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PORTABLE ANALYSER FOR REAL-TIME DETECTION OF THE EPILEPTIC PRE-CURSOR

A. L. Stelle*   R. A. Comley+

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INTRODUCTION

The prospect of determining the underlying activity of the brain through the use of monitoring electrodes attached to the surface of the scalp has aroused varying degrees of interest for a number of years. Some researchers have reported significant results in this area, while others [Stowell, 1970] have been of the opinion that no meaningful information may be obtained from such a complex and distorted signal. Research has progressed rapidly to provide an understanding of the structure and functioning of the brain, largely through invasive techniques. Non-invasive monitoring, the subject of this paper, has concentrated largely on the identification of abnormalities in the EEG record, and has not enjoyed such rapid advances.

A number of factors contribute to this slow rate of progress, not least of which is the abscence of any clear definition or agreement as to what constitutes 'abnormal activity'. Many human analyses would appear to be based more on acquired, intuitive skills rather than any formal criteria. Also, what may be considered abnormal in an EEG record from one patient may be regarded as not unusual in that from another individual.

It has become increasingly apparent in recent years that in order for any degree of confidence to be placed on the results obtained from an EEG record, long term monitoring is required [Binnie, 1988]. This places an unpractical burden on the traditional techniques of hard-copy and manual interpretation owing to the potentially large amounts of data that must be recorded. A further obstacle concerns the amount of freedom a patient is to be allowed. It is clearly not reasonable to expect the patient to remain imobilised or within the confines of the EEG laboratory for considerable periods of time. Idealy, the

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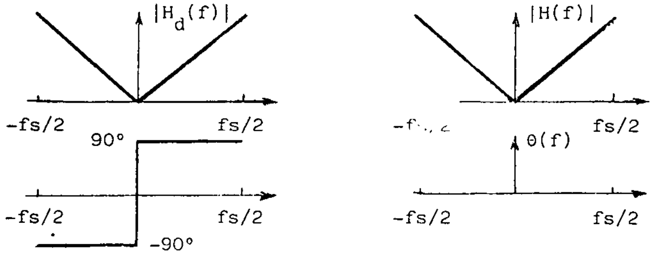
THE BASIC DETECTOR

The differentiation process is an odd function producing a bipolar output. If a simple level checking method is employed to identify the spike features then two detection thresholds are required, (Fig. 3). Since, in general, the output from the differentiator will not be symmetrical, this can present serious problems for reliable detection. If however an even function is chosen, the above problems can be significantly reduced.

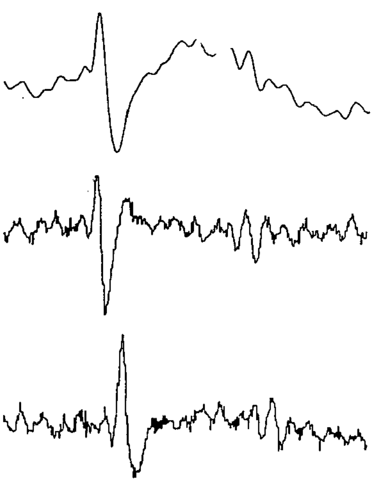
The transfer functions for the differentiator and the desired system response are shown in Figure 2. As can be seen, the degree of enhancement to high frequencies is the same in both cases, but the phase components are all nil for the even function. In other words, the system is equivalent to a differentiator in series with a Hilbert transformer (quadrature phase shifter).



a) Differentiator

b) Differentiator
+ Hilbert Transformer

Figure 2. System frequency and phase characteristics.



Spike-and-wave

Differential

Differential +
Hilbert Transformer

Figure 3. Spike detection algorithm output.

The output from this algorithm has the very desirable property of being unipolar, i.e. the whole signal due to the spike is contained in a single positive pulse. Only one threshold comparison is now required which is immune to the asymmetry problems of the simpler differentiator (Fig. 3). The price paid for this significant improvement is an increase in the computational load. This however is not excessive and the algorithm has proved to be very effective as the basis of a real-time detection system.

DETERMINATION OF THE TRANSFER FUNCTION

To perform the operation illustrated in Figure 2b it is necessary to convolve the input signal with the discrete impulse response, h(n). This may be derived as indicated in Figure 4. Comparing Figure 2b with Figure 4c, it can be seen that the slopes located between - fs/2 and fs/2 correspond respectively to the slopes located between -fo and fo. So, by making t = nTs = n and fo = fs/2 = 1/2, the normalised discrete impulse response is obtained:

$$h\ (n.T_s) = h(n) = A.\mathrm{sinc}^2(n/2)\ .\ \cos(n.\pi)$$

The number of coefficients required for the computation of h(n) can be kept quite low since:

$h(n) = 0$ for even values of n

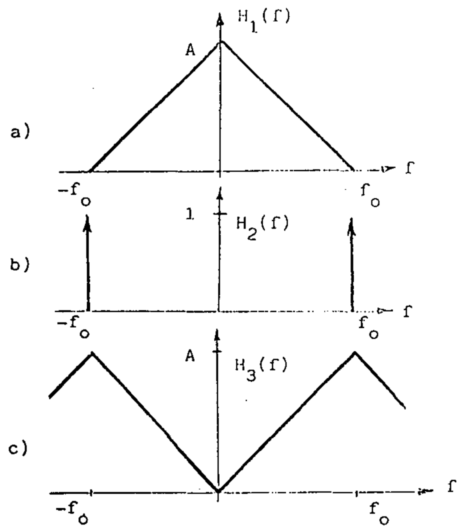
$h(n) = A$ for $n = 0$

and since $h(n) \propto \mathrm{sinc}^2(n/2)$, it decreases rapidly for increasing n (e.g. for n = 5, $\mathrm{sinc}^2(n/2) = 0.016$ and for n = 15, $\mathrm{sinc}^2(n/2) = 0.0018$).

A value of n = 17 was chosen for the preliminary studies as this represented a good compromise between accuracy and speed of computation.

Normally the output from the spike enhancer process would be followed with a low-pass filter (second order min.) and then a level comparison would be employed to identify the spikes. A serious disadvantage of this method is that while the filter reduces the 'noise' output from the enhancement process, it also reduces the amplitude of the spike feature, making level detection less reliable and very sensitive to the threshold setting.

An alternative algorithm has been developed in which the output from the enhancer is raised to the power of three and scaled appropriately. This has the effect of amplifying the features of interest whilst reducing the 'noise' level (Fig. 5).



$$H_1(f) = A.\mathrm{tri}(\frac{f}{f_o})$$

$$h_1(t) = A.f_o.\mathrm{sinc}^2(f_o.t)$$

$$H_2(f) = \delta(f-f_o) + \delta(f+f_o)$$

$$h_2(t) = 2.\cos(2.\Pi.f_o.t)$$

$$H_3(f) = H_1(f) * H_2(f)$$

$$H_3(f) = A.[\mathrm{tri}(\frac{f-f_o}{f_o}) + \mathrm{tri}(\frac{f+f_o}{f_o})]$$

$$h_3(t) = h_1(t).h_2(t)$$

$$h_3(t) = 2.A.f_o\mathrm{sinc}^2(f_o.t) \;. \cos(2.\Pi.f_o.t)$$

Figure 4. The discrete impulse response of the spike detector.

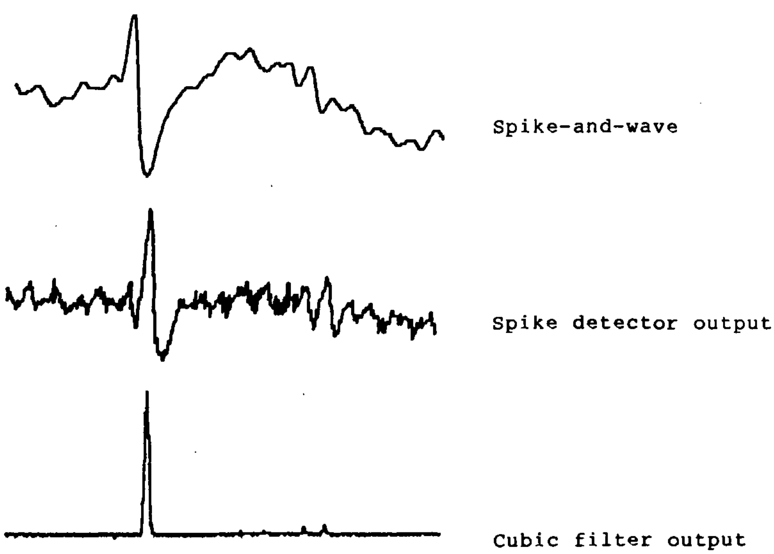


Figure 5. Operation of the complete spike detector.

SLOW WAVE DETECTOR

The spike detector alone can only be considered a reliable means of detection of the onset of an epileptic attack for noise free EEG signals. A major source of corruption of the EEG arises as the result of muscle artifact and generally takes the form shown in Figure 6. This is a particular problem for any portable system where a large amount of muscle activity is to be expected. The addition of a slow-wave detector can provide a significant improvement. This has been implemented in the form of a fourth-order Butterworth low-pass filter with a 7Hz cut-off frequency followed by a level discriminator. The above values were selected as offering the best performance following extensive experimentation on pre-recorded data.

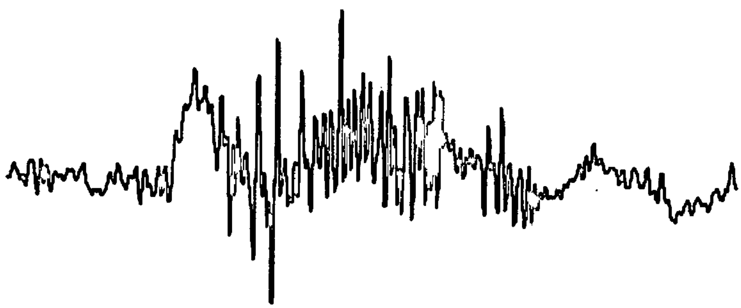


Figure 6. Example of muscle artifact corruption.

EXPERIMENTAL RESULTS

The complete detection algorithm has been tested on the Motorola SYS133 using pre-recorded EEG data. These records were band-limited to 70Hz and played back at normal speed to simulate real-time operation. A sampling frequency of 600Hz has been used throughout the tests but it is planned to reduce this before trials begin using the portable unit.

Initial results have been very encouraging, with a high detection and low false alarm rate being achieved. Artifact rejection however does still pose considerable problems, as can be seen from Figure 6. The basic algorithm has been modified in an attempt to improve this situation. It involves the use of 350ms wide window during which a count is accumulated of the number of spike detections. If more than two spikes are encountered within the window period, then the record is judged to contain artifacts and so any detections are rejected. This improves the performance of the algorithm considerably in terms of artifact rejection without any loss in true spike and wave identification for the test records.

CONCLUSIONS

The ability of a modern microprocessor to analyse a complex signal and to detect specific features in real-time has been demonstrated. Testing of the portable version of the system is about to commence and it is hoped that full clinical trials will be possible in the near future. Major areas of interest to us are the potential for conducting long term analyses on patients for whom there is considerable doubt as to whether they suffer from epilepsy and for such activities as the screening of various drug regimes in order to provide a quantitative measure of their effectiveness.

Our work has to date concentrated on the analysis of EEG records with particular reference to the spike-and-wave complex. Since, however, the functioning of the hardware monitor unit is defined entirely in software, we can foresee numerous other potential applications for the techniques we have developed.

Our future plans include the expansion of the detection algorithm to deal with up to five input channels in real-time. This should allow for a much more reliable artifact rejection routine to be developed. Further, we also plan to investigate the possibility of assigning one or more of the available input channels to monitor muscle movements as we feel that this may be able to provide valuable additional information during the onset of an epileptic attack.

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REFERENCES

1) BINNIE, C. D.; What's the use of EEG in epilepsy?, British Journal of Hospital Medicine, London, pp99-103, 1988.

2) BRIGNELL, J. E., COMLEY, R. A. and YOUNG, R.; The Roving Slave Processor, Microprocessors, IPC Science and Technology Press, Vol. 1, No. 2, pp79-84, 1976.

3) COMLEY, R. A. and BRIGNELL, J. E.; Real-time Detection of the Epileptic Precursor, J.Phys.E: Sci. Instrum., Vol 14, 1981.

4) STOWELL, H; No future in the averaged scalp, Nature, p1074, 1970.