Exploratory Investigation of WCDMA Interference to Hearing Aids

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Executive Summary

Telstra have announced that it will replace the CDMA ("Code Division Multiple Access") digital mobile network by a new digital mobile network that will be introduced by the end of 2007 [1]. This "Third Generation" (3G) digital network has been designated "3G GSM" [1] and is based on a "Wideband CDMA" (WCDMA) network. WCDMA utilizes spread-spectrum technology that uses a coded division multiple access multiplexing scheme [2]. WCDMA can operate in two modes, one based on "Frequency Division Duplex" (FDD) and the other on "Time Division Duplex" (TDD) [2]. WCDMA uses a channel bandwidth of 5 MHz to carry both voice and data information [2]. The WCDMA protocol is not compatible with the CDMA protocol [2].

Telstra requested the National Acoustic Laboratories to collaborate in an investigation into the potential of WCDMA technology to cause interference to hearing aids. A comparison with CDMA and GSM ("Global System for Mobile Communications") technology was also carried out.

Three typical hearing aids with varying radio immunity were subjected to WCDMA, CDMA and GSM test signals at 835MHz. A common test frequency of 835 MHz was used to minimise the effect of any performance differences in the interference characteristics between hearing aids at 835 and 900 MHz.

The evaluation was performed using the same radiofrequency (RF) waveguide exposure system that had been developed by Telstra Research Laboratories and the National Acoustic Laboratories in the 1990s for the original GSM investigations [3]. The test conditions in the RF exposure system were set so that the average field strength levels were the same for each of the three test signals to ensure a fair comparison between technologies.

A subjective rating technique was employed to evaluate the immunity performance of each hearing aid by four test subjects, or observers that had either normal hearing, or a mild hearing loss. The rating system was based on "Perceptibility" (from "Very Annoying" to "Not Perceptible") and "Useability" (from "Not Useable" to "Always Useable") scales to judge the responses in the hearing aids.

The interference produced in the hearing aids was judged at maximum RF exposure and at progressively lower levels (in steps of 6dB).

The test results, which are based on a subjective assessment of audible interference, indicate that WCDMA and CDMA signals produced similar levels of interference in the hearing aids. Also the test results indicate that WCDMA produces a slightly lower level of interference than CDMA. Hearing aid users are likely to experience similar levels of interference from CDMA or WCDMA handsets operating under the same conditions. The GSM signal produced significantly more audible interference in hearing aids than either WCDMA or CDMA signals.

For a hearing aid user to successfully use a WCDMA digital mobile telephone, their hearing aid should have a minimum RF immunity level similar to Class 1 as specified

in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4]. For use with CDMA digital mobile telephones, the hearing aid minimum RF immunity level should be greater than Class 1, but significantly less than Class 2 as specified in AS 1088.9.

In a mobile telephone network such as WCDMA, a handset is capable of executing a "handover" of its calls on to another WCDMA base station frequency or it can change operating modes from WCDMA to GSM to guarantee coverage for the user. The process of "handover" in a WCDMA network is accomplished by using "compressed mode".

"Compressed mode" operation will produce a level of interference in hearing aids between that caused by normal WCDMA "uncompressed mode" operation and GSM digital mobile telephone operation, however, it only occurs over a short interval of time, typically several seconds and is not expected to be a critical factor for most hearing aid users.

During "compressed mode" operation, for interference to be at a level that is "not perceptible", or "just perceptible", the RF immunity requirement for the hearing aid will need to be at a level approximately midway between the Class1 and Class 2 categories specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4].

The results for "compressed mode" operation are detailed in Appendix A.

The test results are based on constant average levels of the test signal during each observation period with the hearing aid in microphone setting. This study does not report on the following options:

1) *Dual mode, 800 MHz WCDMA/GSM handsets*: If this type of handset becomes available then a hearing aid user would experience a significant increase in audible interference when a handset switches from WCDMA to GSM.

2) *WCDMA and CDMA fast fading conditions*: The ramping up and down of the handset power level in response to changing radio propagation conditions can increase the audible interference emanating from a hearing aid. Fast fading conditions are not reported in this publication. However, handset power level changes under fading conditions in a CDMA and WCDMA system will be comparable and experience to date with CDMA suggests that this may not be a critical issue for hearing aid users.

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Introduction

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Telstra requested the National Acoustic Laboratories to collaborate in an investigation into the potential of WCDMA technology to cause interference to hearing aids. A comparison with CDMA and GSM ("Global System for Mobile Communications") technology was also carried out.

Three typical hearing aids with varying radio immunity were subjected to WCDMA, CDMA and GSM test signals at 835MHz. A common test frequency of 835 MHz was used to minimise the effect of any performance differences in the interference characteristics between hearing aids at 835 and 900 MHz.

The evaluation was performed using the same radiofrequency (RF) waveguide exposure system that had been developed by Telstra Research Laboratories and the National Acoustic Laboratories in the 1990s for the original GSM investigations [3]. The test conditions in the RF exposure system were set so that the average field strength levels were the same for each of the three test signals to ensure a fair comparison between technologies.

A subjective rating technique was employed to evaluate the immunity performance of each hearing aid by four test subjects, or observers that had either normal hearing, or a mild hearing loss. The rating system was based on "Perceptibility" (from "Very Annoying" to "Not Perceptible") and "Useability" (from "Not Useable" to "Always Useable") scales to judge the responses in the hearing aids.

The interference produced in the hearing aids was judged at maximum RF exposure and at progressively lower levels (in steps of 6dB).

In a mobile telephone network such as WCDMA, a handset is capable of executing a "handover" of its calls on to another WCDMA base station frequency or it can change operating modes from WCDMA to GSM to guarantee coverage for the user. The process of "handover" in a WCDMA network is accomplished by using "compressed mode".

The results for "compressed mode" operation are detailed in Appendix A.

Acknowledgments

Telstra provided and operated the equipment to generate the WCDMA, CDMA and GSM radio test signals. Test subjects, or observers used to assess any perceived interference within the test hearing aids were recruited from staff at the National Acoustic Laboratories and Telstra.

Program of Work

This research project is an initial investigation into the potential of WCDMA technology to cause interference to hearing aids. Measurements are made to allow comparison with CDMA and GSM technology.

The program of work is as follows:

- Measure the radiofrequency immunity level of three hearing aids used in the study.
- Measure the audiogram to determine the hearing level of each test subject, or observer used for the assessment of any interference produced in the three test hearing aids when exposed to the different radio test signals.
- Measure the acoustic gain of each hearing aid using a 1000 mm length of 2 mm diameter tubing connected to a 2 cc acoustic measurement coupler.
- Set up a radiofrequency generator to drive a waveguide exposure system. The system must be capable of generating WCDMA, CDMA and GSM test signals at 835 MHz and at various test levels. Set the maximum level of the average radio exposure level to a similar magnitude to that expected near the antenna of a digital mobile telephone. A common test frequency of 835 MHz will be used to minimise the effect of any performance differences in the interference characteristics between hearing aids at 835 and 900 MHz.
- Determine the peak-to-average level for the WCDMA, CDMA and GSM test signals.
- A manipulator is used to mount each hearing aid within the waveguide exposure system. The output of the hearing aid is connected by a 500mm length of 2 mm diameter tubing to a 2 cc acoustic coupler and measurement amplifier. With the RF generator set to a 1 KHz modulated carrier at 835 MHz adjust the output level to produce audible interference in the hearing aid. Rotate the hearing aid in three dimensional space, using the manipulator, until the acoustic output due to the radio interference is maximised.
- Remove the output of the hearing aid from the 2 cc acoustic coupler and connect the hearing aid output to a stethoscope listening tube using a 960 mm total length of 2 mm diameter tubing.
- Each observer is to rate the “perceptibility “ and “useability” of any interference produced in each hearing aid when exposed to WCDMA, CDMA and GSM test signals presented at different levels. The RF exposure was progressively lowered in 6 dB steps from the maximum level.
  - The “perceptibility” rating system uses 5 steps:
    - Not Perceptible;
    - Just Perceptible;
    - Moderately Perceptible;
    - Annoying;
    - Very Annoying.

- The “useability” rating system uses 3 steps:
  - Always Useable;
  - Sometimes Useable;
  - Not Useable.

Results

The results pertaining to hearing aid performance, observer hearing levels, radio test signals and subjective observations follow.

Hearing Aid Radiofrequency (RF) Immunity Levels:

The ILM55 Immunity Level for Microphone input to a hearing aid is defined as the carrier field strength in decibels relative to one volt per metre (dB re 1V/m) that produces a response in the hearing aid equivalent to an input referred sound pressure equal to 55 dB SPL, when the carrier is 80% amplitude modulated at 1000 Hz.

> This is a similar definition used to define ILM40 that refers to an input referred sound pressure level of 40 dB SPL as defined on page 13 of Reference [3]. For a hearing aid operating in a linear mode the ILM55 immunity level is approximately 7.5 dB greater than the ILM40 immunity level. The ILM55 immunity level is useful when determining the classification of RF immunity performance of hearing aids according to AS/NZS 1088.9 [4] and also when making a comparison in the RF immunity performance of hearing aids.

At 835 MHz the measured radiofrequency immunity level (ILM55) for the three hearing aids used in this investigation was 18.8, 21.6 and 43.6 dB re 1 Volt per metre. For reference purposes the three hearing aids were designated HA1, HA2 and HA3 and the RF immunity results are depicted in Figure 1.

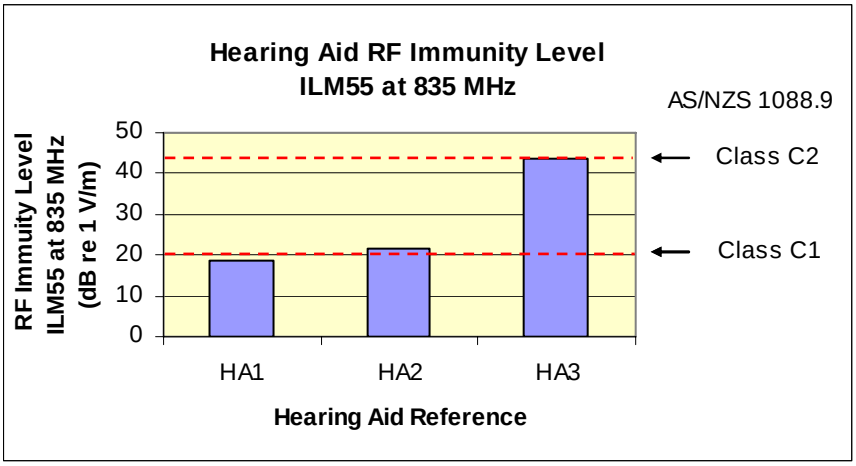

Figure 1: The measured radiofrequency immunity levels for the three hearing aids used to assess any interference produced by the WCDMA, CDMA and GSM test signals.

Hearing Level of Observers:

An audiologist measured the hearing level of the four observers. The results are summarised in Figure 2.

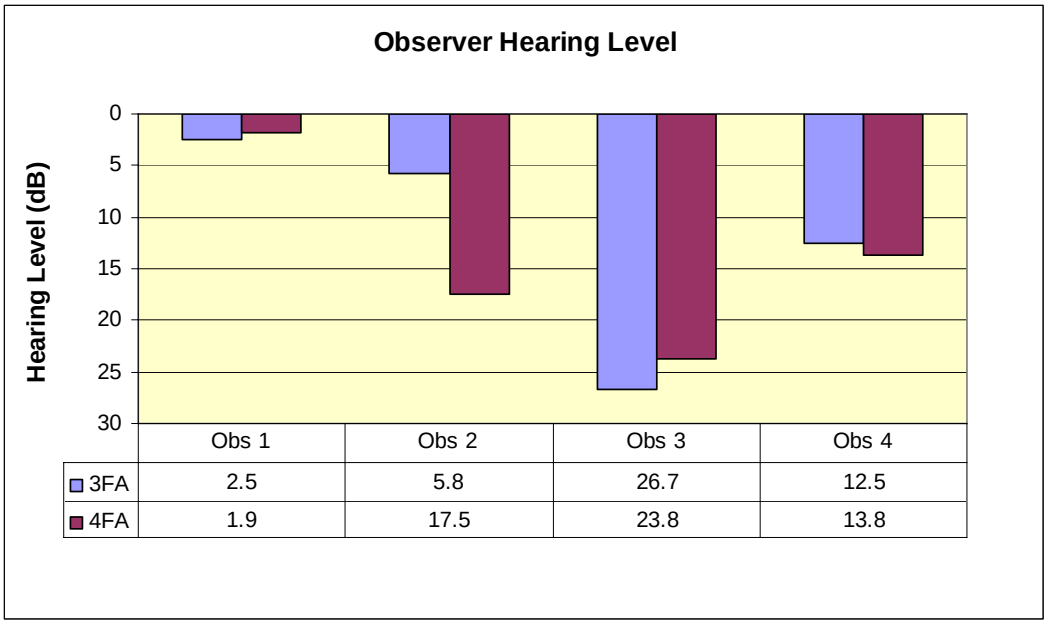

Figure 2: The average three frequency and four frequency hearing level for each observer.

From the audiograms the hearing level at 500, 1000 and 2000 Hertz was averaged for the each ear. In Figure 2 the average value of the left and right ear for each observer is designated as the three frequency average hearing level (3FA). To provide some indication of the variation in hearing level with frequency a similar process was used to compute the four frequency average hearing level (4FA) at 500, 1000, 2000 and 4000 Hertz. Observers 1, 2 and 4 are classified as having normal hearing and observer 3 would be classified as having a mild hearing loss.

Hearing Aid Acoustics:

Using a 1000 mm length of 2 mm diameter tubing connected to a 2 cc acoustic measurement coupler, at 1000 Hz, the acoustic gain of hearing aid HA1 was 27 dB; HA2 was 31 dB and HA3 was 36 dB. Also hearing aids HA1 and HA2 had rising responses of approximately 13 dB per decade and 10 dB per decade respectively and hearing aid HA3 had a falling response of approximately 17 dB per decade.

Peak-to-Average Level for Test Signals:

The peak-to-average level for each of the test signals was determined to be:

- 4dB for WCDMA;
- 5.4 dB for CDMA; and
- 9 dB for GSM.

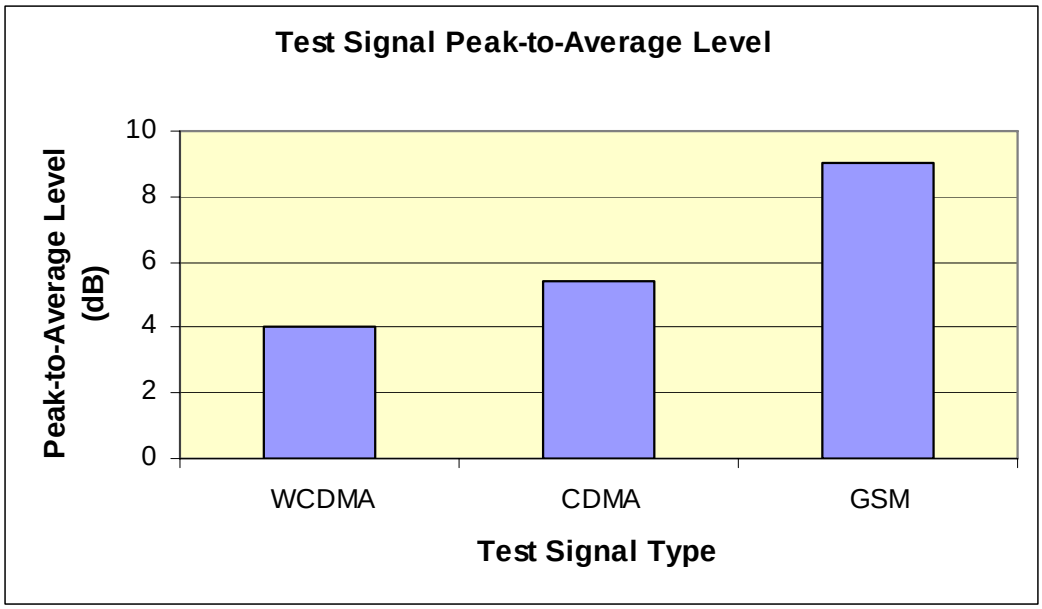

Figure 3: The Test Signal Peak-to-Average Levels

Test Signal Levels:

At maximum exposure levels the average field strength generated within the waveguide for the three test signals was 60.3 volt per meter corresponding to an average power level of 20 dBm. The corresponding peak level of field strength for each test signal was:

- 96 V/m for WCDMA;
- 112 V/m for CDMA; and
- 170 V/m for GSM.

Listening Test Results:

The subjective rating results by the four observers of any interference produced in the three test hearing aids in microphone setting when subjected to the WCDMA, CDMA and GSM radio test signals are recorded in graphical form. For each hearing aid two graphs are provided, one for rating the "perceptibility" of any audible interference and one for rating the "useability" of the hearing aid with a mobile telephone based on listening to the audible interference.

Results of “perceptibility” and “useability” for HA1.

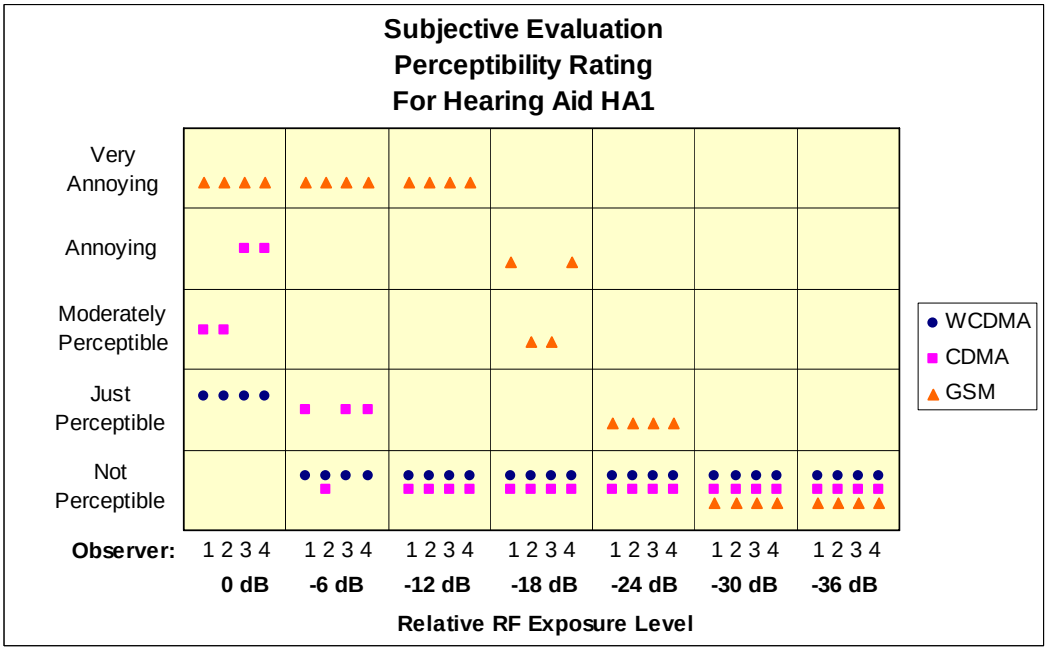

Figure 4: Individual observer results of “perceptibility” rating for hearing aid HA1.

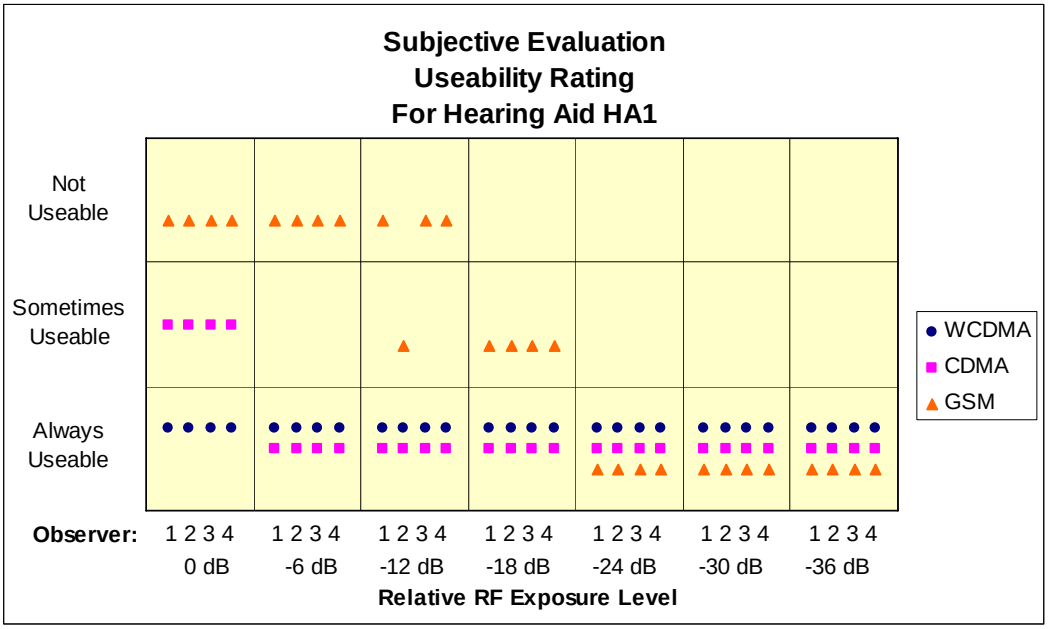

Figure 5: Individual observer results of “useability” rating for hearing HA1.

Results of “perceptibility” and “useability” for HA2.

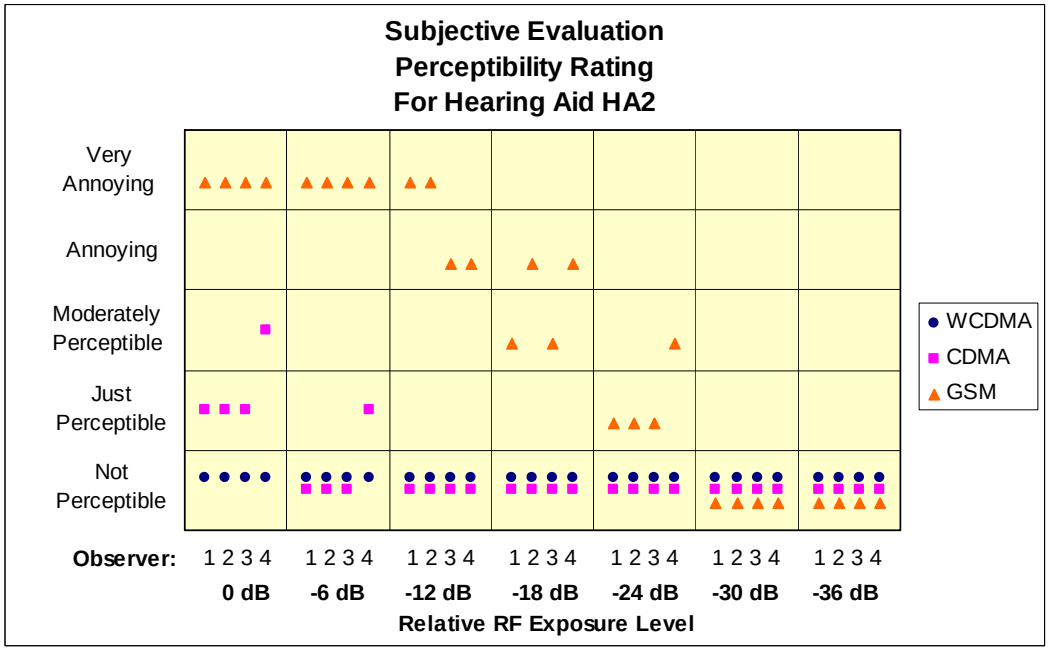

Figure 6: Individual observer results of “perceptibility” rating for hearing aid HA2.

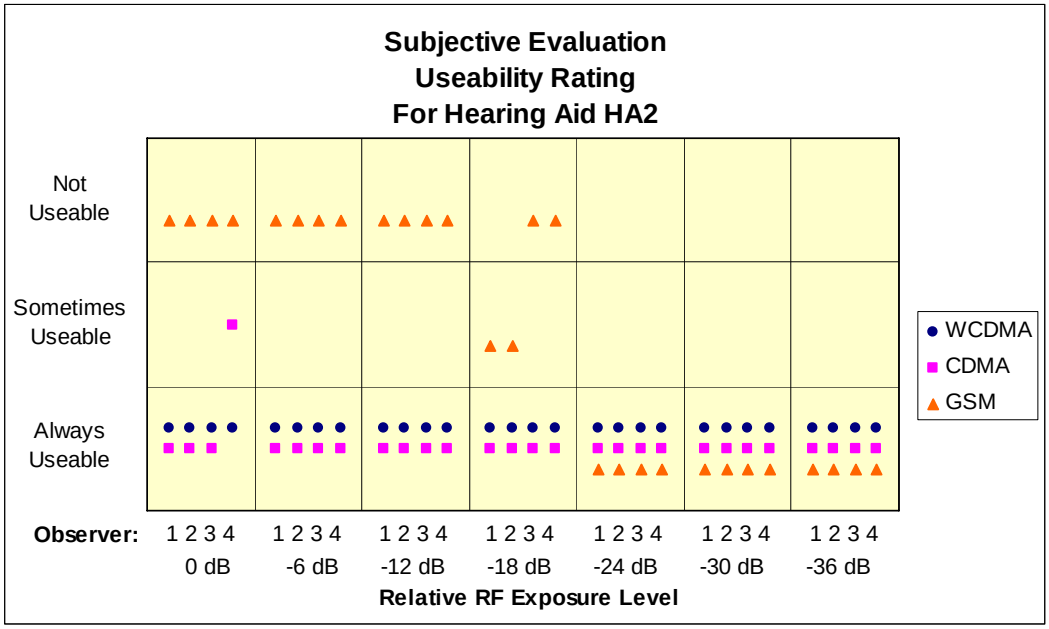

Figure 7: Individual observer results of “useability” rating for hearing HA2.

Results of “perceptibility” and “useability” for HA3.

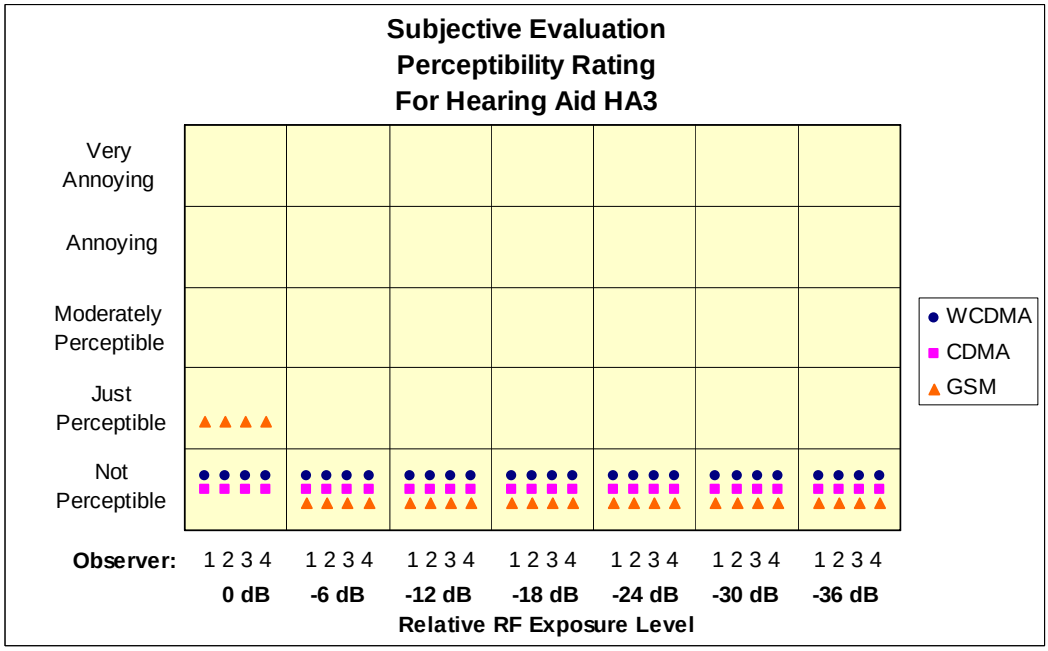

Figure 8: Individual observer results of “perceptibility” rating for hearing aid HA3.

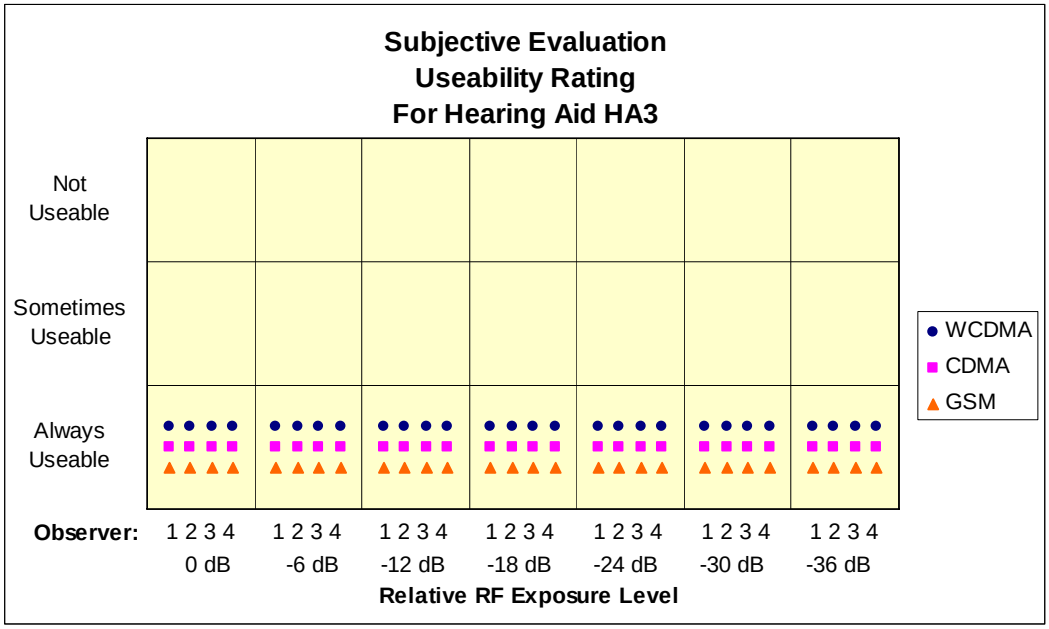

Figure 9: Individual observer results of “useability” rating for hearing HA3.

Analysis of Results

For each radio test signal and for each radio exposure level used the subjective rating results reported by the four observers have been averaged.

Average results of “perceptibility” and ‘useability” for hearing aid HA1 follow.

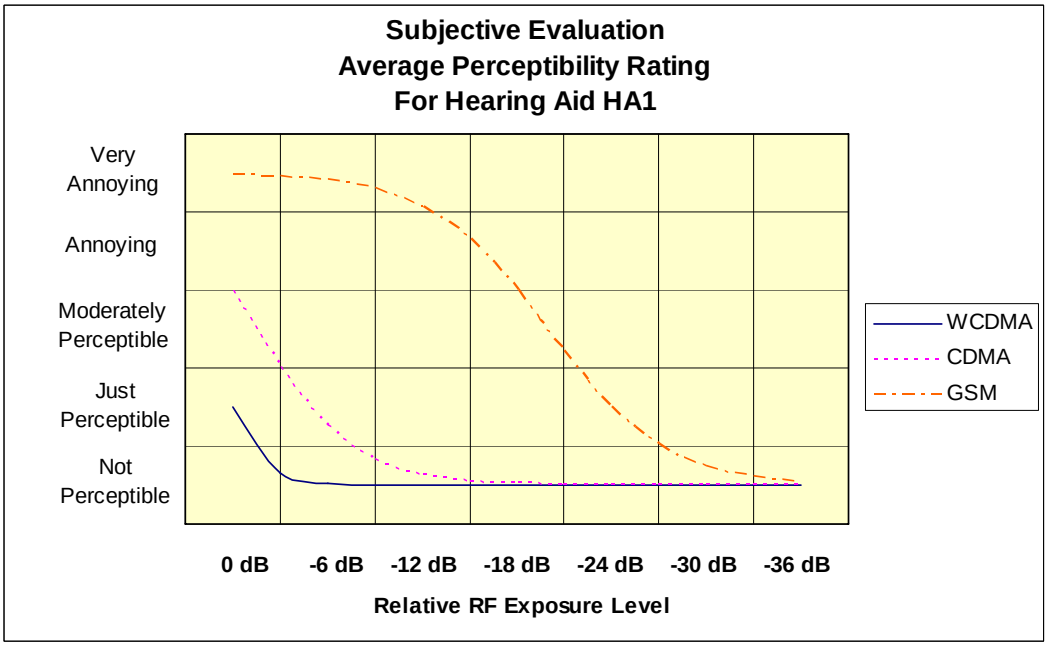

Figure 10: Averaged observer results of “perceptibility” rating for hearing aid HA1.

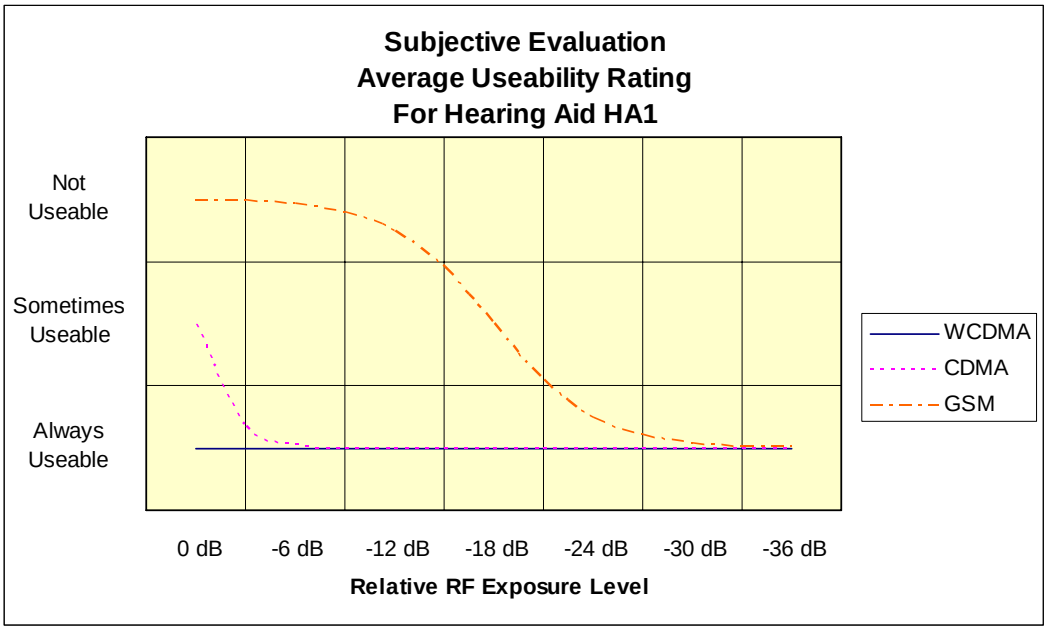

Figure 11: Averaged observer results of “useability” rating for hearing HA1.

Average results of “perceptibility” and “useability” for hearing aid HA2.

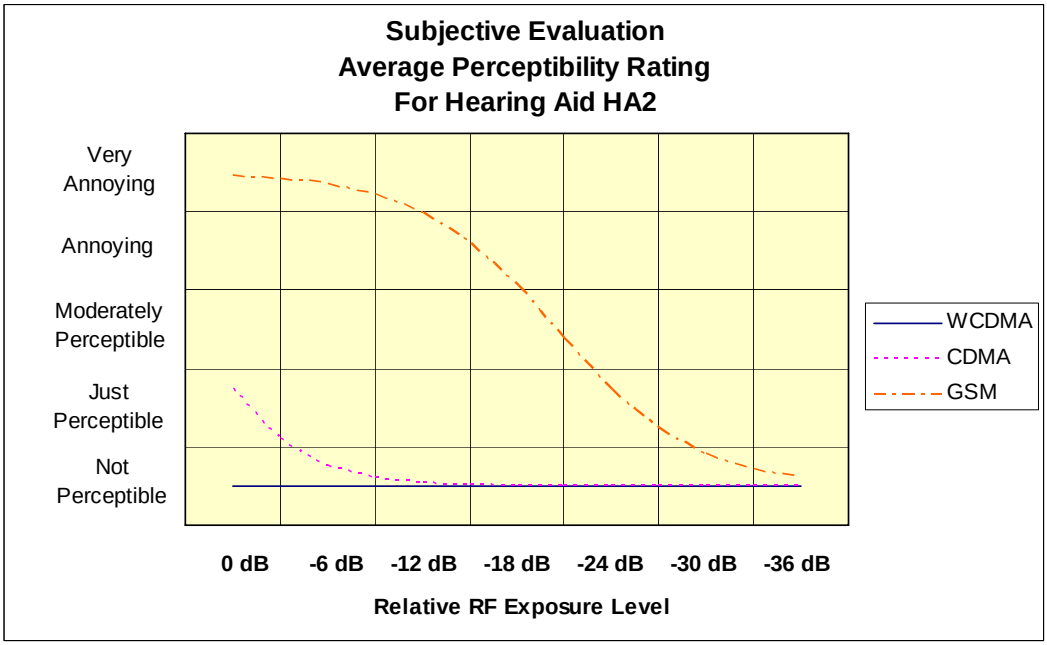

Figure 12: Averaged observer results of “perceptibility” rating for hearing aid HA2.

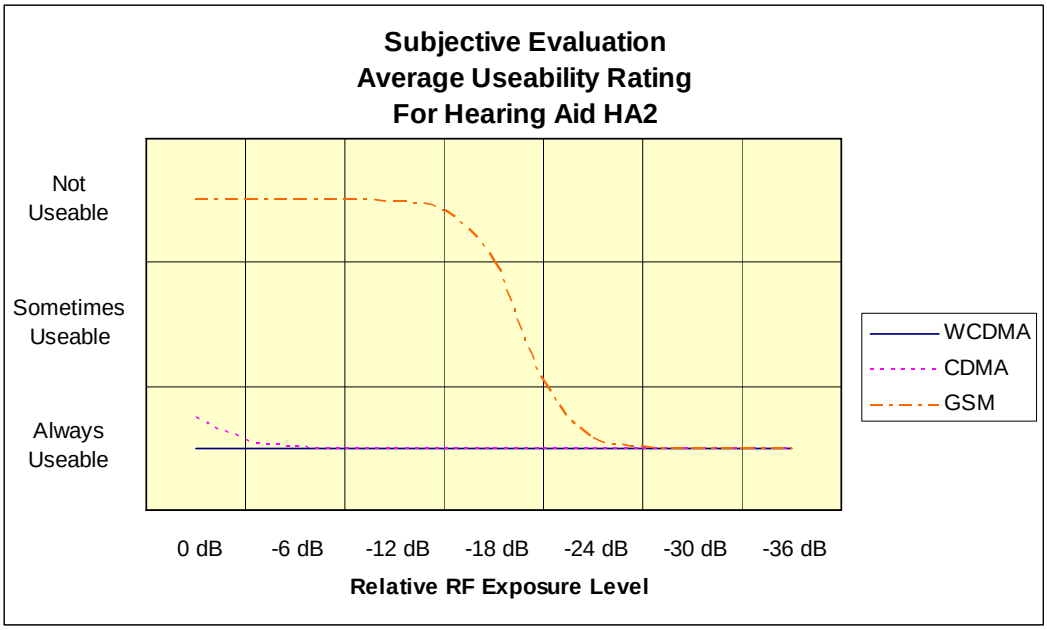

Figure 13: Averaged observer results of “useability” rating for hearing aid HA2.

Average results of “perceptibility” and “useability” for hearing aid HA3.

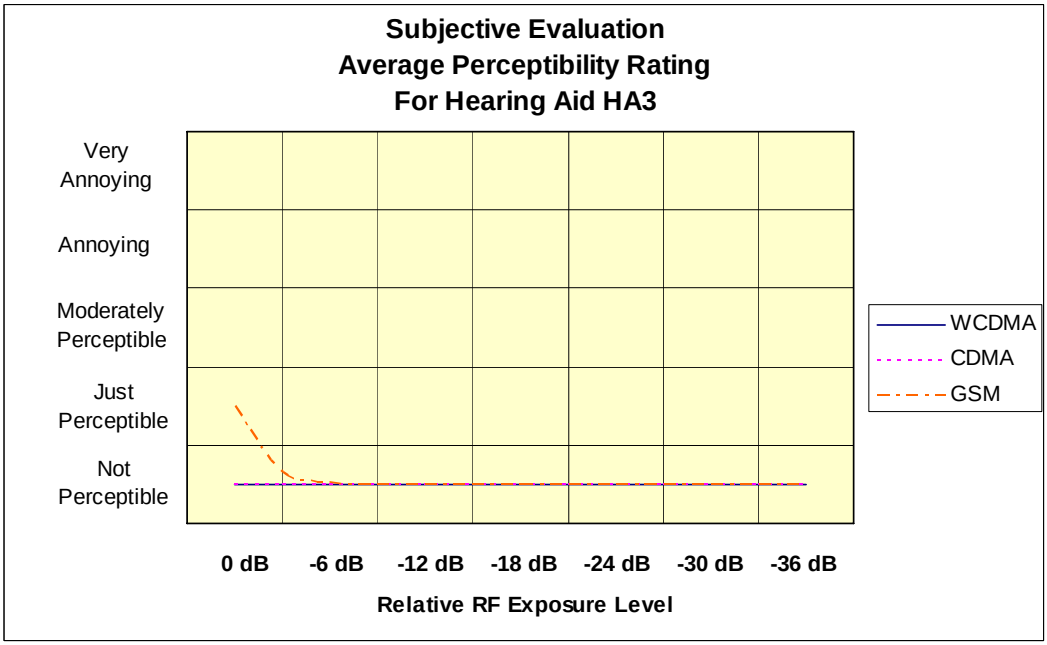

Figure 14: Averaged observer results of “perceptibility” rating for hearing aid HA3.

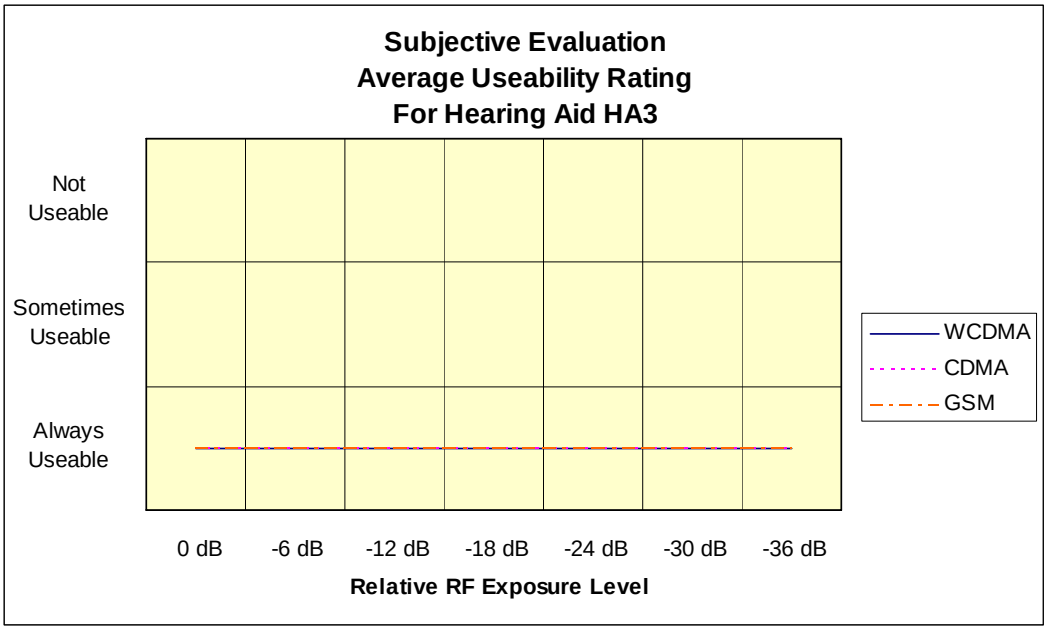

Figure 15: Averaged observer results of “useability” rating for hearing aid HA3.

Discussion of Results

Hearing Aid RF Immunity Levels:

Australian/New Zealand Standard 1088.9 [Ref. 4] describes methods of measurement to determine the immunity of hearing aids to radiofrequency fields. Hearing aids meeting Class C1 requirements ensure that not more than 10% of these hearing aid users will be annoyed by interference from a 2 Watt GSM digital mobile telephone at a distance of 1 metre. Also hearing aids meeting Class C2 requirements will have sufficient immunity to radiofrequency fields to allow users of these hearing aids to use a 2 Watt GSM digital mobile telephone for communication purposes provided that the hearing aid user can use a normal desk telephone for communication purposes.

From Figure 1, hearing aid HA1 has an immunity performance a little below the Class C1 classification, and hearing aid HA2 is a little above the Class C1 requirements. Hearing aid HA3 has immunity that meets the Class C2 requirements and would be considered to have high immunity to interference from radiofrequency fields.

Three different technologies are used in the three behind-the-ear hearing aids. Analogue technology is used in hearing aid HA1, programmable technology in hearing aid HA2 and digital technology in hearing aid HA3. The immunity performance of the three hearing aids is not related to the different technologies used, but is more related to whether the microphone used has inbuilt suppression for radio signals and also with the physical layout of the hearing aid electronics.

Hearing Level of Observers:

From the results of the audiograms of the four observers detailed in Figure 2, it is evident that observers 1, 2 and 4 are classified as having normal hearing and observer 3 is classified as having a mild hearing loss. With the inclusion of the hearing level at 4000 Hertz in the four frequency average hearing loss it is evident that observers 2 and 4 have a greater loss in the high frequency region whereas observer 3 has similar performance for the three and four frequency average results. Observer 1 has normal hearing near the threshold of hearing limit.

With the variation in hearing level of the observers it is expected that there will be some variation in the perceived level of any sound by each of the observers. However, even though this is a small study using four observers, it is still expected that the results averaged over the four observers will provide a useful indication of the trends associated with the level of interference and differences between the effects of the three test signals, namely: WCDMA; CDMA and GSM.

Hearing Aid Acoustics:

The hearing aids were not adjusted to the different hearing levels of the observers, but were connected by a length of 2 mm diameter plastic tubing to stethoscope listening tubes. This length of tubing reduced the level of any sound produced within the hearing aids to a more acceptable level than if a short length of tubing was used.

Normally behind-the-ear hearing aid acoustics are measured using a 25 mm length of 2 mm diameter plastic tubing connected to a 2 cc acoustic coupler that measures the acoustic sound pressure level. However the observers were listening to the hearing aid

acoustic output through a 960 mm length of 2 mm diameter plastic tubing connected to stethoscope listening tubes. This arrangement was simulated by measuring the acoustic gain of each hearing aid with a 1000 mm length of 2 mm diameter tubing connected to a 2 cc acoustic measurement coupler. This method provided an indication of the acoustic gain and response for each hearing aid when used under observer listening conditions.

Test Signals:

The results presented in Figure 3 indicate that the GSM test signal had the greatest peak-to-average value of 9 dB and the corresponding value for CDMA is 5.4 dB and 4 dB for WCDMA.

A 3 MHz bandwidth was used to set up WCDMA, CDMA and GSM test signals for all subjective measurements. The implications of this are:

- That the WCDMA, CDMA and GSM test signals need to be set at a maximum level to produce a radio signal in the waveguide that simulates the radiofrequency field produced in a hearing aid when used near a mobile telephone operating at a maximum average level of 250 mW average.
- That a bandwidth correction factor of 1.5dB must be applied to the WCDMA test signal level. The reason for this is that the WCDMA signal bandwidth is nominally 4.25 MHz whereas during the setup procedure the WCDMA setup level was measured using a 3 MHz bandwidth.

Listening Tests:

The individual observer ratings are documented in Figures 4 to 9.

The results for “perceptibility” and “useability” ratings (see Figures 4 to 9) are consistent for each hearing aid with little variation between the observers.

The individual observer ratings were averaged and the results presented in Figures 10 to 15.

The “perceptibility” and “useability” ratings are based on the subjective assessment of audible interference. The results indicate that WCDMA and CDMA produce similar levels of interference in hearing aids. Therefore hearing aid users are likely to experience similar levels of interference from WCDMA and CDMA handsets operating under the same conditions. When using a GSM handset a hearing aid user will experience significantly more interference than either WCDMA or CDMA.

The test results indicate that WCDMA produces a slightly lower level of interference than CDMA.

The transition of audible interference from “not perceptible” to “very annoying” requires an increase of RF exposure level by approximately 18 dB for GSM radio signals (Figures 10 and 12). From Figure 10, extrapolation of results would suggest that CDMA and WCDMA would have a similar transition range.

The transition of “useability” from “always useable” to “not useable” for a hearing aid user of a GSM digital mobile handset requires an increase of RF exposure level by approximately 12 dB (Figures 11 and 13). There is not sufficient range in the WCDMA and CDMA results to reliably predict this transition range.

Hearing Aid RF Immunity Requirements:

The RF immunity requirements for hearing aids to be used with WCDMA and CDMA digital mobile telephones will be different to those required for use with GSM digital mobile telephones.

From the listening tests, the “useability” results indicate that for a hearing aid to be used successfully by a hearing aid user for communication purposes with a WCDMA digital mobile telephone, it should have a minimum RF immunity level between that of HA1 and HA2. For CDMA the hearing aid RF immunity level should be greater than HA2, but it does not have to be as great as hearing aid HA3.

The implication of this is that for a hearing aid user to successfully use a WCDMA digital mobile telephone, their hearing aid should have a minimum RF immunity level similar to Class 1 as specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4]. For CDMA, the hearing aid minimum RF immunity level should be greater than Class 1, but significantly less than Class 2 as specified in AS 1088.9. Note that this standard was developed to specify the RF immunity requirements for hearing aids used with 2 watt GSM digital mobile telephones. The Class 1 level of protection ensures that hearing aids meeting this requirement do not receive interference from GSM mobile telephones one metre or more distant from the hearing aid. Hearing aids meeting Class 2 requirements can be used for communication purposes with GSM digital mobile telephones.

Other Considerations

This research was a short investigative study and the test results are based on constant average levels of the test signal during each observation period with the hearing aid in microphone setting. This study does not report on the following options:

- *Dual Mode, 800 MHz WCDMA/GSM handsets*: If this type of handset becomes available then a hearing aid user would experience a significant increase in audible interference when a handset switches from WCDMA to GSM.
- *WCDMA and CDMA fast fading conditions*: The ramping up and down of the handset power level in response to changing radio propagation conditions can increase the audible interference emanating from a hearing aid. Fast fading conditions are not reported in this publication. However, handset power level changes under fading conditions in a CDMA and WCDMA system will be comparable and experience to date with CDMA suggests that this may not be a critical issue for hearing aid users.

Another limitation of the research due to its short investigative nature is that only four test subjects, or observers were used. Three of the observers fell into the normal range of hearing and one would be classified as having a mild hearing loss. Even though there were only a small number of test subjects used in this investigative study the trends in the results are expected to be similar to those that might result from a larger study.

Conclusion

The conclusion of this exploratory research that is based on the subjective assessment of audible interference is that WCDMA and CDMA signals produce similar levels of interference in hearing aids used in microphone setting. Also the test results indicate that WCDMA produces a slightly lower level of interference than CDMA.

Hearing aid users are likely to experience similar levels of interference from WCDMA and CDMA digital mobile telephones operating under the same conditions.

Hearing aid users are likely to experience significantly more audible interference from GSM digital mobile telephones than either WCDMA or CDMA digital mobile telephones.

For a hearing aid user to successfully use a WCDMA digital mobile telephone, their hearing aid should have a minimum RF immunity level similar to Class 1 as specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4]. For use with CDMA digital mobile telephones, the hearing aid minimum RF immunity level should be greater than Class 1, but significantly less than Class 2 as specified in AS 1088.9.

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During "compressed mode" operation, for interference to be at a level that is "not perceptible", or "just perceptible", the RF immunity requirement for the hearing aid will need to be at a level approximately midway between the Class1 and Class 2 categories specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4].

The results for "compressed mode" operation are detailed in Appendix A.

References

[1] Telstra brochure: 2005: titled: “Telstra’s strategy for growth”.

[2] Wikipedia: 13/1/2006: “W-CDMA”, http://en.wikipedia.org/wiki/WCDMA.

[3] LeStrange, J.R.; Burwood E.R; Byrne, D.; Joyner, K.H.; Wood, M.P. and Symons, G.L: May 1995: National Acoustic Laboratories Report No. 131, “Interference to hearing aids by the digital mobile telephone system, Global System for Mobile Communications, (GSM)”.

[4] AS/NZS 1088.9/Amdt 1/1996-07-05: Hearing Aids - Part 9: Immunity requirements and methods of measurement for hearing aids exposed to radiofrequency fields in the frequency range 300 MHz to 3 GHz.

Appendix A – Compressed Mode Testing

Introduction

In a mobile telephone network such as WCDMA, a handset is capable of executing a "handover" of its calls on to another WCDMA base station frequency or it can change operating modes from WCDMA to GSM to guarantee coverage for the user. The process of "handover" in a WCDMA network is accomplished by using "compressed mode". During "compressed mode", a gap in transmission is created which allows the handset to "listen" for other frequencies (e.g. WCDMA or GSM carriers) that it can use. To create the gap in transmission, the handset momentarily transmits at twice its normal data rate and up to its maximum transmit power level.

The handover process that triggers the "compressed mode" may occur when the WCDMA reception becomes weak and typically may last for several seconds.

In this report, the potential impact of "compressed mode" on hearing aid immunity has been simulated by turning off the continuous WCDMA transmission for 5 ms and repeating this at a rate of 50 Hz.

Program of Work

The research will investigate the potential for "compressed mode" operation to cause interference to hearing aids. Also a comparison of the level of interference produced during normal WCDMA operation will be made with "compressed mode" operation. Each test will be carried out using the three hearing aids used for investigations completed in the main body of the WCDMA report.

The program of work is as follows:

- Set up a radiofrequency generator to drive a waveguide exposure system. The system must be capable of generating WCDMA test signals at 835 MHz and at various test levels. Set the maximum level of the average radio exposure level to a similar magnitude to that expected near the antenna of a digital mobile telephone.
- A manipulator is used to mount each hearing aid within the waveguide exposure system. The output of the hearing aid is connected by a 500mm length of 2 mm diameter tubing to a 2 cc acoustic coupler and measurement amplifier. With the RF generator set to a 1 KHz modulated carrier at 835 MHz adjust the output level to produce audible interference in the hearing aid. Rotate the hearing aid in three dimensional space, using the manipulator, until the acoustic output due to the radio interference is maximised.
- Simulate the "compressed mode" signal by turning off the continuous WCDMA transmission for 5 ms and repeating this at a rate of 50 Hz.
- Remove the output of the hearing aid from the 2 cc acoustic coupler and connect the hearing aid output to a stethoscope listening tube using a 960 mm total length of 2 mm diameter tubing.
- Each observer is to rate the "perceptibility " and "useability" of any interference produced in each hearing aid when exposed to the simulated "compressed mode" WCDMA test signals presented at different levels. The RF exposure was progressively lowered in 6 dB steps from the maximum level.

- The “perceptibility” rating system uses 5 steps:
  - Not Perceptible;
  - Just Perceptible;
  - Moderately Perceptible;
  - Annoying;
  - Very Annoying.
- The “useability” rating system uses 3 steps:
  - Always Useable;
  - Sometimes Useable;
  - Not Useable.

- Increase the signal generator output by 4 dB and repeat the observer “perceptibility” and “useability” test.

Results

The results for the hearing level of observers and for hearing aid acoustics and radiofrequency immunity are the same as those reported in the main body of the report.

Test Signals:

During “compressed mode”, a gap in transmission is created which allows the handset to “listen” for other frequencies (e.g. WCDMA or GSM carriers) that it can use. To create the gap in transmission, the handset momentarily transmits at twice its normal data rate and up to its maximum transmit power level to keep the quality of the signal unaffected by this reduced processing gain. In this investigation this increase of power has been simulated by increasing the signal generator power by 4 dB.

For the compressed mode investigation the maximum average exposure level for the three 835 MHz test signals is set up as follows:

- WCDMA “uncompressed mode” test signal has been set to a maximum average exposure level of +20 dBm into the waveguide test system. The “uncompressed mode” test results have been taken from the main body of the report.
- WCDMA “compressed mode” test signal has been simulated using a continuous WCDMA transmission that has been set to a power level of +20 dBm into the waveguide test system, then turning the transmission off for 5 ms and repeating this at a rate of 50 Hz.
- The higher level WCDMA “compressed mode” test signal has been simulated using a continuous WCDMA transmission that has been set to a power level of +24 dBm into the waveguide test system, then turning the transmission off for 5 ms and repeating this at a rate of 50 Hz.

The exposure level of each test signal presented to each observer is progressively lowered in 6dB steps from the maximum level.

The maximum levels for the two WCDMA “compressed mode” signals have been selected to represent the lower and upper limits for the range of the maximum exposure level that a hearing aid may be exposed to during “compressed mode” operation within a WCDMA network.

Graphical Results:

In the graphs, Figures A1 to A12, the “0 dB” relative RF exposure level shown in the legend is the power level for the continuous WCDMA transmission, before simulating the “compressed mode” transmission by turning the transmission off for 5 mS and repeating this at a rate of 50 Hz.

Listening Test Results:

The subjective rating results by the four observers of any interference produced in the three test hearing aids in microphone setting when subjected to the WCDMA and the two levels of “compressed mode” radio test signals are recorded in graphical form. For each hearing aid two graphs are provided, one for rating the “perceptibility” of any audible interference and one for rating the “useability” of the hearing aid with a mobile telephone based on listening to the audible interference.

"Compressed mode" test results of "perceptibility" and "useability" for HA1.

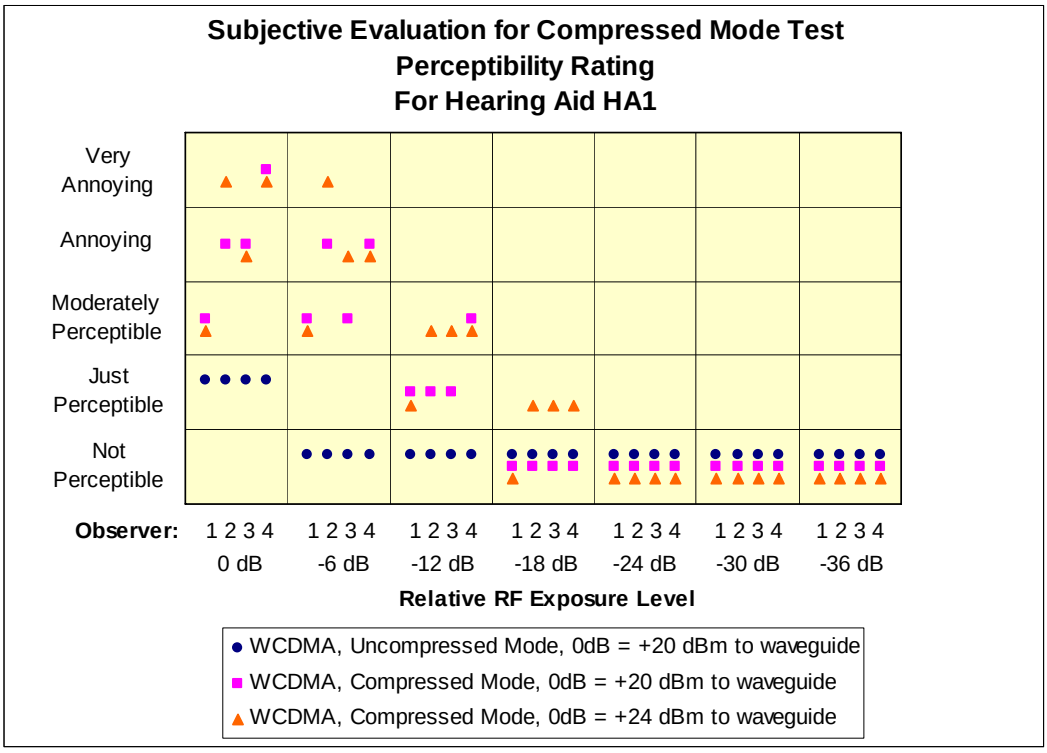

Figure A1: "Compressed mode" observer results of "perceptibility" rating for hearing aid HA1.

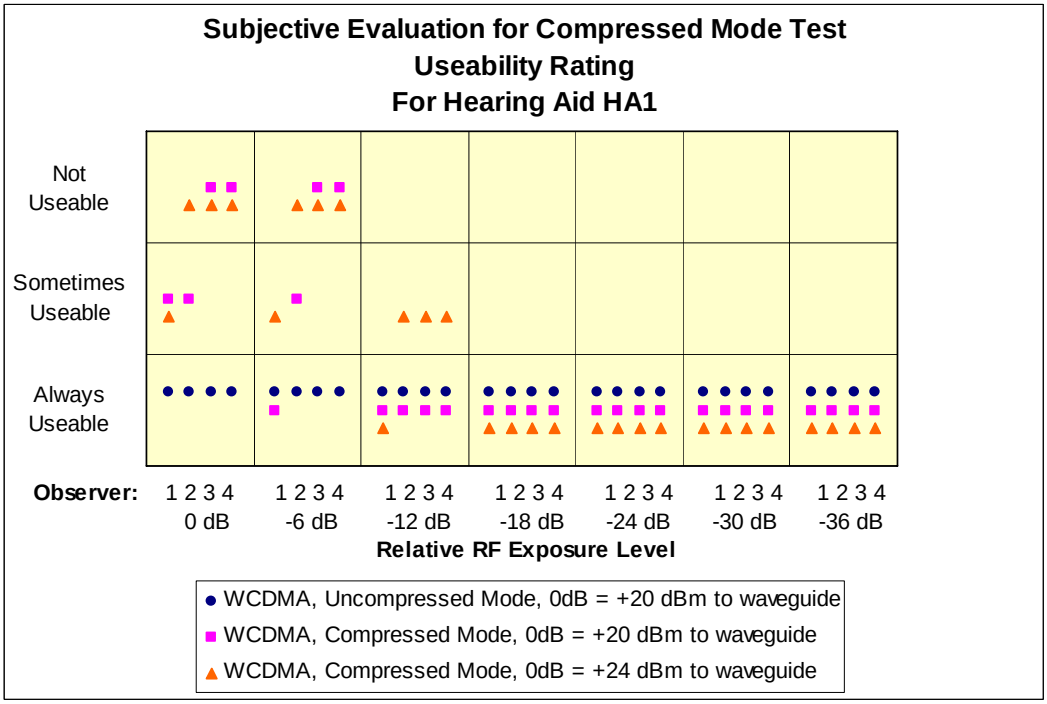

Figure A2: "Compressed mode" observer results of "useability" rating for hearing aid HA1.

"Compressed mode" test results of "perceptibility" and "useability" for HA2.

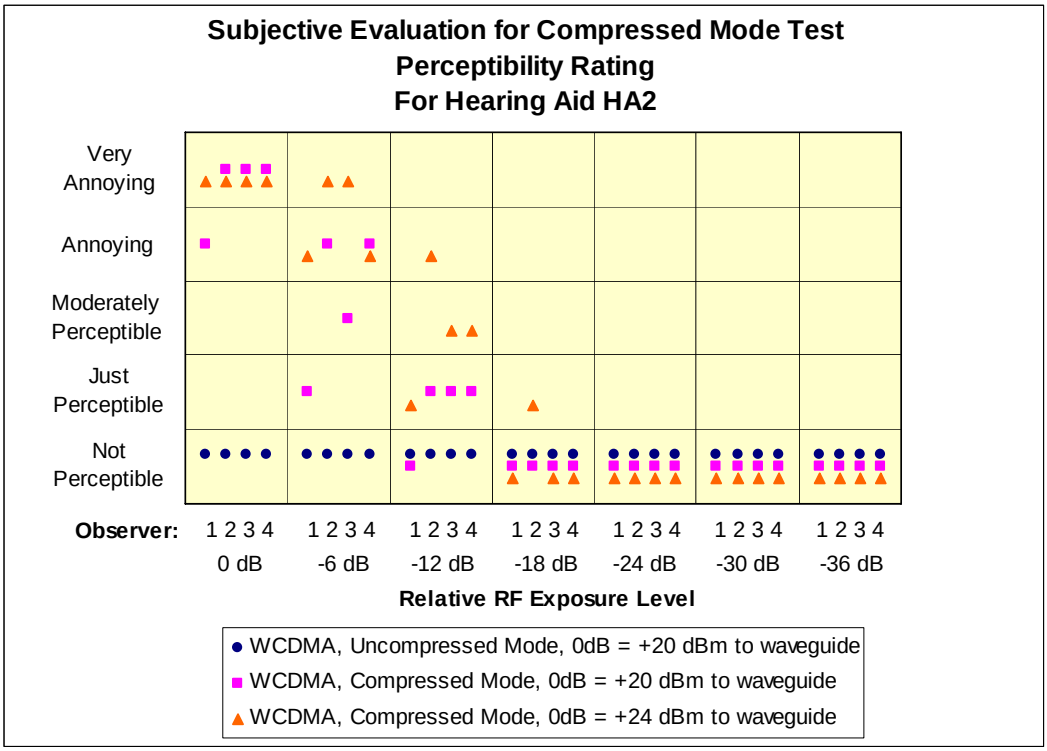

Figure A3: "Compressed mode" observer results of "perceptibility" rating for hearing aid HA2.

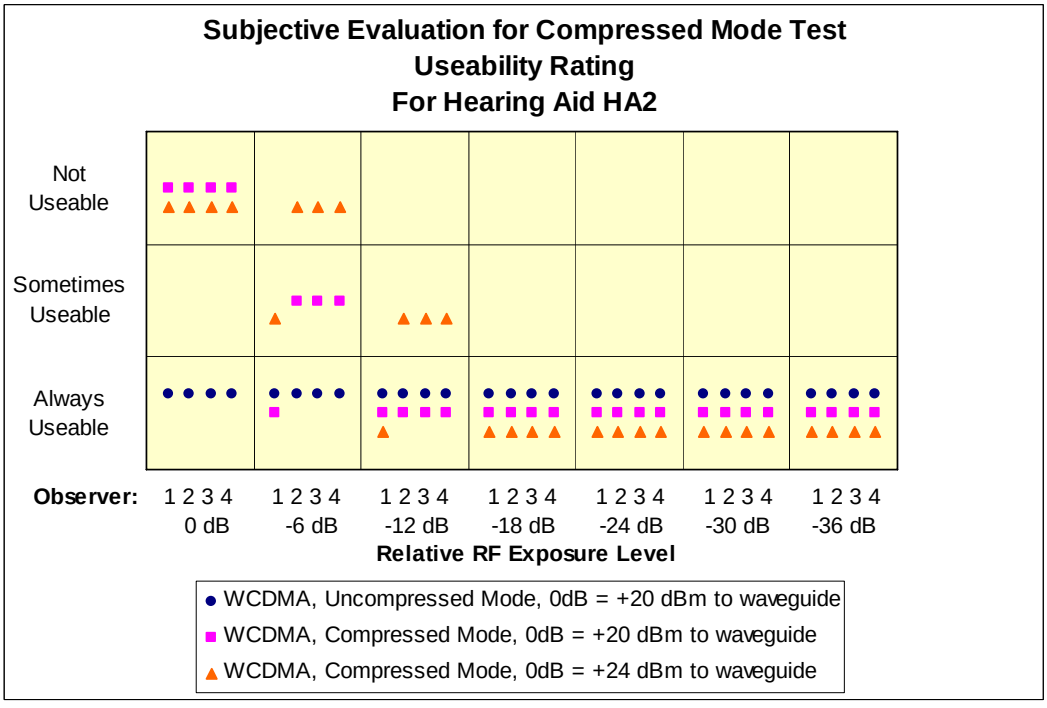

Figure A4: "Compressed mode" observer results of "useability" rating for hearing aid HA2.

"Compressed mode" test results of "perceptibility" and "useability" for HA3.

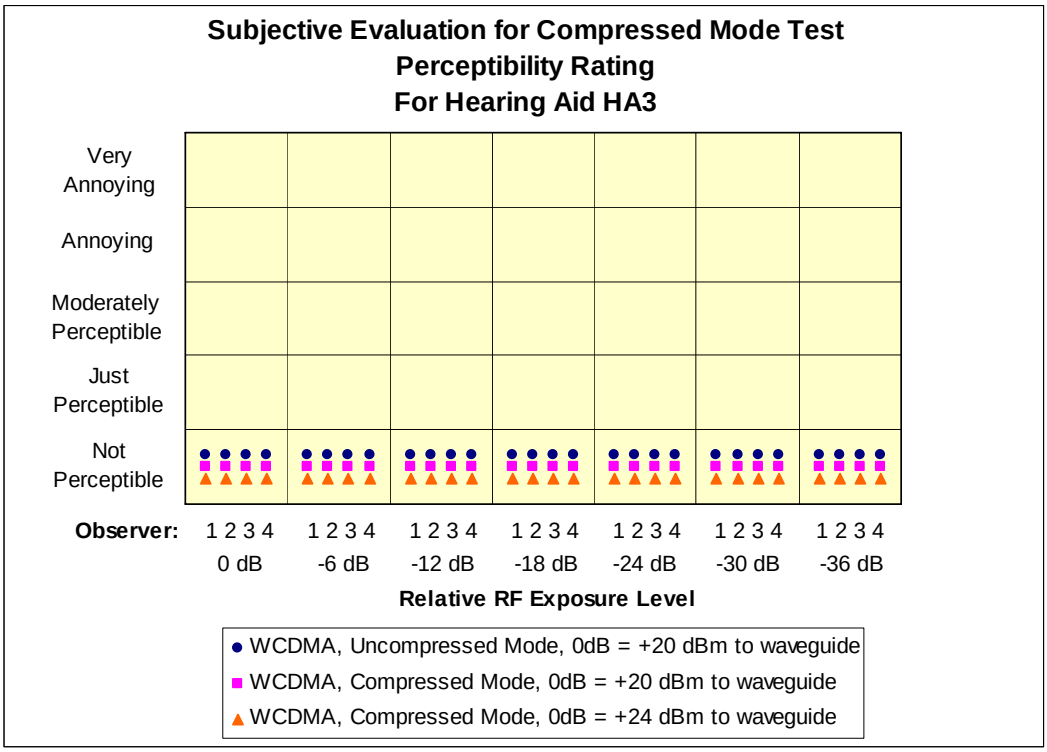

Figure A5: "Compressed mode" observer results of "perceptibility" rating for hearing aid HA3.

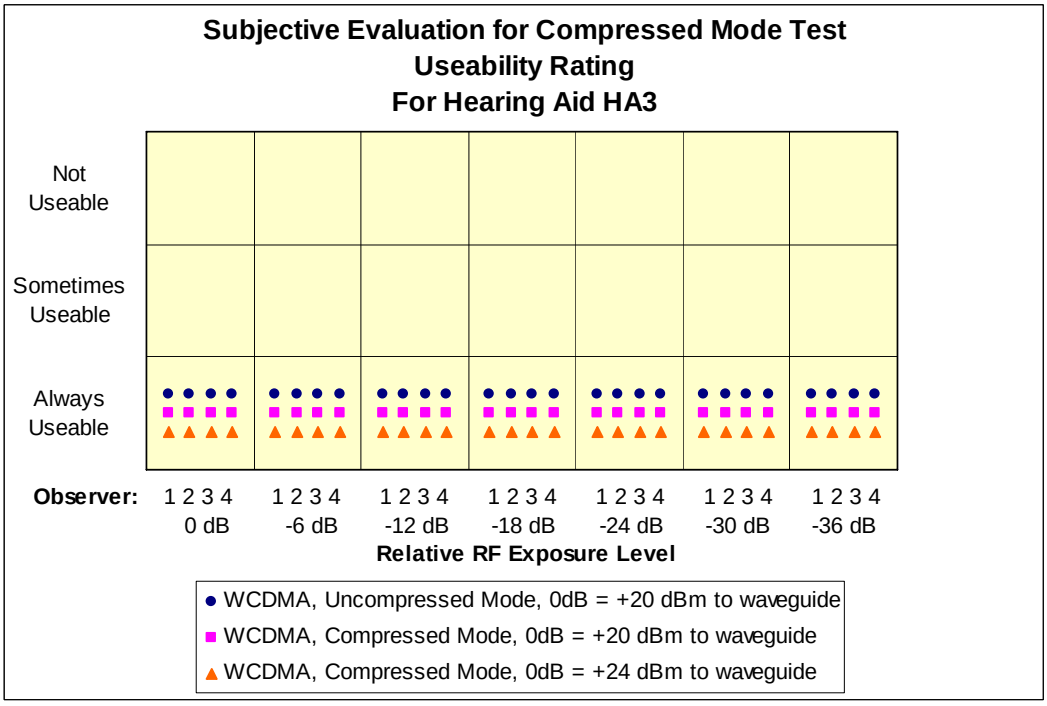

Figure A6: "Compressed mode" observer results of "useability" rating for hearing aid HA3.

Analysis of Results

"Compressed mode" average test results of "perceptibility" and "useability" for HA1.

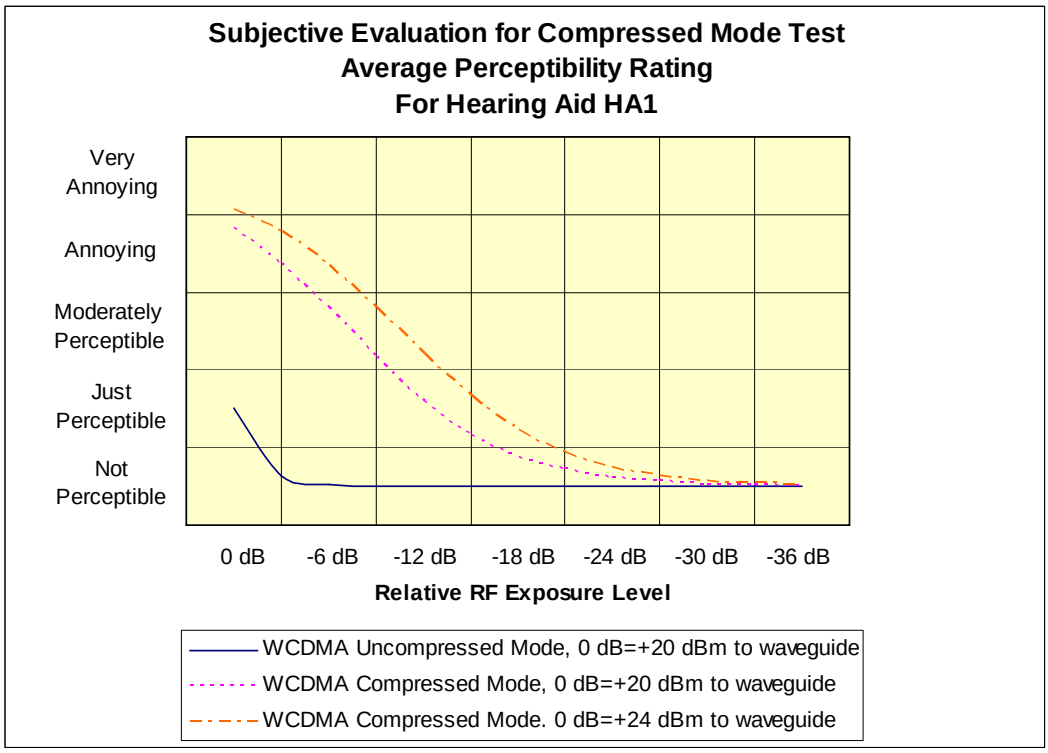

Figure A7: "Compressed mode" averaged observer results of "perceptibility" rating for hearing aid HA1.

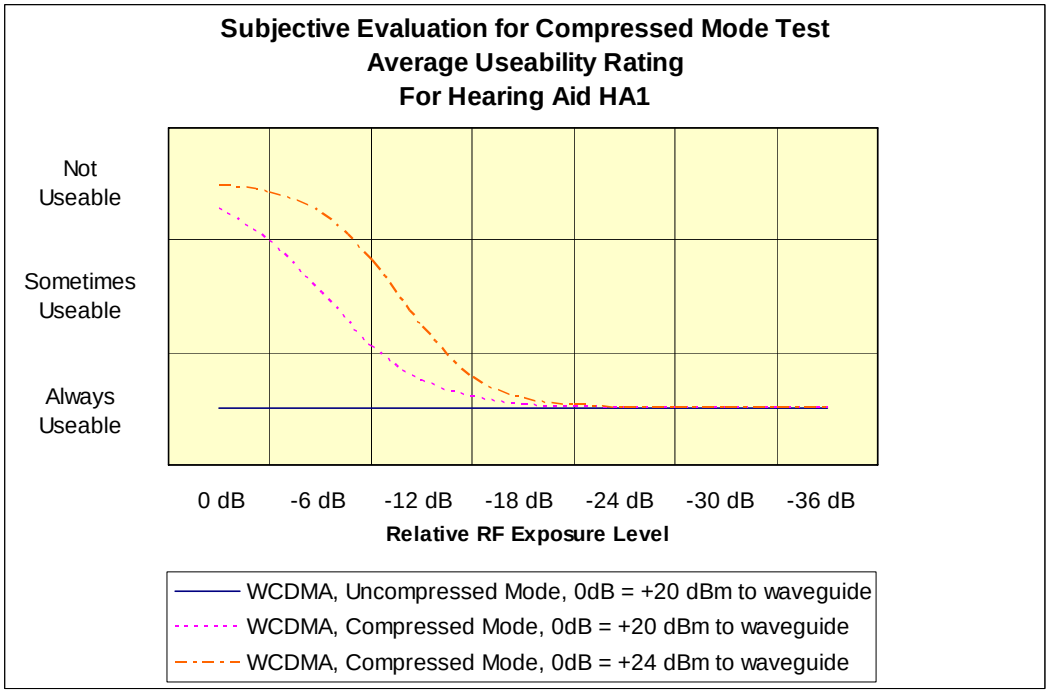

Figure A8: "Compressed mode" averaged observer results of "useability" rating for hearing aid HA1.

"Compressed mode" average test results of "perceptibility" and "useability" for HA2.

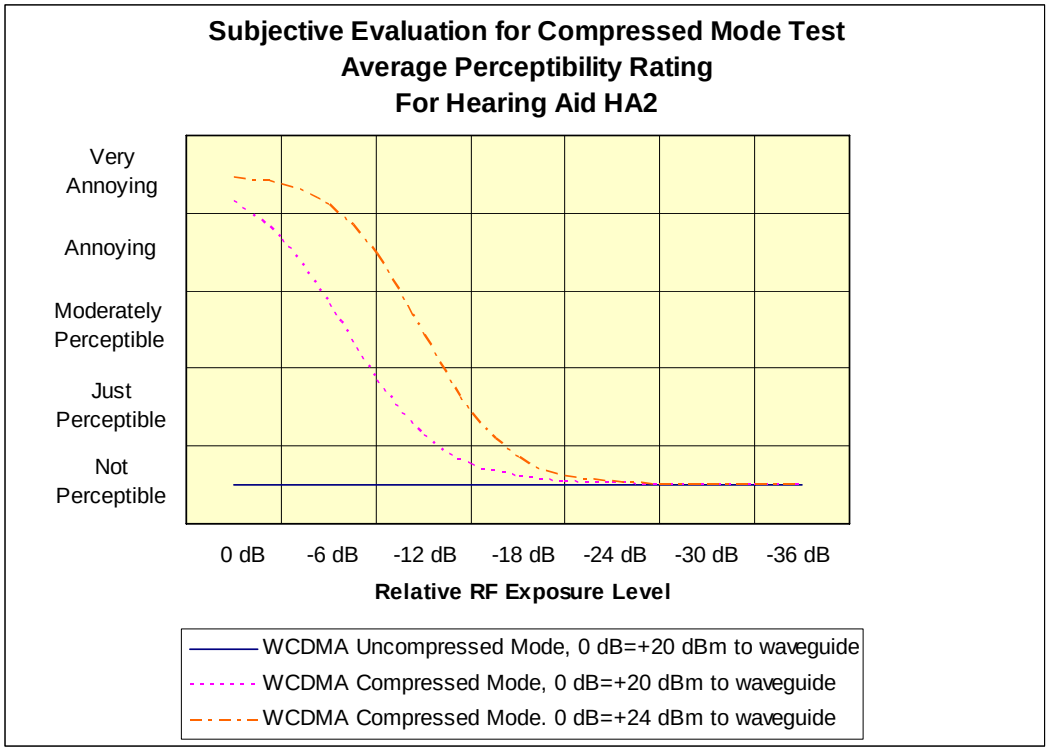

Figure A9: "Compressed mode" averaged observer results of "perceptibility" rating for hearing aid HA2.

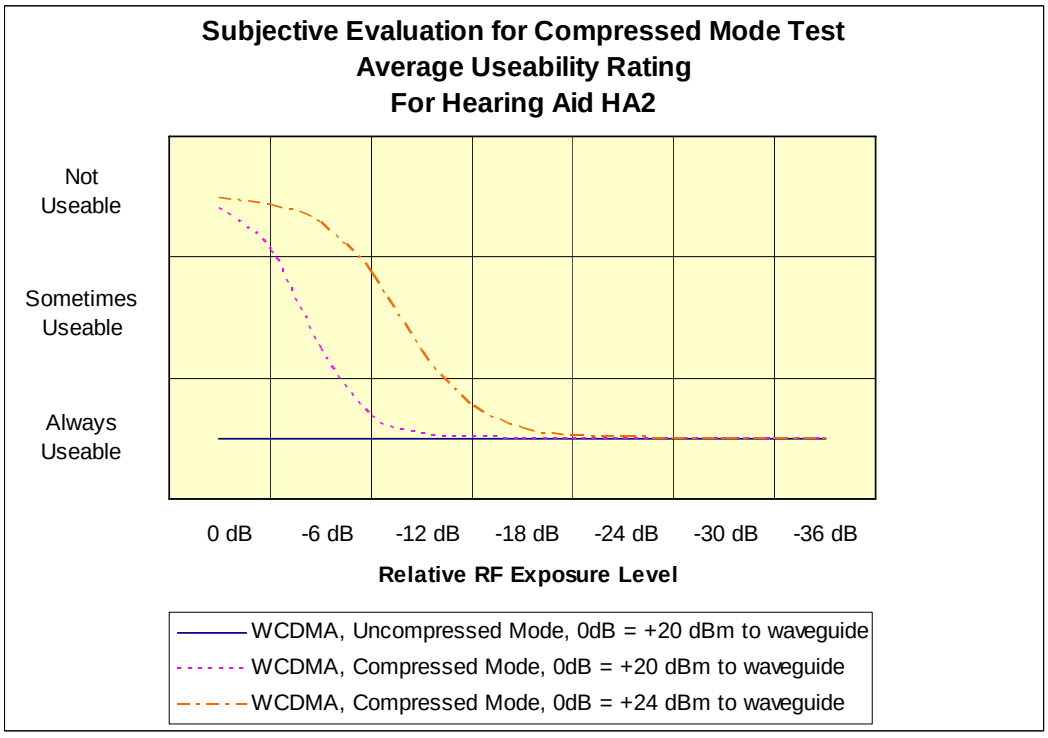

Figure A10: "Compressed mode" averaged observer results of "useability" rating for hearing aid HA2.

“Compressed mode” average test results of “perceptibility” and “useability” for HA3.

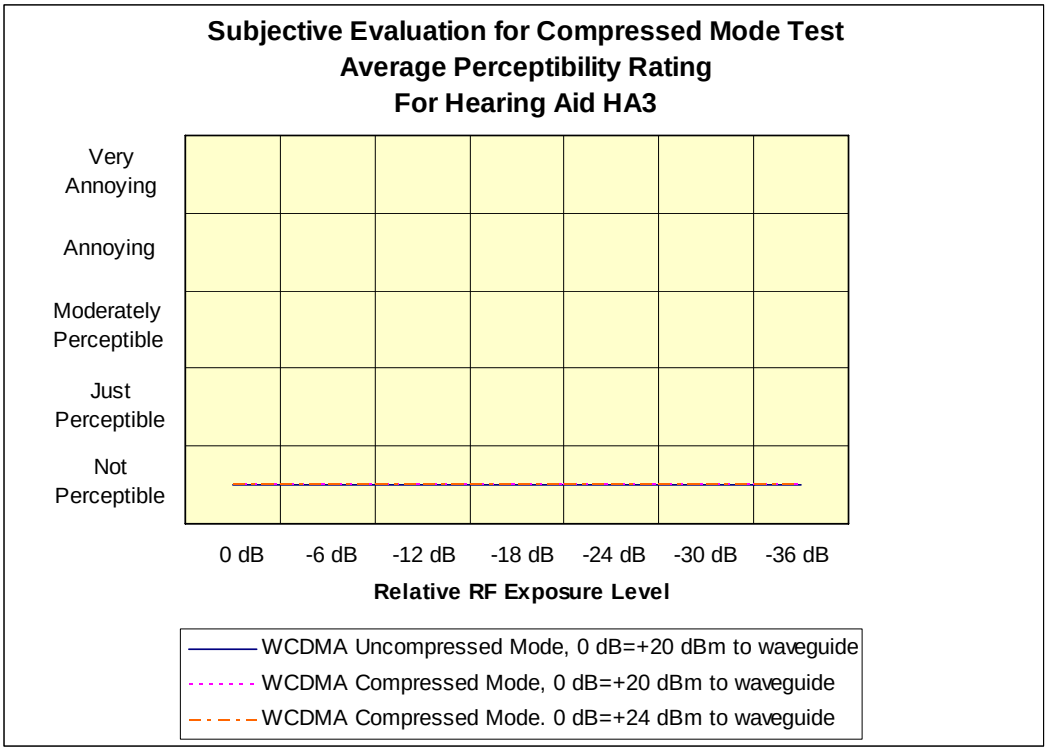

Figure A11: “Compressed mode” averaged observer results of “perceptibility” rating for hearing aid HA3.

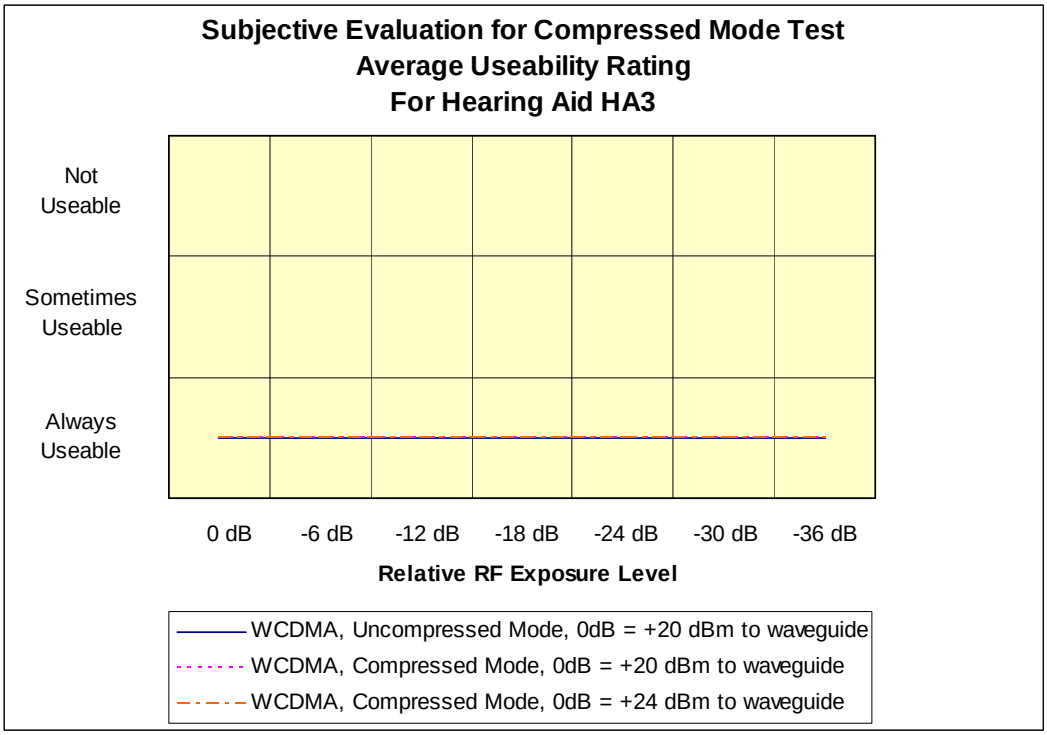

Figure A12: “Compressed mode” averaged observer results of “useability” rating for hearing aid HA3.

Discussion of Results

Listening Tests:

For hearing aids in microphone setting, the individual observer ratings are documented in Figures A1 to A6.

The results for "perceptibility" and "useability" ratings (see Figures A1 to A6) are reasonably consistent for each hearing aid with a little variation between observers. The variations for reported "perceptibility" and "useability" in the "compressed modes" were a little greater than observed for the CDMA, WCDMA and GSM test signals used in the main body of the report.

The individual observer ratings have been averaged and the results presented in Figures A7 to A12.

The "perceptibility" and "useability" ratings are based on the subjective assessment of audible interference. The results for hearing aids HA1 and HA2 indicate that both "compressed mode" WCDMA test transmissions produce significantly higher levels of interference than "uncompressed mode" WCDMA transmission. Also the results for hearing aids HA1 and HA2 indicate that both "compressed mode" WCDMA test transmissions produce significantly lower levels of interference than the GSM transmission results reported in the main body of this report.

Compressed mode interference was not detected in hearing aid HA3.

From the graphs of the averaged results and in those hearing aids where interference was detected, the lower level "compressed mode" transmission (0 dB referenced to +20 dBm) produced lower levels of interference than the higher level "compressed mode" transmission (0 dB referenced to +24 dBm) as would be expected.

For a given level of audible interference in a hearing aid the radiofrequency (RF) signal level during "compressed mode" operation would need to be approximately midway between the RF signal level for an "uncompressed mode" WCDMA and GSM transmission.

An important mitigating factor is that the duration of the "compressed mode" transmission usually only occurs for several seconds when instigated during a normal length phone call.

Hearing Aid RF Immunity Requirements:

During normal WCDMA operation, i.e. "uncompressed mode" operation, the main body of the report indicates that the minimum RF immunity requirement for a hearing aid in microphone setting to be used successfully by a hearing aid user for communication purposes would be similar to Class 1 as specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4].

> The classifications in this standard were developed to specify the RF immunity requirements for hearing aids used with 2 watt GSM digital mobile telephones. The Class 1 level of protection ensures that hearing aids meeting this requirement do not receive interference from GSM digital mobile telephones one metre or more distant from the hearing aid. Hearing aids meeting Class 2 requirements can be used for communication purposes with GSM digital mobile telephones.

A hearing aid with a Class 1 level of RF immunity would produce significant audible interference for a short period of time, typically several seconds, during the

"compressed mode handover" operation. This hearing aid could be described as having a low level of radiofrequency (RF) immunity.

If the interference, during the "compressed mode" operation, is required to be at a level that is near the limit of being "not perceptible", or "just perceptible", then the RF immunity requirement for the hearing aid will need to be at a level approximately midway between the Class1 and Class 2 categories specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4]. This hearing aid could be described as having a medium level of radiofrequency (RF) immunity.

A hearing aid meeting the Class 2 category would be described as having a high level of RF immunity and would not receive any audible interference from "compressed mode" operation.

Conclusion

The following conclusions apply to hearing aids in microphone setting and WCDMA digital mobile telephones operating in “compressed mode”.

“Compressed mode” operation will produce a greater level of interference than normal WCDMA transmission. Interference from “compressed mode” operation will be audible in hearing aids that have a low to medium level of radiofrequency (RF) immunity. Interference from “compressed mode” operation will not be perceptible in hearing aids that have a medium to high level of RF immunity.

“Compressed mode” operation will produce a level of interference in hearing aids between that caused by normal WCDMA “uncompressed mode” operation and GSM digital mobile telephone operation.

“Compressed mode” operation only occurs over short intervals of time, typically several seconds.

During “compressed mode” operation, for interference to be at a level that is “not perceptible”, or “just perceptible”, the RF immunity requirement for the hearing aid will need to be at a level approximately midway between the Class1 and Class 2 categories specified in Australian/New Zealand Standard 1088.9/ Amendment 1/1996 [Ref. 4].