ACOUSTIC COMMUNICATIONS IN WATER PIPES: AN EXPERIMENTAL APPROACH

R. García Acevedo [(1)], A. López Méndez [(2)], E. Álvarez Álvarez[(1)], S. González Suárez[(1)], M. Rodríguez Lastra[(3)],A. Gutiérrez-Trashorras[(3)]

[(1)] *CTIC, C.T, C/Ada Byron 39, Edificios Tecnológicos, 33203 Gijón-Asturias-España. Tlfno: 984291212, e-mail: rodrigo.garcia@fundacionctic.org*
[(2)] *Empresa Municipal de Aguas, S.A., Avda. Príncipe de Asturias 70,33212 Gijón-Asturias-España.*
[(3)] *Dpto. Energía, Universidad de Oviedo, C/Independencia 13. 33004 Oviedo-Asturias-España.*

1. Abstract – This paper presents an experimental approach of establishing a digital communication between two points using water pipes as infrastructure and low-cost piezoelectric based sensors.
A pipe network, that represents a common infrastructure used in water distribution, was installed in the laboratory to carry out different set of tests in order to evaluate the best range of frequencies and different digital communication modes. The tests were performed with two low-cost piezoelectric based sensors connected to a laptop computer.

The results of the experimental tests determine that it is possible to establish a reliable communication in the sound range between 2 and 3 kHz. This is considered as the first step for developing of a new family of low-cost devices to remote control the water distribution network.

2. Introduction – Water distribution networks as well as electricity and gas networks, are a vital infrastructure for today's society. Numerous devices such as consumption meters, control elements, sensors, etc., are installed within the distribution network to control and ensure the correct supply. These devices and the distribution networks, should be monitored and reviewed periodically. However, this can be difficult because most of the time it requires physical access and some places are relatively inaccessible. That is why the use of devices that allow remote control labors with a minimum maintenance, would suppose big benefits in terms of flexibility and cost.

Despite the extensive research in offshore subsea applications [1], [2], there has been very little research on acoustic communication systems in water pipes, and the communication systems developed are of big dimensions and expensive. Acoustic in pipes has been also widely studied, nevertheless, not for communication purposes but for leakages detection [3-7].

The use of devices that, once located at the points of interest, allow the performance of supervision tasks remotely, reduction of maintenance and costs, would make a breakthrough in terms of obtaining information of the distribution network. These conditions impose three objectives to this new kind of devices: to be able to work with a minimum energy consumption, to communicate secure and efficiently, and to be manufactured at low cost.
Taking these objectives into account, this investigation is focused on the development an initial test of an adequate communications system. This communications system is based on digital communication mechanisms using sound waves and low-cost commercial hardware.

It must be taken into account that reverberation is the most important distortional factors of the acoustic waves in pipes and different parameters such as pipe material, geometry, elbows, connections and valves, as well as the length of the ramifications greatly affect the transmission properties [8-13]. Otherwise, for minimizing energy consumption, thus reducing the maintenance costs is necessary that the communications system to be extremely efficient in terms of energy expended per bit of transmitted information.

3. Materials - For this research, a water distribution network was built in the laboratory and two low-cost piezoelectric sensors specially adapted by researchers to use them to communicate through the water pipe were used. The sensors were connected to audio input or output connections of a laptop.

The water distribution network was built with cast iron tubes with mortar inside (inner diameter: 100 mm, mortar thickness: 3-4 mm, cast iron thickness: 5mm). This type of pipe is commonly used in water distribution networks.

The laboratory network was provided with five openings for introducing devices and four valves for modifying the physical characteristics of the network. A scheme of the network and a photography of a section of the installation are shown in Image 1 and Image 2.

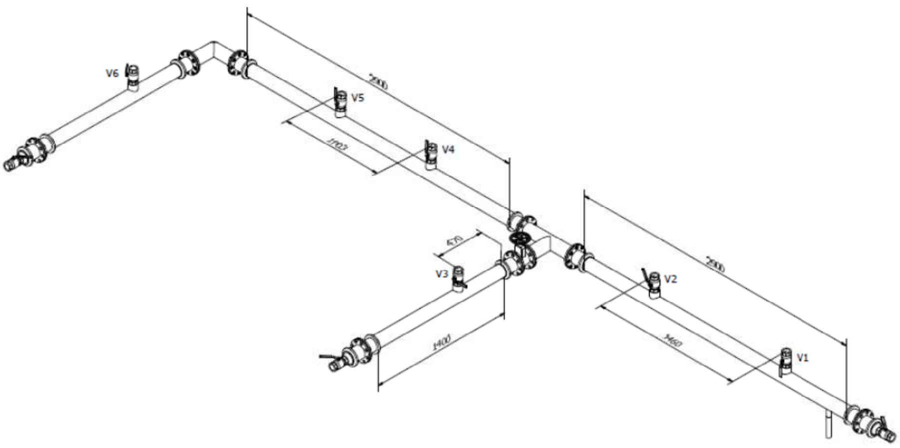


Image 1. Scheme of the network

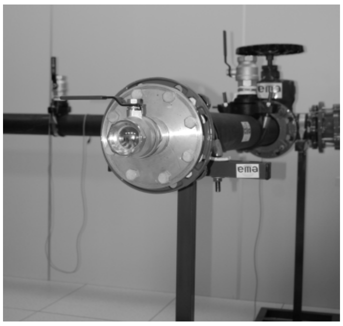


Image 2. Section of the network installed at the laboratory

The sensors used consist in a piezoelectric disk (see Image 3), commonly used inside loud-speakers, mounted in a copper capsule prepared to be connected to the pipe openings (see Image 3).

Image 3. Piezoelectric disc

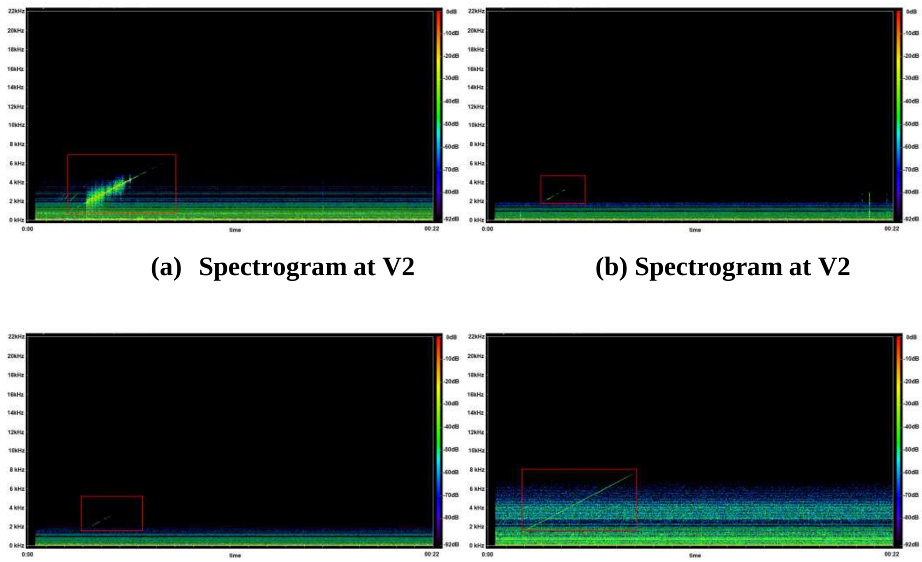
4. Methodology – Two different set of tests were carried out in the network to evaluate, firstly the best range of frequencies to transmit and received, and secondly the feasibility to transmit and receive data using different common digital communication modes.

In both set of tests, a piezoelectric sensor used as transmitter was placed in position V1 (see Image 1), and another piezoelectric sensor used as receiver was placed in different positions V2, V3 and V6 (see Image 1).

In the first set of tests, a sine sweep ranging from 20 Hz to 20 kHz was generated by the transmitter, in order to obtain the frequency response received in different positions of the receiver.

Once obtained the best range of transmitting frequencies for all cases, a frequency was fixed to perform the second set of tests to evaluate different communication modes.

5. Tests – The frequency response obtained in the different points is shown in the spectrograms of Image 4.



(a) Spectrogram at V2 **(b) Spectrogram at V2**

(b) Spectrogram at V4 **(c) Spectrogram at V6**

Image 4. Frequency response spectrograms

Each spectrogram shows the frequency responses for a sine sweep signal between 20 Hz and 20 kHz. Without any attenuation the spectrograms should display a straight line between 20 and 20 kHz. However, due to the attenuation, noise, reverberations and the characteristics of the sensors, only a few frequencies of this line can be distinguished. Those frequencies are marked inside the red square box. The frequencies outside the red square box are too weak and thus cannot be used to communicate reliably. The best frequencies are between the sonic frequencies 2 and 3 kHz.

In the second set of tests, five radio digital modes were tested using a frequency of 2.5 kHz. These modes correspond to two of the most simple and well know communication ones: QPSK and BPSK [14].

The worst case of transmission occurred when the receiver was in position V6, and for this case the results obtained are shown in Table 1. Results also show that using the digital communication mode

QPSK the data transferred can be assured up to 31 bauds while using BPSK communication can be assured up to 63 bauds.

Table I. Communication Results

Digital Mode	Error (%)
QPSK31	0
QPSK63	58
BPSK31	0
BPSK63	0
BPSK125	13

The results of this research show that it is possible to establish a digital communication network in water distribution pipes using simple piezoelectric sensors and digital radio communication modes.

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