UNIVERSITY OF WATERLOO

RescueTouch Emergency System

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1 Introduction

1.1 Background

Emergency services are often difficult to access for people with disabilities, especially in urgent situations where fast communication is critical. Present systems use verbal communication or a complicated interface, which is a barrier for those with mobility, speech, or cognitive impairments. Around 1.3 billion people experience significant disabilities. Many of these individuals face difficulties when trying to contact emergency services, as the primary method is through voice call. In Europe alone, 80 million people with disabilities face such challenges, and while some countries offer alternatives like SMS or video calls, access remains unequal, leaving many vulnerable in emergencies.

1.2 Project Purpose

This project aims to create a system that allows users to quickly communicate essential information, such as name, address, and health care details, to first responders through a simple task like pressing a button or entering a number. This ensures timely assistance for people who may struggle with traditional emergency communication methods. Focusing on user-friendly interface with easy controls and ensures accurate and rapid transmission of vital information.

1.3 Current Implementation

There are current systems placed all around the world to combat this issue; however, many tend to rely on voice communications, which neglect those who have speech impairments or hearing loss. Various wearable devices have been developed by companies to provide adequate services for most groups of people. For instance, Caretrak has created a device that allows individuals to call emergency contacts or 911 with a simple button press. This wearable device also reports the user’s location via GPS, ensuring prompt assistance in emergencies [2]. Another line of devices offered by Medical Alert Systems Canada serves a similar purpose, providing functionalities akin to those of the Caretrak device [3]. Additionally, Daytech has developed a device that includes portable receivers capable of receiving emergency alerts from a call button. Although it has a limited range, it allows different locations to have distinct ringtones, enhancing accessibility for users [3].

As observed from the aforementioned products, while they adequately serve many groups of people, certain individuals, particularly those who cannot communicate verbally, find these services insufficient. Many of these devices require a conversation with 911 to relay crucial information, which can be challenging for those with speech impairments. Therefore, there is a clear need for solutions that better accommodate the communication barriers faced by these individuals.

2 Customer Problem

2.1 Identifying the Group

The client for this project is the Deaf-Blind community. A unique population characterized by their dual sensory impairment, which significantly affects both hearing and vision. This combination of impairments impacts nearly every aspect of their daily lives, making basic communication, independent navigation, and access to services difficult [7]. Many Deaf-Blind individuals rely on specialized tools like Braille, screen readers, or tactile signing to interact with their surroundings and the people around them. However, even with these tools, they face immense challenges in activities, such as using public transportation, accessing healthcare, or receiving emergency alerts. The problem extends into public safety, as the inability to respond to visual or auditory alerts leaves this community particularly vulnerable during emergencies, where immediate action is required for safety and survival.

According to the Canadian Association of the Deaf-Blind (CADB), this group comprises approximately 3,300 individuals in Canada, making them a significant yet underserved population in terms of emergency communication solutions [7]. The absence of adequate communication channels in emergency scenarios can be life-threatening, as current systems largely depend on auditory and visual stimuli, which are inaccessible to this community.

Organizations like the CADB have long advocated for the development of improved accessibility features in public infrastructure and emergency response systems. They emphasize the importance of solutions that accommodate the specific needs of Deaf-Blind individuals, particularly in critical situations where timely access to emergency services is vital [7]. This project aims to address the identified gap by creating an emergency call system designed to serve the Deaf-Blind community effectively. By focusing on tactile and haptic feedback mechanisms, this system will enable users to quickly communicate essential information, such as personal identification and health details, to emergency responders.

2.2 Defining Problem

Deaf-Blind individuals face many barriers in accessing emergency services, primarily due to the absence of communication systems that account for their dual sensory impairments. The current emergency infrastructure in Canada, which is heavily reliant on auditory and visual cues, renders it largely inaccessible for those who cannot hear or see. According to the Canadian Hearing Society (CHS), many Deaf-Blind individuals encounter situations where they are unable to verbally communicate with 911 operators [6]. As a result, operators often misinterpret these silent or incomplete calls as errors or misdials, leading to the premature termination of the call. This miscommunication can have dire consequences, especially in time-sensitive emergencies where swift access to help is critical. Additionally, the "Barrier-Free Emergency Communication Access and Alerting System Research Report" reveals that most alerting systems currently do not support alternative communication methods, such as text-based messaging or tactile alerts, which are vital for Deaf-Blind individuals to convey their needs during crises [6]. This critical gap leaves these individuals particularly vulnerable, unable to communicate effectively in life-threatening situations.

As highlighted by the World Health Organization (WHO), Deaf-Blind individuals often find themselves isolated, struggling to navigate a world that largely overlooks their specific needs [9]. They may lack the means to alert emergency services, further exposing their vulnerability in critical moments. Addressing this problem with a solution would drastically improve the lives of Deaf-Blind individuals. A comprehensive emergency communication system, specifically designed to support alternative communication, would allow these individuals to access emergency services with the same immediacy and effectiveness as any other member of society [8]. Integrating features such as text-based messaging, Braille interfaces, or haptic feedback systems into emergency alert infrastructure would ensure that Deaf-Blind individuals can transmit essential information—such as their location, health condition, or type of emergency—directly to first responders. This would not only empower the Deaf-Blind community by giving them a reliable method to seek assistance but also significantly enhance their safety and independence [8].

By solving this problem, the proposed system would close a critical accessibility gap and provide a tailored solution to meet the emergency needs of approximately 3,300 Deaf-Blind individuals in Canada, as represented by the Canadian Association of the Deaf-Blind [7]. Ultimately, this project would contribute to the creation of an inclusive emergency response system that ensures no individual is left without a means of communication during an emergency.

2.3 Stakeholders

Graduate TA and Professor
The Graduate TA and professor play a role in evaluating the project's design effectiveness, engineering rigor, and client satisfaction. Their expertise in engineering principles and accessibility standards is crucial for guiding the development process. Regular assessments from these stakeholders not only enhance the project's quality but also contribute to a deeper understanding of the ethical implications associated with designing technology for individuals with disabilities.

CADB Customers (Deaf-Blind Individuals)
CADB customers, particularly Deaf-Blind individuals, are at the heart of this project, as their unique needs directly inform the design and functionality of the emergency communication system. This population faces significant barriers in accessing timely emergency alerts, and focusing on assistive technologies that enhance their ability to communicate effectively [7]. Engaging with Deaf-Blind individuals through user interviews and focus groups will provide insights into their communication preferences, ensuring that the developed solution is user-friendly and meets their specific requirements.

Government and Regulatory Bodies
Government and regulatory bodies, such as the Canadian Radio-television and Telecommunications Commission (CRTC) and Public Safety Canada, are vital stakeholders in ensuring that the project complies with relevant accessibility standards. These organizations set regulations that mandate the inclusion of accessible features in communication technologies, which facilitate broader access for all Canadians, including those with disabilities [10]. Their involvement ensures that the project aligns with legal and ethical frameworks, ultimately enhancing the likelihood of successful implementation within national emergency alert systems.

Suppliers to Customer
The Canadian Helen Keller Centre (CHKC) is a key stakeholder in our project, as they are trusted in providing critical emergency services and support to the Deaf-Blind community in Canada. As the primary organization that will distribute the RescueTouch Emergency System to our clients, CHKC's involvement in the design and distribution process is essentia [34]. By collaborating with CHKC, we will gain valuable insights into the specific needs and challenges of Deaf-Blind individuals during emergencies, ensuring that our system is tailored to their requirements.

Moreover, CHKC's expertise in delivering emergency services will provide a clear pathway for integrating our product into their existing service offerings, which includes 24/7 intervenor services [34]. This partnership will also allow us to understand the manufacturing, assembly, and distribution steps needed to ensure the product reaches those who need it. By involving CHKC in the early stages, we can streamline the manufacturing process to meet their operational needs and establish a smooth supply chain that allows Deaf-Blind individuals to purchase and receive the device efficiently. This ensures the system is not only functional but also accessible, effectively bridging the gap between design, production, and the end-user.

Special Interest Groups
Special interest groups, including the Deaf Wireless Canada Committee and the World Federation of the

Deafblind (WFDB), advocate for accessible communication technologies and play an essential role in promoting initiatives that support Deaf-Blind individuals. These organizations not only provide resources and best practices for developing inclusive technologies but also raise awareness of the unique challenges faced by this community [11]. Collaborating with these advocacy groups can improve the project's credibility and foster community support. Leading to a final product that is aligned with the needs of the Deaf-Blind population.

Part Suppliers
Part suppliers are crucial stakeholders, as their collaboration ensures access to the latest assistive devices and technologies necessary for building the emergency communication system. Part suppliers—those providing essential hardware such as STM32 boards, communication modules, and other critical components—play a key role in ensuring the project has the necessary tools and materials for successful implementation. Establishing strong relationships with part suppliers can provide insights into innovative solutions that cater specifically to the needs of Deaf-Blind individuals [12]. By involving part suppliers in the design process, the project can leverage their expertise to identify components that enhance the system's functionality and ensure high-quality outputs.

The Public
The public also plays a role in the project's success, as community awareness and support can help create a more inclusive environment for Deaf-Blind individuals. Raising awareness about the challenges faced by this population is important for mobilizing public support and advocacy efforts [13]. Engaging the community through forums or outreach programs can not only inform the public about the importance of inclusive emergency communication solutions but also foster a culture of empathy and understanding, which can influence policy decisions and funding for similar initiatives.

Emergency Service Providers
Emergency service providers, including police, fire, and medical personnel, are critical stakeholders since they will ultimately utilize the emergency communication system to assist Deaf-Blind individuals in crisis situations. Understanding their existing communication protocols and challenges is essential for designing a system that effectively facilitates clear and immediate communication during emergencies [14]. Collaborating with these stakeholders will ensure that the system is practical and usable in real-world scenarios.

Non-Stakeholders
Potential non-stakeholders may include organizations or individuals focused solely on non-emergency communication technologies, as their interests may not align with the project's primary objectives. These groups often lack relevance to the specific needs of Deaf-Blind individuals in emergency situations, which underscores the importance of targeted stakeholder engagement [15]. By focusing on stakeholders who have a direct impact on accessibility and emergency communication, the project can ensure that its efforts are directed toward addressing the most pressing challenges faced by the Deaf-Blind community.

3 Initial Requirements

3.1 Functional Requirements

The emergency call system for the Deaf-Blind community is designed with several functional requirements that ensure effectiveness and reliability. First, the system must communicate user details, including name, address, and healthcare information, within 120 seconds of triggering. This requirement is quantifiably defined within a range of 0 to 120 seconds (unit: seconds) and is achievable with current technology in emergency communication, ensuring timely responses in critical situations [28]. Additionally, the system must ensure at least a 90% successful transmission rate between STM32 boards, with a quantifiable range of 90% to 100% (unit: percentage). This level of reliability is essential for effective emergency communication and can be measured through test runs and communication logs, as supported by established communication protocols [6].

The system must also support input methods such as button presses or number entry requiring no more than 2 Newtons of force to activate. This specification, ranging from 1.7 to 2 Newtons (unit: Newtons), aligns with ergonomic standards and is critical for users with limited dexterity [18]. Furthermore, the system must transmit data reliably over a range of at least 10 meters in typical indoor environments, with a quantifiable range of 10 to 30 meters (unit: meters). This requirement is necessary for practical scenarios where users may need to communicate from a distance and is supported by studies in wireless communication [21].

An additional functional requirement is that the system must provide haptic feedback to the user upon successful transmission of their emergency information, ensuring they receive confirmation without relying on visual or auditory cues. This haptic feedback must occur within 5 seconds of the transmission being completed, with a quantifiable range of 0 to 5 second (unit: seconds). This feedback mechanism is essential for user assurance and can be measured through simple timing methods. The requirement aligns with best practices in assistive technology design, emphasizing the need for multi-sensory feedback [29].

3.2 Technical Requirements

The emergency call system incorporates several key technical requirements essential for its functionality. First, the system must utilize communication protocols between the STM32 boards that ensure low-latency communication, defined as a response time of less than 50 milliseconds (unit: milliseconds) for data transmission. This requirement is critical for ensuring that emergency communications are timely and efficient, as supported by studies indicating that low latency is essential for effective real-time communications [17].

Additionally, the system must demonstrate power efficiency, with a maximum power consumption of no more than 500 milliwatts (unit: milliwatts) during operation. This requirement, defined within a range of 0 to 500 milliwatts, is achievable using current energy-efficient components and is measurable with standard electrical testing equipment. Maintaining low power consumption is important for ensuring that the system remains operational during emergencies when power sources may be limited [30].

Furthermore, the system must be capable of processing and transmitting data quickly, with the requirement that it can handle a data throughput of at least 1 kilobyte per second (unit: kilobytes per second) during peak usage [30]. This quantifiable requirement, set within a range of 1 to 10 kilobytes per second, is appropriate for the needs of the Deaf-Blind community and can be tested using data transfer benchmarks. Ensuring adequate data throughput is crucial for transmitting user information promptly during emergencies [1].

Finally, the STM32 boards should seamlessly integrate with existing emergency response communication channels, requiring compatibility with standard communication protocols such as UART (Universal Asynchronous Receiver-Transmitter). This integration must adhere to the specifications outlined in relevant technical standards, which provide guidelines on communication compatibility [17].

3.3 Safety Requirements

The emergency call system must incorporate several critical safety requirements to enhance its reliability and user safety. Firstly, the system must be designed to prevent accidental false alerts, ensuring that emergency services are only contacted in real situations. This includes implementing a two-step verification process that requires the user to confirm their intent to send an emergency alert. The response time for this confirmation must be within 3 seconds (unit: seconds), allowing users to quickly cancel any unintentional alerts [29].

Data security and privacy are also paramount, especially when transmitting sensitive personal and medical information. The system must employ encryption protocols that meet at least AES-128 (Advanced Encryption Standard with a 128-bit key) for data transmission, ensuring that all personal information is securely encrypted during transmission. This requirement is quantifiable and can be verified through standard cybersecurity testing methodologies. By adhering to established encryption standards, the system will protect user data from unauthorized access, in alignment with best practices for secure communications [17].

Additionally, the system must be resilient and function reliably under various conditions, including environmental factors such as extreme temperatures (ranging from -20°C to 50°C) and signal interference, to ensure it remains operational during emergencies. This temperature range is specified in degrees Celsius and is supported by guidelines from the World Health Organization [16], indicating that electronic devices should withstand these conditions for consistent performance. The system should also maintain operational capabilities despite signal interference, with a requirement for maintaining at least 80% communication effectiveness in environments with high electromagnetic interference (EMI), which can be measured through standardized testing protocols [6].

In summary, these additional technical requirements ensure that the emergency call system is robust, secure, and user-friendly, ultimately enhancing the safety and reliability of emergency communications for the Deaf-Blind community. Each requirement is quantifiably defined, feasible for a first-year engineering student, measurable, appropriate for the defined problem, and supported by credible references, reinforcing the project's objectives.

4 Principles

4.1 Circuit Theory

The design of the emergency call system for Deaf-Blind individuals will primarily exploit several scientific and engineering principles to ensure optimal performance and reliability. First, Ohm's Law plays a crucial role in the electrical design of the system. This law states that the current flowing through a conductor between two points is directly proportional to the voltage across the two points and inversely proportional to the resistance, as expressed by the equation [19]:

$$V = I \times R$$

By applying Ohm's Law, we can accurately select resistor values for various components, such as LEDs, haptic feedback devices, and transducers, to ensure they operate within safe current limits. This careful management of electrical parameters not only enhances component longevity but also prevents overheating, which is critical in emergency scenarios where system reliability is paramount. Furthermore, understanding the relationship between voltage, current, and resistance enables us to design circuits that can efficiently power all system elements without risking damage or failure during operation.

Additionally, Kirchhoff's Laws, which encompass both the Current Law (KCL) and the Voltage Law (KVL), are integral to analyzing the system's complex circuits. KCL asserts that the total current entering a junction equals the total current leaving it, while KVL states that the sum of the electrical potential differences around any closed circuit is zero, mathematically represented as [20]:

$$\sum I_{in} = \sum I_{out}$$

Implementing these laws allows us to optimize power distribution across the various sensors and actuators within the emergency call system, ensuring that each component receives the appropriate voltage and current. This is particularly important given the system's reliance on multiple inputs and outputs, where accurate current management minimizes the risk of component damage and enhances overall performance. By using Kirchhoff's Laws, we can improve the efficiency of the system, ensuring that it operates reliably even under varying load conditions, which is vital for maintaining communication during critical emergencies.

By employing these scientific principles—Ohm's Law for circuit design, and Kirchhoff's Laws for circuit analysis for effective communication—the emergency call system will be well-equipped to provide a reliable, efficient, and safe means of communication for Deaf-Blind individuals. This comprehensive approach ultimately contributes to enhancing their independence and safety in emergency situations, bridging a significant gap in current emergency response systems.

4.2 Functions and Graphs

Incorporating functions and graphs into the design of the emergency call system enhances our ability to model, analyze, and optimize its performance under various conditions. Graphical representations allow for a detailed assessment of key parameters such as response times, signal strength, and environmental influences, providing a comprehensive understanding of how the system behaves in real-world scenarios. For instance, plotting response time against signal strength helps identify critical thresholds where sufficient signal strength correlates with optimal response times [31]. Research indicates that response delays can occur when signal strength drops below certain levels, underscoring the importance of maintaining robust communication channels during emergencies (see figure 4.2.1) [22].

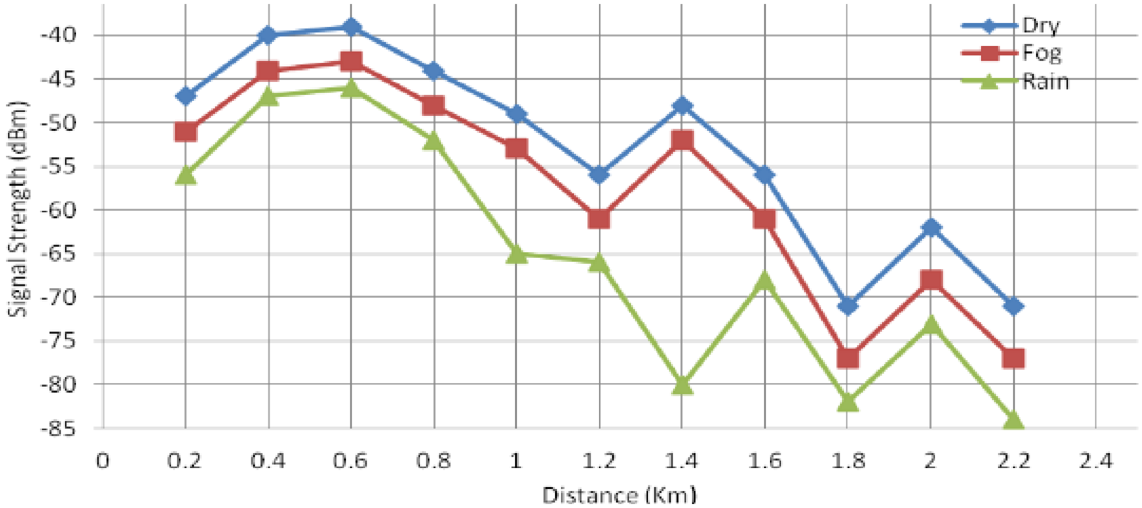

Figure 3: Signal strength variations for different weather

Figure 4.2.1: Signal strength based on weather variations [31]

Using mathematical functions to model environmental factors—such as interference from obstacles, distance from signal sources, or atmospheric conditions—further aids performance analysis. For example, signal degradation over distance can be modeled using the log-distance path loss model, which predicts how signal strength diminishes with increasing distance from the transmitter [23]. Understanding this relationship is essential for ensuring the system remains functional within the expected operating range, allowing for timely communication with emergency responders.

Furthermore, functions can represent battery life, power consumption, and component efficiency, providing a holistic view of the system's operational parameters. Research shows that optimizing power consumption is crucial in emergency communication systems, as limited battery life can impact system reliability [24]. For example, plotting power consumption against usage time can help determine optimal battery specifications, ensuring that the emergency call system remains operational during critical situations without interruption.

In conclusion, integrating functions and graphs into the emergency call system's design aids in modeling and analyzing its behavior, serving as a foundation for optimizing performance. Through careful examination of graphical data and relationships between key variables, we can ensure that the system is effective and reliable, ultimately enhancing the safety and independence of Deaf-Blind individuals in emergency situations.

4.3 Electromagnetism

Electromagnetism plays a crucial role in the design and implementation of the wireless communication components of the emergency call system. Understanding the principles of radio wave propagation is essential for optimizing the design of antennas and transmission systems, enabling effective signal transmission over varying distances. For instance, the relationship between wavelength, frequency, and the speed of light can be described by the equation:

$$c = f \times \lambda$$

where c is the speed of light (approximately 3×10^8 m/s), f is the frequency, and λ is the wavelength [27]. By selecting appropriate frequencies and corresponding wavelengths, we can ensure that the STM32 boards can transmit and receive signals effectively, maximizing performance while minimizing loss [23].

Antenna design involves selecting geometries that maximize gain, which is a measure of how well an antenna converts input power into radio waves in a specific direction. Research indicates that antennas designed to resonate at specific frequencies can significantly enhance signal strength and reception quality [25]. For example, a dipole antenna can be designed to have a length of approximately half the wavelength of the frequency it is intended to transmit or receive, where L is the length of the dipole antenna [25]. As given by the formula:

$$L = \frac{\lambda}{2}$$

Moreover, knowledge of electromagnetic interference (EMI) is vital in designing systems that operate reliably in real-world environments. EMI can arise from various sources, including other electronic devices and natural phenomena, leading to signal degradation and communication failures (see figure 4.3.1). By applying electromagnetic shielding techniques, such as using conductive materials or enclosures, we can protect the system from unwanted signals that could disrupt communication [22]. The effectiveness of these shielding methods can often be assessed through the concept of attenuation, which describes the reduction in power of the signal as it passes through the shield [22].

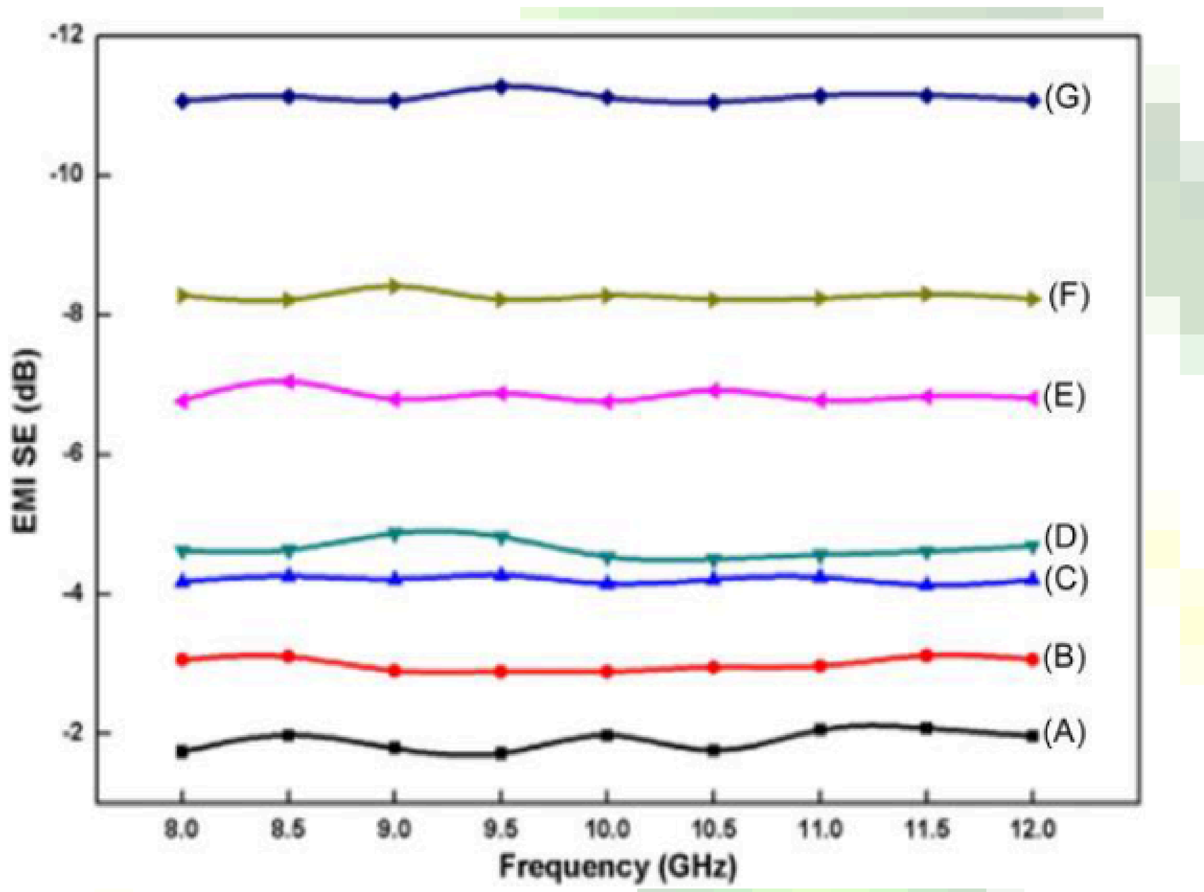

Figure 4.3.1: Interference of EMI signals on the different types of frequency [32]

Furthermore, understanding the electromagnetic spectrum is essential in selecting the optimal frequency band for communication. Different frequencies exhibit varying propagation characteristics, impacting the system's range and penetration through obstacles [23]. For example, lower frequencies tend to penetrate walls more effectively but may suffer from lower data rates, while higher frequencies provide greater bandwidth but have more limited range and penetration capabilities (see figure 4.3.2) [23]. By carefully analyzing these trade-offs, we can select an appropriate frequency that meets the needs of the emergency communication system.

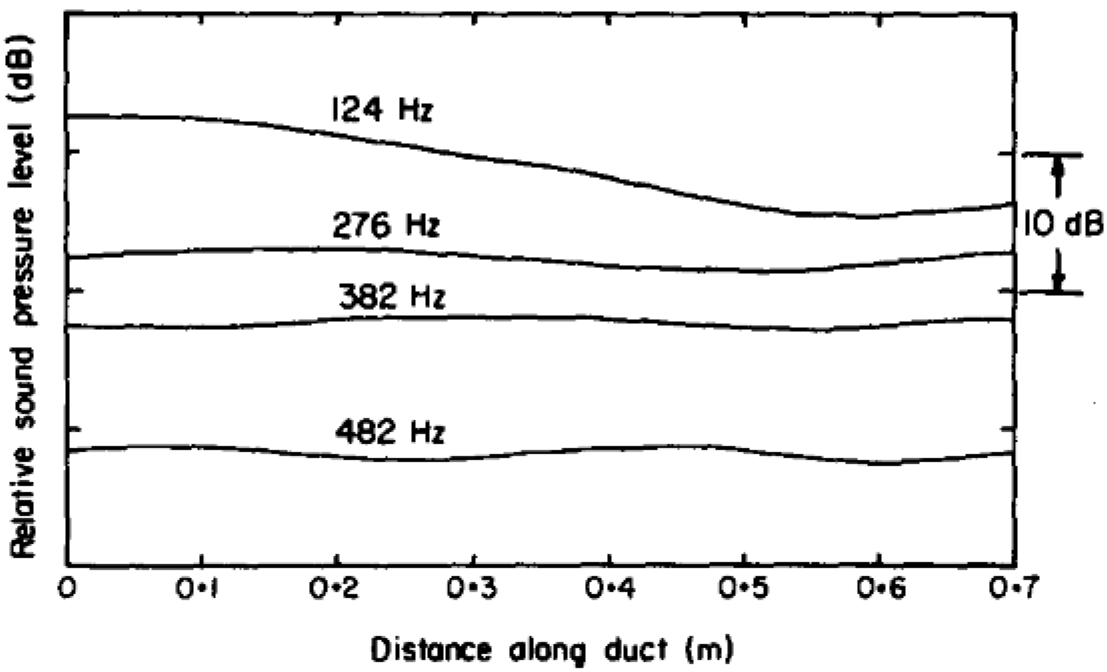

Figure 5. Axial sound pressure patterns in the square duct.

Figure 4.3.2: Lower frequencies penetrating duct walls more effectively [33]

In summary, the principles of electromagnetism are foundational for the effective wireless communication design of the emergency call system. By focusing on antenna design, EMI mitigation, and optimal frequency selection, we can ensure reliable and efficient communication, which is critical for the safety and independence of Deaf-Blind individuals in emergency situations.

5 Conclusion

5.1 Summary of the Problem and Approach

The project addresses the challenge faced by individuals with accessibility issues in quickly contacting emergency services. Present systems often rely on verbal communication or complex interfaces, which can be difficult for those with physical or cognitive impairments. To solve this, we propose an emergency call system using two STM32 microcontroller boards. A simple user action, like pressing a button, will trigger the transmission of personal details (such as name, address, and health information) from one STM32 board to another, which then relays this data to emergency responders. By utilizing efficient communication protocols, the system ensures fast, secure, and reliable data transmission, providing a user-friendly solution for those in need.

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