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Technical Specification

Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical Specification on Preliminary Tests and Trial to verify mitigation techniques used by RFID systems for sharing spectrum between RFID and ER-GSM

Reference
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Foreword

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

Introduction

In order to accommodate the spectrum needs for the increasing number of RFID devices and systems, an extension band has been requested for high power RFID systems in the range between 915 MHz and 921 MHz. This band is already used by RFID in several countries worldwide and its designation in Europe would increase its functionality and simplify the international movement of goods using RFID identification systems. In Europe, part of this new frequency band will be shared between the primary user GSM-R and RFID. In order to guarantee an interference-free coexistence between the two systems, mechanisms should be implemented by RFID systems to reduce the probability of interference to GSM-R to a minimum. These techniques can be either regulatory, or technical mechanisms or of an operational nature.

The present document includes the results of the conformance test, preliminary tests, field trials specification and tests results of UHF RFID systems using the cognitive mitigation techniques and procedures defined in [i.1] and [i.2].

1 Scope

The present document describes the test plan and the results of a series of tests and measurements that were performed to verify the effectiveness of cognitive mitigation techniques applied to UHF RFID systems sharing the band 918 MHz to 921 MHz with GSM-R.

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 referenced document (including any amendments) applies.

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2.1 Normative references

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

[1] ETSI EN 302 208 (V1.4.1): "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".

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 TS 102 902 (V1.2.1): "Electromagnetic compatibility and radio spectrum matters (ERM); Methods, parameters and test procedures for cognitive interference mitigation towards ER-GSM for use by UHF RFID using Detect-And-Avoid (DAA) or other similar techniques".

[i.2] ETSI TS 102 903 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Compliance tests for cognitive interference mitigation for use by UHF RFID using Detect-And-Avoid (DAA) or other similar techniques".

[i.3] ETSI ERM TG34: ERM-TG34#23-03, Measurement Report, Feasibility Tests between E-GSM-R and UHF RFID at Kolberg, Germany, 25th to 26th June 2009.

[i.4] ETSI TR 102 649-2 (V1.3.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Technical characteristics of Short Range Devices (SRD) and RFID in the UHF Band; System Reference Document for Radio Frequency Identification (RFID) and SRD equipment; Part 2: Additional spectrum requirements for UHF RFID, non-specific SRDs and specific SRDs".

[i.5] ISO/IEC 18000-63:2013: "Information technology -- Radio frequency identification for item management -- Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C".

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:

- obtains knowledge of the radio operational environment and established policies and monitors usage patterns and users' needs;
- adjusts dynamically and autonomously 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
- learns from the results of its actions in order to further improve its performance.

demonstrator: interrogator extended with means to detect (E)R-GSM band use by railways under the scope of the present document

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

NOTE: Before transmitting, a system senses the channel within its operational bandwidth in order to detect the possible presence of other systems. If the channel is occupied, the system avoids transmission until the channel becomes available.

Downlink (DL): direction of communication from master to slave, where in the case of a typical RFID system the direction flows from the interrogator to tag

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

ER-GSM: extended Railways GSM 900 band from 873 to 880 MHz / from 918 to 925 MHz (includes R-GSM band)

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

GSM-R: standard based GSM system for use by Railways in the designated R-GSM/ER-GSM band

interrogator: fixed or mobile data capture and identification device using a radio frequency electromagnetic field to stimulate and effect a modulated data response from a transponder or group of transponders in its vicinity

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 (a device that controls the actions of other dependent devices)

mobile: physically moving device

radio environment map: 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.

R-GSM: Railways GSM 900 band from 876 to 880 MHz / from 921 to 925 MHz

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

slave: performs the commands transmitted by its Master

Tari: length of a binary zero for interrogator to tag communication in ISO/IEC 18000-63 [i.5]

Uplink (UL): direction of communication from Slave to Master

white space: 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 national priority

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
Ω	Resistance
Δf	frequency offset

3.3 Abbreviations

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

ARFCN	Absolute Radio Frequency Channel Number
BCCH	Broadcast Control Channel
BLF	Backscatter Link Frequency
BTS	Base Transceiver Station
CEPT	Conférence Européenne des Postes et des Télécommunications
DAA	Detect And Avoid
DB	Deutsche Bahn
DL	Downlink
EPC	Electronic Product Code
ER-GSM	Extended Railways GSM
GSM	Global System for Mobile communications
GSM-R	Global System for Mobile communication for Railways applications
ICE	Inter-City-Express
M	Miller subcarrier index
RBW	Resolution BandWidth
RF	Radio Frequency
RFID	Radio Frequency Identification
R-GSM	Railways Global System for Mobile communications
STF	Special Task Force
TCH	Traffic Channel
TDMA	Time Division Multiple Access
TX	Transmitter
UHF	Ultra High Frequency
UII	Unique Item Identifier
UL	Uplink
USB	Universal Serial Bus

4 Background Information

4.1 DAA process

The flow diagram at figure 1 shows the decision tree for determining whether a channel is available in the ER-GSM band for use by RFID.

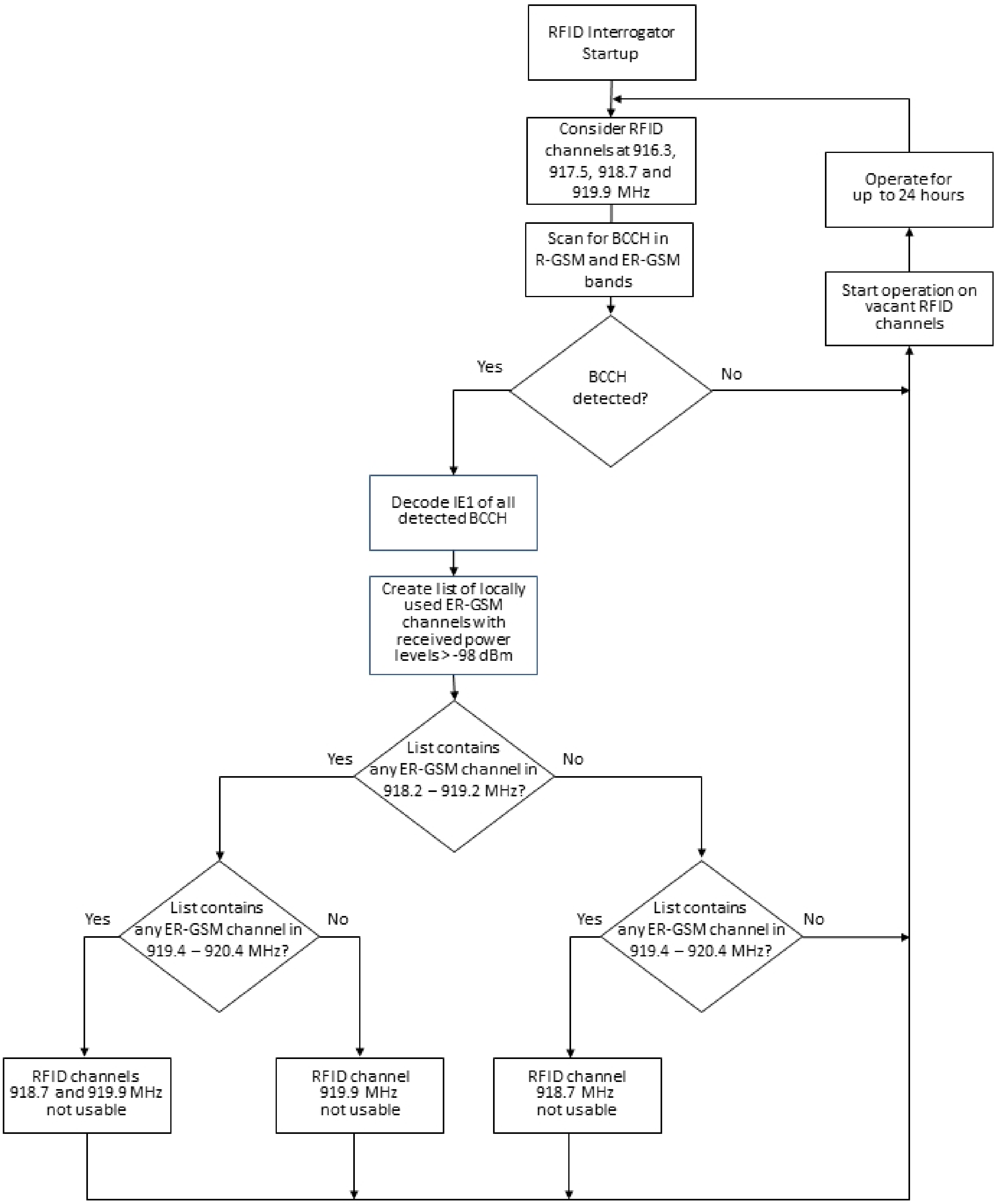


Figure 1: GSM-R DL detection for ER-GSM band and RFID DAA process

4.2 GSM-R

GSM-R is an application based on GSM technology used by the railways. In Europe, GSM-R uses the 876 MHz to 880 MHz band (uplink) and the 921 MHz to 925 MHz band (downlink). In addition, the frequency ranges 873 MHz to 876 MHz (uplink) and 918 MHz to 921 MHz (downlink) may be used by CEPT member states as extension bands for GSM-R. The extension bands are called ER-GSM. In Germany these extension bands are already licensed to Deutsche Bahn AG.

GSM carrier spacing is 200 kHz. Each GSM carrier has 8 logical channels, which means that 8 different communication links are simultaneously possible.

GSM-R is a TDMA system, with frame periods of 4,612 ms for each physical channel. Each TDMA frame consists of 8 logical channels (time slots). One or more of these slots are used for BCCH transmissions.

For GSM-R the first carrier includes one or two time slots for BCCH. Deutsche Bahn for instance always uses two timeslots, which means that the remaining 6 channels are for TCH. Any additional GSM-R carriers provide additional 8 timeslots which can be used for communication while the mobile terminals are listening to the BCCH transmitted on the first carrier.

5 Test Equipment

5.1 RFID equipment

5.1.1 Hardware

The RFID test equipment should comprise two demonstrators (modified interrogators) with RFID antennas and the means to detect (E)R-GSM transmissions. Each interrogator should at least support ISO/IEC 18000-63 [i.5].

Approximately 50 UHF RFID tags should be provided for communication with each demonstrator, which means a total of 100 tags. Each tag should at least support ISO/IEC 18000-63 [i.5] with a 96 bit UII / EPC.

5.1.2 Software

The Check time for Railways Operation t_{CRO} is the interval at which an interrogator automatically checks which ER-GSM channels have been allocated. For equipment in the field this time shall not exceed 24 hours. For the tests t_{CRO} shall be no more than 60 seconds to allow completion of the tests within a reasonable time.

5.2 GSM-R equipment

GSM-R equipment is used for both the R-GSM and ER-GSM band.

In order to perform the tests the following hardware configurations should be made available by the test lab.

A base transceiver station (BTS) configured to generate two GSM-R carriers:

- first carrier with BCCH
- second carrier with only TCH

The first and second carrier transmit power shall be variable to generate a received power at the demonstrator from -47 dBm down to -104 dBm.

In order to ensure that all TCH in the first carrier are occupied, they need to be blocked by either voice or data communication. All additional traffic need to be handled on a separate TCH on the second carrier, which will provide 8 timeslots for voice and data communication.

In order to ensure traffic on the TCH of the second GSM-R carrier, up to 8 GSM-R terminals are required.

6 Specification for conformance tests

Within this clause the term "interrogator" is used instead of "demonstrator" in order to fit to the terminology used in EN 302 208 [1]. The term demonstrator, however, is used in the ToR of ETSI STF 397.

These tests have been taken from [1] and have been modified according to [i.4].

6.1 Radiated power (e.r.p.)

This measurement applies to equipment with an integral antenna and to equipment supplied with an external antenna. Both radiated and conducted methods of measurement are permitted. Where the conducted method is used the conducted power shall be adjusted to take into account the gain of the antenna and be stated as e.r.p.

If the equipment is designed to operate with different carrier powers, the provider shall declare the rated power for each level or range of levels.

6.1.1 Definition

The effective radiated power is the product of the power supplied to the antenna and its gain relative to a half wave dipole in the direction of maximum gain in the absence of modulation.

6.1.2 Method of measurement

These measurements shall be performed with an un-modulated carrier at the highest power level at which the transmitter is intended to operate.

For both methods of measurement the measuring receiver shall be set up in accordance with the requirements of [1], clause 6.6.

6.1.2.1 Radiated measurement

This measurement shall be carried out under normal test conditions only (see [1], clause 5.3).

Step 1: On a test site, selected from [1], annex A, the interrogator shall be placed at the specified height on a support, as specified in [1], annex A, and in the position closest to normal use as declared by the provider.

Step 2: A test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the carrier frequency of the interrogator. The output of the test antenna shall be connected to a measuring receiver.

Step 3: The interrogator shall be set to transmit continuously, without modulation, on one of the high power channels. The measuring receiver shall be positioned in the far field as defined in [1], annex A and tuned to the frequency of the transmission under test.

Step 4: The test antenna shall be raised and lowered through the specified heights until the maximum signal level is detected by the measuring receiver.

Step 5: The interrogator shall then be rotated through 360º in the horizontal plane, until the maximum signal level is detected by the measuring receiver.

Step 6: The test antenna shall be raised and lowered again through the specified heights until the maximum signal level is detected by the measuring receiver. The maximum signal level detected by the measuring receiver shall be noted.

Step 7: The antenna of the interrogator shall be rotated in the horizontal plane in both directions to positions where the signal at the measuring receiver is reduced by 3 dB. The total angle of rotation (which is the horizontal beamwidth of the antenna) shall be recorded.

Step 8: The interrogator shall be replaced by a substitution antenna as defined in [1], clause A.1.5. The substitution antenna shall be connected to a calibrated signal generator. The substitution antenna shall be orientated for vertical polarization and the length of the substitution antenna shall be adjusted to correspond to the frequency of transmission of the interrogator. If necessary, the setting of the input attenuator of the measuring receiver shall be adjusted in order to increase the sensitivity of the measuring receiver.

Step 9: The test antenna shall be raised and lowered through the specified heights to ensure that the maximum signal is received.

Step 10: The input signal to the substitution antenna shall be adjusted to give a level at the measuring receiver that is equal to the radiated power previously measured from the interrogator, corrected for any change to the setting of the input attenuator to the measuring receiver.

Step 11: The input level to the substitution antenna shall be recorded as power level, corrected for any change of input attenuator setting of the measuring receiver.

Step 12: The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

Step 13: The measure of the effective radiated power is the larger of the two levels recorded at the input to the substitution antenna, corrected if necessary for the gain of the substitution antenna.

Step 14: With the interrogator fitted into a suitable test fixture, the relative change of the effective radiated power between normal and extreme test conditions (see clauses 5.4.1 and 5.4.2 applied simultaneously) shall be compared. Any increase in the radiated power under extreme test conditions shall not cause the level to exceed the limit specified in clause 6.1.3.

6.1.2.2 Conducted measurement

Where an interrogator is fitted with an external antenna connector it is permissible to measure the conducted power. In this case the provider shall declare the maximum gain and beamwidth(s) of the external antenna(s) at the time that the equipment is presented for test.

Step 1: The transmitter shall be configured to operate on one of the high power channels shown in figure 2 and shall be connected to an artificial antenna (see [1], clause 6.2). The carrier or mean power delivered to this artificial antenna shall be measured under normal test conditions (see [1], clause 5.3).

Step 2: The measurement shall be repeated under extreme test conditions (see [1], clauses 5.4.1 and 5.4.2 applied simultaneously).

Step 3: The recorded value shall be corrected for each of the antenna gains and be stated in e.r.p. To calculate the allowed conducted power with a circularly polarized antenna, the following formula shall be used:

$$P_C = P_{erp} - G_{IC} + 5{,}15 + C_L \text{ dBm}$$

Where:

P_C = interrogator conducted transmit power in dBm;

G_{IC} = antenna gain of a circular antenna in dBic;

C_L = total cable loss in dB.

Step 4: Where the interrogator switches between multiple transmitter outputs, the power level shall be measured at each output.

6.1.3 Limits

The effective radiated power on each of the four high power channels specified in figure 2 shall not exceed 36 dBm e.r.p.

6.2 Transmitter spectrum mask

6.2.1 Definition

The transmitter spectrum mask defines the limits within the range fc ± 1 MHz for the average power of all modulated signals including all side bands associated with the carrier.

6.2.2 Method of measurement

The RF output of the equipment shall be connected to a spectrum analyser via a 50 Ω connector. In the case of equipment with an integral antenna, the equipment shall be placed in the test fixture (see [1], clause 6.3) and the test fixture shall be connected to the spectrum analyser. Measurements shall be made on the declared channels of operation of the interrogator on those channels requiring full tests.

Step 1: The interrogator shall be operated at the carrier power measured under normal test conditions in clause 6.1. The attenuator shall be adjusted to give an appropriate display on the spectrum analyser screen.

Step 2: The interrogator shall be configured to generate a succession of modulated transmit pulses. Each transmit pulse shall be modulated by the normal test signal (see [1], clause 6.1). The length of each transmit pulse shall be not less than 10 ms and not greater than 50 ms. The interval between successive transmit pulses shall be not less than 1 ms and shall not exceed 10 ms.

Step 3: The output power of the interrogator, with or without a test fixture, shall be measured using a spectrum analyser, which shall be set to the following values:

a) Resolution bandwidth: 1 kHz.

b) Video bandwidth: Equal to the RBW.

c) Sweep Time: Auto.

d) Span: 2 MHz.

e) Trace mode: Max. hold sufficient to capture all emissions.

f) Detection mode: Average.

Step 4: For frequencies inside fc ± 1 000 kHz the measured values are the absolute values. The absolute levels of RF power shall be compared to the spectrum mask at figure 2 (see note).

Step 5: Where the interrogator includes multiple transmitter outputs, all of the outputs shall be connected via a suitable combiner network to the spectrum analyser. With the interrogator set up as in Step 1 and configured to transmit the test signal described in Step 2 while in its operational mode, the spectrum mask shall be measured at the spectrum analyser. The measured values shall be adjusted to compensate for the attenuation of the combiners and compared to the spectrum mask at figure 2.

NOTE: If for any reason the spectrum is measured with a resolution bandwidth other than 1 kHz, the measured values may be converted to the absolute values using the formula:

$$B = A + 10 \log \frac{1kHz}{BW_{MEASURED}}$$

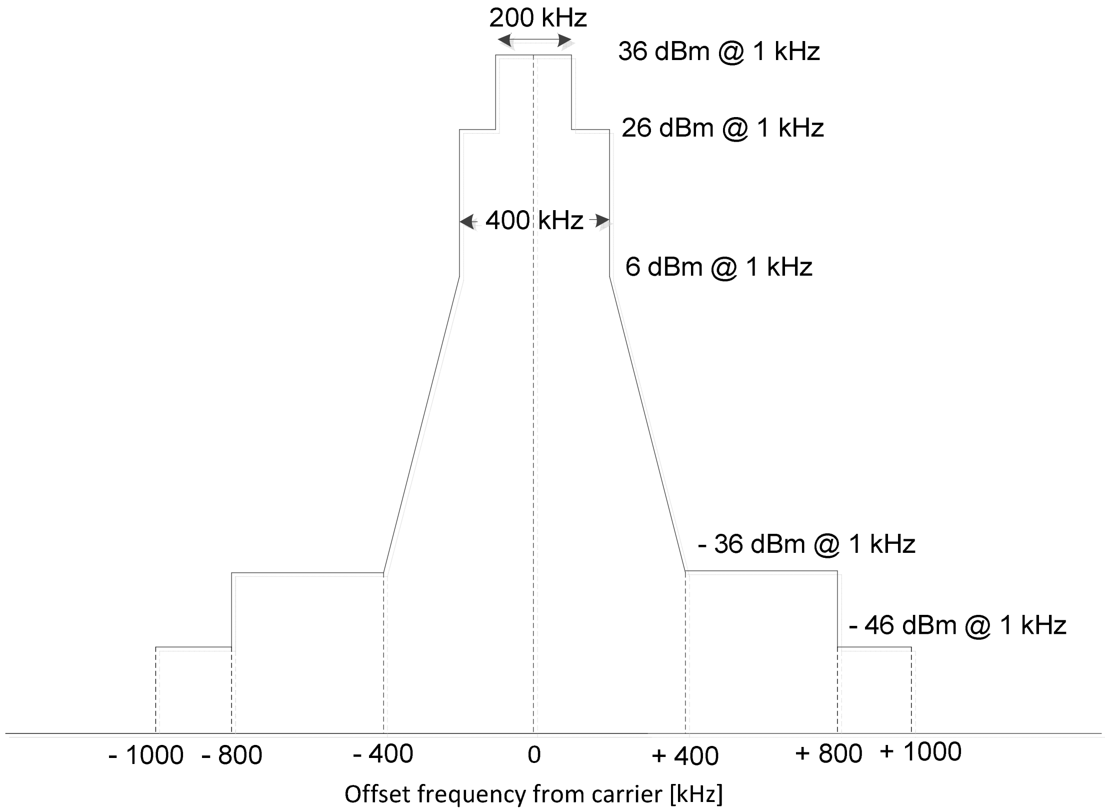
Where:

- A is the value at the measured resolution bandwidth;
- B is the absolute value referred to a 1 kHz reference bandwidth; or

use the measured value, A, directly if the measured spectrum is a discrete spectral line (a discrete spectrum line is defined as a narrow peak with a level of at least 6 dB above the average level inside the measurement bandwidth).

6.2.3 Limits

The absolute levels of RF power at any frequency shall not exceed the limits defined in the spectrum mask envelope at figure 2 in which the X axis shall be in linear frequency and the Y axis shall be scaled in dBm e.r.p.



NOTE: Where fc is the centre frequency of the carrier transmitted by the interrogator.

Figure 2: Spectrum mask for modulated signals

6.3 Unwanted emissions in the spurious domain

6.3.1 Definition

Spurious emissions are emissions at frequencies other than those of the wanted carrier frequency and its sidebands associated with normal test modulation.

6.3.2 Method of measurement

Spurious emissions shall be measured at frequencies outside the band fc ± 1 000 kHz where fc is the carrier frequency of the interrogator. The level of spurious emissions shall be measured as:

either:

a) i) their power level in a specified load (conducted spurious emission); and

ii) their effective radiated power when radiated by the cabinet and structure of the equipment (cabinet radiation); or

b) their effective radiated power when radiated by the cabinet and the integral antenna, in the case of equipment fitted with such an antenna and no external RF connector.

6.3.2.1 Method of measuring the power level in a specified load, clause 6.3.2, a) i)

This method applies only to equipment with an external antenna connector.

Step 1: The interrogator shall be connected to a 50 Ω power attenuator. The output of the power attenuator shall be connected to a measuring receiver. The interrogator shall be set up to generate a succession of modulated transmit pulses as described in Step 2 of clause 6.2.2.

In the event that the carrier signal from the interrogator is too high for the dynamic range of the measurement receiver, a notch filter may optionally be connected between the 50 Ω power attenuator and the measurement receiver to attenuate the carrier signal. This may be used for measurements at greater than 2 MHz from the carrier. The filter shall have a loss of less than 3 dB at ±1 MHz from fc.

Step 2: The measuring receiver, (see [1], clause 6.6) shall be tuned over the frequency range of 30 MHz to 5 GHz. For each of the frequency ranges specified in figure 3, the measuring receiver shall be set to the following values:

a) Resolution bandwidth: In accordance with the figure 3.

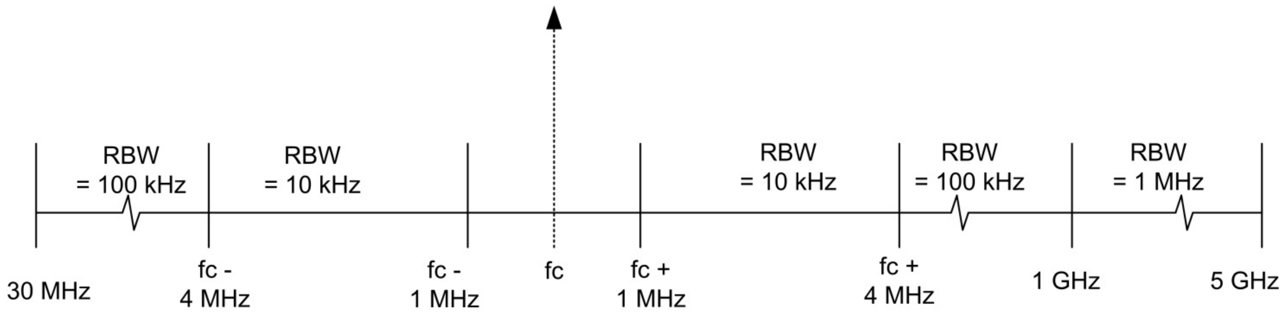
b) Video bandwidth: Equal to the RBW.

c) Sweep time: Auto.

d) Span: As defined by the relevant frequency ranges in figure 3.

e) Trace mode: Max. hold sufficient to capture emissions.

f) Detection mode: Average.



Note: For fc-1 MHz to fc+1 MHz see clause 8.4

Figure 3: Resolution bandwidths for spurious emissions

Step 3: At each frequency outside the band defined by fc ± 1 MHz at which a spurious component is detected, the power level shall be recorded as the conducted spurious emission level delivered into the specified load.

Step 4: The measurements shall be repeated with the interrogator on stand-by.

Step 5: The measurements shall be adjusted to give the output power of the interrogator with its declared antenna in e.r.p.

6.3.2.2 Method of measuring the effective radiated power, clause 6.3.2, a) ii)

This method applies only to equipment with an external antenna connector.

Step 1: On a test site, selected from [1], annex A, the interrogator shall be placed at the specified height on a non-conducting support and in the position closest to normal use as declared by the provider.

Step 2: The antenna connector of the interrogator shall be connected to an artificial antenna (see [1], clause 6.2).

Step 3: A test antenna shall be orientated for vertical polarization and the length of the test antenna shall be chosen to correspond to the instantaneous frequency of the measuring receiver. The output of the test antenna shall be connected to a measuring receiver.

In the event that the carrier signal from the interrogator is too high for the dynamic range of the measurement receiver, a notch filter may optionally be connected between the test antenna and the measurement receiver to attenuate the carrier signal. This may be used for measurements at greater than 2 MHz from the carrier. The filter shall have a loss of less than 3 dB at ± 1 MHz from fc.

Step 4: The interrogator shall be set up to generate a succession of modulated transmit pulses as described in Step 2 of clause 6.2.2.

Step 5: The measuring receiver (see [1], clause 6.6) shall be tuned over the frequency range 30 MHz to 5 GHz, but excluding the band defined by fc ± 500 kHz. The measurements shall be performed with the measuring receiver set to the following values:

a) Resolution bandwidth: In accordance with the figure 4.

b) Video bandwidth: Equal to the RBW.

c) Sweep time: Auto.

d) Span: As defined by the relevant frequency ranges in figure 4.

e) Trace mode: Max. hold sufficient to capture emissions.

f) Detection mode: Average.

Step 6: At each frequency at which a spurious component is detected, the test antenna shall be raised and lowered through the specified heights until a maximum signal level is detected by the measuring receiver.

Step 7: The interrogator shall then be rotated through 360º in the horizontal plane, until the maximum signal level is detected by the measuring receiver and the test antenna height shall be adjusted again for maximum signal level.

Step 8: The maximum signal level detected by the measuring receiver shall be noted.

Step 9: The interrogator shall be replaced by a substitution antenna as defined in [1], clauses A.1.4 and A.1.5.

Step 10: The substitution antenna shall be orientated for vertical polarization and calibrated for the frequency of the spurious component detected.

Step 11: The substitution antenna shall be connected to a calibrated signal generator.

Step 12: The frequency of the calibrated signal generator shall be set in turn to the frequency of each of the spurious components detected. If necessary the input attenuator setting of the measuring receiver shall be adjusted in order to increase the sensitivity of the measuring receiver.

Step 13: The test antenna shall be raised and lowered through the specified range of heights to ensure that the maximum signal is received. (When a test site according to clause A.1.1 is used, the height of the antenna need not be varied).

Step 14: The input signal to the substitution antenna shall be adjusted to give a level at the measuring receiver, that is equal to the level noted while the spurious component was measured, corrected for any change to the setting of the input attenuator of the measuring receiver.

Step 15: The input level to the substitution antenna shall be recorded as a power level, corrected for any change of input attenuator setting of the measuring receiver.

Step 16: The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

Step 17: The measure of the effective radiated power of the spurious components is the larger of the two power levels recorded for each spurious component at the input to the substitution antenna, corrected if necessary for the gain of the substitution antenna.

Step 18: If applicable, the measurements shall be repeated with the interrogator on standby.

6.3.2.3 Method of measuring effective radiated power, clause 6.3.2, b)

This method applies only to equipment without an external antenna connector. The method of measurement shall be performed according to clause 6.3.2.2, except that the interrogator output shall be connected to the integral antenna and not to an artificial antenna.

6.3.3 Limits

The level of any spurious emission, conducted or radiated, outside the frequency range fc ± 1 MHz shall not exceed the values given in table 1.

Table 1: Spurious emission limits in e.r.p.

State	47 MHz to 74 MHz 87,5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	Other frequencies below 1 000 MHz	Frequencies above 1 000 MHz
Operating	4 nW (-54 dBm)	250 nW (-36 dBm)	1 µW (-30 dBm)
Standby	2 nW (-57 dBm)	2 nW (-57 dBm)	20 nW (-47 dBm)

6.4 Limits and methods of measurement for tag emissions - Radiated power (e.r.p.)

6.4.1 Definition

The effective radiated power of a tag is the power radiated by its antenna in its direction of maximum gain under specified conditions of measurement.

6.4.2 Method of measurement

The measurement shall be carried out under normal conditions.

The measurement shall be performed using an interrogator, or an equivalent test fixture, and antenna under the same set-up conditions as used for the measurement of effective radiated power in clause 6.1. The intentional emissions from the tag shall be measured as:

either:

a) the power from a tag configured to emit an un-modulated sub-carrier;

or:

b) the power from a tag configured to emit a continuous modulated response.

6.4.2.1 Method of measuring the power in an un-modulated sub-carrier, clause 6.4.2, a)

This method applies to tags that may be set to emit an un-modulated sub-carrier.

Step 1: On a test site, selected from annex A, the interrogator shall be placed at the specified height on a non-conducting support and in the position closest to normal use as declared by the provider.

Step 2: The interrogator shall be set to operate at a single carrier frequency "fc" on a high power channel as determined by the test house. The interrogator shall provide an initial "wake up response" to activate the tag followed by a continuous carrier at a power level of 4 W e.r.p.

Step 3: The tag under test shall be positioned at a distance of 20 cm from the antenna of the interrogator in its direction of maximum gain and in an orientation that provides optimum coupling with the transmitted signal. The tag shall be configured to emit an un-modulated sub-carrier at an approximate frequency of fc ± 600 kHz, or such other frequency as declared by the manufacturer.

Step 4: The measurement shall be carried out using a measuring receiver set to the following values:

a) Resolution bandwidth: 1 kHz;

b) Video bandwidth: Equal to the RBW;

c) Sweep time: Auto;

d) Span: 1 MHz;

e) Detection mode: Average.

Step 5: A test antenna shall be positioned at a distance of 2 m from the tag in the direction of maximum gain of the antenna of the interrogator. The test antenna shall be connected to the measurement receiver. The test antenna shall be orientated to obtain maximum signal. A diagram of the test configuration is shown in figure 4.

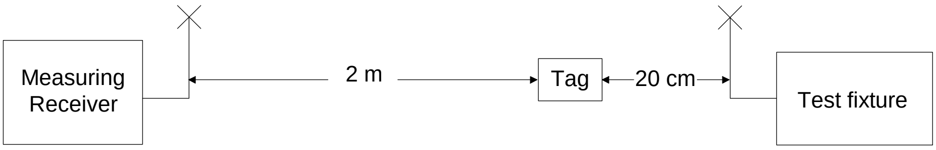


Figure 4: Measurement of tag emissions

Step 6: The measuring receiver shall be tuned to the frequency of the lower sub-carrier of the tag and the level of the combined emissions from both the tag and interrogator shall be recorded. The same procedure shall be repeated for the upper sub-carrier.

Step 7: Without moving the test antenna and the interrogator, the tag shall be removed from the proximity of the test area. The measuring receiver shall be tuned to the same frequencies as in Step 6 and the levels of the emissions from the interrogator shall be recorded.

Step 8: The power emitted by the tag shall be determined by deducting the levels recorded in Step 7 from the corresponding levels recorded in Step 6. The maximum value of the upper and lower sub-carrier frequencies shall be recorded as the emitted power.

Step 9: In normal operation the power emitted by the tag is spread across the necessary band and shall be calculated as power spectrum density in 100 kHz using the formula:

$$A = Pc + 10 \log \frac{100\ kHz}{BW_{necessary}}$$

Where:

Pc is the radiated power of the unmodulated sub-carrier from the tag;

A is the absolute value of the power spectrum density referred to a 100 kHz reference bandwidth;

$BW_{necessary}$ is 600 kHz, which is the necessary bandwidth of the tag.

6.4.2.2 Method of measuring the power in a modulated sub-carrier, clause 6.4.2, b)

This method applies to tags that are able only to emit a modulated sub-carrier.

Step 1: On a test site, selected from annex A, the interrogator shall be placed at the specified height on a non-conducting support and in the position closest to normal use as declared by the provider.

Step 2: The interrogator shall be set to operate at a single carrier frequency "fc" on a high power channel as determined by the test house. The interrogator shall provide an initial "wake up command" to activate the tag followed by a continuous carrier at a power level of 4 W e.r.p.

Step 3: The tag under test shall be positioned at a distance of 20 cm from the antenna of the interrogator in its direction of maximum gain and in an orientation that provides optimum coupling with the transmitted signal. The tag shall be configured to emit a continuous modulated response as described in clause 4.2.4, section 4 centred at an approximate offset frequency of fc ± 600 kHz, or such other frequency as declared by the manufacturer.

Step 4: The measurement shall be carried out using a measuring receiver set to the following values:

a) Resolution bandwidth: 1 kHz;

b) Video bandwidth: Equal to the RBW;

c) Sweep time: Auto;

d) Span: 1 MHz;

e) Detection mode: Average.

Step 5: A test antenna shall be positioned at a distance of 2 m from the tag in the direction of maximum gain of the antenna of the interrogator. The test antenna shall be connected to the measurement receiver. The test antenna shall be orientated to obtain maximum signal. A diagram of the test configuration is shown in figure 4.

Step 6: A plot of the combined emissions from the tag and interrogator shall be recorded in increments of 3 kHz across the lower side-band frequency range fc - 800 kHz to fc - 200 kHz.

Step 7: Without moving the test antenna and the interrogator, the tag shall be removed from the proximity of the test area. A plot shall be made of the emissions from the interrogator in increments of 3 kHz over the same frequency range.

Step 8: The power emitted by the tag shall be determined by deducting the levels recorded in Step 7 from levels recorded in Step 6 for each increment of 3 kHz and summing the results to give the total power emitted by the tag.

Step 9: Steps 6 to 8 shall be repeated across the upper side-band frequency range fc + 200 kHz to fc + 800 kHz. The higher of the values obtained in the upper and lower side-band frequency ranges shall be recorded as the radiated power of the tag.

Step 10: The radiated power of the tag as derived in Step 9 may be referred to a 100 kHz bandwidth using the formula:

$$A = Pc + 10 \log \frac{100\ kHz}{BW_{necessary}}$$

Where:

Pc is the radiated power of the tag;

A is the absolute value of the power spectrum density referred to a 100 kHz reference bandwidth;

$BW_{necessary}$ is 600 kHz, which is the necessary bandwidth of the tag.

6.4.3 Limits

The radiated power of the tag shall not exceed -10 dBm e.r.p., which is equivalent to a power spectrum density of -18 dBm/100 kHz e.r.p.

6.5 Limits and methods of measurement for tag emissions - Unwanted emissions

6.5.1 Definition

The unwanted emissions from a tag include both the out-of-band and the spurious emissions from a continuously modulated tag measured outside its necessary band when the tag is orientated for optimum coupling at a defined distance from the antenna of an interrogator, which is transmitting a continuous un-modulated carrier at a specified power level.

6.5.2 Method of measurement

The measurement shall be conducted under normal conditions.

The measurement shall be performed using an interrogator, or equivalent test fixture, and antenna under the same set-up conditions as used for the measurement of effective radiated power in clause 6.1.

In the event that the carrier signal from the interrogator is too high for the dynamic range of the measurement receiver, a notch filter may optionally be connected between the measurement antenna and the measurement receiver to attenuate the carrier signal. This may be used for measurements at greater than 4 MHz from the carrier. The filter shall have a loss of less than 3 dB at ± 2 MHz from fc.

Step 1: On a test site, selected from annex A, the interrogator shall be placed at the specified height on a non-conducting support and in the position closest to normal use as declared by the provider.

Step 2: The interrogator shall be set to operate at a single carrier frequency "fc" on a high power channel as determined by the test house. The interrogator shall provide an initial "wake up response" to activate the tag followed by a continuous carrier at a power level of 4 W e.r.p.

Step 3: The tag under test shall be positioned at a distance of 20 cm from the antenna of the interrogator in its direction of maximum gain and in an orientation that provides optimum coupling with the transmitted signal. The tag shall be configured to emit a continuous modulated response as described in clause 4.2.4 of EN 302 208-1 [1] at an approximate offset frequency of fc ± 600 kHz, or such other frequency as declared by the manufacturer.

Step 4: The measurement shall be carried out using a measuring receiver set to the following values:

a) Resolution bandwidth: In accordance with the figure 5;

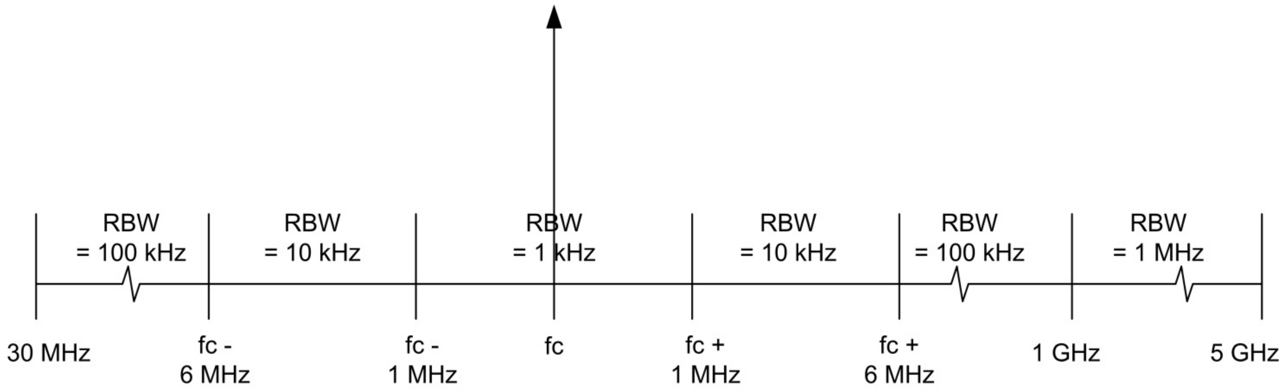
b) Video bandwidth: Equal to the RBW;

c) Sweep time: Auto;

d) Span: As defined by the relevant frequency ranges in figure 5;

e) Trace mode: Average;

f) Detection mode: Average.



NOTE: See clause 6.4 for measurement of the intentional power radiated by tags.

Figure 5: Resolution bandwidths for tag emissions

Step 5: A test antenna shall be positioned at a distance of 2 m from the tag in the direction of maximum gain of the antenna of the interrogator. The test antenna shall be connected to the measurement receiver. The test antenna shall be orientated to obtain maximum signal. A diagram of the test configuration is shown in figure 4.

Step 6: The measurement receiver shall be set to the resolution bandwidths specified in figure 5, which are the same as the reference bandwidths. Alternatively a lower resolution bandwidth may be used to improve the measurement accuracy.

Step 7: A plot of the combined emissions from both the tag and interrogator shall be recorded. This plot shall cover the bands from 861 MHz to fc - 800 kHz and from fc + 800 kHz to 871 MHz.

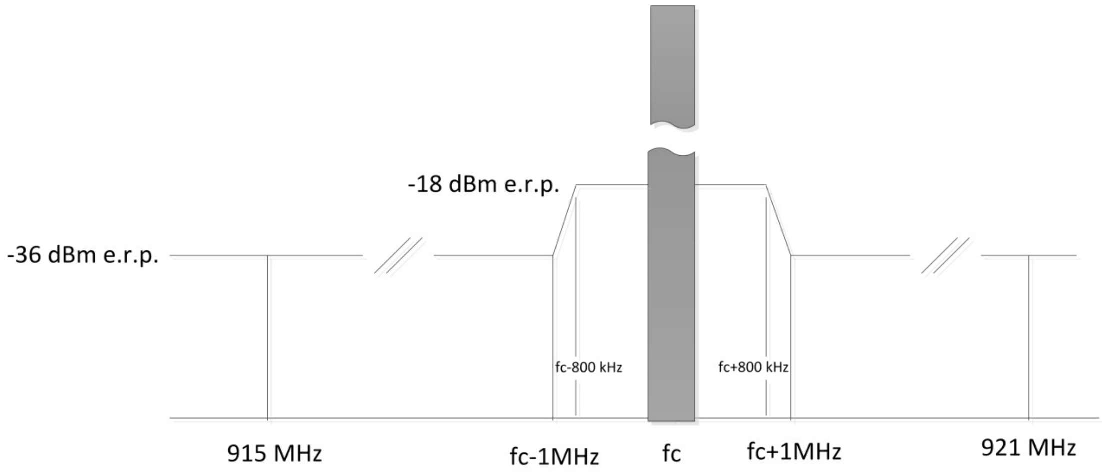
Step 8: The tag shall be removed from the proximity of the test area. Without moving the test antenna and the interrogator a plot shall again be taken across the same frequency range.

Step 9: Where the specified resolution bandwidths in figure 5 are used, the unwanted emissions from the tag shall be determined by deducting the levels recorded in Step 8 from levels recorded in the Step 7.

Step 10: For resolution bandwidths other than the reference bandwidths, the discrete spectral components within each reference bandwidth shall be power-summed to give the corrected values for the unwanted emissions.

6.5.3 Limits

The unwanted emissions from the tag under the above specified conditions at any frequency outside the band fc - 800 kHz to fc + 800 kHz shall not exceed the levels defined in the spectrum mask in figure 6.



NOTE 1: fc is the centre frequency of the carrier transmitted by the interrogator.
NOTE 2: The transmit channel occupied by the interrogator is shown in grey.
NOTE 3: All power levels in the unwanted domain relate to the resolution bandwidths in figure 5.

Figure 6: Spectrum mask for tag

For measurements of the unintentional and spurious emissions between ± (1 MHz to 6 MHz) the permitted limit is -36 dBm/10 kHz. Outside these frequencies the permitted limit is –36 dBm/100 kHz. - See figure 10.

7 Specification for Preliminary tests

7.1 Test site

7.1.1 Location

Funkwerk Aktiengesellschaft

Traffic & Control Communication

Im Funkwerk 5

99625 Kölleda

www.funkwerk-tcc.de

7.1.2 Test lab environment

Figure 7 shows the GSM-R simulation equipment installed at the test lab.

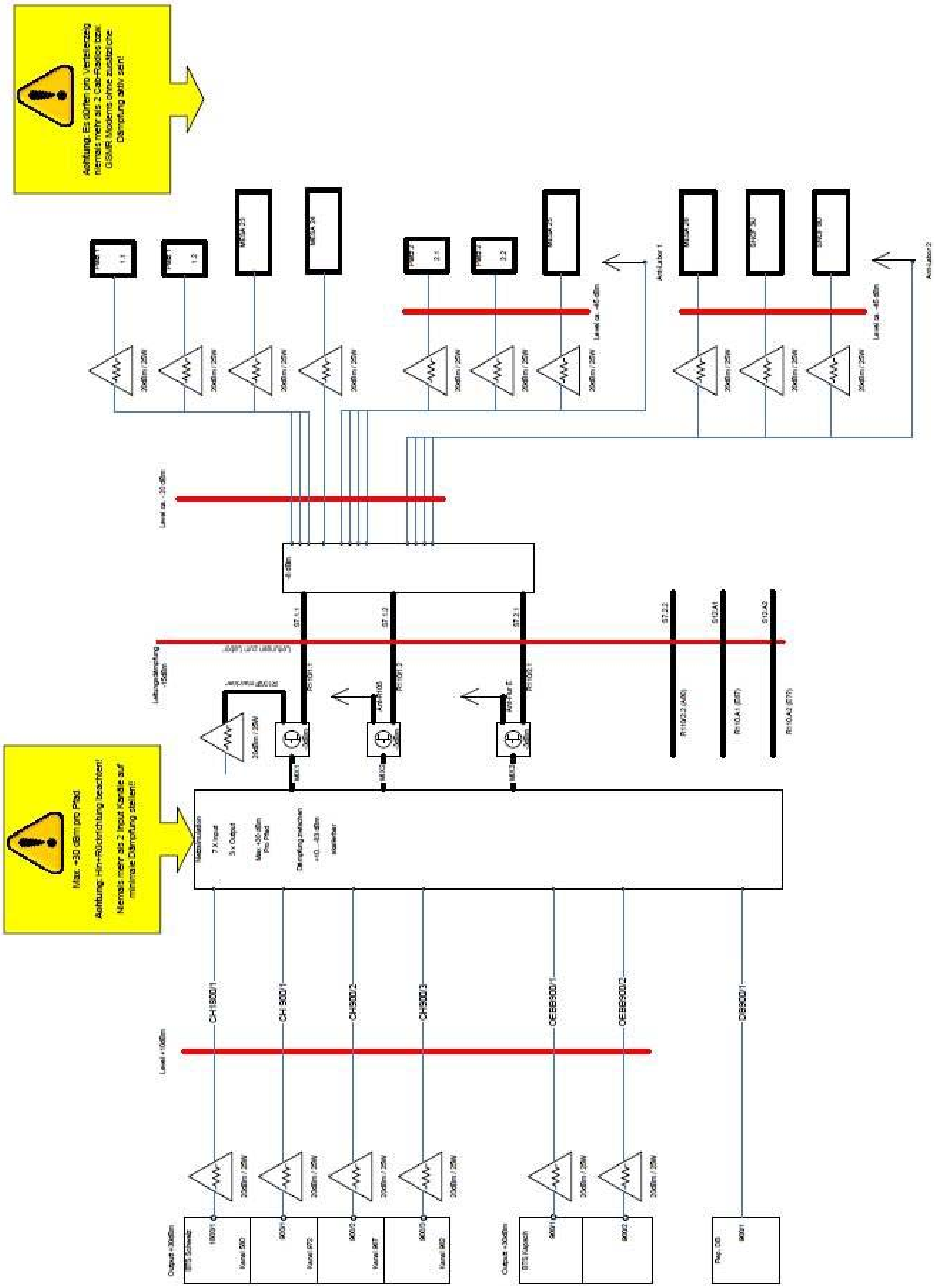


Figure 7: Test lab environment

7.1.3 Test arrangement

Figure 8 shows the test setup for performance tests.

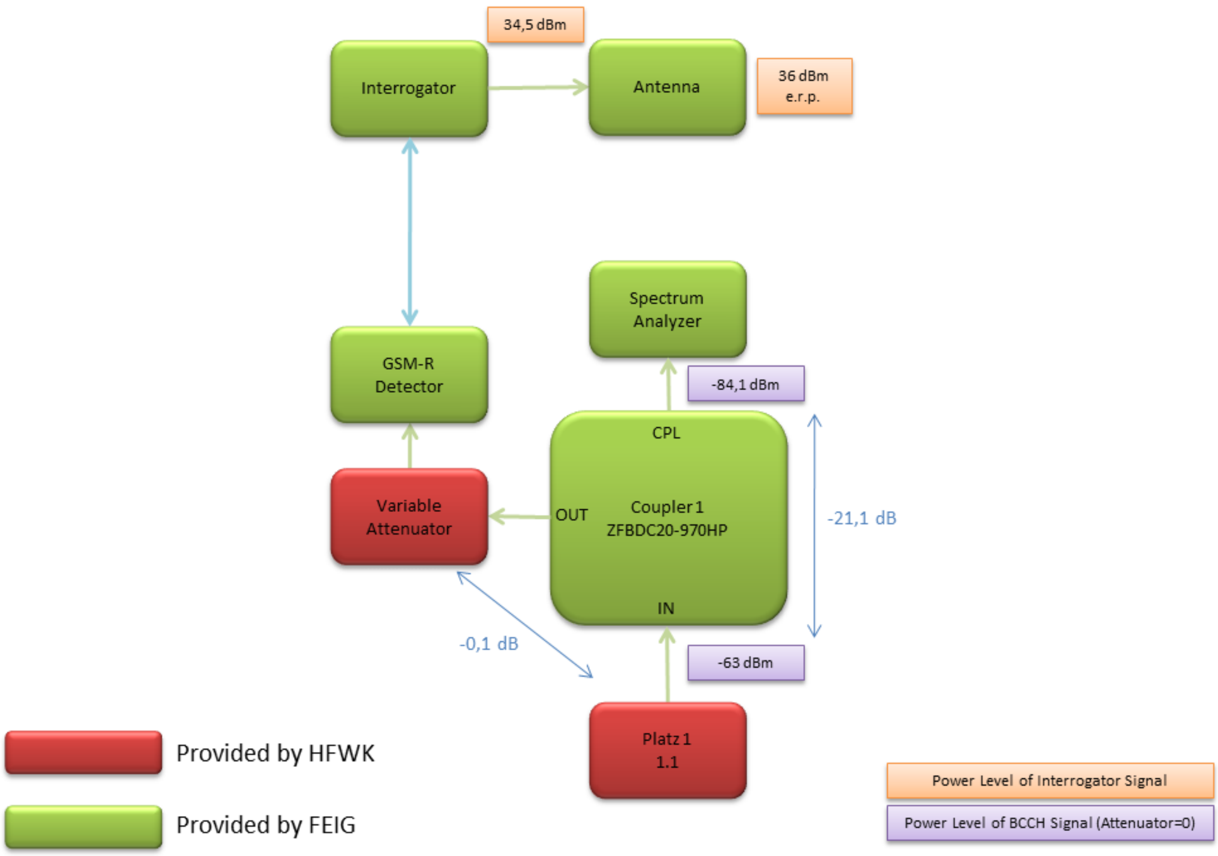


Figure 8: Performance test setup

Figure 9 shows the test setup for detection tests.

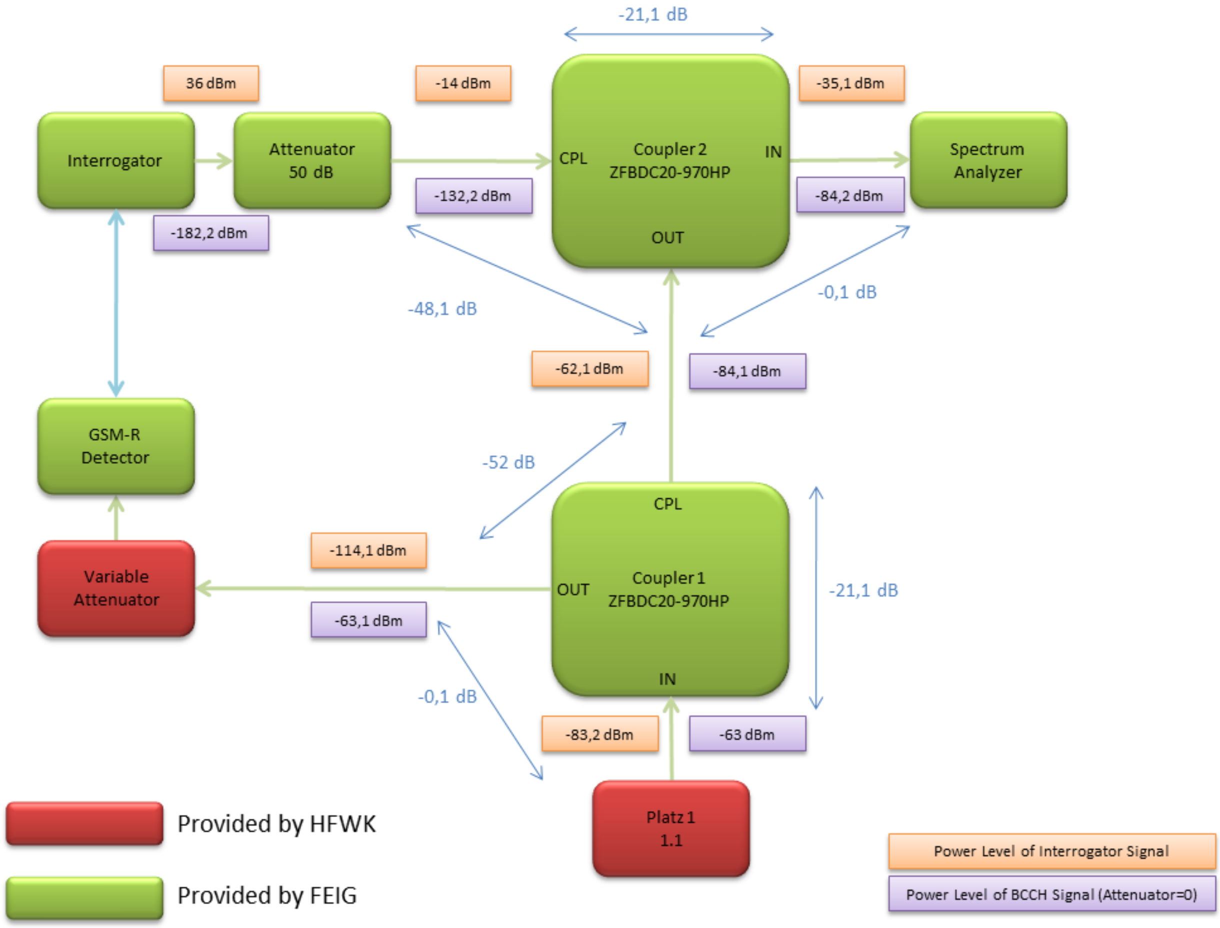


Figure 9: Detection test setup

7.2 Measurement setup

7.2.1 RFID equipment arrangement

Two demonstrators, connected to their respective antenna, should be set up with a separation distance of 5 m between them. The antennas should be oriented in such a way that no demonstrator is able to detect any of the tags placed in front of the other demonstrator. See figure 10.

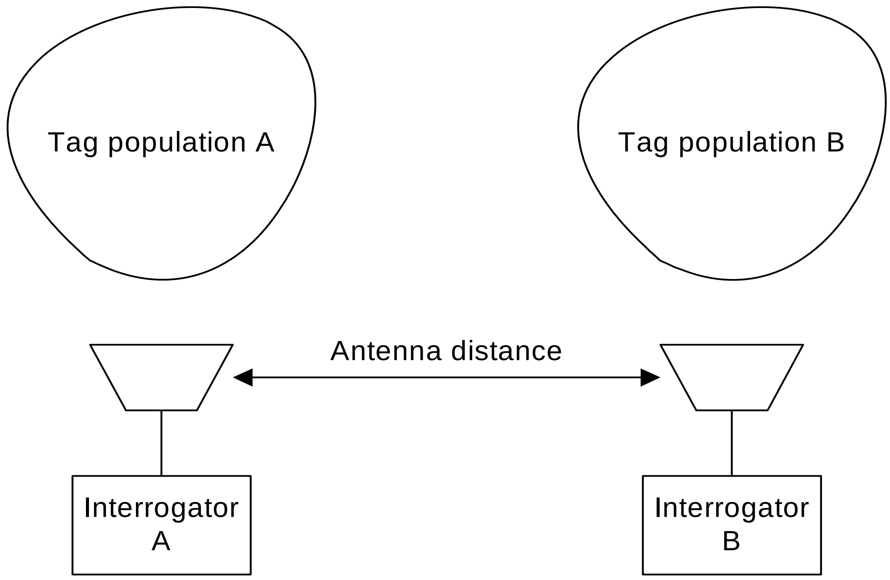


Figure 10: Illustration of demonstrator and tag setup

The GSM-R equipment shall be placed close to the demonstrators. However, no item shall be closer than 1 m from any demonstrator or tag.

7.2.2 Demonstrator settings

The demonstrator settings shall be supported as shown in table 2.

Table 2: Demonstrator setting

Set	M	BLF/kHz	Tari/µs
M4BLF640	4	640	<10

The transmit channel settings shall be supported as shown in table 3.

Table 3: Transmit channel settings

System	Channel Name	Real ER-GSM setting Frequency/MHz (ER-GSM, see note 1)	ER-GSM emulation setting Frequency/MHz (R-GSM, see note 2)
RFID	TX1	916,3	919,3
RFID	TX2	917,5	920,5
RFID	TX3	918,7	921,7
RFID	TX4	919,9	922,9
(E)R-GSM	CH1	918,2	921,2
(E)R-GSM	CH2	918,4	921,4
(E)R-GSM	CH3	918,6	921,6
(E)R-GSM	CH4	918,8	921,8
(E)R-GSM	CH5	919,0	922,0
(E)R-GSM	CH6	919,2	922,2
(E)R-GSM	CH7	919,4	922,4
(E)R-GSM	CH8	919,6	922,6
(E)R-GSM	CH9	919,8	922,8
(E)R-GSM	CH10	920,0	923,0
(E)R-GSM	CH11	920,2	923,2
(E)R-GSM	CH12	920,4	923,4
(E)R-GSM	CH13	920,6	923,6
(E)R-GSM	CH14	920,8	923,8
(E)R-GSM	CH15	921,0	924,0
(E)R-GSM	CH16	921,2	924,2

System	Channel Name	Real ER-GSM setting Frequency/MHz (ER-GSM, see note 1)	ER-GSM emulation setting Frequency/MHz (R-GSM, see note 2)
(E)R-GSM	CH17	921,4	924,4
(E)R-GSM	CH18	921,6	924,6
(E)R-GSM	CH19	921,8	924,8
NOTE 1: To be used if the ER-GSM band is supported by railways' test equipment. NOTE 2: To be used if the ER-GSM band is not supported by railways' test equipment. All the channel frequencies are shifted by 3 MHz to be able to use R-GSM equipment instead.			

7.3 Test criteria

For each test a population of 50 tags shall be read until all 50 tags are identified. In order to avoid delays caused by communication between host and demonstrator, the time from the end of the first tag reply until the end of the last tag reply shall be measured. Alternatively the time between the respective start times may be measured instead.

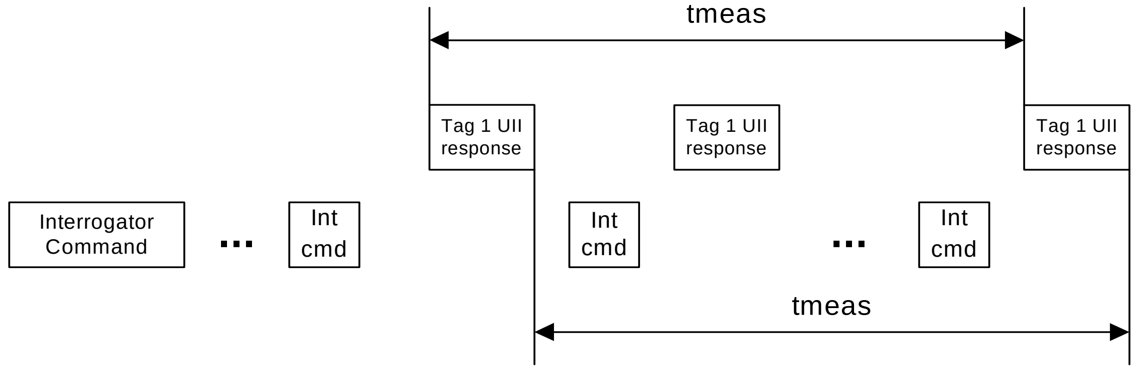


Figure 11: Illustration for time to be measured

The time t_{meas} shall be measured for 10 test rounds and the average time shall be used as test result. This means the following calculation for the identification time t_{id}:

$$t_{id} = \frac{1}{10}\sum_{i=1}^{10} t_{meas,i} \quad (1)$$

Test results shall be seen as equal if the difference of the minimum and the maximum of a set of t_{id} does not differ more than 5 % as shown in the following formula:

$$1 - \frac{\min_{i=1..N}(t_{id,i})}{\max_{i=1..N}(t_{id,i})} \le 5\% \quad (2)$$

7.4 Measurement procedure

7.4.1 Railway operation detection time and level

This test is intended to verify that a demonstrator is able to detect a GSM-R system. During power-up of a demonstrator it should avoid using any channels in the ER-GSM band. In a second scenario a GSM-R BTS should start to transmit on a channel that could be interfered with by a demonstrator that is already operating. In this test the demonstrator shall leave the channel within the railway operation check time t_{CRO}, which is 60 seconds for the purpose of the test.

7.4.1.1 Railway operation detection time when a BTS is powered up after a demonstrator (demonstrator in-operation test)

1) There shall be no transmission from the GSM-R BTS.
2) A demonstrator should be configured such that it may use TX3 or TX4 and with a railway operation check time of t_{CRO} <= 60 s. Furthermore, the demonstrator should record the time when it first detects that a GSM-R carrier with only TCHs is used and when the transmission from the interfering RFID TX channel is turned off.
3) For all measurements a spectrum analyser shall be configured to cover the frequency range 915 - 925 MHz.
4) The GSM-R BTS should be configured so that the BCCH signal level received by the demonstrator is ≥-80 dBm. The time at which the second GSM-R carrier starts to transmit should be noted.
5) Using the spectrum analyser it shall be verified that the demonstrator ceases to occupy a TX channel that conflicts with CH1 within 60 seconds
6) Repeat Steps 4) and 5) for CH2 to CH14.
7) Repeat Steps 4) and 5) for 10 randomly selected second GSM-R carrier frequencies between CH1 and CH14.
8) Compare the GSM-R BTS time log of second GSM-R carrier operation with the demonstrator time log. The test is successful if the demonstrator only starts to transmit if the demonstrator RFID transmit channel carrier is at least 700 kHz separated from the GSM-R first and second carriers.

7.4.1.2 Railway operation detection time when BTS is powered up before the demonstrator (demonstrator start-up test)

1) The GSM-R BTS should be configured to transmit the BCCH on CH18 and adjusted to give a signal level at the demonstrator of at least -80 dBm.
2) For all measurements a spectrum analyser should be adjusted to cover the frequency range 915 - 925 MHz.
3) A demonstrator should be setup to operate on TX3 or TX4.
4) Using the spectrum analyser it should be verified that the demonstrator never uses a TX-channel that is in conflict with CH1.

NOTE 1: The demonstrator may only use TX3.

5) A demonstrator should be configured to use TX4.
6) Using the spectrum analyser it should be verified that the demonstrator never uses a TX-channel that is in conflict with CH8.

NOTE 2: The selected channel TX4 is blocked by CH8 so the demonstrator is unable to transmit.

7.4.1.3 Railway operation detection level

1) For all measurements a spectrum analyser should be set up to cover the frequency range 915 - 925 MHz.
2) The GSM-R BTS should be configured to transmit the BCCH on CH18 and adjusted to give a signal level at the demonstrator of at least -80 dBm.
3) A demonstrator should be configured to operate on TX4.
4) Using the spectrum analyser it should be verified that the demonstrator never uses a TX-channel that is in conflict with CH8.

NOTE 1: The selected channel TX4 is blocked by CH8 so the demonstrator is unable to transmit.

5) The demonstrator and ER-GSM device should be switched off.
6) The GSM-R BTS should be configured to give a BCCH signal level at a demonstrator of -97 dBm. The time at which CH8 starts to transmit should be noted.

7) A demonstrator should be configured to operate on TX4.

8) Using the spectrum analyser it should be verified that the demonstrator never uses a TX-channel that interferes with CH8.

NOTE 2: The demonstrator should not transmit since it is configured to transmit only on channel TX4, which is blocked by CH8.

9) The demonstrator and ER-GSM device should be switched off.

10) The GSM-R BTS should be configured to transmit the BCCH on CH8 and adjusted to give a signal level at the demonstrator of -99 dBm. The time at which CH1 starts to transmit should be noted.

11) A demonstrator should be configured to use TX4.

12) Using the spectrum analyser it should be verified that the channel selection of the demonstrator is not influenced by the transmission from the GSM-R BTS.

NOTE 3: In this scenario operation on channel TX4 is permissible since the power level received from the BTS by the demonstrator is below the specified threshold of -98 dBm.

7.4.2 Impact from GSM-R BTS on RFID system with BLF=640 kHz

This test should show whether RFID communication at BLF=640 kHz is influenced by GSM-R BTS. For this test an GSM-R is configured to transmit a continuous BCCH.

1) A demonstrator shall be set to M4BLF640 with 50 tags placed between 0,5 m and 1,5 m away from its antenna so that all of these tags may be identified reliably.

2) For all measurements a spectrum analyser shall be turned on.

3) The demonstrator should be powered-up on TX3.

4) The GSM-R BTS shall be turned on with a BCCH transmitting at the frequency of CH7 and adjusted to give a signal level at the demonstrator of -100 dBm.

NOTE: The centre frequency difference between CH7 and TX3 is 700 kHz.

5) The demonstrator should read all of the tags using channel TX3.

6) The identification time should be defined as t_{id}. If not all tags are detected then t_{id} shall be calculated for the number of tags identified. The number of tags that fail to be detected should be recorded as well.

7) Steps 4) to 6) should be repeated in increments of 5 dB up to highest achievable level. This test does not have a pass criterion. The results are an input for system setup.

8) This test should show whether RFID communication at BLF=640 kHz is influenced by GSM-R mobile in the ER-GSM band. For this test an GSM-R BTS (E)R-GSM is configured to transmit a continuous BCCH on CH14 so as not to influence the demonstrator.

9) This test does not have a pass criterion. The results are an input for system setup.

7.4.3 Impact from GSM-R Mobile on RFID system with BLF=640 kHz

This test should show whether RFID communication at BLF=640 kHz is influenced by GSM-R Mobile.

1) A demonstrator shall be set to M4BLF640 with 50 tags placed between 0,5 m and 1,5 m away from its antenna so that all of these tags may be identified reliably.

2) For all measurements a spectrum analyser should be turned on.

3) The demonstrator should be powered-up on TX3.

4) The GSM-R BTS shall be turned on with a BCCH transmitting on CH14 and adjusted to give a signal level of -80 dBm at the demonstrator.

5) The demonstrator should read all of the tags using channel TX3.

6) The identification time shall be defined as t_{id}. If not all tags are detected then t_{id} shall be calculated for the number of tags identified. The number of tags that fail to be detected should be recorded as well.

7) A GSM-R mobile shall be placed near the demonstrator to give a signal at its antenna of -80 dBm.

8) The demonstrator should read all of the tags using channel TX3.

9) The identification time should be defined as t_{id}. If not all tags are detected then t_{id} shall be calculated for the number of tags identified. The number of tags that fail to be detected should be recorded as well.

10) Steps 4) to 6) should be repeated in increments of 1 dB up to -20 dBm, Where no difference in the recorded results is observed 5 dB increments may be applied.

11) This test does not have a pass criterion. The results are an input for system setup.

7.4.4 Two demonstrators simultaneously operating on the same high power channel

This test should show that demonstrators do not confuse each other and that another demonstrator on the same channel is not interpreted as an (E)R-GSM signal.

1) Each demonstrator shall be set to M4BLF640 with 50 tags placed between 0,5 and 1,5 m away from its antenna so that all of these tags may reliably be identified.

2) For all measurements a spectrum analyser should be turned on.

3) Demonstrator A shall be turned on and demonstrator B shall be turned off.

4) Demonstrator A should read all of its associated tags using channel TX3.

5) The identification time to read all of the associated tags shall be defined as $t_{id,A0}$.

6) Demonstrator A shall be turned off and demonstrator B should be turned on.

7) Demonstrator B should read all of its associated tags using channel TX3.

8) The identification time to read all of the associated tags should be defined as $t_{id,B0}$.

9) Demonstrator A and demonstrator B should be turned on.

10) Demonstrator A should read all of its associated tags using channel TX3.

11) Demonstrator B should read all of its associated tags using channel TX3.

12) The identification times shall be defined as $t_{id,A1}$ for demonstrator A and as $t_{id,B1}$ as for demonstrator B.

13) The test passes if each of the sets [$t_{id,A0,}$ $t_{id,A1}$] and [$t_{id,B0,}$ $t_{id,B1}$] fulfil formula 2 and the spectrum analyser measurements confirm that the demonstrators only transmitted on the defined channel.

7.4.5 Ability of demonstrators to reliably distinguish between another RFID demonstrator and avoid an GSM-R designated channel

This test should show that demonstrators are able to distinguish between transmissions from other demonstrators and ER-GSM signals. While it is important that a demonstrator avoids an ER-GSM designated channel, it is also essential for system performance that multiple RFID demonstrators share an available transmit channel.

1) Each demonstrator shall be set to M4BLF640 with 50 tags placed between 0,5 and 1,5 m away from its antenna so that all of these tags may be identified reliably.

2) For all measurements a spectrum analyser should be turned on.

3) Demonstrator A should read all of its associated tags using channel TX3.

4) Demonstrator B should read all of its associated tags using channel TX3.

5) The identification times should be defined as $t_{id,A0\ and}\ t_{id,B0}$.

6) The GSM-R equipment should be set to transmit on a TCH channel at a frequency of f(TX3) + 700 kHz.

7) The identification times of the tags should be defined as $t_{id,A1\ and}\ t_{id,B1}$.

8) Demonstrator A should read all of its associated tags using channel TX3.

9) Demonstrator B should read all of its associated tags using channel TX4.

10) The identification times should be defined as $t_{id,A2\ and}\ t_{id,B2}$.

11) The GSM-R equipment should be set to transmit on a TCH channel at a frequency of f(TX3) + 500 kHz.

12) The identification times of the tags shall be defined as tid,A3 and tid,B3.

13) The GSM-R equipment should be set to transmit on a TCH channel at a frequency of f(TX3) + 700 kHz.

14) The identification times of the tags shall be defined as tid,A4 and tid,B4.

15) The test passes if each of the sets [tid,A0 , tid,A1 , tid,A4] and [tid,B0 , tid,B1 , tid,B2 , tid,B3] fulfil formula 2, Tid,A3 should not be measurable since no tags should reply. The spectrum analyser measurements should confirm that the demonstrators only transmitted in the defined channel(s).

8 Specification for field measurements

8.1 Test site

The test site will be in the area of Wiesbaden Hauptbahnhof (main station).

At the test site there will be a GSM-R BTS providing both a first and a second carrier. The first GSM-R carrier has 2 timeslots reserved for BCCH and 6 timeslots available for TCH. The second GSM-R carrier provides 8 timeslots only for TCH. The BCCH should be in the band 923,6-925 MHz, as this is of no relevance for RFID and a TCH below 923,4 MHz.

The configuration at Wiesbaden Hbf is:

- First carrier (with BCCH): 968 (→ 923,8 MHz)
- Second carrier (only TCH): 958 (→ 921,8 MHz)

Trains equipped with GSM-R operate on regular basis in this area. The S-Bahn trains pass at a frequency of at least 6 train pairs per hour. A portable cab-radio controlled by the test team will be available to allow a connection to the GSM-R network.

Figure 12 shows the intended spectrum use for the tests. The first GSM-R carrier with a BCCH has a f_{off} = 900 kHz to the nearest RFID channel TX4. The second GSM-R carrier with only TCH has a f_{off} = 100 kHz to the nearest RFID channel. The use of CH3 for the second GSM-R carrier therefore should prevent the use of TX3 by RFID.

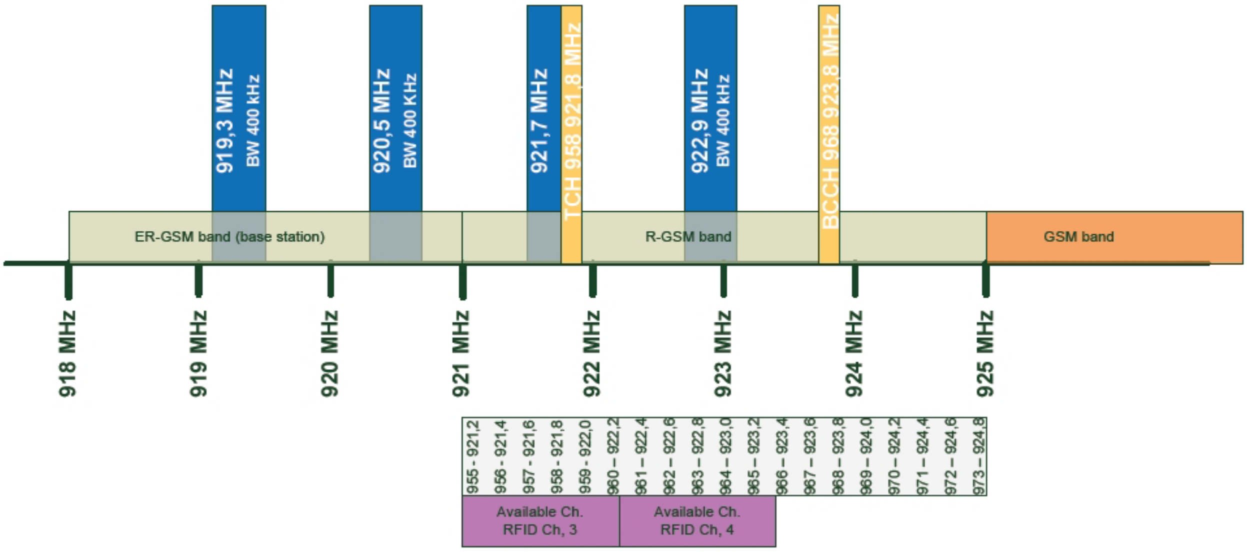


Figure 12: Spectrum used for the tests at Wiesbaden Hbf

Table 4 shows the trains leaving and arriving in Wiesbaden Hbf for a typical hour of operation during the day.

Table 4: Train frequency within one typical hour (source: www.bahn.de)

Direction	Time	Platform	Train number	Additional train number
Departing	11:05	4	S1	(Zug-Nr. 35133)
Arriving	11:09	3	S8	(Zug-Nr. 35826)
Departing	11:11	2	S9	(Zug-Nr. 35933)
Arriving	11:18	2	S9	(Zug-Nr. 35928)
Departing	11:19	3	S8	(Zug-Nr. 35833)
Arriving	11:24	4	S1	(Zug-Nr. 35126)
Arriving	11:25	6	RB15712	
Arriving	11:25	7	VIA25013	
Arriving	11:25	10	VEC25623	
Arriving	11:28	1	VIA25012	
Departing	11:32	7	VIA25013	
Departing	11:33	1	VIA25012	
Arriving	11:33	5	ICE1654	
Departing	11:35	4	S1	(Zug-Nr. 35135)
Departing	11:36	10	VEC25622	
Departing	11:38	6	RB15713	
Arriving	11:39	3	S8	(Zug-Nr. 35828)
Departing	11:41	2	S9	(Zug-Nr. 35935)
Arriving	11:48	2	S9	(Zug-Nr. 35930)
Departing	11:49	3	S8	(Zug-Nr. 35835)
Arriving	11:54	4	S1	(Zug-Nr. 35128)

8.2 Measurement setup

The measurement setup should be as in clause 7.2.1. The channel selection should be set for ER-GSM emulation with the RFID positioned at least 20 m away from the tracks where a train is expected to pass.

8.3 Measurement procedure

All tests shall be monitored by a spectrum analyser, a mobile radio from DB and a railways communication tracker. Tags will be present for each of the tests.

8.3.1 Reference measurements

The following reference measurements shall be made with the demonstrators operating at TX1 and TX2, which do not fall into the ER-GSM band at all. Before each step in the tests the demonstrator shall be turned off. The permitted RFID transmit channels shall be selected and the demonstrator shall be turned on again.

1) A measurement shall be made for reference purposes using channel TX1 for demonstrator A with no train nearby (no GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Demonstrator B shall be turned off.

2) A measurement shall be made for reference purposes using channel TX1 for demonstrator A while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). The measurement shall be made when the train is passing. Demonstrator B shall be turned off.

3) A measurement shall be made for reference purposes using channel TX1 for demonstrator A and TX2 for demonstrator B operating simultaneously. The measurement shall be made when a train is passing. The RFID channels that were used shall be recorded.

4) A measurement shall be made for reference purposes using channel TX1 for demonstrator A and also TX1 for demonstrator B operating simultaneously. The measurement shall be taken when a train is passing. The RFID channels that were used shall be recorded.

8.3.2 Co-existence test in non-busy GSM-R environment

For all tests the use of GSM-R mobiles shall be made in a way that only the first carrier is busy and the second carrier is not in use. If GSM-R is very busy at the test site and the second carrier is in use then the tests in this clause may be skipped. Before each step in the tests the demonstrator shall be turned off. The permitted RFID transmit channels shall be manually selected and then the demonstrator shall be turned on again.

The following measurements shall be made:

1) A measurement shall be made with demonstrator A using either channel TX3 or TX4 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be done when the train is passing. The used RFID channel shall be recorded.

   Anticipated result: The performance should be the same as for reference measurements. The demonstrators should automatically select a permitted TX channel, which will be TX4.

2) A measurement shall be made with demonstrator A using either channel TX3 or TX4 and demonstrator B using either channel TX3 or TX4 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be done when the train is passing. The used RFID channels shall be recorded.

   Anticipated result: The performance should be the same as for the reference measurements. The demonstrators should automatically select a permitted TX channel, which will be TX4.

3) A measurement shall be made with demonstrator A using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be done when the train passing. The used RFID channel shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

4) A measurement shall be made with demonstrator A and demonstrator B using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be made when the train is passing. The used RFID channels shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

8.3.3 Co-existence test in busy GSM-R environment

For all tests the use of GSM-R mobiles shall be performed in a way that the first carrier is so busy, that the second carrier also powers up. Before each step in the tests the demonstrator shall be turned off. The permitted RFID transmit channels shall be manually selected and the demonstrator shall then be turned on again.

The following measurements shall be made:

1) A measurement shall be made with demonstrator B using either channel TX3 or TX4 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be made when the train is passing.. The used RFID channel shall be recorded.

   Anticipated result: The performance should be the same as for reference measurements. The demonstrators should automatically select a permitted TX channel, which will be TX4.

2) A measurement shall be made with demonstrator A using either channel TX3 or TX4 and demonstrator B using either channel TX3 or TX4 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). The measurement shall be made when the train is passing. The RFID channel that was used shall be recorded.

   Anticipated result: The performance should be the same as for reference measurements. The demonstrators should automatically select a permitted TX channel, which will be TX4.

3) A measurement shall be made with demonstrator A using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be made when the train is passing. The used RFID channel shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

4) A measurement shall be made with demonstrator A and demonstrator B using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). The measurement shall be made when the train is passing. The RFID channel that was used shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

8.3.4 Co-existence test while operating from train

Some participants at the trial shall travel on an S-Bahn train from Wiesbaden Hbf to Wiesbaden Ost. The participants on the train shall setup a call to the participants that remain at Wiesbaden Hbf.

NOTE: Depending on the measurement time it might be necessary to do multiple train runs.

The following measurements shall be made:

1) A measurement shall be made with demonstrator A using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). Measurement shall be made when the train is passing. The used RFID channel shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

2) A measurement shall be made with demonstrator A and demonstrator B using channel TX3 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). The measurement shall be made when the train is passing. The RFID channel that was used shall be recorded.

   Anticipated result: The performance should be zero and no RFID tag should be read as the demonstrator should not transmit.

3) A measurement shall be made with demonstrator A and demonstrator B both set to channel TX4 while a train is nearby (at least one GSM-R mobile signal visible in the 876 - 880 MHz band above > -104 dBm). The measurement shall be made when the train is passing. The RFID channel that was used shall be recorded.

Anticipated result: The performance should be the same as for reference measurements. The demonstrators should automatically select a permitted TX channel.

9 Observations and conclusions

The test results (annex A) show that the demonstrators satisfactorily fulfilled the compliance test.

The test results of the preliminary tests with the GSM-R simulator (annex B) confirmed that the mitigation technique works as intended. There was no interference between RFID and GSM-R.

In future there will be a mandatory requirement for GSM-R systems using ER-GSM to support System Information 1 in the BCCH that includes the ARFCN.

The field trial (annex C) showed that the demonstrators were always able to detect GSM-R operation and therefore avoided those RFID transmit channels that could have caused potential interference. The monitoring of the GSM-R communication also confirmed that there was no impact from RFID.

The results of the preliminary tests and field trials showed that the mitigation technique used for spectrum sharing fulfils the requirements set by the railways.

Annex A (informative): Compliance tests

A.1 Introduction

This annex contains the results of the ERM tests on the test interrogators / demonstrators as described in clause 6.

A.2 Radiated power (e.r.p.)

The Demonstrator was configured to transmit with a frequency of 918,7 MHz and a power level of 36 dBm. The Tari value was set to 8 µs which is equal to a forward link bitrate of 125 kHz.

Figure A.1 shows the used test setup for the measurement of the transmit spectrum mask.

Figure A.1: Test Setup for Measurement of the Transmitter Spectrum Mask

A Rhode & Schwarz type FSP3 spectrum analyser was used as measuring receiver. The analyser was configured as follows:

- Centre Frequency 918,7 MHz
- Resolution bandwidth: 1 kHz
- Video bandwidth: Equal to the RBW
- Sweep Time: AUTO
- Span: 2 MHz
- Trace mode Max hold sufficient to capture all emissions
- Detection mode Averaging

The reference level offset was configured so that the un-modulated carrier of the Demonstrator was at a level of 36 dBm. This made it necessary to compensate for the attenuation of the RF cable and the10 dB attenuator. This was achieved by configuring a reference level offset of 10,5 dB.

Figure A.2 shows the result of the calibration of the reference level.

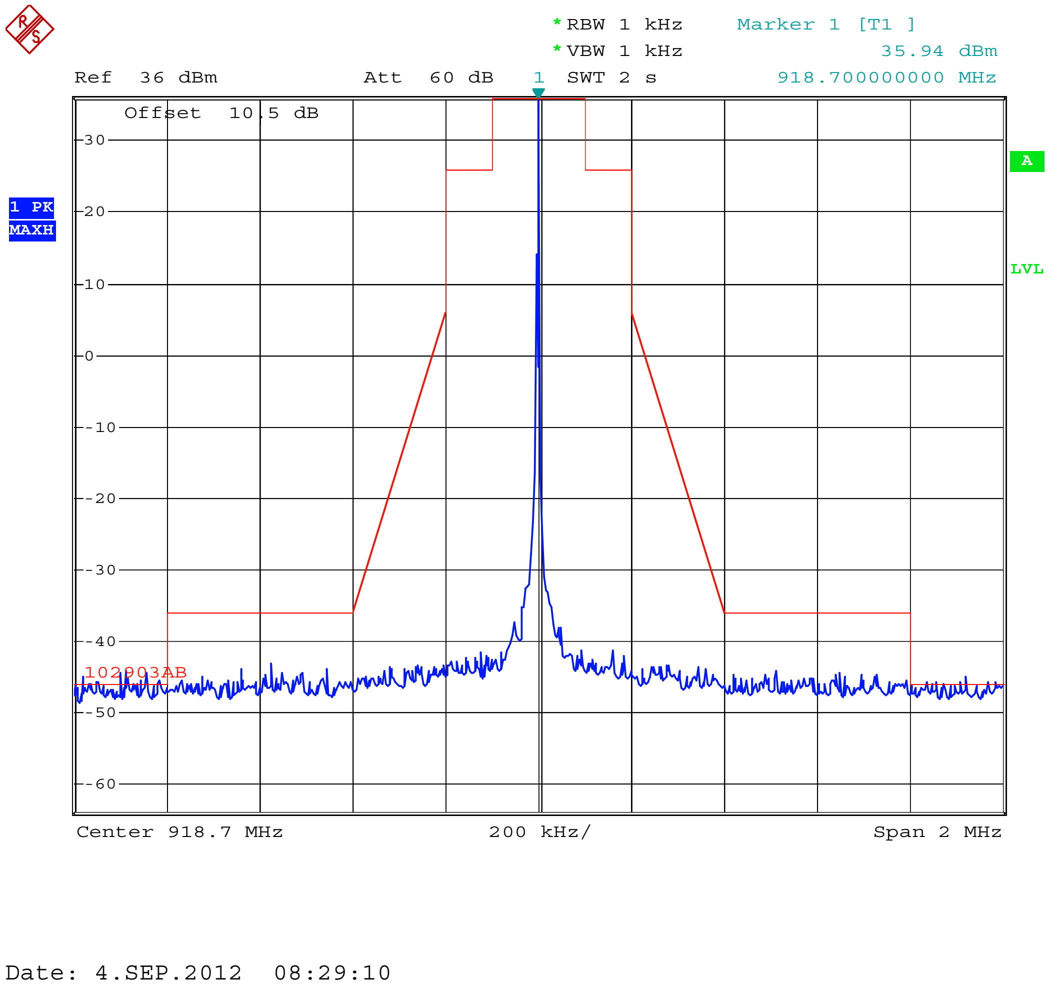


Figure A.2: Calibration of the Reference Level

A.3 Transmit spectrum mask

Measurement of the transmit spectrum mask was compared against the transmitter spectrum mask and the unwanted emissions in the spurious domain.

Figure A.3 shows the transmitter spectrum mask.

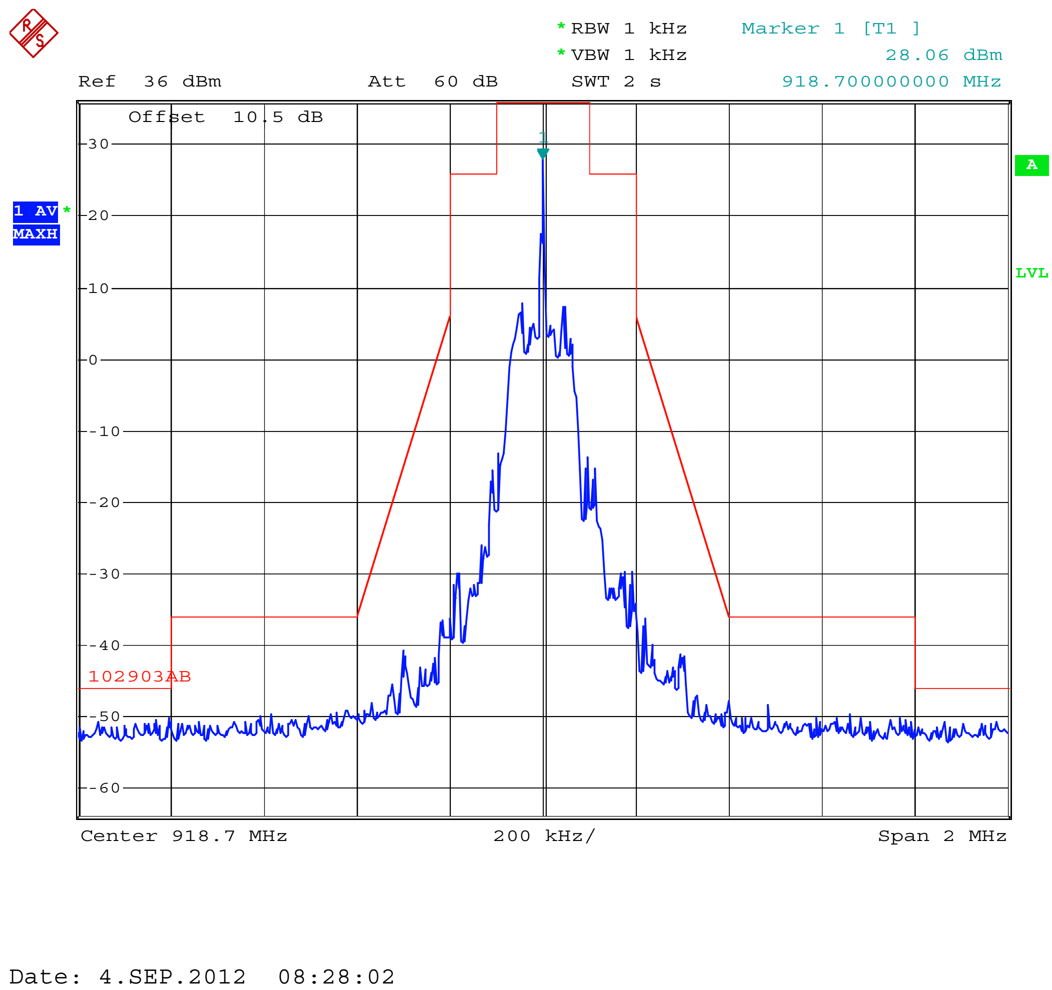


Figure A.3: Transmitter spectrum

Figure A.3 shows that the Demonstrator meets the transmitter spectrum mask when generating a modulated signal.

A.4 Unwanted emissions in the spurious domain

Due to the fact that the spectrum analyser has only a limited dynamic range, it is not possible to see the real level of the signal from the Demonstrators outside the transmit channel. Figure A.3 shows a level of approx. -53 dBm at a separation of ±1 MHz from the transmit frequency. These noise levels were generated by the spectrum analyser. To see the real level of signal from the Demonstrator, an additional notch filter had to be included into the measurement setup as shown in figure A.4.

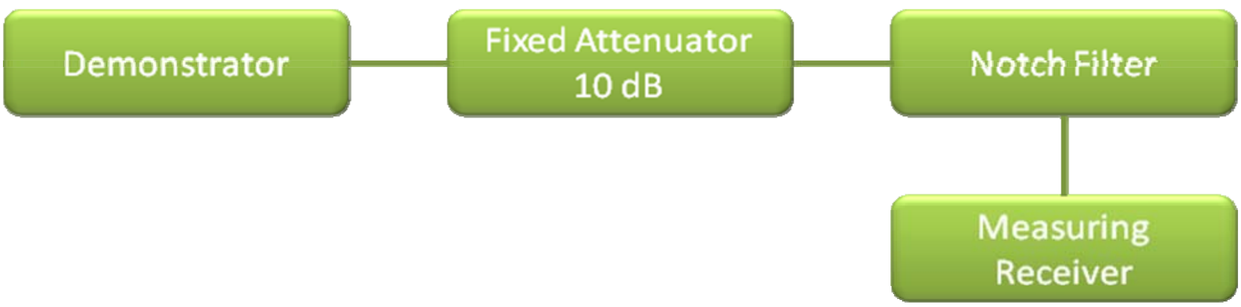


Figure A.4: Test Setup with Notch Filter for Measurement of the Transmitter Spectrum Mask

Figures A.5 and A.6 show the filtering capabilities of the notch filter.

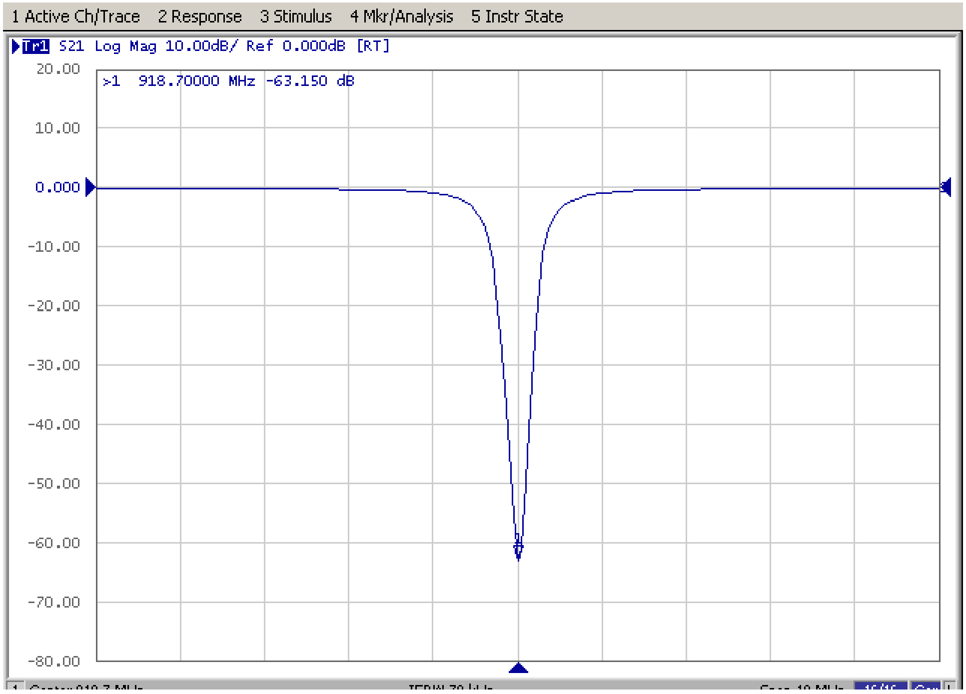


Figure A.5: S21 of the Notch Filter measured with a Network Analyser, Span 10 MHz

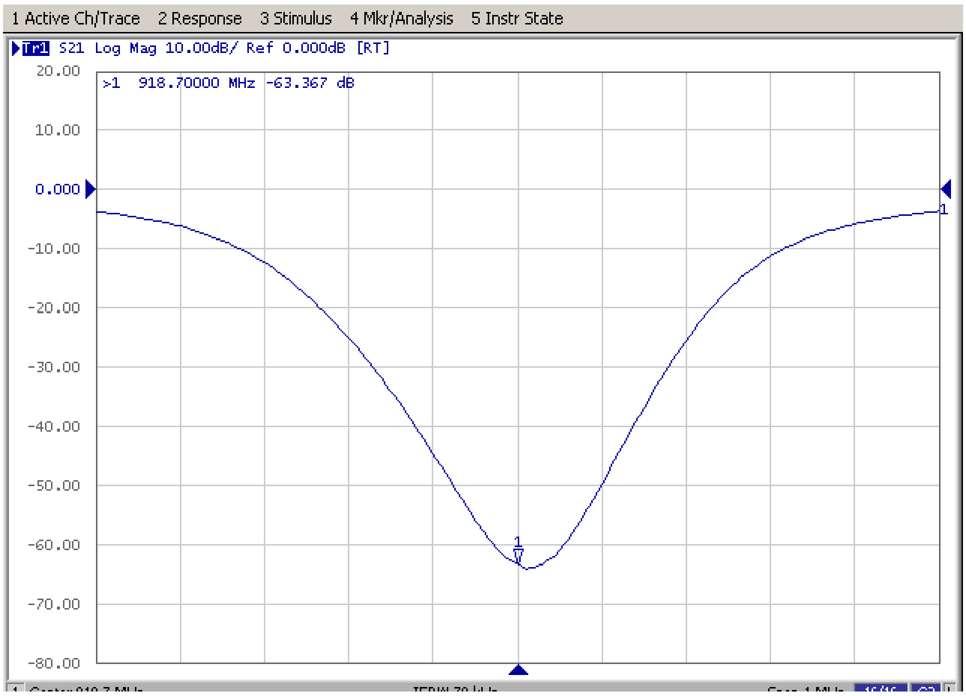


Figure A.6: S21 of the Notch Filter measured with a Network Analyser, Span 1 MHz

The filter attenuated the carrier of the demonstrator by approximately 60 dB. Due to its characteristics the influence of the notch filter can be seen across a range of approx. ±400 kHz around centre frequency of the filter.

Figure A.7 shows the spectrum of the demonstrator with the additional notch filter inserted into the test setup.

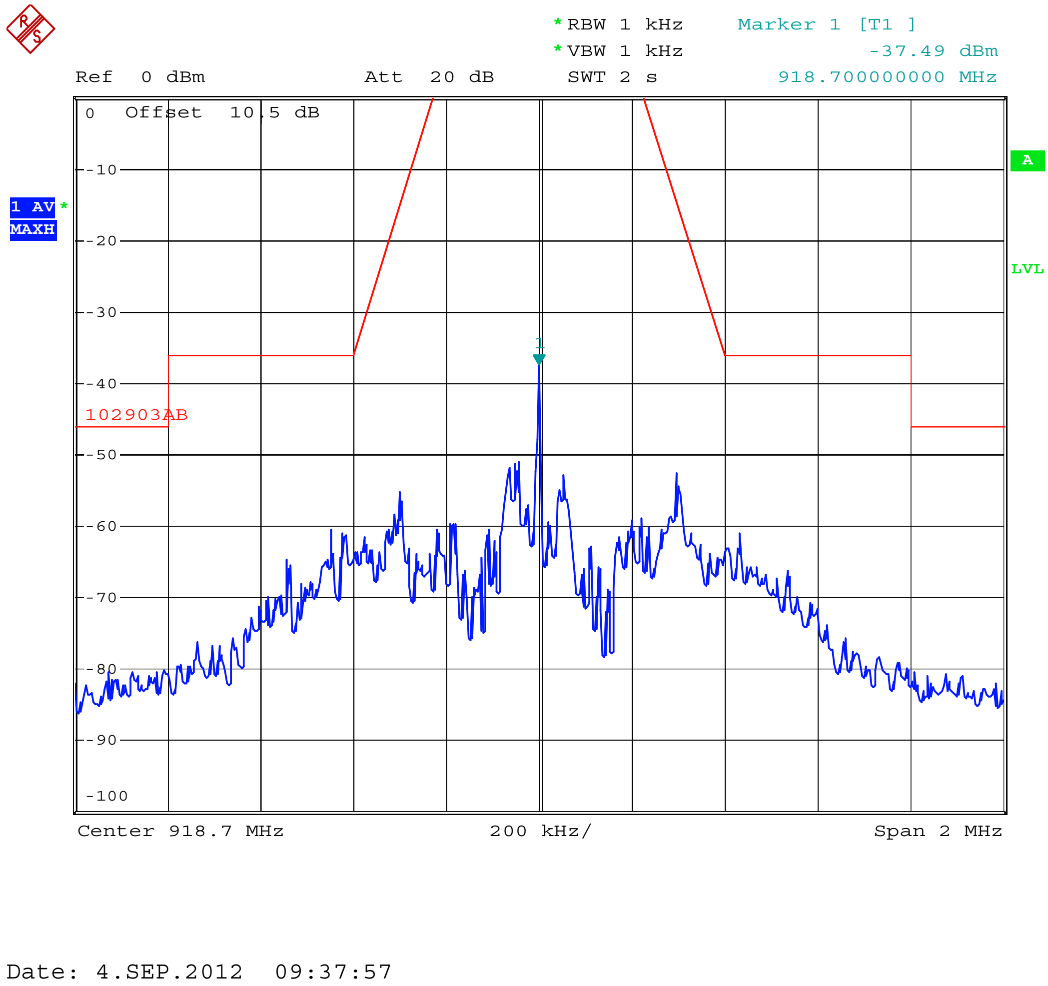


Figure A.7: Demonstrator Spectrum with additional Notch Filter

Figure A.7 shows that the real spurious emissions of the Demonstrator at a separation of ± 1 MHz around the carrier is significantly lower than in the measurement without the additional filter. The spurious emissions of the Demonstrator are below -80 dBm. Therewith the Demonstrator signalling is much below the transmitter spectrum mask.

Figure A.8 shows the original measured spurious emissions levels (blue curve) and the measured "real" spurious emissions levels with the notch filter included. The additional added red curve shows the estimated shape of the spectrum generated by the demonstrator in the range ±400 kHz around the carrier.

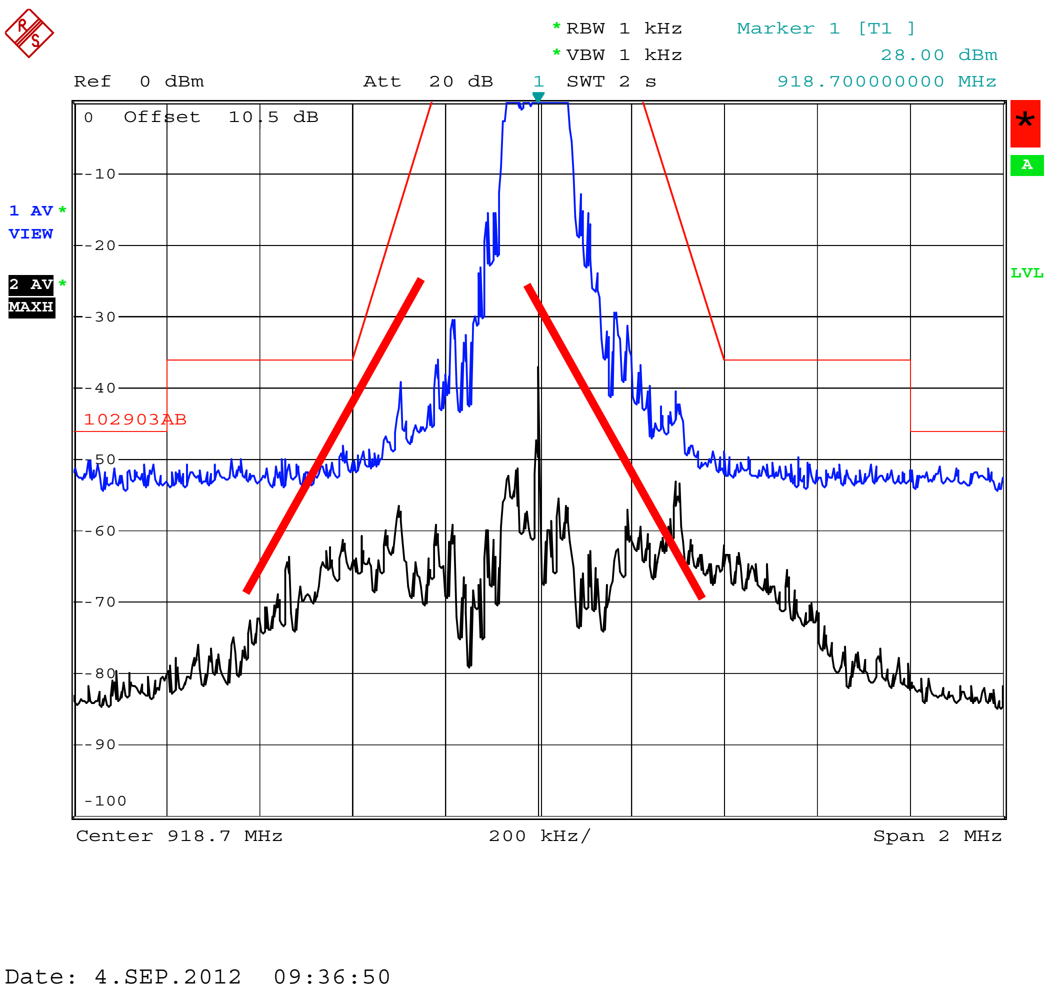


Figure A.8: Combined demonstrator spectrum measured without (blue) and without (black) additional Notch Filter

A.5 Tag spectrum mask

The tag spectrum mask has been measured according EN 302 208-1 (V1.4.1) [1], clause 10 and SRDoc TR 102 649-2 [i.4]. The test setup was aligned as shown in figure A.9.

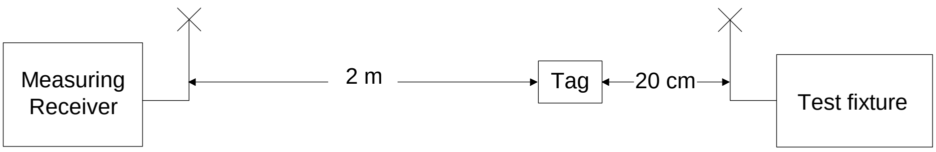


Figure A.9: Measurement of Tag emissions

Tests were performed with a tag that provides a custom specific "Calibrate" command. This was used to set the tag into a mode where it continuously transmitted the content of its user memory. After activation of the tag the interrogator transmitted a continuous wave signal at a frequency of 918,7 MHz. The tag's response was located at a frequency of fc-640 kHz and fc+640 kHz. Both sidebands were considered during the measurement. The measurement antenna had a gain of 5,4 dBi @ 918,7 MHz. The antenna cable had an attenuation of 4,6 dB @ 918,7 MHz. To calculate the correct power level, the measured signals had to be reduced by 0,8 dB. The measured free air attenuation between the position of the tag and the measuring receiver is 35,25 dB, which also needed to be taken into account.

The following figures show the results for the upper sideband.

The analyser was configured in way to give the channel power within the frequency band fc+200 kHz to fc+800 kHz. The channel power was recorded for both with a tag in the field and with no tag present.

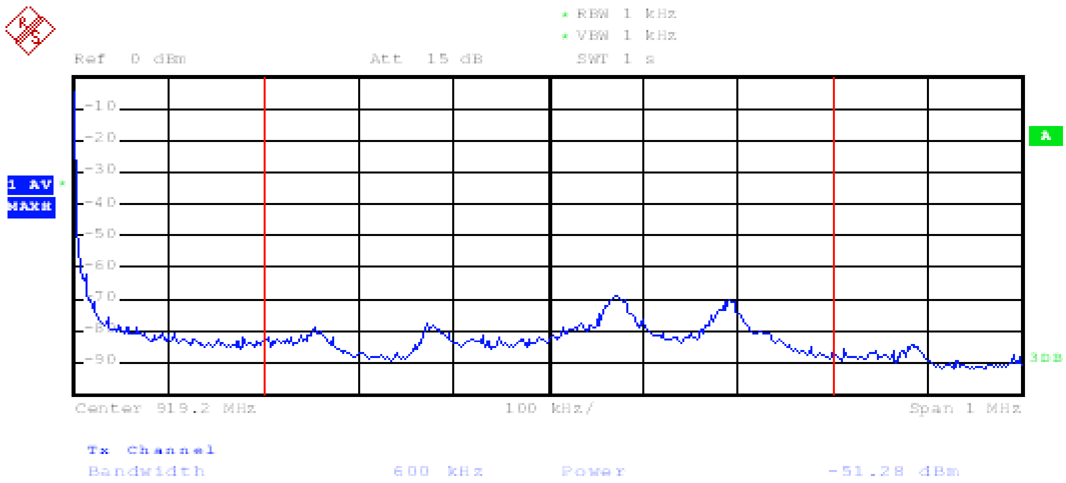


Figure A.10: Channel Power of the upper sideband with tag in the antenna field

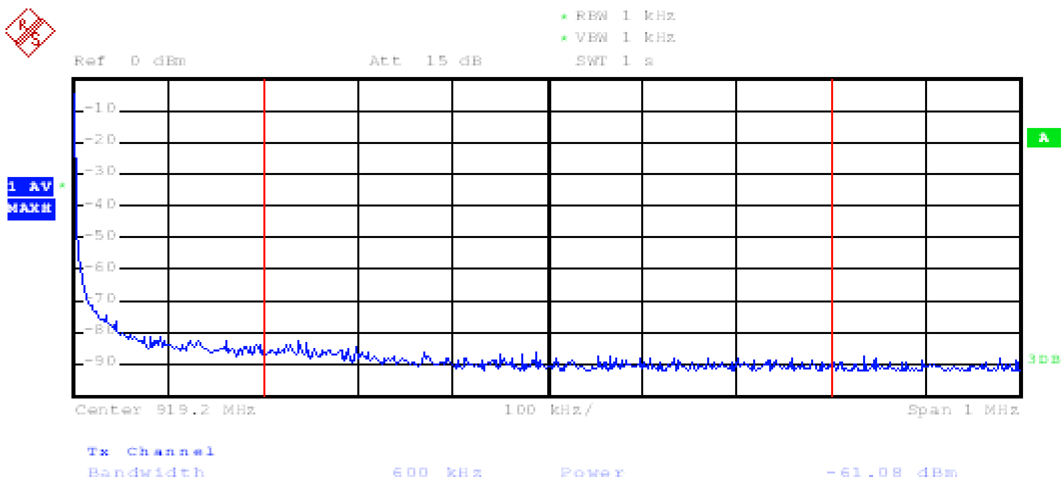


Figure A.11: Channel power of the upper sideband without tag in the antenna field

With a tag in the antenna field a channel power of -51,28 dBm was measured. Without the tag in the antenna field a channel power of just -61,08 dBm was measured.

Both measurements are required to calculate the power level of the tag response. The channel power measured with no tag present shall be subtracted from the measurement with a tag in reader field. In this way the influence of the interrogator was eliminated.

$$Pc = 10 * \log(10^{\frac{-51,28}{10}} - 10^{\frac{-61,08}{10}}) - 0,8\,dB + 35,25\,dB$$

$$Pc = -51,76\,dBm - 0,8\,dB + 35,25\,dB$$

$$Pc = -17,31\,dBm$$

The same measurement was performed for the lower sideband. The results are shown below. The analyser was configured in a way to give the channel power for the frequency band fc-800 kHz to fc-200 kHz. The channel power was recorded for the setup with tag into the field and without a tag into the field.

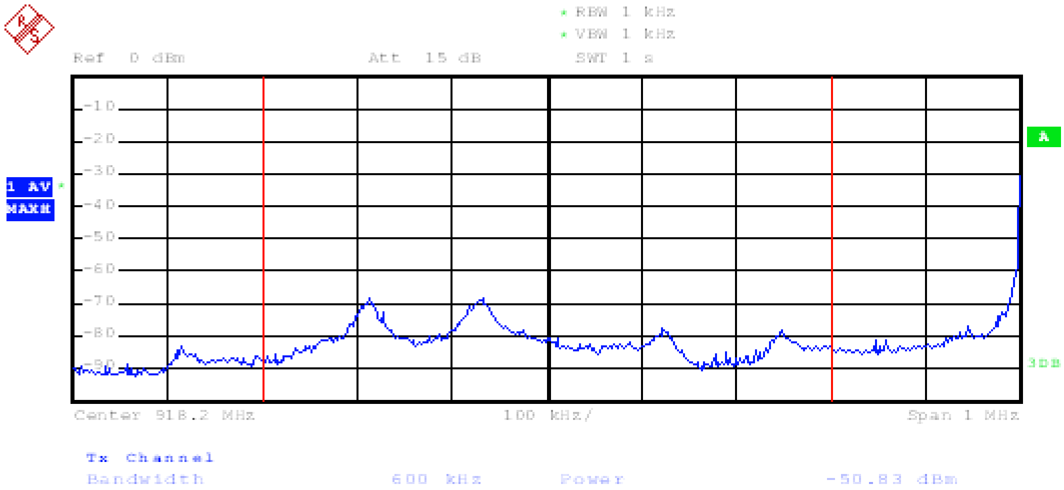


Figure A.12: Channel power of the lower sideband with tag in the antenna field

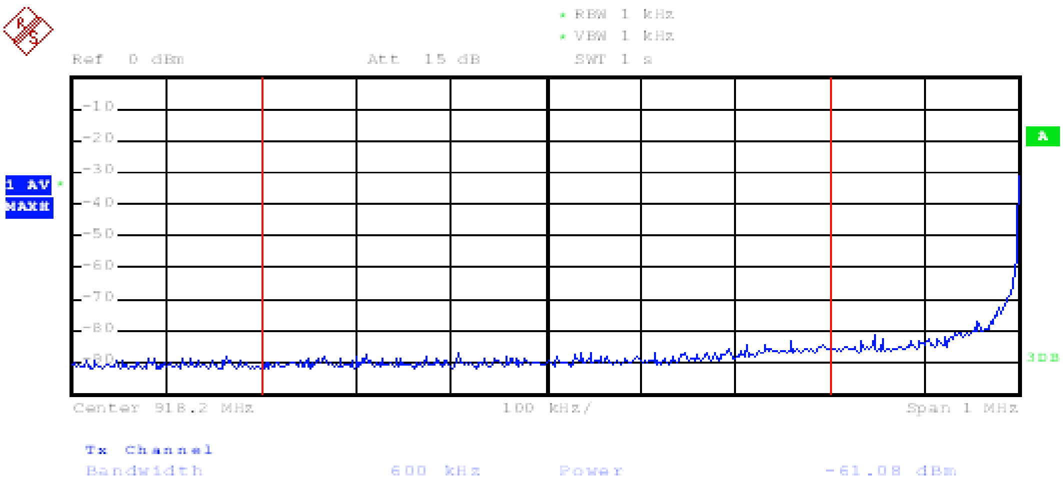


Figure A.13: Channel Power of the lower sideband without tag in the antenna field

With tag in the antenna field a channel power of -50,83 dBm was measured. Without the tag in the antenna field a channel power of just -61,08 dBm was measured.

Both measurements are required to calculate the power level of the tag response. The channel power measured in the sequence without tag in reader field needs to be subtracted from the measurement with tag. In this way the influence of the interrogator can be eliminated.

$$Pc = 10 * \log(10^{\frac{-50,83}{10}} - 10^{\frac{-61,08}{10}}) - 0,8\,dB + 35,25\,dB$$
$$Pc = -51,26\,dBm - 0,8\,dB + 35,25\,dB$$
$$Pc = -16,81\,dBm$$

According to EN 302 208-1 [1], the sideband with the higher power level should be considered as the tags response.

The following formula sets the result in relation to a 100 kHz channel bandwidth.

$$A = Pc + 10 \log \frac{100 \; kHz}{BW_{necessary}}$$

Where:

Pc is the radiated power of the unmodulated sub-carrier from the tag;

A is the absolute value of the power spectral density referred to a 100 kHz reference bandwidth;

$BW_{necessary}$ is 600 kHz, which is the necessary bandwidth of the tag.

$$A = -16,81 + 10 \log \frac{100 \; kHz}{600 \; kHz}$$
$$A = -24,59 \; dBm \; / \; 100 \; kHz$$

This value is below the defined threshold of -18 dBm / 100 kHz e.r.p.

A.6 Conclusions

The demonstrators satisfactory passed the compliance test.

Annex B (informative): Preliminary test results

B.1 Introduction

This annex contains the results of the preliminary tests on the test interrogators / demonstrators as described in clause 7.

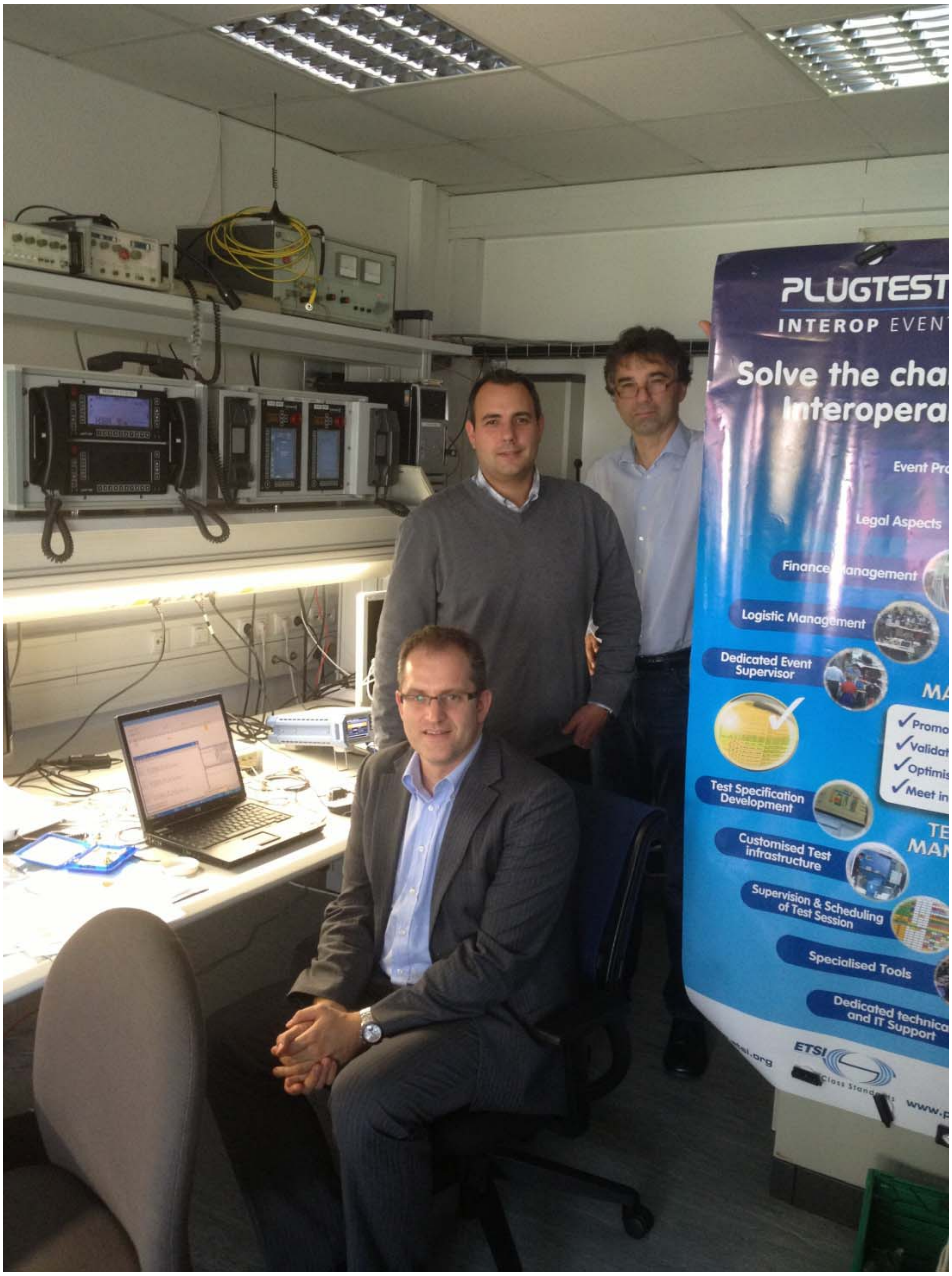


Figure B.1: Test lab with demonstrators on the table, GSM-R cab radios on the shelf and BTS antenna on the top shelf

B.2 Equipment settings applicable for all tests

Unless otherwise stated the following settings in this clause apply for all tests:

The tests were performed with the following setup of the BTS:

First GSM-R carrier (with BCCH and TCH channels) centre frequency $f_{GSM\text{-}R,first}$: = 924,6 MHz (channel 972)

Second GSM-R carrier (with TCH channels only) centre frequency $f_{GSM\text{-}R,secomd}$: = 922,6 MHz (channel 962)

As the effort to change the configurations of the first and second carrier is enormous and would have cost too much time during the tests, the transmit frequencies of the RFID equipment were modified instead in order to get the required frequency offsets.

The following definitions have been used for these measurements:

f_{off} frequency offset between the between the second carrier and RFID transmit channel
f_{off} = centre frequency of RFID transmit channel – centre frequency of second GSM-R carrier

t_{BCCH} Measured time between BTS signal on and detection of BCCH by demonstrator

t_{TCH} Measured time between BTS signal on and extraction of information that second carrier is supported

t_{TXon} Measured time between demonstrator on and RFID transmit on

$f_{GSM\text{-}R,first}$ First GSM-R carrier (with BCCH and TCH channels) centre frequency

$f_{GSM\text{-}R,second}$ Second GSM-R carrier (with TCH channels only) centre frequency

f_{TX} Centre frequency of RFID transmit (TX) channel

f_{TXn} Centre frequency of RFID transmit (TX) channel n (e.g. f_{TX3})

B.3 Tests in respect to clause 7.4.1.1

For this test the signal from the GSM-R BTS was connected through an attenuator to achieve a power level of -80 dBm at the input of the demonstrator GSM-R receiver. Table B.1 shows the measurement results for various f_{off} between $f_{GSM\text{-}r,First}$ and f_{TX}.

Table B.1: Transmit channel settings

f_{off} / kHz	t_{BCCH} / sec	t_{TCH} / sec	t_{TXon} / sec	Remark
-100	11	13	Never	
-100	7	10	Never	
+300	5	19	Never	
+300	5	16	Never	
+300	12	12	Never	
-300	6	22	Never	
-300	9	Infinite	Never	GSM-R receiver hang up
-300	5	Infinite	Never	GSM-R receiver hang up
-300	5	11	Never	Times measured after reset of demonstrator and GSM-R receiver
-300	6	8	Never	Times measured after reset of demonstrator and GSM-R receiver
-500	7	8	Never	
+700	Not measured	Not measured	After 60 seconds	The demonstrator always reserves 60 seconds to check for GSM-R communication and does not turn on the RFID transmit beforehand
-900	9	10	After 60 seconds	The demonstrator always reserves 60 seconds to check for GSM-R communication and does not turn on the RFID transmit beforehand
+900	8	8	After 60 seconds	The demonstrator always reserves 60 seconds to check for GSM-R communication and does not turn on the RFID transmit beforehand

During the test at f_{off} = -300 kHz some strange things happened. After the GSM-R receiver had recognized the BTS with a power level of -80 dBm and the BTS was then disconnected and reconnected again to simulate the turn-on of the BTS, the demonstrator only reported the first carrier, but not the second carrier and instead reported an error. This could not be repeated for varying power levels, as would happen in real life applications. During a subsequent investigation this behaviour was not repeatable. It should be noted that the detection also worked on these settings when the GSM-R receiver's USB connection was quickly disconnected and reconnected from the demonstrator before making the actual measurement.

As shown in table B.1 the demonstrator passed the test since in all cases where the second carrier was identified within the required 60 seconds. For f_{off} < 700 kHz the RFID transmit never turned on. For f_{off} >= 700 kHz the RFID transmit was turned on after 60 seconds. The demonstrator did not transmit immediately it detected the second carrier, as it used the rest of the 60 seconds to search for additional GSM-R carriers. This is necessary in real use since demonstrators will not have information about the number of active carriers.

Figure B.2 shows one example of the spectrum during these measurements.

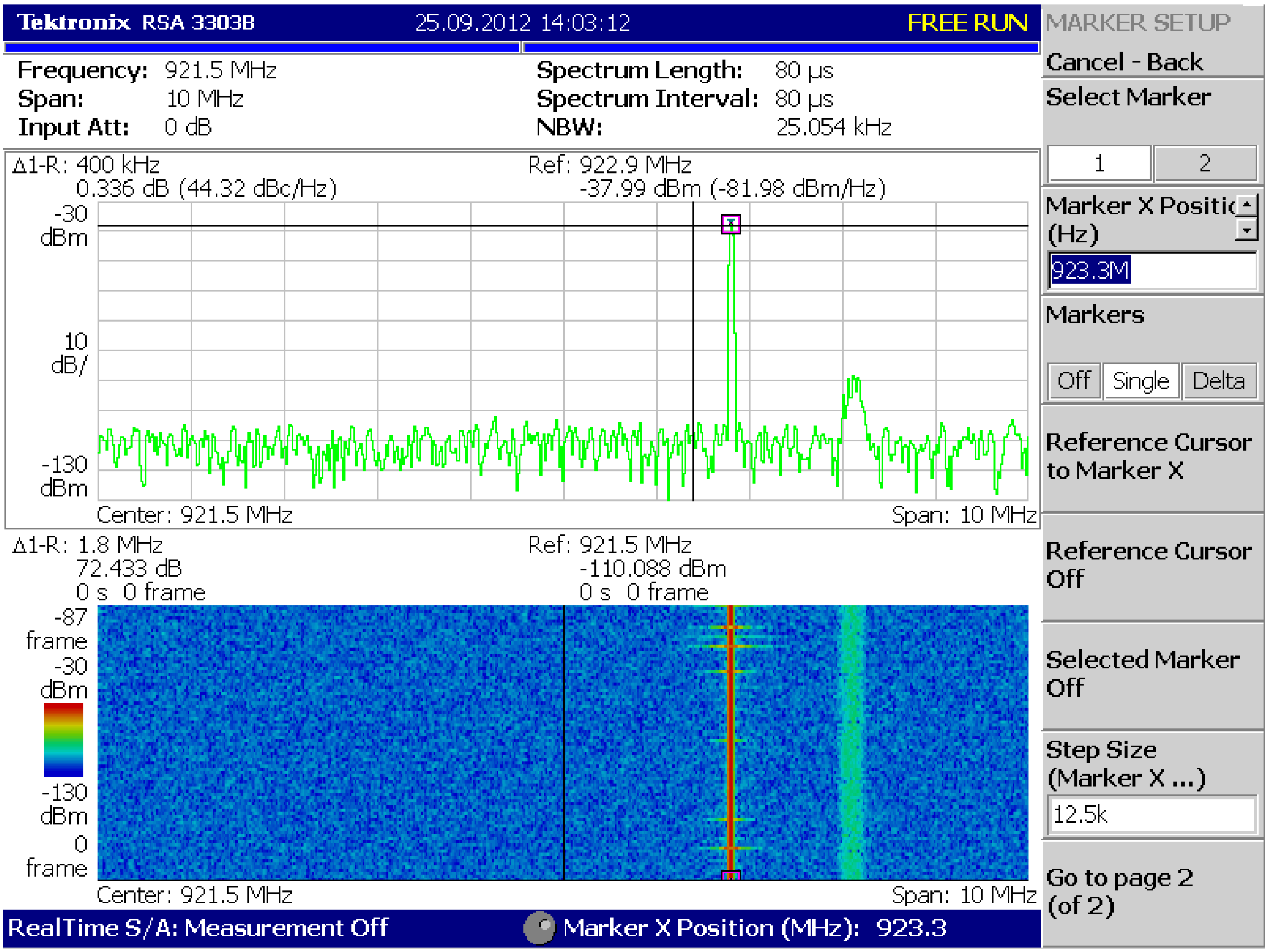


Figure B.2: Reader active with TCH offset of +700 kHz

Figure B.3 shows one example of the demonstrator output during these measurements.

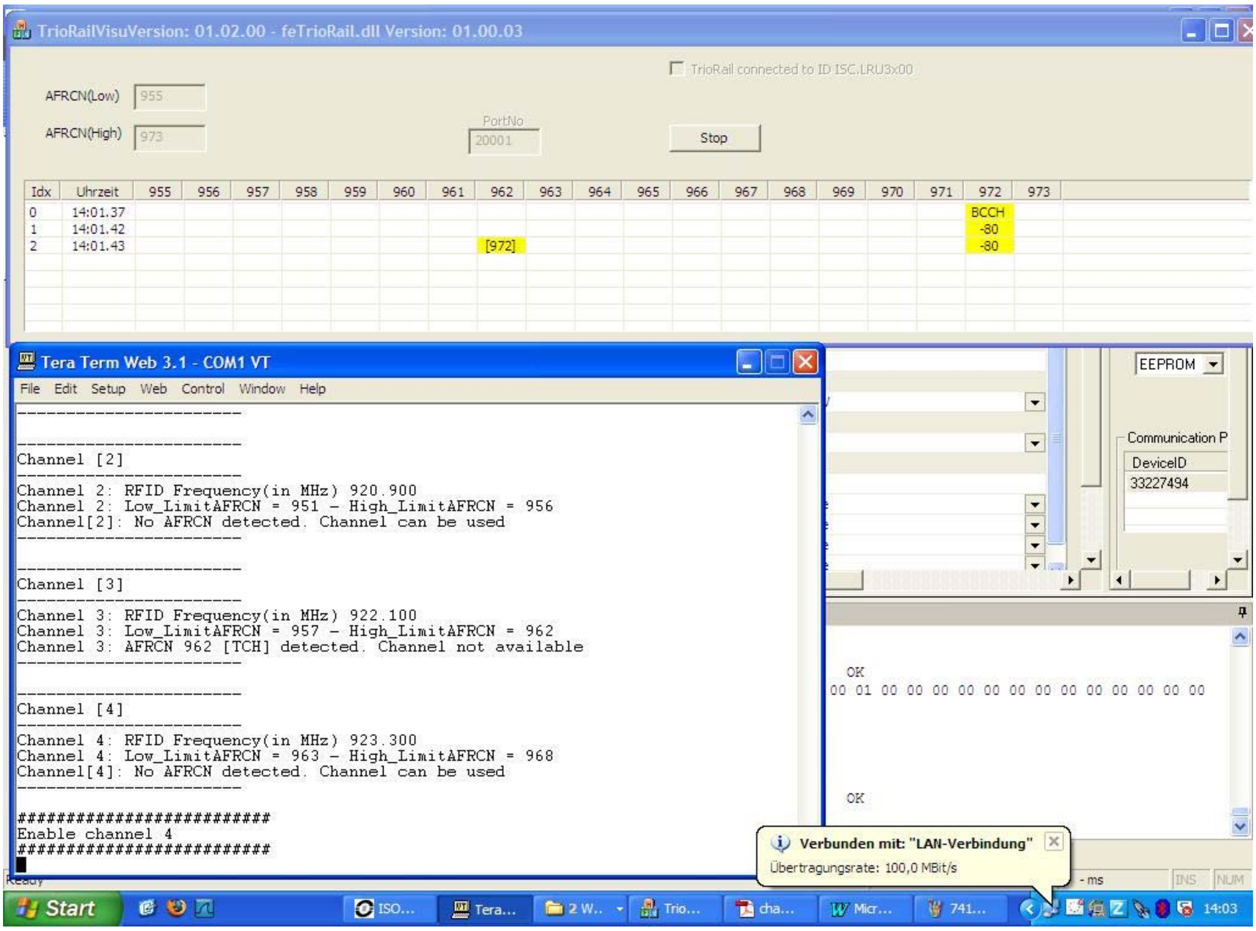


Figure B.3: Detection and Analysis with TCH offset of +700 kHz

B.4 Tests in respect to clause 7.4.1.2

For these tests the signal from the GSM-R BTS was connected through an attenuator to achieve a power level of -80 dBm at the input of the GSM-R receiver which was part of the demonstrator.

Test part 1: Demonstrator configured to use either TX3 or TX4

For the first measurement the demonstrator was configured so that it could use either TX3 or TX4 for transmission.

NOTE 1: As the GSM-R second carrier was at f = 922,6 MHz, this meant that TX4 at 922,9 MHz could not be used for RFID. Only TX3 at f = 921,7 was allowed to make RFID transmissions.

The following observations listed in sequence were recorded:

1) The time when the demonstrator was turned on was recorded as the start time.
2) The first carrier was detected after 12 seconds.
3) The second carrier was detected after 15 seconds.
4) The demonstrator reported that TX3 was available for use but transmission on TX4 was not permitted.
5) The demonstrator reported that TX3 was turned on after 60 seconds, which was verified on the spectrum analyser as shown in figure B.4.

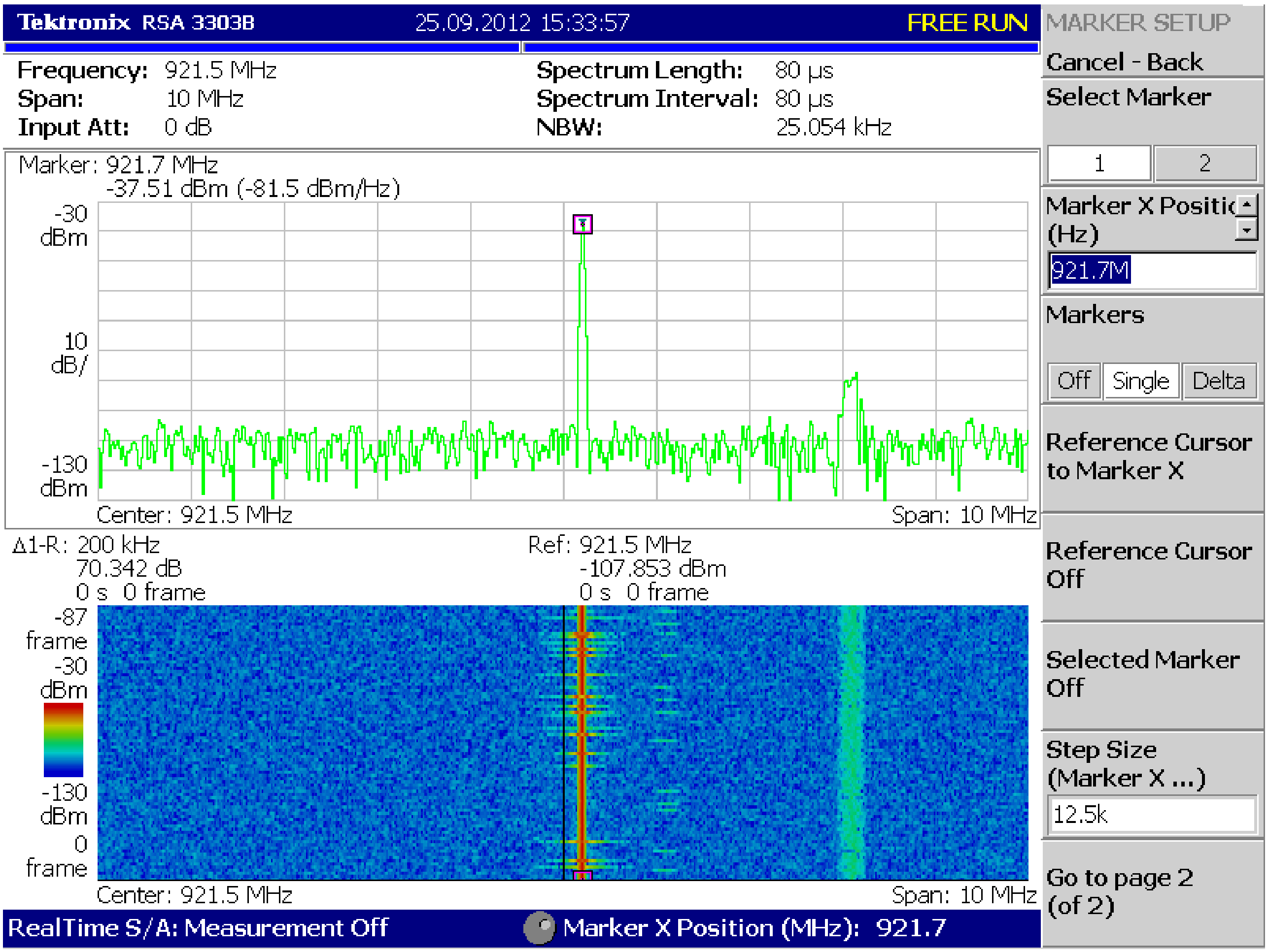


Figure B.4: Demonstrator Transmission at f_{TX} = 921,7 MHz and the GSM-R signal at $f_{GSM-R,first}$ = 924,6 MHz

Test part 2: Demonstrator configured to use only TX4

NOTE 2: The second GSM-R carrier was at 922,6 MHz, which meant that TX4 at 922,9 MHz was not available for RFID. The demonstrator should correctly report that all channels were blocked by GSM-R. This was due to the fact that the transmit channels TX1, TX2 and TX3 were disabled in the demonstrator configuration.

The following observations listed in sequence have been recorded:

1) The time when the demonstrator was turned on was recorded as the start time.

2) The first GSM-R carrier was detected after 2 seconds.

3) The second GSM-R carrier was detected after 10 seconds.

4) The demonstrator reported that all channels were disabled.

5) The demonstrator did not transmit, which was verified on the spectrum analyser as shown in figure B.5.

NOTE 3: The second GSM-R carrier was at 922,6 MHz, which meant that TX4 at 922,9 MHz was not available for use by RFID. The demonstrator should correctly report that all channels were blocked by GSM-R. This was due to the fact that the transmit channels TX1, TX2 and TX3 were disabled in the demonstrator configuration.

The following observations listed in sequence have been recorded

1) The time when the demonstrator was turned on was recorded as the start time.

2) The first GSM-R carrier was detected after 2 seconds.

3) The second GSM-R carrier was detected after 10 seconds.

4) The demonstrator reported that all channels were disabled.

5) The demonstrator did not transmit, which was verified on the spectrum analyser as shown in figure B.5.

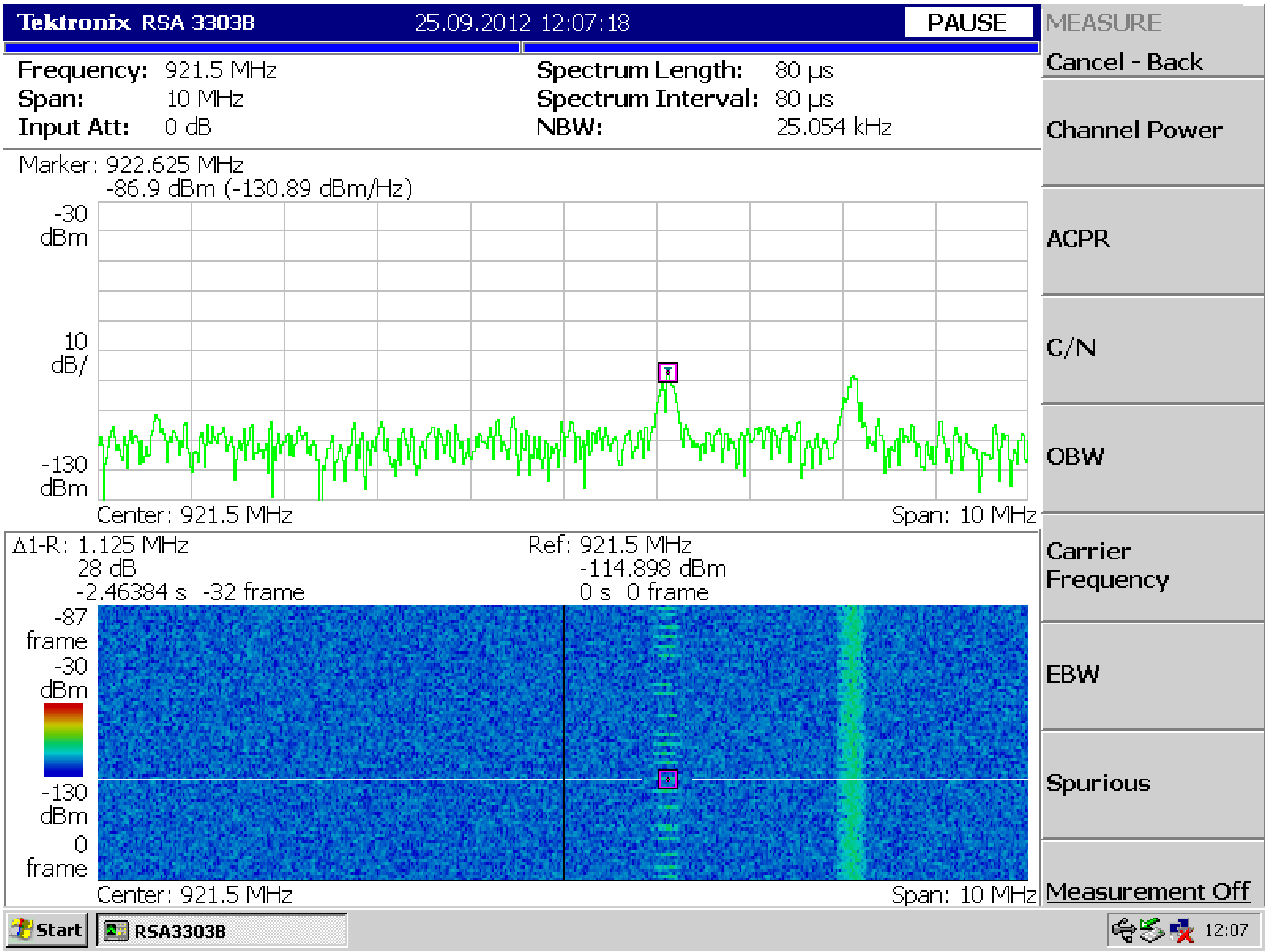


Figure B.5: All channels disabled. Only first and second GSM-R carriers are visible at $f_{GSM\text{-}R,first}$ = 924,6 MHz and $f_{GSM\text{-}R,second}$ = 922,6 MHz

The test passed as the results above show that in all cases the second GSM-R carrier was identified within the required 60 seconds. For f_{off} < 700 kHz the demonstrators never transmitted. For f_{off} >= 700 kHz the demonstrator started transmitting after 60 seconds. The demonstrator did not start to transmit immediately it had detected the second carrier. Instead it used the rest of the 60 seconds to search for additional GSM-R carriers. This is necessary since in real use the interrogator/demonstrator does not have any information about the number of active carriers.

B.5 Tests in respect to clause 7.4.1.3

For these tests the signal from the GSM-R BTS was connected through a variable attenuator to achieve the required power level at the input to the GSM-R receiver module of the demonstrator.

The demonstrator used TX4 which had a carrier frequency of 922,9 MHz. This was separated by less than 700 kHz from the second GSM-R carrier.

The following test runs were made.

First run

Power level / dBm	t_{BCCH} / sec	t_{TCH} / sec	Report by demonstrator
-80	5	14	No channel available for RFID transmit
-97	9	9	No channel available for RFID transmit
-99	6	6	TX4 channel available for RFID transmit

Second run

Power level / dBm	t_{BCCH} / sec	t_{TCH} / sec	Report by demonstrator
-80	5	11	No channel available for RFID transmit
-97	8	8	No channel available for RFID transmit
-99	4	4	TX4 channel available for RFID transmit

Figures B.6 and B.7 show the results of some of these tests.

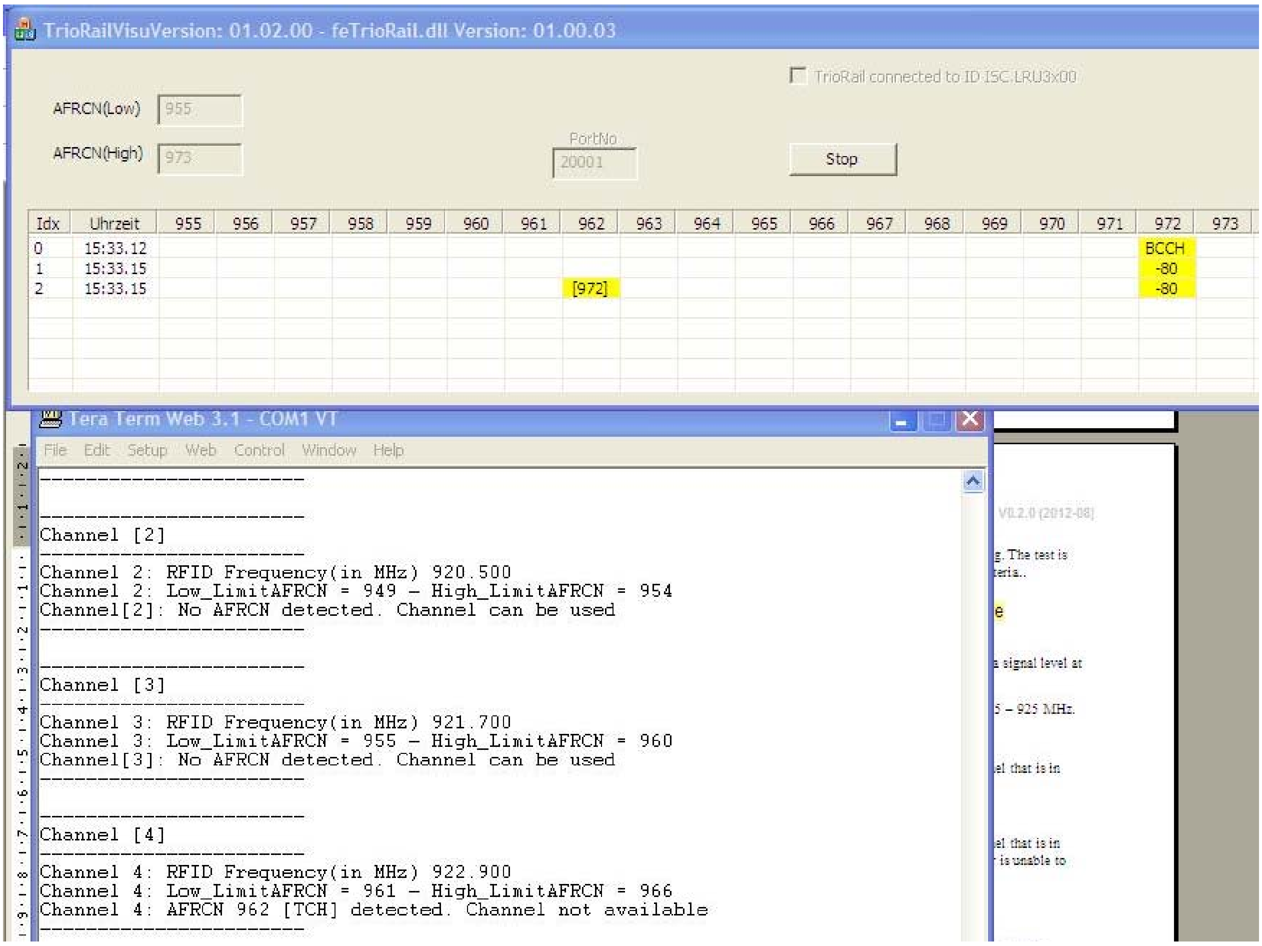


Figure B.6: Detection with GSM-R power level of -80 dBm, TX4 not available

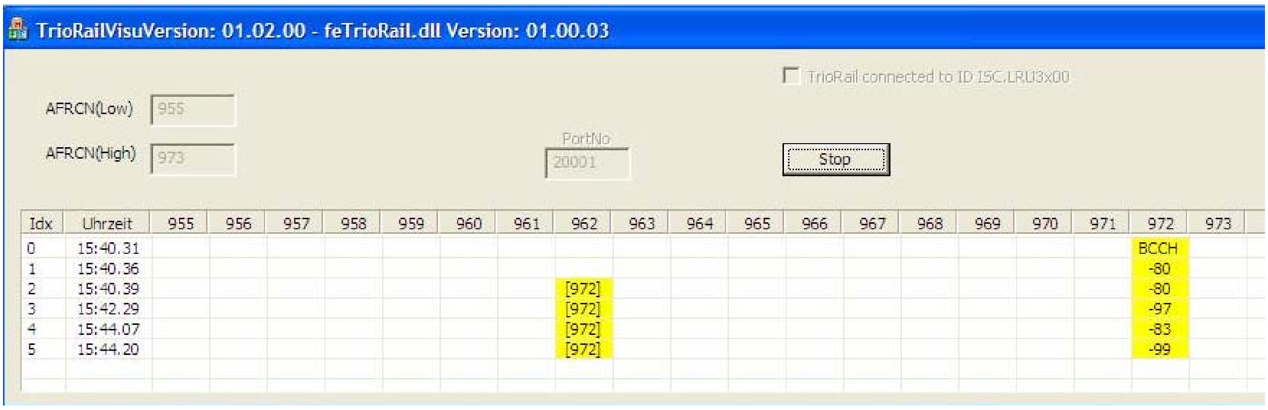


Figure B.7: Detection of various power levels

Figures B.6 and B.7 show the reports for the demonstrator of some of these tests.

Figure B.8 shows an example of where the demonstrator did transmit since the first GSM-R carrier with the BCCH is below -98 dBm.

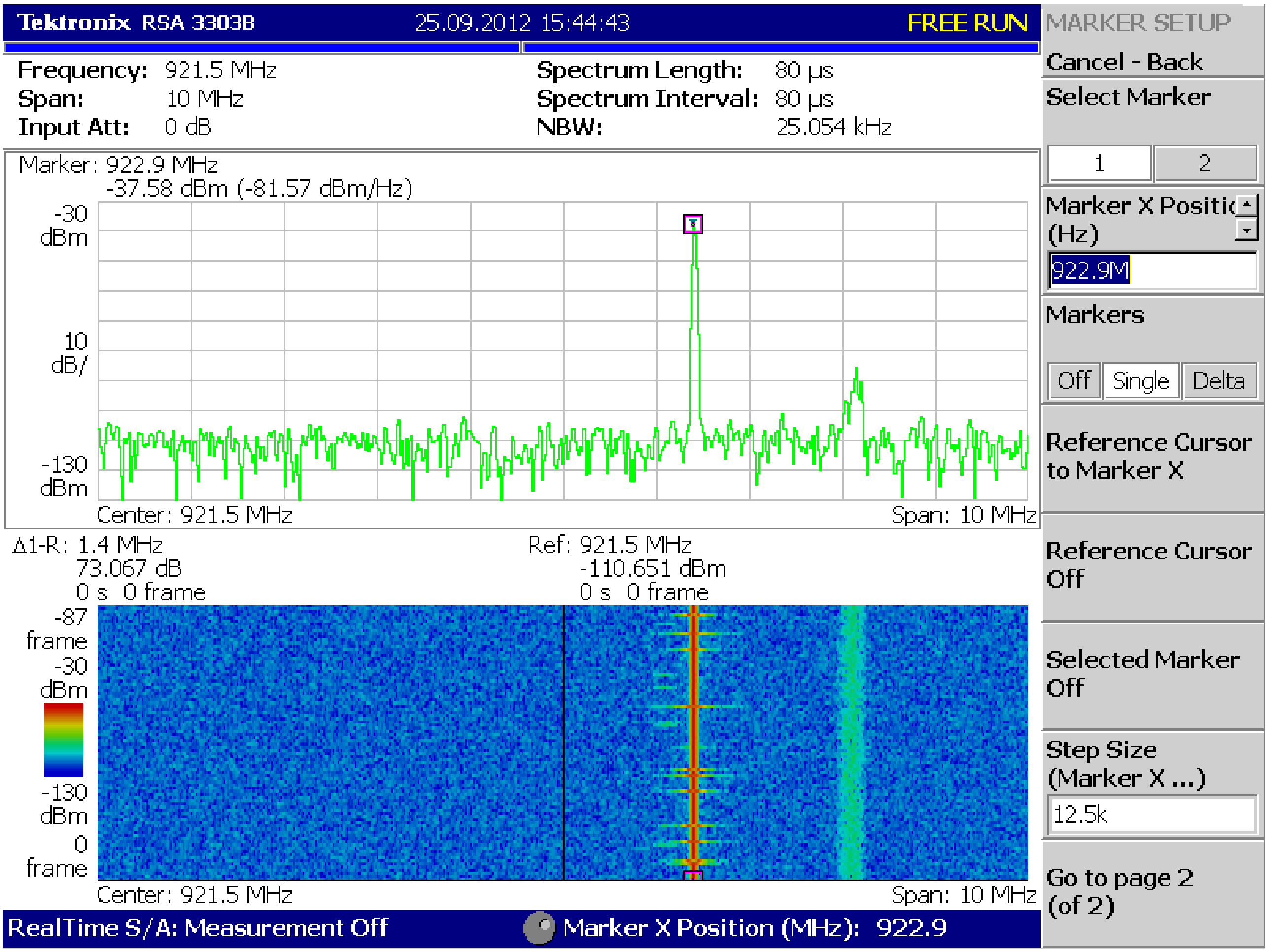


Figure B.8: Transmission at f_{TX} = 921,5 MHz and the GSM-R signal at $f_{GSM-R,first}$ = 924,6 MHz at a power level of -99 dBm

The demonstrator passed the tests as the results above show that in all cases where the first GSM-R carrier is >= -98 dBm the demonstrator did not transmit. In this test f_{off} < 700 kHz was chosen.

B.6 Tests in respect to clause 7.4.2

For this test the power of the GSM-R carrier with the BCCH was measured at the RF input port of the demonstrator.

Figure B.9: Initial position of the GSM-BTS antenna (top left) and the demonstrator antenna (right) and the tags placed in front of the demonstrator antenna

Table B.2: Test results for impact of GSM-R BTS on Demonstrator system with frequency for f_{TX} = 923,3 MHz and frequency of second GSM-R carrier $f_{GSM-R,second}$ = 922,6 MHz (f_{off} = 700 kHz)

Power level of BCCH / dBm	Tag identification time $t_{id,1}$ / ms	No. of tags identified	Comment
-100	111	50	
-95	113	50	
-90	120	50	
-85	136	50	
-80	115	50	
-75	102	50	
-70	120	50	
-65	114	50	
-60			Max. BCCH power level limited to -63 dBm
> -60			Max. BCCH power level limited to -63 dBm

The test results in table B.2 show that up to -65 dBm, no impact was observed. The level of -65 dBm was the maximum that could be achieved by reducing the distance between the demonstrator antenna and the BTS antennas.

In order to make the impact more visible, a series of measurements were made. For these measurements the GSM-R system was setup with the power of the GSM-R carrier adjusted to -74 dBm (conducted) at the input to the demonstrator. Some impact on the RFID performance was detected as may be seen by comparing tables B.3 and B.4.

Table B.3: Test results for Demonstrator system with a GSM-R system active

Measurement no.	Tag identification time $t_{id,2}$ / ms	No. of tags identified	Comment
1	109	49	
2	112	49	
3	113	49	
4	106	49	
5	108	49	
6	104	49	
7	111	49	
8	114	49	
9	113	49	
10	111	49	
Average	110,1	49	

Table B.4: Test results for Demonstrator system showing impact of GSM-R BTS with frequency for first GSM-R carrier = 924,6 MHz and Demonstrator frequency = 921,9 MHz with a first GSM-R carrier power level of -75 dBm a the Demonstrator input

Measurement no.	Tag identification time $t_{id,2}$ / ms	No. of tags identified	Comment
1	239	49	
2	102	48	
3	131	49	
4	117	49	
5	109	49	
6	109	49	
7	138	49	
8	578	49	48 tags were recognized after less than 150 ms. One tag was recognized only after 578 ms
9	119	49	
10	128	49	
Average	177	48,9	

A comparison of the measurement results using formula 2 for Demonstrator A gives:

$$1-\frac{\min_{i=2..3}\left(t_{id,i}\right)}{\max_{i=2..3}\left(t_{id,i}\right)}=37,84\%$$

The above results show that the demonstrator is significantly influenced by the variability in read performance, but the average tag loss rate is still only 1-48,9/49 = -0,2 %.

B.7 Tests in respect to clause 7.4.3

Figure B.10 shows the test setup with a GSM-R mobile placed opposite the demonstrator and very close to the RFID tags.

Figure B.10: GSM-R mobile placed opposite of the demonstrator and just above the RFID tags

During the tests the GSM-R mobile used both the second and the first GSM-R carrier.

Table B.5: Test results for Demonstrator system showing impact of GSM-R Mobile with frequency for first GSM-R carrier = 924,6 MHz

Measurement no.	Tag identification time / ms	No. of tags identified	Comment
1	102	47	
2	809	48	
3	168	49	
4	248	49	
5	116	48	
6	724	48	
7	181	47	
8	116	47	
9	98	47	
10	136	47	
Average	**269,8**	**47,7**	
NOTE: GSM-R Mobile transmit frequency = 879,6 MHz and Demonstrator frequency = 921,9 MHz with a first GSM-R carrier power level of -75 dBm at the Demonstrator input.			

Table B.6: Test results for Demonstrator system showing impact of GSM-R Mobile with frequency for first GSM-R carrier = 924,6 MHz, second GSM-R carrier = 922,6 MHz

Measurement no.	Tag identification time / ms	No. of tags identified	Comment
1	117	47	
2	234	47	
3	111	47	
4	103	47	
5	720	47	
6	122	47	
7	111	47	
8	347	47	
9	110	47	
10	458	47	
Average	**243,3**	**47**	
NOTE: GSM-R Mobile transmit frequency = 877,6 MHz and Demonstrator frequency = 921,9 MHz with a GSM-R mobile moving towards the tags to a close proximity.			

Comparison of the measurement results using formula 2 for tables B.5 and B.6 using table B.3 as a reference for Demonstrator A show the following:

Table B.5 in respect to table B.3:

$$1-\frac{\min_{i=2..3}\left(t_{id,i}\right)}{\max_{i=2..3}\left(t_{id,i}\right)}=1-\frac{110,1}{269,8}=54,7\%$$

Table B.6 in respect to table B.3:

$$1-\frac{\min_{i=2..3}\left(t_{id,i}\right)}{\max_{i=2..3}\left(t_{id,i}\right)}=1-\frac{110,1}{243,3}=59,2\%$$

The above results show that the read performance of the demonstrator is significantly affected,, but the average tag loss rate is still only 1-47,7/49 = -2,7 % and 1-47/49 = -4,1 % respectively.

B.8 Tests in respect to clause 7.4.4

The tests were performed using the configuration listed in table B.7.

Table B.7: Test configuration

Parameter	Value	Remark
Total no. of tags per reader:	50	
Distance Reader-Tags	0,65 m	
$f_{GSM-R,first}$	924,6 MHz	
$f_{GSM-R,second}$	922,6 MHz	CH7
BCCH power level	-85 dBm	
Demonstrator A $f_{TX.A}$	921,7 MHz	TX3
Demonstrator B $f_{TX.B}$	921,7 MHz	TX3

During these tests a GSM-R communication link was setup with four cab radios and five mobiles. Two mobiles communicated over the air. All other GSM-R terminals used a wired link. As a result the second carrier was subject to a certain duty cycle. The first carrier was certainly always turned on.

Initially the two demonstrators were setup at a distance of 3 m from their respective tags as shown in figure B.13. However, the cross-reading between the two tag populations was too high and caused a significant increase in the reading time due to multiple collisions and late detected tags. To overcome this problem, an increased separation between the two tag populations was introduced. Demonstrator A remained in the test lab, while demonstrator B was moved to the corridor. The distance between the two demonstrators was measured at 8 m distance. In addition they were separated by a partition with a very low loss.

Figure B.11: Demonstrator A + tags located in the lab

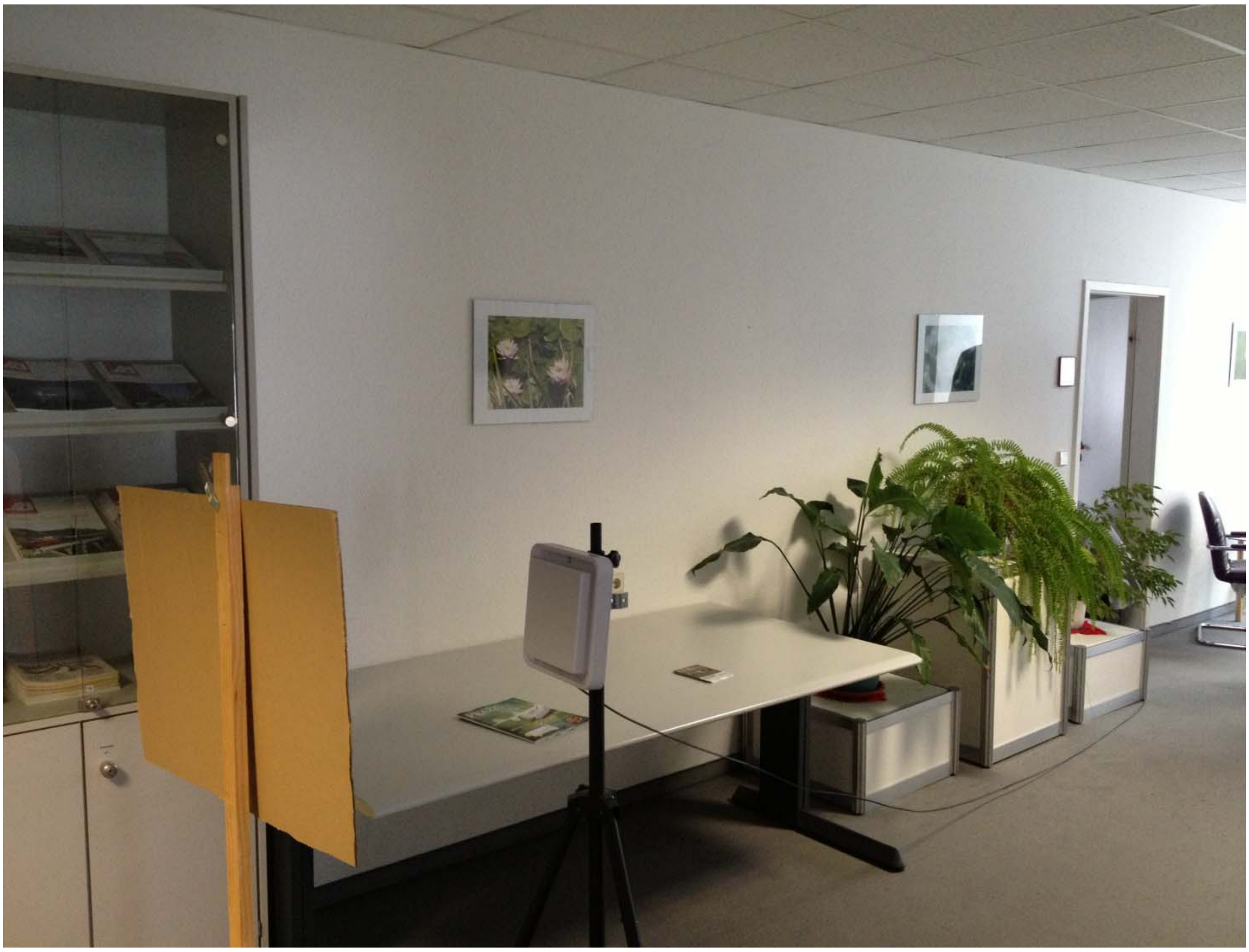


Figure B.12: Demonstrator B + tags located on the corridor

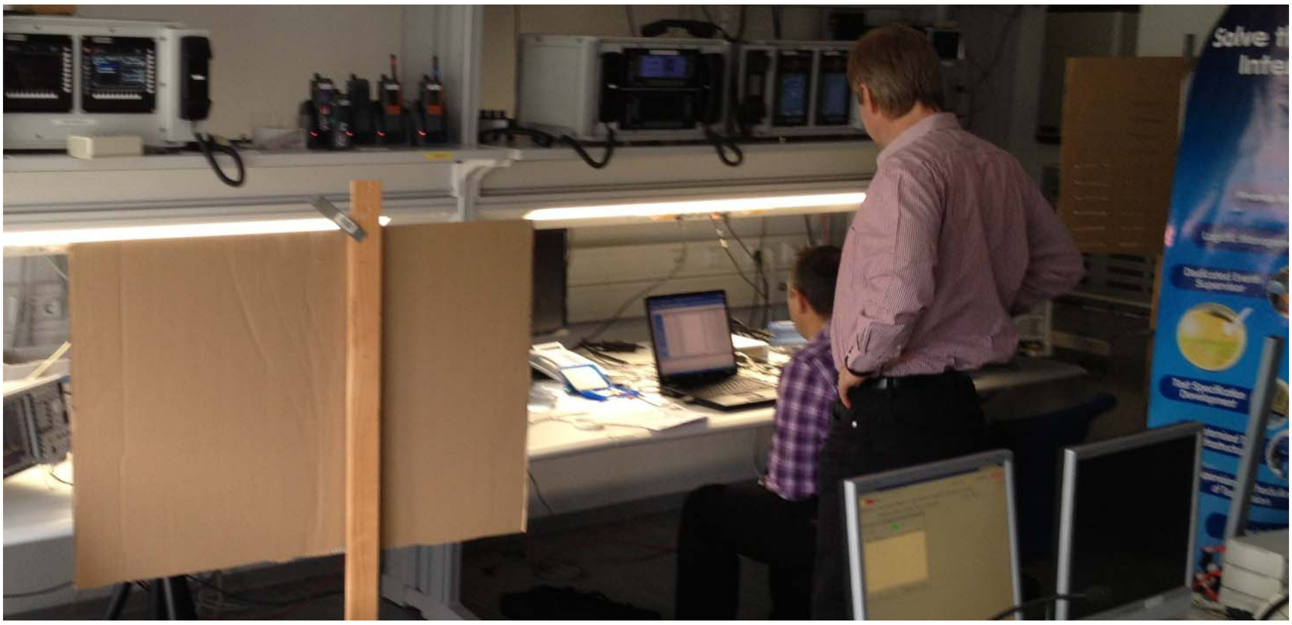


Figure B.13: Demonstrator A + tags and demonstrator B + tags at a distance of 3 m

Table B.8: Test results for Demonstrator A only

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A0 / ms
1	50	116
2	50	104
3	50	114
4	50	105
5	50	124
6	50	112
7	50	114
8	50	117
9	50	108
10	50	125
Average	**50**	**113,9**
Min.	50	104
Max.	50	125

Table B.9: Test results for Demonstrator B only

Meas. No	No. of tags identified (Demonstrator B)	Tag identification time tid,B0 / ms
1	50	125
2	50	116
3	50	109
4	50	116
5	50	124
6	50	123
7	50	127
8	50	117
9	50	119
10	50	119
Average	**50**	**119,5**
Min.	50	109
Max.	50	127

Table B.10: Test results for Demonstrator A and B at distance of 3 m

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B1 / ms
1	50	148	50	147
2	50	136	50	135
3	50	127	50	130
4	50	126	50	110
5	50	204	50	116
6	50	164	50	116
7	50	179	50	156
8	50	118	50	159
9	50	218	50	157
10	50	162	50	186
Average	**50**	**158,2**	**50**	**141,2**
Min.	50	118	50	110
Max.	50	218	50	186

Table B.11: Test results for Demonstrator A and B at distance of 8 m

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B1 / ms
1	50	117	50	116
2	50	106	50	110
3	50	116	50	122
4	50	122	50	118
5	50	112	50	114
6	50	104	50	120
7	50	116	50	119
8	50	111	50	125
9	50	109	50	125
10	50	113	50	112
Average	**50**	**112,6**	**50**	**118,1**
Min.	50	104	50	110
Max.	50	122	50	125

Using formula 2 the results were satisfactory as shown below:

Demonstrator A:

$$1-\frac{\min_{i=1..N}\left(t_{id,Ai}\right)}{\max_{i=1..N}\left(t_{id,Ai}\right)}=1{,}14\% \leq 5\%$$

Demonstrator B:

$$1-\frac{\min_{i=1..N}\left(t_{id,Bi}\right)}{\max_{i=1..N}\left(t_{id,Bi}\right)}=1{,}14\% \leq 5\%$$

NOTE: All measurements were performed with the GSM-R system operating in parallel.

B.9 Tests in respect to clause 7.4.5

The tests were performed with the configuration listed in table B.12.

Table B.12: Test configuration

Parameter	Value	Remark
Total no. of tags per reader:	50	
Distance Reader-Tags	0,65 m	
First GSM-R carrier frequency(BCCH)	924,6 MHz	
Second GSM-R carrier frequency(TCH)	922,6 MHz	CH7
BCCH level	-85 dBm	
Demonstrator A channel	921,7 MHz	TX3
Demonstrator B channel	921,7 MHz	TX3
Distance between demonstrators	8 m	

The output power of the GSM-R BTS was 0,8 W e.r.p. The power at the antenna of demonstrator A and the tag group belonging to demonstrator A, which were both 130 cm away from the BTS antenna, was -63 dBm.

Table B.13: Test results for Demonstrator A with frequency for TX3 = 921,9 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (f_{off} = -700 kHz)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms
1	50	126
2	50	122
3	50	125
4	50	109
5	50	117
6	50	136
7	50	120
8	50	132
9	50	123
10	50	137
Average	**50**	**124,7**
Min.	50	109
Max.	50	137

Table B.14: Test results for Demonstrator B with frequency for TX3 = 921,9 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (foff = -700 kHz)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms
1	50	135
2	50	112
3	50	119
4	50	124
5	50	123
6	50	126
7	50	127
8	50	125
9	50	108
10	50	106
Average	**50**	**120,5**
Min.	50	106
Max.	50	135

Table B.15: Test results for Demonstrators A and B with frequency for TX3 = 921,7 MHz and GSM-R system off

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A0 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B0 / ms
1	50	102	50	138
2	50	118	50	127
3	50	111	50	118
4	50	104	50	112
5	50	107	50	112
6	50	114	50	123
7	50	114	50	132
8	50	126	50	114
9	50	114	50	123
10	50	105	50	117
Average	**50**	**111,5**	**50**	**121,6**
Min.	50	102	50	112
Max.	50	126	50	138

Table B.16: Test results for Demonstrators A and B with frequency for TX3 = 921,9 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (f_{off} = -700 kHz)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B1 / ms
1	50	107	50	120
2	50	136	50	123
3	50	114	50	946
4	50	117	50	122
5	50	121	50	122
6	50	120	50	114
7	50	110	50	127
8	50	138	50	315
9	50	114	50	113
10	50	862	50	108
Average	**50**	**193,9**	**50**	**221**
Min.	50	107	50	108
Max.	50	862	50	946
NOTE: At -700 KHz offset there were several conflicts, which were most probably caused by collisions during reading of the tags and subsequent re-tries. A review of the log of the tag response showed that, without TCH transmission, the tag response time is between 1 ms and 3 ms. In the presence of the TCH signal the tag response time increases up to 25 ms.				

Table B.17: Test results for Demonstrators A with frequency for TX3 = 921,9 MHz

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A2 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B2 / ms
1	50	118	0	Not active
2	50	111	0	Not active
3	50	111	0	Not active
4	50	106	0	Not active
5	50	124	0	Not active
6	50	118	0	Not active
7	50	126	0	Not active
8	50	119	0	Not active
9	50	117	0	Not active
10	50	119	0	Not active
Average	**50**	**116,9**	**0**	**Not active**
Min.	50	106	0	Not active
Max.	50	126	0	Not active
NOTE 1: Demonstrator B is never active as |foff| < 700 kHz. NOTE 2: Demonstrator B with frequency for TX4 = 923,1 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (f_{off},A = -700 kHz; f_{off}.B=500 kHz).				

Table B.18: Test results for Demonstrators A with frequency for TX3 = 922,1 MHz

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A3 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B3 / ms
1	0	Not active	50	122
2	0	Not active	50	123
3	0	Not active	50	114
4	0	Not active	50	116
5	0	Not active	50	122
6	0	Not active	50	115
7	0	Not active	50	135
8	0	Not active	50	133
9	0	Not active	50	115
10	0	Not active	50	117
Average	**0**	**Not active**	**50**	**121,2**
Min.	0	Not active	50	114
Max.	0	Not active	50	135
NOTE 1: Demonstrator A is never active as |foff| < 700 kHz. NOTE 2: Demonstrator B with frequency for TX4 = 923,3 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (f_{off},A = -500 kHz; f_{off}.B = 700 kHz).				

The test failed as using formula 2 the results are as follows:

Demonstrator A:

$$1-\frac{\min_{i=1..N}\left(t_{id,Ai}\right)}{\max_{i=1..N}\left(t_{id,Ai}\right)}=42{,}50\%\geq 5\%$$

Demonstrator B:

$$1-\frac{\min_{i=1..N}\left(t_{id,Bi}\right)}{\max_{i=1..N}\left(t_{id,Bi}\right)}=45{,}17\%\geq 5\%$$

Extra test

For these tests four additional cab radios were turned on in order to increase the duty cycle of the second GSM-R carrier.

Table B.19: Test results for Demonstrators A and B with frequency for TX3 = 921,9 MHz and frequency of second GSM-R carrier (TCH) = 922,6 MHz (f_{off} = -700 kHz)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A3 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B3 / ms
1	0	116	50	126
2	0	122	50	135
3	0	115	50	862
4	0	123	50	291
5	0	125	50	132
6	0	103	50	957
7	0	116	50	143
8	0	112	50	123
9	0	494	50	118
10	0	116	50	120
Average	**0**	154,2	**50**	300,7
Min.	0	103	50	118
Max.	0	494	50	957

From table B.16 the test results show that an increase in the duty cycle of the second GSM-R carrier does not have an impact on the performance of the RFID system.

B.10 Conclusions

The measurement results of the preliminary tests showed that the mitigation technique worked satisfactorily. The RFID equipment behaved as intended. There was no interference between RFID and GSM-R.

The results showed that the mitigation technique used for spectrum sharing fulfilled the requirements set by the railways.

In future there will be a mandatory requirement for GSM-R systems using ER-GSM to support System Information 1 in the BCCH that is included in the ARFCN.

The proposed channel plan for RFID and the mitigation method confirmed the need for a separation of 700 kHz between the channel centre frequency of RFID and the ER-GSM channel centre frequency, which has been proposed in [i.3] due to measured C/I = -72 dB. Furthermore the proposed channel plan for RFID provides a separation of 1 300 kHz between the centre frequency of the highest RFID channel at 919,9 MHz and the lowest channel of the R-GSM band at 921,2 MHz.

Annex C (informative): Field trial test results

C.1 Introduction

This annex contains the results of the field trials as described in clause 8. The test equipment including the demonstrators was setup in a meeting room at Wiesbaden Hauptbahnhof on the first floor alongside Track 1. The exact location can be found on the map in figure C.1.

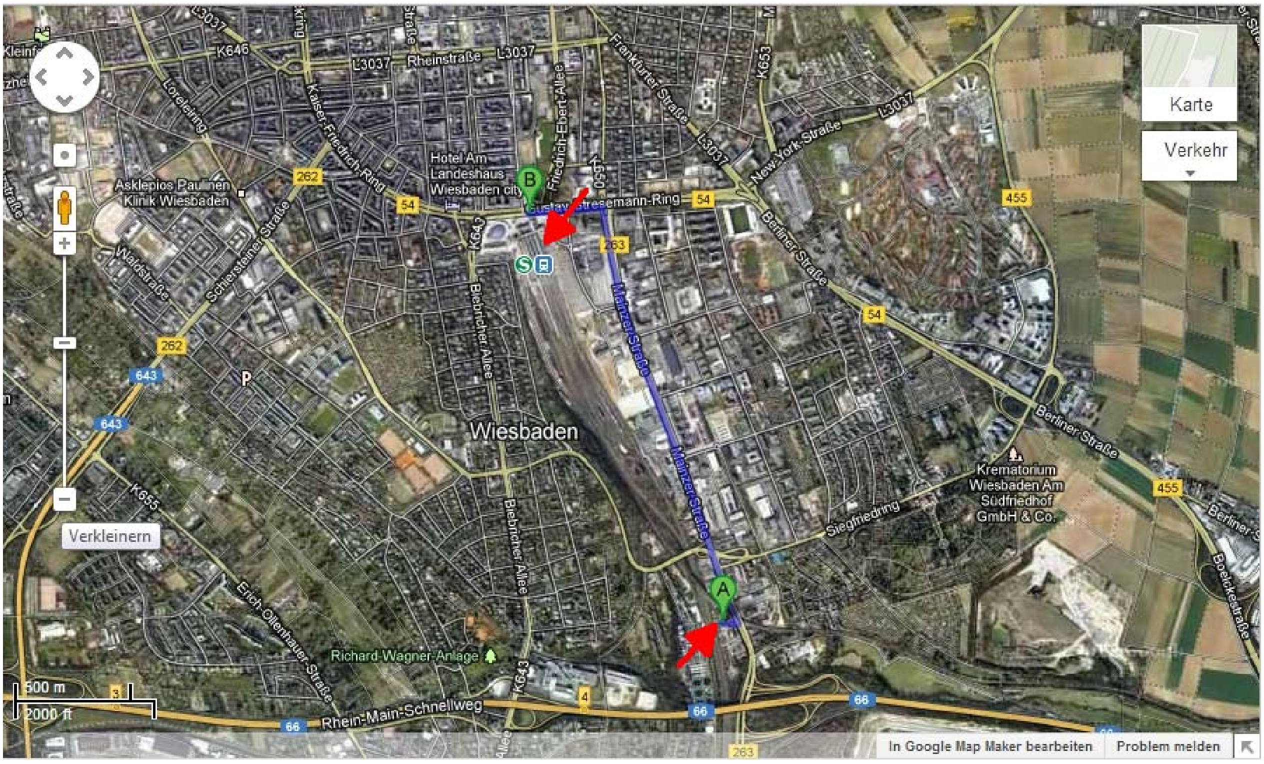


Figure C.1: Test team location (arrow near B) and BTS location (arrow near A) (Source: google.com)

Figure C.2 shows the location of the GSM-R BTS and antenna. The signals from the BTS were identified and used for GSM-R communication during the tests

Figure C.2: BTS with antenna on mast (Source: bing.com)

Figures C.3 and C.4 show the equipment and its placement as used for the test.

Figure C.3: Demonstrator A and Demonstrator B with GSM-R detection module on top

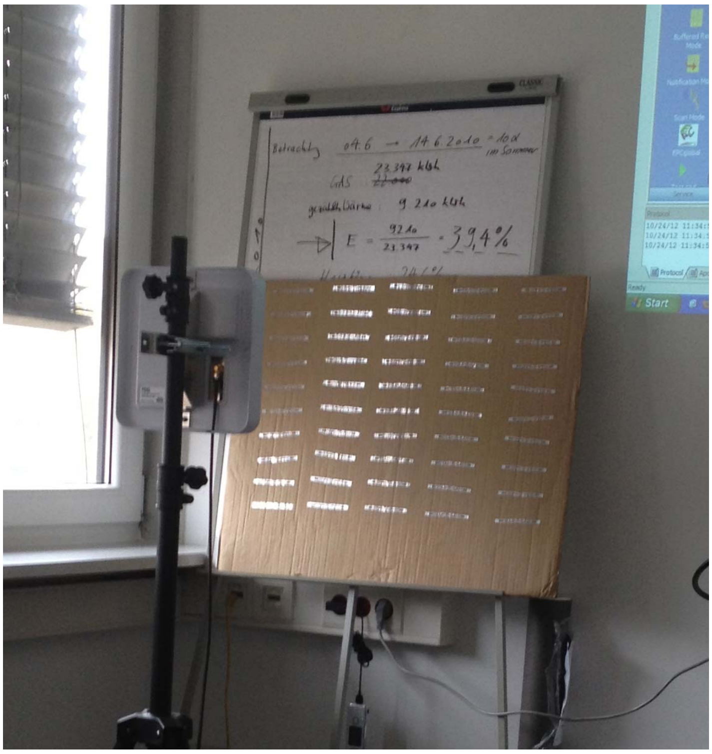


Figure C.4: Demonstrator B antenna with 50 RFID tags

C.2 Tests in respect to clause 8.3.1

The reference measurements were made in order to have a basis for comparison and provided an understanding of the standard operations of the GSM-R system at the trial site.

Whenever the demonstrators were turned on, a check was made for the presence of GSM-R transmissions. As the nearby GSM-R BTS was being used by Deutsche Bahn at Wiesbaden Hauptbahnhof, the signal was always present. Demonstrator A together with 50 tags was placed in the corridor outside the meeting room to avoid the possibility that some tags might be identified by both demonstrators. Demonstrator B was placed in the meeting room as shown in figure C.4.

Figures C.5 and C.6 show the logs from demonstrator A and demonstrator B respectively of detected GSM-R signals and available RFID TX channels after power-up. Both demonstrators reported that they had detected an ARFCN signal on channel 958. This equates to a frequency of 921,8 MHz ($f_{GSM-R,second}$). Figure C.6 showed that demonstrator B had detected another GSM-R carrier transmitting a BCCH message. However, the power level was below the threshold of -98 dBm and therefore it did not have an impact on the RFID operation.

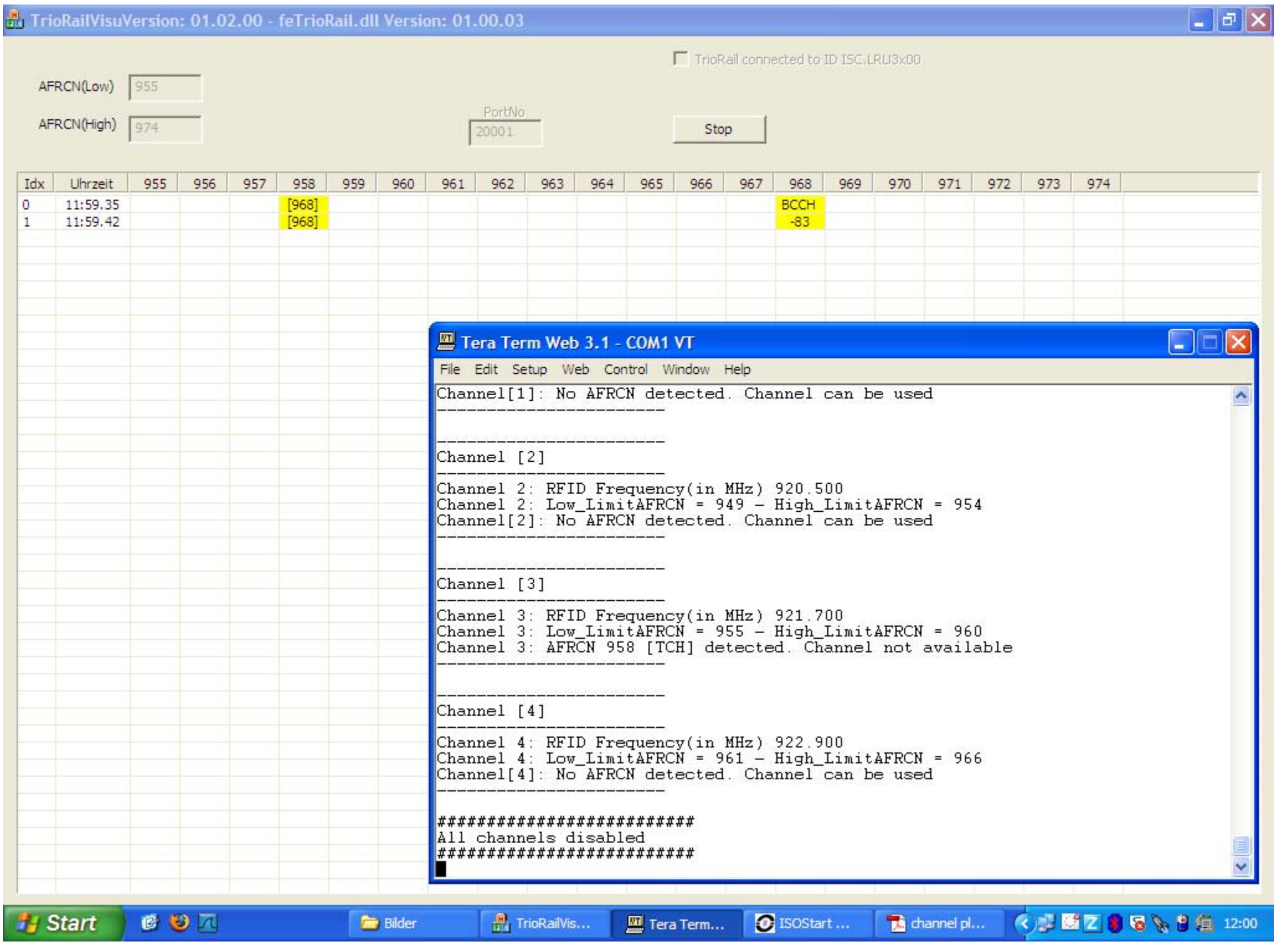


Figure C.5: Report by Demonstrator A on available channels

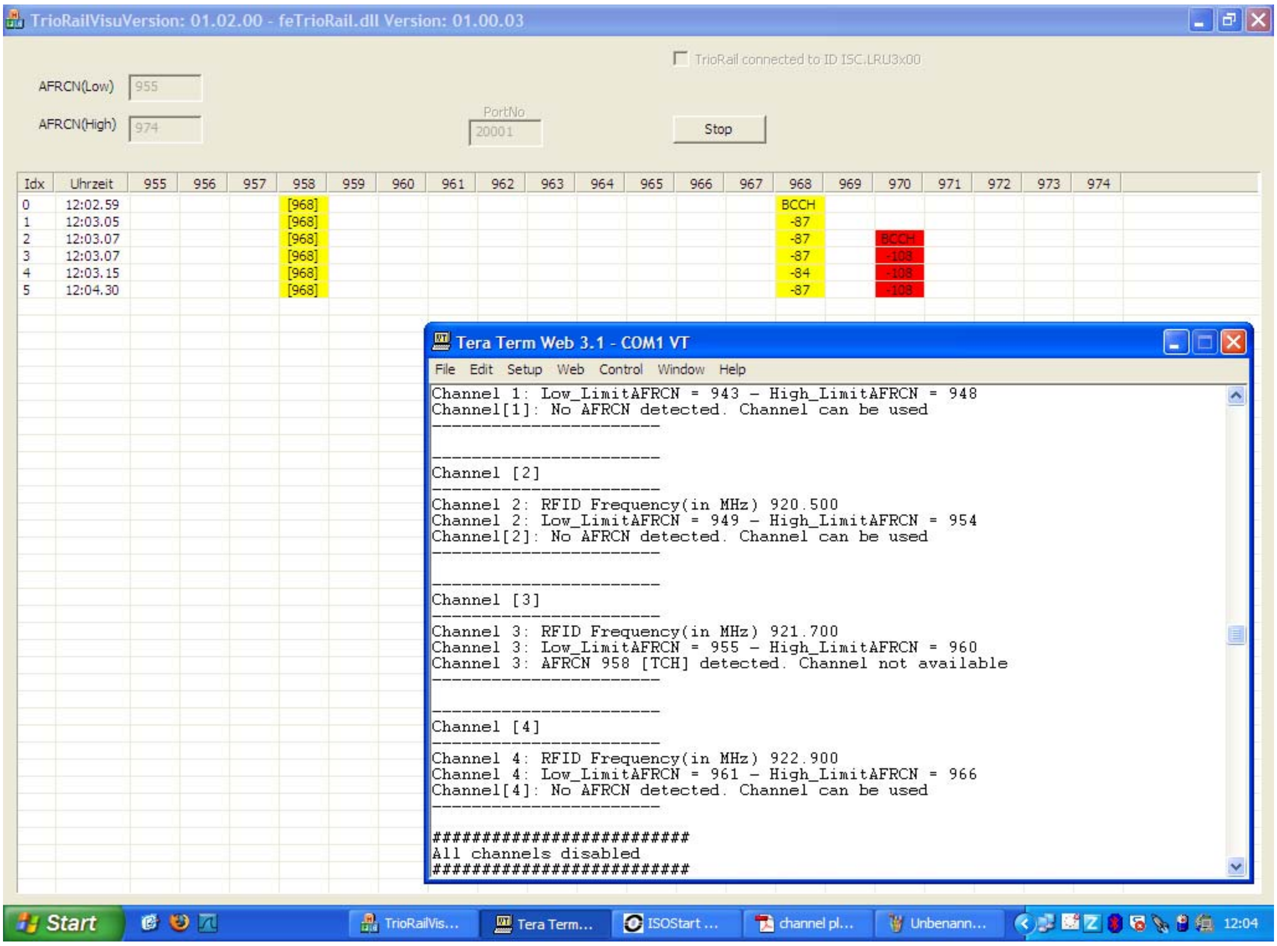


Figure C.6: Report by Demonstrator B on available channels

Figures C.5 and C.6 show that for the configuration with:

- First carrier (with BCCH): ARFCN = 968 (→ $f_{GSM\text{-}R,first}$ = 923,8 MHz)
- Second carrier (only TCH): ARFCN = 958 (→ $f_{GSM\text{-}R,second}$ = 921,8 MHz)

TX 3 with f_{TX} = 921,7 MHz cannot be used as it is only 100 kHz separated from $f_{GSM\text{-}R,second}$ = 921,8 MHz. Within the ER-GSM/GSM-R band only TX 4 with f_{TX} = 922,9 MHz is available for RFID operation. (Note that both TX1 and TX2 are outside the ER-GSM/GSM-R band and are also available.) Figure C.7 shows the signals recorded at the test site including the first and second GSM-R carrier and the available RFID channel.

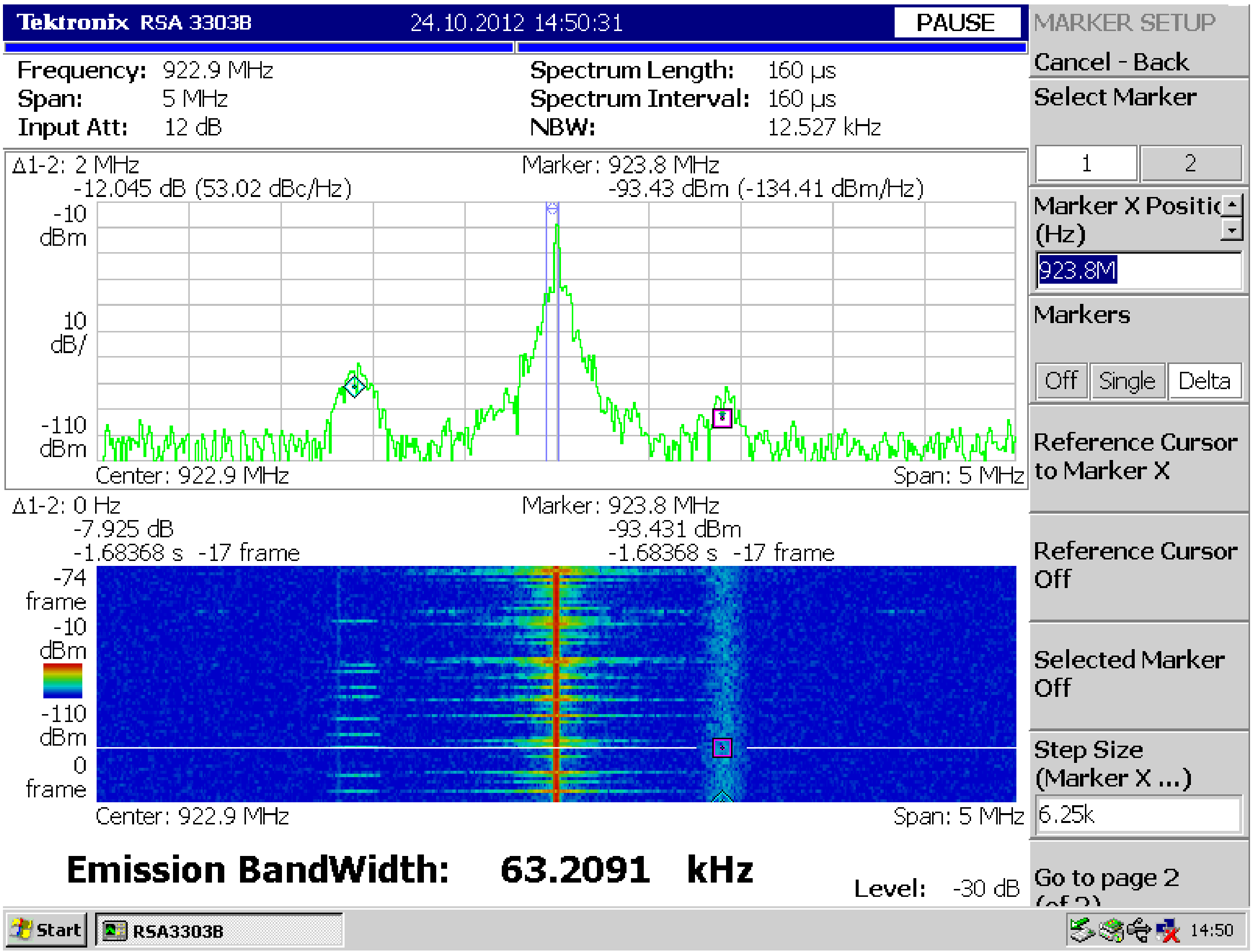


Figure C.7: Measured spectrum at test site with $f_{GSM-R,second}$ = 921,8 MHz, f_{TX4} = 922,9 MHz, $f_{GSM-R,first}$ = 923,8 MHz

Tables C.1, C.2 and C.3 show the test results for the reference measurements using TX1 and TX2 respectively in order to avoid any possible interference to GSM-R.

Table C.1: Test results of reference measurement with demonstrator A using TX1 (f_{TX} = 919,3 MHz) and demonstrator B turned off (Step 1)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A1 / ms
1	50	106
2	50	118
3	50	118
4	50	124
5	50	127
6	50	123
7	50	106
8	50	122
9	50	124
10	50	127
Average	**50**	119,5
Min.	50	106
Max.	50	127

Table C.2: Test results of reference measurement with demonstrator A using TX1 (f_{TX} = 919,3 MHz) and demonstrator B using TX2 (f_{TX} = 920,5 MHz) off (Step 3)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A3 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B3 / ms
1	50	106	50	128
2	50	118	50	109
3	50	116	50	126
4	50	117	50	113
5	50	115	50	121
6	50	132	50	223
7	50	118	50	141
8	50	122	50	149
9	50	112	50	118
10	50	122	50	121
Average	**50**	117,8	**50**	134,9
Min.	50	106	50	109
Max.	50	132	50	223

Table C.3: Test results of reference measurement with demonstrator A using TX1 (f_{TX} = 919,3 MHz) and demonstrator B using TX1 (f_{TX} = 919,3 MHz) off (Step 4)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A4 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B4 / ms
1	50	110	50	122
2	50	113	50	116
3	50	126	50	177
4	50	111	50	113
5	50	122	50	114
6	50	113	50	123
7	50	112	50	118
8	50	122	50	117
9	50	164	50	109
10	50	132	50	135
Average	**50**	122,5	**50**	124,4
Min.	50	110	50	109
Max.	50	164	50	177

Comparing the averages of the various t_{id} times in tables C.1, C.2 and C.3 shows that there is a minor influence between demonstrator A and demonstrator B and also no essential influence on whether the demonstrators are using different channels (TX1 and TX2) or the same channel (TX1 only). Table C.4 shows the results after applying formula 2.

Table C.4: Test results comparison for reference measurements

Reference measurement	Measurement	Reference measurement value	Measurement value	Comparison (According formula 2)
$t_{id,A1}$ / ms	119,5	$t_{id,A3}$ / ms	117,8	1,4 %
$t_{id,A1}$ / ms	119,5	$t_{id,B3}$ / ms	134,9	11,4 %
$t_{id,A3}$ / ms	117,8	$t_{id,A4}$ / ms	122,5	3,8 %
$t_{id,B3}$ / ms	134,9	$t_{id,B4}$ / ms	124,4	7,8 %

Table C.4 shows that there was a small impact on demonstrator B from the GSM-R terminals, which were located in the same room.

C.3 Tests in respect to clause 8.3.2

Tables C.5 and C.6 show the test results for a quiet GSM-R environment.

Table C.5: Test results in a quiet GSM-R environment with demonstrator A using TX4 (f_{TX} = 922,9 MHz) and demonstrator B turned off (Step 1)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time $t_{id,A3}$ / ms
1	50	108
2	50	114
3	50	254
4	50	122
5	50	143
6	50	106
7	50	118
8	50	112
9	50	112
10	50	106
Average	**50**	129,5
Min.	50	106
Max.	50	254

Table C.6: Test results in a quiet GSM-R environment with demonstrator A using TX4 (f_{TX} = 922,9 MHz) and demonstrator B using TX4 (f_{TX} = 922,9 MHz) (Step 2)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A4 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B4 / ms
1	50	128	50	113
2	50	119	50	106
3	50	113	50	113
4	50	116	50	107
5	50	119	50	109
6	50	107	50	104
7	50	109	50	122
8	50	136	50	130
9	50	109	50	114
10	50	116	50	135
Average	**50**	117,2	**50**	115,3
Min.	50	107	50	104
Max.	50	136	50	135

As Steps 3 and 4 requested both demonstrator A and demonstrator B to use TX3 (f_{TX} = 921,7 MHz), the RFID transmission was blocked and no tags could be identified.

Comparison of the measurements is shown in table C.7. The results in column 5 show some impact on performance. However, it should be noted that the test results may also have been influenced by other applications in addition to GSM-R. Table C.7 shows the results after applying formula 2.

Table C.7: Comparison of test results for non -busy GSM-R environment

Reference measurement	Measurement	Reference measurement value	Measurement value	Comparison (According formula 2)
$t_{id,A1}$ / ms	119,5	$t_{id,A3}$ / ms	129,5	7,7 %
$t_{id,A4}$ / ms	122,5	$t_{id,A4}$ / ms	117,2	4,3 %
$t_{id,B4}$ / ms	124,4	$t_{id,B4}$ / ms	115,3	7,3 %

C.4 Tests in respect to clause 8.3.3

Tables C.8 and C.9 show the test results for a busy GSM-R environment.

Table C.8: Test results in busy GSM-R environment with demonstrator A turned off and demonstrator B using TX4 (f_{TX} = 922,9 MHz) (Step 1)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A3 / ms
1	50	111
2	50	118
3	50	106
4	50	137
5	50	112
6	50	114
7	50	114
8	50	115
9	50	106
10	50	108
Average	**50**	114,1
Min.	50	106
Max.	50	137

Table C.9: Test results in busy GSM-R environment with demonstrator A using TX4 (f_{TX} = 922,9 MHz) and demonstrator B using TX4 (f_{TX} = 922,9 MHz) (Step 2)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A4 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B4 / ms
1	50	106	50	108
2	50	118	50	114
3	50	97	50	108
4	50	111	50	106
5	50	119	50	116
6	50	114	50	113
7	50	105	50	111
8	50	116	50	114
9	50	109	50	131
10	50	112	50	123
Average	**50**	110,7	**50**	114,4
Min.	50	97	50	106
Max.	50	119	50	131

As Steps 3 and 4 configured both demonstrator A and demonstrator B to use TX3 (f_{TX} = 921,7 MHz), the RFID transmission was blocked and no tags could be identified.

A comparison of the measurements is shown in table C.10. The results in column 5 show some impact on the performance. However, it should be noted that the test results may also have been be influenced by other applications in addition to GSM-R.

Table C.10: Comparison of test results for busy GSM-R environment

Reference measurement	Measurement	Reference measurement value	Measurement value	Comparison
$t_{id,A1}$ / ms	119,5	$t_{id,B3}$ / ms	114,1	4,5 %
$t_{id,A4}$ / ms	122,5	$t_{id,A4}$ / ms	110,7	9,6 %
$t_{id,B4}$ / ms	124,4	$t_{id,B4}$ / ms	114,4	8,0 %

C.5 Tests in respect to clause 8.3.4

Table C.11 shows the test results for a moving GSM-R mobile. Operation on a train was not possible. Instead one person walked up the platform of the Wiesbaden Hauptbahnhof.

As Steps 1 and 2 configured both demonstrator A and demonstrator B to use TX3 (f_{TX} = 921,7 MHz), the RFID transmission was blocked and no tags could be identified.

Table C.11: Test results with moving GSM-R mobile with demonstrator A using TX4 (f_{TX} = 922,9 MHz) and demonstrator B using TX4 (f_{TX} = 922,9 MHz) (Step 3)

Meas. No	No. of tags identified (Demonstrator A)	Tag identification time tid,A4 / ms	No. of tags identified (Demonstrator B)	Tag identification time tid,B4 / ms
1	50	108	50	146
2	50	107	50	117
3	50	118	50	123
4	50	108	50	124
5	50	105	50	116
6	50	117	50	109
7	50	119	50	124
8	50	103	50	123
9	50	102	50	111
10	50	115	50	137
Average	**50**	110,2	**50**	123
Min.	50	102	50	109
Max.	50	119	50	146

Comparison of the measurements is shown in table C.12. The results in column 5 show some impact on the performance. However, it should be noted that the test results may also have been influenced by other applications in addition to GSM-R. Table C.12 shows the results after applying formula 2.

Table C.12: Test results comparison for moving mobile

Reference measurement	Measurement	Reference measurement value	Measurement value	Comparison (According formula 2)
$t_{id,A4}$ / ms	122,5	$t_{id,A4}$ / ms	110,2	10,0 %
$t_{id,B4}$ / ms	124,4	$t_{id,B4}$ / ms	123	1,1 %

Figure C.8 shows the trace results captured with the Triorail TTS-TRC-5 equipment using the TrioTrace software.

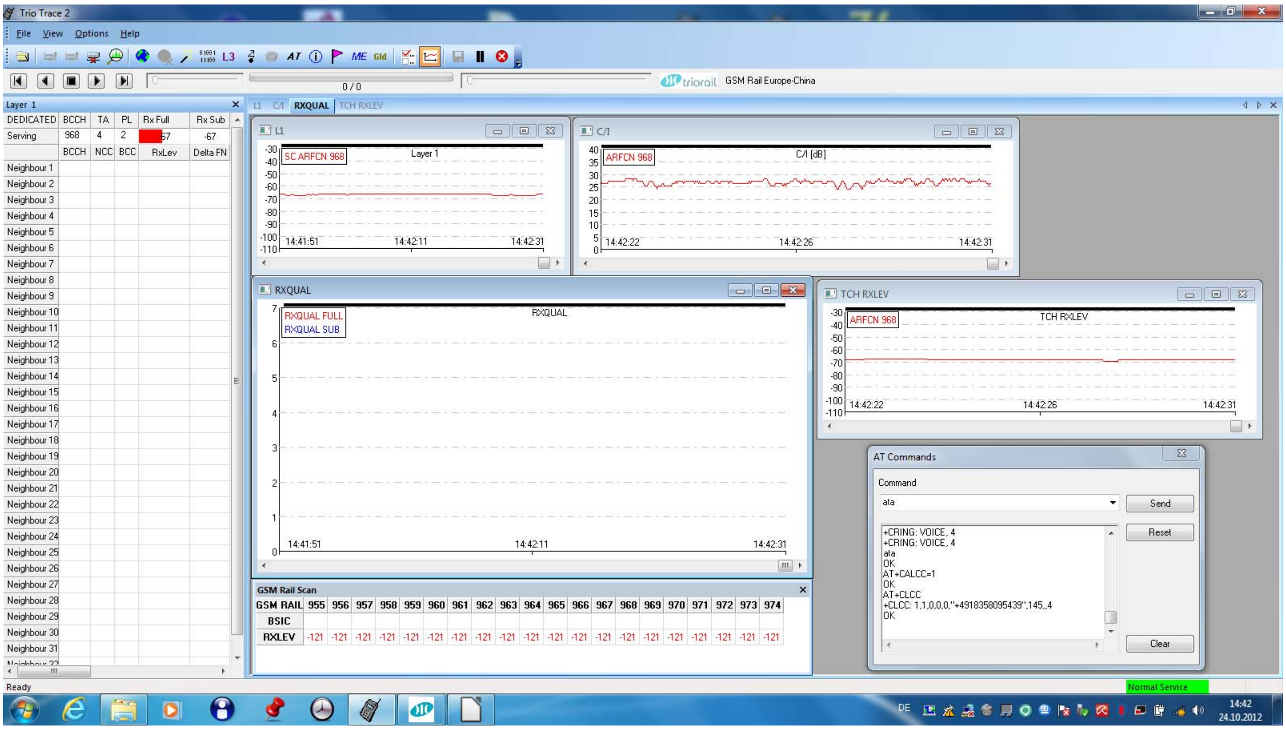


Figure C.8: Trace result of Triorail TTS-TRC-5 displayed with TrioTrace

C.6 Conclusions

The measurements show that the demonstrators were always able to detect GSM-R operation and therefore avoided those RFID transmit channels that could have caused potential interference. The monitoring of the GSM-R communication also confirmed that there was no impact from RFID.

Comparison of the measurement results shows, however, that variation in the RFID performance exceeded the 5 % limit. This applied to all measurements. The analysis shows that the majority of the measurement results were in the same range. However in the few instances where the time to detect a tag was extended, they had a disproportionate impact on the average result.

Annex D (informative): Bibliography

ETSI TS 101 601 (V1.1.1): "Electromagnetic compatibility and radio spectrum matters (ERM); The specification and implementation of design changes to interrogators and specification of the test plan for the Preliminary Tests and the Trial; Modification of interrogators and specification of test plans for the Preliminary Tests and Trial".

History

Document history		
V1.1.1	July 2013	Publication