

# The DPOAE evaluation algorithm of the AccuScreen

DPOAEs are phenomena arising from the non-linear properties of the outer hair cells of the inner ear. They can be measured by presenting a so-called “primary tone pair” at a specified level and analyzing the acoustic information sent back to the ear canal from the cochlea. As shown in a lot of scientific papers, we can claim virtually “normal cochlear function” (here used as “no treatment required”) in the specifically stimulated frequency region by proving that DPs are produced by the hair cells as a response to the primary tones. Therefore, finding a DP means that the screening test can be regarded as “passed” at this frequency.

The crucial task is now to discriminate the sound of the environment that is always present (denoted as “noise”) from the sound originating from the cochlea, the DP. This can never be achieved with absolute certainty. But, by applying a properly designed statistical algorithm, the residual probability to erroneously classify noise as a cochlear signal can be reduced to a known probability, say 0,1 %. This means, in 1000 ears with a significant hearing loss at the defined frequency, 1 ear would pass on the average as a consequence of the statistical evaluation algorithm failure.

It has to be mentioned that conventional criteria used commonly in DP screening devices (based on algorithms using the so-called noise floor) show a false pass rate that is considerably higher (up to 10% for a frequently used “6 dB SNR” criterion)

The statistical solution makes it possible to evaluate the spectrum specifically at the frequency of the expected DP. Thus, no comparison with adjacent spectral lines is necessary.

## Description of the measurement and evaluation algorithm:

1. **Primaries:** The primary tone pair (frequencies F1, F2) is applied as a continuous stimulus by two transducers
2. **Conversion:** During a specified time (i.e. 30 ms), the acoustic activity at the expected DP frequency ( $2F1-F2$ , measured with an insert microphone in the ear canal) is analyzed by reducing the spectral component to a unit vector. It's phase relative to the phases of the primaries is determined mathematically. This reduction of information by stripping the amplitudes is the crucial point of the algorithm. Expressed more shortly: we gain probability information by forgoing amplitude (or power) information. The unit vector with it's calculated phase between 0 and  $360^\circ$  can be depicted as a normalized arrow with length 1 in a polar coordinate diagram.
3. **Vector summation:** By repeating the procedure as described above, we obtain a set of unit vectors with different phases. These vectors can be added using the laws of vector addition in the polar coordinate system.
4. **Statistical evaluation:** The evaluation is based upon the laws of statistical distributions: it can be shown mathematically that the vector sum of  $n$  randomly distributed unit vectors will not exceed  $4*\text{SQRT}(n)$  with a probability 99.9%. Spectral components of random noise with phases that are independent of the primary tones behave like that. A DP with fixed phase relative to the primary phases will now add a constant value to this sum. Therefore, if the vector sum exceeds the limit of  $4*\text{SQRT}(n)$ , the presence of a response can be claimed on a 99.9% confidence level.

5. **Display and Single frequency Pass criterion:** The display of the DP screener exhibits the polar coordinate diagram with the confidence boundary as a circle and the history of the vector sums as points in the coordinate space. A DP therefore will lead to a sort of arrow-like order of the points converging to the circle. If the periphery of the circle is reached the test can be stopped with a PASS.
6. **Single frequency REFER criterion:** The test result is REFER, if after the preset maximal number of frames no PASS could be achieved.
7. **Overall test PASS / REFER criterion:** The test result for the DPOAE screening module is PASS if 3 tests out of 4 pass. For DP Diagnostic/Multilevel the test result is PASS if 6 tests out of 8 pass. In any other cases, it will be a REFER result.