Sim4Life Frequency Modulation Report

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March 17, 2025

Method

Given the following function to calculate threshold intensity (voltage):

$$V_{threshold} = \phi \cdot T \cdot a(t) \tag{1}$$

where:

- $V_{threshold}$ is the threshold intensity in voltage. This is the value we are trying to find.

- ϕ is the stimulated voltage. We keep this value equal to 1 V_{pp} going from -0.5 V to 0.5 V

- $a(t)$ is the intensity of the modulated signal. We vary this value between two values, $10V$ and $20V$, to keep the titration factor as close to 1 as possible.

- T is the titration factor. This value is calculated by the simulation by adjusting the sensitivity of the signal until an action potential is produced.

The chosen sets of parameters for the simulation are:

$a(t)$	$Frequency(Hz)$	$\phi(V)$
20	20	1
20	40	1
20	60	1
10	80	1
10	160	1
20	240	1
10	320	1
10	480	1
10	640	1

Table 1: Parameter Sets 1

$a(t)$	$Frequency(Hz)$	$\phi(V)$
20	800	1
10	1200	1
10	1500	1
10	1700	1
10	3000	1
10	6000	1
10	1200	1
10	2400	1

Table 2: Parameter Sets 2

Other settings of the simulation source are:

- Pulse Type: Sinusoidal

- Frenquency: 20Hz to 24000Hz

- Amplitude: 10V or 20V

- Number Of Half Period Sine: 1/2 of the chosen frequency

- Solver Duration: $0.003s$

- Time Step: $0.0025s$

The three nerve fibers/axon chosen for this simulation along with nodes for placing point sensor are:

- Dorsal root spinal C5 brachial plexus radial right (C5) at nodes 55, 112, and 140.

- Ventral root spinal C8 brachial plexus median right (C8) at nodes 60, 114, and 152.

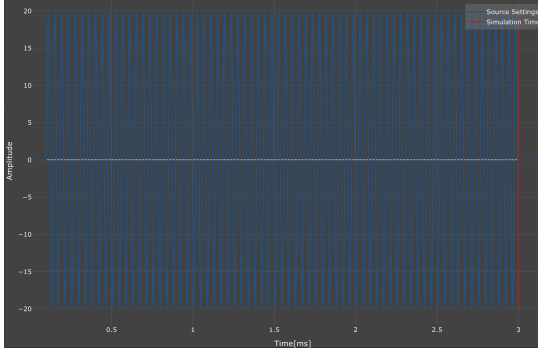- Ventral root spinal T1 brachial plexus ulnar right (T1) at nodes 60, 114, and 150.

The codes for sweeping different pairs of frequency and intensity and for generating this report are available in the following Github repository: `https://github.com/samsam2610/Sim4Life-Sweeping`
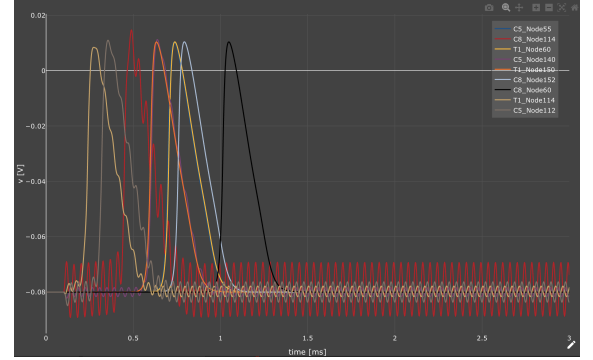
Result

The following figures and tables show the example result at $24kHz$ and the full results of the simulations as pair of frequency and titration factor of an axon.

(a) Titration Factor of different axons

(b) Plot of the source signal

(c) Action Potential Registered at different nodes along the axons

Figure 1: Example output of the simulation at $24kHz$.

$Freq(Hz)$	T_{C8}	T_{T1}	T_{C5}
20	0.148438	1.125	1.84375
40	0.0800781	0.605469	1.02344
60	0.0595703	0.46875	0.789062
80	0.100586	0.84375	1.35938
160	0.0761719	0.710938	1.09375
240	0.0223389	0.330078	0.503906
320	0.0385742	0.632812	0.960938
480	0.0361328	0.597656	0.90625
640	0.0349121	0.582031	0.882812

Table 3: Outputs 1

$Freq(Hz)$	T_{C8}	T_{T1}	T_{C5}
800	0.0172119	0.287109	0.433594
1200	0.0170898	0.289062	0.4375
1500	0.017334	0.292969	0.441406
1700	0.0174561	0.296875	0.449219
3000	0.019043	0.333984	0.503906
6000	0.0240479	0.445312	0.671875
12000	0.0358887	0.679688	1.02344
24000	0.0585938	1.17188	1.73438

Table 4: Outputs 2

By multiplying the titration factor by the stimulated voltage and the intensity of the modulated signal, we can calculate the threshold intensity in voltage required to trigger an action potential in the axon. The following plot shows the relationship between the frequency and the threshold intensity for each of the three axons.
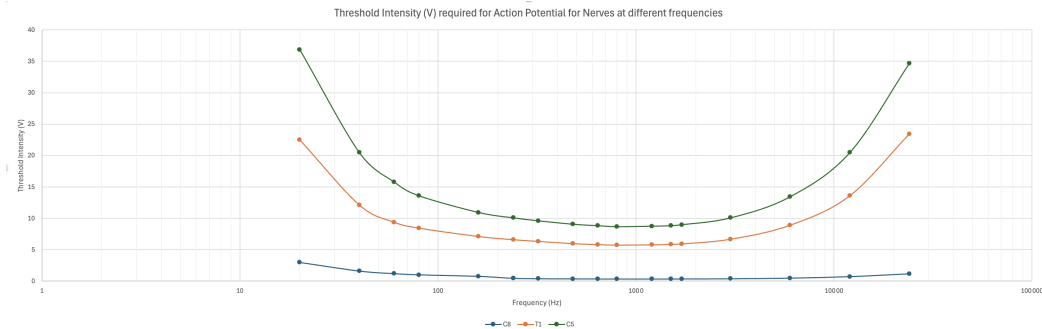

Figure 2: Threshold Intensity vs Frequency