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**Research Article**

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# Design of an Indoor Metal Detector Robot using Radio Frequency Technology (RFT)

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**Abstract** In this work, an indoor metal detector robot using Radio Frequency (Rf) technology was designed. The robot senses a metallic object such as coin and triggers a buzzer alarm on detection. The robot was designed and implemented with an AT89C51 microcontroller for its operation. It is moved in different directions with the help of switches which are placed on the transmitter remote control. The major component in this work includes: metal detector, power supply unit, microcontroller, transmitter and receivers for communication between the robot and its remote, keil micro vision which was used to program the microcontrollers for effective use. The results showed that the system worked at a constant speed without any problem and was tested severally. This research work can be verified to be highly beneficial for security and industrial purposes.

**Keywords** Microcontroller, Metal Detector, Robot

## Introduction

Arguably in no other continent is threat containment and prevention more urgently and significantly required as in Africa. It is a well-documented fact that national security and economic prosperity are inseparably intertwined. The recent and continuous spates of International and Internal Terrorism emanating from several African countries including Sahel, Kenya, Somalia and Nigeria has greatly limited economic development in the affected regions and beyond.

Two major security challenges are facing contemporary societies in Africa and elsewhere. The first stems from natural disasters, and the second is from calamities caused by man-made actions including terrorism and other forms of organized crime.

## Terrorism

These perpetrators, motivated by ethnic, racial, religious, tribal, and national ideologies, include an expanding array of extremist groups and their associates, such as al-Qaida in the Islamic Maghreb (AQIM), Boko Haram, Ansaru, Ansar Dine, Ansar Al-Sharia, the Movement for Oneness and Jihad in West Africa (MJUAO), al-Mourabitoun, the National Movement for the Liberation of Azawad (MLNA) and al-Shabaab.

Boko Haram ("western education is sacrilege") in Nigeria abducted more than 200 schoolgirls and has driven tens of thousands of people from their homes in the northeast as its capture and hold on territories intensifies. Niger, Chad and Cameroon. More than 700 people have died in the restive northeast, while tens of thousands more have fled for their lives, either in fear of further attacks or after militants razed their homes and businesses. In the Central African Republic, clashes are escalating between civilian militias and Muslim rebels. And fresh violence in South Sudan is dragging the global yearning for peace is that region. Terrorism is not the product of isolated action, but it is the unfortunate manifestation of a violent vision of extremist groups, which for misleading ideological purposes, exploit religion for political purposes. That is why Morocco is privileged to have a structured and methodological vision, opting for an inclusive approach, combining human resources development, economic development, and security.

In Nigeria, Boko Haram has proven to be an increasing threat to the Nigeria's national security and the Sahel stability. Ansaru from Cameroon, Islamists in Mali, AQIM, Ansar al-Dine, and MUJAO and other jihadists in Libya, al-Shabaab in Somalia and Kenya all sum up the dangers of ideologically-motivated terrorism and violence in Africa.

The ultimate solution to ideologically motivated terrorism isn't limited to the 'traditional' counter-terrorism approach, which relies on the use of the police, the judiciary and intelligence agencies but should also include:

1. Strengthening bilateral and regional cooperation to maintain the region's peace, security and socio-economic development
2. Pursuing programs for sustainable development to improve people's living conditions, and especially to ensure the social and economic integration of young people,
3. Combating terrorism and criminality by winning the support of local populations,
4. Bolstering judicial cooperation and the monitoring of illicit financial flows, and,
5. Improving coordination among the military high commands of the continent countries [1].

In all these, the most important factor will be technological advancement in security.

Over the years, many innovations have been made in the security sector using robotics. Kuo L. Su, Ting L. Chien and Jr H. Guo [2] designed a low-cost security robot system to detect abnormal and dangerous situations. The transmission interface used was Internet or GSM based. The mobile robot was structured using aluminum flame and a multisensory – based sensor system was used for Fire and Smoke detection, environment detection, intruder detection and power detection. This mobile robot detects a dangerous situation and transmits the sensor signal to the user (via computer internet or a mobile phone). The robot was controlled using a wireless module.

Kuo L. Su, Ting L. Chien and Jr H. Guo [2] proposed an improvement on this system by modifying the internet function and increasing the number of things that can be detected. Also to be considered is the cost of getting a designated mobile phone.

Andrew M. Ladd, Kostas E. Bekris, AlgisRudys, Lydia E. Kavraki and Dan S. Wallach [3] implemented a Robotics-Based Location Sensing Using Wireless Ethernet. The location of the device was determined from inside a building using RF signal on a wireless Ethernet network. This system was used to track the location of objects in a mapped building.

Andrew M. Ladd, Kostas E. Bekris, AlgisRudys, Lydia E. Kavraki and Dan S. Wallach [3] observed some shortcomings in the system. The wireless Ethernet network restricts the system to where signal is available I the building. Obstructions such as walls are capable of making the location sensor ineffective. Also, third-party observers can also determine the location of the device if on that same wireless network frequency without the device's knowledge or permission.

N. Bellotto and Huosheng Hu [4] designed a Multisensory-Based Human Detection and Tracking for Mobile Service Robots. These robots were designed to detect and track the presence of people in the surroundings. A mobile robot that uses multisensory data fusion techniques was used. This system uses lasers to detect human leg patterns coupled with a camera for face recognition. The face recognition is done using a detection algorithm that calculates the bearing and elevation of the face. The Information gotten from the robot's camera is fused with the leg detection technique to determine if an image is human.

N. Bellotto and Huoshenng Hu [4] proposed a more robust tracking of multiple people in front of the robot's line of sight. Also, this design by is only restricted to determining if a captured face and leg is human and does not give the identity of the person captured.

TheodorosTheodoridis and Huosheng Hu [5] carried out a survey on Intelligent Security Robots. In this survey, an investigation of security robots that appeared over the past three decades was made. The survey emphasized on state-of-the-art mobile technologies that have been developed for crime-fighting robots, capable of crafting critical situations with confrontation strategies. The projects examined in this survey were with respect to their intelligent methodology and their significance in security tasks.

The survey emphasizes a revolution in the use of tele-operated, distributed, surveillance, and law-enforcement robot architectures in the past 30 years.

Findings from TheodorosTheodoridis and Huosheng Hu [5] show why intelligence security robots should be further encouraged to curb security challenges.

Athiq, UR Raza, Ahamed M. and Wajid Ahamed [6] designed a Domestic Robot for Security Systems by Video Surveillance Using ZigBee Technology. This surveillance robot consists of automatic docking and recharging capability. It consists of a camera and a PIR sensor which enables it to detect the presence of intruders and send automatic alerts to the server wirelessly. The administrator or user can also watch the robot's movement live through the surveillance camera. The robot automatically goes back to the recharge point when the battery is low.

Athiq, UR Raza, Ahamed M. and Wajid Ahamed [6] proposed improvements in the system such as a visual navigation system such as maps and automatic battery replacement.

K. Jain and V. Suluchana [7] proposed a design and development of a multipurpose Smart Robot Car for Border Security. The robot is to use a wireless camera to detect human intruders, fire, harmful gases, metals, obstacles at remote areas and sends the information to the user's location. This is done with the help of sensors that alert the user when some anomaly appears within the range of eyesight of the robot. The robot moves in automatic mode and controllable mode. In automatic mode, it uses an obstacle detection sensor and an ultrasonic sensor while in controllable mode, the user sends the signal to the robot car using a RF module controller. The wireless camera can also be used for surveillance of the surroundings. A microphone is also attached to the robot to hear human conversations.

This security robot proposal by K. Jain [8] however does not address problem of conspicuousness. This means it is easy for the robot to be seen by an intruder in plain sight. Also, the total cost of setup of the robot still makes it inaccessible to laity.

**Design**

Hardware design

The hardware consist of a voltage regulator, microcontroller, push buttons, motor driver, dc motor, rf module, transistor, diodes, resistors, capacitors, metal detector.

Voltage regulator from the LM78XX/LM78XXA series of three-terminal positive regulators. It is a fixed output voltage regulator. As the name suggests, it contains a fixed output voltage which is preferred for my device.

**Advantages**

Internal Current Limiting, Thermal Shutdown, Safe Operating Area Protection.

**Features**

Output Current up to 1A, Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V, Thermal Overload Protection, Short Circuit Protection.

The microcontroller is the one that coordinates the activities of the system. The microcontroller chosen was because of its low voltage, high performance and cost effectiveness.

**Features**

Compatibility with MCS-51 ™ Products**,** 2K Bytes of Reprogrammable Flash Memory with 1,000 Write/Erase Cycles**,** The operating range of the 2051 is 2.7V to 6V**,** Fully Static Operation: 0 Hz to 24 MHz, Two-level Program Memory Lock, 128 x 8-bit Internal RAM, 15 Programmable I/O Lines, Two 16-bit Timer/Counters, Six Interrupt Sources, Programmable Serial UART Channel, On-chip Analog Comparator, Low-power Idle and Power-down Modes.

Push button is a switch mechanism that may be used to control the processes of a device. They are usually made out of plastic or metal.

Motor driver integrated circuit (IC) with inbuilt dual H-bridge also acts as a current amplifier i.e. it takes a low-current control signal and provides a higher-current signal. This higher current signal is used to drive the motors. Two DC motors can be driven simultaneously by this motor driver. This, amongst others, influenced the choice of L293D.

DC motor is an electric motor that runs on direct current (DC) electricity. This means it can run on batteries.

The RF encoders are a series of CMOS LSIs for remote control system m applications. They are capable of encoding information which consists of N address bits and 12_N data bits. Each address/ data input can be set to one of the two logic states. The programmed addresses/data are transmitted together with the header bits via an RF or an infrared transmission medium.

Diodes are used to convert AC into DC. They are used as half-wave rectifiers or full-wave rectifier.
A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law.
A capacitor is an electronic component consisting of a pair of conductors separated by a dielectric. A capacitor stores electric charges. It is also known as a condenser.
The operation of metal detectors is based upon the principles of electromagnetic induction. It is restricted to simple metallic objects such as coin. The circuit diagram of the transmitter, receiver and metal detectors are in the figures 1 - 4 below. The method and principle were selected based on cost and net weight of the instrument.

**Software Design**

Keil, an ARM Company makes C compilers, macro assemblers, real-time kernels, debuggers, simulators, integrated environments, evaluation boards, and emulators for ARM7/ARM9/Cortex-M3, XC16x/C16x/ST10, 251, and 8051 MCU families. Keil is a cross compiler. Cross compilers have been extensively discussed in the Literature Review. This was used to program the microcontrollers for effective use. My use of Keil as a software tool is influenced by my familiarity with the C and C++ programming environment.
Proload (Program Loader) is a software working as user friendly interface for programmer boards. It takes in compiled HEX files and loads it to the hardware. Any compiler, Assembly or C, as all of them generates compiled HEX files.

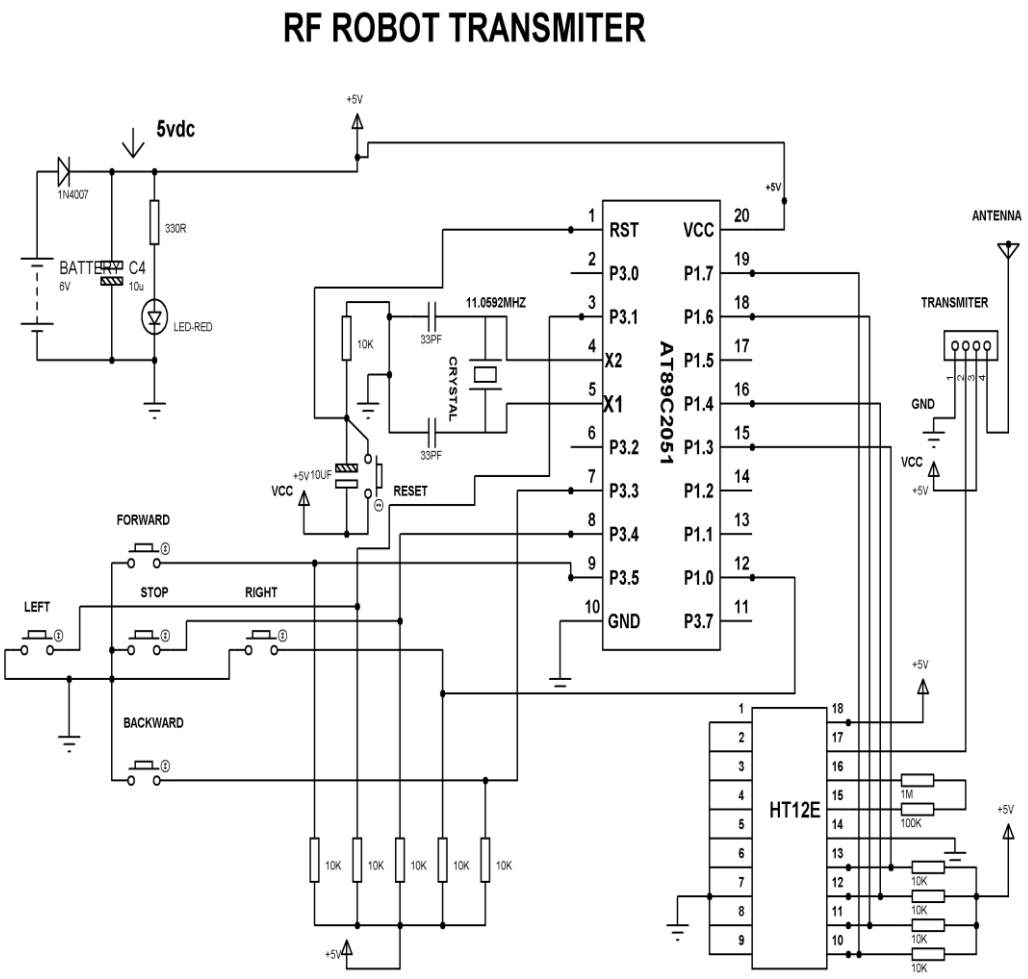


*Figure 1: Circuit Diagram for the Transmitter (Courtesy of CircuitLab Simulation)*

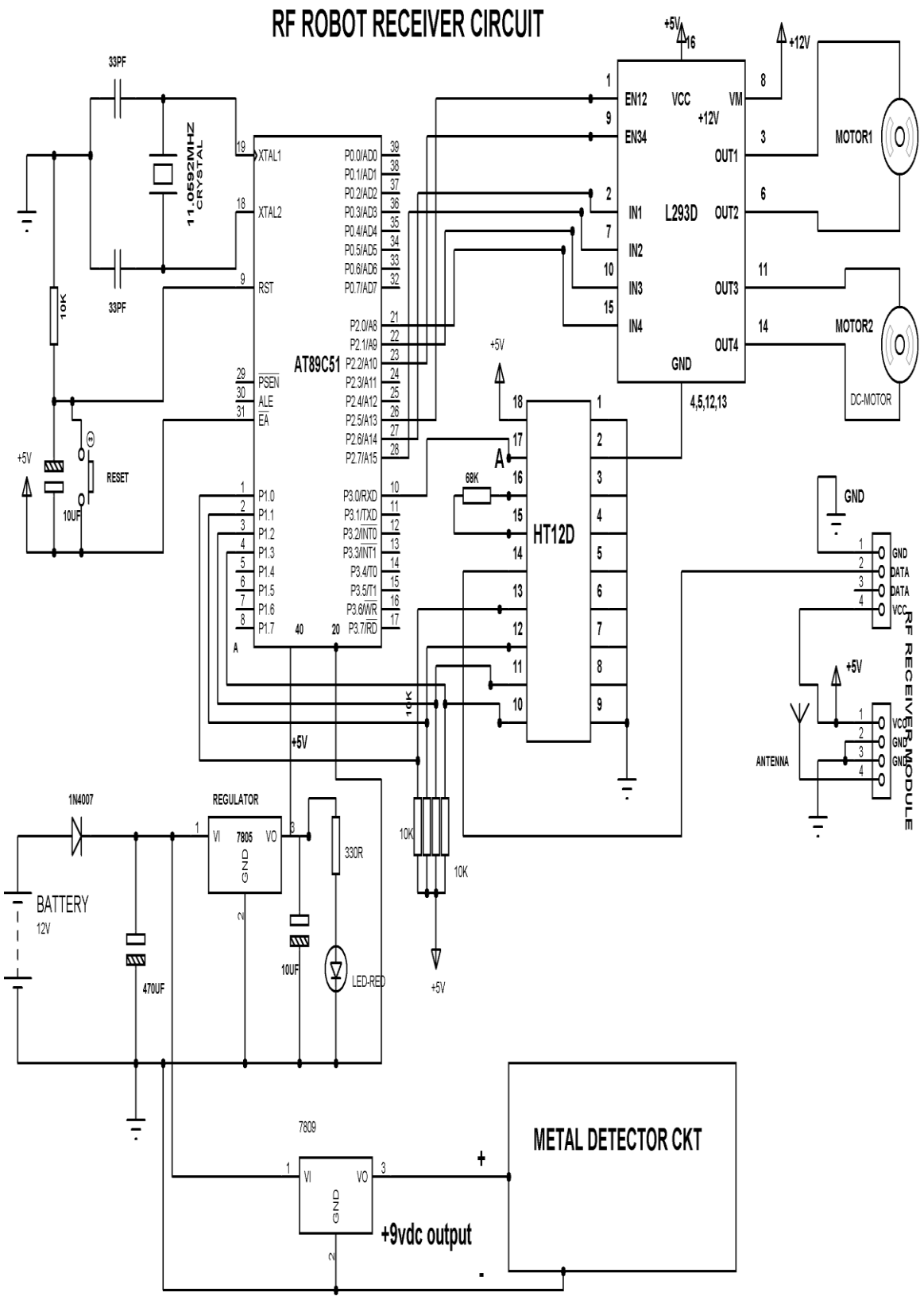


*Figure 2: Circuit Diagram for the Reciever (Courtesy of CircuitLab Simulation)*

Metal Detector Circuit

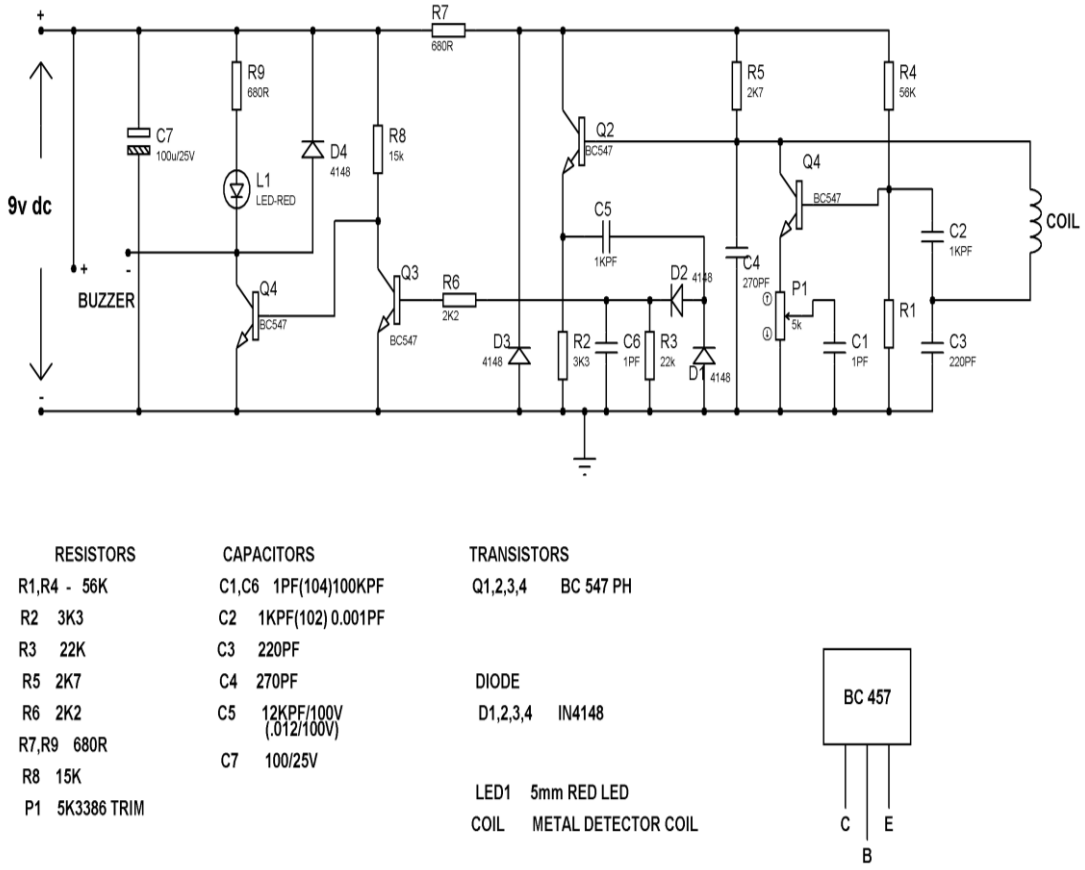


*Figure 3: Circuit Diagram for the Metal Detector Section (Courtesy of CircuitLab Simulation)*

**Test and Results**

**Hardware testing**

The following hardware tests were carried out on this device.

**Continuity Test**

A continuity test was performed on my device just after the hardware soldering and configuration was completed. The test aimed at finding any electrical open paths in the circuit after the soldering. A multi meter was used to perform this test. The multi meter was kept in buzzer mode and the ground terminal of the multi meter was connected to ground. Both terminals were then connected across the path that needs to be checked. A beep sound was made by the multi meter to attest continuity.

**Power- on test**

This test was performed to check whether the voltage at different terminals was according to the requirement or not. A multi meter was used for this operation. The multi meter was placed in voltage mode. The voltage across the battery terminal was first checked whether it was fully charged or not (The battery used in this device is 12V). It was fully charged. Power was then applied to check whether proper voltage was reaching at 'VCC' and 'GND' pins of each IC base or not (This was done without the IC inserted). The LEDs were also checked whether they were in working condition or not.

**Device Testing**

Metal Detection: Measurements were made with a coin of about 10 Karats and the frequency generated was measured at different positions away from the metal detector coil. Table 1 below shows the corresponding frequency with respect to distance which was measured in centimetres. Frequency was measured using an oscilloscope.

**Table 1:** Test results from the metal detector

| Distance from the Coil (cm) | Frequency (Hz) |
|---|---|
| 0 | 176.57 |
| 1 | 176.55 |
| 2 | 176.51 |
| 3 | 176.46 |
| 4 | 176.45 |
| 5 | 176.45 |
| 6 | 176.44 |
| 7 | 176.43 |
| 8 | 176.43 |
| 9 | 176.42 |
| 10 | 176.40 |

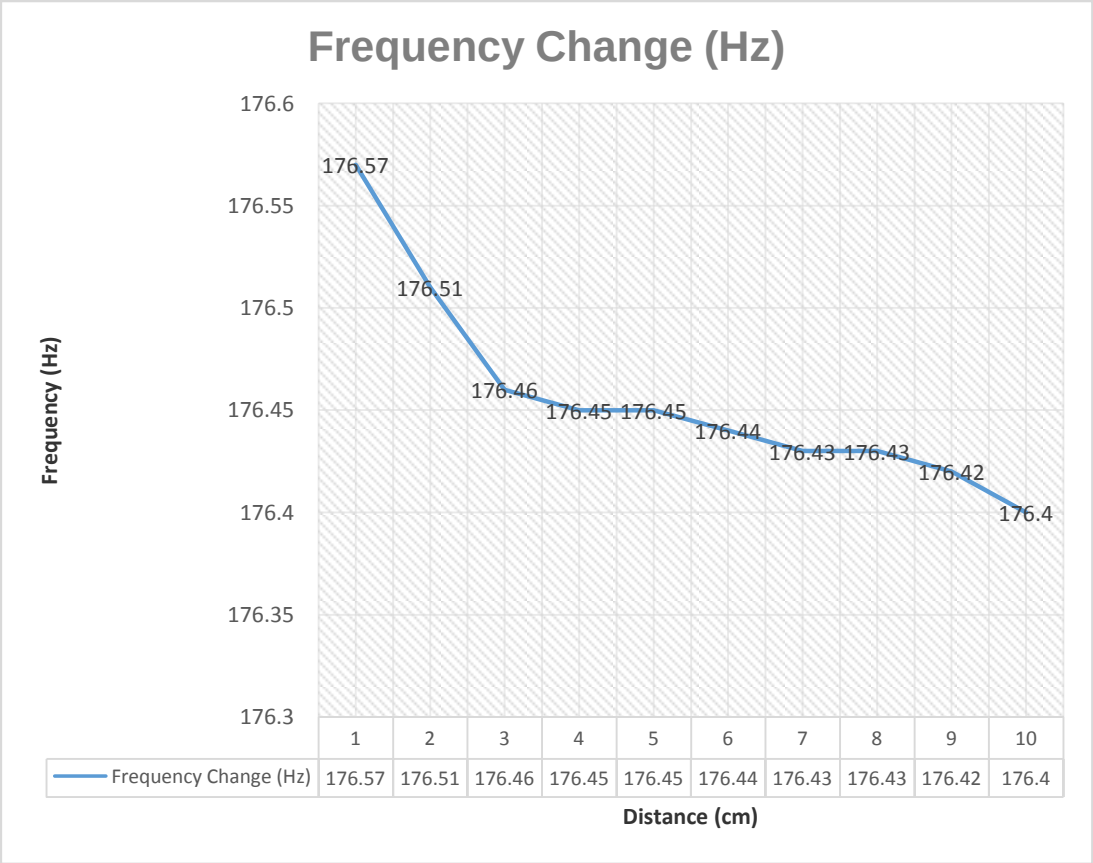


*Figure 4: Frequency change in the metal detector per distance*

**RF Transmitter Range**

The transmitter remote control can operate the device for a distance between 80 to 100 meters in open space. This is true because the operating frequency of the RF Module is 433MHz. from figure 4 we can see that the farther the metal from the coil the lower the frequency which implies a reduced possibility of detecting an object because the efficiency would be reduced.

**Conclusion**

The robot was designed and implemented with an AT89C51 microcontroller for its operation. It is moved in different directions with the help of switches which are placed on the transmitter remote control. It is verified to

be highly beneficial for security and industrial purposes. The robot can detect objects within a very good radius which is a highly beneficial characteristic; it can also work at a constant speed. The radio frequency transmission is not blocked by common materials. This means, it can penetrate most solids and pass through walls, control of the device can be maintained at a range of up to 100m, the robot is not sensitive to the light and it is not much sensitive to the environmental changes and weather conditions.

**Recommendation**

For the metal detector aspect of the robot to achieve greater results, the coil must have a longer detection distance beyond 10 metres. Also, the robot can be further upgraded with a mounted surveillance camera which can record real time events and transmit on a Television.

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