Comparison of Three Distortion Product Otoacoustic Emission Devices

Victoria Young*, Robert Harrison++, Alf Dolan*, and Hans Kunov*

*Institute of Biomaterials & Biomedical Engineering, University of Toronto, Toronto, Ontario, M5S 3G9.

++Department of Otolaryngology, Hospital for Sick Children, Toronto, Ontario, M5G 1X8.

1.0 Introduction

Distortion Product Otoacoustic Emissions (DPOAEs) are low amplitude sounds generated from within a normal cochlea in response to simultaneous acoustic stimulation by two pure tones. In humans, this type of testing is used to assess the normalcy of cochlear function, specifically outer hair cell function. Current DPOAE devices are highly susceptible to noise, both physiological and environmental. In test conditions where there is a low signal to noise ratio artifacts may appear that negatively affect the repeatability and reliability of the measured DPOAEs. Secure probe placement and low noise conditions are thus necessary to accurately measure DPOAEs. Typical DPOAE devices use data averaging with artifact rejection to increase the signal to noise ratio in the recorded DPOAE signal [4]. A new type of DPOAE device that obtains signals in real-time and uses digital signal processing techniques to reduce background noise level could also minimize testing time and decrease data variability. A prototype DPOAE device with real-time ability was developed at the University of Toronto.

The goal of this study is to perform a comparison of noise susceptibility and DPOAE variability between the University DPOAE device prototype and two different DPOAE recording devices, on a small sample of adults, in quiet and noisy conditions. The results of this study are presented.

Apparatus and Method

DPOAE devices have a basic equipment design including the probe assembly (two speakers, low-noise microphone(s), ear tips); a digital signal processing (DSP) board; operational software; and an isolation transformer for patient safety [1,4].

The DPOAE device operation follows a basic pattern with different features associated with different machines. See Figure 1. The two DPOAE instruments used in the comparison study were the ILO 92, made by Otodynamics, and the GSI 60, made by Grason-Stadler. These instruments were available from the Hospital for Sick Children, in Toronto, Ontario. The ILO 92 is a "research tool" rather than a clinical tool, but the GSI 60 is used for clinical applications. Both the ILO 92 and the GSI 60 use a "check probe-fit" routine to test probe placement, use Fast Fourier Transforms (FFT) and data averaging to reduce noise, and possess an artifact rejection capability. The University prototype uses only signal modeling and digital signal filtering to process the acquired signal, remove noise and minimize artifacts [3].

Testing for this study was conducted inside an audiology booth in the Audiology Department at the Hospital for Sick Children. The background noise level of the audiology booth was measured at 57 dB SPL and the simulated noisy environment, generated by a HIFI Stereo system and a pink noise CD, was measured at 65 dB SPL. The high background noise level measured inside the quiet booth was a result of the hum from the printer and computers of the three instruments. The sound level was measured using a Brüel & Kjaer, BZ7110 sound level meter.

The typical DPOAE test begins by having the volunteer sit comfortably in a chair close to the test device. An ear probe is fitted into the volunteer's ear canal with a rubber probe tip or a foam piece used to seal and hold the probe in place. If a 'check probe fit' routine is available the position of the probe is checked before the DPOAE test is executed. Once the probe is positioned properly, two pure tones are simultaneously presented to the ear. The receiver portion of the ear probe receives and transmits the distortion product otoacoustic emission, if present, and the data is subsequently processed and analyzed by the computer for display.

Before subject testing could be conducted, it was necessary to calibrate the three DPOAE machines to ensure that the pure tones, F1 and F2, and sound levels, L1 and L2 were approximately the same for each machine. Previous studies have shown that the DPOAE amplitude is affected by the F1 and F2 frequencies as well as the L1 and L2 sound pressure levels [1,2]. The default setting on the ILO 92 was used as the parameter template since specific frequencies and sound level outputs could not be pre-set for this machine.

The sound level for the first pure-tone, F1, was set at L1 = 60 dB SPL, and the level for the second pure-tone, F2, was set at L2 = 50 dB SPL. The F1 and F2 ratio was kept constant at 1.22, and a total of nine frequencies groups were included in a test sweep: F1 values were at 818 Hz, 1038 Hz, 1306 Hz, 1636 Hz, 2063 Hz, 2600 Hz, 3284 Hz, 4126 Hz and 5200 Hz.

For each frequency, the L1 and L2 sound pressure levels were measured from the ILO 92 using a dead (dummy) ear and a sound level meter. These L1 and L2 values were recorded and used to configure both the GSI 60 and the University Prototype. The default clinical settings for sampling rate and bin number were also used for the GSI 60 and ILO 92. Each device had its own specific ear probe: the GSI 60 and the University prototype each had disposable ear tips of various sizes and the ILO 92 had disposable foam seals to place around the probe tip.

In total, nine adult ears (eight males and one female between

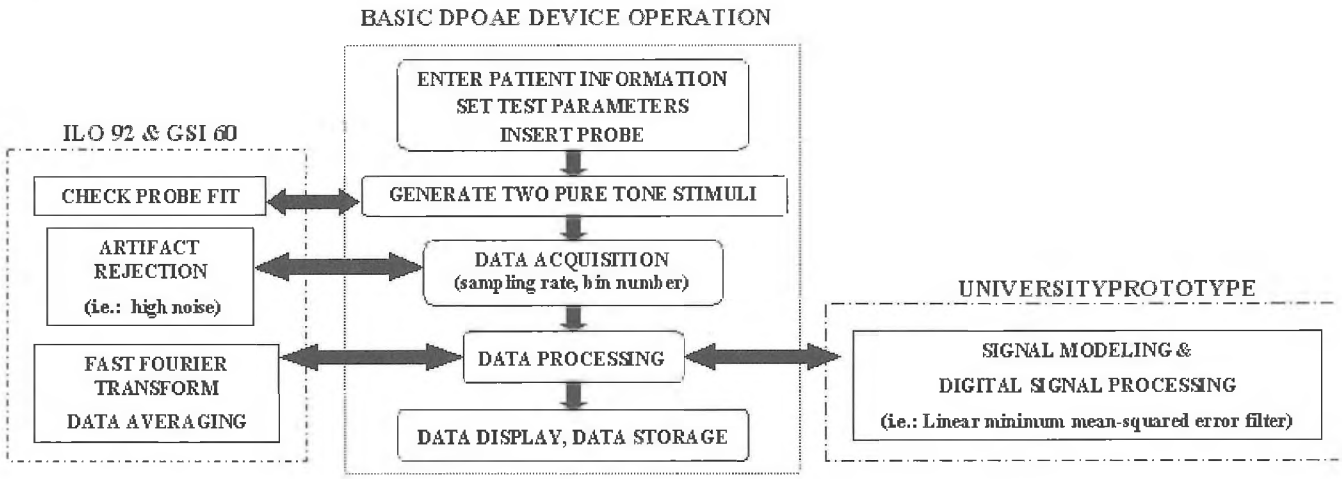

Figure 1: Basic DPOAE device operation with ILO 92, GSI 60 and University Prototype special features identified [1,2,3,4].

the ages of twenty and sixty years) were tested on each DPOAE device. Five tests in total were conducted per ear. Three test sweeps were conducted in the quiet environment. Two test sweeps were conducted in the noisy environment.

Results and Discussion

To compare machine susceptibility to noise the effect of background noise level on measured DPOAE values for each machine was examined. It was necessary to compare DPOAE data acquired in low noise conditions with DPOAE data acquired in high noise conditions.

For each of the nine subjects, the data was divided into 'low noise' and 'high noise' sections. In the low noise section, the tests were repeated three times, where one test was a sweep over nine frequencies, so the median DPOAE value at each tested frequency was selected as the final DPOAE value. The corresponding background noise value for the DPOAE value was also used. In the high noise section, the tests were repeated two times only, so the average DPOAE and background noise value was used for the comparison.

In analyzing the DPOAE data, it is important to note that DPOAEs are visually inspected at each test frequency and the presence of a DPOAE is determined qualitatively. Since the background noise conditions may change even during one sweep of a test (i.e. subject coughs or moves), the variance of the DPOAE amplitude may be quite a bit. The median DPOAE value will account for these odd variances in the data. For the high noise conditions, similar changes in background noise are less likely to affect the signal and since the test sweeps were repeated only two times, the average DPOAE value is sufficient for the study's purpose.

For each subject, the difference in DPOAE amplitude, measured in low noise and high noise conditions, was calculated and then the average difference over all subjects at each frequency was determined. The results indicate that the University prototype has the lowest difference value at 6/9 frequencies, followed by the GSI 60 at 3/9 frequencies. The ILO 92 has the highest difference values at all frequencies. See Figure 2. An average difference over all subjects across all test frequencies gives the same results. The University prototype has an average difference between low noise and high noise DPOAE amplitudes of 3.39 dB SPL, the GSI 60 has an average difference of 6.34 dB SPL, and the ILO 92 has an average difference of 10.75 dB SPL.

To compare data variability over repeated testing the standard deviations of the DPOAE amplitude values in the 'low noise' and 'high noise' sections were calculated. Three tests were used in the low noise section and two tests were used in the high noise section. The standard deviations were then averaged over all subjects at each frequency. For the low noise conditions (LN) and the high noise conditions (HN), the University prototype had the lowest data variability, LN: 6/9 frequencies, HN: 6/9 frequencies, followed by the GSI 60 with low variability at LN: 2/9 frequencies and HN: 4/9 frequencies. The ILO 92 had the lowest variability for LN: 1/9 frequencies and HN: 0/9 frequencies. See figure 3 and 4. In figure 4, values are missing for the ILO 92 at frequencies 818 Hz-1306 Hz because the noise was too loud for the device to obtain valid data.

In this study, the three DPOAE machines were compared by

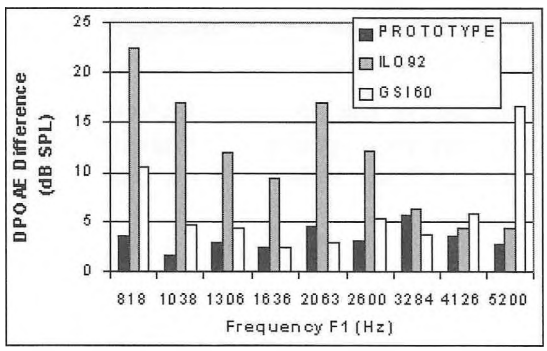

Figure 2: Average DPOAE Amplitude Difference, Low Noise – High Noise (average over 9 subjects)

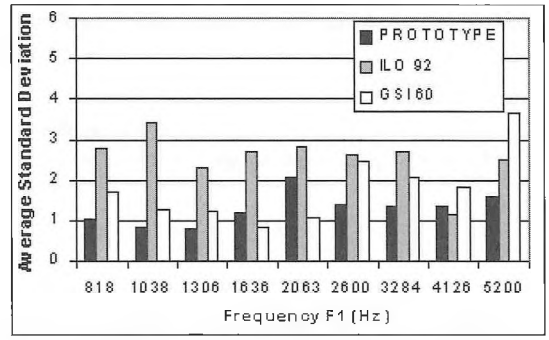

Figure 3. Low Noise Tests – Data Variability

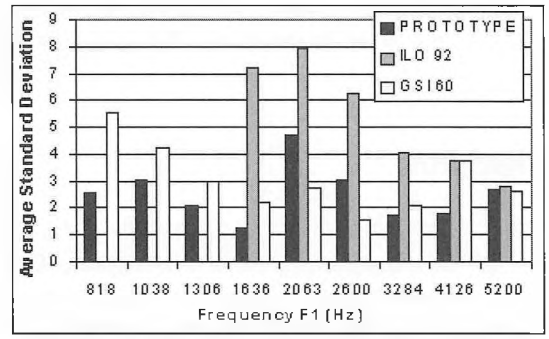

Figure 4. High Noise Tests – Data Variability

examining the affect of background noise level on the measured DPOAE values and the variability of the measured DPOAE values over repeated test trials. Overall, the University Prototype was the least susceptible to the pink noise than both the GSI 60 and the ILO 92. The GSI 60, in turn, was less susceptible than the ILO 92. The results of the study also suggest that the University Prototype provides more repeatable data than either the GSI 60 or the ILO 92. The GSI 60 provides more repeatable data than the ILO 92.

In general, the University Prototype acquired data faster than the GSI 60, which in turn acquired data faster than the ILO 92. Probe placement was more difficult with the ILO 92 than with either the GSI 60 or the University Prototype, however comfort level varied among subjects. The difficulty in probe placement for the ILO 92 may be a reason the measured data from this machine was more susceptible to noise and more variable than either the GSI 60 or the University Prototype.

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