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COMMENT ON: 'TIME-BASED NOISE REMOVAL FROM MAGNETIC RESONANCE SOUNDING SIGNALS' BY M. SHAHI, H. KHALOOZADEH AND M. K. HAFIZI

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Abstract. *A paper in the December 2011 issue of International Journal of Innovative Computing, Information and Control, 'Time-Based Noise Removal from Magnetic Resonance Sounding Signals' by M. Shahi, H. Khaloozadeh, and M. K. Hafizi proposes a noise cancellation method on Magnetic Resonance Sounding (MRS) signals based on a statistical procedure. We believe it worthwhile to call attention to certain aspects of this paper which may not be recognized by some readers.*

1. The corresponding method consists of two criteria (mean criterion and variance criterion). In the first stage and in the mean criterion the major assumption is, the mean or the area under the curve of the real signal is equal to the summation of the mean or the area of the ideal signal and the noise. According to the paper claim, the area of the random noise added to the ideal signal (or its mean) is assumed zero. Therefore, by cancelling the noise on the real signal, the mean remains unchanged. Using the above assumption and considering the time series of the real signal, the ideal signal and the noise, the following equation is presented:

$$\sum_{i=1}^{N} S_n(i) = \sum_{i=1}^{N} (S(i) - S_s(i)) \tag{1}$$

where $S(i)$ depicts the ith sample of the real signal, $S_s(i)$ is the ith sample of the ideal signal and $S_n(i)$ is the ith sample of the noise time series.

The recent equation as an optimization problem can be used to estimate the optimal T_2^* on the condition that the left side of the equation becomes zero. In the paper under discussion, the S_s signal is implemented according to the simulated MRS signal and according to Equation (2) with initial amplitude E_0 and decay time T_2^*. E_0 is set equal to $S(1)$ (the first sample of the recorded signal on the field) and T_2^* is considered as the equal to the signal recording time (on page 6638).

$$S(t) = E_0 \exp(-t/T_2^*) \tag{2}$$

The selection of E_0 as the first sample of the S signal, in some cases that the $S(1)$ value is less than the mean of the S signal leads to the area under the real signal to be always greater than the area of the estimated signal (the ideal signal obtained in the optimization problem). In other words, according to the paper claim in the optimization process in which the difference between the area under the curve of the real signal and the area of the ideal signal must become zero (on page 6638), will never happen. We believe that under the circumstance mentioned above, even if when $T_2^* \to \infty$ Equation (2) approaches a horizontal straight line with the amplitude of E_0 ($E_0 = S(1)$) and hence, the condition of minimizing the difference of the area under the real signal and the area of the ideal signal will not be satisfied.

Figure 1 illustrates the real signal used in this paper (in this signal, E_0 is less than the mean value of the signal, E_0 is 31.76 nv while the mean value of the signal is 34.59 nv), the estimated signal obtained using the mean criterion in two conditions when T_2^* is acquired from the optimization problem and when $T_2^* \to \infty$ with black, blue and red curves, respectively. As shown when $T_2^* \to \infty$ the estimated signal approaches a horizontal straight line with the amplitude of E_0. We also obtained the mean values of the real signal and the estimated signal with the aid of the proposed approach in the paper. The mean of the real signal is 34.59 nv and the mean values of the estimated signal derived from the optimization problem and when $T_2^* \to \infty$ are 25.74 nv and 31.76 nv, respectively. It is noted that the difference of the mean values of the real signal and the estimated signal is not zero (or approximately zero). Even if $T_2^* \to \infty$ the difference never becomes zero. Thus there is a substantial difference. Therefore, setting E_0 as equal to $S(1)$ in some cases that the $S(1)$ value is less than the mean of the S signal leads to the result contrary to the principle assumption of the paper. The following two equations show the relative errors between the mean value of the real signal and the mean values of the estimated signal where T_2^* is obtained from the optimization problem and $T_2^* \to \infty$.

$$\left|\frac{34.57 - 25.74}{34.57}\right| = 0.2515$$

$$\left|\frac{34.57 - 31.76}{34.57}\right| = 0.0822$$

2. Figure 1 (on page 6637) shows noise, a pulse of alternating current and the received signal from the subsurface. According to [1,2] the pulse of the alternating current energizes the antenna can be written as

$$i(t) = I_0 \cos(w_0 t), \quad 0 \le t \le \tau \tag{3}$$

where I_0 and τ are respectively the pulse amplitude and duration and $w_0 = 2\pi f$ is the Larmor frequency of protons in the geomagnetic field. Also the MRS signal has an

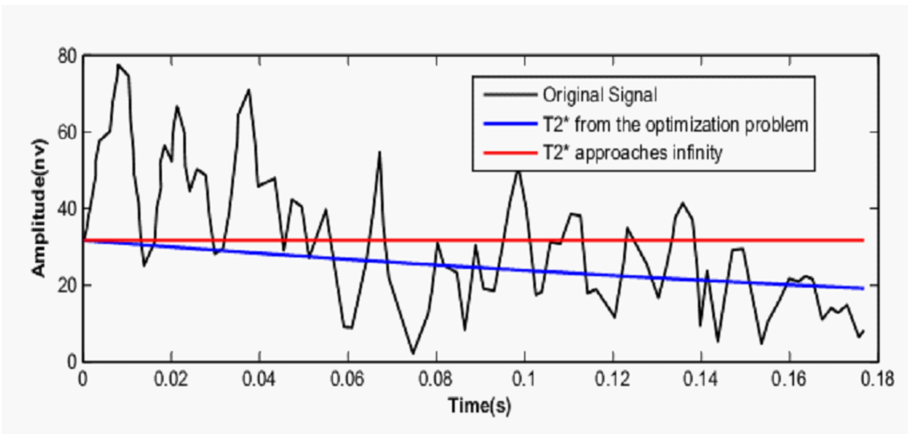

FIGURE 1. The real MRS signal used in the paper and the de-noised signal after applying the mean criteria and the de-noised signal after applying the mean criteria when T_2^* approaches infinity

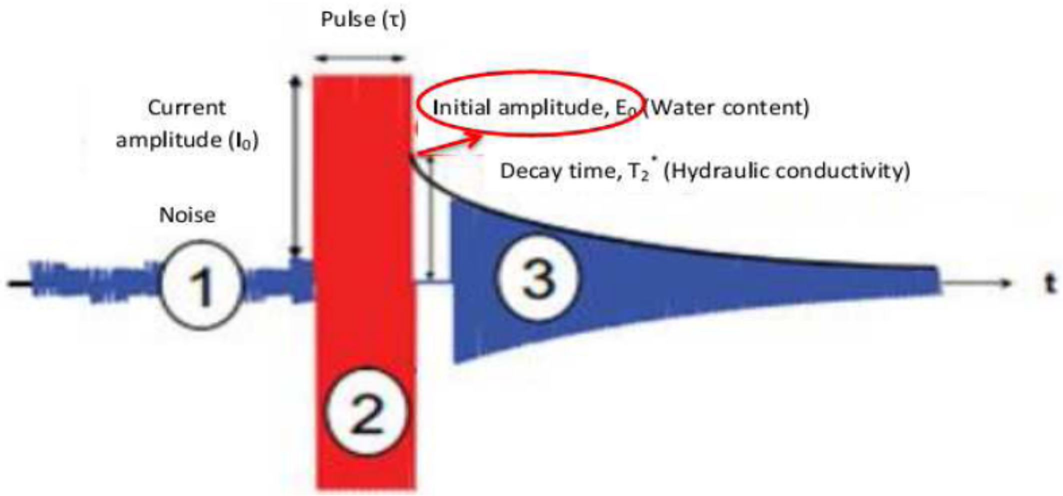

Figure 2. MRS measuring sequence: (1) noise, (2) excitation pulse and (3) relaxation signal [7]

exponential envelope presented as [1]

$$e(t,q) = e(q)\exp(-t/T_2^*)\cos(w_0 t + \varphi_0) \tag{4}$$

where T_2^* is the spin-spin relaxation time and φ_0 is the phase of the MRS signal. The corresponding figure illustrates the envelope of the signal, while the noise is shown in its real part values. Whereas the different parts of the signal measurement process must be compatible, this type of the illustration of the time diagram of MRS measurement is not recognized in scientific papers [3,4]. An appropriate and correct time diagram of the signal measurement process is displayed in Figure 2.

3. On page 6638 we read: *T_2^* is considered as equal to the signal recording time, this time is five times the true T_2^* value.* In the optimization process, the value of T_2^* is reduced until the mean of the noise will approach to zero. It should be noted that the signal recording time can be even shorter than the true T_2^* value. On the field data of MRS, the signal recording time is usually 240 ms, while the max value of the T_2^* is 600 ms to 1000 ms. Therefore, the claim (which the signal recording time is five times the true T_2^*) is not valid for all cases, in practice [1, Page 5, Table 1]. For further study, interested readers are referred to [5,6].

4. In this paper, the main assumption in the mean criterion is to use $S(1)$ as E_0 constant and then based on the associated assumption, the T_2^* parameter is estimated. It should be noted in the NUMIS equipment the E_0 value is evaluated 30 ms before the first data recording. In other words, E_0 is not the first sample of $E(t)$, it is the signal value for t that equals to zero (when current is cut off), but measurement of $E(t)$ starts after some milliseconds (time delay) due to need of switching the coil from active to passive status. In practice it is calculated by extrapolation of the measured value to $t = 0$. The location of the initial amplitude E_0 is depicted in Figure 2. As seen, it is calculated some milliseconds (30 ms, in NUMIS equipment) before the first sample $S(1)$ [1,5,8].

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