International Journal of Scientific Research & Engineering Trends
Volume 12, Issue 2, Mar-Apr-2026, ISSN (Online): 2395-566X

Mobile Phone Detection System Using ESP32, HMC5883L, NRF24L01, LCD Display, and Buzzer

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Abstract- — This paper presents the design and implementation of a Mobile Phone Detection System intended for deployment in restricted environments such as examination halls, secure meeting rooms, and classified zones. The proposed system integrates an ESP32 microcontroller with an NMC5883L digital compass module (HMC5883L-compatible) to detect the electromagnetic and magnetic field signatures associated with active mobile devices. Upon detection, the system triggers an audible alarm via a buzzer and displays status information on a 16×2 LCD screen. Wireless data transmission using the NRF24L01 module enables communication between multiple sensor nodes and a central monitoring unit. The system is designed to be low-cost, energy-efficient, and scalable for multi-zone surveillance. Experimental results confirm reliable detection of active mobile phones within a defined proximity range, demonstrating the practical viability of the proposed approach.

Keywords—Mobile Phone Detection; ESP32; HMC5883L; NRF24L01; Electromagnetic Field; Wireless Sensor Network; Security System.

I. INTRODUCTION

The proliferation of mobile phones has introduced significant security concerns in environments where communication devices are strictly prohibited. Examination halls, court proceedings, confidential business meetings, and military establishments represent scenarios where unauthorized use of mobile phones can result in information leakage, academic dishonesty, or breach of national security. Conventional methods of detection, such as manual inspection or signal jamming, are either inefficient or legally restricted in many jurisdictions.

Automated detection systems provide a technically sound and legally compliant alternative. By exploiting the electromagnetic and magnetic field characteristics that active mobile phones emit, it is possible to identify the presence of such devices without disrupting legitimate communications in adjacent areas. This paper proposes a compact, cost-effective detection system utilizing commercially available embedded hardware components.

The ESP32 microcontroller, owing to its dual-core processing capability, integrated Wi-Fi and Bluetooth, and broad peripheral support, serves as the central processing unit of the proposed system. The HMC5883L magnetometer measures ambient magnetic field variations caused by the electromagnetic emissions of active mobile devices. Detected events are communicated over a wireless personal area network (WPAN) using the NRF24L01 transceiver module, while local feedback is delivered through an LCD and buzzer interface.
The remainder of this paper is structured as follows: Section II reviews related work; Section III describes the system architecture and hardware components; Section IV details the working methodology; Section V presents experimental results; and Section VI concludes the paper.

II. LITERATURE REVIEW

Several approaches to mobile phone detection have been documented in the literature. Radio frequency (RF)-based detection systems analyze signals in the GSM, CDMA, and LTE frequency bands to identify active mobile devices [1]. However, such systems require complex RF front-ends and may have limitations in dense signal environments. Signal jamming, while effective, is illegal in most countries and causes collateral disruption to emergency services [2].

Magnetic field-based detection has emerged as a complementary approach. Mobile phones contain ferromagnetic components including speakers, vibrators, and battery contacts that perturb the local magnetic field. Studies have demonstrated that magnetometers can detect such perturbations with high sensitivity [3]. The HMC5883L three-axis digital compass, manufactured by Honeywell, provides a resolution of up to 2 milligauss, making it suitable for this application [4].

Wireless sensor networks (WSNs) have been widely employed in security and surveillance systems. The NRF24L01 module, operating in the 2.4 GHz ISM band, offers a reliable, low-power communication protocol suitable for multi-node deployment in indoor environments [5]. Integration of these technologies with low-cost microcontrollers such as the ESP32 has been explored in various IoT security contexts [6].

The proposed system builds upon these foundations to deliver an integrated, real-time mobile phone detection solution with wireless reporting capability.

III. SYSTEM ARCHITECTURE AND HARDWARE

The proposed mobile phone detection system comprises five primary hardware components: the ESP32 microcontroller, the HMC5883L magnetic field sensor, the NRF24L01 wireless transceiver, a 16×2 LCD display, and a buzzer module. The system operates as a distributed sensor network, where each detection node independently monitors its coverage area and transmits alerts to a central receiver node.

A. ESP32 Microcontroller

The ESP32 (Espressif Systems) serves as the master controller for each node. It features a 240 MHz dual-core Xtensa LX6 processor, 520 KB of SRAM, integrated Wi-Fi (802.11 b/g/n), and Bluetooth 4.2/BLE. Its I2C, SPI, and UART interfaces facilitate seamless integration with peripheral modules. The ESP32 executes the detection algorithm, processes sensor data, controls the output peripherals, and manages wireless communication via the SPI-connected NRF24L01 module.

B. HMC5883L Magnetometer

The HMC5883L is a three-axis surface-mount linear hybrid digital compass circuit featuring magneto-resistive (MR) sensors. It communicates via the I2C protocol and delivers 12-bit ADC resolution across a field range of ±8 gauss. In the proposed system, the sensor continuously samples the ambient magnetic field. A statistically derived threshold is established for each deployment environment during calibration. When a mobile phone is introduced within the detection range, its electromagnetic components produce a measurable deviation from the baseline field, triggering the detection logic.

C. NRF24L01 Wireless Transceiver

The NRF24L01 module operates in the 2.4 GHz ISM band and supports data rates of 250 kbps, 1 Mbps, and 2 Mbps. It employs the Enhanced ShockBurst protocol, providing automatic packet handling, acknowledgment, and retransmission. The module is interfaced with the ESP32 via the SPI bus. In the proposed architecture, one node is configured as the primary receiver (PRX), while detection nodes operate as primary transmitters (PTX). Upon detection, the transmitting node sends a structured data packet containing the node identifier, detection status, and timestamp to the central receiver.

D. 16×2 LCD Display

A standard HD44780-compatible 16×2 alphanumeric LCD module provides local visual feedback at each node. It is interfaced with the ESP32 in 4-bit parallel mode. Under normal operating conditions, the display shows the system status and the current magnetic field reading. Upon detection of a mobile phone, the display updates to indicate an alert condition along with the node identifier, enabling rapid localization by security personnel.

E. Buzzer

An active piezoelectric buzzer is connected to a GPIO pin of the ESP32 through a transistor driver circuit. When a detection event is confirmed, the buzzer is activated to produce an audible alarm. The buzzer operates at 5V DC and produces a sound pressure level of approximately 85 dB at 10 cm, sufficient to alert personnel in a typical examination hall environment. The alarm pattern is programmable to differentiate between alert levels.

IV. WORKING METHODOLOGY

Upon system initialization, the ESP32 configures the HMC5883L via I2C and establishes a baseline magnetic field vector $B_0 = (B_{x0}, B_{y0}, B_{z0})$ by averaging 100 consecutive samples in the absence of mobile devices. This calibration phase lasts approximately two seconds.

During the monitoring phase, the sensor samples the magnetic field at a rate of 75 Hz. For each sample, the Euclidean deviation ΔB is computed as:

$$\Delta B = \sqrt{[(B_x - B_{x0})^2 + (B_y - B_{y0})^2 + (B_z - B_{z0})^2]}$$

If ΔB exceeds a predefined threshold B_{th} (empirically set to 25 milligauss in experimental trials), the detection flag is raised. A debounce filter requiring five consecutive threshold-exceeding samples within a 200 ms window is applied to eliminate false positives due to environmental interference. Upon confirmed detection, the ESP32 activates the buzzer, updates the LCD display, and transmits an alert packet via the NRF24L01 module to the central receiver node.

The central receiver node, also built around an ESP32, listens on a dedicated data pipe and logs incoming alerts, enabling centralized monitoring of multiple zones simultaneously.

V. EXPERIMENTAL RESULTS

The system was tested in a controlled laboratory environment approximating an examination hall setting. Mobile phones of varying form factors, including smartphones operating on GSM 900/1800 MHz and LTE 2100 MHz networks, were positioned at distances ranging from 5 cm to 60 cm from the sensor module. Active phones (with cellular data or calls in progress) were consistently detected within a range of up to 45 cm, while idle phones (screen off, no active communication) were detectable up to approximately 15 cm due to residual magnetic field emissions from internal components.

The false positive rate, assessed over 500 test cycles with environmental interference (movement of metallic objects, nearby electronics), was measured at 2.4%. The wireless transmission latency between a detection node and the central receiver was measured at 8–12 ms, confirming suitability for real-time alerting. The system demonstrated stable operation over continuous 8-hour test sessions with no observed hardware failures or communication dropouts.

VI. CONCLUSION

This paper has presented a functional and cost-effective mobile phone detection system based on the ESP32 microcontroller, HMC5883L magnetometer, NRF24L01 wireless transceiver, 16×2 LCD, and buzzer. The system successfully detects the presence of active mobile devices through magnetic field anomaly analysis and provides both local and centralized real-time alerts. The distributed architecture supports scalable deployment across multiple zones, making it suitable for examination halls, secure facilities, and other restricted environments.

Future work will investigate the incorporation of machine learning-based classification algorithms to improve detection accuracy, reduce the false positive rate, and distinguish between different categories of electronic devices. Integration with cloud-based monitoring platforms and mobile alert notifications are also planned as enhancements to the current prototype.

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