SmartEP provides real-time SNR and RN estimation of signals being acquired. The SNR and RN measures are calculated from the signal and noise estimates based on a split-sweep technique.

![Figure 1 - Split-Sweep technique showing buffers A and B used to calculate the signal estimate (A+B) and noise estimate (A-B).]

The SNR and RN measures are calculated using the following algorithms:

SmartEP uses an internal variable, EP, of data type, EPType, that contains data buffers and acquisition and analysis parameters. For example, in the equations below EP.A[i] denotes Buffer-A array position i and EP.B[i] denotes Buffer-B array position i.
The SNR and RN measures are calculated over a period of time that can be specified by the user. The default analysis starting (SNRStartMS) and ending (SNREndMs) time values for an ABR are set to 4.0 and 9.0 ms, respectively. A starting time of 4.0 was selected in order to avoid any stimulus artifact during tone pip stimulation. The ms starting and ending times are converted to the corresponding array numerical values based on the sampling rate and stimulus location and are stored in the EP.SNRStart and EP.SNREnd variables using Equations 1a and 1b.

\[
\text{EP.SNRStart} = \text{EP. Stimulus ZeroTimePosition} + \left(\frac{\text{SNRStartMS}}{\text{SamplingRate}}\right) \quad \text{(Equation 1a)}
\]

\[
\text{EP.SNREnd} = \text{EP. Stimulus ZeroTimePosition} + \left(\frac{\text{SNREndMS}}{\text{SamplingRate}}\right) \quad \text{(Equation 1b)}
\]

The total number of data points used for the analysis may be calculated using Equation 2.

\[
\text{Datapoints} = \text{EP.SNREnd} - \text{EP.SNRStart} + 1 \quad \text{(Equation 2)}
\]

Before performing the SNR and RN calculations, the mean of each buffer (Equations 3a and 3b) and uV conversion factor (Equation 4) must be calculated:

Calculate of Mean values of buffers A and B using MeanValue function call.

\[
A\text{Mean} = \text{MeanValue(EP.A)} \quad \text{(Equation 3a)}
\]

\[
B\text{Mean} = \text{MeanValue(EP.B)} \quad \text{(Equation 3b)}
\]

A uV Conversion Factor is used to convert numerical values from the system A/D to uV values, where ADVolts is the range of the A/D which is 10Volts and ADRange is the numeric range of the A/D which is 32767.

\[
\text{uVFactor} = \frac{\text{EP.ADVolts} \times 1.0E6}{\text{Ep.SweepCount} \times \text{EP.ADRange} \times \text{Ep.AmpGain}} \quad \text{(Equation 4)}
\]

All Sum and Sum-Squared variables (Sss, Ns, Nss, NssuV, cAB, cAA, cBB) described below must be initialized to Zero.

Sum and Sum-Squared values are calculated over the analysis region using the following algorithm:

For \( i = \text{EP.SNRStart} \) to \( \text{EP.SNREnd} \)

Begin

\[
A = (\text{EP.A}[i] - \text{Amean}) \quad \text{//Demeaned value of buffer A at point i}
\]

\[
B = (\text{EP.B}[i] - \text{Bmean}) \quad \text{//Demeaned value of buffer B at point i}
\]

\[
S = (A + B) \quad \text{//Signal Estimate at point i}
\]

\[
N = (A - B) \quad \text{//Noise Estimate at point i}
\]

\[
\text{Sss} = \text{Sss} + (S \times S) \quad \text{//Signal Sum-Squared}
\]

\[
\text{Ns} = \text{Ns} + (N) \quad \text{//Noise Sum}
\]

\[
\text{Nss} = \text{Nss} + (N \times N) \quad \text{//Noise Sum-Squared}
\]

\[
\text{NssuV} = \text{NssuV} + ((N \times \text{uVFactor}) \times (N \times \text{uVFactor})) \quad \text{//Noise Sum Square in uV}
\]

//For Cross Correlation Calculation...
\[
c_{AB} = c_{AB} + (A*B) \\
c_{AA} = c_{AA} + (A*A) \\
c_{BB} = c_{BB} + (B*B)
\]

End;

The SNR is calculated using the following equation:

\[
EP\text{.SNR} = 0.5 \times \text{SquareRoot}(Sss) / \text{SquareRoot}(Nss)
\]

(Equation 5)

Prior to Sep. 2005, the RN was estimated as a simple Peak-to-Peak value of the noise estimate (A-B) array as shown in Equation 6. Fast transient noise activity will result in an overestimation of the residual noise using this technique.

\[
EP\text{.RN}_{\text{old}} = (\text{NoiseDataRange}(EP.A, EP.B) \times uV\text{Factor});
\]

(Equation 6)

Starting version 3.87 in Sep. 2005, the RN is calculated based on the standard deviation of the noise estimate array to account for 95% of the noise amplitude as shown in Equation 7. The modification was conducted in order to have consistent noise measurements in both SNR and RN equations.

\[
EP\text{.RN} = 4.0 \times \text{SquareRoot}(NssuV/datapoints);
\]

(Equation 7)

The relation between the new and old RN values can be estimated with the following equation:

\[
EP\text{.RN} = EP\text{.RN}_{\text{old}} \times 0.70
\]

(Equation 8)

The Split-Sweep Cross Correlation is also calculated:

\[
EP\text{.CrossCorr} = cc / \text{SquareRoot}(cA*cB)
\]

(Equation 9)

Before performing the actual calculations, the range of the values should be checked to avoid runtime errors.

These measures are intended to be used as an indication of response quality. They have not been validated as an objective measure of response determination. Recording containing responses may vary significantly with respect to SNR and the values obtain also depend on the analysis window and stimulation parameters.

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