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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Tests on the immunity of Wind Profiler Radar to transmissions from RFID, ALDs and GSM

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Contents

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Foreword

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

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

The present document was prepared with the assistance of the UK Met Office without whose support the present document would not have been possible.

Introduction

Recently ETSI made a request to CEPT for use by SRDs and RFID of the band 915 MHz to 921 MHz. Since this band was already allocated to the railways and to government services, SE24 was asked to investigate if sharing in these bands by SRDs and RFID with the primary services would be possible. In the course of their compatibility studies SE24 has learnt that two sites exist in the UK where Wind Profiler Radar (WPR) are in use operating within the band 915 MHz to 917 MHz. It was decided that some practical tests should be made at one of these sites to find out if SRDs and RFID caused unacceptable levels of interference.

Further technical information on the Wind Profiler Radar is provided in annex A.

The UK Met Office kindly agreed to make their site and facilities at Camborne available in order to perform practical tests. The tests took place on 14th and 15th February and involved personnel from the Met Office who operated the WPR and recorded data and ETSI ERM TG 34/17 who operated the interferers. Two items of equipment were made available as interferers for the tests. One of these was a prototype Assisted Listening Device (ALD) operating at 10 dBm and the other was an RFID interrogator transmitting at levels up to 36 dBm in free space (It should be noted that this equipment is normally mounted in a shielded portal, which contains the RF). The actual ERP at a distance of 10 m from a distribution centre where RFID is installed is in the region of -36 dBm. See annex C for typical use cases. In addition it was also possible to generate signals that emulated the transmissions from 3G and UMTS.

The Met Office had previously carried out testing on a similar WPR operating at 1 290 MHz and considered the results would echo the testing on the 915 MHz unit.

1 Scope

The present document gives a report on compatibility tests between the Wind Profiler Radar at the Met Office site in Camborne UK, a prototype ALD device and a RFID interrogator. In addition the report also provides results on the compatibility between WPR and simulated transmissions of GSM and UMTS.

2 References

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

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

2.1 Normative references

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

Not applicable.

2.2 Informative references

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

[i.1] OFCOM Report SES/10/12: "Wind Profiler Radar Measurements Camborne".

[i.2] ETSI TR 102 791: "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Short Range Devices; Technical characteristics of wireless aids for hearing impaired people operating in the VHF and UHF frequency range".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Assistive Listening Devices (ALD): systems utilizing electromagnetic, radio or light waves or a combination of these, to transmit the acoustic signal from the sound source (a loudspeaker or a person talking) directly to the hearing impaired person

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

Telecoil: Audio Induction Loop systems, also called audio-frequency induction loops (AFILs) or hearing loops are an aid for the hard of hearing

NOTE: They is a loop of cable around a designated area, usually a room or a building, which generates a magnetic field picked up by a hearing aid. The benefit is that it allows the sound source of interest - whether a musical performance or a ticket taker's side of the conversation - to be transmitted to the hearing-impaired listener clearly and free of other distracting noise in the environment. Typical installation sites would include concert halls, ticket kiosks, high-traffic public buildings (for PA announcements), auditoriums, places of worship, and homes. In the United Kingdom, as an aid for disability, their provision where reasonably possible is required by the Disability Discrimination Act 1995, and they are available in the back seats of all London taxis, which have a little microphone embedded in the dashboard in front of the driver; at 18 000 post offices in the U.K.; at most churches and cathedrals.

Wind Profiler Radar (WPR): instrument that uses radar to measure the wind velocity at different altitudes

3.2 Symbols

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

dB	decibel
kHz	kilohertz
km	kilometre
s	seconds
m	metre
MHz	Megahertz
min	minute
ns	nano second

3.3 Abbreviations

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

AFIL	Audio-Frequency Induction Loops
ALD	Assisted Listening Device
CW	Carrier Wave
ECC	Electronic Communications Committee
ERP	Effective Radiated Power
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile communication
HQ	HeadQuarters
LTE	Long Term Evolution
MFCN	Mobile/Fixed Communications Networks
NE	North East
NW	North West
NWP	Numerical Weather Prediction
PR ASK	Phase Reversal Amplitude Shift Keying
PR	Phase Reversal
PRF	Pulse Repetition Frequency
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RFID	Radio Frequency Identification
RMS	Root Mean Square
SE	South East
SRD	Short Range Device
SW	South West
TRS	Telecoil Replacement System
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
VAC	Volts Alternating Current

WCDMA	Wideband Code Division Multiple Access
WPR	Wind Profiler Radar

4 Description of equipment

4.1 Facilities at Camborne

The Met Office site at Camborne is located in a grass field of approximately 170 metres square surrounded by open farmland. The wind profiler radar on site provides important information on the state of the atmosphere that is used to drive NWP (Numerical Weather Prediction) models and inform forecasts - this particular location in the west of the UK is notably important in respect of this being the prevailing direction from which weather approaches the UK.

The antennas for the Wind Profiler Radar have been installed inside a fibreglass container positioned approximately in the centre of the site. The equipment was controlled from a building, adjacent to the antennas. The site is shown in figure 1.

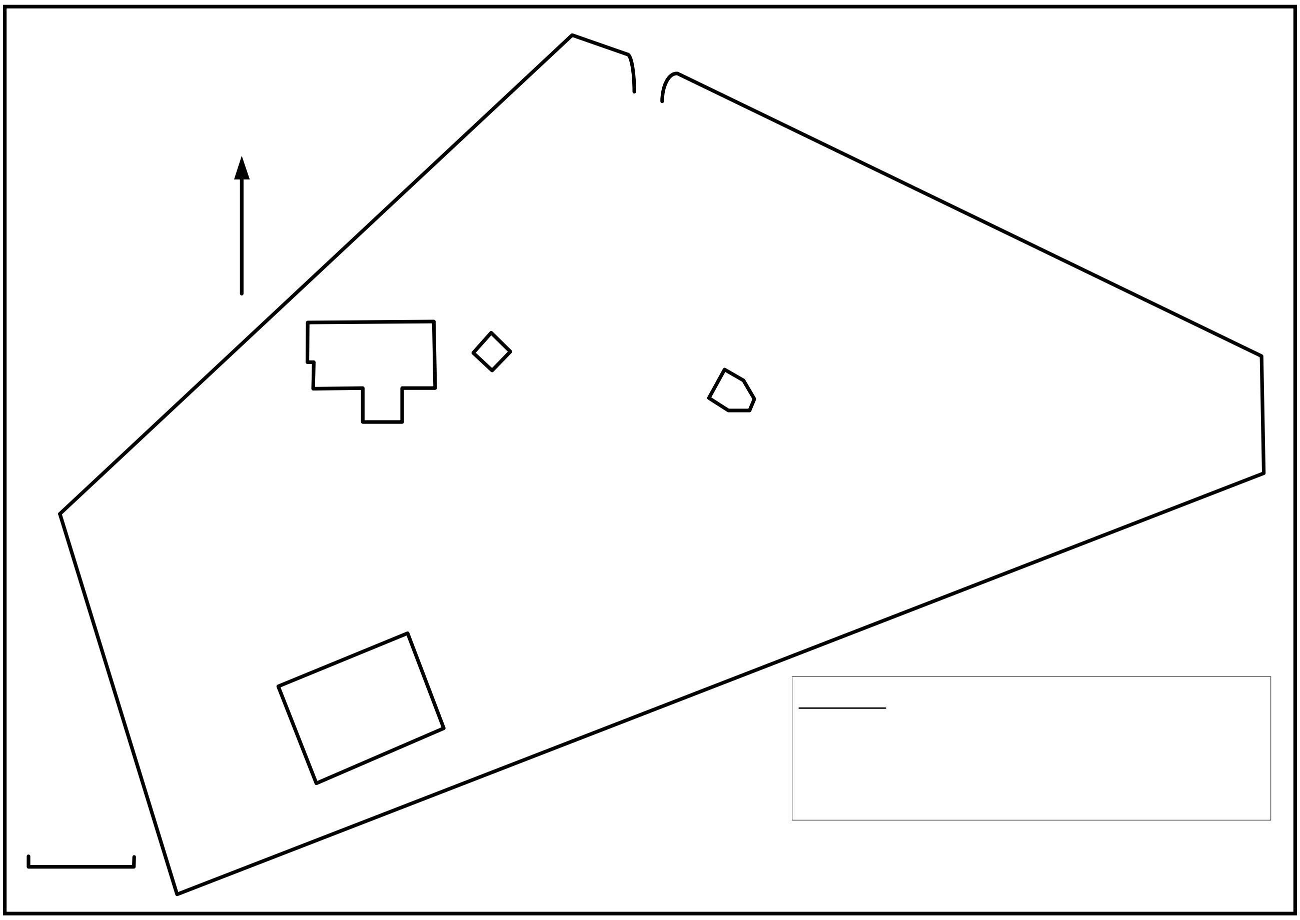


Figure 1: Camborne Meteorological Station

In December 2012 OFCOM made measurements at Camborne of the isolation provided by the container. (See [i.1].) Their measurements showed that at a height of 1,5 m the sidewall attenuation varied between 7,3 dB and 10,6 dB. A picture of the fibreglass container is shown in figure 2.

Figure 2: WPR Antenna housing

In normal operation the four antennas of the WPR are steered electronically to measure reflections from the atmosphere in NE, SE, SW, and NW, directions. After processing, this information gives details of direction and wind-speed at different altitudes, as well as reflectivity data (see annex A for full description of available parameters). Two different pulse lengths and PRFs are used to measure the conditions at low (up to 2 km) and high (up to 8 km) altitudes. For the higher altitudes a radar pulse length of 1 400 ns having a 3 dB bandwidth of 632 kHz is used (High mode). For low altitudes a pulse length of 400 ns is transmitted with a 3 dB bandwidth of 2,5 MHz (Low mode). Each measurement is made over a period of about one minute.

It was believed that the WPR equipment has been operational on the site for some 15 years. During this time it has operated almost continuously to provide valuable information to the Met Office for their weather forecasts.

Further technical information on the Wind Profiler Radar is provided in annex A. However whilst the data sheet refers to the transmitter bandwidth there is no information available on the receiver. From the testing carried out this appears to be considerably wider than the 2,5 MHz shown.

4.2 Description of Interferers

4.2.1 RFID Interrogator

The RFID equipment was provided by a manufacturer and comprised a standard interrogator connected to its patch antenna. The antenna, which had a gain of 7 dBi, was mounted vertically on a post 0,8 m above the ground so that it transmitted in a horizontal direction. The transmission from the antenna was circularly polarized. The interrogator was controlled from an application installed on a laptop. The interrogator was fitted with test firmware, which allowed it to transmit on a fixed frequency with either continuous CW or a continuously modulated signal. The modulation used was PR ASK. It should be noted that in a typical application, such as a distribution centre, an RFID interrogator would only transmit for between 1,5 s and 2 s every 10 s over a period of about 10 min. This might be repeated up to 4 times during a day.

For the purposes of the tests at Camborne, the interrogator was set initially to transmit at a level of 36 dBm at a fixed frequency of 916,25 MHz. Subsequently measurements were also made with the interrogator set to output powers of 8,6 dBm and -2,6 dBm and at a transmit frequency of 917,25 MHz.

4.2.2 ALD Prototype

A prototype system was used providing an output of some 10 mW into a 0 dbi calibrated ½ wave dipole at 915 MHz (see annex E for details) mounted on a wooden tripod some 1,5 m above the ground. The system was programmed with the following parameters:

1) nominal 200 kHz bandwidth 124 kbit/s 4GFSK modulation (BT = 0,5) with 40 kHz deviation (outer symbols), 5 ms packets, 5 ms interval between packets (50 % duty cycle), 0 dBi antenna at 1,5 m above ground level;

2) nominal 600 kHz bandwidth, 360 kbit/s 4GFSK modulation (BT = 0,5) with 162 kHz deviation (outer symbols), continuous PN9 data modulated transmission (100 % duty cycle), 0 dBi antenna at 1,5 m above ground level.

Other system features not used in tests:

- The system is designed to spectrum sense and frequency hop to minimize interference to other spectrum users.
- Can be pre-programmed to the spectrum available at that site.

4.2.2.1 ALD Use

The ALD system under test is referred to as the Telecoil Replacement System (TRS) designed to take an input such as a railway or airport information service normally provided by a public address system and provide hard of hearing customers with a direct input to their hearing aids. The problem for the majority of hard of hearing is not volume but clarity. The system is designed to replace the inductive telecoil system (see definitions for description) currently used in some religious buildings, theatres and similar locations. TR 102 791 [i.2] provides full information on these issues but briefly the telecoil only has one channel and cannot be used in large areas such as railway stations and airports and is extremely difficult to retrofit to existing buildings whereas the TRS can provide multiple channels for translation services, school and theatre use and is simple to install and run

The vast majority of systems will be indoor.

4.2.3 GSM and UMTS emulation

A Rhode and Schwarz SMIQ generator was fed into the 0 dBi cable-mounted ½ wave 915 MHz dipole mounted on a wooden tripod some 1,5 m above the ground and set to the following configurations:

R&S SMIQ to transmit a standard GSM GMSK waveform, nominal 200 kHz bandwidth.

This transmission used 100 % duty cycle and a relatively low power level due to limitations of the test equipment. In practice a single mobile device would typically transmit at 1/8 duty cycle (in speech) or less during signalling, but in many locations can be expected to use significantly higher power (up to 2W for typical mobile devices).

Set up R&S SMIQ to transmit a standard WCDMA QPSK waveform, nominal 5 MHz bandwidth.

This transmission used 100 % duty cycle, representative of a phone with a connected channel. The relatively low power level was due to limitations of the test equipment. Mobile devices in this band are understood to be able to transmit at up to +24 dBm, though power control in the system means that this will usually occur only in the outer parts of a cell.

5 Description of Tests

5.1 Tests with RFID

Initially the RFID equipment was mounted on a table about 10 m from the WPR with the RFID antenna directed at the centre of the fibreglass container. The antenna was approximately 1,2 m above the ground. A picture of the set-up is shown at figure 3.

Figure 3: Initial RFID test setup

With the interrogator transmitting at 916,25 MHz and an output of 36 dBm, measurements were made at the monitor of the WPR. For both CW and continuous modulated transmissions, significant levels of interference were evident in both the high and low modes of the WPR. The measurements were made in all four orientations of the WPR. The results together with a control measurement are shown at figures B.1 to B.9.

The RFID equipment was then moved to the perimeter of the site, which put it at a distance of 85 m from the fibreglass container. Measurements were again made at 916,25 MHz and 36 dBm (see annex C for real site calculations where a typical figure of -52 dBm e.r.p. would be experienced at this distance) with both CW and continuous modulation. Examination of the results from the monitor of the WPR showed that in the low mode RFID was still causing levels of interference. In the high mode interference from RFID was not immediately apparent. However any possible harmful effects will need to be confirmed by the team in Exeter who interpret the output.

Figure 4: Setup of RFID and ALD at perimeter of site

The WPR can be seen at to the right of the building.

By the insertion of attenuators in the feeder cable to the RFID antenna, the transmitted power was reduced first to -2,6 dBm and then 8,6 dBm. The interrogator was set to transmit a continuously modulated transmission (from previous measurements this represented the worst case condition). The WPR monitor appeared to show no evidence of interference in the low mode at a transmit level of -2,6 dBm but interference was just evident at 8,6 dBm.

The measurements were repeated with an output power of 8,6 dBm and the interrogator operating at a frequency of 917,25 MHz. In this configuration there was no obvious sign of any interference on the monitor of the WPR.

In a final test the RFID system was set-up in the conference room of the site office with its antenna directed at the fibreglass container. Although the RFID equipment was probably no more than 20 m from the fibreglass container, the transmission had to pass through at least three brick walls. With the interrogator again set to 916,25 MHz and 36 dBm transmit power in continuous modulation; an inspection was made of the traces at the monitor. There was no immediate evidence of interference in the high mode but there was clear evidence of interference from RFID in the low mode.

Figure 5: Tests carried out in left hand room of the building

5.2 Tests with ALDs

5.2.1 Measurement Sequence

Power levels for all of the following tests except for WCDMA were measured using the R&S ZVL using input resolution bandwidth at least 3x the signal bandwidth, and the peak detector in max hold mode run for at least 10 s. For WCDMA, because of the waveform's crest factor, power was measured with 10 MHz input bandwidth and the RMS detector. All power levels quoted here are referred to the antenna connector.

The antenna for all of the ALD, GSM and WCDMA tests was a 0 dBi cable-mounted ½ wave 915 MHz dipole from Taoglas (see note), with an omnidirectional response in the horizontal direction. (Datasheet in annex C). For the tests at 1,5 m height, this antenna was mounted on a non-metallic antenna stand via a cable. For the indoor tests the antenna was fitted directly to the ALD prototype. Figures 3 and 4 provide an overview of the test setup.

NOTE: See http://www.taoglas.com/images/product_images/original_images/TI.09.0111%20915MHz%200dBi%20Teminal%20Antenna%20090409.pdf

This antenna has performance typical of professional-grade SRD, ALD and mobile devices - in many consumer devices, antenna gain will be lower than this.

Antenna for RFID tests was a nominal +7 dBi directional patch antenna, Symbol branded. Input power is noted here. In all RFID tests, the antenna centre was directed at the radar.

5.2.2 Test sequence

Thursday 14 February 2013 - measurements at 85 m from WPR:

- Set up ALD1, nominal 200 kHz bandwidth, 124 kbit/s 4GFSK modulation (BT = 0,5) with 40 kHz deviation (outer symbols), 5 ms packets, 5 ms interval between packets (50 % duty cycle), 0 dBi antenna at 1,5 m above ground level
- Baseline (no tx)

- ALD1 915,2 MHz, 9,92 dBm
- ALD1 915,2 MHz, -1,67 dBm
- Baseline
- ALD1 915,2 MHz, 10,40 dBm
- ALD1 916,2 MHz, 9,79 dBm
- ALD1 916,2 MHz, -1,72 dBm
- Baseline
- ALD1 918,0 MHz, 9,65 dBm
- ALD1 918,0 MHz, -1,76 dBm
- Baseline
- Set up ALD2, nominal 600 kHz bandwidth, 360 kbit/s 4GFSK modulation (BT = 0,5) with 162 kHz deviation (outer symbols), continuous PN9 data modulated transmission (100 % duty cycle), 0 dBi antenna at 1,5 m above ground level
- Power level 0x40 used for 10 mW, 0x12 used for 1 mW
- ALD2 915,6 MHz, 10,54 dBm
- ALD2 915,6 MHz, -0,42 dBm
- Baseline
- ALD2 916,2 MHz, -0,58 dBm
- ALD2 916,2 MHz, 10,63 dBm
- Baseline (some measurements were missed first time and were repeated)

Friday 15 February 2013 - measurements at 85 m from WPR:

- Baseline
- Set up ALD2 in the same configuration as before, 0 dBi antenna at 1,5 m above ground level
- ALD2 918,0 MHz, 11,17 dBm
- ALD2 918,0 MHz, -0,50 dBm
- Set up R&S SMIQ to transmit a standard GSM GMSK waveform, nominal 200 kHz bandwidth:
    - Note that this transmission used 100 % duty cycle and a relatively low power level due to limitations of the test equipment. In practice a single mobile device would typically transmit at 1/8 duty cycle (in speech) or less during signalling, but in many locations can be expected to use significantly higher power (up to 2W for typical mobile devices)
    - 0 dBi antenna at 1,5 m above ground level
- GSM 914,8 MHz 14,33 dBm
- GSM 914,8 MHz -0,41 dBm

- Set up R&S SMIQ to transmit a standard WCDMA QPSK waveform, nominal 5 MHz bandwidth:
  - Note that this transmission used 100 % duty cycle, representative of a phone with a connected channel. The relatively low power level was due to limitations of the test equipment. Mobile devices in this band are understood to be able to transmit at up to +24 dBm, though power control in the system means that this will usually occur only in the outer parts of a cell
  - 0 dBi antenna at 1,5 m above ground level
- WCDMA 912,6 MHz, 13,49 dBm
- WCDMA 912,6 MHz, -0,20 dBm
- Baseline
- Modulated RFID was set up at 916,25 MHz with attenuators
- RFID 916,25 MHz, 1,56 dBm into 7 dBi antenna at 0,8 m above ground level (table mounted)
- RFID 916,25 MHz, -4,33 dBm into 7 dBi antenna at 0,8 m above ground level
- RFID 916,25 MHz, 8,34 dBm into 7 dBi antenna at 0,8 m above ground level
- Baseline

Friday 15 February 2013 - measurements with the radio devices indoors in the conference room on the site:

- Baseline
- Set up ALD1 in the same configuration as before, 0 dBi antenna, 0,8 m above ground level (table mounted)
- ALD1 915,2 MHz, 13,11 dBm
- ALD1 915,2 MHz, -0,59 dBm
- RFID 916,2 MHz nominal +29 dBm into 7 dBi antenna (actual power level was not calibrated)
- Baseline

5.3 Tests with GSM and UMTS

It should be noted that the WPR has a centre frequency of 915 MHz. The manufacturer claims that the transmitter has a bandwidth of 2,5 MHz. However, from these tests, the receiver appeared to have a bandwidth of greater than 2,5 MHz in the low mode. The exact bandwidth has not been determined but may be in the order of double that of the transmitter. This brings the receiver bandwidth into the MFCN band which may at some point be used for LTE.

Annex B shows the masks produced by the signal generator (R&S ZVL).

6 Analysis of Results

During a wash-up session at the end of the tests, both met office personal made it clear that they had as yet been unable to analyse the data to determine whether harmful inference was present. All of the data would be subject to post-analysis at Exeter, including retrieval of data archive files.

The results of the tests for RFID at the perimeter of the site for transmit levels of 10 dBm and above showed that interference was detectable when the WPR was operating in its low mode. RFID operation produced effects at 10 m and 85 m from the WPR, as well as indoors at approximately 25 m (see figure 5). However there was no immediately obvious interference present even at transmit levels of 36 dBm when the WPR was operating in the high mode, though subsequent analysis did indicate changes to the signal-to-noise ratios. A possible explanation for this difference in behaviour was that the bandwidth of the filters used by the receiver of the WPR were wider in the low mode.

In many applications an RFID interrogator will transmit for up to 2 s while it reads a collection of tags. Subsequently interrogations will be repeated at intervals of about 10 s, depending on the nature of the application. The experts at Exeter confirmed that even intermittent transmission can have a harmful effect on the data. Additional information on the typical levels of transmissions from RFID systems from common applications is given in annex C.

Assessment of the tests with the ALD emulator, by contrast, showed a range of results with a level of disruption to the WPR, but without the distinction between low and high modes in this instance.

Although the power from the emulated G3 and UMTS transmissions was restricted to just 10 mW, they still caused significant levels of interference to the WPR when operated in both its high and low modes. This indicated that the WPR would be vulnerable to interference from mobile phones, which are likely to be in general use around Camborne or at the adjacent school.

The likelihood of interference is largely dependent on the proximity of RFID or ALD operating above 915 MHz or from the primary UMTS operating below 915 MHz. RFID are typically operated within buildings, with their greatest density of use in commercial distribution facilities. ALD are used typically indoors at educational and public facilities such as museums and airports. The likelihood of a facility operating either RFID or ALD in close proximity to the WPR site would need to be considered before setting appropriate parameters for the authorization of RFID or ALD.

6.1 Met Office Test Result and Interference Level Criteria

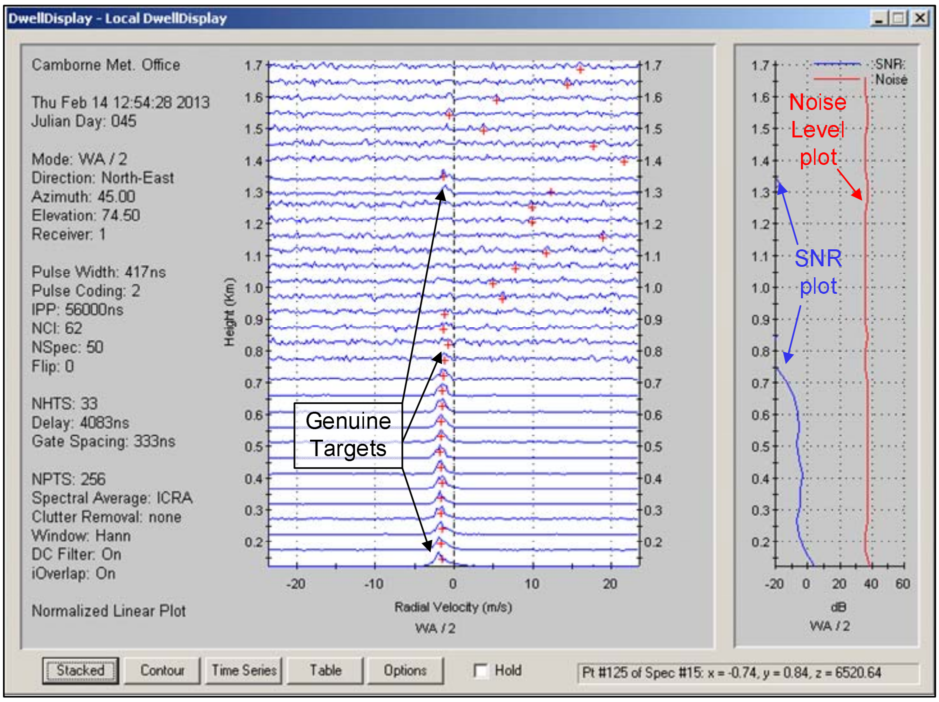
Full results for all devices tested is provided in annex D. This includes results of testing focussed on interference to radial (average) velocity measurements. Below is the Met Office's criteria for interference to the WPR system.

Table 1: Criteria for interference to WPR system

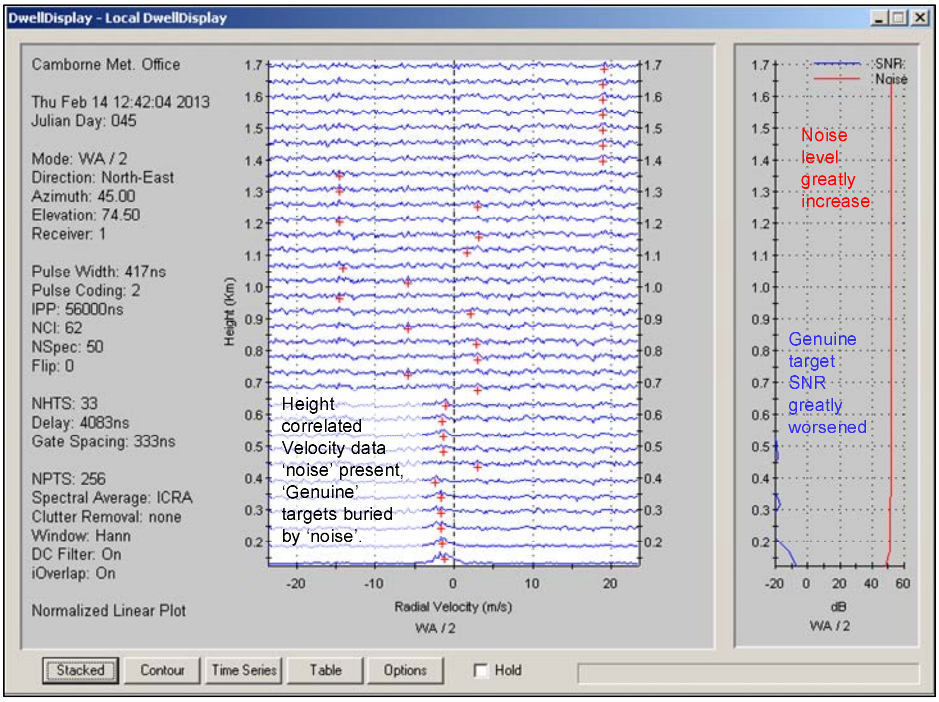
	Interference Level		
Criterion	**Severe**	**Moderate**	**Slight**
Visually Effects Plots	Obvious	Noticeable	Detectable
False Velocity Data Points	Consistently	Mostly	Some
Increased Noise Level	≥ 5 dB	≥ 2 dB	≥ 1 dB
Necessary Conditions	1 out of 3	1 out of 3	1 out of 3

An annotated dwell display example of observed radial velocity interference to the WPR from RFID is given below.

Case 1a - Windprofiler Low Height Mode – RFID Outdoors at 85 metres



Baseline Data with RFID TX OFF



Data with RFID TX ON

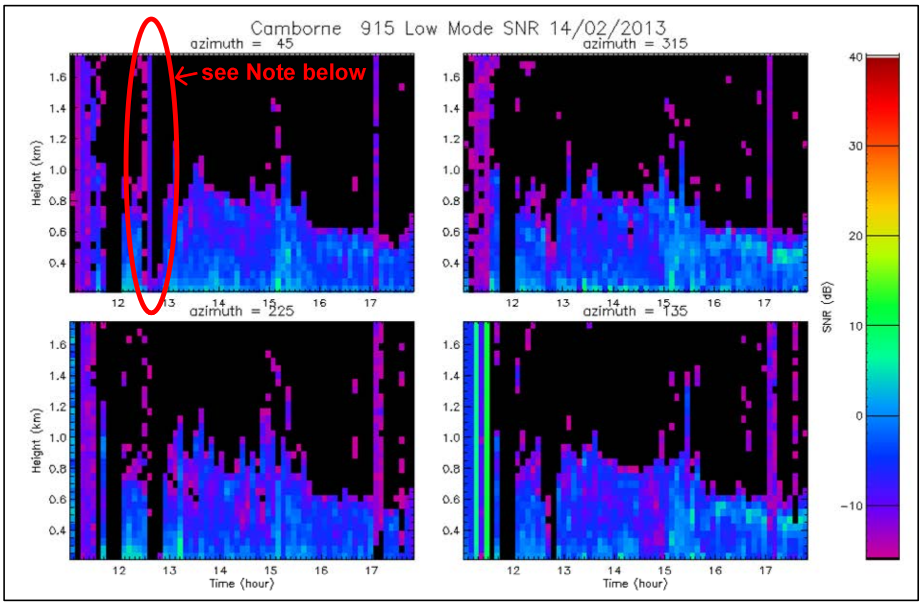
RFID Test Conditions Frequency: 916.25 MHz Modulation: ON	Location: Outdoors ~85 metres from Wind Profiler Radar Power Level: 8.34 dBm into 7 dBi antenna Antenna: 0.8m above ground level

Impact - Severe
Radial Velocity: Height correlated Velocity data 'noise' present, 'Genuine' targets buried by 'noise'.
SNR (blue): Genuine target SNR greatly worsened. Noise (red): Noise level greatly increase.

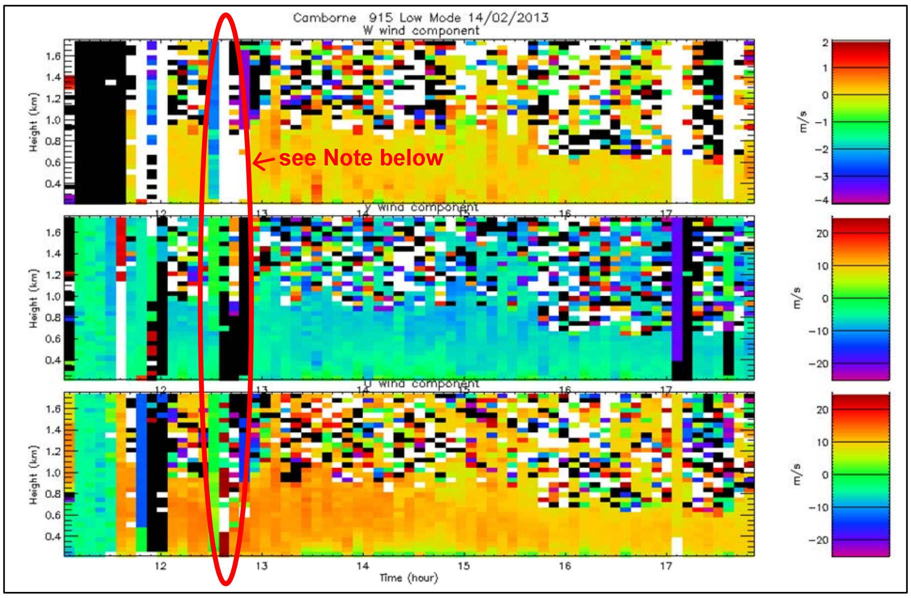
Figure 6: Display of WPR for RFID at 85 m with power set to 36 dBm

The RFID interference indicated in figure 6 was also reflected in the broader WPR spectral plots for the same time.

Camborne Windprofiler - Low Height Mode
Interference Artifacts – 14 February 2013



SNR vs Height Plots - Low Height Mode Beam Directions - 11:00 to 18:00 UTC 14/02/13



W, V and U Wind Component Plots – Low Height Mode – 11:00 to 18:00 UTC 14/02/13

NOTE: These plots cover the test period on 14th February 2013. The red ovals highlight the time around 12:40 during which the Case 1a RFID tests were being performed. The impact on the data is apparent with the SNR worsening over the entire Height Range and the corresponding W (Vertical, +ve = upwards), Y (Meridional, +ve = towards North) and U (Zonal, +ve = towards East) Wind Vector component data being severely degraded. Further examples of interference can be readily seen during the rest of the test period as other scenerios were examined.

NOTE: See note for explanation of ringed identified interference.

Figure 7: Annotated WPR spectral plots for 14/2/2013

See annex D for further annotated dwell display interference plots and a full directory of results for all devices tested.

6.2 Possible Mitigation for the WPR

In common with many other radar systems the original design did not envisage transmissions within its receiver bandwidth and therefore the receiver skirts are quite wide. Unfortunately the use of MFCN has introduced a potential major interference issue for WPR centred at 915 MHz from both base station and mobile equipment. The following mitigation techniques are valid for this situation and SRD use:

- Consider if the skirts of the filters in the receiver circuit of the WPR could be tightened.
- Consider a band pass or band stop filter.
- Consider how the immunity of the antenna system/enclosure could be improved, possible ways forward are: reflective/absorbent paint could be applied to the fibreglass container or a wiremesh fence around the container.
- Consider how an exclusion zone for SRD use may be applied around the WPR - sufficient distances would need to be calculated based on appropriate additional testing at varying distances.

7 Conclusions

Following the analysis of the results of the tests, the following conclusions may be drawn:

The tests showed that RFID systems operated (in free space pointing at the WPR) at the perimeter of the site at Camborne may generate interference to the WPR. However taking into account the analysis in annex C, the level of interference will be similar to that produced by an SRD operating at 20 dBm e.r.p. inside a building that will further absorb signals

The tests showed that ALD systems also operating in free space, operated at the perimeter of the site at Camborne may generate interference to the WPR, but to a lesser extent than for 4W ERP RFID devices.

Noise into the WPR receiver bandwidth is additive. Therefore any interference received from RFID or ALD operating above 915 MHz will add to any signal received from the primary service of UMTS operating below 915 MHz. The impact of this additional noise needs to be considered against the noise generated by any local UMTS transmissions.

The Interference Level Criteria in clause 6.1 of $> 1 - 2$ dB suggest that any noise floor increase however generated (a GSM phone used adjacent to the perimeter fence or even sun spot activity increasing propagation) may have influenced the output of the WPR in the past and will do so in the future. This is coupled with a lack of pre processing clarity of interference on the local screen.

Any future roll-out of 4G (LTE modulation) in the band below 915 MHz may change the risk of interference from this primary service.

In practice, given the location of the sites, the probability of interference from RFID and ALDs into WPR will be extremely low.

ALD

ALD equipment is designed to assist the hearing of persons primarily inside buildings and any interference, if noted, would be significantly reduced by the absorption from the building and the additional distance. The closest use would be at the adjacent school which at least doubles the test distance and the school could use spectrum above the WPR frequency.

Annex A:
Details of Wind Profiler Radar

A.1 Operational description

Used to continually assess wind conditions at a site from some 120 m to 8 km above ground level, the system has four steerable aerials operating in a set sequence. The acquired data is fed back to the Met Office HQ in Exeter and is used for a variety of purposes including ingestion into Numerical Weather Prediction (NWP) models on a 15 minute cycle. A local screen shot below provides information on a "good" i.e. non interfered with plot.

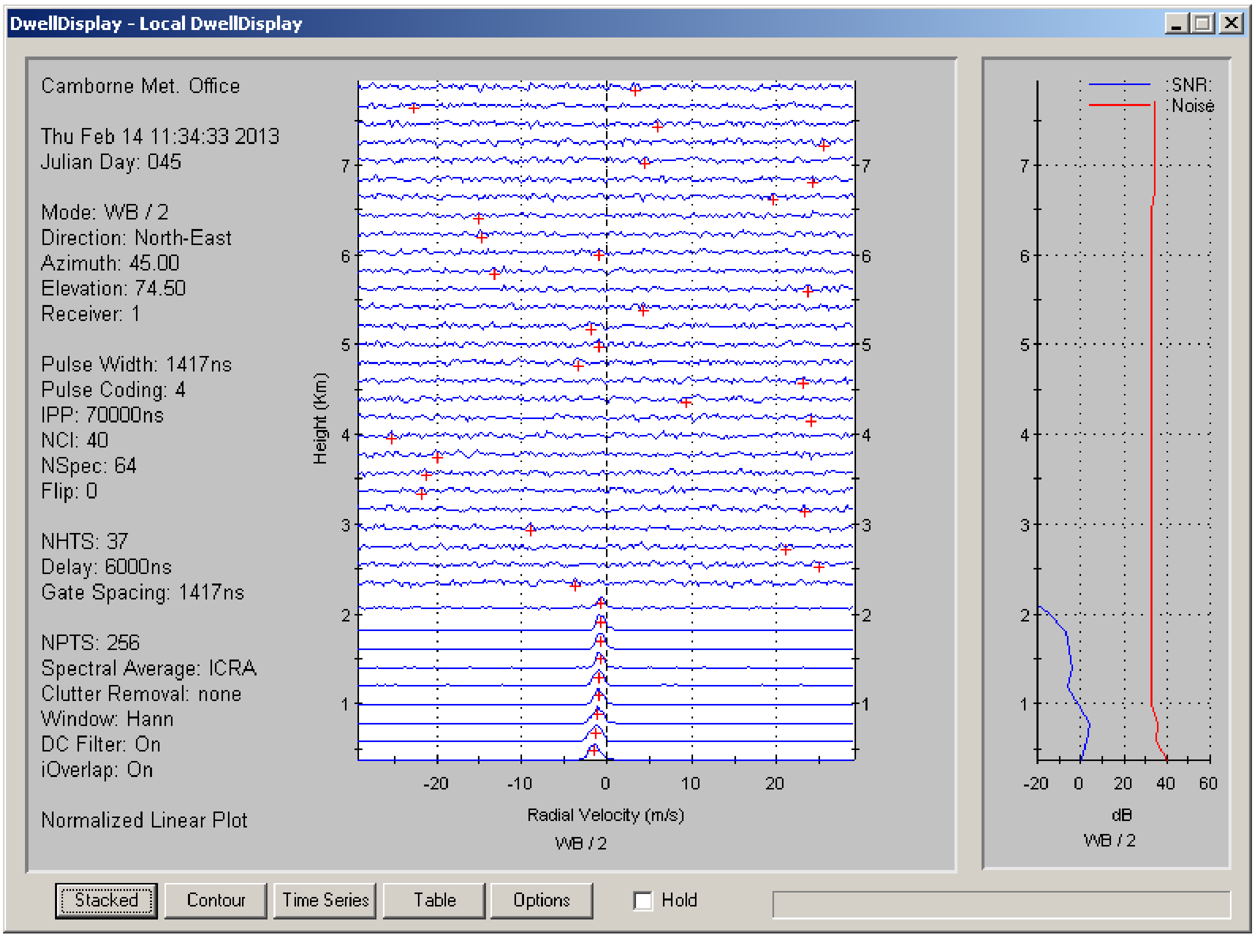


Figure A.1: Example of a non-interfered plot

Atmospheric parameters derived by wind profiler (based on moments profiles and profiles of full spectra) include:

- Reflectivity - the 0^{th} moments profile is indicative for the gradients in atmospheric temperature and humidity. Applying a forward operator on profiles of these atmospheric parameters from forecast model outputs allows verification of the model output and assimilate data for improving the forecast accuracy. In extreme cases, early warning for quickly developing severe weather can be significantly improved.

- Average Velocity - the 1^{st} moment profile is utilized in deriving the wind profiles (wind speed and direction). In addition it can be used for deriving profiles of the vertical wind velocity, e.g. for assessing severe convection. It also can be indicative for the presence of precipitation.

- Spectral width - the 2^{nd} moment profile enables assessment of atmospheric turbulence. It also can be indicative for the presence of precipitation.

- Profiles of full spectra enable assessment of many atmospheric information, e.g.:
  - Drop size distribution, allowing to derive Rain Rate and Precipitation Liquid Water content.
  - Precipitation type.
  - Freezing / melting level height.
  - Discrimination between clear air contribution and contribution from hydrometeors to the spectrum, allowing to better interpret the moments profiles.

A.2 Specifications for Wind Profiler Radar LAP-3000

Operating frequency Typically 915 or 1 290 MHz

Minimum height 1 120 m

Maximum height 2 up to 3 km

Range resolution (typical) 60, 100, 200, 400 m

Factory configurable 45 - 500 m

Wind speed accuracy 3 < 1 m/s

Wind direction accuracy < 10°

Wind averaging time 33 - 60 minutes

RF power output ≥ 600 W peak

0,1 - 100 W average

Occupied bandwidth @1 290 MHz Less than 12,5 MHz @ 400 ns pulse (99 % ITU)

Antenna

Type Electrically steerable micropatch

Phased-array panels

Gain ~26 dBi

~29 dBi with the extended antenna aperture

RF beam width ~9°

~6° with the extended antenna aperture

Aperture 2,7 m^2 @ 1 290 MHz, 3,0 m^2 @ 915 MHz

6,0 m2 @ 1 290 MHz, 6,2 m2 @ 915 MHz

(extended antenna aperture)

Power requirements 115 VAC/60 Hz; 15 A

230 VAC/50 Hz; 10 A

Specifications for the LAP®-3000 Wind Profiler

Operating frequency	800 to 1400 MHz, typically 915, 924, 1280, 1290, 1299, or 1357.5 MHz.

Transmitting characteristics for a LAP®-3000 wind profiler employing pulse modulation without rise and fall time control

Bandwidth		
@400 ns pulse	2.5 MHz (-3 dB)	12.7 MHz (-20 dB)
@700 ns pulse	1.26 MHz (-3 dB)	9.6 MHz (-20 dB)
@1400 ns pulse	632 KHz (-3 dB)	6.8 MHz (-20 dB)
@2800 ns pulse	316 KHz (-3 dB)	4.8 MHz (-20 dB)
Peak power	600 W	
Average power	0. 1 - 80 W	

Transmitting Characteristics for a LAP®-3000 wind profiler employing Pulse modulation having rise and fall time control

Bandwidth (< 15 MHz, 99% bandwidth)		
@ 400 ns pulse	2.5 MHz (-3 dB)	6.5 MHz (-20 dB)
@ 700 ns pulse	1.26 MHz (-3 dB)	5.1 MHz (-20 dB)
@ 1400 ns pulse	632 KHz (-3 dB)	3.3 MHz (-20 dB)
@ 2800 ns pulse	316 KHz (-3 dB)	2.0 MHz (-20 dB)
Peak power	600 W	
Average power	0.1 - 70 W	

Receiver Characteristics

Noise Figure	<= 1.2 dB (excludes antenna, T/R switch components)
Linear dynamic range	>= 84 dB
+3 dB Input Sensitivity	< -130 dBm
Image Rejection	> 45 dB
Spurious Rejection	> 45 dB

Figure A.2a

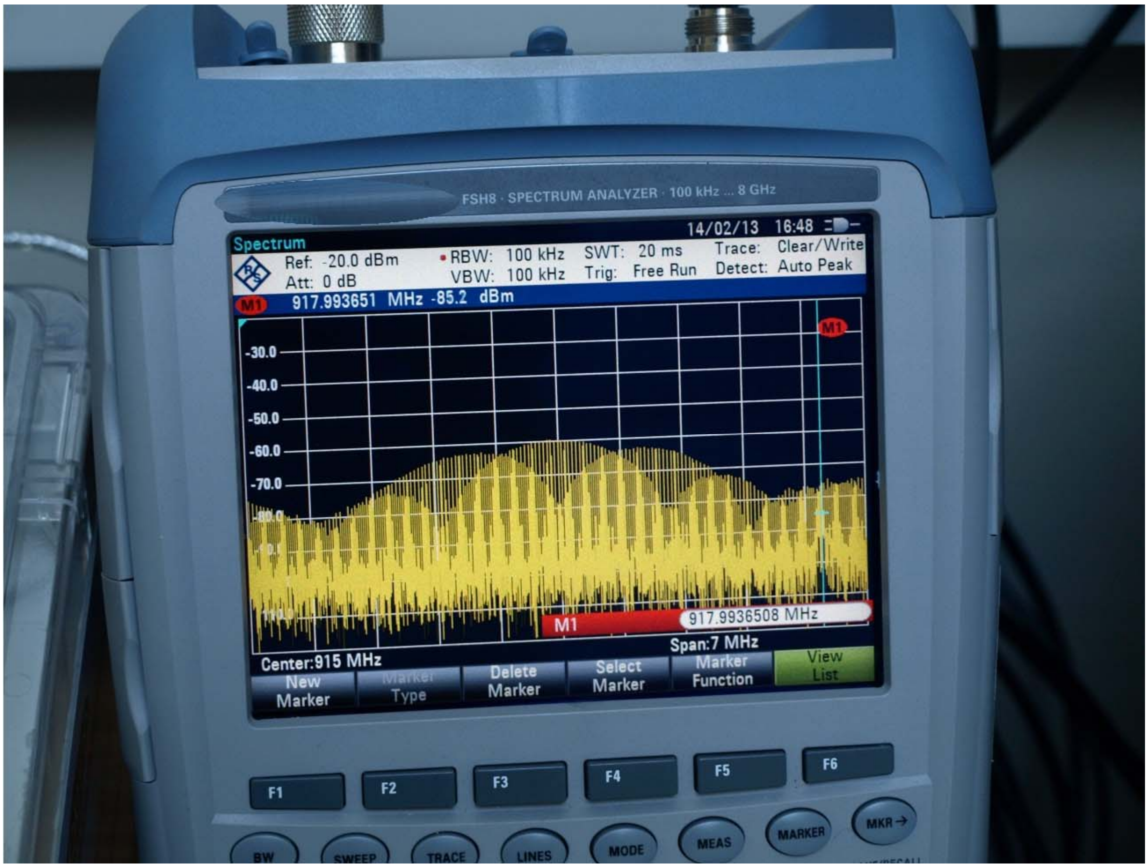


Figure A.2b: Plot of WPR waveform

Annex B: Spectrum masks

B.1 ALDs

Spectrum plots were taken with an R&S FSV spectrum analyser once equipment was returned to the lab, using the same settings that were used at Camborne.

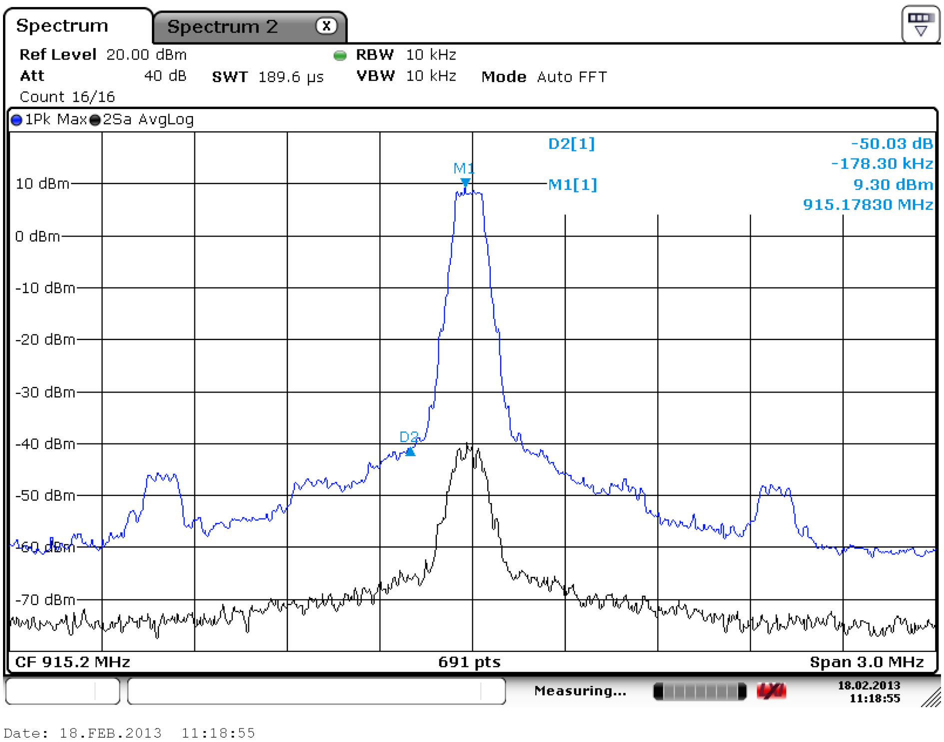


Figure B.1: Spectrum of ALD1 at 915,2 MHz, +10 dBm nominal peak output power, 50 % duty cycle; 3 MHz span

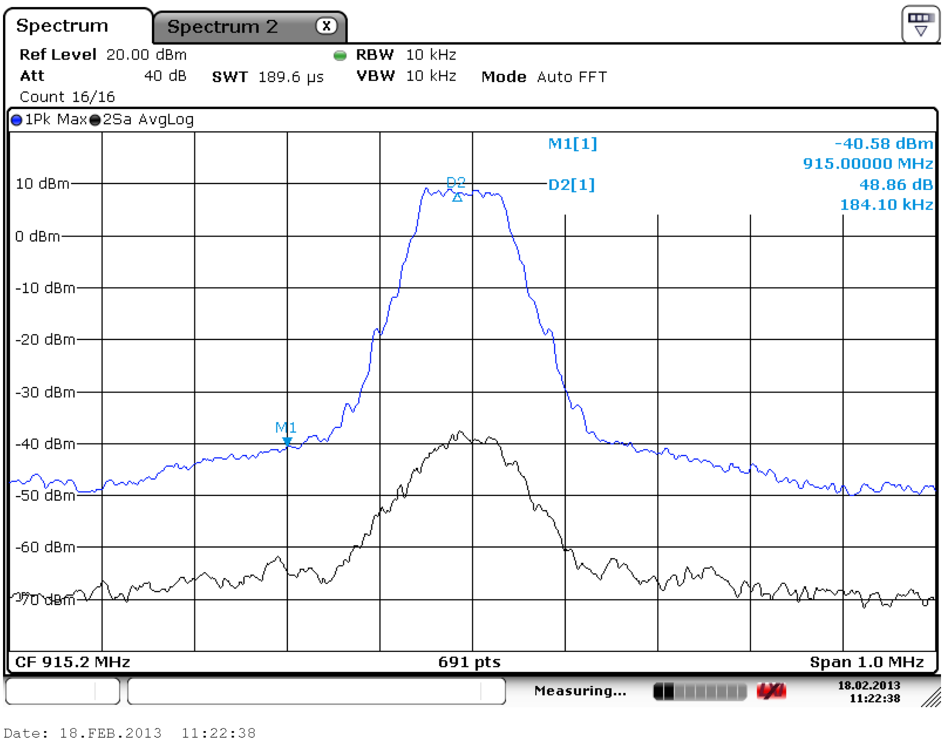


Figure B.2: Spectrum of ALD2 at 915,6 MHz, +10 dBm nominal peak output power, 100 % duty cycle, 1 MHz span

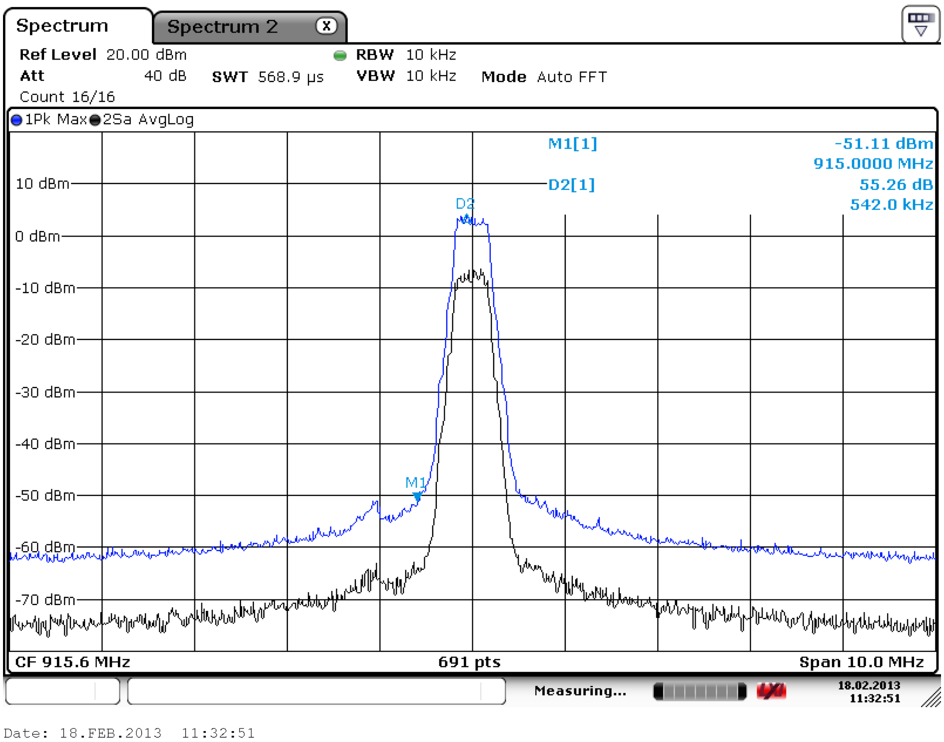


Figure B.3: Spectrum of ALD2 at 915,6 MHz, +10 dBm nominal peak output power, 100 % duty cycle, 10 MHz span

B.2 RFID

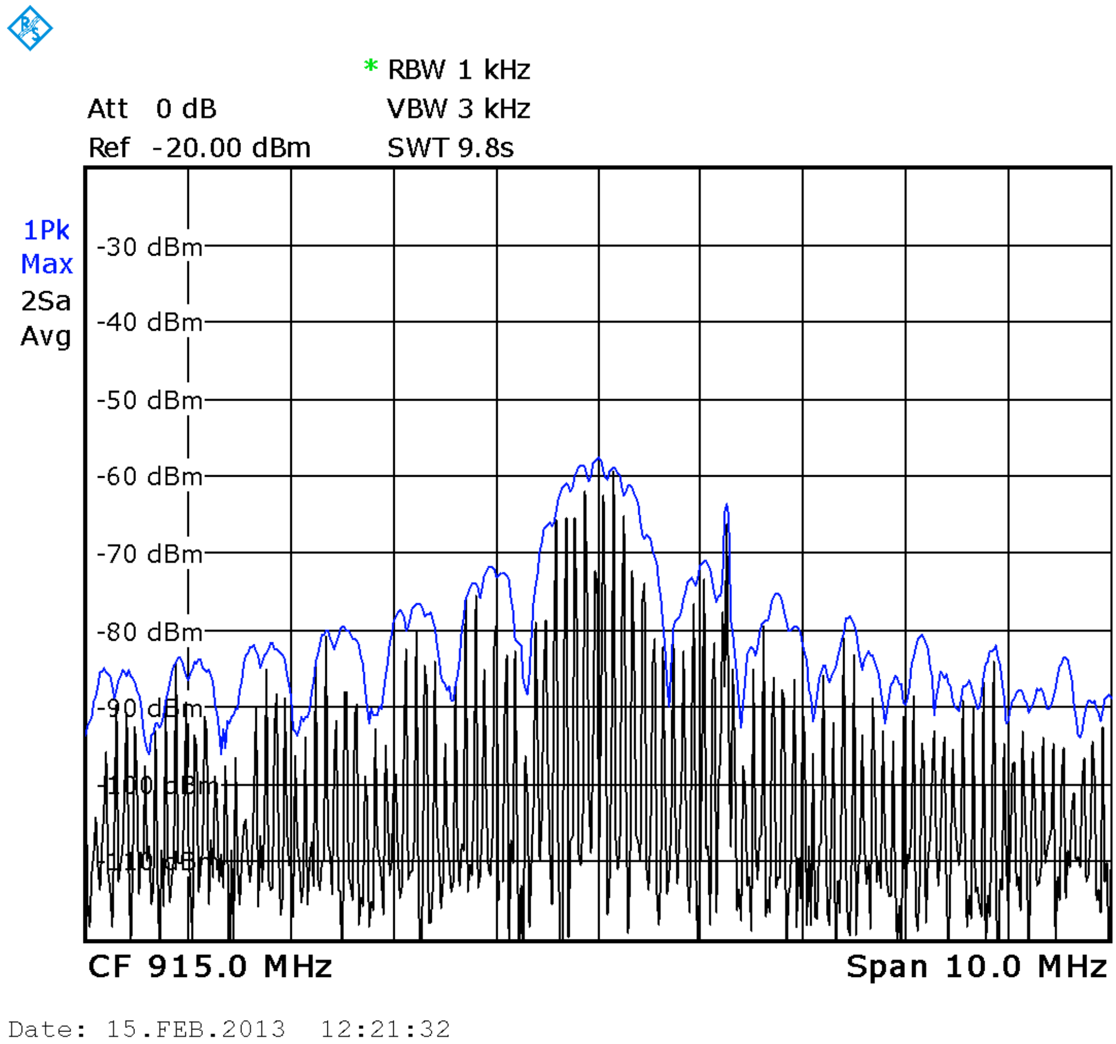


Figure B.4: Spectrum plot of RFID and WPR in high mode

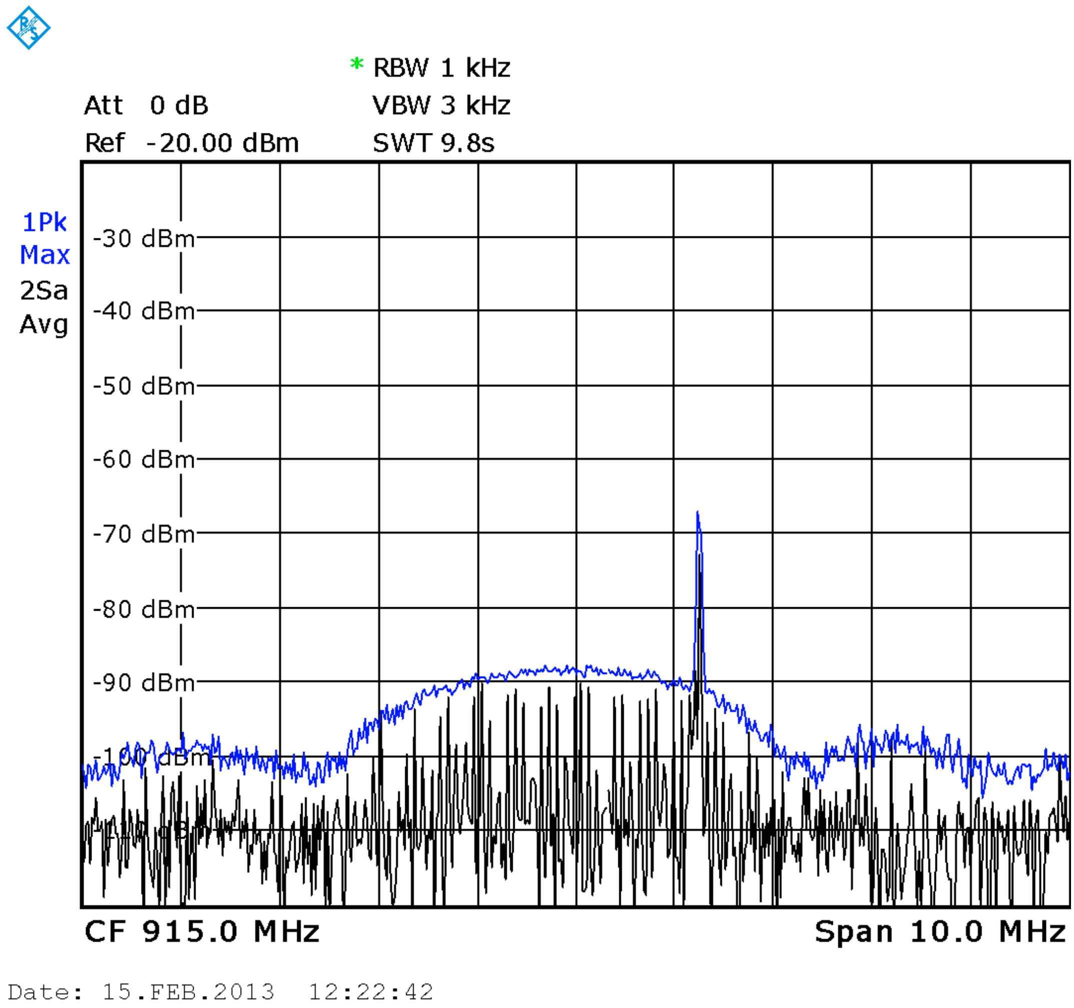


Figure B.5: Spectrum plot of RFID and WPR in low mode

B.3 GSM and UMTS

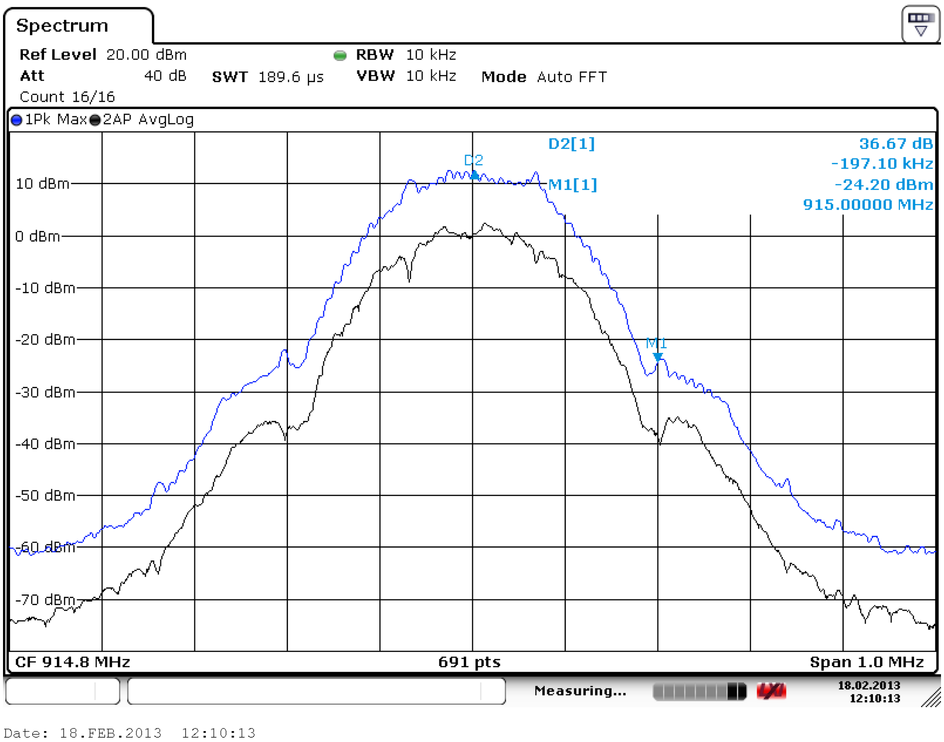


Figure B.6: GSM GMSK 914,8 MHz, +14 dBm nominal peak output power, 100 % duty cycle 1 MHz span

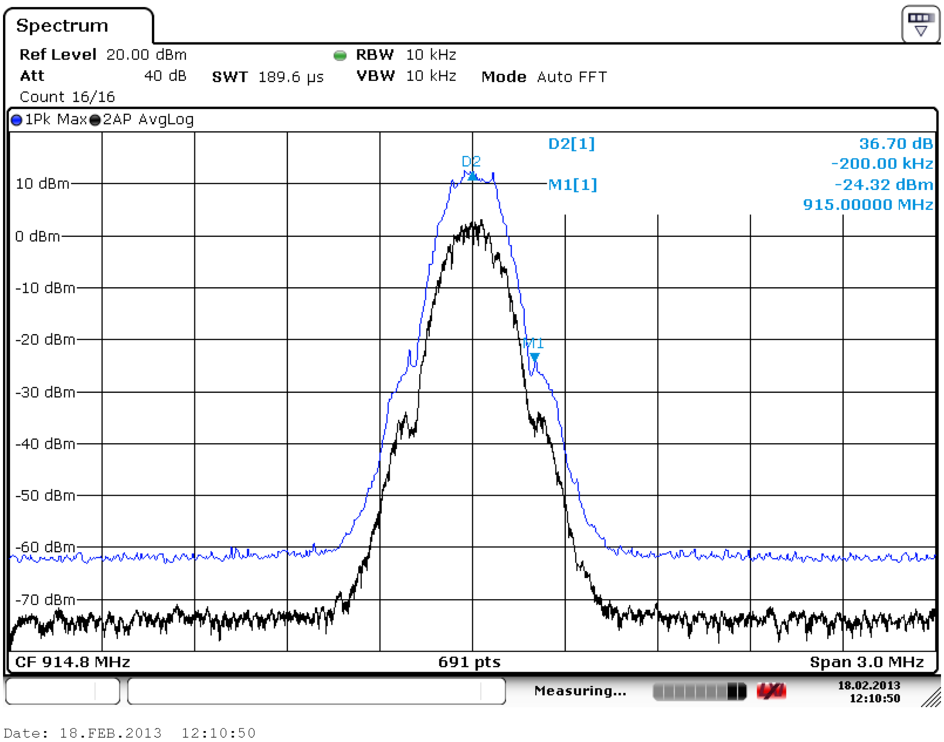


Figure B.7: GSM GMSK 914,8 MHz, +14 dBm nominal peak output power, 100 % duty cycle, 3 MHz span

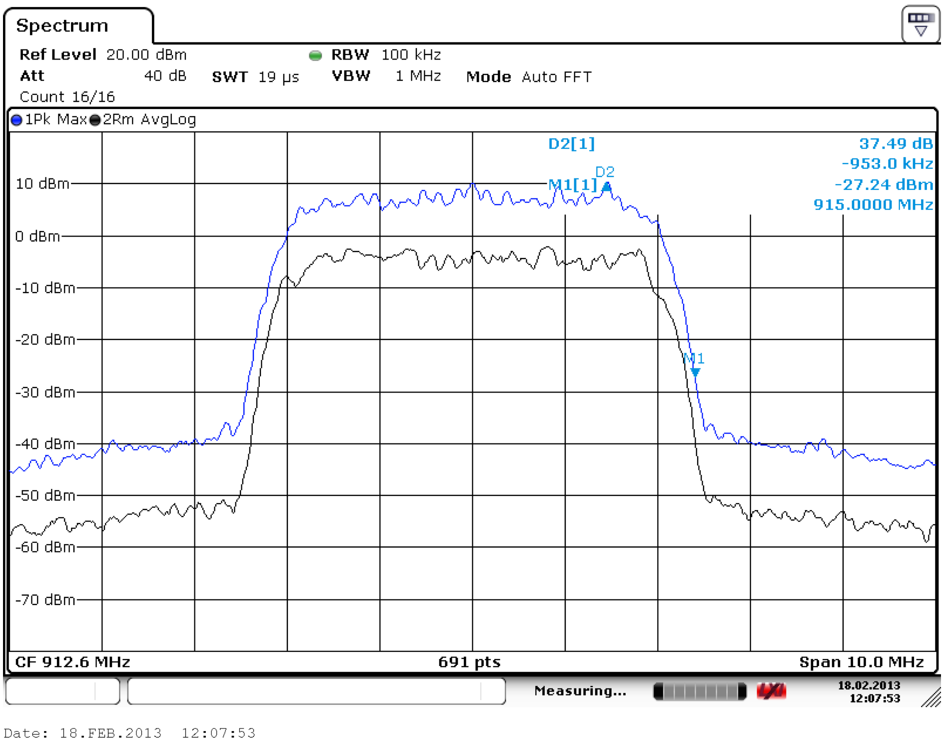


Figure B.8: 3G WCDMA QPSK 912,6 MHz, +14 dBm nominal peak output power, 100 % duty cycle: 10 MHz span

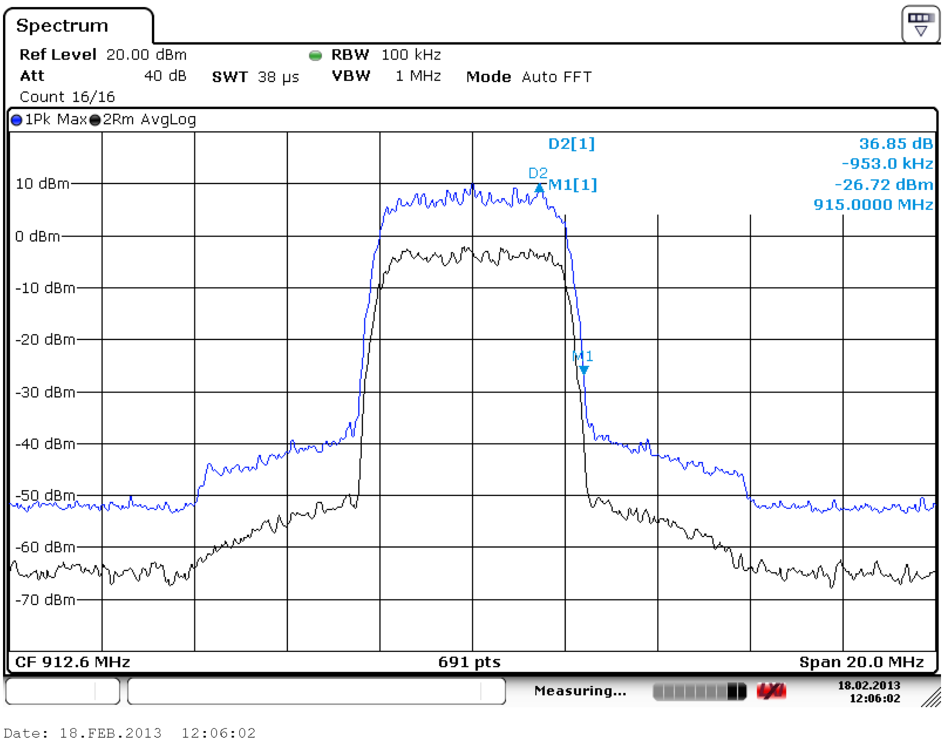


Figure B.9: 3G WCDMA QPSK 912,6 MHz, +14 dBm nominal peak output power, 100 % duty cycle, 20 MHz span

Annex C: Typical emissions from RFID systems

This annex provides information on the typical field levels that will be experienced outside the interrogation zone of an RFID system. In most installations the power transmitted by an interrogator is concentrated in the area where the user wishes to identify the "wanted" tags. Steps are taken to minimize field levels outside the interrogation zone to avoid the unintentional activation of "unwanted" tags in the surrounding area.

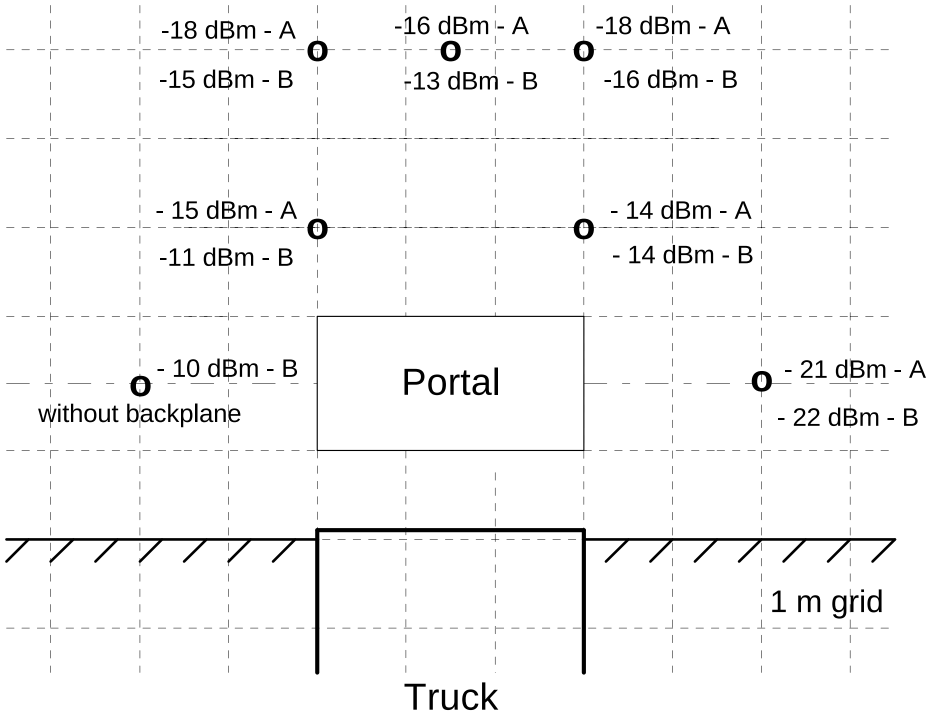
One of the more important applications for RFID at UHF is in materials handling. Pallets carrying tagged cartons are delivered on trucks from suppliers to distribution centres. The pallets from different suppliers are broken down and the cartons re-assigned as required onto other pallets for shipment to the retail outlets. Movement in and out of the distribution centre takes place through dock-doors. A portal equipped with antennas and an interrogator is positioned about 1 m inside each dock door. See figure C.1.

Figure C.1: Portals at dock doors on the left hand side of the photo inside a distribution centre

One of the engineering challenges facing such an installation is to achieve good reading performance of tags within the portal while avoiding the unintentional interrogation of tags fitted to other items inside the building. A number of features are introduced to achieve this objective, which are listed below:

- Antennas with narrow beam-widths are used, which are directed across the portal. This focuses the power transmitted by the interrogator within the interrogation zone and minimizes stray transmissions into the distribution centre.
- The portal includes a metal mesh, which attenuates the level of signal that penetrates into adjacent portals.
- By means of an infra-red curtain, the transmit time of the interrogator is limited to no more than is necessary to read the tags on a pallet as it passes through the portal - typically this is of the order of 1,5 to 2 seconds.

Measurements of the emissions using two different designs of portal were made at trial installations at distribution centres in Hamm and Unna. The results are shown in figure C.2.



NOTE: The readings annotated with an A were made with portals using E.M. shielding material.
The readings annotated with a B were made with portals using metal mesh screens.

Figure C.2: Comparison between portals with E.M., and metal mesh shielding

As a control one side of the portal was initially measured without shielding. Subsequently the portal was fitted firstly with E.M. shielding and then with a metal mesh. Due to the relatively small difference in performance and the large difference in cost, the metal mesh has been adopted.

It will be seen that the signal level at 2 m inside a truck is typically -13 dBm e.r.p. The field level was also measured at a number of points at a distance of 10 m outside the building and found never to exceed a level of -36 dBm e.r.p. For an interrogator transmitting at 36 dBm e.r.p. this would equate to a field level at a distance of 85m of -52 dBm. This is slightly less than the field experienced from an SRD transmitting at 20 dBm operating at the same distance. The value of 85 m was selected as it is typical of the distance from a distribution centre to the site perimeter.

Measurements at other installations at a different distribution centre measurements were also made at various distances from an RFID interrogator mounted in the doorway of a loading bay.

In this example an RFID interrogator and antenna were mounted in a loading bay with the following parameters:

- The antenna faced across the doorway with no shielded portal (and thus with none of the reductions shown in the previous example) as close to the doorway as was reasonably possible. This represented a worst case, even though such an installation was unlikely.
- The loading bay door was open and there was no truck parked outside. This again represents a worst case situation although such conditions are unlikely.
- The output was adjusted to 32 dBm e.r.p. at 866 MHz.
- The measurements were made in conjunction with a major UK retailer who operated the distribution centre being used.

Figure C.3: Location of RFID Antenna

The Distribution Centre was part of an industrial and distribution park near Daventry in the UK. Measurements were taken around the park to determine the signal levels at different distances from the antenna. The Reader antenna was then moved to another position and orientated in another direction. Measurements were repeated along the line of maximum output from the antenna. All of the results are given in figure C.4.

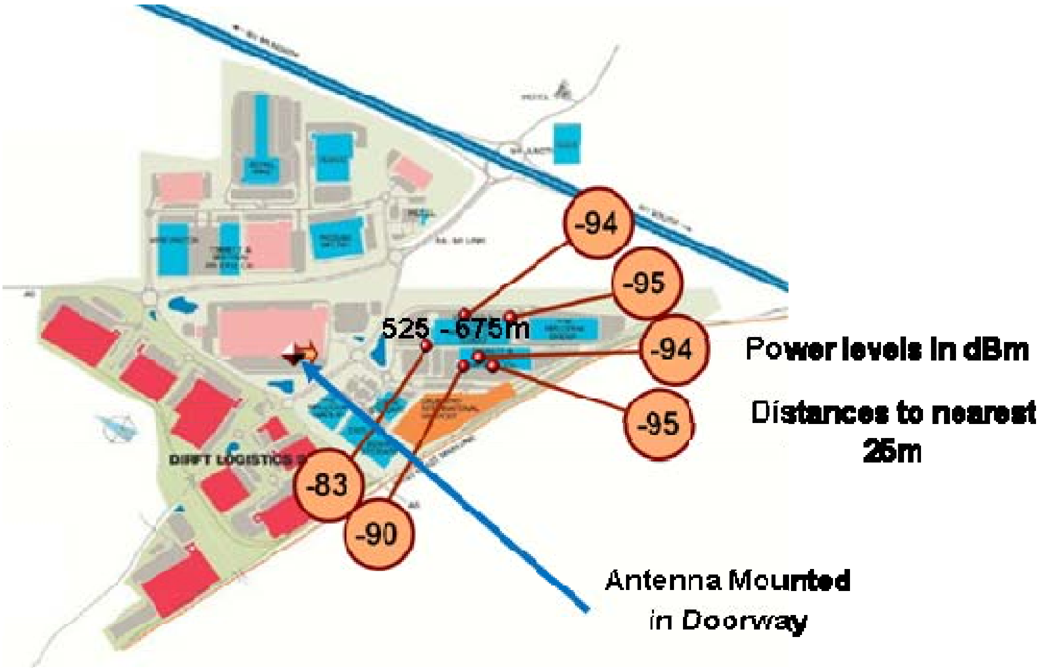


Figure C.4: Measurements recorded at distances of 525 m to 675 m from a dock door

The measured levels varied but were all more than 25 dB lower (and in some cases more than 40 dB lower) than would have been expected from a normal free space measurement. This clearly shows that in real terms any effect demonstrated in free space would be significantly reduced due to absorption and reflections in the buildings together with increased path loss.

Measurements at a small shopping centre. In this example an RFID interrogator and antenna were mounted at the open entrance to a retail store at one end of the ground floor of a shopping centre in Harlow UK, with the following parameters:

- The antenna was mounted facing across the entrance with no shielding, as close to the doorway as was reasonably possible.
- The entrance was open.
- The output was adjusted to 32 dBm e.r.p. at 866 MHz.
- The measurements were made in conjunction with a major UK retailer who operated the retail store being used.

Measurements were taken at various distances along the shopping area. The picture in figure C.5 shows the relative size of the centre and the measurements are shown on a floor plan in figure C.6.

Figure C.5: Picture showing upper and lower levels of Harlow shopping centre in 2006

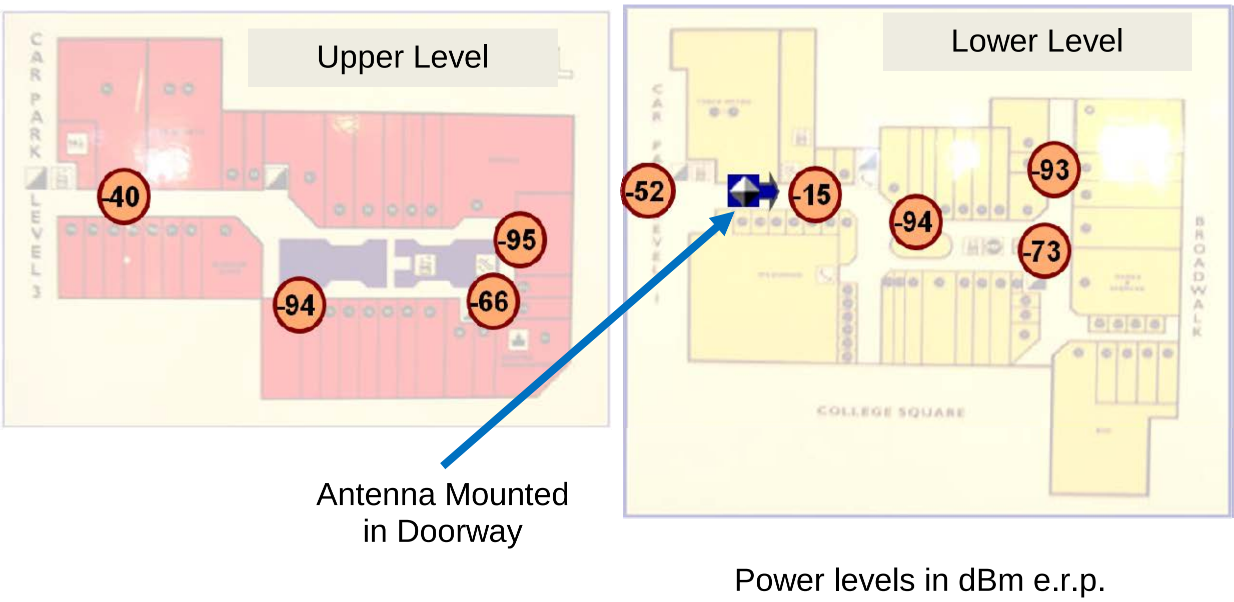


Figure C.6: Measurements at distances from the antenna in a shopping area

While the results show some variation due to reflections within the building, they do show significant reductions from the signal level at the shop exit. Furthermore, in the car park adjacent to where the antenna was mounted, the signal level was reduced to -52 dBm.

NOTE: The results from the last two examples were reported to ETSI TG34 during 2006. The frequency difference from 866 MHz to 915 MHz is unlikely to make a significant impact to the results.

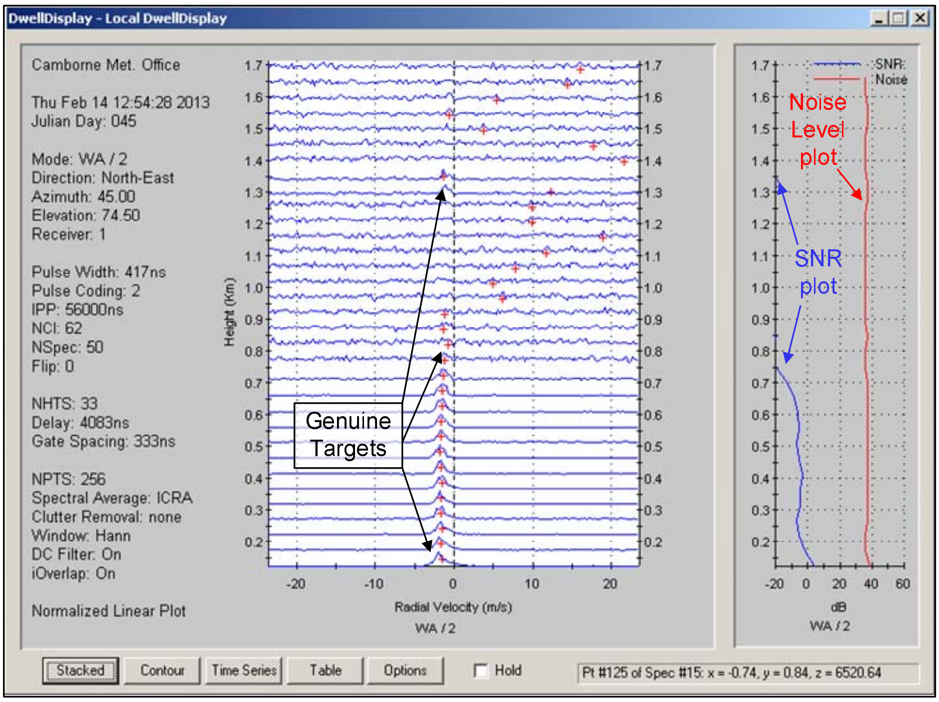
RFID at UHF is also used in many other applications such as industrial processes. In such applications, where there is often a high metal content, it is frequently unnecessary to operate at extended ranges. This enables the transit levels of interrogators to be reduced, which reduces the probability of reading "unwanted" tags. For example many RFID installations in car manufacturing plants successfully operate at transmit power levels of between 20 and 24 dBm e.r.p.

From these examples it can be seen that the field levels outside a building equipped with RFID are unlikely to cause harmful interference to other equipment operating in the immediate surrounding area.

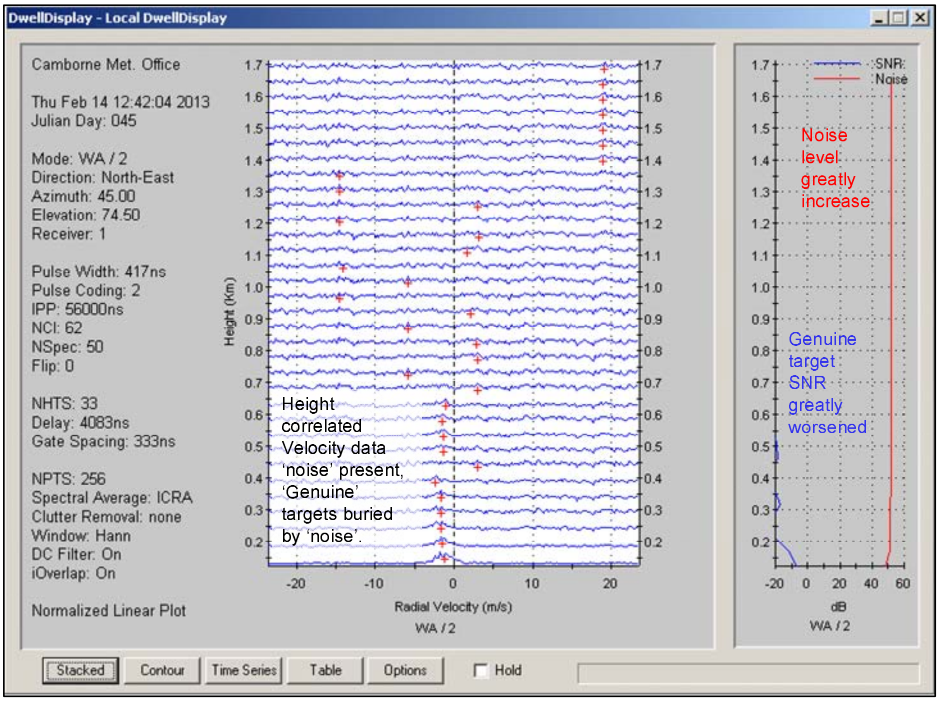
Annex D: Camborne test results (14-15th February 2013)

D.1 Annotated WPR interference screenshots - radial velocity dwell display

Case 1a - Windprofiler Low Height Mode – RFID Outdoors at 85 metres



Baseline Data with RFID TX OFF



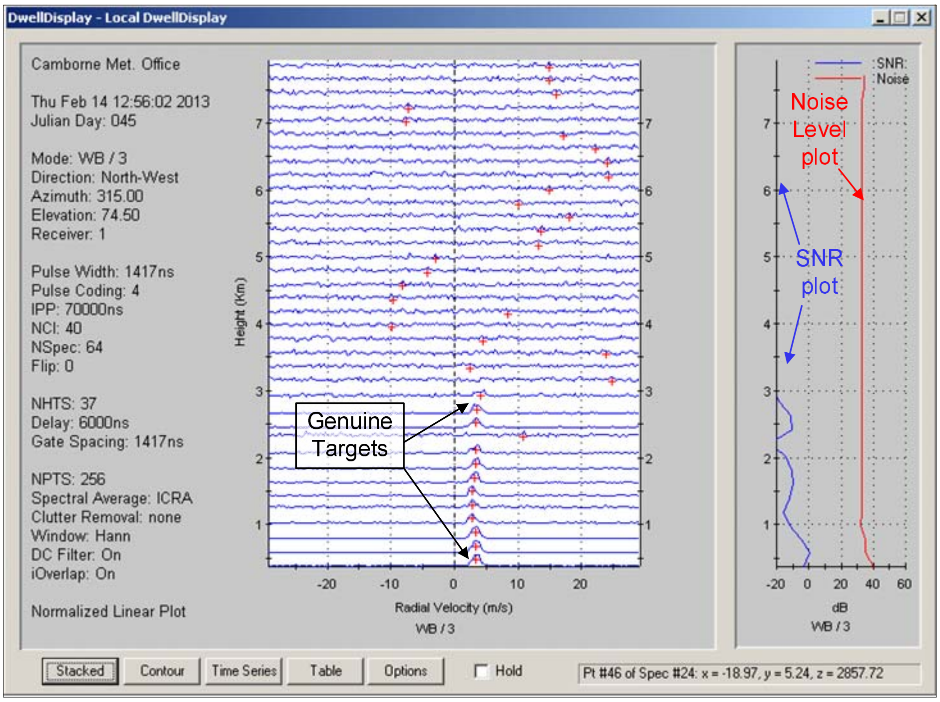
Data with RFID TX ON

<u>RFID Test Conditions</u> Frequency: 916.25 MHz Modulation: ON	Location: Outdoors ~85 metres from Wind Profiler Radar Power Level: 8.34 dBm into 7 dBi antenna Antenna: 0.8m above ground level

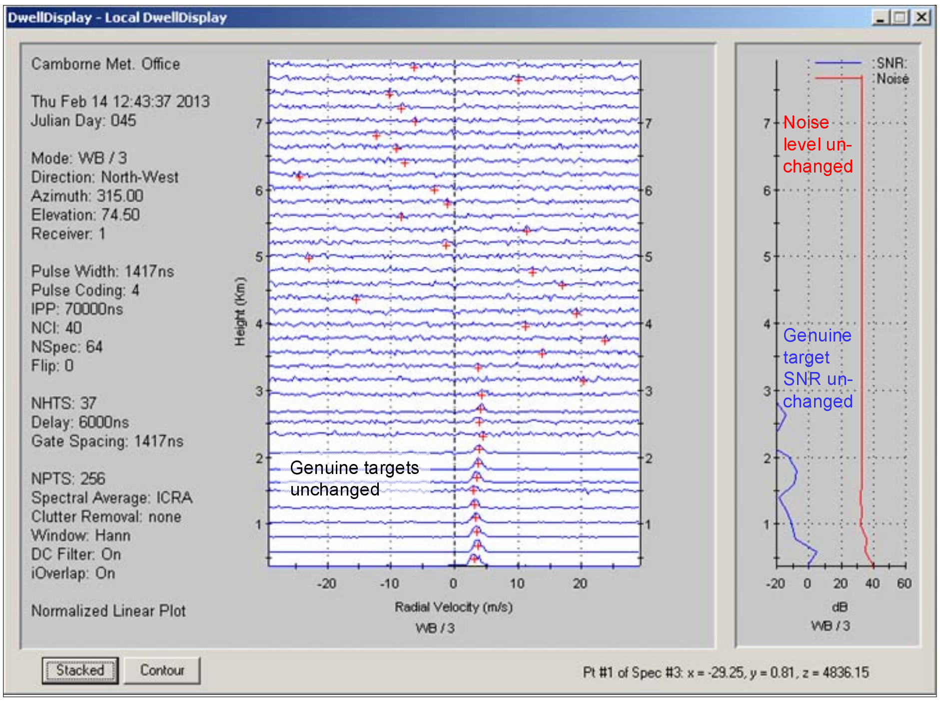
<u>Impact - Severe</u>
Radial Velocity: Height correlated Velocity data 'noise' present, 'Genuine' targets buried by 'noise'.
SNR (blue): Genuine target SNR greatly worsened. Noise (red): Noise level greatly increase.

Figure D.1

Case 1b – Windprofiler High Height Mode – RFID Outdoors at 85 metres



Baseline Data with RFID TX OFF



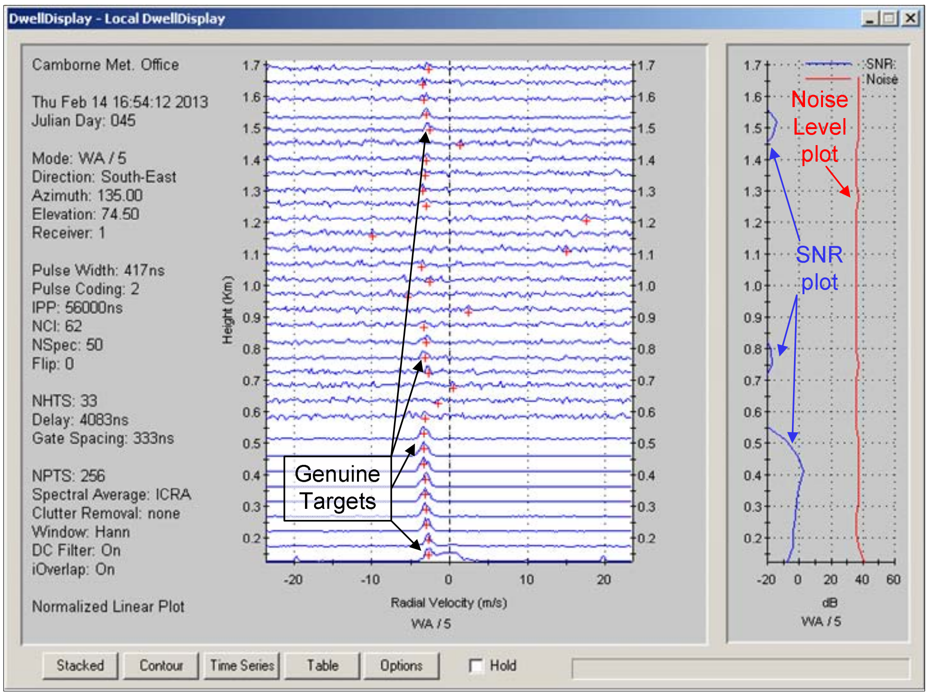
Data with RFID TX ON

RFID Test Conditions	Location: Outdoors ~85 metres from Wind Profiler Radar
Frequency: 916.25 MHz	Power Level: 8.34 dBm into 7 dBi antenna
Modulation: ON	Antenna: 0.8m above ground level

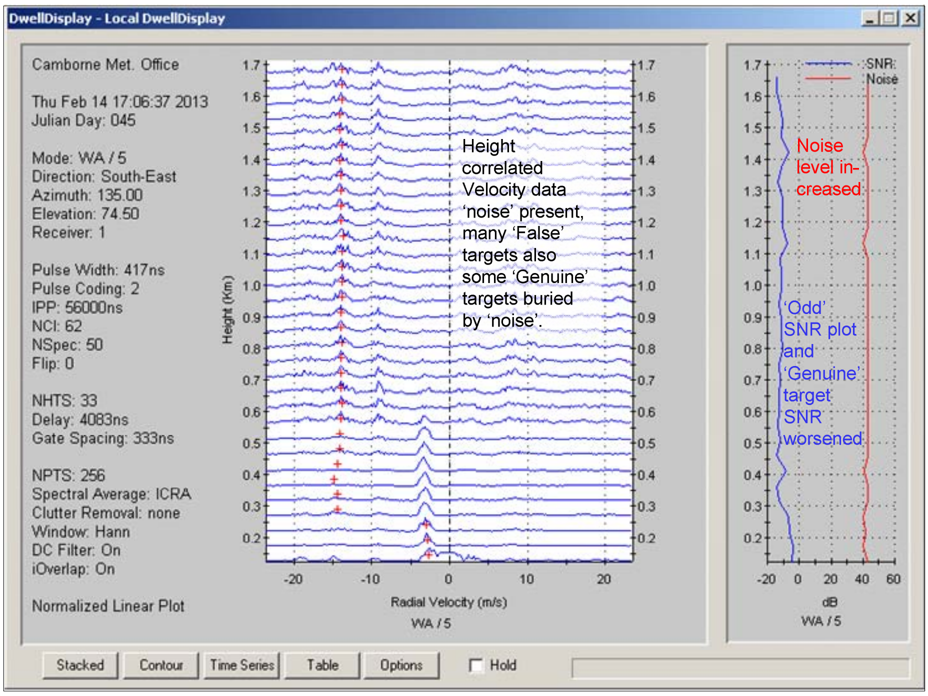
Impact - Nil
Radial Velocity: 'Genuine' targets unchanged.
SNR (blue): Genuine target SNR unchanged. Noise (red): Noise level unchanged.

Figure D.2

Case 2a – Windprofiler Low Height Mode – ALD Outdoors at 85 metres



Baseline Data with ALD TX OFF



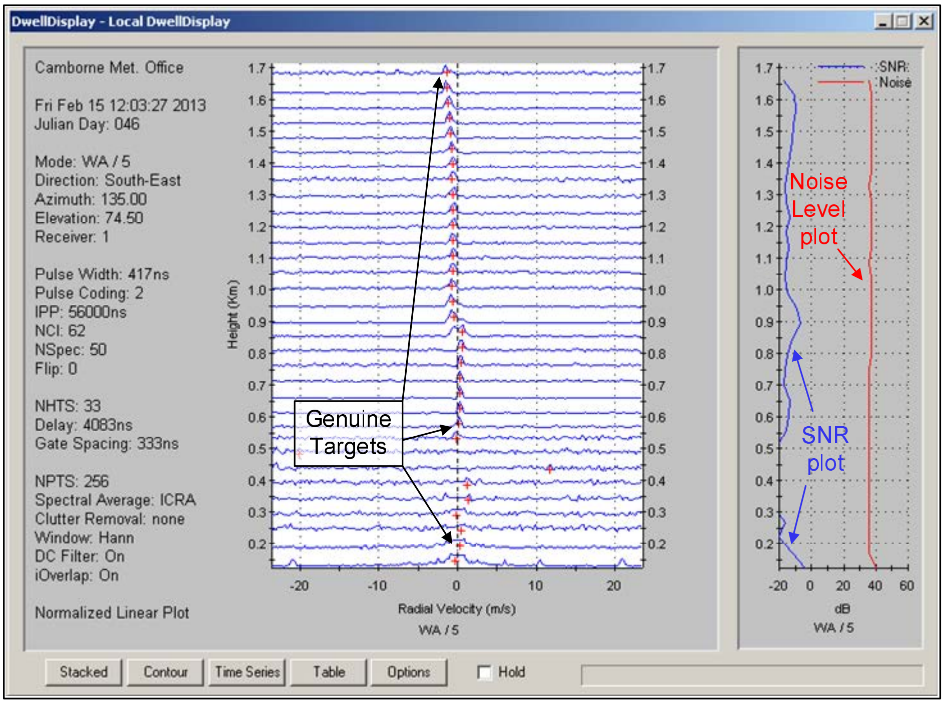
Data with ALD TX ON

<u>ALD2 Test Conditions</u>	Location: Outdoors ~85 metres from Wind Profiler Radar
Frequency: 915.6 MHz	Power Level: 10.54 dBm
Modulation: 4DFSK	Antenna: 1.5m above ground level

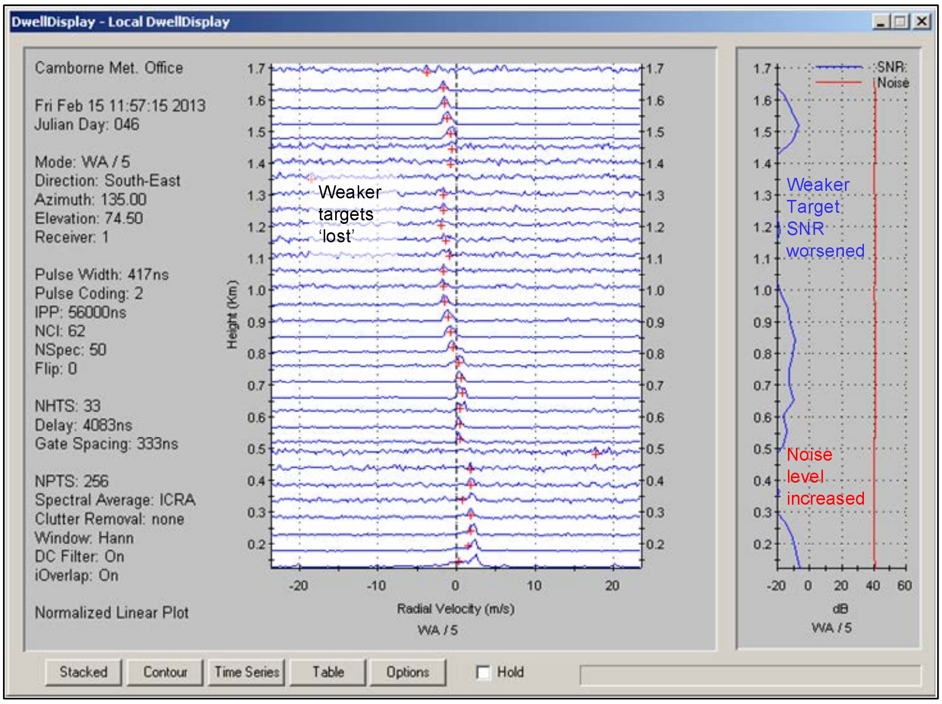
<u>Impact - Severe</u>
Radial Velocity: Height correlated Velocity data 'noise' present, many 'False'targets also some 'Genuine' targets buried by 'noise'.
SNR (blue): Odd SNR plot and 'Genuine' target SNR worsened. Noise (red): Noise level increase.

Figure D.3

Case 3a – Windprofiler Low Height Mode – RFID Indoors at 25 metres



Baseline Data with RFID TX OFF



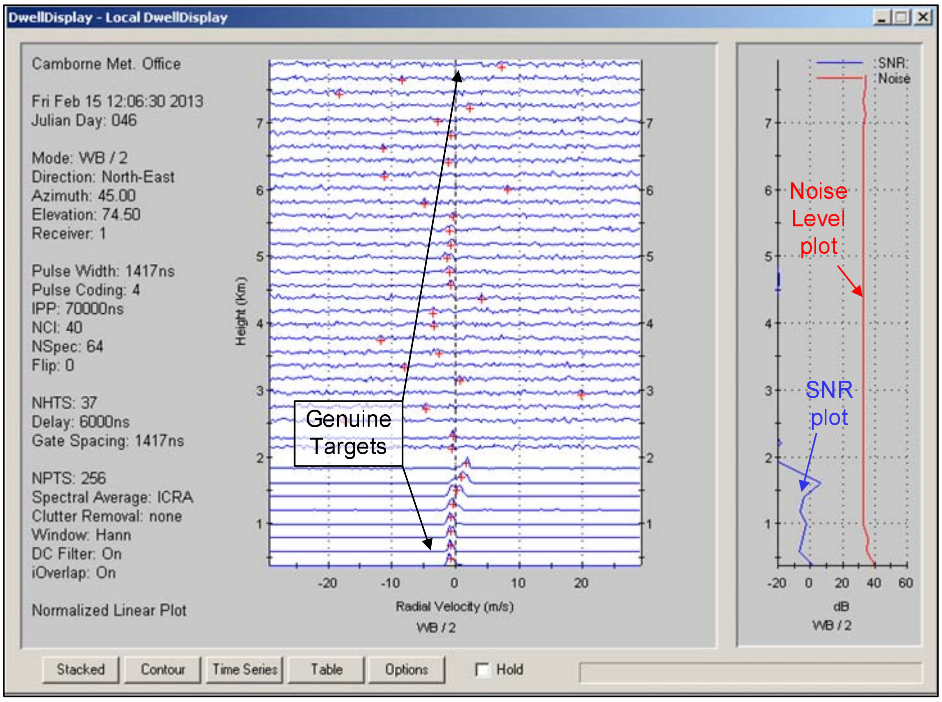
Data with RFID TX ON

<u>RFID Test Conditions</u>	Location: Indoors ~25 metres from Wind Profiler Radar
Frequency: 916.2 MHz	Power Level: 29 dBm into 7 dBi antenna
Modulation: ON	Antenna: 0.8m above floor level

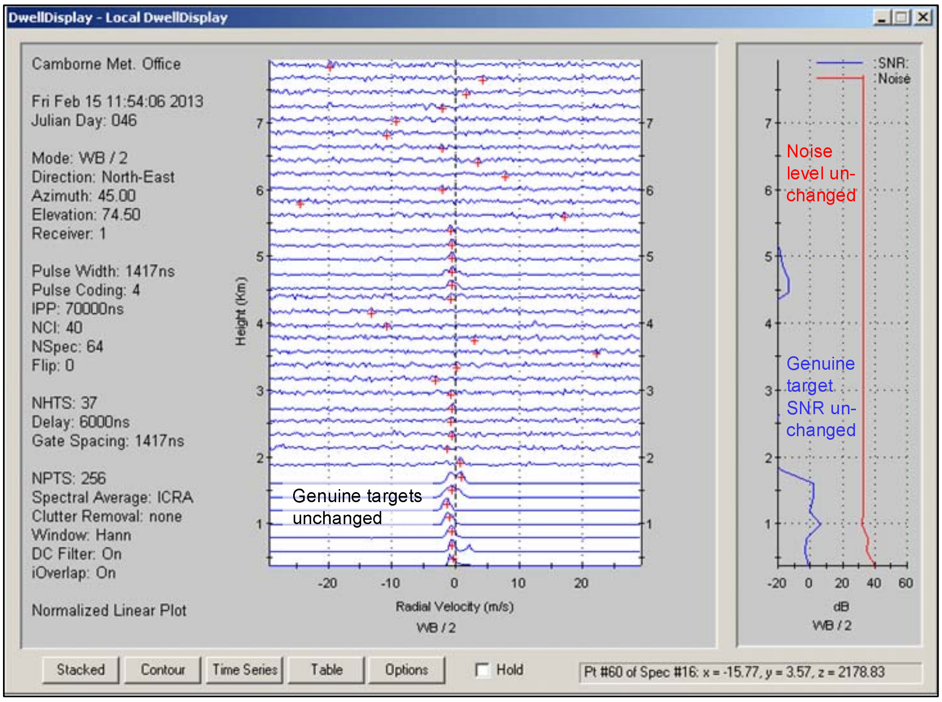
<u>Impact - Moderate</u>
Radial Velocity: Weaker targets 'lost'.
SNR (blue): Weak target SNR worsened. Noise (red): Noise level increased.

Figure D.4

Case 3b – Windprofiler High Height Mode – RFID Indoors at 25 metres



Baseline Data with RFID TX OFF



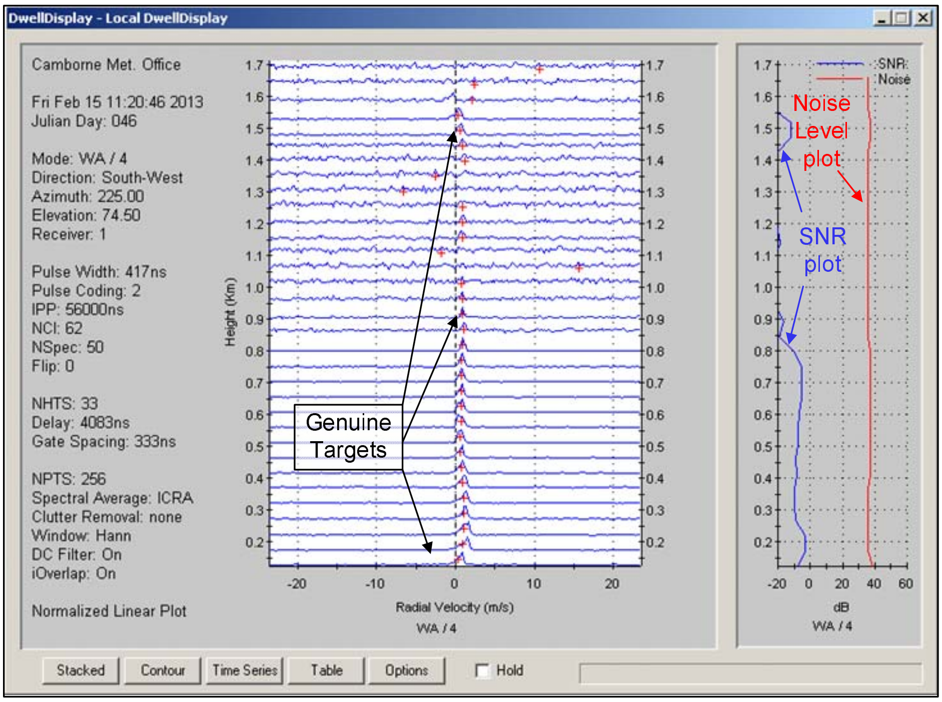
Data with RFID TX ON

RFID Test Conditions	Location: Indoors ~25 metres from Wind Profiler Radar
Frequency: 916.2 MHz	Power Level: 29 dBm into 7 dBi antenna
Modulation: ON	Antenna: 0.8m above floor level

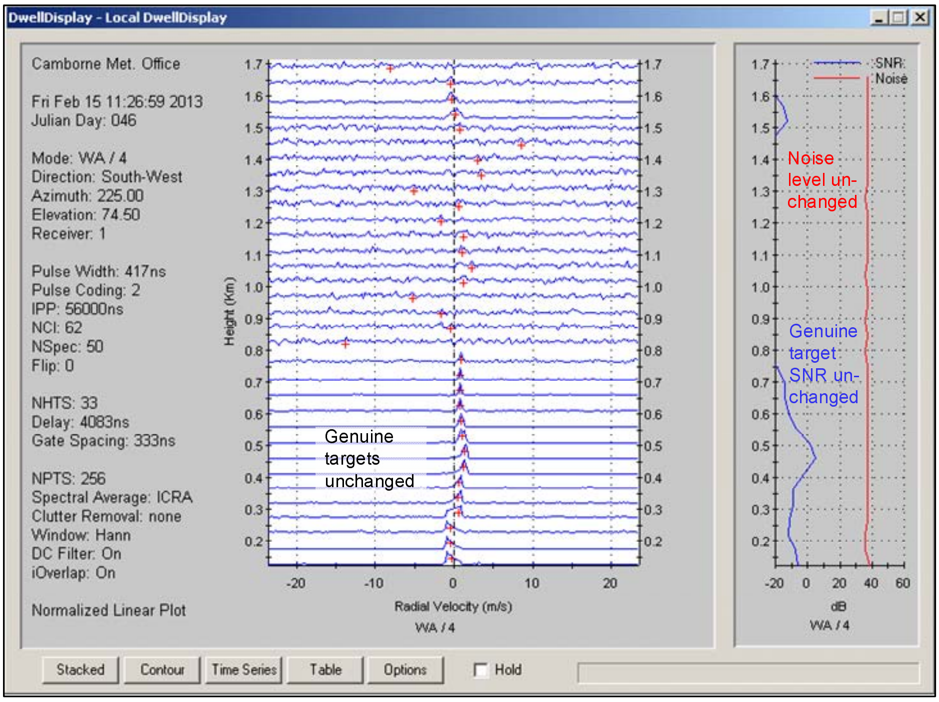
Impact - Nil
Radial Velocity: 'Genuine' targets unchanged.
SNR (blue): Genuine target SNR unchanged. Noise (red): Noise level unchanged.

Figure D.5

Case 4a – Windprofiler Low Height Mode – ALD Indoors at 25 metres



Baseline Data with ALD TX OFF



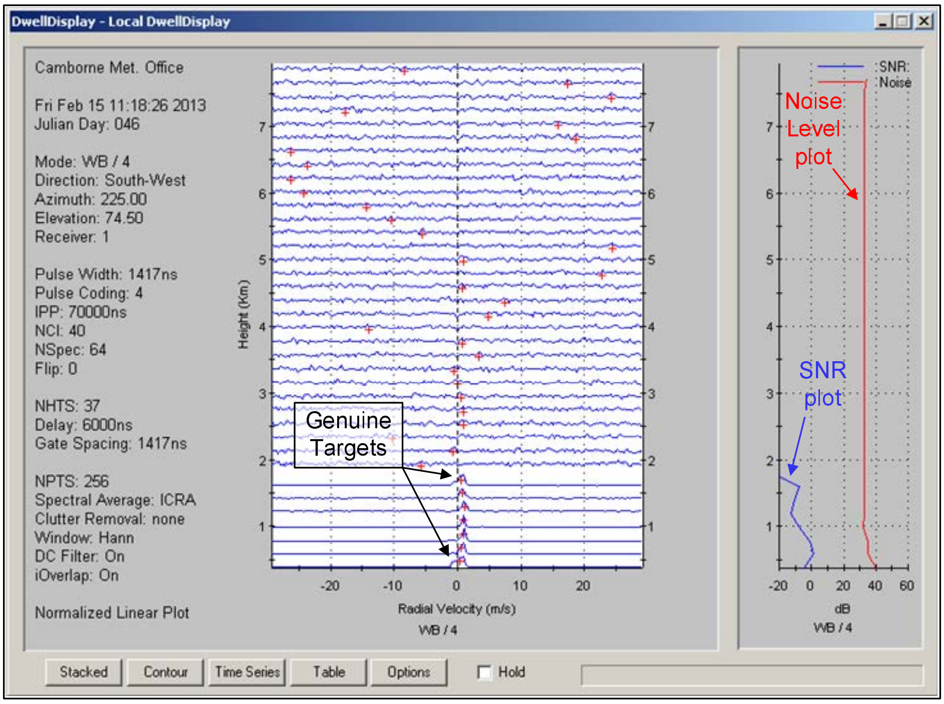
Data with ALD TX ON

<u>ALD1 Test Conditions</u> Frequency: 915.2 MHz Modulation: 4DFSK	Location: Indoors ~25 metres from Wind Profiler Radar Power Level: 13.11 dBm Antenna: 0.8m above floor level

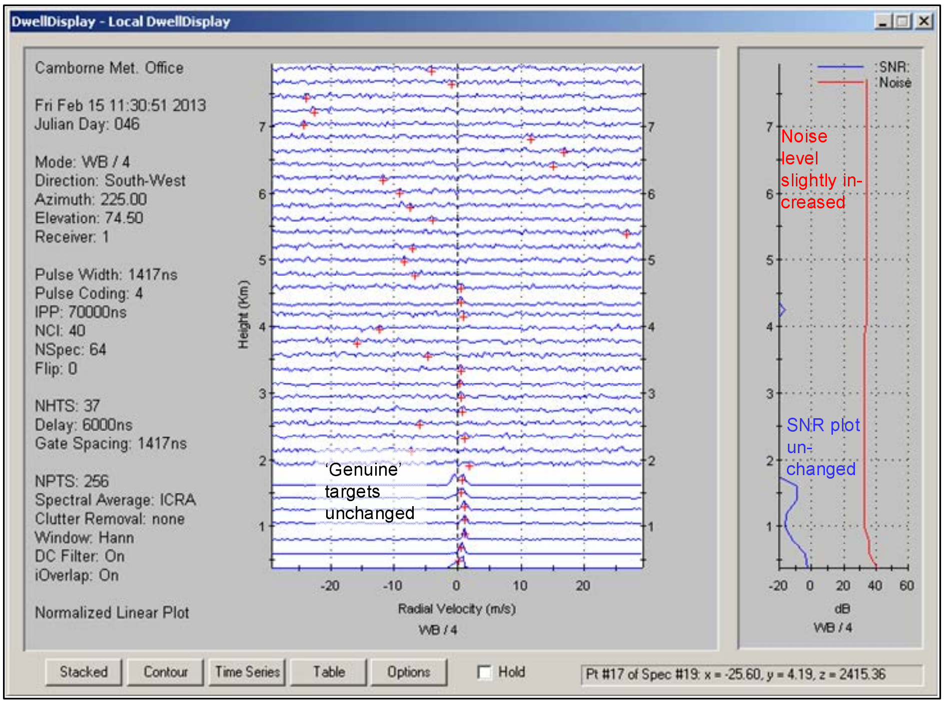
<u>Impact - Nil</u>
Radial Velocity: 'Genuine' targets unchanged.
SNR (blue): Genuine target SNR unchanged. Noise (red): Noise level unchanged.

Figure D.6

Case 4b – Windprofiler High Height Mode – ALD Indoors at 25 metres



Baseline Data with ALD TX OFF



Data with ALD TX ON

<u>ALD1 Test Conditions</u>	Location: Indoors ~25 metres from Wind Profiler Radar
Frequency: 915.2 MHz	Power Level: 13.11 dBm
Modulation: 4DFSK	Antenna: 0.8m above floor level

<u>Impact - Slight</u>
Radial Velocity: 'Genuine' targets unchanged.
SNR (blue): SNR plot unchanged. Noise (red): Noise level slightly increased.

Figure D.7

Windprofiler Dwell Display Screenshots Directory Structure and contents list

Table D.1

Directory Name **Dwell_Display_screenshots\01_RFID_cw_local**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_high	14/02/2013	11:04:19	WB / 3	NW	Hi		-
2	sw_high	14/02/2013	11:05:06	WB / 4	SW	Hi		-
3	se_high	14/02/2013	11:05:54	WB / 5	SE	Hi		-
4	se_low	14/02/2013	11:06:41	WA / 5	SE	Lo		Severe
5	sw_low	14/02/2013	11:07:27	WA / 4	SW	Lo		Moderate
6	nw_high2	14/02/2013	11:10:31	WB / 3	NW	Hi	repeat of 1	unchecked
7	sw_high2	14/02/2013	11:11:19	WB / 4	SW	Hi	repeat of 2	unchecked
8	ne_high	14/02/2013	11:22:09	WB / 2	NE	Hi		-
9	nw_low	14/02/2013	11:26:50	WA / 3	NW	Lo		Severe
10	ne_low	14/02/2013	11:27:35	WA / 2	NE	Lo		Severe

Table D.2

Directory Name **Dwell_Display_screenshots\02_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	ne_high_off	14/02/2013	11:34:33	WB / 2	NE	Hi	RFID off
2	se_low_off	14/02/2013	11:37:43	WA / 5	SE	Lo	

Table D.3

Directory Name			Dwell_Display_screenshots\03_RFID_mod_local					
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	se_high	14/02/2013	11:43:08	WB / 5	SE	Hi		-
2	se_low	14/02/2013	11:43:55	WA / 5	SE	Lo		Severe
3	sw_low	14/02/2013	11:44:41	WA / 4	SW	Lo		Severe
4	nw_low	14/02/2013	11:45:27	WA / 3	NW	Lo		Severe
5	ne_low	14/02/2013	11:46:12	WA / 2	NE	Lo		Severe
6	ne_high	14/02/2013	11:46:58	WB / 2	NE	Hi		-
7	nw_high	14/02/2013	11:47:45	WB / 3	NW	Hi		-
8	sw_high	14/02/2013	11:48:33	WB / 4	SW	Hi		-
9	se_high2	14/02/2013	11:49:20	WB / 5	SE	Hi	repeat of 1	unchecked
10	se_low2	14/02/2013	11:50:07	WA / 5	SE	Lo	repeat of 2	Unchecked
11	sw_low2	14/02/2013	11:50:53	WA / 4	SW	Lo	repeat of 3	Unchecked
12	nw_low2	14/02/2013	11:51:39	WA / 3	NW	Lo	repeat of 4	Unchecked
13	ne_low2	14/02/2013	11:52:25	WA / 2	NE	Lo	repeat of 5	Unchecked

Table D.4

Directory Name			Dwell_Display_screenshots\04_RFID_cw_dist					
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	se_low	14/02/2013	12:27:22	WA / 5	SE	Lo		Moderate
2	sw_low	14/02/2013	12:28:07	WA / 4	SW	Lo		Severe
3	nw_low	14/02/2013	12:28:53	WA / 3	NW	Lo		Severe
4	ne_low	14/02/2013	12:29:39	WA / 2	NE	Lo		Severe
5	ne_hi	14/02/2013	12:30:25	WB / 2	NE	Hi		-
6	nw_hi	14/02/2013	12:31:12	WB / 3	NW	Hi		-
7	sw_high	14/02/2013	12:31:59	WB / 4	SW	Hi		-
8	se_high	14/02/2013	12:32:47	WB / 5	SE	Hi		-

Table D.5

Directory Name **Dwell_Display_screenshots\05_RFID_mod_dist**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	se_low	14/02/2013	12:39:46	WA / 5	SE	Lo		Severe
2	sw_low	14/02/2013	12:40:32	WA / 4	SW	Lo		Severe
3	nw_low	14/02/2013	12:41:18	WA / 3	NW	Lo		Severe
4	ne_low	14/02/2013	12:42:04	WA / 2	NE	Lo		Severe
5	ne_high	14/02/2013	12:42:49	WB / 2	NE	Hi		-
6	nw_high	14/02/2013	12:43:37	WB / 3	NW	Hi		-
7	sw_high	14/02/2013	12:44:24	WB / 4	SW	Hi		-
8	se_high	14/02/2013	12:45:11	WB / 5	SE	Hi		-

Table D.6

Directory Name **Dwell_Display_screenshots\06_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	ne_low_off	14/02/2013	12:54:28	WA / 2	NE	Lo	with RFID off
2	nw_high_off	14/02/2013	12:56:02	WB / 3	NW	Hi	

Table D.7

Directory Name **Dwell_Display_screenshots\07_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	se_low_off	14/02/2013	14:25:16	WA / 5	SE	Lo	with ALD off
2	ne_high_off	14/02/2013	14:28:19	WB / 2	NE	Hi	

Table D.8

Directory Name **Dwell_Display_screenshots\08_ALD1_915_2_10dBm_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	se_low	14/02/2013	14:50:05	WA / 5	SE	Lo		Moderate
2	sw_low	14/02/2013	14:50:51	WA / 4	SW	Lo		Slight
3	nw_lo	14/02/2013	14:51:37	WA / 3	NW	Lo		Slight
4	ne_lo	14/02/2013	14:52:22	WA / 2	NE	Lo		Slight
5	ne_high	14/02/2013	14:53:08	WB / 2	NE	Hi		Slight
6	nw_high	14/02/2013	14:53:55	WB / 3	NW	Hi		Slight
7	sw_high	14/02/2013	14:54:43	WB / 4	SW	Hi		Slight
8	se_high	14/02/2013	14:55:30	WB / 5	SE	Hi		Slight

Table D.9

Directory Name **Dwell_Display_screenshots\09_ALD1_915_2_0dBm_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	se_high	14/02/2013	15:07:55	WB / 5	SE	Hi		Slight
2	se_low	14/02/2013	15:08:42	WA / 5	SE	Lo		-
3	sw_low	14/02/2013	15:09:28	WA / 4	SW	Lo		-
4	nw_low	14/02/2013	15:10:14	WA / 3	NW	Lo		-
5	ne_low	14/02/2013	15:11:00	WA / 2	NE	Lo		-
6	ne_high	14/02/2013	15:11:45	WB / 2	NE	Hi		Slight
7	nw_high	14/02/2013	15:12:33	WB / 3	NW	Hi		Slight
8	sw_high	14/02/2013	15:13:20	WB / 4	SW	Hi		Slight

Table D.10

Directory Name **Dwell_Display_screenshots\10_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	nw_high_off	14/02/2013	15:24:57	WB / 3	NW	Hi	
2	se_low_off	14/02/2013	15:27:19	WA / 5	SE	Lo	
3	sw_low_off	14/02/2013	15:28:05	WA / 4	SW	Lo	

Table D.11

Directory Name **Dwell_Display_screenshots\11_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	nw_low_off	14/02/2013	15:41:16	WA / 3	NW	Lo	

Table D.12

Directory Name **Dwell_Display_screenshots\12_ALD1_915_2_10dBm_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	ne_high	14/02/2013	15:42:47	WB / 2	NE	Hi		Moderate
2	nw_high	14/02/2013	15:43:45	WB / 3	NW	Hi		Moderate
3	sw_high	14/02/2013	15:44:22	WB / 4	SW	Hi		Moderate
4	se_high	14/02/2013	15:45:09	WB / 5	SE	Hi		Moderate
5	se_low	14/02/2013	15:45:57	WA / 5	SE	Lo		Slight
6	sw_low	14/02/2013	15:46:42	WA / 4	SW	Lo		Slight
7	nw_low	14/02/2013	15:47:28	WA / 3	NW	Lo		Slight
8	ne_low	14/02/2013	15:48:14	WA / 2	NE	Lo		Slight

Table D.13

Directory Name **Dwell_Display_screenshots\13_ALD1_916_2_10dBm_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_low	14/02/2013	15:53:40	WA / 3	NW	Lo	ne_low missed	Slight
2	ne_high	14/02/2013	15:55:12	WB / 2	NE	Hi		-
3	nw_high	14/02/2013	15:55:59	WB / 3	NW	Hi		-
4	sw_high	14/02/2013	15:56:47	WB / 4	SW	Hi		-
5	se_high	14/02/2013	15:57:34	WB / 5	SE	Hi		-
6	se_low	14/02/2013	15:58:21	WA / 5	SE	Lo		Slight
7	sw_low	14/02/2013	15:59:07	WA / 4	SW	Lo		Slight

Table D.14

Directory Name **Dwell_Display_screenshots\14_ALD1_916_2_0dBm_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	ne_low	14/02/2013	16:06:51	WA / 2	NE	Lo		-
2	ne_high	14/02/2013	16:07:37	WB / 2	NE	Hi		-
3	nw_high	14/02/2013	16:08:24	WB / 3	NW	Hi		-
4	sw_high	14/02/2013	16:09:11	WB / 4	SW	Hi		-
5	se_high	14/02/2013	16:09:59	WB / 5	SE	Hi		-
6	se_low	14/02/2013	16:10:46	WA / 5	SE	Lo		-
7	sw_low	14/02/2013	16:11:32	WA / 4	SW	Lo		-
8	nw_low	14/02/2013	16:18:30	WA / 3	NW	Lo		-

Table D.15

Directory Name		Dwell_Display_screenshots\15_baseline					
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	sw_high_off	14/02/2013	16:21:36	WB / 4	SW	Hi	
2	se_high_off	14/02/2013	16:22:23	WB / 5	SE	Hi	
3	se_low_off	14/02/2013	16:23:11	WA / 5	SE	Lo	
4	sw_low_off	14/02/2013	16:23:56	WA / 4	SW	Lo	
5	nw_low_off	14/02/2013	16:24:42	WA / 3	NW	Lo	
6	ne_low_off	14/02/2013	16:25:28	WA / 2	NE	Lo	
7	ne_high_off	14/02/2013	16:26:14	WB / 2	NE	Hi	
8	nw_high_off	14/02/2013	16:27:01	WB / 3	NW	Hi	

Table D.16

Directory Name		Dwell_Display_screenshots\16_ALD1_918_0_10dBm_remote						
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	sw_high	14/02/2013	16:34:01	WB / 4	SW	Hi		-
2	se_high	14/02/2013	16:34:48	WB / 5	SE	Hi		-
3	se_low	14/02/2013	16:35:35	WA / 5	SE	Lo		-
4	sw_low	14/02/2013	16:36:21	WA / 4	SW	Lo		-
5	nw_low	14/02/2013	16:37:07	WA / 3	NW	Lo		-
6	ne_low	14/02/2013	16:37:53	WA / 2	NE	Lo		-
7	ne_high	14/02/2013	16:38:38	WB / 2	NE	Hi		-
8	nw_high	14/02/2013	16:39:26	WB / 3	NW	Hi		-

Table D.17

Directory Name		Dwell_Display_screenshots\17_ALD1_918_0_0dBm_remote						
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_low	14/02/2013	16:43:19	WA / 3	NW	Lo	ne_low missed	-
2	ne_high	14/02/2013	16:44:51	WB / 2	NE	Hi		-
3	nw_high	14/02/2013	16:45:38	WB / 3	NW	Hi		-
4	sw_high	14/02/2013	16:46:25	WB / 4	SW	Hi		-
5	se_high	14/02/2013	16:47:13	WB / 5	SE	Hi		-
6	se_low	14/02/2013	16:48:00	WA / 5	SE	Lo		-
7	sw_low	14/02/2013	16:48:46	WA / 4	SW	Lo		-

Table D.18

Directory Name **Dwell_Display_screenshots\18_baseline**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_high_off	14/02/2013	16:51:50	WB / 3	NW	Hi		-
2	sw_high_off	14/02/2013	16:52:38	WB / 4	SW	Hi		-
3	se_high_off	14/02/2013	16:53:25	WB / 5	SE	Hi		-
4	se_low_off	14/02/2013	16:54:12	WA / 5	SE	Lo		-
5	sw_low_off	14/02/2013	16:54:58	WA / 4	SW	Lo		-
6	nw_low_off	14/02/2013	16:55:44	WA / 3	NW	Lo		-
7	ne_low_off	14/02/2013	16:56:30	WA / 2	NE	Lo		-
8	ne_high_off	14/02/2013	16:57:15	WB / 2	NE	Hi		-

Table D.19

Directory Name **Dwell_Display_screenshots\19_ALD2_915_6_11dBm_mod_100per_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_high_mod	14/02/2013	17:04:15	WB / 3	NW	Hi		Severe
2	sw_high_mod	14/02/2013	17:05:02	WB / 4	SW	Hi		Severe
3	se_high_mod	14/02/2013	17:05:50	WB / 5	SE	Hi		Severe
4	se_low_mod	14/02/2013	17:06:37	WA / 5	SE	Lo		Severe
5	sw_low_mod	14/02/2013	17:07:23	WA / 4	SW	Lo		Severe
6	nw_low_mod	14/02/2013	17:08:09	WA / 3	NW	Lo		Severe
7	ne_low_mod	14/02/2013	17:08:54	WA / 2	NE	Lo		Severe
8	ne_high_mod	14/02/2013	17:09:40	WB / 2	NE	Hi		Severe

Table D.20

Directory Name **Dwell_Display_screenshots\20_ALD2_915_6_0dBm_mod_100per_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	ne_low_mod	14/02/2013	17:15:07	WA / 2	NE	Lo		Slight
2	ne_high_mod	14/02/2013	17:15:52	WB / 2	NE	Hi		-
3	nw_high_mod	14/02/2013	17:16:40	WB / 3	NW	Hi		-
4	sw_high_mod	14/02/2013	17:17:27	WB / 4	SW	Hi		Slight
5	se_high_mod	14/02/2013	17:18:14	WB / 5	SE	Hi		Severe
6	se_low_mod	14/02/2013	17:19:02	WA / 5	SE	Lo		Severe
7	sw_low_mod	14/02/2013	17:19:48	WA / 4	SW	Lo		Slight
8	nw_low_mod	14/02/2013	17:20:33	WA / 3	NW	Lo		Slight

Table D.21

Directory Name **Dwell_Display_screenshots\21_ALD2_916_2_0dBm_mod_100per_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_low_mod	14/02/2013	17:26:46	WA / 3	NW	Lo		Slight
2	ne_low_mod	14/02/2013	17:27:31	WA / 2	NE	Lo		Slight
3	ne_high_mod	14/02/2013	17:28:17	WB / 2	NE	Hi		-
4	nw_high_mod	14/02/2013	17:29:05	WB / 3	NW	Hi		-
5	sw_high_mod	14/02/2013	17:29:52	WB / 4	SW	Hi		-
6	se_high_mod	14/02/2013	17:30:39	WB / 5	SE	Hi		-
7	se_low_mod	14/02/2013	17:31:27	WA / 5	SE	Lo		Moderate
8	sw_low_mod	14/02/2013	17:32:12	WA / 4	SW	Lo		Slight

Table D.22

Directory Name **Dwell_Display_screenshots\21_ALD2_916_2_0dBm_mod_100per_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_low_mod	14/02/2013	17:26:46	WA / 3	NW	Lo		Slight
2	ne_low_mod	14/02/2013	17:27:31	WA / 2	NE	Lo		Slight
3	ne_high_mod	14/02/2013	17:28:17	WB / 2	NE	Hi		-
4	nw_high_mod	14/02/2013	17:29:05	WB / 3	NW	Hi		-
5	sw_high_mod	14/02/2013	17:29:52	WB / 4	SW	Hi		-
6	se_high_mod	14/02/2013	17:30:39	WB / 5	SE	Hi		-
7	se_low_mod	14/02/2013	17:31:27	WA / 5	SE	Lo		Moderate
8	sw_low_mod	14/02/2013	17:32:12	WA / 4	SW	Lo		Slight

Table D.23

Directory Name **Dwell_Display_screenshots\22_ALD2_916_2_11dBm_mod_100per_remote**

No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	nw_high_mod	14/02/2013	17:35:17	WB / 3	NW	Hi		-
2	sw_high_mod	14/02/2013	17:36:04	WB / 4	SW	Hi		-
3	se_high_mod	14/02/2013	17:36:52	WB / 5	SE	Hi		-
4	se_low_mod	14/02/2013	17:37:39	WA / 5	SE	Lo		Severe
5	sw_low_mod	14/02/2013	17:38:25	WA / 4	SW	Lo		Severe
6	nw_low_mod	14/02/2013	17:39:10	WA / 3	NW	Lo		Moderate
7	ne_low_mod	14/02/2013	17:39:56	WA / 2	NE	Lo		Moderate
8	ne_high_mod	14/02/2013	17:40:42	WB / 2	NE	Hi		-

Table D.24

Directory Name			Dwell_Display_screenshots\23_baseline				
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment
1	se_high_off	14/02/2013	17:43:04	WB / 5	SE	Hi	ne_high missed 6 is a repeat of 1
2	se_low_off	14/02/2013	17:43:51	WA / 5	SE	Lo	
3	nw_low_off	14/02/2013	17:45:23	WA / 3	NW	Lo	
4	ne_low_off	14/02/2013	17:46:09	WA / 2	NE	Lo	
5	nw_high_off	14/02/2013	17:47:42	WB / 3	NW	Hi	
6	se_high_off2	14/02/2013	17:49:16	WB / 2	NE	Hi	
7	sw_low_off	14/02/2013	17:50:50	WA / 4	SW	Lo	
8	sw_high_off	14/02/2013	17:54:41	WB / 4	SW	Hi	

Table D.25

Directory Name		Dwell_Display_screenshots\24_RFID_chsn917_25_mod_remote						
No.	File Name	Date	Data Time	Mode	Dirn.	Height	Comment	Level of interference
1	ne_low	14/02/2013	17:58:33	WA / 2	NE	Lo		Slight
2	ne_high	14/02/2013	17:59:19	WB / 2	NE	Hi		-
3	nw_high	14/02/2013	18:00:06	WB / 3	NW	Hi		-
4	sw_high	14/02/2013	18:00:54	WB / 4	SW	Hi		-
5	se_high	14/02/2013	18:01:41	WB / 5	SE	Hi		-
6	se_low	14/02/2013	18:02:28	WA / 5	SE	Lo		Severe
7	sw_low	14/02/2013	18:03:14	WA / 4	SW	Lo		Severe
8	nw_low	14/02/2013	18:04:00	WA / 3	NW	Lo		Moderate

Annex E: Bibliography

ETSI TR 102 649-2: "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".

History

Document history		
V1.1.1	September 2013	Publication