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The Acoustic Transparency of Ad*Hear Wax Guards When Measuring DPOAEs

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THE ACOUSTIC TRANSPARENCY OF AD*HEAR WAX GUARDS WHEN MEASURING DPOAEs

by

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STATEMENT OF THE PROBLEM

Approximately one to six of every 1,000 children is born deaf or with some degree of permanent hearing loss (Parving, 1993; Watkins, Baldwin, & McEnery, 1991; White, & Behrens, 1993). Reduced hearing acuity during infancy and early childhood may interfere with the development of the child's speech and verbal language skills (NIH, 1993). Reduced auditory input can also have harmful effects on the child's social, emotional, cognitive, and academic development (NIH, 1993). Because hearing is crucial for the development of speech and verbal language skills, the developmental future of a child born with a significant hearing loss depends greatly on early identification of the loss (Healthy People 2000, 1990).

Unfortunately, the average age of identification of children with a hearing loss in the United States of America is close to three years of age (NIH, 1993). When a hearing loss is identified this late, much of the crucial period for language development is disrupted (NIH, 1993). Therefore, audiologists have tried to change the factors leading to this process of late identification. For the last fifty years, infant hearing screenings have been attempted with a number of different test methods. The most recent test method, and one of the most promising for universal neonatal hearing screening, is the measurement of otoacoustic emissions (OAEs) (NIH, 1993). One type of OAEs is distortion product otoacoustic emissions (DPOAEs). DPOAEs are sounds that are emitted from all healthy ears in the presence of acoustic stimulation (Kemp & Ryan, 1993). The measurement of OAEs is not very expensive, and it is noninvasive, quick and easy to perform (NIH, 1993).

To measure DPOAEs, a computer system called the Otodynamic Analyzer ILO92 is used. This system presents two pure tones (f1 and f2) through a specially designed probe

assembly that is placed in the infant or child's ear canal. The probe assembly then picks up the emitted DPOAEs through a microphone. The results of the screening are averaged and the sound amplitudes are displayed in a line graph form on the computer screen (Kemp & Ryan, 1993).

One problem with the ILO92 Analyzer is the probe's structure. The structure contains a microphone, two transducers, and open ports leading to each of these. When the probe is placed in a newborn's ear it may come in contact with vernix, blood, amniotic fluid, or other debris still present in the ear canal after birth. Because the probe tubes and other structures are open, debris may get inside the probe and damage it. As such, something is needed that will protect the probe without interfering with the accuracy of the screening results.

One potential means of probe protection lies in a new, commercially available product called Ad*Hear Guards (shields), which are used to protect hearing aids from cerumen build-up. These shields are advertised as acoustically transparent. If this advertisement is true for DPOAE measurement, the shield could be placed over the top of the probe and protect it from the debris in the infant's ear canal, and the assessment procedure would still result in accurate screening results. The purpose of this study, therefore, is to test the acoustic transparency of these shields.

REVIEW OF LITERATURE

During the early 1900s in the field of hearing science and audiology, there was a common belief that the cochlea was linear, passive, rather broadly tuned, and thus relatively unimportant in auditory perception (Norton, 1992). But this idea was puzzling to many people (Norton, 1992). In 1946, a young English physicist, Thomas Gold, was also baffled

by the common belief of his time. He found through studying the ears of humans and animals that the cochlea must have a sharply tuned mechanical response system, or how would we account for the high sensitivity sharp frequency and wide dynamic range of the ear (Gold, 1948)?

Gold's (1948) theories were accurate, but not accepted by other scientists. It was not until 1978 that another English Physicist, David Kemp, published a paper demonstrating the existence of otoacoustic emissions (OAEs) (Kemp, 1978). Kemp discovered OAEs to be sounds that are generated within the normal cochlea that are capable of being recorded in the external auditory canal (Norton, 1992). Kemp also found from his research that OAEs are a frequency specific response that emerges about 5 ms after the onset of a stimulus and slowly decays over 25 ms (Norton, 1992).

Over the past 15 years, Kemp's reports and studies have been confirmed and extensive studies have been performed by other scientists. The common belief of the early 1900s had changed.

In essence, recent studies have shown that the cochlea is non-linear, and within the organ of Corti, an active biomechanical process uses metabolic energy to create additional small vibrations. These vibrations enhance the sound-induced motion of the cochlear structure (Burch-Sims & Ochs, 1992). This process also increases the sensitivity and frequency selectivity of the ear (Lonsbury-Martin, Whitehead, & Martin, 1991). These enhancement processes are labeled as the "cochlear amplifier" (Lonsbury et al., 1991).

In other words, the cochlea actively produces energy as part of the normal hearing process. Some of this energy converts into an acoustic signal. This signal is emitted into the external ear canal where it can be detected and measured by a mechanical probe placed

tightly in the ear canal. The energy that is actively produced and released by the cochlea is called otoacoustic emissions.

Since their discovery by David Kemp, OAEs have become the topic of many studies involving the inner ear. The results of these studies indicate that when there is a damage or loss of function of the cochlear outer hair cells, there is a reduction or absence of OAEs. Therefore, it was concluded that OAEs are generated by the mobile outer hair cell system of the cochlea (Lonsbury-Martin, McCoy, Whitehead, & Martin, 1992).

Other studies have demonstrated that OAEs are objective, noninvasive, rapid, easy to measure, repeatable, frequency specific, and precise (Decker, 1992). Also, OAEs are specific to the outer hair cells, present in essentially all ears with normal cochlear function, and absent in damaged ears (Hall, 1992). Because of these qualities, the measurements of OAEs are a valuable screening tool in clinical audiology (Lonsbury-Martin et al., 1992). This is particularly true for neonates, infants, and children.

There are two general types of OAEs. One is spontaneous (SOAEs), which are emissions that occur naturally without acoustic stimulation (Prieve, 1992). SOAEs are present in only 50% of the population. The second type of otoacoustic emissions is called evoked (EOAE). EOAEs are elicited by low-to-moderate auditory stimuli delivered through a mechanical probe (Lonsbury-Martin & Martin, 1990).

One type of EOAE, DPOAEs, are created at mathematically predictable frequencies by the nonlinear elements of the cochlea in response to two pure tone stimuli (f1 and f2) at moderate intensity levels, separated in frequency that are presented to the ear (Lonsbury et al., 1991). DPOAEs are most frequently measured in a frequency region between 1000 and 8000 Hz and have a dynamic range of 40-50 dB SPL. One advantage is that they allow

selected test frequencies to be examined in detail. They are found in nearly all normal ears, and can also be found in individuals with up to 50 dBHL hearing loss (DeVries & Decker, 1992). Because of these attributes, the flexibility is increased and a greater range of the auditory system may be covered during testing (Lonsbury et al., 1991).

Clinical advantages of using DPOAEs for screening purposes are that DPOAEs are frequency detailed, noninvasive, objective sensitive and cost-efficient (Lonsbury-Martin & Martin, 1990). Other advantages of using DPOAEs is that they provide an objective measurement tool for studying cochlear function in human individuals. These qualities ensure DPOAEs to be a reliable method for identifying infants with a hearing loss (Kemp & Ryan, 1993).

To test for the emission of DPOAEs, a computer program called Otodynamic Analyzer ILO92 is used. A probe, which contains a microphone, two transducers, and open ports leading to each of these, is placed in the subject's external ear canal. The probe assembly delivers the stimuli (two pure tones) to the ear while the microphone receives the combination of stimulus and emissions present in the ear canal (DeVries & Decker, 1992).

Unfortunately, when testing newborns, the results of a screening when measuring DPOAE can be affected by the presence of debris in the external ear canal. Balkeny et al. reported that, "100% of 50 newborn infants less than 24 hours old had at least partial obstruction of the external ear canal due to vernix caseosa (cited in Kemp & Ryan, p. 37)".

The debris in the ear canal causes two problems when measuring DPOAEs: (a) It may affect the results of the screening; and (b) It can damage the expensive probe assembly. The purpose of this study was to investigate one means of controlling the second problem.

PURPOSE AND OBJECTIVES

The general purpose of this study was to determine if Ad*Hear Wax Guards (shields), designed for hearing aids, are actually acoustically transparent when used on the probe assembly used for measuring DPOAEs.

The specific objectives of this study are:

1. To look at the test-retest reliability of the 2f1-f2 DPOAE amplitudes with the removal and replacement of the probe within the ear canal.

2. To test the acoustic transparency of Ad*Hear Wax Guards (shields) using 2f1-f2 DPOAE amplitudes for f2 frequency regions from 574-4919 Hz.

METHODS AND PROCEDURES

Subjects

The subjects tested were randomly chosen out of a population from Utah State University (USU) students and faculty. Subjects were required to have normal hearing (20 dBHL or better for 500-4000 Hz), normal typanometric results on the day of testing, and no significant history of middle ear pathology. Fifteen individuals met the selection criteria and were used as subjects.

Design

Subjects were seated comfortably in a quiet room. An appropriate-sized personal probe tip was put over the probe and placed into the opening of the subject's ear canal.

DPOAEs were measured using an Otodynamic Analyzer ILO92. To control testing variability, three runs were tested on each ear: run A, without using the shields; run B using the shield; and run C, without using the shield. Two pure tones (f1 and f2) were presented simultaneously to elicit distortion-product response (2f1-f2). The pure tones were presented

in systematic steps from low to high frequency with f2 ranging from 574 to 4919 Hz. To prevent distortion generation in the probe assembly transducer, the two primary pure tones are presented through separate transducers housed within the probe assembly. Intensity levels were 70 dB SPL for f1 and 60 dB SPL for f2. The frequency separation ratio was 1.22. This ratio has been tested as the most effective stimulus for eliciting DPOAEs (Bright, 1994). During testing the microphone within the probe's structure picked up all acoustic energy present in the subject's ear canal. The Otodynamic Analyzer received the signal, then amplified and averaged the signal to improve the signal-to-noise ratio. The 2f1-f2 (f1 represents the lower frequency and f2 represents the high frequency) DPOAEs measured were stored in the data in the Analyzer for future statistical analysis.

Noise floor measurements were also recorded throughout the testing procedures. DPOAE amplitudes had to be at least 3 dB SPL above the noise floor to be averaged in the statistical data. Test sessions lasted approximately thirty minutes.

Comparison of runs A and B, or B and C, allowed for determination of the effects of the Shields while comparison of the results between A and C allowed for determination of the test-retest reliability when the probe assembly was removed and replaced in the ear canal.

RESULTS

The primary purpose of study was to investigate the acoustic transparency of Ad*Hear Wax Guards (shields) during the measurement of DPOAEs. Fifteen people met the selection criteria and were selected as subjects.

Objective #1: Test-Retest Reliability

The results collected from measuring DPOAEs from 15 subjects are summarized in Table 1.

Table 1

Summary Statistics For 2f1-f2 DPOAE Amplitudes With Or Without Using Ad*Hear Wax Guards (Shields)

Amplitude Frequency	Run	Mean	SD	Range
574	A-natural	3.64	5.47	-8.7 to 15.6
	B-shielded	3.99	7.98	-21.1 to 23.9
	C-natural 2	4.01	5.84	-5.1 to 17.8
818	A	6.76	6.24	-13.3 to 17.8
	B	7.33	5.14	-4.5 to 18.4
	C	8.04	4.58	-.70 to 19.0
1233	A	11.22	5.26	-6.7 to 19.1
	B	11.18	5.15	-3.0 to 18.4
	C	11.49	4.81	-7.1 to 19.0
1636	A	9.33	5.23	-3.1 to 18.4
	B	9.83	5.03	-3.1 to 17.2
	C	9.78	5.34	-4.0 to 18.3

Table 1 (continued)

Amplitude Frequency	Run	Mean	SD	Range
2454	A	8.56	5.85	-5.2 to 16.2
	B	7.96	5.60	-7.3 to 15.7
	C	8.72	5.44	-5.7 to 17.8
3284	A	12.46	3.88	2.0 to 18.5
	B	11.85	4.00	2.1 to 19.8
	C	12.45	4.66	-.20 to 20.8
4102	A	14.63	4.21	4.6 to 22.3
	B	13.69	4.75	.70 to 22.6
	C	15.03	4.00	5.1 to 24.2
4919	A	13.16	5.70	-.20 to 24.3
	B	13.08	5.59	1.8 to 24.1
	C	13.50	5.56	-.50 to 24.1

Note: A=Without Shield B=With Shield C=Without Shield(test-retest)

Table 1 summarizes the mean, standard deviation (SD), and range of each 2f1-f2 DPOAE amplitude for the f2 frequency range from 574 to 4919 Hz. Each amplitude frequency was tested in three runs: A-without the Ad*Hear shield; B-with the shield over the probe, and; C-again with the shield to test for test-retest reliability.

During testing for DPOAEs, noise floor was calculated to ensure that the presence of environmental and physical noise would not contaminate the data. Table 2 summarizes the results of those calculations.

Table 2

Summary Statistics For DPOAE Noise Floor

Noise Frequency	Run	Mean	SD
574	A	-.52	4.25
	B	1.47	5.45
	C	-.31	5.16
818	A	-2.73	3.95
	B	-1.07	4.62
	C	-1.80	4.40

Table 2 (continued)

Noise Frequency	Run	Mean	SD
1233	A	-6.64	2.72
	B	-5.08	4.20
	C	-5.86	3.73
1636	A	-9.39	2.76
	B	-9.08	3.50
	C	-8.05	2.28
2454	A	10.80	1.87
	B	-10.33	2.36
	C	-9.91	1.53
3284	A	-11.63	1.63
	B	-12.20	2.24
	C	-11.22	1.52
4102	A	-12.57	1.92
	B	-12.62	1.97

Table 2 (continued)

Noise Frequency	Run	Mean	SD
4102	C	-12.15	1.72
4919	A	-12.20	1.49
	B	-11.87	1.70
	C	-11.75	2.00

A One-Way Analysis of Variance (ANOVA) was performed for each 2f1-f2 DPOAE mean amplitude for f2 frequency range from 574 to 4919 Hz and for mean noise floor data. The results of these statistical tests showed that there were no statistically significant differences in the data collected for the entire frequency region or the noise floor ($p > .05$). Refer to Appendix A for F scores and P values for each of the ANOVA measures.

Figures 1, 2, and 3 compare the relationships of the 2f1-f2 DPOAE mean amplitudes, with the noise floor for each group. In each Figure, the amplitudes are much higher than the noise floor. The amplitude means were above the noise floor and therefore did not contaminate the data results.

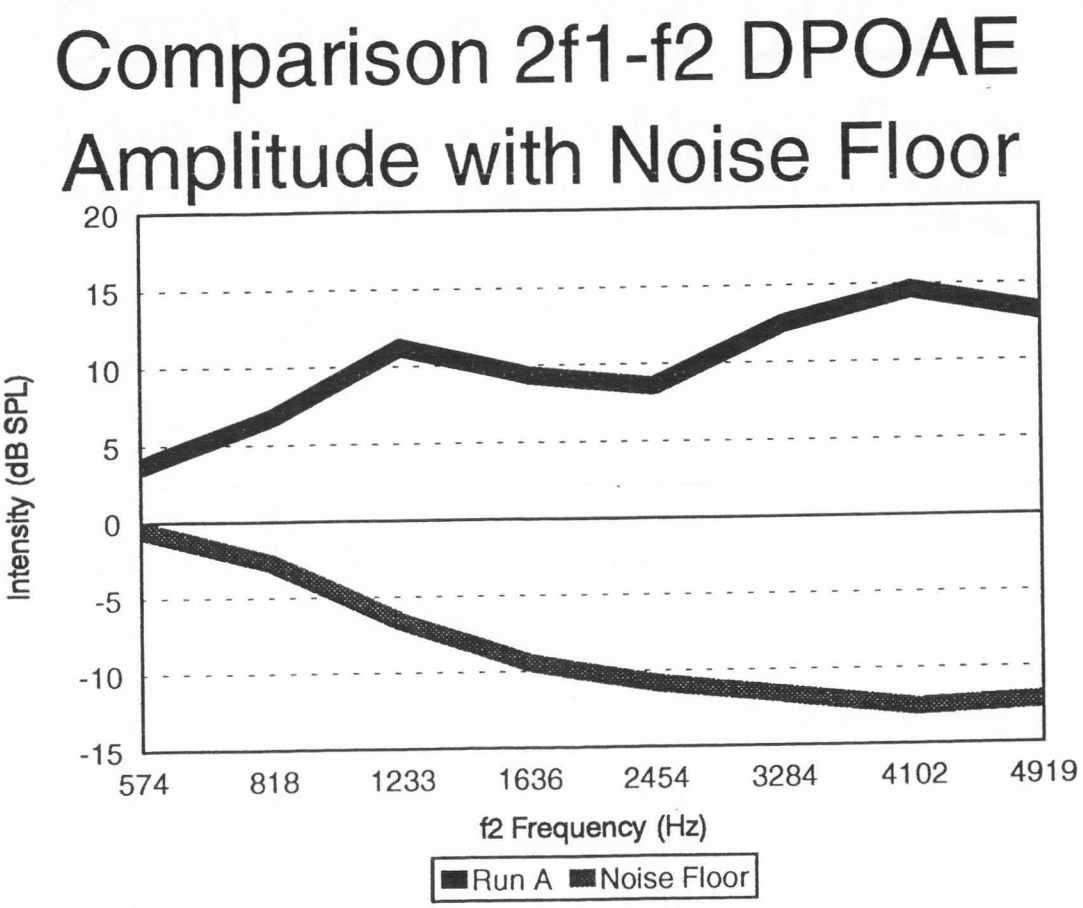

Figure 1. Relationship between the DPOAE 2f1-f2 amplitude in run A with the noise floor results.

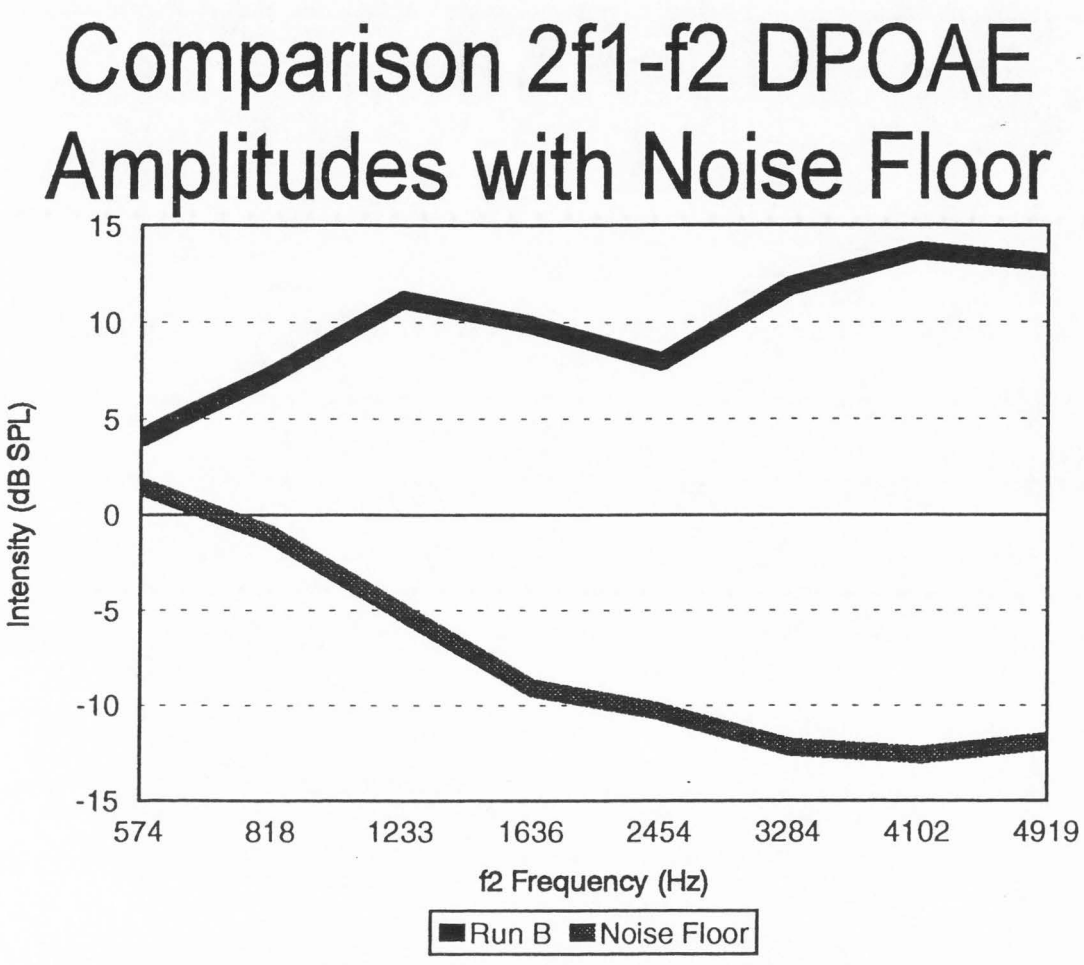

Figure 2. Relationship between DPOAE 2f1-f2 amplitude of run B with noise floor results.

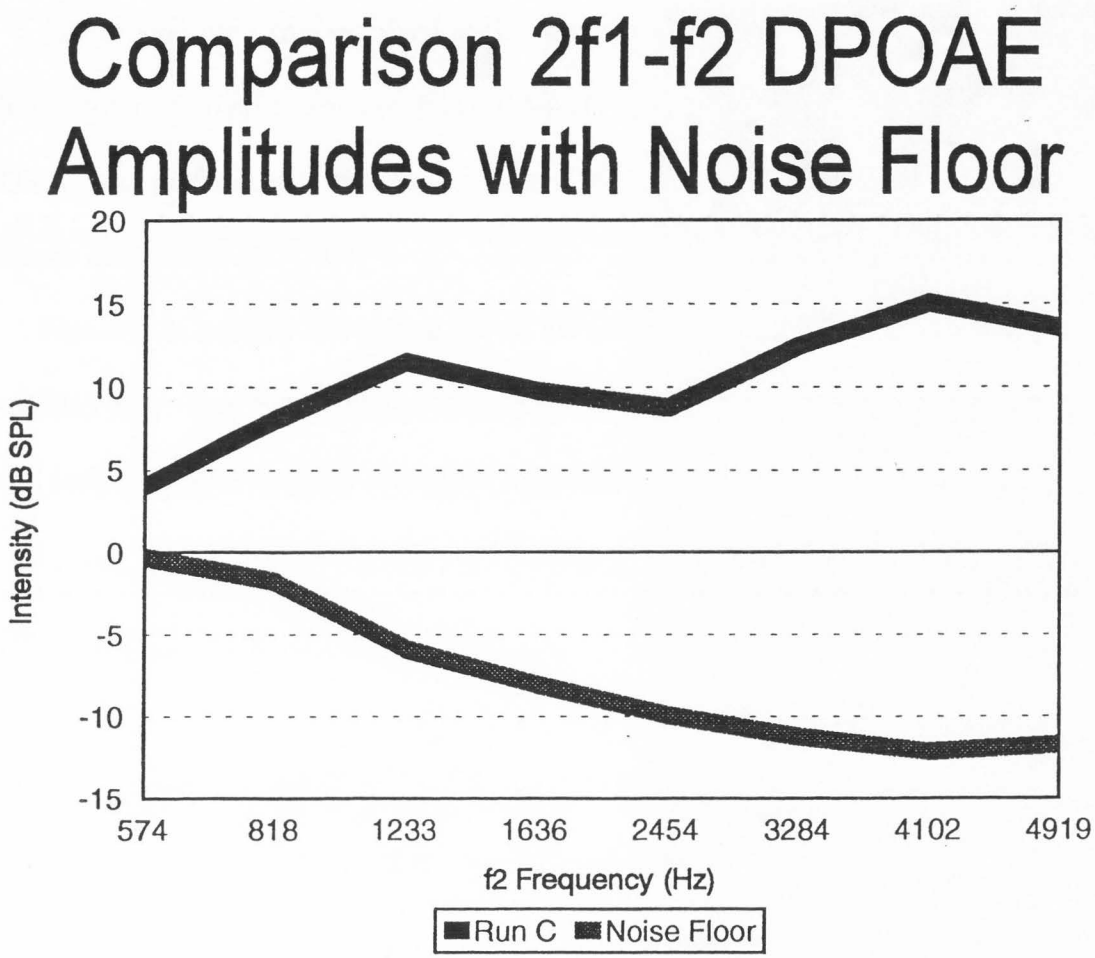

Figure 3. Relationship between DPOAE 2f1-f2 amplitude of run C with noise floor results.

Objective #2: Acoustic Transparency

The second objective involved testing the acoustic transparency using 2f1-f2 DPOAE amplitude for f2 frequency regions from 574-4919 Hz. Another Analysis of Variance (ANOVA) was performed to test for acoustic transparency. The results showed no significant differences ($p > .05$).

Figure 4 is a graph comparing 2f1-f2 DPOAE amplitudes for each frequency from 574 to 4919 Hz. This Figure shows that there are minimal effects of Ad*Hear Shields. Similar variability was seen for test-retest reliability.

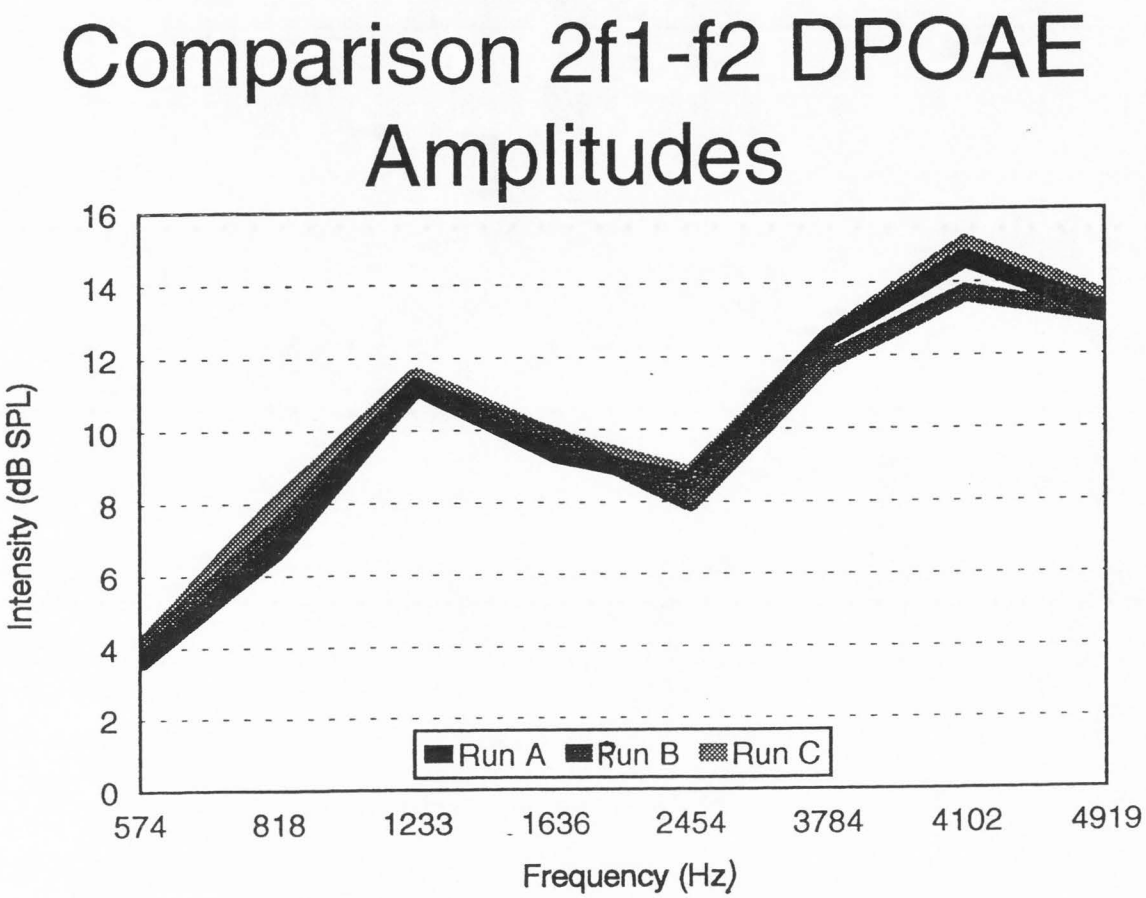

Figure 4. Relationship between DPOAE 2f1-f2 amplitudes for runs A, B, and C.

In Figure 5, run A is plotted as zero to magnify the small insignificant amplitude differences between runs A, B and C.

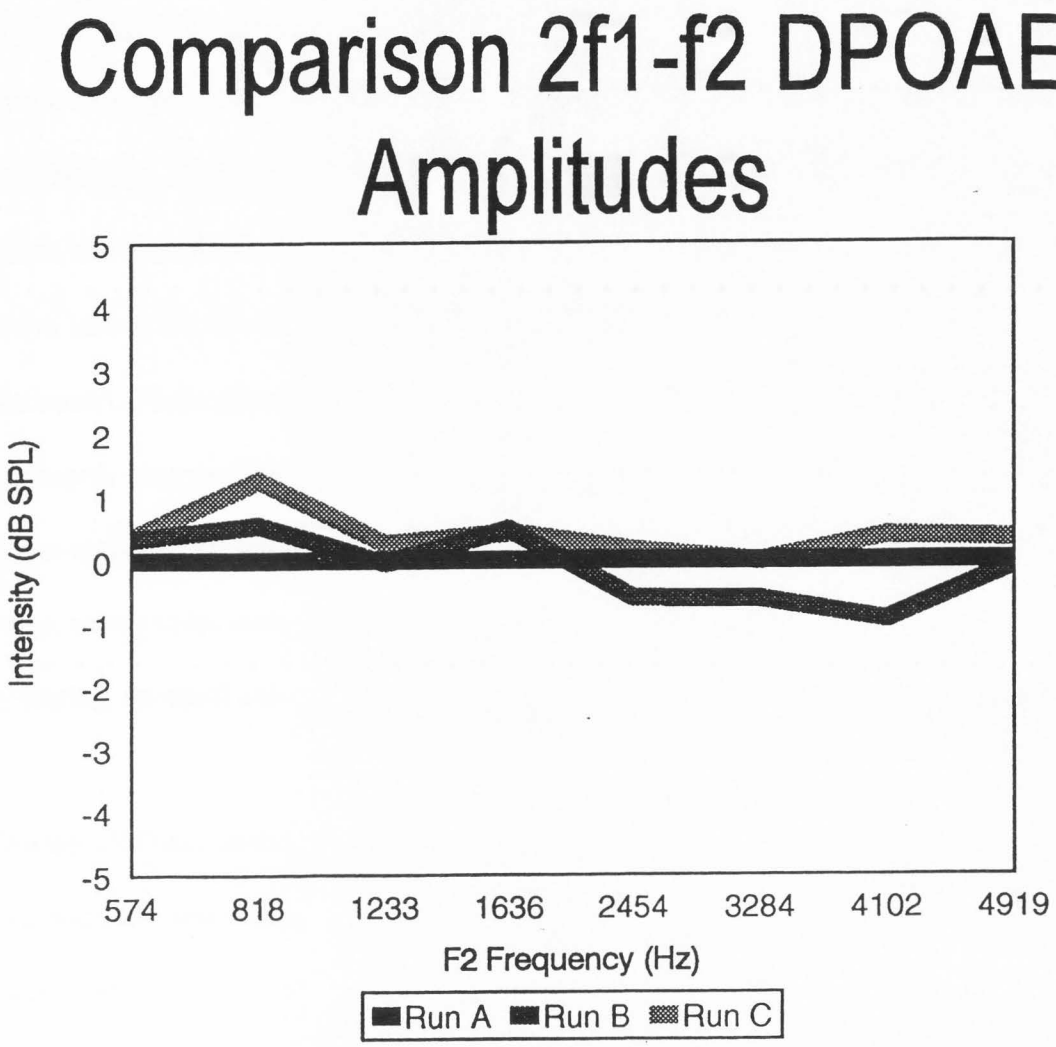

Figure 5. Differences between 2f1-f2 DPOAE amplitudes for runs A, B, and C.

DISCUSSION

The findings of this study indicate that there were minimal deviations (less than 2 dB

SPL) between the 2f1-f2 DPOAE amplitudes with or without using the Ad*Hear Shields. The data taken without Ad*Hear Shields are very similar to that taken when the Shields were on the probe assembly. The results of runs A and C showed no significant statistical differences between 2f1-f2 DPOAE amplitudes, which means that the test-retest results were reliable, and show similar variability as shown with the use of Shields. Noise floor data were always below the 2f1-f2 DPOAE amplitudes, and therefore had no affect on the results.

Because of their apparent acoustic transparency and good test-retest reliability, Ad*Hear Guards may be used over the delicate probe during neonatal screenings without affecting the response measurement and protect the probe assembly from damage. However, more testing needs to be done concerning the actual use of Ad*Hear Shields over the probe assembly during neonatal screening to assess how well the Shields will protect the probe.

IMPLICATIONS

During DPOAE testing, there were no differences found with or without the Ad*Hear Shields, or with test-retest reliability. These results provide strong implications for neonatal hearing screening due to the fact that we may use the Ad*Hear Shields without affecting the measurements.

These findings may resolve two of the problems faced by professionals who administer the neonatal screenings; (a) saving money, and (b) protection of the delicate probe without affecting the hearing screening results. The next step will be to determine if using the Ad*Hear Shields will actually protect the probe assembly from debris. This study may hopefully facilitate the neonatal screening process and encourage other professionals and hospitals to become more aware and concerned about early identification of hearing disabilities in infants and children.

APPENDIX A

F-Scores and P-Values for ANOVA Measures

Amplitude Frequency	F-Scores	P-Values
574	.3505	.9699
818	.4288	.6526
1233	.0326	.9679
1636	.0823	.9211
2454	.1510	.8601
3284	.2069	.8135
4102	.7451	.4548
4919	.0468	.9543

Shows the probability and F-scores from the ANOVA measurements.

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