JAVA APPLICATION FOR COMPUTING THE WATER LEVEL IN A PIPELINE

Adrian LUCA, Alexandru ENE
FECC, University of Pitesti, Romania
adi_luk@yahoo.com, alexandru.ene@upit.ro

Keywords: ultrasonic wave, acoustic wave propagation, steel – water interface, graphics in Java

Abstract: *In this paper we present a Java application used for computing the water level in a pipeline starting from signals which are obtained during experiments. The measurement principle is based on the properties of the ultrasonic wave propagation in the steel-water-steel structures. The signals are formed from echoes of an ultrasonic impulse sent in a steel pipeline with different filling levels. By computing the difference between two echoes we find the time needed by the impulse to leave the transducer, to reach the water surface and then again the transducer. The developed application is a graphical interface that allows the user to load a signal, to analyze it using a detection algorithm and then to display the results.*

INTRODUCTION

The measurement of the water level in pipelines has a lot of applications, especially in industry, in installations where it is impossible to use internally mounted sensors because of the temperature, turbulence or other factors.

An alternative to classical measurements is the ultrasonic system, which is based on the properties of ultrasonic wave propagation in water and different interfaces like steel-water-steel and water-air. The ultrasonic wave is propagating linearly in a homogeneous medium. [1]

The propagation speed is depending on the crossed medium, it is independent on the wave frequency and is not the same for the longitudinal waves and the transverse waves. In solids, the transverse waves speed is about half of the longitudinal waves speed.

The absorption coefficient is depending on the material elasticity and viscosity and increases with frequency. For this reason, for the temperature or flow measurements it is preferable to use a frequency range around 1 MHz.

Reflection and refraction of ultrasonic waves at the border of two mediums are more complicated then the ones of light because in optics the longitudinal waves do not exist. When an ultrasonic wave reaches a surface, it creates more types of waves, like waves with normal incidence and waves with oblique incidence. [2]

In this paper, for level measurement we use the echoes of the emitted ultrasonic wave, reflected by the water-air interface. Knowing the time of propagation and the speed of the wave in water we can determinate the level of the water.

1. EXPERIMENT PERFORMED

The principle of this experiment consists in sending an ultrasonic wave from the bottom side to the upper side of the pipeline and receiving the echoes that appear when the wave reaches the water-air interface. For this, we need a pipeline section with a system for changing water level, an ultrasonic generator, an ultrasonic transducer and an oscilloscope to save the obtained signals.

We used an ultrasonic transducer at 1MHz that can work in emission-reception mode. We sent an impulse and received the echoes. There are two types of reflections in this structure: reflections in steel, the material from which the pipeline is made, and reflections that appear when the wave reaches the water-air interface. The second type of reflections can not be seen because we do not have a transducer placed there. A general scheme of the experiment principle can be seen in **Fig. 1**.

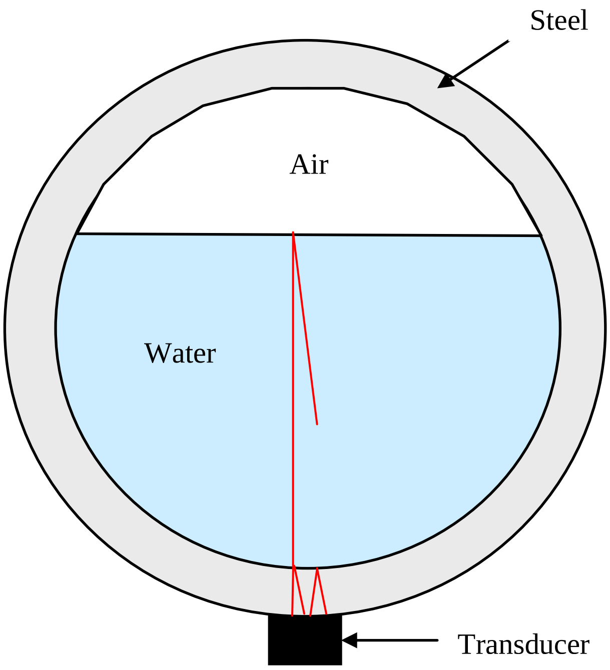

Fig. 1: Scheme of the experiment principle

The ultrasonic wave, represented in **Fig. 1** with a red line, follows the same trajectory until it is entirely attenuated. Generally it can make four or five round trips depending on the amplitude of the emitted wave.

2. RECIVED SIGNAL STRUCTURE

The received signals consist in four trains of echoes, the fourth one being so attenuated that it can not be used for computing the water level.

Each train contains reflections of the emitted ultrasonic wave in the steel. The time difference between the first and the second train is the time needed by the wave to cross the steel and the time needed to make a round trip. The difference between the second and the third train of echoes represents only the time needed for a round trip. With our application we have computed both distances but the second one returns better results. This can happen due to the fact that in the composition of the first train of echoes we find also the emitted impulse. Another reason can be the saturation in amplitude. An example of a received signal is illustrated in the next figure.

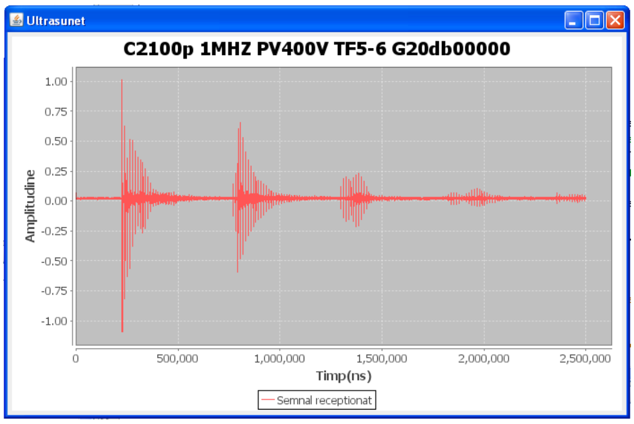

Fig. 2: Received signal structure

For each of the trains the echoes are well separated as we can see in **Fig. 3**.

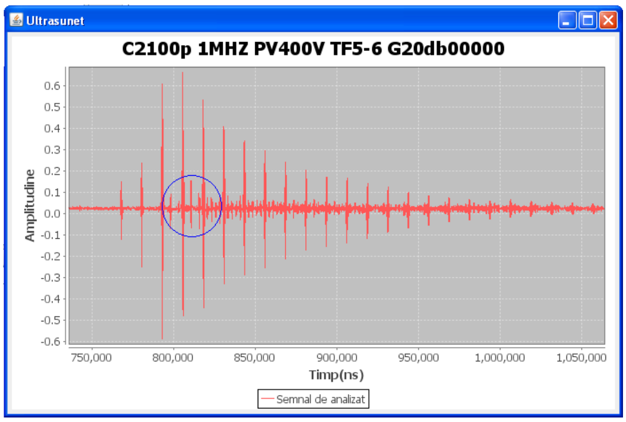

Fig. 3: Zoom on the second train of echoes

The goal of our applications is to make an automatic detection of each echo from each train and then to compute the difference between the echoes with the same position in the trains so we can compute the water level by multiplying with the propagation speed of ultrasonic in water and then dividing by two.

By looking at the signal above we can say that a simple amplitude threshold is enough for the detection of the most significant echoes.

Taking a closer look we can see also some noise having an amplitude comparative or even bigger than the amplitude of the last echoes as we can see in the blue circle from **Fig. 3**. Using an amplitude threshold we detect also this noise and therefore our measurement is inaccurate.

To avoid this problem we created a detection algorithm that we present in the following section.

3. DETECTION ALGORITHM

By analyzing the signal we saw that the distance between two consecutive echoes of the same train is constant. This distance is in fact the pipeline thickness divided by celerity in steel.

Using an amplitude threshold we have delimited the first three trains of echoes of the signal, and then by using a segmentation step (with a value around the pipeline thickness) we chopped the signal in small segments, each one containing a single echo. In each segment we computed the maximum amplitude value and then the corresponding index value. After this procedure we can be sure that we do not have any high amplitude noise in our detection signal.

To construct the detection signal we took to the right and to the left of the maximum value a certain number of samples so we can fit well the echo.

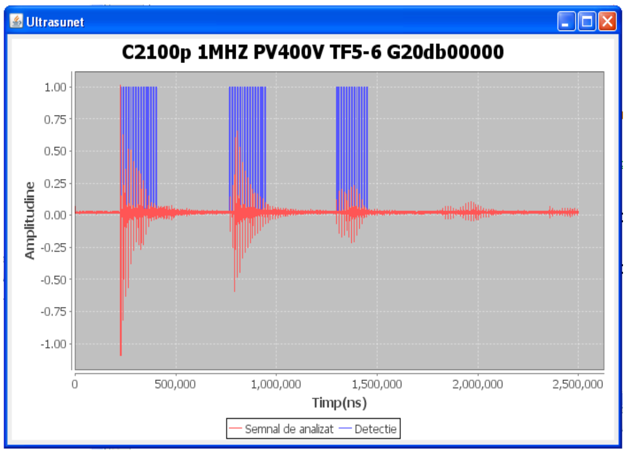

Fig. 4: Result of the detection algorithm

In **Fig. 4**, the detection signal represented in blue is overlapped on the analyzed signal. It fits well each echo and it ignores the high amplitude noise. To better see the result we made a zoom on the second train of echoes. It can be seen in **Fig. 5**.

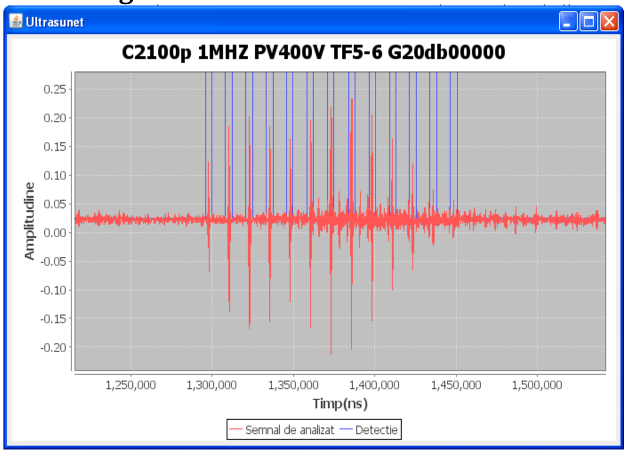

Fig. 5: Zoom on the second train of echoes

After finishing with the detection algorithm we have to compute the level of water in the pipeline. As we said, we have received the best results by computing the difference between the second and the third train of echoes. This difference means in fact one round trip of the ultrasonic wave in the water. To compare the results we computed also the difference between the first and the second train of echoes and then the difference between the first and the third one.

4. THE WATER LEVEL

To determinate the water level we computed the difference between the echoes with the same position in the trains.

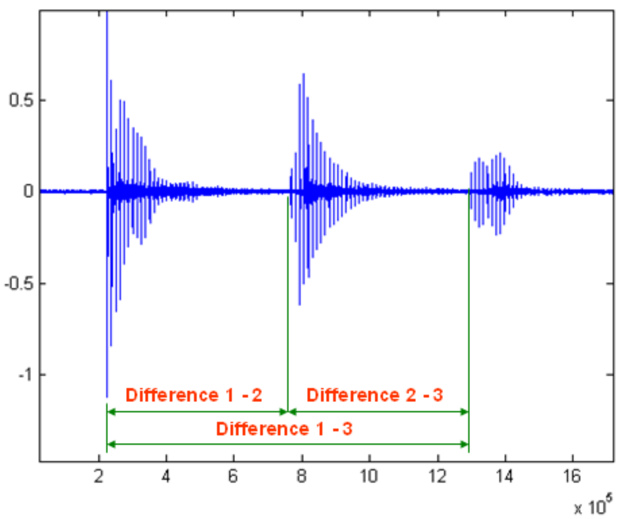

Fig. 6: Water level calculation

We have computed the differences illustrated in **Fig. 6** by using the simple difference between the maximal values from each segment and also by correlation, that gave us better results ~~in some~~in some cases.

When we used the correlation, we computed also the difference between the first and the third train just to compare it with the sum of the other two differences to see if we have errors. The biggest error found using the correlation has a value of 30 ns which is equivalent to 45 μm for a propagation speed in water of 1500 m/s. When using just the simple difference between the peaks we found an error of 499.81 ns which is corresponding to 0,75 mm for the same propagation speed (the imposed error being 1 mm).

5. THE GUI

The graphical interface is built to facilitate the work with signals. It allows the user to load a signal, to display it, to analyze it using the detection algorithm and then to display the obtained results.

Another utility of the GUI is that it lets the user change the detection algorithm parameters by editing the corresponding text fields.

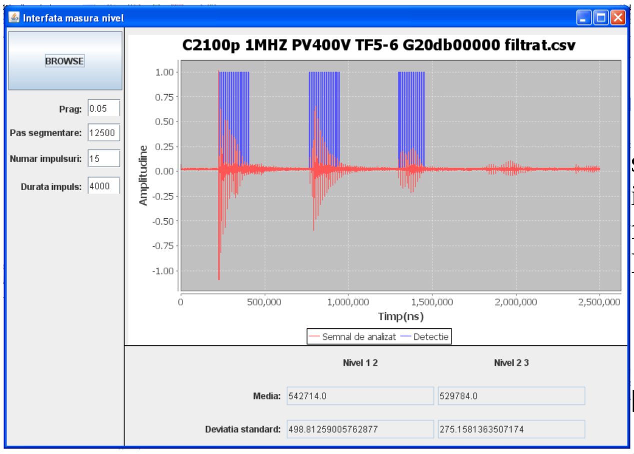

Fig. 7: Graphical user interface

By pressing the *BROWSE* button the user can choose the signal that he wants to analyze. After the signal is loaded, the interface starts analyzing it and then displays the detection signal in blue. Then, the interface continues with the calculation of the water level. When it's done, it is displayed in the bottom of the window.

The interface allows the user to zoom portions of interest of the plot by simply selecting them with the mouse.

6. CONCLUSION

By using the Java programming language, we built an application for processing the data in order to determine the water level in a pipeline.

The core of the application is the detection algorithm that is able to detect and fit well each echo in order to facilitate the computation of the water level.

By using two methods for this computation, the simple difference between peaks and the correlation, we obtained results in the limits of the imposed error.

We tested the interface for six different signals corresponding to six different filling levels of the pipeline and the obtained results are comparable to the real values.

The interface can be improved by reducing the time needed to compute the correlations and also the time needed to display the signals, all this being caused by the big number of samples contained by the signals.

ACKNOWLEDGEMENT

This work was partially supported by the strategic project POSDRU 107/1.5/S/77265, inside POSDRU Romania 2007-2013 co-financed by the European Social Fund – Investing in People.

7. REFERENCES

[1]. CTT ECOTECH – *Ultrasonic wave tutorial (http://www.cttecotech.ro/fisaultrasunete.pdf).*

[2]. Jérôme LE FRIANT, Emmanuel THIBERT - *Mesures Thermo - hydrauliques par analyse non-stationnaire de signaux ultra-sons, EDF CHATOU, France,2009*.

[3]. Lyon A. DOUGLAS, Rao V. HAYAGRIVA – *Java Digital Signal Processing, N.Y., 1998*