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(54) **Improvements relating to noise reduction arrangements.**

(57) An active noise reduction arrangement which comprises at least one ear defender or earphone structure which embodies a small noise pick-up microphone and associated noise-cancelling transducer, in which a front cavity defined between the structure and the ear of its wearer when the arrangement is in use is coupled to a further cavity and/or source of low frequency noise-cancellation signals by means of low-pass acoustic filter means.

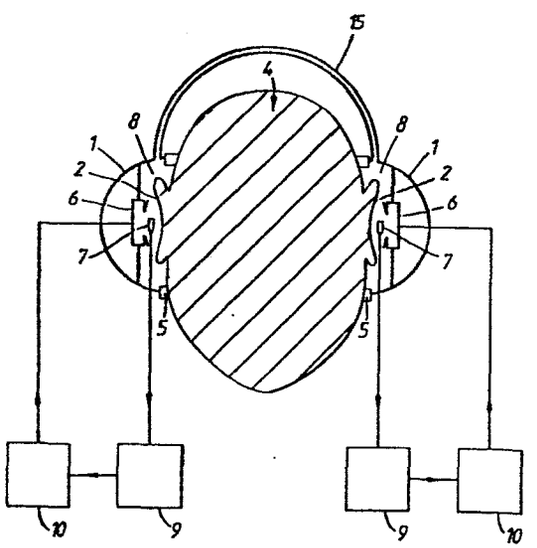


FIG.2.

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# IMPROVEMENTS RELATING TO NOISE REDUCTION ARRANGEMENTS

This invention relates to arrangements for reducing the level of acoustic noise fields within the internal cavities or enclosures of so-called ear defenders or earphone structures when being worn by personnel (e.g. pilots, vehicle drivers, industrial workers etc.) in high noise environments.

Known active noise reduction (ANR) arrangements for reducing the aforesaid acoustic noise field in ear defenders comprise small noise pick-up microphones and noise cancelling transducers mounted within the inner cavities or enclosures of the respective ear defenders. The noise pick-up microphones produce electrical signal outputs in response to the noise fields within the aforesaid cavities and these signal outputs are utilised in a feedback loop arrangement for the production of noise-cancelling signals fed to the noise-cancelling transducers which accordingly produce noise-cancelling acoustic signals of substantially the same amplitude but of opposite phase to the acoustic noise field waveform. However, this feedback arrangement will only function effectively if linear operation of the transducers producing the noise-cancelling acoustic signal waveforms is maintained throughout operation of the arrangement. Moreover, for practical reasons, the

transducers must also be of small and lightweight construction, moving coil transducers typically being used at present for such active noise reduction arrangements.

The maximum linear sound output that can be produced by these small transducers for noise-cancellation purposes is necessarily limited by such matters as the moving surface area of the transducer diaphragm, the maximum deflection of the transducer diaphragm before the transducer becomes non-linear and the particular acoustics of the ear defender cavities or enclosures in which the transducers are operating.

The levels of noise occurring in some environments may be so high that the small noise-cancelling transducers referred to cannot generate sufficiently high level noise cancellation signals. In attempting to cancel such high level noise the transducers may be overdriven into non-linear operation thereby resulting in a substantial drop in the active noise reduction produced by the ANR arrangement and also resulting in the generation of noise within the defender cavities due to distortion in the noise-cancelling outputs of the transducers when operating non-linearly. The noise generated by the non-linear operation of the transducers will depend upon the form of the non-linearity but in general will be spread across the entire frequency range of operation of the arrangement. Moreover, under very high noise conditions there is the risk of the transducers suffering permanent damage. In the case of ear

defenders or earphone structures which when fitted over the ears of the wearer define front cavities in the region of the wearer's ears and which embody compliant cushions for the resilient mounting of the structures on the wearer's head, very large acoustic pressure levels of low frequency can be produced within the front cavities due to vibratory movement of the earphone structures relative to the head of the wearer as permitted by the compliant cushions.

The present invention is directed to active noise reduction arrangements of the general form hereinbefore described but which provide additional means for the avoidance or reduction of noise produced within the aforesaid front cavities of ear defenders or earphone structures due to vibratory movement of the earphones on the wearer's head permitted by the compliant material and/or of noise that would otherwise be generated by noise-cancelling transducers when overdriven into non-linear mode of operation to combat high level noise in high noise environments.

According to the present invention there is provided an active noise reduction arrangement comprising at least one ear defender or earphone structure which embodies a small noise pick-up microphone and associated noise-cancelling transducer, in which a front cavity defined between the structure and the ear of its wearer when the arrangement is in use is coupled to a further cavity and/or a source of low frequency noise-

cancellation signals by means of low-pass acoustic filter means.

The acoustic filter means preferably comprises a flexible tube of relatively small cross-section.

According to one mode of carrying out the present invention, a tubular low-pass filter may be arranged to transmit to the aforesaid front cavity low frequency noise-cancellation signals generated by a relatively large transducer in response to receiving low frequency noise signals which are phase-inverted after being derived from the pick-up microphone located within said front cavity, the large transducer being located externally of the earphone structure so as not to increase the weight or size thereof.

Electrical signals derived from the pick-up microphone in response to noise may be fed through phase inverter means and then through high and low-pass filters respectively to derive relatively high and low frequency phase inverted signals. These signals are then fed respectively to the aforesaid noise-cancelling transducer within the earphone structure and the relatively large separately located transducer coupled to the front ear cavity of the earphone structure by the tubular low-pass filter.

In practice such an active noise reduction arrangement will normally be provided in respect of each earpiece of an ear defender or earphone structure when the invention is carried

out according to this mode.

According to another mode of carrying out the present invention a tubular low-pass filter serves to interconnect the front cavity of the aforesaid ear defender or earphone structure of the active noise reduction arrangement with the corresponding front cavity of the ear defender or earphone of an active noise reduction arrangement associated with the user's other ear. In this mode the effective doubling of the volume of the front cavity of each ear defender or earphone structure serves to reduce (i.e. halve) the peak sound pressure levels that may otherwise be developed in the earphones due to the vibratory movement of the latter permitted by the compliant cushions.

The tubular low frequency pass filter may produce similar results by alternatively being connected to some other external cavity of appropriate volume.

By way of example a number of embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of an active noise reduction arrangement according to the invention; and,

Figure 2 is a schematic diagram of a modified active noise reduction arrangement according to the invention.

Referring to Figure 1, this shows one channel arrangement of a two channel active noise reduction system for the

cancellation of noise signals in earphones.

The active noise reduction arrangement illustrated comprises a generally cup-shaped earphone structure 1, arranged to enclose the user's ear 2 as shown. The rim 3 of the cup shaped earphone is cushioned against the side of the user's head 4 by means of a compliant ring cushion 5. The earphone structure 1 includes a small lightweight transducer 6 (e.g. moving coil transducer) and a small pick-up microphone 7. Electrical signals generated by the pick-up microphone 7 in response to noise entering the truncated generally hemispherical front air cavity 8 through the wall of the earphone structure 1 are inverted by means of a phase inverter 9, after which they are filtered by filter 10. In known active noise reduction arrangements the full frequency spectrum of phase-inverted signals derived from the microphone 7 would then be fed to a noise-cancelling transducer, such as the transducer 6 in the present embodiment, which would produce noise cancellation acoustic signals for reducing the noise levels within the front ear cavity 8. As has already been explained, in very high noise environments, the noise cancellation signals fed to the transducer 6 could well cause the transducer to be overdriven into a non-linear mode of operation and itself caused to generate noise in the overdriven condition. Additionally, vibratory movement of the earphone structure 1

relative to the user's head 4 permitted by the compliant cushion ring 5 also sets up low frequency noise pressure levels within the front ear cavity 8. With a view to overcoming or at least alleviating this problem arising from the generation of such low frequency noise within the front cavity 8, the illustrated embodiment of the present invention introduces relatively high frequency and low frequency pass filters 11 and 12, respectively, in parallel branches of the output circuit of the filter 10. The high frequency noise-cancelling signal output from filter 11 is fed to the transducer 6 which accordingly produces relatively high frequency noise-cancelling signals within the front cavity 8. The relatively low frequency noise-cancellation output signals from the filter 12 are fed to a relatively large transducer (e.g. moving coil) 13. This relatively large transducer 13 which is entirely separate from the earphone structure 1 and which may be located remotely therefrom, produces low frequency acoustic signals which are transmitted to the front ear cavity 8 of the earphone by means of a flexible tube 14 which acts as a low-pass filter. The flexible tube 14 which defines a relatively low frequency acoustic transmission line having a cut-off frequency determined by the internal diameter of the tube 14 and the tube length allows the use of an external larger noise-cancelling transducer than would normally be possible within the earphone. The relatively large transducer 13 can produce a much larger

level of sound output before being overdriven into non-linearity with the aforesaid disadvantages. Although the tube 14 introduces a constant time delay between the output from the transducer 13 and the user's ear 2, only a small phase difference is produced due to the low frequency and long wavelength of the signals concerned. The relatively large transducer 13 may for example be mounted in the user's seat, as may also the other electronics equipment apart from the earphone itself, in those applications where the user (e.g. pilot, vehicle driver etc.) will normally be sitting when carrying out his particular functions. In cases where the user needs to be mobile the transducer 13 may form part of a portable electronics pack or harness.

Referring now to Figure 2 of the drawings, this shows an alternative active noise reduction arrangement which effectively reduces the sound pressure levels which are produced by vibratory movements of the earphone structures 1 on the user's head, such movements being permitted by the compliant ring cushions 5. As in the case of the Figure 1 embodiment the earphone structures 1 include small microphones 7, the outputs from which are phase-inverted and filtered by the inverters 9 and filters 10. In this embodiment the entire output from the filter 10 is applied to the transducer 6 for the generation of noise-cancelling signals. For the purpose of increasing the effective volume of front cavity 8 of each

earphone, thereby reducing the peak sound pressure levels developed by a given earphone vibratory movement, the two earphone front cavities 8 are interconnected by means of a flexible tube 15 having a small internal diameter so that the tube acts as a low-pass filter but isolates the two earphone front cavities 8 at high frequencies. For a typical circumaural earphone structure as shown (i.e. earphone structure encloses the ear) most of the sound energy is in the 5-10 Hz band. At these low frequencies the presence of the flexible tube 15 gives the front cavity 8 of the earphone an apparent doubling of volume so that for relative movement of just one earphone the peak sound pressure levels developed by the earphone concerned will be halved.

It may here be mentioned that the flexible tube 15 need not interconnect the two earphone front cavities 8. Two such tubes could alternatively couple the respective earphone front cavities 8 to any convenient external enclosed volumes in order to increase the effective front cavity volumes of the earphones at low frequency.

In yet another embodiment of the invention the earphone front cavities may be interconnected by means of a flexible tube as shown in Figure 2 and then one or both of the front cavities 8 joined to an external low frequency transducer or transducers. If the flexible tube joining the two front cavities 8 were of sufficient internal diameter then at low

frequencies the earphone front cavities could be treated as a single cavity and a single remote transducer could be used to provide low frequency noise reduction.

Although the present invention has been described with particular reference to earphones enclosing the user's ear (circumaural type) it could also be applied to earphones which actually sit on the user's ear (super-aural type) and also to structures inserted in the ear canal itself.

CLAIMS:

1. An active noise reduction arrangement comprising at least one ear defender or earphone structure which embodies a small noise pick-up microphone and associated noise-cancelling transducer, in which a front cavity defined between the structure and the ear of its wearer when the arrangement is in use is coupled to a further cavity and/or a source of low frequency noise-cancellation signals by means of low-pass acoustic filter means.

2. An acoustic noise reduction arrangement as claimed in claim 1, in which the acoustic filter means comprises a flexible tube of relatively small cross-section.

3. An active noise reduction arrangement as claimed in claim 2, in which the tubular low-pass filter is arranged to trasmit to the front cavity low frequency noise-cancellation signals generated by a relatively large transducer in response to receiving low frequency noise signals which are phase inverted after being derived from the pick-up microphone located within said front cavity, the large transducer being located externally of the earphone structure so as not to increase the weight or size

thereof.

4. An active noise reduction arrangement as claimed in claim 3, in which electrical signals derived from the pick-up microphone in response to noise are fed through phase inverter means and then through high and low-pass filters, respectively, to derive relatively high and low frequency phase inverted signals, these signals being fed respectively to the noise-cancelling transducer within the earphone structure and the relatively large separately located transducer coupled to the front ear cavity of the earphone structure by the tubular low-pass filter.

5. An active noise reduction arrangement as claimed in claim 2, in which the tubular low-pass filter interconnects the front cavity of the said ear defender or earphone structure with a corresponding front cavity of an ear defender or earphone of an active noise reduction arrangement associated with the wearer's other ear.

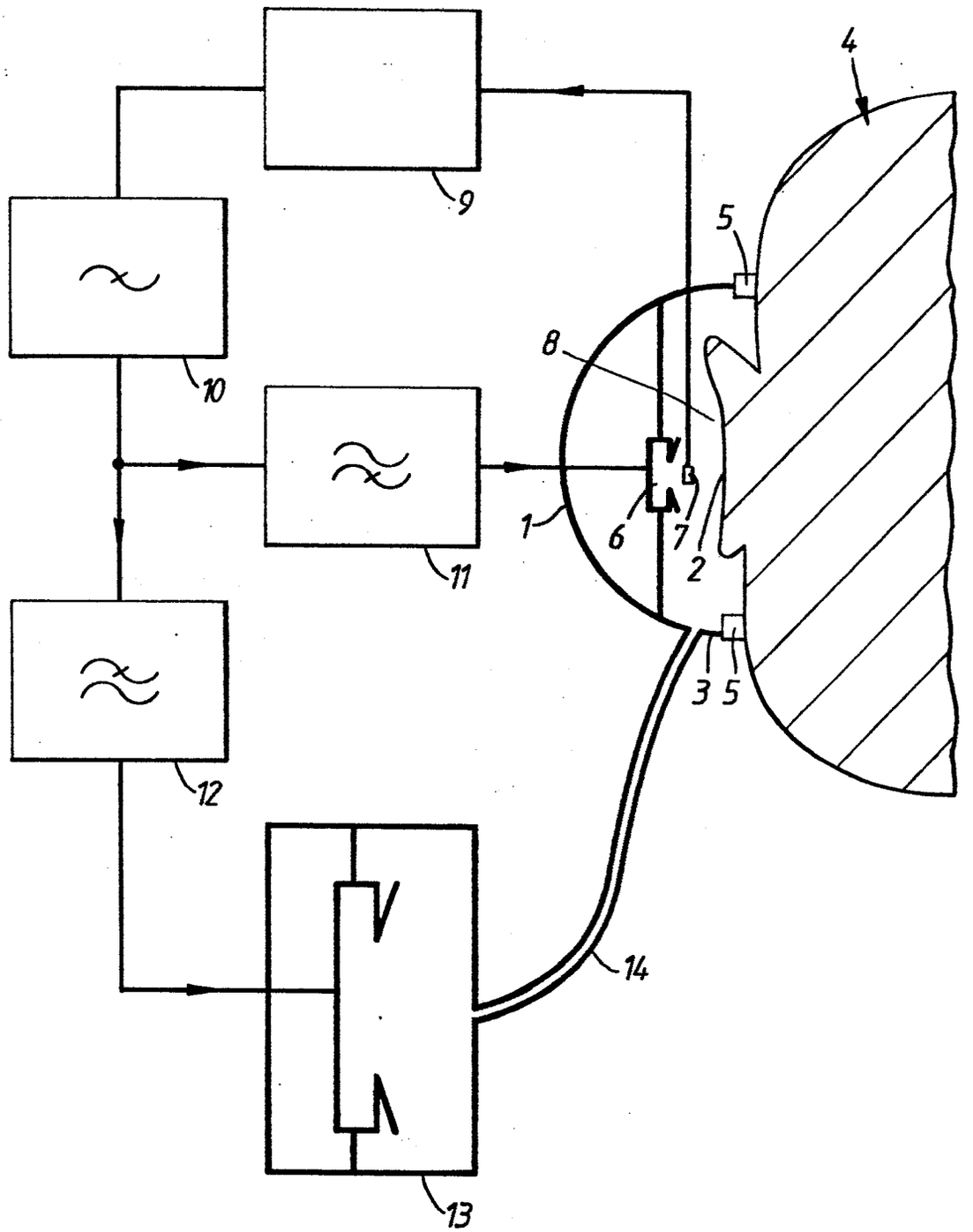


FIG. 1.

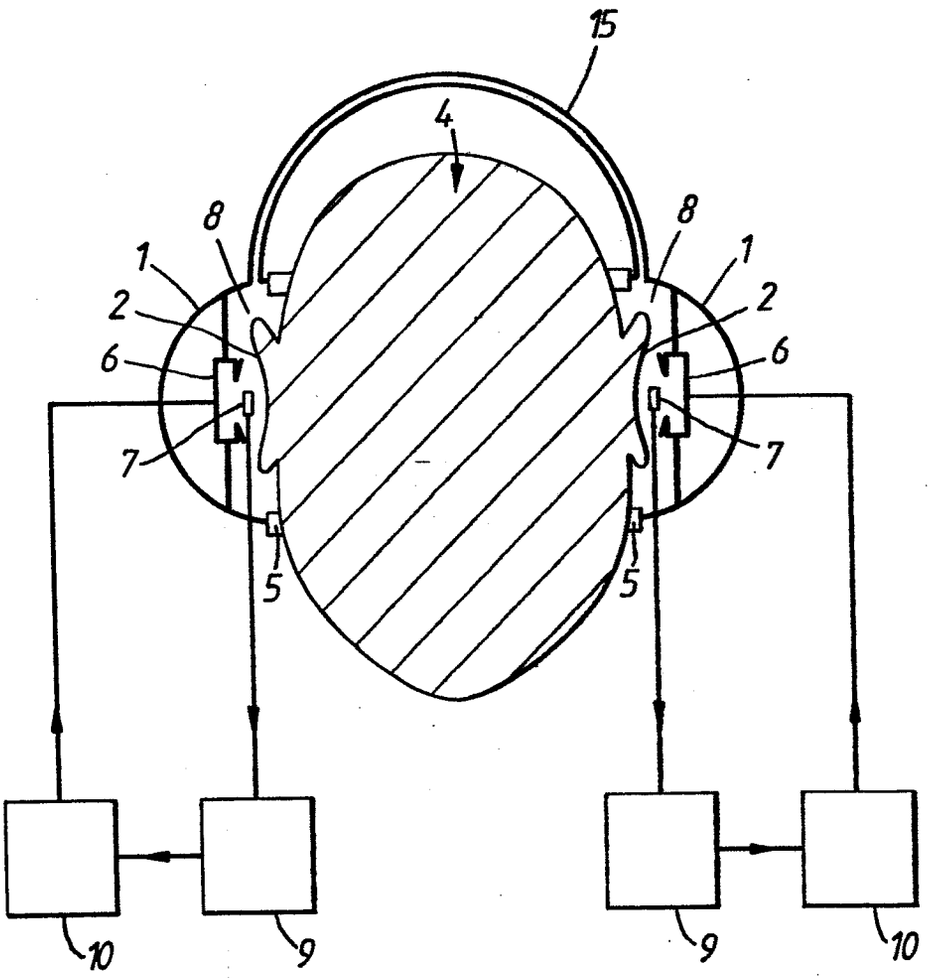


FIG.2.