Rapid Detection of Pesticide Residues based on Telemetry Platform

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***Abstract*—Pesticides are very important in improving agricultural production, but can harm beneficial insect species, soil, air, water, plants and their fruits. The purpose of this paper is to describe a telemetry solution together with a novel generation of immunobiosensors that will be used in order to gather data to a platform for remote monitoring of pesticide residues. The paper is an overview of the techniques and interfaces proposed for rapid detection of pesticide residues. LabVIEW is the preferred solution to create the graphical interface in order to insure the visualization of data. Furthermore, the platform can be applied for tele-monitoring pesticides in an agricultural production by performing a qualitative and quantitative assessment of pesticides. The paper fills a gap in the biosensors domain literature by proposing a solution based on data from immunobiosensors for rapid detection of pesticide through a telemetry platform.**

Keywords*— telemetry; biosensors; pesticides; immunobiosensors; LabVIEW.

I. Introduction

The concern about the presence of pesticide residues in water, soil, and food has prompted the search for alternative methods able to detect low levels of these compounds in a simple way [1]. Biosensors offer great advantages over conventional analytical techniques, including high specificity for real-time analysis in complex mixtures, high sensitivity, simple operation without the need for extensive sample pre-treatment, and low cost [2].

When losing control of pesticides, these can accumulate in water systems and pollute the environment, which can be detected by basic sensors [3]. The main contribution of this article is to demonstrate that, for a better detection and control of pesticides, telemetry solutions and equipment can be used. Sensors can provide concentration-dependent signals in fruit products, but there does not exist a qualitative and quantitative assessment of pesticides in the plantations [4].

Immunobiosensors which can provide concentration-dependent signals, appear to be appropriate for identification of a single pesticide or, in some cases, small groups of similar pesticides in environmental monitoring, as they are rapid, specific, sensitive and cost-effective analytical devices [5].

The major challenge for immunobiosensors is the development of appropriate antibodies with desired specificity and high binding ability, as these critical biological reagents are usually requiring bio-medical labs with experience in immunoassays research and development. In most cases, antibody affinity and specificity are the limiting factors of these assays. In this context, biosensing based on nanomaterials is one of the hottest topics in nanotechnology and nanoscience. Furthermore, this paper is intended to present the principles of using telemetry solutions to gather data from novel generation of immunobiosensors.

Pesticides are substances meant for attracting, seducing, and then destroying any pest. They are a class of biocide. The most common use of pesticides is a plant protection products (also known as crop protection products), which in general protect plants from damaging influences such as weeds, fungi, or insects. In general, a pesticide is a chemical or biological agent (such as a virus, bacterium, antimicrobial, or disinfectant) that deters, incapacitates, kills, or otherwise discourages pests. Target pests can include insects, plant pathogens, weeds, mollusks, birds, mammals, fish, nematodes (roundworms), and microbes that destroy property, cause nuisance, or spread disease, or are disease vectors. Furthermore, in this paper we present the telemetry platform for transmitting the detected level of pesticide residues in water, soil, and food.

The rest of the paper is organized as follows: Section II presents related work in immunobiosensors domain, while Section III describes the proposed system and Section IV presents the methodologies for telemetry solutions. Section V concludes the paper.

II. Related work

Inductive-based devices integrated with Si technology for bio detection applications are among the most used pesticide detection sensors, using simple resonant differential filter configurations [6]. This has allowed the corroboration of the viability of the proposed circuits, which are characterized by their very high simplicity, for microinductive signal conditioning in high-sensitivity sensor devices.

Immunomagnetic biosensors based on the use of superparamagnetic particles (MPs) as the biological markers have received strong interest for the detection and quantification of biological substances [4]. This interest is motivated by their potential for the development of systems with very high sensitivity, low cost, and high specificity. Among the different sensor strategies, different groups have proposed the use of inductive-based devices, where sensing is determined by the changes in the inductance of a solenoid due to the presence of the MPs in the sample under analysis [6].

In relation to other magnetic immunoassays, these biosensors are characterized by their very high simplicity, since in this case, the application of permanent magnetic fields is not necessary for sensor operation. This simplifies the design of the device and its integration in the whole system.

The potential of these inductive devices for the development of high-sensitivity sensors is strongly conditioned to the availability of a suitable signal conditioning circuit. One of the most used approaches is based on the measurement of the resonant frequency of an LC circuit containing the inductive sensor. However, for very high-sensitivity applications, this approach is compromised by the stability required for the oscillator circuit.

This has lead Kriz et al. [7] to use a modified Maxwell bridge in their sensor configuration. This is based on the measurement of the magnetic permeability of a sample formed by silica particles, which wear MPs that are immobilized on their surface through antigen–antibody–antigen sandwich complexes involving the analyte. This system has allowed the achievement of a detection limit of 250 nM using Concanavalin A as the target analyte.

According to Richardson et al. [8], an improvement of the sensor sensibility requires the development of conditioning circuits alternative to these classical bridge topologies. It was developed a circuit with a voltage-controlled oscillator and a phase-locked loop detector to determine the resonant frequency of an LC circuit, including the sensor solenoid, that allows overcoming the limitations that are related to the stability required for the oscillator. The sensor proposed uses a plastic strip where the MPs are immobilized at the end of the assay, and the amount of bounded MPs on the surface of the strip is determined by measuring the change in the inductance of the measuring coil when the strip is placed in the coil nucleus. This has allowed detection down to 105 MPs that are immobilized on the strip surface. The system has been applied to the detection of human transferrin, obtaining a linear response with femtomolar detection limit (260 fM).

E. coli is an important human pathogen of public health concern and rapid and accurate detection of it become urgent. The experiment in [9] reported the immunobiosensor produced on the surface of salinized ITO electrodes, based on electrochemical impedance technology. The fitting results of the electrochemical impedance spectroscopy proved the real system was similar to simple R or RC circuit. The detection indicated the biosensor was highly sensitive. Although the repeatability of the ITO electrodes not so good, the insulative layer of the electrode surface was rather stable in a solution with a definite ionic strength and acidity. Besides, they have excellent selectivity and good portability, can be used for real time detection and clinical diagnosis.

III. Methodologies for Telemetry

Telemetry equipment is being successfully utilized in environmental monitoring and plant disease management, the aim being to measure anything that a sensor can transform into an electric signal. Furthermore, we exploit the telemetry equipment and solutions and design applications characterized by precision, sustainability and rich data provided by the system.

The RTU (Remote Telemetry Unit) receives data from sensors and transmit them to the processing server either through radio in the UHF 450 MHz band, or through GSM-GPRS or UMTS. The Gateway is the base station in the system together with the user’s personal computer. This component passes further in the network the data requests from the RTUs and temporarily stores the received data. Therefore, the Gateway can provide control for a number of RTUs depending on the receiver type, and some receiver models can handle over 1000 units [10].

The SaaS and PaaS components which follow a client/server architecture, collect data from one or several Gateways and make it available for viewing or for specialized analysis. The server is responsible for downloading and storing data and controlling the system. At this level, several components that resemble the RTU are added to the description of the architecture, including the sensor network that includes the following sensors: rain gauge, solar panel, wind speed sensor, total radiation sensor (pyranometer), combined air relative humidity & temperature sensor, leaf wetness sensor).

The telemetry system also relies on software components. The software and telemetry devices resemble the system, which can provide features for measuring selected parameters over a predefined area, deliver the data collected over relatively large distances to a central point (Gateway) and process the measurement data to serve different applications such as agriculture, meteorology, irrigation control, water management and environmental analysis.

LabVIEW is a highly productive development environment that contains numerous components for creating custom measurement or control applications that interact with real-world data or signals. Besides the control feature, in LabVIEW can be implemented a mechanism to build reporting graphics that can be saved in a CSV file format. Based on block diagrams, the program contains a highly optimized compiler to generate the machine code, making it easy to connect any hardware devices including scientific instruments, data acquisition devices, sensors and more.

IV. Proposed Architecture for Rapid detection of Pesticides Residues

In this section we present the proposed architecture of the system which it is intended to transmit data from the immunobiosensors containing specific antibodies with a high affinity directed against carbaryl and carbendazim / similar molecules (carbaryl and carbendazim are residues of pesticides most frequently detected in analyzes of food worldwide), with high sensitivity and reliability for rapid detection of these residues in horticultural products.

A. Hardware architecture

Regarding the hardware architecture of data collection system, it will be comprised of two components: biosensors and Concept Board module for data transmission from biosensors.

Biosensors are devices that recognize autonomous transduction elements used to convert a (bio) chemical signal resulting from the interaction of an analyte with a bioreceptor in an electronic sensor. In concordance with the technique of transduction of the signal, biosensors are classified into: electrochemical, optical, piezoelectric and mechanical. Immunosensors are characterized by highly selective affinity interactions between immobilized antibodies or antigens and their specific analytes and are specific for a molecule. The system proposed will use the immunosensors based on carbon nanomaterials / magnetic and antibodies for detection of pesticide carbamates (carbaryl and / or carbendazim or related molecules) in horticultural products.

Immobilization of nanomaterials on detection devices generate new interfaces that allow optical or electrochemical detection of analytes sensitivity. Recently, some nanomaterials have been used to design the enzymatic electrochemical biosensors. Electrocatalytic action of the nanomaterials reduce the potential associated of electroactive compounds, minimizing the interference present in the samples. In some cases, nanomaterials may be used as labels to amplify the measured signal.

There were been identified three types of immunobiosensors based on nanomaterials, such as:

- Electrochemical biosensors based on nanoparticles - provide a microenvironment suitable for immobilization of biomolecules by retaining their bioactivity.
- Optical biosensors based on nanoparticles - works on the basis of semiconductor particles that induce the change in fluorescence intensity depending on the concentration of the pesticide.
- Electrochemical biosensors based on carbon nanotubes - promotes electron transfer reactions of species enzymatically generated and can be used for analysis of pesticide carbamates (carbaryl and / or carbendazim or related molecules) in horticultural products.

These immunosensors offer great advantages such as high specificity for the analysis of complex mixtures in real time, high sensitivity, simple operation without the need for expensive pre-treatment of samples and low costs. In environmental monitoring, immunobiosensors can provide concentration-dependent signals, can be a viable, analytical and competitive alternative in price, sensitivity and response time for identification of a single pesticide or, in some cases, some small groups of similar pesticides.

In the hardware architecture, biosensors or immunosensors will be designed to detect and measure the amount of pesticide (carbaryl, carbendazim and related molecules) in horticultural products.

Concept Board Module is composed of a compact GSM modem used in the transfer of data, voice, SMS and fax into a GSM network and multiple standard interfaces, a SIM card reader integrated, elements that enable the use of this terminal as GSM terminal quad band.

In Fig.1 a block diagram of the data transmission module architecture is described, represented by Concept Board module, which incorporates a transmission module of the parameters and typical accessories connected thereto (USB, communication interfaces, switches).

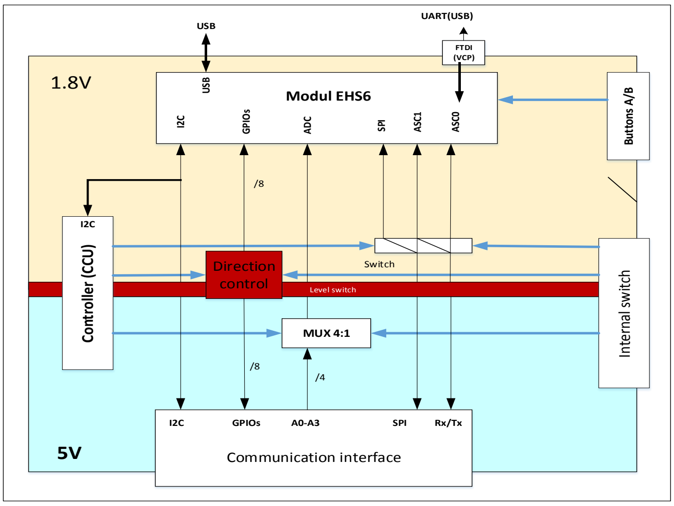

Fig. 1. Architecture of Concept Board module for data transmission

The solution makes it possible to transfer data via GPRS, Class 12 multislot, supporting multiple coding schemes and a PPP stack (Point to Point Protocol). The data could also be sent by CSD (Circuit Switched Data), representing the original form of data transmission developed for mobile systems based on TDMA (Time Division Multiple Access) protocol USSD (Unstructured Supplementary Service Data). The transmission rate of 9.6Kbps is considered sufficient, as there is no large amount of data to be transferred.

The terminal includes a Java platform that includes an API (Application Programming Interface) for parsing AT type commands, USB interface, file system type Flash or TCP / IP and allows programming of multi-threaded and execution of multi-application and transmitting data over HTTP / SSL.

Concept Board module will act as gateway for biosensors measured data acquisition and will send the parameters to the database via the Internet. The Internet connection can be set-up on demand because the device has a built EHS6 TCP / IP stack that can be controlled via AT commands and so the host application can easily access the data layer. The stack can be used for the following Internet services: Non Transparent/ Transparent TCP client, Non Transparent/ Transparent TCP listener, Non-Transparent / Transparent UDP client, Non-Transparent UDP destination, FTP client, HTTP client and SMTP client.

It is possible to make a connection to the Internet in two ways: by using the FileZilla FTP application via a connection to a FTP server, through which it will create a .txt file that can be downloaded to the module memory using AT commands, or by using a Java API that contains HTTP functions.

Measurements from the biosensors will be taken in Board Concept module via a Java application through a data object class and will be sent through a Java application in the database.

B. Software architecture

In terms of software architecture, the main component is represented by a database that will store the data retrieved from biosensors through the Concept Board. The database will have a simple structure that contains fields for the measurements (sensor ID, sensor parameters, value and timestamp), as is shown in Fig. 2.

WIN-PQK0RR57L...ct - dbo.Graf | WIN-PQK0RR57...o.IDparam

Column Name	Data Type	Allow Nulls
ID	int	☐
IDparam	int	☐
value	nvarchar(50)	☑
time	time(7)	☑
		☐

Fig. 2. Table for Storing Measured Values from Different Parameters

Other software components are designed on the Concept Board for transmission, storage and display of the measured parameters, before sending to the database. The database will contain a table for current measurements and a table for processing the historical values. This database is created by using phpMyAdmin and accessed through a web application. Furthermore, the measurements can be manually entered or modified in the database by using a web application created using CodeIgniter PHP framework.

After the creation of the web application, a GUI can be developed for it, which can be viewed the Concept Board module data take from the biosensors and report them to the database. An initial version of the GUI to view the measured parameters was designed as shown in Fig. 3, presenting dilutive for the three substances.

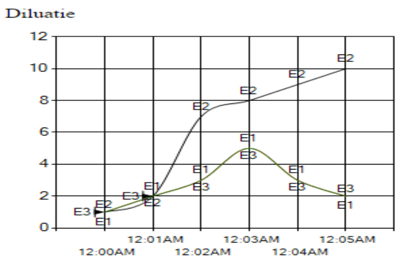

Fig. 3. GUI data visualization

Furthermore, the GUI will be designed for the input of some parameters such as: pesticide type, antibody type, protein, link type, the type of carbon or magnetic link, fluorescent (Yes/No), label the sample, concentration, dilution, incubation time.

V. CONCLUSIONS

The concern about the presence of pesticide residues in water, soil, and food has prompted the search for alternative methods able to detect and transmit low levels of these compounds in a simple way. Biosensors offer great advantages over conventional analytical techniques, including high specificity for real-time analysis in complex mixtures, high sensitivity, simple operation without the need for extensive sample pre-treatment, and low cost.

In this paper we presented the principles of using immunobiosensors and telemetry solutions for monitoring and rapid detection of pesticides residues. As future work we intend to develop the platform for other applications, such rapid detection of these residues in air or water.

ACKNOWLEDGMENT

The work has been supported in part by UEFISCDI Romania under grants no. 20/2012 “Scalable Radio Transceiver for Instrumental Wireless Sensor Networks - SaRaT-IWSN” and CarbaDetect project.

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