A Radio Frequency Coupled Tissue Stimulator

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Electronic technique has advanced to the point where it is relatively easy to provide an electrical stimulus of almost any desired wave form, amplitude, and timing. There has been no satisfactory answer, however, to the problem of isolating these stimuli both conductively and capacitively from ground. Such isolation, if achieved, at once eliminates several of the persistent difficulties familiar to all electrophysiologists. Amplifiers may once again be operated grounded or, if used differentially, permit new freedom from shock artifact; any number of stimuli of assorted form and timing may be applied simultaneously or in sequence; and different impulses may be applied at various points on the tissue without any nonphysiological interaction.

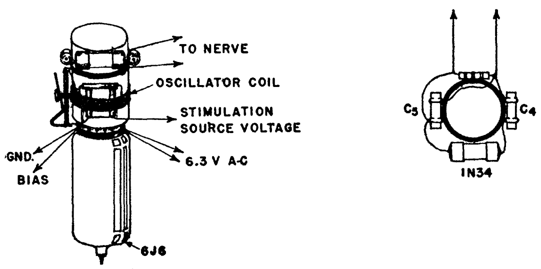

FIG. 1. General form of R.F. stimulator (*left*); top view of receiving coil (*right*).

The desired isolation may be provided surprisingly simply through utilization of a high-frequency radio link, the desired stimulation wave forms being converted to amplitude or frequency modulation of a carrier frequency and this carrier energy being reconverted, after transmission across an isolating air gap, into the desired stimulus by a tiny demodulator utilizing a germanium varistor as a linear rectifier.

In the primitive form in which the apparatus is now being used in our studies on single nerve fibers, the apparatus takes the form sketched in Fig. 1. It consists of a single miniature or subminiature tube with an associated grounded-plate Hartley oscillator circuit tuned to about 5 MC and a receiving coil tuned to the same frequency and with attached demodulator and R.F. filter.

The circuit is that shown in Fig. 2. It will be noted that no power supply except 6 v for the filament is required, since all power for the oscillator is drawn from the stimulator itself. The usual thyratron, or hard tube stimulator, is amply capable of supplying the necessary energy because the voltage delivered to the tissue circuit under typical conditions is nearly one-third as great as the incoming voltage. The R.F. stimulator is thus nearly as efficient as usual coupling transformers and may be used interchangeably with them if an additional prong for filament voltage is included in the cable connection. Some care must be taken to shield against direct transfer of R.F. voltage to the tissue circuit.

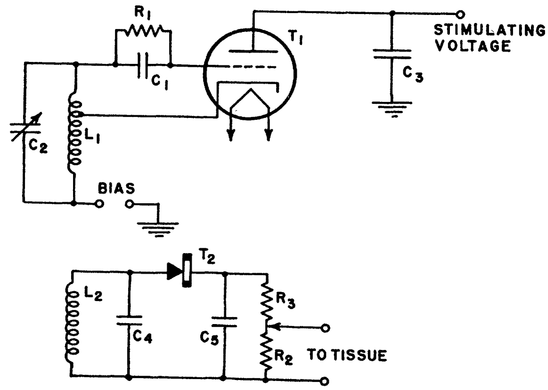

FIG. 2. C_1, 100 MMF; C_2, 25 MMF; C_3, 30 MMF; C_4, 20 MMF; C_5, 100 MMF; R_1 22K; T_1, 6J6; T_2, 1N34; L_1, 36 turns #32 enameled wire bank wound on ¾″ i.d. coil form, winding ⅜″ long with cathode tap 6 turns from grid; L_2, 30 turns #32 enameled wire, circular coil ¾″ i.d. of circular cross section.

The over-all linearity of performance is demonstrated in Fig. 3, which plots stimulator output voltage against input voltage. Precise linearity for weak stimuli is not obtained unless a small DC bias is applied to the input to bring the tube up to nearly oscillating voltage. It is customary to adjust the voltage-dividing resistors, R_2 and R_3, to bring the stimulator into its linear range for the general stimulus strength being used. Stability of the stimulator is within a fraction of a per cent after a short warm-up period, and adjustment is almost entirely noncritical. For very short pulse stimulation (less than 0.1 m sec pulses) special care must be exercised in the design of the plate by-pass circuit, and it is advisable to increase the oscillator frequency.

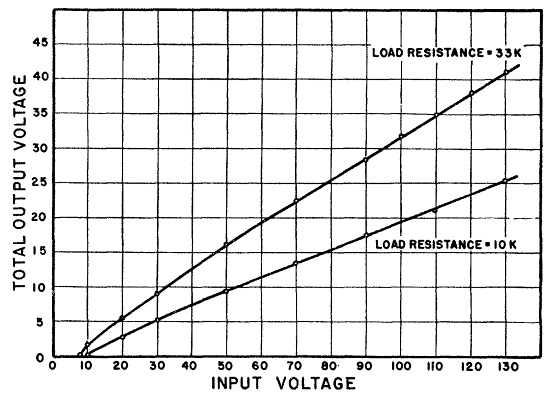

FIG. 3

While this preliminary note will not discuss them, many modifications of the stimulator for special purposes are possible. In nearly all cases the design can be made almost completely on paper, as the stimulator works in a region where electrical behavior is easily predictable. A more detailed paper presenting some of the design analyses will be published in the near future.