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GSM module for wireless radiation monitoring system via SMS

Nur Aira Abd Rahman^{1,3}, Noor Hisyam Ibrahim², Lojius Lombigit¹, Azraf Azman¹, Zainudin Jaafar¹, Nor Arymaswati Abdullah¹, and Glam Hadzir Patai Mohamad¹

¹Malaysian Nuclear Agency, 43000, Bangi, Selangor, Malaysia

²Rocksolid Simplified Solution PLT, 43000, Kajang, Selangor, Malaysia

³nur_aira@nm.gov.my

³nur_aira@nm.gov.my

Abstract. A customised Global System for Mobile communication (GSM) module is designed for wireless radiation monitoring through Short Messaging Service (SMS). This module is able to receive serial data from radiation monitoring devices such as survey meter or area monitor and transmit the data as text SMS to a host server. It provides two-way communication for data transmission, status query, and configuration setup. The module hardware consists of GSM module, voltage level shifter, SIM circuit and Atmega328P microcontroller. Microcontroller provides control for sending, receiving and AT command processing to GSM module. The firmware is responsible to handle task related to communication between device and host server. It process all incoming SMS, extract, and store new configuration from Host, transmits alert/notification SMS when the radiation data reach/exceed threshold value, and transmits SMS data at every fixed interval according to configuration. Integration of this module with radiation survey/monitoring device will create mobile and wireless radiation monitoring system with prompt emergency alert at high-level radiation.

1. Introduction

There are various types of nuclear instruments that are used to detect, measure, and identify radiation. These instruments are typically intended for safety purposes; to monitor the radiation level and to ensure the safety of radiation worker, public, and environment. An essential feature that could be added to enhance the capability of these instruments is wireless communication. Integration of the instruments with wireless communication will enable continuous radiation monitoring especially for remote locations, early radiation emergency warning, as well as wireless device setup, change, or query that satisfy the needs specific application.

Wireless technology has evolved from 1G (First Generation) to 4G LTE (Fourth Generation Long Term Evolution); each generation has brought improvement in terms of communication speed, bandwidth, security, and reliability. However, detail consideration must be done in selecting the best wireless technology that will suit the application of the system. Factors that should be taken into consideration are the strength and quality of cellular signal especially in rural monitoring sites and



offshores, power supply types and power consumption, size of data transfer, speed of data transfer or bandwidth, as well as design and production costs.

This paper reports the development of GSM module for radiation safety instruments such as survey meter and area monitor. The module is intended for wireless monitoring and early emergency warning. Data transmission involves radiation measurement data, instrument status, and configuration parameters that did not require big bandwidth or high transfer speed. On the other hand, reliability of the data to be sent on time, no data loss, low power consumption and low telecommunication signal are crucial. Hence the Short Messaging Service or SMS fits perfectly as it enable the device to reliably send data at low signal, and no data loss.

2. System design

Hardware and firmware development of the GSM module were done in parallel. Initially, the firmware was developed on Arduino platform; Arduino Uno [1] and GSM Shield for Arduino. The Serial Monitor in Arduino IDE is a very useful tool to echo communication between the microcontroller and GSM shield. This tool enables programmer to monitor and verify firmware operation in GSM shield responds and SMS data processing. Hence, the proof-of-concept prototype is successfully developed on Arduino platform. However, the Arduino GSM library was not utilized; instead, the microcontroller communicates with GSM shield by using AT Command to avoid dependency on the library as well as to maintain the flexibility of the firmware.

2.1. Hardware Design

A customized PCB is designed to create a single board that housed all the necessary design blocks as shown in figure 1. The voltage regulator circuit provides voltage supply to all the components on board based on their respective voltage specifications. Microcontroller Atmega328P controls and synchronizes the operation of the module; it controls the operation of GSM module, and handles data and commands from the external device. Telit GL865-DUAL/QUAD V3 module (Telit) is a compact GSM/GPRS module that suits portable and battery operated device. This IC acts as GSM modem that transmits and receives all the SMS for the GSM module.

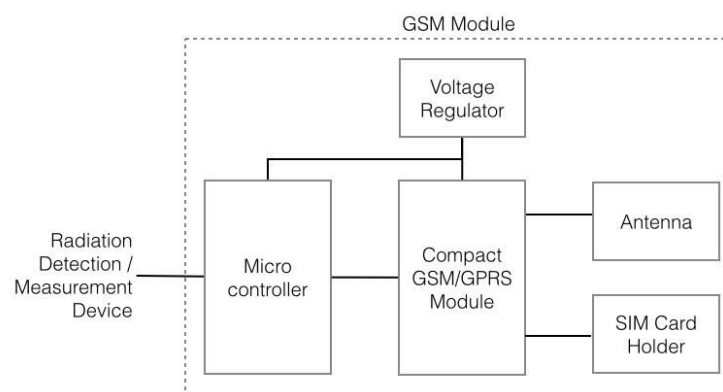


Figure 1. Block diagram of GSM PCB Module.

The PCB is designed based on Telit design recommendation. Voltage regulators are 3.8 Volts for GSM Module and 3.3 Volts for Atmega328P microcontroller. The resulting PCB is shown in figure 2. The compact size enables the PCB to be easily incorporated into the same enclosure of survey meter/area monitor or small compact casing for external connection.

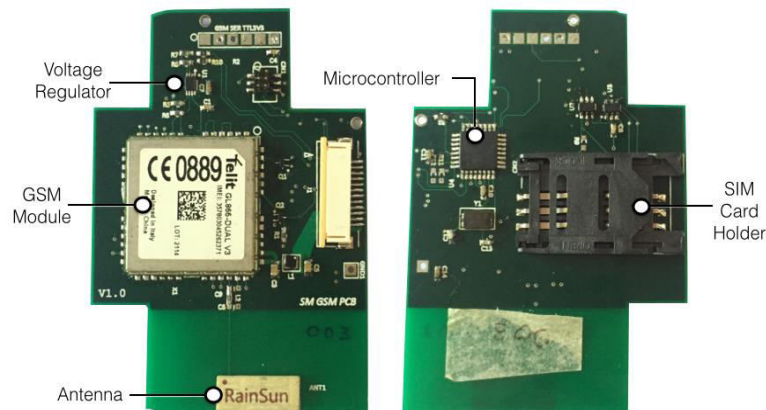


Figure 2. GSM PCB module and the main components placements for front view (left) and back view (right).

2.2. Firmware Design

Communication between GSM module and microcontroller is done using AT commands by using standard serial connection [2]. The GSM module is designed to enable wireless communication for radiation monitoring instrument intended for continuous data monitoring and emergency alert. There are three configuration parameters that are essential to complete the task; the Host number, time interval for data transmission, and threshold level for alert SMS. These parameters are stored in EEPROM of microcontroller. User will be able to change and update the configuration parameters via SMS. Firmware of GSM microcontroller is implemented as a finite state machine as shown as the state diagram in figure 3. The firmware is responsible to handle task related to GSM/SMS communication with the Host server.

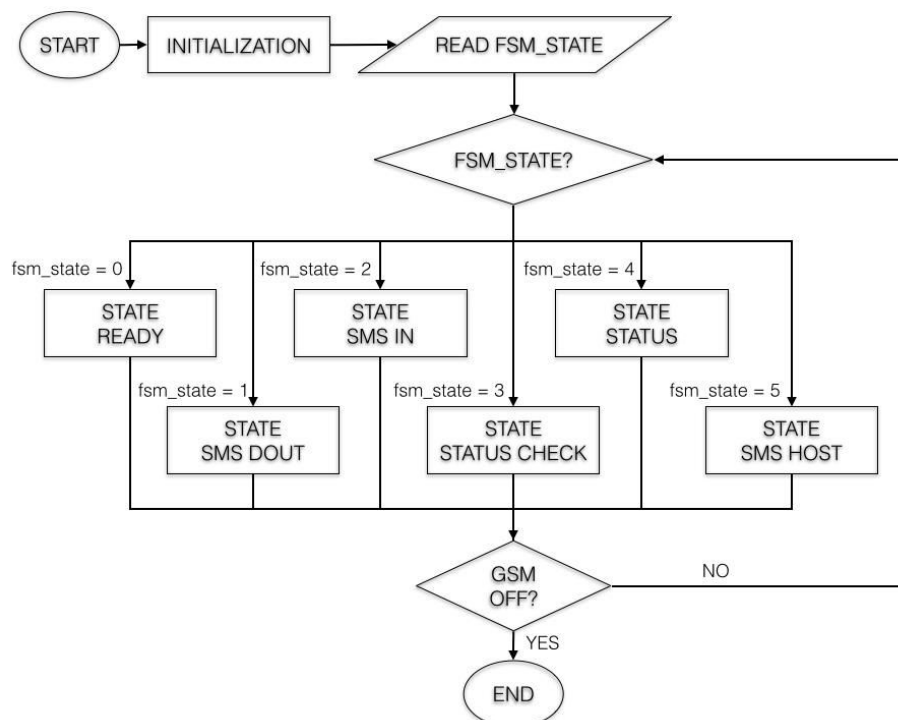


Figure 3. Finite State Machine (FSM) for the GSM microcontroller firmware.

Each state in the FSM handles specific tasks of the GSM module as listed below:

- State Ready (St_Ready) - the default state that determines the other states priorities and initiate the state events execution. Each state priority is shown in St_Ready flowchart in figure 4.
- State SMS Data Out (St_SMS_Dout) - send SMS at every fixed time interval according to configuration parameter.
- State SMS In (St_SMS_In) - process all incoming SMS. There are there possibilities for the received SMS; SMS from host to change parameter configuration (either host number, data transmission time interval, or alert threshold value), SMS from any senders to query instrument status, and unrelated SMS. St_SMS_In compute the SMS type, and execute further process accordingly. All the SMS will be deleted at the end of the process to avoid full SMS inbox in the SIM card.
- State Status Check (St_Status) - handles in-situ status query from the connected instrument. It will returns all three configuration parameters to the instrument. This is useful if the user on-site wants to view the information. Optionally the information can be displayed on the instrument display. This state will also update new configuration status upon configuration change via SMS.
- State SMS Alert (St_SMS_Alert) - handles alert notification SMS to Host whenever the radiation data reach or exceed threshold value parameter.

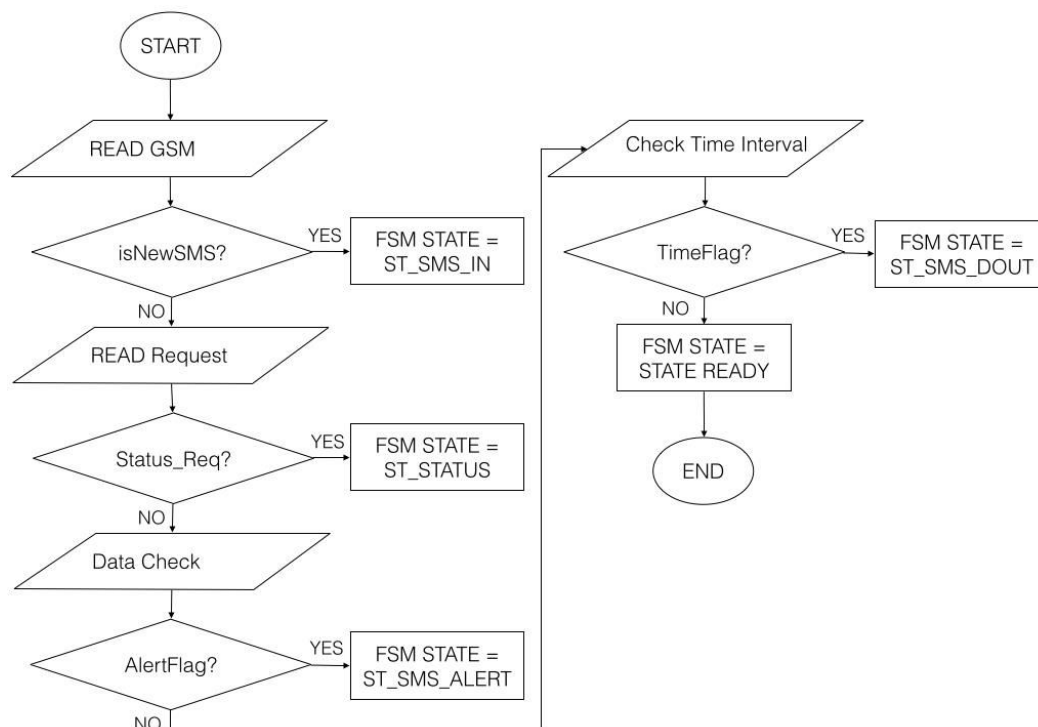


Figure 4. St_Ready (default state) flowchart and the states priorities.

2.3. AT Command and SMS PDU Processing

Communication between microcontroller and Telit is done by using AT Command via serial connection. AT commands are list of standard instructions that is used to control a modem. For example, AT+CMGD is a command used to instruct Telit to delete SMS. In order to simplify the SMS processing, AT+CMGF=1 is used to instruct Telit for SMS in text mode. In default state (St_Ready),

microcontroller frequently checks its serial receive buffer in case there is new notification or status from Telit GSM (ReadGSM). All incoming SMS is temporarily copied and stored in the firmware array buffer. It is crucial for the microcontroller to identify and process SMS intended for the system. In this case, the module is expected to receive three types of SMS:

- SMS from Host or any sender to check the status
- SMS from Host to change configuration parameter (Host number, data time interval, threshold value for alert)
- Other unrelated SMS

An example of a received SMS is as follows:

```
+CMGL: 5, "REC UNREAD", "+60123030224", "", "2016/06/09 11:27:35+32"
@HOST SCFG H+60162324045 I5 T3
```

The first line consists of information on location index of the SMS in the message storage area, status of the SMS message ("received unread", "received read", etcetera), originator phone number, and timestamp at which the SMS message arrived at the SMSC. The second line is the body of SMS that might contain request instruction or configuration parameter from the host. Hence, the SMS body is designed to contain markers or keywords that could be identified by the microcontroller. The keyword '@HOST' is used to identify that the SMS is a host SMS and 'SCFG' is a marker for configuration SMS. Subsequently, the microcontroller will be able to extract the information from the SMS and execute the next function respectively.

3. Results and Discussions

The first variant of this GSM module is designed to be integrated with a survey meter prototype. The PCB is connected to survey meter PCB by a customised flexible PCB cable and fitted inside the same enclosure as shown in figure 5.



Figure 5. GSM module for survey meter.

The GSM module has been tested to verify its functionality. These involved transmitting a series of SMS to the GSM module to update the configuration parameters i.e. the time interval, host number, and threshold values. Results had shown that the GSM module was able to identify and compute incoming SMS and responded accordingly. The result for time interval configuration update for 3, 5, and 10 minutes is shown by the timestamp in figure 6.

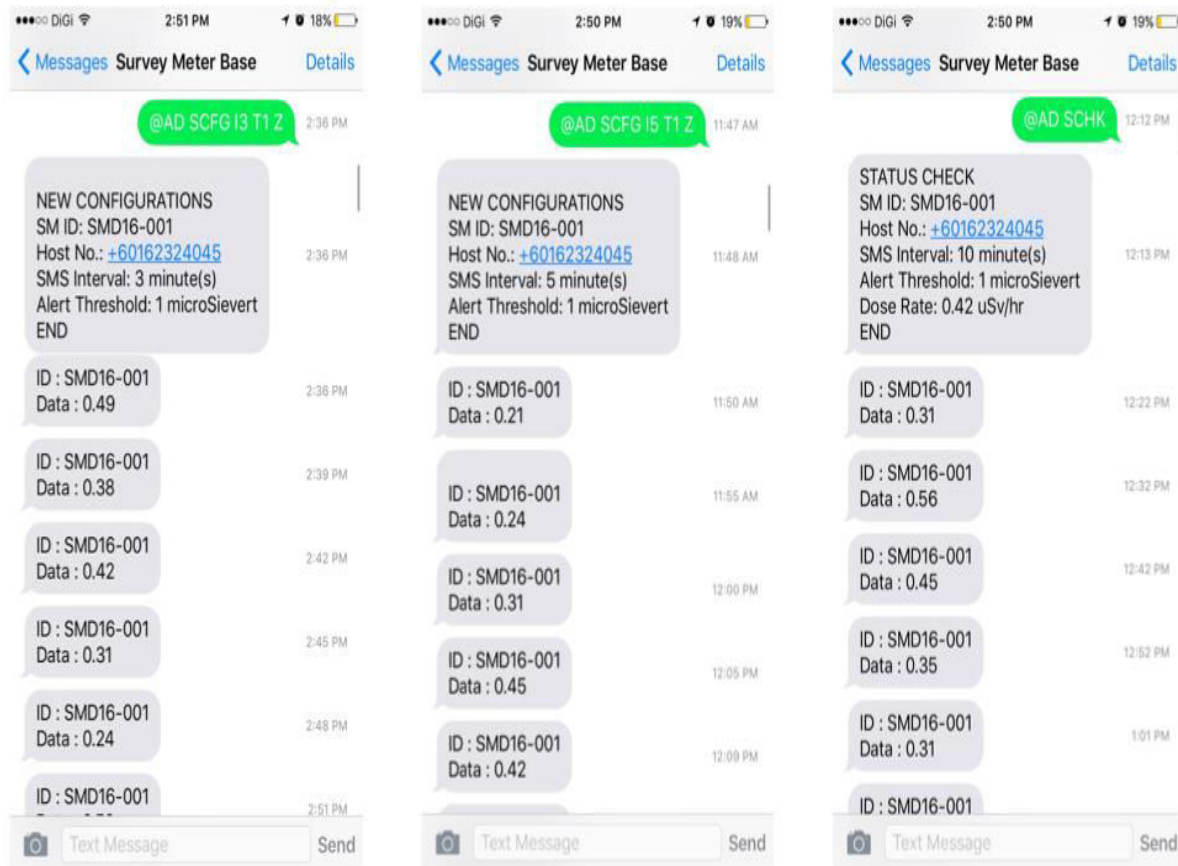


Figure 6. Data SMS at interval of 3, 5 and 10 minutes.

The GSM module also enables user to query the status of device and current data at anytime. The microcontroller firmware is programmed to identify keywords “@AD SCHK” for status query and returns status SMS to the sender as shown in figure 7. On the other hand, Host can change the configuration parameter via SMS with keywords “@AD SCFG”. The microcontroller will extract the configuration data and update the EEPROM respectively. This new configuration will be retained until the next configuration SMS. Upon successful update, the GSM module will return the configuration SMS to Host as shown in figure 7.

Finally, the GSM module is tested to send alert SMS whenever the radiation measured exceed the threshold value. This feature is beneficial for prompt or early emergency alert in radiation monitoring and safety. The GSM module should respond by transmitting alert SMS immediately, regardless of the data time interval. In this case, the GSM module is tested with a check source and the corresponding alert SMS is shown in figure 8.

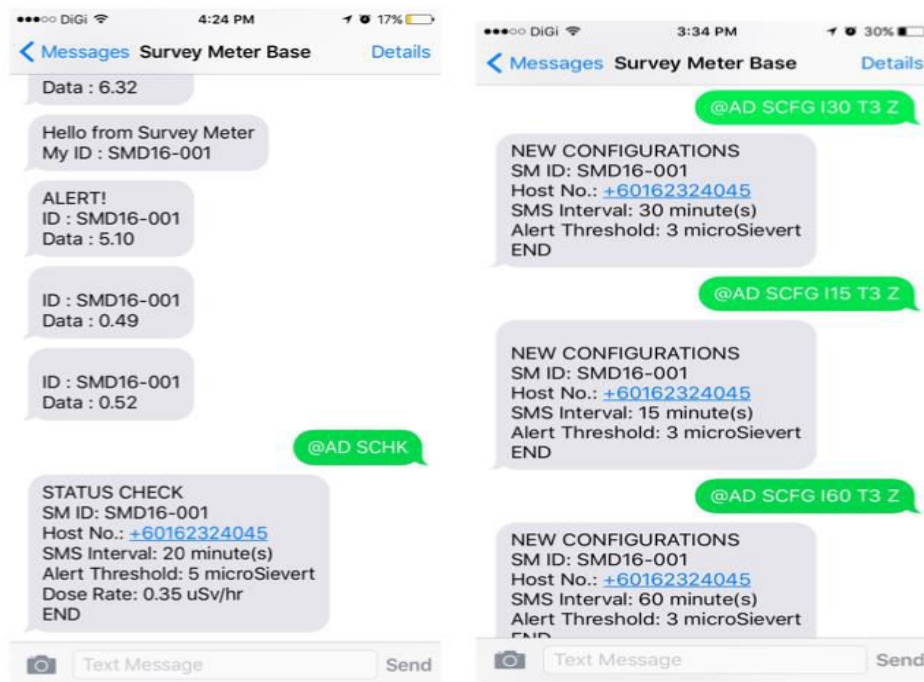


Figure 7. Status query SMS (left) new configuration update SMS (right).

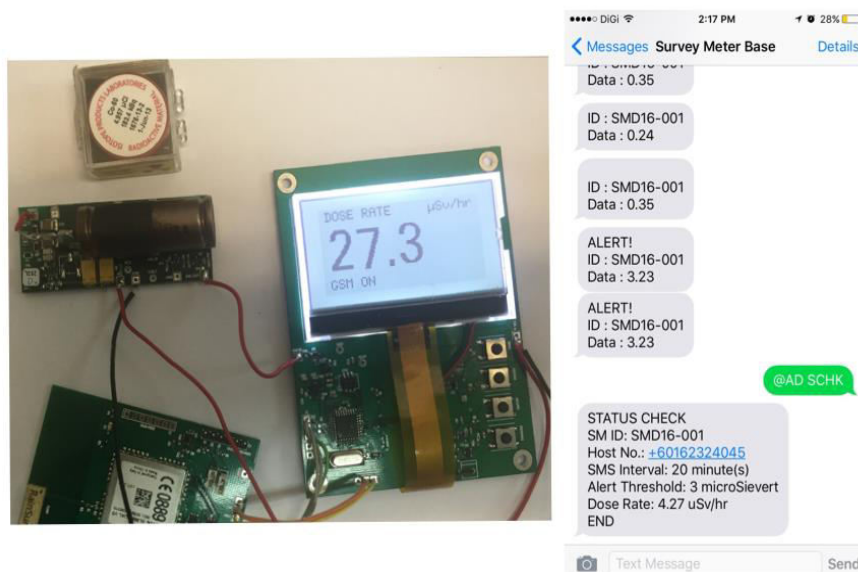


Figure 8. Alert SMS for radiation level higher than threshold value.

4. Conclusion and Future Works

A small and compact GSM module has been successfully designed, fabricated, and tested. The GSM module was designed to be integrated with radiation detection and measurement instrument such as survey meter and area monitor to enable wireless radiation monitoring and early warning system. The main components of the module were Atmega 328P microcontroller (Arduino Uno) and Telit compact GSM/GPRS module. A series of tests has proven that the module was functioning according to designed specifications. Future works includes power saving implementation on the firmware to prolong the battery life.

5. References

- [1] Projects M 2015 The Evil Goat (Arduino Project) 102–103
- [2] Zhang L, Wang X, Wang C, and Gu X 2011 The application of stolen radioactive source tracking system based on internet of things technology *Proc. 3rd Int. Conf. on Measuring Tech. and Mechatronics Automation ICMTMA 2011* **3** 696–698.

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