3M™ E-A-Rfit™ Validation System
Frequently Asked Questions (FAQs)

E-A-R 13-17/HP

Elliott H. Berger, M.S.
Jim D. Brown, B.S., PMP
Pegeen Smith, RN, MS

3M Personal Safety Division
E•A•RCAL Laboratory
7911 Zionsville Road
Indianapolis, IN 46268-1657
desk: 317-692-3031
Elliott.Berger@mmm.com

April 18, 2014

Version 1.5

The 3M™ E-A-Rfit™ Validation System has been demonstrated to be an important tool for use in employee training and evaluation of fit and performance of hearing protection devices (HPDs). The purpose of this document is to address questions and concerns that arise from time to time regarding the technical performance aspects of the system.

Contents

1. **When mounting the dual-element microphone on the system loudspeaker for daily calibration purposes, why is the orientation important? Why do the calibration curves change for different orientations, and doesn't this affect the PAR results?**

When predicting the personal attenuation rating (PAR) of an earplug with the E-A-Rfit system, the fundamental metric recorded is the difference between the sound pressure levels (SPLs) measured by the two microphones encapsulated within the dual-element microphone assembly. One mic (called the reference mic) measures the SPL outside the ear and the other one (the measuring mic) measures the SPLs in the earcanal. The difference between these two microphone readings is the Noise Reduction (NR). In order to make an NR correspond to a real-ear attenuation measurement as found with human-subject testing in the laboratory, a number of computational correction factors must be made. One correction accounts for the difference in the frequency response and sensitivity of the two mics. Ideally the two mics should be acoustically identical. However, regardless of how tightly controlled are the manufacturing tolerances, identical performance cannot be achieved. Therefore the differences between the acoustical responses of the two mics must be accounted for within the E-A-Rfit system.

The accounting is accomplished each time the E-A-Rfit system is started up by requiring a calibration of the microphone assembly. This calibration does not adjust the absolute sensitivity of the mics, but simply verifies the difference in their responses when measuring a given steady sound source emitted from the loudspeaker. This difference is used as part of the correction factor that is applied during the process of measuring the hearing protector NR and computing the PAR.

For the calibration to work properly it is important that the mic assembly is positioned at the center of the loudspeaker. This ensures that the same sound field is equally incident on both mics (i.e., the sound hits both mics at the same angle). If the mics are moved substantially from the area of the sound field where the sound levels are uniform, the difference between the readings of the two mics may change. The discrepancy will be greater in the high frequencies (above 4 kHz) where the wavelengths are shorter, and this can be seen on the E-A-Rfit graph that is presented during the calibration process. Small movements or rotations of the microphone assembly will cause only small differences over most of the frequency range (less than approximately 1 dB), somewhat higher above 4 kHz. Regardless, it is best to always carefully position the mic assembly on the mounting bracket for the daily calibration process. Even though small movements may create visible changes on the calibration graph, they will not materially affect the computation of PAR, since PAR is computed in octave bands that sum values across a range of the narrow-band frequencies shown on the calibration graphs. The octave-band nature of the computation tends to smooth out small differences that are apparent when viewed frequency by frequency.

2. **What is the method used to calibrate the dual-element microphone assembly in the E-A-Rfit system?**

During manufacture, or upon return of the microphone assembly for repair or calibration, an absolute calibration is completed. The process involves a laboratory microphone system to calibrate the E-A-Rfit microphone that measures the exterior SPLs (i.e., the reference mic) to assure that it provides a useful estimate of the sound levels present during F-MIRE testing. In addition to the absolute calibration of the reference microphone, the difference in sensitivity and response between the reference and measurement microphones in the dual-element assembly is checked to make sure that their match is within design limits. If not, the assembly is rebuilt or discarded.

Upon receiving a new or recalibrated microphone assembly, the EARfit software requires an initial microphone response test. This initial test is compared by the software to the factory-design limits and it should be found to fall between them. Presuming it does, the initial response plot is recorded as the microphone's baseline values. (If the assembly fails this test refer to the user manual for trouble shooting instructions.) On subsequent uses of the same microphone, the system checks the response against the baseline to assure that it has not changed significantly.

It should be noted that although the response plot is displayed in narrow-band format, the result is checked in octave-band format since PAR computations are based on octave-band data. It is rare, but possible, to have a spike in the response slightly outside the displayed limit lines that still meets the measurement requirement.

The daily calibration response test indicates whether the microphone has changed from the baseline and whether this change is slight or "excessive," the later being denoted as a critical failure. The limits for these results are based on design performance requirements. The "slight change" notice can be the result of small variations in calibration position, the result of not having the microphone tip well tightened, or atmospheric conditions. If careful repositioning or tip tightening does not improve the response, it is likely that the microphone is experiencing a gradual degradation. Since the changes are small, the measurement results are still valid. However, in this case it is advisable to have the microphone serviced at a convenient future date.

3. **If E-A-Rfit systems are used in geographic areas with substantial elevation above sea level does the calibration of the microphones account for this and give reliable results?**

Since the E-A-Rfit field-microphone in real ear (F-MIRE) process is a difference measurement, i.e. it records the difference between two microphones of identical construction for a constant input signal, the absolute calibration is unimportant. Whatever the effects of altitude are on one mic, they will be the essentially the same on the other mic in the dual-element assembly. Therefore the daily calibration accounts for small changes and the accuracy of the F-MIRE measurement will be unaffected.

What may be affected slightly is the readout on the measurement screen of the internal and external A-weighted sound levels. However, those values are only provided as general indicators for educational purposes and have no effect on the resultant PARs.

4. **How do you control the frequency response and its consistency from unit to unit, for the E-A-Rfit loudspeaker?**

   The specific response of the speaker is not critical since the E-A-Rfit measurement is a noise reduction (NR) value that records the difference in sound pressure levels (SPLs) at two different locations for a consistent sound source. As long as the sound is consistent during the measurement process, the precise frequency spectrum is not critical. What is important is that there is enough energy present at all frequencies at which data are acquired so that there is an adequate signal present for the mics and the analysis system to measure.

   The response of the speaker is controlled via the design of the speaker acoustic components and its on-board power amplifier electronics.

5. **The uncertainty of the measurements seems rather large at +/- 6 to +/- 8 dB. Cannot something be done to improve that uncertainty?**

   The uncertainty of the PAR is due to three separate components of the measurement and prediction process: measurement uncertainty, fit variability, and spectrum uncertainty, each of which amounts to approximately 3 to 4 dB. The combined uncertainty is the square root of the sum of the squares of all three values. Only the measurement uncertainty is an inherent feature of the E-A-Rfit field-microphone-in-real-ear (F-MIRE) process. The fit variability results from the subject fitting of the earplug differently from fit to fit, and the spectral uncertainty is due to the use of a single-number A-weighted prediction factor. The fit variability can be reduced by taking additional measurements for multiple fits on the same subject. Uncertainty is explained in greater detail in a separate memo on uncertainty by Berger (2012).

   Although the uncertainty values may seem high, they serve as a good reminder that the uncertainty of measuring noise reduction and predicting workplace protection must be considered when evaluating whether a given hearing protection device is appropriate for the worker who is being tested. The E-A-Rfit™ software automatically includes the uncertainty values when it reports the Protection Sufficiency results.

6. **The E-A-Rfit measurements are conducted with steady noise levels but I would like to use them for impact and/or impulsive noises. Is there a way to adapt the E-A-Rfit data accordingly?**

   For conventional hearing protection devices (HPDs), those that are not specifically intended to provide attenuation that changes with sound level, the E-A-Rfit data will be representative of their performance in steady noise and/or impulsive noise for peak levels up to about 170 dB SPL. This statement is supported by the note in Table 1 of ANSI S12.42-2010. That note stipulates that even measurements conducted with steady test signals at sound pressure levels much lower than those used by an F-MIRE measurement, such as used in real-ear attenuation at threshold tests, are acceptable for testing passive earmuffs and earplugs in impulsive noise.

   The E-A-Rfit system is not intended to measure the performance of intentionally level-dependent hearing protection devices (HPDs) such as the 3M™ Combat Arms™ earplug in its open position, or electronic level-dependent products in their active mode. Measurement of those devices is complex and requires special high-level sound sources such as described in ANSI S12.42-2010. E-A-Rfit measurements cannot support that type of testing nor do any other field measurement systems. However, one can test those types of devices with the E-A-Rfit system in their non level-dependent modes when suitable test probes are available. For example, proper fit and maximum-attenuation can be assessed for the Combat Arms plug in its closed position or an electronic device in its off position.

7. **Does sound penetrate the thin transparent tube that connects the probed test plug to the microphone tip? If so, would this contaminate the E-A-Rfit measurements and cause the results to be inaccurate?**

   In the design of the probed earplugs three key features are taken into account. First and foremost, the tube needs to be small and flexible so that it is unobtrusive and allows the wearer to fit the test plug in substantially the same way as an unmodified earplug. Secondly, the tube's sound channel must be large enough to let enough sound through for proper measurements. And thirdly, it is important that the tube have high levels of self-insertion loss (IL) so that sound does not excessively penetrate its side walls and contaminate the measurement process. The only sound the microphone should sense is that which goes through the earplug into the earcanal and that consequently exits back out through the tubing mounted in the earplug.

   The E-A-Rfit tubing and the assembly design were selected to accomplish these goals. The IL of the tubing is assured at the time of the development of the compensation factors for each probe. The attenuation of the probed earplugs with the tubing sealed shut at its outer end is compared to the attenuation of unmodified (i.e., unprobed) earplugs. The values must agree within specified limits for the test plugs to be accepted. This assures that significant sound energy is not leaking thru the tubing walls or between the tubing and the test plug body. However, should there be a small amount of sound leakage, the error is a conservative one. It will cause the E-A-Rfit measurements to underestimate, rather than overestimate, the actual performance of standard earplugs.

8. **Does the tube through the E-A-Rfit test plugs change the fit of the plug or the way a user can fit the plug? For example, some users of in-ear dosimetry systems have noticed the tubes seem to affect how easily and how well the earplugs for those systems can be fit.**

   The probes through the E-A-Rfit test plugs have been specifically designed to be as thin and flexible as possible, and yet to be adequately robust so that they do not let sound penetrate through their side walls. If consequential sound were to penetrate the tube walls it would contaminate the E-A-Rfit measurements and lead to underestimates of the actual attenuation provided by the test plugs. (See FAQ #7 for additional details.)

   The outside diameter of the tubes is 0.060" (1.5 mm) so that its small and flexible design neither interferes with the ability to roll down and fit foam earplugs, nor materially assists in the insertion of those products. The tubes in 3M probed earplugs are about one-half the outside diameter of the tubes typically used by in-ear dosimetry system. Since they are smaller and more flexible they are less likely to affect the fitting process. The dosimetry-type tubes need to be larger because of the types of measurements that are taken with such systems.

   Regardless of the thinness and flexibility of the tubing it may, for some users, help with their insertion to a small extent. However, the fact that the subject has now felt/experienced a better/deeper fit of the earplug will likely be useful going forward as s/he works to repeat that fit with unmodified earplugs on a daily basis.

9. **How have you demonstrated that the results provided by an E-A-Rfit validation truly measure the attenuation that an individual obtains? Has the E-A-Rfit system been independently validated?**

3M extensively evaluated the performance of the E-A-Rfit system when it was developed in 2006, and since then has continued to test the system and all of the test plugs designed to work within that system.

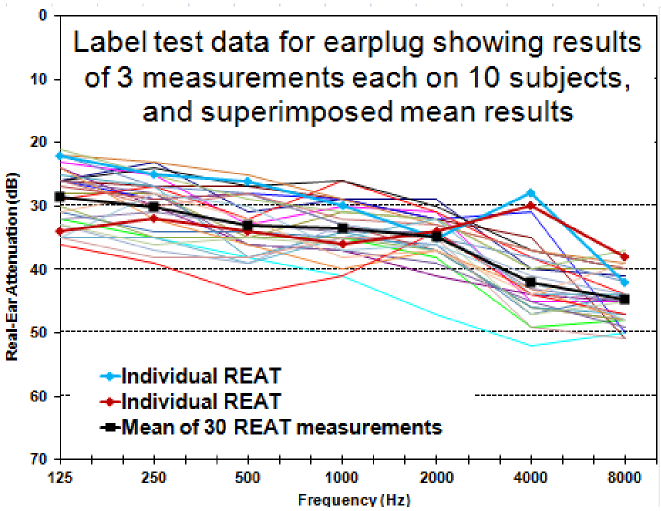
When probed plugs are designed and manufactured, we evaluate them in our laboratories to determine the appropriate compensation factors to include in the E-A-Rfit software. A controlled study is conducted on each type of test plug to help ensure that the noise-reduction measurements taken with field-microphone-in-real-ear technology (F-MIRE) are correct. Groups of 20 subjects are tested with both properly and poorly fitted earplugs. For each fit of an earplug it is tested using both the E-A-Rfit system and a standardized laboratory real-ear attenuation approach (ANSI S12.6-2008). The testing is conducted in a facility accredited for hearing protector attenuation measurements (NVLAP). The process has been described by Berger et. al. (2011)

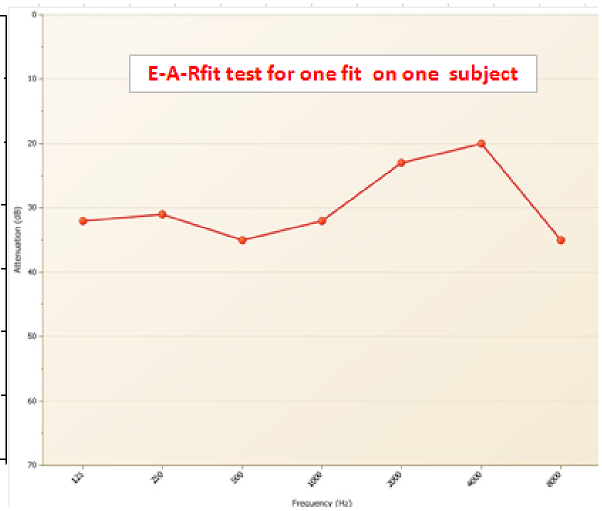
In 2013 the E-A-Rfit system was independently validated by Jeremie Voix and his associates at the University of Quebec. Three of the probed test plugs: 3M™ Classic™ Probe Tips, 1100 probe tips, and 3m™ UltraFit™ Probe Tips were examined. In all cases agreement was found within approximately 2 dB, between the F-MIRE-measured PARs and those found using classical real ear attenuation at threshold (REAT) test methods. That report is available on the E-A-Rfit support site (Voix et al., 2014). Additionally, a paper was presented in September 2013 at InterNoise by the French National Noise at Work Laboratory (INRS) (Trompette and Kusy, 2013), that evaluated four different fit-test systems, including the E-A-Rfit validation system, and it was one of the three systems that they found acceptable for use.

10. **Why do the E-A-Rfit attenuation charts sometimes show unusual shaped attenuation curves, even for well-fitted plugs, such that the attenuation drops to lower values at some of the high frequencies like 4 kHz, than found for the lower test frequencies?**

We are accustomed to looking at manufacturers' data sheets that report mean attenuation values over 10 or more subjects with multiple fits (typically three) per subject. This average real-ear attenuation at threshold (REAT) data typically increases with increasing frequency, reaching a plateau in the higher frequencies, but for high-attenuation products, sometimes showing a drop at 2 kHz (due to bone-conduction limitations). The key point is that these are data averaged across tests and across subjects. Below is an example of mean REAT data for a group of 10 subjects that includes all of the individual 30 measurements (10 subjects x 3 fits each) that comprise the average. It is compared to a single E-A-Rfit measurement on one subject for the same type of earplug.

The mean curve has a notably different shape from the E-A-Rfit curve. However, if one examines in detail each of the individual REAT curves shown on the left, a wide range in data and curve shapes is observed. For some subjects and individual fittings their curves will have unusual shapes that indeed look like the E-A-Rfit curve on the right. Two such curves (bold red and bold blue) are highlighted. Thus, when unusual curves are observed in a single E-A-Rfit measurement, in many instances they will reflect the actual attenuation being achieved by that person, and which would have been observed with a REAT evaluation on that individual, had such a test been conducted.





11. **What is the math that underlies the computation of the E-A-Rfit compensation factors?**

The E-A-Rfit system utilizes a dual-element microphone assembly and dedicated built-in spectrum analyzer to rapidly determine the noise reduction (NR; difference between the levels inside and outside the hearing protector), at the seven octave-band test frequencies from 125 Hz to 8000 Hz. The hearing protector that is tested is a special probed-version as discussed in FAQs #7 and #8. Based on extensive laboratory tests, compensation factors have been developed that can be used to predict the equivalent real-ear attenuation at threshold (REAT) of the actual hearing protectors, as used in practice, from the E-A-Rfit measured results.

The method of estimating REAT using NR measurements and associated compensation factors was presented by Voix and Laville (2002). It requires the following correction factors:
a) a correction for the difference between the sound-field sound pressure level that would be measured at the eardrum in the open ear and the actual value measured by the reference microphone in the dual-element assembly mounted outside the ear,
b) a microphone correction to account for the length of probe tube between the microphone and the inner face of the test plug,
c) a correction for the difference between the pressure on the inner face of the test plug and that occurring at the eardrum, which can be thought of as a resonance of the occluded earcanal,
d) an adjustment to include the physiological-noise masking that causes REAT data to be inappropriately high by a few decibels at the low frequencies (Berger and Kerivan, 1983),
e) a computational correction to limit the amount of measured F-MIRE attenuation in order to account for the bone-conduction pathways that F-MIRE cannot measure.

The compensation factors are experimentally determined in the E•A•RCAL laboratory using 20 subjects and the production versions of the probed earplugs. The results are validated by comparison to real-ear attenuation at threshold (REAT) data for the same group of subjects and fit of the plugs. REAT values are recognized as the "gold standard" in evaluating hearing protection noise reduction.

12. **Are the PARs produced by the E-A-Rfit systems accepted in industry and among regulatory agencies such as OSHA? Especially, what happens when an individual PAR may be substantially higher than the nominal laboratory rating on the product?**

    Fit testing systems started to be introduced to the marketplace in the late 1990s and developments accelerated in the early 2000s. The E-A-Rfit validation system was introduced in 2007 and a number of other systems have appeared since that time. This is an exciting technology being widely evaluated and discussed, reported on at national conferences and featured in the press circa 2013. A NIOSH/OSHA/NHCA alliance document (2008) speaks to the values of this technology and how it may be useful in industry. An American National Standards Institute (ANSI) working group (WG11) is currently developing an American National standard describing this technology designated as field attenuation estimation systems (FAES).

    In a letter of interpretation (2013), the U.S. Occupational Safety and Health Administration (OSHA) declined to answer a question about whether employers can use PARs to estimate the adequacy of hearing protectors worn by employees in workplace hearing conservation programs rather than using the methods defined in appendix B of OSHA regulation 29 CFR 1910.95. The letter stated that OSHA plans to respond to the question after consulting with National Institute for Occupational Safety and Health (NIOSH) but no timetable was given for such a response.

    Using individual personal attenuation ratings (PARs) in place of the gross estimates of individual attenuation provided by laboratory test data averaged across subjects, is seen by many as an enhanced method of estimating individual protection values. The fact that a user's PAR may exceed the labeled Noise Reduction Rating (NRR) on a given product is not surprising. Recall that NRRs are a statistical predictor at the 98th percentile. Thus, for example, an NRR of 28 on a given earplug indicates that 98% of laboratory test subjects fitting the device properly will obtain 28 dB of protection or more. The NRR does not speak to what an individual worker gets on a given fit. Even if the NRR can be believed at face value, most well-fitted users (and users should be reasonably well fit after undergoing a fit test) should obtain attenuation that equals or exceeds that number. Thus it would be surprising indeed, even in real-world situations, if many users did *not* have PARs that exceeded the NRR on a given product.

13. **Why does the E-A-Rfit system use seven test frequencies when so many of the other fit testing systems use fewer?**

    Various authors have examined the number of frequencies required to properly assess hearing protector attenuation. The standard laboratory protocols utilized today (ANSI S3.19 and ANSI S12.6-2008) routinely include at least seven test frequencies (125, 250, 500, 1000, 2000, 4000, and 8000 Hz). Although fewer frequencies can indeed be utilized and an overall personal attenuation rating (PAR) or Noise Reduction Rating (NRR) can be predicted from such a reduced set of data, the results are not as accurate. The reasons to use fewer frequencies involve the time it takes to conduct a test, and equipment and environmental noise limitations.

In an objective system such as the E-A-Rfit validation system where data at seven frequencies can be acquired as quickly and easily as at one or three frequencies there is no reason to compromise between accuracy, and ease and speed of use, and thus all important test frequencies are included.

14. **Why doesn't the E-A-Rfit system test hearing protector attenuation at the standard audiometric frequencies of 3000 and 6000 Hz?**

Standard audiometric test frequencies for hearing evaluations include 3 and 6 kHz because hearing loss due to noise often appears first in the range between those frequencies. While important to evaluate those frequencies to assess hearing, it turns out to be unimportant in measuring HPD attenuation. The current ANSI hearing protector attenuation test standard (ANSI S12.6-2008) no longer requires testing at 3 and 6 kHz because research and computations have shown that data at those frequencies are not useful in computing protection. Workplace noise measurements rarely include specifically the 3- and 6-kHz bands and even if those data are measured, they are averaged together with the values at 4- and 8- kHz respectively, and have little effect. Furthermore, the 3- and 6-kHz data have no affect on the computation of the overall A-weighted noise reduction which is what is typically used to predict noise hazard. The E-A-Rfit system already captures attenuation values at seven frequency bands important to hearing protector evaluations (see FAQ #13), and 3M has no plans to add 3 and 6 kHz to this testing protocol.

15. **How is the binaural PAR computed and why can it sometimes be even lower than that of either the right or left PARs?**

The purpose of measuring a PAR is to estimate the actual protection that an individual user achieves. The best measure of that, i.e. the gold standard, is a real-ear attenuation at threshold (REAT) method. REAT is conducted in a diffuse field with both ears responding. The E-A-Rfit system uses field microphone-in-real-ear (F-MIRE) measurements that are conducted on each ear separately. Individual-ear information is important to guide users in getting a good fit in each ear. However, individual-ear data must then combined to estimate the overall protection, called the binaural (both ears) PAR. Binaural PAR represents the most conservative prediction for the given fitting. Clearly if one ear is less well protected than the other that should be accounted for in considering the individual's overall protection.

The binaural attenuation at each test frequency is controlled by the ear that is receiving the least protection. Generally this is the same as the ear that is receiving the least attenuation, but the controlling ear can be offset by differences in hearing sensitivity between the two ears. This subtlety can be accounted for by the E-A-Rfit system if an employee's audiometric data are entered in the

Left-Ear Attenuation			
1000 Hz	2000 Hz	4000 Hz	PAR
16	20	24	20

Right-Ear Attenuation			
1000 Hz	2000 Hz	4000 Hz	PAR
22	20	19	20

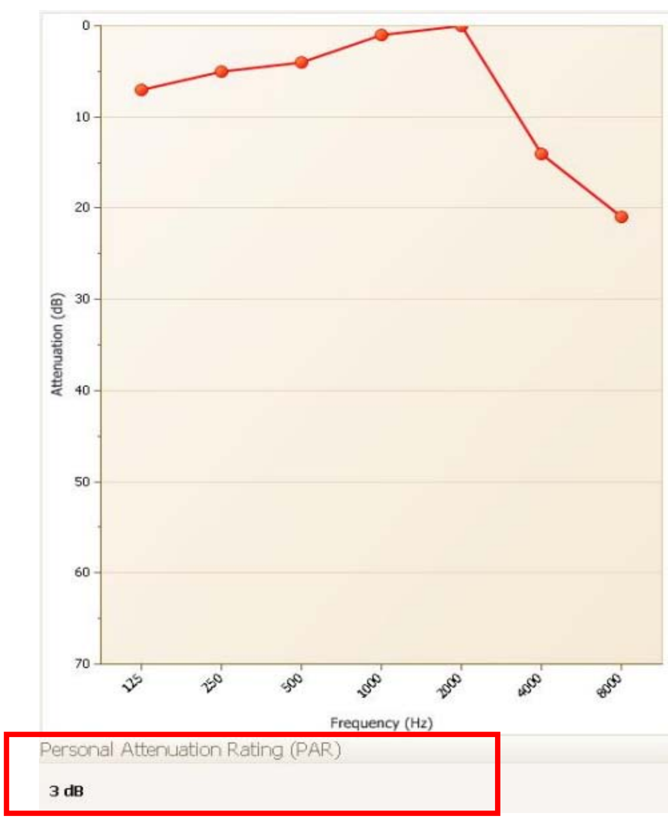
Binaural Attenuation			
1000 Hz	2000 Hz	4000 Hz	Binaural PAR
16	20	19	18

software, but for purposes of the example that follows, only the attenuation values (no audiometric data included) are utilized for each ear.

To simplify the example let's presume that the octave-band attenuation values are measured at only three frequencies (instead of the normal seven-frequency protocol) and a PAR is computed therefrom, for each ear separately. When comparing the attenuation values for the left and right ears at each frequency it is common for one ear to be greater than another at most, if not all, of the frequencies. In such instances the binaural PAR is simply equal to the weaker protector. But in the example shown in the table above (with values color coded by ear), the results between the ears are close, with the left ear controlling at 1000 Hz, the right ear at 4000 Hz, and both ears contributing equally at 2000 Hz (hence the bi-color binaural value at 2000 Hz). For this example, as sometimes occurs, the binaural PAR is lower than that of either ear computed individually. Using the weaker value as the controlling factor prevents over-estimation of protection.

16. **What is the range of PARs that can be measured by the E-A-Rfit system? Will very poorly fitted plugs give values near 0 dB?**

The range of PARs that is typically observed is approximately 5 – 43 dB. Although with some test plugs such as the Classic™ Plus foam earplug we have observed PARs up to 44 dB, the highest PARs that can typically be measured are in the range of 41 to 43 dB. This is in part due to the attenuation of the earplugs, but also due to the fact that E-A-Rfit measurements simulate the bone-conduction limits present in real-ear testing, and also due to the limits of the measurement system itself. If higher values are observed the tubing through the test plugs may have a blockage, so discard that test plug and select another.



At the low end of the range of attenuation values, one can measure PARs down to 3 to 4 dB for a very poorly fitted plug as illustrated in the example above for a Classic™ plug placed in the concha, just barely blocking the entrance of the earcanal. The measured PAR for this fitting was 3 dB. Notice that in spite of the poor fit, the attenuation values are 14 and 20 dB at 4 and 8 kHz, and those values were validated by correspondence to the wearer's subjective impression of the E-A-Rfit pink-noise test signal which was plainly audibly attenuated in the high frequencies.

When PARs are very low, approximately 5 dB or less, the protection can compute to less than 0 dB when you include the subtraction of uncertainty of 6 – 7 dB. What does this mean when the effective protection is negative?

For such low levels of protection clearly the plug needs to be refitted or a different earplug evaluated. The fact that the PAR minus uncertainty is less than 0 can be largely attributed to the fact that the statistical corrections are based on typical (symmetrical) distributions, but when attenuation approaches 0 dB the actual distributions tend to be skewed. However, it is also true that a very leaky earplug can provide small amounts of gain thru a Helmholtz resonance effect in the low to middle frequencies, so that indeed negative attenuation (i.e. amplification) is indeed possible.

17. **Can I use E-A-Rfit validation system tests on 3M products to estimate the PARs obtained by similar products for which test plugs are not available, be they other 3M products or ones made by other manufacturers?**

Substantial engineering design and quality control are involved in the manufacture of each of the test plugs included in the E-A-Rfit system to assure they perform as closely as possible to their conventional counterparts sold as hearing protectors. Additionally, extensive laboratory testing is required to compute appropriate compensation factors specific to each 3M earplug. This is key to the accuracy and reliability of the E-A-Rfit predictions. 3M has not tested and cannot speak to the performance that would be obtained by products for which test plugs are not available, including those produced by other companies. Therefore, PARs derived for 3M products cannot be used to make predictions for other earplugs even if they are similar in appearance. This is emphasized in the 3M E-A-Rfit Validation software end-user license agreement (EULA), Clause 3.2.2, that limits the "use or allow [ing] the use of the Software to assess the performance of any hearing protection product or device not provided as part of the System."

On occasion, users may wish to apply the E-A-Rfit system as a training tool to improve an employee's ability to fit an earplug that is not included in the E-A-Rfit system. This approach may be of value given that the hearing protector for which the training is intended is of similar style, material characteristics, and size to the 3M test plug. However, 3M has no data on or suggestions about the accuracy of this approach and cannot advocate the use of E-A-Rfit-system measured PARs to estimate protection for hearing protectors for which test plugs are not available. Accordingly, 3M makes no representation or warranty regarding, and takes on no risk from, any actions using non-3M products in conjunction with the E-A-Rfit system.

18. **How much improvement in user protection is actually attributed to the use of a fit-test system like the E-A-Rfit system, versus what is gained by simply conducting one-on-one training?**

    An experiment designed to specifically answer this question would be difficult to design and to execute and as such we are unaware of any published studies addressing this question. However, consider that hearing conservationists have always recommended one-on-one training as the “gold standard” in employee training and motivation. If the use of a fit testing system is the “excuse” to make this happen, that is an excellent outcome in and of itself.

    When using a tool like the E-A-Rfit validation system, the most time- consuming aspect of testing is the one-on-one training and discussion with the employee. The testing itself takes only about 15 seconds per ear including the time to connect the microphone. And of course, if the professional has already invested the time for the training, it only makes sense to add a small time surcharge to obtain an estimate of achieved protection and to document the findings. Furthermore, since a visual and tactile check, although important, is not completely reliable, the fit-test results provide added information. This can help prevent the trainer from returning an employee to work with a presumably well-fitted plug that in fact is not providing adequate protection.

References

ANSI (1974). “Method for the measurement of real-ear protection of hearing protectors and physical attenuation of earmuffs,” American National Standards Institute, S3.19-1974 (ASA STD 1-1975), New York, NY.

ANSI (2008). “Methods for measuring the real-ear attenuation of hearing protectors,” American National Standards Institute, S12.6-2008, New York, NY.

ANSI (2010). “Methods for the measurement of insertion loss of hearing protection devices in continuous or impulsive noise using microphone-in-real-ear or acoustic test fixture procedures,” American National Standards Institute, S12.42-2010, New York, NY.

Berger, E. H. (2012). “Presentation of the uncertainty/variability value in the 3M™ E-A-Rfit™ Validation System Software (V4.4),” retrieved from http://solutions.3m.com/wps/portal/3M/en_US/E-A-Rfit/User/Support/ResourceGuide/

Berger, E. H., and Kerivan, J. E. (1983). “Influence of Physiological Noise and the Occlusion Effect on the Measurement of Real-Ear Attenuation at Threshold,” J. Acoust. Soc. Am., 74, 81–94.

Berger, E. H., Voix, J., Kieper, R. W., and Le Cocq, C. (2011). “Development and Validation of a Field Microphone-in-Real-Ear Approach for Measuring Hearing Protector Attenuation,” Noise & Health, 13, 163–175.

NIOSH/OSHA/NHCA Alliance (2008). Best Practice Bulletin: Hearing Protection - Emerging Trends: Individual Fit Testing. OSHA. Retrieved from www.osha.gov/dcsp/alliances/niosh_nhca/niosh_nhca.html

NVLAP accreditation. National Laboratory Voluntary Accreditation Program. http://www.nist.gov/index.html

OSHA (2013). Reply to Mr. Lee Hager of 3M from Thomas Galassi, Director, Directorate of Enforcement Programs, U.S. Dept. of Labor, June, 10.

Trompette, N. and Kusy, A. ((2013). "Suitability of Commercially Available Systems for Individual Fit Tests of Hearing Protectors," InterNoise 2013, Innsbruck, Austria.

Voix, J., and Laville, F. (2002). “Expandable Earplug with Smart Custom Fitting Capabilities,” In A. Selamet, R. Singh, and J. Maling GC (Eds.), Proceedings of Inter-Noise 02, Inst. of Noise Control Eng. of the USA, Poughkeepsie, NY.

Voix, J., Pienkowski, J., and Delnavaz, A. (2014). "Performance of 3M™ E-A-Rfit™ Validation System," ETS at the Univ. of Quebec, Montreal, Quebec.