Appendix 1: Russian Currents

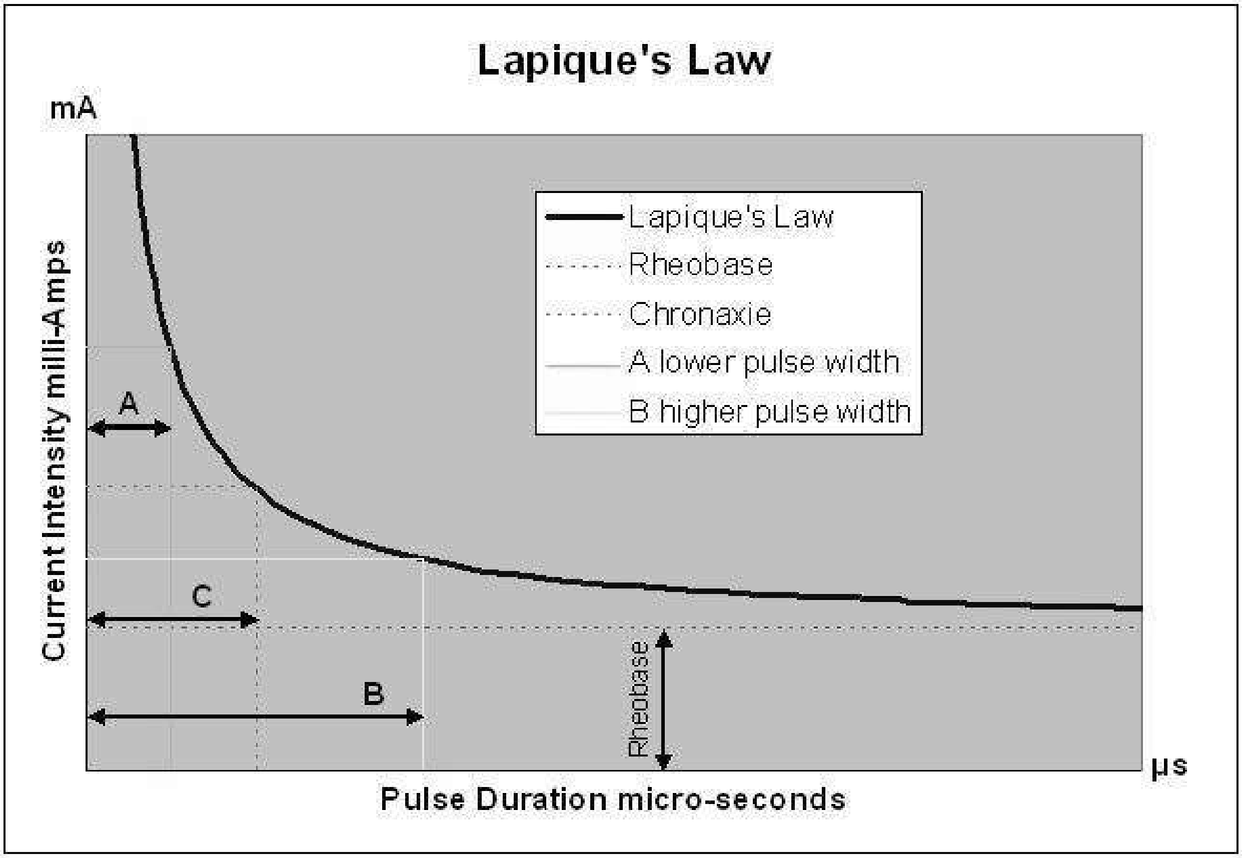
Improvement of Square-Wave Currents over Russian Currents.

Russian currents encounter the sympathies of many practitioners, and many are still using them. The reasons are historical: Russian currents were the first to succeed at professional sport training. Although modern training currents have evolved toward square wave currents, old habits get entrenched and are culturally difficult to change, because they are transmitted from early users to newer users.

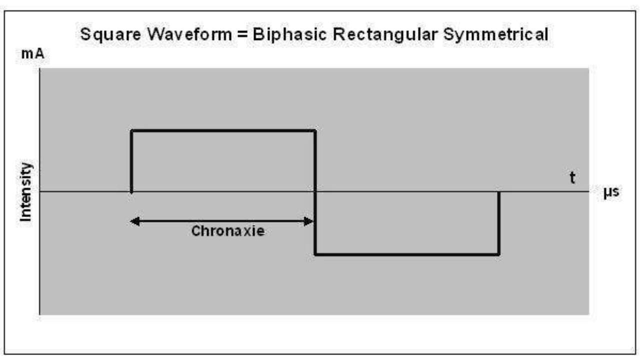
I will explain using the principles of EMS theory presented, why Russian stimulation works, how a square wave compares with it, and why the latter is more performing. I will interchangeably use the term Russian current, Russian program or Russian stimulation for the same protocol introduced by Russian scientist Yakov Kots. I will also use interchangeably use the term rectangular current, square wave, or Biphasic Rectangular Symmetrical waveform for the electrostimulation current we have considered so far.

Back to Lapique's law. We have seen that there is a direct relationship between current intensity and pulse width to excite a nerve cell. This is true for nerve cells innervating muscles, also known as motor neuron (measured in microseconds, that is millionth of a second, and for short μs). Keep in mind that we are exciting a motor neuron and not a muscle fiber. The motor neuron then triggers the muscle fiber in a physiologically-natural way.

With reference to the diagram shown, we can see that if we use a pulse width equal to the chronaxie of the muscle, we strike an intuitively sweet spot in the muscle: the intensity doesn't need to be too high, and we don't need to stimulate the muscle for too long.

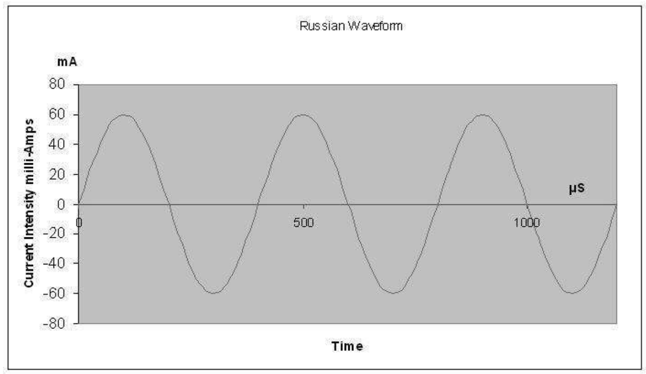


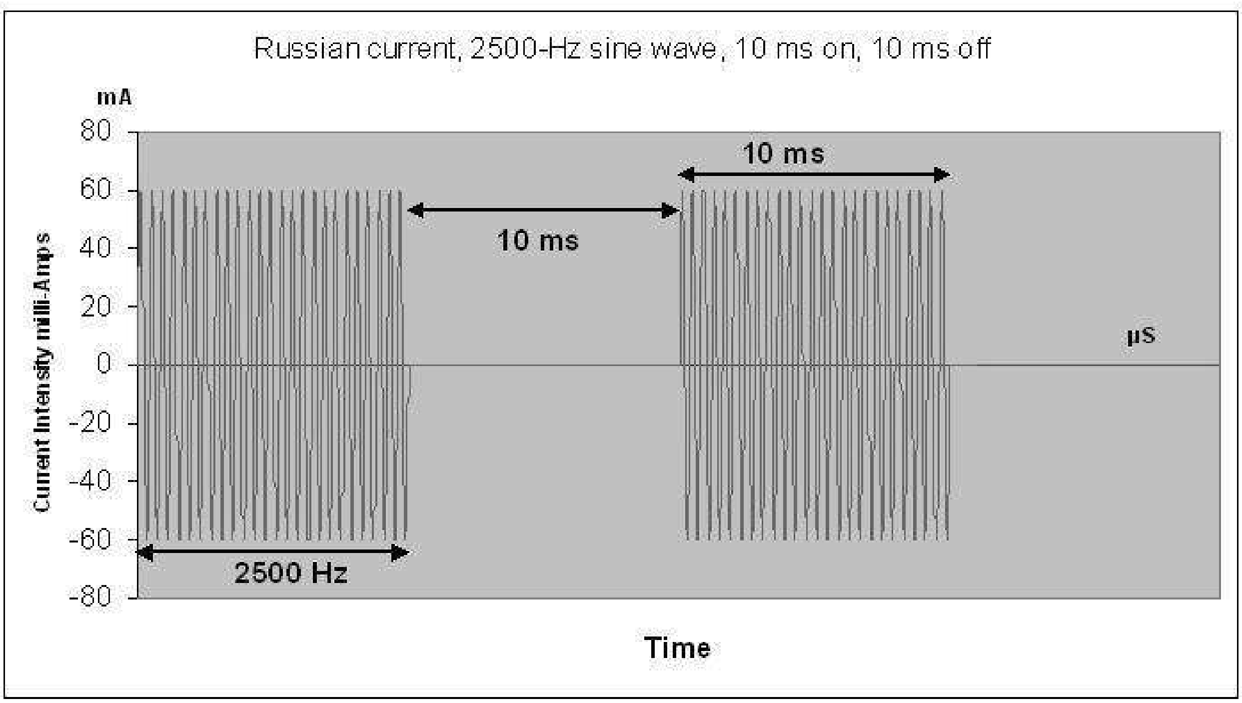
With reference to the alternatives: square wave A excites the motor neuron for a shorter time, but requires percentage wise a much higher intensity; square wave B excites the motor neuron for a longer time, thus requiring lower intensity; the gain in lower intensity though has to be compensated percentage wise by a much longer stimulus which stresses the nerve cell. We are left with curve C which uses pulse width equal to chronaxie, the best compromise in terms of energy expensed to excite the nerve (an in turn the muscle it innervates). (Minimal energy expenditure can be demonstrated with high-school calculus starting from Lapique's law I=Rheobase + Rehobase*Chronaxie/T). We utilize this chronaxie to generate the proper square wave.

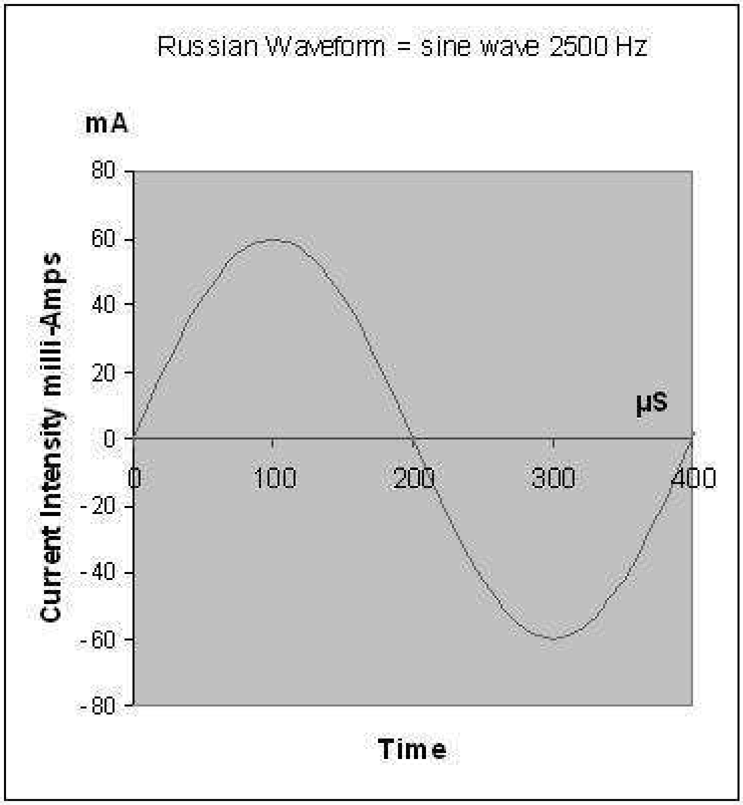


Although Lapique's law dates from the early 20th century, its full implications for training and measurement of parameters involved were not fully understood until much later. Many researchers were therefore experimenting with a wide range of many parameters: different waveforms, different frequencies, different pulse widths, different current intensities, as well as on/off times, duration of the training, repetitions, sessions per week etc. One can understand that to try all the possible combinations, and having to wait a few weeks for each experiment, to measure results, would take too long. Science advances by both understanding of the phenomenon, intuition of possible implications, and trial and error. Then somebody has a better intuition, or hits a lucky attempt. The better results obtained are studied, more light is shed on why it works, and from the new knowledge more experiments are tried to advance even further.

This is what happened to Russian scientist Yakov Kots: guided by profound understanding, and experimenting with various combinations of parameters that made sense to him, in the ‘60s he started hitting on a combination that produced results. You have to remember than in the 60’s solid-state electronic was at the beginning and miniaturization was not available (it was just being invented to put a man on the moon with NASA's Apollo program). It was far simpler for a researcher to generate an electric pulse with readily available electronic tubes rather than to experiment with transistors. Therefore the waveforms that Kots had at his disposal were so called sine-wave pulses as in this picture. Experimenting with various frequencies, he refined his results and consolidated the findings in a training current at 2500 Hz, on for 10 ms (milliseconds) and of for 10 ms.

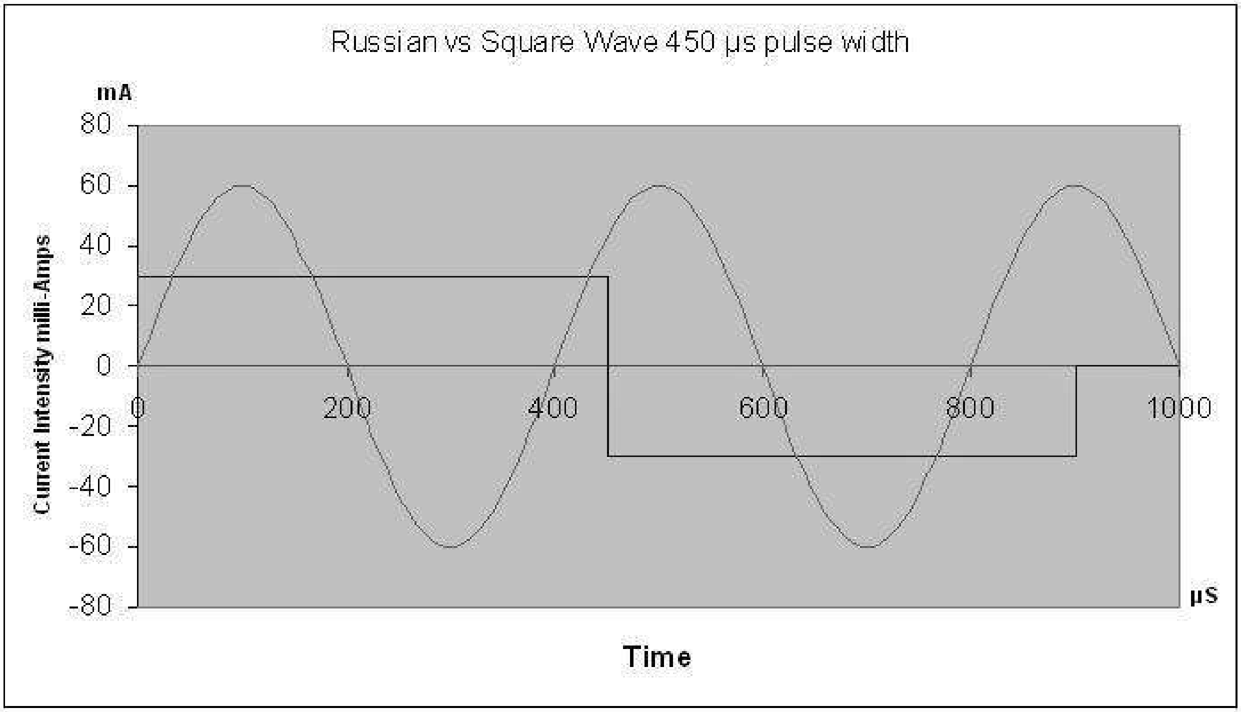






Let's take a look at a single 2500-Hz wave, we obtain the following curve (sine wave). Looking at its shape one can see that 2500 Hz translates into one full wave every 400 µs: 2500 Hz means that the wave repeats itself 2500 times every second, therefore 1/2500 = 0.0004 s = 0.4 ms = 400 µs. That also means that the positive half of the sine-wave pulse, which triggers the motor neuron, concludes itself within 200 µs.

Let's superimpose it on a square wave. The excitation roughly correlates with the area under the curve. If you look at the area enclosed under the Russian wave, you can easily see why to get the same excitation, the peak of the Russian has to be turned to much higher intensity (i.e. more uncomfortable or painful) than a square wave to obtain the same excitation.



In other words a square wave gets more bang for the buck than a sine wave. However, sine wave was the best technology available at the time, and electronic was not sophisticated enough to produce a good square wave.

Another comparison factor is that Russian stimulation is fixed, whereas square wave stimulation is more flexible. We have seen in previous sections explaining the theory of EMS, that the chronaxie of different muscle group may vary between 200 µs and 450 µs. Russian stimulation has always the characteristics of approximating 200 µs pulse width duration. This value is just too low for certain muscle groups like the legs, whereas the pulse width of a square wave can be changed at leisure, adapting it to the muscle group.

The last parameter of Russian current to understand is its on/off time of 10 ms. For Kots, it was presumably easy to interrupt his 2500 Hz sine wave every 10 ms, because in Europe AC current from an outlet is available at 50 Hz, and this was used as the triggering signal to turn it on and off. Thus Kots obtained a train of sine-wave pulses at 50 Hz as shown in the following picture. The sequence of pulses is called a pulse train; you can fit 25 of these sine waves within the first 10 ms of the Russian wave; then there is an interval of another 10 ms during which there is no current, and the whole sequence restarts: all this takes place in 20 ms, which results in the 50 Hz frequency. Thus it is directly comparable to a square wave at 50 Hz and pulse width 200 µs.