2nd International Conference on Electrical and Electronics Engineering (ICEEE) and XI Conference on Electrical Engineering (CIE 2005)
Mexico City, Mexico. September 7-9, 2005

Distributed Retinal Stimulation Model Based on Adaptive System

D. Robles, L. Niño de Rivera, A. Alcalá
IPN-ESIME-CU-SEPI, México D.F., México
Phone (55) 5624-2000 Ext. 73266   Fax (55) 5656-2058   E-mail: danielrc@calmecac.esimecu.ipn.mx

Abstract — **We propose in this paper a new methodology to generate the output signals of an artificial retinal stimulator to selectively stimulate the human optic nerve. The output signal generator is based on clinical electrical patterns recorded from a multi-focal electroretinography. An adaptive filter is proposed to estimate the weights of a set of finte impulse response (FIR) filters, that generate each electrical response highly correlated with the visual patterns. The proposed model let to analyse the behaviour of the retina coded signals with a set of linear FIR filters.**

Keywords — **Adaptive filter, elctroretinography, retinal artificial prosthesis.**

I. Introduction

In the last three decades, researchers around the world, have focused their attention on the creation of some models to describe faithfully the most complicated functions of the human eye [1]. Among others, is required to model the electrical response of the human retina to different light patterns. The purpose of these research is not only to determine electrical thresholds required for extra cellular activation of retinal ganglion cells as part of a project to develop a retinal prosthesis, but also to understand what kind of information is preserved by the electrical signals the human retina produces. It is required to understand properly the codification processes involved in the light to electrical signal conversion and modulation signals to be transmitted throughout the optic nerve.

We can find in recent literature, basically square electrical signals for stimulation of the human optic nerve like proposed by F. Prämaβing [2], Warren E. Finn [3] and J.F. Rizzo [4]. We propose in this paper an alternative procedure for the generation of stimulus signals. The main idea is to get a multi output electrical signals system to simulate the ganglional cells of retina looking the more alike stimulation waveforms like the biological retina does. The waveforms proposed to stimulate the optic nerve are extracted from the ones acquired from a multifocal electroretinograpy (MF-ERG). The MF-ERG used is known as *"Vision Monitor WIN 8000A"* made by *Metrovision* [5]. The base system proposed to generate the stimulation waveforms is a set of finite impulse response (FIR) filters, which impulse response is the same obtained by the MF-ERG, then we can generate highly correlated stimulation waveforms with the visual pattern used.

We show in Fig. 1 results of an electroretinography (ERG) common test of a patient without retinal illness.

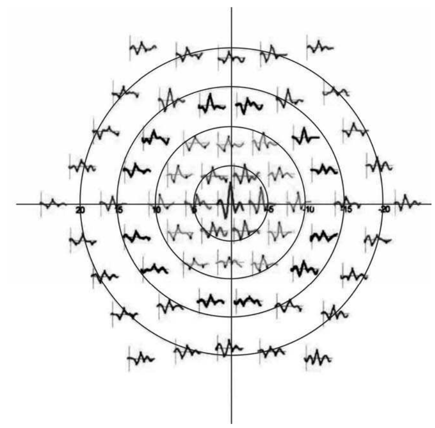

Fig. 1 ERG, distributed by zones.

The electrical signal is taken by means of a gold ring electrode, located in the inner face of a polimetil-metacrylate (PMMA) contact lens connected by a monopole electrical wire to a CPU. The electrical response corresponds to a visual pattern as can be seen in Fig. 2.

We can appreciate that the pattern distribution of the signals, keeps a hexagonal form, corresponding to the same luminous patterns that are used to stimulate the retina by a screen of the MF-ERG during the test. Then each signal, represents the retinal electrical response in that zone, or summation of the electrical response of the cones or rods inside each hexagon [5].

We represent in Fig. 2 the black areas like dark points or points not illuminated, and the white areas indicate the luminous points. The circles surrounding the sample indicate the opening angle and therefore the area where the voltage reading occurs.

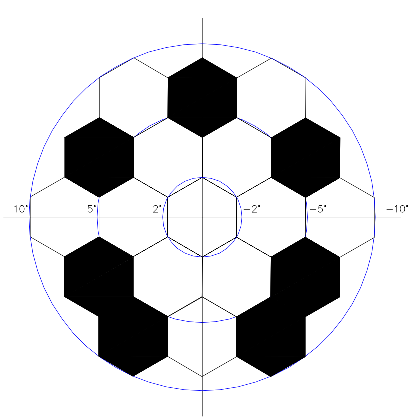

Fig. 2 Example of test's pattern with 19 points.

IEEE Catalog Number: 05EX1097
ISBN: 0-7803-9230-2

II. METHODOLOGY

With the purpose to obtain a mathematical function that describes in a precise way the dynamic behaviour of the electrical ocular response to a light pulse, we model the electroretinogram (ERG) curves by both: a set of continues polynomials and an a set of discrete values as will be describe in the next paragraph [6].

In this way, it is possible to get a group of data that allow the description of the ERG by means of a continuous polynomial. We use the statistical regression method *mean square* [6, 7], to model each signal as indicated in equation (1).

$$\text{Approach}(x) = a_0x^0+a_1x^1+a_2x^2+\ldots+a_nx^n \quad (1)$$

The polynomial approach presents some fitting errors when the hole curve is fitted by only one polynomial, to avoid those difficulties the curve fitting was divided in three sections, then we founded an approach with a maximum error of 0.03%, as shown in Fig. 4 [7]. This approach is a non linear approximation of the waveform required, even this approximation is good enough to describe the signal, the synthesis of the function is much more complicated, in comparison with a set of *adaptive finite impulse response filters* (AFIR filters).

An adaptive filter is then proposed to estimate each output signal, the filter coefficients are estimated from an adaptive identification system which coefficients are calculated by the *normalized least mean square* (NLMS) algorithm. The desired signals are represented like S1, S2 ... Sn, in Fig. 3, are modeled from equation (1). All tests were made with 10 delay blocks per each digital filter.

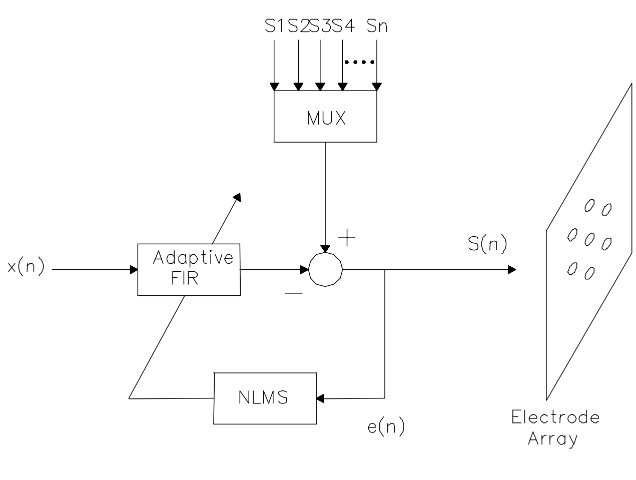

Fig. 3. Scheme of the AFIR, variant of the *system recognition* configuration, with the electrodes array proposed.

The system's adaptation is carried out using the normalised convergence algorithm or, NLMS algorithm shown in equation (2) [8].

$$w(n+1) = w(n) + \frac{\alpha}{x(n) * x(n)^T} * x(n) * e(n) \quad (2)$$

The proposed system output in Fig. 3, is connected to an array of electrodes, the selected electrode is taken by an output multiplexer, a DAC is needed for the digital to analog conversion [4, 9, 10].

III. RESULTS

We show in Fig. 4 a graphical comparison between the discrete data from the FIR filter, the polynomial approach, and the required system, the shown results are for a single waveform.

We show in table 1 time intervals and values of the coefficients of each section polynomial and for such adjustment are respectively.

TABLE 1
TIME INTERVALS AND FITTING POLYNOMIAL FOR 2 DEGEES CENTRAL GRAPH.

	Section 1	Section 2	Section 3
Start time (ms)	0	36.95	71.73
End time (ms)	39.13	69.56	100

Section	Fitting Polynomial for Fig. 4
1st	$-0.1517-0.1683t+0.1234\,t^2-0.1798\,t^3+0.1293\,t^4$
2nd	$(1x10^4) * (1.1975-0.1024t+0.0032\,t^2-0.000012\,t^3)$
3rd	$(1x10^4) * (3.0895-0.1463t0.0026t^2-0.00001346t^3)$

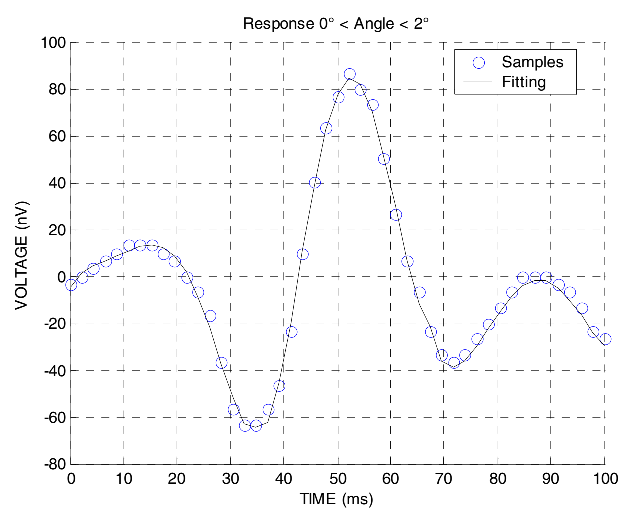

Fig. 4 Graphical representation of the polynomial approach into the curve of 2° central.

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In order to verify that the proposed system fulfils the design expectations, we evaluated its performance for the 5° central test. We show in the Fig. 5-a), a zoom into the obtained graph with the MF-ERG test, and in the Fig. 5-b), the simulation of the system, for the same areas.

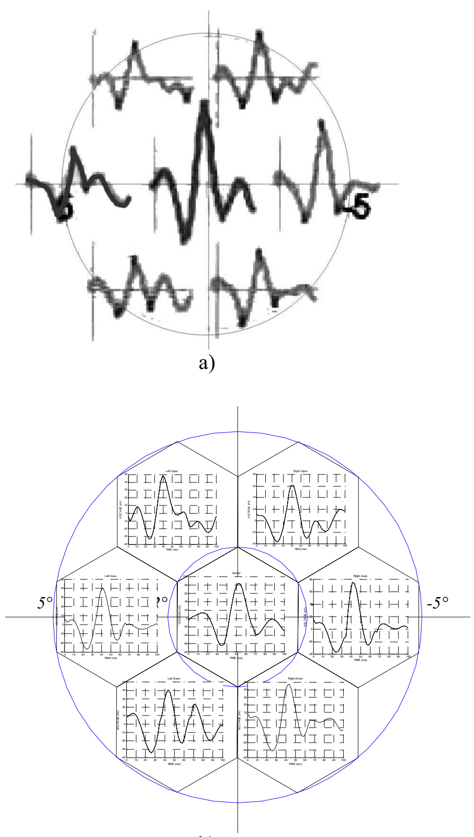
The simulation for the electrode array in Fig. 6, is shown in Fig. 7, 8 and 9, we can see that the AFIR system response has the morphology and amplitude corresponding to the graphs given by the MF-ERG tests, observed in Fig. 5-b), with a maximum error about 0.03% [7].

IV. Discussion

The waveform in the MF-ERG [2, 3, 4], has by nature, two parts, the negative and the positive. The negative part corresponding to the depolarization of the ganglional cells of the retina. The positive part seems to represent the conversion from the luminous energy to the ionic energy.

We can see from the results that output signals from the proposed system, keep a very close correlation with the ERG signals clinically obtained.

The electrodes array proposed (Fig. 6), is totally feasible to be implemented [9, 10].



a)

b)

Fig. 5 a) ERG of 5° central, b) Simulations for 5° central.

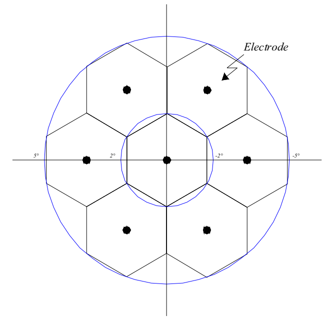
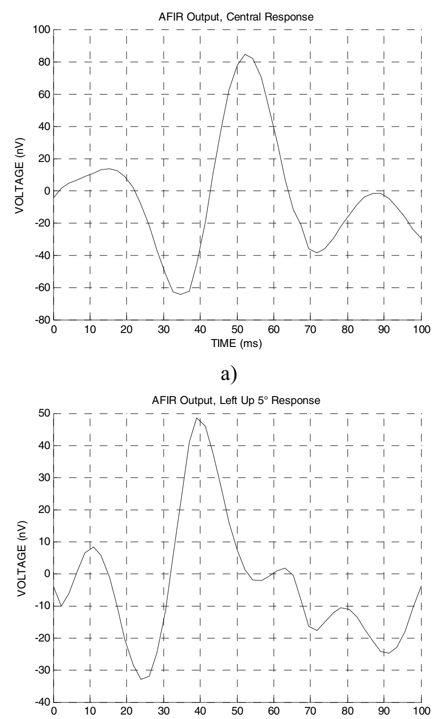


Fig. 6 Array of micro-electrodes proposed.

V. Conclusion

The graphical analysis of the signals obtained by the AFIR, takes us to the conclusion that, the proposed system reproduces with a high correlation, the graphical result that provides the MF-ERG test, and allows to make future meticulous analyses for the response to the light pulse of each zone of the retina under test.

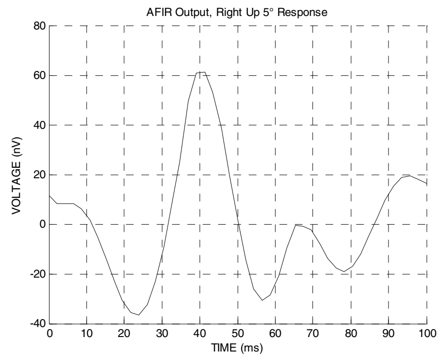
The application of the electrodes array, for epiretinal tests, justifies that the present investigation acquires the challenge to develop an intra-eyeglass investigation prosthesis, with the purpose of verifying different hypotheses respect to the codification from visual signals. Those hypotheses can be studied in terms of the coefficient variation of the adaptive filters which performance is very well known.



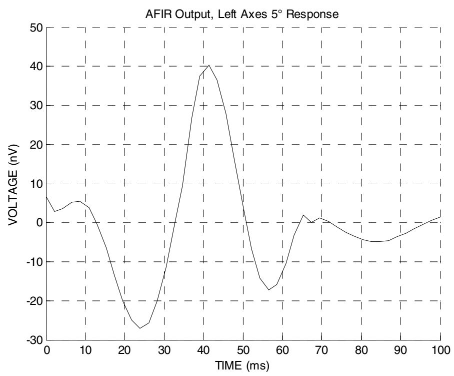
a)

b)

Fig. 7 AFIR system responses.



a)



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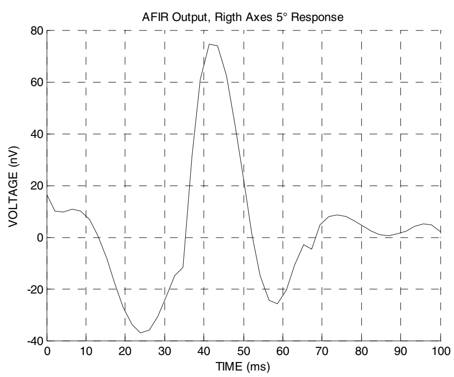
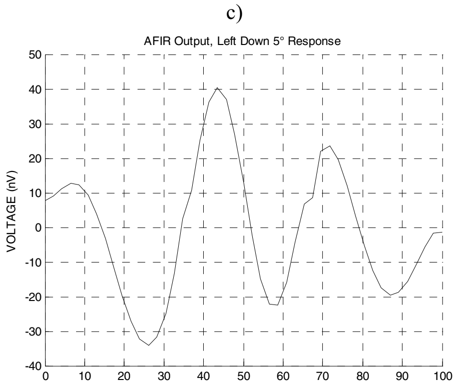


c)



d)

Fig. 8 AFIR system responses (continuation).

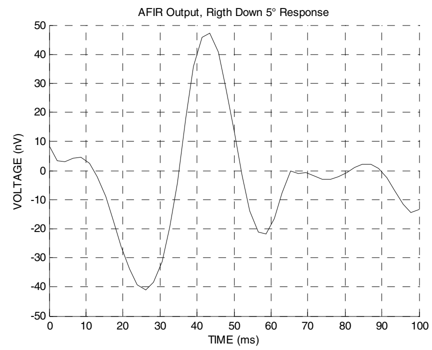


Fig. 9 AFIR system responses (continuation).

ACKNOWLEDGMENT

Authors of the present paper express their sincere gratitude to the National Council of Science and Technology (CONACyT), the support part of the accomplishment of the present investigation.

REFERENCES

[1] L.K. Swan, "Gross Anatomy of the Eye, Introduction". Biomedical Research Institute, University of Ontario 1999.
[2] F. Prämaβing, D. Püttjer, R. Buβ and D. Jäger "Intraocular Vision Aid (IOS) Optical Signal Trasmission and Image Generation" Proceedings of the 22nd Annual EMBS International Conference, July 23-28, 2000, Chicago IL.
[3] W.E. Finn and P.G. LoPresti, "Wavelength and Intensity Dependence of Retinal Evoked Responses Using *in vivo* Optic Nerve Recording", IEEE Trans. On Neural Systems and Rehabilitation Engeneering, Vol. 11, No. 4, December 2003.
[4] J.F. Rizzo, J. Wyatt, J. Loewenstein, S. Kelly and D. Shire, "Methods and Perceptual Thresholds for Short-Term Electrical Stimulation of Human Retina with Microelectrode Arrays", Investigative Ophtalmology & Visual Science, December 2003, Vol. 44, No. 12, Association for Research in Vision and Ophtalmology.
[5] G. Rizant, (2000, June 15) User's Help On Line Guide. Available: http://www.metrovision.fr/costumers/fhelp/m8ka.htm
[6] D. Robles, L. Niño de Rivera, "Adaptable Model to Obtain the Dynamic Response of the Photoreceptor's Ionic Current", Inter-students on Electronics, Computing and Electric Congress 2005, March 7-9 Puebla, México (In Spanish).
[7] C. Chapra, P. Canale, "Numerical Methods for Engineers and Software Applications, 3rd Edition". Mc Graw Hill, 1998, pp. 465-482.
[8] J.D. Gordana, "Multirate Systems: Design & Applications", Chapter VII Speech and Audio Signal Applications, National Institute for Astrophysics Optics and Electronics, 2002, pp. 1-2, 6-14.
[9] J.L. del Rio-Valdés, L. Niño de Rivera, "Micropoints: Towards an Encapsulated Retinal Prosthesis", 8° National Congress on Systems and Electronic Engeneering, México, D.F. 2004 (In Spanish).
[10] J. L. del Rio-Valdés, "Micropoints Design to Ocular Implant by Mean of MEMS Tecnology", dissertation, Microelectronics Master Degree, IPN, ESIME-CU, SEPI, México D.F. 2004 (In Spanish).