DESIGNING A LIGHTING SYSTEM THAT IS CONTROLLED BY A REMOTE AND USES A LOW VOLTAGE USING LOCALLY AVAILABLE MATERIALS

BY

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DECLARATION

I Onyango Samuel, the undersigned declare that this project is my original work and has never been submitted for any award to Busitema University or any other institution of higher learning.

Signature .... Date 19TH/MAY/2026 ....

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APPROVAL

This research by Onyango Samuel has been done under my supervision and is now ready for submission as a partial fulfilment for the award of the bachelor's degree of science education of Busitema University

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DEDICATION

This work is dedicated to my beloved parents, Mr. Janasi Wilber and Mrs. Taabu Dinah for their tireless effort towards my studies and success.

ACKNOWLEDGEMENT

I would like to appreciate the almighty God for granting me the gift of life, and all the abilities I possess to be able to carry out this research study.

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LIST OF ACRONYMS AND ABBREVIATIONS

TV- Television

LED- Light Emitting Diode

BW- Band width

T_{r}- Rise Time

DC- Direct Current

PWM- Pulse Width Modulation

DALI- Digital Addressable Lighting Interface

IoT- Internet of Things

ABSTRACT

The aim of this study was to design a lighting system that is controlled by a remote and uses a low voltage as low as 5 Volts. In this study, a lighting system that is controlled by a remote was designed using a sensor, resistors, USB socket, remote and LED lamp beads. The band width of the lighting system was measured and found to decrease with increase in distance. These results suggest that the remote would be effective if it is used at a nearby distance with no obstacle.

CHAPTER ONE INTRODUCTION

1.1 Background of the study

A remote is a device that is used to control other devices from a distance using different technologies like infrared radiations. It provides convenience to the user allowing control of lighting systems from a distance. Several remote-controlled systems have been in existence for example the Quick-break light switch which was the first practical mechanism to prevent electrical fire hazard when turning a light off (John Henry Holmes, 1884), the first TV remote which was tied by a wire was Lazy Bones (Zenith Radio Corp, 1950), the first wireless remote that used visible light to hit sensors was called Flashmatic though it was often triggered accidentally by sunlight (Eugene Polley, 1955).

The transition to digital allowed for addressable lighting where a remote could control a specific bulb in a large network. Infrared technology replaced ultrasonic sound as the standard for remotes improved and it required a line of sight to function (Infrared Era, 1981). The blue LED was the missing link that allowed for white LED light and high-efficiency digital lighting (Shuji Nakamura. 1992). The Digital Addressable Lighting Interface (DALI) allowed commercial lighting systems to be managed via a digital remote (DALI Group, 1998)

The fundamental principle behind a remote-controlled low-voltage lighting system is the separation of power and logic (Kroschwitz & Seidel, 2007). Instead of a high-voltage switch physically breaking a circuit, this system uses a low power signal to tell a controller to manage a higher-power load (Gulliver & Arndt, 1991). The remote doesn't actually power the lights but it sends a command and this usually happens via one of the two mediums: The radio frequency which don’t require a line of sight and can pass through walls and the Infrared which requires a direct line of sight to the receiver. The remote converts the button press into a wireless data packet and the receiver waits for that specific frequency and decodes the message.

A lighting system that is controlled by a remote and uses a low voltage has the advantages of having a low voltage rather than standard voltage providing for significantly lower risks, flexible and easy installation, advanced control and customization in which the remote aspect moves the system from a simple circuit to a smart network, lower power consumption and longer bulb life. The following are some of the existing remote controlled lighting systems. Smart bulbs and Plugs which are enabled devices that automate home lighting and appliances. Smart bulbs are LED lights with in-built Wi-Fi and Bluetooth which allow adjustments for brightness and color via apps or voice. Smart plugs are intermediaries between wall outlets and dumb devices which turn them into smart and remote controlled devices. The challenges of Smart Bulbs and Plugs are reliance on Wi-Fi stability and loss of functionality when physical switches are turned off, the need for complex and incompatible app set ups (masters, 2013), they can also cause security risks if not updated regularly and lead to faster functional failure compared to traditional devices (Gumiller and tommy, 1993)

Wireless Protocols are smart systems which use mesh networking to allow devices to communicate without relying on the home's primary Wi-Fi hence enhancing reliability. The challenges of Wireless Protocols are signal interference from physical obstacles, limited range, high latency compared to wired networks and significant security vulnerabilities due to the open nature of radio waves.

There has been some work done on the designing a lighting system that is controlled by a remote and uses a low voltage forex ample Architectural Linear Tape Lighting, Low-Voltage Landscape, Integrated Furniture and Display Lighting. These systems are however characterized by signal interference and higher initial cost (Smeaton, 2007). This research intends to address some of these challenges specifically by using locally available materials.

This research focuses on the designing of a lighting system that is controlled by a remote using locally available materials.

1.2 Problem statement

There is need to design a more accessible, efficient and economically viable remote control lighting systems for home use.

1.3 Objectives of the study

1.3.1 Aim of the study

To design a lighting system that is controlled by a remote and uses a low voltage using locally available materials.

1.3.2 Specific objectives

(i) To design a lighting system that is controlled by a remote and uses a low voltage using locally available materials.

(ii) To determine the band width of a remote.

1.4 Significance of the study

This innovative idea of designing a lighting system that is controlled by a remote and uses a low voltage using locally available materials allows users including the disabled to manage lighting systems without direct physical interaction with switches typically through a remote.

CHAPTER TWO LITERATURE REVIEW

2.1 Description and purpose of remote control lighting systems

Remote control lighting systems represent a sophisticated integration of electrical engineering, wireless communication and automation designed to manage the illumination of residential, commercial and industrial environments. At their core, these systems allow for the manipulation of light intensity, color temperature and operational scheduling without the requirement of physical contact with a manual wall switch. The evolution of these systems has moved from simple mechanical toggles to complex networked infrastructures that utilize electromagnetic spectrum frequencies such as infrared and radio waves to transmit data packets from a controller to a receiver integrated within a lamp (F. L. H. M. van de Ven and J. M. K. C. van der Vleuten, 2008). The fundamental purpose of remote control lighting is to enhance human comfort, improve energy efficiency, and provide a layer of security through automation.

The functionality of remote control lighting is predicted on the transmission of signals between a user interface and the lighting load. Several distinct technologies govern this interaction and these include; infrared technology and these infrared systems operate using pulses of non visible light to send binary codes to a receiver. This technology is line of sight meaning the transmitter must be pointed directly at the sensor and this happens typically within a range of 15 to 30 feet and it's advantageous because of it being cost effective and simple. Infrared technology is limited by physical obstructions like walls or furniture (Larry W. Mays, 2011). Radio Frequency utilizes radio waves to communicate. (E. L. K. M. van der Vleuten and F. L. H. M. van de Ven, 2013). Unlike infrared technology, radio frequency technology signals can penetrate walls and floors, offering a significantly larger control radius often up to 150 feet or more (John Twidell and Tony Weir, 2015). Radio frequency is the backbone of most modern smart lighting ecosystems due to its reliability and range. Wi-Fi and Bluetooth mesh are modern systems often leveraging the existing local area networks (Wi-Fi) or low energy mesh networks (Bluetooth) (Allan R. Hambley, 2014). Wi-Fi-based lights connect directly to a home router allowing for global control via smartphone applications while bluetooth mesh allows bulbs to talk to one another extending the range of the network by hopping the signal from one device to the next. The power line communication technology sends control signals over the existing electrical wiring of a building (B. M. Weedy and B. J. Cory) and this eliminates the need for new data cables or wireless interference concerns making it a robust choice for industrial applications and large scale.

A comprehensive remote lighting system consists of three primary layers: the input device, the controller and the output device (Larry W. Mays, 2011), sensors and inputs consist of a Passive infrared or ultrasonic photocells for daylight harvesting and manual interfaces like handheld remotes, wall mounted keypads or smartphone apps. The Controller consists of a central hub which processes input data for example if a photocell detects high levels of natural sunlight, the controller calculates the necessary reduction in artificial light to maintain a constant light level. Output device consists of the LED driver that receives the command and adjusts the current flowing to the light source.

The benefits of remote control lighting systems are energy conservation and sustainability through light accounting for a significant portion of global energy consumption, reduction in waste by ensuring lights are only active when they are in need, security and safety by allowing homeowners to set vacation modes where lights turn on and off in a randomized pattern to simulate presence.

2.2 How a remote control lighting systems works

Remote control lighting systems are integrated technological frameworks that allow for the wireless management of illumination within a built environment and these systems function by translating user inputs delivered via handheld remotes, wall mounted keypads or mobile applications into electromagnetic signals that are captured by a receiver and processed by a controller to adjust the electrical output to a light source (Gulliver & Arndt, 1991). The operation of a remote control lighting system relies on a transmitter receiver relationship. The transmitter (the remote) sends a coded signal through a specific medium such as infrared light to a receiver integrated into a smart switch and once the receiver decodes the signal, it triggers a dimming circuit to alter the state of the lamp (Paish, 2002). Remote control lighting is defined by the specific frequency and method used to transport data from the user to the device that produces light.

There are four primary communication protocols utilized in modern systems and these include infrared transmission, radio frequency transmission, Wi-Fi and cloud integration, Bluetooth and Mesh networking.

Infrared Transmissions are systems that utilize pulses of non visible light to communicate and this technology is identical to that used in standard television remotes. The transmitter in the remote flashes rapidly to send a binary code to a sensor on the light fixture and because Infrared is a light based signal, it requires a line of sight path and any physical obstruction such as a wall or a piece of furniture will block the signal and the advantages of infrared transmission are high security, immunity to electromagnetic interference and low power consumption suitable for battery operated devices. The challenges of infrared transmissions are that a line of sight is required, environmental interference, limited range, low data rates, safety hazards and unreliability in adverse weather.

Radio Frequency Transmissions are systems that utilize radio waves to send commands, unlike infrared, radio waves can penetrate solid objects and thus allowing a user to control lights in a different room or even from outside the building. Radio frequency systems are favored for their range and their ability to operate without direct aiming and have the disadvantages such as interference, signal propagation losses, and spectrum congestion.

Wi-Fi and cloud integration systems connect directly to a local area network and when a user presses a button on a smartphone app, the command is sent to a router which then routes the data packet to the specific IP address of the smart bulb or switch and this allows for out of home control where a user can manage their lights from a different geographical location via the internet and they are accompanied by the following benefits such as enabling centralized management, enhanced scalability and reduced infrastructure costs for businesses and users and face challenges such as security vulnerabilities and unreliability.

Bluetooth and Mesh networking systems allow direct point-to-point communication between a mobile device and a light bulb and advanced mesh versions of this technology allow bulbs to act as repeaters passing the signal from one to another to extend the network's reach across a large facility without requiring a central router.

Once a signal is received by the lighting fixture, an internal electronic sequence occurs to execute the command as follows signal reception, decoding, power modulation and feedback. Signal Reception is where the receiver captures the incoming electromagnetic wave. Decoding is where the microprocessor within the light fixture interprets the frequency pattern to determine the specific command. Power Modulation is when the controller interacts with the LED driver and for dimming, it often uses pulse width modulation which cycles the light on and off at a frequency so high that the human eye perceives it as a continuous, lower intensity of light. Feedback is when high end systems utilize two way communications where the light fixture sends a confirmation signal back to the remote or app to verify that the command was successfully executed.

2.3 Types of remote control lighting systems

Remote control lighting systems are categorized based on their communication protocols, the medium through which signals travel, and the level of integration within a building's infrastructure. These systems range from localized point to point solutions to complex decentralized mesh networks. The primary types of remote control lighting systems include infrared, radio frequency, Wi-Fi, Bluetooth, and power line communication, each system offers distinct advantages regarding range, reliability, and ease of installation catering to diverse needs from simple residential dimming to large scale industrial automation.

2.3.1 Infrared Systems

Infrared systems utilize electromagnetic radiation with wavelengths longer than those of visible light and these systems require a line of sight connection between the handheld transmitter and the receiver integrated into the light fixture and because the infrared signals cannot penetrate solid objects, they are ideal for single room applications where interference with other rooms must be avoided such as in home theaters or private offices

2.3.2 Radio Frequency Systems

Radio Frequency Systems transmit data via radio waves typically operating on frequencies such as 433 MHz or 2.4 GHz unlike infrared, radio frequency signals can pass through walls, floors and furniture. Radio frequency systems often utilize a transmitter (remote) and a receiver module wired into the junction box to allow the control of standard bulbs without internal smart circuit.

2.3.3 Bluetooth and Bluetooth Mesh

Bluetooth enabled lighting allows for direct communication between a smartphone and a bulb, more advanced mesh systems allow individual lamps to act as signal repeaters and if one bulb receives a command it can relay that signal to the next bulb effectively extending the network's range across an entire facility without requiring a central router.

2.3.4 Wi-Fi and Cloud-Based Systems

Wi-Fi lighting systems connect directly to a local network and this allows for integration with the internet of things enabling users to control lights from anywhere in the world via cloud-based applications and these systems are frequently integrated with voice assistants.

2.4 How to design a lighting system that is controlled by a remote using locally available materials.

People can design a lighting system that is controlled by a remote and uses a low voltage using locally available materials such as a sensor, resistors, USB socket, remote and LED lamp beads. In order to design a lighting system that is controlled by a remote and uses a low voltage using the above materials, a sensor, integrated circuit and transistor were fixed on the circuit board. The USB was connected to the input of a circuit board and the LED lamp beads were connected to the output of the circuit board and power source. The power button of the remote was pressed and the LED lamp beads gave light and when it was pressed again, the light went off.

2.5 Measurement of bandwidth

Bandwidth is the maximum rate of data transfer across a given path and it represents the volume of information that a network connection can handle in a set of time. It is determined by an oscilloscope. An oscilloscope is the best instrument for measuring the bandwidth of a low voltage, remotely controlled lighting system. An oscilloscope is an electronic test instrument that creates a visual graph of electrical signals over time.

Measuring the bandwidth of a remote-controlled lighting system using an oscilloscope involves determining the fastest rise time the system can produce. The bandwidth indicates the frequency range over which the lighting system can effectively operate.

Rise time is the duration a signal takes to transition from a low state to a high state. It measures response speed where shorter times indicate faster systems.

The following factors affect the rise time; System Bandwidth which is inversely proportional to rise time, a lower bandwidth circuit acts as a filter that rounds off sharp transitions increasing rise time. Parasitic capacitance and inductance for which Stray capacitance and inductance in circuits delay the voltage/current response which increases the rise time. Input Signal Rise Time in which the speed of the input signal directly impacts the output, a slow input edge cannot produce a fast output edge. Load capacitance and drive Strength: In digital circuits, higher load capacitance requires more time for the transistor to charge/discharge increasing rise time. Stronger drive transistors reduce it. Component Selection: High speed electronic devices and high-frequency connectors are designed to minimize rise times and Operating Conditions like temperature and pressure can affect component impedance in electronic devices while in medical devices like ventilators, settings for inspiratory flow rate can be adjusted to change the rise time.

The bandwidth of a remote controlled lighting system was determined by the sensor being connected to the oscilloscope input, the oscilloscope was set to single trigger mode and the trigger level was adjusted to capture the rapid signals produced when buttons were pressed on the remote. The remote was then used to turn the light on and off and the risen edge on the oscilloscope was captured and the cursors were used to measure the time it took for the signal to rise from 10% to 90% of its maximum amplitude and this was the rise time.

The bandwidth was then determined from; Band width $=\frac{0.35}{Rise\ Time}$

The band width from this experiment varied because of factors such as signal to noise ratio in which a higher signal to noise ratio meant that the signal was much stronger than the background noise which allowed for higher bandwidth and faster data rates. Signal congestion by interference from other devices or physical obstacles that restricted the effective bandwidth.

CHAPTER THREE MATERIALS AND METHODS

3.1 Materials and equipments

The following materials were used in the design of the remote-controlled lighting system. These materials can easly be accessed on market at friendly prices.

3.1.1 A sensor

It was used to detect the presence of signals without physical contact.

Figure 3.1: Diagram of a sensor

3.1.2 Resistors

Resistors were used to reduce current flow

Figure 3.2: Diagram of Resistors

3.1.3 USB (Universal Serial Bus)

A USB was used to supply electrical power to the lighting system

Figure 3.3: Diagram of a USB

3.1.4 Remote

A remote was used to send signals to the sensor.

Figure 3.4: Diagram of a remote

3.1.5 LED lamp beads

LED lamp beads were used to produce light when they received current

Figure 3.5: Diagram of a LED lamp beads

3.1.6 Transistor

It was used to amplify electronic signals

Figure 3.6: Diagram of a Transistor

3.1.7 Integrated circuit

It manipulated signals for the system.

Figure 3.7: Diagram of an Integrated circuit.

3.1.8 Circuit board

It is where electronic components were placed in a circuit for their effective functioning.

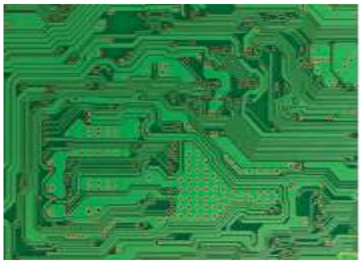

Figure 3.8: Diagram of a Circuit board

3.2 Methodology

A sensor, integrated circuit and transistor were fixed on the circuit board. The USB was connected to the input of a circuit board and the LED lamp beads were connected to the output of the circuit board. The power button of the remote was pressed and the LED lamp beads gave light and when it was pressed again, they went off as shown in the figures below.

Figure 3.9: Diagram of a lighting system when it was turned on.

Figure 3.10: Diagram of a lighting system when it was turned off.

CHAPTER FOUR PRESENTATION AND DISCUSION OF RESULTS

4.1 The designed lighting system that is controlled by a remote and uses a low voltage

The designed lighting system consists of a USB port that provides power to the system and output system that controls the bulbs.

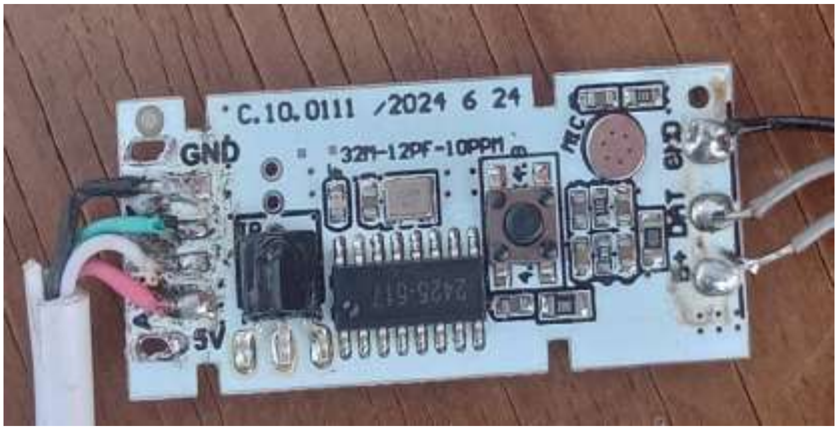

Figure 4.1: Diagram of a designed lighting system that is controlled by a remote and uses a low voltage

4.2 Measuring the band width of the lighting system

The bandwidth of a remote controlled lighting system was measured by the sensor being connected to the oscilloscope input, the oscilloscope was set to single trigger mode and the trigger level was adjusted to capture the rapid signals produced when buttons were pressed on the remote. The remote was then used to turn the light on and off and the risen edge on the oscilloscope was captured and the cursors were used to measure the time it took for the signal to rise from 10% to 90% of its maximum amplitude and this was the rise time.

The bandwidth was then determined from; Band width $=\frac{0.35}{Rise\ Time}$

The band width from this experiment varied because of factors such as signal to noise ratio in which a higher signal to noise ratio meant that the signal was much stronger than the background noise which allowed for higher bandwidth and faster data rates. Signal congestion by interference from other devices or physical obstacles that restricted the effective bandwidth.

The bandwidth was recorded for different distances from 1-9m as shown in table 4.1 below.

Table 4.1: Table showing the band width of the lighting system

Distance (m)	1	2	3	4	5	6	7	8	9
Bandwidth (KHz)	250	220	200	170	150	130	110	100	85

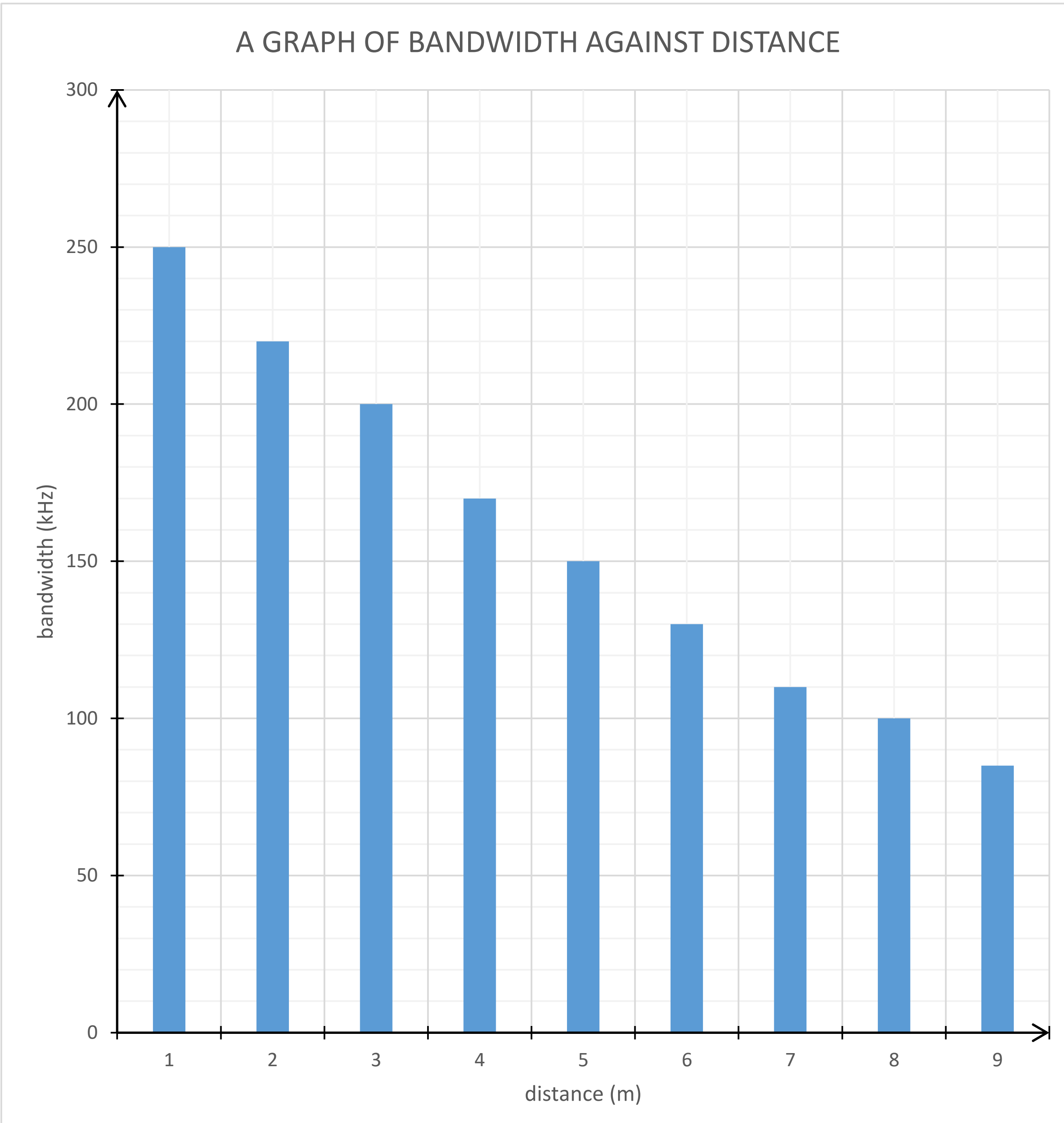

Figure 4.3: A graph of bandwidth against distance.

As illustrated in table 4.1 and figure 4.3, the bandwidth decreased with an increase in distance.

Higher bandwidths allow less time for signal detection decreasing the signal to noise ratio leading to lower sensitivity, greater susceptibility to noise and increased potential for dispersion while lower bandwidths allow more time for signal detection increasing the signal to noise ratio to higher sensitivity, lower susceptibility to noise and decreased potential for dispersion.

From the graph it can be seen that bandwidth decreases with increase in distance because of some factors such as signal to noise ratio: A higher signal to noise ratio meaning the signal is much stronger than the background noise which allows for higher bandwidth and faster data rates. Signal Congestion: Interference from other devices or physical obstacles restricted the effective bandwidth.

These results are comparable to the findings of Mert Duygan and Rea Perli whose research was on designing public lighting system with a smart lighting control system using a motion sensor, LED bulbs, integrated circuit, remote, resistors and transistors. Their research found out that bandwidth reduces with increase in distance.

CHAPTER FIVE CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

At the end of this project, a lighting system that is controlled by a remote and uses a low voltage was designed which could solve the problem of the disabled people who can't manage to turn on electricity using their hands, lighting systems that are economically viable and consume less power.

This lighting system can be used in homes, offices and elsewhere depending on the needs making life easy for the next generation.

5.2 Recommendations

Further studies should consider increasing the brightness of the lighting system by increasing the number of LED lamp beads. The bandwidth of the lighting system should also be increased by maximizing the transmitter's power through using fresh batteries or boost infrared radiation range by placing a tin foil reflector behind the LED.

5.3 Limitations

Interference from other electronic devices and regular battery changes in the remote which reduced the experimental reliability causing data inconsistencies and restricting the operational range, these factors introduced variables that complicated the evaluation of system performance and responsiveness

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