# Not such a dummy head

## A potted history of artificial head sound recording

by D. J. Mearess, B.Sc.

*BBC Research Department*

Several recent articles[1] have extolled the virtues and potentials of "artificial head" recording as a means of producing "surround-sound" effects and, as most enthusiasts will be aware, Sennheiser have recently released two documentary discs which demonstrate some of these effects. This article is intended to fill in some of the history of artificial head recording and to look at recent developments in this field.

The concept of using an artificial head for recording stereophonic types of signal is not new; as far back as 1940 De Boer[2] was experimenting in this field. In the early days of stereophony, the BBC looked into the use of a relatively crude artificial head, fitted with microphones, as a means for improving the spatial presentation of stereo reproduced by loudspeakers. Although some interesting effects were produced, the stereo results were not significantly different from those produced by the simple spaced-microphone technique, and so this work was discontinued. (High quality stereo headphones were not available at that time.)

More recently two teams of workers in Germany have been concentrating on artificial head recording[3, 4] in connection with work on speech intelligibility, auditory acuity and the evaluation of the acoustic qualities of concert halls, etc., using only aural information (i.e. the listener has no visual information to bias his judgement). One of these teams, the one based at the Heinrich Hertz Institute in Berlin, gave a demonstration of some of their recordings at the time of the 1971 AES Convention. They demonstrated a concert-hall recording made using an artificial head fitted with microphones, the replayed signals being fed directly to a pair of headphones. The second images created by this technique exhibited good left-to-right separation with a marked lack of "in-the-head" sensations. Front-to-back separation, however, was rather poor, and there were frequent occasions where images, which should have been created at the front, appeared to be located behind the listener; further, the images generated by this arrangement were rather broad and diffuse.

In 1973, at the Berlin Radio Show, Sennheiser released a demonstration disc, which was made using the latest "Heinrich Hertz" artificial head (the one shown on the record sleeve). This comprises a skull construction attached to which are the flesh-like artificial pinnae-facial features and hair are all realistically modelled. The head attempts to match the acoustic properties of a real human head, both externally and internally, as far as the ear drums. At this point the model's ear canals are terminated by an acoustic impedance such that, in the presence of a microphone placed at that point, the correct sound pressure is produced.

The intended method of reproduction, for the demonstration disc, is over Sennheiser "open-air" headphones and this implies that the acoustic signals will have passed through ear canals twice, once in the artificial head and once, during replay, in the listener's head. The signals from the artificial head were therefore processed in an attempt to reduce the errors introduced by this double passage through ear canals.

The recording is, comparatively, a significant improvement on the earlier-mentioned demonstration, and is extremely intriguing in the subjective impressions that it generates. The section of the recording where the narrator moves behind the listener and whispers in his ear is particularly impressive, and offers considerable potential for audience involvement in, say, radio drama.

When examined analytically, however, there are still some errors in the reproduced sound images. In the recording the narrator is intended to walk in a circle around the listener; in fact his image moves in an ellipse with the major axis going from left to right and with considerable elevation of the image (approximately 70° on average) in front, of the listener. There are also occasions when the image of his voice does not occupy a position consistent with the activity verbally described (e.g. the noise made when switching on a light seems rather far from the narrator).


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These are the sound impressions given to a listener using open-air (super-aural) headphones. Limited tests, have been carried out using "closed-air" (circum-aural) headphones and much poorer results were obtained, to the extent that front-to-back ambiguity was once more noticeable.

A most significant point is the fact that different people perceive different things from the recording. This is particularly true of intended front-centre sounds. Here the subjective impressions appear to vary from in front and elevated by 45°, to slightly behind and close to the listener. This is probably due to the complex way in which the ear perceives the direction of arrival of sound, the most important factor being the intricate changes introduced into the sound waves by the pinnae and ear canals[5.6.]. Since these changes will vary from person to person, it is hardly surprising that a single model of the ear is unable to produce a recording which completely satisfies all listeners. That it goes as far as it does is a considerable achievement.

Due to the impressiveness of the Sennheiser recording several radio dramas have been (or are being) recorded in Germany. At least one of them has already been broadcast as an experiment, and German radio stations plan more such events. The dramas were, in general, recorded using an artificial head manufactured by Neumann and Co of Berlin. This is, in principle,very similar in design to the Heinrich Hertz artificial head, inasmuch as the ears are reasonably life-like and the ear canals are terminated in a combination of acoustic impedance and microphone. In detail, however, the two heads have slight but possibly significant differences; for example, the Neumann ears are made of a harder rubber and the rest of the head is more stylised. In use the head is intended to be placed on top of its carrying case, to simulate the effect of a half-torso, in a good seat in a concert hall or wherever the recording is to be made.

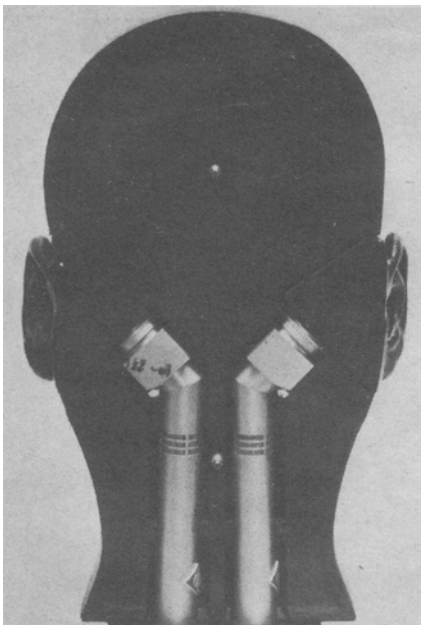
The author has had limited access to material recorded on the Neumann head and has found, generally, that it is less satisfying than the previously-mentioned Sennheiser disc. In particular, front centre sources are much more difficult to locate, and usually become confus,ed with back centre sources. Whether this is due to the "possibly significant" differences between the Neumann and Heinrich Hertz heads, or whether it is the lack of correction for the double passage through ear canals has not yet been established.

The second Sennheiser documentary disc, released at the 1974 Hannover-Messe, demonstrates a slightly different approach to "dummy head" recording. This method requires a real head and a lightweight stereo microphone assembly. Two condenser microphones are fitted in a curved framework, which is hung loosely in the outer ear, so that the microphone diaphragms are within 10 mm of the entrance of the ear can. In this way an attempt is made to record the precise nature of sounds at a person's ears. The recording is reproduced in exactly the same way as the artificial head recordings, viz. on open-air headphones. The sound impressions produced by this method are satisfying, inasmuch as a convincing sense of spaciousness and distribution of images is reproduced, but unfortunately the images are blurred and front/back ambiguity is experienced by most listeners, even though the record sleeve shows precisely where the images ought to be. So compared to the first demonstration disc, the second is rather disappointing.

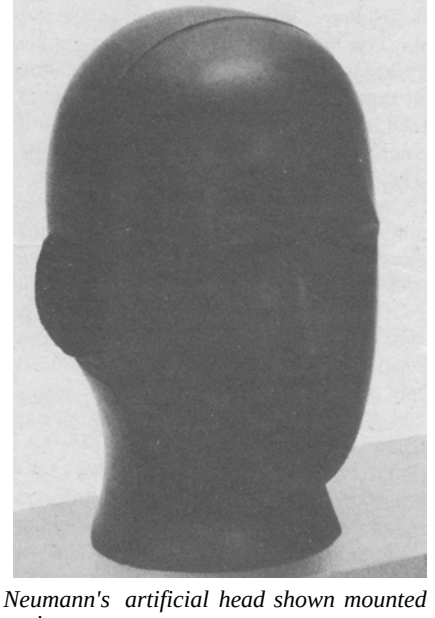
The same idea, i.e. that of using a real head, has been investigated in some detail by Dr E. T. Rolls of Oxford University [7]. His recordings are made with miniature microphones actually inside the ear canals of the subject. I had the slightly painful pleasure of being involved in one such recording session with some rather surprising results. For me, this recording not only demonstrated extremely good azimuth and distance information, but also a remarkably realistic sense of height, on both the main sound sources and the incidental environmental noises, such as the tape recorder noises and attenuator clicks. The directional acuity was, however, not duplicated nearly as well for other listeners to the recording, implying that each person is attuned, by the process of learning, to the individual characteristics of his own ears[5].

To quantify these results the recording was used in a crude subjective test to establish the accuracy with which the position of sounds could be reproduced. On average the results were better than those obtained in recent tests[8] on some matrixed quadraphony systems. Unfortunately, however, the positional errors for this form of head-related recording were concentrated in the front quadrant, other positions being reproduced with greater accuracy. So once again the front-centre images seem to be the illusive ones.

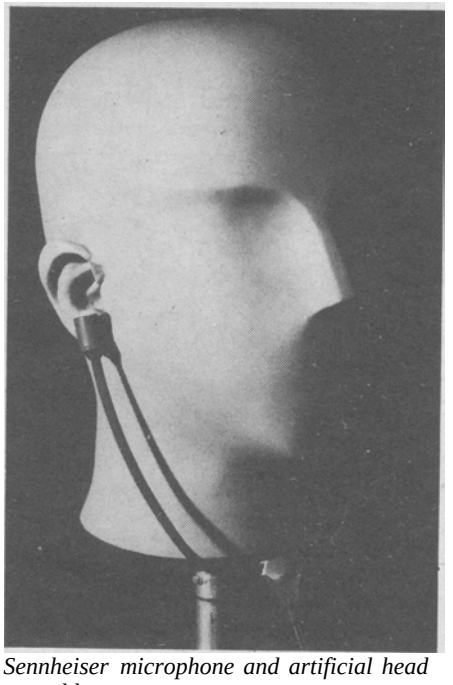
Supposing, however, that future experimentation with one, or other, of the above systems can solve the problem of creating front-centre images with headphones, there still remains the difficulty of adapting the technique for use in normal recording situations. Much of the light music and pop music that is recorded at present is obtained under conditions of gross acoustic imbalance by using many microphones placed fairly close to the individual (or grouped) instruments. Even with orchestral music in "good" concert halls, difficulties have been encountered [9], in quadraphonic work, in finding acoustically balanced positions for placing coincident groups of microphones, and the same difficulty may arise with the artificial head recordings. Furthermore, there is the problem of audience reaction to this sort of device. A normal stereo microphone suspended above one's head at a concert is fairly unobtrusive, but the same cannot be said of an artificial head.



*Showing the ear/microphone assembly of the Neumann "head".*



*Neumann's artificial head shown mounted on its case.*



*Sennheiser microphone and artificial head assembly.*

The most likely long-term development of this idea is that the artificial head work may enable investigators to acquire a greater understanding as to how the ear/brain combination locates a sound from a particular direction, and thence to determine whether it would be possible to simulate the artificial-head sounds (or even better, to simulate true three-dimensional sound sensations) by electrical processing of normal microphone signals[3]. If this could be achieved and if compatible monophonic and stereophonic listening on loudspeakers were possible, we would most certainly have an interesting alternative to the presently proposed quadraphonic arrangements.

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