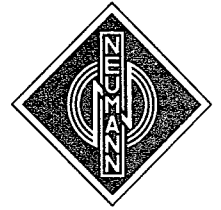


NATURAL LISTENING WITH A DUMMY HEAD

Development of a new Studio Dummy Head

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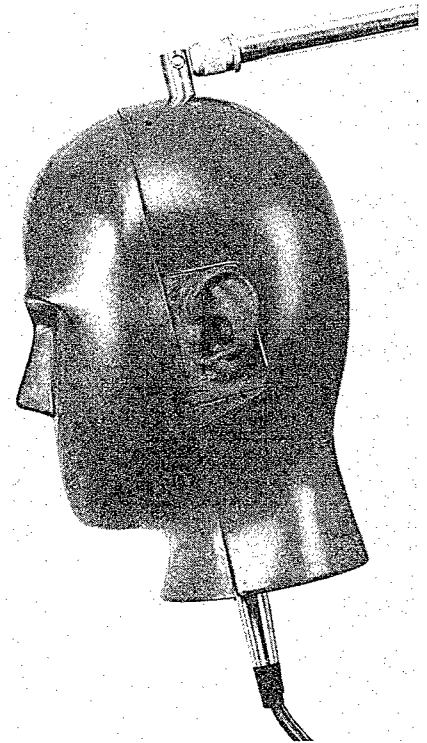
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Newest research shows that diffuse field equalized dummy head recordings provide better results than free (direct) field equalized ones.

Neumann has now built such a dummy head.

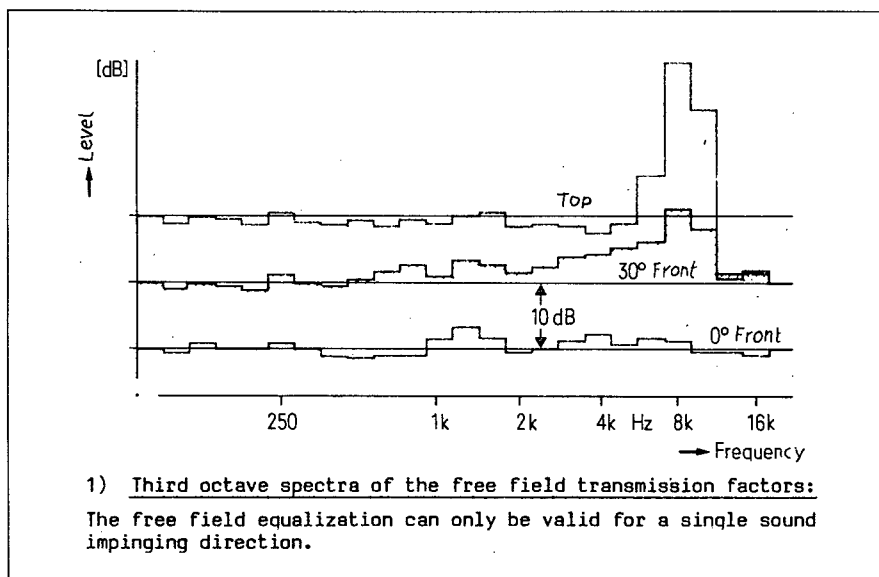
Many years of applications of the KU 80 dummy head by Neumann, first introduced at the IFA in 1973, has shown several insufficiencies which have become the subject of considerable research, both by the manufacturer as well as by users in diverse institutions (1). It finally came to a revision of the dummy head with funds provided by the Institute for Broadcast Technology (IRT) in Munich. By using electronic filtering as had been the case in previous work, an attempt was made to "correct" the 0° axis frequency response of the dummy head, considering that to be the principal problem.

While in the old KU 80 dummy head one tried to simulate the free field frequency response of the human ear at a particular point in the ear canal, there were subsequent suggestions to equalize the dummy head for a linear free field frequency response. for instance for a sound impinging direction from in front. That was supposed to make the dummy head signal sound compatible for loudspeaker listening, since a "normal" studio microphone also has a linear frequency response at the zero axis.



2) The diffuse field equalized dummy head:

Recordings made with this dummy head are also suitable for reproduction through loudspeakers.



Because of the very complicated shape of the outer ear, its directional characteristic is highly frequency dependent. Free field equalization can only be made for one sound impinging direction at a time (figure 1), but it influences the transmission characteristic for all sound impinging directions and falsifies the dummy head signal for them (2).

If one makes the assumption that in most cases the dummy head will be set up at a considerable distance from the sound source in acoustically very differential surroundings, then one has to examine the proper relationships in the diffuse sound field. (The diffuse sound field is one in which equal sound partials reach the microphone from all directions, by contrast to the free sound field used for acoustical measurements, in which only a single sound source direction is present.) While one can simulate a free sound field by means of a nonechoic chamber, one uses an echoic chamber for measurements in the diffuse sound field.

If the dummy head is now equalized in such a way that its diffuse field frequency response is linear as is also the case for stereo microphones used in studio work, then there is no longer a preferential direction. That avoids the accentuation of specific, frequency dependent properties of the outer ear for a particular selected direction.

DIFFUSE FIELD EQUALIZATION REPLACES FREE FIELD EQUALIZATION

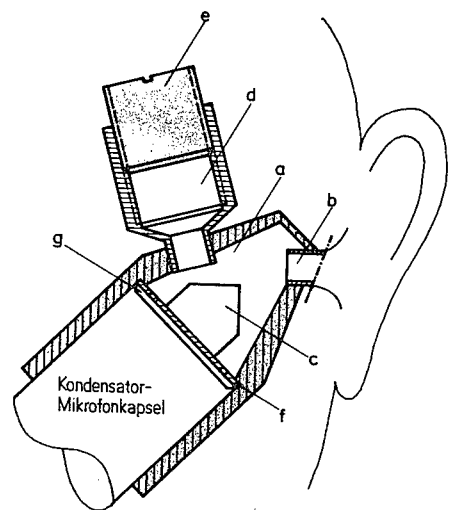
Diffuse field equalization, which is the deciding new property of the KU 81 dummy head (fig. 2), makes possible sound integrity both for earphones as well as for loudspeaker reproduction.

Prior investigations have shown that in designing of the dummy head one may neglect the simulation of the entire ear canal and the eardrum independence because the outer sound field only has a directional dependent influence on the ear canal to the depth of about 4 mm (3). Further inside the ear canal there is only a direction independent (linear) frequency response change, which can be practically corrected in any desired way.

In the prototype of the IRT dummy head the desired diffuse field equalization of the head was achieved principally using electrical, passive filters which were inserted into the audio modulation line. In the dummy head itself there was a coupler as a transition from the ear canal diameter (5 mm) to the microphone capsule diameter (21 mm) (4).

This conically shaped transition piece (seen in figure 3) was equipped with a short soldered-in tube (b) as the ear canal, an inside cone (c) to reduce the enclosed air volume, as well as two coupled Helmholtz resonators. The resonator attached at the side (d) was tunable by means of a screw (e) for the purpose of damping the coupler resonance. The cushion effect of the air in the perforated disk (f) which had the inside cone mounted upon it, was tuned, in connection with the air mass (g) remaining in front of the microphone membrane, to the roll-off of the transmission factor which otherwise would occur too early.

This arrangement provided the free field frequency response for frontal sound impingement shown in figure 4 (top). A comparison with the frequency response of the electrical filter (fig. 4-bottom) shows that direction dependent anomalies, such as the sharp dip at 8 kHz for frontal sound,



3) The IRT prototype:

A passive filter was required in order to achieve diffuse field equalization.

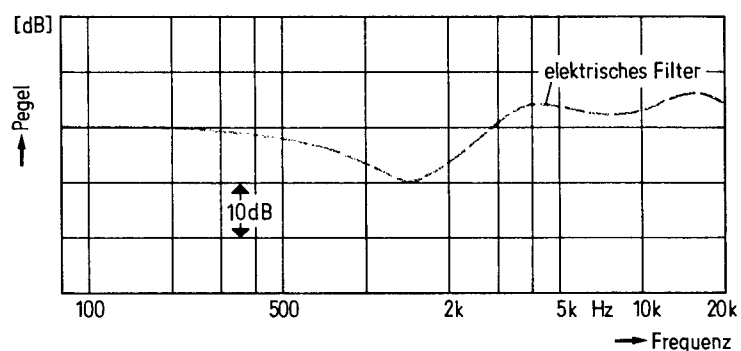
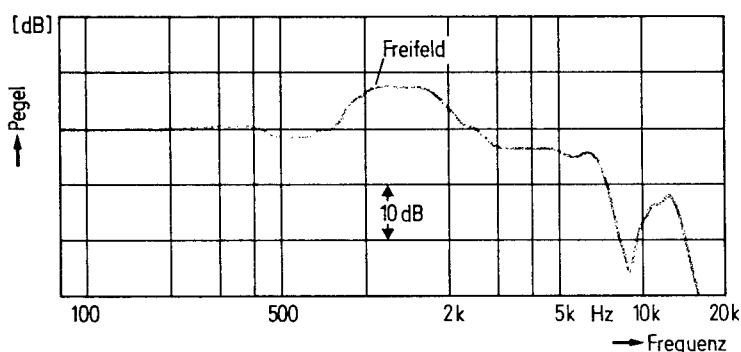
were not equalized out and therefore were also not lost.

MAKING OVER THE OLD HEAD

The concept which was set up for this project included the wish to be able to use the microphone parts which had been built into the earlier KU 80 dummy head also for its successor, the KU 81, and to be able to upgrade the existing dummy heads without any problems to the newer version conforming to the latest knowledge. This proved to be unworkable because of demands made by users of the KU 80 dummy head concerning the new dummy head: 1) that it deliver the properly equalized signal without the necessity of any additional piece of equipment, 2) that it have a higher SPL tolerance than the KU 80 dummy head, and 3) that it have better mounting and suspension possibilities than its predecessor.

While the last item only concerned the outer construction and was solvable by inserting a mike stand female threaded part and suspension eyes, both of the outer requirements made it clear that the desired diffuse field equalization had to be realized mostly acoustically in the coupler, and required a new amplifier type which made possible the frequency response correction: i.e. raising of the upper three octaves.

The acoustic equalization was achieved by rebuilding the coupler as shown in figure 5. First of all the microphone capsule, the coupler and the ear canal were axially arranged. That not only makes the insertion of the ear canal tube easier, but removes the "dead space" in the upper conical protrusion which, in the prototype version, was used principally to damp the frequency partials above 10 kHz (figure 3).



4) Dummy head frequency response curves:
A comparison between the original frequency response (top, free field equalization) and frequency response electronically corrected to the "diffuse" field (bottom).

IMITATING THE EAR

In the second step the inside cone, which is mounted on the perforated disk, was equipped with a cavity and a drilled hole such that a Helmholtz resonator was created for $F=1.5$ kHz. This replaces the resonator (d from figure 3) mounted at the side and does away with a part of the frequency response boosts created by the air mass in the coupler (a), which oscillates back and forth through the ear canal (b).

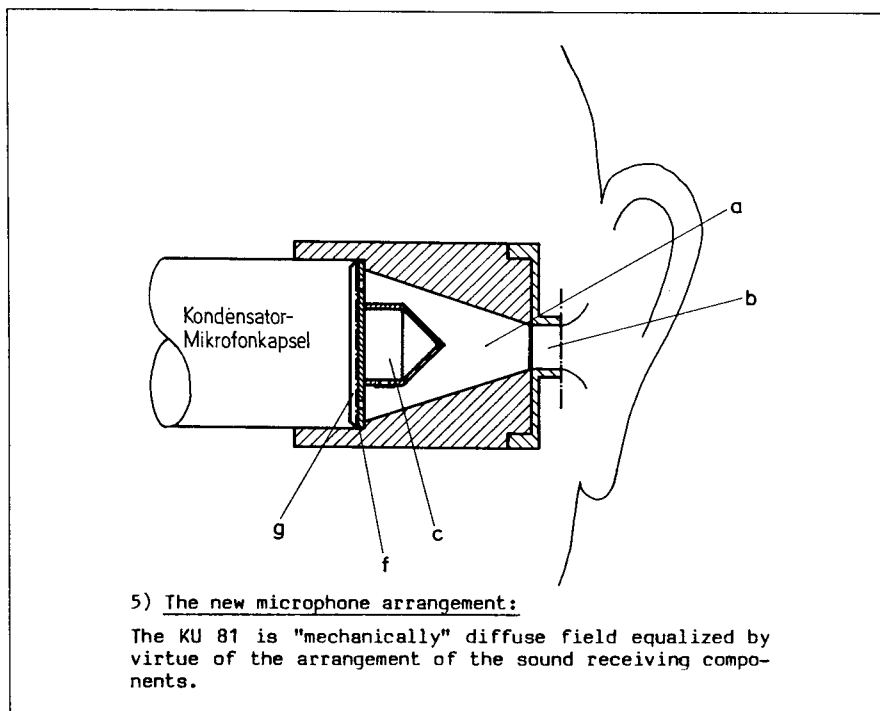
Since the oscillating air particles in the opening of the resonator cavity have the highest velocity, resulting from the smallest opening, it is easy to inhibit them as a result of friction at that point. This is done by means of a fine meshed gauze over the opening of the resonators (a & c) which are then damped by it.

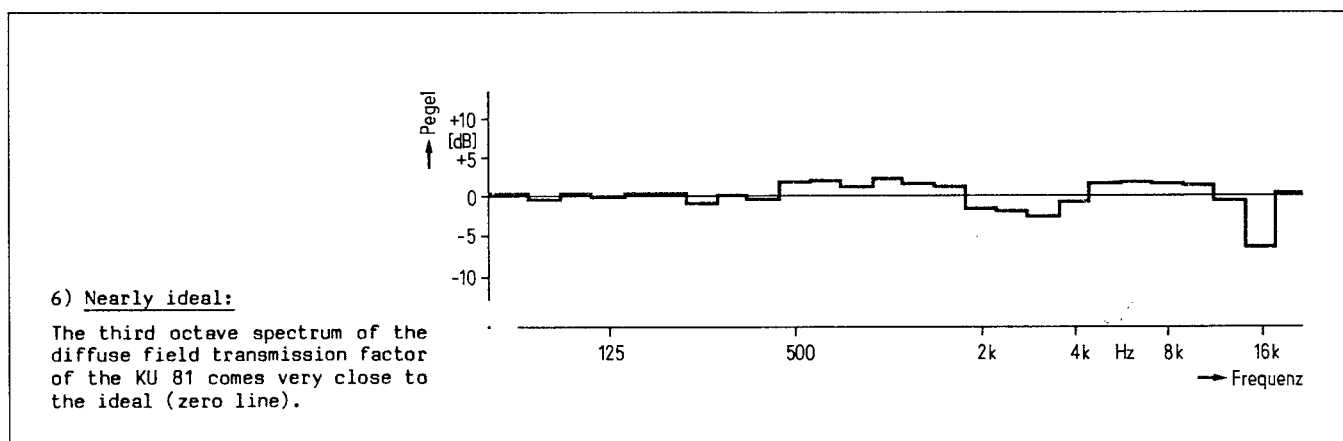
The acoustic resonant circuit (g, f) which is in series with the resonator (a, b) remains, but is also damped, since the frequency range around 7.5 kHz would otherwise be excessively boosted by it. The measures described together replace the rather complex filter of the old model and give the new KU 81 dummy head the diffuse field frequency response shown in figure 6.

The dummy head obtains its directional information through the complex shaping of the outer ear (frequency dependent directional characteristic) and through the delay times and diffraction of the sound around the head itself.

New outer ear forms were produced after investigations at Ruhr University Bochum. In fact this is a casting of the ears of a "typical" test person ascertained through intensive investigations. The form is elastic and uses a new casting material which allows the ears to be reproduced with all their folds, creases and crevices, thus conforming completely real ears.

Many recordings made with the newly developed dummy head have meanwhile confirmed that the measures taken in this new head not only produce impressive aural improvements when listening to the dummy head signal with earphones, but that reproduction through loudspeakers produced a natural sound picture which gives good directional resolution within the listening horizon, with precise recreation of both the sensation of the depth of the room as well as its roominess.





DUMMY HEAD NOW ALSO USEABLE FOR LOUDSPEAKER REPRODUCTION

The possibility of high quality loudspeaker reproduction is, as already indicated previously, one of the most significant differences between the KU 81 dummy head and its predecessor the KU 80. Pressure microphones (omni-directional) as they're used in the dummy head can only provide a linear frequency response either in the diffuse or free sound field, since the sounds impinging at right angles onto the membrane (0°) provide a pressure build-up in front of the membrane for high frequencies with a wavelength on the order of magnitude of the membrane diameter. As a result, for example, the 0° transmission factor for this frequency band rises if the transducer has been developed for a linear frequency response in the diffuse sound field, since this pressure build-up is not created for sounds from all of the other directions. Conversely, the diffuse field transmission factor rolls off at the higher frequencies, if we are talking about a pressure transducer with a linear free field frequency response.

The KU 80 dummy head which was free field equalized for a point at the eardrum, therefore had to sound dull when listened to via loudspeakers. A rise in the range of 1.5 kHz which exists at the eardrum and which was recreated in the KU 80 provided a loudspeaker sound which additionally sounded too "barrelly". By contrast to pressure transducers, good pressure gradient transducers, for example with cardioid or figure-8 directional characteristic, have a linear frequency transmission factor both in the free as well as the diffuse sound field. Most users are unaware of this property in spite of the fact that these microphone types are the most widely used ones. Nevertheless, it was obviously this diffuse field property which one had to clearly build into the pressure transducer dummy head, in order that it obtain a sound for loudspeaker reproduction equal to the one that we are used to in intensity stereo recording.

The valid standards (DIN 45 500/45 619) recommend a linear free field frequency response for earphones and provide a rather broad tolerance field into which the response curve of such earphones has to fall. Recent measurements have shown that many high quality headphone models, by fully utilizing this tolerance field, provide a linear frequency response in the diffuse field rather than the one that is required in the standard. This equalization was selected consciously on the basis of listener tests which showed that a more natural and a more agreeable sound picture was created as a result (5).

Headphones with a linear diffuse field frequency response are not only the proper reproducing device for the diffuse field equalized dummy head, but also appear better suited for the reproduction of traditional intensity stereo programs than the free field equalized headphones.

Considering the diffuse field frequency response of the new dummy head does not necessarily make it an "exotic" item in acoustics, merely because the usual reference is the free sound field, but rather integrates it well into the newest knowledge about the compatibility of the different recording technique and reproducing possibilities.

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