# A solution for monitoring operations in harsh environment: a RFID reader for small UAV

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***Abstract*** **– RIFD technologies are applied in a various number of environmental monitoring applications. Efficient energy management is one of the most important prerequisites for the realization of such systems and the power consumption of the RFID tag during radio transmissions must be kept low. The proposed system is composed by the RFID tags distributed on the territory and a reader installed on an Unmanned Aerial Vehicle (UAV). The idea is to use the UAV to collect data from the RFID sensors scattered throughout the area by simply approaching them, flying above them, and downloading measured data. This solution can be adopted to implement a grid of independent RFID sensors covering a large area, or to query sensors located in dangerous scenarios for humans. RFID tags are equipped with measuring sensors and store locally the measured parameters; the reader is mounted on the UAV and through an appropriate communication protocols it identifies the tags, downloads the data and sends them to the Ground Control Station (GCS). At the GCS a technician can control the reader through a GUI console: it is possible to start the discovery, download the sensor data (manually or automatically) and clear the RFID tags memory. An ad-hoc mechanisms has also been implemented to join fast tag discovery procedure, fast data downloading and energy saving. The present paper describes the system, presents the testing methodology and analyses some achieved performances in a test scenario.**

## 1 INTRODUCTION

A large number of Wireless Sensor Networks (WSNs) and RFID tags have been developed to monitor various environmental parameters and to be installed in outdoor environment. Some examples can be:

- WSNs developed to monitor hanging glacier reported in [1] and [2].
- A low cost GPS WSN to monitor a landslide described in [3].
- A feasibility analysis of a WSN to monitor water parameters on a lake presented in [4].

Nowadays UAVs (Unmanned Aerial Vehicles) are often used to reach dangerous places where human operators, devoted to environmental monitoring, cannot operate in safety conditions. UAVs can be powerful monitoring instruments if used along with RFID tags.

The common structure of a sensor network for environmental monitoring is very simple: a set of RFID tags sensors are scattered on the territory to be monitored and a single collecting node reader acquires the measurements. In the present work each RFID tag is standalone (does not cooperate in any network) it is equipped with measuring sensors and it stores locally the measured parameters. The reader is mounted on the UAV and exploiting an appropriate communication protocols it identifies the tags, downloads the data and sent them to a central node devoted to collect them. All the operations are made by simply flying over the area where the tags are distributed.

In the following, the technological solutions to realize the RFID tags and the reader installed on UAV are presented. Moreover, the set of performed tests are descripted, paying particular attention to the use of the reader installed on UAV. Some results are reported and discussed.

## 2 SYSTEM DESCRIPTION

The whole system (Figure 1) is made by three different entities:

- RFID tags scattered on the area that should be monitored.
- UAV reader mounted on board on the UAV.
- Ground Control Station (GCS).

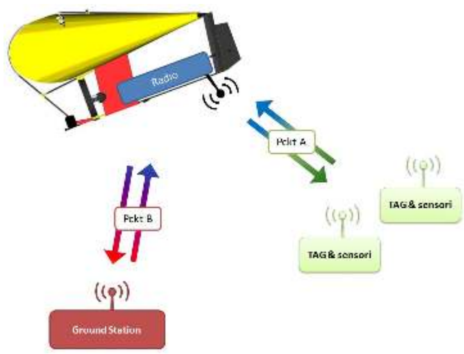


Figure 1. Schematic view of the system

Both RFID tags and UAV reader are based on the same electronic board (a Printed Circuit Board, PCB, with size 110 mm x 40 mm, 4-layer). They can record data from different interfaces (e.g. Digital RS232 standard, Digital I2C standard, Analog input) and store them in an internal solid state memory. Tags can potentially transmits stored data over a RF channel operating at a frequency of 315 MHz. Envisens Technologies s.r.l (EST) has had a good experience in designing multipurpose board (e. g. [5]) and one of the major goal achieved also with the realization of the PCB for the described system, is the flexibility. In fact the board itself can be used for different purposed by simply changing the firmware.

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The solution to monitor harsh environments here presented requires the development of three different firmware versions:

- The RFID tag firmware which is dedicated to query each sensor gets the measured data and store them on its memory.
- The UAV Reader firmware which allows communicating with the GCS and, at the same time, looking for the tags and downloading data using the same radio interface.
- The GCS Firmware on the board connected to a PC through a USB interface. It acts as a gateway because it allows the communication with the UAV.

### 2.1 RFID Tags

The single RFID tag was developed to work with an autonomous off-line power supply (e.g. common lithium batteries). Low power consumption techniques are implemented providing, an adequate sampling rate of the values measured by the digital and analogic sensors installed on it.

The electronic board functionalities can be divided into the following subsystems:

- Power supply systems.
- Analog and digital sensors (temperature, humidity, pressure, accelerometer).
- Flash memory (Microchip, 2 MBit).
- Microcontroller (Texas Instruments CC340 Family);
- Radio frequency and serial communications.

The RFID tag is programmed to store the values measured by all the sensors every 60 minutes. Thanks to the Real-Time Clock (RTC), the microcontroller is able to wake up from the state LPM3 (Low Power Mode 3, the best in term of power consumption optimization), to read all the available sensors (also the sensors are switched off during stand by) and to store them on the flash memory. The data are formatted and compressed in order to store more than a year of records within the memory with a capacity of 2 Mbits and minimize transfer time. Each single record is composed by the following fields:

- Sensor ID (2 bytes).
- Date and Time of acquisition (6 bytes).
- Pressure sensor data (4 bytes).
- Humidity sensor data (6 bytes).
- Accelerometer sensor data (6 bytes).
- Temperature (2 bytes).

The total length of the record is 26 bytes (208 bits).

### 2.2 UAV Reader

The UAV Reader permits the radio connection between all the RFID tags to the GCS.

Figure 2. UAV and RFID reader

The reader is mounted on the UAV (Figure 2) which fly over the sensors according to a predefined route (if it is set by auto-pilot compatible software, e. g. APM Planner 2.0, Mission Planner or Andropilot) or being remotely controlled by a qualified operator. The first operation is to discover active RFID tags. Then each tags can transmits the stored parameters according to a specific anti-collision algorithm. Each radio message coming from the RFID tags is therefore routed to the GCS by the UAV Reader.

A special function to avoid a massive discharging of UAV batteries was required during the discovering phase, because of the intensive radio usage. To wake up the idle RFID tags, a burst of broadcast message is sent.

### 2.3 Ground Control Station (GCS)

The GCS is the main manager of the entire system. It consists in two elements:

- GCS Console.
- GCS RF Frontend.

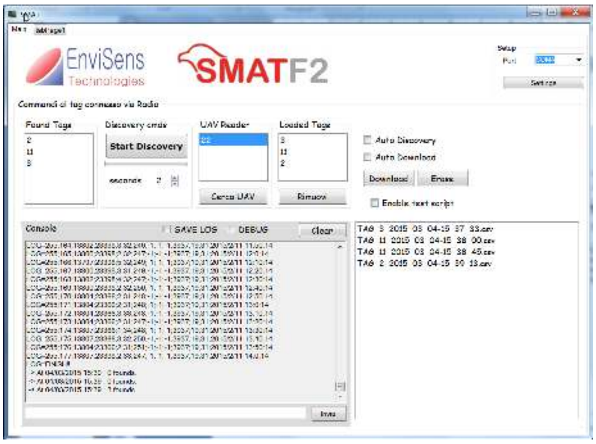


Figure 3. Ground Control Station Console

The GCS Console (Figure 3) is an application running on a PC, capable to manage all the functions of the systems. It is used to start the discovering procedure, to inquire the available RFID tags, to download data measured by each tag and to log a set of system information useful to keep under control the state of the entire system.

The commands corresponding to the functionalities activated by the GCS console are sent to the UAV reader exploiting the GCS RF Frontend (Figure 4). It is the radio interface of the GCS and it is connected through a RS-232 interface to the PC. All messages received from RS-232 are transmitted on RF channel and vice versa since it simply acts as a bridge.


Figure 4. Ground Control Station

## 3 TEST AND RESULTS

Three types of test have been performed:

- Laboratory test.
- Tags reading test in open fields.
- UAV test.

### 3.1 Laboratory test

Aim of the first set of tests was to check the proper working of the sensors, the basic radio communications features and the correct operation of the entire system.

At the end of the development a set of three tags was installed inside the EST s.r.l. laboratory for a week and sensors data were stored in memory every 10 minutes. The reader was not mounted below the UAV but it was placed in a specific point inside the laboratory as well as the GCS. Four times a day the discovery procedure was performed followed by data download (Figure 5).

The intensive test lasts the entire week and each tag collected more than 500 records. All record fields were correct except for the timestamp on a board (one over three). In fact the RFID tags are equipped with a watchdog system which reset and restarted automatically the tag if something anomalous happened and in this case a restart of the board caused once a reset of the timestamp (this error can be recovered if it is happen only once or if there are all the measures).

Results of this set of test show that the system is stable and could be tested in a more realistic situation.

### 3.2 Tags reading test in open field.

Aim of this second group of tests was to understand how fast the UAV can approach and fly over the tags to discover them and to correctly download data. Three RFID tags are placed over a straight path 100 m long and the GCS was located inside the EST s.r.l. laboratories with the RF Frontend communicating with the outside.

Three tests were performed. During the first test, the reader was held in the hand by an EST s.r.l. researcher walking at the common speed of 1.5 m/s (about 5 km/h). All the three tags were correctly discovered and data were downloaded without errors with a single passage of the operator in proximity of the RFID tags installations.

The second test was performed fixing the reader on a car moving at a speed of about 5 m/s (18 km/h), which is a common speed for multirotor UAV during patrol operations.

Also in this case, the tags discovery and download worked fine.

The third test was performed fixing the reader on a car moving at a speed of about 10 m/s (36 km/h), which is a common speed of a fixed wing UAV.

In this case, to discover the tags and download the measured data, the reader needed two passages.

The open field tests show that to discover all the tags and correctly download the data stored in their memory, the UAV needs to keep a flying speed of 5 m/s or at least two passages over the tags installation areas are required to discovery all the tags. This scenario is not a problematic if the monitored area is not too large and the UAV can flight without completely discharge its batteries before completing the entire route or the trajectory is composed by a round trip path-way.

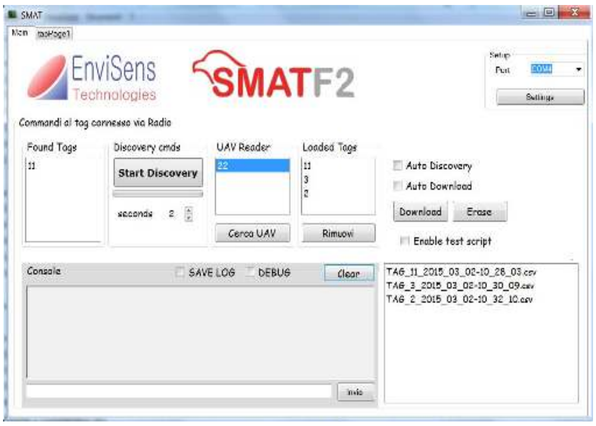


Figure 5. Laboratory tests results reported on the GCS console.

### 3.2 UAV test

During the final test the, UAV Reader has been fixed using a simple and economic four helix UAV, the 3DR IRIS, with a payload capability of 0.4 kg. All the functions were checked with three tags placed on the ground and the entire system works without problems. The download procedure was tested with the drone flying at 5 m/s at an altitude above ground of about 10 m and following a straight plan right above the tags.

Figure 6. UAV final test of the entire system

## 4 CONCLUSIONS AND OUTLOOKS

A solution for monitoring operation in harsh environment is presented. It is a system made by a set of RFID tags that can be equipped with a various set of sensors and distributed over the monitored area and a reader installed on the UAV. The UAV flies over the RFID tags, downloads data measured by the sensors and sends them to the GCS where the operator can manage all the system and even remotely control the UAV.

During the system realization great effort was dedicated to the implementation of low power consumption techniques in order to increase the operative life of each RFID tags without replacing their batteries.

The performed tests show that the system works properly.

In the future, two main different activities will be performed: the system will be tested in a real scenario (e. g. to monitor a landslide) and a further functionality will be implemented: the localization of RFID tags exploiting the RSSI (Received Strength Signal Indicator) measurements that can be made by the UAV reader by simply adding one more functionality to the firmware.

## References


[1] K. Martinez, R. Ong, and J. Hart, "Glacsweb: a sensor network for hostile environments", First IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks, Santa Clara, USA, 2004.

[2] O. Rorato, G. Greco, S. Bertoldo, C. Lucianaz, M. Allegretti, M. Curtaz, A. Roasio, S. Barone and G. Perona, "An ad-hoc RFID tag for glaciers monitoring", IEEE APWC 2014, Palm Beach, Aruba, 3-7 August 2014, pp. 864-867.

[3] C. Lucianaz, O. Rorato, M. Allegretti, M. Mamino, M. Roggero, F. Diotri, "Low Cost DGPS Network", IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications, Torino, 12-16 September 2011, pp. 792-795

[4] M. Allegretti, "Concept for Floating and Submersible Wireless Sensor Network for Water Basin Monitoring", Wireless Sensor Network, Vol 6, No. 6, pp. 104-108, 2014.

[5] O. Rorato, S. Bertoldo, C. Lucianaz, M. Allegretti, G. Perona, "A multipurpose node for wireless sensor network", IEEE APWC 2012, Cape Town, South Africa, 2-7 September 2012, pp. 247-250.