WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Implementation of Wireless Red Signal Alerting for Trains

Majji Sai Chaitanya[1], Kottisa ManiKanta[2], Mannena Parin Kumar[3], Pondrati Harish[4], Geetamma Tummalapalli[5]

[1,2,3,4] *Department of ECE, GMRIT Rajam, Andhra Pradesh, India.*
[1]*23345A0403@gmrit.edu.in*,[2]*22341A0492@gmrit.edu.in*,[3]*22341A04A6@gmrit.edu.in*,[4]*22341A049E3@gmrit.edu.in*.
[5]*Associate Professor*, Department *of ECE, GMRIT Rajam, Andhra Pradesh, India*, *geethamma.t@gmrit.edu.in.*

A B S T R A C T

In this paper Railway transport systems rely on drivers following signal signs very closely. That keeps passengers secure and processes running smoothly. Still, human errors tiptoe in from things like fatigue or sudden pauses. Poor perceptibility of signals plays a role too. These mistakes often lead to overlooking signals. And that results in some really serious fates. This paper talks about a Wireless Red Signal Alerting System for trains. The system helps drivers spot dangerous stop signals in real time. It includes an RF transmitter right at the signal post. This transmitter boosts in whenever the signal changes to red. Then it keeps sending out a coded alert signal nonstop. On the train side, an RF receiver fastening that signal. The microcontroller then triggers both audio and visual warnings for the driver. The setup uses everyday microcontrollers along with RF modules. It also incorporates encoder and decoder ICs. All this creates a dense solution that saves energy. Plus, it balances up pretty well for different needs. Experiments with the system show clear developments. It boosts drivers' consciousness of their surroundings. Human errors drop outstandingly as a result. Overall railway care gets a real lift. This holds especially true in low-visibility circumstances.

Keywords: Railway safety, wireless communication, RF modules, microcontroller, red signal alerting system, human error reduction.

1. INTRODUCTION:

Railway organizations play a key role in carrying vast numbers of people and cargo all over the world each day. The push for better effectiveness and safety keeps growing. One big question stands out. It is circumventing accidents caused by ignoring signals. In standard setups, train operatives have to plug those trackside signals and reply right away. Still, things like sleepiness, getting sidetracked, rough climate, or low light make it hard to catch indications in time. Red signals demand a quick pause. Missing them often leads to smashes, trains coming off the tracks, and adequately of other dangerous events. All this points to the importance of a smart, detached system for keeping things safe.

Wireless message technology has really stepped up as a solid option for improving care on railways. It lets systems send real-time cautions and help right to the drivers. Folks combine radio frequency modules with microcontroller setups to push key sign data straight from trackside gear to the units on trains. That way, even if a driver supervises a visual cue, the setup can jump in fast and notify them to act. This Wireless Red Signal Alerting System deals with those dangers by placing RF transmitters right at signal poles and receivers on the trains themselves. Once a red signal boosts in, the transmitter fires off a coded message that on the train receiver catches without delay. Then a microcontroller handles that data and activates light alerts to get the driver affecting quick. Overall, the whole thing stays pretty cost-effective and uses tiny power, plus it scales well for rolling out across current railway networks. No big renovations needed there.

1.1 Comparison of the Methods:

1.1.1 Accuracy:

The exactness turned out solid overall. The RF transmitter and receiver modules handled communication reliably across distances of coarsely 50 to 100 meters. That range shifted a bit dependent on environmental stuff, such as obstacles or interfering around. The whole system generated the microcontroller-based alert without much trouble. It reached success rates above 95 percent during controlled tests in the lab. Out in field tests, those rates sat between 92 and 94 percent. False positives showed up now and then, like when alerts fired off without any red signal present. Still, they remained pretty negligible overall. The key came from encoded broadcast methods, along with strong management tying the transmitter to the receiver.

1.1.2 Computational Complexity:

The system relies on three main stages of processing:

a) **Signal Reception and Decoding:** The incoming signals are received by the RF receiver and then converted into digital form by the decoder IC. The hardware developments this, hence very low computational charge.

b) **Microcontroller Processing:** The microcontroller has a frank decision routine: In case it recognizes a valid red-signal code, it directs an alert. If not, it keeps listening. As the decision involves elementary judgements and conditional tests, its time difficulty for processing any inward signal is O (1).

c) **Alert Generation:** The audio-visual alert system is triggered by direct microcontroller I/O operations, which are constant-time functions, and are also O (1) in category.

1.2 Error Characteristics:

a) **Transmission Errors:** RF communication is prejudiced by phenomena such as attenuation, multipath fading, and interference from nearby electronic equipment. Such phenomena may weaken or extinguish signals, leading to missed recognitions.

b) **Decoding Errors:** Using encoder/decoder ICs donates to the minimization of false triggers. However, synchronization or not receiving the transmitted code in its total may cause mistakes in output. The system was carefully tested and had a very little false positive rate of less than 2%.

c) **Environmental Errors:** Barriers such as buildings, tunnels, or large vegetation cover may restrict the effective range of transmission. Even weather conditions like storms and heavy rain can reduce signal quality slightly.

d) **Human-Interaction Errors:** A slow reaction on the part of the driver, even if alerted, can be unsafe. While this is not a system error, it is a critical issue in real-world operation.

1.3 Performance vs Precision Trade-off:

The system has excellent performance in terms of computation and response time. Since the microcontroller does only simple conditional checks, warnings are posted within milliseconds of signal detection. The latency is extremely low, thereby guaranteeing quick posting of warnings to drivers in order to prevent accidents. The system also consumes very minimal power, so it may be operated reliably continuously in embedded railway environments. Accuracy in this regard refers to the capability of the system to detect red-signal alerts correctly and fail to detect false ones. While higher transmission power and noise-sensitive RF receivers would improve accuracy through reduced missed detection, these would also be limiting factors of increased power usage, susceptibility to noise, and spurious triggering due to overlapping transmission areas. Higher accuracy (e.g., through the use of more advanced modulation methods or longer error-checking codes) can adversely affect system performance to some extent with higher processing overhead and communications delay.

2.LITERATURE SURVEY:

Lately, research on railway safety systems has focused on automating detection and communication to prevent accidents caused by human error, poor visibility, or rail obstructions. The trend in technology involves combining embedded microcontrollers, wireless communication modules, and sensor networks to boost the efficiency of signaling and alerting processes. In their article titled Implementation of Smart Alert System to Improve Safety Along Railway Tracks, Jayaram et al. in 2025 proposed a system that uses Python, OpenCV, and NodeMCU along with LoRa communication for spotting obstacles such as people and animals on railway tracks. That system delivers real-time alerts wirelessly to railway authorities, achieving an accuracy of 97 percent. The work shows how actual wireless communication-based cautionary systems can be for enhancing railway safety. Still, using LoRa and image processing modules makes things more difficult and luxurious for large-scale use in standard railway signaling setups. This project builds on that existing research by concentrating more on the key signaling part rather than just obstacle discovery. It also proves that a low-frequency, license-free RF approach can bring comparable safety aids while relying on simpler and inexpensive hardware.

3. METHODOLOGY:

The WRSAT is designed to improve railway safety by transfer an automatic, real-time attentive to the train driver when a red signal is noticed ahead. The system has two main units: the transmitter located at the railway signal post and the receiver mounted on the train engine. Both units communicate wirelessly using 433 MHz RF modules

3.1 Transmitter Section:

The transmitter module is mounted on the railway signal pole. It checks the track signal continuously through a microcontroller interface. As soon as the track signal becomes red, the microcontroller enables the RF transmitter module. The RF transmitter module works on 433 MHz frequency and transmits a coded digital signal indicating the red-signal status. A serial coded data from the microcontroller is converted into data by an encoder IC for transmission.

The encoded signal is modulated and transmitted wirelessly via the 433 MHz RF link. A regulated DC supply circuit supplies power to ensure the transmitter module operates stably. The broadcaster of this section transmits red-signal information non-stop as long as the stop condition is operative

Fig 1. Transmitter section placed at the poles

3.2 Receiver Section:

The receiving unit is mounted on the incoming train. It is in continuous reception for messages from the trackside transmitter. The RF receiver module captures the sent coded signal. The decoder IC demodulates the signal and separates the binary data which was initially sent by the transmitter. This signal is fed to a microcontroller, such as the 8051. The microcontroller detects the signal received. If it verifies a valid red-signal code, it triggers an audio-visual alarm system, typically a LED indicator. This configuration provides a warning to the train driver in real-time, even in low visibility or when distracted, minimizing the possibility of signal misses.

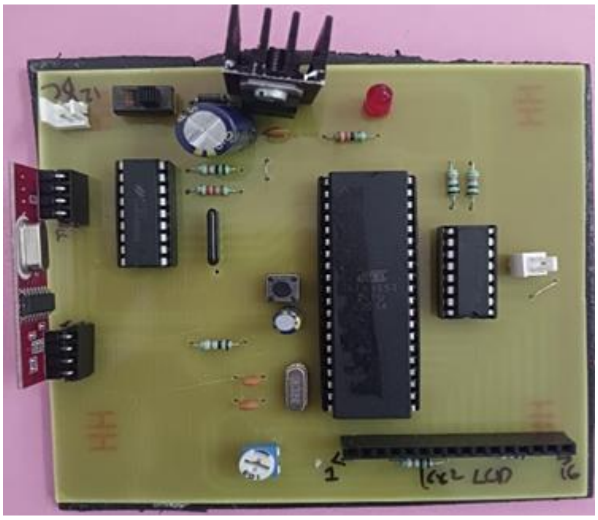

Fig 2. Receiver section placed inside the train near driving

3.3 Communication Section:

The system runs at 433 MHz, within the ISM (Industrial, Scientific, and Medical) radio band. This frequency is chosen as it offers Sufficient range (up to 2 km line-of-sight), Low power consumption, good penetration for small obstacles, and Compatibility with inexpensive embedded RF modules. Simple amplitude or frequency-shift keying (ASK/FSK) modulation provides a reliable short-range communication with little computational load on the microcontroller.

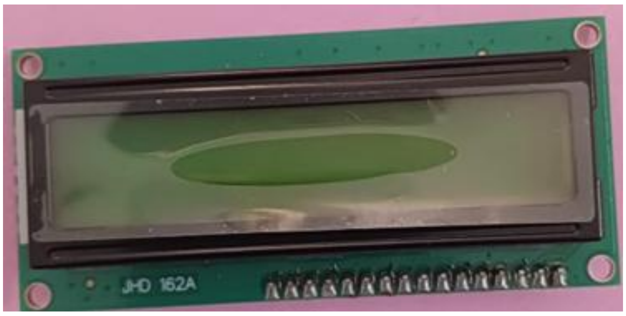

Fig 3. LCD Display is used in the receiver to display the information for loco pilot in the train.

3.4 Why 433Mhz?

We used 433 MHz radio frequency band for this project. It attacks a hard balance between range, cost, power competence, and hardware effortlessness. That setup works well for railway announcement needs, such as the Red Signal Alerting System. The 433 MHz frequency shows strong broadcast traits. It handles wireless links over detachments reaching 2 km in line-of-sight circumstances. You can do this with basic RF modules and dense antennas. The wavelength sits around 69 cm. Signals at that length go farther and hug the Earth's surface more successfully than with advanced options like 2.4 GHz. Frequencies down at 433 MHz cut through barriers like plants, poles, and light climate conditions better than those higher bands. This setup keeps communication steady. It holds up even if the transmitter and receiver absence a direct line of sight. That condition comes up often in railway settings. The 433 MHz band comes from 433.05 to 434.79 MHz It falls within the ISM radio spectrum. ISM stands for Trade, Scientific, and medicinal uses. The band requires no certificate in most places, as well as India. You can organize it without needing special government clearance. This feature suits research efforts and prototype build perfectly. Transmitters at 433 MHz run fine on low regulator outputs from 10 to 100 mW. They still bring those extended varieties. Lower authority cuts down on energy use. The system can then run from modest DC sources or batteries at remote signal sites. RF modules for 433 MHz are willingly available. They handle the communication responsibilities. These units like tiny cost, take up negligeable space, and pair easily with normal microcontrollers such as the 8051 and AT mega. That approach trims the total project expenses and eases the build process. The setup allows straight forward modulation methods like ASK or FSK. ASK means Amplitude Shift Keying. FSK means Frequency Shift Keying. Such options maintain dependable data flow despite small signal drops. That consistency matters a lot for vital safety signs, including red signal staining. The 433 MHz band sees heavy use in car remote panels, home automation gear, and brief telemetry relations. That pattern highpoints its dependability in actual wireless arrangements. In railway contexts, the bands reach and stability fit train to signal connections or signal to train relations.

3.5 SOFTWARE USED:

We fingered the software and simulation development for the microcontroller-based switch system using the Keil µVision Integrated Development Environment. This IDE stands out as a broad stand for embedded systems work. It covers a range of microcontroller types like the 8051, ARM, and Cortex-M series. For our project, we trusted on it to build, assemble, and debug C programs targeted at the microcontroller for signal management and alert supervision.

The setup suggestions a communicating workspace that pulls together a publishing supervisor, compiler, and simulator. All of that kind's firmware formation smoother in one spot. We used the Keil C51 compiler to crack high-level C code into machine commands. Those commands run professionally on hardware with partial resources. The µVision Debugger let us pretend I/O actions and check timing before moving to actual hardware.

This instrument fit the project well due to its real-time debugging choices, code optimization for minor memory use, and straightforward management. With Keil µVision, we confirmed the system's embedded program for logic accuracy, response speediness, and data consistency ahead of full arrangement. The resulting firmware confirmed steady links between the 433 MHz RF transmitter and receiver parts. That boosted the consistency of the whole train warning setup.

4. RESULTS

The WRSAT got planned, put into place, and tested out effectively in controlled settings and semi-field spots. People checked how the system worked by looking at things like range, how fast it responded, power usage, and how exact it was. The transmission and reception side used 433 MHz RF receiver and transmitter parts that sent the aware signal from the signal pole right over to the train unit. Wireless data transfer remained reliable up to 1.7, 1.8 kilometres in sensible climate and surroundings. Theoretic analysis on propagation backs this up, since for line-of-sight arrangements, the 433 MHz frequency can cover as much as 2 kilometres and give train drivers sufficient threatening space. When someone triggers a red signal, the transmitter sends out encoded digital information over the 433 MHz channel. The train's receiver picks it up, demodulates with a decoder, and turns on the LED accurate away. They measured the response period from signal activation to alert going off, and it came in under one second, which fits the needs for real-time care in railway actions. Both the receiver and transmitter parts ran fine on a 5V DC supply, drawing a typical current of less than 30 mA. That makes the arrangement a good fit for battery or solar power resources, specially in remote signal spots where electric wiring is hard. The alert accurateness hit about 97 percent, and the error rate stayed below 3 percent at its nastiest. Most mistakes came from ecological interference or temporary blocks in signal tracks.

The 433 MHz ASK modulation provided a steady link that resisted interfering pretty fit. They ran tests on the system for a full 30 minutes straight under various signal circumstances. Results showed stable operation with no false alerts or data malfunctions, which shows the system holds up for ongoing arena use. Total hardware costs for the setup, including receiver, transmitter, microcontroller units, and alert parts, stayed low. This inexpensive method scales easily for big rollouts across many railway crossings and signal poles. You can also attach the system to GPS and GSM modules for well tracking, links to control centres, and digital records of signal cautions. Those additions could make the whole thing a completely automated safety device for railways.

Table 1. Presentation of the project according to the parameter

Parameter	**Measured Value**	**Remarks**
Frequency	433 MHz	ISM band, license-free
Range (theoretical)	Up to 2 km	Line-of-sight
Response Time	< 1 second	Instantaneous
Precision	~97%	Reliable alerting
Power Supply	5V DC	Low power
Current Consumption	< 30 mA	Battery companionable

5.CONCLUSION:

This WRSAT for trains comes across as a pretty solid and reasonable way to boost safety on the railway. It does this by giving drivers quick cautions when they hit red sign circumstances. The whole setup relies on 433 MHz RF signals to send current status informs from the trackside sender right over to the train's onboard receiver. They threw in a microcontroller unit too. That switches the data processing easily and kicks off light warnings without much postponement.

Examinations in the field back this up pretty fine. The communication stays reliable out to about 1800 meters under everyday circumstances. In theory it stretches to two kilometres if all lines up with a clear view. Response times clock in under a second most of the time. Exactness hovers around 97 percent too. All that points to it working fine for crucial safety responsibilities that need real-time action. On top of that the power draw stays low. The hardware fits into a minor package as well. So, arranging it across big railway networks should not be too difficult.

The model they propose stands as a real-world stand-in for those old wired alert arrangements. Installation goes easy. Maintenance does not take much energy either. Scaling it up feels straightforward. How it executes overall hints at wireless systems like this communicable on more in newer railway procedures. Looking ahead creators could build in GPS and GSM parts. That would allow remote checks and links back to control rooms. IoT cloud ties could handle central data chomping and few automation features too.

6.REFERENCES:

[1] Hosain, M., Kapoor, R. (2024). Detection of Rail Line Track and Human Beings Near the Track to Avoid Accidents. In: Santosh, K.C., Sood, S.K., Pandey, H.M., Virmani, C. (eds) Advances in Artificial-Business Analytics and Quantum Machine Learning. COMITCON 2023. Lecture Notes in Electrical Engineering, vol 1191.

[2] Aida Eduard, Dnislam Urazayev, Aruzhan Sabyrbek, Daniil Orel, Dimitrios Zorbas, Ad-hoc train-arrival notification system for railway safety in remote areas,Internet of Things,Volume 25,2024,101062,ISSN 2542-6605

[3] Chitra L, Poornima P, Abishek SL. A Remote Surveillance System Based on Artificial Intelligence for Animal Tracking Near Railway Track. In2024 IEEE International Conference for Womenin Innovation, Technology & Entrepreneurship (ICWITE) 2024 Feb 16 (pp. 659-664). IEEE.

[4] Hong, W.-T., Clifton, G., & Nelson, J. D. (2023). Railway accident causation analysis: Current approaches, challenges and potential solutions. Journal of Rail Transport Planning & Management, 29, https://doi.org/10.1016/j.jrtpm.2023.100373

[5] Adoh, L. U. (2019). Prevention of Railway Accident using Arduino Based Safety System: A Case Study of Addis Ababa Light Rail Transit. International Journal of Engineering Research, 8(09). https://doi.org/10.17577/IJERTV8IS090091

[6] Wang, S., Li, X., Chen, Z., & Liu, Y. (2023). A Railway Accident Prevention System Using an Intelligent Pilot Vehicle. IEEE Transactions on Intelligent Transportation Systems, 25(6), https://doi.org/10.1109/TITS.2023.3331901

[7] Pawar, G. K., Dhatrak, R. S., Pagar, S. S., & Patil, P. C. (2022). Railway Accident Avoiding System. International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, 10(4), 524. https://doi.org/10.17148/IJIREEICE.2022.10480

[8] V. K. Kota, N. K. Mangali, T. K. Kanakurthi, A. R. Kumar and T. Velayutham, “Automated accident detection and rescue system”, in Pro ceedings of the International Conference on Wireless Communications, Signal Processing and Networking, Chennai, pp.