

Application of the z-transform to biological impedance measurements

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I. Introduction

The electric stimulation of bone growth and healing using a variable magnetic field appears to proceed by induction of currents in the fractured limb (Bassett, 1977). In order, to determine the distribution of these currents, it is necessary to know the electrical characteristics of the various intervening tissues. We are concerned here with the ratio between an electrical tension applied to the tissue and the resulting current, i.e. the electrical impedance.

II. Method

Biological tissues, immersed in a physiological solution, are enclosed in a four electrode cell (fig. 1) (Dubois, 1978).

The input signal is applied to the two current electrodes.

The output signal, obtained from the two voltage electrodes is amplified and stored in a digital memory. The unknown impedance is then computed from the input and output signals.

The amplitude of the input signal obtained from the signal generator (SG) must be small enough to avoid changes in the tissue parameters (Kandel, 1976). So the experimental set-up is carefully shielded from the influence of external noise.

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The amplifier (A) has a wide bandpass because of the very small sampling rate (0.5 microseconds) of the digital memory (DM).

The storage, conversion and transmission of the data to the computer are performed by a microprocessor (MP) in the interface (I) so that data transfer is very fast : a complete measurement, including the computation, can be achieved in a few minutes. Data processing takes into

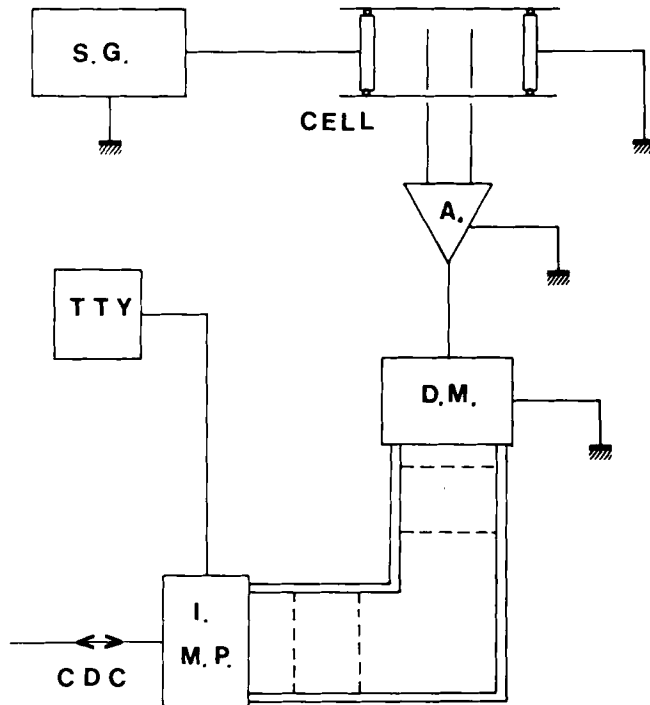


FIG. 1. — Diagram of the experimental device (S.G. : signal generator. A. : amplifier. D.M. : digital memory. I.M.P. : interface (microprocessor). TTY : teletype. CDC : computer).

account noise and quantization error. The program computes the best z-transform transfer function using an instrumental variable algorithm (Eykhoff, 1977).

The continuous Laplace transform, with a user defined number of poles, is then computed, taking the sampling rate into account.

The component values of an electrical network with the same transfer function are finally obtained (Van Eck, 1978).

III. Model and results

Before proceeding with calculations, we had to make the choice of a model describing the electrical behavior of the tissue under investigation. This choice led to the equivalent network. We adopted a simple diagram (fig. 2) only taking into account the cellular structure of living tissue (Cole, 1972).

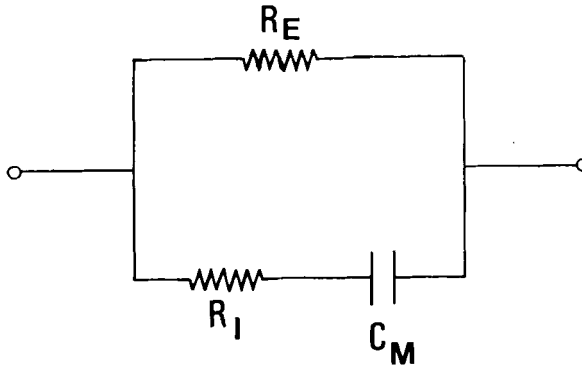


FIG. 2. — Diagram of the equivalent network (R_E : resistivity of extracellular medium, R_I : resistivity of intracellular medium, C_M : membrane permittivity).

TABLE
Impedance of different tissues 'in vitro'

	Number of measurements	R_E		R_I		C_M	
		Ω/cm	σ (%)	Ω/cm	σ (%)	pF/cm	σ (%)
Blood	13	220	5	398	9	184	13
Muscle (long)	8	512	9	2046	13	229	15
Muscle (transv.)	9	445	8	1782	14	217	15
Bone marrow	7	627	5	1885	8	294	10
Fat tissue	6	813	10	1549	12	317	16

The table sums up the results for certain pertinent tissues : all measurements were made *in vitro* (sampling tissues taken on 1 hour sacrificed calves and on human transfusion blood).

These results are in agreement with those yielded by more conventional methods (Cole, 1972).

IV. Conclusion

The first conclusion is that all investigated tissues have an impedance of the same order of magnitude. To determine the distribution of the currents induced by a variable magnetic fields, it is necessary to know the distribution of the electric field, which is heterogeneous (Dierickx, 1982). Nevertheless, it would appear that all tissues are traversed by currents of the same order. Different models for each investigated tissue can be easily compared due to the rapidity and the flexibility of the used method.

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