



Hybrid Mobile Phone Detection Technologies Using Metal Detection and Radio Frequency Sensing

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ABSTRACT

Mobile phones are ubiquitous, including in restricted and security-sensitive environments, so reliable detection of active and inactive handsets is required. This work reviews phone-detection technologies and focuses on fusing metal detection with radio-frequency (RF) sensing in a hybrid system. RF sensing detects transmitting devices but misses silent ones; metal detection finds metallic objects whether or not they transmit, yet can false-positive on nearby metal. Combining the two methods widens coverage and offsets single-sensor limits. Microcontroller processing, sensor fusion, and intelligent decision-making can improve reliability and support real-time alerts. The hybrid approach is a practical base for more precise, scalable detection in examination halls, secure facilities, confidential workplaces, and other restricted areas.

1. INTRODUCTION

In recent years, the use of mobile phones in the modern world has created new problems with discipline, security and confidentiality in closed areas like examination rooms, military bases, research laboratories, safe rooms and high security institutions. Mobile devices are vital for communication and connectivity, but the illegal use of such devices in a controlled environment may result in examination malpractice, unauthorized data transmission, information leakage and severe security incidents. Thus, the need of an efficient and reliable mobile phone detection system has increased [1].

The existing methods of mobile phone detection mainly include manual check and standalone sensing technology [2, 3]. Metal detectors detect metal by the disruption of electromagnetic fields; however, they are not able to tell the difference between a mobile phone and any other object such as keys, coins, watches and accessories. Radio Frequency (RF) detectors, however, can detect radio waves that are emitted by mobile phones during a phone call, sending text messages or transferring data. RF-based systems can detect active devices, but not necessarily a switched off mobile phone in "airplane mode" or a device not actively transmitting. Environmental noise, signal loss, and interference from other wireless devices also can interfere with an RF detection system's performance [4].

To resolve such difficulties, this work suggests a Hybrid (Hybridization), which is the combination of Metal detection and RF (Radio Frequency) sensing, Mobile Phone Detection System (MPD) that is implemented on an embedded platform. The metal detector can detect conductive objects such as the metal parts of a mobile phone, and the RF sensor can detect the electromagnetic emissions produced by devices that are in active communication. The proposed system uses both sensors' outputs as a pair to create a dual-verification mechanism, which allows for more reliable detection since the false detections are reduced due to the correlation of both sensors' outputs [5].

In the proposed system, an Arduino UNO microcontroller is adopted as the central processing unit for the real-time monitoring and decision-making of the sensors. A 16×2 LCD allows a user to see the result at a glance and a buzzer sounds an alarm when the detection condition is met. The system is easily portable, cost-effective and convenient to be used, which is ideal for examination monitoring, security screening, confidential workplaces and other limited areas [6]. The multiple use of different sensing technologies shows a feasible method for achieving accurate and smart mobile phone detection systems.

2. MATERIALS AND METHODS

The proposed Hybrid Mobile Phone Detection System was a combination of metal detection and Radio Frequency (RF) sensing techniques that would be used to detect either mobile phones that were inactive or actively transmitting. The system was designed on the embedded platform based on Arduino UNO and included a metal detector sensor, an RF sensor module, a 16 × 2 LCD, a buzzer and a regulated power supply. The main brain was the Arduino UNO which constantly reads the sensor input, checks the condition of the sensor, and activates the visual and audible alerts.

The metal detector detected conductive items by detecting changes in an electromagnetic field. The sensing method allowed the system to differentiate between the metal parts of a mobile phone, whether it was on or off. The problem is that the metal detector was not reliable enough for mobile phone confirmation as it is prone to detecting unrelated metallic objects. The RF sensor was cooperating with this function by tracking the electromagnetic emissions of active mobile phones during communication activities as calls and data transmission.

The hardware components were wired together based on the system architecture and the control program was written with the help of the Arduino Integrated Development Environment (IDE). This program was designed to continually read the binary state of the metal and RF sensors and test four possible combinations of inputs. If both sensors were not activated the system showed “NO DETECTION.” “The METAL DETECTED” was generated by metal-only activation, while the “RF DETECTED” was generated by RF-only activation. If both sensors were activated at the same time, then “MOBILE PHONE DETECTED” was displayed and the buzzer was activated.

The prototype was tested in various detection scenarios, such as changing metallic objects and the presence of RF emitting mobile phones. The system performance was tested by checking the correctness of the four detection states programmed, the real time output response and the consistency of LCD and buzzer indications. The limitations observed, such as RF signal instability, environmental interference, limited detection range, and metal related false positive were also taken into account for the evaluation. **Figure 1** presents block diagram.

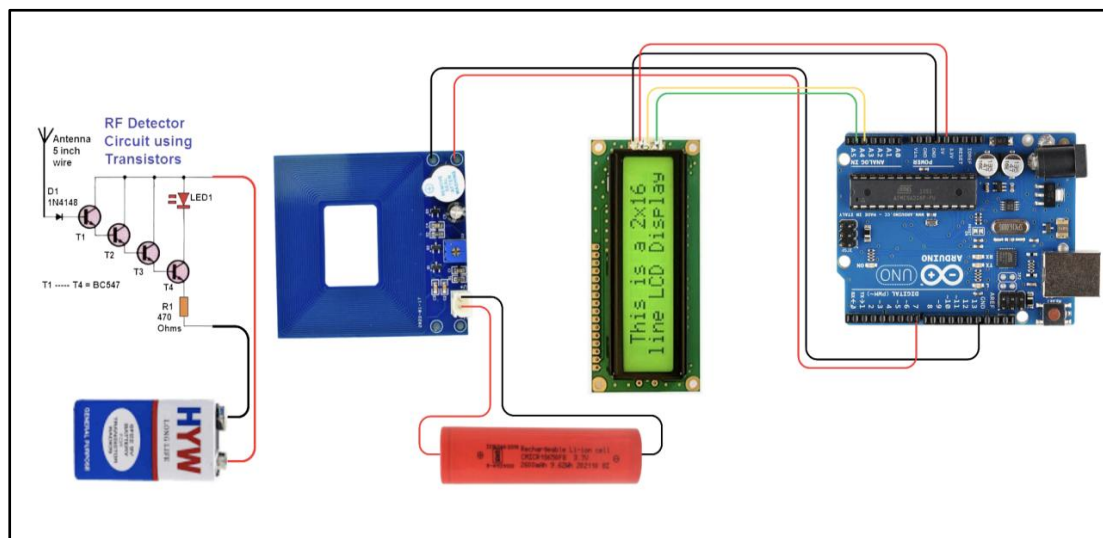


Figure 1. Block Diagram

2.1 Study Design

In this study, an experimental prototype-based design process has been used to design and test a Hybrid mobile phone detection system based on metal detection and Radio Frequency (RF) sensing. The system was intended to overcome the disadvantages of the individual detection processes by integrating two complementary sensing processes on a single embedded platform. The physical presence of conductive materials (metals) was detected using metal detection and the electromagnetic emissions generated by the mobile devices were detected using RF sensing.

This study has been carried out in four phases: System Design, Hardware Integration, Software Implementation, and Experimental Testing. The functional requirements and decision logic were determined during system design. The second part of the hardware stage was the integration of the metal detector, RF sensor, Arduino UNO, LCD (16 × 2) and the buzzer. The software stage involved real time acquisition of the sensors data and conditional decision-making with the use of the Arduino Integrated Development Environment (IDE).

The four combinations of the two sensor inputs were considered during the experimental evaluation, namely no sensor activated (Metal = 0, RF = 0), metal activated only (Metal = 1, RF = 0), RF activated only (Metal = 0, RF = 1); and both sensors activated (Metal = 1, RF = 1). A predetermined output state was given for each condition. The system displayed “NO DETECTION,” “METAL DETECTED,” or “RF DETECTED” for the first three conditions, respectively. A simultaneous detection of both metals and RF was categorized as “MOBILE PHONE DETECTED” and caused the buzzer to sound. This design allows the functional performance of the hybrid detection logic to be tested with different operating conditions.

3. RESULTS AND DISCUSSION

The Hybrid Mobile Phone Detection System we developed was tested under the four possible operating conditions created by the two binary sensor inputs. The prototype successfully captured signals from both the metal detector and the Radio Frequency (RF) sensor, processed these inputs using the Arduino UNO, and then produced the matching visual and audible alerts. A summary of the system’s responses is shown in Table 1.

Table 1. Functional response of the hybrid mobile phone detection system under different sensor conditions.

Metal Sensor	RF Sensor	System Classification	LCD Output	Buzzer
0	0	No detection	NO DETECTION	OFF
1	0	Metallic object detected	METAL DETECTED	OFF
0	1	RF activity detected	RF DETECTED	OFF
1	1	Mobile phone detected	MOBILE PHONE DETECTED	ON

As shown in Table 1, the system correctly distinguished among the four programmed sensor conditions. When neither sensor was activated, the system remained in the normal scanning state. Metal-only activation indicated the presence of a conductive object, whereas RF-only activation indicated electromagnetic activity from a transmitting device. Simultaneous activation of both sensors produced the highest-confidence detection state, resulting in mobile phone confirmation and buzzer activation.

Figure 2 shows the developed hardware prototype consisting of the Arduino UNO, metal detector, RF sensing circuit, 16×2 LCD, buzzer, and associated interconnections. The integrated prototype continuously monitored the sensor states and updated the displayed output in real time.



Figure 2. Developed prototype of the Hybrid Mobile Phone Detection System.

The results demonstrate that the two sensing technologies provide complementary information. Metal detection can identify conductive components regardless of whether a mobile phone is actively transmitting, but it cannot distinguish a phone from unrelated metallic objects. RF sensing provides evidence of active wireless communication but is influenced by signal strength, distance, and electromagnetic interference. Combining the two sensor outputs therefore provides broader detection coverage than relying on either sensing mechanism alone [7].

The prototype also revealed several practical limitations. RF responses varied in the presence of nearby Wi-Fi, Bluetooth, and other electronic sources, while the metal detector responded to different conductive objects without identifying their type. The detection range was also limited by sensor sensitivity. These observations are consistent with the limitations of standalone mobile phone detection approaches discussed in the related literature. The hybrid architecture addresses some of these limitations through sensor-level cross-verification, although improved RF filtering, adaptive threshold calibration, repeated quantitative trials, and intelligent signal classification are required for a more robust practical system.

Hybrid fusion architectures that couple complementary sensing or feature streams have improved discrimination under data scarcity in adjacent application domains [8]. As automated detection moves into examination and security-screening workflows, the governance of algorithmic agency becomes a deployment consideration for such platforms [9].

4. CONCLUSION

This study shows that combining metal detection with Radio Frequency (RF) sensing offers a practical way to detect mobile phones under various operating conditions. The Arduino-based prototype we developed successfully brought together these two sensing methods, along with real-time decision logic, an LCD status display, and an audible alert. Metal detection allowed us to find conductive objects regardless of whether the

device was active, while RF sensing helped identify when a phone was actively transmitting wirelessly. By merging these two approaches, we were able to cover a wider detection range than using either method on its own.

That said, the prototype did have some limitations, including unstable RF signals, vulnerability to electromagnetic interference, a limited detection range, and the metal detector's inability to distinguish mobile phones from other metallic items.

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