The Artificial Ear Dilemma: The challenges of modern handset testing

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Transmission quality is an important parameter in modern communication equipment. In the first half of the 20th century it was often dealt with using subjective testing with a group of people reading a text and another group listening and giving scores for the intelligibility. In order to obtain an objective measured quality, artificial ears were designed by different administrations.

The ambition was often to obtain a human-like performance of the artificial ear, which lead to complicated designs like the French artificial ear made by CNET (Fig. 1) or the Swiss P.T.T. (Fig. 2) The American standard Z24.5-1951 describes the NBS 9-A 5,6ccm coupler, which is simple and reproducible and is still being used today ANSI S3.7-1995 (Fig. 3).

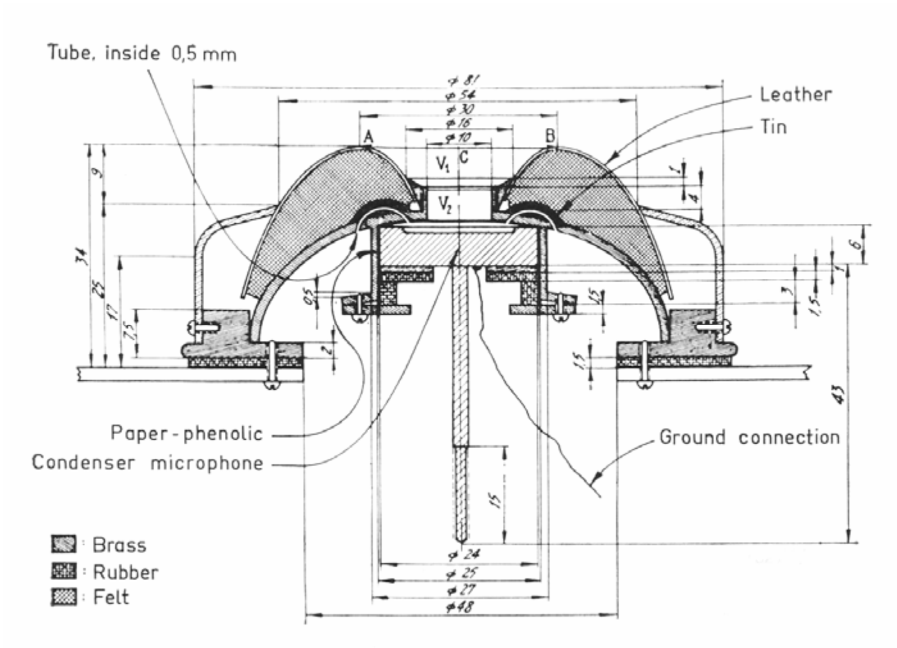

Fig. 1 Drawing of a French Artificial Ear as made by CNET

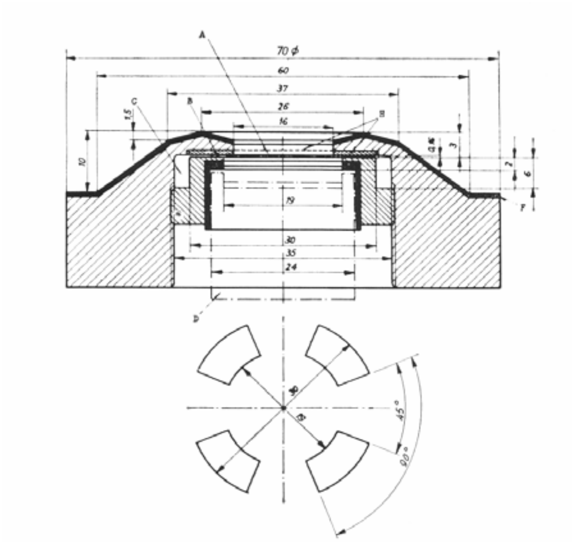

Fig. 2 Drawing of a Swiss Artificial Ear as made by P.T.T.

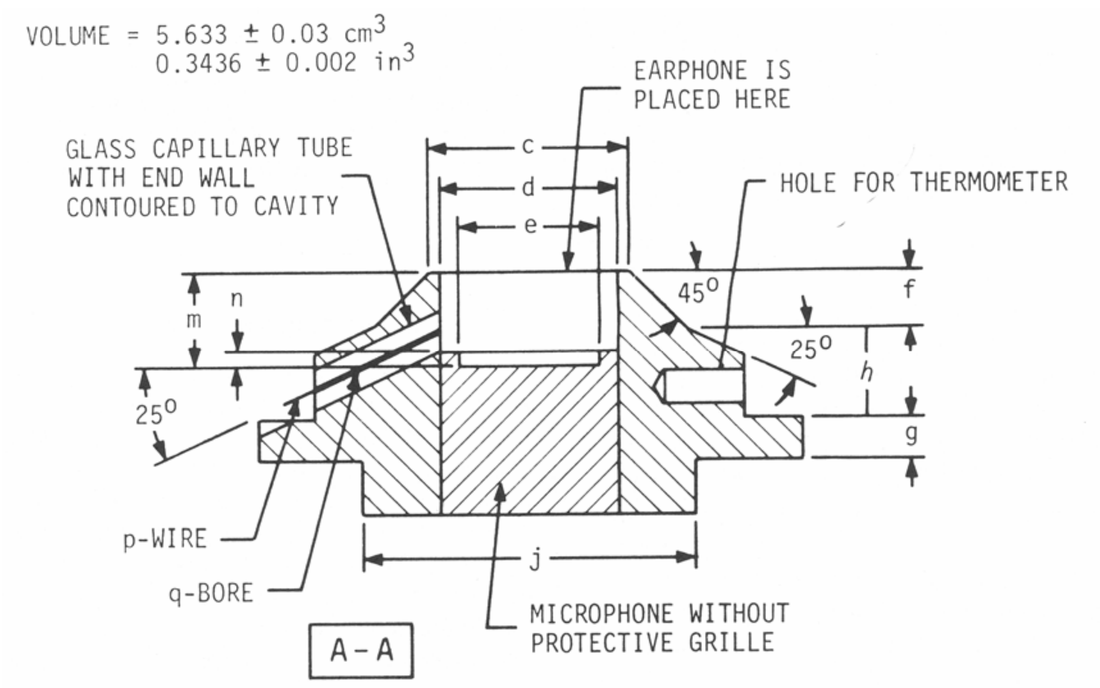

Fig. 3 National Bureau of Standards 9-A Coupler

As telecommunication became international, it became important to coordinate the measurements, and the simple volume-based reference couplers allowed comparisons to be made.

The early versions of artificial ears (Fig. 1 and 2) were very difficult to reproduce in larger numbers. The simpler coupler did not perform very well compared to the human ear. This lead to the development of IEC 60318 and IEC 60711.

IEC 60318 is now commonly used for measurements on traditional telephone sets and IEC 60711 is used for insert type ear phones coupled closely to the ear canal.

The IEC 60318 designated type 1 by ITU is recommended for use with with measurements on supra-aural and supra concha ear phones. The sealing between the ear phone and the artificial ear is important. An application force of 5N and 10N is recommended and the force should be reported. The force should not be replaced by a mass as is sometimes seen in practice.

The IEC 60318 simulator is shown in Fig. 4. The microphone is placed at the ear entrance.

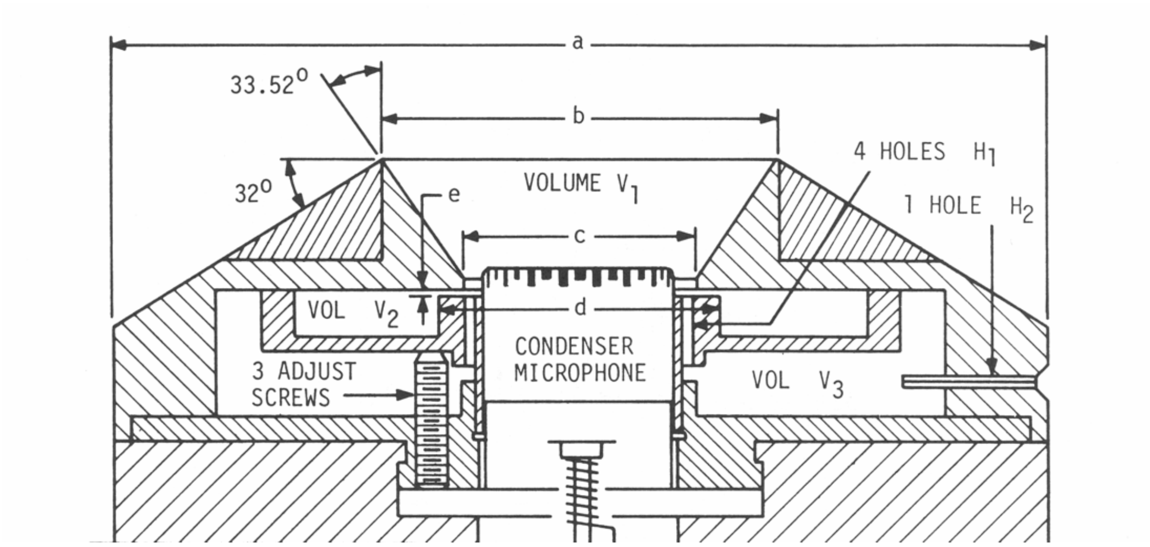

Fig. 4 The IEC 60318-1 ear. The impedance and lumped parameter electrical network is shown in the IEC 60318-1 standard.

The dimensions of the front cavity of 2500mm^3 is important for the high frequency performance. See figs. 5 and fig. 6.

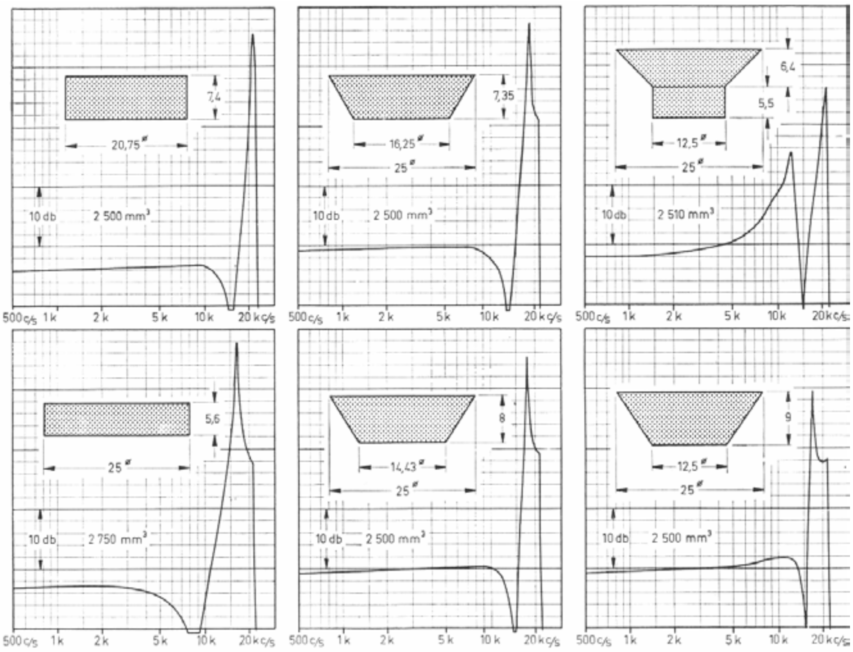

Fig. 5 **Frequency response obtained by a ½" condenser microphone receiver and transmitter mounted concentrically at the top and bottom of the variously shaped coupler volumes. Valid for the range 500-20000 Hz. All coupler dimensions are given in millimeters. Vertical scale 2dB per line, 50dB full scale.**

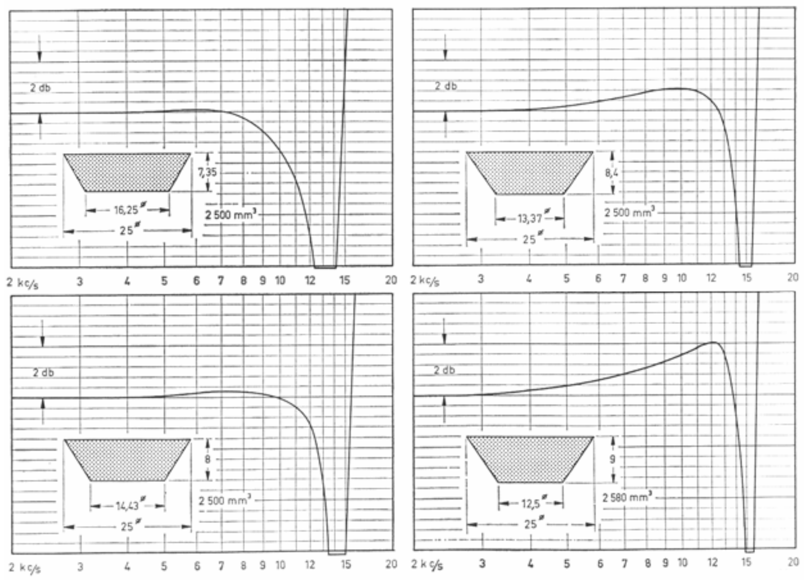

Fig. 6 **Detailed measurements to determine the optimum dimensions for the best possible linearity over the widest frequency range. 10dB full scale. 0.4 dB per line.**

The IEC 60711 occluded ear simulator is used when it is desired to measure at the ear drum (Fig. 7).

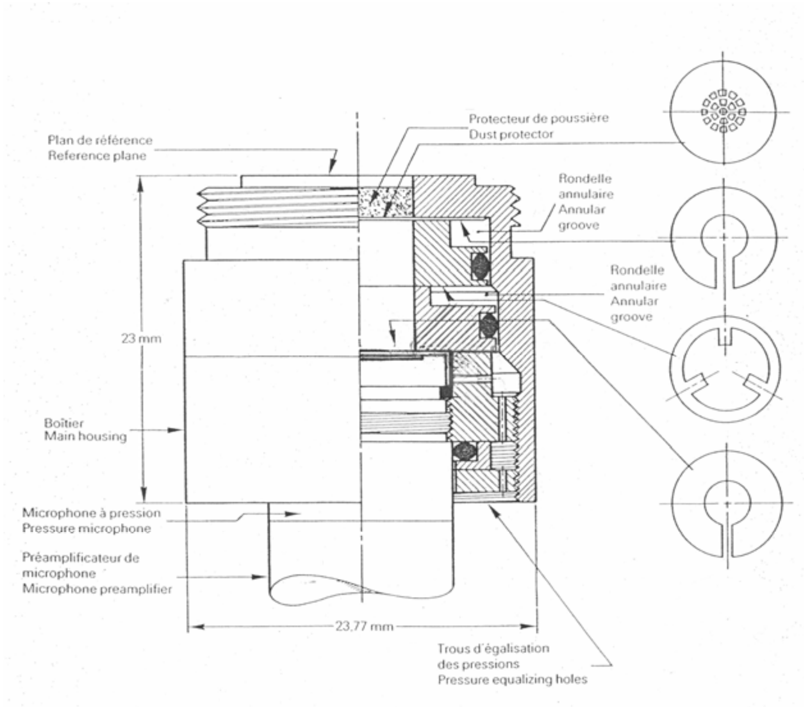

Fig. 7 G.R.A.S. RA0045 occluded ear simulator as used in KEMAR

IEC ears are very reproducible and may normally have identical characteristics with an uncertainty of less than 0.2 dB in the range 100Hz - 4000Hz.

Human perception of sound for average young people goes from below 20Hz to above 20kHz. A large part of audio communication between people is covered within the frequency range 300 to 3000Hz.

For modern wide band communication it is often desirable to cover a wider frequency range.

The acoustical difference between people is large at higher frequencies. Individual physical differences between right and left ears may also be as large as that shown in Fig. 8 (Ear moulds from the same person. Right and left ears. The width at the most narrow passage is 6mm for the left ear and 9,6mm for the right ear.)

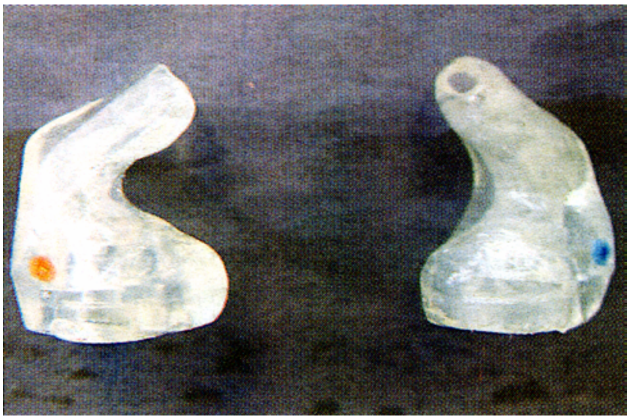

Fig. 8 Ear moulds from same person. Right and left ears. The width at the most narrow passage is 6mm for the left ear and 9.6mm for the right ear.

We cannot expect to find an average human being who will be willing to serve as an international standard. At best we may seek out a device as close to mean values as we can get today and at least reproducible to get as common references. Several such devices exist. KEMAR is the oldest and best described of the manikins available today for acoustic research in the field of telecommunications and hearing aids. It offers high stability and reproducibility based on a 30-year history of practical use.

KEMAR and other HATS are of course important only for use in free-field testing. For closed-coupler testing, we only need the ear. This could be the pinna model with a representative part of the surrounding “physiognomy” shown in Fig. 9.

Fig. 9 Type 43AG Ear and Cheek Simulator with IEC 60711 Coupler

This will allow ear phone tests using KEMAR ears of various sizes and hardness; 55 or 35 “00 shore”. The ear coupler is an IEC 60711 ear coupler with microphone included. The clamping force is adjustable if used. The Type 43AG is particularly useful for evaluating the performance of handsets used for pinnas differing in both size (large or small) and hardness; 55 or 35 “00 shore”.

If we measure the hardness of the ear lobe for a number of people it is 35 00 shore in average. If we test the pinna above the concha it is 55 to 70 00 shore. The tissue is backed by a cartilage of varying thickness and shape. If we measure the hardness above the concha a realistic average could be 55 “00 shore”.

The Type 43AG is equivalent to ITU-T Rec. p.57, type 3.3 - Pinna simulator (anatomically shaped). The IEC60711 coupler used in the Type 43AG may also be used with type 3.2 simplified pinna simulators.

The Telephone Test Head (Fig. 10) is meant to be used for electro-acoustic measurements on handset telephones in the standardised speaking positions LRGP, HATS, REF and AEN. It may be used with IEC 60318 or IEC 60711.

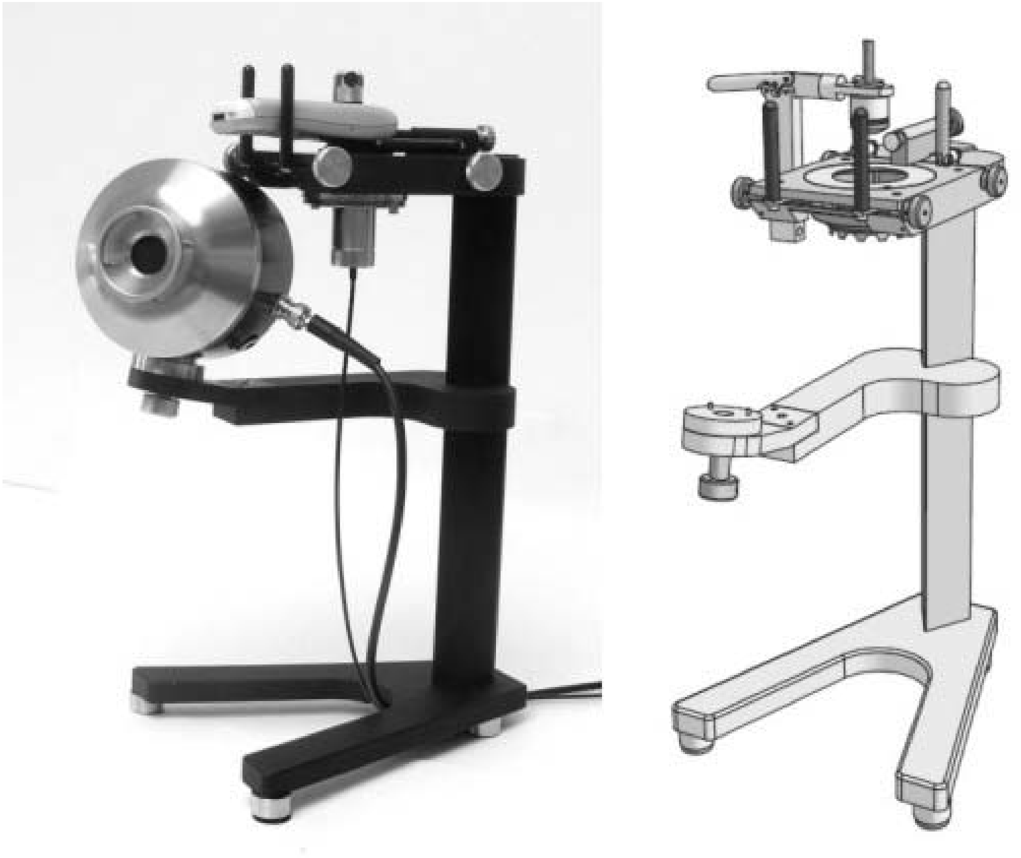

Fig. 10a Telephone Test Head Type 45AA showing:
Left; fitted with a G.R.A.S. Mouth Simulator & IEC 60318 Ear Simulator Type 43AD.
Right; computer rendering outlining its chief components

Speaking Position	Recommendation
LRGP	ITU-T Rec. P76
AEN	ITU-T Rec. P76
HATS	ITU-T P58
REF	OREM A

Fig. 10b Speaking positions according to current recommendations

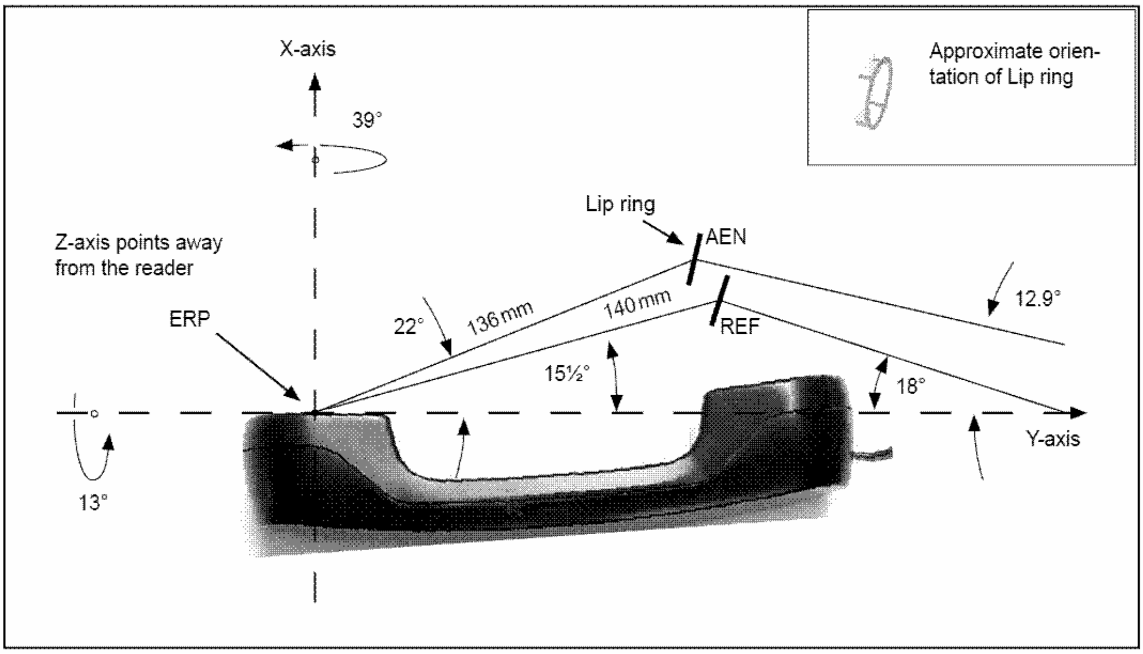

Fig. 10c Showing where the lip ring (of the type 44AA/44AB) should be for both AEN and REF positions. The angular distances of 39° and 13° (in that order) will move the handset from the AEN position to the LRGP.

The Telephone Test Head is not suited for the free-field testing of communication devices. For realistic free-field testing, the KEMAR manikin is provided with a neck ring and a special positioning fixture mounted for either left or right ear. The fixture simulates a hand grip with adjustable finger positions and several degrees of freedom for adjustment of the telephone handset to the intended user position. The positioning fixture simulates as realistic as possible a hand holding the handset to the ear. The application force is adjustable and the distance from the ear entrance may be adjusted in a well defined way (Fig. 11).

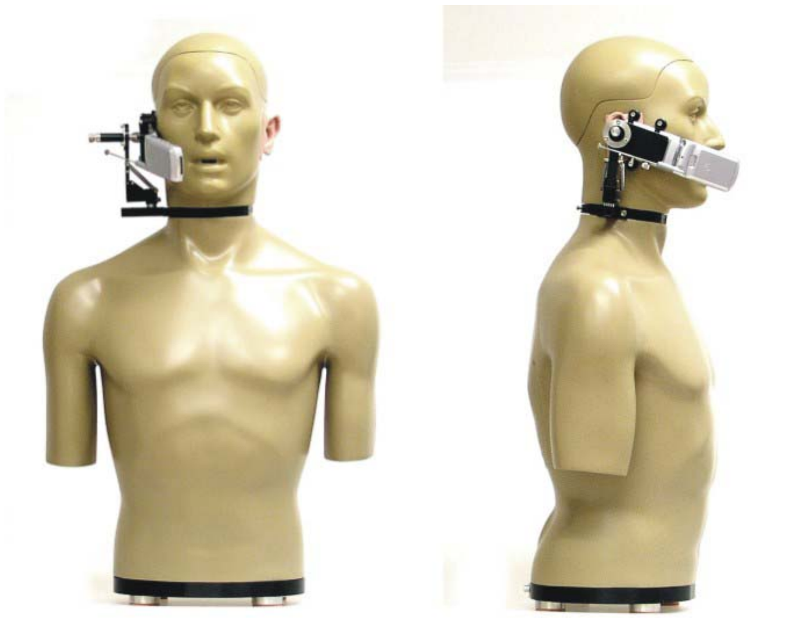

Fig. 11 KEMAR with positioning device

KEMAR is also available with a built-in mouth. Linearization is done 25mm in front of the lip plane so complete testing of transmitter and receiver is possible. Complete testing in a free field of handsets for design and development as well as type approval is possible (Fig. 12). KEMAR represents, as-well-as-possible, a good and reproducible compromise for an average human torso that we offer at the moment. People are all different and more often than not asymmetric.

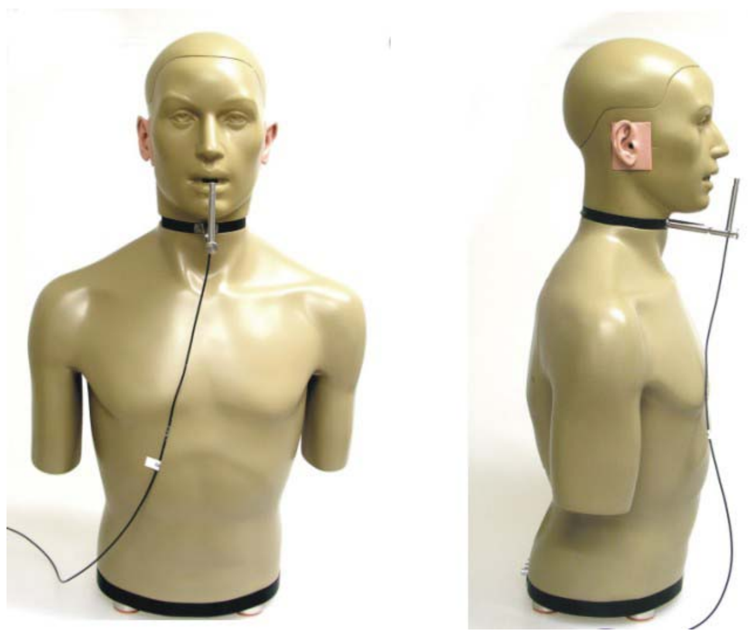

Fig. 12 KEMAR with reference microphone for linearisation

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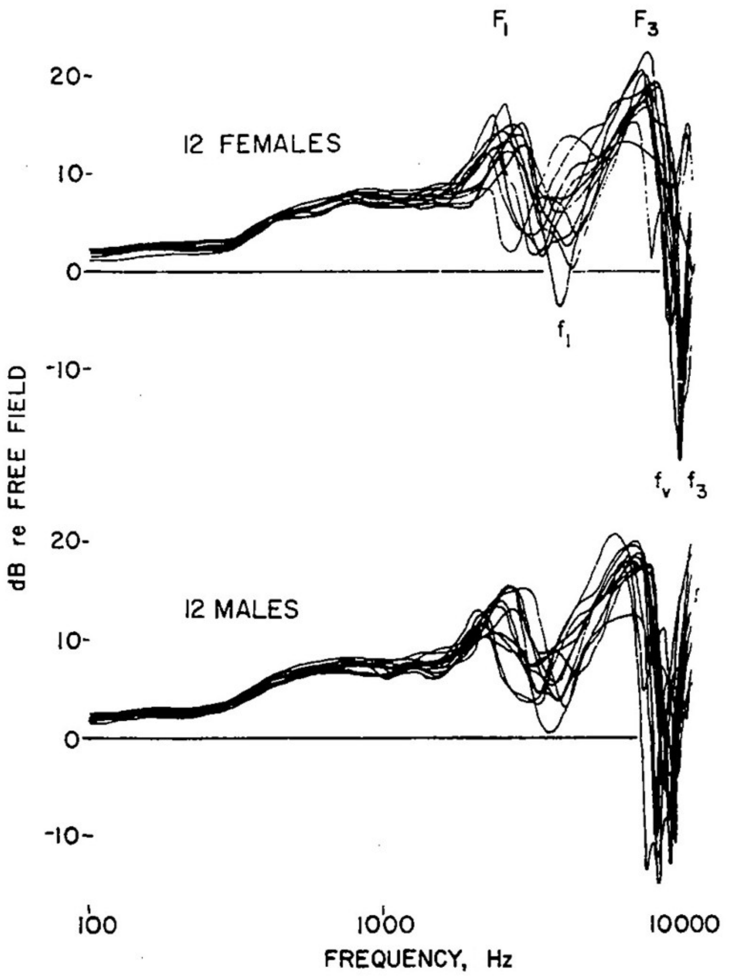

Fig. 13 Ear canal entrance sound pressures, 12 males, 12 females, sound source at 90° azimuth angle, 1m. Free field is the reference pressure condition.

For testing and reporting data we need a common reference. It is therefore important that a HATS is well documented.

The KEMAR documentation is very extensive. In fig. 14 is shown the ear drum pressure for free-field sound at incidences of: 0° - 90° - 180° - 270° as measured and as desired for modelling. The model was made by Dr. Edgar Shaw at NRC Ottawa, Canada.

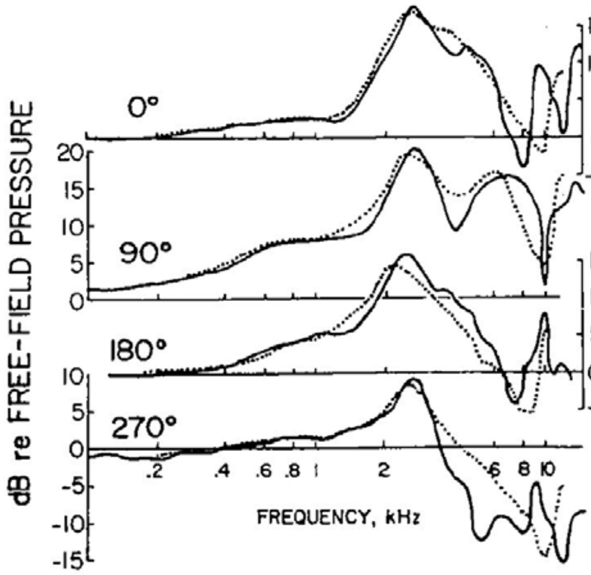

Fig. 14 KEMAR Ear drum sound pressure for a free sound field with source azimuth angles of 0°, 90°, 180°, and 270°.

The IEC 60711 coupler is mounted inside the KEMAR head and a choice of pinnas enables comparisons between ears of different sizes and hardness. The IEC 60711 coupler replaces the Zwislocki occluded ear simulator as described in ANSI S3,25-1989, where the transfer impedance function from ANSI to IEC 60711 is given (Fig. 15).

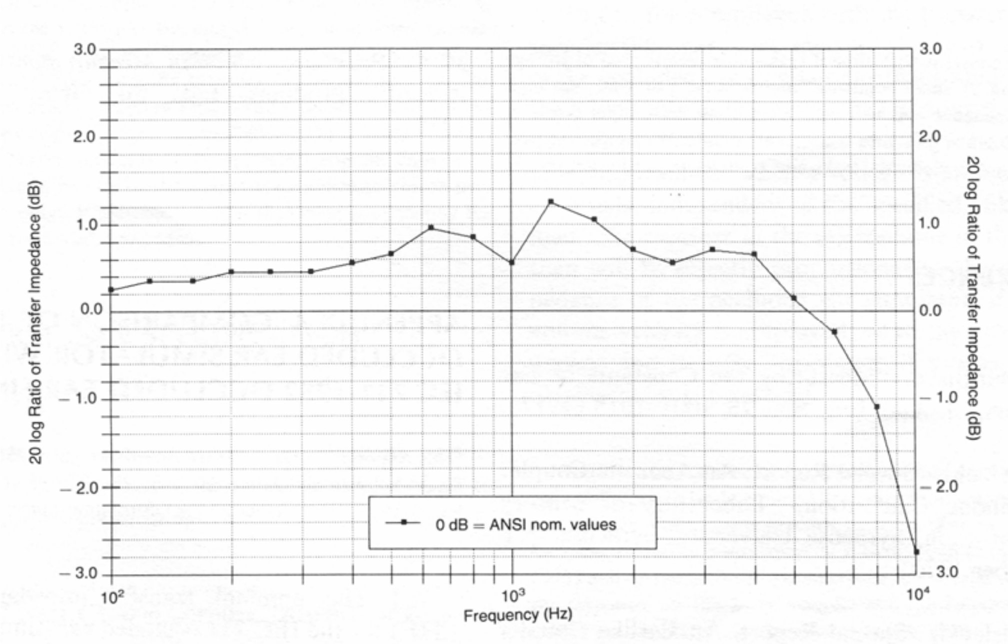

Fig. 15 IEC Modulus values of the acoustic transfer impedance function from IEC 711-1982 relative to the ANSI modulus values of the acoustic transfer impedance function.

A number of different devices are available from different vendors. The ears are well standardised. The microphones are well standardised and documented. The mouth is reasonably well documented when used in a telephone test stand in one of the recognised speaking positions. For free-field testing much more work needs to be done. It is important to report the devices being used, the positioning between sound source and test body, the position of the test object related to the HATS. At frequencies above 3000Hz the positioning becomes very important. Reproducible measurements will be the reward, if you follow these rules.

References:

B&K Technical Review Part 1-2 1962/63 “Artificial Ears for the Calibration of Earphones of the External Type”, Per V. Brüel, Erling Frederiksen and Gunnar Rasmussen

IEC 60318-1

IEC 60711

ANSI S3,25-1989

ANSI S3,7-1995

Manikin Measurement – Mahlen D. Burkhard (available from G.R.A.S. Sound & Vibration)