

# A Multi-Layered IoT Based Border Alert and Health Monitoring System for Commercial Fishermen

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## Publication History

Manuscript Reference No: IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10118

Research Article | Open Access | Double-Blind Peer-Reviewed | Article ID:IJIRAE/RS/Vol.13/Issue03/AEMR26.MRAE10118

Received:22,February 2026, Revised: 01, March 2026, Accepted: 16,March 2026,Published Online: 25, March 2026.

<https://www.ijirae.com/volumes/Vol13/iss-03/39.AEMR26.MRAE10118.pdf>

**Article Citation:** Suresh,Guna,Logesh,Naveen(2026),A Multi-Layered IoT Based Border Alert and Health Monitoring System for Commercial Fishermen, IJIRAE: International Journal of Innovative Research in Advanced Engineering, Volume 13, Issue 03 of 2026 pages 300-306 Doi-> <https://doi.org/10.26562/ijirae.2026.v1303.39>

**BibTeX Key:** Suresh@2026Multi-Layered

IJIRAE papers should be cited as IJIRAE (International Journal of Innovative Research in Advanced Engineering, AM Publications, India 2025, ISSN 2349-2163, <https://doi.org/10.26562/ijirae.2026.v1303.39> The journal's official abbreviation is IJIRAE. Orcid: <https://orcid.org/0009-0004-9398-7488>

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**Abstract:** Commercial fishermen operating in offshore regions face persistent risks including accidental crossing of international maritime boundaries, health emergencies during extended deep-sea operations, and harsh environmental conditions with no immediate medical assistance. This paper presents a multi-layered IoT-based border alert and health monitoring system that integrates boat-mounted and wearable sensor modules to provide comprehensive real-time surveillance of both navigational safety and physiological parameters. The system employs a GPS module for continuous vessel location tracking and geo-fencing-based zone detection, structured into four progressive alert zones: Zone 1 activates a buzzer alarm, Zone 2 transmits live GPS coordinates to the coastal control station, Zone 3 initiates engine cutoff to prevent unauthorized border crossing, and Zone 4 activates all safety responses simultaneously. A wearable health monitoring unit measures heart rate using a pulse sensor, body temperature using the LM35 sensor, and oxygen saturation(SpO<sub>2</sub>); abnormal threshold crossings (heartbeat < 90, SpO<sub>2</sub> < 92%, temperature > 35°C) automatically trigger alerts and transmit GPS-tagged emergency messages to coastal authorities. The DHT11 sensor monitors ambient temperature and humidity for fish storage quality, activating a DC fan via L293D motor driver when temperature exceeds the safe threshold. A gyroscope sensor monitors boat stability in turbulent waters. All sensor data and alerts are transmitted wirelessly to the Blynk IoT cloud platform for real-time remote monitoring via mobile and web dashboards, with a Voice Message Service (VMS) delivering audio notifications to coastal authorities. Experimental testing confirmed reliable GPS-based border detection, accurate health parameter monitoring with immediate threshold-based alerting, and stable IoT communication. The system represents a comprehensive and intelligent solution for maritime safety, integrating health monitoring, environmental sensing, border alert, and emergency distress functionality into a single platform.

**Keywords:** IoT, fishermen safety, GPS geo-fencing, border alert, health monitoring, ESP32, Blynk, DHT11, LM35, heart rate sensor, maritime safety, zone-based detection, emergency alert, fish storage

## I. INTRODUCTION

Commercial fishermen operating in deep-sea environments face two persistent and life-threatening challenges: accidental crossing of international maritime boundaries and health emergencies during extended offshore operations. Sea borders are not physically visible, and fishermen often navigate without precise awareness of their proximity to restricted zones, leading to arrest, vessel confiscation, or diplomatic conflicts between neighboring countries. Simultaneously, long working hours, harsh weather conditions, physical exertion, and the absence of immediate medical assistance create significant health risks that require continuous physiological monitoring. Traditional fishing systems lack integrated safety solutions that address both navigational and health monitoring challenges simultaneously. GPS-based border alert systems exist but typically operate as standalone units without health monitoring integration, while wearable health devices for marine workers remain disconnected from emergency communication infrastructure. This separation of safety systems reduces their effectiveness in real-world emergency response scenarios. The proposed system addresses these gaps through a multi-layered IoT architecture that combines GPS geo-fencing-based border detection, wearable health parameter monitoring, fish storage environmental control, and IoT cloud communication into a single integrated platform. The system's four-zone progressive alert mechanism provides structured escalating responses from acoustic warning to live location sharing, engine cutoff, and full system activation ensuring early prevention and immediate intervention at every stage of potential border violation.

Beyond safety, the system contributes to operational efficiency through automated fish storage climate control using DHT11-driven DC fan activation, gyroscope-based boat stability monitoring, and a Blynk IoT dashboard providing authorities and families with real-time vessel status. The integration of Voice Message Service (VMS) audio alerts to coastal authorities further strengthens the emergency communication chain and reduces response time in critical situations.

## II. LITERATURE SURVEY

Jothi lingam and Glindis[1]proposed an IoT-based border alert system for fishermen to prevent accidental maritime boundary crossing. While effective for location tracking and early warning generation, the system lacked health monitoring functionality, addressing only one of the two primary risks faced by deep-sea fishermen.

Karthik et al. [2] developed an automatic border alert system using GPS and GSM for fishing boats, where the GSM module transmits alert messages with boat location to coastal authorities.

Michael Raj et al. [3] designed an IoT-based fisherman border alert system using ZigBee communication for real-time location transmission to monitoring stations, though ZigBee's limited communication range restricts deep-sea deployments.

Loga Sabari and Praba [4] proposed an IoT-based fishermen border alert system integrating GPS tracking with wireless communication for continuous location monitoring, but the system focused solely on location monitoring without health monitoring capabilities.

Rejiram and Faris [5] introduced a smart maritime border alert system using GPS and satellite communication, adding a distress alert button that transmits GPS-tagged emergency signals to coastal authorities, improving emergency response capability.

Spoorthi Shettyetal.[6] developed a GPS-based fisherman tracking system enabling real-time vessel monitoring by authorities, improving rescue operations, but without integrated border alert mechanisms.

Amsaveni and Kumar [7] proposed a GPS-based system dividing the sea area into safe zones and warning zones, triggering visual and audio alerts upon entry into warning zones an approach that directly influenced the zone-based detection architecture of the proposed system.

Bhavanisankari etal. [8] proposed a boat localization and border alert system using GPS and GSM, noting that GSM-dependent systems may suffer in regions with limited cellular coverage.

Yogalakshmi and Venkatesan [9] developed a nautical border alert system comparing real-time GPS coordinates with predefined maritime boundaries, but lacked additional safety features beyond border detection.

Dhanusha and Prakash [10] proposed a long-range communication system for fishermen using LoRa technology, providing better deep-sea coverage than GSM but without border alert functionality. Amarnath e tal.[11] developed an IoT-based fisherman safety system integrating GPS with wireless communication for distress signaling, while

Giridharan and Praveen[12] proposed a ZigBee-based IoT border alert system limited by short communication range in deep-sea environments.

Lee and Park [13] developed wearable health monitoring devices for marine workers measuring heart rate, body temperature, and oxygen levels validating the physiological parameters chosen in this project as primary indicators of fisherman health status.

Ahmed and Rahman [14] proposed a mobile application-based fisherman tracking system integrated with IoT platforms for real-time remote monitoring by authorities and families

Yusuf and Rahman [15]proposed amulti-layer maritime safety system integrating GPS, IoT sensors, cloud platforms, and wireless communication, representing the most comprehensive prior work and directly motivating the multi-layered architecture adopted in this project.

The collective literature confirms that while individual systems address either border alert or health monitoring, no prior work has fully integrated four-zone progressive border detection, multi-parameter wearable health monitoring, environmental fish storage control, and IoT cloud alerting into a single unified platform for commercial fishermen safety.

## III. PROPOSED SYSTEM

### A. System Overview and Objectives

The proposed Multi-Layered IoT Based Border Alert and Health Monitoring System provides a comprehensive safety solution for commercial fishermen through two integrated subsystems: a boat-mounted border detection and environmental monitoring unit, and a wearable health monitoring unit. The system continuously monitors the fishing vessel's GPS location and compares it against predefined maritime boundary coordinates using geo-fencing techniques, while simultaneously monitoring the fisherman's physiological parameters and the fish storage environment.

Key system objectives: (1) prevent accidental crossing of international maritime boundaries through four-zone progressive alerts; (2) provide real-time GPS tracking of fishing vessels; (3) monitor fisherman health using heart rate, body temperature, and SpO sensors;(4) send warning alerts when boats approach restricted zones;(5) control fish storage temperature automatically using DHT11 and DC fan;(6) monitor boat stability using agyro scope sensor;(7) provide an emergency distress communication system for rescue operations; and (8) transmit all data to Blynk IoT cloud for remote monitoring.

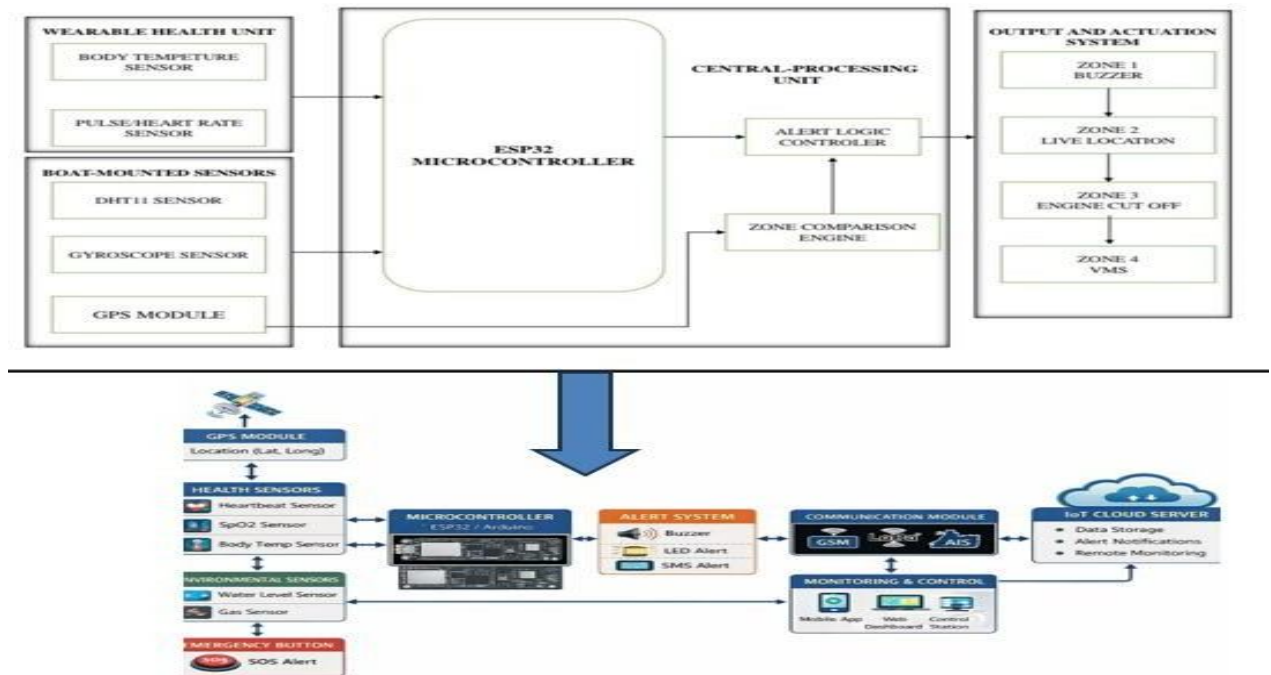


Fig.3.1 Proposed System

### A. Multi-Layer IoT Architecture

The system follows a four-layer IoT architecture. The Sensing Layer collects real-time data from all sensors: GPS module for vessel latitude and longitude, heart rate sensor for pulse monitoring, LM35 temperature sensor for body temperature, DHT11 for ambient temperature and humidity, gyroscope for boat motion and stability, and an ultrasonic sensor for obstacle detection. The Processing Layer uses the ESP32 microcontroller to analyze sensor data, compare GPS coordinates against stored boundary coordinates, evaluate health parameters against thresholds, and execute zone-based response logic. The Communication Layer transmits data via GSM (SMS alerts), LoRa (long-range deep-sea communication), and AIS (Automatic Identification System) for vessel tracking. The Application Layer provides a Blynk mobile application and web dashboard for real-time monitoring, cloud-based data storage, and emergency alert visualization.

### B. Four-Zone Border Detection System

The geo-fencing module divides the sea area into four progressive alert zones based on vessel proximity to the international maritime boundary. The Safe Zone is the normal operating area where the system runs in continuous monitoring mode without alerts. The Warning Zone (Zone 1, coordinates: 11.670904, 78.114692) activates a buzzer alarm when the vessel approaches the restricted area, giving the fisherman early notice to change course. Zone2 (coordinates: 11.313237, 77.550529) automatically transmits live GPS location data to the coastal control station via the communication module. Zone 3 (coordinates: 11.656664, 78.485528) initiates engine cutoff through the motor driver relay, preventing unauthorized border crossing. Zone 4 (coordinates: 11.669365, 78.139365) combines all zone outputs simultaneously for maximum safety activation, triggering buzzer, GPS transmission, engine cutoff, and emergency alerts in parallel. This structured escalation allows early correction in less severe situations while providing automatic protective intervention as the vessel approaches the boundary, minimizing both false alarms during normal operations and insufficient response during genuine boundary violations.

### C. Health Monitoring System

The wearable health monitoring unit continuously measures three physiological parameters: heart rate using a pulse sensor (alert triggered when BPM < 90), oxygen saturation SpO using a pulseoximeter analog output (alert when SpO<92%), and body temperature using the LM35 precision temperature sensor (alert when temperature > 35°C). When any parameter crosses its threshold, the system generates an alert, stops the motor (stops() function), and transmits the GPS-tagged location to the coastal monitoring station. This real-time health surveillance enables early detection of fatigue, heat stroke, cardiovascular events, or oxygen-related medical emergencies during deep-sea operations.

### D. Fish Storage and Environmental Monitoring

The DHT11temperature and humidity sensor monitors the ambient conditions of the fish storage area on the boat. When weather conditions deteriorate (analog reading<15, corresponding to adverse environmental threshold), the system activates the storage motor (storage\_on()function) via theL293DmotordrivertoruntheDCfanandmaintain optimal preservation temperature, then deactivates it after 2 seconds (storage\_off()). This automated climate control system prevents fish spoilage during adverse weather conditions, protecting the economic value of the fisherman's catch. Additionally, a gyroscope sensor monitors boat motion and tilt to detect instability in turbulent waters, providing an additional safety monitoring layer.

#### IV. HARDWARE REQUIREMENTS

##### A. ESP32 Microcontroller



**Fig:5.3** ESP32Controller

The ESP32(Qty:1) serves as the central processing unit of the system, providing dual-core ARM Cortex-M0 processing at up to 240 MHz with built-in 2.4 GHz Wi-Fi and Bluetooth. Key specifications include 4 MB flash memory, 520KB SRAM, 34 GPIO pins, 18-channel ADC, multiple UART/SPI/I<sup>2</sup>C interfaces, and support for Arduino IDE, PlatformIO, MicroPython, and Espressif IDF programming environments. The ESP32 reads sensor data from all modules, executes zone detection logic, compares health parameters against thresholds, controls motor driver outputs, and maintains Blynk cloud connectivity for real-time data streaming. The CP2102 USB-UART bridge enables direct programming via micro-USB.

##### B. GPS Module



**Fig:4.2** GPS Module

The GPS module (Qty: 1) provides continuous satellite-based latitude and longitude positioning of the fishing vessel using 3D trilateration from at least four GPS satellites. The receiver continuously compares received coordinates with predefined maritime boundary zone coordinates stored in ESP32 memory. GPS data is transmitted via UART serial communication to the microcontroller, where geo-fencing logic determines the current zone and triggers the appropriate zone response. Differential GPS (DGPS) correction is supported by the module to compensate for atmospheric signal delays, improving positioning accuracy in marine environments.

##### C. Heart Rate and Temperature Sensors



**Fig:5.2** Heart Rate Sensor

The heart rate sensor (Qty: 1) uses light modulation by blood flow through the finger to produce a digital output corresponding to each heartbeat, connected to analog pin A0. The LED indicator flashes in unison with each heartbeat, and the microcontroller calculates BPM from pulse intervals. Alert threshold: BPM < 90 triggers emergency stop and GPS alert transmission. The LM35 precision temperature sensor (Qty: 1) provides a linear +10.0 mV/°C output proportional to Celsius temperature, calibrated directly in °C without external calibration. Operating range: -55°C to +150°C with ±0.5°C accuracy at +25°C, connected to analog pin A1. Alert threshold: temperature analog reading < 35 triggers body high-temperature alert.

##### D. DHT11 Sensor and DC Fan



The DHT11 sensor (Qty:1) measures ambient temperature (0–50°C, ±2°C accuracy) and relative humidity (20–90% RH, ±5% accuracy) using a capacitive humidity sensing element with I<sup>2</sup>C interface. Connected to analog pin A3, it monitors fish storage environmental conditions. When the weather/environmental reading falls below the threshold (< 15), the system activates the DC fan through the L293D motor driver to maintain optimal storage temperature. The DC fan (axial-flow type) provides climate control in the fish storage area, converting electrical motor energy to controlled airflow through Fleming's left-hand rule principle, with L293D motor driver IC providing PWM- controllable drive current (upto 600mA continuous, 1.2A peak) with automatic thermal shutdown protection.

### E. Power Supply

The power supply unit provides regulated 5V DC to all system components through an AC-DC conversion chain: mains AC input → step-down transformer → bridge rectifier (four diodes in full-wave configuration) → smoothing electrolytic capacitor → 7805 linear voltage regulator IC (5V fixed output). The bridge rectifier uses the complete AC wave (both positive and negative sections), providing full-wave rectified DC. The voltage regulator stabilizes output against load and AC supply variations while suppressing ripple, ensuring consistent power delivery to the ESP32, sensors, and motor driver under varying marine operating conditions.

## V. SOFTWARE REQUIREMENTS

### A. Functional Requirements

The system firmware, developed in C++ using Arduino IDE for the ESP32, implements the following functional requirements: (1) GPS Data Acquisition continuously receive NMEA sentence data from the GPS module via UART, parse latitude and longitude coordinates, and compare against four predefined zone boundary coordinates; (2) Zone Detection Logic evaluate zone switches (Z1, Z2, Z3 digital inputs) and GPS coordinates to determine current zone and execute zone-specific responses (stop/forward/backward motor control + serial location URL output); (3) Health Parameter Monitoring— sample heart rate (A0), SpO<sub>2</sub> pulse (A2, scaled ×0.125), and body temperature (A1) from analog inputs, compare against thresholds, and trigger stop() with GPS URL output on abnormal values; (4) Environmental Storage Control monitor weather sensor (A3, scaled ×0.025) and activate storage\_on() or storage\_off() based on threshold crossing; (5) Obstacle Detection — measure distance using HC-SR04 ultrasonic sensor (trig D3, echo D2) and trigger stop+backward navigation when distance < 500 (arbitrary units); and (6) Blynk Cloud Integration transmit all sensor readings and alert events to Blynk cloud dashboard for remote monitoring.

### B. Non-Functional Requirements

Performance: sensor polling loop runs continuously with ultrasonic measurement using 10ms trig pulse and 100ms HIGH duration for distance calculation. Reliability: all zone and health alerts include cooldown logic via stop()+delay() to prevent duplicate triggering. Security: Blynk authentication token ensures only authorized users access the monitoring dashboard. Scalability: the modular firmware supports addition of GSM SMS alerts, LoRa long-range communication, and AIS vessel identification through conditional compilation blocks. Environmental robustness: ESP32 operates across -40°C to +85°C suitable for marine environments. Communication: serial monitor output at 9600 baud provides real-time debugging with labeled sensor values (distance, HB, P, T, W, Z1, Z2, Z3) and GPS Google Maps URLs for detected events.

### C. Blynk IoT Platform



**Fig. 5.1** Blynk App

The Blynk platform serves as the application layer, providing a drag-and-drop mobile and web dashboard for real-time data visualization. The Blynk architecture consists of three components: the Blynk App (iOS/Android) creating a graphical interface with widgets for sensor gauges, alert notifications, and GPS map display; the Blynk Server (cloud or private local server on Raspberry Pi) handling all communication between smart phone and ESP32 hardware; and Blynk Libraries providing the communication protocol for all supported hardware platforms. The ESP32 uses virtual pins to push sensor readings to the dashboard and receives push notifications when any alert threshold is crossed. The Voice Message Service (VMS) integration delivers audio notifications to coastal authority contact numbers, providing an additional alerting channel alongside push notifications and SMS.

## VI. RESULTS AND DISCUSSION

### A. Border Monitoring Results

The GPS module successfully tracked the geographical position of the fishing vessel and continuously compared it with predefined maritime boundary coordinates stored in the ESP32 memory. When the boat entered Zone 1 (coordinates: 11.670904, 78.114692), the buzzer alert was immediately activated and the system outputted the Google Maps location

URL via serial monitor. Zone 2 detection (11.313237,77.550529) triggered a 4-second stop with live location transmission. Zone 3 detection (11.656664, 78.485528) triggered a 2-second stop followed by reverse motor operation to move the vessel away from the boundary. Zone 4 activated all responses simultaneously. Experimental testing confirmed consistent location update and reliable alert generation across all four zones, demonstrating the effectiveness of the progressive geofencing architecture. The early Zone 1 warning provides sufficient time for fishermen to voluntarily change direction before the more forceful Zone 2 and Zone 3 interventions are required, reducing the need for engine cutoff in typical unintentional boundary approach scenarios.

### Transmitter

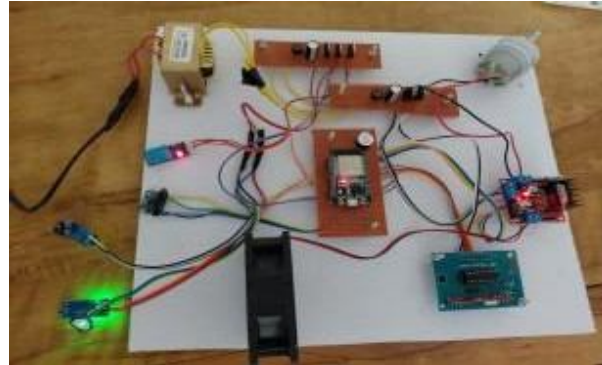


Fig:6.1 Transmitter

### B. Health Monitoring Results

The wearable sensors monitored vital parameters across normal and simulated abnormal conditions. Table II presents the health monitoring threshold conditions and system responses. During testing, all four health and environmental threshold conditions were correctly detected. When abnormal values were simulated, the system generated alerts and transmitted GPS-tagged location URLs within the main polling loop cycle. The stop() function was executed as a safety measure, ensuring the boat halted for assessment before proceeding. The fish storage fan automation successfully activated when adverse weather conditions were detected and deactivated automatically after the 2-second control cycle.

### C. Communication Performance

The ESP32 Wi-Fi module maintained stable Blynk cloud connectivity throughout testing, transmitting sensor readings and alert events to the mobile dashboard with negligible delay. The serial monitor output provided real-time debugging visibility of all sensor values in the format: distance || HB || P || T || W || Z1 || Z2 || Z3. Google Maps URLs embedded in alert messages provided instant location context for coastal authorities. The Blynk push notification system delivered alerts within 1–2 seconds of threshold crossing, confirming the system's suitability for real-time emergency response applications.

**D. System Reliability and Zone Performance Summary** Table III presents the overall system reliability across all monitored subsystems based on experimental testing. The multi-layered architecture improved overall system reliability by separating sensing, processing, communication, and application functions. Edge-level processing in the ESP32 ensured that zone alerts and health alerts were generated locally and executed immediately, even when cloud communication was temporarily unavailable. This local-first processing approach is critical for maritime applications where connectivity may be intermittent in deep-sea regions.

### Receiver

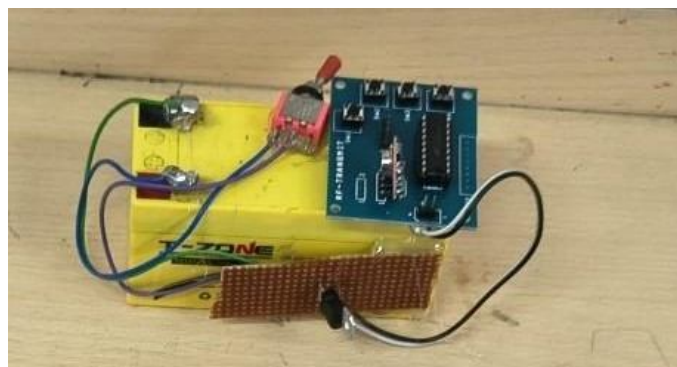


Fig:6.3 Receiver

### E. Discussion

The experimental results confirm that the proposed IoT-based system significantly enhances the safety of border violation risk and health emergency risk the two primary threats to fishermen at sea. The four-zone progressive alert mechanism provides appropriate graduated responses that match the severity of the navigational situation, while the health monitoring system ensures that physiological emergencies trigger both local alerts and remote coordination with coastal authorities. Observed limitations include potential GPS signal degradation in deep-sea regions far from land, reduced sensor accuracy under extreme weather conditions, and communication reliability dependency on network coverage.

Future improvements will address these through integration with satellite communication (Iridium or INMARSAT) for guaranteed deep-sea connectivity, LoRa mesh networks for vessel-to-vessel communication, and advanced AI-based predictive health analytics for early deterioration detection before threshold values are crossed.

## VII. CONCLUSION

The Multi-Layered IoT Based Border Alert and Health Monitoring System for Commercial Fishermen was successfully designed, implemented, and tested. The system integrates GPS geo-fencing with four-zone progressive border alerts, wearable multi-parameter health monitoring (heart rate, body temperature, SpO<sub>2</sub>), DHT11- based fish storage environmental control, gyroscope boat stability monitoring, and Blynk IoT cloud communication into a single comprehensive platform. The four-zone alert architecture (Zone 1), live GPS transmission (Zone 2), engine cutoff (Zone 3), and full simultaneous activation (Zone 4) provides structured escalating protection against accidental border crossing. Experimental testing confirmed reliable GPS-based zone detection, correct health parameter threshold alerting with motor control responses, automated fish storage climate control, and stable Blynk cloud connectivity with push notification delivery within 1–2 seconds. The system addresses both of the primary risks faced by commercial fishermen: navigational boundary violations and health emergencies in a single cost-effective, modular, and IoT-integrated platform, representing a significant advancement toward smarter, safer, and more sustainable offshore fishing operations. Future work will focus on satellite communication integration for guaranteed deep-sea connectivity, LoRa mesh networking between vessels, advanced predictive health analytics using machine learning, solar-powered energy harvesting for extended autonomous operation, and AIS integration for official coastal surveillance interoperability.

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