Spring 2012

Bluetooth headset specifications and its possible effects on hearing loss

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BLUETOOTH HEADSET SPECIFICATIONS AND ITS POSSIBLE EFFECTS ON HEARING LOSS

by

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A Dissertation Presented in Partial Fulfillment
Of the Requirements for the Degree
Doctor of Audiology

COLLEGE OF LIBERAL ARTS
LOUISIANA TECH UNIVERSITY

MAY 2012

LOUISIANA TECH UNIVERSITY

THE GRADUATE SCHOOL

January 4, 2012

Date

We hereby recommend that the dissertation prepared under our supervision by Kristi Ann Anderson

entitled

Bluetooth Headset Specifications And Its Possible Effects on Hearing Loss

be accepted in partial fulfillment of the requirements for the Degree of

Doctor of Audiology

Supervisor of Dissertation Research

Head of Department

Speech

Department

Recommendation concurred in:

Advisory Committee

Approved:

Director of Graduate Studies

Dean of the College

Approved:

Dean of the Graduate School

GS Form 13a
(6/07)

ABSTRACT

The purpose of this study was to determine Bluetooth headset specifications and its potential effects on hearing loss. The following research questions were assessed: (1) what is the maximum peak output of various Bluetooth headsets coupled to a cellular phone; (2) what is the average output of various Bluetooth headsets coupled to a cellular phone; and (3) what is the frequency response of various Bluetooth headsets coupled to a cellular phone? Sixteen Bluetooth headset devices of various manufacturers were used for this study. Bluetooth headsets used for this study were determined by consumer demands and lack of output specifications provided by their manufacturers. Each Bluetooth device was coupled to a Blackberry Curve cellular phone and volume level was set to maximum intensity for both devices. Sound pressure levels were obtained for each Bluetooth device using KEMAR to measure average SPLs using the A-weighted scale and a speech stimulus at input levels of 50, 70, and 75 dB SPL and a 90 dB SPL input swept-tone. SPLs measurements were also obtained using a 2cc coupler for a 50, 70, and 75 dB input speech stimulus and a 90dB swept-tone. The results revealed that most Bluetooth devices measured on KEMAR produced peak and average SPL values greater than 90 dBA SPL using a 70 and 75 dB SPL input speech stimulus and a 90 dB SPL swept-tone. Measurements obtained on a 2cc coupler showed that most Bluetooth devices produced mean averages of 90dB SPL or more using a 70 and 75 dB SPL input speech stimulus. Mean peak values exceeded 100 dB SPL with a 70 and 75 dB input speech stimulus. Additionally, frequency response for most Bluetooth devices measure on KEMAR and 2cc coupler produced a relatively flat frequency response in the low frequency range, peaked around 2500 Hz, and then rolled-off. Overall, most Bluetooth devices coupled to a cellular phone produced SPL values that exceeded OSHA standards. Therefore, Bluetooth devices used for an extended amount of time could possibly but hearing sensitivity at risk resulting in temporary and/or permanent hearing loss.

Keywords: *Hearing loss, Bluetooth, Bluetooth Specifications, Noise induced hearing loss, Maximum sound pressure level*

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GS Form 14
(5/03)

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ACKNOWLEDGEMENTS

I would first like to thank God Almighty, my Lord, and Savior Jesus Christ for giving me this opportunity and making this possible, because without Him, I am nothing. I would like to give a special thanks to my father, Alexander L. Anderson, my mother, Martha S. Anderson, and my sister, Lashunda L. Anderson for all their love, support, and encouragement throughout this process. I would also like to thank a special friend, Brian Lindsey and Johnell Anderson-Goins for their friendship and support throughout the years. I would like to acknowledge my Dissertation Committee, Melinda F. Bryan; Ph.D., CCC-A, Matthew D. Bryan; Au.D., CCC-A, and Steve G. Madix; Ph.D., CCC-A for their guidance, support and assistance throughout this process. I would like to give a special acknowledgement to my Dissertation Director, Melinda F. Bryan, Ph.D.; CCC-A for all her time, patience, dedication and support to this project. Last but not least, I would like to thank my church family, friends, and classmates for all their support throughout my academic career.

CHAPTER I

INTRODUCTION

Hearing loss affects about 40 million people in the United States. Furthermore, nearly 26 million hearing impairments are caused by over exposure to loud levels of sounds from noise at work or leisure activities (NIDCD, 1999). The current rise of noise induced (NIHL) hearing loss has resulted from the increased use of personal listening devices (Loftis, 2007). Personal listening devices that are used with earbuds, such as portable radios, iPods, MP3 players, cellular phones, and Bluetooth headsets, can cause increased sound levels up to 10 decibels compared to headphones. Both, however, can produce listening levels that are potentially harmful to hearing acuity (Loftis, 2007).

To this end, the American Speech and Hearing Association (2009) measured output levels of various popular personal listening devices. Devices used in this study included (1) Apple iPod; (2) Creative ZEN Nano Plus; (3) Sony Walkman MP3/ATRAC3plus; (4) iRiver T10; (5) Dell Latitude D610 Laptop; (6) Dell Axim X5; (7) Motorola Motostart H700 Bluetooth; (8) Bratz: Liptunes MP3 Player, and (9) Disney Mix Stick. All of these devices were found to exceed federal safety regulations with sound levels greater than 85 decibels (OSHA, 2002). The Motorola H700 Bluetooth produced output levels up to 106 dBA SPL. Moreover, childhood social and educational issues associated with hearing loss can potentially be influenced by the use of personal listening devices (ASHA, 2009). Currently, research has revealed warning signs of NIHL and produced guidelines to minimize the risks that are associated with personal listening devices; however, these specifications are often times not listed in the user manuals for these devices (Loftis, 2007).

Consequently, consumers of Bluetooth headset devices that couple to cellular phones are suing manufactures for not producing warning labels for potential hearing damage caused by exposure to loud levels of sound. Recently, a California resident sued Motorola Inc. for failing to warn users of potential hearing damage caused Bluetooth headsets that are used at high volumes for extended use of time (Glenn, 2006). Similarly, three residents of Virginia are suing Motorola Inc. for selling Bluetooth headsets and failing to warn users of potential hearing loss (McGlone, 2007). This law suit also points out other manufactures like Plantronics and Jabra for producing Bluetooth headset technology that could be pose potential damage on hearing sensitivity (McGlone, 2007). Consumers of Bluetooth devices are focusing on Bluetooth headsets that are worn directly over the ear allowing extreme signals to be streamed directly into the ear posing a threat of permanent hearing damage (McGlone, 2007).

Furthermore, evaluations have been conducted to assess hearing loss associated with intensive use of cellular phones that correlate with electromagnetic field transfer and acoustic stimuli. Callejo et al. (2005) evaluated the relationship between phone time use and hearing loss based on an increase in auditory thresholds, which possibly related to overexposure to high volumes of sound and electromagnetic field transmission.

The study revealed a relationship between frequent cellular phone use over a medium time period with mild hearing loss. Specifically, subjects showed an increase in air conduction thresholds ranging from one to five dB HL higher than the control group (Callejo, et al., 2005). On the other hand, Filgor (2009) argues that previous research does not prove an overwhelming relationship between personal listening devices and hearing loss. He believes that the increase in thresholds were not significant enough to isolate personal listening devices as a primary cause.

Moreover, researchers have begun measuring sound output levels for some personal listening devices in order to warn users of potential hearing damage (ASHA, 2009). However, detail output specifications of Bluetooth headsets coupled to cellular phones have not been produced. With these specifications, indications of the possible effects of hearing loss caused by Bluetooth headsets coupled to cellular phones may be established. Therefore, the purpose of this study is to determine Bluetooth headsets specifications. With these specifications, indications of the effect of Bluetooth headphone output on hearing acuity can be determined. The following specific research questions will be assessed:

1. What is the maximum peak output of various Bluetooth headsets coupled to a cellular phone?
2. What is the average output of various Bluetooth headsets coupled to a cellular phone?
3. What is the frequency response of various Bluetooth headsets coupled to a cellular phone?

CHAPTER II

REVIEW OF LITERATURE

Bluetooth

Bluetooth wireless technology allows short range communication through radio waves without the use of cables or electric devices (Bluetooth Special Group, 2009). Bluetooth wireless technology often comes built into electronic devices. Bluetooth devices come with a computer chip and software that contains a Bluetooth radio, allowing an exchange of information like music, voice, and videos between two devices (Bluetooth Special Group, 2009). This exchange of information takes place within a small isolated area known as Personal Area Network (PAN), which covers up to 10 meters or 33 feet in distance (Bluetooth Special Group, 2009).

In a recent study, the Bluetooth Special Interest Group (SIG) partnered with research firm *Millward Brown* to evaluate Bluetooth wireless technology when compared to other wireless technology. Consumer awareness, attitude, and use of Bluetooth devices were assessed (Bluetooth Special Interest Group, 2005). The study included 1300 participants between the ages of 18-70 in the United States, United Kingdom, and Japan. It was conducted during the Fall of 2003 and then again during the Fall 2004. Results revealed that consumers in the United States, United Kingdom, and Japan showed an increase in awareness and recognition of Bluetooth technology from 44 to 77 percent.

Awareness of Bluetooth technology nearly doubled in the United States. Research also showed an increase in consumer selection of Bluetooth wireless technology when compared to other wireless technology and an increase in awareness for Bluetooth compatible devices (e.g., mobile phones, PDAs, and personal computers, (Bluetooth Special Interest Group, 2005). This rise in Bluetooth knowledge, sales, and compatibility has resulted in more Bluetooth headsets coupled to cellular phones.

Consequently, consumers of Bluetooth headset devices coupled with cellular phones could be exposed to loud levels of sound. Recently, a California resident is suing Motorola Inc. for failing to warn consumers of the potential hearing damage caused by its Bluetooth headset device when used at high volume levels for an extended amount of time. The suit alleges that Motorola had specific knowledge that their Bluetooth headset device could cause a noise induced hearing loss from normal and extended use. The suit also points out that Motorola Bluetooth headset produced sound levels up to 100 dB, which cannot be easily determined by consumers during use (Glenn, 2006).

Additionally, three residents of Virginia have filed law suits against Motorola Inc. for selling Bluetooth headsets without warning consumers of potential hearing loss (McGlone, 2007). The lawsuit also acknowledges two other Bluetooth companies, Plantronics and Jabra for developing technology that is damaging hearing sensitivity without fair warning. The suit points out that companies like Motorola Inc. are selling Bluetooth headsets that attach to the ear allowing high sound level to stream directly into the ear that could cause permanent hearing loss.

Furthermore, the American Speech and Hearing Association (ASHA) evaluated the effects of personal listening devices on hearing loss. Nine popular personal listening devices including (1) Apple iPod; (2) Creative ZEN Nano Plus; (3) Sony Walkman MP3/ATRAC3plus; (4) iRiver T10; (5) Dell Latitude D610 Laptop; (6) Dell Axim X5 Handheld; (7) Motorola Motostart H700 Bluetooth; (8) Bratz: Liptunes MP3 Player and (9) the Disney Mix Stick were assessed. Measurements were taken at the following volume levels: (1) full-on; (2) 3 quarters; (3) half-on; (4) 1 quarter, and (5) low. Music was randomly tested on each device except for the Motorola Motostart H700 Bluetooth, which was only tested with voice. Results showed with volume level set to full-on that these personal listening devices produced output levels above 85 dBA, which exceeds federal safety regulations (OSHA, 2002). However, full-on volume with a voice signal compared to music appeared to be slightly reduced in output. Researchers suggest that manufactures collaborate with ASHA to better inform consumers of the high risk of hearing loss associated with personal listening devices, especially devices targeted for children's use. ASHA stressed that the slightest hearing impairment can have negative effects on educational and social progress for children (ASHA, 2009).

Noise Induced Hearing Loss

Hearing loss can be diagnosed in many forms and affects about 40 million people in the United States. Nearly 26 million hearing impairments are caused by auditory damage from loud levels of sound (NIDCD, 1999). Approximately 20 million people are exposed to dangerous levels of sound on a daily bases (National Institutes of Health, 1990). Therefore, studies are constantly being conducted on sources of hearing loss and the importance of hearing conservation.

A recent study addressed the need for health care professional to promote education on noise induced hearing loss from portable listening devices like music players and cellular phones (Loftis, 2007).

Specifically, Loftis (2007) warned individuals of the warning signs of overexposure to loud levels of sound such as ringing in the ears and temporary threshold shifts (Loftis, 2007). Loftis (2007) stressed that smaller earbuds with longer battery power and direct insertion into the ear cause an increase risk of noise induced hearing loss. Specifically, earbuds that are placed inside the ear canal could increase volume level up to 10 decibels compared to headphones. Furthermore, users of cell phones coupled to Bluetooth headsets often listen at increased volume levels to diminish the effects of the ambient background noise. This study produced some general guidelines to help listeners reduce the risk of hearing loss associated with personal listening devices. The guidelines included (1) if music or sound can be heard by others not wearing the headset, the volume should be reduced; (2) parents of children who listen to portable devices should set limitations on volume control and purchase modified earbuds; (3) avoid turning volume up to block surrounding noise; (4) use headphones instead of earbuds; and (5) apply the 60/60 rule: listen to volume at 60% of its potential up to one hour a day (Loftis, 2007).

Additionally, a study was conducted to evaluate noise level measurements of personal stereo players in 'real world' situations (Williams, 2005). Selection of participants was based on individuals using personal listening devices while passing on the streets. Measurements were taken using a Knowles Electronic Manikin for acoustic research (KEMAR) from their personal listening devices at the initial volume when asked to participate. The measured time was two minutes. Also, participants answered a short survey about use of their personal listening device. The questions included: (1) hours of daily use; (2) years of use; (3) age; (4) incidence of tinnitus; (5) self-reported family history of hearing loss; (6) conventional difficulty in background noise, and (7) occupation. The results showed that the there was not a significant risk of hearing loss from the measured noise exposure alone. There failed to be any correlation between self-reported hearing loss and tinnitus (Williams, 2005).

Oktay & Dasdag, (2006) further investigated the effects of intensive and moderate cell phone use on hearing acuity. Specifically, the purpose of this study was to evaluate the radiation transfer from mobile phones and its effects on hearing sensitivity. The following three groups participated in this study: (1) 20 men who used the cellular phone for about two hours per day for approximately four years; (2) 20 men who have used a cellular phone for 10-20 minutes per day for four years, and (3) 20 healthy men who have never used a cellular phone. Pure tone audiometric and brainstem evoked response audiometric (BERA) were used to measure hearing sensitivity of subjects. Results revealed higher thresholds for subjects who used cellular phones for two hours a day compared to moderate users and the control group. Overall, BERA show no significant difference between moderate mobile users and the control group.

Furthermore, Filgor (2009) pointed out that previous research has failed to show an overwhelming relationship between hearing loss and use of personal listening devices (Filgor, 2009). He argued that there is no damage risk criterion for recreational use of personal listening devices because it is based on hearing loss accumulating over a 40 year period and that children and adolescents' exposure to personal listening devices do not fall with that criterion. He noted that the clinical evaluation of pure tones and otoacoustic emissions that are measured immediately following exposure to high output levels from personal listening devices are not significant enough to correlate to permanent hearing loss. Filgor (2009) further states that his patients can listen to their personal devices at free will, keeping in mind that listening to evaluated levels for long durations of time might cause damage to hearing.

In a similar study, the correlation between hearing loss and its association with high volume and electromagnetic field transfer from cellular phones was assessed (Callejo et al., 2005). Cellular phones transmit signals through electromagnetic waves. The electromagnetic waves generally penetrate through the skull were cellular phones are placed near the ear and have been speculated to cause potential damage to auditory system (Callejo et al., 2005). Therefore, this study focused on high volume levels of cellular phone use and electromagnetic transmission and its effect on hearing loss (Callejo et al., 2005).

Two groups of listeners (control and experimental) were evaluated. The experimental group included 204 men and 119 women between the ages of 21 and 39 years. The inclusion criteria included (1) mobile phone use for less than one year; (2) no outer or middle ear disorders or growths; (3) normal hearing sensitivity; (4) no overexposure to work or recreational noise, and (5) no exposure to ototoxic drugs. The control group consisted of a group of age-matched listeners with normal hearing who were not cell phone users. All participants were asked to participate in two sessions. The first session consisted of otoscopy and the measurements of pure tone audiometry. The second evaluation was carried out 36 months later, and hearing sensitivity was measured at 500, 1000, 2000, and 3000 Hz. The sum of air conduction thresholds, pure-tone average, and percentage of hearing loss measurements were calculated from these frequencies. Results revealed a threshold increase of 1-6 dB HL for the cell phone users at the tested frequencies when compared to the control group. However, thresholds did not fall outside the normal range of hearing. The results also revealed an insignificant but strong correlation between time of phone use and amount of hearing loss. According to the results of this study, the relationship between cell phone use and hearing loss/auditory damage should be further investigated over a longer time and including subjects with pre-existing health conditions like diseases and exposure to ototoxic medication. Future study might also focus on other test environments that may enhance electromagnetic field transmission during cellular phone use.

In an additional study, the effects of the electromagnetic field of mobile phones on hearing was evaluated by outer hair cell function (Ozturan, Erdem, Miman, Kalcioglu, & Oncel, 2002). Changes in evoked otoacoustic emission (OAEs) were evaluated immediately following electromagnetic field transfer from mobile phone use. Thirty normal hearing adults (17 males and 13 females) between the ages of 19 and 36 years were studied. Subjects were excluded from this study if they had tinnitus, middle ear pathology, or a history of noise exposure. OAEs were conducted on each subject four times. Subjects held the activated mobile phone to their right ear for ten minutes without conversation to ensure that the measurement was one of electromagnetic field transmission only. Next, two baseline measures were taken. The third measure was conducted immediately following phone use, and the fourth test was conducted ten minutes after the third measure.

Results of this study showed that ten minute exposure to electromagnetic field transmission from mobile phones did not produce any changes in evoked OAEs.

Statement of the Problem

Noise induced hearing loss is a rapidly growing health concern within the United States. The use of personal listening devices coupled to Bluetooth devices could be a leading cause for the increase of hearing loss. Currently, research has shown an increase in Bluetooth developments; however, previous research does not indicate Bluetooth output specifications for headset devices. Presently, Bluetooth manufactures only present users with a general warning against loud volume levels during extended time of use (Plantronics Sound Innovation, 2009). Therefore, this study will determine maximum output, frequency response, and average output for various Bluetooth headset devices and its possible effects on hearing acuity.

CHAPTER III

METHODS AND PROCEDURES

Materials

Bluetooth devices were selected for this study based on high consumer use and lack of specific specifications from their manufactures pertaining to maximum levels of volume outputs. Two Blackberry cellular phones were used to receive and send test signals to the Bluetooth devices, respectively. The Audioscan Verifit was used to create a continuous speech noise and to measure 2cc coupler responses for each Bluetooth device. Knowles Electronic Manikin for Acoustic Research (KEMAR) torso and head was used to obtained A-weighed measures, which emulate the resonance of the natural human ear. Recording software by National Instruments was used to download sound pressure level parameter measurements from KEMAR for each Bluetooth device. Lastly, a computer with Microsoft Excel was used for subsequent data analysis.

Procedures

Bluetooth headsets were obtained from sending an email to Louisiana Tech University faculty and staff. It should be noted that because testing was completed using KEMAR and a 2cc coupler, this study was exempt from rules governing the Institutional Review Board (see Appendix A for exemption letter). Measures were obtained in quiet a room where ambient noise levels were monitored throughout testing with a sound level meter. When obtained, each Bluetooth headset was powered on and then paired to a

Blackberry Curve cellular phone (FCC ID: L6ARBU20CW) served by Verizon Wireless; this cell phone received the call and transmitted the received message through the Bluetooth device. An additional Blackberry Curve cellular phone served by Verizon Wireless was used to connect a call to the paired Blackberry Curve (i.e., phone that transmitted the call). The volume level for the Bluetooth device and both cellular phones was set to its maximum intensity. The Bluetooth device was then puttied on the right ear of KEMAR. The Blackberry Curve cellular phone transmitting the signal was placed inside the Audioscan Verifit with the top closed and calibrated for each Bluetooth device. This phone transmitted a continuous speech signal to the Blackberry cellular phone that was paired to the Bluetooth device and puttied to KEMAR's ear. The Audioscan Verifit transmitted a continuous speech signal using 50, 70, and 75 dB SPL input signals. A 90 dB swept-tone was also used to obtain maximum output with an intense input signal. Two 30 second measurements of the output signal were taken to be averaged for each of the input levels with each Bluetooth device using KEMAR. A-weighted sound pressure level measures for each Bluetooth device were obtained and download from KEMAR using sound level meter (SLM) software developed by National Instruments. Data was then downloaded to an IBM computer and placed in Microsoft Excel for subsequent data analysis.

Using the same set-up, an additional measure was made on a 2cc coupler using the Audioscan Verifit. The Bluetooth device remained paired to the Blackberry Curve cellular phone at its maximum volume level. The transmitting cellular phone remained inside the Audioscan Verifit with the top closed to receive the input signal.

The Bluetooth device was puttied to the 2cc coupler (Audioscan Verifit) and placed outside the Audioscan Verifit testbox. The transmitting Blackberry phone transmitted the continuous speech signal to the Blackberry cellular phone that was paired to the Bluetooth device and puttied onto the 2cc coupler. The Audioscan Verifit again transmitted a continuous 50, 70, and 75 dB SPL speech signal. Four measures were obtained for each of these input intensities for a total of 12 total measurements. Additionally, four 90 dB swept-tones were collected to measure the maximum output. For each input level, the four measurements were averaged and one overall output curve was obtained for each device. Furthermore, the sound pressure level measures obtained using the Audioscan Verifit were downloaded and converted into a Microsoft Excel spreadsheet for subsequent data analysis.

CHAPTER IV

RESULTS

The purpose of the current study was to obtain Bluetooth headset specifications while coupled to a cellular phone. Sixteen Bluetooth devices were obtained, coupled to a cellular telephone, and output sound pressure levels (SPLs) were measured for each device using both KEMAR and a 2cc coupler. First, KEMAR and a recording software developed by National Instruments was used to obtain average SPLs using the A-weighted scale (in 1/3 octave bands across the frequency range of 20 to 20,000 Hz) and a speech stimulus at input levels of 50, 70, and 75 dB SPL. A 90 dB SPL input swept-tone was also used to measure maximum power output for each Bluetooth device. Output SPLs for each Bluetooth device measured using KEMAR were downloaded into Microsoft Excel to determine a mean frequency response for each input level (i.e., 50, 70, 75, and 90 dB SPL). It should be noted that because the output SPL for most devices was greatly reduced below 200 Hz and at or above 8000 Hz, the frequency response curves are displayed from 200 to 8000 Hz for each device.

Additionally, SPLs were obtained using a 2cc coupler on the Audioscan Verifit. Four SPL measurements were obtained for each speech input signal of 50, 70, and 75 dB SPL, and a 90 dB SPL swept-tone for each Bluetooth device. SPL measurements were obtained in 1/12 octave bands across the frequency range of 200 to 8000 Hz.

Means were obtained for the four peak, average, and valley, and maximum output (i.e., 90 dB SPL swept-tone) measurements at each frequency for each Bluetooth device.

Figures 1- 32 show SPL values from 200 to 8000 Hz obtained using KEMAR (i.e., measurements taken using an A-weighted scale) and a 2cc coupler (i.e., measurements taken in SPL) for each Bluetooth device.

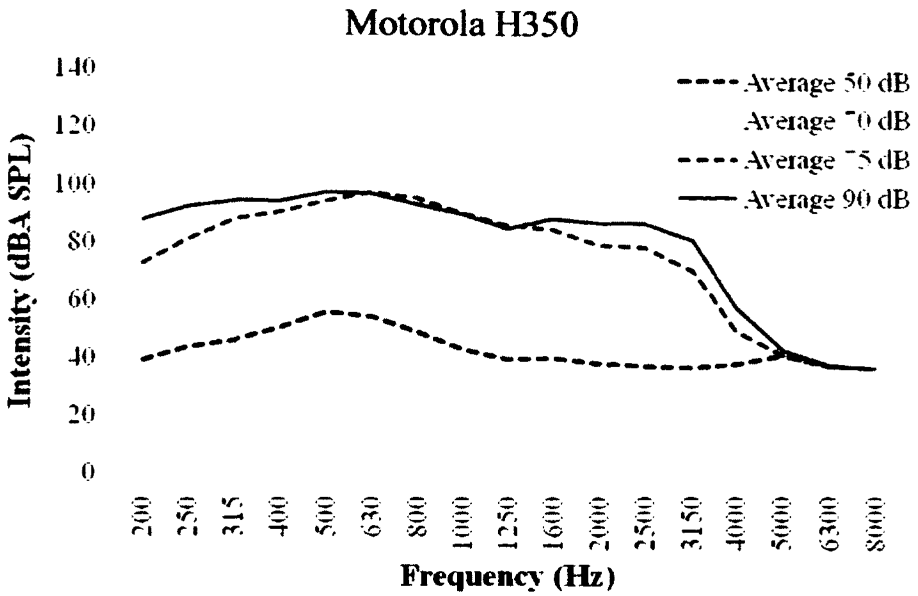

Figure 1. Motorola H350: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

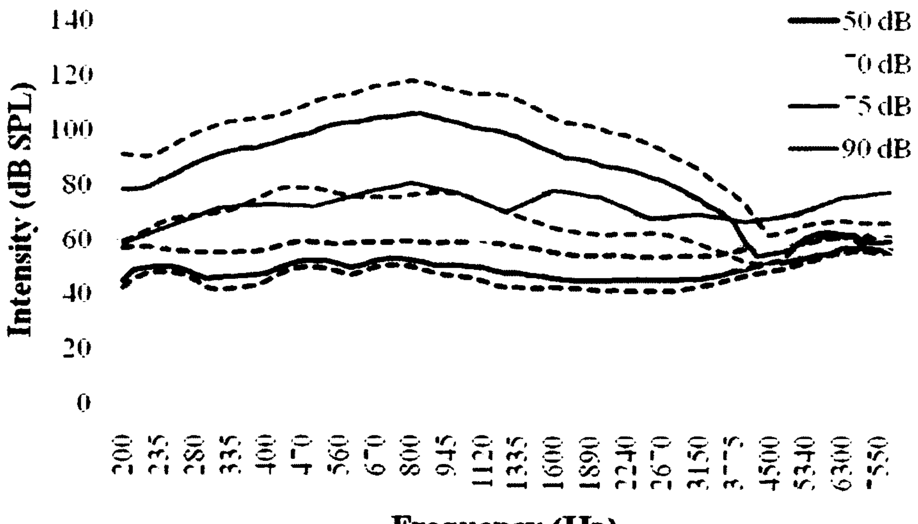

Figure 2. Motorola H350: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

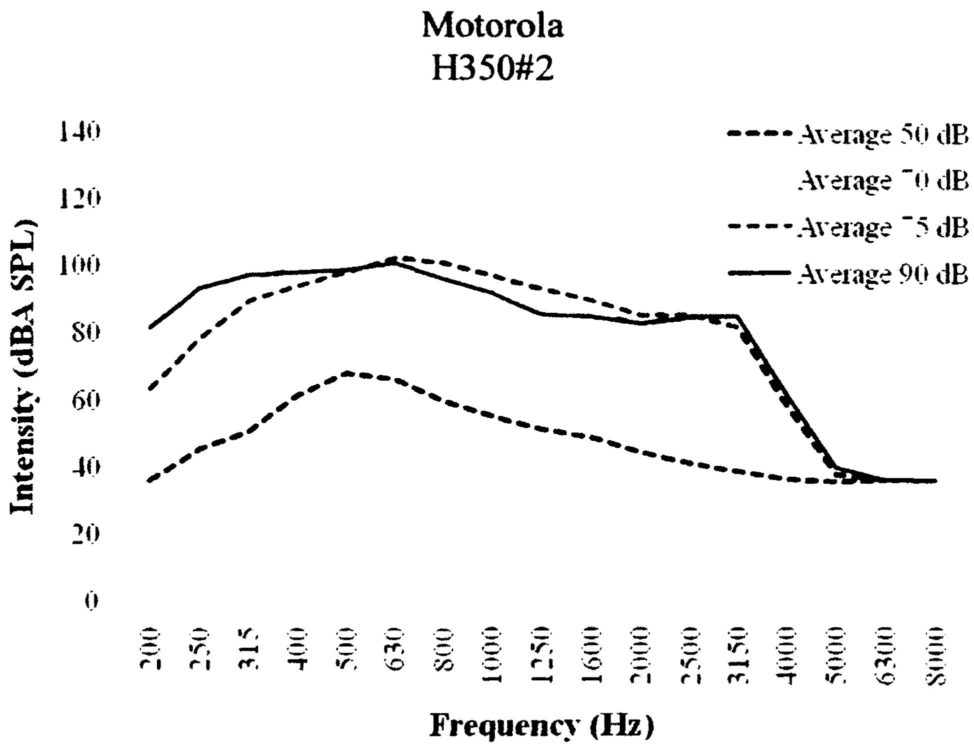

Figure 3. Motorola H350 #2: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

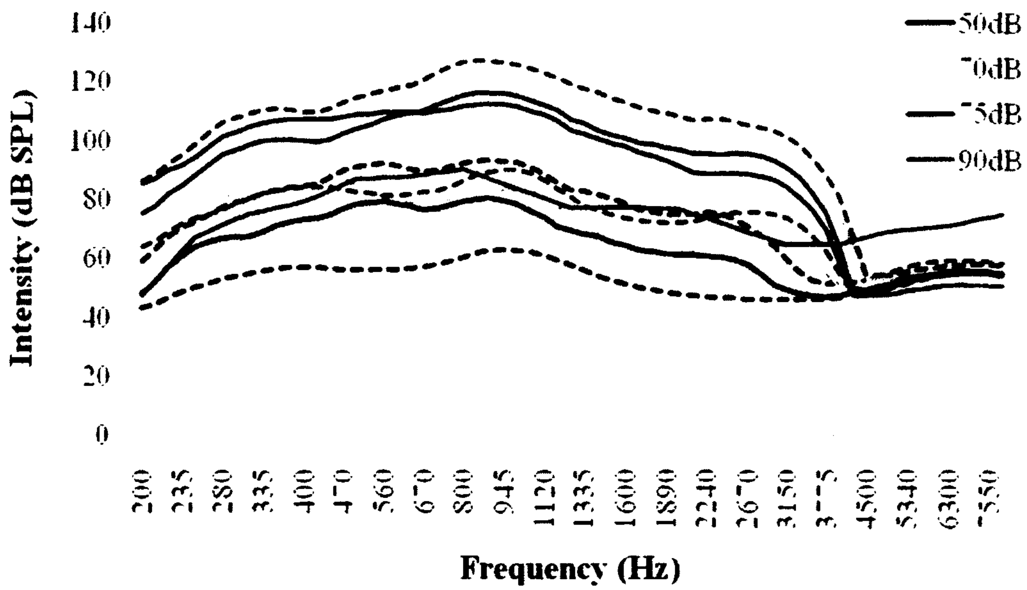

Figure 4. Motorola H350 #2: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

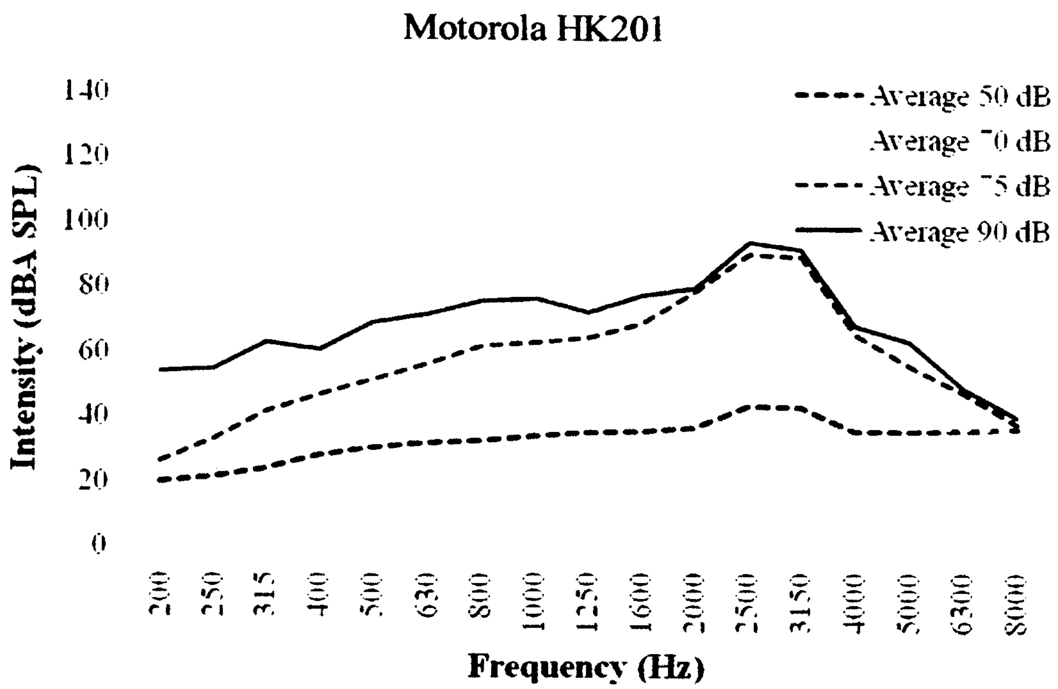

Figure 5. Motorola HK201: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

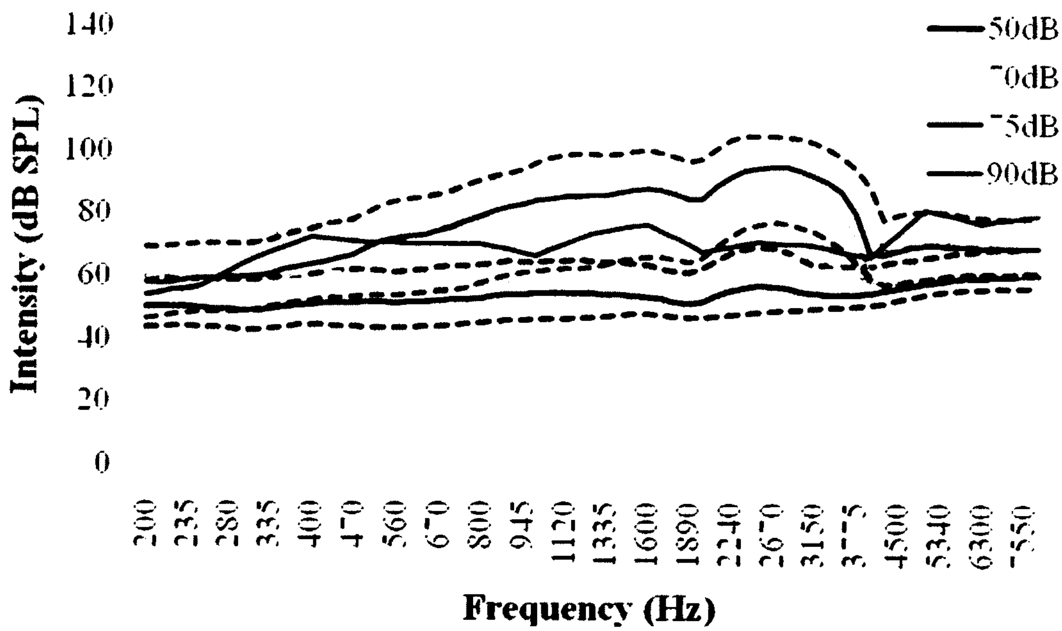

Figure 6. Motorola HK201: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

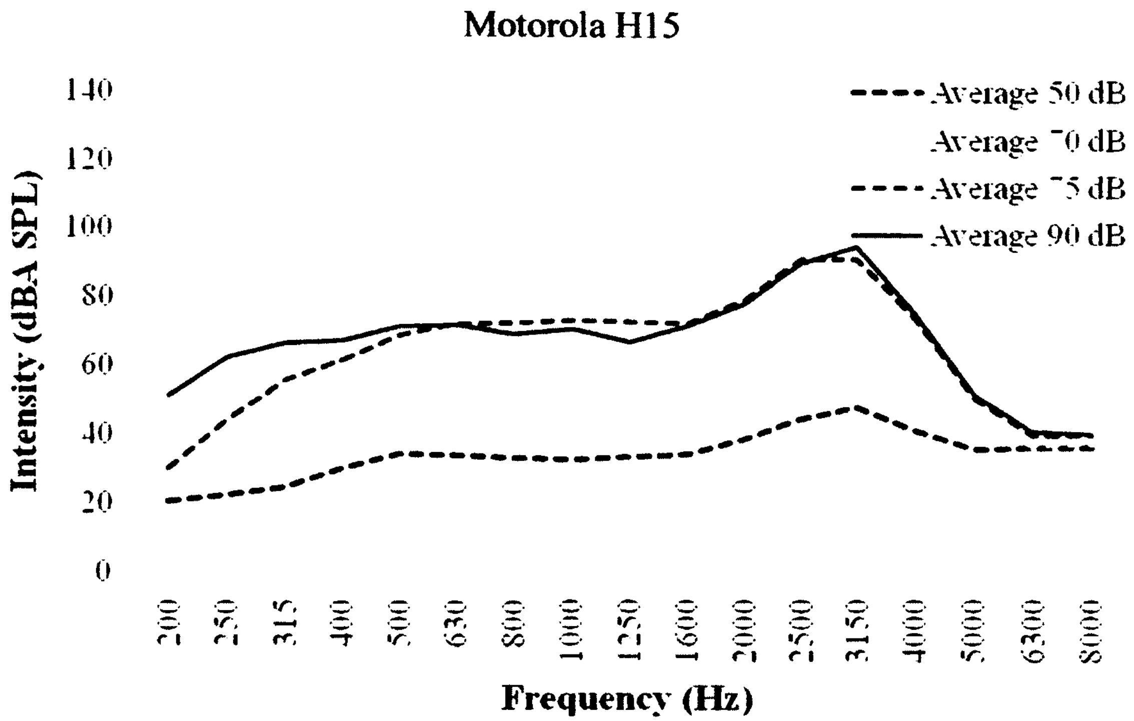

Figure 7. Motorola H15: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

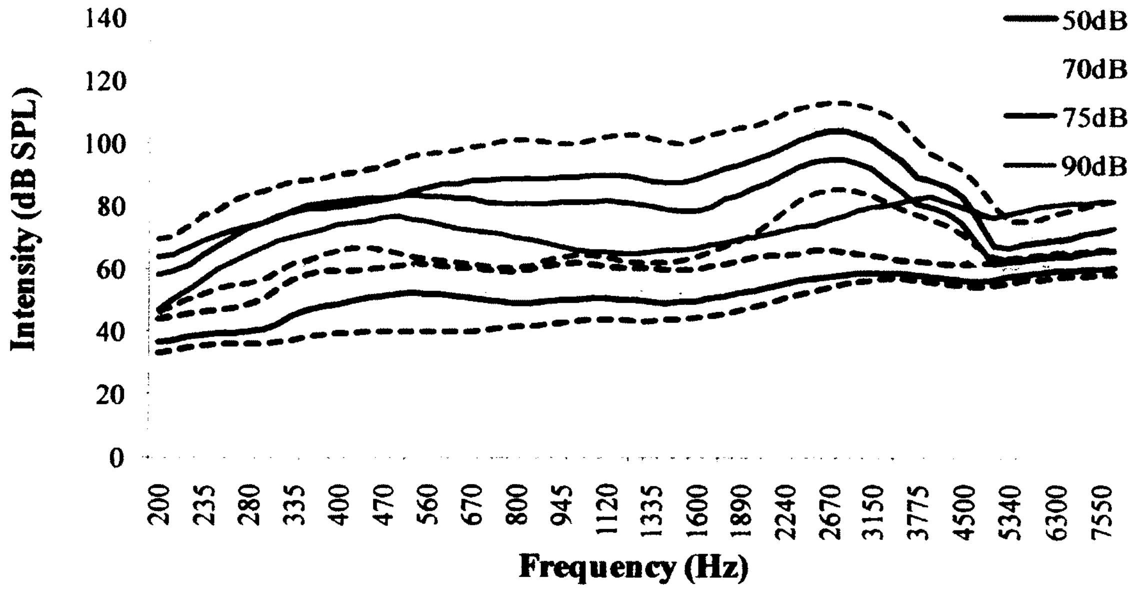

Figure 8. Motorola H15: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

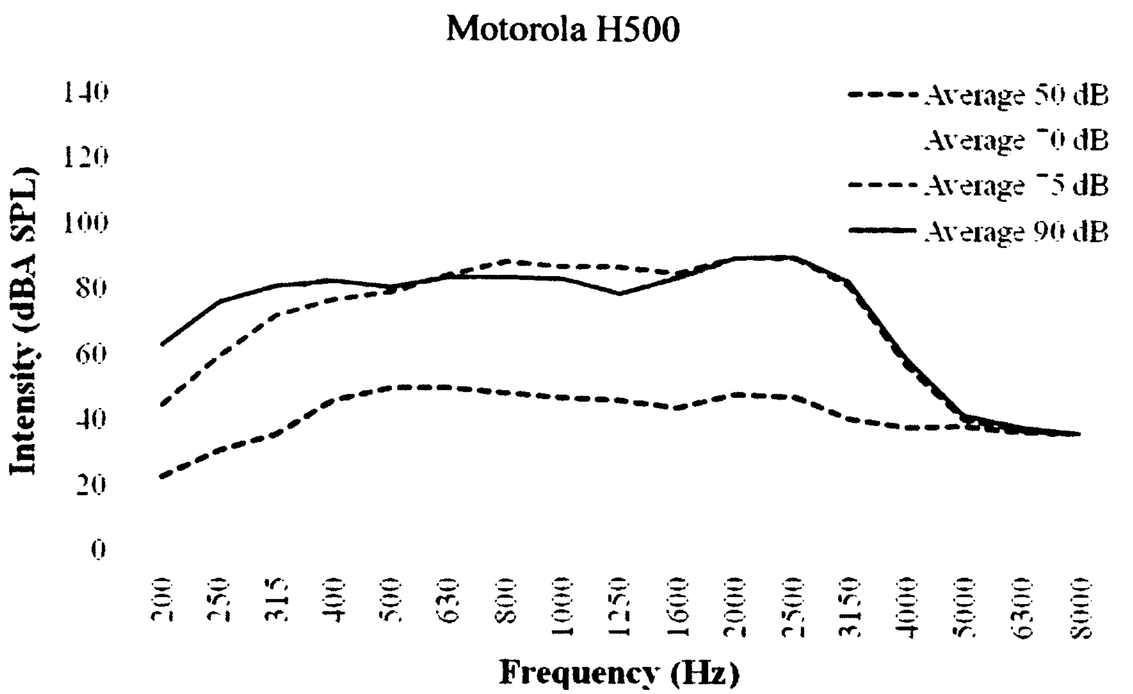

Figure 9. Motorola H500: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

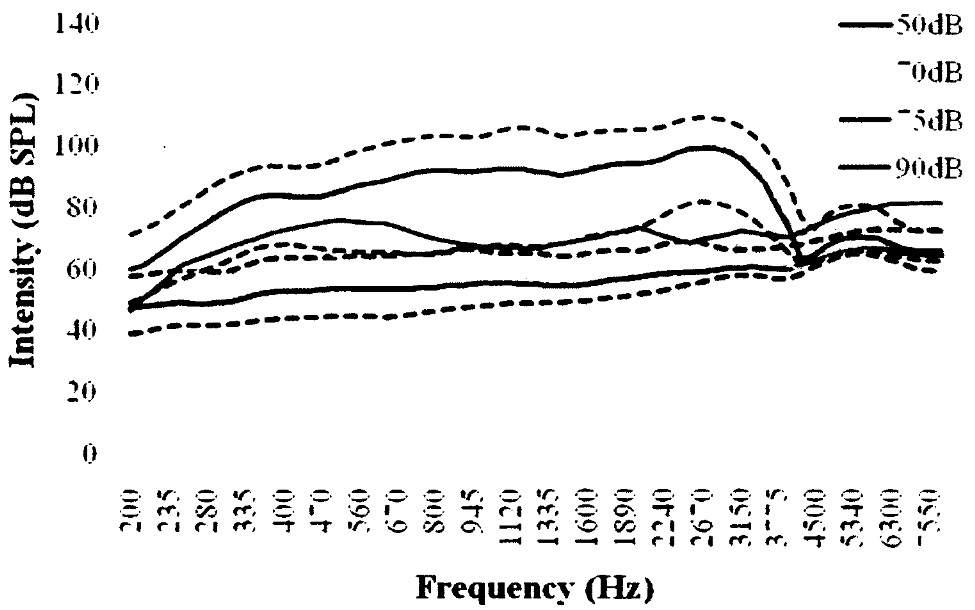

Figure 10. Motorola H500: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

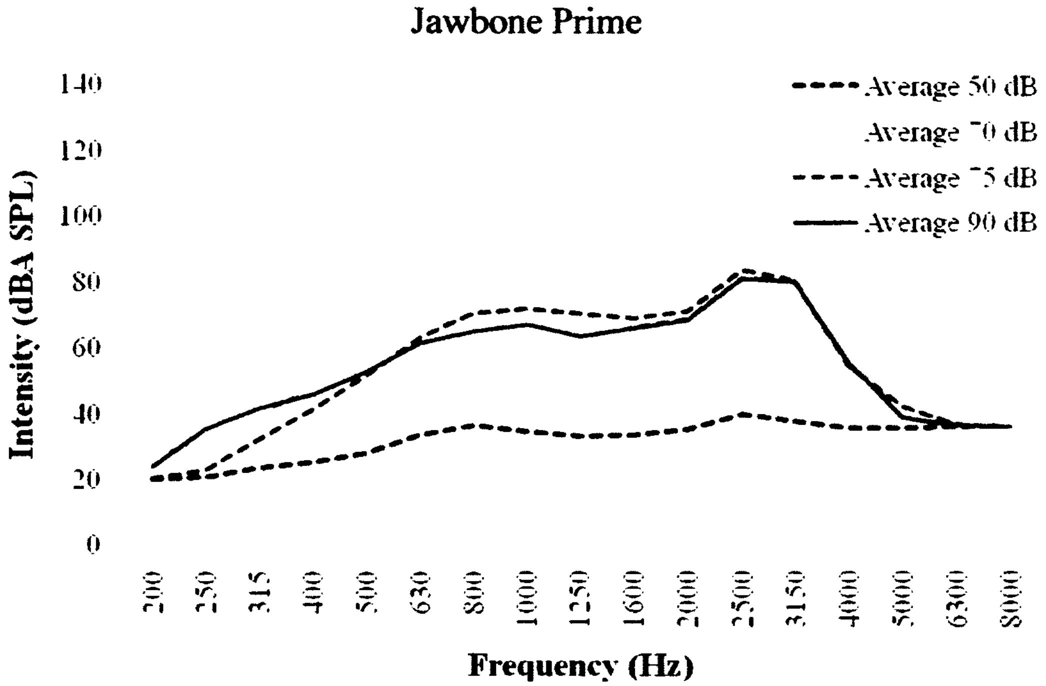

Figure 11. Jawbone Prime: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

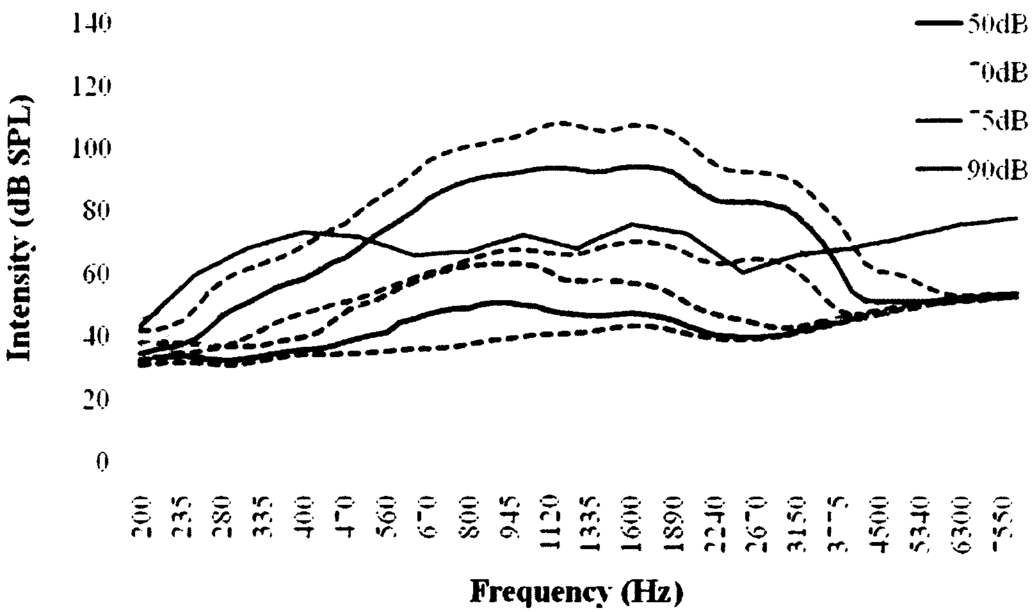

Figure 12. Jawbone Prime: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

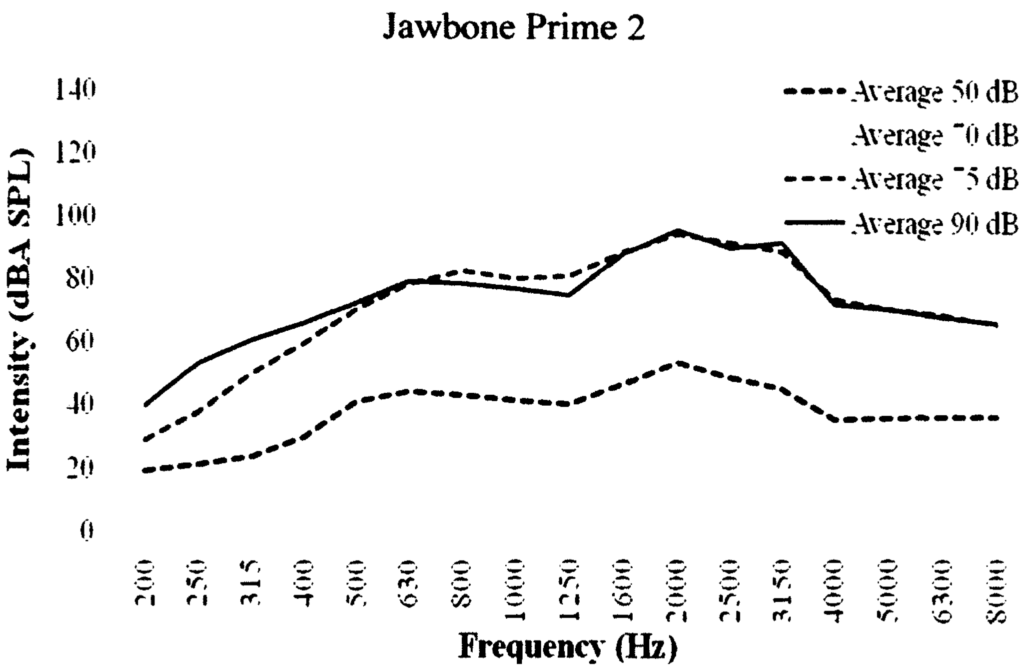

Figure 13. Jawbone Prime #2: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

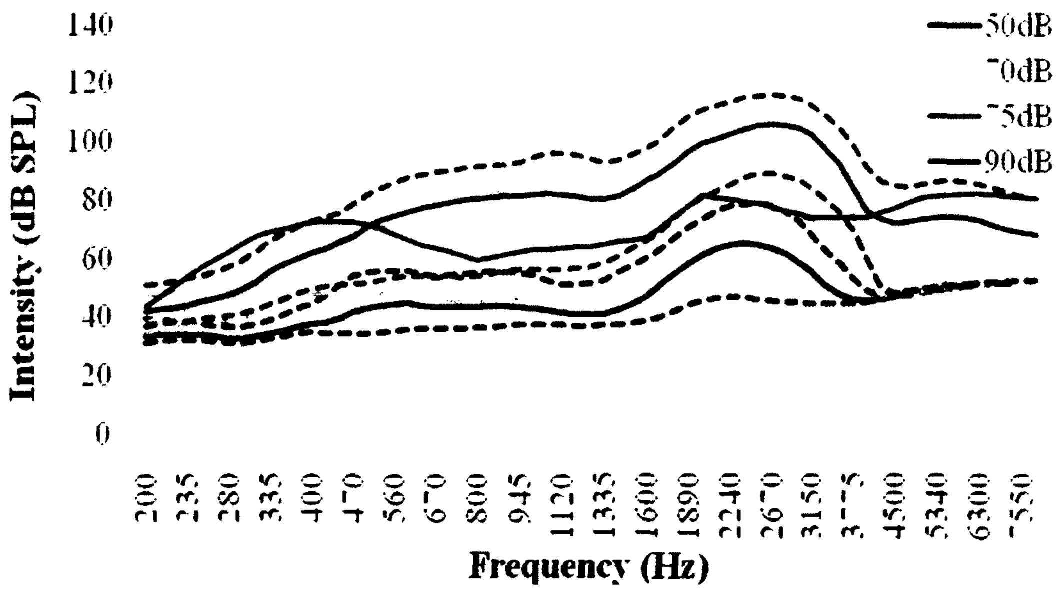

Figure 14. Jawbone Prime #2: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

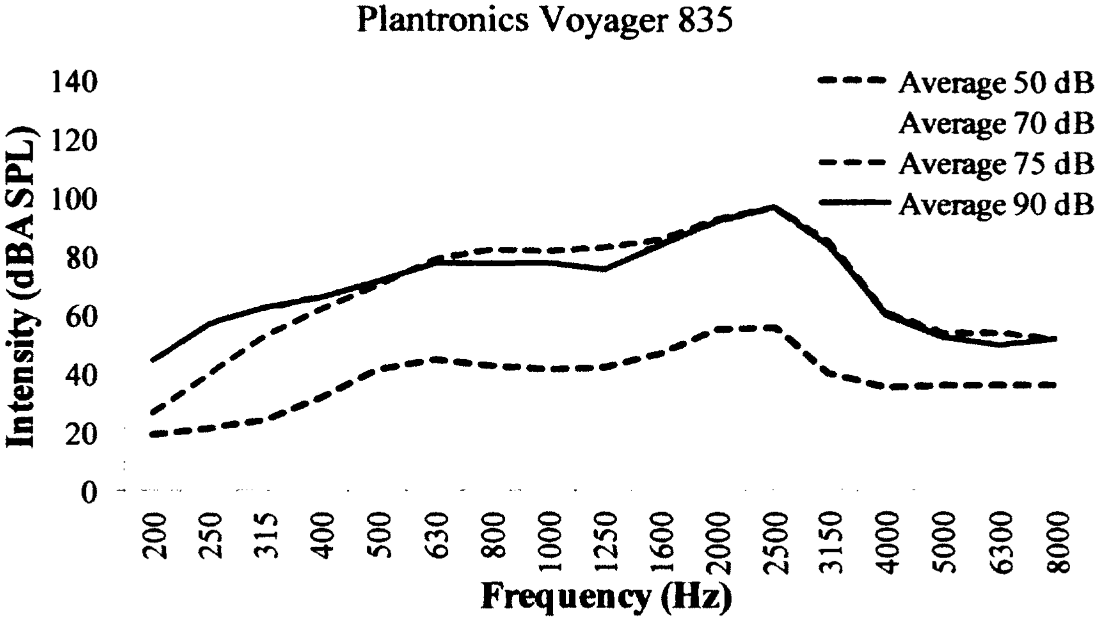

Figure 15. Plantronics 835: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

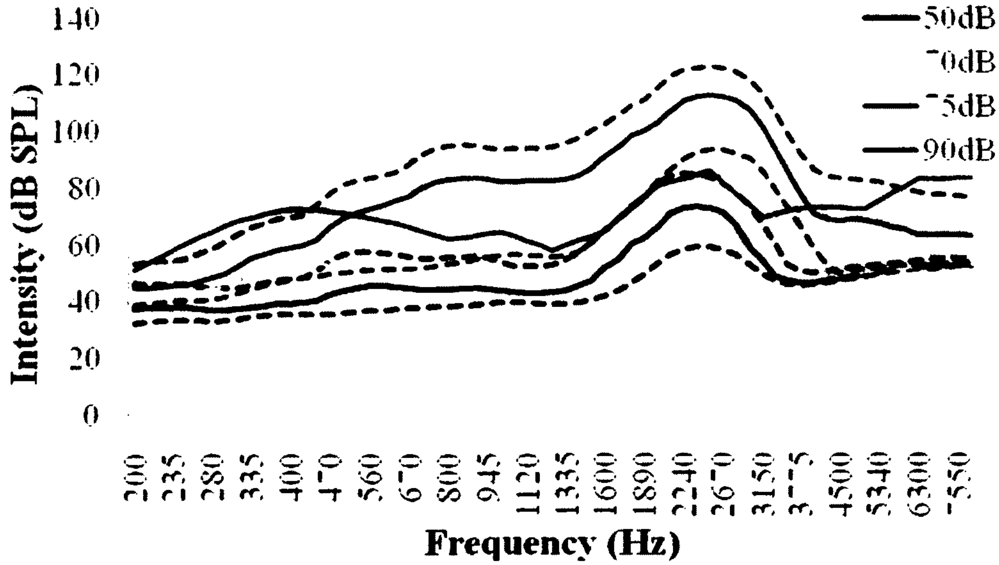

Figure 16. Plantronics 835: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

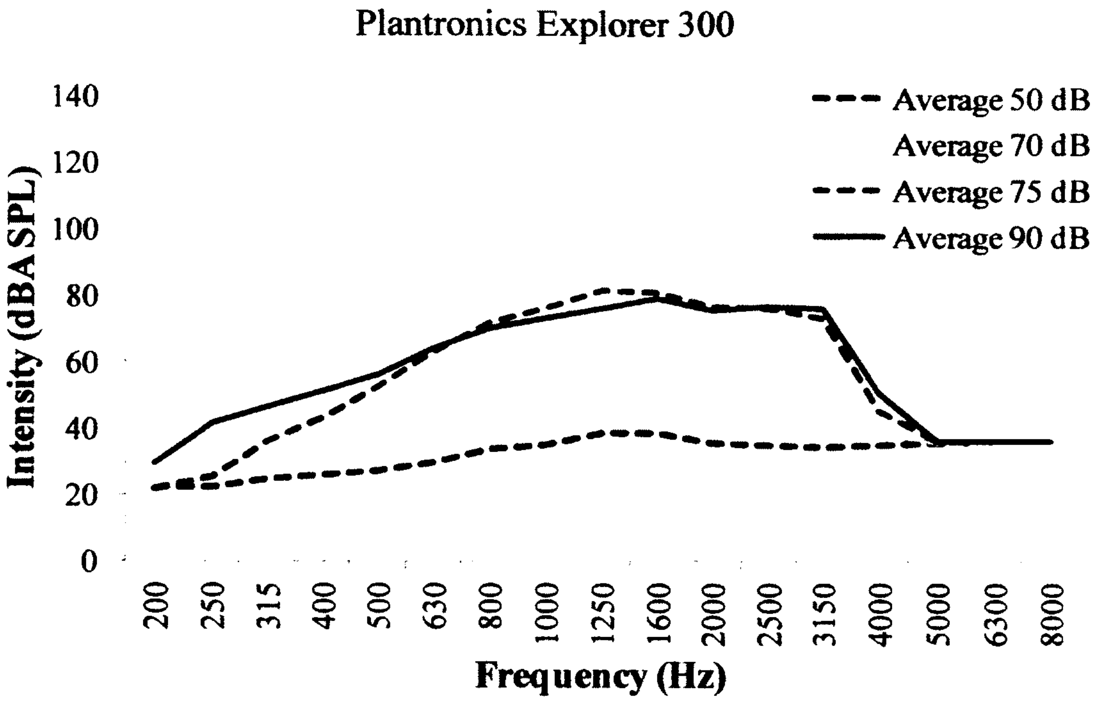

Figure 17. Plantronics 300: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

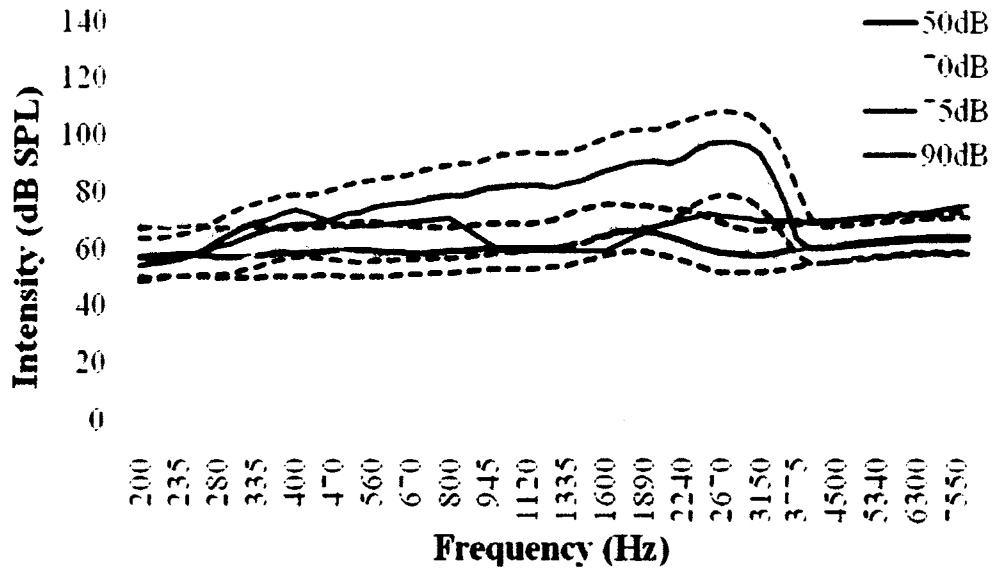

Figure 18. Plantronics 300: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

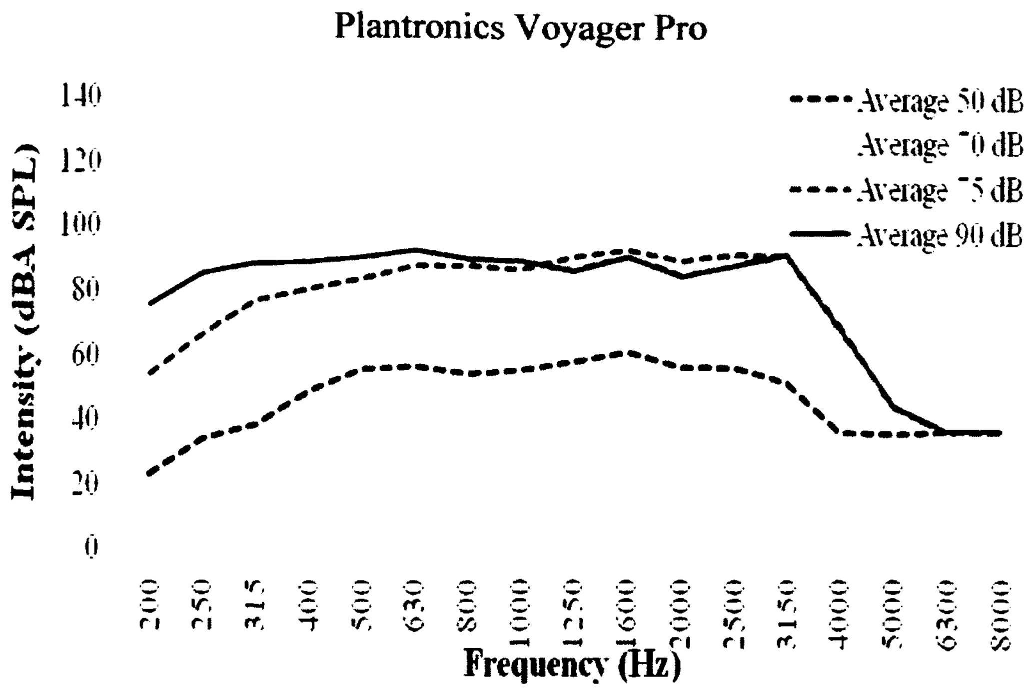

Figure 19. Plantronics Voyager Pro: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

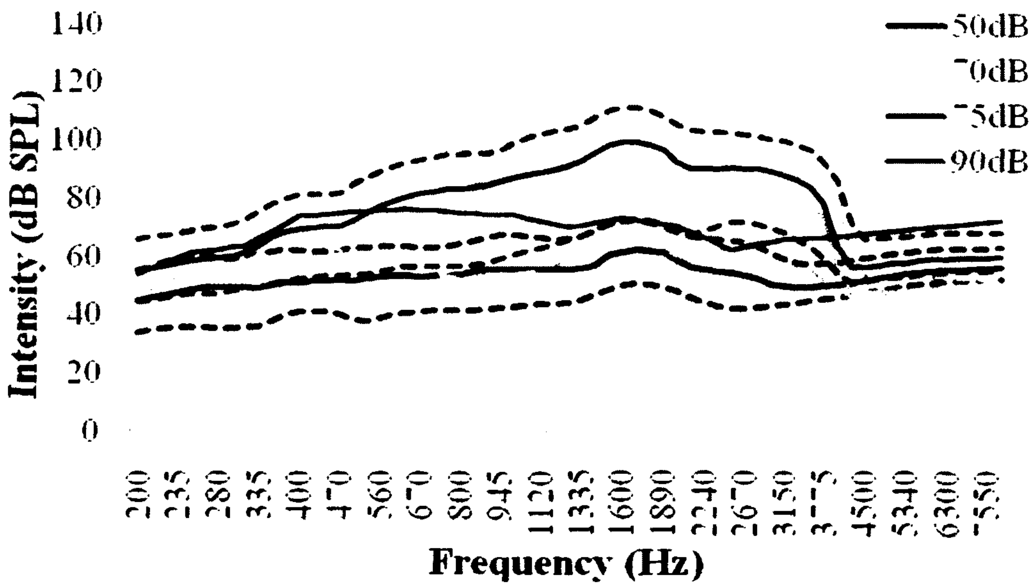

Figure 20. Plantronics Voyager Pro: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

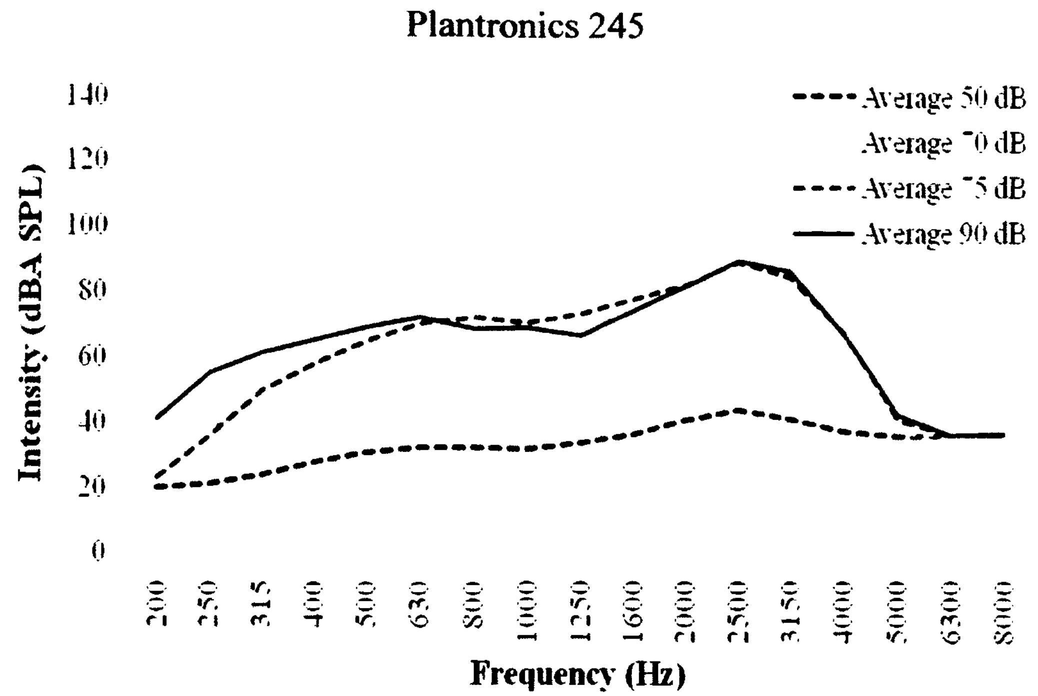

Figure 21. Plantronics 245: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

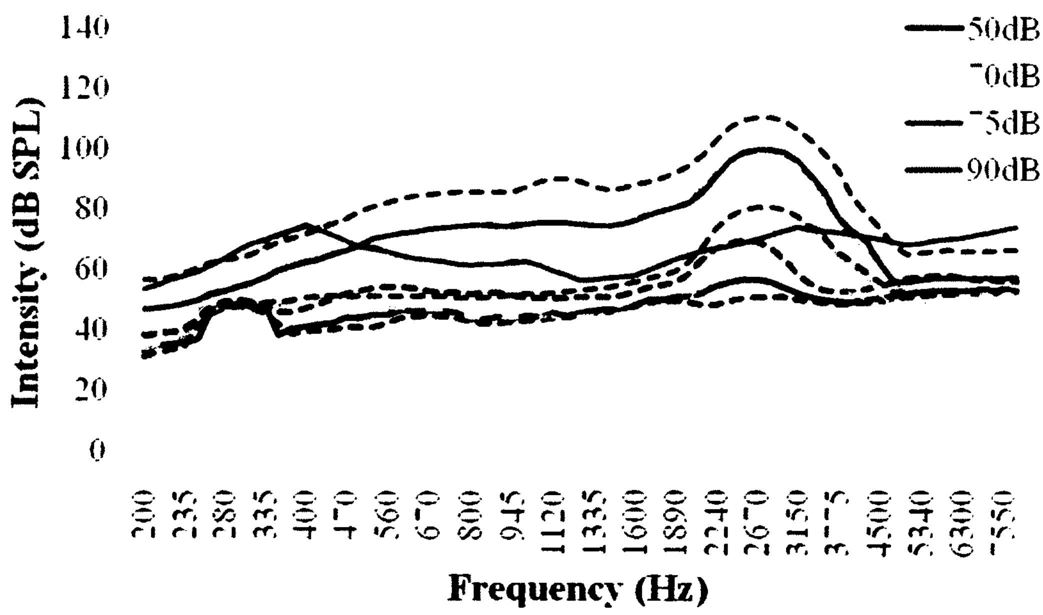

Figure 22. Plantronics 245: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

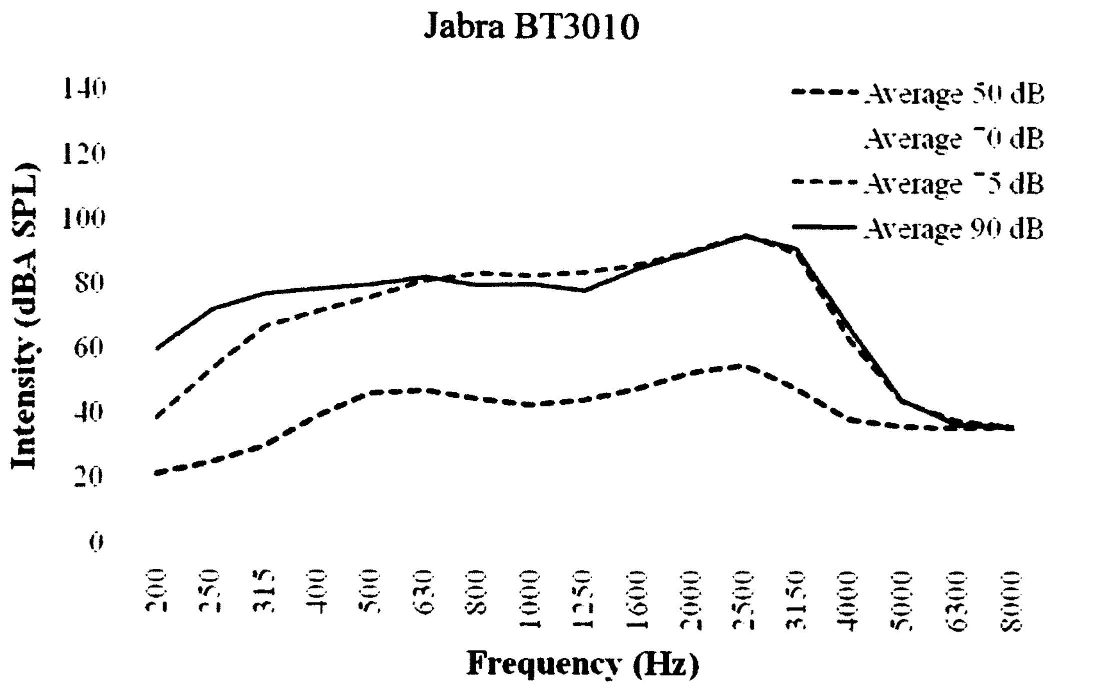

Figure 23. Jabra BT3010: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

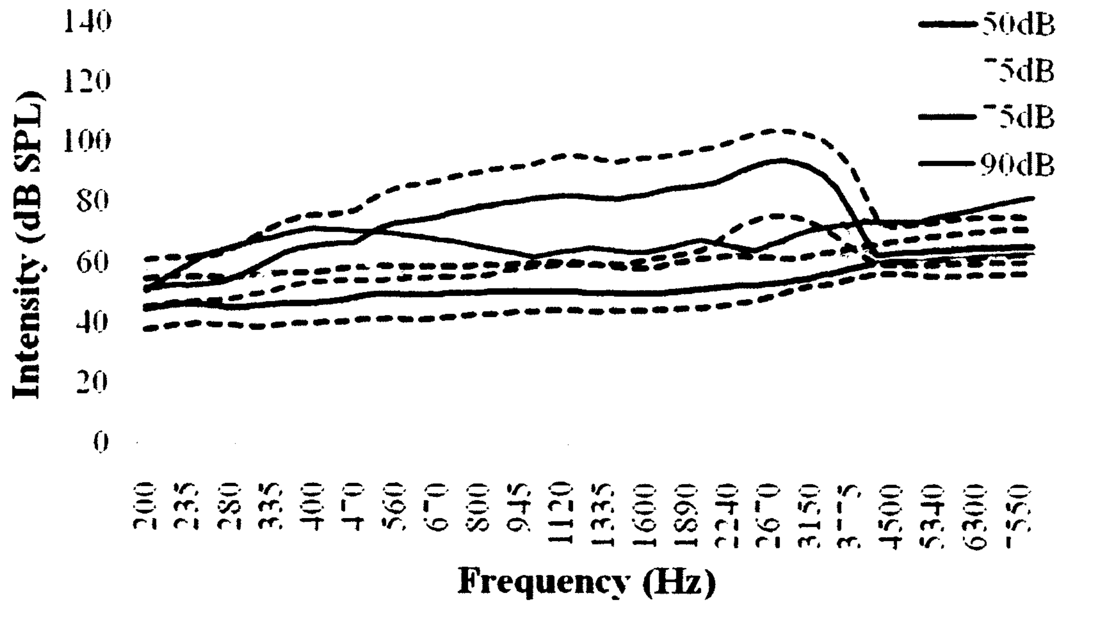

Figure 24. Jabra BT3010: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

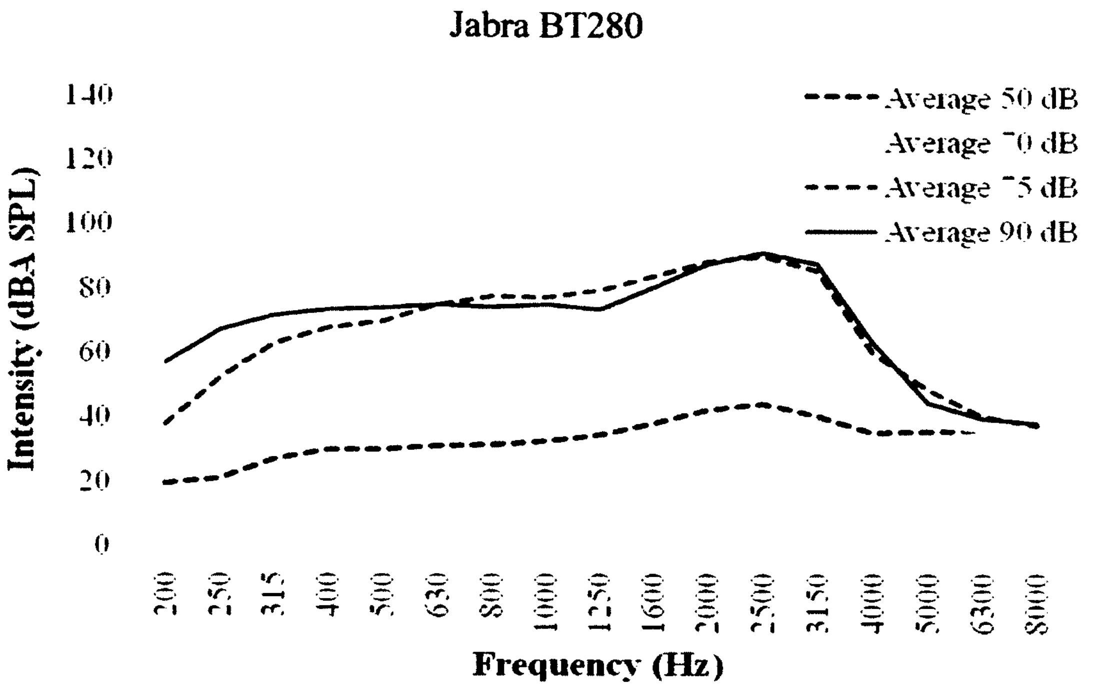

Figure 25. Jabra BT280: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

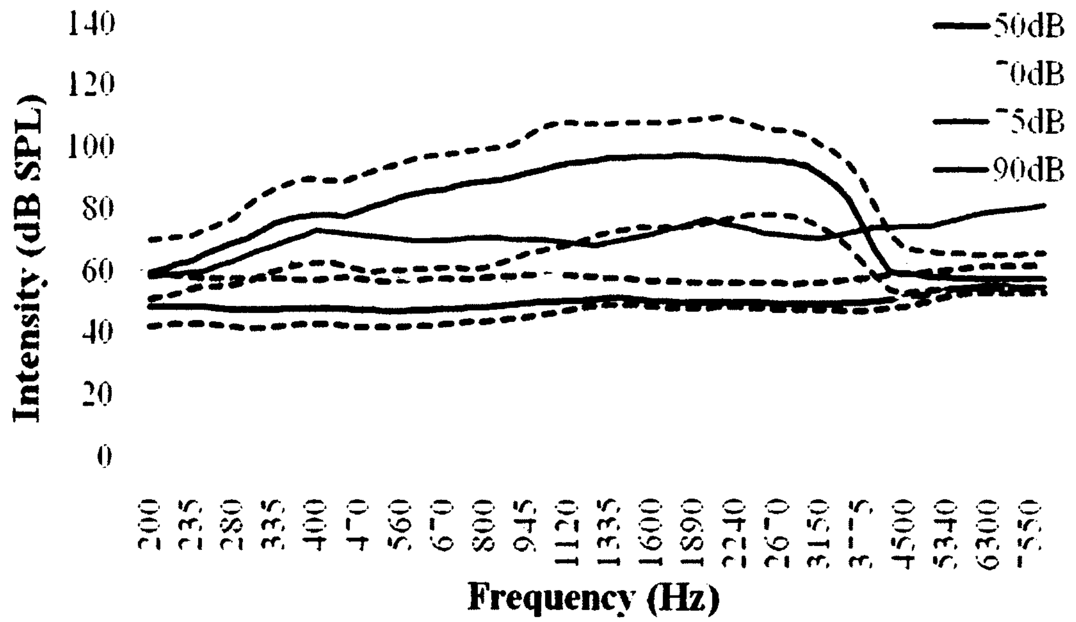

Figure 26. Jabra BT280: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

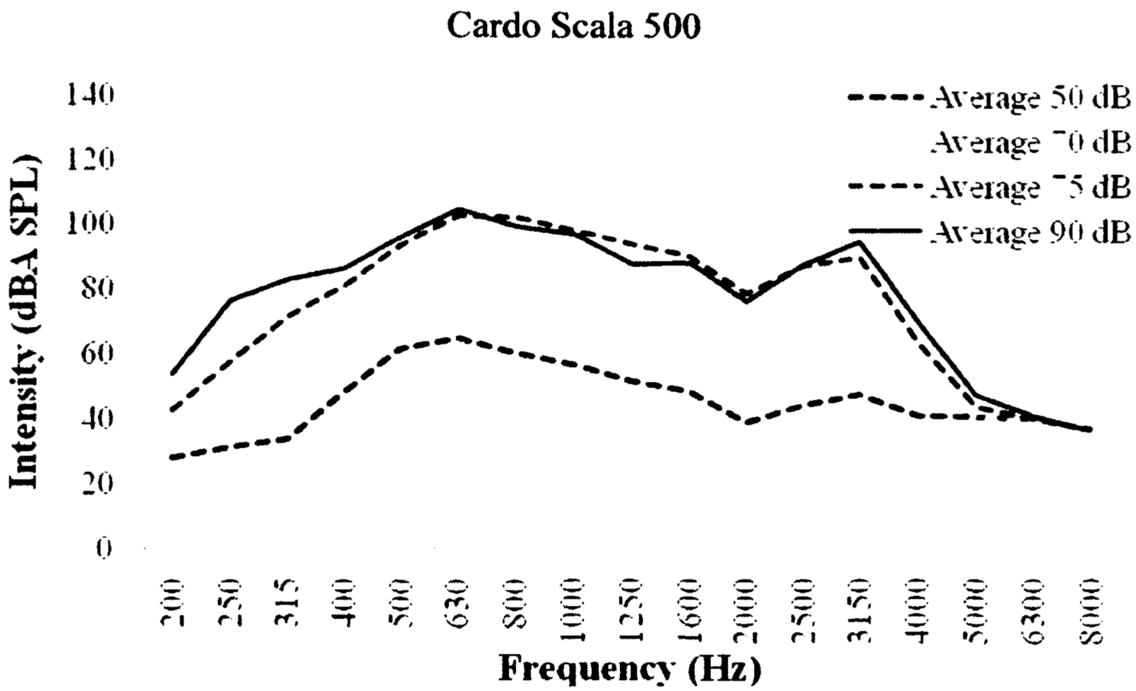

Figure 27. Cardo Scala 500: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

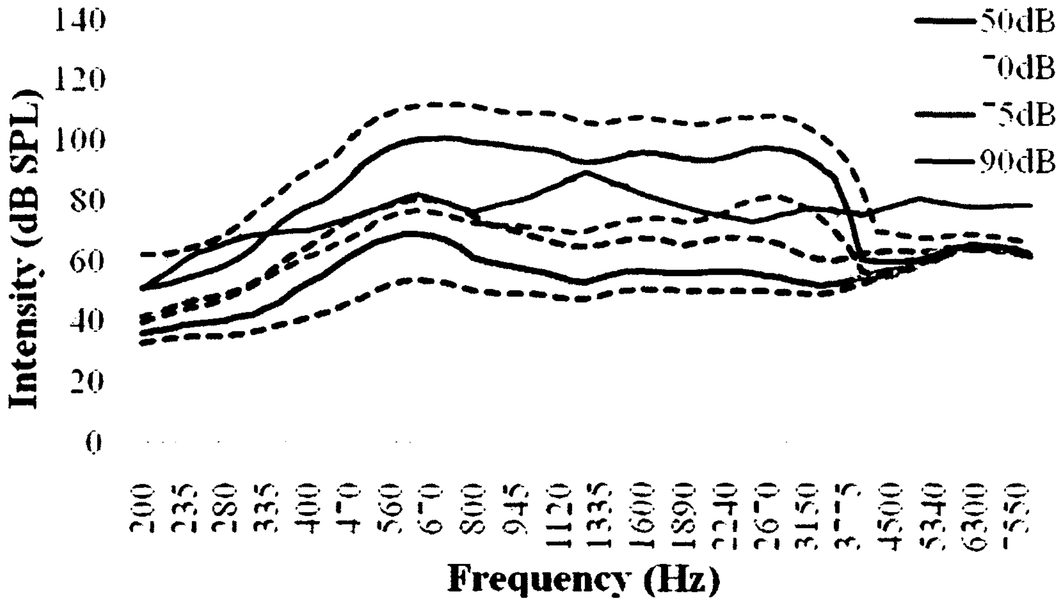

Figure 28. Cardo Scala 500: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

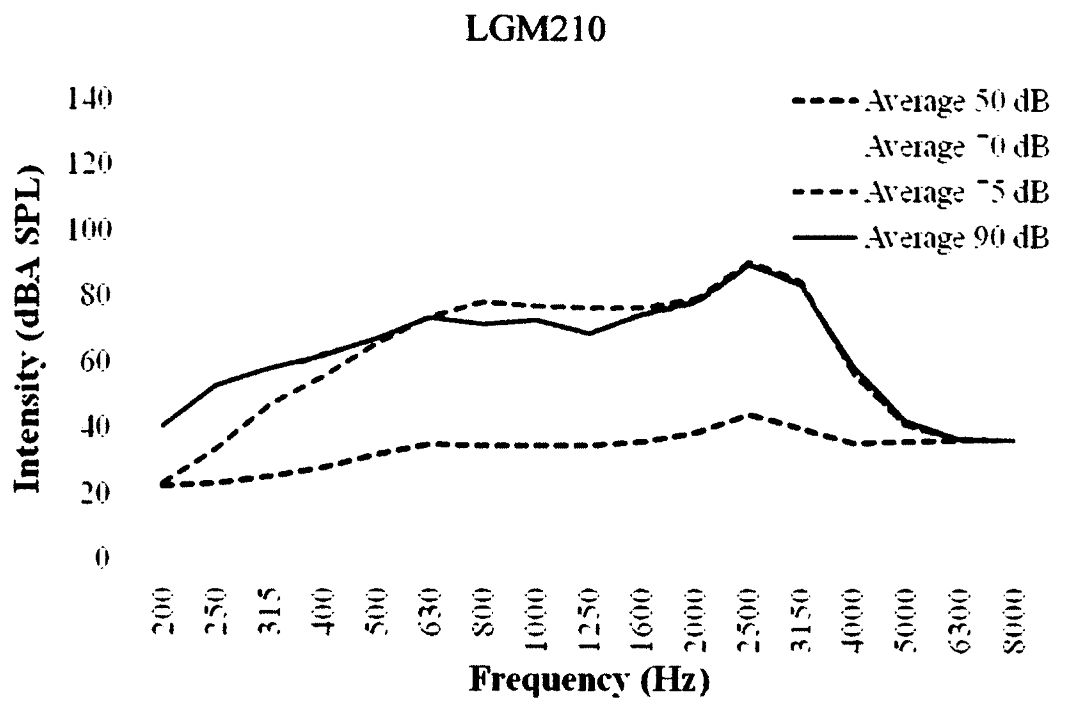

Figure 29. LGM210: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

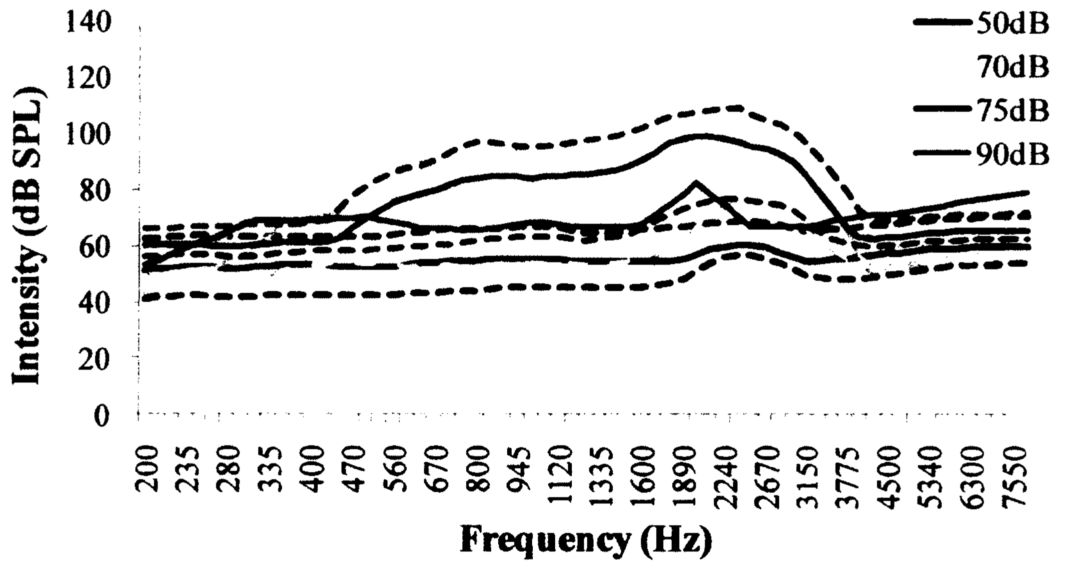

Figure 30. LGM210: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc. coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

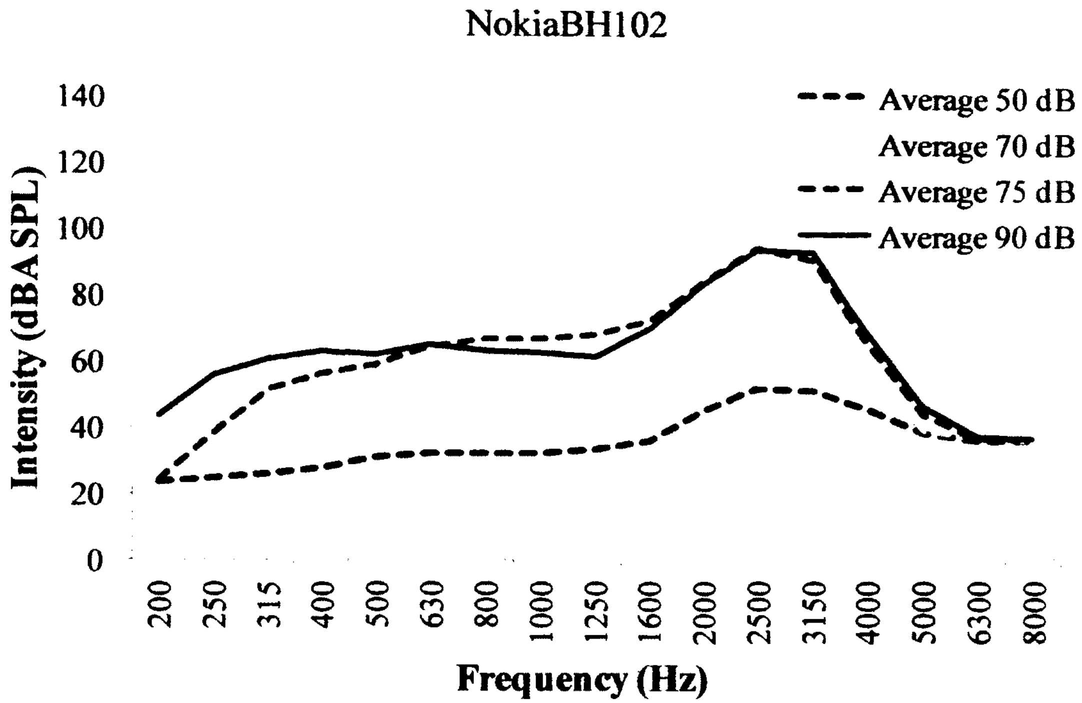

Figure 31. Nokia BH102: SPL as a function of frequency measured using KEMAR with an input speech stimulus at 50, 70, and 75 dB SPL and a 90 dB swept-tone.

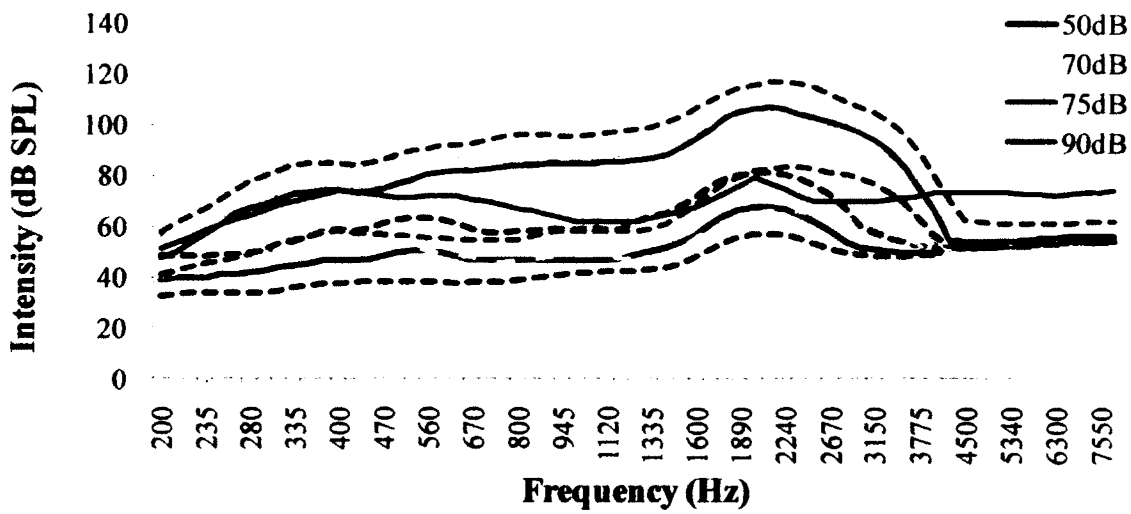

Figure 32. Nokia BH102: Mean peaks, averages, and valleys displayed as SPL as a function of frequency and measured on a 2cc. coupler with a speech stimulus at 50, 70, and 75 dB SPL and a 90 dB SPL swept-tone.

As displayed in Figures 1-32, A-weighted measures for each Bluetooth device coupled to a cellular phone were obtained on KEMAR (odd numbered Figures 1-32) to emulate the natural canal resonance of the human ear. The results showed that the frequency response for most Bluetooth devices were primarily flat in the low frequencies (200-2000 Hz) and peaking around 2500-4000 Hz. After that point, most frequency response curves showed significant roll-off. Furthermore, figures representative of SPL values taken on KEMAR showed that most Bluetooth devices exceeded SPL measures of 90 dBA , which is the permissible exposure limit of noise for an 8 hour time period (OSHA, 2002). Furthermore, Figure 3, the second Motorola H350, and Figure 27, the Cardo Scala 500, showed that both Bluetooth devices exceeded SPL values of 100 dBA. Most devices produced peak output levels of 90 dBA with the input of 70, 75, and 90 dB SPL. These results suggest that when input levels of 70-75 dB SPL (i.e., loud conversational speech) are heard through most Bluetooth headsets, the output levels could put hearing sensitivity at risk when used for an extended amount of time.

Measurements were also obtained on a 2cc coupler (even Figures 2-32), which represented averaged valley, average, and peak measurements for input speech stimuli of 50, 70, and 75 dB SPL and average peaks using a 90 dB SPL swept-tone for each Bluetooth device coupled to a cellular phone. Frequencies evaluated ranged from 200 to 8000 Hz. Again, most Bluetooth devices produced a frequency response that was relatively flat in the low frequency range, peaked around 2500-4000 Hz and then rolled-ff. Most Bluetooth devices produced mean averages of 90 dB SPL or more using the 70 and 75 dB SPL input speech stimulus and mean peaks over 100 dB SPL with the 70 and 75 dB SPL speech stimulus, again possibly producing dangerous levels of sound and possible damage to hearing sensitivity (OSHA, 2002). Most of the devices showed a significant decrease in output using the 90 dB SPL swept-tone. Furthermore, the 50 dB SPL input speech stimulus generally produced output levels ranging from 55 to 60 dB SPL. Yet, the second Motorola H350 (Figure 3) produced SPL values that exceeded 90 dB SPL even for the mean valley measurements using a 50 dB SPL input speech stimulus, while the 90 dB SPL input swept-tone showed a significant reduction in peak output SPL value.

Secondary Analysis

A secondary analysis evaluating numerical average and absolute peak values for each Bluetooth device using the two loudest input stimuli (i.e., a 75 dB SPL speech stimulus and a 90 dB SPL swept-tone measured using KEMAR; a 70 and 75 dB SPL speech stimuli measured using a 2cc coupler) was completed. Specifically, A-weighted mean peak values obtained on KEMAR were averaged across a specific frequency range for each Bluetooth device coupled to a cellular phone (see Table 1).

The specific frequency range for each Bluetooth device was chosen based on range of maximum output produced before the point of roll-off as displayed in Table 1, column 2. The results of Table 1 showed that most Bluetooth devices produced peak averages of about 75-85 dBA for the 75 dB SPL input speech stimulus and 85-90 dBA for the 90 dB SPL swept-tone input stimulus. Absolute peak values, however, ranged from 90-100 dBA for 12 of 16 (i.e., 75%) Bluetooth devices with the Cardo Scala 500 producing the greatest absolute peak value of 104.8 dBA SPL with a 90 dB SPL swept-tone input signal.

Table 1. Mean peak values averaged over a specified frequency range using a 75 dB SPL speech stimulus and a 90 dB SPL swept-tone for each Bluetooth device and absolute peak values for each Bluetooth device. All measurements were obtained using KEMAR.

Device	**Frequency Range (Hz)**	**Average SPL w/ a 75 dB Input**	**Average SPL w/ a 90 dB Input**	**Absolute Peak (Input)**
Motorola 350 (1)	220-3150	84.9	89.9	96.8 (75)
Motorola 350 (2)	250-3150	91.4	91.7	100.8 (90)
Motorola HK201	2000-3150	85.9	83.3	93.8 (90)
Motorola H15	630-4000	77.4	76.3	94.7 (90)
Motorola H500	315-3150	83.5	83.3	89.9 (90)
Jawbone Prime (1)	800-3150	73.9	70.1	83.6 (75)
Jawbone Prime (2)	500-3150	83.9	83.0	95.7 (90)
Plantronics 835	500-3150	83.9	81.5	96.5 (75)
Plantronics 300	1000-3150	77.2	75.8	81.2 (75)
Plantronics Pro	315-3150	85.3	88.7	92.7 (75)
Plantronics 245	630-3150	77.2	75.8	89.4 (90)
Jabra BT3010	315-3150	82.5	83.3	95.4 (75)
Jabra BT280	630-3150	82.0	80.5	91.1 (90)
Cardo Scala 500	315-3150	89.9	91.0	104.8 (90)
LGM210	630-3150	79.4	76.3	90.4 (90)
Nokia BH102	630-3150	75.5	73.8	93.9 (75)

Peak mean values were also measured using a 2cc coupler and were averaged across a specific frequency range for each Bluetooth device coupled to a cellular phone (see Table 2). Peak values were obtained with a 70 and 75 dB SPL speech stimulus input for each Bluetooth device. Peak values obtained with the 90 dB SPL swept-tone input stimulus were not included in the mean peak averages measured on the 2cc coupler because of the drastic reduction in output for each Bluetooth device using this signal. Results of the numerical data showed most Bluetooth devices produced mean peak averages over 90 dB SPL with the 70 dB input speech stimulus for 8 of 8 (i.e.; 50%) of the Bluetooth devices.

Table 2. Mean peak values averaged over a specified frequency range using a 70 and 75 dB SPL speech stimuli for each Bluetooth device and absolute peak values for each Bluetooth device. All measurements were obtained using a 2cc coupler.

Device	**Frequency Range (Hz)**	**Average SPL w/ a 70 dB Input**	**Average SPL w/ a 75 dB Input**	**Absolute Peak (Input)**
Motorola 350 (1)	200-4000	90.6	102.5	117.9 (75)
Motorola 350 (2)	200-3775	110.7	127.2	127.2 (75)
Motorola HK201	250-3775	89.7	90.2	105 (75)
Motorola H15	200-3365	92.5	97.0	112.9 (75)
Motorola H500	200-3150	93.8	98.3	109.8 (75)
Jawbone Prime (1)	420-3365	89.3	96.2	108 (75)
Jawbone Prime (2)	375-3550	89.6	96.0	115.8 (75)
Plantronics 835	315-3150	95.6	95.4	122.8 (75)
Plantronics 300	280-3775	91.7	91.3	108.8 (75)
Plantronics Pro	280-3775	97.7	94.9	111.5 (75)
Plantronics 245	375-3550	81.6	89.8	110.6 (75)
Jabra BT3010	335-3550	89.7	91.2	104.2 (75)
Jabra BT280	225-3550	93.9	97.6	109.9 (75)
Cardo Scala 500	300-3775	84.6	85.7	112 (75)
LGM210	335-3365	77.3	77.3	110 (70)
Nokia BH102	265-3365	76.9	97.0	116.8 (75)

Ninety to 100 dB SPL mean peak averages were produced with the 75 dB input speech stimulus for 13 of 16 (i.e., 81%) of the Bluetooth devices. Furthermore, all absolute peak values exceeded over 100 dB SPL for 16 of 16 (i.e.; 100%) of the Bluetooth devices with the second Motorola H350 producing a maximum absolute value of 127.2 dB SPL using a 75 dB SPL speech input stimulus. These results indicate that Bluetooth devices can produce SPL values of extreme magnitude for loud conversational speech stimuli, thus possibly putting hearing sensitivity at an even greater risk for damage upon instant auditory stimulation over a short time period. In summary, mean peak averages and absolute values measured using KEMAR and a 2cc coupler both produced SPL values ranging from 90 to 100 dB SPL, indicating that Bluetooth devices coupled to cellular phones may cause damage to hearing sensitivity when used at elevated volume levels.

CHAPTER V

DISCUSSION

The purpose of the present study was to determine Bluetooth headset specifications and potential effects on hearing loss. Three research questions were assessed: 1) what is the maximum peak output of various bluetooth headsets coupled to a cellular phone, 2) what is the average output of various bluetooth headsets coupled to a cellular phone, and 3) what is the frequency response of various bluetooth headsets coupled to a cellular phone? Sixteen Bluetooth devices were evaluated in this study and were selected based on consumer demands and lack of specific specifications from their manufactures pertaining to maximum levels of volume outputs. Each device was coupled to a Blackberry Curve cellular phone and SPLs were measured using both KEMAR and a 2cc coupler. KEMAR and a recording software developed by National Instruments were used to obtain average SPLs using the A-weighted scale (in 1/3 octave bands across the frequency range of 20 to 20,000 Hz) and a speech stimulus at input levels of 50, 70, and 75 dB SPL. A 90 dB SPL input swept-tone was also used to measure maximum power output for each bluetooth device. SPL measures were also obtained using a 2cc coupler on the Audioscan Verifit for input speech signals of 50, 70, and 75 dB SPL, and a 90 dB SPL swept-tone for each Bluetooth device.

SPL measurements were obtained in 1/12 octave bands across the frequency range of 200 to 8000 Hz. Means were obtained for the four peaks, average, valley, and maximum output (i.e., 90 dB SPL swept-tone) measurements at each frequency for each bluetooth device.

Maximum Peak Output

Measurements taken on KEMAR were completed to emulate the natural human ear canal resonance and produced a frequency response range of 200-5000 Hz. Furthermore, the results showed SPL output levels greater than 90dBA when using an input signal of 70, 75, and 90 dB SPL (i.e., loud conversational speech). Absolute peak values typically ranged from 90-100 dBA SPL with the Cardo Scala 500 producing the greatest absolute peak value of 104.8 dBA SPL with a 90 dB SPL swept-tone input signal measured on KEMAR. Additionally, the Motorola 350 produced a maximum peak value of 96.8 dB SPL with a 75dB input speech stimulus measured on KEMAR.

Furthermore, results showed Bluetooth devices measured on the 2cc coupler produced mean and absolute peak averages of 100dB SPL or greater for all Bluetooth devices. The Motorola 350 produced a maximum peak value of 127.2 with a 75dB input speech stimulus. Maximum peak outputs of such high SPL values significantly puts hearing acuity at risk, if devices are worn for a long period of time daily/weekly. Below is Table 3 of maximum peak outputs and peak output frequencies measured on KEMAR and the 2cc coupler for each Bluetooth device.

Table 3. Maximum/absolute peak values and peak frequencies measured on KEMAR and in the 2cc coupler using a75 dB HL speech stimulus and a 90 dB SPL swept-tone for each Bluetooth device.

Device	Maximum Peak Output KEMAR (Input)	Maximum Peak Frequency(Hz) KEMAR	Maximum Peak Output Coupler (Input)	Maximum Peak Frequency(Hz) Coupler
Motorola 350 (1)	96.8 (75)	630	117.9 (75)	800
Motorola 350 (2)	100.8 (90)	630	127.2 (75)	900
Motorola HK201	93.8 (90)	2500	105 (75)	2500
Motorola H15	94.7 (90)	31500	112.9 (75)	2800
Motorola H500	89.9 (90)	2500	109.8 (75)	2670
Jawbone Prime (1)	83.6 (75)	2500	108 (75)	1190
Jawbone Prime (2)	95.7 (90)	2000	115.8 (75)	2670
Plantronics 835	96.5 (75)	2500	122.8 (75)	2500
Plantronics 300	81.2 (75)	1250	108.8 (75)	2670
Plantronics Pro	92.7 (75)	1600	111.5 (75)	1600
Plantronics 245	89.4 (90)	2500	110.6 (75)	2670
Jabra BT3010	95.4 (75)	2500	104.2 (75)	2670
Jabra BT280	91.1 (90)	2500	109.9 (75)	2120
Cardo Scala 500	104.8 (90)	630	112 (75)	750
LGM210	90.4 (90)	2500	110 (70)	2380
Nokia BH102	93.9 (75)	2500	116.8 (75)	2240

Average Outputs Using Speech Signals

Average output for most devices was noted within the frequency response range of 200 to 3150 Hz using a 75dB input speech stimulus measured on KEMAR. Furthermore, ten of the 16 devices produced average SPL outputs greater than 80 dB SPL produced with a 75 dB SPL speech stimulus. The Motorola H350 produced the greatest average output value of 91.4 dB SPL, and the Cardo Scala 500 produced the second highest average output value of 89.9 dB SPL. Both device output values were averaged over a frequency range of 200-3150 Hz.

Measurements of Bluetooth devices obtained on 2cc coupler produced a frequency response range of 1500 to 3150 Hz. Most Bluetooth devices measured on the 2cc coupler produced mean averages of 90 dB SPL or greater with a 70 and 75 dB SPL speech signal. However, there was a drastic reduction in output when measured using a 90 dB swept-tone. Furthermore, 13 of the 16 devices produced average SPL values over 90 dB SPL using a 75dB SPL speech stimulus. The Motorola H350 devices produces average SPL values over 100 dB SPL using a 75 dB speech stimulus averaged over a frequency range of 200-4000 Hz. Therefore, average output specifications indicate Bluetooth devices can produce dangerous SPL values for loud conversational speech stimuli, possibly putting hearing sensitivity at a high risk for auditory damage upon instant auditory stimulation. Below is Table 4 of average SPL outputs measured on KEMAR and a 2cc coupler.

Table 4. Average outputs and average output frequencies measured on KEMAR and a 2cc coupler using a75 dB HL speech stimulus for each Bluetooth device.

Device	**Average Output KEMAR (75dB SPL Input)**	**Frequency Range KEMAR**	**Average Output Coupler (75dB SPL Input)**	**Frequency Range Coupler**
Motorola 350 (1)	84.9	220-3150	102.5	200-4000
Motorola 350 (2)	91.4	250-3150	127.2	200-3775
Motorola HK201	85.9	2000-3150	90.2	250-3775
Motorola H15	77.4	630-4000	97.0	200-3365
Motorola H500	83.5	315-3150	98.3	200-3150
Jawbone Prime (1)	73.9	800-3150	96.2	420-3365
Jawbone Prime (2)	83.9	500-3150	96.0	375-3550
Plantronics 835	83.9	500-3150	95.4	315-3150
Plantronics 300	77.2	1000-3150	91.3	280-3775
Plantronics Pro	85.3	315-3150	94.9	280-3775
Plantronics 245	77.2	630-3150	89.8	375-3550
Jabra BT3010	82.5	315-3150	91.2	335-3550
Jabra BT280	82.0	630-3150	97.6	225-3550
Cardo Scala 500	89.9	315-3150	85.7	300-3775
LGM210	79.4	630-3150	77.3	335-3365
Nokia BH102	75.5	630-3150	97.0	265-3365

Frequency Response Range

The frequency responses for the Bluetooth devices were variable. Results showed that 12 of the 16 devices measured on KEMAR and 10 of the 16 devices measured on a 2cc coupler were primarily flat in the low frequencies (200-2000 Hz), peaked around 2500-4000 Hz, and then sloped off.

Furthermore, four of the 16 devices measured on KEMAR and 6 of the 16 devices measured on a 2cc coupler were relatively flat across the entire frequency response, sometimes peaking between 800-2000 Hz and then rolling off.

Clinical Implications

Most Bluetooth manufactures produce consumer manuals that provide general information about Bluetooth headset devices, such as proper device use, device care and device special features. For example, general information like pairing of the device, indicators, wireless range and connectivity were all provided for the Motorola H350 (Motorola, 2011). However, output SPL specifications were not included for the Motorola H350, which produced the greatest absolute SPL measured on 2cc coupler when compared to all other devices evaluated in this study. However, in the manual Motorola did note that noise reduction was not provided for the Motorola H350. Additionally, the Cardo Scala 500 Bluetooth device produced the greatest absolute SPL value measured on KEMAR; however, sound output level specifications were not provided in the consumer quick start manual (Cardo). Although some Bluetooth manufactures like Jawbone, Motorola and Plantronics provided audio features like noise, wind and echo reduction technology, none of the manufacturers provided output specifications for any of the Bluetooth devices used in this study.
Therefore, consumers are not being made aware of sound level output specifications and the potential for hearing loss of Bluetooth headset devices.

Currently, there are three Bluetooth manufactures being sued by consumers claiming hearing loss and that manufacturers failed to warn them of the potential danger of hearing loss caused by their Bluetooth headset devices. Motorola Inc. is currently being sued by a consumer claiming that Motorola Inc. did not warn users of potential hearing damage caused by their Bluetooth headset device when used at high volume levels. The law suit also alleges that Motorola Inc. had specific knowledge that their

Bluetooth headset device produced sound levels over 100 dB, which could possibly result in noise induced hearing loss (Glen, 2006). The law suit also contends that consumers cannot easily determine how much output in being produced by the Motorola Bluetooth device. Therefore, the suit claims that consumers should be provided with sound output specifications or devices should be pulled from the market until sound output levels specifications are provided (Ogg, 2006).

The Motorola H500 is one of the Bluetooth headset models that are being advertised by extended talk time and no warning against full volume use and the risk it may pose on hearing sensitivity (Ogg, 2006) in the current Motorola law suit. In this study, the Motorola H500 produced an absolute peak value of 89.9 dBA SPL measured on KEMAR with a 90 dB swept-tone. Sound level measurements obtained on 2cc coupler produced an absolute peak value of 109.8 dB SPL with an input speech stimulus of 75dB SPL. These sound level values suggest that the Motorola H500 is capable of producing dangerous sound levels and puts hearing sensitivity at risk, especially when used for an extended about of time.

Plantronics and Jabra manufacturers also have law suits pending from failing to warn users about potential hearing loss possibly caused by Bluetooth headset devices. The law suit alleges that manufactures are not providing a warning label of potential hearing damaged caused by their Bluetooth headset devices. Four of the 16 Bluetooth headset devices used for this study provided warnings of permanent hearing loss caused by use of devices at loud volume for extended amount time, including the Plantronics 245(Plantronics, 2009), Jabra BT208080 (Jabra, 2009), Jabra BT3010 (Jabra, 2007), and the LG HMB 210 (LG, 2009). For instance, LG Electronics clearly states in their LG

HMB210 Bluetooth user's manual that "permanent hearing loss may occur if you use your headset at a high volume" (LG Electronics 2009). LG also provide consumers with symptoms associated with hearing damage such as ringing in the ears and muffled speech (LG, 2009).

Although previous research has argued that there is not a direct correlation between personal listening devices like Bluetooth headsets and hearing loss (Fligor, 2009), the present study revealed that Bluetooth devices can produce output levels of 90 dB or more which clearly puts hearing sensitivity at risk, especially when exposed to excessive loud sounds for an extended period time (OSHA, 2002). This is why it is imperative that all Bluetooth manufactures provide consumers with sound level outputs and warning labels that state that devices can cause permanent listening damage when used at high volume levels. Additionally, Bluetooth manufactures could also provide output specifications for various volume levels so that consumers could determine at what volume level hearing sensitivity could be put at risk.

Currently, the rise of noise-induced hearing loss could be credited to the increase use of personal listening devices like Bluetooth headset (Loftis, 2007). Loftis (2007) pointed out those personal listening devices with smaller ear buds with deeper insertion into the ear canal could increase volume level up to 10 dB over regular supra-aural headphones (Loftis, 2007). Several Bluetooth devices used for this study, such as the Motorola HK201, Jawbone Prime, Plantronics Explorer 300 and 835 all have ear buds that have direct insertion into the ear canal. All of these Bluetooth devices with canal insertion produced sound output levels that exceeded federal safety regulation greater than 90 dBA SPL, possibly posing an even greater threat on hearing sensitivity.

Two possible limitations to the current study should be noted. First, SPL measurements where obtained on one type of cellular phone, the commonly used Blackberry Curve. Therefore, SPL measurements of Bluetooth devices coupled to other cellular phones may produce different SPL values as a result of various volume output levels of other cellular phones. Additionally, it is important to acknowledge that each Bluetooth device used in this study was puttied onto the ear of KEMAR possibly producing a greater seal on KEMAR's ear as compared to seal of the Bluetooth device when worn on the human ear. This change in seal may have resulted in elevated SPLs measures in the current study as compared to SPLs seen when coupled to a person's ear.

OSHA Standards

The permissible exposure limit of sound is 90 dBA within 8 hours; however, most of Bluetooth headset devices used for this study produced sound output level that exceeded federal safety regulations when measured at the full-on volume level (OSHA, 2002). A-weighted measurements were obtained using KEMAR to emulate the natural resonance of the human ear canal. A-weighted measurements are also the standard scale used to measure noise in a noisy occupational environment to help regulate noise hazard and mandate hearing conservation. Consequently, most Bluetooth devices produced averaged peak outputs of 90 dBA or more with an input speech stimulus of 70 to 75 dB SPL (loud conversational speech) measured on KEMAR. Measurements obtained on 2cc coupler produced average peak outputs of 100 dB SPL or more for Bluetooth devices with an input speech stimulus of 70 and 75 dB SPL. Most absolute peaks values of Bluetooth devices obtained on KEMAR and 2cc coupler also produced sound levels 100 dB SPL. With that in mind, federal regulations of permissible exposure limit decreases the standard 8 hour exposure limit by half the time for every 5 dB increase of exposure above 90dBA (OSHA, 2002). Therefore, consumers of Bluetooth headsets coupled to cellular phones are possibly putting hearing sensitivity at a great risk within a shorter time frame when exposed to sound output level greater than 90 dBA. Specifically, some of the measured devices in the current study should be used at a maximum of 2 hours daily.

Conclusions

In conclusion, the purpose of this study was to determine Bluetooth headset specifications by evaluating maximum output, frequency response and average output for various Bluetooth headset produced by various manufacturers and its possible effects on hearing sensitivity. The results revealed that sound output levels obtained on KEMAR showed that most Bluetooth devices exceeded SPL measures of 90 dBA when using a loud conversational speech signal. Furthermore, absolute peak values ranged up to 100 dBA for several Bluetooth devices. These results indicated that loud sounds (i.e., both speech and non-speech sounds) can produce hazardous output levels putting hearing sensitivity at risk. Sound level outputs measured on a 2cc coupler produced mean averages of 90dB SPL for loud conversational speech stimuli while mean peaks exceeded 100 dB SPL, further supporting the fact that these devices could be detrimental to hearing sensitivity. Overall, the results revealed that Bluetooth headset devices can produce dangerous output levels when used at high volumes, putting hearing sensitivity at risk when used for an extended amount of time. The results also showed that most Bluetooth manufactures do not provide consumers with specifications or warning labels about using their Bluetooth headsets at high volume levels and the risk it could possibly pose on hearing sensitivity. Consequently, using Bluetooth headsets at high volume levels for extended amounts of time may be detrimental to hearing acuity, which could cause temporary or permanent hearing loss.

APPENDIX A

EXEMPTION OF HUMAN USE COMMITTEE

LOUISIANA TECH
UNIVERSITY
MEMORANDUM

OFFICE OF UNIVERSITY RESEARCH

TO: Dr. Melinda Freyaldenhoven

FROM: Barbara Talbot, University Research

SUBJECT: HUMAN USE COMMITTEE REVIEW

DATE: July 22, 2009

RE: Exemption of HUC 677

In order to facilitate your project, an EXPEDITED REVIEW has been done for your proposed study entitled:

"Blue Tooth Devices"

HUC-677

Dr. Livingston has determined that your proposal meets requirements for exemption since humans are not being used for data collection.

If you have any questions, please contact Dr. Mary Livingston at 257-4315.

A MEMBER OF THE UNIVERSITY OF LOUISIANA SYSTEM

P.O. BOX 3092 • RUSTON, LA 71272 • TELEPHONE (318) 257-5075 • FAX (318) 257-5079
AN EQUAL OPPORTUNITY UNIVERSITY

APPENDIX B

SOUND LEVEL METER SOFTWARE SETTINGS

FOR KEMAR BLUETOOTH

EVALUATION

SOUND LEVEL METER SOFTWARE SETTINGS

FOR KEMAR BLUETOOTH

EVALUATION

This procedure was adapted from Alexander's (2009) dissertation on iPod Measurement using KEMAR.

1) Place bluetooth on the right ear of KEMAR.
2) Click Short cut to channel of SLM.
3) Under "physical channel" select browse
   A. Select ai0/ ail.
4) Change averaging type from exponential to linear. The following settings should be changed:
   A. Intermediate Integration time = 100ms.
   B. Total integration time = 60s for white noise.
   C. Sensor sensitivity = 10.5 for ai0 and ai1.
   D. Weighting filter = linear
   E. Octave bandwidth = 1/3 octave.
5) Select Weighting as either "linear" or "a-weighting" depending on measurement being taken
6) Other setting on the SLM program that should not be changed are:
   A. Frequency Range [Hz]
      i. Low Frequency = 20.00
         High Frequency = 20000.00
   B. Sample Rate = 50000
   C. Sensor Information
      i. dB Reference [EU] = 20.0E-6
      ii. Weighting filter = linear
      iii. Engineering units = Pa
      iv. Custom label = EU
      v. Pregain [dB] = 0.00
7) Select the box "write octave data to file?"
8) Start the continuous speech stimulus created by the Audioscan Verifit, which should be transmitted to the Blackberry in the Audioscan Verifit coupler to the Bluetooth puttied on KEMAR's right ear.
9) Click Start *Acquisition* on the software.
10) After 30 seconds of measuring, Click *Stop* and *Close* on the software.
11) Change to file name from Session D to the name of the name of the manufacture of the Bluetooth device and click ok.
12) The file will go into the folder on the "measures from KEMAR" on the desktop.
13) Repeat steps for all measuring all Bluetooth devices.

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