Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Implementing Real-Time Electromagnetic Field Monitoring Systems: A Methodological Approach to Enhancing Workplace Safety in the Digital Age

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In today's diverse workplaces, electronic devices emit various types of radiation, including electromagnetic fields (EMF). Health concerns, especially related to EMF radiation, are recognized due to its unique characteristics. EMF radiation, generated by everyday electronics like computers and Wi-Fi routers, as well as specialized equipment in medical and industrial settings, poses potential health risks with prolonged exposure. Governments often lack sufficient regulations for managing EMF exposure. This abstract suggests a proactive approach: a sophisticated monitoring system assessing both general and EMF radiation in workplaces, offering real-time warnings and protective recommendations. This proposed model aims to set a precedent for comprehensive workplace safety in our technologically driven environment.

Keywords: EMF, Monitoring, Magnetic Field, Hall Effect Sensor, Radiation.

1. Introduction

Electronic devices emit radiation, notably electromagnetic fields (EMF), prompting health concerns (Devra Davis 2023). Regulatory gaps exist. A proposed monitoring system measures radiation levels, especially EMF, in workplaces, enabling real-time assessments and protective measures (Chen 2023). The project emphasizes radiation monitoring and safety practices to enhance well-being, considering potential impacts on ecosystems and human health (Agbakhamen Eco 2024).

2. Related Works

Recent strides in radiation science have expanded our knowledge across detection methods, exposure estimation, and response strategies. A groundbreaking approach involves utilizing SAPANS glass for retrospective dose assessment, offering practical implications for prolonged evaluation of radiation doses even after unnoticed exposure (Hiroshi Yasuda 2023). Simultaneously, there is a focus on developing a cost-effective gamma-ray radiation sensor integrated into an Internet of Things (IoT) platform, enabling remote and efficient detection across various radiation doses and emphasizing accessibility in monitoring (A. Sharafa 2022).

In the context of societal implications, an analysis delved into the public's response to radiological incidents, yielding valuable insights into preferences for information sources and opinions on mobile apps for dose measurements (Liudmila Liutsko 2023). Understanding these public perceptions is crucial for effective communication and preparedness in the face of radiological events.Separately, researchers extensively discussed analytical methods for radioactivity, underscoring the importance of choosing detection methods based on emitted particle types (Nida Tabassum Khan 2017). This comprehensive analysis provides guidance for accurate and efficient radioactivity measurement.

Furthermore, an exploration into the impact of non-ionizing electromagnetic fields (EMF) on non-human species revealed evidence suggesting detrimental effects on flora and fauna at an ecosystem and biosphere level due to rising anthropogenic EMF levels (B. Blake Levitt 2022). This research underscores the need for a holistic approach to setting exposure standards, considering ecological implications.

In the domain of artificial intelligence (AI) applications, endeavors have been made to integrate AI into radiation therapy, particularly focusing on generative adversarial networks (GANs) for organ segmentation and therapy adaptation (Yabo Fu 2022). This application of AI introduces innovative techniques to enhance the precision and effectiveness of radiation therapy.

3. Existing System

The system integrates various advanced radiation detectors, such as Geiger-Muller Counters, Scintillation Counters, Dosimeters, Neutron Detectors, and a Hall-Effect Sensor for magnetic field detection (Arpit Patel 2023). Each detector is carefully selected for precise identification and measurement of specific radiation types, ensuring accuracy. Geiger-Muller Counters detect ionizing radiation, while Scintillation Counters measure radiation through light flashes in scintillating materials. Additionally, tools like Ionization Chambers gauge air ionization, Dosimeters provide continuous monitoring of radiation exposure, and specialized instruments like Alpha Spectrometers, Beta Particle Detectors, Gamma Spectrometers, X-Ray Detectors, and the Magnetic Field Detector with Hall-Effect Sensor cater to identifying and measuring distinct particles (Ahmad 2021). Environmental Radiation Monitors and EMF meters offer real-time assessments of background radiation levels and electromagnetic field strength, respectively, addressing exposure concerns efficiently.

4. Proposed Methodology

The operational cycle begins with detecting electromagnetic radiation, processing data for transmission to a centralized server, and organizing it in a dedicated database give in figure 1. When radiation levels exceed predefined thresholds, an instant alert system activates, notifying individuals and company leadership via mobile devices.

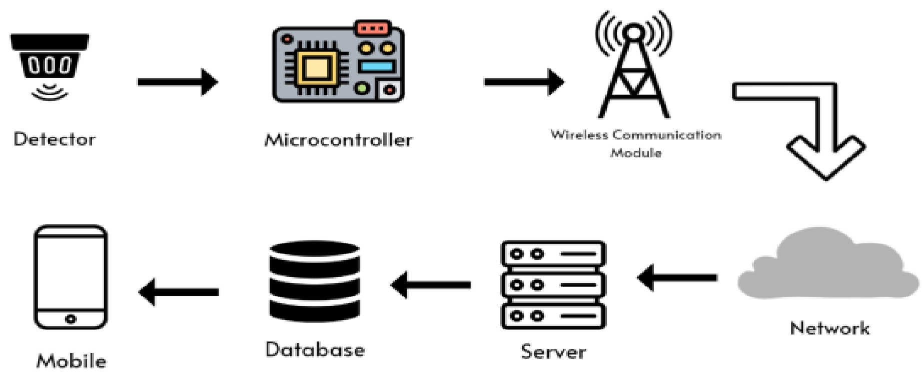

Figure 1.Work Flow Model

This multi-tiered communication approach enables swift responses, fostering cohesive organizational reactions to potential hazards. By connecting individuals, databases, and leadership, the system proactively addresses radiation challenges, enhancing workplace safety and ensuring prompt, coordinated responses for a safer environment.

4.1. Magnetic Strength Analysis

This experiment explores the relationship between magnetic strength and distance, with practical applications in sensor calibration and magnet detection. As the magnet nears the sensor, magnetic flux intensifies, affecting voltage output. This facilitates calibration of other magnetic sensors and measurement of unknown magnet strengths by comparing voltage readings. It also aids in developing magnetic proximity sensors, detecting nearby magnets through voltage changes. Increased flux leads to voltage fluctuations, reflected in consistent changes in flux and corresponding peaks and valleys in the voltage graph. These insights into magnetic field dynamics advance sensor technologies.

4.2. EMF exposure limit

Limits are typically set by international or national organizations: World Health Organization (WHO), International Commission on Non-Ionizing Radiation Protection (ICNIRP), Institute of Electrical and Electronics Engineers (IEEE), and Federal Communications Commission

(FCC) in the US which is illustrated in the table 1.

Table 1 EMF Exposure Limit

Type of Exposure	Frequency Range	E-Field Strength (Volt/Meter (V/m))	H-Field Strength (Amp/Meter (A/m))	Power Density (Watt/ Sq.Meter (W/Sq.m))
General Public	400MHz to 2000MHz	$0.434f^{\frac{1}{2}}$	$0.0011f^{\frac{1}{2}}$	f/2000
		19.29	0.05	1
Occupational	2Ghz to 300Ghz	$3f^{\frac{1}{2}}$	$0.008f^{\frac{1}{2}}$	f/40
		NA	NA	50

5. Deriving the threshold of EMF

In the case that we suggest, the inertial reference frames K(XOY) and K'(X'O'Y') have parallel axes, and K’ is moving in the positive direction of the common OX(O'X') axis at a constant speed U with respect to K. O and O' origins converge in space at time t=t'=0. As seen in figure 2, a point charge w is at rest in K’ when it is at its origin O'. The observer R″(x″= s″cosθ″, y″= s″sinθ″) is situated at a location M ″(x″= s″cosθ″, y″= s″sinθ″) and measures the electric field produced by this charge (stationary in K'). The point charge w generates a radial electric field in K' if Coulomb's law is true in the charge's rest frame.

$$F' = \frac{w}{4\pi\varepsilon_0 s'^2} = \frac{kw}{s'^2} \qquad (1)$$

The components of which are

$$F_x'' = \frac{kw}{s''^2}\cos\theta'' \qquad (2)$$

$$F_y'' = \frac{kw}{s''^2}\sin\theta'' \qquad (3)$$

The charge B'=0 doesn't produce K magnetic field when it is in its rest frame.

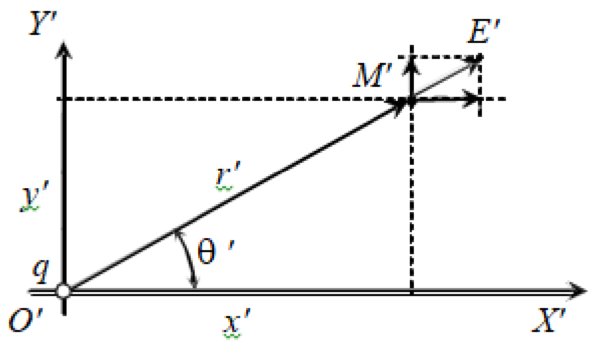

Figure 2. A scenario for calculating the magnetic and electric fields produced by a point

charge traveling uniformly in its rest frame is shown in K' (X'O'Y').

$$F_x = F_x! \quad (4)$$

$$F_y = \frac{F_y}{\sqrt{1-\left(\frac{U}{b}\right)^2}} \quad (5)$$

(6) and (7) becoming ,

$$F'_x = \frac{kwx'}{s'^3\sqrt{1-\left(\frac{U}{b^2}\right)}} \quad (6)$$

$$F_y = \frac{kwy'}{s'^3\sqrt{1-\left(\frac{U}{b^2}\right)^2}} \quad (7)$$

$$x' = \frac{s\cos\theta}{s'^3\sqrt{1-\left(\frac{U}{b}\right)^2}} \quad (8)$$

$$y' = y = s\sin\theta \quad (9)$$

$$s' = s\frac{\sqrt{1-\delta^2\sin^2\theta}}{\sqrt{1-\left(\frac{U}{b}\right)^2}} \quad (10)$$

Equations (10) and (11) become,

$$F_x = kw\frac{\left(1-\delta^2\right)\cos\theta}{s^2\left[1-\delta^2\sin^2\theta\right]^{3/2}} \quad (11)$$

$$F_y = kw\frac{\left(1-\delta^2\right)}{}$$

or

$$F = k\left(1-\delta^2\right)\frac{s}{s^3\left[1-\delta^2\sin^2\theta\right]^{3/2}} \qquad (12)$$

In an alternative method that is closer to classical electromagnetism, we assume that the knowledge that charge w travels in free space at a speed of b and arrives at t'=0 at position O'(0,0) at time t!= s!/b ais what creates the event E!(x!= s!cosθ!, y!= s!sinθ!,t!= s!/b). The information from K's c start is linked to an event M″ (x″= s″cosθ″, y″= s″sinθ″). The identical occurrences found in K areE_0(0,0,0) and E(x = s cosθ, y = s sinθ,t = s/b).

$$x' = \frac{\cos\theta - \delta}{\sqrt{1-\left(\frac{U}{b}\right)^2}} \qquad (13)$$

$$y' = y = s\sin\theta \qquad (14)$$

$$s' = s\frac{1-\delta\cos\theta}{\sqrt{1-\left(\frac{U}{b}\right)^2}} \qquad (15)$$

$$F_x = kw\frac{\left(\cos\theta-\delta\ \right)\left(1-\delta^2\right)}{s^2\left(1-\delta\cos\theta\right)^3} \qquad (16)$$

$$F_y = kw\frac{\left(1-\delta^2\right)\sin\theta}{r^2\left(1-\delta\cos\theta\right)} \qquad (17)$$

$$F = kw\frac{\left(1-\delta^2\right)}{r^3\left(1-\delta\cos\theta\right)^3}\left(s - s\frac{U}{b}\right) \qquad (18)$$

By appling the Lorentz-Einstein c transformations, we are able to produce a "tour-de-force" that requires a large number of intermediate stages. The well-known formula that links the electric and magnetic fields can be used to compute the magnetic field.

$$P = b^{-2}U \times F \qquad (19)$$

We believe that our second method, which uses a radar detection mechanism to determine the space coordinates of the location where the field is detected, is more in line with electrodynamics than the first method, which uses the simultaneous detection of the moving rod coordinates. We also note that the idea of retardation and detection are very similar.

6. Proposed System

The EMF detection system prioritizes user safety by alerting them when EMF levels exceed thresholds. It records detailed data for analysis and offers guidance on reducing exposure. With secure encryption, privacy is ensured, while real-time interaction empowers users to manage their environment for long-term health.

6.1. System Architecture

Our system utilizes a Linear Hall Effect sensor to accurately measure electromagnetic field (EMF) levels represented in figure 3. This data is sent to an ESP32 microcontroller, which employs a sophisticated algorithm to analyze it against predefined thresholds. If radiation exceeds these limits, notifications are swiftly sent to the user via integrated Wi-Fi or Bluetooth, ensuring immediate awareness of heightened EMF levels. This integration enhances reliability and performance, promoting proactive management of EMF exposure.

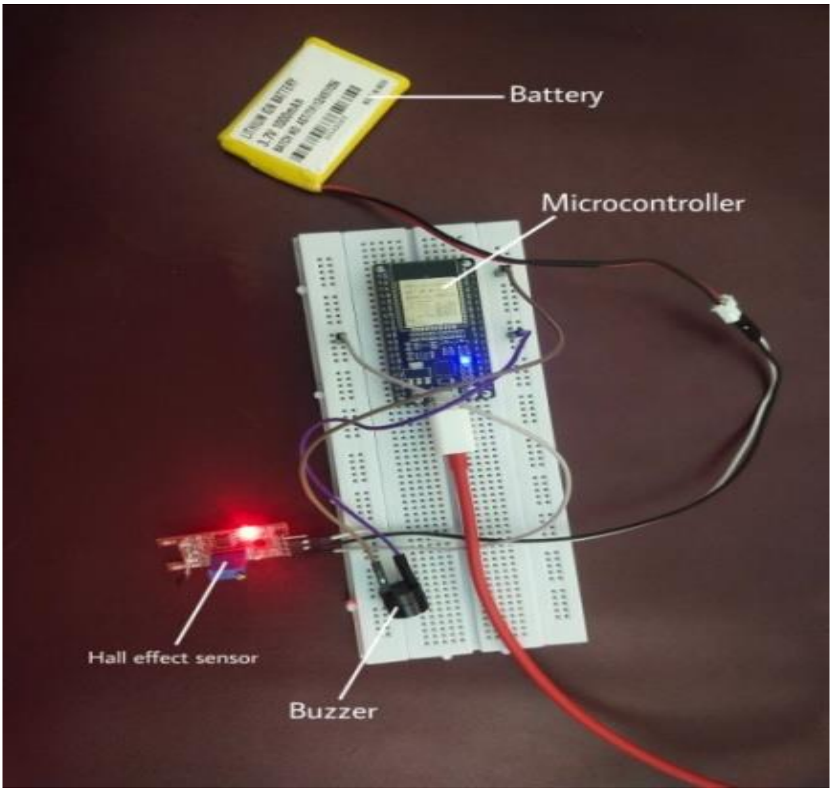

Figure 3: Architecture Diagram

6.2. Why Hall Effect Sensor?

To measure the electromagnetic field (EMF) in our vicinity, we have the option of utilizing either Tunnel Magnetoresistance (TMR) sensors or Hall Effect sensors. The rationale behind our preference for the Hall Effect sensor lies in its specific attributes. The Hall Effect sensor is chosen due to its proven reliability, precision, and suitability for our intended application, ensuring accurate and consistent EMF measurements which is given in table 2, the comparision of the sensors with respective criteria is given in table 3and the comparision graph is illustrated in figure 4.

Table 2 Sensor Comparison

Criteria	Hall Effect Sensors	TMR Sensors
Operating Principle	Based on the Hall effect, generating a voltage.	Based on Tunneling Magnetoresistance effect.
	Perpendicular to both the current and magnetic field.	Through a magnetic tunnel junction (MTJ).
Sensitivity	Lower sensitivity compared to TMR sensors.	Higher sensitivity, capable of detecting weaker magnetic fields.
Resolution	Typically offers lower resolution.	Provides higher resolution, allowing for more precise detection and measurement of magnetic fields.
Temperature Stability	Can be affected by temperature variations.	Generally exhibits better temperature stability.
Power Consumption	Generally lower power consumption.	Can consume more power, especially at higher sensitivities.
Cost	More cost-effective.	More expensive to manufacture.
Complexity of Fabrication	Simpler fabrication processes.	Involves complex processes such as thin film deposition.
Environmental Sensitivity	More robust to environmental factors.	May be more sensitive to temperature variations and stress.
Integration Flexibility	Easily integrated into various system architectures.	May have limitations in integration due to complex fabrication.
Standardization	Widely standardized and compatible across industries.	May lack standardization, leading to compatibility issues.
Detection Strength	Generally lower detection strength.	Higher detection strength, capable of detecting weaker magnetic fields with greater accuracy.

Table 3 Sensor Comparison with respective Criteria

Criteria	Hall Effect Sensors	TMR Sensors
Sensitivity	3	5
Resolution	2	4
Temperature Stability	4	5
Power Consumption	5	3
Cost	4	2
Complexity of Fabrication	4	2
Environmental Sensitivity	5	3
Integration Flexibility	5	2

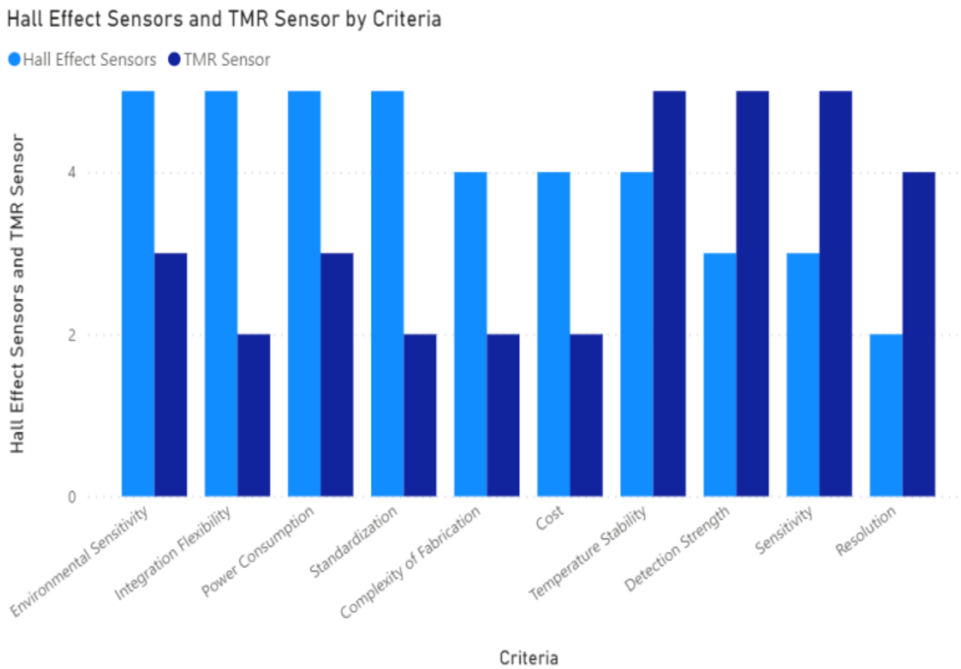

Figure 4: Hall Effect Sensor vs TMR Sensor

7. Results

The system effectively assesses workplace safety and EMF radiation levels, offering real-time alerts and recommendations for risk mitigation. Continuous monitoring enables targeted interventions in high EMF areas, fostering a safer work environment and refining safety protocols through data analysis.

8. Discussion

The monitoring system advances EMF radiation management in workplaces, offering real-time monitoring and protective recommendations for employee well-being. It identifies and intervenes in high-risk areas, enhancing workplace safety represented in figure 5 and 6.

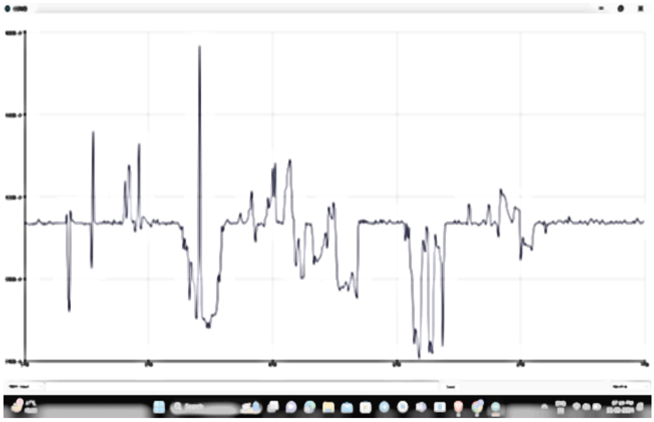

Figure 5: With EMF

Ongoing research and development are essential for improving capabilities and collaborating with regulatory agencies. It symbolizes an innovative approach to prioritize employee well-being in tech-driven environments.

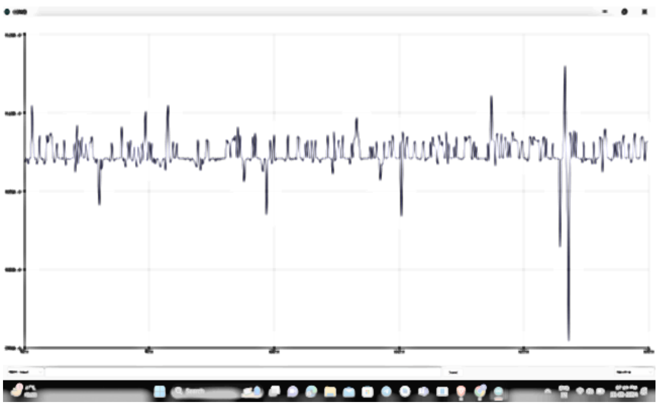

Figure 6: Without EMF

9. Conclusion

Conclusively, the implementation of our proposed system has demonstrated promising results in effectively assessing workplace safety and EMF radiation levels, offering real-time alerts and targeted interventions to mitigate potential health risks. By empowering employees to proactively manage their exposure and fostering a culture of safety, this approach enhances overall workplace safety in technologically driven environments. Ongoing research and collaboration with regulatory agencies are essential for refining the system and establishing guidelines, ensuring the continued well-being of employees. This proactive strategy sets a precedent for comprehensive workplace safety, prioritizing the health and welfare of workers in today's diverse workplaces.

Acknowledgment

I would like to express my very great appreciation to the co-authors of this manuscript for their valuable and constructive suggestions during the planning and development of this research work.

Conflicts of Interest

The authors declare no conflict of interest.

Ethical Approval

No humans or any living beings are involved in this research.

Consent to Participate

No humans or any living beings are involved in this research.

Consent to Publish

I, Jackulin Chin, hereby provide consent for the abstract titled "Comprehensive Workplace Safety in the Digital Age: A Proactive Approach to Monitoring Electromagnetic Fields (EMF) and its Environmental Implications" to be published in Environmental Science and Pollution Research. I understand that this abstract may be made available to the public and that it may be reproduced and distributed by the publisher in various formats, including print and electronic. I acknowledge that the abstract will be published with proper attribution to the authors, and any subsequent use of the abstract will also include appropriate citation to the original publication.

Funding Information

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors contribution

All authors have made substantial contributions to conception and design, revising the manuscript, and the final approval of the version to be published. Also, all authors agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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