HEARING PROTECTORS

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Development of an amplitude-sensitive ear defender (Gundefender)

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An ear defender which would protect the ear against high noise levels while allowing speech to pass unhindered would overcome one of the principal objections associated with ear protection. Such a defender is attainable in practice if the noise and the speech differ markedly in some physical characteristic. For instance, if the noise and speech are different in frequency, as is the case in a few specialised applications, it is comparatively simple to construct an ear defender to remove the offending frequencies.

An alternative approach is possible if the noise consists of very high intensity impulses of short duration, as is the case with gunfire. Obviously if the ear defender attenuation can be made to increase with intensity, the ear will be protected against the impulses while the speech will still be heard in the intervening quiet periods. There are several methods by which this can be attained; one such is the ERDEfender, which consists essentially of a microphone, peak-limiting amplifier and telephone built into each ear cup of a pair of ear muffs. This system is effective but bulky and expensive, and a simpler system which could be built into something as small as an ear plug seems desirable.

One system having the required properties turned out to be very simple indeed. When air passes through a small orifice the flow is proportional to pressure until a critical point is reached where the originally laminar flow breaks down and becomes turbulent. At this point resistance to flow increases, and a disproportionate increase in pressure is required to produce a further increase in flow.

This property can easily be used to provide an ear defender with the required characteristics. Such an orifice placed in an ear plug at the entrance to the ear canal is backed by a mainly capacitive load formed by the compliances of the air in the canal and of the ear drum. The air flow through this orifice will then depend on this capacitive load, on the dimensions of the orifice and on the intensity and frequency of the external sound field. High sound pressures will cause the air flow through the orifice to become turbulent, and the increased resistance to flow will give the desired amplitude-sensitivity.

Such a defender will of course affect the frequency response of the ear even at low sound intensities. Normally the ear canal has a distinct resonance at about 3 kHz; with the flow at the entrance restricted, a Helmholtz resonator is formed with a much lower resonant frequency. Thus the effect of an ear plug pierced by a small orifice will be to increase slightly the pressure at the ear drum at the Helmholtz resonant frequency, and to reduce the pressure at higher frequencies, particularly at the resonant frequency of the unobstructed canal. The attenuation will however be less than that of a normal "solid" ear plug, and the interference with speech also less. For the orifice size used in the "Gundefender" plug, a heavily damped Helmholtz resonance occurred at about 700 Hz, and the speech attenuation in quiet conditions was approximately 5 dB. The increase in attenuation resulting from turbulence in the flow through the orifice was first apparent at 120 dB SPL but was not large enough to be useful until higher levels were reached.

The properties of various orifice sizes were measured first in an artificial ear with simulated ear drum compliance; this confirmed theoretical predictions and indicated the optimum configuration for the orifice. The pure-tone attenuation was then checked by measurements of real-ear attenuation at threshold. A rather unusual confirmation of these results was then provided by a series of measurements (using several different types of ear plug) on cadaver ears, in which a microphone was placed near the ear drum. The properties of the device, which by this time had taken shape as a thin steel disc pierced by a 0.025-inch diameter orifice set in a V.51R-type (Sonex) ear plug, could therefore be said to be thoroughly evaluated. However, further confirmation of the ability of the plug to protect the ear against gunfire noise has been obtained using temporary threshold shift techniques. An

account of both the functioning of the plug and the validation of its performance is given in reference 1 and more fully in reference 2, and independent confirmation is supplied in reference 3.

The plug was called the "Gundefender" (a term which appears to have been shortened to "Gunfender") in order to indicate its intended function as protection against gunfire-type noise. Evidently a device specifically designed to pass low-level sound will be of little use against the lower levels encountered with continuous noise; but in the case of the very high peak levels (160 - 190 dB SPL) associated with gunfire and similar noise, the protection is of the same order as that of a conventional ear plug. It is hoped that the greater ease of speech communication will allow, in the situations for which the plug was designed, a wider use of ear protection than hitherto.

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REFERENCES

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