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Is Equivalent Input Noise an Adequate Measure of Audible Circuit Noise?

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Abstract

This presentation will examine some of the factors that confound Equivalent Input Noise (EIN) measurements. Issues include inflated EIN values when non-linear gain is applied and the possibility of elevated noise floors in some hearing aid analyzers. These factors may reduce the usefulness of EIN measures as an indicator of hearing aid circuit noise. EIN performance data will be presented using a variety of hearing devices, measurement procedures, and test equipment. The clinical relevance of EIN will also be discussed.

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INTRODUCTION

The circuit noise produced by hearing devices can be problematic and aversive for some end-users, particularly in quiet listening situations. This problem is often found in those with normal or near-normal hearing in the low to mid-frequencies. For this reason, hearing care professionals may be tempted to select hearing devices that minimize such internal noise by looking at the Equivalent Input Noise (EIN) value provided on a manufacturer's device specification sheet. Relying on EIN measures may not be an optimal strategy as it is not only influenced by such factors as the hearing aid components (microphone, receiver, amplifier), but also, the amount of gain produced, compression levels, hearing device bandwidth, and the test equipment noise floor.

This presentation focuses on some of the confounds inherent in EIN estimation. Particular emphasis is placed on the clinical relevance of this measure when selecting hearing instruments. This will be achieved by measuring EIN on a sample of hearing devices using the current ANSI S3.22-1996 procedure. This method will be contrasted with an alternate, third-octave band approach which is intended to provide more frequency-specific information and also take into consideration the ambient noise within the test chamber. Test equipment limitations will also be presented and discussed.

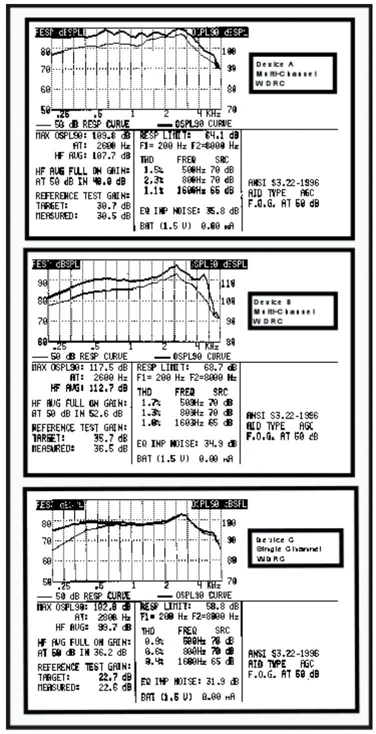
WHAT IS EIN?

EIN is intended to provide an estimate of the internal noise generated by a hearing device. The ANSI S3.22-1996 procedure for determining EIN requires that the aid be tested in the 2cm3 coupler using the Reference Test Gain (RTG) setting at a prescribed input signal of 60 dB SPL. Averaged responses are recorded at 1000, 1600, and 2500 Hz with the source signal turned on. The acoustic signal is then removed and additional electroacoustic responses are obtained. Gain is subtracted from the response (without the sound source) at the specified frequencies to calculate the residual output. This residual output is assumed to be the internally generated circuit noise or EIN of the device. In effect, EIN is an indirect measure of circuit noise as it is calculated rather than measured directly.

MEASURING EIN IN THE TYPICAL HEARING AID ANALYZER

EIN is easily measured by selecting "ANSI" on the front panel of the FONIX 6500 test system. The hearing aid analyzer will automatically prompt the user to set the device to the RTG setting,

Figure 1 illustrates how EIN is represented, for each device, in this typical test system along with the other performance measures. The different ITE devices used in this study were set at their respective RTG settings as specified by the test equipment. Two of these were multi-channel, WDRC instruments (Devices A and B) while the other was a single-channel, WDRC device (Device C).



Both multi-channel devices appear to perform equivalently with respect to EIN while the single-channel device appears to possess less internal noise. It would be premature, however, to conclude that the single-channel device is inherently quieter, as will be shown later in this presentation.

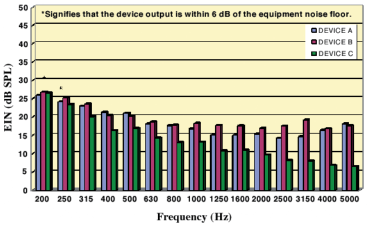
One fundamental problem with these EIN values is the 60 dB source signal built into the default test condition. On average, a 1.25:1 compression ratio was present at the prescribed RTG setting for the test devices. The problem is that the gain of the device is greater without the presence of the input signal, thus artificially inflating the EIN value. To avoid this scenario, EIN should be measured at the 50 dB input level for those AGC devices with lower knee-points (see ANSI S3.22 -1996).

There is also a possibility that the EIN values depicted in Figure 1 may not only originate with the hearing devices themselves, but may also reflect the noise levels in the test equipment, including the ambient noise level within the test chamber. Since EIN is also dependent on bandwidth, modern hearing devices with extended frequency ranges also tend to show higher EIN, perhaps explaining why some advanced technology devices have slightly increased EIN levels over single-channel instruments.

REPORTING EIN IN THIRD OCTAVE BANDS

The ANSI 3.22-1996 standard proposes that measuring hearing aid noise in third octave bands would circumvent the possibility of high ambient noise in the test chamber from

Figure 2: Third Octave Band EIN at the RTG Setting Using a 50 dB Input Signal in the Typical Hearing Aid Analyzer



contaminating the EIN measurement. The third octave band approach also provides frequency-specific information about the circuit noise itself which is not equal across the frequency continuum.

Figure 2 depicts the EIN in third- octave bands between 200 and 5000 Hz using the same devices and RTG settings as before. Additionally, a 50 dB input signal was used to minimize the previously-discussed effect of compression on the artificial inflation of the EIN estimate. This third-octave method demonstrates that circuit noise is greatest in the low-frequency region and tapers somewhat at the mid- to high-frequencies. The increased level of "noise" in the low frequencies may also reflect the preponderance of low-frequency energy entering the test chamber, despite conscious efforts to minimize noise levels in the laboratory. Note the asterisks in Figure 2 at both 200 and 250Hz which signify that the device output (without a sound source) was within 6 dB of the test equipment noise floor. In effect, this symbol (or any other) can be used to denote those situations in which the device noise floor approaches that of the test equipment. Whenever an asterisk symbol is displayed, the reported EIN can be considered to be no higher than the noise floor of the test equipment.

EIN MEASUREMENTS USING THE PATIENT'S FITTING

EIN measurements require that devices be set at the Reference Test Gain (RTG) level to prevent output saturation (the rationale was based on such factors as the typical long-term average intensity of speech and associated peaks). Unfortunately, the RTG setting probably does not reflect the setting that will be actually worn by the end-user. Although the ANSI Standard for measuring hearing instrument performance was never intended to be clinically useful, we will nevertheless try to make the EIN measure relevant by modifying the third-octave procedure to take into account the end-user's fitting.

The test fitting example used here reflects the prescribed gain and output for an individual with a high-frequency sensorineural hearing impairment with relatively normal hearing in the low- to mid-frequency region (see Figure 6 in the next panel). This hearing loss was selected to represent a "difficult" case with respect to the potential for audible circuit noise.

In order to evaluate EIN with this "real" fitting, it was necessary to work within the control limitations imposed by the fitting

Figure 3: 2cm^3 Test Fitting Response Curves for All Devices.

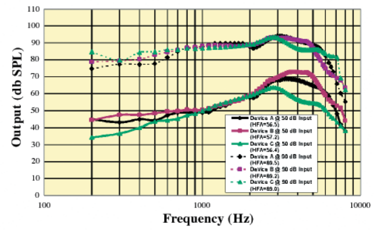


Figure 4: Third Octave Band EIN in the Test Fitting Condition Using the Typical Hearing Aid Analyzer

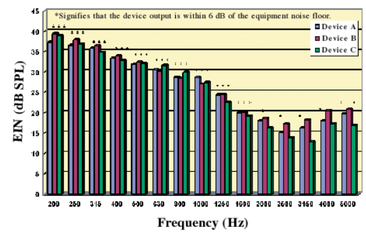
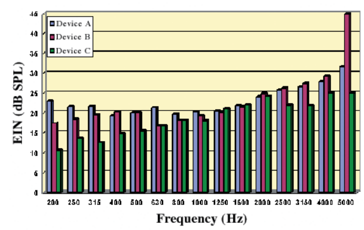


Figure 5: Third Octave EIN in the Test Fitting Condition using the B&K Test System



software (or trimpots) of the test devices. Since all instruments varied in the number of available frequency channels, it was not always possible to match performance exactly. The frequency-shaping control allowed by the multi-channel instruments facilitated target-matching efforts considerably over the single channel device. Despite these differences, great effort was placed on ensuring that the HFA of all the test devices was set to within 1 dB of the prescribed target. Figure 3 depicts the 2cm3 coupler performance of the three devices.

As shown by the asterisks in Figure 4, the noise level produced by the hearing devices at the test fitting could not be evaluated owing to the ambient noise levels within the Fonix 6500 test chamber. However, measurement was still possible using the inherently quieter (and considerably more expensive) B&K test system. As seen in Figure 6, EIN values were actually very low for all devices compared to the result obtained in the first test system. This contrast in EIN performance clearly demonstrates the importance of sound attenuation in the test chamber, as well as in the test environment. This finding suggests that any EIN measurement is suspect unless great care is taken to ensure absolute quiet during the test. This point must be stressed as the noise levels in the test environment of the typical hearing aid manufacturer and dispensing clinic are often not ideal.

WHY NOT USE SPECTRUM NOISE INSTEAD OF EIN?

As shown in the previous section, the amount of so-called circuit noise generated by a hearing device is often influenced by external factors such as of the noise level within the test environment, test chamber, measurement equipment, and testing methodology. Although displaying EIN in third-octave bands is more informative, it is questionable whether EIN can be a useful indicator of audible circuit noise. EIN is derived from other physical measures and does exists in isolation. EIN cannot be "heard" directly as it is almost always accompanied by gain. When listening to a hearing device in quiet, the end-user hears output, which is the sum of all amplified environmental and internal sounds. Thus, it becomes relevant to ask whether the spectrum noise would be a more clinically useful indicator of audible circuit noise.

Figure 6 depicts the spectrum noise produced by the test devices using the previous fitting. These measurements were converted to the HL scale to make them clinically meaningful. Unlike EIN, the third octave spectrum noise provides a direct indication of the audibility of the circuit noise for a particular individual. Figure 6 suggests that the multi-channel devices produced more internal noise than the single channel instrument. Despite this, the sensation level of the noise did not exceed 20 dB SL. The noise reduction feature on one of the multi-channel devices rendered the circuit noise inaudible.

Most advanced technology hearing instruments incorporate some form of expansion, microphone squelch, and/or active noise reduction technologies. On some devices, these features are enabled through the programming interface and can reduce internal noise to negligible or inaudible levels (Figure 7). In this example, the third-octave spectrum noise was recorded on one test device using various noise reduction and expansion settings.

In conclusion, EIN, in and of itself, is probably not a useful indicator of audible circuit noise. Many factors can confound EIN measurements, including the sound attenuating properties of the test equipment, the degree and number of compression channels, as well as frequency bandwidth. Displaying EIN in third-octave bands may provide a more useful picture of how this noise is distributed. However, reporting the third octave spectrum noise of the device and superimposing this information over the end-user's audiogram provides a better, and clinically relevant estimate of the audibility of this noise. Fortunately, hearing aid features such as noise reduction and expansion can render theses noises inaudible, making life easier (and quieter) for both the hearing care professional and the end-user.

Figure 6: Third Octave Spectrum Noise Measurements for the Test Devices Converted to the HL Scale.

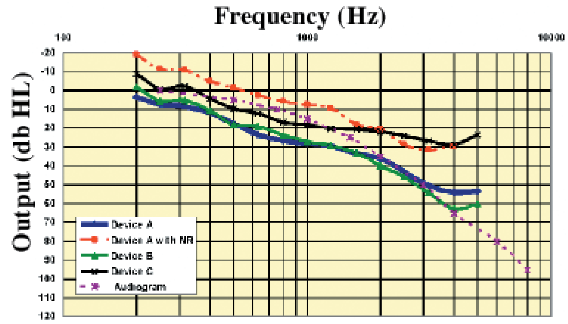
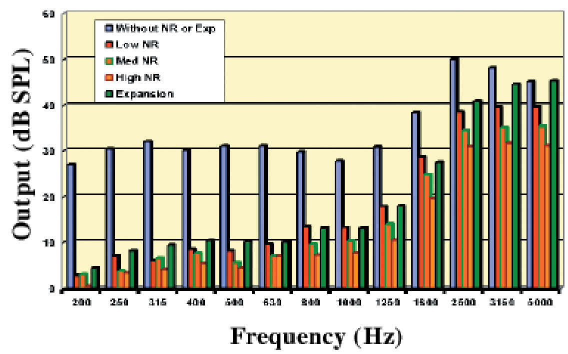


Figure 7: Effects of Noise Reduction and Expansion on the Attenuation of Circuit Noise



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