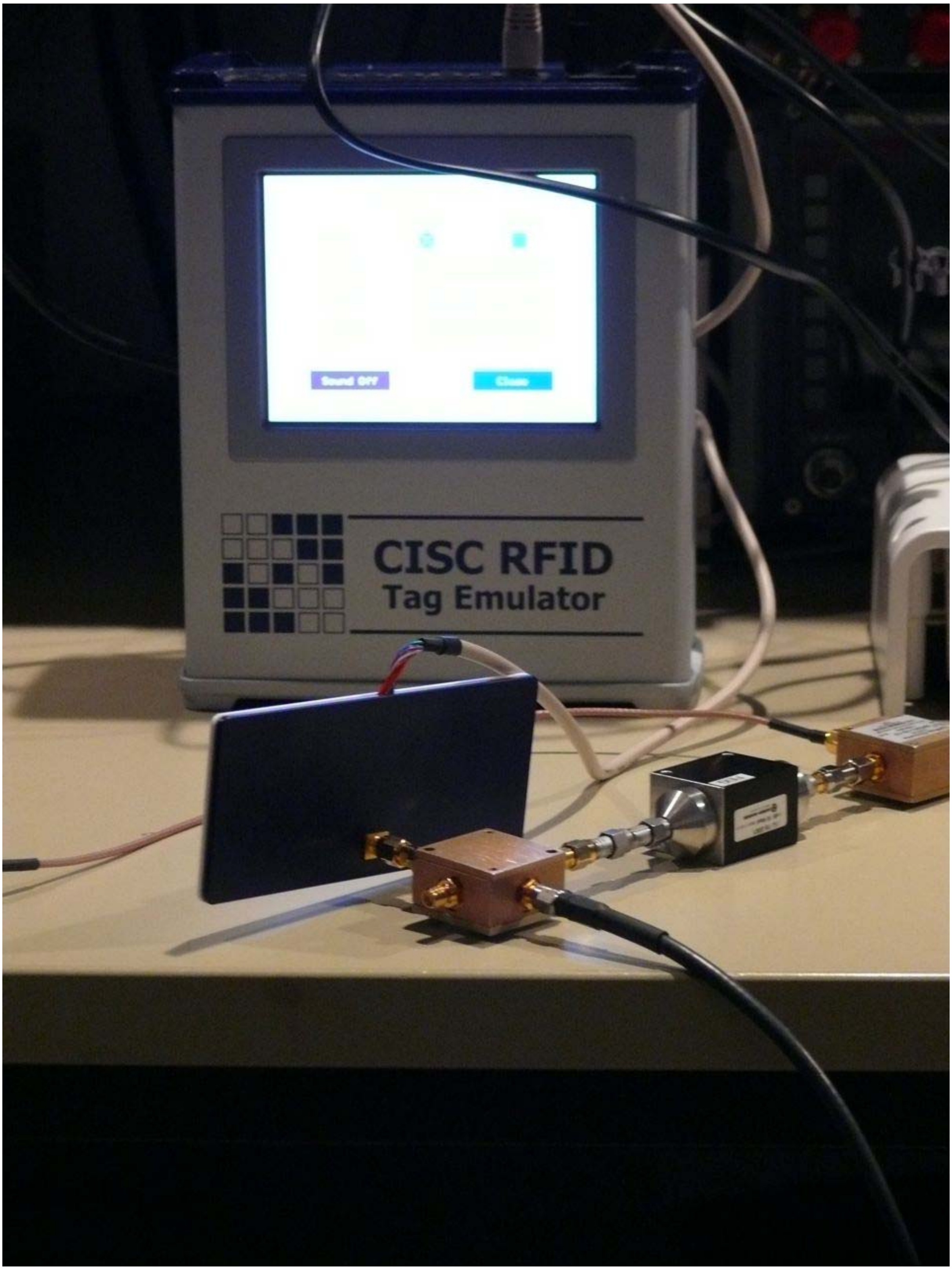


Figure D.6: Tag Emulator

Annex E: Bibliography

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- ERC Recommendation 70-03 (Tromso 1997 and subsequent amendments) relating to the use of Short Range Devices.

History

Document history		
V1.1.1	February 2011	Publication