**Appendix**

The purpose of dynamic focusing is to change the proportion of the current compensation applied to flanking electrodes relative to the active electrode as a function of stimulation level.

Computing dynamic focusing

With dynamic focusing, for each channel, σ will need to be computed in real time. In general, σ defines the proportion of the current of the compensation electrodes relative to the active electrode. Let N(t) indicate the normalized energy level in the envelope, with 0 at threshold (T) level and 1 at most comfortable listening (M) level. In addition, Wu(t) indicates a warped function specified by the user which can differ from linear. Then, σ is defined as a function of normalized energy level as follows:

$$σ\left(N\left(t\right)\right)=MIN\left[σ\_{Max},MAX\left\{σ\_{Min},\left(N\left(t\right)-N\_{0}\right)S+σ\_{0}\right\}\right]$$

The following parameters are needed for the computation.

|  |  |
| --- | --- |
| σ0 | Value of σ for N(t) = 0. |
| σ1 | Value of σ for N(t) = 1. |
| N0 | Point in the normalized dynamic range where σ will start to change. |
| S | Slope of the change. |

N0 and S are computed from σ0 and σ1, as well as values of M and T as follows:

$$N\_{0}=W\_{U}^{-1}\left(\frac{M-T}{M\frac{1+KFσ\_{1}}{1+KFσ\_{0}}-T}\right)$$

In the above equation, M and T represent the M level and T levels representing current on the compensation electrodes. WU(N) is the user-defined warping function. K is the interaction coefficient, discussed further in the description, which is a fitting parameter that indicates the degree to which compensation electrodes interact with the other electrodes. The K parameter can vary from 0 to 1. *F* is a parameter related to the channel-to-electrode map. In particular, *F equals to the ratio of the sum of the dynamic compensation electrodes to other electrodes in the map*. Note that *F* can be positive or negative.

In addition, slope S is computed as follows:

$$S=\frac{σ\_{1}-σ\_{0}}{1-N\_{0}}$$

Finally, σmin and σmax are computed as follows:

σmin = Min{σ0, σ1}

σmax = Max{σ0, σ1}

Computing current levels

The current delivered to each of the electrode will equal to the product of the electrode-to-weight map and the mapped value according to

I(t)σ(t)

In order to preserve proper loudness growth in the presence of changing compensation, the current value I(t) will be computed according to envelope warping function W(N). According to Litvak et al (2007), both at M level and T level, the current needed to achieve equivalent loudness to monopolar stimulation is governed by the following equation:

$$I\_{σ}=\frac{I\_{0}}{1+KFσ}$$

In the above equation, K is the interaction coefficient, which depends on the patient, electrode type and spacing between the compensating and the primary electrode. For non-positioner patients, and near spacing, interaction coefficient varies from 0.8 to 1. As in previous section, *F* is the ratio between total current delivered to dynamically compensated electrodes to the ratio delivered to the other electrodes when σ=1.

In order to balance loudness to monopolar-like loudness growth, and assuming that M and T have been measured with compensation σ1 and σ0 respectively, equivalent monopolar loudness at any envelope level N equals to:

$$I\_{0}\left(N\right)=\left(M\left(1+Kσ\_{1}\right)-T\left(1+Kσ\_{0}\right)\right)W\_{U}\left(N\right)+T\left(1+Kσ\_{0}\right)$$

The equivalent compensated current would then equal to:

$$I\_{σ}\left(N\right)=\frac{I\_{0}(N)}{1+Kσ(N)}$$

Finally, the warping function was set to:

$$W\left(N\right)=\frac{\frac{\left(M\left(1+Kσ\_{1}\right)-T\left(1+Kσ\_{0}\right)\right)W\_{U}\left(N\right)+T\left(1+Kσ\_{0}\right)}{1+Kσ\left(N\right)}-T}{M-T}$$

The computation of the warping function coefficients was performed in advance. Then, in real time, I(t) will be computed as follows:

$$I\left(t\right)=\left(M-T\right)W\left(N(t)\right)+T$$