Autonomous and In-situ Water Quality Monitoring System for Real-World Applications

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***Abstract*—In order to improve the routine of water quality monitoring and reduce the risk of accidental or deliberate contaminations, this paper presents, the development of low cost and durable on-line water quality system includes multi-parameter sensors, acquisition card, communication system and another accessories. These sensors can be installed across water distribution networks within an interface to control the continuous flow and pressure of the large volume water samples (rivers, lakes). The flow water is made through a channel which is designed on one side of this interface. In our system, we propose to use the small satellite technology offered by the international spatial project such as HumSat. Data collected by various sensors such as temperature, pH, and turbidity are sent via bluetooth to bluetooth-UHF Bridge which is equipped with a Bluetooth module, memory, microcontroller, modulator, transceiver and UHF antenna. The bridge is responsible for the satellite communication. A novel WSN architecture was proposed.**

***Index Terms*—flow channel interface, autonomous, on-line water monitoring, sensor networks.**

I. Introduction

Surface water quality monitoring is one of the most important activities in environment monitoring domain. The number of scientific research and development systems in this area is extremely large.

The MENA region is projected to experience an increase of 3°C to 5°C in mean temperature and 20% decline in precipitation by the end of this century (IPCC, 2007). The consequence of this climate change on water run-off is estimated to drop by 20% to 30% in this region by 2050. An example of interest, the World Bank, USAID and NASA are collaborated for establishing a sciences program based on earth observations for water management in this region. This initiative was launched in October 2011 and it is scheduled by the end of 2015. [1]

In order to effectively fill observational gaps and increase the powerful of decision makers MENA region and others, we propose to combine data between the satellite observation programs and the in-situ water quality monitoring system developed in this paper.

The implementation of on-line water quality sensors in real distribution water system [2] requires certain conditions such as reduction of pressure and flow rate. The available devices for flow control are complicated and expensive. Among the objectives of this study is the development of a simple interface to reduce and control the pressure and flow rate change occurs in water mains. The other objective of this work is the development of an acquisition card equipped with the appropriate I/O, signal conditioning circuit, memory, microcontroller and a bluetooth module for important water quality parameters pH, temperature, turbidity and level.

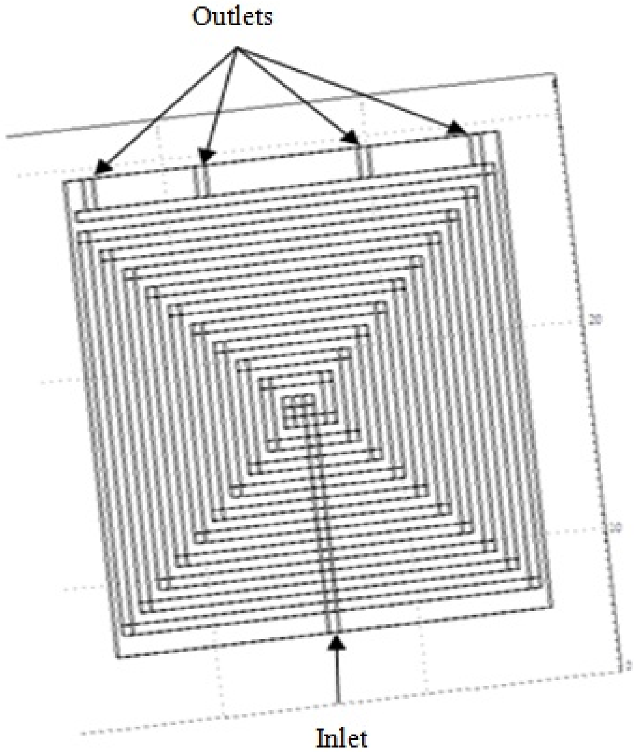

Fig. 1. Schematic of the channel designed

A wireless sensor network is proposed, it is made up of set of sensor nodes. The topology and the technics used in this network provide easy deployment of the nodes anywhere in the distribution water system without any particular limitation. The sensor nodes collect the information and send them via bluetooth to bluetooth-UHF Bridge which is responsible on communication with the nanosatellite constellation. This network architecture is proposed in order to reduce the conflict and improve the communication between the sensor network and the nanosatellites. It also allows predicting test applica-

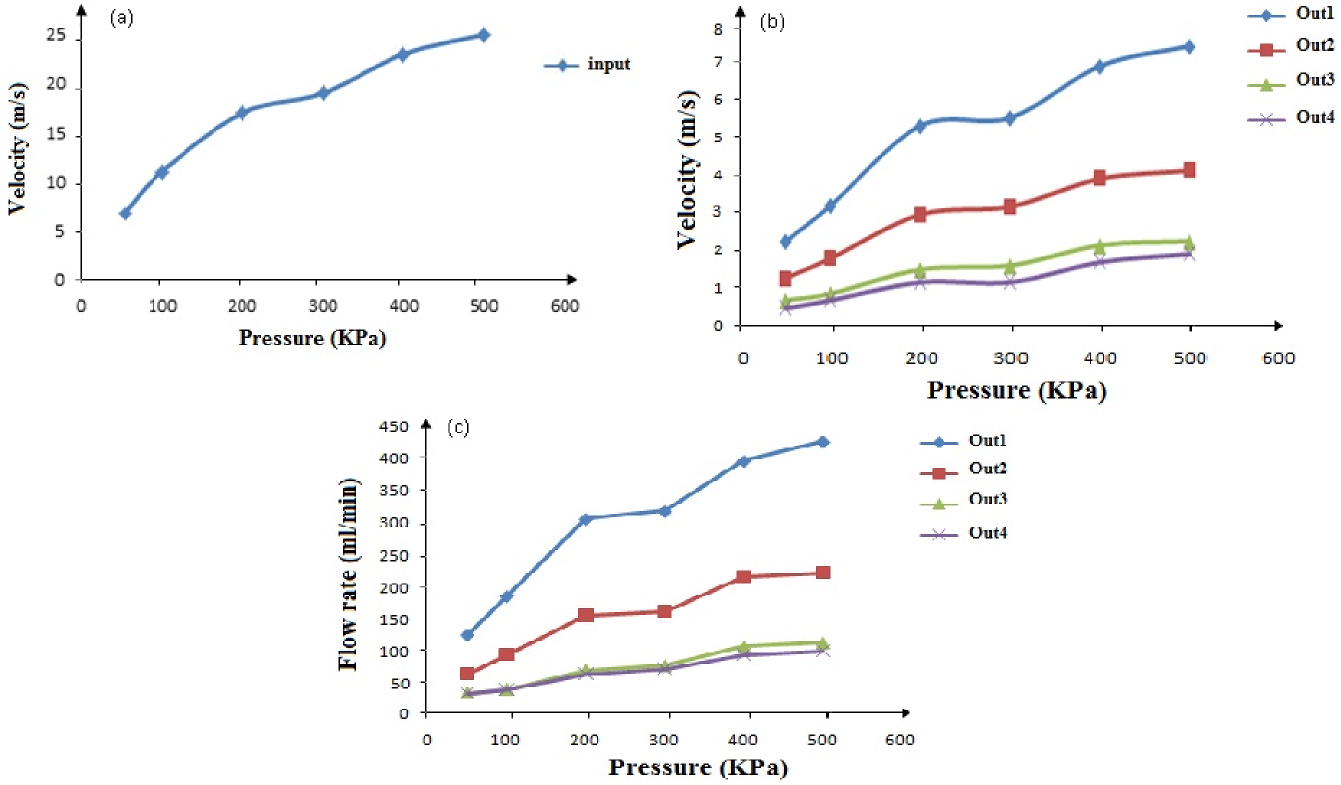

Fig. 2. (a) Velocity at the inlet (b) Velocity at the outlets (c) Flow rate at the outlets

tions on smartphones.

II. Interface Simulation

Fig. 1 shows the design of an interface with flow channel to connect the water quality sensors to the high flow rate and pressure in the water distribution system. The water flow is performed through the channel interface. The pressure at the inlet is varied and the velocity at the outlet is measured. In order to obtain the Navier-Stocks equations from the conservation of mass and linear momentum, we need to make some assumptions about our fluid (water), about the density, the body forces and the matrix of stress tensor. The Navier-Stocks equations are presented in Eq.1 and Eq.2.

$$\nabla . V = 0 \tag{1}$$

$$\frac{\delta}{\delta t}\rho V + \nabla.(\rho V V) = -\nabla.P + \rho g + \nabla.\bar{T} \tag{2}$$

The constant water density is considered as = 1000 kg/m^3,

V: The fluid velocity (m/s),
P: The fluid pressure (Pa),
g : The acceleration due to gravity (m/s^2),
$\bar{T}$: The matrix of stress tensor.

Multi-physics simulation tools have been used to simulate the flow in the channel shown in fig. 1. At the inlet, the pressure was varied to observe his effect on the velocity. At the outlet, the pressure is set to the atmospheric pressure (P0 = 0 kPa). Fig.2(a) shows the velocity at the inlet, Fig.2(b) the velocity of each outlets and Fig.2(c) the flow rate at the outlets.

III. System Bloc Diagram

The main objective of our system is to monitor water quality parameters (hydrodynamic and physic-chemical) in real time and remotely. Therefore, the entire system consist on three segments: space segment which includes a constellation of nanosatellites offered by the University international space projects, ground segment entailing the ground stations included in radio amateur University Network such as GENSO [3] and users segment contains the on-line multi-parameters water quality sensors, acquisition card(conditioning signal circuits, ADC, microcontroller) and the communication module. In this paper, we focus on the users segment. Fig.3. shows the bloc diagram of the segment.

The signal conditioning circuits consist of four electronic circuits (one for each measured parameters) which adapt and amplify the output signal of each sensors to be easily processed by the microcontroller. One example of those circuits is shown in Fig.4; it is a pH probe circuit sensing.

A. pH Sensor Interfacing

High accuracy pH probe is used as a pH sensor. The theoretical output is approximately 59.16 mV/pH at 25°C.

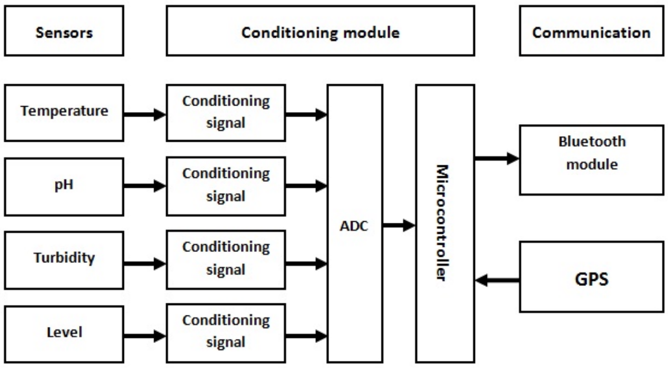

Fig. 3. System block diagram

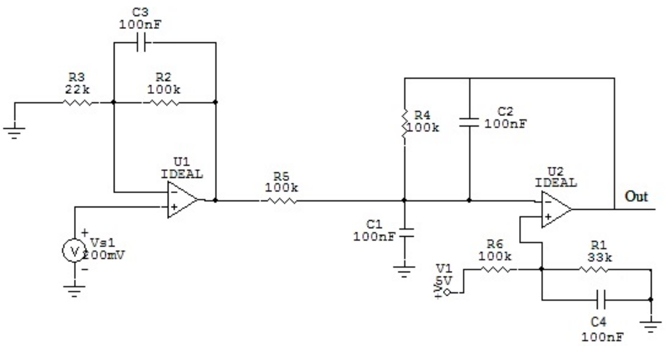

Fig. 4. pH probe circuit sensing

Temperature affects the output voltage thus it is required to compensate. Fig.4 shows the pH probe circuit sensing, the output voltage of the sensor from -400mV to 400mV is converted into 0 5V range which is further given to PIC 18F4450 for processing. Due to the high impedance of the probe, a high-input impedance will be required. The simulation result for the pH probe circuit sensing is shown in Fig.5.

The transfer function of the pH probe is presented in Eq.3.

$$pH(x) = pH(s) + \frac{E_S - E_X}{RT\ ln(10)} \tag{3}$$

Where

$pH(x)$: pH of water solution,
$pH(s)$: pH of standard solution = 7,
E_S : Electric potential at reference,
E_X : Electric potential at pH measuring,
F is the Faraday constant = 9.6485309*10^4Cmol^{-1},
R is the Universal gas constant = 8.3145 J K^{-1} mol^{-1},
T is the temperature in Kelvin.

B. Temperature Sensor Interfacing

A K-type thermocouple is used for the temperature measuring. It's inexpensive, accurate, reliable and has a wide temperature range (-270 – 1260°C). The K-type thermocouple has an almost linear part between 0 and 1000°C with a seebeck coefficient fluctuating around 40µV/°C. In our application, we focus only on the range of 0 – 100°C. The temperature interfacing circuit is shown in Fig.6. The output voltage (mV) measured by the thermocouple in 0-100°C range is converted into 0-5V range. The cold junction compensation is affected by software. Fig.7 presents the characteristic curve of temperature.

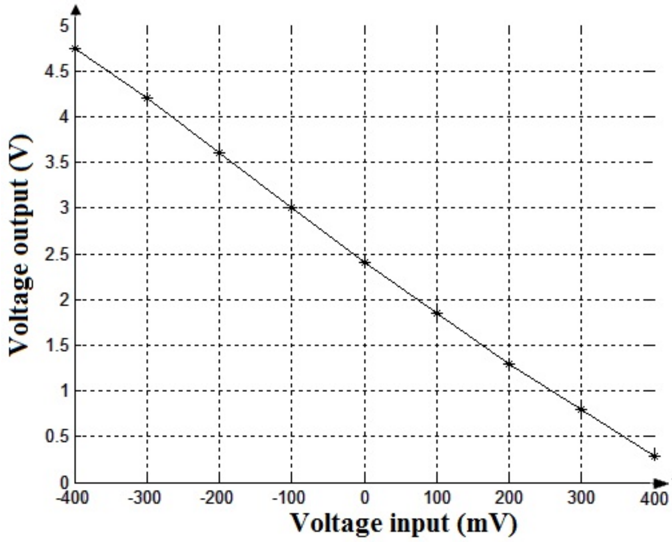

Fig. 5. Characteristic curve of pH probe circuit sensing

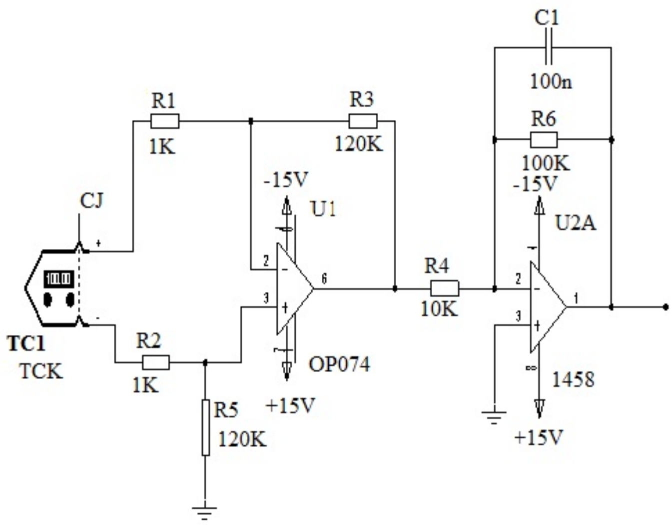

Fig. 6. Temperature interfacing circuit

IV. Communication System

A. Satellite communication

The HumSat project is an international initiative for building a constellation of nanosatellites providing communication capabilities to the entire earth. Basic service expected given by this system is the environment monitoring of our planet. The initial version of the HUMSAT constellation consists of 9 cubesats distributed on three orbital plans (500-700km). Each plan contains three cubesat with inclination of 97.8°

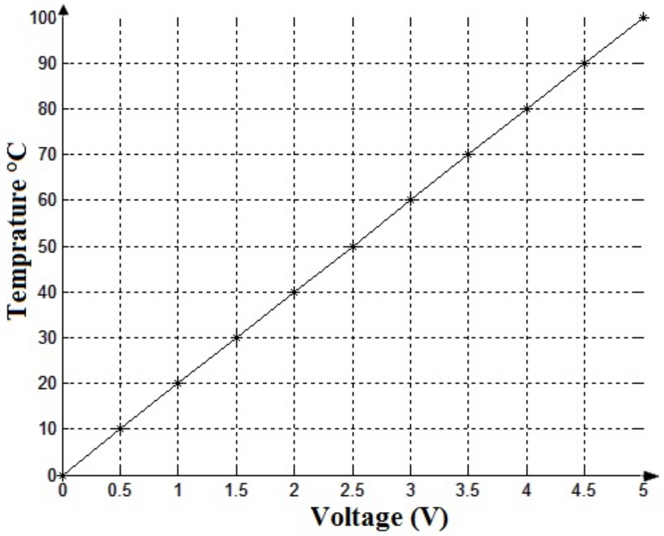

Fig. 7. Temperature characteristic curve

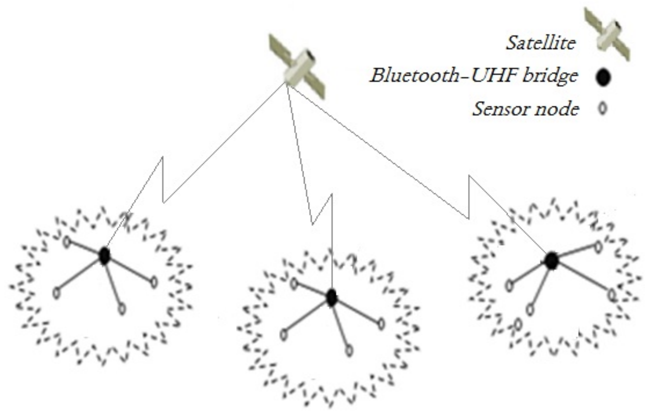

Fig. 8. Sensors network architecture

and a period revolution of 98 minutes. SSI (Sensors-to Space Interface) is the standard interface between the on-line water quality sensors and the HumSat constellation. It provides communication capabilities in the UHF amateur band at 437MHz. The type of signal modulation is GMSK (Gaussian Minimum Shift Keying) with 1200bps data rate. This interface includes a new communication protocol for nanosatellites [4].

B. Sensors network architecture

In order to reduce the sensor nodes that communicate with the nanosatellite constellation, the conflict and improve the capacity of transmission channel access, we propose the wireless sensor networks shown in Fig.8 which is based on bluetooth-UHF Bridge. This bridge is an electronic component equipped by bluetooth module, memory, microcontroller, modulator, transmitter and UHF antenna.

Each sensor node is equipped by the four on-line water quality sensors. We propose to distribute these sensor nodes on circle with 100 m of diameter (four nodes by circle) for implementing a piconet topology. The bluetooth-UHF bridge has a function of master and the sensor nodes are the slaves in this topology. The communication scenario is listed below:

- On-line water quality sensors collect the water parameters,
- Send these parameters through the bluetooth module,
- The bluetooth-UHF bridge receives data, adapts to the appropriate communication protocol and sends them to nanosatellite constellation.

V. CONCLUSION

This paper presents the design of autonomous and on-line water quality monitoring system based on bluetooth and small satellite technology.

Important part of this work is the development of a low cost interface which can embed the multi-parameter sensors, in order to control the pressure and the flow rate in real distribution water system. The main objective of this paper is to monitor the surface water quality in real time and remotely. Thus was designed, a low cost system includes the multi-parameter sensors, acquisition card and the wireless sensor network based on bluetooth technology and Bluetooth-UHF bridge. In this system we introduce the small satellite technology for water quality monitoring through the international space project HumSat. Future work will be related to field of miniaturized water quality sensors.

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