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Wise-Project Measurement Report:

PMSE Measurements in Helsinki City Theatre

A measurement campaign to study the PMSE protection from WSD was organized 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 AND OBJECTIVES

The Tekes-Wise project decided to study the technical aspects related to the protection of PMSE (radio microphones) equipment from the White Space Devices (WSD). This is mainly related to the development of data base test bed within the project, but also in general to better understand the questions related to the microphones. PMSE is an important topic in Finland currently as the devices have been operating in the 800 MHz band in past and now it has been decided that the band 792-862 MHz will be used for mobile application with LTE. Therefore all the PMSE-devices will have to be moved to the lower UHF-band covering 470-792 MHz. The move will not happen instantly as there will be certain grace periods for the old equipment. The new regulatory environment may also contain certain elements of a data base to include the used PMSE-equipment.

The basic idea in the campaign was to use a few devices operating in the new lower band, say at 600 MHz, and install them in a real environment where the PMSE-equipment is usually deployed and then try to cause interference to them by a simulated WSD operating in the same or adjacent frequency. The WSD would then be moved to different locations inside and outside the test building and power level would be adjusted to cause interference. It was also plan to do some qualitative spectrum measurements at the WSD-locations to get an understanding of the visibility of the radio microphones. This would give a feeling of the feasibility of sensing.

The Wise-project got permission from the Helsinki City Theatre to conduct the measurements in the main theatre and in a smaller nearby Arena Theatre also part of the Helsinki City Theatre.

2. MEASUREMENT SET-UP

2.1 Locations

The Helsinki City Theatre, located in Kallio, is the biggest theatre in Helsinki. The main building has been built in the 1960's and is traditional concrete/steel construction. It has two stages, a big one with 947 seats and a smaller one with 400 seats. The theatre is shown in Figure 1 and the main stage on Figure 2. Currently the theatre is operating during a big play about 40 microphone channels in the 800 MHz band. These will be replaced by new equipment operating in the lower band in the coming years. The receiving antennas for the current microphones are located high at both sides of the stage (see Figure 2).

The Arena Theatre is a smaller 515 seat theatre nearby the main theatre. Arena is located in a larger brick building, which has been built in 1923. The theatre spaces have originally been built for a movie theatre. The building and the theatre are shown in Figure 3 and Figure 4. In the Arena theatre the existing microphone receiver antennas are located in the balcony railing.

In both places the existing DVB-T signal levels inside were measured and compared to the outside values in the order to get a rough understanding of the building penetration loss. In the main stage the average building penetration loss values calculated from the measured signal levels over all DVB-T channels were between 19 and 26 dB depending on the location. In the small stage the value was 35 dB. In the Arena theatre the DVB-T signal levels inside were too low to be measured. More than telling about a high building loss this is due to the different location of the building, the DVB-T signals outside also being very low.

Figure 1 Helsinki City Theatre main building

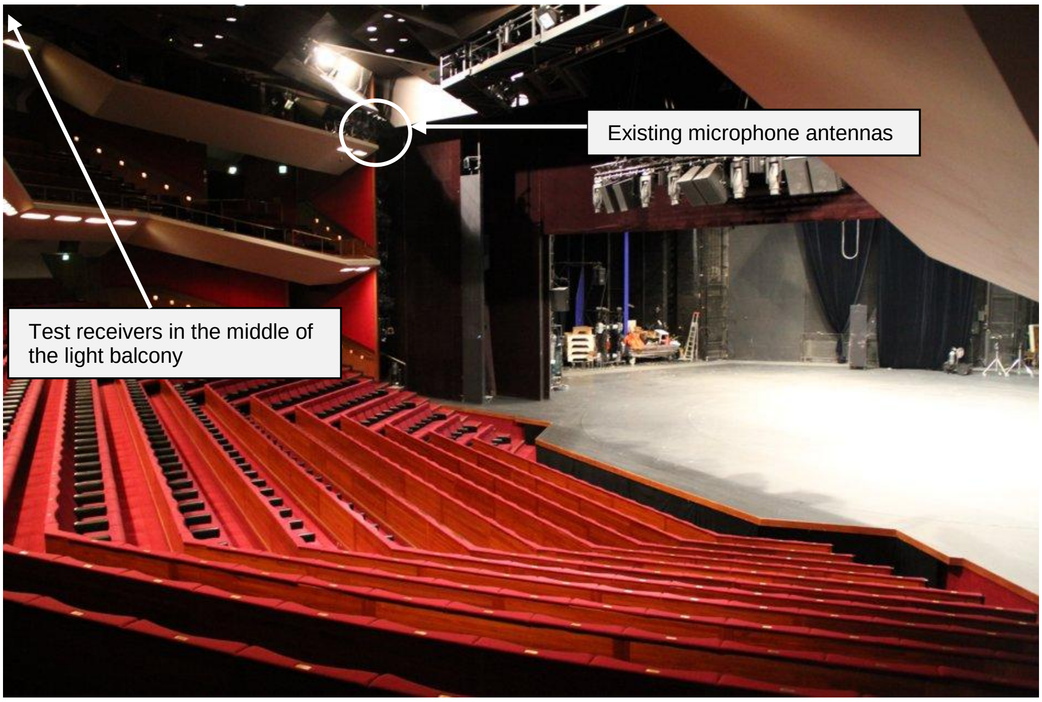


Figure 2 The main stage

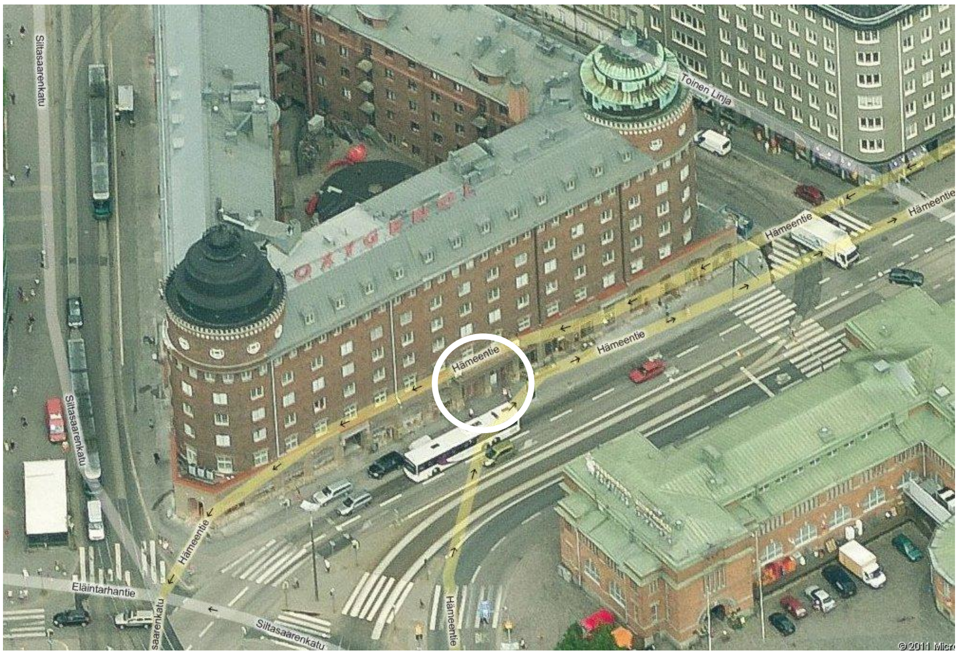


Figure 3 Arena theatre

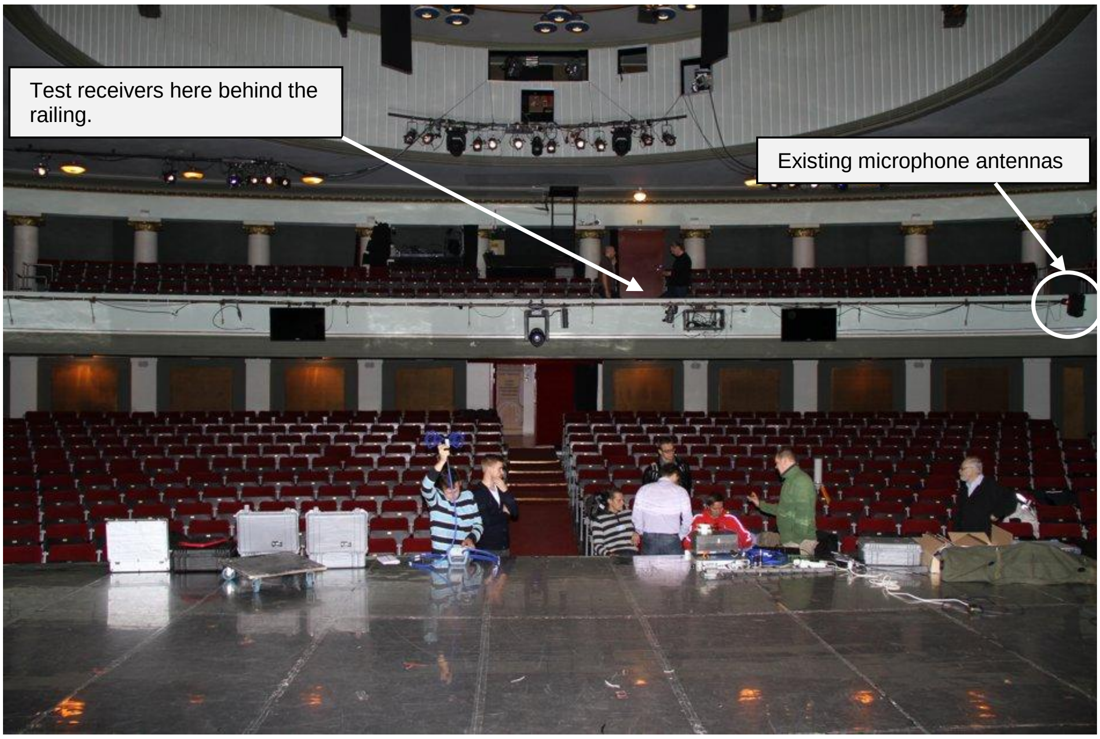


Figure 4 Arena theatre inside

2.2 Microphones and receivers

Two Sennheiser analogue microphone kits were available for the measurements, one operating at frequencies 470-638 MHz and one at frequencies 614-798MHz. Both kits had one receiver of type EM3732 and several microphones both belt pack and usual hand held types. In some measurements only one belt pack microphone at 618 MHz at the center of channel 39 was used, but most measurements were done with four microphones, one hand held and three belt pack, operating within the channel 39 at pre-assigned frequencies. Both receivers were used each supporting two microphones. The used frequencies are shown in Table 1. 50 mW transmitting power option was used in all microphones. The microphones were fed with audio from a MP3-player when appropriate. Receiver status indicators and earphones were used for monitoring the quality of the operation.

Table 1 Used microphone frequencies

Set	Type	Frequency [MHz]
1	Belt pack	615.875
1	Belt pack	616.400
2	Hand	617.075
2	Belt pack	621.425

The purpose was to use microphones in real conditions and therefore the receivers were placed a realistic places in the theatres. In the main stage the receiver was placed in the center of a light balcony above the audience (see Figure 2). The existing receiving antennas are roughly at the same height, but on both sides of the stage. This arrangement increased the distance from the microphones to the receiver to approximately 40 m, but it was considered that this is just making the conditions somewhat more demanding, which is good for the measurements.

The microphone receivers were using small whip antennas attached directly to the receivers.

In the Arena theatre the receivers were placed on the balcony (see Figure 4) as well and close to the existing antennas, but behind the concrete railing, so also here the path loss from the microphones to the receiver was increased slightly.

During the measurements it was found out that there is a big difference in the results depending how the microphones are used. The worst, but also realistic, case being the belt pack microphone attached to a person and the person moving in the stage. Therefore to get most realistic scenarios the microphones were attached to people and they were moving in the stage simulating the actors, even sometimes going behind the sets used for the plays. In the main stage this was not possible as there was some rehearsal activity going on, but the microphones were placed in this case to the back of the stage to an unfavorable place.

2.3 WSD signal

The WSD signal was simulated with a constant OFDM-signal from a Pro Television PT5780 DVB-T signal generator. This set up was chosen because we were interested especially in the uplink part. Also the signal bandwidth was 7.6 MHz filling the whole channel and covering all the microphone signals at once. The used signal generator was able to provide output power levels only up to +20 dBm, which was not enough for all measurement scenarios so an additional power amplifier was added to the set up. This had a gain of 40 dB and maximum output power of approximately 1W. The output was limited by the IM-products, which would rise to too high level with higher output powers. The output power was set with the step attenuator between the signal generator and the power amplifier. The set-up is shown in Figure 5 and Figure 6.

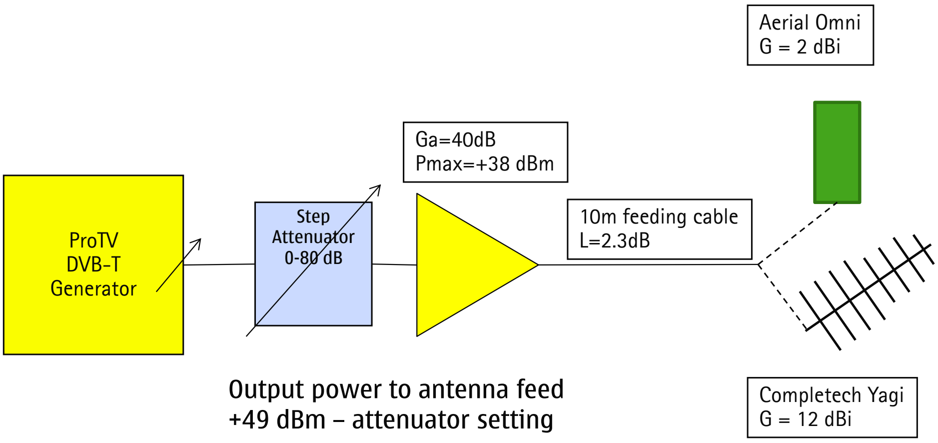


Figure 5 Block diagram of the WSD-signal generation

Figure 6 WSD signal generation equipment

The output power to the antenna feed point was measured in the theatre and it was found to be +49 dBm – Att, where Att is the step attenuator setting.

The Adjacent Channel Leakage Ratio (ACLR) of the set-up is heavily dependent of the output power level as the shoulders of the amplifier are rising with the higher powers. The ACLR was measured in the laboratory after the field measurements. The measured ACLR-values for the offsets N-1 and N+1 and for different attenuator settings (Att) are shown in Table 2 and Figure 7. Note that the power levels are not exactly matching with the field values due to different power measurement detector.

Table 2 WSD signals ACLR with various power levels

Att [dB]	Pwr [dB]	ACLR N-1	[dB] N+1
66	-15	>50	>50
46	4.7	48	48
23	27.7	39	39
21	29.5	35	35
18	32	27	27
17	32.9	25	25
12	35.2	15	15

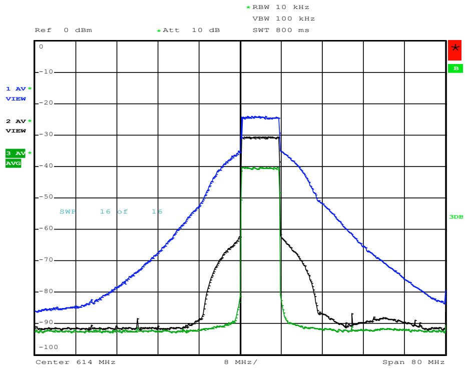


Figure 7 WSD spectrum shapes with attenuator settings 12, 22 and 32 dB

2.4 Channels and licenses

A license to operate the WSD interference signal and the microphones was obtained from Ficora for the period of the measurements. The license for the WSD covered channels 39 (610 MHz), 40 (618 MHz) and 41 (626 MHz) with a maximum EIRP of 42 dBm.

The microphones were normally operating at the channel 40 so that both N-1 and N+1 case could be covered.

3. SPECTRUM MEASUREMENTS

To get better understanding of the microphone signals in a big theatre a spectrum measurement was done with the existing 800 MHz microphones during a musical where a large number of actors were performing simultaneously. Altogether 38 microphone channels were in use.

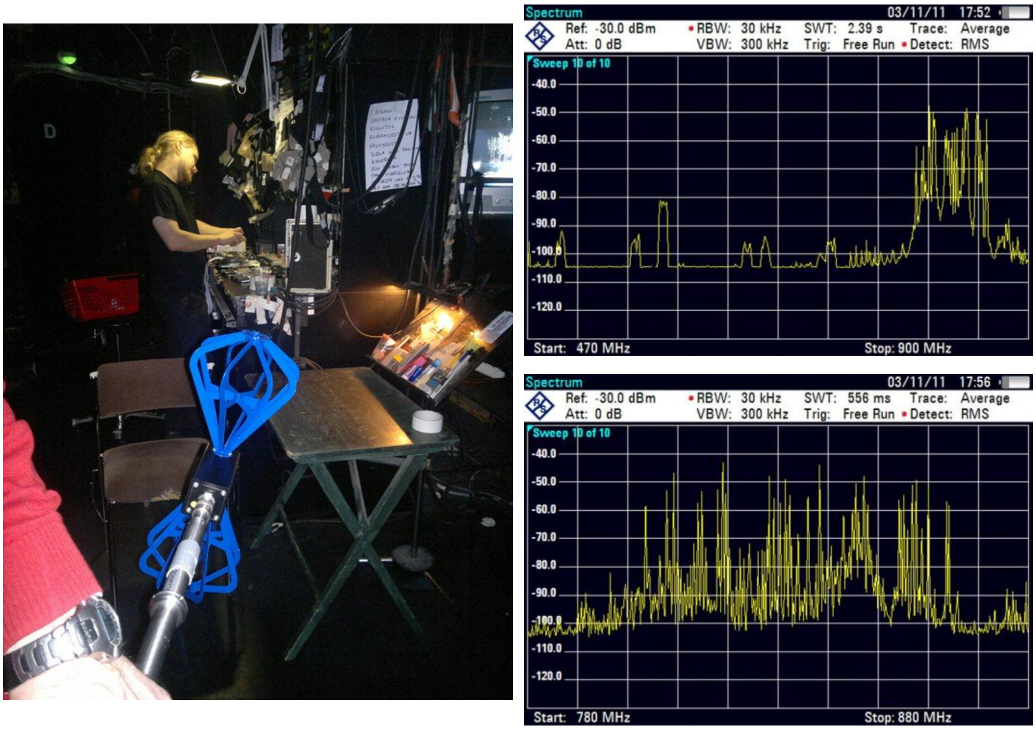


Figure 8 800 MHz microphone signals before the performance

First measurement was done before the sound check when all the transmitters were in the same place. This was performed with R&S FSH spectrum analyzer and R&S DPA4000A bi-conical antenna. The results shown in Figure 8 reveal the DVB-T signals lower in the spectrum and then the microphones between 800 and 870 MHz.

The main measurement was done during a performance from the middle of the light balcony at the back of the theatre, where later the test receivers were placed. R&S FSP spectrum analyzer and a wideband log-periodic antenna with vertical polarization was used.

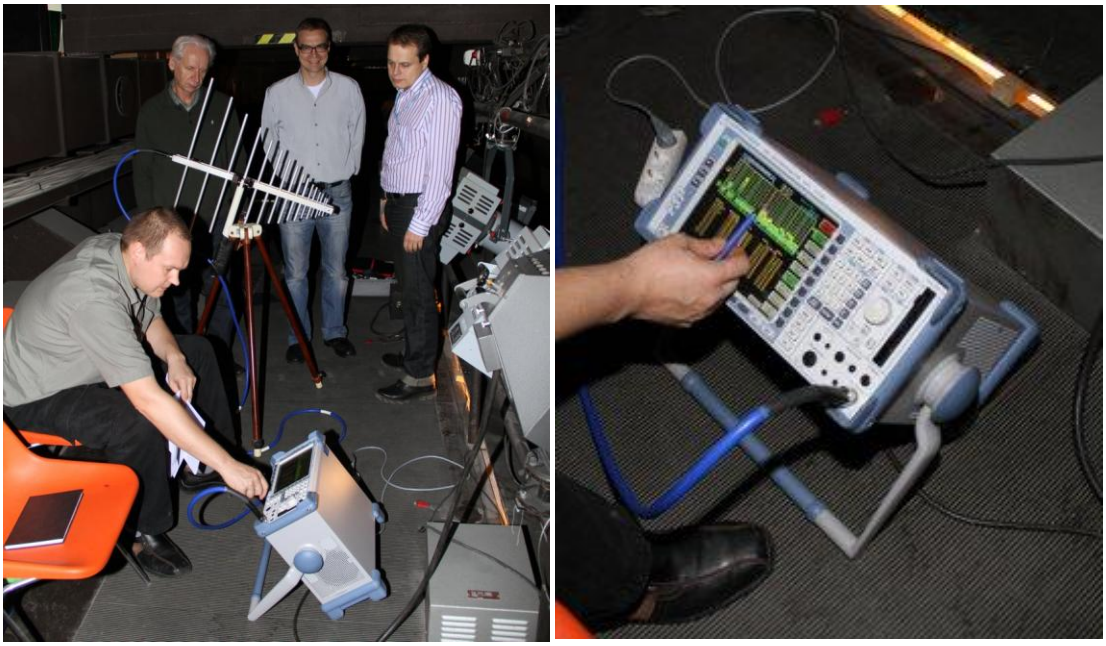


Figure 9 Spectrum measurements at the light balcony during a play

The set-up is shown in Figure 9 and some of the results in Figure 10.

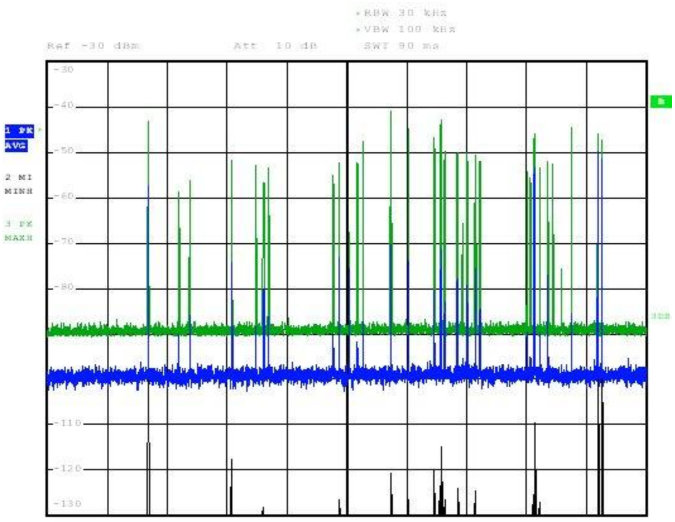


Figure 10 Spectrum measurement during the performance. Span is from 780 -870 MHz

As can be seen the signals are not uniformly spread, but are in groups and even within the group not uniformly spaced. This is due to the performance optimization by minimizing the IM-products and internal interference. Typically the microphone signals are between -50 and -60 dBm when the players were at stage well placed, but dropping when moving out from the stage. Approximately 80 MHz of spectrum is used although not continuously.

4. LAB MEASUREMENTS

Some of the microphones were measured in the laboratory after field measurements, but as the lab measurements help to understand the field measurements they are presented here before the field results.

4.1 Set up

As the antenna connector of the tested microphone was not usable for cable connection, the microphone was place inside a small TEM-cell, which was then connected to the measurement set up by a cable. The arrangement block diagram is shown in Figure 11.

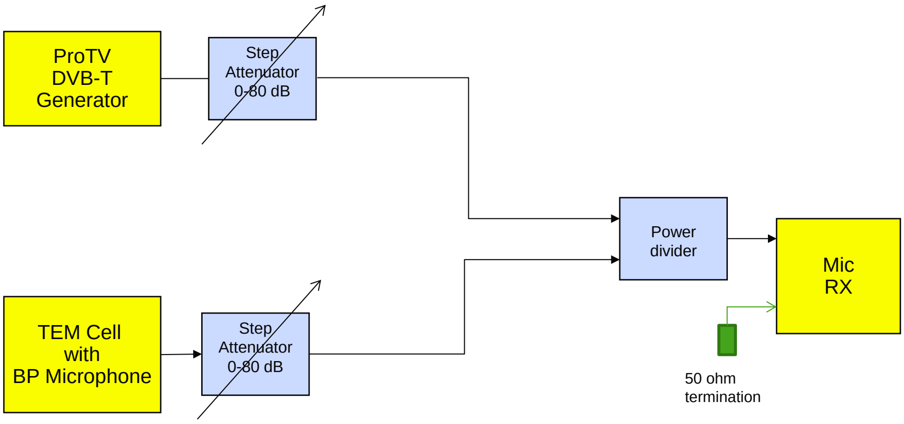


Figure 11 Laboratory measurement set-up

The microphone receiver is a diversity receiver, but only one branch was used and the other input was terminated.

4.2 Sensitivity

First the DVB-T signal was turned off and the microphone branch step attenuator was adjusted until the microphone was muted or the quality was otherwise disturbed. Then the signal level was increased until a good quality was reached. After that the signal level was measured with a spectrum analyzer using channel power function with 200 kHz bandwidth. This was considered as the sensitivity and was found to be -85 dBm(200 KHz), which corresponds 22 dBµV. Roughly the same reading was visible on the microphone receiver. After this measurement it was possible to calibrate the step attenuator, so that the microphone power level would be known at any setting.

4.3 WSD-interference

Next the same set up was used to find the WSD (DVB-T) levels which would interfere with the microphone. This was done at several microphone signal levels starting at 4 dB above the sensitivity level. The results are shown in Table 3.

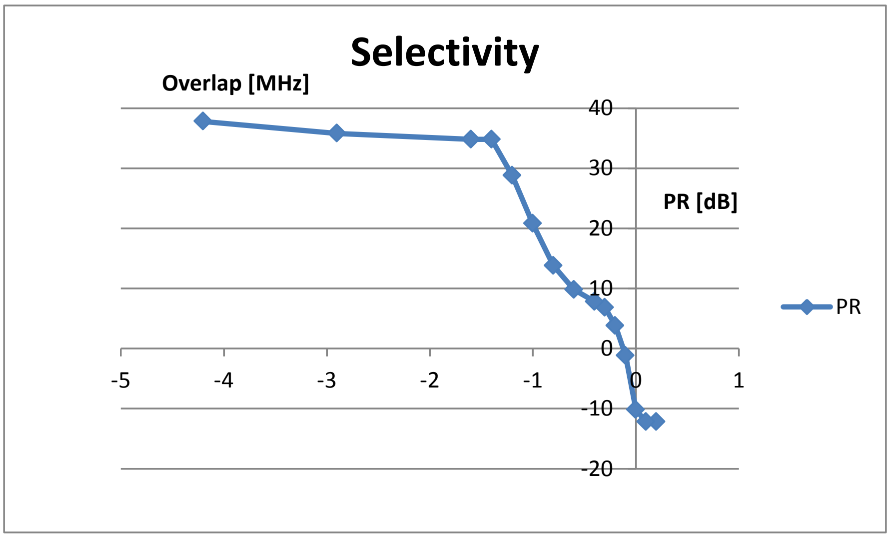
Table 3 Laboratory interference measurement results

		Max interference power								
Microphone [200 kHz]	[dBm]	-81.0	-78.0	-75.0	-72.0	-69.0	-66.0	-63.0	-60.0	-50.0
WSD [200 kHz]	[dBm]	-93.2	-91.2	-87.2	-85.2	-82.2	-77.2	-74.2	-72.2	-61.2
C/I	[dB]	12.2	13.2	12.2	13.2	13.2	11.2	11.2	12.2	11.2

Both power levels are measured in this case with 200 kHz bandwidth. Corresponding power level for the DVB-T signal level at 8 MHz bandwidth would be 16 dB higher. C/I can be calculated from the measured levels and as can be seen this is fairly constant within 2 dB, so there seems to be a linear dependency between the input an interference levels. It should be noted that the measurement accuracy is only +- 1dB (or more) as 1 dB steps were used.

4.4 Selectivity

Next a simple selectivity measurement was done. The microphone was set to a fixed frequency of 618 MHz with -65 dBm input level and the interfering DVB-T signal was moved with 100 kHz steps from overlapping to 1 channel separation. The result is shown in Figure 12, which also includes a table where the results are in numerical form. Pi is the interfering power at the microphone input measured at 200 kHz bandwidth and C/I is the resulting C/I-value when compared to the -65 dBm microphone signal level.



DVB-T [MHz]	Overlap [MHz]	Pi [dBm]	C/I [dB]
614.4	0.2	-77.2	12.2
614.3	0.1	-77.2	12.2
614.2	0	-75.2	10.2
614.1	-0.1	-66.2	1.2
614.0	-0.2	-61.2	-3.8
613.9	-0.3	-58.2	-6.8
613.8	-0.4	-57.2	-7.8
613.6	-0.6	-55.2	-9.8
613.4	-0.8	-51.2	-13.8
613.2	-1	-44.2	-20.8
613.0	-1.2	-36.2	-28.8
612.8	-1.4	-30.2	-34.8
612.6	-1.6	-30.2	-34.8
611.3	-2.9	-29.2	-35.8
610.0	-4.2	-27.2	-37.8
626.0	11.8	-29.2	-35.8
634.0	19.8	-25.2	-39.8
642.0	27.8	-21.2	-43.8

Figure 12 Selectivity of the microphone toward DVB-T signal

The steep slope is probably the true selectivity of the microphone receiver and the shallow slope is caused by the slowly decreasing sideband noise of the signal generator (ACLR improving with increasing offset). Note that the ProTV DVB-T generator was used without the amplifier, so the ACLR values are not comparable with the signal used in the field (see also 2.3).

5. WSD-POWER MEASUREMENTS

5.1 Measurements in the Arena theatre

WSD-maximum power was measured in the Arena-theatre in 6 different WSD locations. The side and plan views of the theatre are shown in Figure 13 and Figure 14.

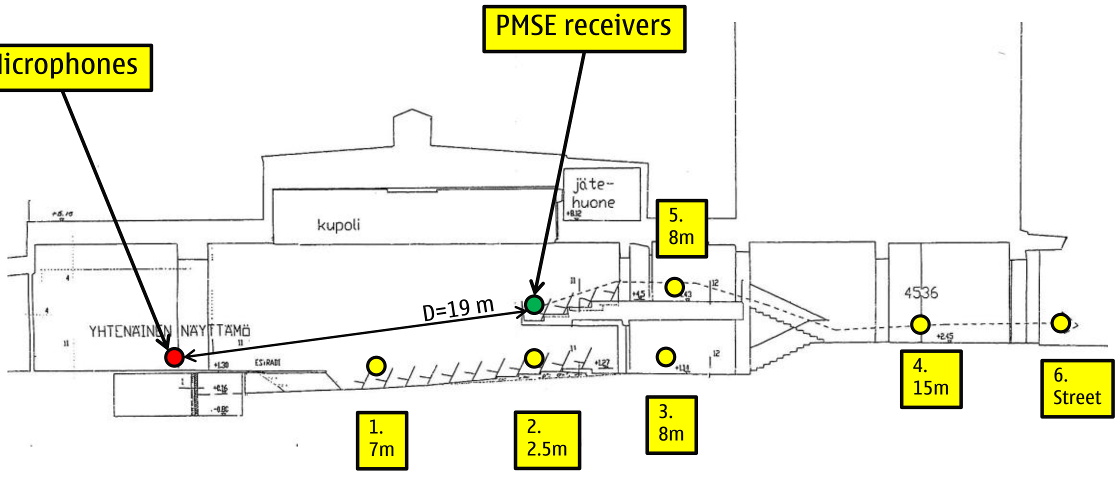


Figure 13 Arena theatre side view

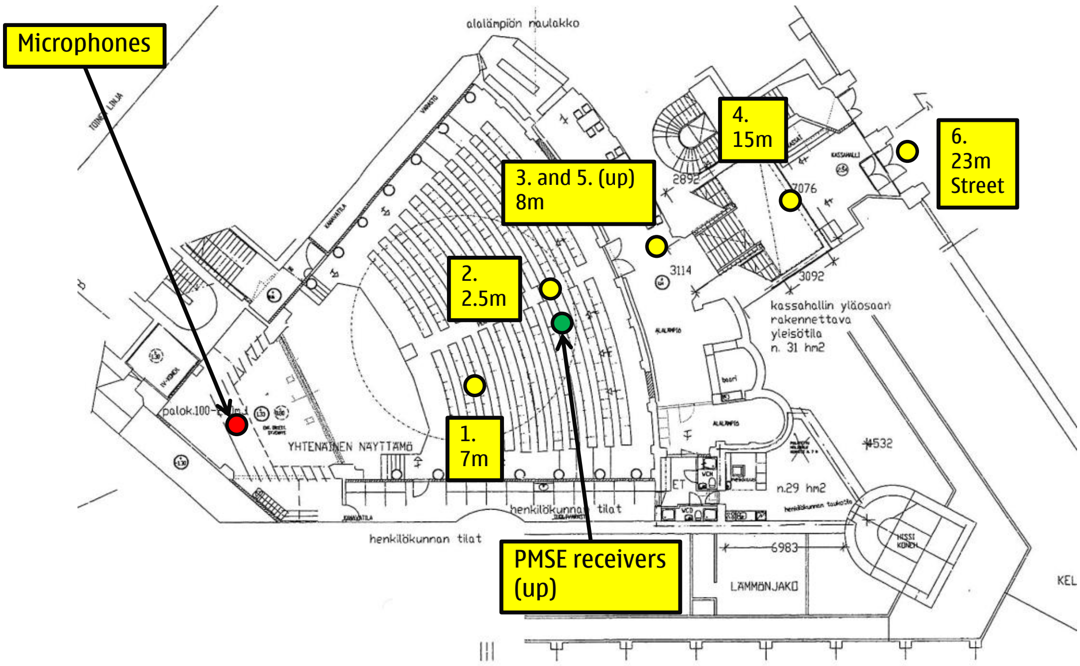


Figure 14 Arena theatre plan view

The microphone location in the stage is marked with red circle and the test receiver location with green circle. The test spots are marked with yellow circles. The WSD- antenna was a 2dBi Omni antenna attached 1.5 m height with a wooden tripod. Typical antenna installations are shown in Figure 15. In spot 6, on the street outside the theatre, 12 dBi Yagi was used to boost the power.

As explained in 2.2, the microphones were in most cases attached to moving people on the stage. The measurements were done so that the WSD-power was increased until interference was heard in any of the used microphones, then the power level was decreased until no interference was observed and the attenuator reading was taken. Typical measurement situation is shown in Figure 16, where people can be seen on the stage with the microphones and other people observing the microphone receivers.

Figure 15 WSD tx antenna in spot 2 and in spot 6

Figure 16 Typical measurement situation in the Arena theatre

Some tests at the spot 1 were done with N-2, N-1 and N+1, but in the other test spots only the co-channel (N) case was tested as the available WSD-power was limited. Finally the path losses from the WSD test spots to the microphone receivers were measured. This enabled the calculation of the true WSD interference power at the receiver.

Table 4 Summary of the results in the Arena theatre

Set up							Distances [m]			Results						
#	Place	Spot	Mic Ch	N Mics	DVB-T Ch	Case	Mic to Rcvr	WSD to Rcvr	WSD to Mic	Att [dB]	EIRP [dBm]	Note	Type	Path loss	WSD pwr at Mic rcvr	pwr/200kHz
1	Arena	1	618	1	618	N	19	7	13	25	26	LOS no movement	BP	54.4	-28.4	-44.4
2	Arena	1	618	1	618	N	19	7	13	39	12	Body loss	BP	54.4	-42.4	-58.4
3	Arena	1	618	1	618	N	19	7	13	55	-4	Attached, moving	BP	54.4	-58.4	-74.4
4	Arena	1	626	1	618	N-1	19	7	13	11	36.3	LOS, no errors	BP	54.4	-18.1	-34.1
5	Arena	1	626	1	618	N-1	19	7	13	20	31	Attached, moving	BP	54.4	-23.4	-39.4
6	Arena	1	626	1	610	N-2	19	7	13	12	35.3	Attached, moving	BP	54.4	-19.1	-35.1
7	Arena	1	618	4	618	N	19	7	13	55	-4	Attached, moving	BP	54.4	-58.4	-74.4
8	Arena	1	618	4	618	N	19	7	13	30	21	Proper hold	Hand	54.4	-33.4	-49.4
9	Arena	1	618	4	618	N	19	7	13	50	1	Worst hold	Hand	54.4	-53.4	-69.4
10	Arena	2	618	4	618	N	19	2.5	19	55	-4	Attached, moving	All	55.6	-59.6	-75.6
11	Arena	3	618	4	618	N	19	8	26	46	5	Attached, moving	All	60.6	-55.6	-71.6
12	Arena	4	618	4	618	N	19	15	34	40	11	Attached, moving	All	72	-61	-77.0
13	Arena	5	618	4	618	N	19	8	26	54	-3	Attached, moving	All	56.8	-59.8	-75.8
14	Arena	6	618	4	618	N	19	22	42	33	28	Attached, moving	All	78.2	-50.2	-66.2
30	Arena	1	618	4	618	N	19	7	13	55	-4	Attached, moving	BP	54.4	-58.4	-74.4
31	Arena	1	618	4	610	N-1	19	7	13	21	30	Attached, moving	BP	54.4	-24.4	-40.4
32	Arena	1	618	4	626	N+1	19	7	13	22	29	Attached, moving	BP	54.4	-25.4	-41.4
52	Arena	1	618	1	618	N	Spot 4	7	22	69	-18	Attached, moving	BP	54.4	-72.4	-88.4
53	Arena	1	618	1	610	N-1	Spot 4	7	22	21	30	Attached, moving	BP	54.4	-24.4	-40.4
54	Arena	1	618	1	626	n+1	Spot 4	7	22	21	30	Attached, moving	BP	54.4	-24.4	-40.4

The results are summarized in the Table 4. The attenuator settings marked with yellow were not able to produce enough power for interfering the microphones and therefore the corresponding WSD interference powers are just lower estimates, true values could be higher. In spot 6, outside in the street, interference was only generated if the doors were kept open. This means that the doors were causing at least 10 dB more attenuation.

The first three measurements (#1,#2,#3) are studying in the co-channel case the difference in WSD-power depending how the microphone is used. It can be seen that the if the microphone is left alone (#1), this is about 30 dB “easier” case than when the microphone is attached to a person who is moving around at the stage, even sometimes going behind the sets.

The next three (#4,#5,#6) are studying the adjacent channel behavior. As can be seen the N-1 tolerance is about 35 dB better than co-channel, increasing to more than 43 dB better in N-2. It should be noted here that the WSD-signal ACLR was very bad with the 12 dB attenuator setting, being only in the order of 15 dB in N-1 (see 2.3). With the 22 dB setting in N-1 the ACLR was already 35 dB.

Measurements #7,#8 and #9 study the microphone type. In #7 the belt pack is used and the result is a 55 dB attenuator setting (repetition of #3). In #8 a hand microphone is used with a proper hold in the microphone handle and the result is 30 dB attenuation, 25 dB better than with the belt pack. In #9 the hand microphone is held so that antenna is inside the hand and the result is 50 dB attenuation, very close to the belt pack result of 55 dB.

Measurements #10 to 14 are made at the co-channel in spots 2 to 6.

Measurements #30 and #31 are similar as #3, but now with 4 microphones on the air. The results are very similar as with just one microphone.

The last three (#52, #53, #54) were done so that the microphones were moved to the lobby at spot 4. According the spectrum measurement the path loss between the microphone receivers and the microphones was increased by 14 dB. It is interesting to note that there is exactly similar decrease in the allowed interference power. This is matching the observation done in the laboratory measurement.

The protection mask was measured in a similar way as the in the laboratory, but this time the with over the air signals, WSD being in spot 1 and both signal generator and power amplifier in use.

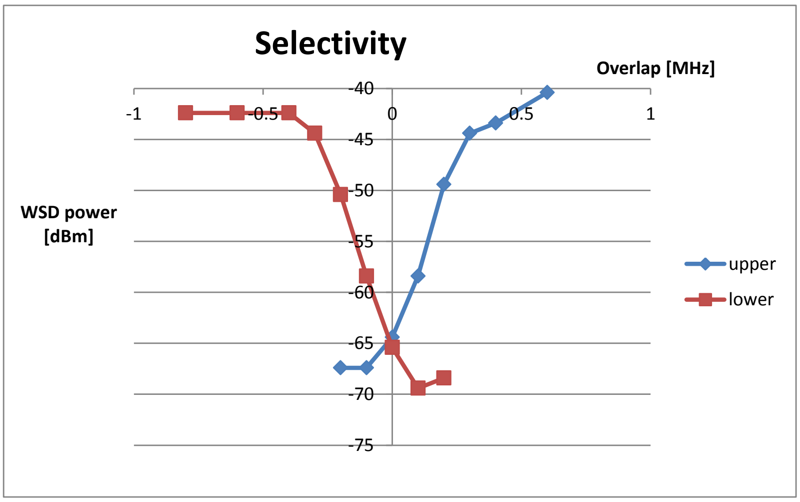


Figure 17 Microphone selectivity at the Arena theatre

The result shown in Figure 17 is somewhat different from the laboratory measurement. The reason is the varying ACLR performance of the WSD signal. The curve seems to flatten out already after 25 dB (-67 dBm to -42 dBm) as the power setting and ACLR is increased.

5.2 Measurements in the Main Stage

WSD-maximum power was measured at the main stage in 9 different locations of which 6 were outside the theatre building. The placement of the microphone receivers and the microphones are explained in 2.2 and shown in Figure 18.

Figure 18 Test receivers at the main stage light balcony and WSD Tx at row 10 up just below the receivers

Figure 20 also shows the WSD Tx antenna in spot 2. The measurement spots and rough locations of the microphones and receivers are shown in Figure 20 and Figure 21. These also show approximate distances to the microphone receivers.

The measurements inside of the theatre were in principle done in similar way as in the Arena theatre, but other activities in theatre prevented moving the microphones during the measurements. It was also not possible to measure the path losses between the WSD and microphone receivers although in some cases these have been estimated from spectrum measurements.

Summary of the measurements are shown in Table 5.

Table 5 Summary of the results in the main theatre

	Set up						Distances [m]			Results						
#	Place	Spot	Mic Ch	N Mics	DVB-T Ch	Case	Mic to Rcvr	WSD to Rcvr	WSD to Mic	Att [dB]	EIRP [dBm]	Note	Type	Path loss	WSD pwr at Mic rcvr	pwr/200kHz
15	Main Stage	1	618	4	618	N	40	row 10		46	5	Mics alone	All			
16	Main Stage	1	618	4	610	N-1	40	row 10		18	32.4	Mics alone	All			
17	Main Stage	1	618	4	626	N+1	40	row 10		17	33.4	Mics alone	All			
18	Main Stage	2	618	4	618	N	40	row 2 up		66	-15	Mics alone	All			
19	Main Stage	2	618	4	610	N-1	40	row 2 up		23	28	Mics alone	All			
20	Main Stage	2	618	4	626	N+1	40	row 2 up		21	30	Mics alone	All			
21	Main Stage	3	618	4	618	N	40	lower lobby		28	33	Mics alone	All	97	-64	-80.0
22	Main Stage	3	618	4	610	N-1	40	lower lobby				Mics alone	All			
23	Main Stage	3	618	4	626	N+1	40	lower lobby				Mics alone	All			
24	Main Stage	out 1	618	4	618	N	40	60		12	45.3	Mics alone	All	110.8	-65.5	-81.5
25	Main Stage	out 2	618	4	618	N	40	35		30	31	Mics alone	All	86.5	-55.5	-71.5
26	Main Stage	out 3	618	4	618	N	40	62		26	35	Mics alone	All	97.5	-62.5	-78.5
27	Main Stage	out 4	618	4	618	N	40	120		28	33	Mics alone	All	90.5	-57.5	-73.5
28	Main Stage	out 5	618	4	618	N	40	560		12	45.3	Mics alone	All	100.8	-55.5	-71.5
29	Main Stage	out 6	618	4	618	N	40	105		31	30	Mics alone	All			

Measurements #15, #16 and #17 were done so that the WSD Tx was at row 10 and cases N, N-1 and N+1 were measured. For the next three (#18, #19, #20) the WSD was moved to the upper part of the theatre to row 2 at the balcony. This was just below the light balcony where the receivers were located. It is interesting to note that the co-channel WSD power is decreased by 20 dB, but the adjacent only by 4 to 5 dB. Next measurements (#21, #22, #23) were done in the lower lobby of the theatre. Here the available WSD-power was only able produce any errors with the co-channel case. Even changing the Tx-antenna to a directional yagi would not help.

The rest of the measurements were done outside the theatre. Yagi-antenna was used in all cases and the power to the WSD-signal generation was provided by a Ficora measurement van. A measurement set up in spot out 1 is shown in Figure 19. Measurement #24 in spot out 1 was about 60 m away from the receiver, but no errors were found even at the co-channel. Measurement #25 in spot out 2 was in an easier place, but still only co-channel produced any errors. This was the case for all the rest of the outdoor measurements. Measurement #26 was a bit further, but still close to the theatre. #27 was on the other side of the road passing the theatre. All these three measurements produced very similar results from +31 dBm to +35 dBm on the co-channel. The next spot (#28) was much further away on the other side of the "Eläintarhanlahti" bay. Here no errors were found even with the highest available WSD-power. The last spot (#29) was the on the other side of the theatre, again producing very similar result as on the other nearby measurement spots.

Figure 19 Measuring outside the theatre at spot out 1

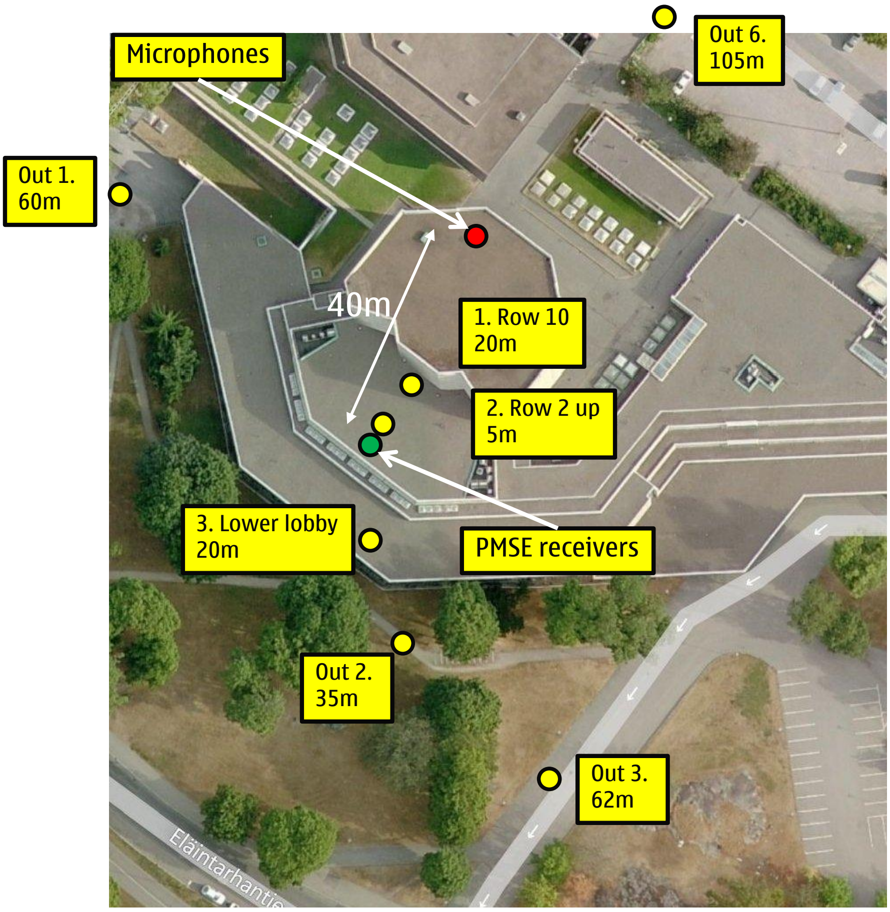


Figure 20 Measurement spots outside the main theatre

uu

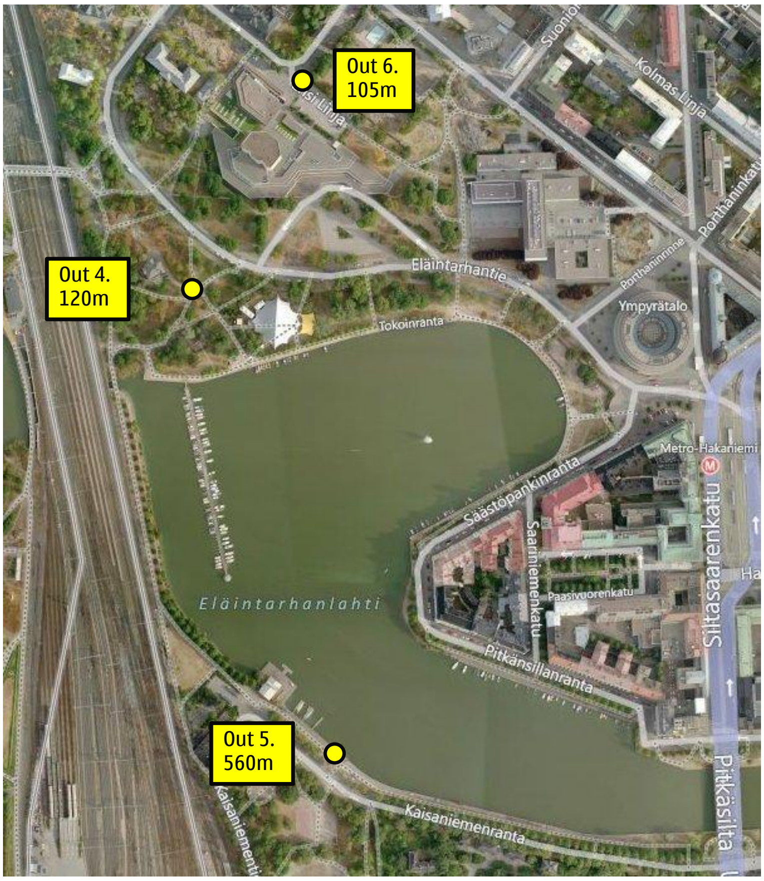


Figure 21 Measurement spots further away from the theatre

All the path losses Table 5 have been calculated using the WSD Tx EIRP values and the power levels measured using R&S FSH spectrum analyzer and biconical antenna close by the microphone receivers. An example of such a measurement is shown in Figure 22.

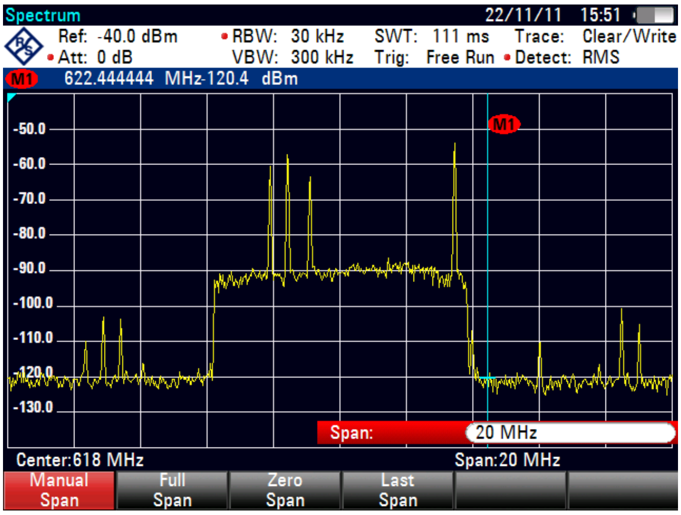


Figure 22 Spectrum at the microphone receiver, WSD Tx at spot "out 1"

In this figure the WSD-power is at -90 dBm measured with 30 kHz RBW. If this is converted to 8 MHz channel power we get -65.5 dBm and as the transmitting power (EIRP) was +49 dBm (with the Yagi), the path loss is 114.5 dBm. The biconical antenna is roughly corresponding the antennas attached to the microphone receivers. The microphone signals are clearly visible.

In all measurement locations the microphone signals were observed either with the WSD-antenna and spectrum analyzer or with the fixed omni antenna of the measurement van. Although this was only qualitative observation, still the microphone signals were clearly visible in all locations where it was possible to cause interference. In fact also in spot out 5, where it was not possible to cause interference the microphone signal were clearly visible.

6. CONCLUSIONS

The measurement campaign studied PMSE (radio microphone) protection in a realistic environment in two different theatres in Helsinki.

The tested microphones were installed and used like the operational microphones in theatres, but with somewhat more demanding conditions for the receivers as the diversity antennas were attached directly to the receivers and the receivers were placed in slightly worse places. Also the microphones were at the maximum distance.

The microphone receivers were interfered with a simulated WSD-signal until interference was observed. This was repeated in several locations with both co- and adjacent channels.

It was found that there is a major effect on how the microphones are used. An attached belt pack microphone with the person moving around can be 30 dB worse than a microphone alone with no movement or obstacles.

The observed WSD-power level to cause interference within the theatre hall among the audience was found to be between -15 to +5 dBm in the co-channel case. For the first adjacent channel this was found to be about +30 dBm and for the next adjacent +40 dBm or more. The co-channel can still cause interference within the theatre building (lobby etc.) with a few + dBm levels.

Outside the theatre building, but not more than around 100 m away, the observed interference levels for the co-channel case were around +30 to +35 dBm. For the adjacent channel the levels are at least +42 dBm, probably more, as the power was limited by available test set-up. At a distance of 560 m it was not possible to cause interference anymore with the available WSD-power.

In the Arena theatre also the path losses between the WSD-transmitter and microphone receiver were measured and this enabled to calculate the true WSD interference power at the microphone receiver input. In the normal case this was found to be around -60 dBm@8Mhz corresponding -76 dBm@200kHz. When the microphone was moved to a location where the path loss between the microphone and the receiver was increased by 14 dB also the WSD interference power decreased by 14 dB giving a linear dependency between microphone signal level and allowed interference level.

Laboratory measurements confirmed this linear dependency between the microphone signal and the interference power levels, average C/I values being around -12 dB over a range of input levels.

Selectivity curves were measured both in the laboratory and in the field.

At least in the geometries studied in these measurements, it was possible to identify the microphone signals with a spectrum analyser in all measurement spots. This is at least an indication that sensing might have been possible in this case although not a proof as the practical aspects of sensor implementation are not considered.

7. ACKNOWLEDGEMENTS

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