Quantum model for nerve pulse

1. Basic assumptions of the model.

   (a) Cell is super conductor. The minimum assumption is that only electronic super-conductivity is involved but also protonic and ionic super-conductivities can be considered.

   (b) The lipid layers of axonal membrane form cylindrical Josephson junction of thickness about 10 nm.

   (c) The angular frequency associated with phase difference is Josephson frequency $f_J = ZeV/h_{eff}$. Large values of h_{eff} allow arbitrarily small frequencies. The energy ZeV for Z=2 is just above thermal thres hold meaning minimization of metabolic energy lost as Josephson radiation.

   (d) In improved resolution membrane proteins defining receptors, channels and pumps define the Josephson junctions (not all the time). They carry Josephson current and generate Josephson radiation.

   (e) The idealization as cylindrical Josephson junction is made for modeling purposes.

2. Mathematical treatment.

   (a) The equations for the cylindrical Josephson junction redu ce to Sine-Gordon wave equation for the phase difference over the junction. This can be interpreted as a limit of dynamics for a sequence of mathematical penduli coupled to each other.

   (b) For propagating waves the equations reduces to that of mathematical pendulum but with time coordinate replaced with z-vt so that one can use the intuition provided by it.

   (c) The solutions correspond to either small oscillations analogous to oscillations of pendulum around the minimum of gravitational potential or to a full rotation possible when the kinetic energy is high enough.

   (d) For small oscillations the resting potential would oscillate sinusodally around zero so that the solution is not physical.

   (e) Physical solutions represent rotation a soliton sequence propagating along the axon. The angular velocity of rotation is essentially $\Omega = ZeV/h_{eff}$, where V is the restring potential and $h_{eff} = n \times h$ the Planck constant. The propagation velocity v of solution sequence is a new para- meter.

   (f) There are two types of propagating solutions. Type I depends on x-vt and reduces to a solution depending on coordinate z for $v \to 0$. Type II depends on t-vx/c and depends only on t at this limit. The velocity parameter could correspond to the velocity of nerve pulse conduction for type I and velocity of propagation of EEG waves for type II.

3. A model for nerve pulse generation.

   (a) Nerve pulse is generated when the membrane voltage goes below the critical value defined by action potential.

   (b) Potential is reduced below the action potential if the rotation rate of the pendulum reduces below its critical value. A possible interpretation for the critical value would be in terms of the critical value of oscillation frequency for small oscillations above which oscillation is transformed to rotation.

   (c) The anatomy of nerve pulse shows that the rotation rate must go through zero to opposite value for time of about 1 ms and then return to the original value with magnitude slightly higher than before the pulse (hyperpolarization). As if one of the penduli in the sequence were kicked so that it starts to rotate in opposite direction and returns back. In order to conserve angular momentum it kicks the next pendulum in the sa- manner. Nerve pulse results as a kind of domino effect.