

MULTISCALE WAVELET ANALYSIS OF THE RADARGRAM TRACE

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The results of the wavelet analysis of the radargram trace are given in the article. The analysis and purification of the signal from noise was carried out with the help of wavelets from Haar and Daubechies. The graphs of the approximating and detail coefficients of the wavelet decomposition of the signal are presented.

Keywords: radarogram, Daubechies wavelets, Haar wavelets.

Introduction

The essence of processing of georadar locating data consists, first of all, in allocation of a useful signal against a background of interference waves and noise. To distinguish useful signals, the characteristics of these signals differ from the corresponding characteristics of noise and interference waves [1]. One way to process the radargram is wavelet transformation. With help of wavelet transformation of a digital signal in a radargram, high-frequency components can be removed from the signal spectrum. It is well known that the analysis of non-stationary signals by the wavelet transformation method is better than the filters based on the Fourier transform. After the wavelet clearing of the traces, the radargram more clearly shows the local features of the subsurface. The discrete wavelet transform of the radargram trace is obtained using low-frequency (LF) and high-frequency (HF) filters. Applying a low-frequency filter, we obtain the approximation coefficients and, decomposing the trace, with high-frequency filter we get detailed coefficients. Removing high-frequency components from the signal spectrum is one of the ways to suppress noise. Applied to wavelet decompositions, this can be realized directly by removing the detailed coefficients of the high-frequency levels [2].

The object of the study is an iron barrel with a diameter of 59 cm buried at a depth of 220 cm. (Figure 1).



Figure 1: Iron barrel object

Figure 2 shows a sketch of the “Iron Barrel” object.

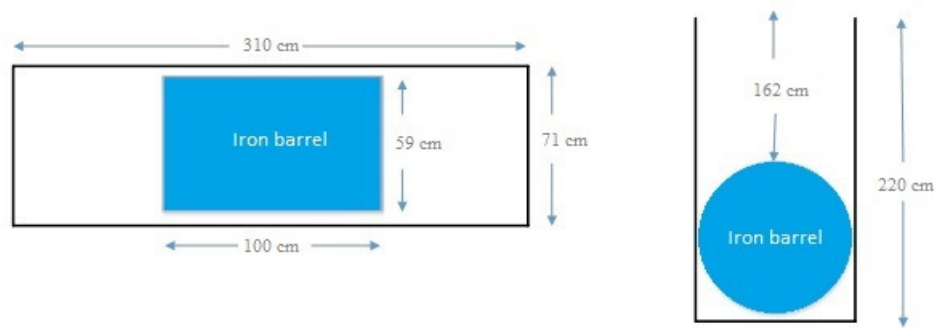


Figure 2: Location map of the iron barrel

The result of the georadar survey is a set of single traces (signals) registered by the receiving antenna at each position of the radar. The radargram of the barrel scanning was obtained by the georadar “Loza”. The single trace of this radargram (Figure 3) is processed by the Wavelet Toolbox of the MatLab numerical-mathematical modeling system [2].

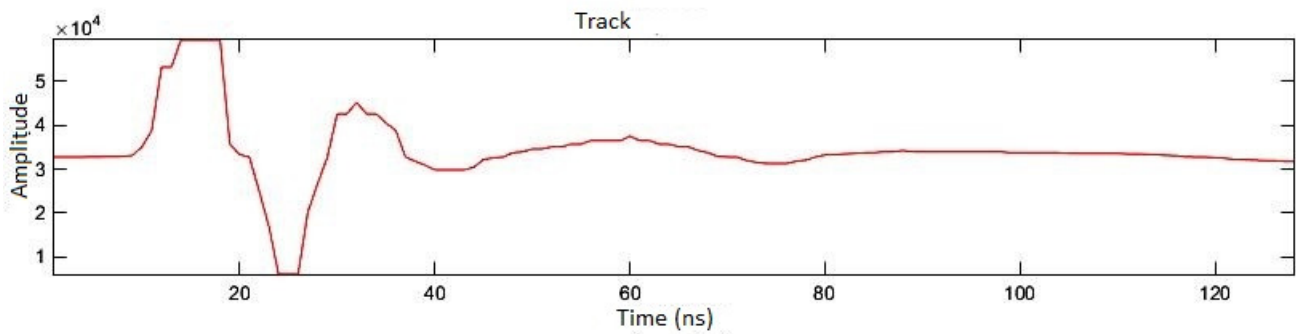


Figure 3: The graph of the radargram trace

1 Processing of the trace by Haar wavelets

The discrete wavelet Haar transformation for the one-dimensional signal s is calculated as follows [3]:

$$a_j = \frac{s_{2j} + s_{2j+1}}{2}, \quad d_j = \frac{s_{2j} - s_{2j+1}}{2}$$

A similar operation is applied to the signal a_j and it also receives two signals, one of which is an approximate version of a_j , and the other contains the detailed information necessary to reconstruct the a_j .

Multiple application of wavelet processing of the georadar signal is possible, which leads to an increase in the detail of the original signal up to the frequency of the wavelet itself. In practice, excessive detailing makes the signal less visible. For most georadar tracking signals, 5 repetitions of wavelet processing are sufficient to increase the resolving power of the signal without loss of the envelope of the pulse.

The inverse Haar transformation is as follows:

$$s_{2j} = a_j + d_j, \quad s_{2j+1} = a_j - d_j$$

The results of the transformation of the trace by Haar wavelets are shown in figure 4.

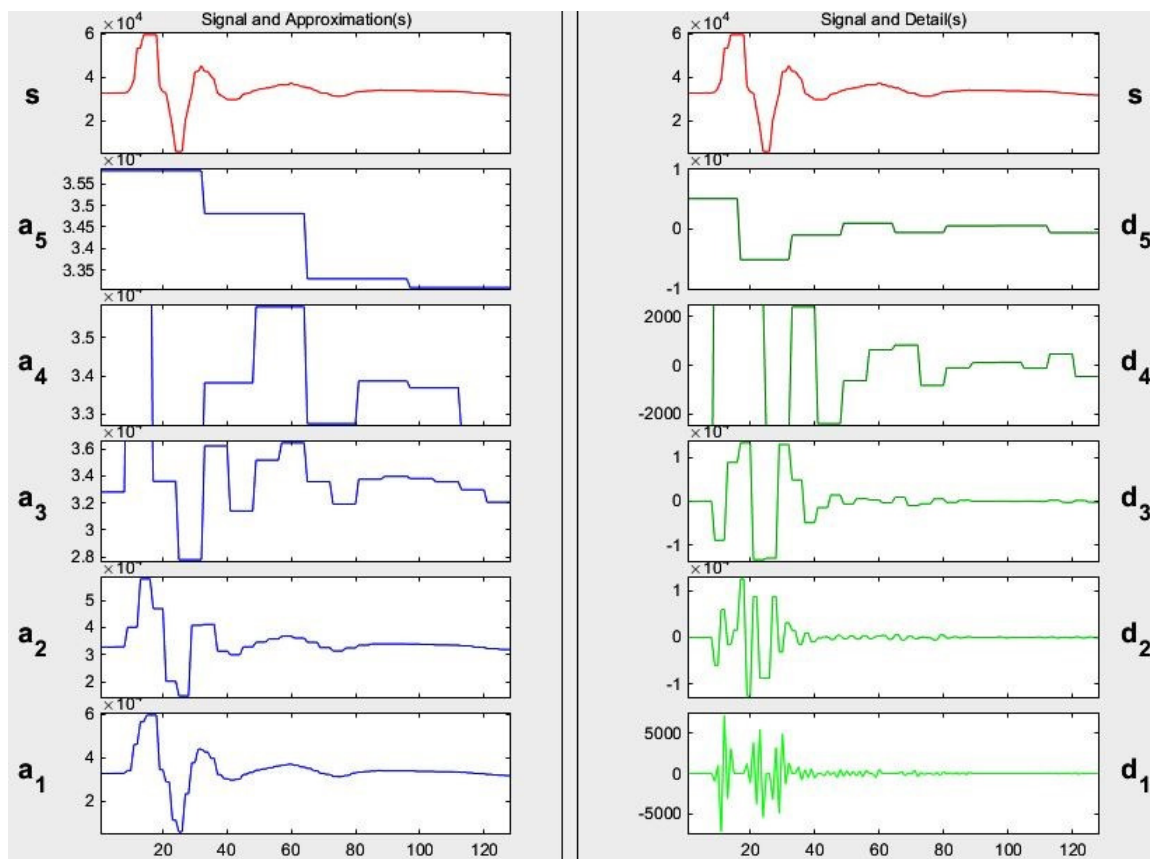


Figure 4: Results of processing the trace by Haar wavelets

A discrete wavelet transform can be used to easily and quickly remove noise from a noisy signal. If we take only a limited number of the highest coefficients of the spectrum of the discrete wavelet transform, and carry out the inverse wavelet transform (with the same basis), we can get a signal cleared of noise (Figure 5).

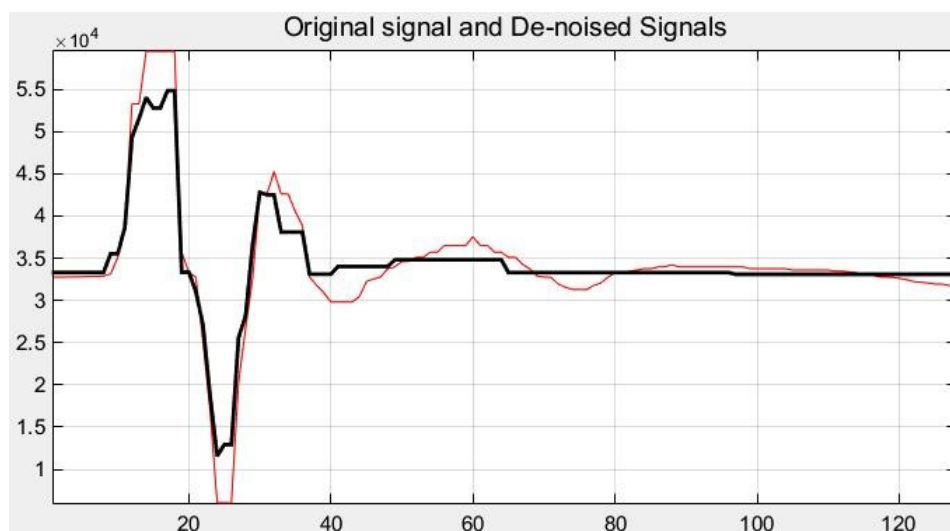


Figure 5: Trace cleared by Haar wavelets

2 Track processing with Daubechies wavelets

The Daubechies wavelets have no analytical expression and are determined only by filters. In practical applications, detailed h_k and g_k -approximating wavelet coefficients are used, without computing the specific form of the wavelets [3].

The decomposition into components of the discrete wavelets of Daubechies is carried out according to the formulas:

$$s_{j+1,k} = \sqrt{2} \sum_i h_i s(j, 2k + i),$$

$$d_{j+1,k} = \sqrt{2} \sum_i g_i s(j, 2k + i),$$

in which $s_{j,k}, d_{j,k}$ — are the coefficients of approximation and detalization of the decomposition, j is the number of the decomposition level, k is the sequence number of the coefficients, the vectors h, g are the coefficients of the scaling and wavelet filters.

$$h_0 = \frac{1 + \sqrt{3}}{4\sqrt{2}}, \quad h_1 = \frac{3 + \sqrt{3}}{4\sqrt{2}}, \quad h_2 = \frac{3 - \sqrt{3}}{4\sqrt{2}}, \quad h_3 = \frac{1 - \sqrt{3}}{4\sqrt{2}}$$

or

$$h_0 = 0.4829629131445341;$$

$$h_1 = 0.8365163037378097;$$

$$h_2 = 0.2241438680420134;$$

$$h_3 = -0.1294095225512604;$$

$$g_0 = h_3;$$

$$g_1 = -h_2;$$

$$g_2 = h_1;$$

$$g_3 = -h_0;$$

the details of the high-frequency filter h_k coefficients and the approximating g_k coefficients of the low-pass filter determine the Daubechies wavelets of 2-order.

The results of the transformation and clearing of the path by Daubechies wavelets are shown in figures 6, 7.

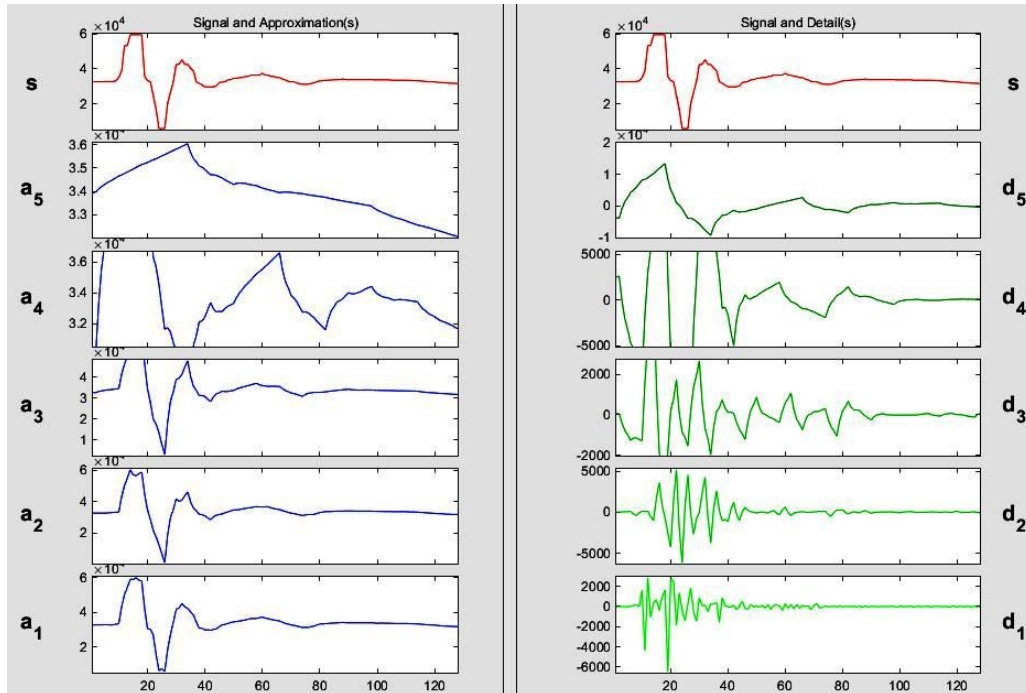


Figure 6: Results of the processing of the trace by Daubechies wavelets

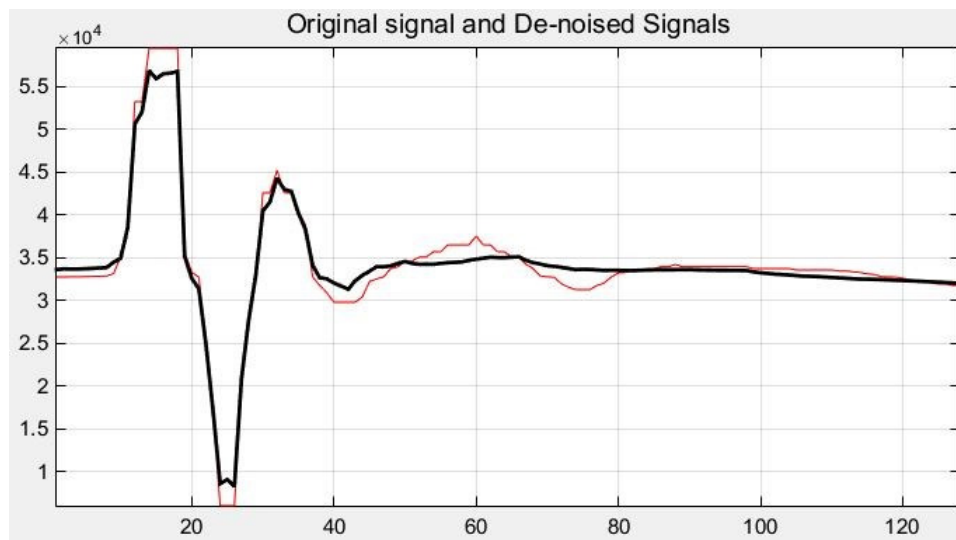


Figure 7: Trace cleared by Daubechies wavelets

3 Conclusions

1. Based on the analysis of existing approaches to the purification of georadar signals, a multiscale wavelet analysis is chosen as a mathematical apparatus, the application of which allows one to isolate and preserve the local features of georadar signals.
2. The mother wavelet for a radargram must have the property of orthogonality and the possibility of signal reconstruction. The paper used the Haar wavelet and Daubechies wavelets db2.
3. Developed programs in the MatLab environment, which realize the purification of the signal from noise using wavelet transform.
4. The conducted researches showed that the best result is given by the wavelet of Daubechey of the 2nd order.

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