The ear is an extremely sensitive organ. If healthy, it is capable of processing sounds with an extremely wide dynamic range. Nevertheless, it can easily be damaged by long-term exposure to, say, industrial noise or excessive noise levels in discos or from walkmen. As the effect on hearing is often only noticed later on, there is an increasing number of young people with hearing defects that have to be corrected with a hearing aid.

Hearing defects are caused by a wide range of impairments of the hearing capacity, for example by frequency-dependent sensitivity losses in specific frequency ranges or by a shifting of the complete sensitivity curve. Modern hearing aids must, therefore, be capable of compensating for a variety of defects, and a precise determination of their electroacoustic characteristics is essential.

There are several national and international standards (e.g., IEC 118 Parts 0 to 12 and ANSI S3.22) that define measurements on hearing aids using sinusoidal tones. Further standards (e.g., ANSI S3.42) defining measurements on hearing aids using a broadband noise signal are in preparation. For the latter type of measurements, a signal with precisely defined frequency distribution and crest factor will be generated and the correlation between the output signal of the hearing aid and the input signal determined. Manufacturers of hearing aids, especially those supplying the US market, will shortly be obliged to test their products to these standards. With its Audio Analyzer UPD [1] and High-Speed Option UPD-B3, Rohde & Schwarz can already provide the test and measuring equipment required.

Special application programs for Audio Analyzers UPD and UPL [2] make it possible to perform measurements on hearing aids to IEC 118 and ANSI S3.22. Measurements are performed in an acoustic test chamber, which may be an anechoic room or a small test chamber with appropriate damping. Commercial test microphones can be used, and the loudspeaker of the test chamber can be driven directly by UPD (FIG 1) or UPL if efficiency is sufficiently high. A coupler to IEC 126 or an ear simulator to IEC 711 can be used for connecting the microphone to the hearing aid. No further equipment is required except for a printer if the user wishes to log results.

The application program runs under the UPD or UPL universal sequence controller and is operated via softkeys or function keys on a keyboard. After starting the program, the user can select the standard according to which measurements are to be performed, i.e., ANSI S3.22 or IEC 118. Test settings are stored separately for each standard and are recalled each time the program is started.

The measurement menu of the application program offers the following choice of settings and test functions: CONFIG, DUT, FRQ-RESP, IN-OUT, DIST, NOISE, ATTACK, CALIB.

Prior to initial measurement, the microphones and test chamber must be calibrated using the CALIB menu item. The calibration data of the microphones and the frequency response of the test chamber are stored and taken into account automatically each time the program is restarted. After each calibration, the microphone data are added to a file named MICRO.HST. This file can be analyzed to verify the stability of the microphone data.

The parameters for the test steps are defined using the CONFIG menu item, for instance scaling for frequency response measurements, broadband or selective measurements, etc. The data are permanently stored and used in all subsequent measurements.
The DUT data are entered using the **DUT** menu item. These data are printed out with the result graphics.

One of the most important characteristics of a hearing aid is its frequency response: **FRQ-RESP** menu item. To measure the response, the hearing aid is first of all set to maximum gain and the output sound level measured at 90 dB sound pressure. This gives the sound pressure saturation curve. Next, the reference gain of the hearing aid is set and the frequency response measured at 60 dB or 50 dB sound pressure level, depending on the type of hearing aid. The resulting curve is displayed in the same diagram as the sound pressure saturation curve (FIG 2). On completion of the measurement, the user can rescale the Y axis as desired, display the frequency response curve as the acoustic gain curve and, in this display mode, generate further curves, for instance to determine the effect of frequency response controls by means of a set of curves. Results can be output using a HPGL printer, so providing documentation that meets the standards for official product approval.

The acoustic transfer characteristic – **IN-OUT** menu item – of a hearing aid is needed to correct sensitivity losses of the ear as a function of volume. How the transfer characteristic varies with frequency can be determined by performing measurements to obtain up to five traces (sound pressure level, gain or compression ratio) at selectable frequencies (FIG 3).

A hearing aid should output the amplified signal with as little distortion as possible if the original sound is to be reproduced as faithfully as possible. Only the acoustic signal should be amplified, the inherent noise of the hearing aid being kept as low as possible. The **NOISE** measurement is made to determine the acoustic noise pressure output level of the hearing aid with no input. From these data and the gain of the hearing aid, the equivalent input noise pressure level can be calculated. Naturally, external noise must be sufficiently attenuated by the test chamber if this measurement is to produce useful results.

A characteristic of hearing aids that is particularly difficult to describe is the AGC response time. State-of-the-art hearing aids often have multistage control circuits with different time constants. For example, individual gain control or compression is applied to syllables, so the response time must be milliseconds. The **ATTACK** menu item is used to perform automatic measurements on the attack and release times of hearing aids with AGC. The test conditions can be user-defined. Attack and release curves are displayed and evaluated by the program, and the results output as numerical values. For the first time ever, a function has been implemented that provides an easy way of making measurements on and documenting the complex control response of hearing aids from fractions of milliseconds up to several seconds in one go.

Precise measurement of the electro-acoustic characteristics of a hearing aid is essential if the development, production and quality management of the product are to be improved. This information is also vital for the case notes of patients whose hearing aids have been adapted to compensate for a specific hearing problem. Like other electromedical equipment, hearing aids must undergo type testing before they can be sold. In Germany, such tests are performed by the Physikalisch-Technische Bundesanstalt (Federal German Bureau of Standards) in Brunswick. This federal test agency uses Audio Analyzer UPD and the special application program to carry out type-approval tests on hearing aids. Every hearing aid manufacturer that uses Audio Analyzer UPD or UPL can be sure that he will meet all relevant technical requirements for type-approval tests.

Tilman Betz

**REFERENCES**
