J. Membrane Biol. 32, 195–196 (1977)

Letter to the Editors

Diffusion as a Source of $1/f$ Noise

Received 23 November 1976

Recently M.E.Green (1976), with reference to the experiments of Dorset and Fishman (1975), has considered the $1/f$ noise associated with ion transport through porous membranes as a diffusion process of the charge carriers themselves. Green has put particular attention to the occurence that, in a special membrane system (mica) studied by Dorset and Fishman containing pores of constant dimensions, the power spectrum was steeper than f^{-1} and close to $f^{-\frac{3}{2}}$. From this behavior Green has drawn the conclusion that diffusion is the source of the $1/f$-type noise. For it has been stated by a number of authors (references in Green's paper) that the high frequency spectra associated with diffusion are $\alpha f^{-\frac{3}{2}}$. Though 1 agree with Green's basic assumption that one-dimensional diffusion is generating the $1/f$-type noise in the experiments of Dorset and Fishman (Frehland, 1976), some remarks concerning Green's theoretical discussion should be made. Green regards the *concentration* fluctation spectrum (*see* Eq. (1) in Green's paper). Indeed all the authors cited by Green have considered the power spectra of *concentration* fluctuations. This may be justified if the relevant measured fluctuating quantities (current or voltage) are *linearly* coupled to the diffusing medium (e.g., temperature fluctuations linearly coupled to resistance). If the current carriers themselves are the diffusing medium, this linear coupling generally does not exist. Regard the one dimensional flux equation for flux Φ and concentration c:

$$\Phi = -D\frac{\partial c}{\partial x} - EDc$$

($E = \partial\bar{V}/\partial x$, D: diffusion coefficient, $\bar{V} = V/kT$, V: potential energy, k: Boltzmann constant, T: absolute temperature).

The first term on the right-hand side is ordinary diffusion, the second takes into account the influence of the electrical field; thus, flux (current) is given not only by concentration c but also by its spatial derivative.

Hence $1/f$-like fluctuations in carrier concentration do not necessarily mean $1/f$-like current fluctuations. Indeed, it can be shown for one-dimensional diffusion in an infinite medium that concentration fluctuations are $1/f$-like while current fluctuations are not (Frehland, 1976).

Nevertheless, 1 agree with Green's opinion that the diffusion of the current carriers may be an important source of $1/f$ noise. Generally, in electrical systems $1/f$ noise has been observed, if strong inhomogeneities (boundaries) in resistance exist. Then a correlation between current and concentration is given by the condition that current through is proportional to concentration at such a boundary. Indeed, the explicit calculations for this modified diffusion model (Frehland, 1976) have resulted in $1/f$-type current fluctuations over many orders of magnitude in frequency f and in a high frequency behaviour $\propto f^{-\frac{3}{2}}$.

Note Added in Proof

A further point should be noted: Green uses van Vliet and Fassett's result for concentration fluctuations in a finite domain within an infinite diffusion regime. But in Green's case, aqueous solution-pore- aqueous solution, the regime is not homogeneous and the boundary conditions for the diffusion through the pore mouths should be taken into account.

References

Dorset, D.L., Fishman, H.M. 1975. Excess electrical noise during current flow through porous membranes separating ionic solutions. *J. Membrane Biol.* **21**:291

Frehland, E. 1976. $1/f$-noise generated by constrained diffusion through a flux-controlling boundary. *Z. Naturforsch.* **31 a**:942

Green, Michael E. 1976. Diffusion and $1/f$ noise. *J. Membrane Biol.* **28**:181

Dr. Eckart Frehland
Universität Konstanz, Fachbereich Physik
Postfach 7733
D-7750 Konstanz