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Summary

This report presents the results of a short measurement programme undertaken in a West End Theatre to evaluate the loss on a transmitted signal from a belt-pack PMSE transmitter. The measured losses are a combination of body absorption as well as multipath effects caused by scattering and reflection from objects in the auditorium.

The measurements were repeated for two test subjects of different height and build wearing the transmitter in slightly different positions to represent real performance scenarios. Measurements were made for two different transmit locations on the stage and a number of receiver locations around the auditorium. A standard wireless belt-pack transmitter was used radiating at 50 mW and operating in Channel 69 at 860.15 MHz.

The results are summarised in the table below.

Summary of measured loss

Location	Measured loss (dB)	
	Subject 1	Subject 2
Tx1-Rx1	22	17
Tx1-Rx2	23	21
Tx1-Rx3	31	19
Tx1-Rx4	28	23
Tx2-Rx4	9	20
Tx2-Rx5	22	14

Typical losses varied from 9 to 31 dB for subject 1 and 14 to 23 dB for subject 2. In general, the losses for subject 2 were lower than for subject 1, indicating that the location on the body as well as the build of the person wearing the transmitter has an impact on the results. The coupling loss, due to the PMSE transmitter being so close to the body, may also be a factor. European Radiocommunications Committee (ERC) Report 42 [1] gives an indicative value of 14 dB, but again this will vary depending on the location of the transmitter on the body as well as shape and size of the subject wearing the device. Further work would be required to confirm this figure.

A limited set of measurements were also performed under ideal conditions in a fully anechoic chamber for subject 2, removing the multipath effects experienced in the theatre environment. Results under these conditions suggest a body absorption loss of 22 to 25 dB,

in line with the body loss figure in ERC Report 42 [1]. Comparing this with the results for subject 2 in the table above suggests that some enhancement of the signal could be obtained in a theatre environment due to scattering and reflection from walls, scenery and props etc used in an auditorium. However, this enhancement is only likely to be of the order of 3 – 6 dB.

Contents

Tables List

Page No.

Figures List

Page No.

Abbreviations List

DDR	Digital Dividend Review
ERC	European Radiocommunications Committee
PMSE	Programme Making and Special Events

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1. Introduction

Ofcom's Digital Dividend Review (DDR) has been considering how to make the spectrum freed up by digital switchover available for new uses. In February 2009 Ofcom published a consultation on licence exempting cognitive devices using interleaved spectrum[1] as part of the DDR. The document consults on parameters for licence-exempt cognitive devices using interleaved spectrum to prevent harmful interference to licensed users.

One of the parameters used to determine the margin required to protect wireless microphones used in Programme Making and Special Events (PMSE) is 'body loss'. This is caused when a person wearing a wireless microphone is oriented such that their body is between the transmitter and receiving antenna.

This report presents the results of a short measurement programme to determine the loss experienced in a theatre environment and to determine whether reflections from walls, scenery, equipment etc could enhance the received signal.

The results obtained from the study will allow some conclusions to be drawn on whether a typical performance environment alters the degree of body absorption loss assumed in the consultation document.

[1] http://www.ofcom.org.uk/consult/condocs/cognitive/summary/

2. Measurement Methodology

2.1 Measurement Location

The measurements were made at a number of locations on stage and around the auditorium of a West End theatre to determine the impact of reflections from props and scenery typically used in a performance. Two transmit locations were chosen, one at the centre of the stage and one towards the back at stage right. At each location a small turntable was used in order to obtain a 360° polar plot of the transmitted signal, as shown in Figure 1 below. The figure also shows part of the stage set and props in place during the measurements.

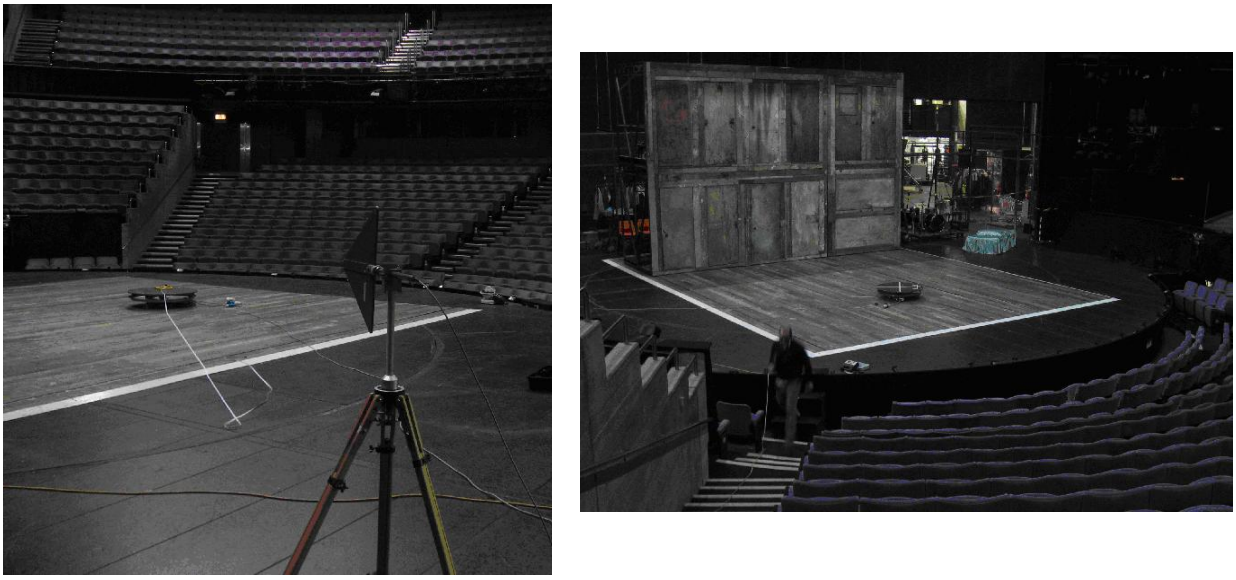

Figure 1: Example measurement location and stage set

The measurements were repeated for two test subjects of different height and build. Each subject wore the transmitter in a different location to represent different operating scenarios. Subject 1 wore the transmitter against the skin in the small of the back and test subject 2 wore the transmitter in a right hand back pocket. Other typical transmitter locations used during a live performance are listed below but it was not possible to consider these in the time available:

- Inner thigh
- Under an arm
- Inside a hat

- Between the shoulder blades

Figure 2 shows the general seating plan for the theatre and the measurement locations.

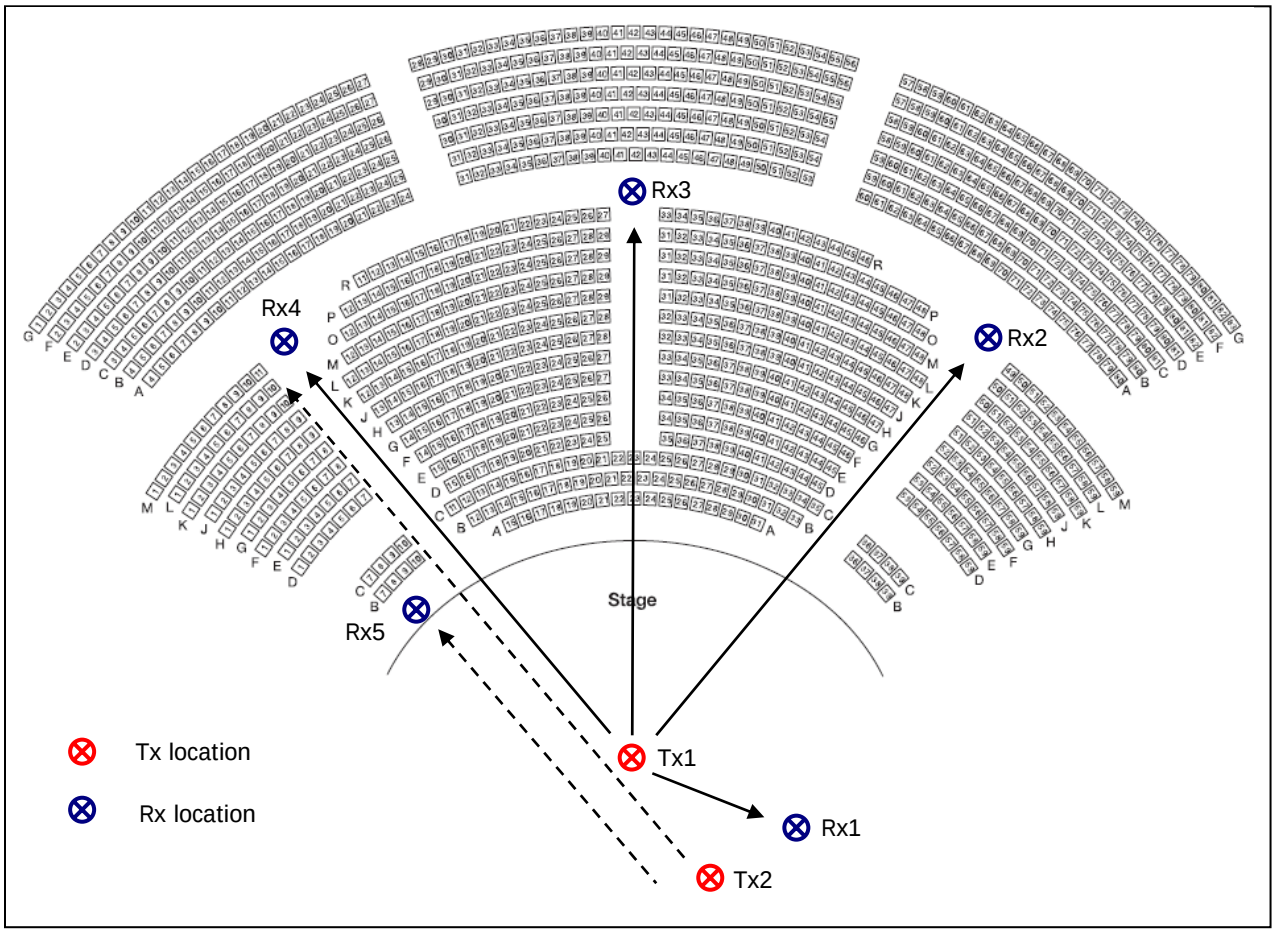

Figure 2: Seating plan and measurement locations

The distance between each transmit and receive location is summarised in Table 1 below.

Table 1: Distance between measurement locations

Location	Distance (m)
Tx1 → Rx1	10.0
Tx1 → Rx2	18.0
Tx1 → Rx3	18.0
Tx1 → Rx4	18.0

Location	Distance (m)
Tx2 → Rx4	23.0
Tx2 → Rx5	14.7

2.2 Test Set-Up

Measurements were made on a typical body-worn PMSE wireless transmitter radiating at a maximum permitted power of 50 mW. The transmitter was tuned to frequency 860.15 MHz in Ch69. The received signal strength was measured at a relative height of 1.0 m for receiver locations Rx1 and Rx5 on the stage and in gantries approximately 5 m above the transmitter for receiver locations Rx2, Rx3 and Rx4, using a typical UHF spade antenna mounted co-polar with the transmitted signal. The gain of the antenna is typically 5 dB with a half-beam width of 78° at 860.15 MHz. The test set-up is shown in Figure 3 below.

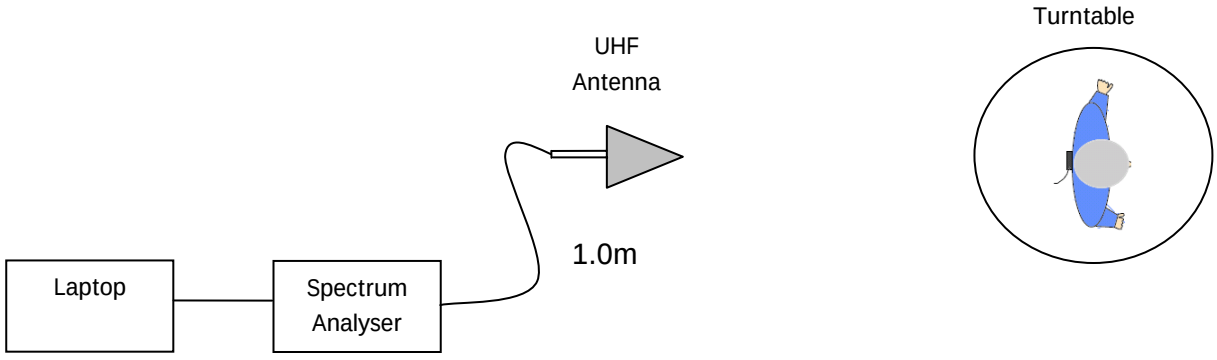

Figure 3: PMSE measurement test set-up

3. Results

The results presented below have been normalised to the power received with the body-worn transmitter directly facing the antenna measuring the received PMSE signal, i.e. along the 0-180° axis. All results shown are for co-polar incidence with both transmitter and receiver orientated in the vertical plane.

3.1 Theatre Measurements

3.1.1 Results from Transmit Location Tx1

The polar plots from location Tx1, located at the centre of the stage, to each of the receiving locations Rx1 – Rx4 are shown in Figure 4 to Figure 7 below. Each figure shows two plots, one for each of the test subjects.

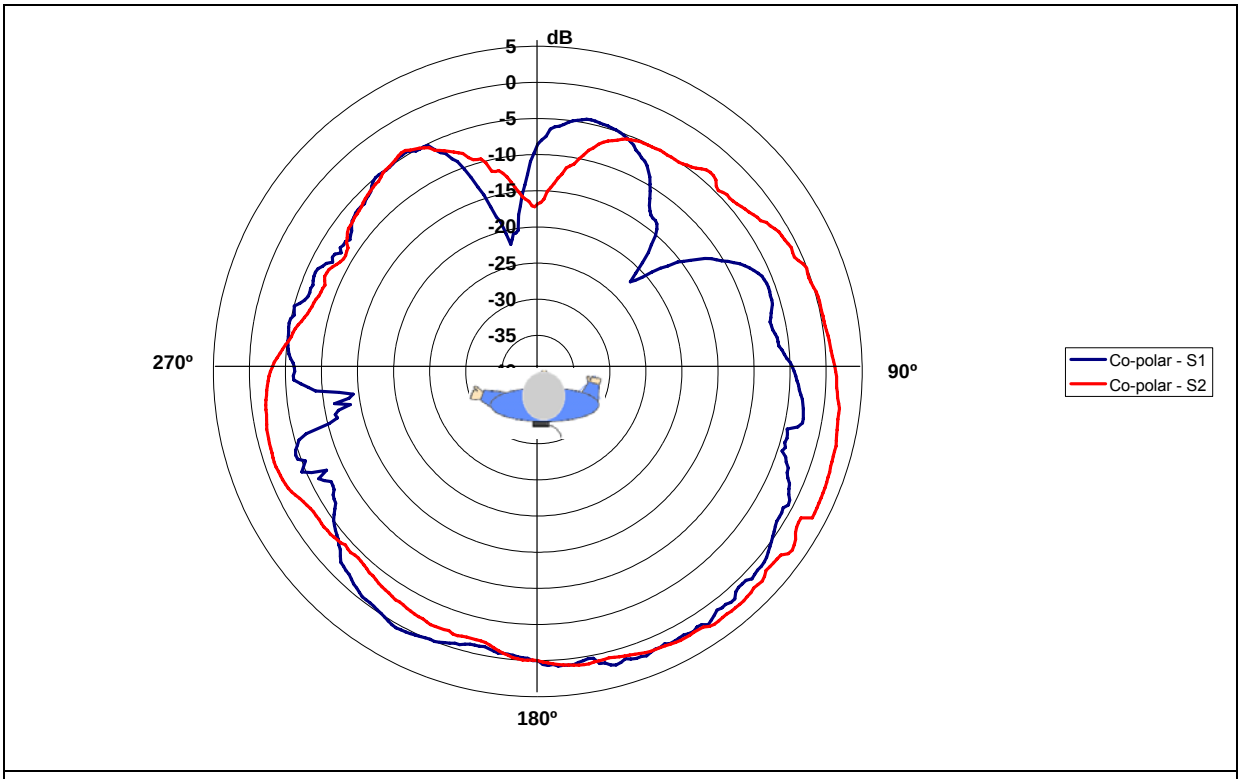

Figure 4: Loss measured at Rx1 from Tx1

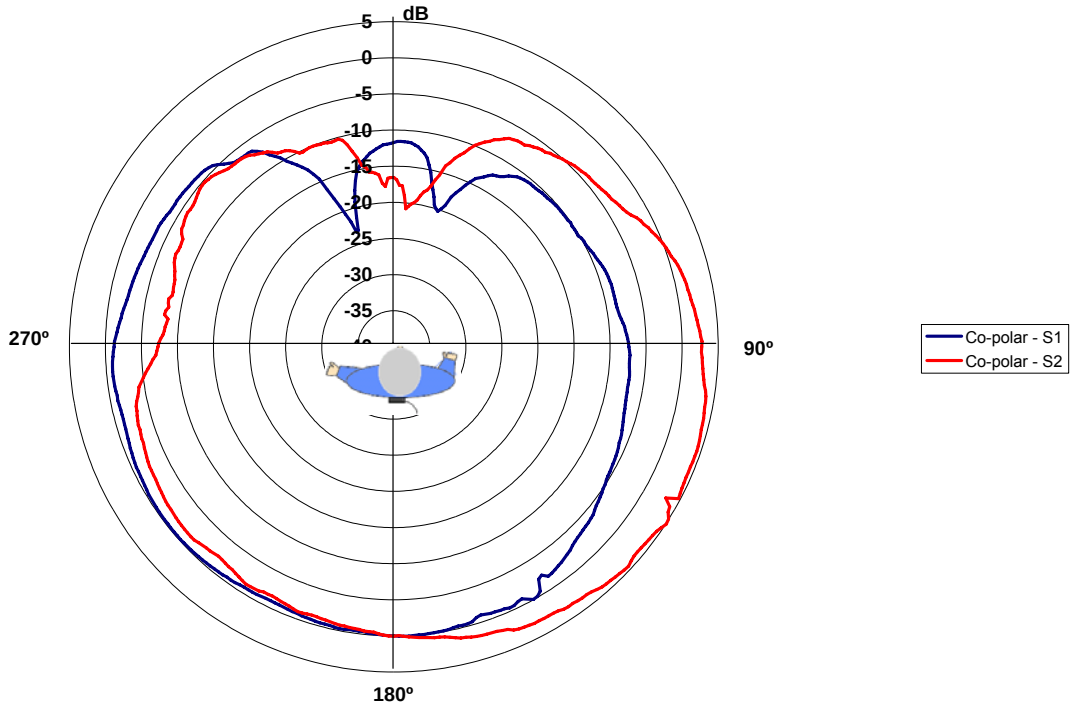

Figure 5: Loss measured at Rx2 from Tx1

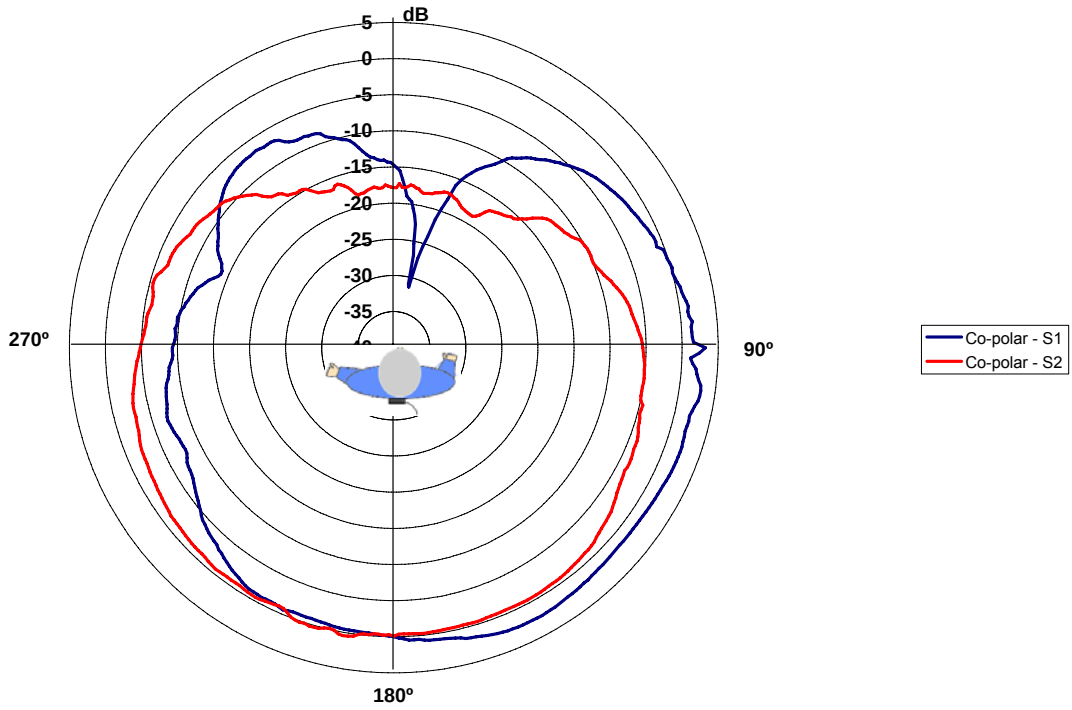

Figure 6: Loss measured at Rx3 from Tx1

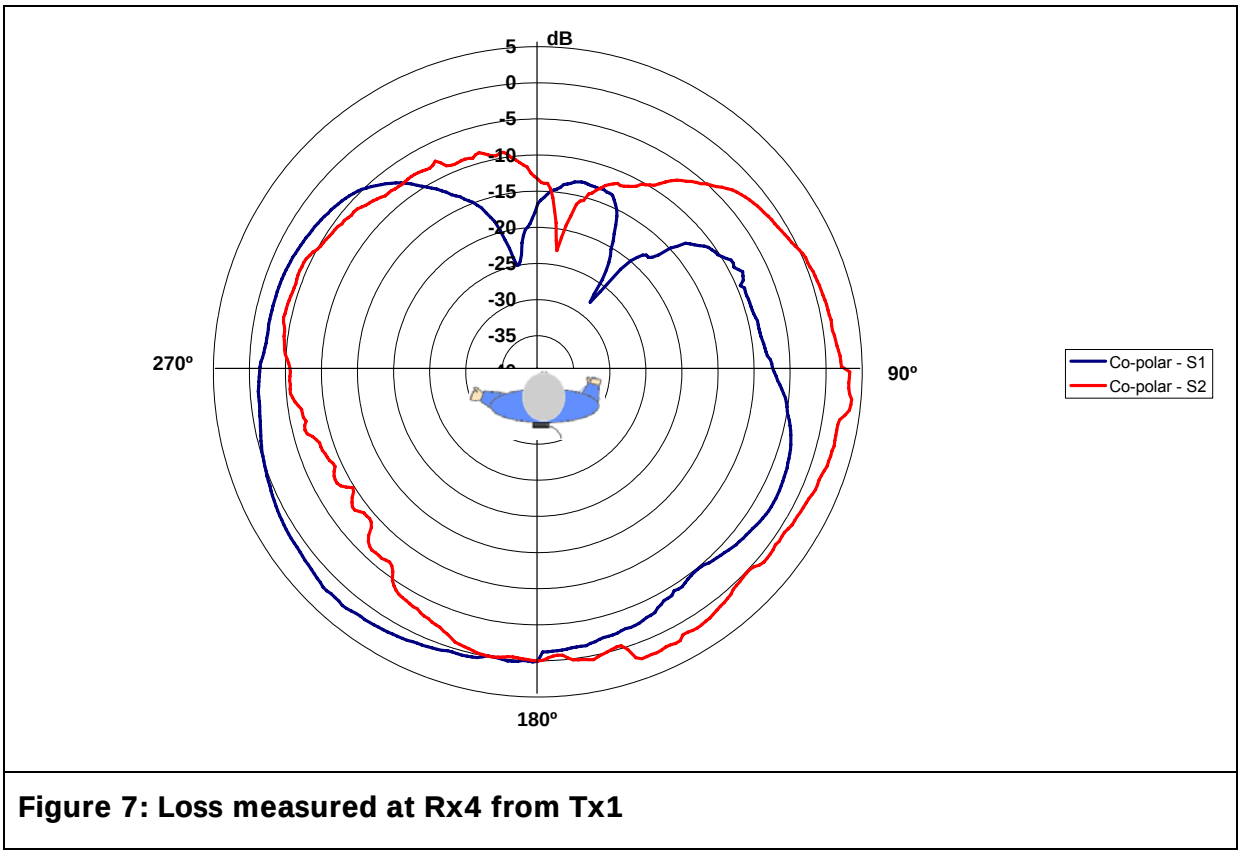

Figure 7: Loss measured at Rx4 from Tx1

The results are summarised in the table below:

Table 2:
Measured loss from transmit location 1

Location	Measured loss (dB)	
	Subject 1	Subject 2
Tx1-Rx1	22	17
Tx1-Rx2	23	21
Tx1-Rx3	31	19
Tx1-Rx4	28	23

The measured losses are a combination of body absorption as well as scattering and reflection effects from objects in the auditorium.

The highest loss was observed at receiver location 3 from subject 1, with the transmitter worn in a back right pocket. This sharp dip could be due to the incident and reflected waves

arriving out of phase at the measuring receiver for this particular transmitter and receiver orientation.

The lowest loss was observed at locations 1 and 3 from subject 2, with the transmitter worn in the small of the back. In general, subject 2 exhibited lower losses than subject 1 by on average 6 dB. This is likely to be due to a combination of transmitter location on the body and the difference in build between the subjects.

3.1.2 Results from Transmit Location Tx2

The polar plots from Tx2, located at the back right of the stage, to each of the receiving locations Rx4 – Rx5 are shown in Figure 8 and Figure 9 below. As before, each figure shows two plots, one for each of the test subjects.

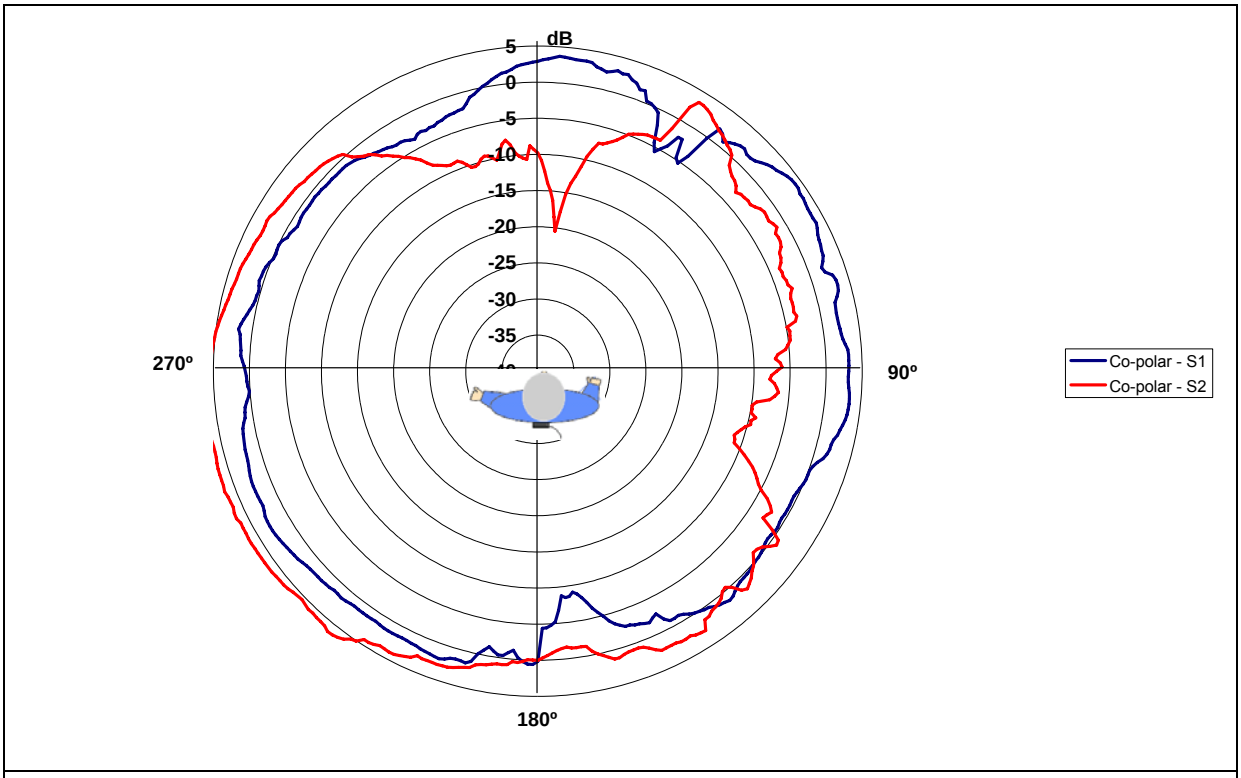

Figure 8: Loss measured at Rx4 from Tx2

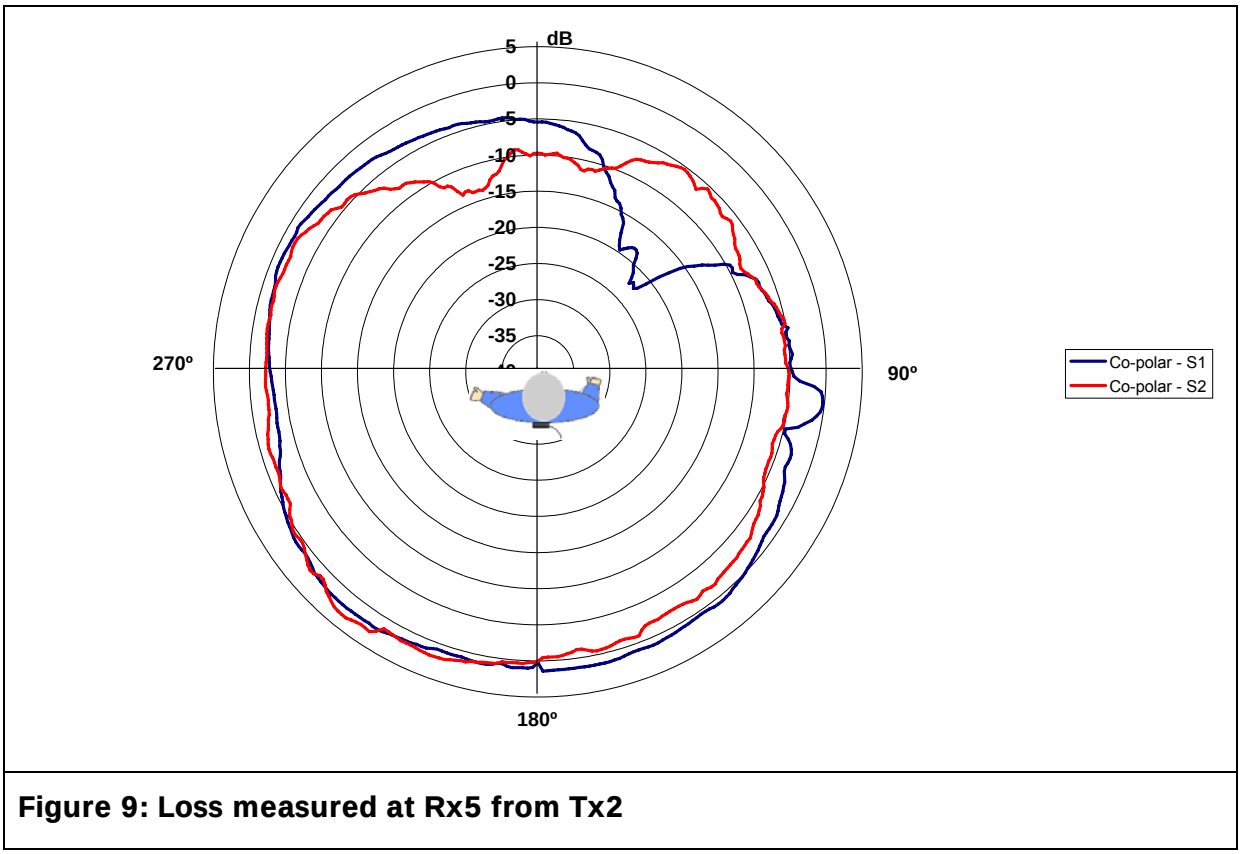

Figure 9: Loss measured at Rx5 from Tx2

The results are summarised in the table below:

Table 3:
Measured loss from transmit location 2

Location	Measured loss (dB)	
	Subject 1	Subject 2
Tx2-Rx4	9	20
Tx2-Rx5	22	14

The results for location Tx2 show that the highest loss observed was 22 dB for subject 1 at receiver location 5, while the lowest loss was 9 dB at location 4. Since location 4 was further from the transmitter than location 5 the results suggest that the signal is being enhanced by reflections and scattering from objects in the theatre.

In general the losses measured from location Tx2 were lower than those from Tx1. Location Tx2 was at the back right of the stage close to a metal cage and other objects as shown in the figure below. This may have helped to enhance the received signal level.

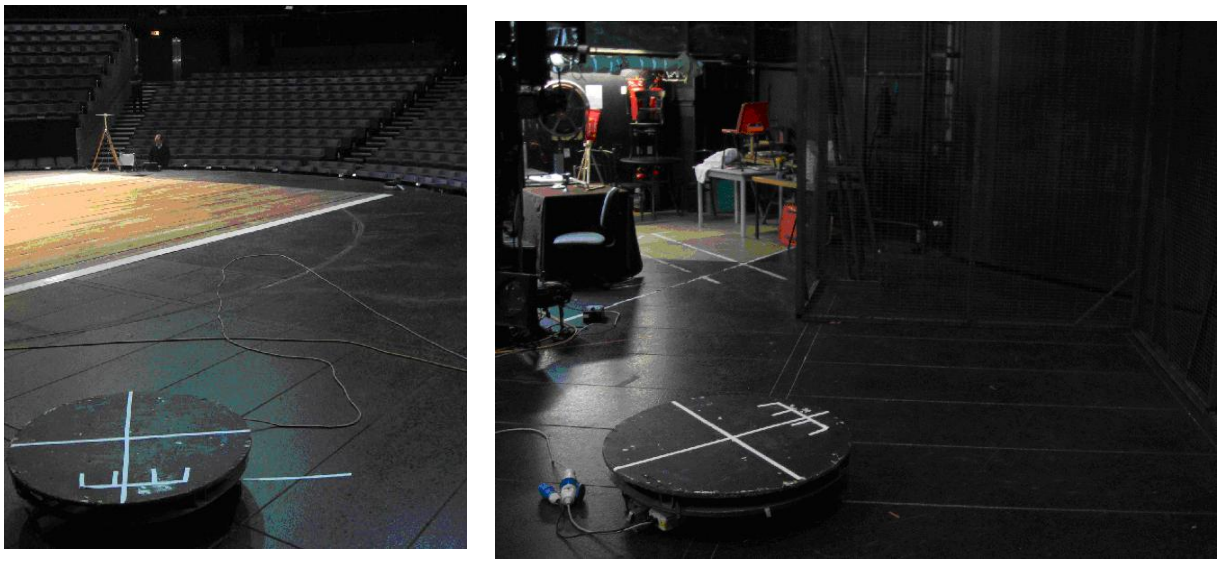

Figure 10: Transmitter location 2 at back right of stage

3.1.3 Comparison between different test subjects

The results from transmitter location Tx1 for each test subject are compared in the figure below.

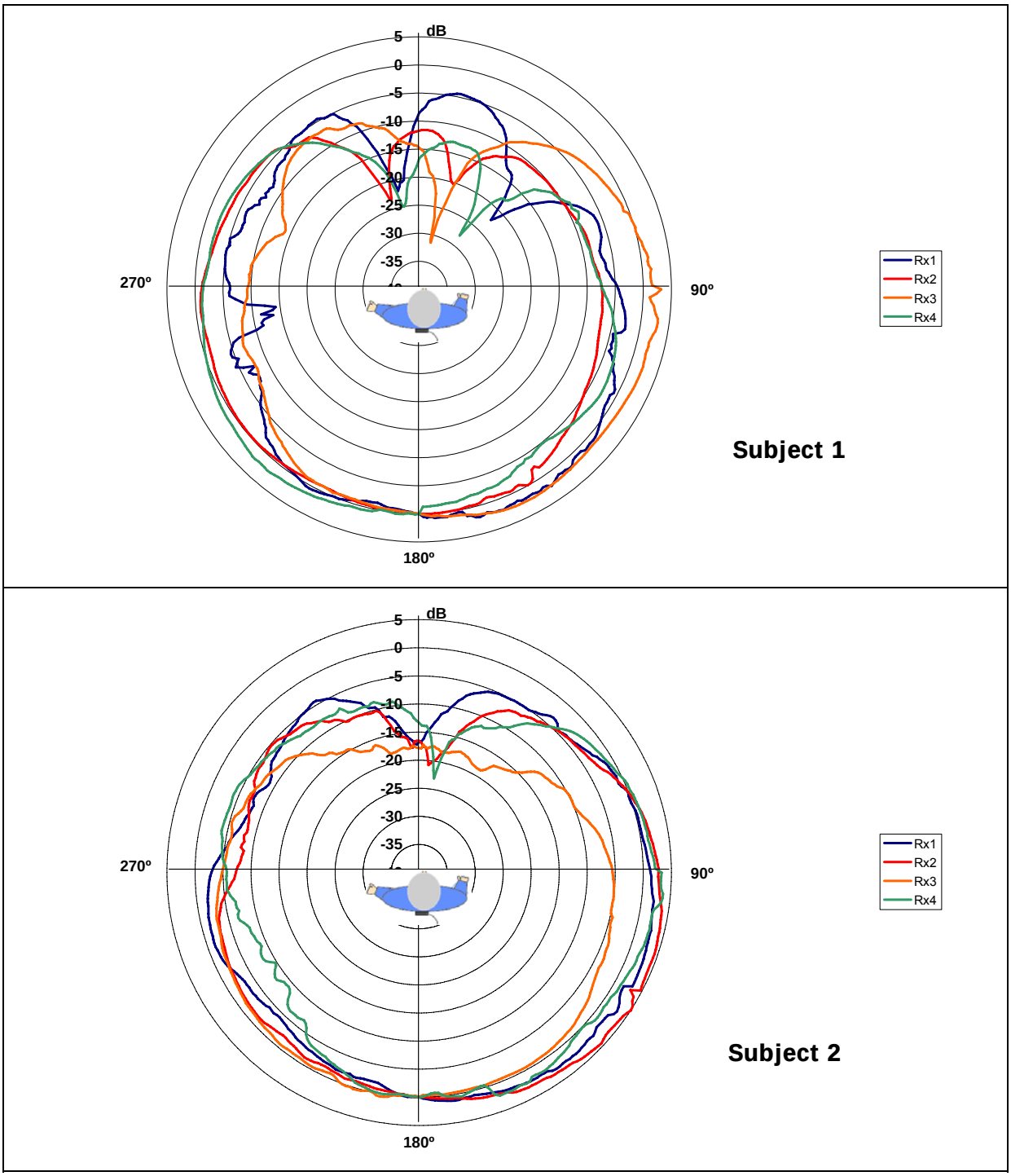

Figure 11: Comparison of losses between different test subjects

In general the results follow the same trend, with the highest losses occurring between -5 and 30°, when the body is between the PMSE transmitter and receiving antenna. The results suggest that the location of the transmitter on the body, as well as the height and build of the person wearing the transmitter, has an impact on the measured losses.

3.1.4 Comparison of loss for different body-worn locations

A limited set of measurements were made for a third test subject at Tx1 – Rx4 wearing the transmitter at three different locations on the body: back left hand trouser pocket, small of the back and back right hand trouser pocket

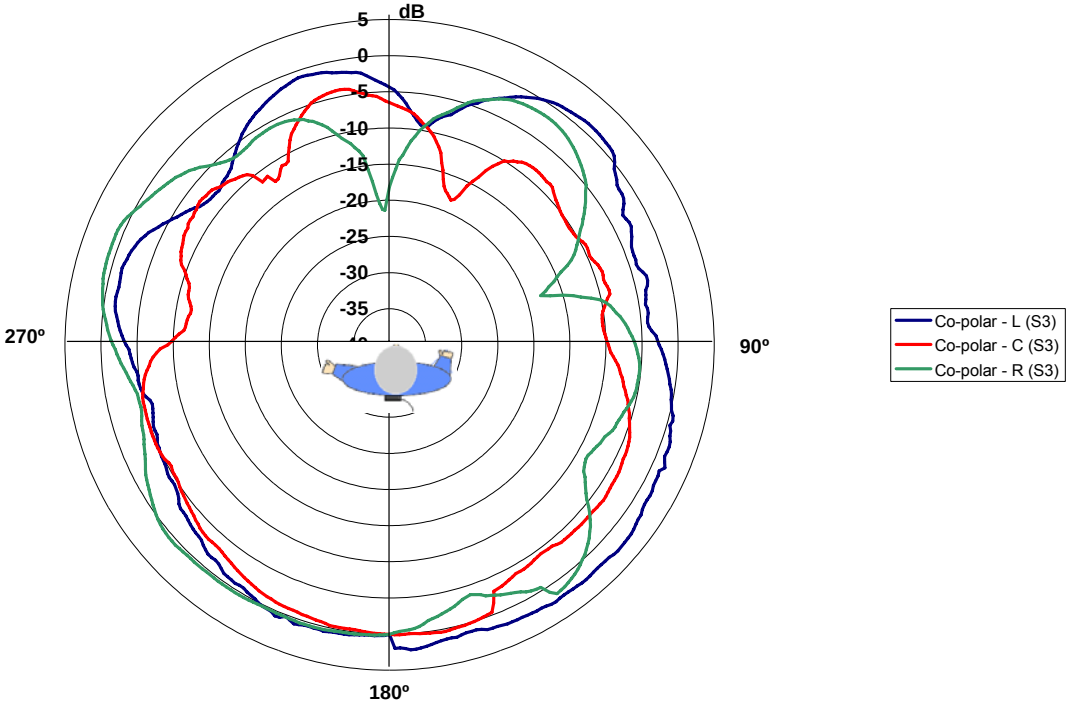

Figure 12: Comparison of losses between body-worn locations

The polar plot shows that for subject 3 the maximum loss observed varies between 9, 18 and 21 dB for a PMSE transmitter located in the left pocket, the small of the back and the right pocket respectively. The plot also suggests that the transmitter radiation pattern from the PMSE device can change significantly depending on where it is worn on the body due to the coupling loss. ERC report 42 [1] gives an indicative value of 14 dB for coupling loss, but this will vary depending on the location of the transmitter on the body as well as shape and size of the subject wearing the device. Further work would be required to confirm this value.

3.2 Anechoic Chamber Measurements

Measurements were also undertaken in an anechoic chamber to provide true values of body loss without the multipath effects experienced in a theatre environment. The measurements were undertaken on subject 2 with the PMSE transmitter worn in the small of the back. The polar plot is shown in the figure below.

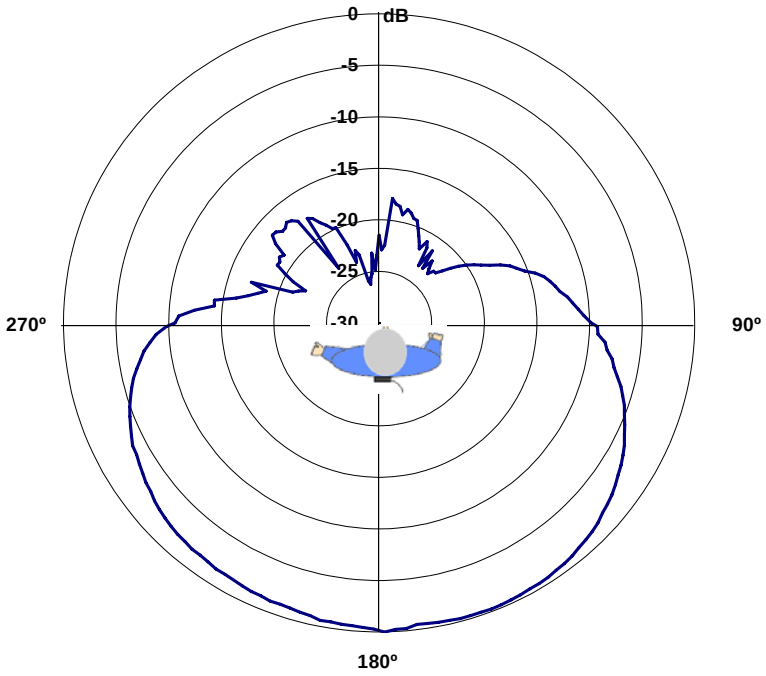

Figure 13: Polar plot of body loss as a function of angle measured inside an anechoic chamber

The results performed under ideal conditions in the anechoic chamber suggest body loss values of 22 to 25 dB along the main vertical axis. These results are similar to those contained in ERC Report 42 [1] for a transmitter operating at a frequency of 650 MHz.

4. Conclusions

This report presents the results of a short measurement programme in a West End theatre to determine whether reflections from walls, scenery, equipment etc could enhance the received signal from a PMSE wireless belt-pack transmitter. The measured losses are a combination of body absorption as well as multipath effects caused by scattering and reflection from objects in the auditorium. A limited set of measurements were also

undertaken under ideal conditions in an anechoic chamber in order to obtain the true body loss without the multipath effects seen in the theatre.

The measurements were repeated for two test subjects of different height and build wearing the transmitter in slightly different positions to represent real performance scenarios. A small turntable was used in order to obtain 360° polar plots of the transmitted signal.

Table 4 below shows the measured losses for co-polar incidence at five separate receive locations and two transmit locations.

Table 4:
Summary of measured losses

Location	Measured loss (dB)	
	Subject 1	Subject 2
Tx1-Rx1	22	17
Tx1-Rx2	23	21
Tx1-Rx3	31	19
Tx1-Rx4	28	23
Tx2-Rx4	9	20
Tx2-Rx5	22	14

Typical losses varied from 9 to 31 dB for subject 1 and 14 to 23 dB for subject 2. In general, the losses for subject 2 were lower than for subject 1, indicating that the location on the body as well as the build of the person wearing the transmitter has an impact on the results. The coupling loss, due to the PMSE transmitter being so close to the body, may also be a factor. ERC Report 42 [1] gives an indicative value of 14 dB, but again this will vary depending on the location of the transmitter on the body as well as shape and size of the subject wearing the device. Further work would be required to confirm this figure.

Results obtained in an anechoic chamber for subject 2, removing the multipath effects experienced in the theatre environment, suggest a body absorption loss of 22 to 25 dB. This is line with the value for body loss given in ERC Report 42. Comparing this with the results for subject 2 in the table above suggests that some enhancement of the signal could be obtained in a theatre environment due to scattering and reflection from walls, scenery and props etc used in an auditorium. However, this enhancement is only likely to be of the order of 3 – 6 dB.

5. References

[1] ERC report 42, “Handbook on Radio Equipment and System Radio Microphones and Simple Wideband Audio Links”, Rome October 1996

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Appendix A: Test Equipment List

A.1. Test Equipment

- Rhode and Schwarz EPSI-7 spectrum analyser
- Schwarzbeck UHALP 9107 antenna
- PMSE body worn transmitter pack
- Lorch filter 500 to 1000 MHz tuneable filter