# Next G™ [1] Compatibility with Hearing Aids in Telecoil and Microphone Setting.

Reference: EB973

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Author: Eric Burwood
(National Acoustic Laboratories)

Collaborators: James Corkill
(Telstra Wireless Network Engineering)

George Raicevich
(National Acoustic Laboratories)

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# Executive Summary

Telstra have rolled out a third generation digital mobile telephone network. It is designated the Next G™ network and is based on a "wideband code division multiple access" (WCDMA) network utilizing spread-spectrum technology. The Next G™ network operates in the 850 megahertz (MHz) band of radiofrequencies.

Telstra requested the National Acoustic Laboratories to investigate the operation of a number of Next G™ mobiles with hearing aids in telecoil setting. The purpose of this study was to determine whether there were Next G™ mobiles that would be viable for communication purposes with hearing aids in the telecoil mode when used by hearing aid users. Also two "Bluetooth" magnetic induction neckloops were tested with each mobile and hearing aid in telecoil setting. The Bluetooth technology is used as the wireless communication system between the Next G™ mobile and the neckloop. For comparison purposes each mobile was tested with each hearing aid in the microphone setting.

Two hearing aids were used in each test situation. One had a user volume control and the other had a fixed volume level and no volume control. An audiologist set up both hearing aids with the appropriate preset volume control level when initially switched on that was suitable for a person with a mild hearing loss. Each observer listened through a "stethoscope like" listening tube connected by a 500mm length of 2mm diameter plastic tubing to the hearing aid output.

Three test subjects, or observers, were used to evaluate various test situations. Two of the observers had normal hearing and one had a mild hearing loss. A subjective rating technique was employed to evaluate each test system. The rating system was based on the perceptibility of any interference, the loudness of the speech and the useability of the total system by each observer.

Near worst case test conditions were used for each test situation by ensuring that each Next G™ mobile was transmitting near the limit of its performance as indicated by the signal strength display.

Good communication using all ten mobiles occurred with the two test hearing aids in microphone setting. The speech loudness was always at a *"comfortable"* or *"loud"* level and there was no audible interference.

Viable communication was possible with hearing aids in telecoil setting when used directly with some Next G™ mobiles. The speech loudness was generally between a *"soft"* and *"comfortable"* level and was generally at a lower level than when the hearing aid was in microphone setting. Two small brick mobiles produced the greatest level of interference.

It was possible to get excellent communications with all ten mobiles when using a hearing aid with a volume control with either of two Bluetooth loopsets positioned under the shirt collar.

Some Bluetooth loopsets coupled to mobile phones produce greater output in a hearing aid than others.

When using the hearing aid without a user volume control with the higher output loopset, excellent communication resulted with all ten mobiles after a reduction in the mobile volume level on two of the mobiles that significantly reduced distortion levels observed in the hearing aid when using these two mobiles.

When using the lower output loopset with a hearing aid with a preset volume control then some hearing aid users will obtain good communication while others will have difficulty depending upon the mobile and hearing aid performance.

Observers noted that the quality of speech was better when using a hearing aid in the telecoil setting than when using microphone setting.

When a hearing aid user is using one hearing aid to listen to a mobile conversation in a noisy acoustic environment then improved results will occur if their second hearing aid is switched off so that it does not pick up unwanted acoustic environmental sounds.

When using a Bluetooth loopset it is recommended that both hearing aids be switched to telecoil setting for best reception by the hearing aid user.

A loopset will provide better performance under a shirt collar rather than when placed under the shirt and directly around the neck.

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# 1 Introduction

Telstra have rolled out a third generation digital mobile telephone network. It is designated the Next G™ network and is based on a "wideband code division multiple access" (WCDMA) network utilizing spread-spectrum technology. The Next G™ network operates in the 850 megahertz (MHz) band of radiofrequencies.

Telstra requested the National Acoustic Laboratories to investigate the operation of a number of Next G™ mobiles with hearing aids in telecoil setting. The purpose of this study was to determine whether there were Next G™ mobiles that would be viable for communication purposes with hearing aids in the telecoil mode when used by hearing aid users. Also two "Bluetooth" magnetic induction neckloops were tested with each mobile and hearing aid in telecoil setting. The Bluetooth technology is used as the wireless communication system between the Next G™ mobile and the neckloop. For comparison purposes each mobile was tested with each hearing aid in the microphone setting.

Three test subjects, or observers, were used to evaluate various test situations. Two of the observers had normal hearing and one had a mild hearing loss. A subjective rating technique was employed to evaluate each test system. The rating system was based on the perceptibility of any interference, the loudness of the speech and the useability of the total system by each observer.

Near worst case test conditions were used for each test situation by ensuring that each Next G™ mobile was transmitting near the limit of its performance as indicated by the signal strength display.

# 2 Acknowledgements

Telstra provided part funding for this project and also the Next G™ digital mobile telephones and magnetic induction neckloops. Also a Telstra employee participated as one of the test subjects and also set up the test settings on each of the mobiles.

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# 3 Definitions and Criteria

## *3.1 Immunity Level*

The idea of immunity level for a hearing aid was developed to provide a measure of how immune a hearing aid is to radio signals. The need for this arose with the introduction of mobile telephones as they were the first electronic consumer item that could produce a radiofrequency signal of sufficient strength that it may cause interference to hearing aids. The main reason for the interference was the proximity of the relatively low power mobile telephone transmitter to the hearing aid. Also mobiles eventually would be available to the majority of people and used in many public places. Previous to this time the main cause of interference to hearing aids by radio signals was more likely to occur when a hearing aid user was near a very powerful transmitter of radio signals such as a television tower transmitter. The radiofrequency immunity level of a hearing aid provides a one number rating for a hearing aid in microphone setting and a one number rating for a hearing aid in telecoil setting at each particular radio frequency. These ratings allow the comparison of how different hearing aids will be affected by radio signals. The immunity level rating system works particularly well for hearing aids in microphone setting. However for hearing aids in telecoil setting another overriding factor must be considered where the hearing aid telecoil picks up interference from audio frequency fluctuating magnetic fields that surround a mobile handset. This is referred to as base band interference.

The immunity level [1] for a hearing aid has been determined by noting the electric field strength of a radiofrequency test signal that produces a *standard response*.

In microphone setting the *standard response* has been chosen to be an *input referred sound pressure level* of 55 dB SPL. In telecoil setting the *standard response* has been chosen to be an *input referred magnetic field level* of 25 decibel relative to one milliampere per metre (dB re 1mA/m). Both *standard responses* correspond to the immunity limits used in Australian Standard AS/NZS 1088.9:1995 and amendment 1/1996-07-05 [2].

*Definition of Immunity Levels*

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

Telecoil Input: The *immunity level* (ILT25), is the radiofrequency carrier field strength in decibels relative to one volt per metre (dB re 1 V/m) that produces a response in the hearing aid equivalent to a 1000 Hz *input referred magnetic field strength* equal to 25 dB relative to one milliampere per metre (25 dB re 1 mA/m), when the radiofrequency carrier is 80% amplitude modulated at 1000 Hz.

## *3.2 Subjective Criteria*

The test subjects, or observers, were asked to evaluate each test situation. The rating system was based on the perceptibility of any unwanted interference, the loudness of the speech and the useability of the total system. The following scales were used.

Perceptibility of Interference

The "perceptibility" rating system uses five steps:

- *Not Perceptible;*
- *Just Perceptible;*
- *Moderately Perceptible;*
- *Annoying;*
- *Very Annoying.*

Speech Loudness Rating

The "speech loudness" rating system uses five steps:

- *Not Perceptible;*
- *Soft;*
- *Comfortable;*
- *Loud;*
- *Very Loud.*

Useability Rating

The "useability" rating system uses three steps:

- *Always Useable;*
- *Sometimes Useable;*
- *Not useable.*

# 4 Program of Work

The program of work for this study has been broken down into the following division of work:

- Test Subject Related Information;
- Hearing Aid Testing;
- Subject Testing Program.

## *4.1 Test Subject Related Information*

For each test subject, or observer measure the audiogram for each ear to determine their hearing level. Also calculate the three and four frequency hearing level for each ear. The three frequency hearing level is the average hearing level at 500, 1000 and 2000 Hertz. The four frequency hearing level is the average hearing level at 500, 1000, 2000 and 4000 Hertz. For reference purposes use the average of the left and right ears for the three and four frequency average hearing level for each observer.

## *4.2 Hearing Aid Testing*

Using a hearing aid test facility and waveguide test apparatus:

- Program the performance characteristics for two hearing aids to that required by a person with a mild hearing loss. For the hearing aid with volume control this presets the volume control level when switched on and for the hearing aid with no volume control this is the default preset volume control level.
- Measure the acoustic performance for two hearing aids in microphone setting using a 25 mm length of 2mm diameter plastic tubing to verify normal operation. Also measure the acoustic gain of each hearing aid at 1000 Hertz using a 500 mm length of 2mm diameter plastic tubing for an input level of 55 decibel sound pressure level (dBSPL).
- Measure the performance for two hearing aids in telecoil setting when placed in a magnetic field of 17.76 milliampere per metre (mA/m), i.e. 25 dB re 1 mA/m, and when using a 25 mm length of 2mm diameter plastic tubing to verify normal operation. Also measure the magneto-acoustic gain for each hearing aid at 1000 Hertz using a 500 mm length of 2mm diameter plastic tubing.
- Using a waveguide test apparatus measure the radiofrequency immunity level of the two hearing aids in both the microphone and telecoil settings.

## 4.3 Subject Testing Program

*Hearing Aid Setup*

Setup each observer with a "stethoscope like" listening tube that is easily attached to the acoustic output of each hearing aid using a 500 mm length of 2 mm diameter plastic tubing. The stethoscope listening tube is used to allow quick change between test devices and also to have an identical test set up for each observer as not all the observers had customised ear moulds.

*Mobile Setup*

For each test, set the mobile volume control to the maximum level. Also make sure that each mobile is transmitting at maximum, or near maximum transmit level. This is accomplished by placing the test subject with mobile and hearing aid inside a radiofrequency (RF) screened room and gradually closing the door until the mobile signal strength display indicates zero or one bar. Another indicator is when the received speech begins to break up.

The same continuous speech discourse test signal is used as the test signal for all tests. This has been arranged by dialling a specific telephone number.

*Microphone Test for Hearing Aid with each Mobile*

For this test set the hearing aid to microphone setting. For the hearing aid with volume control, adjust the volume control to a comfortable listening level for normal speech communication at approximately 1 metre. For the hearing aid without a volume control use the level preset by an audiologist.

A small piece of open cell foam is to be used to separate the hearing aid under test from the mobile under test. The thickness of the foam is 12 mm, the width is 15 mm and length 50 mm. This foam is used to provide spacing consistent with that between a hearing aid behind the ear and a mobile handset.

The hearing aid is positioned with its microphone opening in line with the sound outlet of the mobile and the hearing aid is rotated to the correct orientation as would occur on the head. Note that orientation for the left side of the head is the mirror image to that for the right side of the head.

For both the left and right side orientation between the hearing aid and each mobile the observer listens to the received continuous speech discourse and makes an assessment according to the subjective criteria for:

- any sound of unwanted interference, rating it between *"not perceptible"* and *very "annoying"*;
- speech loudness, rating it between *"not perceptible"* and *"very loud"*; and
- useability of the hearing aid with the mobile, rating it between *"always useable"* and *"not useable"*.

*Telecoil Test for Hearing Aid with each Mobile*

For this test set the hearing aid initially to microphone setting. For the hearing aid with volume control, adjust the volume control to a comfortable listening level for normal speech communication at approximately 1 metre. For the hearing aid without a volume control use the level preset by an audiologist. Next switch the hearing aid to telecoil mode.

A small piece of open cell foam is to be used to separate the hearing aid under test from the mobile under test. The thickness of the foam is 12 mm, the width is 15 mm and length 50 mm. This foam is used to provide spacing consistent with that between a hearing aid behind the ear and a mobile handset.

The hearing aid is initially positioned with its body in line with the sound outlet of the mobile and the hearing aid is rotated to the correct orientation as would occur on the head. Note that orientation for the left side of the head is the mirror image to that for the right side of the head. Keeping the orientation of the hearing aid to the mobile fixed, move the hearing aid around until the speech is at a maximum level. This will correspond to the maximum magnetic coupling between the mobile telephone and hearing aid telecoil at that orientation.

For both the left and right side orientation between the hearing aid and each mobile handset the observer listens to the received continuous speech discourse from each mobile and makes an assessment according to the subjective criteria for:

- any audible sound of unwanted interference, rating it between *"not perceptible"* and *"very annoying"*;
- speech loudness, rating it between *"not perceptible"* and *"very loud"*; and
- useability of the hearing aid with the mobile, rating it between *"always useable"* and *"not useable"*.

*Induction Loopset Test with both Hearing Aids and each Mobile*

Each time that a Bluetooth induction loopset is used with one of the test mobiles a protocol must be followed to pair the two devices to allow communication. The loopset is then placed around the neck on the outside of a shirt, but under the shirt collar.

The hearing aid being tested is placed over and behind the ear. The output of the hearing aid is piped via 500 mm length of 2 mm diameter plastic tubing to the stethoscope listening tube.

For this test set the hearing aid initially to microphone setting. For the hearing aid with volume control, adjust the volume control to a comfortable listening level for normal speech communication at approximately 1 metre. For the hearing aid without a volume control use the level preset by an audiologist. Next switch the hearing aid to telecoil mode.

With the hearing aid initially positioned behind the left side ear and then behind the right side ear, the observer listens to the received continuous speech discourse and makes an assessment according to the subjective criteria for:

- any audible sound of unwanted interference, rating it between *"not perceptible"* and *"very annoying"*;

- speech loudness, rating it between *"not perceptible"* and *"very loud"*; and
- useability of the hearing aid with the mobile and neckloop, rating it between *"always useable"* and *"not useable"*.

# 5 Results

The results for this study are presented under three heading:

- Test Subject Related Information;
- Hearing Aid Testing;
- Subject Testing Program.

## *5.1 Test Subject Related Information*

The three frequency and four frequency hearing level for each of the three test subjects (observers) averaged over both ears is presented in the Figure 1.

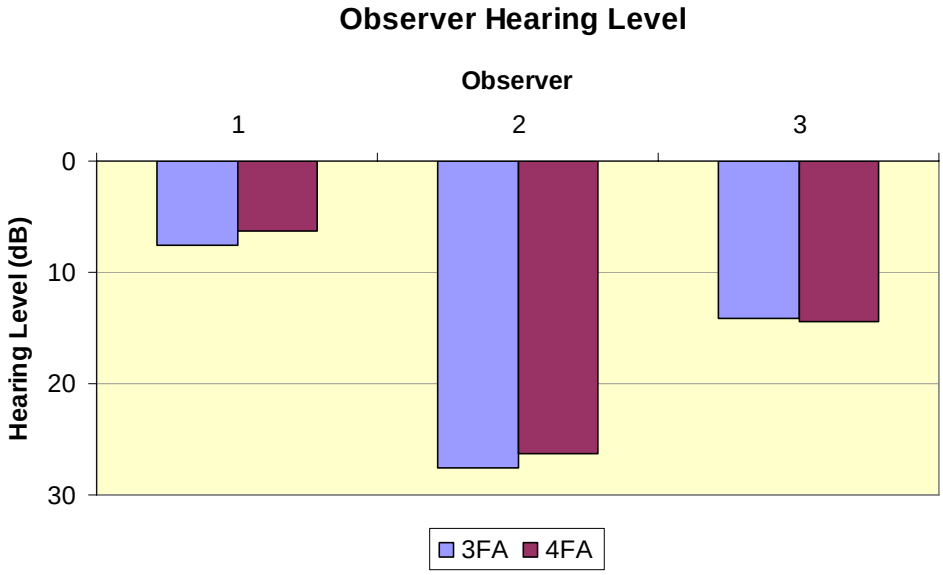


**Figure 1: The three frequency and four frequency hearing level for each observer.**

## 5.2 Hearing Aid Testing

The hearing aid with volume control will be referenced as HA1 and the hearing aid without volume control will be referenced as HA2 (see Appendix 1 for details).

The following table presents the hearing aid parameters at 1000 Hertz.

**Table 1: Hearing Aid Parameters at 1000 Hertz**

| Item | Test Condition | Units | HA1 | HA2 |
|---|---|---|---|---|
| Acoustic Gain: | | | | |
| | 25mm of 2 mm tubing | (dB) | 23 | 21 |
| | 500 mm of 2 mm tubing | (dB) | 12 | 16.5 |
| Magneto-acoustic Gain: | | | | |
| | 25mm of 2 mm tubing | (dB SPL re 1mA/m) | 50 | 47 |
| | 500 mm of 2 mm tubing | (dB SPL re 1mA/m) | 38 | 42 |

Note that it was the intention to set the volume control of hearing aid HA1 to a comfortable listening level for speech at a distance of 1 metre from a speaking person. As the volume control level preset by an audiologist provided comfortable listening for speech at 1 metre, this preset level was used for testing unless otherwise stated.

The radiofrequency immunity levels for the two hearing aids were measured using a waveguide test system. The results at 800 MHz were:

- The radiofrequency immunity level for hearing aid HA1 in microphone setting was ILM55 = 45 dB re 1 V/m;
- The radiofrequency immunity level for hearing aid HA1 in telecoil setting was ILT25 = 37 dB re 1 V/m;
- The radiofrequency immunity level for hearing aid HA2 in microphone setting was ILM55 = 35 dB re 1 V/m; and
- The radiofrequency immunity level for hearing aid HA2 in telecoil setting was ILT25 = 30 dB re 1 V/m

## *5.3 Subject Testing Program*

The hearing aid with volume control will be referenced as HA1 and the hearing aid without volume control will be referenced as HA2. The ten "wideband code division multiple access" (WCDMA) Next G™ mobiles used in this study are documented in Appendix 2. The two induction loopsets are referenced as LS1 and LS2 are documented in Appendix 3.

### 5.3.1 Subject Test Results

Note that subjective measurements were carried out in a radiofrequency screened room that was also an acoustic anechoic room. This room was vibration isolated from an outer room shell. As the door was opened and closed to adjust the level of the received radio signal the acoustic levels within the room were not constant. The sound pressure levels of the acoustic background noise varied with adjustment of the door. Typically the measured A-weighted level varied from 14 to 20 dBA and the C-weighted levels varied from 25 to 55dBC. The 14 dBA measurement is at the specified noise limit of the microphone and should be taken into account when interpreting the lower level result.

The results are presented in the following order:

- *Microphone Test for Hearing Aid HA1 with each Mobile;*
- *Microphone Test for Hearing Aid HA2 with each Mobile;*
- *Telecoil Test for Hearing Aid HA1 with each Mobile;*
- *Telecoil Test for Hearing Aid HA2 with each Mobile;*
- *Induction Loopset LS1 Test with each Mobile for Hearing Aid HA1;*
- *Induction Loopset LS1 Test with each Mobile for Hearing Aid HA2;*
- *Induction Loopset LS2 Test with each Mobile for Hearing Aid HA1;*
- *Induction Loopset LS2 Test with each Mobile for Hearing Aid HA2.*

*Microphone Test for Hearing Aid HA1 with each Mobile*

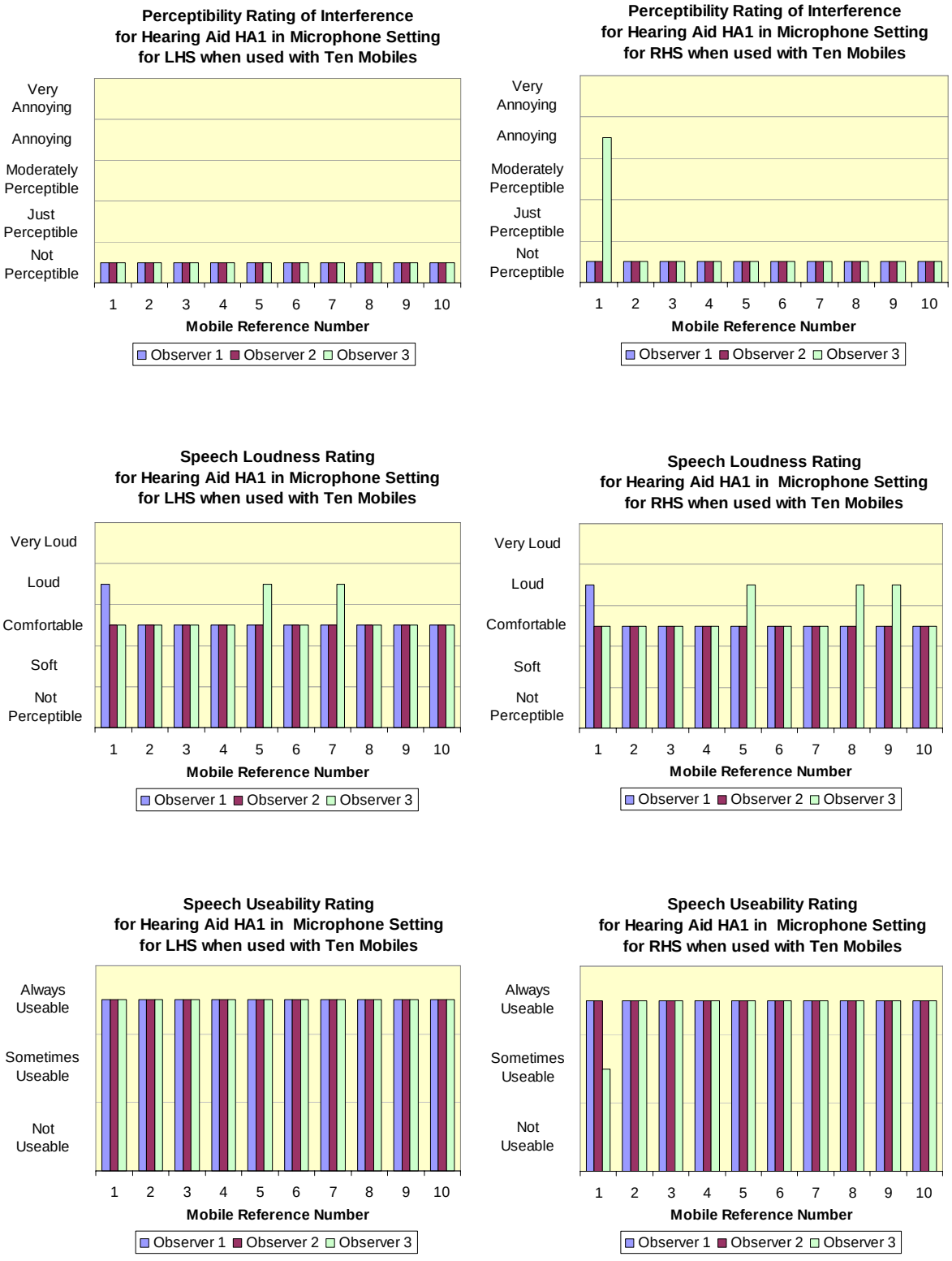


**Figure 2: Results for each observer using hearing aid HA1 in microphone setting when placed near speaker sound outlet for each of the ten mobiles.**

*Microphone Test for Hearing Aid HA2 with each Mobile*

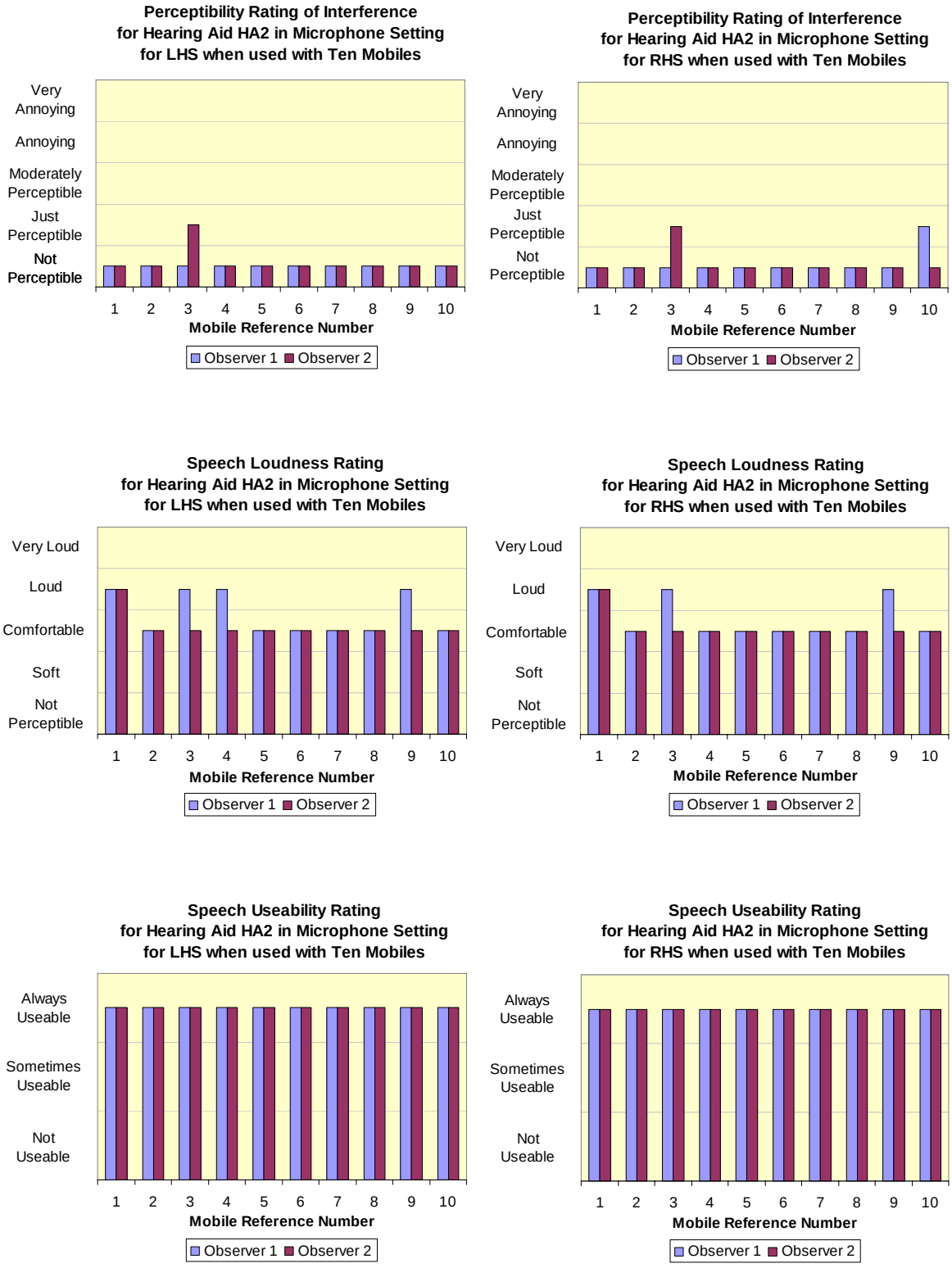


**Figure 3: Results for each observer using hearing aid HA2 in microphone setting when placed near speaker sound outlet for each of the ten mobiles.**

*Telecoil Test for Hearing Aid HA1 with each Mobile*

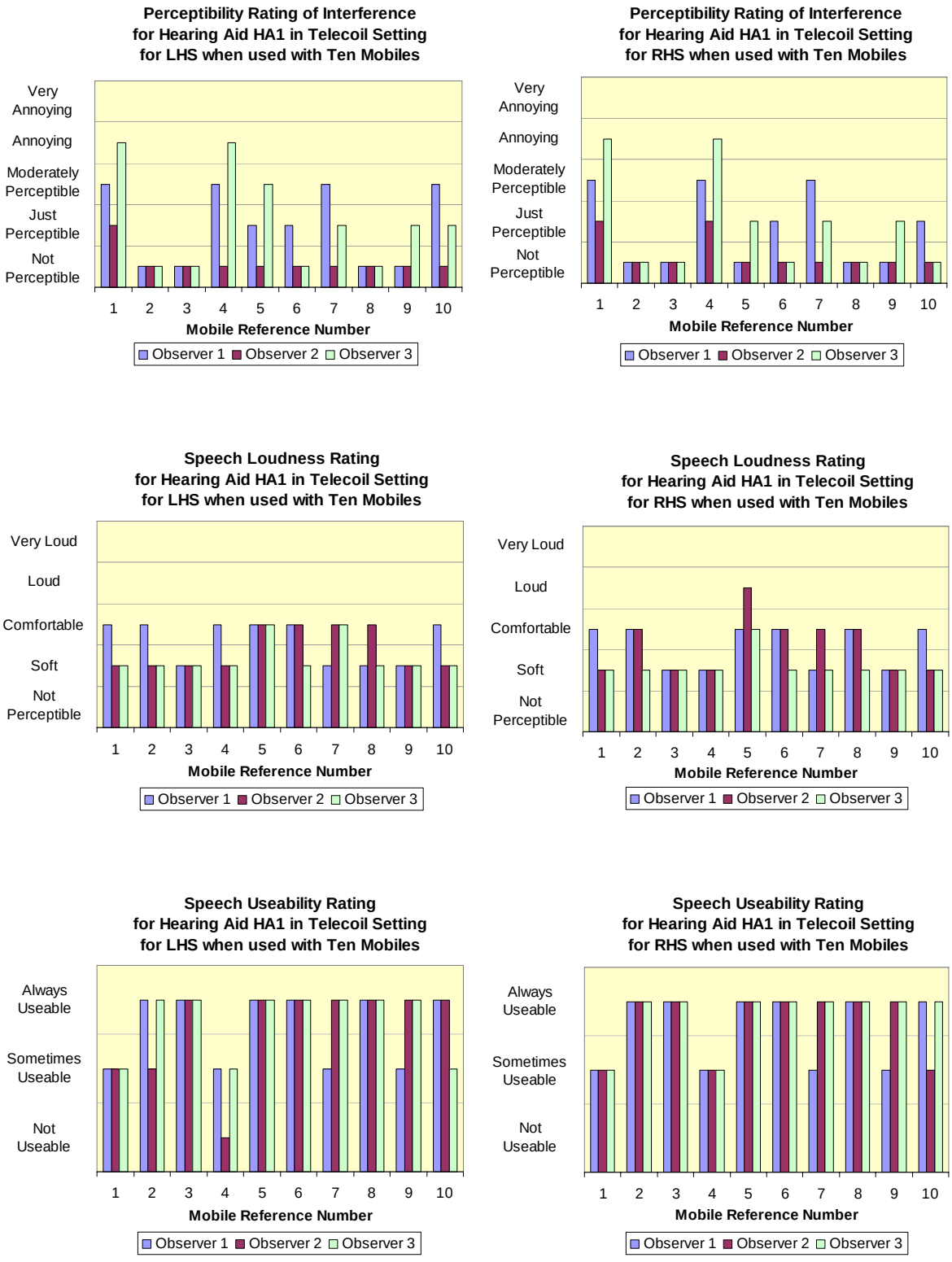


**Figure 4: Results for each observer using hearing aid HA1 in telecoil setting when placed near speaker sound outlet for each of the ten mobiles.**

*Telecoil Test for Hearing Aid HA2 with each Mobile*

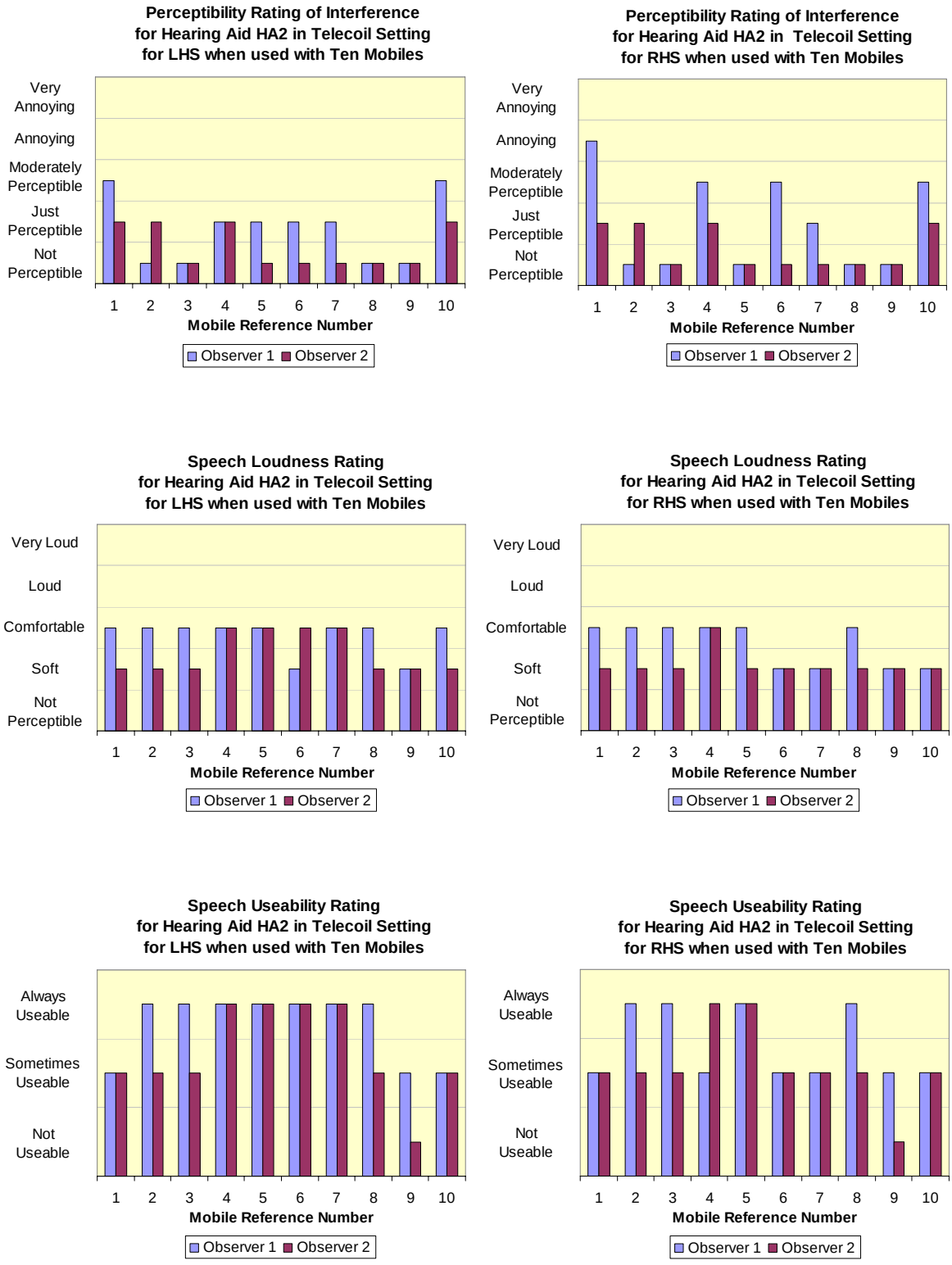


**Figure 5: Results for each observer using hearing aid HA2 in telecoil setting when placed near speaker sound outlet for each of the ten mobiles.**

*Induction Loopset LS1 Test with each Mobile for Hearing Aid HA1*

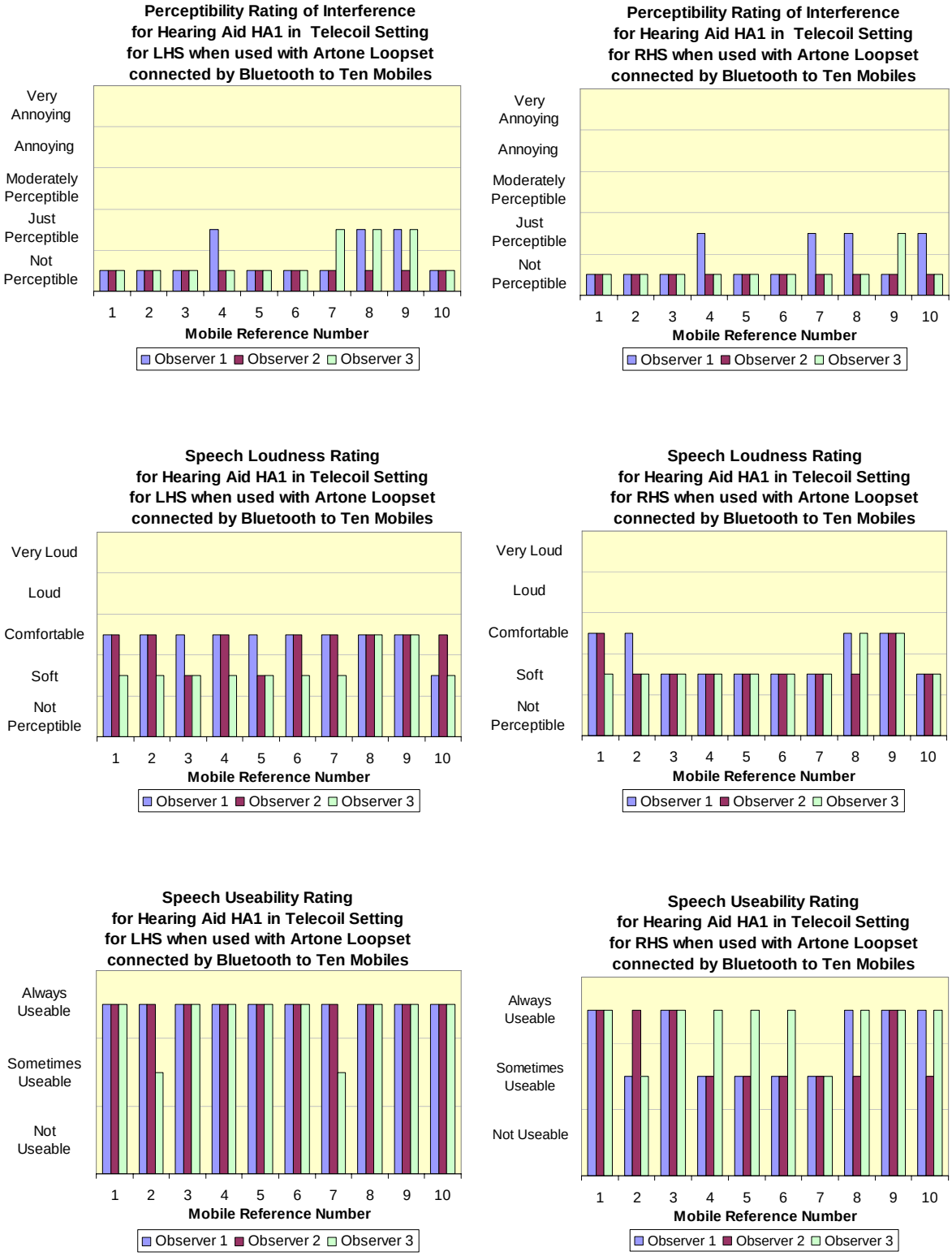


**Figure 6: Results for each observer using hearing aid HA1 in telecoil setting when used with an Artone Induction Loopset, designated LS1 in this study, and connected by Bluetooth to each of the ten mobiles.**

*Induction Loopset LS1 Test with each Mobile for Hearing Aid HA2*

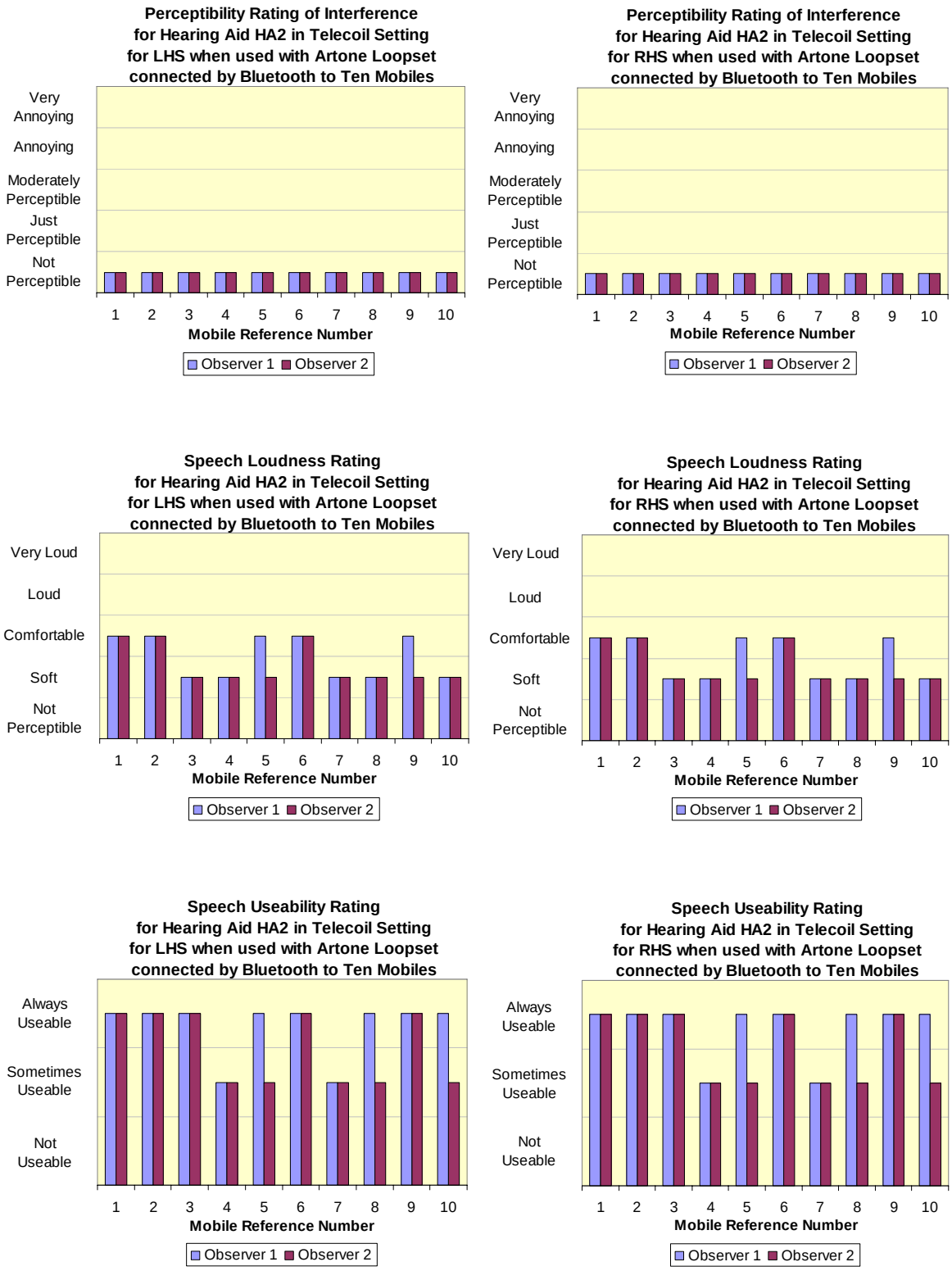


**Figure 7: Results for each observer using hearing aid HA2 in telecoil setting when used with an Artone Induction Loopset, designated LS1 in this study, and connected by Bluetooth to each of the ten mobiles.**

*Induction Loopset LS2 Test with each Mobile for Hearing Aid HA1*

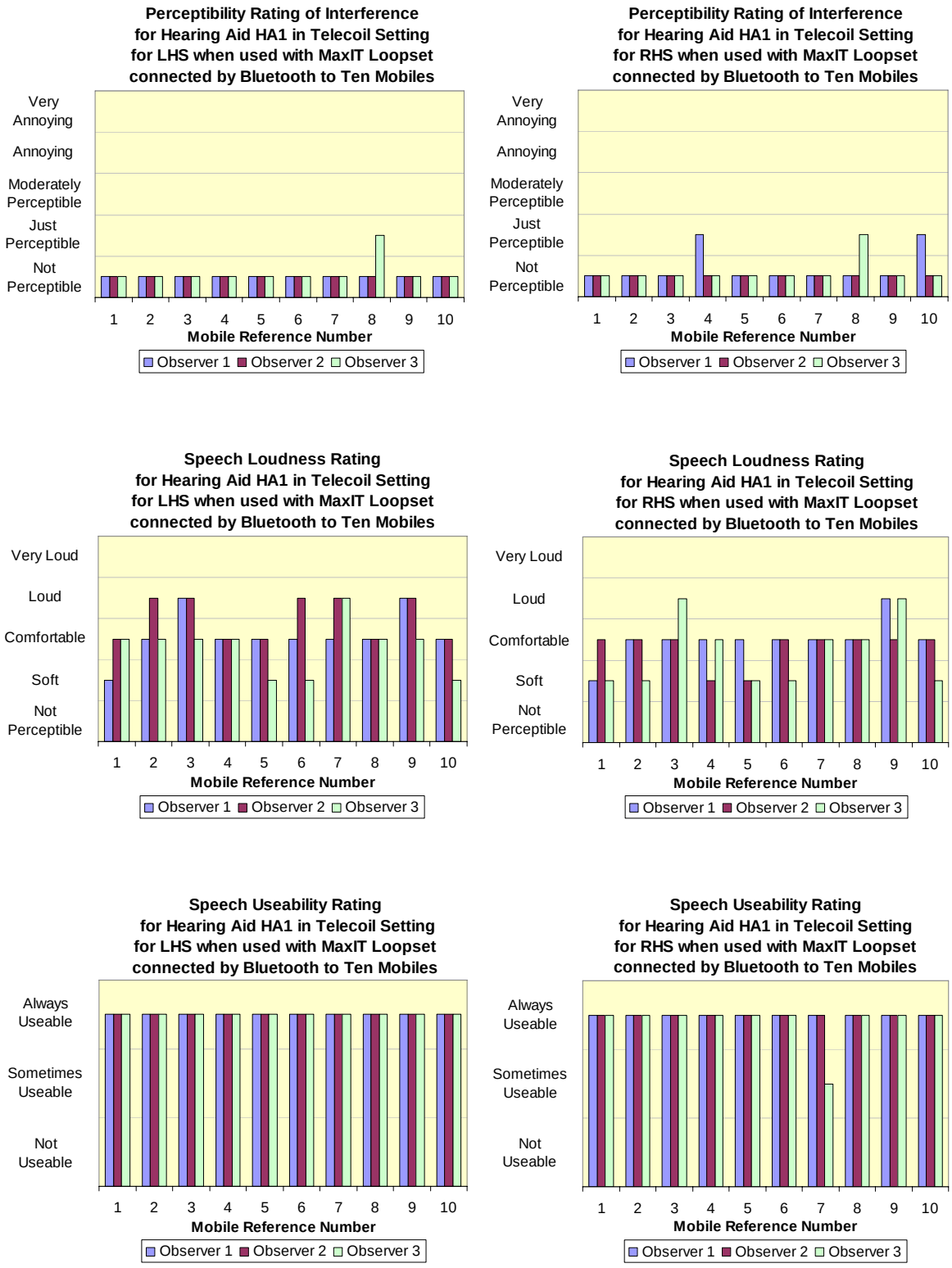


**Figure 8: Results for each observer using hearing aid HA1 in telecoil setting when used with a MaxIT Induction Loopset, designated LS2 in this study, and connected by Bluetooth to each of the ten mobiles.**

*Induction Loopset LS2 Test with each Mobile for Hearing Aid HA2*

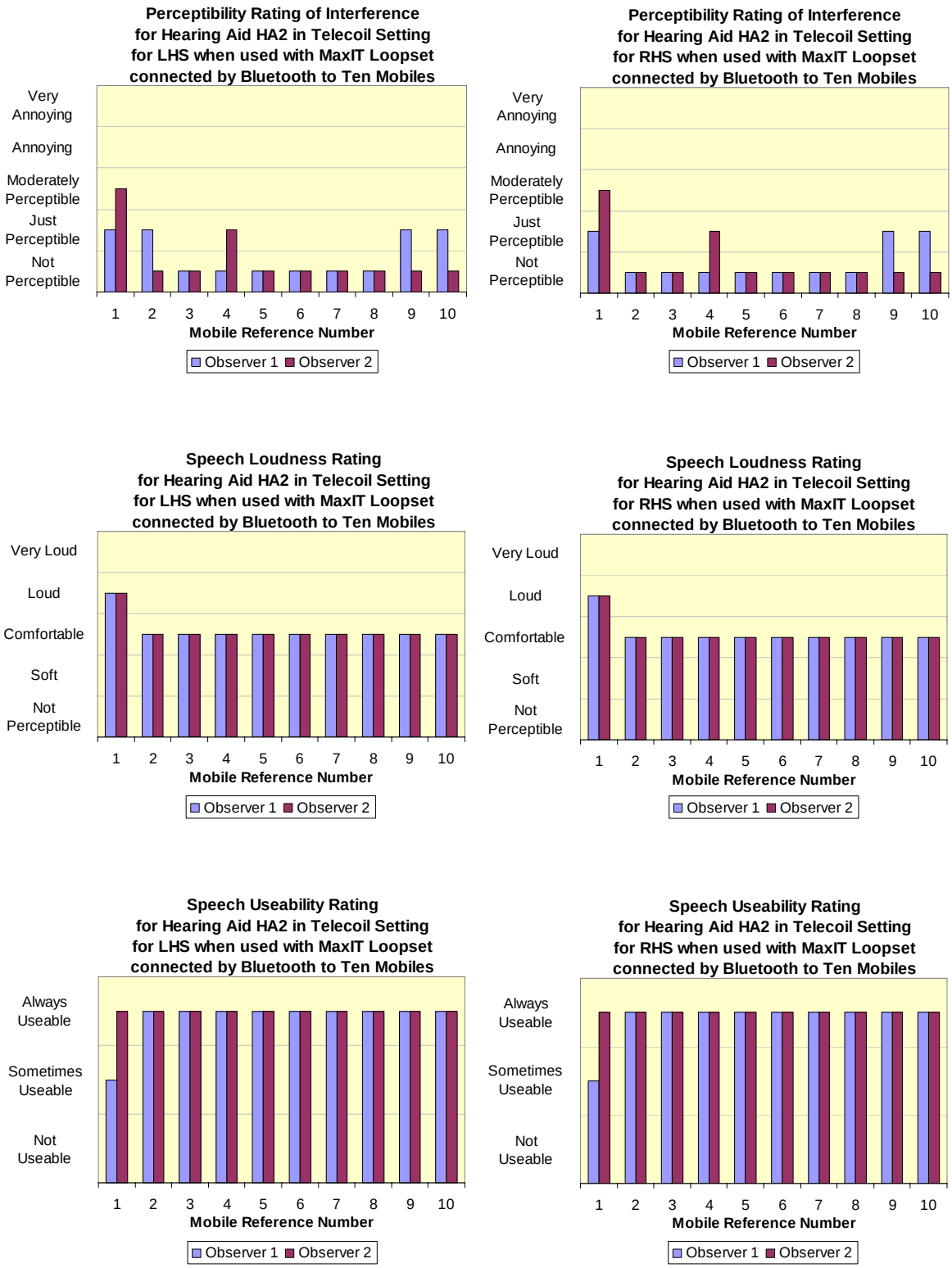


**Figure 9: Results for each observer using hearing aid HA2 in telecoil setting when used with a MaxIT Induction Loopset, designated LS2 in this study, and connected by Bluetooth to each of the ten mobiles.**

### 5.3.2 Observer Comments

Some observer comments about interference:

- “Interference is like static plus other noise, but not 50 hertz hum. The ‘other noise’ is due to screen related noise, in that it occurs near screen”. (Observer 1 when using Mobile 4)

Other observer comments:

- “Clear sound on telecoil”. (Observer 2 when using Mobile 5)
- “Telecoil provides good quality sound, better quality than microphone setting” (Observer 1, a general comment)

# 6 Analysis of Results

## 6.1 Test Subject Related Information

The three frequency hearing level of an observer is the average hearing level at 500, 1000 and 2000 Hertz. The four frequency hearing level is the average hearing level at 500, 1000, 2000 and 4000 Hertz. The data provided in Figure 1 is the average of both the left and right ear for each observer. From the results observers one and three would be classified as having normal hearing and observer two would be classified as having a mild hearing loss. For all three observers the three and four frequency hearing level is similar indicating that there is not a significant loss of hearing at the higher frequency of 4 kHz.

## 6.2 Hearing Aid Testing

The gain of the hearing aids has be set to compensate for loss of signal in the 500 mm length of 2 mm diameter plastic connecting tube and to provide a small amount of gain.

The immunity of the hearing aids to radiofrequency signals was reported in Section 5.2. These results indicate that at 800 MHz:

- hearing aid HA1 has a high level of immunity to radio signals in microphone setting and a medium to high level of immunity in telecoil setting; and
- hearing aid HA2 has a medium to high level of immunity to radio signals in microphone setting and a medium level of immunity in telecoil setting.

## 6.3 Subject Testing Program

*Microphone Test for Hearing Aid with each Mobile*

Figure 2 presents the data for three observers using hearing aid HA1 in microphone setting when it is used near each of the ten Next G™ mobiles. The first column of graphs indicate the results when the hearing aid and mobile are oriented for the left side of the head and the second column of graphs presents the results when the hearing aid is oriented for the right side of the head. Figure 3 presents the results when using hearing aid HA2 in microphone setting. Due to time limitations only two observers were used for testing with the second hearing aid.

With both hearing aids in microphone setting there was no audible interference as it was *"not perceptible"* in most of these tests apart from two observations with hearing aid HA2 where the audible interference was *"just perceptible"* and one observation with HA1 used with mobile 1 where the interference was reported as *"annoying"*. This last result may be an outlier result as it seems substantially different from the other two observers. However this was not further investigated at the time. This test was carried out at full volume control on each mobile. Observers generally reported that the received contiguous speech was at a *"comfortable"* level and in some cases at a *"loud"* level. In all cases where the volume level

was classified as *"loud"* it would be possible for the hearing aid user to turn the mobile volume down to a comfortable listening level. If the hearing aid has a volume control there maybe an advantage to turn the hearing aid volume down rather than the mobile volume control as this would reduce the level of any acoustic ambient background noise. Apart from the one outlier result, all observers reported that all ten Next G$^{TM}$ mobiles were *"always useable"* with both hearing aids in microphone setting when used at the preset volume setting. There did not seem to be any significant difference when positioning the hearing aid and mobile for use at either the left or right side of the head.

The fact that the subjective testing was carried out in a quiet acoustic environment must be considered when the hearing aid is in microphone setting as any unwanted nearby acoustic sounds have the potential to interfere with conversation when using a mobile. Also another important factor is that it is generally not possible to make an acoustic seal between the mobile and hearing aid and this has two effects. The first is that the low pitch speech sounds can be reduced due to leakage of sound due to the poor acoustic seal. Also any unwanted background acoustic noises can still enter the hearing aid through the poor acoustic seal between the mobile and hearing aid. These two effects would create a problem if the speech loudness was "soft" and the unwanted competing noises were greater than the wanted speech sounds. However in every subjective test with the ten mobiles and two hearing aids the speech loudness was always at a "comfortable" or "loud" level". Therefore good communication using all ten mobiles would result with the two hearing aids in microphone setting in all but the worst of listening conditions that would also affect people not using a hearing aid. In difficult listening condition another improvement for the hearing aid user would be to switch off their second hearing that is not being used with the mobile.

*Telecoil Test for Hearing Aid with each Mobile*

Figure 4 presents the data for three observers using hearing aid HA1 in telecoil setting when it is used near each of the ten Next G$^{TM}$ mobiles. The first column of graphs indicate the results when the hearing aid and mobile are oriented for the left side of the head and the second column of graphs presents the results when the hearing aid is oriented for the right side of the head. Figure 5 presents the results when using hearing aid HA2 in telecoil setting. Due to time limitations only two observers were used with the second hearing aid.

In telecoil setting there was audible interference when using either of the two hearing aids with many of the ten mobiles. In the telecoil test any audible interference was perceived by the observers as being *"just perceptible"*, *"moderately perceptible"* or *"annoying"*. However for hearing aid HA1 there was no audible interference when used with mobile numbers 2, 3 and 8. Also with hearing aid HA2 there was no audible interference when used with mobiles 3, 8 and 9. There were some differences in observer responses when using the hearing aids in either the left side or right side orientation with respect to the mobile phones. These differences maybe related to the orientation of the telecoil within each hearing aid and also whether the external magnetic field generated about each mobile is symmetrical about the centre line of the mobile. The results for hearing aid HA1 were very similar for the left and right side orientation, where as the results for hearing aid HA2 were more varied between the left and right side orientation. This may indicate that the telecoil in hearing aid HA2 may not be mounted symmetrically about the vertical plane of the hearing aid. The speech loudness was rated by the observers as *"soft"* or *"comfortable"* with one observation with mobile 5 used with hearing aid HA1 as *"loud"*. The listening conditions for these tests were very good as the test venue was an acoustically quiet area. When rating the useability of a mobile with a

hearing aid the observer would take into account the level of any audible interference and the acoustic output level from the hearing aid. When the audible interference was at a "moderately perceptible" or "annoying" level then the observers down rated the useability of the mobile and hearing aid combination. With hearing aid HA1, mobiles 2, 3, 5, 6, and 8 were rated by the observers as *"always useable"* under the test conditions. With hearing aid HA2, mobiles 2, 3, 4, 5 and 8 gave generally useable results, however note that there were differences between the left side and right side results. In telecoil setting for both hearing aids on both sides of the head, mobiles 2, 3, 5 and 8 provided the best overall performance.

Hearing aid HA1 had a volume control that allowed the sound output to be increased or decreased by 8 dB above or below the preset level. In cases where the speech loudness was rated as *"soft"*, useability rated as *"sometimes useable"* and interference rated as *"not perceptible"* by an observer, when the volume control was increased by 8 dB the speech loudness rating increased to a *"comfortable"* rating and the useability rating increased to *"always useable"* and the interference was rated as either *"not perceptible"* or *"just perceptible"*. If the interference is originally rated as "moderately perceptible" then increasing the volume level will also increase the level of both the interference and speech loudness, but the useability may be rated at a lower level probably due to the interference moving into the *"annoying"* range. Using the volume control on hearing aid HA1 would also allow satisfactory communication when used with mobiles 9 and 10 in addition to the other five stated above. When considering operation on both the left and right side of the head then mobiles 1, 4 and 7 produced an unacceptable level of interference to take advantage of using the volume control in hearing aid HA1.

The two small brick handsets, mobiles 1 and 4, produced the greatest level of interference in hearing aid HA1 in telecoil setting. Also a slide handset, mobile 10, produced moderate levels of interference in both hearing aids HA1 and HA2.

The subjective testing was carried out in a quiet acoustic environment. With the hearing aid in telecoil setting and when using the hearing aid directly against the mobile telephone the effect of acoustic background noise should be considered. When the hearing aid is in telecoil setting the microphone is usually disabled. If the hearing aid user also switches off their second hearing aid then any unwanted acoustic background noise will not be picked up by either of the hearing aids. Under these conditions a speech loudness of "soft" to a "comfortable" level will provide good quality speech for the hearing aid user. The quality of the speech sound will be better than in microphone setting as there is no loss of low pitch sounds of speech as occurs in microphone setting. In some situations it is possible that the telecoil operation may pick up unwanted hum from the 240 volt mains supply. Should this occur then it is recommended that the hearing aid user move away until the hum level drops to an acceptable level. Then the level of the wanted speech sounds will be much greater than any unwanted sounds. The subjective results indicate that when the hearing aid is in telecoil mode some mobiles can produce levels of interference at the *"moderate"* or *"annoying level"* while other combinations of mobile and hearing aid will produce interference that is *"not perceptible"* or *"just perceptible"*. It is important that the hearing aid user try any mobile before purchasing the unit to make sure that the hearing aid and mobile are compatible.

*Induction Loopset Test with both Hearing Aids and each Mobile*

Two induction loopsets were tested with each hearing aid and Next G™ mobile handset. The neckloops were positioned around the neck and under the collar of the shirt. In all cases when using either loopset the hearing aids were set to telecoil mode.

When using loopset LS1 with hearing aid HA1 the observers rated the interference as *"not perceptible"* or *"just perceptible"* and the level of speech in the hearing aid at the preset volume level as either *"soft"* or *"comfortable"*. When hearing aid HA1 was position over the left side ear the three observers rated the system useability as *"always useable"* apart from two observations of *"sometimes useable"*. Over the right side ear the ratings were *"always useable*" for just over 50% of observation and *"sometimes useable"* for the remainder of the observations. It is not known if these different results were due to differences in the symmetry of the position of the telecoil in the hearing aid or due to positioning variations in the loopset. At the hearing aid reset volume level and considering both left and right side operation, mobile 1, 3 and 9 provided consistent good results followed by mobiles 2 and 8, then mobiles 4, 5, 6, 7 and 10. Using the volume control on hearing aid HA1 would allow all mobiles to be used with loopset LS1.

When using loopset LS1 with hearing aid HA2 both observers indicated that any interference was inaudible as it was rated as *"not perceptible"*. The level of the speech in the hearing aid was rated as either *"soft"* or *"comfortable"*. Hearing aid HA2 produced similar results over both the right and left side ears where 65% of observations were *"always useable*" and 35% were *"sometimes useable"*. Mobiles 1, 2, 3, 6 and 9 were rated as *"always useable"* by both observers when using loopset LS1 with hearing aid HA2 that had a fixed preset volume control. However the speech loudness for mobiles 1, 2 and 6 were rated as *"comfortable"* by both observers, whereas for mobiles 9 it was rated as *"comfortable"* by observer 1 and *"soft"* by observer 2 and mobile 3 was rated as *"soft"* by both observers. Mobiles 5, 8 and 10 were rated as *"always useable"* by observer 1 and *"sometimes useable"* by observer 2 and the speech loudness was rated as *"soft"* for mobiles 8 and 10 by both observers and mobile 5 was rated as *"soft"* by observer 2 and *"comfortable"* by observer 1. When using the same hearing aid setting these results are consistent with the fact that the hearing level of observer 1 is better than that of observer 2 as indicated in Figure 1. Mobiles 4 and 7 were rated as *"soft"* and *"sometimes useable"* by both observers.

When using loopset LS2 with hearing aid HA1 with its volume control in the preset level and with each of the ten mobiles the observers rated any interference as *"not perceptible*" in 93% of tests and *"just perceptible*" in 7% of tests when analysing the total left and right side results. Also the speech loudness was rated as *"comfortable"* in 62% of tests, *"soft"* in 20% of tests and *"loud"* in 18% of tests. The speech useability for loopset LS2 used with each of the ten mobiles and hearing aid HA1 was rated as *"always useable"* in 98% of tests and *"sometimes useable"* in 2% of tests. In some of the cases where the speech loudness was rated *"soft"* the hearing aid volume control was increase by 8dB and in all cases tested the volume level was then rated as *"comfortable"*. When using hearing aid HA1 and its volume control with loopset LS2 positioned under the shirt collar it was possible to get excellent results with all ten mobiles.

When using loopset LS2 with hearing aid HA2 that had a preset fixed volume control with each of the ten mobiles the observers rated any interference as *"not perceptible"* in 72% of observation tests, *"just perceptible"* in 23% of tests and *"moderately perceptible"* in 5% of

tests when considering both total left and right side tests. The speech loudness was rated as "comfortable" in 90% of tests and "loud" in 10% of tests. The speech useability for loopset LS2 used with each of the ten mobiles and hearing aid HA2 was rated as *"always useable"* in 95% of tests and *"sometimes useable"* in 5% of tests. Note that there was significant distortion when using mobiles 1 and 8. This distortion was eliminated by reducing the volume of either the mobile or the Bluetooth loopset LS2. This increased the speech useability rating with acceptable distortion when using loopset LS2 with hearing aid HA2 and allowed excellent communication when using each of the ten mobiles with the Bluetooth loopset LS2 and hearing aid HA2.

With the hearing aid in telecoil setting and when using a loopset with the mobile telephone the effect of acoustic background noise should be considered as the subjective testing was carried out in a quiet environment. When using a loopset with a hearing aid the mobile is not adjacent to the hearing aid and the possibility of direct interference from a Next G$^{TM}$ mobile is greatly reduced. Also nearby acoustic background noises are not picked up by the telecoil. There is still the possibility of an interfering hum from the 240 Volt mains power supply and it maybe necessary for the hearing aid user to move a short distance to reduce any unwanted mains hum. Different loopsets produce different levels of sound when used with different mobiles and different hearing aids, so it is important for the hearing aid user to try the mobile and loopset with their hearing aid before entering into any purchase agreement. It is recommended that both hearing aids be switched to telecoil for best reception by the hearing aid user. This provides binaural hearing, which is hearing with both ears, and also cuts out acoustic background noise as the microphones in both hearing aids normally will be disabled in the telecoil mode. Under some circumstances when using a loopset it is sometimes possible to overload the sound to the point where distortion occurs. Under these circumstances it is suggested that the volume control on the mobile or loopset be reduced. When the volume control is adjusted correctly loopsets provide better quality sound than that received with the hearing aid in microphone setting.

Note that all tests were carried out with the both loopsets positioned under the shirt collar. It would be expected that the speech loudness maybe reduced a little if the loopset was placed under the shirt and directly around the neck. The reason for this is that the vertical component of the magnetic field maybe reduced a little at the hearing aid over the ear with the loopset directly around the neck when compared with placing the loopset under the shirt collar. This is related to the geometry of the neckloop in the two different positions and also the position of the telecoil within the hearing aid. Time did not permit an extensive investigation into this matter.

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# 7 Summary

The Next G™ transmission network is based on a "wideband code division multiple access" (WCDMA) network using spread-spectrum technology. All testing was carried out with each Next G™ mobile transmitting at, or near maximum output as indicated by the signal strength display being at zero or one bar. The volume control of each mobile was set to maximum for each test. Both hearing aids were set up for a person with a mild hearing loss by an audiologist with the appropriate preset volume control level when initially switched on. Each observer listened to the hearing aid output through a "stethoscope like" listening tube connected by 500mm length of 2mm diameter plastic tubing. Also testing was carried out in good acoustic listening conditions and this factor has been taken into account in the analysis of the results. Observers one and three used for the subjective testing were classified as having normal hearing and observer two had a mild hearing loss. The testing was carried out such that the results are applicable for people using hearing aids.

*Microphone Test for Hearing Aid with each Mobile*

Good communication using all ten mobiles occurred with the two test hearing aids in microphone setting. The speech loudness was always at a *"comfortable"* or *"loud"* level and there was no audible interference.

In difficult listening conditions that would affect people not using a hearing aid it is recommended that hearing aid users switch off their second hearing aid that is not being used with the mobile.

*Telecoil Test for Hearing Aid with each Mobile*

In telecoil setting for both hearing aids on both sides of the head, mobiles 2, 3, 5 and 8 provided the best overall performance.

Mobiles 6, 9 and 10 were satisfactory to use with a hearing aid that had a volume control however were not satisfactory for a hearing aid without a volume control.

Mobile 7 gave variable results between the two hearing aids. Interference caused in hearing aid HA1 was too great to take advantage of the hearing aid volume control.

The two small brick handsets, mobiles 1 and 4, produced the greatest level of interference in both hearing aids in telecoil setting. Also a slide handset, mobile 10, produced moderate levels of interference in both hearing aids HA1 and HA2.

*Induction Loopset Test with both Hearing Aids and each Mobile*

When using a Bluetooth induction loopset any hearing aid will need to be set to the telecoil mode. Not all hearing aids have a telecoil installed.

Loopset LS2 used with the ten Next G™ mobiles generally provided a little greater output than loopset LS1 with both hearing aids.

It was possible to get excellent communications with all ten mobiles when using hearing aid HA1 and its volume control with either loopset positioned under the shirt collar.

When using loopset LS1 with hearing aid HA2 that has a preset volume control then mobiles 1, 2, 3, 6 and 9 were rated as *"always useable"* where the speech loudness for mobiles 1, 2, and 6 was at a *"comfortable"* level and with mobiles 3 and 9 at lower levels. Mobiles 5, 8 and 10 were rated differently by different observers between *"always useable"* and *"sometimes useable"*. Mobile 4 and 7 were rated as *"soft"* and *"sometimes useable"* by both observers. When loopset LS1 is used with a hearing aid with a preset volume control then some hearing aid users will obtain good communication while others will have difficulty depending upon the mobile and hearing aid performance.

When using loopset LS2 with hearing aid HA2 that had a preset volume control there was significant distortion when using mobiles 1 and 8. This distortion was eliminated by reducing the volume of either the mobile or the Bluetooth loopset LS2. This increased the speech useability rating with acceptable distortion when using loopset LS2 with hearing aid HA2 and allowed excellent communication when using each of the ten mobiles with the Bluetooth loopset LS2 and hearing aid HA2.

*General comments*

Observers noted that the quality of speech was better when using a hearing aid in the telecoil setting than when using microphone setting.

When a hearing aid user is using one hearing aid to listen to a mobile conversation in a noisy acoustic environment then improved results will occur if the second hearing aid is switched off so that it does not pick up unwanted acoustic environmental sounds.

When using a Bluetooth loopset it is recommended that both hearing aids be switched to telecoil setting for best reception by the hearing aid user.

A loopset will provide better performance under a shirt collar rather than when placed under the shirt and directly around the neck.

# 8 Conclusion

Good communication using all ten mobiles occurred with the two test hearing aids in microphone setting. The speech loudness was always at a *"comfortable"* or *"loud"* level and there was no audible interference.

Viable communication was possible with hearing aids in telecoil setting when used directly with some Next G™ mobiles. The speech loudness was generally between a *"soft"* and *"comfortable"* level and was generally at a lower level than when the hearing aid was in microphone setting. Two small brick mobiles produced the greatest level of interference.

It was possible to get excellent communications with all ten mobiles when using a hearing aid with a volume control with either of two Bluetooth loopsets positioned under the shirt collar.

Some Bluetooth loopsets coupled to mobile phones produce greater output in a hearing aid than others.

When using the hearing aid without a user volume control with the higher output loopset, excellent communications resulted with all ten mobiles after a reduction in the mobile volume level on two of the mobiles that significantly reduce distortion levels observed in the hearing aid when using these two mobiles.

When using the lower output loopset with a hearing aid with a preset volume control then some hearing aid users will obtain good communication while others will have difficulty depending upon the mobile and hearing aid performance.

Observers noted that the quality of speech was better when using a hearing aid in the telecoil setting than when using microphone setting.

When a hearing aid user is using one hearing aid to listen to a mobile conversation in a noisy acoustic environment then improved results will occur if the second hearing aid is switched off so that it does not pick up unwanted acoustic environmental sounds.

When using a Bluetooth loopset it is recommended that both hearing aids be switched to telecoil setting for best reception by the hearing aid user.

A loopset will provide better performance under a shirt collar rather than when placed under the shirt and directly around the neck.

# 9 References

[1] 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)”.

[2] 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 1 – Hearing aids

The hearing aids used in this study and their report reference numbers.

| Hearing Aid Report Reference Number | Picture | Details |
|---|---|---|
| HA1 |  | Manufacturer: Siemens<br>Model: Centra HP<br>Serial Number: EZ75270<br>Comments: Has User Volume Control and Presetable Gain when initially switched on. |
| HA2 |  | Manufacturer: Siemens<br>Model: Acuris S<br>Serial Number: ZM81303<br>Comments: No User Volume control, has Presetable Gain. |

# Appendix 2 – Next G™ Mobiles

(Note: IMEI = International Mobile Equipment Identity)

| Mobile Report Reference Number | Picture | Details |
|---|---|---|
| 1 |  | Manufacturer: ZTE<br>Model: F165<br>IMEI: 357407010018857<br>Comments: Extendable Stub Antenna |
| 2 |  | Manufacturer: LG<br>Model: TU550<br>IMEI: 355855010110334<br>Comments: Flip, Internal Antenna |
| 3 |  | Manufacturer: Samsung<br>Model: SGH-A412<br>IMEI: 357903010197220<br>Comments: Flip, Stub Antenna |

| Mobile Report Reference Number | Picture | Details |
|---|---|---|
| 4 |  | Manufacturer: Nokia<br>Model: 6120C<br>IMEI: 356252010012943<br>Comments: Internal Antenna |
| 5 |  | Manufacturer: Motorola<br>Model: V9<br>IMEI: 357715010058057<br>Comments: Flip, Internal Antenna |
| 6 |  | Manufacturer: Motorola<br>Model: V3xx<br>IMEI: 355059010223839<br>Comments: Flip, Internal Antenna |

| Mobile Report Reference Number | Picture | Details |
|---|---|---|
| 7 |  | Manufacturer: Motorola<br>Model: RAZR Maxx V6<br>IMEI: 353296010097654<br>Comments: Flip, Internal Antenna |
| 8 |  | Manufacturer: Sony Ericsson<br>Model: Z750i<br>IMEI: 358936010659848<br>Comments: Flip, Internal Antenna |
| 9 |  | Manufacturer: Samsung<br>Model: SGH-A701i<br>IMEI: 353104010015033<br>Comments: Flip, Internal Antenna |

| Mobile Report Reference Number | Picture | Details |
|---|---|---|
| 10 |  | Manufacturer: Nokia<br>Model: N95<br>IMEI: 358981010035524<br>Comments: Slide, Internal Antenna |

# Appendix 3 – Bluetooth Induction Loopsets

Bluetooth induction loopsets used in this study and their report reference numbers.

| Loopset Report Reference Number | Picture | Details |
|---|---|---|
| LS1 |  | Manufacturer: Artone<br>Model: Bluetooth Loopset<br>Comments: Bluetooth Inductive Loopset for Hearing Aids |
| LS2 |  | Manufacturer: MaxIT<br>Model: MA007<br>Comments Bluetooth Inductive Loopset for Hearing Aids |