
Measurements on Hearing Aids with the Audio Analyzers UPL and UPD

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Subject to change

Products:

Audio Analyzer UPL

Audio Analyzer UPD



ROHDE & SCHWARZ

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1. Conclusion

The ears of many people are impaired in its hearing capacity. To compensate these defects, hearing aids with a highly complex behaviour are used, on which the acoustic gain has to be accurately adjusted. To allow optimum compensation of the patient's hearing problem, the measurements to characterize the technical performance of the hearing aids are defined by different national and international standards. This application note describes the necessary measurements and presents a test program allowing the measurements to be done in a sequence automatically.

2. Introduction

The human ear is exposed to a multitude of influences and its hearing capacity can be impaired by various causes, eg illness, strain caused by noise, etc. Modern hearing aids can in many cases compensate for such defects to a large extent so that the normal hearing capacity can be nearly restored. Since hearing defects can take many forms, hearing aids must be accurately adapted to individual requirements. For this it is necessary to analyze a hearing defect by audiometric measurements and to adjust the acoustic gain of the hearing aid to compensate for this defect. To put it in a nutshell, a hearing aid must produce the inverse characteristic of the hearing defect. Hearing impairments come in a variety of forms, depending on their seriousness so that, for example, selective compensation may be needed over specific frequency ranges and, in addition, static and dynamic matching of the complete hearing characteristic. Hearing aids therefore have a highly complex behaviour and require a great deal of measurements to allow optimum compensation of the patient's hearing problem.

There are several national and international standards defining measurements on hearing aids and the representation of results. The most important standards at present are the European IEC 118 Parts 0 to 12, Hearing Aids, and the American National Standard ANSI S3.22, Specification of Hearing Aid Characteristics. The application described here offers measurements to both standards and thus fulfils on the whole the stipulated measurements. It is also possible to modify the program to comply with other national standards.

There are proposals for broadband measurements on hearing aids, for example the proposed standard ANSI S3.42. Such measurements are intended to simulate more accurately the behaviour of hearing aids under normal hearing conditions also in the presence of ambient noise. Audio Analyzer UPD fitted with High-Speed Option UPD-B3 makes it possible already now to generate the proposed test signal and to perform all the related measurements including coherence and transfer functions. These measurements may become more and more important in the future but have scarcely been performed up to now as they require highly complex test equipment. Audio Analyzer UPD enables the user to measure to tomorrow's standards even today.

3. Preparatory Operations and Starting of Application Software

3.1 Required Equipment

The BASIC programs and setups required for automatic measurements are stored on a disk available from your local Rohde & Schwarz representative.

The following software requirements must be fulfilled on UPD or UPL:

- UPD firmware version 3.0 or higher,
- UPL firmware version 1.0 or higher,
- Universal Sequence Controller UPD-K1 or UPL-B10 installed,
- external keyboard connected,
- Universal Sequence Controller configured for 64Kbyte program memory and 32-Kbyte data memory (select setting 3 with UPDSET or UPLSET configuration tool).

For measurements, a test chamber is required. This may be an anechoic chamber or a small test chamber, eg from Brüel & Kjaer. Furthermore, a sound level calibrator, eg Brüel & Kjaer 4231, is needed, if necessary with adapters, for absolute calibration of the microphone sensitivity.

Commercial test microphones, eg from Brüel & Kjaer, Microtech Gefell or Sennheiser, can be used. Any power supplies or preamplifiers connected must match the characteristics of the microphones. In the minimal configuration, a single microphone is sufficient. The latter can be connected to the measurement coupler and also be used without coupler for calibrating the test chamber. For this minimal configuration, a microphone of the favourably priced Sennheiser MKE2 series with a matching coupler can be used. Microphones of this type of course do not offer a long-term stability as good as real test microphones; this is however not so important since absolute calibration of the microphone with a sound level calibrator must be performed in any case. Frequency response is appropriate because of the small size of the diaphragm. It is advisable, however, to repeat calibration at adequate intervals when using microphones of this type.

Depending on the design and type of the hearing aid under test, the test microphone can be connected to a 2 cm³ coupler to IEC 126 or an ear simulator to IEC 118 or IEC 711.

3.2. Test Setup

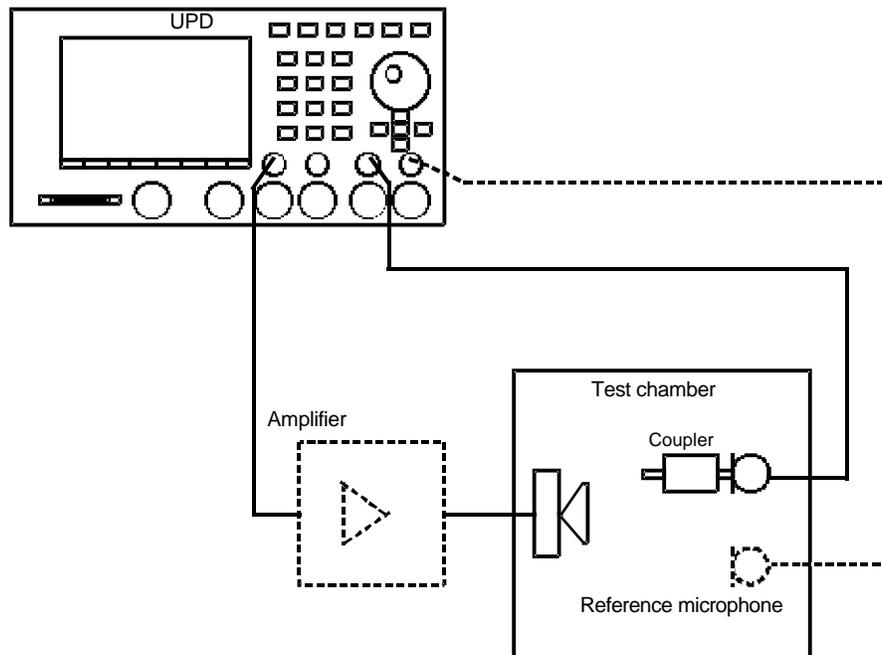


Fig 1: Test setup with audio analyzer, test chamber, one or two test microphones and amplifier (optional) for driving the loudspeaker of the test chamber

With Audio Analyzer UPD, connections are made via the unbalanced (BNC) inputs and outputs; with Audio Analyzer UPL, cables with XLR connectors are used or adaptation to BNC inputs and outputs is made via XLR/BNC Adapter Set UPL-Z1.

3.3. Installation of Software

The application software is to be installed by means of the HEARINST.BAT installation program stored on the application disk. Proceed as follows:

- Exit the UPD or UPL software by pressing the SYSTEM key or CtrlF9 on the keyboard.
- Insert application disk.
- Select disk drive A (enter A:).
- Activate installation program (enter HEARINST).
- Return to UPD or UPL program (enter UPD or UPL).

The HEARINST program generates the directory C:\HEARING on UPD or UPL (unless the directory exists already), and copies the BASIC programs and the setups required for the application into this directory.

3.4. Starting the Application Software

The application program runs under the UPD or UPL Universal Sequence Controller. After starting the analyzer, switchover must be made to the Universal Sequence Controller by pressing key F3 (on the external keyboard).

For executing the application program, the logging function must be switched off (this can be seen from the text "logging off" displayed in the lower right of the screen). With the logging function left on, any manually entered command would be added to the program and thus take memory space unnecessarily. The logging mode can be switched on and off in the UPD or UPL program by means of key F2 on the external keyboard.

The application program must be called via path C:\HEARING since the software will search all program modules and setups on this path. Switchover to this path can be made in the following ways:

- in the UPD or UPL program by means of command "Working Dir" in the FILE panel
- by calling a setup needed for the intended measurements
- from UPD-K1 or UPL-B10 Universal Sequence Controller with BASIC command line
UPD OUT "MMEM:CDIR 'C:\HEARING' "
- via the shell of UPD-K1 by entering CD C:\HEARING and then EXIT

The program disk contains the BASIC measurement program HEARTST.BAS. The program can be loaded and started by entering

- LOAD"HEARTST"
- RUN

or by pressing the corresponding softkeys. The softkeys are displayed in the bottom part of the screen when UPD-K1 or UPL-B10 is activated.

3.5. Printer Configuration

For performing the measurements, a number of setups are used that are stored on the application disk.

On delivery, the setups are configured for use with a default printer, ie the printer configuration is not determined by the setups but the printer last active will be used, thus adaptation will be made automatically to the existing hardware. An exception are Laserjet hardcopies, which require a printer of sufficient storage capacity for full-page representation in HPGL. Any attempts to obtain hardcopies in this mode on a printer of inadequate storage capacity will not produce acceptable results. For data output to a Laserjet printer in HPGL, no modification of the setups is required since the printer is driven directly by the BASIC program.

3.6. Conversion of Setups for Firmware Updates

For firmware updates of UPD or UPL, it may be necessary to convert the setups to take into account any new features of the firmware that may have been added. Conversion is performed automatically with practically no delay during setup loading. Alternatively, the setups can be converted and stored by the user. This can be done in two ways:

- At DOS level by calling the converter program: `DO_CONV \HEARING`
All setups in the HEARING directory will be converted.
- At UPD or UPL program level by loading, converting and storing each setup.

IMPORTANT: with READ ONLY setups, the "r" attribute must be erased prior to conversion (at DOS level using the "ATTRIB -r" command).

4. Operation

The program is used for measurements on hearing aids in compliance with Standards IEC 118 or ANSI S3.22.

The program is operated for the most part via the softkeys on the screen or via function keys F5 to F12 on the external keyboard.

After starting the program with RUN, the desired standard must be selected by means of the associated key. Then the following menu will appear:

CONFIG	DUT	FRQ-RESP	IN-OUT	DIST	NOISE	ATTACK	CALIB
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4.1. Calibrating the Microphones and Test Chamber

Before measurements are started, the microphones and the test chamber must be calibrated. For this, the microphones must be connected to a sound level calibrator, eg Brüel & Kjaer 4231, or to a pistonphone. The actual calibration sound level, eg 124dB, is to be entered in dBSPL. Depending on the microphone used, adapters may be required for the sound level calibrator.

After absolute calibration of the microphones, the test chamber must be calibrated. The measured frequency response of the chamber will be stored automatically in an equalization file for the generator.

If only one microphone is used, test chamber calibration must be performed with the microphone disconnected from the coupler and placed in the reference position instead. With two microphones, the second microphone is used for test chamber calibration and must be placed in the reference position.

When carrying out the measurements, it is vitally important that the DUT is placed at exactly the same position as the reference microphone. A displacement by only a few millimeters may in the case of a small chamber have a pronounced effect on the frequency response. In the case of larger anechoic chambers, a deviation from the calibration position is less critical. Commercial test chambers have a crosshairs marked on the net taking up the DUT, which makes it easy to find the right position for the calibration microphone and later for the DUT.

The equalization file generated during calibration is used in all subsequent measurements; this ensures accurate setting of the sound pressure level in the test chamber at every frequency.

The calibration data and the equalization file are stored and activated automatically each time the program is started so that calibration is required only on initial operation and at certain intervals to prevent any impairment of measurement accuracy resulting from variations in sensitivity of the microphone or the loudspeaker or modifications made to the test setup or test chamber.

After each calibration, the microphone data are added to a file named MICRO.HST. With this file, the stability of the microphone data can be verified. It may be expedient to delete the file on initial operation to eliminate any obsolete data from the history file.

4.2. Making the Required Test Settings

The test settings are made under the CONFIG menu item. These include, for example, the maximum Y value for frequency response measurements, broadband or selective measurement, etc.

The selected settings are stored separately for ANSI and IEC118 measurements in files ANSI322.INI and IEC118.INI, respectively. Storage is made by pressing key F12. The data are permanently stored and used in all subsequent measurements, also on a restart of the program.

It is also possible to create several INI files for different measurements and to copy the desired file into ANSI322.INI or IEC118.INI before starting the program.

The following settings can be selected to perform different types of measurement:

HFA-REF:

- Here the user defines the test frequencies to be used for adjusting the hearing aid to the reference gain. Standard ANSI S3.22 defines three frequencies (1000Hz, 1600 Hz and 2500 Hz); from the results, the average value is to be calculated. Of course, other frequencies can be entered to perform non-standard measurements.
- If IEC 118 is selected, only one frequency is to be entered for setting the reference gain; this is 1600 Hz according to the standard.

FRQ-RESP:

- Several quantities can be defined for frequency response measurements. The maximum of the Yaxis scale is entered first. This value is also used for the display of the transfer characteristics. The Y axis can be rescaled by means of the function keys after a measurement.
- If a second microphone is provided, it can be defined under this item if it is to be used as a tracking reference in frequency response measurements. In this way the sound level can be measured even more accurately since any residual deviation from calibrated values of the test chamber is detected at every test frequency and the result corrected accordingly. The disadvantages of this measurement are longer test time and additional noise produced by the reference microphone, which again reduces accuracy. This method should therefore be employed only in special cases and with due consideration of the advantages and disadvantages in each case.
- The query if test reports are to be output on a Laserjet or another printer applies both to frequency response measurements and to the measurement of transmission characteristics represented as output sound pressure versus input sound pressure. If the query is answered with "Y", the measured frequency response and transmission characteristics will be output to the printer in HPGL when HARDCOPY is pressed. In this mode, graphics are printed in landscape format on a DINA4 sheet with a scaling of 20 mm per 10 dB in the Y axis and 100 mm per decade in the X axis. This conforms to the PTB requirements for approval tests. It is assumed that a Laserjet printer with sufficient memory capacity for full-page display in HPGL is used. It is advisable to select the Laserjet printer also in the UPD or UPL option panel so that other hardcopies too are produced correctly.
- The last query refers to broadband or selective frequency response measurements. It is recommended that broadband measurement be selected as standard as it is much faster than selective measurement. The selective mode may be chosen for measurements involving high ambient noise levels or for measurements performed at the limit of sensitivity of the hearing aid under test. The test bandwidth is 1/12 octave in this case, and noise is suppressed correspondingly.

IN-OUT:

- For transfer characteristic measurements, the number of curves (max. 5) to be measured and the associated frequencies can be defined. As a result, a set of curves (transfer characteristics) will be obtained. The curves will be assigned numbers in the graphical representation and the associated frequencies printed out.
- Transfer characteristic measurements start at 40 dBSPL and stop at a maximum sound pressure level to be defined by the user. With this entry, the user can adjust the maximum sound pressure level to the capacity of the test chamber to handle this level. Not every test chamber is capable of generating a sound pressure of 100 dBSPL (without damaging the loudspeaker). As a rule, 90dB is entered here.
- Furthermore, the type of representation of the measured curves can be defined. These can be shown as output sound level versus input sound level, acoustic gain of the hearing aid under test or as compression ratio of the transfer characteristics. It is also possible, after completion of a measurement, to switch between these display modes by pressing the associated key.

DIST:

- It can be selected whether the distortion is shown in percentage or as 20 dB-offset curves.

NOISE:

- For noise measurements it is necessary to integrate results over a certain period of time in order to obtain stable results. Under this menu item, the desired integration time, eg 1s, can be defined.
- The sound pressure level at which the acoustical gain is determined can be defined. According to standards this is 60 dBspl.
- Input noise can be displayed as equivalent input noise spectral density versus frequency. Measurement is done using 1/3-octave filters.

ATTACK:

- The attack and release times of automatic gain control (AGC) are difficult to measure with conventional test methods. Therefore a special measurement versus time has been implemented in Audio Analyzers UPD and UPL, this measurement being referred to as compressed waveform function. With this function it is possible to measure and record the level within one cycle of the test signal, the time resolution being determined mainly by the cycle time or frequency of the test signal. For automatic measurements, a signal is generated whose level increases by a defined step for a defined period of time and then returns to the initial level. What is measured is the time it takes for the gain or the measured output sound pressure to attain steady state within specified tolerances. The following parameters can be set for this measurement:
- Initial level of acoustic signal in dBSPL (55dB according to standards). Any desired start levels may be entered to test the response of the AGC at various levels.
- Step height of burst signal in dB (25dB according to standards). It must be ensured that the sound level resulting from the initial level plus the step height does not exceed the value that can be handled by the test chamber. Step height should be at least 10 dB in order to ensure triggering of the analyzer.
- Step time, ie the time required for the level increase from the initial to the maximum value. The step time must be long enough to allow for the AGC to settle during the level increase. In general, the AGC of a hearing aid responds so fast that 0.1 s is sufficient.
- Interval for the complete measurement. This is the measurement time displayed along the Xaxis. The interval must be long enough to allow for the release time of the AGC, eg 1s.
- Frequency of test signal (2 kHz according to standards). The time resolution for the measurement is mainly dependent on the test frequency since measurements take at least one signal cycle per test point. This yields a resolution of 0.5s at 2 kHz, for example. The maximum number of test points along the X axis is approx. 7000. If an interval is entered for which more than 7000 test points would result at a specific test frequency, the measurement time for each test point and thus the time resolution are adapted automatically by the program. For example, an interval of up to 3.5s is possible for a test frequency of 2kHz with full resolution of 0.5ms.
- The attack and release times to be measured are, according to definition, the times from the beginning of a burst and the end of a burst to the point at which steady state is attained within a specified tolerance (2 dB according to standards). This tolerance may be changed to cater for specific requirements.

4.3. Information on DUT for Printout of Reports

Under the DUT menu item, information on the hearing aid under test such as type, serial number, manufacturer, name of person carrying out the test, etc. Moreover, it is queried if the hearing aid is an AGC or a linear device. Depending on the entry made, frequency response measurements will be performed at a sound pressure level of 50dB or 60 dB. The current date and time are supplied by the system clock.

5. Performing the Measurements

5.1. General

Each measurement is started by pressing the associated function key. The keys usually have no function during the measurements. On completion of a measurement, several options are available via the function keys. With "CONT", the program returns to the measurements menu. The same happens if results are output on a printer.

The program can be aborted at any time by pressing the keys CTRL+ BREAK. It is then possible to go to manual operation of the audio analyzer by means of F3. The test setup last active will be saved and can be used for further manual measurements. In the event of a program restart, there will be no loss of data since the test setup and calibration values are stored in files and will be loaded automatically on restart of the program.

5.2. Measurement of Frequency Response

A frequency response measurement is started under the FRQ-RESP menu item. The operating sequence is shown on the screen.

It must be ensured that the microphone of the hearing aid under test is placed as accurately as possible at the reference position at which the test chamber was calibrated.

If a second microphone is used as a tracking reference (FREQ-RESP under "Required Settings"), the reference microphone should be positioned as closely as possible to the microphone of the hearing aid, also see the instructions given in the standards.

Set the hearing aid for maximum gain and measure the output sound level at 90dB sound pressure. As a result, the sound pressure saturation curve or OSPL90 curve will be obtained.

On completion of this measurement, a bargraph will appear on the screen for setting the reference gain of the hearing aid.

For measurements to ANSI S3.22, the reference gain is to be set to 17dB below the value obtained with full gain. The measurement is made with a 3-tone signal, and the averaged value is represented by means of a bargraph with 1-dB divisions on which the -17-dB value is marked.

The gain of the hearing aid must be set so that $-17\text{dB} \pm 1\text{dB}$ are indicated. If this value cannot be obtained, set the hearing aid for maximum gain and make a note of this in the test report.

For IEC 118, measurements are made at a fixed frequency only, and the measured value is to be set to -15 dB on the bargraph, which consequently has a mark at -15 dB. Otherwise, the gain of the hearing aid is set in the same way as for ANSI.

After adjusting the correct gain (tolerance $\pm 1\text{dB}$), the setting must be confirmed with the SPACE key. Then a second frequency response measurement is to be made at a sound pressure level of 60dB or 50 dB depending on whether the hearing aid under test is a linear or an AGC device.

On completion of the above two measurements, the associated curves are displayed, ie the curve for the maximum output sound level and the curve for the sound level at the reference frequency. In addition, the difference between the output sound levels of the OSPL90 curve and the 60dB or 50-dB curve, both measured at the reference frequency, is determined and printed in the hardcopy.

It is possible to rescale the Y axis so that the 60-dB or 50-dB curve indicates the acoustic gain of the hearing aid instead of the output sound pressure. In this display mode, further curves can be included by means of the MORE function. For example, the effect of frequency response controls on the hearing aid can be shown by displaying the associated set of curves.

Each time the MORE key is pressed a further measurement is started. If switchover is made back to the sound level display by means of the corresponding function key, the curves displayed with MORE will be erased.

Results can be output on a printer with the HARDCOPY menu item (in accordance with user-selected configuration on UPD or UPL). If a Laserjet printer is selected under FRQ-RESP in the CONFIG menu, the frequency response will be output in HPGL to a Laserjet printer with a scaling conforming to standards. Output to another printer is not possible with this configuration. To obtain hardcopies in non-HPGL mode, it is advisable to select the corresponding Laserjet printer with appropriate scaling also in the UPD or UPL option panel.

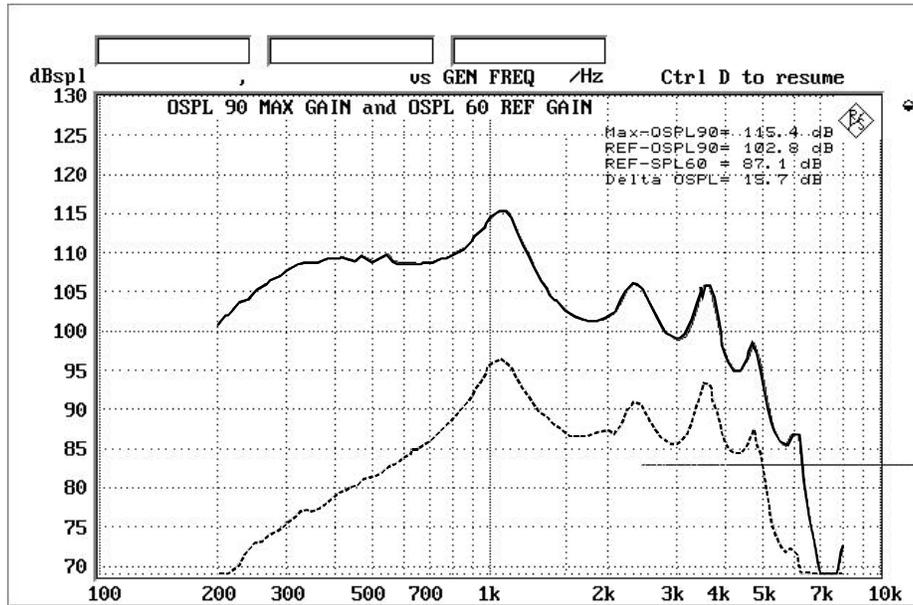


Fig. 2: Frequency response curves obtained for 90-dB and 60-dB sound pressure as a non-HPGL printout

5.3. Measurement of Transfer Characteristics

Measurements of the transfer characteristics of the hearing aid are started with the IN-OUT menu item. Up to five test frequencies can be entered under CONFIG, ie up to five transfer curves can be generated.

Furthermore, the maximum sound pressure for this measurement can be defined under CONFIG to prevent overloading of the loudspeaker of the test chamber. Measurements always start at a sound pressure of 40 dB SPL and can be performed up to a maximum level of 100 dB SPL depending on the sound pressure handling capacity of the test chamber.

The curves obtained are assigned numbers and the test frequencies are indicated in the graphic diagram.

The curves can be displayed as sound pressure curves, gain curves or compression ratio curves. The gain is calculated from the difference between the output sound pressure and the input sound pressure, while compression is calculated as the ratio of input level variation and output level variation and represented as a non-dimensional figure.

Same as for frequency response measurements, the Yaxis can be rescaled here too and results can be output in HPGL to a Laserjet printer if such a printer is selected under FRQ-RESP in the CONFIG menu.

The representation of transfer characteristics as output sound level versus input sound level is an especially suitable method for adapting a hearing aid to the deteriorated sensitivity curve of a patient. In the ideal case, the transfer characteristic of the hearing aid complements the patient's sensitivity curve in such a way that a normal auditory impression is obtained at all volumes, ie the transfer characteristic forms the mirror image of the patient's sensitivity curve referred to the standard sensitivity curve.

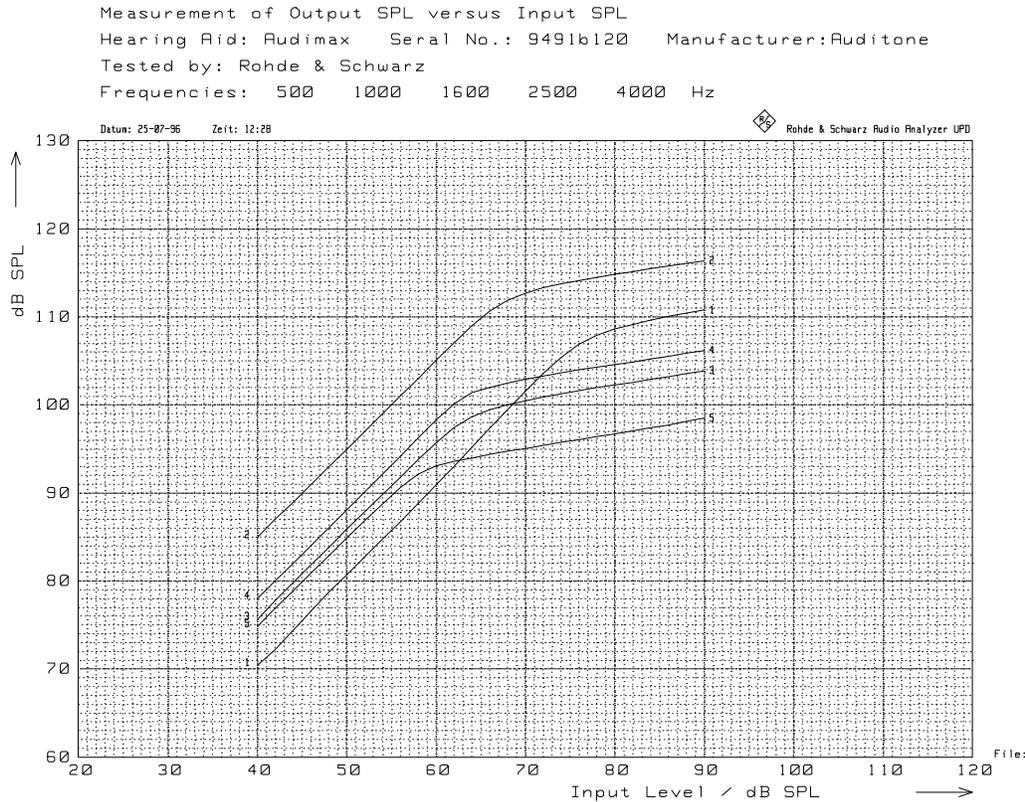


Fig. 3: Printout of transfer characteristics generated on a Laserjet printer

5.4. Measurement of Distortion

Distortion measurements are started with the DIST menu item. ANSI S3.22 as well as IEC 118 define a sound pressure level of 70 dB for distortion measurements.

First the output sound pressure is measured at an input sound pressure of 70dB and represented graphically. Then the 2nd- and 3rd-order distortion products (D2) and (D3) are measured and likewise displayed as curves with an additional scale at the righthand margin of the diagram. Distortion is indicated in %, see Fig.4.

If the choice in CONFIG was made to show distortion curves as output sound pressure level, the distortion values are calculated as distortion sound pressure level + 20 dB. So if distortion curves are below frequency response curve distortion is less than 10% or more than -20 dB down, see Fig. 5.

The curves for the D2 and D3 distortion products differ in that D2 is measured at max. 4kHz and D3 at max. 2.7 kHz; this corresponds to an upper frequency limit of 8kHz for the distortion products in each case.

In contrast to making measurements only at a few frequency points as stipulated by the standards, the representation of distortion as a curve over the complete frequency range provides much more detailed information on the response of the hearing aid.

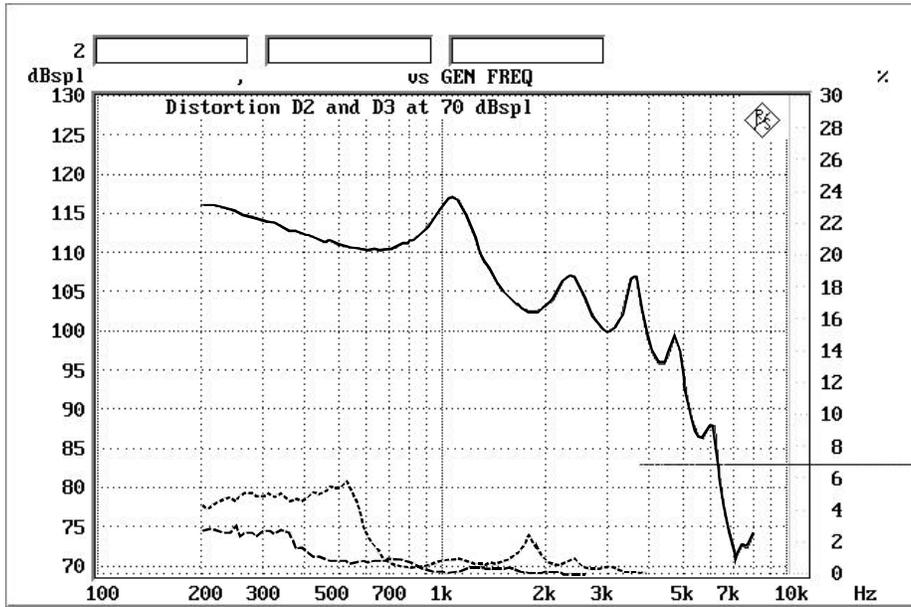


Fig. 4: Measurement of D2 and D3 distortion products at 70 dB sound pressure level shown as distortion factor in %

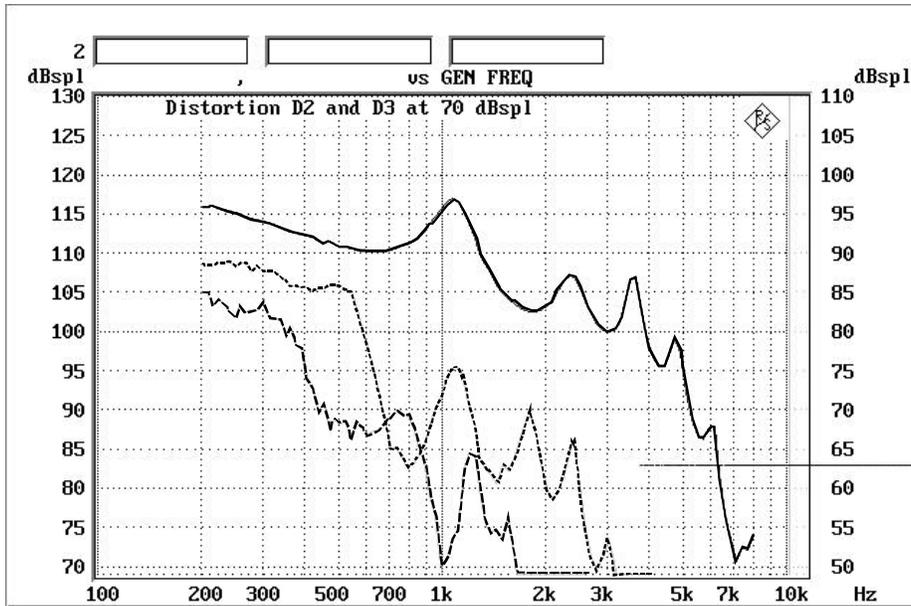


Fig. 5: Measurement of D2 and D3 distortion products at 70 dB sound pressure level shown as output sound pressure level with offset 20 dB

5.5. Measurement of Equivalent Input Noise

With the NOISE menu item, a reference measurement is started at a sound pressure level defined in the CONFIG menu. From the result, the acoustic gain of the hearing aid at this sound pressure level is calculated, then the sound source is switched off.

The noise pressure level measured with the sound source switched off is related to the sound pressure level obtained in the reference measurement, ie the equivalent input noise pressure level is calculated from the measured output sound pressure level and the gain of the hearing aid. Together with the measured equivalent input noise the measured gain of the hearing aid is displayed.

The measurement can be repeated any number of times by pressing the function key to eliminate the effects of short-term interference that may be introduced by external sources. If the results obtained for the individual measurements vary strongly, this may be due to the integration time being too short. The integration time for noise measurements can be entered under CONFIG; it should be at least 1s.

If the selection in CONFIG was made to show spectral input noise, the gain of the hearing aid will be measured and the spectral response of output sound pressure level due to noise will be measured with 1/3-octave filtering and calculated as equivalent input noise using the measured gain curve. In the diagramm spectral input noise is displayed together with the measured gain curve, see Fig.6.

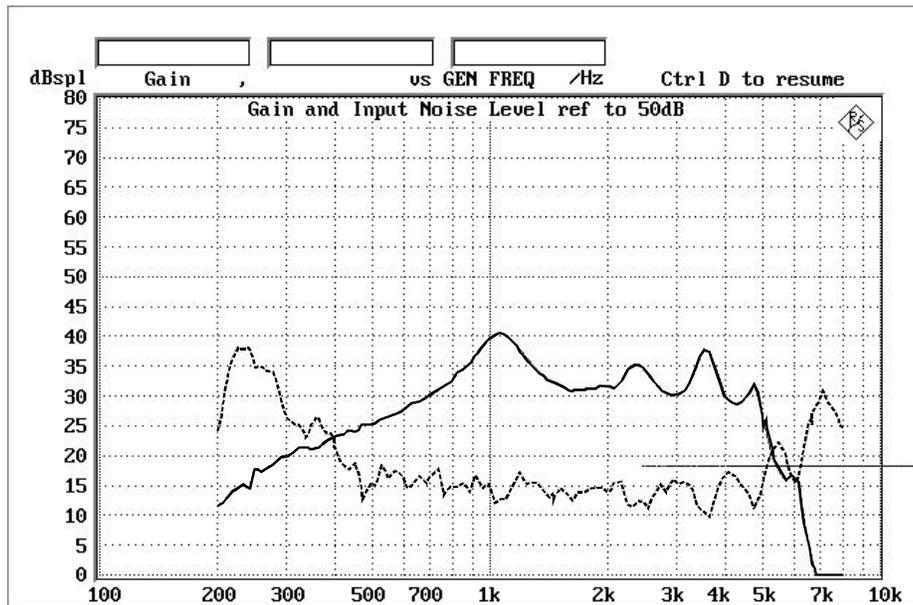


Fig. 6: Measurement of gain and spectral response of noise calculated as equivalent input noise

5.6. Measurement of AGC Attack and Release Times

With the ATTACK menu item, automatic measurement of the attack and release times for hearing aids with AGC is started.

The dynamic response of an AGC has a decisive influence on the intelligibility of the amplified signal, especially in the presence of strong ambient noise. Gain control should on the one hand lead to a medium sound level audible and agreeable for the patient, and on the other hand compensate rapidly for fast volume variations, eg from syllable to syllable, to avoid unpleasant sound level peaks.

This is in most cases achieved by means of a fast-responding control, operating in the millisecond range to reduce the gain to prevent overloading, and increasing the gain again when the sound level drops. The latter must be performed considerably more slowly to prevent excessive distortion of the input signal. Modern hearing aids often use multistage control circuits with a correspondingly complex control response. Especially for such devices it is of interest to check the control response at different noise levels.

The test conditions such as start level, level burst, burst duration, interval and tolerance check can be defined under CONFIG.

The measurement is performed automatically, and the attack and release curves are evaluated by the program.

The achievable time resolution depends on the selected test frequency, since one full cycle of the test signal must be covered in each measurement.

The maximum display length is 7000 test points. If the selected interval involves more than 7000 cycles of the test signal, the time resolution is adapted so that 7000 points are obtained.

The burst duration and the interval must be selected long enough to allow for the AGC of the hearing aid to attain steady state at the end of the burst and at the end of the interval.

This is illustrated by the test curve below. The program checks if the required conditions are met and outputs a warning if the burst duration or interval was selected too short. This measurement, too, can be repeated at a keystroke.

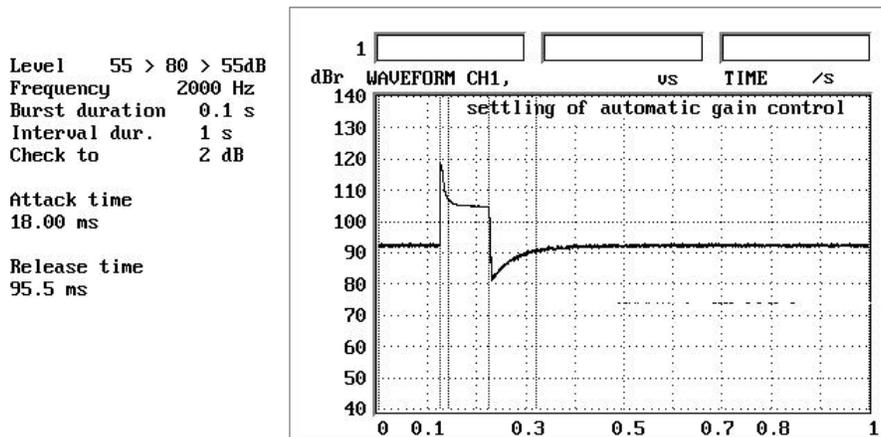


Fig. 7: Measurement of attack and release times of hearing aid with AGC

6. Logging of Results

Results can be output on a printer after each measurement.

Data output will be made to the printer selected on the audio analyzer. The setups for measurements on hearing aids are all stored with the printer set to "default", ie the setups do not determine the printer and associated settings. This has the advantage that the printer configuration automatically adapts to the existing hardware and data output is made in accordance with the configuration previously selected by the user. It is for this reason necessary however that data be printed without a comment as otherwise the same comment would be added to all reports (which may be desirable in some special cases).

In addition to the graphic diagram, reports state the DUT data, the person performing the test, and the date and time. This information is entered under the DUT menu item.

When printing is completed, the program returns to the measurement menu.

If a Laserjet printer is selected, frequency response as well as transfer characteristics can be logged with standard-conforming scaling on any printer of the Laserjet family that has sufficient memory for full-page printing in HPGL. With insufficient memory it is possible that only part of the graphics is printed. For Laserjet hardcopies, the complete graphics is calculated by the program and the data are output to the printer which is driven directly in HPGL. The printer is automatically set to HPGL by means of an escape sequence and reset on completion of the hardcopy. Outputting the data to another printer will not produce the desired result.

If a Laserjet printer is connected, the printer in question should be defined also in the UPD/UPL option panel so that other hardcopies too can be produced on the connected printer.

7. Terminating the Application Program

The program will return to the next higher menu level when ESCAPE on the external keyboard or the CANCEL key on UPD is pressed. At the highest menu level, the program will be terminated when one of these keys is pressed. It is thus possible to terminate the program from any menu level by pressing ESCAPE or CANCEL the required number of times.

To avoid inadvertent termination of the program, the user is prompted to confirm the command in each case.

Moreover, the program can be aborted at any point by pressing keys CTRL + BREAK simultaneously. On entering CONT, the program will be continued, on entering RUN, a restart will be made. In the latter case, all variables and all results obtained until this point will be deleted.