3. ORIGIN OF THE $2f_1 - f_2$ DISTORTION PRODUCT

The other cochlear emission which has become of clinical importance is the simple intermodulation distortion component, variously known as the cubic distortion product (CDT, after the polynomial simplification for it's mathematical analysis), the intermodulation distortion product (IDP), $2f_1 - f_2$ (the formula for calculating its frequency from those of the primaries) and, simply, the distortion product (DP). It arises as one of several spectral lines which are generated by the inner ear when presented with two, pure sine waves. The largest, most easily seen and certainly the most easily heard of the lines is the one at frequency $2f_1 - f_2$. It has been found useful in clinical practice but has the perceived disadvantage that it monitors hearing at only a single site along the cochlea. The basic mode of generation, however, is still very poorly understood.

Perhaps one of the biggest mysteries is why this particular spectral line should be most prominent. Theoretically, its symmetrical counterpart, at $2f_2 - f_1$, should be just as prominent but it is only seen at somewhat higher intensities. Des Kirk and I have been studying electrically-evoked emissions and we believe we know the answer. Electrically-evoked oto-acoustic emissions (EEOAEs) are similar to other emissions but are generated by direct electrical stimulation of the cochlea. Of course, we can do this only on experimental animals at the moment, but it tells us a great deal about the mechanisms by which emissions propagate within the cochlea. We have found that energy generated at any particular place along the cochlea will only propagate back to the middle ear, where it emerges into the external ear canal as emissions, will only propagate if its frequency is below that at which the particular site responds best, its characteristic frequency (CF). This is not a clear-cut rule, the separation is not absolute, but there is a very great asymmetry on the magnitude of propagation above and below CF. The explanation lies, however, in the fluid mechanics of the basilar membrane, which analyses the incoming sound signal into its Fourier components. Although its tuning properties are bandpass, its propagation properties are lowpass, i.e., any given place along the cochlea will propagate a wave so long as its frequency is lower than the local CF, but the magnitude will vary. For frequencies above CF, however, the wave motion is evanescent and decays away exponentially and, since the physics is reversible, no energy will propagate as an emission if its frequency is greater than the CF of the site at which it is generated. When we consider the distortion products, it is clear that the frequency $2f_1 - f_2$ is always below the CF of the primary generation site, i.e., somewhere between the f_1 and f_2 sites, whereas $2f_2 - f_1$ is always above the primary site CF.

4. CONCLUSION

Ours is basic research. Our day-to-day efforts are not immediately directed to solving practical problems of audiology. Rather, we are taking the longer-term view, that if we can understand the basic physics and biology behind the hearing process we will then be better equipped to tackle the other, clinically-relevant problems of hearing.

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Withnell, R.H and Yates, G.K. (1998). Enhancement of the transient-evoked otoacoustic emission produced by the addition of a pure tone in the guinea pig. *J. Acoust. Soc. Am.* (in press).

Correction

Sound Proofing of a Forge

by Stephen Cooper

Acoustics Australia, vol 26, no 1, page 22

Figures 1 and 2 in original should be replaced by figures below.

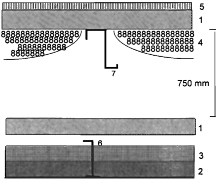

Figure 1. Forge Roof Construction

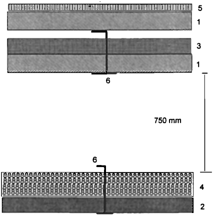

Figure 2. Forge Wall Construction