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The Development and Testing for Fiber Optic Cable Fault Detector in Communication System

G. C. Wong[1], Z. Haron[1]

[1]Department of Electrical Engineering, Politeknik Sultan Salahuddin Abdul Aziz Shah, 40150 Shah Alam, Selangor, Malaysia.
Corresponding Author's Email: [1]guanchengg.wong@gmail.com

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ABSTRACT – Optical fiber technologies are crucial for delivering genuine broadband connectivity. Ensuring continuous service by monitoring and identifying fiber failures is essential, as any disruption can cause significant financial losses for telecom carriers. This innovation addresses the problem of service interruptions caused by fiber optic cable failures by developing an intelligent fault detection system. The primary objective is to create a system that accurately pinpoints the location of faults in optical fiber cables, thus saving money, manpower, and time. Utilizing ESP 32 and an IR Brightness Sensor, the system monitors the received light source to detect faults and integrates with the Blynk Application for real-time data analysis and remote monitoring. This approach allows repairmen to target only the faulty sections of the cable, reducing the need for extensive excavation. The benefits include reduced repair time, lower costs, and minimized manpower requirements. By enabling precise fault location and remote monitoring, the system enhances operational efficiency and ensures continuous service delivery. This innovation represents a significant advancement in maintaining the reliability and efficiency of broadband services.

KEYWORDS : Fiber Optic, ESP 32, IR Brightness Sensor, Cable Fault Detection and Blynk Application

1.0 INTRODUCTION

The principle of fiber-optic communication involves transmitting signals via optical fibers, utilizing light as an electromagnetic carrier wave to carry information. Primarily used for transmitting telephone signals, optical fiber boasts significantly lower attenuation and interference compared to copper wire, making it advantageous for long-distance and high-demand applications. While the initial installation and operation of fiber-optic systems were challenging and costly, particularly within urban infrastructure, they have become a needs in modern communications due to their high data rate transmission capabilities [1]. Optical fiber, a silica-based glass strand wrapped in transparent cladding, can transfer light over long distances, making it an ideal medium for information transport [2].

The developed concept of an intelligent fault detection system aims to pinpoint the exact location of faults in fiber optic cables by monitoring the received light source and other parameters. This system, leveraging IoT technology, allows for real-time monitoring and remote fault detection, thereby reducing repair time, costs, and manpower [3]. Additionally, fiber optics are more environmentally friendly and durable, capable of enduring tough conditions and requiring minimal maintenance over a lifespan of more than 25 years [4]. The system's results are displayed on an LCD monitor, further simplifying repair processes and enhancing service reliability [5].

Underground fiber optic installations, essential for urban and rural connectivity, face challenges such as environmental damage and wear, requiring efficient fault detection and repair methods. Leveraging IoT technology and principles similar to Optical Time Domain Reflectometer (OTDR) and Visual Fault Locator, the system identifies faults precisely, minimizing excavation to only the affected areas [6]. This approach not only enhances network reliability but also integrates with the Blynk Application for remote monitoring and data analysis, ensuring prompt issue resolution and minimal service disruptions [5]. By optimizing fault detection and repair processes, the innovation aims to contribute significantly to the efficiency and sustainability of fiber optic networks. The proposed intelligent fault detection system for fiber optic cables, utilizing IoT technology and advanced monitoring techniques, aims to significantly improve network reliability and efficiency. By pinpointing faults with precision and minimizing excavation, the system reduces repair costs, time, and manpower. Integrated with the Blynk Application, it facilitates real-time monitoring and swift issue resolution, thereby enhancing overall service reliability and contributing to the sustainability of fiber optic networks.

2.0 LITERATURE REVIEW

Various methods and technologies can be employed to develop a fault detection system for underground cables. One approach utilizes Ohm's Law to detect changes in current and voltage, pinpointing fault locations that are displayed on an LCD and IoT connected webpage [7]. Another method involves constructing a cable fault detector robot equipped to measure cable pressure and temperature underground [8]. Alternatively, combining Arduino and GSM technologies offers advantages in flexibility and connectivity, particularly when integrating Fiber Optic Distributed Temperature (FODT) sensors for detecting faults in long-distance and multi-circuit lines [9]. Neural network-based fault diagnosis systems provide high accuracy over distances up to 10 km with rapid detection times [10].

Additionally, systems akin to Optical Time Domain Reflectometers (OTDR) enable precise fault location in fiber optic cables over distances exceeding 100 km, optimizing service initiation and reducing downtime [11]. Finally, integrating a power sensor with Arduino allows real-time fault detection, displaying alerts on an LCD and logging fault timestamps on a web server. These approaches highlight diverse strategies for enhancing fault detection efficiency and reliability in underground cable systems. Table 1 presents a comparison table that outlines the findings of the study conducted to meet the innovation objectives.

Table 1. Comparison Table of Previous Research.

Articles/ Journals	**IOT Based Underground Cable Fault Detector [7]**	**Under Ground Cable Fault Detection using a Robot [8]**	**Arduino based Underground Cable Fault Detection [9]**	**Underground Cable Fault Distance Locator over GSM Technology [10]**	**Fault Detection System in an Optical Fiber Using Arduino [11]**
Sensor	-	-	-	-	LDR
Concept	Ohm’s law	Ohm’s law	Ohm’s law	Ohm’s law	Ohm’s law
Objective	The goal of the innovation is to use a PIC16F877A controller to locate faults in underground cable lines from the base station, measured in kilometers.	Implementing a robot equipped with a camera, temperature sensor, pressure sensor, and other sensors to detect cracks and assess conditions, addressing the existing system's issues.	Using an Arduino and a basic application of Ohm's law, this innovation calculates the distance in kilometers from the base station to an underground cable fault.	The primary goal of this innovation is to find and locate faults in underground cables. In metropolitan areas, electrical cables run underground instead of using overhead wires, making it difficult to address faults when they occur.	This fault monitoring module is designed to oversee the received power supply in optical fiber.

Hardware	PIC 16F877A, ESP8266 Wi-Fi and 16X2 LCD	Arduino Uno, LM 35 Temperature Sensor, Gas Sensor, Microcontroller	Arduino Uno, LCD Display	Microcontroller 8051, FODT sensor, LCD Display	Arduino Uno, Atmega 328 microcontroller, LDR, LCD
Method	The current changes based on the cable length. When a problem occurs, the voltage between series resistors changes accordingly. This altered voltage is sent to an ADC to generate precise digital data, which is then fed to a programmable PIC IC. The PIC IC displays the fault location in terms of distance.	The robot detects the temperature, pressure, and other properties of the pipes. Its built-in camera captures images of the problem area and sends them via Bluetooth to an Android app for end users.	The current fluctuates depending on the location of the fault in the cable when a low voltage from the power supply device is applied across a series resistor. The voltage between the series resistors changes in response to a short circuit (a grounded line). This altered voltage is then supplied to the ADC on the Arduino board to generate precise digital data indicating the fault location in kilometers.	The system established here is based on Ohm's law. The proposed method not only identifies faults but also sends detailed information about the defect to authorities using GSM and cuts the power supply at the specific point for public safety. The type of issue is also displayed on LCD screens. An FODT sensor is used for fault detection in cable lines.	The simulation's sensor unit consists of an LDR and an op-amp. It detects any sudden changes in the optical line's power, displaying a fault message on the Arduino-interfaced LCD. The date and time of the fault occurrence are then communicated to the web server.
Data/ Result	Using the PIC 16F877A, the system automatically displays the phase, distance, and time of fault occurrence on a webpage.	Enhance test coverage of pipeline and cable faults by incorporating live video feed from the robot-mounted camera. Capture screenshots depicting faults and conditions inside pipe galleries for detailed analysis.	Arduino proves advantageous for quickly detecting and rectifying defects. Its versatility offers several benefits over traditional microcontrollers, making it the preferred choice for underground fault detection compared to other microcontroller options.	FODT sensors are suitable for detecting faults in low resistance grounded systems, long-distance lines, and multi-circuit lines. A neural network-based fault diagnosis system for underground transmission systems can detect faults up to 10 km away with an accuracy and response time requirement of 15 to 30 seconds.	The Arduino programming language (C++) is used to generate and display output on the LCD. Simultaneously, a Java program transfers the output from the Arduino to the computer via a serial connection and stores it in a MySQL database.

3.0 METHODOLOGY

Figure 1 illustrates the working flow of the overall system for the IoT-based Fiber Optic Type Underground Cable Fault Detector Innovation. The system attempts to establish a Wi-Fi connection initially, retrying until successful. Once connected, it identifies the power source and displays the results on an LCD, presenting readings as percentages for transmitted and received powers. These results are periodically uploaded to Blynk and displayed on the LCD. Notifications and emails are sent to the user upon fault detection, along with relevant conditions displayed on Blynk. Data gathered can be visualized in graph form, allowing users to monitor cable conditions over periods ranging from 30 minutes to 2 months based on the gathered readings.

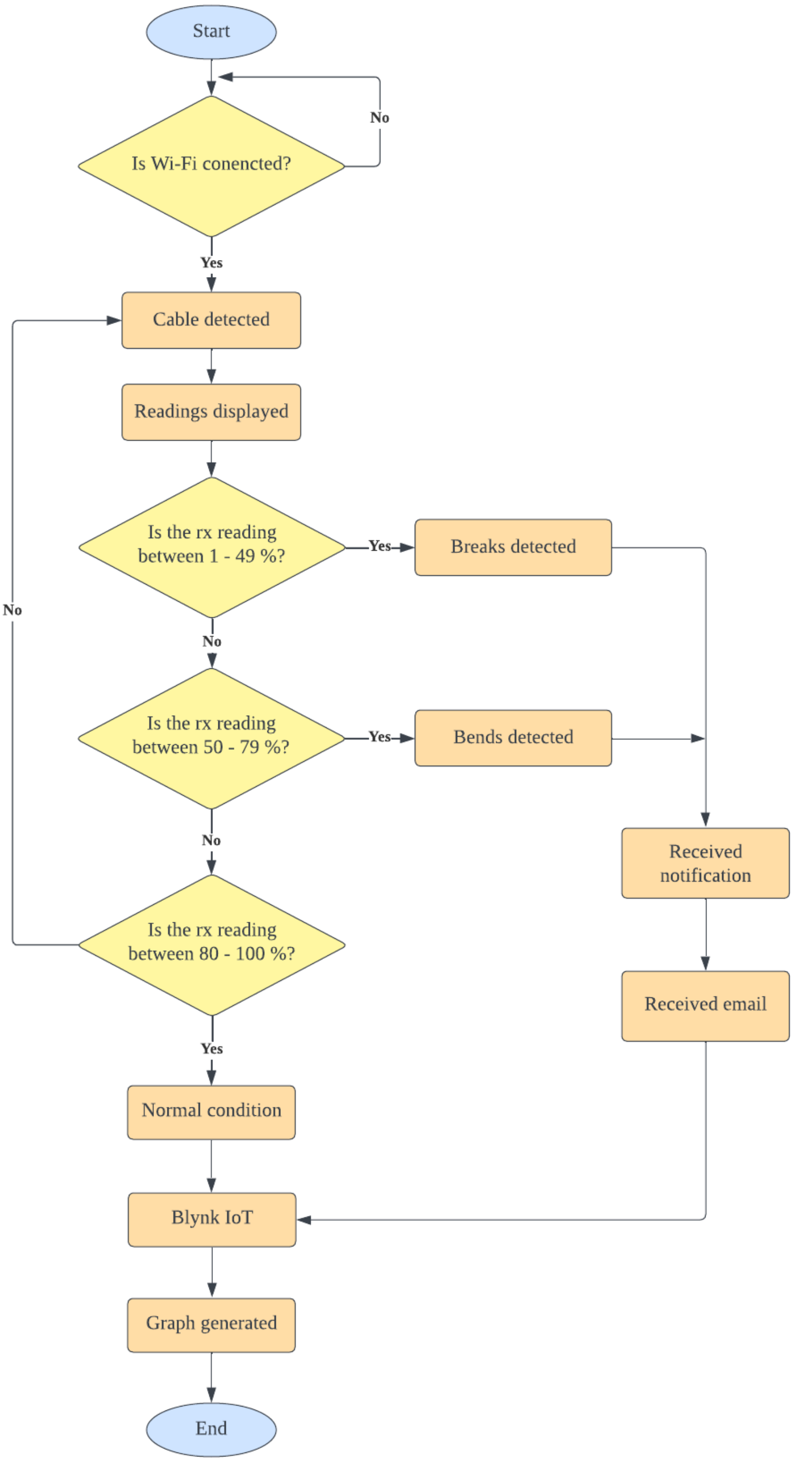


Figure 1. IoT-based Fiber Optic Type Underground Cable Fault Detector Innovation Working Flow**.**

3.1 CONDITIONAL TABLE

The LED light source serves as the transmitter signal for testing the fiber optic cable in this system. The light from the LED travels through the fiber to the developed system, where it is received by the IR Brightness Sensor LM 393. The sensor converts the received light into a percentage, indicating whether the cable is faulty. This data is then processed by the ESP 32 and displayed on an LCD to indicate the presence of a cable fault. Additionally, the system can notify the user via Blynk, email, and messages about the fault condition detected. Data collected can be visualized in a graph, allowing users to monitor cable health over time. Table 2 presents the condition table of the innovation, detailing different fiber conditions for easy differentiation. When an abnormal fiber condition is detected, such as receiving a signal percentage between 1% to 79%, users will receive notifications not only through Blynk but also via email.

Table 2. IoT-based Fiber Optic Type Underground Cable Fault Detector Innovation Conditional Table**.**

UNDERGROUND FIBER OPTIC TYPE CABLE FAULT DETECTOR

CONDITION TABLE	
Rx Signal Range	**Condition**
≥ 100%	Normal
60% - 79%	Bends Detected
1% - 49%	Breaks Detected
0%	No Fiber Optic Cable Detected

3.2 Product Layout

Figure 2 illustrates both the top and bottom views of the innovation along with their respective descriptions. From the top perspective, the innovation is designed on a board where the transmitter, receiver, and power supply components are mounted. The transmitter section includes components such as a 330-ohm resistor, a 1k-ohm potentiometer, LEDs, ESP 32, and an LCD. The potentiometer adjusts LED brightness, with the LEDs serving as the optical signal source, the ESP 32 functioning as the central component, and the LCD displaying received optical signal percentages for Line 1 and Line 2 fibers. The receiver part of the innovation incorporates two IR Brightness Sensor LM 393 units to receive the optical signal. A multi-output power supply is employed to power the system. The bottom view of the innovation diagram depicts the connection between the IR Brightness Sensors and the ESP 32, facilitating their communication interface.

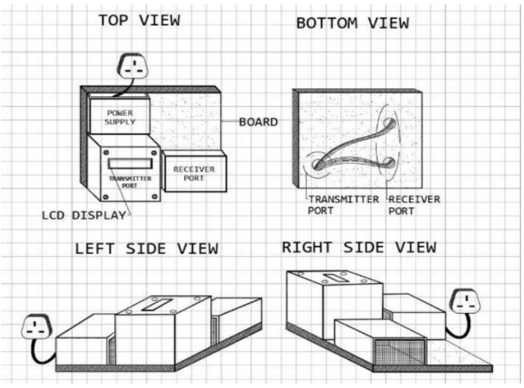


Figure 2. IoT-based Fiber Optic Type Underground Cable Fault Detector Innovation Product Layout**.**

3.3 Basis for Component Utilization

In this innovation, four main components have been utilized. The ESP 32 serves as the central control unit, acting as the "heart" of the innovation. The Potentiometer is connected to the LED and is used to adjust its brightness, which functions as the transmitter in this system. The IR Brightness Sensor LM 393 is employed to receive the light signal transmitted through the fiber optic. Table 3 describes the use of these four main components in this innovation.

Table 3. IoT-based Fiber Optic Type Underground Cable Fault Detector Main Components Description

Component Name	Description
ESP 32	The ESP 32 is a low-cost, low-power system-on-a-chip microcontroller family featuring built-in Wi-Fi and dual-mode BluetoothThe ESP 32 includes built-in antenna switches, RF balun, power amplifier, low-noise receive amplifier, filters, and power-management modules. The ESP 32 is the replacement to the ESP 8266 microcontroller [12]. In this innovation, the ESP 32 functions as the central control unit, managing input and output as well as the overall process flow of the system.
Potentiometer	A potentiometer is a three-terminal resistor with a sliding or rotating contact that functions as a variable resistor or rheostat when only two terminals are used (one end and the wiper). It serves as a voltage divider and is commonly used to measure electric potential [13]. In this innovation, the potentiometer adjusts the brightness of an LED, which is then used to transmit data through a fiber optic cable. By varying the LED's brightness, different data values are encoded and sent via the fiber optic system.
LED	An LED's forward voltage typically ranges from 1.8 to 3.3 volts, and this can vary depending on the LED's color. In this innovation, red LEDs are used. For red LEDs, the forward voltage is around 200 mV, which is significantly lower compared to blue or white LEDs [14]. This lower forward voltage for currents below 10 mA is one of the reasons why red LEDs are chosen as the transmitter in this innovation.
IR Brightness Sensor LM 393	A photoelectric sensor module is designed to measure distances between barriers, detect environmental changes, and more. It consists of an IR transmitter, an IR receiver, an LM393 comparator, and a potentiometer for adjusting the digital output threshold. When the ambient light level is below the set threshold, the digital output (DO) is high. When the ambient light level exceeds the threshold, the digital output is low [15]. In this innovation, the photoelectric sensor module is used as the receiver at the end of the fiber optic cable, detecting signals transmitted through the cable from the LEDs.

4.0 RESULT

The optical signal used for both Line 1 and Line 2 fibers employs red LEDs as the light source. Each line is equipped with its own set of resistors, 220Ω for Line 1 and 1kΩ for Line 2 to regulate electrical current flow within the system. This setup ensures a strong signal for Line 1 and a moderate signal for Line 2. The potentiometer is utilized to adjust the brightness of the optical signals emitted by the LEDs. The receiving sensors are positioned 7.1 cm away from the transmission source, ensuring reliable signal reception.

Table 3, Figure 3, and Figure 4 present the results of a 30-minute test conducted on May 13, 2023. To minimize errors, the results are averaged over 1-minute intervals, with each average based on 60 data points. The measurements recorded during this test show optical signal percentages ranging from 44% to 60% for Line 1, indicating the presence of bends or breaks that exceed acceptable limits, potentially causing the fiber to fail.

For Line 2, the recorded percentages range from 51% to 66%, suggesting bends in the fiber cable. It's important to note that due to offline issues, only an average of 5 data points were collected at 2:21 pm, which may affect the accuracy of these values. This limitation is recognized within the innovation's scope. Figure 5 illustrates the comparison of the received signals for Line 1 fiber and Line 2 fiber. The data indicates that Line 2 fiber exhibits better performance and condition compared to Line 1 fiber.

Line 1 shows a wider range of signal percentages between 44% to 60% than Line 2 between 51% to 66%. This suggests that Line 1 is more affected by issues like breaks or severe bends. On the other hand, Line 2 maintains a more stable signal, with fewer and less severe drops. Line 1 has more instances of "Breaks Detected," especially between 1:54 pm and 2:12 pm, which matches its lower signal percentages. Line 2, while also experiencing "Bends Detected," has a more stable signal and fewer drops below 55%. Line 2 is less affected by bends and shows better overall performance compared to Line 1. This is supported by its higher and more consistent signal percentages, suggesting that Line 2 is in better condition or is set up more effectively to maintain signal quality.

The different resistor values used for Line 1 (220Ω) and Line 2 (1kΩ) appear to influence the overall signal quality and stability. The higher resistance in Line 2 likely reduces the current flow, resulting in a more moderate but consistent signal. Meanwhile, the lower resistance in Line 1 allows for a stronger signal, but it may also lead to more sensitivity to physical disruptions like bends or breaks. This difference in design could explain why Line 2 shows better performance and fewer faults compared to Line 1. Future experiments could investigate how varying resistor values impact signal strength and stability to find the optimal configuration for both lines.

Based on the recorded results and observations, this innovation is effective in quickly finding faults in fiber optic cables. It can detect and differentiate between bends and breaks in real time, allowing for more targeted maintenance. This means that only the damaged areas need to be repaired, reducing service disruption and improving the efficiency of maintenance efforts.

Table 3. Data Collected 13 May 2024 for Line 1 Fiber and Line 2 Fiber**.**

Time	***Collected Results***			
	Line 1 (%)	***Condition***	***Line 2 (%)***	***Condition***
1.51 pm	*55.44*	*Bends Detected*	*57.32*	*Bends Detected*
1.52 pm	*53.13*	*Bends Detected*	*55.87*	*Bends Detected*
1.53 pm	*51.78*	*Bends Detected*	*54.44*	*Bends Detected*
1.54 pm	*48.09*	*Breaks Detected*	*54.63*	*Bends Detected*
1.55 pm	45.71	Breaks Detected	58.67	Bends Detected
1.56 pm	52.97	Bends Detected	60.22	Bends Detected
1.57 pm	49.06	Breaks Detected	61.98	Bends Detected
1.58 pm	57.33	Bends Detected	58.33	Bends Detected
1.59 pm	60.43	Bends Detected	56.50	Bends Detected
2.00 pm	59.01	Bends Detected	57.88	Bends Detected
2.01 pm	60.17	Bends Detected	60.31	Bends Detected
2.02 pm	49.14	Breaks Detected	66.21	Bends Detected
2.03 pm	46.77	Breaks Detected	60.17	Bends Detected
2.04 pm	53.47	Bends Detected	59.89	Bends Detected
2.05 pm	45.09	Breaks Detected	51.11	Bends Detected
2.06 pm	44.46	Breaks Detected	54.44	Bends Detected
2.07 pm	57.98	Bends Detected	56.46	Bends Detected
2.08 pm	57.76	Bends Detected	56.17	Bends Detected
2.09 pm	50.88	Bends Detected	55.08	Bends Detected
2.10 pm	47.21	Breaks Detected	58.81	Bends Detected
2.11 pm	46.03	Breaks Detected	52.03	Bends Detected
2.12 pm	53.88	Bends Detected	60.01	Bends Detected
2.13 pm	47.89	Breaks Detected	61.98	Bends Detected
2.14 pm	48.03	Breaks Detected	67.65	Bends Detected
2.15 pm	52.41	Bends Detected	61.07	Bends Detected
2.16 pm	50.38	Bends Detected	59.77	Bends Detected
2.17 pm	51.06	Bends Detected	62.76	Bends Detected
2.18 pm	50.77	Bends Detected	66.81	Bends Detected
2.19 pm	50.81	Bends Detected	64.19	Bends Detected
2.20 pm	50.99	Bends Detected	60.34	Bends Detected
2.21 pm	87.17	Normal	37.90	Breaks Detected

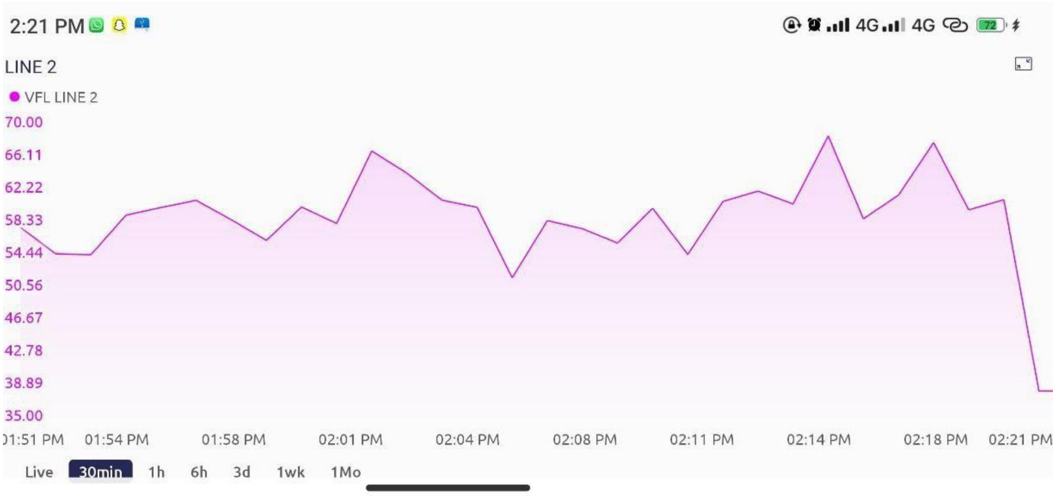


Figure 3. Graph for Line 1 Fiber (Data Collected on 13 May 2024).

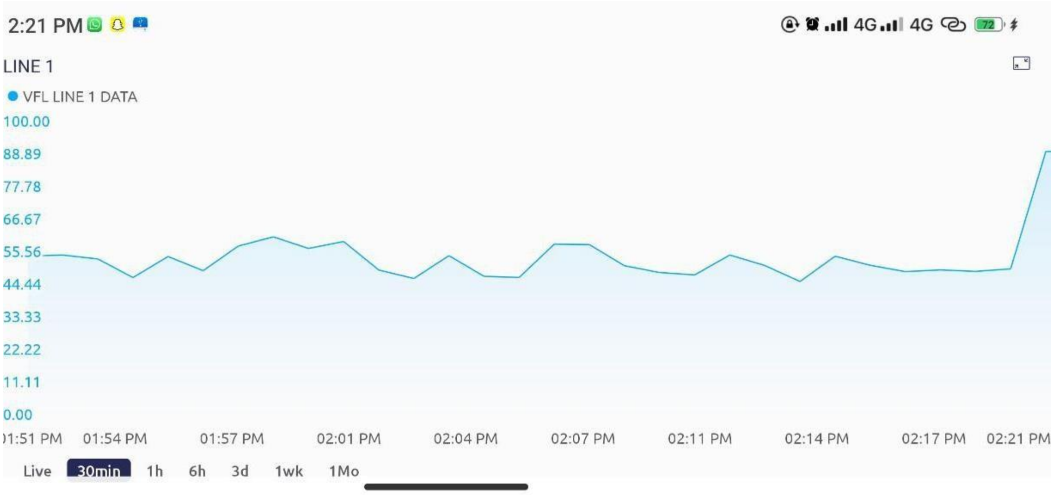
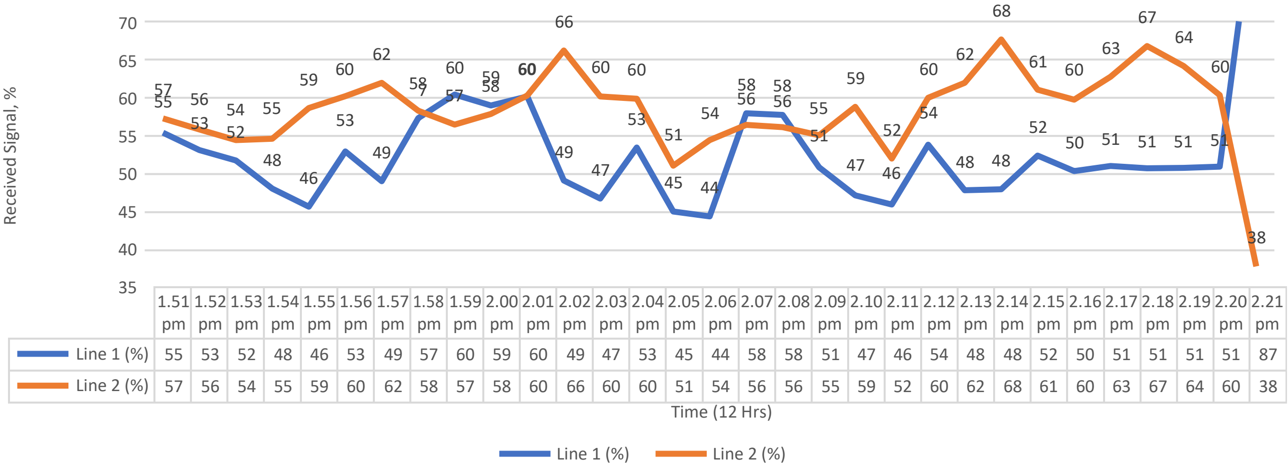


Figure 4. Graph for Line 2 Fiber (Data Collected on 13 May 2024).



	1.51 pm	1.52 pm	1.53 pm	1.54 pm	1.55 pm	1.56 pm	1.57 pm	1.58 pm	1.59 pm	2.00 pm	2.01 pm	2.02 pm	2.03 pm	2.04 pm	2.05 pm	2.06 pm	2.07 pm	2.08 pm	2.09 pm	2.10 pm	2.11 pm	2.12 pm	2.13 pm	2.14 pm	2.15 pm	2.16 pm	2.17 pm	2.18 pm	2.19 pm	2.20 pm	2.21 pm
Line 1 (%)	55	53	52	48	46	53	49	57	60	59	60	49	47	53	45	44	58	58	51	47	46	54	48	48	52	50	51	51	51	51	87
Line 2 (%)	57	56	54	55	59	60	62	58	57	58	60	66	60	60	51	54	56	56	55	59	52	60	62	68	61	60	63	67	64	60	38

Figure 5. Comparison of The Received Signals for Line 1 Fiber and Line 2 Fiber (Data Collected on 13 May 2024).

5.0 CONCLUSION

This innovation has successfully achieved its main goals of providing a cost-effective method for detecting faults in fiber-optic cables, reducing labor requirements, and minimizing repair times. By enabling precise, real-time fault detection and monitoring through IoT technology and the Blynk app, it allows for targeted repairs that minimize network disruption and enhance maintenance efficiency.

The results show that this approach offers accurate information on the condition of underground fiber-optic cables, significantly saving time, money, and effort in their maintenance. Early detection of damage helps prevent network disruptions, demonstrating the value of this innovation in maintaining smooth operations. It also showcases the country's technological advancement in fiber-optic management.

For future improvements, research should address electromagnetic interference, bandwidth, data transmission distances, and optimize the design of the light collector for better signal accuracy. Additionally, enhancing the coding parameters for the Blynk app, selecting an appropriate power source, and developing specialized sensors could further improveperformance and reliability.

By following these recommendations, future versions of this innovation can strengthen its fault detection capabilities and operational efficiency, contributing to advancements in fiber-optic maintenance and technology.

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AUTHOR CONTRIBUTIONS

G. C. Wong: Conceptualization, Data Collection and Analysis, Writing-Original Draft Preparation, Methodology, Software; **Z. Haron:** Supervision, Writing-Reviewing, Technical Content.

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