# DESIGN & IMPLEMENTATION OF REMOTE RADIATION SURVEILLANCE UNIT

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

**Submitted by**
Name: Md. Mohibbul Hasnat Naim    ID: 212-33-5396
Name: Md. Nazmul Islam    ID: 212-33-5397

**Supervised by**
Sagor Hazra
Lecturer
Department of Electrical and Electronic Engineering

Department of Electrical and Electronic Engineering
Faculty of Engineering
DAFFODIL INTERNATIONAL UNIVERSITY

**JANUARY, 2025**

# DECLARATION

I hereby declare that this project, “**Design & Implementation of Remote Radiation Surveillance Unit**” represents our own work, which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. We have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged my obligations and the rights of the participants.

**Signature of the candidates**

Name: Md. Mohibbul Hasnat Naim
ID: 212-33-5396

Name: Md. Nazmul Islam
ID: 212-33-5397

# APPROVAL

The project entitled **“Design & Implementation of Remote Radiation Surveillance Unit”** submitted by **Md. Mohibbul Hasnat Naim (212-33-5396) & Md. Nazmul Islam (212-33-5397)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **January, 2025.**

Signed

15/01/25

**Sagor Hazra**
Lecturer
Department of Electrical and Electronic Engineering
Faculty of Engineering
Daffodil International University

Dedicated

To

Our beloved parents for their unwavering support and our teachers for their guidance. We are also grateful to everyone who has inspired us along this journey.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF ABBREVIATIONS

| | |
|---|---|
| GM | Geiger Muller |
| CF | Conversion Factor |
| CPS | Count Per Second |
| CPM | Count Per Minute |
| mR | Mili Rontgen |
| µSv | Micro Sievert |
| GM | Geiger Muller |
| VCC | Positive Supply Voltage |
| GND | Ground Line |
| LED | Light Emitting Diode |
| LCD | Liquid Crystal Display |
| OLED | Organic Light Emitting Diode |
| USB | Universal Serial Bus |
| UAV | Unmanned Arial Vehicle |
| DPDT | Double Pole Double Through |
| PCB | Printed Circuit Board |
| RF | Radio Frequency |
| I2C | Inter-Integrated Circuit |
| Li-Po | Lithium Polymer |
| CCB | Copper Clad Board |

# LIST OF SYMBOLS

| | |
|---|---|
| Bq | Becquerel |
| Ci | Curie |
| Gy | Gray |
| Sv | Seivert |
| R | Roentgen |
| eV | Electro Volt |
| µ | Micro |
| m | Mili |
| h | Hour |
| Co | Cobalt |

# ACKNOWLEDGEMENT

We want to thank **Almighty Allah**. With his blessing, we are able to complete our work with the utmost effort.

We want to pay our utmost respect to our Supervisor **Sagor Hazra, Lecturer** of the **Department of EEE, Daffodil International University,** for who has given us the chance to work on an impactful idea and taken care of every issue of development of this concept. Then, we would like to take this opportunity to express gratitude to our supervisor for being dedicated to supporting, motivating, and guiding us throughout this project. This project couldn't have been done without his helpful advice and help. Also, thank him very much for giving us the opportunity to work on this project.

We also want to thank the late **Dr. Md. Shahid Ullah, Professor and Head of the Department of EEE**, **Daffodil International University**, for his support and encouragement.

We would like to thank our entire class fellows for sharing knowledge and information and helping us make this project a success. To our beloved family, we want to give them our deepest love and gratitude for their support, inspiration, and encouragement during our studies at this Institution.

# ABSTRACT

This project report presents the design and development of a "Remote Radiation Surveillance Unit", which is a cost-effective solution for remotely monitoring radiation levels in hazardous environments. Continuous radiation monitoring is essential in various sectors, including nuclear power plants, industry, and healthcare. While many radiation measurement devices are available, most require manual operation by the user and are costly. This project aims to address the need for remote monitoring while keeping the costs to a minimum. The device is designed to detect radiation levels, transmit real-time data, and navigate difficult terrains for remote monitoring, minimizing human exposure risk.

The system consists of a remote-controlled vehicle that carries the radiation detector to hazardous areas. The radiation detector module is based on a GM Tube. The device accurately measures ionizing radiation and records GPS coordinates. It then transmits this data to the user via wireless communication and a server, allowing anyone to monitor from anywhere in the world.

This project successfully achieves its goal of developing a low-cost and efficient radiation monitoring system. Additionally, it provides a foundation for future enhancements, such as better radiation detection capabilities, greater range, and improved durability. This innovation has considerable potential for use in Bangladesh and other areas that need affordable radiation monitoring solutions.

**Keywords:** *Radiation Monitoring, Remote Control, Geiger-Müller Tube, Ionizing Radiation, Portable System, Remote Surveillance, Hazardous Environments, Real-Time Data Transmission, Cost-Effective Solution.*

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Radiation monitoring plays a critical role in ensuring the safety of individuals and the environment, particularly in areas exposed to harmful radiation. However, traditional radiation detectors, such as the Gamma-Scout or other commercially available devices, are often expensive and lack real-time remote monitoring capabilities. These limitations make them inaccessible to many users, especially in resource-constrained environments.

The growing need for an affordable and accessible solution led to the conceptualization of a Remote Radiation Surveillance Unit. By leveraging the capabilities of modern microcontrollers and IoT technology, this project aims to design a low-cost radiation detection system that can transmit real-time data to an online platform. This ensures continuous monitoring and access to radiation levels from anywhere in the world, addressing both cost and functionality challenges.

## 1.2 Problem Statement and Proposed Solution

Conventional radiation detection systems are limited in functionality. They are either too expensive or lack features such as remote monitoring and mobility. They are unsuitable for situations where radiation levels are too high for humans to approach, as they require manual operation. Furthermore, most existing systems cannot provide the real-time location of radiation measurements.

This project proposes the development of a *Remote Radiation Surveillance Unit* integrated with a mobile platform—a remote-controlled car—designed to carry the radiation detector into hazardous areas. The vehicle is controlled via an NRF24L01 module, allowing it to be operated remotely. The system measures radiation levels and determines the GPS location using the A9G GPS/GPRS module, sending the radiation data and location to a cloud server like ThingSpeak. This solution ensures a low-cost, real-time, online monitoring system with enhanced functionality and user safety.

## 1.3 Objectives

The primary objectives of this project are:

- To design and build a low-cost radiation detection system using affordable components like GM tubes.
- Integrate the system with a remote-controlled vehicle, enabling it to measure radiation levels in areas inaccessible or dangerous for humans.
- To utilize the A9G GPS/GPRS module to capture and transmit the GPS location along with radiation data to a cloud server for real-time monitoring.
- To ensure reliable communication between the remote-controlled car and the user using the NRF24L01 module.
- To ensure the affordability of the system while maintaining accuracy and efficiency.

## 1.4 Implementation Schedule

The project is divided into the following phases:

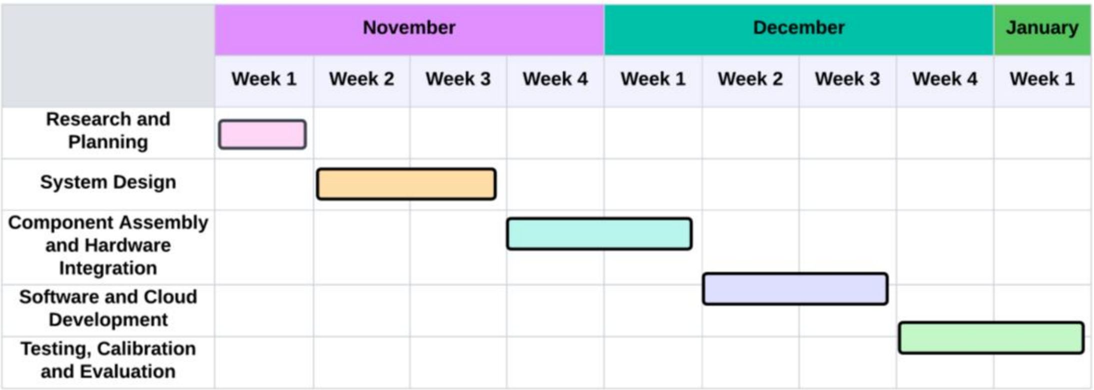
**Phase 1 (Weeks 1) Research and Planning:** Research the current radiation detectors and IoT systems. Choose cost-effective components, including the GM tube, NRF24L01 module, and A9G GPS/GPRS module.

**Phase 2 (Weeks 2-3) System Design:** Design the system architecture with a focus on integrating the radiation detector with the A9G Module, the remote-controlled car, and the communication modules. Develop the communication interface for the NRF24L01 module.

**Phase 3 (Weeks 4-5) Component Assembly and Hardware Integration:** Assemble the car's radiation detector, GPS module, and control system based on NRF24L01. Complete PCB Design and make PCB. Ensure a seamless data flow from the detector and GPS module to the microcontroller.

**Phase 4 (Weeks 6-7) Software and Cloud Development:** Develop firmware for data acquisition and wireless transmission to the ThingSpeak server. Set up the ThingSpeak dashboard for real-time monitoring of radiation levels and location.

**Phase 5 (Weeks 8-9) Testing, Calibration, and Evaluation:** Test the car’s movement and communication reliability. Evaluate the system's accuracy for radiation detection and GPS data under various conditions, and make adjustments to improve efficiency and performance.



| | November | | | | December | | | | January |
|---|---|---|---|---|---|---|---|---|---|
| | Week 1 | Week 2 | Week 3 | Week 4 | Week 1 | Week 2 | Week 3 | Week 4 | Week 1 |
| Research and Planning | ■ | | | | | | | | |
| System Design | | ■ | ■ | | | | | | |
| Component Assembly and Hardware Integration | | | | ■ | ■ | | | | |
| Software and Cloud Development | | | | | | ■ | ■ | | |
| Testing, Calibration and Evaluation | | | | | | | | ■ | ■ |

Fig. 1.4.1 Gantt Chart

## 1.5 Structure of the Report

This report is organized into the following chapters:

**Chapter 1 Introduction:** This section provides an overview of the project, including the background, problem statement, proposed solutions, aims, and timeline.

**Chapter 2 Literature Review:** Examines existing radiation detection technologies, remote monitoring systems, and IoT applications. It identifies the limitations of current systems and explains how this project addresses those gaps.

**Chapter 3 Methodology:** Details the methods and working principles used to design and implement the system, including the design specifications, standards, constraints, and system analysis.

**Chapter 4 Hardware and Software Integration:** Describes the system's hardware and software architecture, focusing on the integration of the Geiger-Müller tube, GPS/GPRS module, and remote-controlled car. It includes the design, assembly, testing, and programming of the NRF24L01-based control system, GPS data acquisition, and cloud-based data transmission.

**Chapter 5 Result and Discussion:** This section presents the system's performance, including test results for radiation detection, GPS accuracy, and remote car control under different conditions.

**Chapter 6 Project Management:** Discusses the project’s budget, resource allocation, time management strategies, and overall system management throughout the development cycle.

**Chapter 7 Impact Assessment of the Project:** This chapter evaluates the broader implications of the Remote Radiation Surveillance Unit, discussing its technical, economic, and societal impacts.

**Chapter 8 Conclusion and Recommendation:** Provides a summary of the project, highlighting key takeaways, challenges encountered, and recommendations for enhancing the system in future iterations.

**References:** Lists all sources cited in the report, including technical papers, manuals, and online resources.

**Appendices:** Includes supplementary materials such as hardware schematics, source code, and additional documentation.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

Radiation detection and monitoring have been critical areas of research and development due to their importance in various fields, including nuclear safety, medical diagnostics, and environmental protection. Over recent years, the development of compact, efficient, and cost-effective radiation monitoring devices has gained attention. This literature review aims to explore existing technologies, devices, and methodologies for radiation detection, identify gaps in current systems, and provide a foundation for the proposed Remote Radiation Surveillance Unit.

## 2.2 Related Research/ Works

Yang Ishigaki et al. (2015) developed the Pocket Geiger (POKEGA), a low-cost and mobile radiation detector aimed at personal radiation monitoring after the 2011 Fukushima disaster. The device uses a p-i-n photodiode detector connected to a smartphone, which handles data processing and utilizes GPS for logging and sharing results. Field tests in the Fukushima evacuation zone addressed issues like vibration noise and energy consumption. Over 12,000 units were shipped, and 2,000 users joined a Facebook community to discuss improvements. The study highlights a new approach to sensor networking for emergency response and consumer-driven measurement [1].

M. J. Hossen et al. from Hajee Mohammad Danesh Science and Technology University studied the background radiation levels in the northwestern mining area of Bangladesh, focusing on radiation from cosmic rays and naturally occurring radioactive materials such as 40K, 226Ra, 238U, and 232Th. Using a GM counter, the team measured radiation levels at various locations in granite and coal mining areas. Their results indicated no abnormal radiation counts, suggesting that there is minimal risk of acute health effects on workers and the general public due to background radiation in the area. The study highlights the importance of monitoring background radiation in mining regions to ensure public safety [2].

Muhammad Ikmal Ahmad et al. from Universiti Kebangsaan Malaysia introduced a wireless radiation monitoring system designed for use in nuclear facilities. This system utilized an Arduino microcontroller paired with a Geiger-Muller tube to monitor radiation levels. The collected data is wirelessly transmitted to a central station for real-time processing and display. The system aims to reduce human exposure to radiation by allowing continuous remote monitoring. The prototype was tested successfully, demonstrating its ability to function effectively in radiation-prone environments, offering a safer and more efficient way of monitoring radiation. This system provides a cost-effective solution for nuclear facilities [3].

V. A. Kulikova et al. from Peter the Great St. Petersburg Polytechnic University, Russia, developed a model for a remote radiation monitoring system that can automatically collect and transmit environmental radiation data. The system is designed to support both radiation detection and environmental monitoring, especially around nuclear facilities. It helps reduce the need for human involvement in hazardous radiation zones. The system also improves the safety of workers by ensuring real-time data transmission to a central monitoring station. This technology provides significant advantages in maintaining continuous radiation safety and is especially valuable during nuclear emergencies [4].

Wiboi et al. from the University of Strasbourg, France, examined the impact of environmental factors on radiation detection systems and proposed enhancements for improving sensitivity and performance. They developed algorithms that can minimize background noise and enhance the accuracy of the readings. Their study emphasized the importance of adapting radiation detection systems to complex and challenging environments where conventional systems might fail. The research aimed to improve radiation monitoring in environments with fluctuating or complex conditions, ensuring more accurate detection and fewer false alarms. These innovations are crucial for ensuring reliable tracking in sensitive or high-risk areas [5].

Newaz Morshed Remon et al. from the Military Institute of Science and Technology, Dhaka developed a simple and cost-effective Geiger-Muller (GM) counter. The project aimed to create a low-cost detector capable of identifying radiation, leveraging the GM tube's ability to detect the presence and intensity of radiation efficiently. Despite its simplicity, the GM tube offers practical utility in nuclear science applications where detailed analysis is not required. This study underscores the accessibility of radiation detection tools through affordable and straightforward designs, making them suitable for educational and basic research purposes [6].

Ahnaf Tahmid Chowdhury et al. from the Military Institute of Science and Technology, Dhaka, explored the development of an advanced radiation monitoring system that combines Geiger-Muller tubes and ionization chambers. The data collected from these devices is transmitted to a centralized monitoring station for real-time analysis and alerts. The system is designed to ensure radiation safety in both industrial and residential settings. The integration of real-time data processing allows immediate action if radiation levels rise above acceptable thresholds. This approach enhances the ability to prevent accidents and ensures better protection for people in radiation-sensitive environments [7].

N.N. Ghuge et al. from JSPM’s BSIOTR, India, developed a radiation survey meter using a Geiger-Muller tube to measure gamma radiation levels. The device is powered by a boost converter that powers the GM tube and provides data to an LCD screen. It is aimed at non-technical users, allowing them to monitor radiation in both work and home environments easily. The system also includes a USB interface to store and transfer radiation data for further analysis. This portable, low-cost solution offers a practical radiation detection and monitoring tool, ensuring safety and early detection in everyday settings. The prototype was tested and demonstrated effective in various conditions [8].

Daniel Gomes de Assunção et al. from UNIARA, Brazil, developed a remote radiation monitoring system to enhance the safety of workers during nuclear facility maintenance. The system integrates radiation monitoring devices with video cameras and an interface that transmits data over an Ethernet connection. Collecting radiation data and images provides comprehensive monitoring of potentially hazardous environments, ensuring that workers can access real-time information. The system's design aims to improve operational efficiency by providing immediate feedback and reducing the need for personnel to enter radioactive zones. This solution can potentially reduce radiation exposure during routine operations. The device was successfully designed and tested, confirming its practicality [9].

Saja S. Hasan et al. from Mustansiriyah University, Iraq, proposed a radiation monitoring system using a Geiger-Muller counter integrated with an Arduino microcontroller. The system transmits real-time radiation data to the microcontroller, which processes and displays the information on an LCD screen. It is designed to be used in radiation-contaminated areas for quick and effective monitoring. The data collection process is automated and offers an easy-to-use interface. The results showed that the system was efficient and feasible to successfully deliver reliable radiation monitoring. This modular design proves practical for applications in hazardous environments [10].

Mahammad D.V from Rayalaseema University, India, designed an Internet of Things (IoT)-based portable Geiger-Muller counter to monitor radiation levels. The system uses a SparkFun Geiger counter board (SEN-11345) and a NodeMCU microcontroller for data collection, while the Blynk app serves as the IoT cloud server to store and visualize data. This setup allows users to monitor radiation levels from any location in real-time, using a mobile app to receive alerts and track changes. The system transmits data over a Wi-Fi network, offering easy access and remote monitoring capabilities. It was tested successfully, with the performance meeting the required standards. The device provides an accessible solution for radiation detection in real-world applications [11].

Shin-ichi Okuyama et al. from the Japan Atomic Energy Agency, Japan, conducted a feasibility study of a remote radiation monitoring system using an autonomous unmanned helicopter. The system, equipped with radiation detectors and cameras, automatically flies to specified destinations and collects data during its flight. It transmits real-time data, including images, to a monitoring station on the ground, providing a comprehensive view of radiation distribution. This system allows for remote surveying of environmental radiation, which can be particularly valuable during nuclear emergencies. Flight tests confirmed that the system successfully measured fluctuations in radiation levels on the ground, making it an effective tool for emergency situations. This autonomous system offers enhanced safety and operational efficiency in radiation monitoring [12].

A report on remote data transmission for nuclear inspections outlined the growing importance of remote monitoring for nuclear facilities. It highlighted the increasing strain on inspection resources due to the rise in spent fuel casks in storage and the potential radiation exposure to inspectors. The report discussed the challenges of implementing remote data transmission, including security issues, data collection, and reliable communication. It also emphasized the importance of such systems for monitoring new facility types, like small modular reactors, which rely heavily on remote data. The need for these technologies is becoming more urgent, as remote data transmission can significantly reduce inspection efforts and improve safety. The challenges, however, remain a barrier to widespread implementation [13].

Fábio Lacerda et al. from Comissão Nacional de Energia Nuclear, Brazil, introduced the Modular Remote Radiation Monitor (MRRM), a low-power, portable device designed for environmental radiation monitoring. This microprocessor-based system is compact and modular, allowing for customization based on application needs. It supports wired and wireless communication to transmit monitoring data to other systems, offering flexibility in setup. The MRRM is capable of being connected to a network of monitors, enabling remote control and visualization of radiation levels. The prototype was successfully tested in a nuclear reactor environment, demonstrating its effectiveness. Future development aims to create a consumer version of this device, providing an efficient solution for radiation monitoring [14].

Volodymyr Burtniak et al. from the Institute of Environmental Geochemistry, Ukraine, developed a system for mapping radiation fields in the Chornobyl zone using an unmanned aerial vehicle (UAV). The UAV is equipped with a radiation detector and collects real-time data on radiation sources in heavily contaminated areas. With a spatial resolution of approximately 0.5 meters, the system can accurately map radioactive hotspots, even in undulating forested terrains. The technology effectively identified small radioactive spots and measured surface contamination with high sensitivity. This UAV-based system is valuable for monitoring areas where ground access is difficult or dangerous, offering a reliable method for radiation mapping in hazardous zones [15].

Ivan Morales et al. from Texas Instruments, USA, presented a Geiger-Muller dose rate meter designed to be low-cost and high-quality for radiation detection. Using an MSP430 microcontroller, the device includes an analog front-end and high-voltage electronics for efficient operation. The meter is intended for use in delicate environments like hospitals and hazardous waste storage, where radiation exposure must be monitored closely. The device was calibrated to measure ambient dose rates and showed promising results in accuracy and performance. It serves as an affordable alternative for environments requiring precise radiation monitoring, with the potential to prevent radiation accidents. The successful prototype validation confirmed its capability as a reliable radiation detection tool [16].

Marcia Dutra R. Silva (2015) discussed the omnipresence of ionizing radiation in the natural environment and its potential health risks when levels exceed acceptable limits. The study emphasized the necessity of systematic monitoring to prevent adverse health effects, including overexposure and fatalities. Detection methods rely on interactions between radiation and sensitive materials, utilizing various detectors in solid, liquid, or gaseous states to measure specific types of ionizing radiation. The research also highlighted the exploration of new materials, such as organic semiconductors, as promising candidates for innovative ionizing radiation sensing technologies [17].

Several commercial radiation detection systems have been developed to ensure precise and reliable monitoring. For example, the Gamma Scout Meter is a widely used device for detecting gamma, beta, and alpha radiation [18]. It is portable and provides long-term data logging capabilities. Another notable product, the DMC 3000 Personal Dosimeter (Stuart Hunt), is designed for personal radiation monitoring in professional environments, with features like real-time dose measurement and alarm functions. However, these devices lack real-time data transmission and remote monitoring capabilities, which limits their usability in hazardous environments [19].

Open-source and DIY solutions provide affordable alternatives for radiation detection. The Geiger Counter Project on GitHub [20] and the ESPHome Geiger Counter [21] are low-cost designs using GM tubes and microcontrollers. These projects often prioritize simplicity and affordability over features like data transmission or integration with IoT platforms. The DIY Geiger Counter project also highlights the versatility of GM tubes, providing insights into their application and calibration [22].

Several studies and technical resources provide detailed analyses of GM tube performance and radiation detection principles. For example:

**Comparison of GM Tubes**: This study compares different GM tubes (SBM20, J305, and LND712) regarding sensitivity and efficiency, concluding that J305 is cost-effective for general radiation detection. At the same time, LND712 excels in detecting alpha radiation [23].

**Radiation Units and Quantities:** This section provides an overview of radiation units, conversion factors, and measurement standards, which are crucial for interpreting Geiger counter data accurately [24].

**Advanced Detector Technologies**: Discusses the evolution of semiconductor detectors and their applications in high-precision radiation monitoring [25].

## 2.3 Compare and Contrast

**Strengths of Existing Systems:** Commercial radiation detection systems, such as the Gamma Scout and DMC 3000, provide high accuracy and reliability, making them ideal for professional applications. They are designed to ensure precision in radiation measurement, which is critical in environments requiring stringent monitoring. On the other hand, DIY solutions offer cost-effective alternatives, promoting accessibility and customization. These solutions empower individuals and hobbyists to develop functional radiation monitoring devices at a fraction of the cost of commercial systems.

**Weaknesses of Existing Systems:** Despite their benefits, commercial systems are frequently too costly and do not integrate with the Internet of Things, which restricts their ability to provide real-time remote monitoring. Despite being reasonably priced and adaptable, do-it-yourself products typically lack accuracy and are not sturdy enough for long-term or professional use. This compromise between cost and usefulness is a major drawback of current systems.

**Research Gaps and Recommendations:** Current systems reveal several research gaps, such as the lack of an affordable radiation monitoring device equipped with real-time data transmission. Furthermore, there is a noticeable absence of IoT platform integration to facilitate remote monitoring and advanced data analysis. Another critical gap is the limited capability of low-cost solutions to detect alpha radiation, which is vital in specific applications.

The proposed *Remote Radiation Surveillance Unit* addresses these gaps by combining affordability with IoT integration and modularity. This design ensures usability in hazardous environments while enabling efficient remote monitoring, thereby overcoming the limitations of both commercial and DIY systems.

## 2.4 Summary

This chapter reviewed existing radiation detection systems, from commercial products to DIY projects, and highlighted their strengths and limitations. While commercial systems are precise, they are often expensive and lack remote monitoring capabilities. DIY solutions offer affordability but are not robust for professional use. The identified research gaps validate the need for a low-cost, IoT-enabled radiation monitoring system, paving the way for the proposed project's development.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter presents the organized approach followed in the development of the *Remote Radiation Surveillance Unit*. It highlights the systematic steps taken to define system requirements, design the architecture, analyze system performance, and comply with relevant standards. This structured process ensures that the project achieves its goals of affordability, accuracy, and reliability while adhering to safety and technical benchmarks.

## 3.2 System Overview

The project integrates a mobile platform, radiation detection, GPS tracking, and wireless data communication to enable real-time monitoring of radiation levels in high-radiation areas.

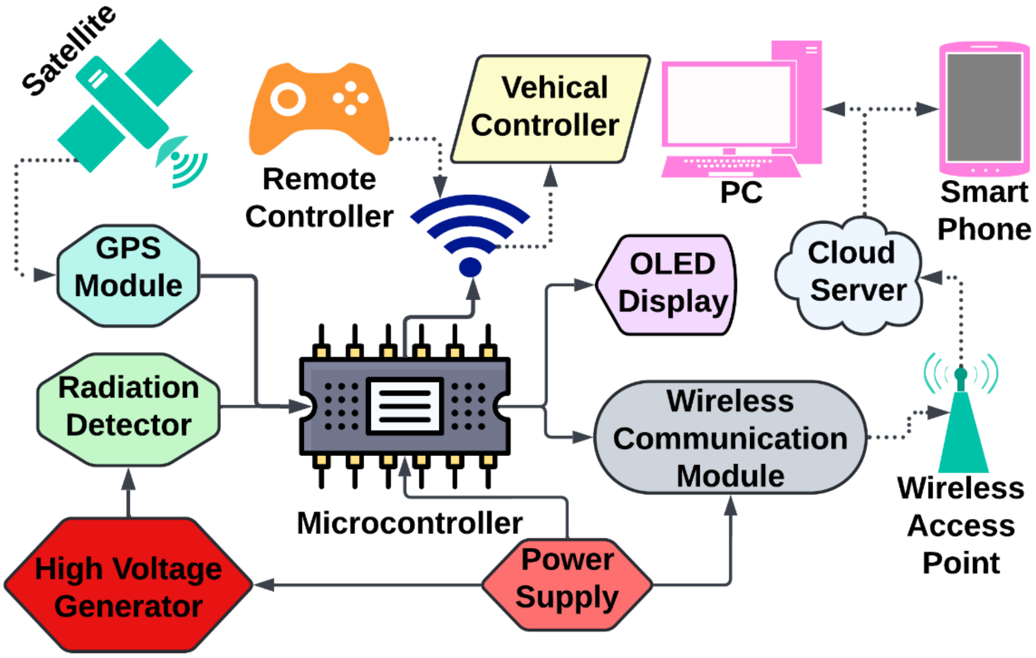


Fig. 3.2.1 Block Diagram of the System

The system is composed of two main parts:

**Radiation Detection and Data Processing Unit**: The A9G GPS/GPRS module acts as the primary microcontroller to detect radiation using a GM tube, read GPS location, process data, and transmit it to a cloud-based server via GPRS.

**Remote Mobility**: The radiation detector is carried on a remote-controlled car platform, which is controlled using an Arduino Pro Mini connected to an NRF24L01 module. This allows remote operation in hazardous environments. Integrating these subsystems ensures the user can safely monitor radiation levels from a distance while accessing live updates online.

**Circuit Diagram of Remote Controller:** The circuit diagram for the remote controller consists of two primary sections: the power supply and the microcontroller with the display interface. The power supply section ensures the stable operation of the components. A TP4056 module is used for charging a lithium-ion battery via a USB connection, with its output connected to a boost converter to step up the voltage to 5V. An AMS1117 voltage regulator further steps down the voltage to 3.3V for components requiring lower power. A double-pole double-throw (DPDT) switch enables seamless selection between charging and operational modes.

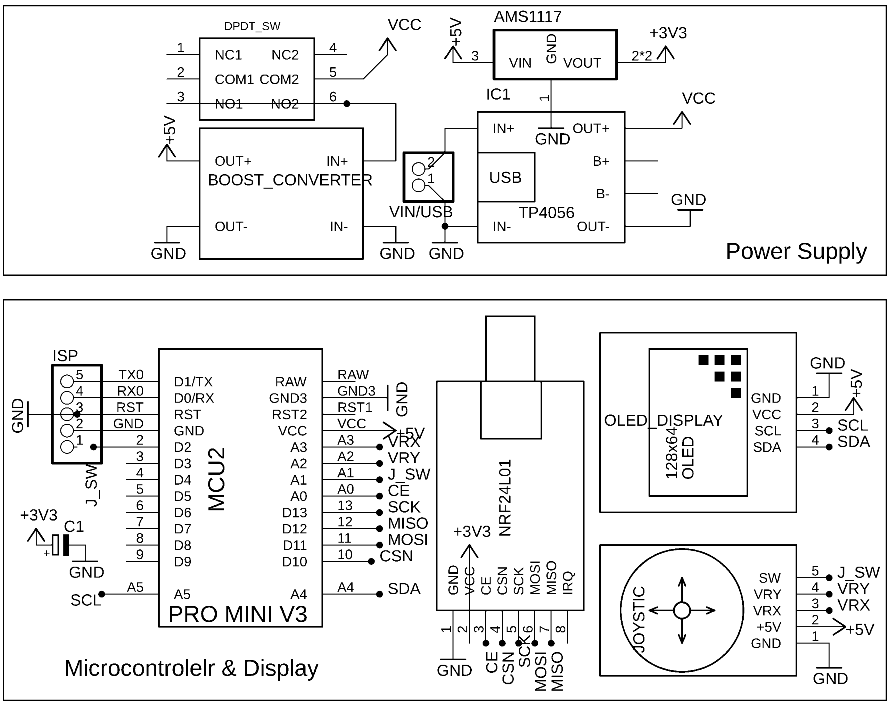


Fig. 3.2.2 Schematic Diagram of Remote Controller

The microcontroller section is based on the Arduino Pro Mini, the core processing unit. The joystick module provides user input, sending X-axis and Y-axis movement data and a selection button signal to the microcontroller. An NRF24L01 wireless transceiver is integrated for communication with the central controller. The 128x64 OLED display shows relevant data, such as system status and joystick commands. Proper connections between the modules are maintained with careful attention to power, ground, and communication lines. This integrated system ensures reliable control and communication for the radiation surveillance vehicle.

**Circuit Diagram of Main Controller:** The central controller's circuit diagram consists of three key sections: the power supply, the microcontroller with communication modules, and connectors for peripherals. The power supply section ensures the system operates reliably. It uses a combination of DC-DC converters to regulate the input voltage. A TP4056 module and an AMS1117 voltage regulator are employed to provide 5V and 3.3V outputs as required by various components. A DPDT switch is included for mode selection between power input sources.

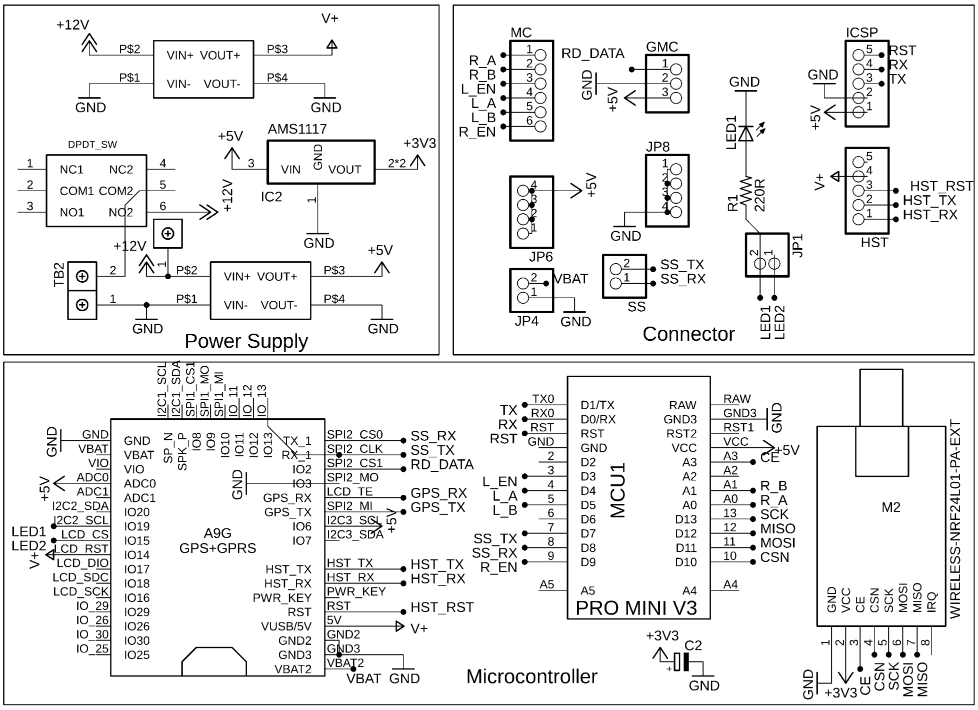


Fig. 3.2.3 Schematic Diagram of Main Controller

The microcontroller section is built around the Arduino Pro Mini, which acts as the main processing unit. It interfaces with the A9G GPS/GPRS module for location tracking and data transmission. The NRF24L01 wireless transceiver module facilitates communication with the remote controller. Additionally, motor control is managed through an interface connected to motor driver pins.

The connectors provide convenient interfacing points for components such as the GM tube, LEDs, GPS module, and motor driver. These connections are organized to ensure efficient signal routing and power distribution. LEDs are included for status indication during operation. This integrated system forms the core of the radiation surveillance unit, enabling data collection, wireless communication, and system control.

## 3.3 System Workflow

This section explains the overall operation of the system, detailing how the remote controller and the main controller board interact to achieve seamless functionality. The workflow is visually represented in the accompanying flowchart to provide a clear and concise understanding of the system's operation:

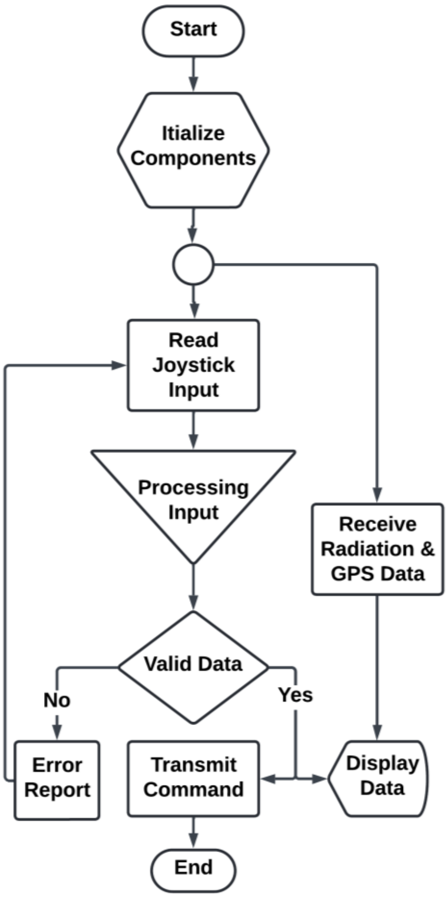


Fig. 3.3.1 Flow Chart of Remote Controller

**Remote Controller:** This flowchart illustrates the operation of the Remote Controller in the Remote Radiation Surveillance Unit. The process starts with initializing all essential components, including the Arduino Pro Mini, joystick, NRF24L01 module, and OLED display. Once initialized, the system reads input from the joystick, processes the data, and checks its validity. If the data is valid, the corresponding command is transmitted to the main controller via the NRF24L01 module; otherwise, an error is reported, and the system loops back to read joystick input again. Simultaneously, the remote controller receives radiation and GPS data from the main controller, which it displays on the OLED screen for real-time monitoring. This cycle ensures seamless communication between the controllers, allowing for effective control and monitoring of the system. The process continues until the controller is powered off or tasks are completed.

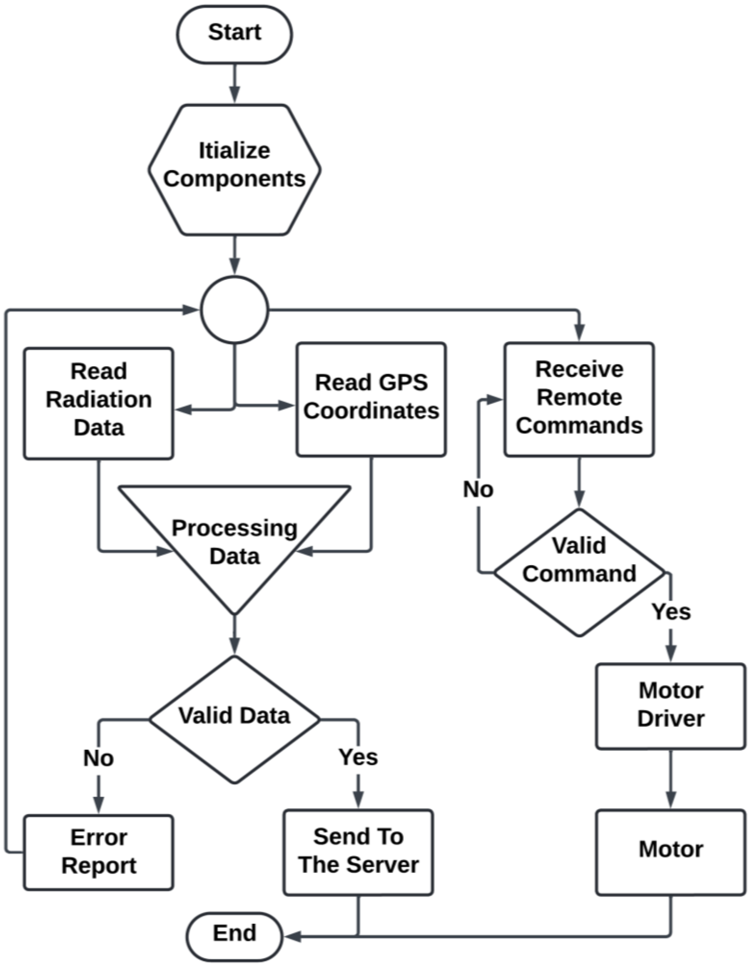


Fig. 3.3.2 Flow Chart of Main Controller

**Main Controller Board:** This flowchart represents the operation of the Main Controller in the Remote Radiation Surveillance Unit. The process begins with initializing all the components, including the Arduino Pro Mini, GM tube, A9G GPS/GPRS module, NRF24L01 module, and motor driver. The system then simultaneously reads radiation data from the GM tube, GPS coordinates from the A9G module, and remote commands from the NRF24L01 module. Commands from the remote controller are validated to ensure they are accurate and actionable. If a valid command is received, it is passed to the motor driver, enabling motor movement. The radiation and GPS data are processed and validated; if valid, they are transmitted to the server via the GPRS functionality of the A9G module for further analysis. If data or commands are invalid, an error is reported, and the system loops back to continue reading inputs. This ensures that the main controller consistently handles data acquisition, command processing, and motor control, enabling the efficient and safe operation of the radiation surveillance unit.

## 3.4 Methods

The Geiger Müller Tube, also known as the GM Tube, is the main element in a Geiger counter, which detects ionizing radiation. Hans Geiger developed the principle in 1908 [26], and Walther Müller worked with Geiger to advance the technique in 1928, resulting in a practical tube capable of detecting various types of radiation [27]. This device is a gaseous ionization detector that uses the Townsend avalanche phenomenon to generate an easily detectable electronic pulse from even a single ionizing event produced by a radiation particle. The Geiger–Müller tube can detect gamma radiation, X-rays, and alpha and beta particles effectively. The tube operates within the "Geiger" region, generating ion pairs.

The modern halogen-filled Geiger Müller Tube was invented by Sidney H. Liebson in 1947 and offers several advantages over older tubes that use organic mixtures [28]. The discharge in a halogen tube utilizes a metastable state of the inert gas atoms, allowing for easier ionization of halogen molecules than organic vapors. As a result, these tubes can operate at much lower voltages, typically between 400 and 600 volts, instead of the 900 to 1200 volts required by older models.

**Working Principal:** A Geiger Müller Tube is a chamber filled with a gas mixture at a low pressure of approximately 0.1 atmospheres. Inside the chamber are two electrodes separated by a potential difference of several hundred volts. The tube walls are either made of metal or coated on the inside with a conducting material or a spiral wire to form the cathode, while a wire mounted axially in the center of the chamber serves as the anode.

When ionizing radiation strikes the tube, the radiation directly affects some gas molecules. If the cathode is an electrical conductor, such as stainless steel, ionization can also occur indirectly through secondary electrons emitted from the walls of the tube, which then enter the gas. This process creates positively charged ions and free electrons, known as ion pairs, within the gas. The strong electric field generated by the voltage across the electrodes accelerates the positive ions toward the cathode and the electrons toward the anode.

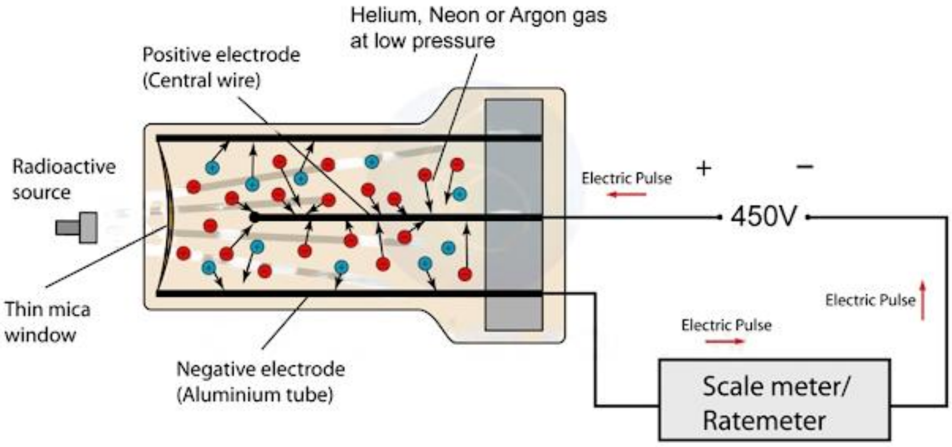


Fig. 3.4.1 Working Principal of GM Tube

In the "avalanche region," close to the anode, the electric field strength increases inversely with distance as one approaches the anode. Here, free electrons gain enough energy to collide with and ionize additional gas molecules, resulting in the formation of a large number of electron avalanches. These avalanches propagate along the anode and throughout the avalanche region. This phenomenon, known as "gas multiplication," is a key characteristic of the GM Tube, allowing it to produce a significant output pulse from a single ionizing event [28].

**Geiger Plateau:** The Geiger plateau refers to the voltage range in which a GM Tube operates correctly, allowing ionization to occur along the length of the anode. When a GM Tube is exposed to a steady radiation source and the applied voltage increases from zero, the tube's current behavior can be represented on a graph. This specific range is known as the "Geiger region," where the slope of the current plot flattens out. This area is referred to as the Geiger plateau [29]. As the voltage applied to the tube gradually increases from zero, the detection efficiency improves until the most energetic radiation produces pulses that the electronic circuitry can detect; this is known as the "starting voltage." Further increasing the voltage leads to a rapid rise in the count of detected events until a point known as the "knee" or threshold of the plateau is reached. At this point, the rate of increase in counts begins to decrease. This indicates that the tube voltage is sufficient for a complete discharge along the anode for each detected radiation event, making the effects of different radiation energies equivalent. The relationship is illustrated in more detail in the Geiger Plateau Curve below.

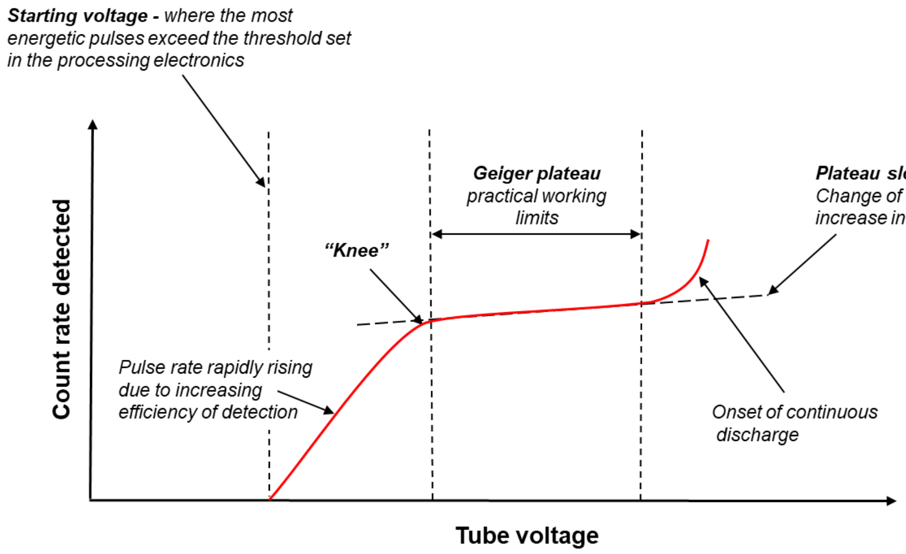


Fig. 3.4.2 Geiger Plateau Curve

**Calculation of Dose Rate:** The microcontroller can count the impulse signals generated by the GM tube in real-time through interrupt events. Measure the counts per second (CPS) to determine counts per minute (CPM). The CPS calculation method for the proposed device involves counting the number of interrupts every 15 seconds and multiplying that figure by four to obtain the CPM. The internal memory for CPM data is then updated, increasing data reporting frequency and improving accuracy.

According to the radiation protection recommendations from the International Commission on Radiological Protection, an average person should not be exposed to more than one millisievert (mSv) per year in addition to background radiation [29].To convert CPM into sieverts, we must measure the calibrated sensitivity of the GM tube to cobalt (Co-60) and calculate the conversion factor (CF) [30].

A standard radioactive source cobalt sample is used to determine the CF. The events generated by the gamma rays of the cobalt are counted every second. The count will vary for different types of GM tubes. In this study, the J305 model was used, which yielded a cobalt-calibrated sensitivity of 44 CPS/mR/h. This calibration procedure was conducted at a room temperature of 25 degrees Celsius.

Using Equation (2) is used to convert milliroentgens to µSieverts. Multiply 44 CPS/mR/h by 60 seconds per minute to obtain 2640 CPM/mR/h. By dividing this result by 8.77 µSv/mR, get 301 CPM /µSv/h CF. The absorption rate value used for air is 8.77 [31]. Following this, the dose rate resolution represented by each event count for J305 is 0.003321969697 µSv/h.

The microcontroller calculates the current CPM and applies Equation (2) to determine the dose rate in µSv/h.

$$1\,mR = 8.77\ \mu\frac{Sv}{h}$$

$$CF = \frac{44 \times 60}{8.77} = 2640 = 301.026226\ \mu\frac{Sv}{h}$$

$$1\,CPM = \frac{1}{301.026226} = 0.0033219697\ \mu\frac{Sv}{h} \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$\mu Sv/h = CPM\ \times 0.00332 \ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

The development process followed a sequential methodology to ensure clarity and precision. The following steps were undertaken:

**Requirement Gathering:** Identified the main functional and non-functional requirements for the radiation surveillance system. Conducted a literature review to understand existing systems and identify gaps and consulted with academic advisors and industry experts to validate the project's feasibility.

**Design Specification:** Created comprehensive specifications for hardware and software components. Developed block diagrams, flowcharts, and system-level schematics to visualize the system better. Choose modular components to facilitate integration and enhance scalability. The GM Tube, A9G module, Arduino Pro Mini, and NRF24L01 were chosen for their cost-effectiveness, compatibility, and performance. The components were soldered and connected with careful attention to wiring and power requirements. Custom firmware was developed for the A9G module and the Arduino Pro Mini. The A9G was programmed to manage radiation detection, GPS tracking, and GPRS communication, while the Arduino Pro Mini was programmed for motor control and NRF24L01 communication.

**System Integration:** Developed a prototype for proof-of-concept validation and conducted iterative testing to assess system performance and enhance the design. Then combined hardware and software components to form a cohesive system. Validated functionality through comprehensive testing in simulated field conditions.

**Testing and Validation:** The GM tube was calibrated using known radiation sources to ensure accurate measurements. Readings from the GM tube were cross-checked with a commercial Gamma Scout Meter for validation. Additionally, the car's mobility was assessed to confirm its stability and responsiveness to control commands. GPRS communication and ThingSpeak integration were tested to ensure reliable data transmission. The team also maintained detailed documentation, which included system designs, code repositories, and test logs. It continuously sought feedback from advisors and peers to improve the system.

## 3.5 Design Specifications. Standards and Constraints

This section provides a detailed overview of the design specifications, standards, and constraints that shaped the development of the project. It outlines the key technical requirements, safety considerations, and practical limitations that were considered during the design and implementation phases. These factors ensured the system met its objectives while adhering to industry standards and addressing real-world challenges effectively.

### 3.5.1 Design Specifications

The GM tube features a high-voltage generator circuit and can detect gamma radiation levels ranging from 0.01 µSv/h to 100 µSv/h. It generates pulses in response to radiation events and is compatible with the A9G input. This component has a compact design, measuring approximately 10 cm by 6.5 cm, and is integrated into the main PCB.

The remote-controlled car platform operates within a range of 100 meters using a 2.4 GHz NRF24L01 module. It is capable of navigating uneven terrain while carrying the radiation detection module and its associated electronics.

The A9G GPS/GPRS module collects data from the GM tube, reads GPS coordinates, and transmits this information to the ThingSpeak server in real time. It operates on 5V DC with an average current consumption of 500 mA during transmission.

For communication, the system utilizes a 2.4 GHz NRF24L01 module. The Arduino Pro Mini serves as the processor, collecting directional data from a joystick interface, while an OLED display provides feedback.

### 3.5.2 Standards Compliance

GM Tube and high-voltage circuits adhere to IEC 60532 standards for radiation detectors. Wireless communication complies with IEEE 802.15.4 guidelines for low-power RF modules. Data is transmitted securely using standard protocols for IoT devices.

### 3.5.3 Constraints

The system is limited by the battery capacity of both the car and the remote controller. Additionally, the operating range of the NRF24L01 module restricts the distance to approximately 100 meters. Budget constraints keep the system low-cost. Furthermore, the remote-controlled car may struggle to operate efficiently on very rough or steep terrain.

## 3.6 System Analysis

The project design balances cost, performance, and functionality by optimizing key components:

**Radiation Detection Optimization:** Using a GM tube with a high-voltage generator reduces complexity while maintaining sensitivity. Pulses from the GM tube are processed directly by the A9G, eliminating the need for an additional microcontroller.

**Mobility Platform Optimization:** A simple four-motor car platform was chosen for easy assembly and cost-effectiveness. The remote-control interface ensures real-time maneuverability in hazardous areas.

**Data Transmission Efficiency:** The A9G module consolidates GPS and GPRS and processes them into one unit, reducing power and space requirements. Data sent to the cloud is minimized to only essential information (radiation level and GPS coordinates) to optimize bandwidth usage. NRF24L01 was selected for low-power, short-range communication despite its limited range. Arduino Pro Mini was used for its simplicity and compatibility, even though higher-performance microcontrollers are available.

## 3.7 Summary

The development of the Remote Radiation Surveillance Unit followed a structured methodology that included requirements gathering, design, prototyping, and iterative testing. The system was designed to be reliable, cost-effective, and efficient by adhering to established standards and carefully accounting for constraints. Key insights from system analysis played a crucial role in mitigating risks and achieving the project’s objectives.

# CHAPTER 4

# HARDWARE AND SOFTWARE INTEGRATION

## 4.1 Introduction

The *Remote Radiation Surveillance Unit* project required the integration of multiple subsystems, including a radiation detector, a GPS/GPRS module, and a remote-controlled car. This chapter outlines the system design approach, the materials used, and the methods for achieving the desired functionality. It includes component selection, system specifications, design constraints, and implementation details to ensure a low-cost and functional solution for real-time radiation monitoring and data transmission.

## 4.2 System Design and Components

This section outlines the materials and methods used to develop the *Remote Radiation Surveillance Unit*, with a detailed description of the system design, key components, and their roles.

### 4.2.1 Materials and Components

The main components used in the project include:

**Geiger-Müller (GM) Tube with High-Voltage Generator Module:** The Geiger-Müller (GM) tube detects ionizing radiation by generating electrical pulses that are proportional to the intensity of the radiation. GM tubes are reliable, affordable, and commonly used in radiation detection systems. They are connected to a high-voltage generator circuit that boosts a 5V DC input up to 450V DC, providing the necessary voltage for the tube to operate effectively.

Fig. 4.2.1 Geiger-Müller (GM) Tube with High-Voltage Generator

**A9G GPS/GPRS Module:** This device collects radiation data from a Geiger-Müller (GM) tube, functions as a GPS tracker, processes the information, and transmits it to the cloud. It features a powerful microcontroller equipped with integrated GPS and General Packet Radio Service (GPRS) capabilities. The device operates on GSM bands (850/900/1800/1900 MHz), offers GPS accuracy of ±2.5 meters, and supports multiple data protocols for GPRS transmission.

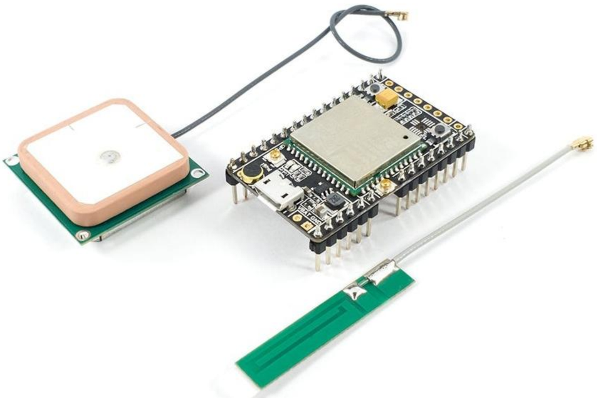


Fig. 4.2.2 A9G GPS/GPRS Module

**Arduino Pro Mini:** The system functions as the controller for a remote-controlled car platform. It receives commands from the remote controller and manages the car's motors accordingly. The Arduino platform provides a user-friendly development environment and allows for integration with various components. Its compact size, low power consumption, and adequate number of I/O pins facilitate motor control and communication via the NRF24L01 module.

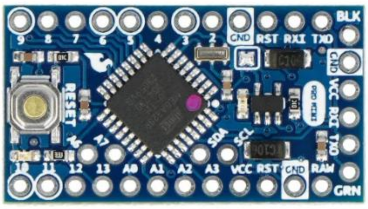


Fig. 4.2.3 Arduino Pro Mini

**NRF24L01 Module:** This system enables wireless communication for the car's remote control, allowing the operator to manage the car's movement from a safe distance. It is low-cost and energy-efficient, operating at a frequency of 2.4 GHz with a range of up to 100 meters in open areas.

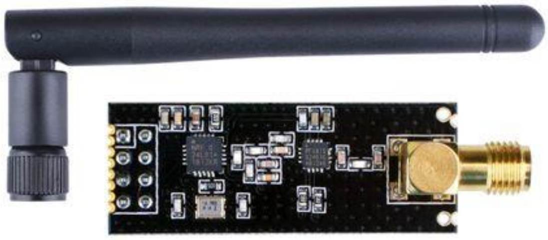


Fig. 4.2.4 NRF24L01 Module

**OLED Display:** Displays real-time data on the remote controller, including radiation levels and GPS location. Features a 0.96” 128x64 dot matrix module with an I2C interface.

Fig. 4.2.5 OLED Display

**Motor Driver:** Controls the car platform's motors, allowing movement via remote commands. A dual H-Bridge motor driver enables speed and direction control for two DC motors, operating within a voltage range of 5-35V.

Fig. 4.2.6 Motor Driver

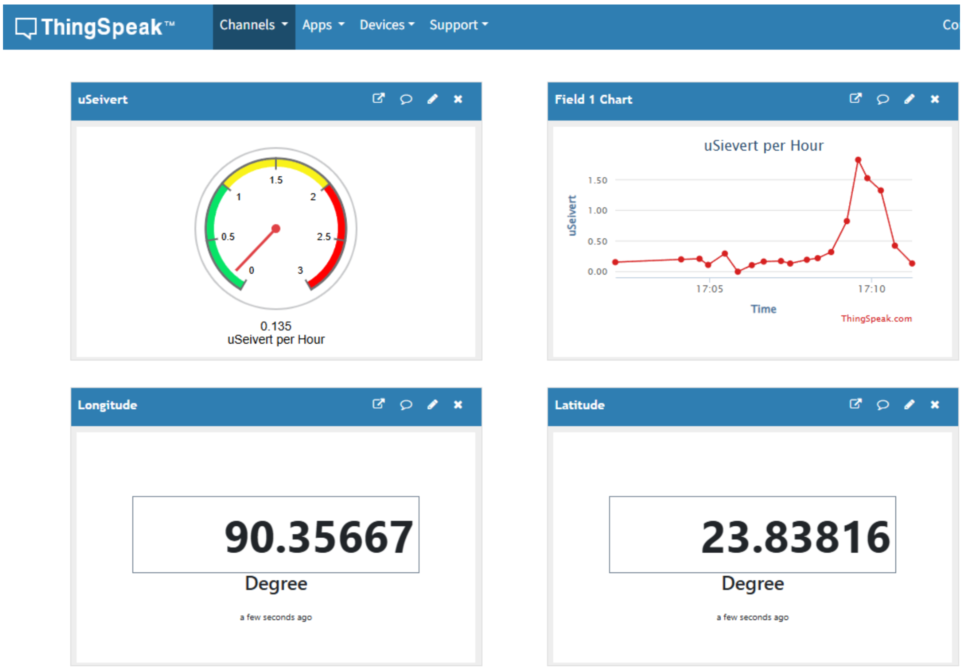
**Thumb Joystick:** Generates control signals to move the car in forward, backward, left, and right directions. It features an analog module with X and Y potentiometers for directional control and a Z-axis push-button. The module operates on 5V and outputs variable voltage signals.

Fig. 4.2.7 Thumb Joystick

**Remote-Controlled Car Platform:** This platform acts as the mobile base for the radiation detector, allowing access to high-radiation zones. It ensures the system can traverse high-radiation areas while transmitting real-time data. The platform is powered by DC motors controlled by the Arduino Pro Mini.

Fig. 4.2.8 Remote-Controlled Car Platform

**ThingSpeak Server:** A cloud-based IoT platform for collecting, visualizing and storing real-time radiation and GPS data. In the context of radiation and GPS monitoring, ThingSpeak serves as a centralized hub for aggregating data from sensors, such as radiation levels from a Geiger-Muller counter and GPS coordinates from a positioning module. It provides an accessible interface for users to monitor radiation levels and the car's location.



Longitude

90.35667

Degree

a few seconds ago

Latitude

23.83816

Degree

a few seconds ago

Fig. 4.2.9 ThingSpeak Server

**Power Supply**: It includes a 12V rechargeable Li-Po battery for the car and power supply to other components.

A Mini 360 DC-DC buck converter supplies 5V to the microcontroller and sensors, ensuring portability for extended operation.

Fig. 4.2.10 Power Supply

### 4.2.2 PCB Design and Fabrication

This section describes the process of designing the PCB, fabricating, and integrating the remote controller and the main controller board.

**PCB Design in EAGLE**: The remote controller and primary control board circuits were designed using EAGLE software to ensure precise layout and component placement.

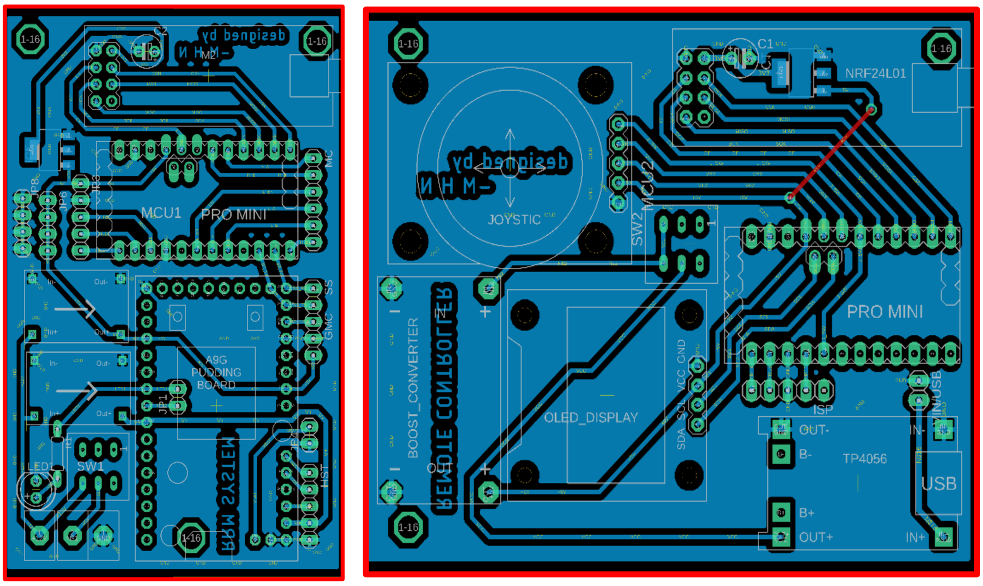


Fig. 4.2.1 PCB Design

**PCB Fabrication by Toner Transfer Method**: The designed circuits were fabricated using the toner transfer method at home. The process involved:

- Printing the circuit layout onto photo paper.
- Transferring the layout onto a CCB using heat.

- Etching the board with ferric chloride ($FeCl_3$) to remove unwanted copper, leaving the desired traces.
- Drill holes for components and solder them onto the PCB.

**Remote Controller Board**: This board includes a joystick, an OLED display, an NRF24L01 module, an Arduino Pro Mini, a DC-DC booster, and a charging circuit, all assembled on a compact PCB.

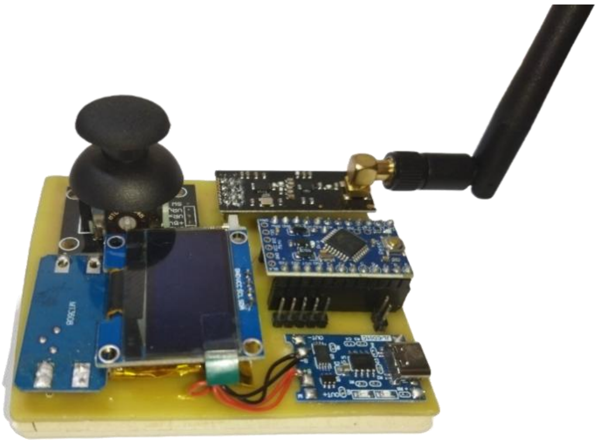


Fig. 4.2.2 Remote Controller

**Main Control Board**: This board houses the A9G module, GM tube, High-Voltage Generator circuit, Motor Driver, NRF24L01 module, and Arduino Pro Mini. It is mounted on the car platform inside a box.

Fig. 4.2.3 Main Control Board

### 4.2.3 System Integration

The integration of hardware components is a critical part of the system design:

**Hardware Integration:** The GM tube is connected to the high-voltage generator circuit to ensure it operates at the correct voltage. The pulse output from this circuit is then linked to the A9G module, which processes radiation data. The A9G module is configured to combine GPS coordinates with the radiation readings and send this information to the ThingSpeak server via GPRS. The remote-controlled car is equipped with an Arduino Pro Mini, which controls the motors based on commands received from the NRF24L01 module. All components are securely mounted in a box on the car platform to ensure stability during operation.

**Software Integration:** This system processes radiation pulses and calculates counts per minute (CPM) as well as microSieverts per hour (µSv/h). It integrates GPS data, formats it for GPRS transmission, and sends the information to ThingSpeak. The system also receives wireless control signals via the NRF24L01 module, which it uses to operate the motors accordingly. Custom dashboards and data visualization settings are employed to display real-time radiation levels and location.

## 4.3 Experimental Setup

This section integrated hardware and software to enable remote radiation monitoring. The hardware implementation included testing and calibrating the high-voltage generator circuit, GM tube, and vehicle platform for reliable performance. Complementing this, the software enabled real-time data acquisition, processing, and transmission using modules like the A9G and NRF24L01. Both systems were rigorously tested and calibrated to ensure accurate radiation measurement, mobility, and remote operability.

### 4.3.1 Hardware Implementation

**Laboratory Setup:** The high-voltage generator circuit was tested using a multimeter and an oscilloscope to confirm its output of 450V DC. The GM tube was calibrated by exposing it to standard radiation sources and measuring the resulting pulse output. Additionally, a prototype of the A9G and GM tube was assembled on a breadboard to facilitate data acquisition and transmission prior to finalizing the PCB assembly. The vehicle was built using standard components, including a chassis with four motors, a battery pack, and a motor driver circuit. Performance testing was performed on various terrains to assess its effectiveness.

**PCB Assembly and Testing:** Two printed circuit boards (PCBs) were created using the toner transfer method and assembled with various components. Debugging was conducted to verify connections and ensure the functionality of the components.

### 4.3.2 Software Implementation

The A9G module was designed to count radiation pulses over a fixed interval and calculate the counts per minute (CPM) and microSieverts per hour (µSv/h). It reads the GPS location and formats the data for transmission. The module sends the data to the ThingSpeak server via GPRS. Additionally, it interprets joystick inputs to transmit directional commands using the NRF24L01 module. The radiation data and vehicle status are displayed on an OLED screen.

### 4.3.3 Experimental Testing

The accuracy of the GM tube and A9G processing was tested using a small radioactive source. The communication range of the NRF24L01 module was evaluated in an open area to assess its reliability. Additionally, real-time data uploads to the ThingSpeak server were verified under various conditions.

## 4.4 Summary

This chapter outlines the design and implementation of the Remote Radiation Surveillance Unit, emphasizing the integration of hardware and software. It discusses key components, including the Geiger-Müller tube, GPS/GPRS module, Arduino Pro Mini, and motor driver, detailing their specific functions.

The chapter also explains the processes involved in designing and fabricating the printed circuit board (PCB) using EAGLE software and the toner transfer method. System integration is a primary focus, highlighting the coordination of components for radiation detection, GPS tracking, and data transmission. It describes the experimental setups, including testing, calibration, and the assembly of the remote-controlled car. Furthermore, the software implementation is emphasized, particularly regarding data processing, wireless communication, and real-time visualization on the ThingSpeak server.

Overall, this chapter illustrates how the project's design achieved a balance between affordability, functionality, and reliable real-time monitoring.

# CHAPTER 5
# RESULTS AND DISCUSSIONS

## 5.1 Results

This section presents the observations and findings from the radiation detection system, remote-controlled car, and data transmission tests.

### 5.1.1 GPRS Data Transmission and Accuracy

The A9G module successfully transmitted radiation and location data over the General Packet Radio Service (GPRS) network. The average transmission delay was approximately 1.5 seconds, indicating efficient real-time data communication. This performance is within acceptable limits for remote monitoring applications, ensuring timely updates without significant latency. The system's integration of GPRS technology facilitates effective remote surveillance of radiation levels, contributing to enhanced safety and responsiveness.

### 5.1.2 Radiation Detection Accuracy

The GM tube successfully detected radiation levels between 0.01 µSv/h and 10 µSv/h during calibration tests. The measured radiation closely matched with the expected radiation levels. The accuracy of the detector is shown below.

Table 5.1.1 Radiation Detector Accuracy

| **Test Environment** | **Expected Radiation (µSv/H)** | **Measured Radiation (µSv/H)** | **Deviation** |
|---|---|---|---|
| Background Environment | 0.05-0.15 | 0.05-0.17 | ± 6.7 |
| Low-Intensity Source | 1.50 | 1.48 | ± 1.3 |
| Moderate-Intensity Source | 10.00 | 10.20 | ± 2.0 |

The figures below illustrate real-time radiation level measurements collected during field tests. The data, plotted over time, shows fluctuations in radiation levels, highlighting the system's responsiveness to changes in the environment. Notably, the readings rise when exposed to increased radiation sources and then fall as the intensity decreases.

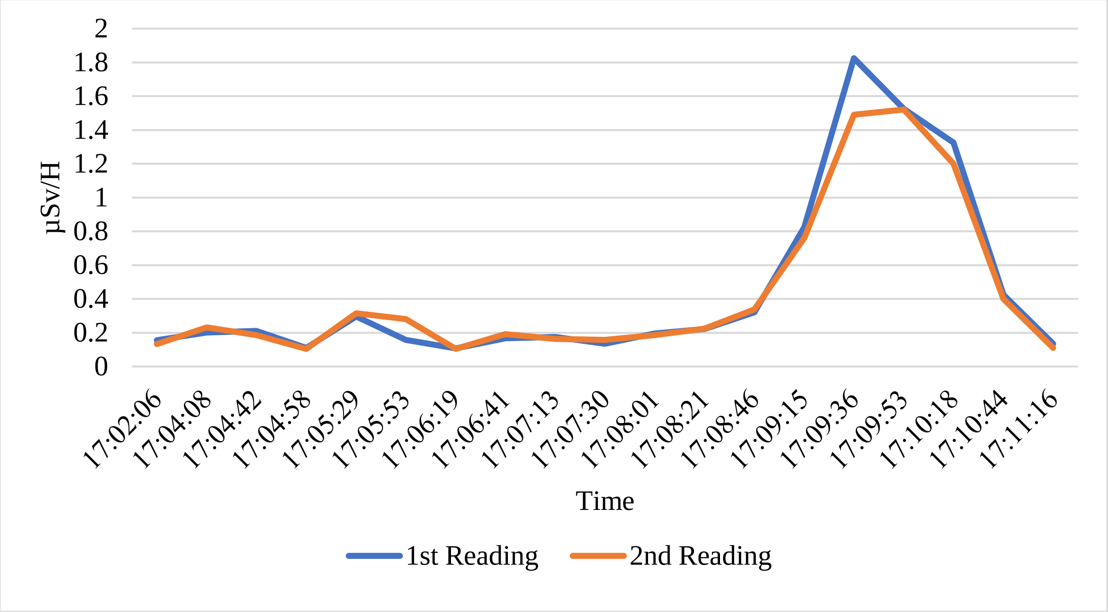


Fig. 5.1.1 Graph of Radiation Reading

This trend confirms the system's reliability in accurately detecting dynamic radiation levels. The graph also emphasizes the precision of the GM tube in capturing minor variations in background radiation, demonstrating its sensitivity.

## 5.2 Discussions

This section analyzes the results of the Remote Radiation Surveillance Unit, evaluates uncertainties and limitations, and compares the system with existing solutions. The achievements of the project are assessed, and opportunities for further improvements are explored to enhance the system's performance, reliability, and applicability in real-world scenarios.

### 5.2.1 Analysis of Results

The results indicate that the GM tube module effectively detected radiation levels, with deviations remaining within acceptable limits. The high-voltage generator circuit and pulse-processing mechanism functioned as intended. Although the real-time data upload to ThingSpeak was smooth, there were delays in GPRS transmission during periods of network congestion, which could impact the responsiveness of real-time monitoring applications. The NRF24L01 module maintained stable communication within its range of approximately 100 meters; however, its performance weakened in areas with significant RF interference and obstacles, such as walls. The vehicle was capable of navigating moderately uneven terrain, but it struggled on extremely rough surfaces.

### 5.2.2 Uncertainties and Limitations

The inability of the J305 tube to detect alpha particles limits comprehensive radiation assessment. Moreover, reliance on GPRS for data transmission introduces latency, which limits the system's effectiveness in critical scenarios. Additionally, battery life constraints hinder prolonged operation, especially for the car platform.

### 5.2.3 Comparison with Existing Systems

The Gamma Scout Standard is a handheld radiation detector that measures alpha, beta, and gamma radiation and offers data storage and analysis capabilities. However, it does not feature real-time data transmission for remote monitoring. In contrast, standalone radiation detectors like the Gamma Scout Meter and Pocket Dosimeter do not provide remote data monitoring, which gives the Gamma Scout Standard a significant advantage in hazardous environments. Additionally, its integration with a car platform adds unique mobility functionality that is not available in other existing systems.

### 5.2.4 Achievement of Goals

The project successfully achieved its main objective of developing a low-cost, remote radiation surveillance unit. The system effectively demonstrated capabilities in radiation detection, GPS location tracking, and real-time data transmission within the specified parameters. There are plans to create a low-cost radiation detection unit, similar to the Gamma Scout Meter, but enhanced with real-time data transmission to a server for remote monitoring.

### 5.2.5 Opportunities for Improvement

Integrating the LND712 GM tube will enhance the detection of alpha radiation, allowing for a more comprehensive assessment of environmental radioactivity. Future developments could include more advanced wireless communication technologies, such as LoRaWAN, which would extend the operating range. Optimizing battery performance and ruggedizing the vehicle platform could improve the system's reliability in harsh conditions. Additionally, designing a cost-effective, handheld radiation detector with server connectivity would enable real-time monitoring and address the need for accessible radiation detection in Bangladesh.

## 5.3 Summary

This chapter presented the findings and evaluations of the Remote Radiation Surveillance Unit, focusing on radiation detection, data transmission, and system performance. The A9G module effectively transmitted radiation and GPS data via GPRS, although network congestion caused occasional delays. The NRF24L01 module maintained stable communication within a 100-meter range but experienced reduced performance in environments with significant RF interference. The car platform successfully navigated moderately uneven terrain but struggled on extremely rough surfaces.

The discussion highlighted the system's key achievements, such as meeting the project’s objectives of creating a low-cost, remote radiation detection unit capable of real-time data transmission. Limitations were analyzed, including the J305 tube’s inability to detect alpha particles, GPRS latency, and battery life constraints. A comparison with existing systems, like the Gamma Scout Standard, showed that the developed system provided unique mobility and real-time monitoring capabilities. Opportunities for improvement were also identified, including integrating the LND712 GM tube for alpha radiation detection, adopting advanced communication technologies like LoRaWAN, and enhancing battery performance and vehicle ruggedness. The chapter concludes by envisioning a more robust and versatile radiation detection system that effectively addresses real-world challenges.

# CHAPTER 6
# PROJECT MANAGEMENT

## 6.1 Task, Schedule, and Milestones

At the start of the project, a comprehensive Gantt chart was developed *(refer to Section 1.4)* to outline the planned schedule for various tasks and milestones. While the project largely followed the proposed timeline, some deviations occurred due to unforeseen technical challenges and the need for additional testing. This section compares the planned schedule and the actual progress, along with justifications for delays.

Table 6.1.1 Progress Report

| Milestone | Planned Completion | Actual Completion | Remarks |
|---|---|---|---|
| Literature Review | Week 1 | Week 2 | The extended research period caused a slight delay. |
| PCB Fabrication | Week 4 | Week 5 | Minor delay due to debugging of circuit design. |
| Prototype Assembly | Week 5 | Week 6 | Required additional testing and rework. |
| System Integration | Week 7 | Week 8 | Debugging and wireless communication tests took longer than expected. |
| Final Testing and Data Logging | Week 8 | Week 9 | Successful testing with extended runtime. |
| Report Writing and Finalization | Week 10 | In Progress | On track for submission. |

### 6.1.1 Analysis of Deviations

The literature review phase required more time than expected because it explored additional sources related to GM tube technology and remote data transmission systems.

Debugging the high-voltage generator circuit and ensuring reliable connections between components extended the timeline for the PCB fabrication phase.

While integrating the car platform and the detector module was successful, debugging issues in wireless communication (NRF24L01) added delays. Testing was also prolonged to ensure accurate data transmission and GPS localization.

Despite minor deviations, the project adhered closely to the planned schedule. Adjustments were managed effectively to ensure all milestones were met within an acceptable timeframe. The timeline flexibility proved valuable in accommodating delays without compromising the project's goals.

## 6.2 Resources and Cost Management

As project manager, I ensured efficient utilization of resources and adhered to the allocated budget plan wherever possible. Below is the summary of resources used and their costs:

Table 6.2.1 Project Expenses

| **Component/Resource** | **Quantity** | **Unit Price (BDT)** | **Total Price (BDT)** |
|---|---|---|---|
| A9G GPS/GPRS Module | 1 | 2650 | 2650 |
| GM Tube (J305) with High Voltage Generator Module | 1 | 5890 | 5890 |
| Arduino Pro Mini | 2 | 430 | 860 |
| NRF24L01 PLA+NA Module | 2 | 350 | 700 |
| NRF24L01 Breakout Board | 2 | 70 | 140 |
| Joystick | 1 | 90 | 180 |
| OLED Display | 1 | 630 | 630 |
| 4WD Car Chasis | 1 | 990 | 990 |
| Motor Driver | 1 | 200 | 200 |
| 12V 2200 mAh Li-Po Battery | 1 | 2500 | 2500 |
| B3 Pro Battery Charger | 1 | 600 | 600 |
| Buck & Boost Converter | 3 | 80 | 240 |

| Component/Resource | Quantity | Unit Price (BDT) | Total Price (BDT) |
|---|---|---|---|
| Miscellaneous Components (Connector, PCB, Chemical, Resistors, Capacitors, Wires, etc.) | - | - | 2,500 |

**Total Cost:** ~ 18,000 BDT

The project was completed within budget, with additional expenses accounting for unexpected issues during fabrication and assembly—reusing tools and components where possible reduced costs.

## 6.3 Lesson Learned

This project provided valuable insights into the technical and managerial aspects of designing and implementing a complex system. Adhering to timelines necessitates detailed planning and efficient task allocation. Delays in any phase can impact the overall schedule, making contingency planning crucial. Debugging and testing are iterative processes, and thorough documentation is essential for quick resolutions. Working with high-voltage circuits and sensitive components, such as GM tubes, requires precision and patience. Effective communication among team members is vital, particularly during the debugging and system integration phases. Efficient resource utilization and staying within budget demand careful selection of components and the reuse of available materials.

The current project also presents opportunities for improvement, such as optimizing the car platform and adopting advanced communication technologies to enhance reliability. Overall, this project underscores the importance of balancing technical proficiency, time management, and cost-effectiveness to achieve a successful outcome.

# CHAPTER 7
# IMPACT ASSESSMENT of THE PROJECT

## 7.1 Economical, Societal and Global Impact

The development of the *Remote Radiation Surveillance Unit* demonstrates significant potential for both local and global applications. Its impacts can be analyzed across the following dimensions:

### 7.1.1 Economical Impact

The project aims to create a low-cost alternative to commercially available radiation detection devices. By utilizing affordable components like the GM Tube and A9G module, the device will be accessible for small-scale industries, nuclear research facilities, and healthcare sectors in developing countries such as Bangladesh. This initiative seeks to reduce reliance on imported devices like the Gamma Scout, which can help lower radiation monitoring costs, thus enhancing accessibility and generating savings for various industries. If the project is scaled up to mass production, it could also create employment opportunities in the electronics and IoT sectors.

### 7.1.2 Societal Impact

The capability to remotely monitor radiation levels is essential for ensuring the safety of personnel in hazardous environments, such as nuclear facilities or areas impacted by radiation leaks. This technology helps protect human lives. The project aims to raise awareness of radiation hazards and encourage proactive safety measures, particularly in medical imaging, mining, and nuclear power sectors.

### 7.1.3 Global Impact

This system aligns with global initiatives aimed at improving nuclear safety and reducing risks associated with radiation exposure. It has the potential to be utilized for disaster response during nuclear accidents, such as those at Fukushima or Chernobyl, thereby contributing to worldwide safety efforts.

By incorporating IoT technology into radiation detection, this project enhances the development of smart monitoring systems, which are increasingly becoming a global standard for safety across various industries.

## 7.2 Environmental and Ethical Issues

The system improves environmental safety by detecting and monitoring radiation leaks, enabling swift actions to prevent air, water, and soil contamination. It is designed to use minimal energy, thus reducing its environmental footprint. However, the project must also address the safe disposal of high-voltage circuits and other electronic components to alleviate concerns about electronic waste (e-waste).

The project utilizes readily available components, which supports sustainable manufacturing practices. Future versions could incorporate recyclable materials and eco-friendly PCB designs to enhance sustainability further.

Ensuring data privacy and security presents an ethical concern, as the system transmits radiation and location data to a remote server. Proper encryption and data protection protocols are crucial to prevent misuse of this information.

The project emphasizes safety standards, ensuring that all components, such as high-voltage circuits, are designed to minimize risks during use.

## 7.3 Utilization of Existing Standards or Codes

The project adheres to various standards and codes to ensure reliability and safety. The GM Tube module complies with international radiation monitoring guidelines, guaranteeing accurate and reliable detection. The selection of components indirectly considers ISO 4037-1 standards for X and gamma radiation. Additionally, the high-voltage generator circuit and other electrical components follow safe design and operational guidelines to prevent short circuits and overheating hazards. The NRF24L01 and A9G modules comply with IEEE standards for wireless communication, ensuring stable and interference-free data transmission. Furthermore, data transmission to platforms like ThingSpeak adheres to modern IoT communication protocols, guaranteeing compatibility and scalability.

## 7.4 Other Concerns

This section discusses important considerations related to the project's deployment and adoption that go beyond technical and environmental factors. Deploying radiation detection devices typically requires compliance with government regulations and industry-specific certifications. In Bangladesh, obtaining regulatory approval for electronic or radiation-monitoring equipment may involve testing and validation from nuclear or safety authorities. Competing with established products like the Gamma Scout can be challenging, especially when it comes to gaining user trust and delivering comparable quality. Therefore, marketing the unit as a reliable and affordable alternative will be crucial for fostering adoption.

The current design is optimized for specific use cases, such as remote radiation detection using a mobile platform. However, to scale the system for industrial or global applications, it may be necessary to add features, such as multi-sensor integration and improved precision in radiation measurement.

# CHAPTER 8

# CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

The Remote Radiation Surveillance Unit successfully achieved its main goal of developing a low-cost, online radiation detector that integrates with a mobile platform. The system has demonstrated its ability to remotely detect radiation levels using a GM tube, accurately transmit data and GPS location via the A9G GPS/GPRS module, and send the collected information to an online server for real-time monitoring.

This project met all design specifications and showed robust performance in both controlled environments and field testing. It addressed a critical safety need by enabling remote-controlled mobility through the NRF24L01 module, allowing users to monitor hazardous areas without direct exposure to radiation.

The design and functionality of this project could have significant applications in industries such as nuclear power plants, research laboratories, and disaster management scenarios, particularly during nuclear accidents. Moreover, its cost-effective approach makes it a promising option for educational, industrial, and governmental use in regions with limited resources.

## 8.2 New Skills and Experiences Learned

This project provided numerous opportunities to learn and enhance technical and non-technical skills. I strengthened my PCB design skills using EAGLE for circuit design and the toner transfer method for PCB fabrication. Gaining experience with the Arduino Pro Mini and the A9G module significantly improved my ability to program embedded devices and process data. Additionally, using GPRS for real-time data transfer and the NRF24L01 module for remote control deepened my understanding of wireless communication technologies.

I also improved my managerial and organizational skills by effectively allocating resources, creating and adhering to schedules, and tracking progress. Critical thinking was cultivated as I tackled challenges in software debugging, optimizing power consumption, and integrating high-voltage circuits.

## 8.3 Future Recommendations

Several recommendations for future development and improvements include:

- To extend detection capabilities to alpha radiation, replace the current J305 GM tube with the LND712 model.
- Design a cost-effective standalone version of the unit, similar to the Gamma Scout meter, but with real-time data transmission features for remote monitoring.
- Integrate sensors for terrain analysis and obstacle avoidance into the remote-controlled car to improve navigation in hazardous environments.
- Optimize power management to extend the unit's operational time, particularly for field use.
- Modify the design to meet industrial standards, making it suitable for large-scale deployment in nuclear facilities and research laboratories.
- Expand the cloud platform integration to work with other IoT ecosystems, enabling multi-device connectivity and improved data visualization options.

# REFERENCES

1. "Y. Ishigaki, Y. Matsumoto, R. Ichimiya, and K. Tanaka, “Development of Mobile Radiation Monitoring System Utilizing Smartphone and Its Field Tests in Fukushima,” IEEE Sensors Journal, vol. 13, no. 10, pp. 3520–3526, Oct. 2013, doi: https://doi.org/10.1109".

2. "M. Hossen, M. Mim, M. Islam, and M. Bhuiyan, “Background Radiation Detection and Measurement by Using a GM Counter at Northwestern Mining Area of Bangladesh,” Journal of Applied Physics (IOSR-JAP) E, vol. 14, pp. 10–17, 2022, doi: https://doi.org/10.9790/".

3. "M. I. Ahmad, M. H. Ab. Rahim, R. Nordin, F. Mohamed, A. Abu-Samah, and N. F. Abdullah, “Ionizing Radiation Monitoring Technology at the Verge of Internet of Things,” Sensors, vol. 21, no. 22, p. 7629, Nov. 2021, doi: https://doi.org/10.3390/s21227629.".

4. "V. A. Kulikova, V. V. Yakovlev, A. Y. Tumanov, V. A. Tumanov, and A. V. Kulinkovich, “Remote Radiation Monitoring Device,” Journal of Physics: Conference Series, vol. 1614, no. 1, p. 012108, Aug. 2020, doi: https://doi.org/10.1088/1742-6596/1614/1/01210".

5. "T. Wilbois, Y. Ren, U. Neff, W. Scheuermann, C. Grimm, and M. Hagmann, “Remote Monitoring of Nuclear Power Plants in Baden-Wuerttemberg – from Measurement to Emergency Protection,” Radioprotection, vol. 48, no. 5, pp. S95–S102, Jan. 2013, doi: https://doi".

6. "N. Hassan, C. Hassan, and M. Zakir, “Build Very Simple Design and Cost Effective geiger-muller Counter,” Journal of Recent Advances in Applied Sciences, no. 1, pp. 1–10, 2018".

7. "A. T. Chowdhury, Md. S. Muktadir, and Md. G. Zakir, “Smartgeiger – Development of Background Radiation Monitoring with IoT Based Device,” 2021 International Conference on Automation, Control and Mechatronics for Industry 4.0 (ACMI), Jul. 2021, doi: https:".

8. "N. N. Ghuge, S. Jasrotia, Anamika, and C. Sadhu, “Geiger Muller: A Thin End Window Tube Radiation Detector,” IJRET: International Journal of Research in Engineering and Technology, India".

9. "D. Gomes De Assunção, D. Carlos, R. Minhoni, M. Sant'anna De Farias, I. Luquetti, and Santos, “Remote System for Monitoring and Control of Controlled Area of Nuclear Installation,” 2011".

10. "S. S. Hasan, A. H. Miry, and T. M. Salman, “Implementation of Radiation Monitoring System,” Journal of Engineering and Sustainable Development, vol. 25, no. Special, pp. 1–631–72, Sep. 2021, doi: https://doi.org/10.31272/jeasd.conf.2.1.9".

11. "M. D.V, “Design and Development of IoT Based Geiger Muller Counter,” International Research Journal of Engineering and Technology, India, Dec. 2019".

12. "S. Okuyama, T. Torii, A. Suzuki, M. Shibuya, and N. Miyazaki, “A Remote Radiation Monitoring System Using an Autonomous Unmanned Helicopter for Nuclear Emergencies,” Journal of Nuclear Science and Technology, vol. 45, no. sup5, pp. 414–416, Jun. 2008, d".

13. "H. Smartt, “SANDIA REPORT SAND20XX-XXXX Remote Monitoring Systems/Remote Data Transmission for International Nuclear Safeguards.”".

14. "F. Lacerda, M. Farias, M. Aghina, and M. Oliveira, “Modular Remote Radiation Monitor,” International Nuclear Atlantic Conference - INAC 2013, Nov. 2013.".

15. "V. Burtniak, Y. Zabulonov, M. Stokolos, L. Bulavin, and V. Krasnoholovets, “Application of a Territorial Remote Radiation Monitoring System at the Chornobyl Nuclear Accident Site,” J. Appl. Remote Sens, vol. 12, no. 4, p. 46007, 2018.".

16. "I. Morales, A. Monterroso, and S. Urizar, “Design, Assembly and Calibration of a microcontroller-based Geiger-Müller Doserate Meter,” 2016.".

17. "M. D. R. Silva, Ionizing Radiation Detectors. IntechOpen, 2015. Available: https://www.intechopen.com/chapters/48796".

18. "GAMMA-SCOUT® – Your Radiation Detector Made in Germany," Gamma Scout. https://www.gamma-scout.com/en/".

19. "DMC 3000TM Personal Electronic Dosimeter," Mirion, 2024. https://www.mirion.com/products/technologies/health-physics-radiation-safety-instruments/dosimetry-telemetry-systems/electronic-dosimeters/dmc-3000-solutions/dmc-3000-electronic-radiation-dosim".

20. "SensorsIot. "GitHub - SensorsIot/Geiger-Counter-RadiationD-V1.1-CAJOE-: Do-It-Yourself Geiger Counter YouTube Video." GitHub, 2017, github.com/SensorsIot/Geiger-Counter-RadiationD-v1.1-CAJOE-?tab=readme-ov-file. Accessed 30 Dec. 2024.".

21. "Geiger Counter RadiationD v1.1 (CAJOE)," devices.esphome.io, 2021. https://devices.esphome.io/devices/geiger-counter (accessed Dec. 31, 2024)".

22. "DIYGeiger - GM Tube Info." Sites.google.com, sites.google.com/site/diygeigercounter/technical/gm-tubes-supported.".

23. "Geiger Tube J305: How to Calculate the Conversion Factor of CPM to µSv/h. Technical Note - IoT-devices, LLC - Electronics Manufacturer for IoT," IoT-devices, LLC - Electronics Manufacturer for IoT, Jan. 08, 2024. https://iot-devices.com.ua/en/geiger-tube-".

24. "Radiation Quantities and Units | Automess," Archive.org, 2023. https://web.archive.org/web/20230402162906/https:/www.automess.de/en/service/radiation-quantities-and-units (accessed Dec. 31, 2024)".

25. "G. Lutz and R. Klanner, "Solid State Detectors," Particle Physics Reference Library, pp. 137–200, 2020, doi: https://doi.org/10.1007/978-3-030-35318-6_5".

26. "Rutherford, E.; Geiger, H. (1908). "An electrical method of counting the number of α particles from radioactive substances". Proceedings of the Royal Society. Series A. 81 (546). London: 141–161.".

27. "Geiger, H.; Müller, W. (1928). Electron counting tube for measurement of weakest radioactivities. Die Naturwissenschaften (in German). 16 (31): 617–618.".

28. "S. H. Liebson, “The Discharge Mechanism of Self-Quenching Geiger-Mueller Counters,” Physical Review, vol. 72, no. 7, pp. 602–608, Oct. 1947, doi: https://doi.org/10.1103/physrev.72.602.".

29. "G. F. Knoll, Radiation Detection and Measurement, 4th ed. New York: John Wiley & Sons, Cop, 2010.".

30. "A. D. Wrixon, “New ICRP Recommendations,” Journal of Radiological Protection, vol. 28, no. 2, pp. 161–168, May 2008, doi: https://doi.org/10.1088/0952-4746/28/2/r02.".

# APPENDIX A

# TURNITIN REPORT

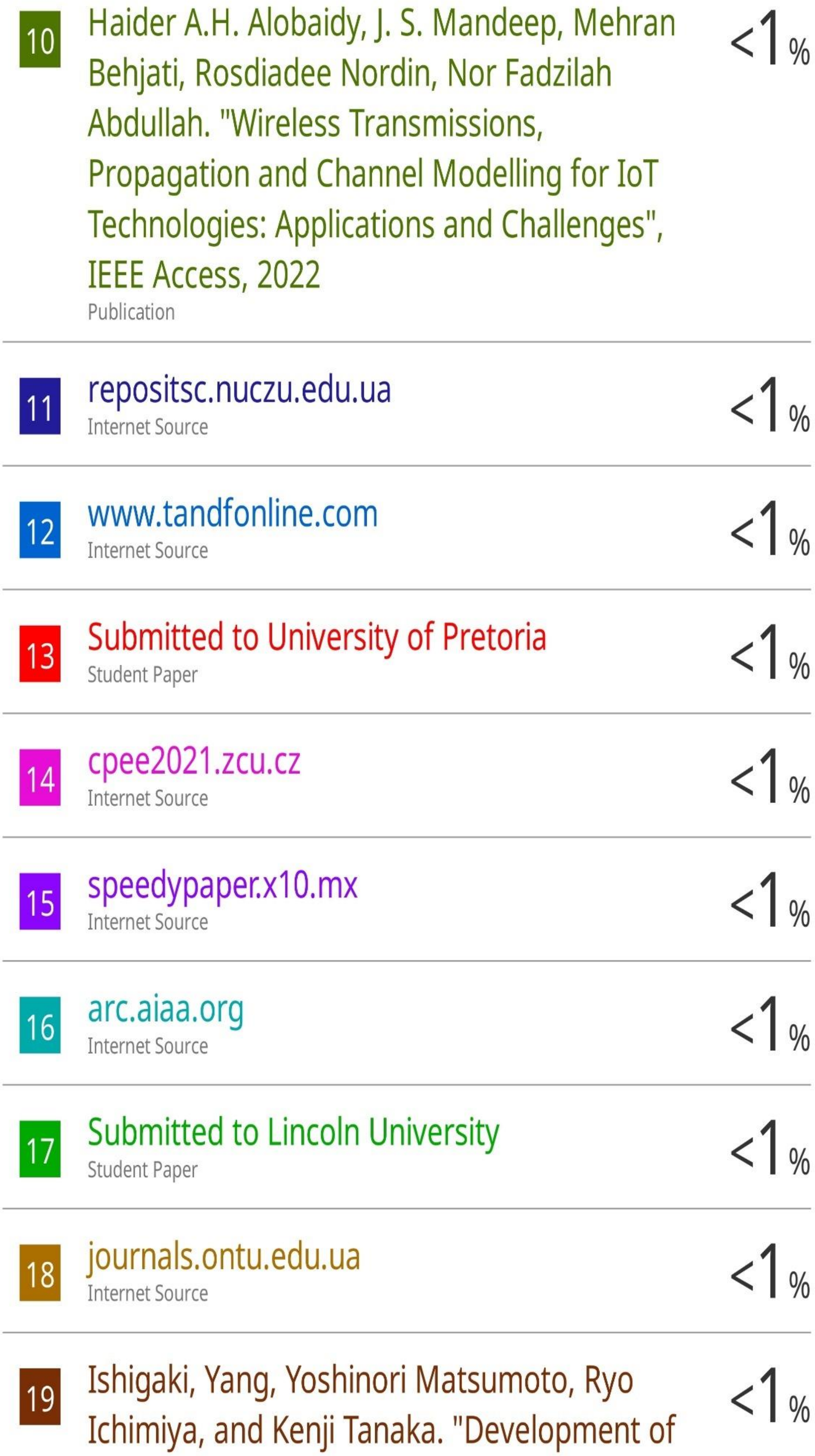
212-33-5396

ORIGINALITY REPORT

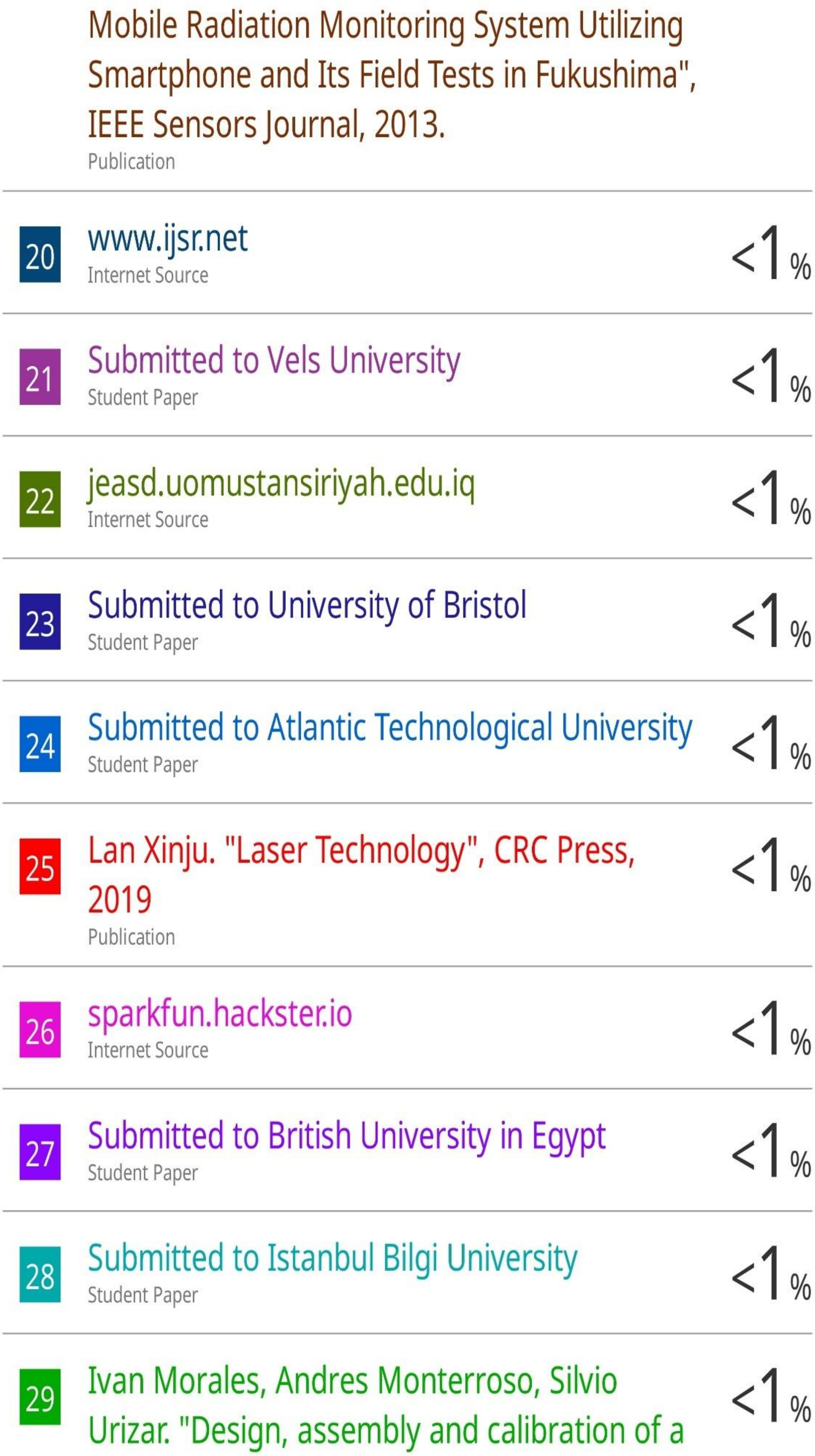
| | | | |
|---|---|---|---|
| 23% | 22% | 8% | 9% |
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | forum.flprog.ru<br>Internet Source | 7% |
| 2 | dspace.daffodilvarsity.edu.bd:8080<br>Internet Source | 4% |
| 3 | en.wikipedia.org<br>Internet Source | 2% |
| 4 | www2.mdpi.com<br>Internet Source | 1% |
| 5 | Submitted to University of Witwatersrand<br>Student Paper | 1% |
| 6 | forum.arduino.cc<br>Internet Source | 1% |
| 7 | github.com<br>Internet Source | 1% |
| 8 | ijirset.com<br>Internet Source | <1% |
| 9 | www.epj-conferences.org<br>Internet Source | <1% |

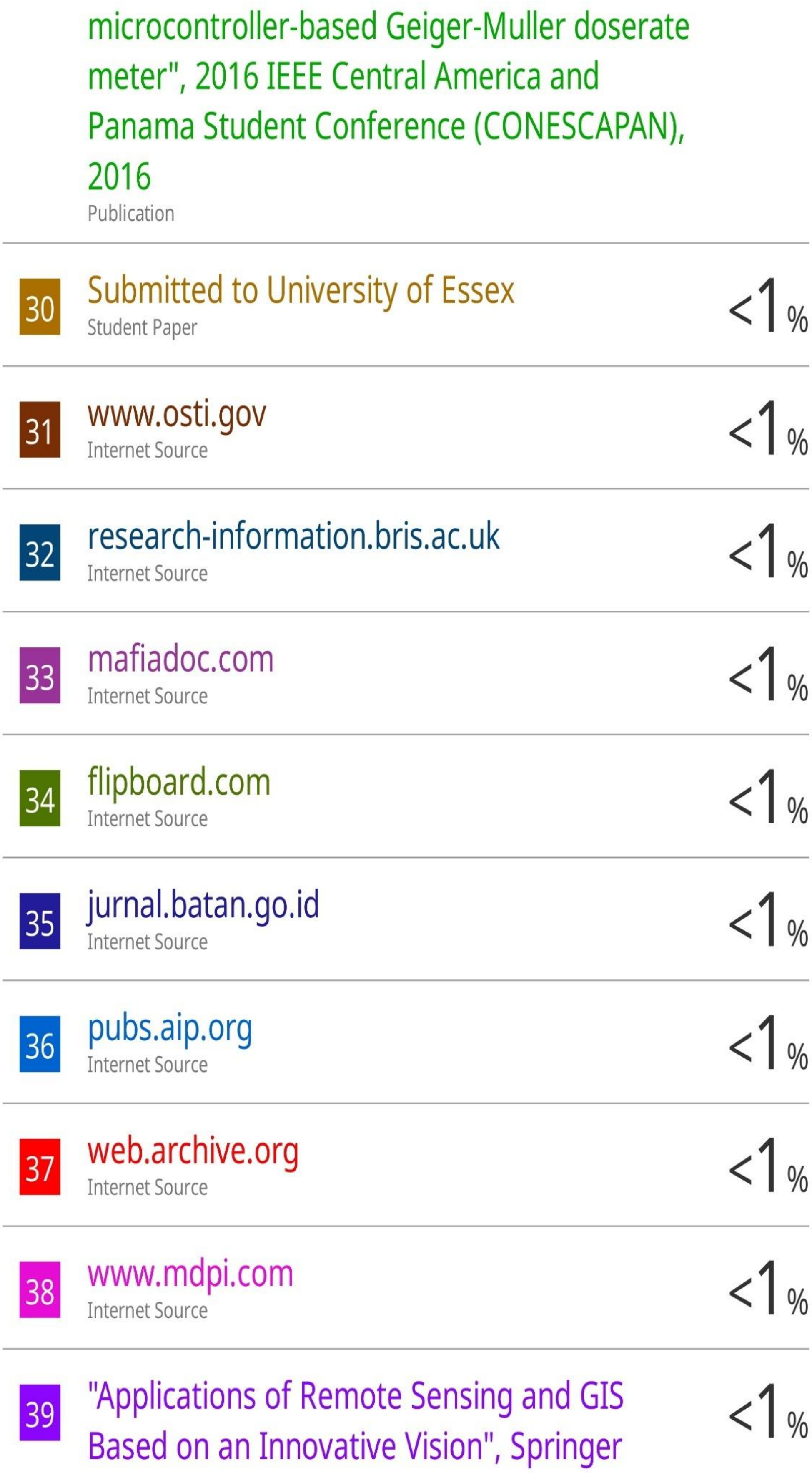


| | | |
|---|---|---|
| 10 | Haider A.H. Alobaidy, J. S. Mandeep, Mehran Behjati, Rosdiadee Nordin, Nor Fadzilah Abdullah. "Wireless Transmissions, Propagation and Channel Modelling for IoT Technologies: Applications and Challenges", IEEE Access, 2022<br>Publication | <1 % |
| 11 | repositsc.nuczu.edu.ua<br>Internet Source | <1 % |
| 12 | www.tandfonline.com<br>Internet Source | <1 % |
| 13 | Submitted to University of Pretoria<br>Student Paper | <1 % |
| 14 | cpee2021.zcu.cz<br>Internet Source | <1 % |
| 15 | speedypaper.x10.mx<br>Internet Source | <1 % |
| 16 | arc.aiaa.org<br>Internet Source | <1 % |
| 17 | Submitted to Lincoln University<br>Student Paper | <1 % |
| 18 | journals.ontu.edu.ua<br>Internet Source | <1 % |
| 19 | Ishigaki, Yang, Yoshinori Matsumoto, Ryo Ichimiya, and Kenji Tanaka. "Development of | <1 % |

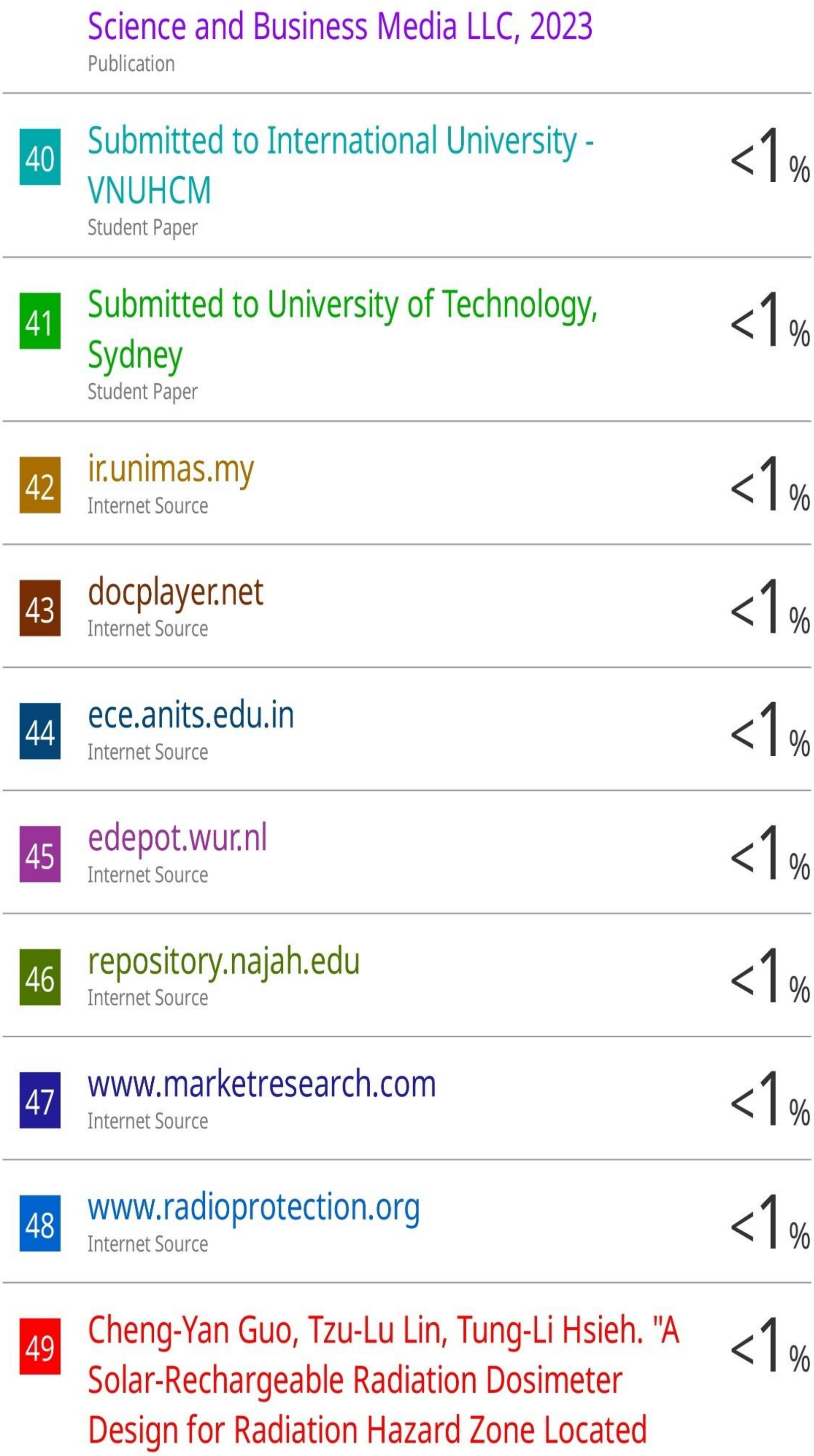


Mobile Radiation Monitoring System Utilizing Smartphone and Its Field Tests in Fukushima", IEEE Sensors Journal, 2013.
Publication

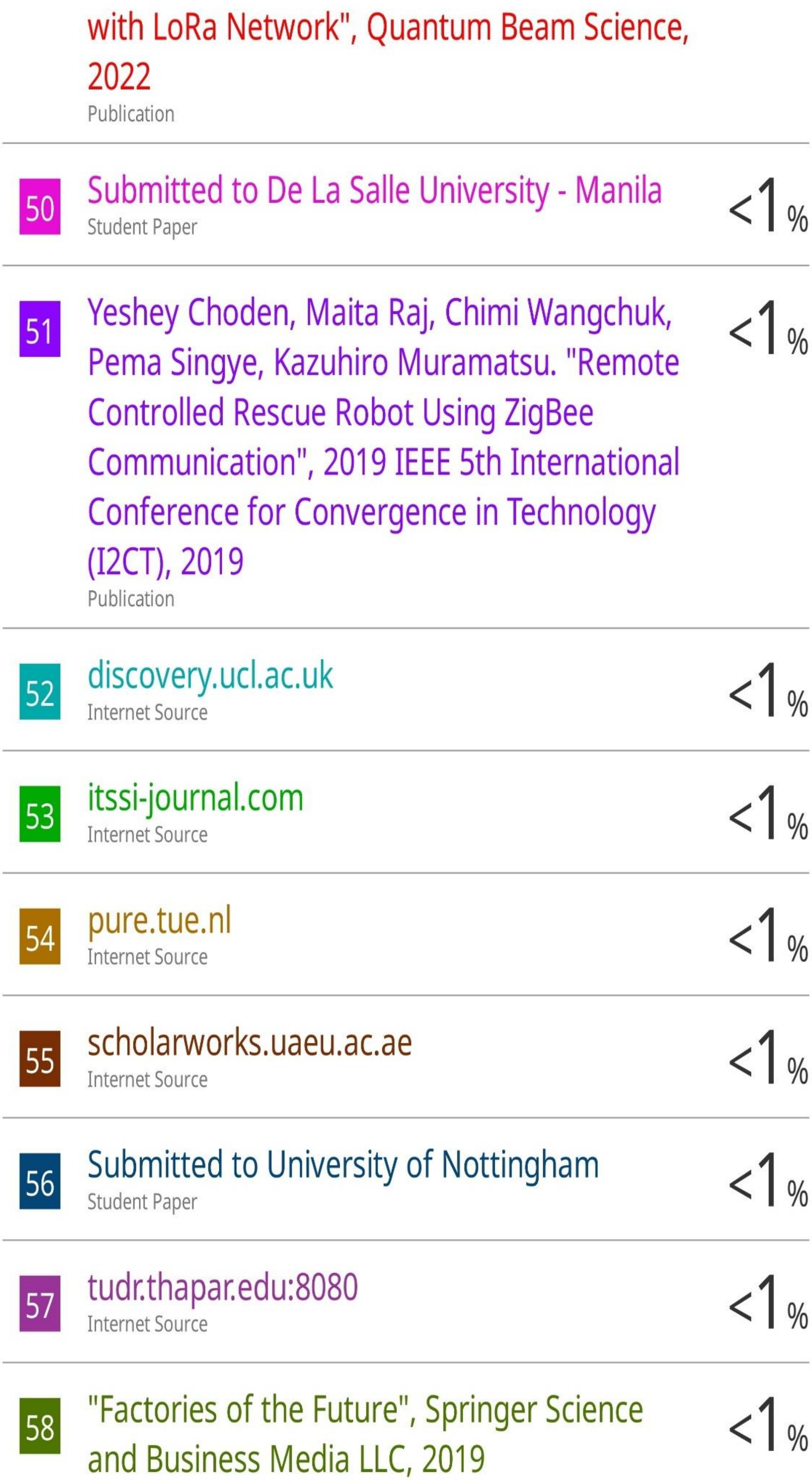
| | | |
|---|---|---|
| 20 | www.ijsr.net<br>Internet Source | <1 % |
| 21 | Submitted to Vels University<br>Student Paper | <1 % |
| 22 | jeasd.uomustansiriyah.edu.iq<br>Internet Source | <1 % |
| 23 | Submitted to University of Bristol<br>Student Paper | <1 % |
| 24 | Submitted to Atlantic Technological University<br>Student Paper | <1 % |
| 25 | Lan Xinju. "Laser Technology", CRC Press, 2019<br>Publication | <1 % |
| 26 | sparkfun.hackster.io<br>Internet Source | <1 % |
| 27 | Submitted to British University in Egypt<br>Student Paper | <1 % |
| 28 | Submitted to Istanbul Bilgi University<br>Student Paper | <1 % |
| 29 | Ivan Morales, Andres Monterroso, Silvio Urizar. "Design, assembly and calibration of a | <1 % |



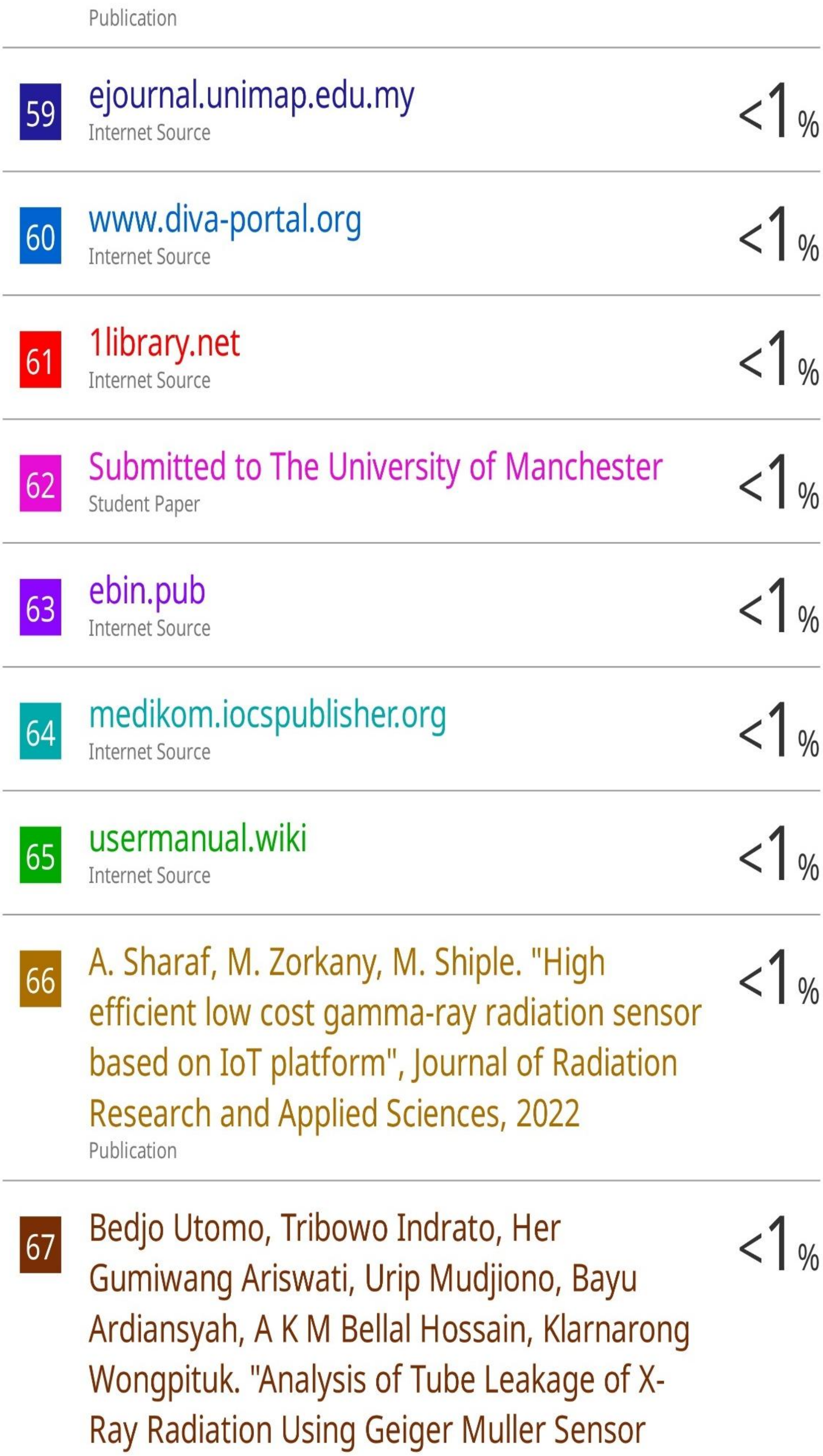
| | | |
|---|---|---|
| | microcontroller-based Geiger-Muller doserate meter", 2016 IEEE Central America and Panama Student Conference (CONESCAPAN), 2016<br>Publication | |
| 30 | Submitted to University of Essex<br>Student Paper | <1 % |
| 31 | www.osti.gov<br>Internet Source | <1 % |
| 32 | research-information.bris.ac.uk<br>Internet Source | <1 % |
| 33 | mafiadoc.com<br>Internet Source | <1 % |
| 34 | flipboard.com<br>Internet Source | <1 % |
| 35 | jurnal.batan.go.id<br>Internet Source | <1 % |
| 36 | pubs.aip.org<br>Internet Source | <1 % |
| 37 | web.archive.org<br>Internet Source | <1 % |
| 38 | www.mdpi.com<br>Internet Source | <1 % |
| 39 | "Applications of Remote Sensing and GIS Based on an Innovative Vision", Springer | <1 % |



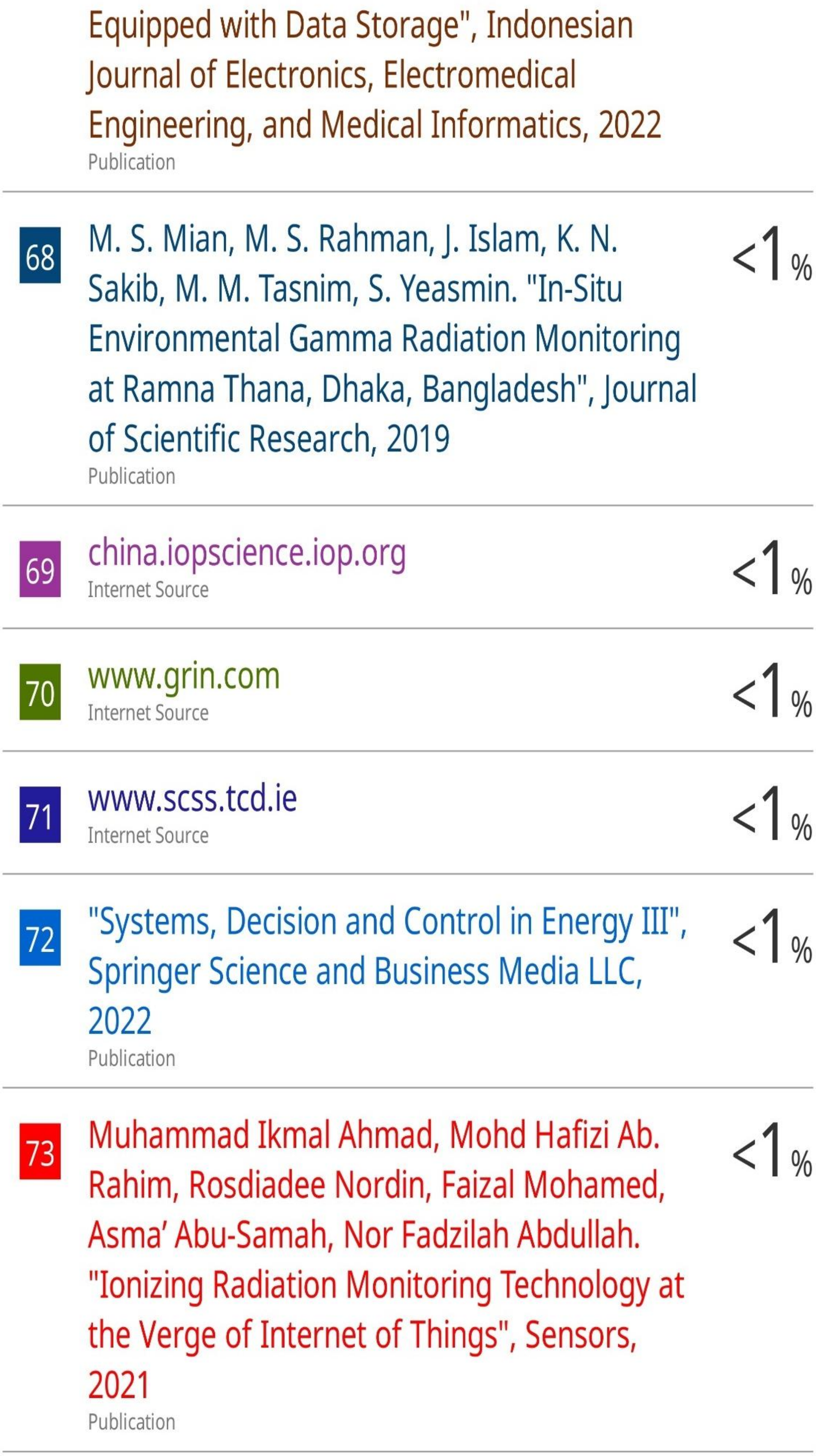
| | | |
|---|---|---|
| | Science and Business Media LLC, 2023<br>Publication | |
| 40 | Submitted to International University - VNUHCM<br>Student Paper | <1 % |
| 41 | Submitted to University of Technology, Sydney<br>Student Paper | <1 % |
| 42 | ir.unimas.my<br>Internet Source | <1 % |
| 43 | docplayer.net<br>Internet Source | <1 % |
| 44 | ece.anits.edu.in<br>Internet Source | <1 % |
| 45 | edepot.wur.nl<br>Internet Source | <1 % |
| 46 | repository.najah.edu<br>Internet Source | <1 % |
| 47 | www.marketresearch.com<br>Internet Source | <1 % |
| 48 | www.radioprotection.org<br>Internet Source | <1 % |
| 49 | Cheng-Yan Guo, Tzu-Lu Lin, Tung-Li Hsieh. "A Solar-Rechargeable Radiation Dosimeter Design for Radiation Hazard Zone Located | <1 % |



| | | |
|---|---|---|
| | with LoRa Network", Quantum Beam Science, 2022<br>Publication | |
| 50 | Submitted to De La Salle University - Manila<br>Student Paper | <1 % |
| 51 | Yeshey Choden, Maita Raj, Chimi Wangchuk, Pema Singye, Kazuhiro Muramatsu. "Remote Controlled Rescue Robot Using ZigBee Communication", 2019 IEEE 5th International Conference for Convergence in Technology (I2CT), 2019<br>Publication | <1 % |
| 52 | discovery.ucl.ac.uk<br>Internet Source | <1 % |
| 53 | itssi-journal.com<br>Internet Source | <1 % |
| 54 | pure.tue.nl<br>Internet Source | <1 % |
| 55 | scholarworks.uaeu.ac.ae<br>Internet Source | <1 % |
| 56 | Submitted to University of Nottingham<br>Student Paper | <1 % |
| 57 | tudr.thapar.edu:8080<br>Internet Source | <1 % |
| 58 | "Factories of the Future", Springer Science and Business Media LLC, 2019 | <1 % |



| | | |
|---|---|---|
| | Publication | |
| 59 | ejournal.unimap.edu.my<br>Internet Source | <1 % |
| 60 | www.diva-portal.org<br>Internet Source | <1 % |
| 61 | 1library.net<br>Internet Source | <1 % |
| 62 | Submitted to The University of Manchester<br>Student Paper | <1 % |
| 63 | ebin.pub<br>Internet Source | <1 % |
| 64 | medikom.iocspublisher.org<br>Internet Source | <1 % |
| 65 | usermanual.wiki<br>Internet Source | <1 % |
| 66 | A. Sharaf, M. Zorkany, M. Shiple. "High efficient low cost gamma-ray radiation sensor based on IoT platform", Journal of Radiation Research and Applied Sciences, 2022<br>Publication | <1 % |
| 67 | Bedjo Utomo, Tribowo Indrato, Her Gumiwang Ariswati, Urip Mudjiono, Bayu Ardiansyah, A K M Bellal Hossain, Klarnarong Wongpituk. "Analysis of Tube Leakage of X-Ray Radiation Using Geiger Muller Sensor | <1 % |



| | | |
|---|---|---|
| | Equipped with Data Storage", Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics, 2022<br>Publication | |
| 68 | M. S. Mian, M. S. Rahman, J. Islam, K. N. Sakib, M. M. Tasnim, S. Yeasmin. "In-Situ Environmental Gamma Radiation Monitoring at Ramna Thana, Dhaka, Bangladesh", Journal of Scientific Research, 2019<br>Publication | <1% |
| 69 | china.iopscience.iop.org<br>Internet Source | <1% |
| 70 | www.grin.com<br>Internet Source | <1% |
| 71 | www.scss.tcd.ie<br>Internet Source | <1% |
| 72 | "Systems, Decision and Control in Energy III", Springer Science and Business Media LLC, 2022<br>Publication | <1% |
| 73 | Muhammad Ikmal Ahmad, Mohd Hafizi Ab. Rahim, Rosdiadee Nordin, Faizal Mohamed, Asma' Abu-Samah, Nor Fadzilah Abdullah. "Ionizing Radiation Monitoring Technology at the Verge of Internet of Things", Sensors, 2021<br>Publication | <1% |

| | | |
|---|---|---|
| 74 | Raghbir Singh Khandpur. "Compendium of Biomedical Instrumentation", Wiley, 2020<br>Publication | <1% |

| | | | |
|---|---|---|---|
| Exclude quotes | Off | Exclude matches | Off |
| Exclude bibliography | Off | | |

# APPENDIX B

# PROGRAM

```
#include "api_hal_gpio.h"
#include "stdint.h"
#include "stdbool.h"
#include "api_debug.h"
#include "api_os.h"
#include "api_hal_pm.h"
#include "api_event.h"
#include <string.h>
#include <stdio.h>
#include <api_gps.h>
#include <api_hal_uart.h>
#include "buffer.h"
#include "gps_parse.h"
#include "math.h"
#include "gps.h"
#include "time.h"
#include "api_info.h"
#include "assert.h"
#include "api_socket.h"
#include "api_network.h"

#define MAIN_TASK_STACK_SIZE (1024 * 2)
#define MAIN_TASK_PRIORITY 0
#define MAIN_TASK_NAME "MAIN Test Task"

#define TEST_TASK_STACK_SIZE (1024 * 2)
#define TEST_TASK_PRIORITY 1
#define TEST_TASK_NAME "GPIO Test Task"

#define SERVER_IP "api.thingspeak.com"
#define SERVER_PORT 80
#define SERVER_PATH "/update?api_key=46UJ3ML8HPUL57D9&field1=%d"

static HANDLE mainTaskHandle = NULL;
static HANDLE secondTaskHandle = NULL;

#define UPLOAD_DATA_LED GPIO_PIN28
#define statusLedPin GPIO_PIN28
#define radiationPin GPIO_PIN2

#define LOG_PERIOD 17000  //Logging period in milliseconds, recommended value 15000-60000.
#define MAX_PERIOD 60000  //Maximum logging period without modifying this sketch
```

```
#define conversionFactor 0.00750// 301.03    //SBM-20 = 151.00, j305
= 264.00/0.00332/301.03

bool networkFlag = false;
bool isGpsOn = true;

uint8_t buffer[1024], buffer2[400];
float radiationCount = 0;
bool statusLed = 0;
static uint32_t count = 0;
static uint16_t cpm = 0;
float uSvt = 0;       // variable for uSvt
float multiplier = MAX_PERIOD / LOG_PERIOD; // variable for
calculation CPM in this sketch
float latitude = 23.8461333, longitude = 90.3654296;

void ISR()
{
    count++;
    // Trace(1, "Radiaiton !! Count: %d", count);
    // statusLed = !statusLed;
    // GPIO_Set(statusLedPin, statusLed); // Set level
}

void checkRadiation()
{
    // if(count == 0) {radiationCount++; count = radiationCount;}
    cpm = count * multiplier;
    // uSvt = cpm/conversionFactor;
    uSvt = cpm * conversionFactor; // 0.00332
    Trace(1, "Count: %d -- CPM: %d -- uSvt: %f", count, cpm, uSvt);
    count = 0;
}

void initGps(){
    GPS_Info_t* gpsInfo = Gps_GetInfo();
    // uint8_t buffer[300];

    //wait for gprs register complete
    //The process of GPRS registration network may cause the status
supply voltage of GPS to drop,
    //which resulting in GPS restart.
    while(!networkFlag)
    {
        Trace(1,"Waiting for GPRS register");
        statusLed = !statusLed;
        GPIO_Set(statusLedPin, statusLed);
        OS_Sleep(1000);
```

```
    }
    statusLed = 0;
    GPIO_Set(statusLedPin, statusLed);

    //open GPS hardware(UART2 open either)
    GPS_Init();
    GPS_Open(NULL);

    //wait for gps start up, or gps will not response command
    while(gpsInfo->rmc.latitude.value == 0)
        OS_Sleep(1000);

    // set gps nmea output interval
    for(uint8_t i = 0;i<5;++i)
    {
        bool ret = GPS_SetOutputInterval(10000);
        Trace(1,"set gps ret:%d",ret);
        if(ret)
            break;
        OS_Sleep(1000);
    }
    if(!GPS_SetOutputInterval(1000))
        Trace(1,"set nmea output interval fail");

    Trace(1,"GPS init ok");
}

void getGps()
{
    GPS_Info_t* gpsInfo = Gps_GetInfo();
    if(isGpsOn)
    {
        //show fix info
        uint8_t isFixed = gpsInfo->gsa[0].fix_type > gpsInfo-
>gsa[1].fix_type ?gpsInfo->gsa[0].fix_type:gpsInfo->gsa[1].fix_type;
        char* isFixedStr;
        if(isFixed == 2)
            isFixedStr = "2D fix";
        else if(isFixed == 3)
        {
            if(gpsInfo->gga.fix_quality == 1)
                isFixedStr = "3D fix";
            else if(gpsInfo->gga.fix_quality == 2)
                isFixedStr = "3D/DGPS fix";
        }
        else
            isFixedStr = "no fix";
```

```
        //convert unit ddmm.mmmm to degree(°)
        int temp = (int)(gpsInfo->rmc.latitude.value/gpsInfo-
>rmc.latitude.scale/100);
        latitude = temp+(double)(gpsInfo->rmc.latitude.value -
temp*gpsInfo->rmc.latitude.scale*100)/gpsInfo-
>rmc.latitude.scale/60.0;
        temp = (int)(gpsInfo->rmc.longitude.value/gpsInfo-
>rmc.longitude.scale/100);
        longitude = temp+(double)(gpsInfo->rmc.longitude.value -
temp*gpsInfo->rmc.longitude.scale*100)/gpsInfo-
>rmc.longitude.scale/60.0;

        snprintf(buffer,sizeof(buffer),"fix quality:%d, Sat Trac:%d,
Total Sat:%d, Fix:%s, Lat:%f, Long:%f",
        gpsInfo->gga.fix_quality, gpsInfo->gga.satellites_tracked,
gpsInfo->gsv[0].total_sats, isFixedStr, latitude,longitude);
        //show in tracer
        Trace(2,buffer);
    }
}

void EventDispatch(API_Event_t *pEvent)
{
    switch (pEvent->id)
    {
    case API_EVENT_ID_NO_SIMCARD:
        Trace(10, "!!NO SIM CARD%d!!!!", pEvent->param1);
        networkFlag = false;
        break;
    case API_EVENT_ID_NETWORK_REGISTER_SEARCHING:
        Trace(2, "network register searching");
        networkFlag = false;
        break;
    case API_EVENT_ID_NETWORK_REGISTER_DENIED:
        Trace(2, "network register denied");
    case API_EVENT_ID_NETWORK_REGISTER_NO:
        Trace(2, "network register no");
        break;
    case API_EVENT_ID_GPS_UART_RECEIVED:
        // Trace(1,"received GPS data,length:%d,
data:%s,networkFlag:%d",pEvent->param1,pEvent->pParam1,networkFlag);
        GPS_Update(pEvent->pParam1, pEvent->param1);
        break;
    case API_EVENT_ID_NETWORK_REGISTERED_HOME:
    case API_EVENT_ID_NETWORK_REGISTERED_ROAMING:
    {
        uint8_t status;
        Trace(2, "network register success");
```

```
        bool ret = Network_GetAttachStatus(&status);
        if (!ret)
            Trace(1, "get attach staus fail");
        Trace(1, "attach status:%d", status);
        if (status == 0)
        {
            ret = Network_StartAttach();
            if (!ret)
            {
                Trace(1, "network attach fail");
            }
        }
        else
        {
            Network_PDP_Context_t context = {
                .apn = "cmnet",
                .userName = "",
                .userPasswd = ""};
            Network_StartActive(context);
        }
        break;
    }
    case API_EVENT_ID_NETWORK_ATTACHED:
        Trace(2, "network attach success");
        Network_PDP_Context_t context = {
            .apn = "cmnet",
            .userName = "",
            .userPasswd = ""};
        Network_StartActive(context);
        break;
    case API_EVENT_ID_NETWORK_ACTIVATED:
        Trace(2, "network activate success");
        networkFlag = true;
        break;
    case API_EVENT_ID_UART_RECEIVED:
        if (pEvent->param1 == UART1)
        {
            uint8_t data[pEvent->param2 + 1];
            data[pEvent->param2] = 0;
            memcpy(data, pEvent->pParam1, pEvent->param2);
            Trace(1, "uart received data,length:%d,data:%s", pEvent-
>param2, data);
            if (strcmp(data, "close") == 0)
            {
                Trace(1, "close gps");
                GPS_Close();
                isGpsOn = false;
            }
```

```
            else if (strcmp(data, "open") == 0)
            {
                Trace(1, "open gps");
                GPS_Open(NULL);
                isGpsOn = true;
            }
        }
        break;
    default:
        break;
    }
}

// http post with no header
int Http_Post(const char *domain, int port, const char *path, const
char *body, uint16_t bodyLen, char *retBuffer, int bufferLen)
{
    uint8_t ip[16];
    bool flag = false;
    uint16_t recvLen = 0;
    // connect server
    memset(ip, 0, sizeof(ip));
    if (DNS_GetHostByName2(domain, ip) != 0)
    {
        Trace(2, "get ip error");
        return -1;
    }
    else
        Trace(2, "get ip success:%s -> %s", domain, ip);
    char *servInetAddr = ip;
    char *temp = OS_Malloc(2048);
    if (!temp)
    {
        Trace(2, "malloc fail");
        return -1;
    }
    snprintf(temp, 2048, "POST %s HTTP/1.1\r\nContent-Type:
application/x-www-form-urlencoded\r\nConnection: close\r\nHost:
%s\r\nContent-Length: %d\r\n\r\n",
             path, domain, bodyLen);

    char *pData = temp;
    int fd = socket(AF_INET, SOCK_STREAM, IPPROTO_TCP);
    if (fd < 0)
    {
        Trace(2, "socket fail");
        OS_Free(temp);
        return -1;
```

```
    }
    struct sockaddr_in sockaddr;
    memset(&sockaddr, 0, sizeof(sockaddr));
    sockaddr.sin_family = AF_INET;
    sockaddr.sin_port = htons(port);
    inet_pton(AF_INET, servInetAddr, &sockaddr.sin_addr);
    int ret = connect(fd, (struct sockaddr *)&sockaddr,
  sizeof(struct sockaddr_in));
    if (ret < 0)
    {
        Trace(2, "socket connect fail");
        OS_Free(temp);
        close(fd);
        return -1;
    }
    Trace(2, "socket connect success");
    Trace(2, "send request:%s", pData);
    ret = send(fd, pData, strlen(pData), 0);
    if (ret < 0)
    {
        Trace(2, "socket send fail");
        OS_Free(temp);
        close(fd);
        return -1;
    }
    ret = send(fd, body, bodyLen, 0);
    if (ret < 0)
    {
        Trace(2, "socket send fail");
        OS_Free(temp);
        close(fd);
        return -1;
    }
    struct fd_set fds;
    struct timeval timeout = {12, 0};
    FD_ZERO(&fds);
    FD_SET(fd, &fds);
    while (!flag)
    {
        ret = select(fd + 1, &fds, NULL, NULL, &timeout);
        // Trace(2,"select return:%d",ret);
        switch (ret)
        {
        case -1:
            Trace(2, "select error");
            flag = true;
            break;
        case 0:
```

```
            Trace(2, "select timeout");
            flag = true;
            break;
        default:
            if (FD_ISSET(fd, &fds))
            {
                memset(retBuffer, 0, bufferLen);
                ret = recv(fd, retBuffer, bufferLen, 0);
                recvLen += ret;
                if (ret < 0)
                {
                    Trace(2, "recv error");
                    flag = true;
                    break;
                }
                else if (ret == 0)
                {
                    Trace(2, "ret == 0");
                    break;
                }
                else if (ret < 1352)
                {
                    GPS_DEBUG_I("recv len:%d,data:%s", recvLen,
retBuffer);
                    close(fd);
                    OS_Free(temp);
                    return recvLen;
                }
            }
            break;
        }
    }
    close(fd);
    OS_Free(temp);
    return -1;
}
void send_gprs()
{
    while (!networkFlag)
    {
        Trace(1, "Wait for GPRS register");
        statusLed = !statusLed;
        GPIO_Set(statusLedPin, statusLed);
        OS_Sleep(1000);
    }
    char *requestPath = buffer2;
    memset(buffer, 0, sizeof(buffer));
    if (!INFO_GetIMEI(buffer))
```

```
        Assert(false, "NO IMEI");
    Trace(1, "device IMEI:%s", buffer);
    snprintf(requestPath, sizeof(buffer2),
"/update?api_key=46UJ3ML8HPUL57D9&field1=%.3f&field2=%.6f&field3=%.6
f", uSvt, latitude, longitude);

    uint8_t status;
    Network_GetActiveStatus(&status);
    if (status)
    {
        GPIO_Set(statusLedPin, 1);

        if (Http_Post(SERVER_IP, SERVER_PORT, requestPath, NULL, 0,
buffer, sizeof(buffer)) < 0)
            Trace(1, "send location to server fail");
        else
        {
            Trace(1, "send location to server success");
            Trace(1, "response:%s", buffer);
        }
        GPIO_Set(statusLedPin, 0);
    }
    else Trace(1, "no internet");
}

void initialization_Task()
{
    GPIO_config_t status = {
        .mode = GPIO_MODE_OUTPUT,
        .pin = statusLedPin,
        .defaultLevel = GPIO_LEVEL_LOW};
    GPIO_config_t rdData = {
        .mode = GPIO_MODE_INPUT_INT,
        .pin = radiationPin,
        .defaultLevel = GPIO_LEVEL_LOW,
        .intConfig.debounce = 50,
        .intConfig.type = GPIO_INT_TYPE_FALLING_EDGE,
        .intConfig.callback = ISR};

    PM_PowerEnable(POWER_TYPE_VPAD, true);
    Trace(1, "Starting...");
    GPIO_Init(status);
    GPIO_Init(rdData);
    initGps();

    while (1)
    {
        checkRadiation();
```

```
        getGps();
        send_gprs();
        PM_SetSysMinFreq(PM_SYS_FREQ_32K);
        OS_Sleep(LOG_PERIOD);
        // OS_Sleep(15000);
        PM_SetSysMinFreq(PM_SYS_FREQ_178M);
    }
}

void MainTask(void *pData)
{
    API_Event_t *event = NULL;

    secondTaskHandle = OS_CreateTask(initialization_Task,
                                     NULL, NULL,
TEST_TASK_STACK_SIZE, TEST_TASK_PRIORITY, 0, 0, TEST_TASK_NAME);

    while (1)
    {
        if (OS_WaitEvent(mainTaskHandle, (void **)&event,
OS_TIME_OUT_WAIT_FOREVER))
        {
            EventDispatch(event);
            OS_Free(event->pParam1);
            OS_Free(event->pParam2);
            OS_Free(event);
        }
    }
}

RRSU_v4_Main()
{
    mainTaskHandle = OS_CreateTask(MainTask,
                                   NULL, NULL, MAIN_TASK_STACK_SIZE,
MAIN_TASK_PRIORITY, 0, 0, MAIN_TASK_NAME);
    OS_SetUserMainHandle(&mainTaskHandle);
}
```