ARTIFICIAL HEAD TECHNOLOGY - APPLICATIONS FOR HEADSET MEASUREMENTS IN CALL CENTRES

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1 INTRODUCTION

The application of headphones in call centres is quite common. In contrast to handsets, headsets are worn more or less statically, fast movements or a fast remove of the headset from the ear e.g. in case of excessive acoustic sound pressures are impossible. The same headset used by different persons may produce significant different sound pressure in the listeners ears, depending on the individual ear geometry and impedance, depending on the acoustical construction of the headset and depending on the positioning of the headset on the listeners ear. The general adaptation of the perceived acoustical sound pressure e.g. by changing the pressure of the receiver to the ear which is intuitively made by the listener when using a handset is not possible with a headset, therefore a receiving volume control is integrated in mostly all headsets. Under these conditions special care has to be taken in order to avoid such excessive acoustic pressures. The paper concentrates on two issues: 1. a reliable and reproducible testing technology which allows a realistic testing of the average receiving characteristics and 2. a methodology which allows a realistic in situ measurement of the individual sound pressure in the listeners ear in call center applications.

2 THE BASICS: HUMAN EAR MEASUREMENTS

The general way of testing headphones at humans is the use of a probe microphone which is inserted in the ear canal of the individuals. The probe microphone has to be chosen such that the sound field in the ear canal is not affected by the probe microphone and that the wires of the probe microphone do not disturb the positioning of the headset. Furthermore the positioning in the different human ear canals should not deviate too much from individual to individual. Therefore a positioning gig should be used. A typical test setup is shown in Fig. 1. First experiments are reported in [2]. 6 different headsets were measured at 12 test persons using a probe microphone. The probe microphone was a small electret microphone with a very flexible cable which is inserted inside the ear canal of each test person. The frequency response measured was corrected to the drum reference point. By this correction the results can be compared to the HATS measurements.

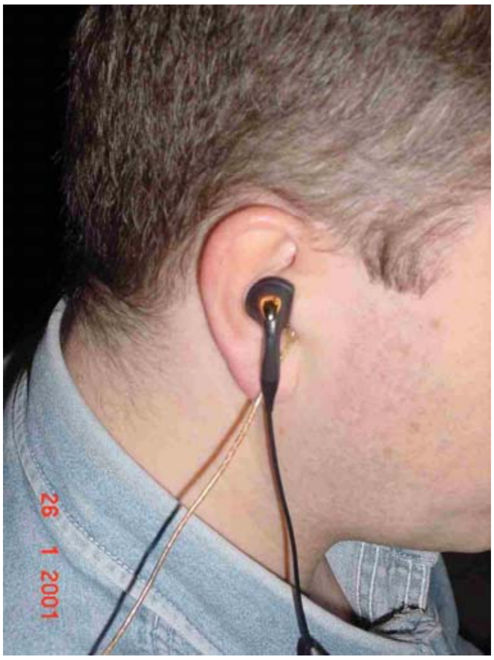

Fig. 1: Probe microphone test arrangement [2]

For one headset the transfer characteristics measured on individuals are shown in Fig. 2. The results are typical for most of the heasets: Although all test persons were advised to position the headset optimally with respect to an optimum fit to the ear the interindividual differences are in the range of +/- 10 dB in the whole frequency range. The differences can be explained by individually different leackages , by individually different geometries of the ears and the ear canals and individually diffferent impedances which partly depend on the different ear geometry. For acoustically low impedance headsets the individual differences may be less (+/- 5 dB) for supraconcha headsets which are sensitive to positioning the individual differences maybe even higher.

The individual wearing position, which was not taken into account in the studies ([1], [2]) contributes additionally to the interdividual differences.

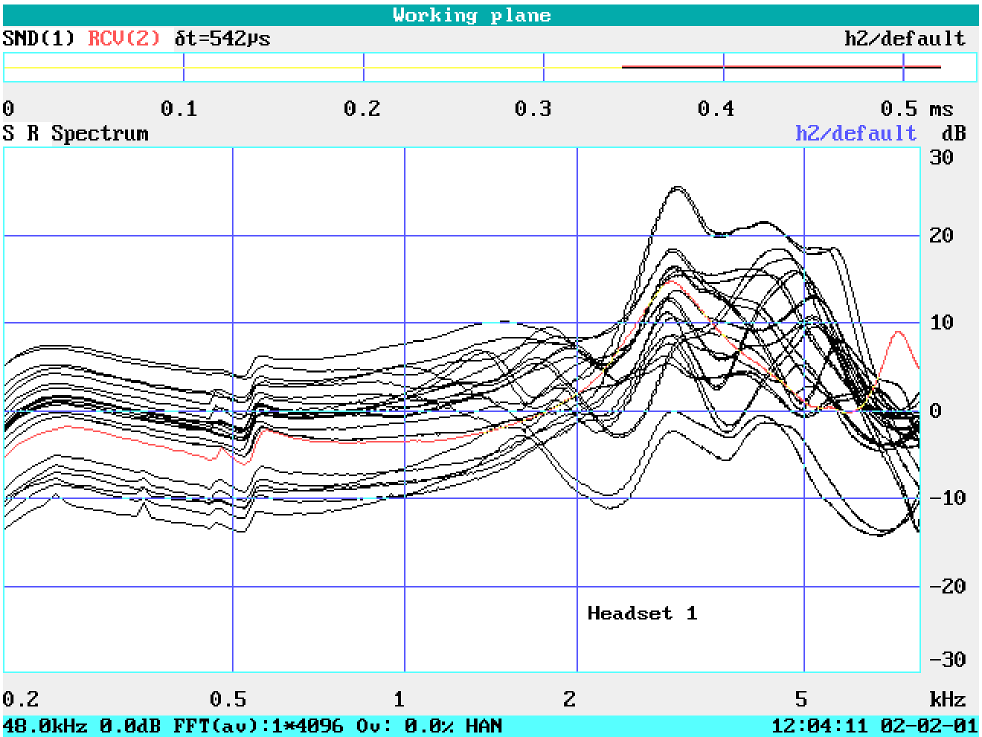

Fig. 2: Measurements of 12 test persons (black) compared to HATS with 3.4 pinna (red)

3 COMPARISON TO ARTIFICIAL HEAD MEASUREMENTS

Since the individual differences are high a proper representation of the “average” human ear is needed in order to find average frequency responses which can be used for comparison of headsets, for certification purposes and others. Initiated by the tests described in [2] and based on these experiments in 2001 the ITU started a study of headset measurement techniques. Different types of headphones were tested on subjects in different labs and compared to artificial head measurements made on ITU-T P.57 [3] and P. 58 [4] compliant artificial heads and using the ITU-T specified artificial ears type 3.3 and 3.4 (P.57). The result of this study is reported in [5].

The result of the studies confirms, that the use of artificial head technology in combination with IEC 711 ear simulator and with the ITU-T type 3.3 or 3.4 artificial ears (see Figs. 3 and 4) provide the most realistic results of headset measurements in receiving direction when comparing the data to average human ear characteristics. The study shows, that most of the measurements are within the standard deviations of human ear measurements. For all measurements it can be shown, that the results of these measurements are much more realistic than the measurements achieved on any other artificial ear or coupler. Therefore it can be concluded, that the use of the artificial head technology based on ITU-T recommendations P.57 and P.58 is the appropriate way for headset testing in order to achieve an average representation of the human ear response. The study furthermore indicates, that for some types of headsets the ITU-T type 3.4 artificial ear and the ITU-T type 3.3 artificial ear provide similar results. For supra aural headsets and supra concha headsets the leakage provided by the IUT-T type 3.4 artificial ear may be not realistic enough and therefore the type 3.3 artificial ear should be used. The HMS II.3 from HEAD acoustics provides both types of artificial ears and therefore the user can select the appropriate type of ear for his application. Within ITU-T SG12 a new standard describing the measurement of headsets based on artificial heads is in preparation.

Fig. 3: ITU-T type 3.3 artificial ear for HMS II.3 [6]

Fig. 4: ITU-T type 3.4 artificial ear for HMS II.3 [6]

4 SIGNAL PROCESSING IN HEADPHONES AND CALL CENTER APPLICATIONS

Although the use of artificial head technology based on ITU-T Recommendation P.57 and P.58 allows a realistic measurement of the headphone characteristics more advanced analysis techniques for qualifying headphones are required. In many cases the headphones in combination with the terminals are connected to cannot be regarded as linear and time invariant devices. Besides speech activated signal processing (AGC, companding, silence suppression, voice activity detection) other techniques such as echo cancellation or background noise suppression are used.

In order to measure the complete headset transfer characteristics besides the typical frequency response and loudness ratings measurements additional tests are needed for qualifying headsets. Some examples are shown here. Fig. 5 shows frequency responses measured with different test signals. In can be seen that depending on the type of test signal chosen the measured frequency response varies by about 10 dB. The long term average frequency response can be assessed by long term averaging and using artificial voice [7]. For short term testing the CS-Signal [8] may give representative results. Also the dynamic behaviour in receiving direction should be tested. Therefore test signals as described in ITU-T Recommendation P. 501 [8] and analysis methods as described in ITU-T Recommendation P. 502 [9] can be used. Fig. 6 gives one example for the dynamic behaviour of one non LTI headset. In Fig. 6 the variation of the amplification is shown while a speech like test signal with decreasing level and again increasing level is applied. During the first 5 seconds of the test the test signal is decreased starting with a level of – 15 dBV, during the last 5 seconds it is increased again to –15 dBV. The level variation is in the range –15 dBV to –65 dBV. Fig. 6 shows that with decreasing signal level the output amplification is adjusted in steps of two dB in a range of 8 dB. For increasing signal levels the output amplification is kept at its maximum and then reduced constantly (no steps) to the minimum amplification.

Additional measurements are required for measuring the echo and noise canceller characteristics, switching characteristics and double talk performance. More information can be found in [10].

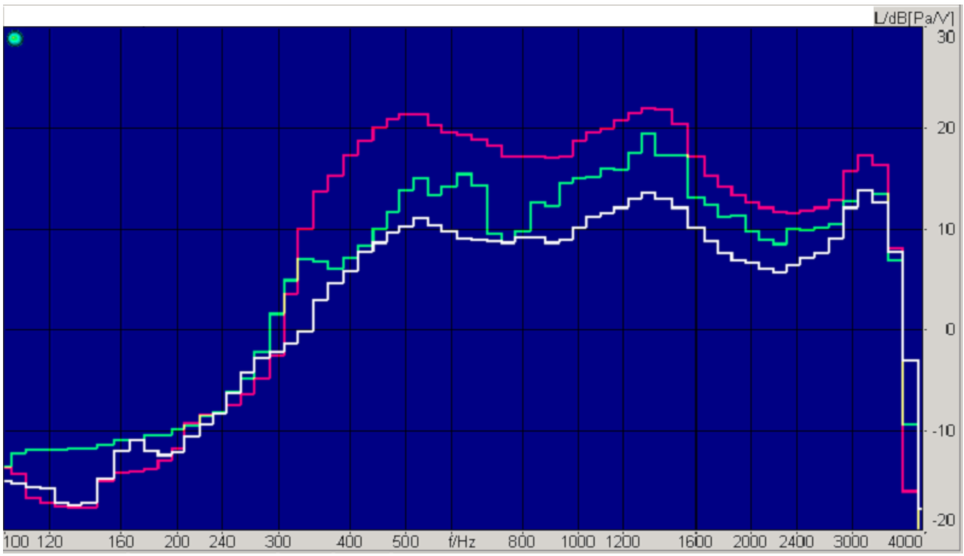

Fig. 5: Receiving frequency response of one headset measured with different test signals:
- red: sweep signal
- green: Composite Source Signal (ITU-T P.501)
- white: Artificial Voice (ITU-T P.502)

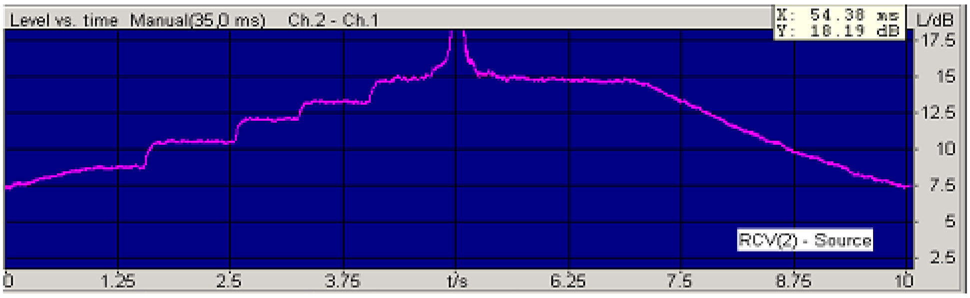

Fig. 6: Amplification of a headset in receiving direction, measured from network input to the receiver output using a speech like test signal with varying signal level (see text)

5 DOSIMETRIC TECHNIQUES FOR CALL CENTRE APPLICATION: DOSE

Despite of the general selection of headphones which can be solved using artificial head technology in combination with proper signal analysis techniques there is the need in monitoring the sound pressure level in the operators ears in order to avoid hearing damages due to short term or long term excessive acoustic sound pressure. As seen in chapter 1 the sound pressure delivered to the users ear highly depends on the individual ear characteristics, the type of headphones used, and certainly upon the individual wearing condition. Therefore a general monitoring of the electrical signal driving the headphones receiver will not give a reliable representation of the sound pressure really delivered to the individual ear. For hearing loss related measurements or the study of noise annoyance there is no other way than monitoring the sound pressure in the individual ear.

The problem described above was studied in the European Project DOSE [11]. Within this project a new portable, light-weight noise exposure meter has been developed using binaural sound pick-up in the ear. Thus, a lot of important individual influences can be taken into consideration: the perturbation of the sound field by the body, directional effects of incoming sounds, especially relevant for impulsive noises, the shielding of the ears by headphones and/or hearing protectors and sound generation by headphones. The influence of the wearer's own voice on the measurement results is reduced using a new voice subtraction algorithm. Compared to the conventional noise exposure meter according to IEC 1252 some additional parameters are calculated in order to achieve a better evaluation of impulsive noises.

The optimal measurement position from a theoretical point of view - at the eardrum - is too dangerous for a device that should be used by non-experts. In addition, a certain level of wearing comfort has to be achieved, otherwise the sound exposure meter is not suitable for practical use. Within the DOSE project the ear canal entrance has been selected as best position taking into account the corrections needed in order to calculate the actual ear drum sound pressure level. For headsets this position might be even more external e.g. in the cavum concha. Positioning the microphone at this point may be easily achieved by integrating the probe microphone in the headset. Clearly this position is less individual compared to the ear canal entrance position however it may be close enough in order to ensure both, reliable individual sound pick up and comfortable wearing of the headset. Furthermore the microphone signal in combination with the simultaneous monitoring of the electrical signal delivered to the headphone allows to clearly separate sound pressure coming from the headset and sounds produced by other sources in the room. Furthermore the microphone signal can be used to eliminate sound s produced by the users own voice which generates high airborne noise in the listeners ear but which should not contribute to the sound pressure monitored.

Within DOSE various methods for monitoring the sound in the human ear were used:

- various damage risk criteria for stationary noise
- damage risk criteria for impulsive noise
- criteria for determining noise annoyance

The most important standard for stationary noise in this area is ISO 1999. It only provides information - statistical relationships between hearing loss and both noise exposure and age - that can be used to set such limits but no limits are set directly. They vary (in particular the criterion level) to some degree across countries. In the USA and some other countries the national OSHA standard is used. The most important difference between the OSHA and ISO standards lies in the way in which noise exposure is integrated. This is quantified by the exchange rate: the level increase in dB that compensates for halving the duration of the exposure. According to ISO 1999, the sound energy should be integrated, which is equivalent to an exchange rate of 3 dB. The OSHA standard specifies an exchange rate of 5 dB. In addition, different criterion levels are used, they vary between 80 and 90 dB(A) for an 8 h exposure. Maximum allowable peak levels range from 130 to 140 dB SPL. In the DOSE hardware (Fig. 7) both methods are available.

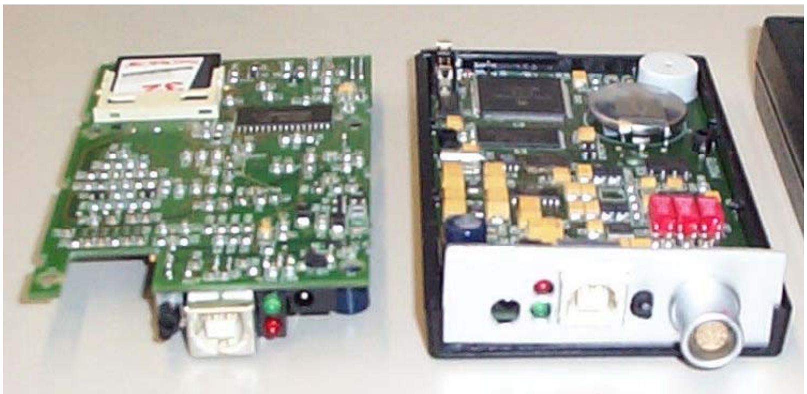

Fig. 7: Prototype Hardware form the European project DOSE

A more complex picture emerged from the overview of work relating to (hazardous) impulse noise. Four different measures of impulse duration are used currently: A-duration (the time from onset to first zero crossing, for simple waveforms), B-duration (the total time that the envelope of the waveform has an amplitude within 20 dB of the peak level, for complex waveforms), C-duration (the total time that the waveform - not the envelope - has an amplitude within 10 dB of the peak level [12]) and D-duration (the total time that the envelope of the waveform has an amplitude within 10 dB of the peak level [13]). Again within the DOSE project, all methods are implemented in parallel.

Furthermore criteria for noise annoyance were integrated which may be relevant for call centre applications as well. More information can be found in [7].

6 CONCLUSIONS

Realistic measurements for selection and qualification purposes of headsets require the use of artificial heads which include ear simulators. The characteristics of the artificial heads are described in the ITU-T Recommendations P. 57 and P.58. Recent investigations show that headsets measurements derived from these artificial heads are close to the average measured on humans.

Besides traditional testing the headset qualification requires more advanced tests in order to asses and quantify the non linear and time variant behaviour of modern headsets in combination with the relevant signal processing in the terminals and call centres.

The monitoring of the sound pressure level and the daily exposure time of operators e.g. in call centres should be based on individual monitoring of the sound pressure in the individual ear since it may deviate from the average response by +/- 10 dB. A testing methodology suitable for this purpose including a prototype hardware was developed in the European project DOSE and could be used for this application with minor modifications.

7 REFERENCES

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