What is a
Personal Attenuation Rating (PAR)?

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ABSTRACT

The PAR is a “personal attenuation rating” for a given hearing protector, that can be used to estimate the noise attenuation achieved by the individual for whom it has been measured. It can be directly subtracted from an A-weighted sound pressure level (dBA value) to predict that person’s protected noise level or exposure. The beauty of the PAR is that it requires no field derating. Unlike a laboratory-derived number based on a group of test subjects evaluated under ideal conditions, the only corrections that are applicable to PARs are statistical corrections to account for the uncertainty of the measurement data and noise spectral variation. This document describes the computation and application of the PAR and compares it to standardized values in common use such as the Noise Reduction Rating (NRR), the Single Number Rating (SNR), and the Sound Level Conversion (SLC_{80}).

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INTRODUCTION

As has been discussed for many years in the literature, the appropriate assignment of hearing protection devices (HPDs) based on labeled attenuation values and measured employee noise exposures is fraught with inaccuracies. The labeled attenuation values, usually in the form of Noise Reduction Ratings (NRRs) in North America, Single Number Ratings (SNRs) in Europe, or Sound Level Conversion values (SLC_{80}s) in Australia and New Zealand, are based on tests conducted on small populations of laboratory subjects (from 10 to 20 subjects depending on the standard) tested under ideal conditions. The resulting prediction of representative field performance for groups of employees lacks the desired accuracy (Berger et al., 1994); if individual predictions are required, as is the case when assignment of particular HPDs for given noise exposures is the goal, then the results are wholly unsuitable due to a large degree of individual variability (Berger et al., 2007). Clearly the proper approach to estimate performance on individual users is to take some measure of that performance on the individuals in question.

Due to the recent development of systems that can measure individual performance under field conditions with reasonable accuracy and speed, the concept of individual fit testing is now feasible. Though this dramatically improves the reliability of individual predictions there is still the question of how to use the data, as well as the uncertainty of the field measurements themselves. For a brief review of the various methods of field testing see Berger et al, 2007. This paper will focus solely on an F-MIRE (field microphone-in-real-ear) approach as implemented by Aearo Technologies and Sonomax Hearing Healthcare in the E•A•Rfit™ system.

SUMMARY OF THE F-MIRE METHOD

The E•A•Rfit system (Figure 1) utilizes a dual-microphone measuring element and dedicated spectrum analyzer to rapidly determine the noise reduction (NR; difference between the levels outside and underneath the hearing protector), as fitted, at the seven octave-band test frequencies from 125 Hz to 8000 Hz. The test device is a special probed-version of the hearing protector. Based on extensive laboratory tests from which suitable compensation factors have been developed, the measured data are transformed into values suitable to predict the equivalent real-ear attenuation at threshold (REAT) of the actual hearing protectors as fitted.

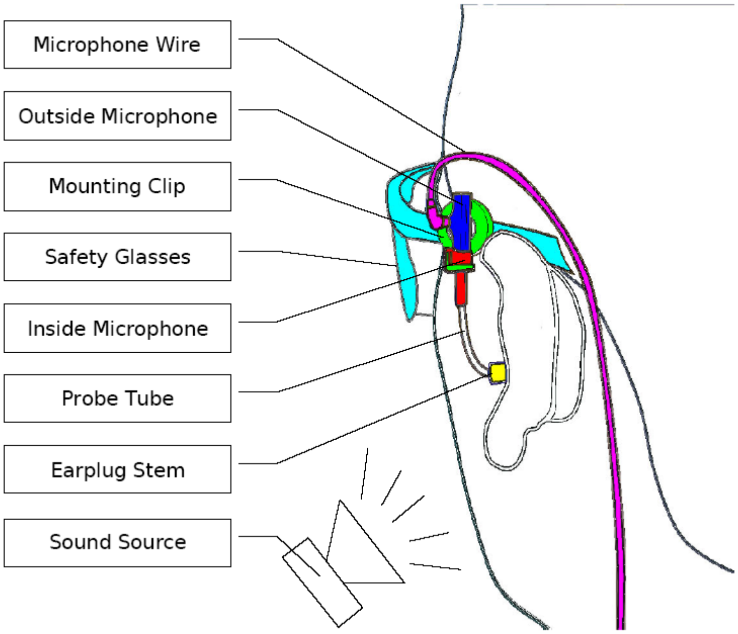

Figure 1 – F-MIRE setup for an earplug viewed from behind the left ear, with callouts for all important components.

The method of estimating REAT using NR measurements and associated compensation factors was presented by Voix and Laville (2002). In brief, it requires a microphone correction to account for the length of probe tube between the microphone and the eardrum and a post-computational correction to account for the bone-conduction pathways that F-MIRE misses, combined with a compensation factor that incorporates the following experimentally measured values.

1) The correction for the difference between the sound-field sound pressure level that would be measured at the tympanic membrane and the actual value measured by the external microphone above the ear, using the dual-microphone system
2) the correction for the difference between the pressure on the inner face of the hearing protector and that occurring at the eardrum, which can be thought of as a resonance of the occluded earcanal,
3) physiological-noise masking that causes REAT data to be inappropriately high by a few decibels at the low frequencies (Berger and Kerivan, 1983).

The correction and compensation factors are experimentally determined in the E•A•RCAL^{SM} laboratory using 20 subjects and the actual probed earplugs that are utilized in the field. Additionally, uncertainty factors are computed that describe the variability inherent in the measurement system, the variability in the fitting/positioning of the earplug by the subjects in their earcanals, and the variability of the hearing protector's attenuation in different noise spectra.

THE PERSONAL ATTENUATION RATING (PAR)

The PAR[1] is a value that is computed for a single fit, or averaged over multiple fits, of a probed Aearo product in each ear of an individual. Both left-ear and right-ear PARs are individually computed from the F-MIRE-predicted 1/3-octave-band NR values at the frequencies from 125 Hz to 8000 Hz. A binaural PAR is computed as well.

The PAR is calculated in a manner similar to the Noise Reduction Statistic for use with A weighting (NRS_A) as described in the U. S. standard on number ratings for hearing protectors, ANSI S12.68-2007. The subtle differences in the PAR and NRS computation stem from the fact that the PAR is based on the data for one individual and the NRS is based on group data from 10 or 20 subjects. The unique features of the NRS_A as compared to the well-known NRR and most other single number ratings, are that it is presented as two numbers, an 80th and 20th percentile value, that define a range of performance, and it can be directly subtracted from dBA noise measurements instead of requiring the use of dBC values. In the same vein, the E•A•Rfit system will provide PAR_{80} and PAR_{20} values (to be further discussed in an accompanying report), and also computes a median PAR, effectively a PAR_{50}, that can be directly subtracted from A-weighted sound levels to estimate protected noise levels or exposures.

The PAR is the overall average attenuation for a given fitting of the probed plug in a large ensemble of representative noise spectra. These spectra have been colloquially referred to as the NIOSH 100. They are the "gold" standard in representing typical industrial noise spectra and may be found listed in ANSI S12.68. The PAR is effectively an NRR-like number, but it does not include the 3-dB spectral safety factor that is built into the NRR (not needed because it is inherent in the computation across the NIOSH

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[1] Those familiar with previous E•A•RFit and SonoPass software will recall the Predicted Personal Attenuation Rating (PPAR). The PAR and PPAR are similar except that the PAR includes more sophisticated statistical corrections and it is intended for subtraction from A-weighted sound measurements whereas PPAR required the use of C-weighted values.

noises) and it does not include a subtractive 2-standard-deviation correction (not needed because it is measured on the particular individual in question). There is still the question of measurement variability, technically termed "uncertainty," to be discussed below.

European users of the E•A•Rfit system will be familiar with the SNR, another single-number rating intended for use with C-weighted sound levels, but computed in a slightly different manner than the NRR. Also, the SNR relies on test data taken in accordance with ISO 4869-1 instead of ANSI S3.19-1974. Likewise Australian and New Zealand users will be used to the SLC_{80} with its own slightly different mathematics and test data, as defined in AS/NZS 1270. Each of these numbers attempt to predict the same type of population-based or group (as opposed to individual) hearing protector performance, and provide similar estimates. For a comparison of the various ratings see *Comparing hearing protector ratings - NRR, SNR, SLC, and others* on the FAQ page of www.e-a-r.com/hearingconservation.

Finally, the binaural PAR noted above is the value that reflects the poorest overall HPD performance in each ear at each test frequency, taking into account both the attenuation for the left and right ears as well as the hearing thresholds for those ears, if available. This represents the most conservative prediction for the given fitting. Clearly if one ear is more poorly protected than the other, that should be accounted for in considering the individual's overall protection, as is always the case with the binaural procedure that is routinely implemented when real-ear attenuation is measured in a sound field. Although the binaural PAR is best for predicting overall protection, the utility of also reporting both left-ear and right-ear PARs is that if substantial differences are noted between the two ears, this can guide the fitter to attend to and resolve the issues in the problem ear.

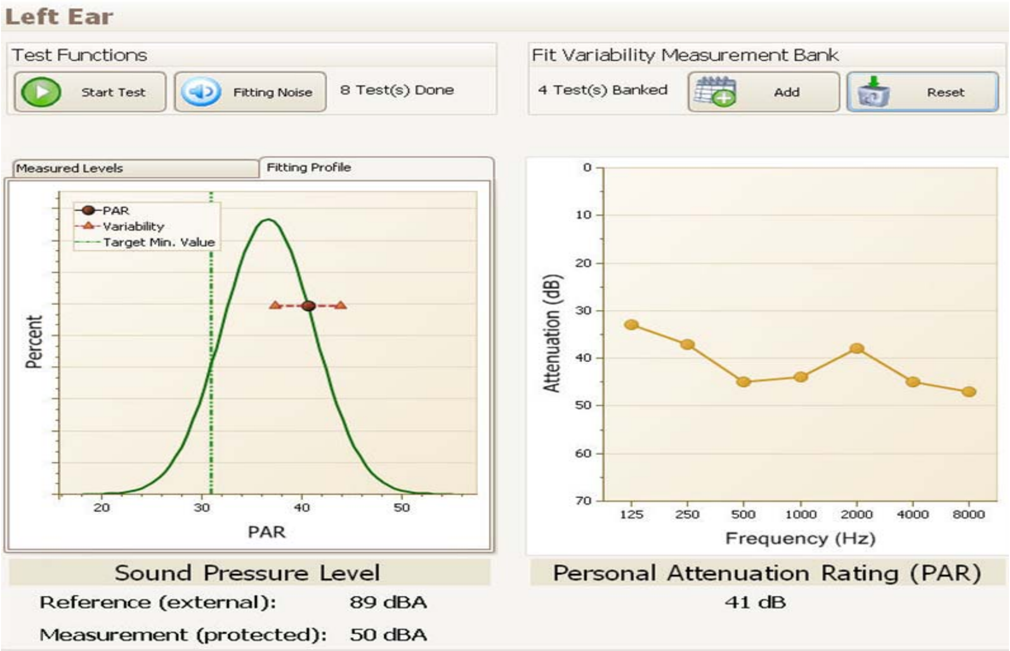
UNCERTAINTY

Even though the PAR is based on a particular measurement for the employee being evaluated, there is uncertainty in that measured value. It is due to an inherent uncertainty in the measurement process (in terms of its ability to predict the actual REAT values), as well as a larger uncertainty in the particular fit of the plug that was evaluated. Just because the subject fitted the plug one way for a given test, does not assure s/he will fit it precisely that same way on a subsequent test. Additionally since the attenuation of the hearing protector varies with frequency, the overall noise reduction will be affected by the frequency content of the noise in which the device is worn. The goal is to estimate all components of uncertainty, including:

1) the measurement uncertainty as assessed from the laboratory measurements involved in developing the appropriate compensation factors described earlier in the paper,
2) the fitting uncertainty based on either the individual's own results or laboratory data as described below,
3) the noise-spectrum uncertainty as assessed by computing the variability in the overall noise reduction for each of the NIOSH 100 noises.

When there is only time to capture a single measurement on the individual, the uncertainty is estimated by applying the fit-variability values found in our prior laboratory experiments on 20 subjects. A better estimate can be gained if the employee fits the probed plug repeatedly so that the E•A•Rfit software can measure his or her own variability. When sufficient repeat measures are accomplished (that value is currently set at four, but ongoing research will determine if a smaller number of repeats is acceptable) the variability of those individual data are used for the computation of individual fit variability.

In the E•A•Rfit testing process, the PAR's uncertainty-error bar that is shown on the Testing/Attenuation Measurements/Fitting Profile screen (Figure 2), represents the measurement uncertainty based only on the variability previously measured with subjects in our laboratory; no fitting or spectrum uncertainty are included in this value. However, for the PAR value on the Results/Fitting Profile screen (Figure 3), all three uncertainties are included: measurement, fit, and spectral.



Sound Pressure Level

Reference (external): 89 dBA

Measurement (protected): 50 dBA

Personal Attenuation Rating (PAR)

41 dB

Figure 2 – Testing, Attenuation Measurement screen

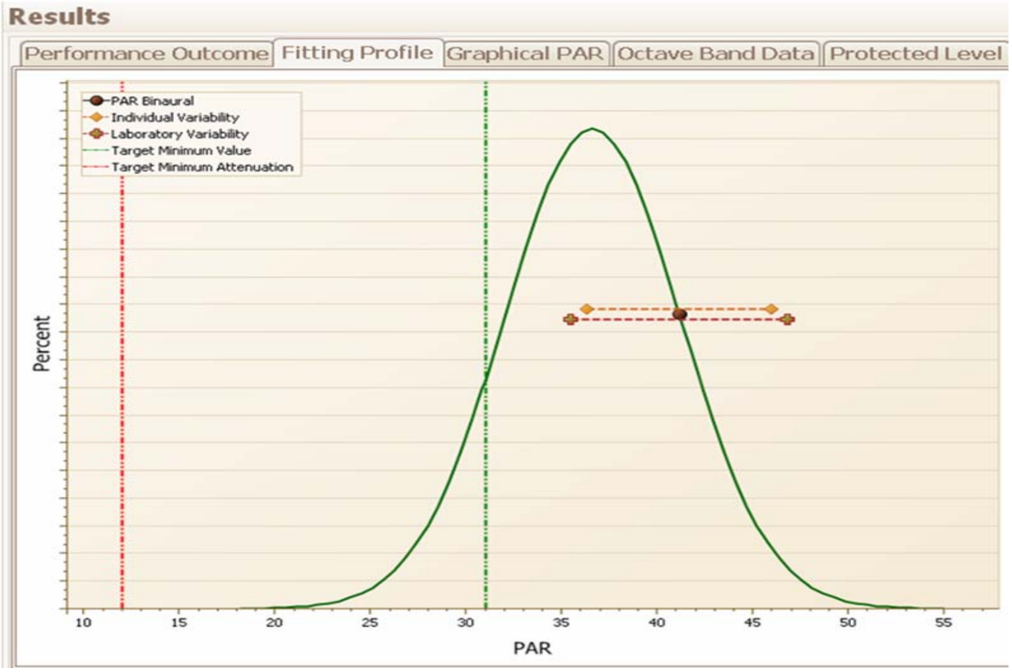


Figure 3 - Results, Fitting Profile screen

Furthermore, two uncertainty bars may be presented on the Results/Fitting Profile screen. One error bar, labeled Laboratory Variability provides the fit variability from the variability across laboratory test subjects. If sufficient repeat measurements are conducted on the employee being tested, than a second uncertainty bar labeled Individual Variability is shown. As its name implies, it is based on the fit variability in that individual's own data, (while still including the measurement and spectral variability components). That value may be larger than the laboratory value if the individual cannot consistently fit the plug as well as the test subjects, or can indeed be smaller, if the user is more consistent in fitting the plug than a typical laboratory subject.

SUMMARY

The PAR, as its name implies, is a personal attenuation value applicable to an individual for a given product. It is based on measurements of one or more fits of that product in each ear using the E•A•Rfit system, and it is reported as left-ear, right-ear, and a binaural PAR. The individual-ear PARs are best used for exploring fitting issues; the binaural PAR for predicting overall protection. The PAR can be directly subtracted from A-weighted sound level measurements to estimate equivalent protected noise levels. Though the median PAR (the PAR_{50}) is provided and is a useful indication, using the PAR_{80} value that includes all the measurement and application uncertainties discussed above (measurement variability, fit variability, and spectral variability), will yield the most conservative estimate of the actual protection that is likely to be achieved. With that in mind, either Equation (1) or (2) may be applied.

$$\text{Estimated protected dBA} = \text{measured dBA} - \text{PAR} \tag{1}$$

$$\text{Estimated protected dBA (with 80\% confidence)} = \text{measured dBA} - \text{PAR}_{80} \tag{2}$$

NOTES:

Equation (1) predicts the average protected sound levels or exposures, whereas Equation (2) provides a more conservative value with a higher level of certainty. Even more precise predictions are possible by using additional sophisticated metrics included in the E•A•Rfit package. Those will be discussed in an accompanying report.

The measured dBA values entered in Equations (1) and (2) may be sound levels or time-weighted average (TWA) exposures, whichever metric is selected for use by the professional in question. For best predictions for daily exposures, TWA measurements are recommended. Adequate statistical sampling of exposures should be conducted (Royster et al., 2000).

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