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Wise-Project Measurement Report: Airspan Wimax Radio Laboratory Measurements

Measurements to study the Airspan Wimax Radio characteristics as a WSD were conducted in the laboratory as part of the Finnish WISE-project. WISE (White space test environment for broadcast frequencies) is a project with the aim to construct an open, cognitive radio geolocation database test bed for studying the use of cognitive radios in the UHF television broadcast bands. This includes simulations, test database, test network and measurement platform. The project partners are Aalto University, Digita, Fairspectrum, Ficora, Nokia, University of Turku, Turku University of Applied Sciences and it is funded by Tekes, the national technology funding organization, as part of a larger cognitive radio Trial-program.

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1. BACKGROUND

In the autumn 2010, before the Wise-project, Nokia and Digita conducted field trials with TV white space devices in the Helsinki area using Wimax based Airspan radios operating in the 702 – 746 MHz band. The intension of the Wise project is use the same radios for further demonstrations in TVWS but this time using the Fairspectrum data base. To better understand the WSD characteristics of the radios a short laboratory measurement session was organized to measure the main RF-characteristics of the radios, which are relevant for operating in the TVWS regime. These include Adjacent Channel Leakage Ratios (ACLR) and protections ratios towards DVB-T. Also DVB-T interference potential towards the WSD uplink was studied.

2. MEASUREMENT SET UP

2.1 Airspan Wimax radios

The base station unit (BS) is Airspan MicroMAX using frequency range 702MHz – 746 MHz. (channels 50-54 and partly 55). The BU supports bandwidths from 1.75 to 10 MHz, from which 5 MHz band was used in the trial and in the measurements. The Customer Premises Equipment (CPE) was Airspan ProST Outdoor unit. The radios are shown in Figure 1.

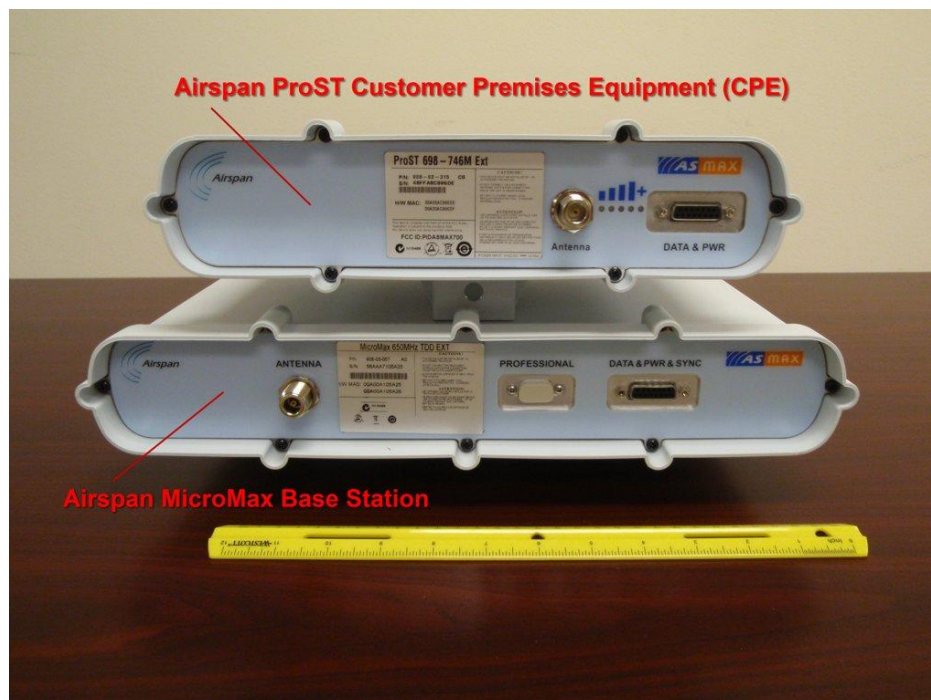


Figure 1 Airspan radios

The base station is connected to a laptop where an agent program is running. The agent is connected to a data base (in this case Spectrum Bridge), which gives the permission to the radios to operate. Location of the radio is manually fed to a setup file.

2.2 Connection of the radios

All the measurements were done in the laboratory and the BS and CPE were connected together with a cable setup so that no radio signals were transmitted in the air. Slightly different setups were used for different measurements, but in general the BS and CPE were physically separated by several meters to avoid any direct coupling by leaks. The connection cable between had a directional coupler and adjustable attenuators on both sides of the coupler so that it was possible to get a sample of either the BS or the CPE signal to the measurement device with the unwanted signal attenuated. Due to the rather high output powers of the devices fixed attenuators were attached to the BS and CPE, these being either 30 dB or 4.8 dB depending on the measurement case. A suitable path loss was achieved with the step attenuators.

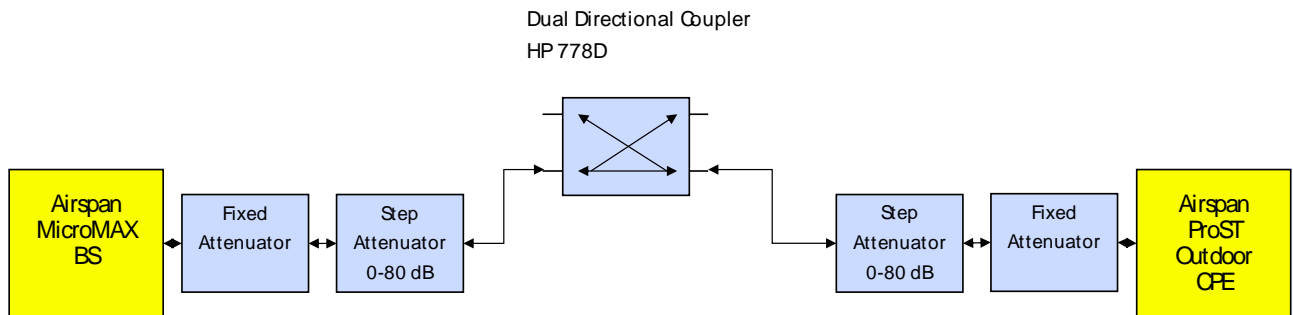


Figure 2 General setup for the measurements

The general setup is shown in Figure 2. More detailed setups for each measurement are shown in the respective chapters. All cable and component attenuations were checked with a network analyser.

2.3 Power and spectrum measurement equipment

All the spectrum and power measurements were done with R&S spectrum analyser.

2.4 DVB-T signals and receivers

The DVB-T signals were generated Pro Television PT5780 DVB-T signal generator and the signal was combined to the WSD radio path with a MiniCircuits ZAPD 2-252-N+ power divider. Two different DVB-receivers were used in the measurements. Most of the measurements were done with Sony Bravia KDL-32EX713 TV-set. This is rather modern integrated set with DVB-T2 capability. As comparison set a Topfield TF5100PVR Set Top Box was used in some protection ratio measurements. The reception quality was observed from the TV-picture so that no errors were visible during a 20 second observation period. The levels were first adjusted so that errors were occurring, and then the interference was reduced until the wanted error free state was reached.

2.5 Traffic on the link

The radios were used in two different modes during the measurements. In general the laptop connected to the CPE was used for downloading a large file so that full traffic pattern was achieved. For some measurements idle state of the link was simulated by just making a ping from the CPE. In this case the uplink signal had an occasional short burst every now and then. This was used to test the DVB-receiver AGC performance with time variant signals.

3. MEASUREMENTS

3.1 Spectrum and power measurements

Spectrum and power measurements for the BS and CPE were done with the general set up so that the spectrum analyser was connected to one of the outputs of the directional coupler. 30 dB fixed attenuators were used and the step attenuators were set on one side to 0 dB and on the other side to 40dB. This gave for the total path loss with 4 dB cable loss roughly $30\text{dB}+30\text{dB}+40\text{dB}+0\text{dB}+4\text{ dB} = 104\text{dB}$. By this arrangement the unwanted (either CPE or BS) was attenuated by $30\text{dB}+40\text{dB}+36\text{dB} = 106\text{ dB}$, where the 36 dB figure is the directional coupler isolation. The 104 dB path loss would correspond a 1.5 km link with 10 dBi antenna gains and 10m and 3m antenna heights in suburban environment (OH) or 4.5 km link in open area (OH).

The measured BS spectrum is shown in Figure 3.

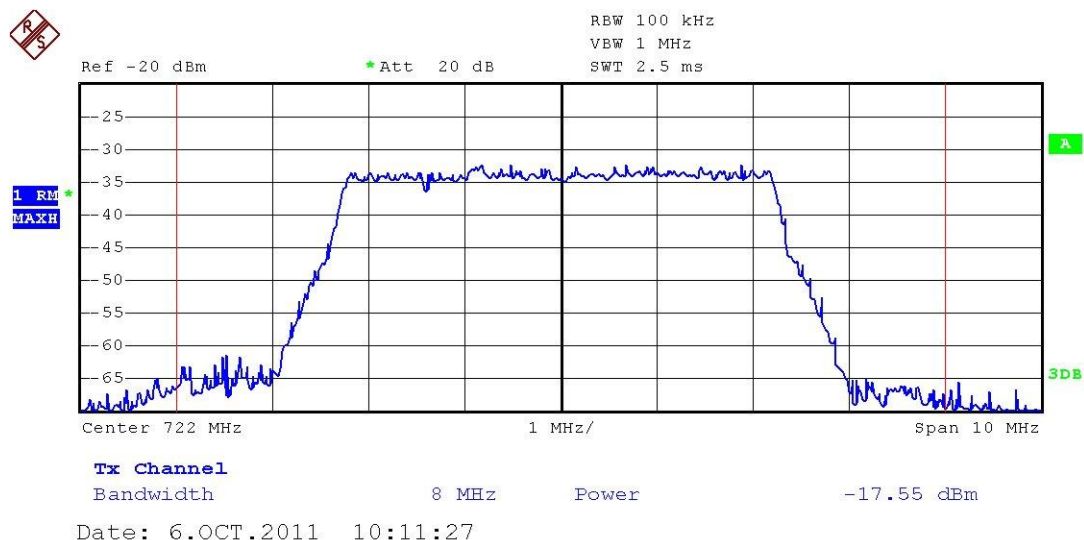


Figure 3 BS Spectrum and power

The measurement is done with RMS detection and max hold (due to the TDD) in channel power measurement mode and the figure -17.55 dBm corresponds the peak average power of the Wimax signal. The BS output power can be calculated by adding the losses of directional coupler (19.36 dB), attenuators (30dB) and cables (1dB). This gives: -17.55

$\text{dBm} + 30\text{dB} + 19.36\text{dB} + 1\text{dB} = 32.8 \text{ dBm}$. As can be seen the signal bandwidth is about 5 MHz and the shoulders are -30 dB down at 6 MHz bandwidth (+-3 MHz).

A similar measurement with the CPE is shown in Figure 4..

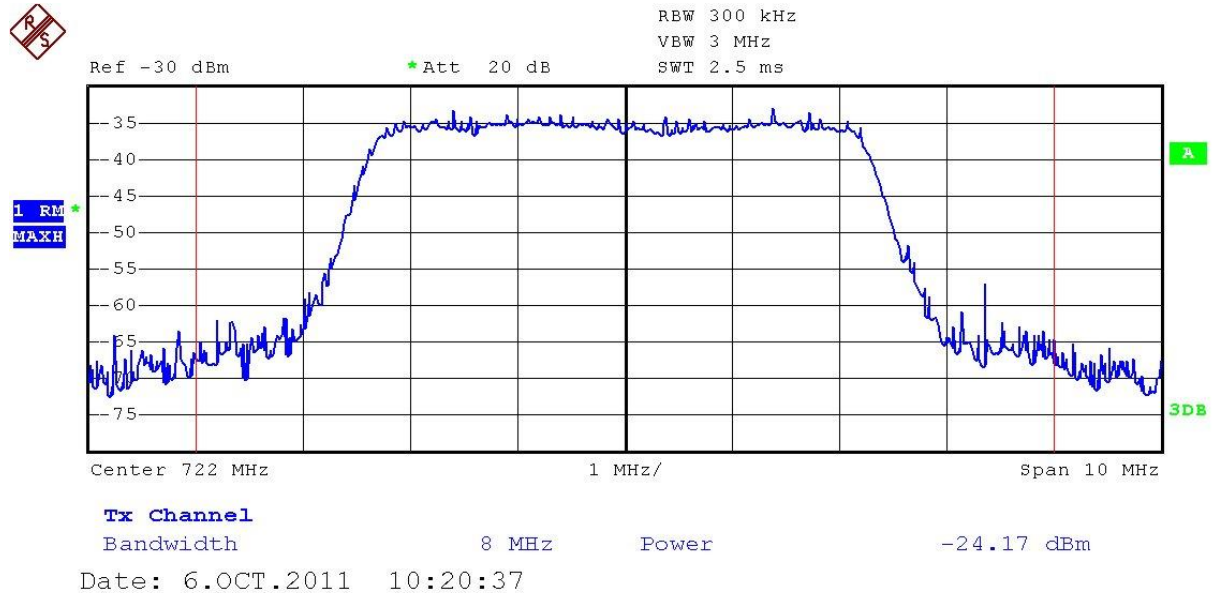


Figure 4 CPE Spectrum and power

As can be seen the spectrum shape is very similar, the more rounded appearance is probably more due to the different RBW setting (300 kHz). The CPE output power can be calculated by adding the losses of directional coupler (19.36 dB), attenuators (30dB) and cables (1.5dB). This gives: $-24.17 \text{ dBm} + 30\text{dB} + 19.36\text{dB} + 1.5\text{dB} = 26.7 \text{ dBm}$.

3.2 BS ACLR

The BS ACLR was measured using the same general setup as the power and spectrum measurements. In all but N+1 cases the 30 dB fixed attenuator was changed to 4.8 dB attenuator to boost the available power so that the dynamics of the spectrum analyser would allow the measurement of the low leakage powers. A sample of the measured leakage power over the 8 MHz channel bandwidth is shown in Figure 5. This is the N+1 case where the centre frequency is 730 MHz. The measurements are done in a similar way as the on channel power measurement using the channel power function with max hold due to the TDD nature of the signal.

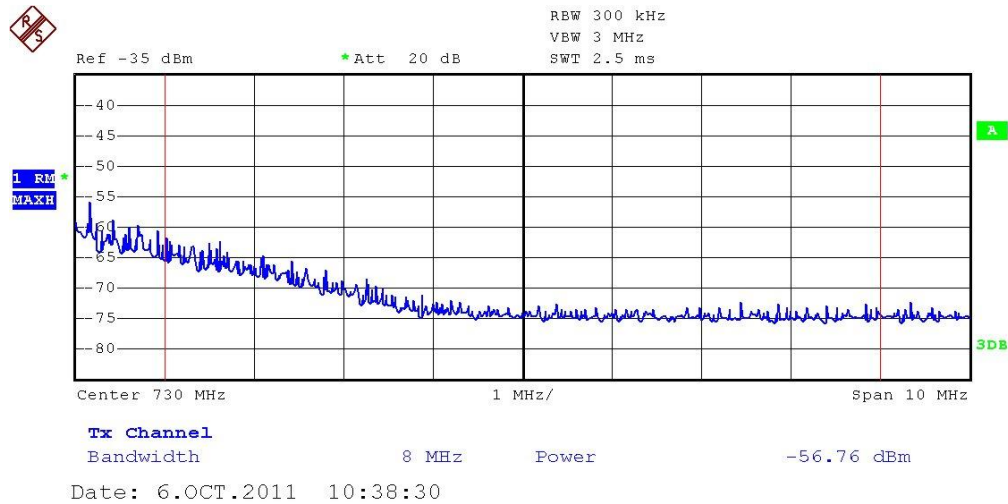


Figure 5 BS ACLR for N+1

From the measured power the true leakage power is calculated using the attenuation values between the spectrum analyser and the BS output. This value is then compared with the on channel power and the ACLR is calculated.

Table 1 BS ACLR results

N	BS power [dBm]	Measured power [dBm]	Attenuation [dB]	Leakage power [dBm]	ACLR [dB]
BS ACLR N-4 [690]	32.86	-60.4	25.16	-35.24	68.1
BS ACLR N-3 [698]	32.86	-57.9	25.16	-32.74	65.6
BS ACLR N-2 [706]	32.86	-51	25.16	-25.84	58.7
BS ACLR N-1 [714]	32.86	-30	25.16	-4.84	37.7
BS ACLR N+1 [730]	32.86	-56.6	50.36	-6.24	39.1
BS ACLR N+2 [738]	32.86	-52.3	25.16	-27.14	60
BS ACLR N+3 [746]	32.86	-59.3	25.16	-34.14	67
BS ACLR N+4 [754]	32.86	-61	25.16	-35.84	68.7

The results are shown in Table 1. As can be seen the values at N+1 offset are close to 40 dB increasing then for N+2 to about 60 dB. For higher offset the values are even more increased, but the dynamic range of the measurements system does not allow anything higher than roughly 70 dB measured. The BS ACLR is shown graphically in Figure 6. The measured ACLR is rather good even in the adjacent channel, but it should be kept in mind that the actual signal is only 5 MHz wide leaving 1.5 MHz wide guard bands from the signal edge to next channel.

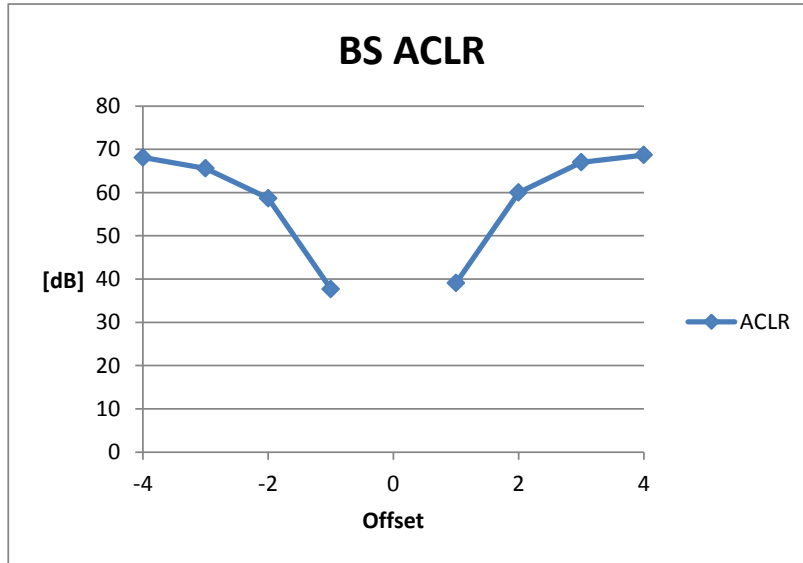


Figure 6 BS ACLR

3.3 CPE ACLR

The CPE ACLR was measured using the same general setup as the power and spectrum measurements, but in all cases the fixed attenuator was 4.8 dB to boost the power. Also the on channel power reference was re-measured due to slightly different settings. The results are shown in Table 2.

Table 2 CPE ACLR results

N	CPE power [dBm]	Measured power [dBm]	Attenuation [dB]	Leakage power [dBm]	ACLR [dB]
CPE ACLR N-4 [690]	26.56	-70.5	25.66	-44.84	71.4
CPE ACLR N-3 [698]	26.56	-69.2	25.66	-43.54	70.1
CPE ACLR N-2 [706]	26.56	-62.4	25.66	-36.74	63.3
CPE ACLR N-1 [714]	26.56	-38.8	25.66	-13.14	39.7
CPE ACLR N+1 [730]	26.56	-39.3	25.66	-13.64	40.2
CPE ACLR N+2 [738]	26.56	-58.8	25.66	-33.14	59.7
CPE ACLR N+3 [746]	26.56	-69	25.66	-43.34	69.9
CPE ACLR N+4 [754]	26.56	-70	25.66	-44.34	70.9

The results are show graphically in Figure 7. As can be seen the results are very similar to the BS results and the ACLR radio performance can be considered to be the same for both BS and CPE.

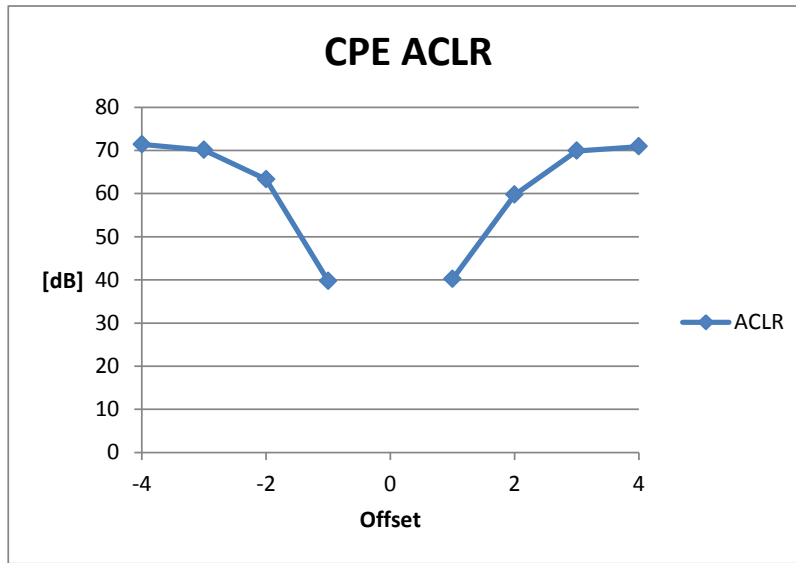


Figure 7 CPE ACLR

3.4 DTT protection ratio from CPE measurements

The measurement set up is shown in Figure 8.

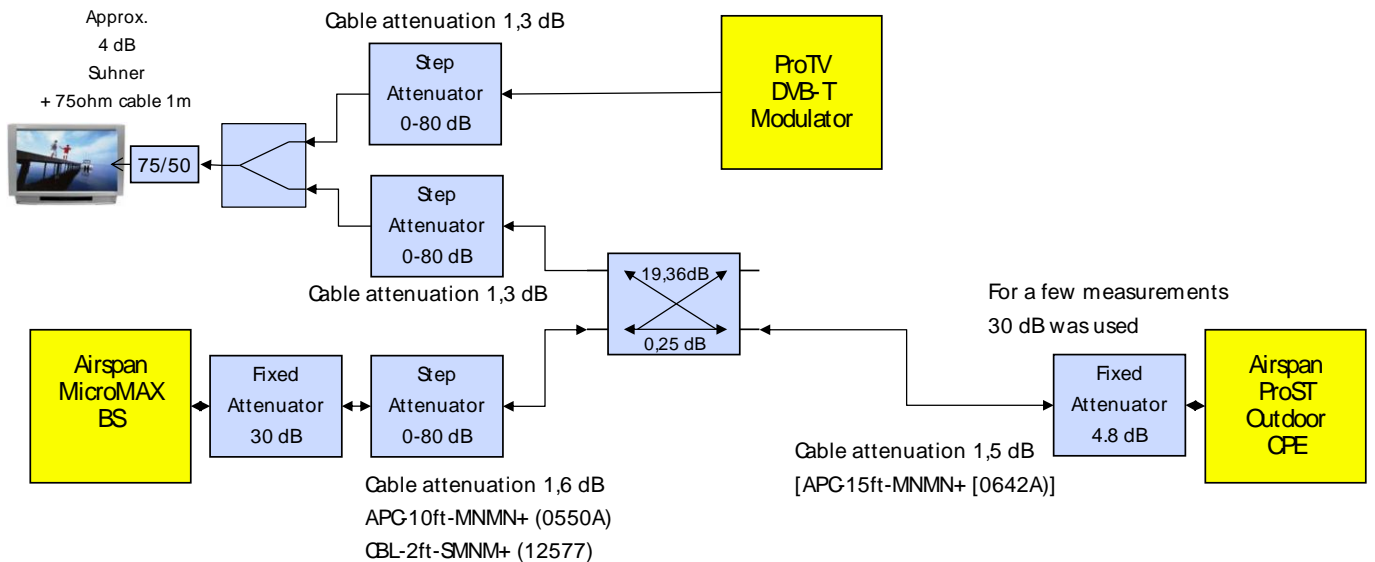


Figure 8 CPE PR measurement setup

The WSD BS and CPE are working normally. Interfering power is obtained from the directional coupler and the attenuators are set so that there is minimum attenuation between the CPE and DC. The DVB-T signal comes from the modulator and a suitable level is set with a step attenuator. DVB-T and the interfering signals are combined with a 3 dB power combiner and the resulting signal is fed to the TV set via an impedance matching adaptor (50/75Ω). The DVB-T signal is kept at a wanted level corresponding roughly -80, -

70 or -60 dBm at the TV input connector and the WSD signal level is changed until interference threshold (see 2.4) is reached. The protection ratio is calculated with the signal levels measured at the input of power combiner avoiding the need to know the exact losses between the combiner and the TV input. The measurements are done with both full downloading traffic and with idle mode (just a ping). Measurements at -70 dBm TV input level were repeated with a comparison DTT receiver.

The results are shown in Table 3. CPE/S means protection ratio from CPE towards the Sony TV-set and CPE/T means protection ratio from CPE towards the Topfield STB.

Table 3 CPE Protection ratios in dB

N	CPE / S -80		CPE / S -70		CPE / T -70		CPE / S -60	
	Full	Idle	Full	Idle	Full	Idle	Full	Idle
-2	54.1	50.1	54.1	44.1	44.0	45.0	51.1	38.1
1	29.9	31.9	34.9	36.9	25.0	26.0	34.9	30.9
2	51.0	47.0	52.0	41.0	43.0	44.0	51.1	37.1
3	53.0	50.0	57.1	46.1	51.0	54.0	51.1	43.1
4	55.1	52.1	57.1	48.1	56.0	59.0	51.1	40.1
5	56.1	50.1	57.1	48.1			51.1	39.1

The Sony results are shown in graphical form in Figure 9.

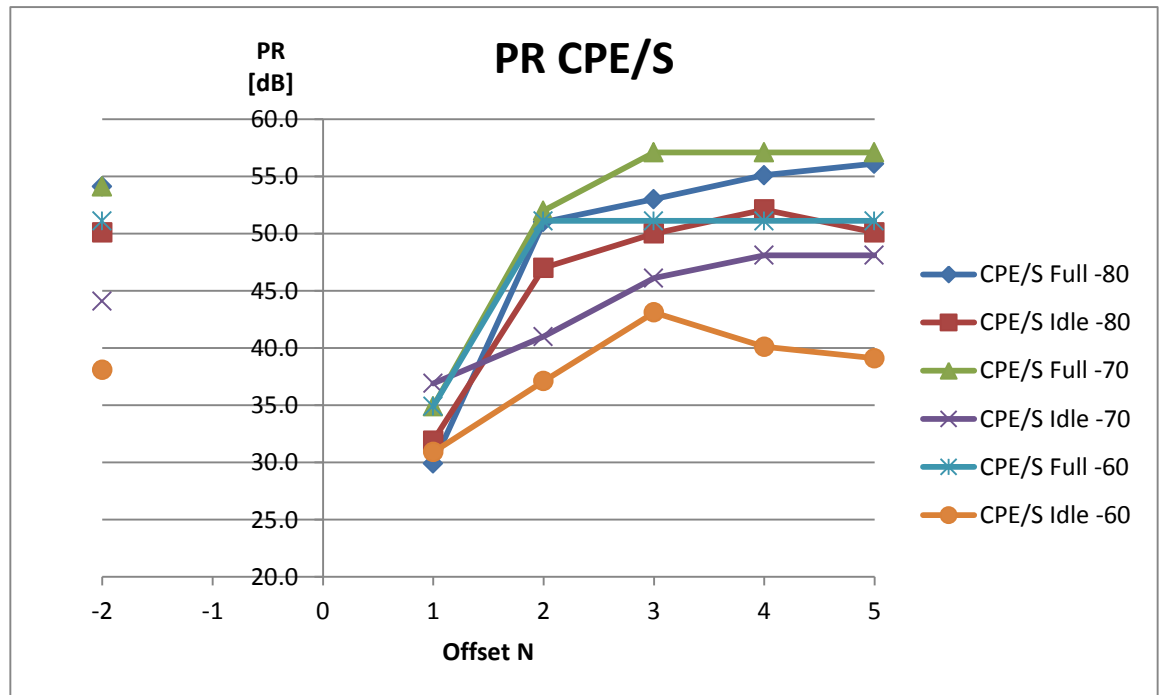


Figure 9 CPE protection ratios towards Sony TV set

The full and idle mode curves are separated in Figure 10.

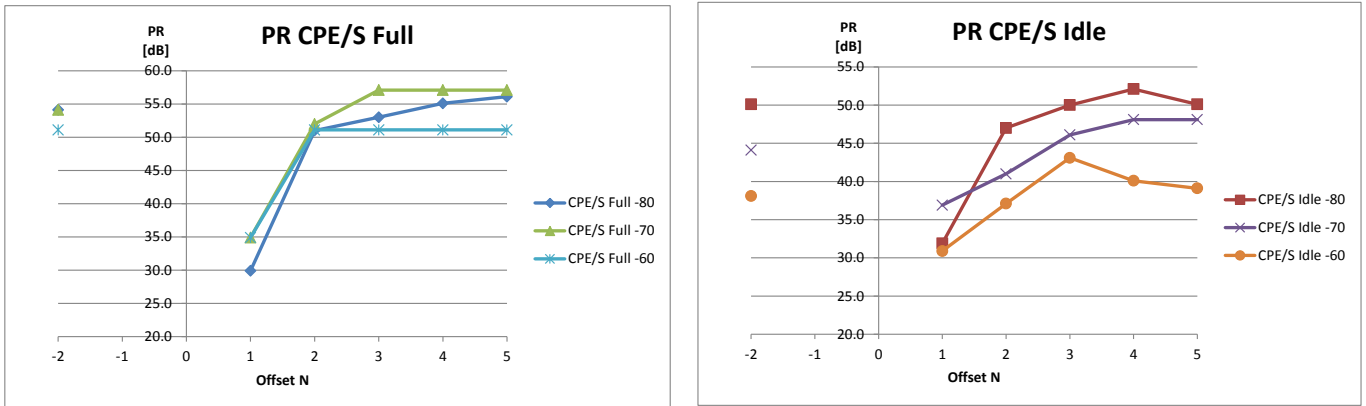


Figure 10 CPE protection ratios with full and idle modes

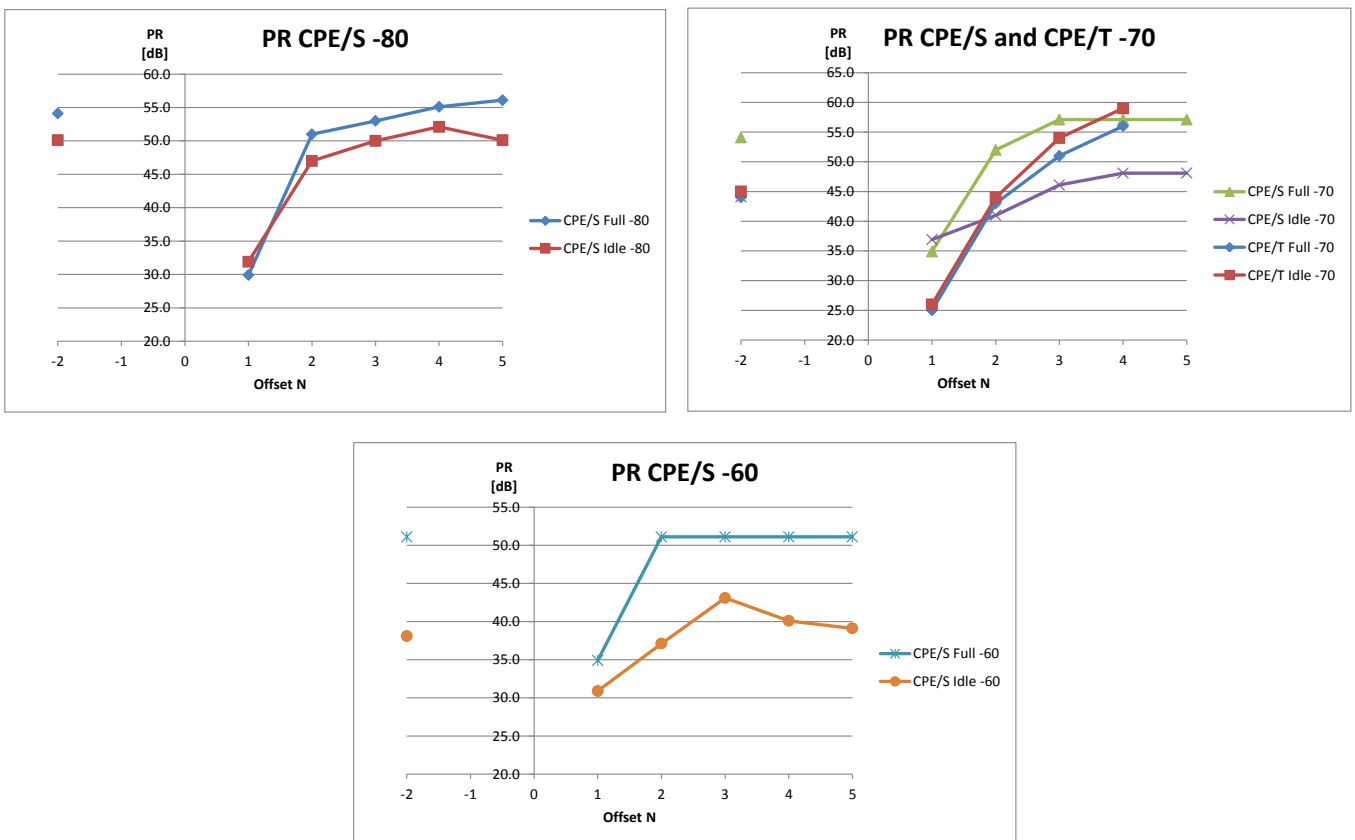


Figure 11 CPE protection ratios for each input level

To be able to compare the difference between the full and idle modes better, the curves for each input level are shown in different graphs in Figure 11. For comparison the -70 dBm graph also includes the protection ratios for the Topfield STB.

As can be seen there is a clear difference in the protection ratio for the Sony receiver depending whether the CPE is in full download mode or in idle mode. The bursty idle mode seems to be worse in this respect one possible explanation being the receiver AGC-setting getting confused by the short bursts. It should be noticed that the effect is smallest at the -80 dBm input level and greatest at the -60 dB level. The comparison receiver, which was measured only at the -70 dBm level seems not to have this effect, but has a worse protection ratio at N-1, increasing then at N+4 to the same level as the other receiver at it's best without the burst effect.

The effect of the envelope in a time variant TDM-signal to the protection ratio has been reported in several measurement reports. The exact reason in detail is not known, but both the AGC-loop behaviour or the overall AGC strategy has been mentioned as one candidate and the channel estimation as a second one. It could also be a combination of both.

Overall the measured protection ratios are rather good even in the worst cases, this probably depending at least partly on the narrow 5 MHz WSD signal, which gives additional 1.5 MHz separation between the DTT and WSD signals.

3.5 DTT protection ratio from BS measurements

A similar measurement setup as in the CPE case was used for the DTT protection from BS measurement. The setup is shown in Figure 12.

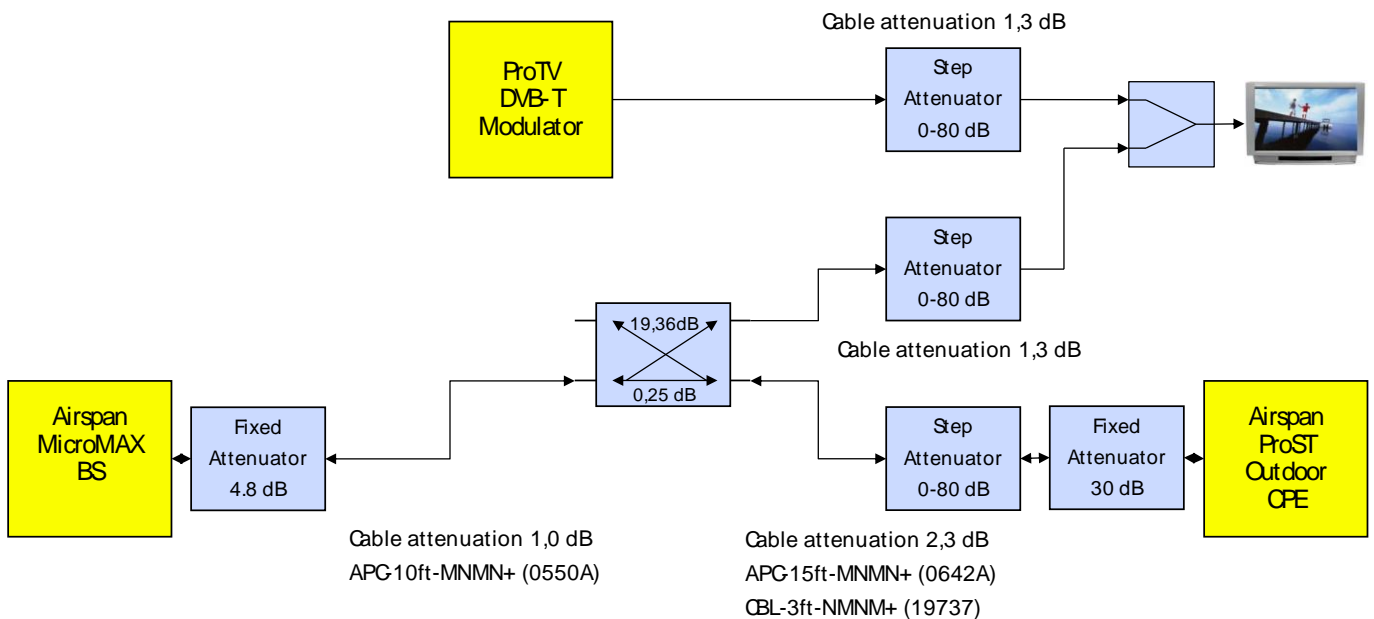


Figure 12 BS protection ratio measurement setup

The use of the attenuators is reversed around the directional coupler so that a high level from the BS can be obtained from the DC output port. Otherwise the measurement procedure is the same as in the case of the CPE:

The results are shown in Table 4 and in Figure 13.

Table 4 Protection ratios towards the DTT from the BS in dB

N	BS / S -80		BS / S -70		BS / S -60	
	Full	Idle	Full	Idle	Full	Idle
-2	48.4	48.4	50.4	49.4		
1	35.4	34.4	36.4	36.4	36.4	36.4
2	48.4	49.4	49.4	50.4	50.4	50.4
3	52.4	53.4	54.4	54.4	54.4	54.4
4	53.4	53.4	55.4	56.4	54.4	54.4
5	53.4	54.4	55.4	56.4		

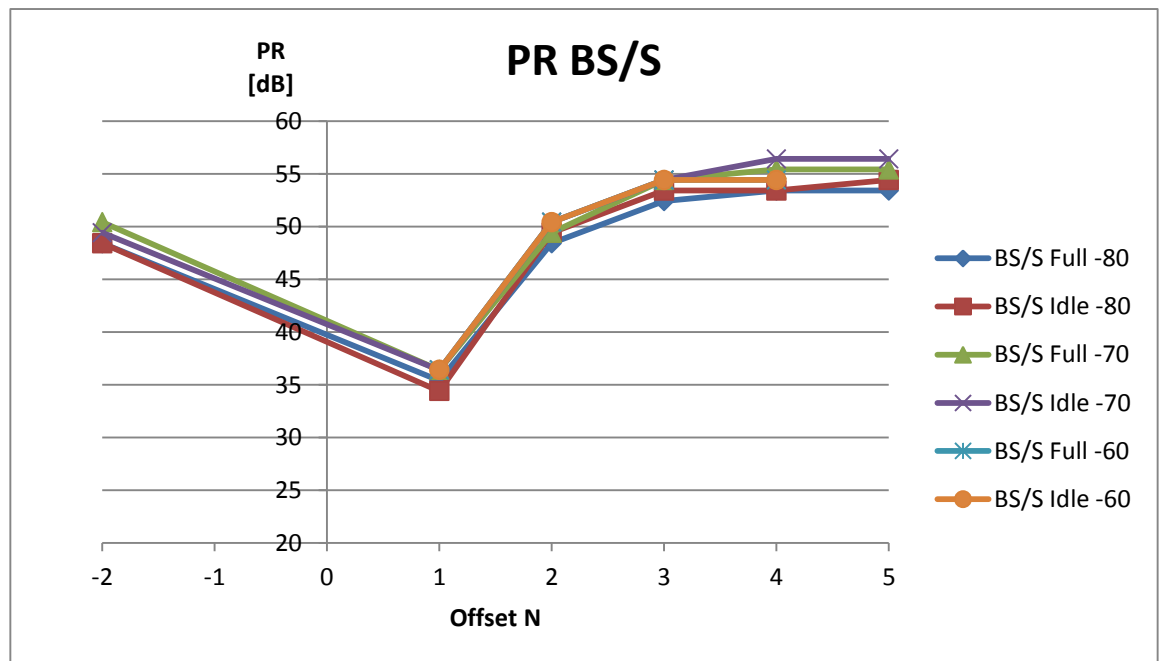


Figure 13 BS protection ratios towards the DTT

As can be seen the protection ratios vary much less in the BS case. The full/idle mode don't have any effect and the effect of the level is also smaller. It seems that the BS signal envelope is in any case less bursty than the CPE signal and the BS signal is on for a longer period and more often even in the idle mode. Otherwise the results are very much in line with the best CPE results ignoring the effect of the idle mode.

3.6 WSD uplink protection from the DTT

The purpose of this measurement was to study how a co-channel DTT signal is interfering the WSD uplink signal. The justification comes from the fact that the WSD base station antenna height can be rather high and signals from far away DTT transmitter operating at

the same frequency may be received by the BS antenna even if the WSD installation is clearly outside the DTT operating area.

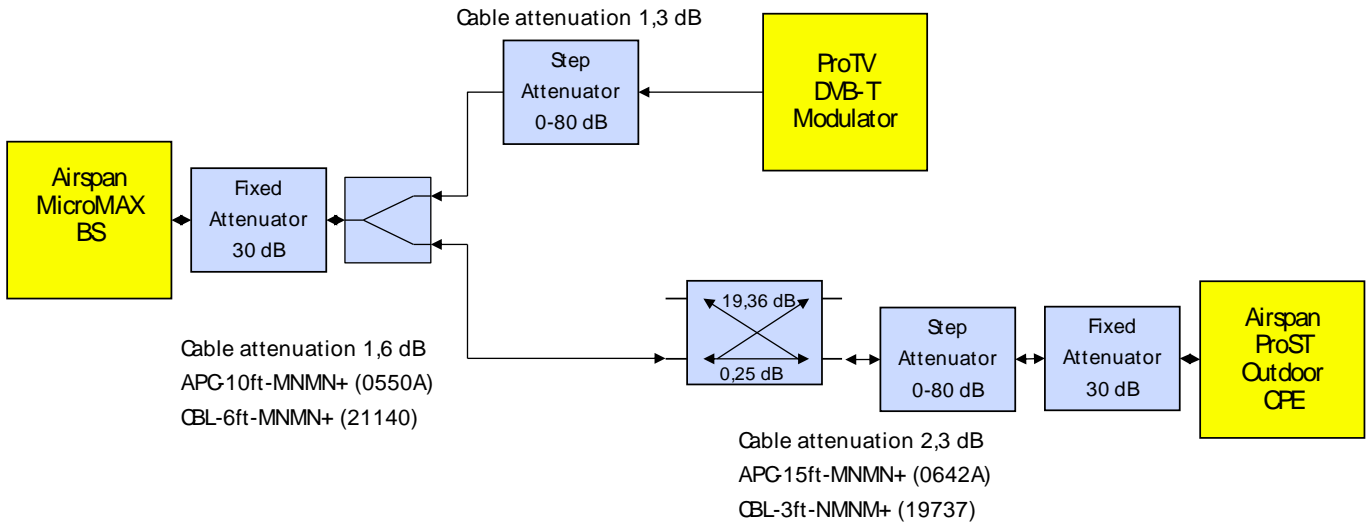


Figure 14 WSD Uplink protection from DTT interferer

The measurement set up is shown in Figure 14. The idea is that the both BS and CPE are operating normally and an interfering DVB-T signal is fed close to the BS input, most of the path loss attenuation being on the other side of the feed point. At the beginning of the measurement the uplink is using the highest order modulation available, 64 QAM. Then the interference level is increased until the uplink modulation is changed from 64 QAM to 16 QAM. The DVB-T level measured at this point. Next the interference level is again increased so that the uplink is changing from 16QAM to QPSK and the DVB-T level is measured. The procedure is then repeated still twice so that first the modulation is changed from QPSK to BPSK and finally the link is broken.

Change	Uplink Rx level at 5 MHz [dBm]	DVB T at 8 MHz [dBm]	DVB T at 5MHz [dBm]	C/I [dB]
64 QM to 16 QAM	-69.1	-99.2	-97.2	28.1
16 QAM to QPSK	-69.1	-86.2	-84.2	15.1
QPSK to BPSK	-69.1	-81.2	-79.2	10.1
BPSK to break	-69.1	-71.2	-69.2	0.1

Figure 15 Uplink protection from DTT interferer

The results are shown in Table 4. The DVB-T power was measured at the 8 MHz channel and therefore the values are converted to correspond the power at the 5 MHz WSD bandwidth. The values should not be considered as direct C/N values, but rather co-channel protection ratios at the specific WSD uplink signal power.