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Design of an Optimized Visible Light Communication Link System using MATLAB for Hospital Communication

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Abstract:
Visible Light Communication (VLC) is an emerging wireless technology that uses light-emitting diodes (LEDs) for high-speed data transmission and offers a reliable alternative to traditional Radio Frequency (RF) communication, especially in hospital environments where RF signals may cause electromagnetic interference with sensitive medical equipment. In this paper, an optimized VLC-based communication system for hospital applications is proposed and implemented using MATLAB to ensure safe and efficient transmission of patient data such as heart rate and oxygen levels. The system performance is analyzed using key parameters like Signal-to-Noise Ratio (SNR) and Bit Error Rate (BER), and further improved using optimization techniques and Artificial Neural Networks (ANN) under varying conditions such as distance and ambient light noise. The results demonstrate that the proposed VLC system provides secure, interference-free, and energy-efficient communication, making it highly suitable for modern healthcare environments.

Keywords: Visible Light Communication (VLC), Hospital Communication, SNR, BER, MATLAB

1. INTRODUCTION

In recent years, the demand for reliable and high-speed wireless communication has significantly increased, especially in healthcare environments where continuous monitoring and real-time data transmission are essential. Traditionally, Radio Frequency (RF) communication has been widely used for wireless systems; however, in hospital environments, RF signals may cause electromagnetic interference with sensitive medical equipment, which can affect their accuracy and performance. This limitation creates the need for an alternative communication technology that is both safe and efficient.

Visible Light Communication (VLC) has emerged as a promising solution that utilizes light-emitting diodes (LEDs) for data transmission. VLC offers several advantages such as high data rate, enhanced security, energy efficiency, and immunity to electromagnetic interference. Since hospitals already use LED lighting systems, VLC can be easily integrated without requiring additional infrastructure, making it a cost-effective solution for healthcare communication systems.

In this paper, an optimized VLC-based communication system for hospital environments is proposed and implemented using MATLAB. The system focuses on transmitting patient monitoring data such as heart rate and oxygen levels while maintaining high Signal-to-Noise Ratio (SNR) and low Bit Error Rate (BER). Advanced techniques such as Artificial Neural Networks (ANN) and optimization methods are incorporated to improve system performance under varying conditions like distance and ambient light noise. The proposed system aims to provide secure, reliable, and interference-free communication, making it a suitable replacement for RF-based systems in hospitals.

2. LITERATURE REVIEW

Visible Light Communication (VLC) has emerged as a promising wireless communication technology due to its high data rate, energy efficiency, and immunity to electromagnetic interference. In recent years, several researchers have explored the application of VLC systems, particularly in healthcare environments where secure and interference-free communication is critical.

In [1] investigated LED-based VLC systems for hospital communication and demonstrated that VLC can effectively transmit patient data without causing RF interference. Their work highlighted the suitability of VLC in sensitive medical environments.

In [2] analyzed the performance of Multiple Input Multiple Output (MIMO) VLC systems and reported significant improvements in data rate and system reliability. Their study emphasized the importance of spatial diversity in enhancing communication efficiency.

In [3] focused on high-speed VLC systems using advanced modulation techniques such as Orthogonal Frequency Division Multiplexing (OFDM). Their results showed improved data transmission capacity and spectral efficiency.

In [4] explored the use of Artificial Neural Networks (ANN) for optimizing VLC system performance. The study demonstrated that ANN can effectively predict and minimize Bit Error Rate (BER) under varying channel conditions.

In [5] applied Genetic Algorithms (GA) to optimize VLC system parameters, including transmission power and modulation schemes. Their findings indicated improved Signal-to-Noise Ratio (SNR) and reduced BER.

3.BASIC CONCEPTS

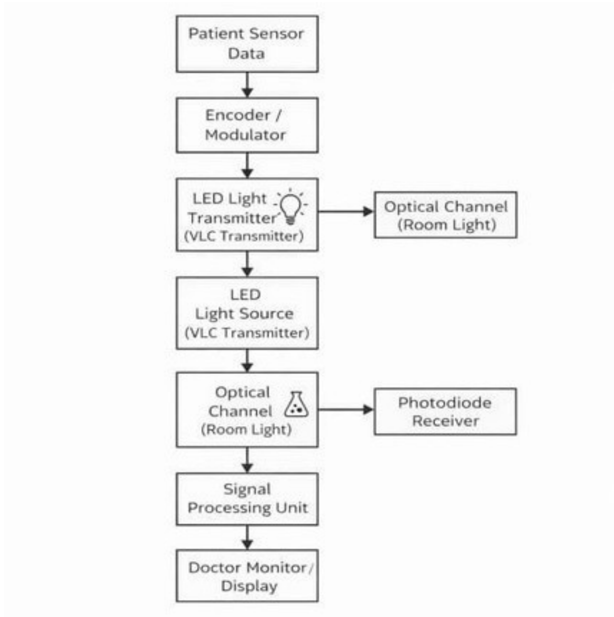
1.1 **Transmitter (LED Source) :** The transmitter in a VLC system uses an LED to convert electrical signals into optical signals. Input binary data is modulated using techniques like On-Off Keying, causing the LED to switch rapidly. This high-speed variation in light intensity carries information without affecting normal illumination or human visual perception.

1.2 **Channel (Optical Medium) :** The channel in VLC is the free space through which light travels from transmitter to receiver. Signal strength reduces with distance and may be affected by obstacles, reflections, and ambient light sources. Both line-of-sight and reflected paths influence performance, while noise and interference can degrade communication quality significantly.

1.3 **Receiver (Photodiode) :** The receiver uses a photodiode to detect incoming light signals and convert them into electrical signals. The generated current is proportional to the received light intensity. This signal is amplified, filtered, and demodulated to recover the original data accurately, even in the presence of noise and environmental disturbances.

4.SYSTEM DESIGN

BLOCK DIAGRAM



1.4 Patient Sensor Data: This is the input stage of the system. Sensors attached to the patient (like heart rate, temperature, ECG, oxygen level) collect real-time health data. These sensors convert physical parameters into electrical signals that can be processed and transmitted.

1.5 Encoder / Modulator: Here, the sensor data is converted into digital form and prepared for transmission. The encoder removes errors and compresses data if needed. The modulator (usually OOK – On-Off Keying) converts binary data into a signal suitable for light transmission (LED ON = 1, OFF = 0)

4.3LED Light Transmitter (VLC Transmitter):

This block drives the LED using the modulated signal. It controls how the LED blinks at very high speed (invisible to human eyes). This rapid switching carries the data through light waves.

4.4 LED Light Source: This is the actual physical LED bulb used for transmission. It performs two functions: Provides illumination (lighting in hospital room)Transmits data simultaneously using visible light

4.5Optical Channel (Room Light / Medium): This represents the free space through which light travels. The signal moves through air inside the hospital room. It may be affected by noise, obstacles, or ambient light (sunlight, tube lights)This is the main communication path

4.6. Photodiode Receiver: At the receiving end, a photodiode detects the incoming light signal. It converts light energy back into an electrical signal. The stronger the light, the stronger the signal

4.7. Signal Processing Unit: This block processes the received signal to recover original data: Removes noise, Amplifies weak signals, Demodulates (converts light signal → binary data), Ensures accurate data recovery

4.8 Digital Monitor / Display: Finally, the processed data is shown on a monitor system or display: Doctors can view patient health.

Parameters in real-time Used for monitoring, alerts, and decision-making.

4.9 Algorithm Steps

1.Generate binary input signal

2.Apply for OOK modulation

3.Pass through VLC channel with noise

4.Detect signal using photodiode model

5.Demodulate received signal

6.Calculate BER and SNR

5. RESULT AND DISCUSSION

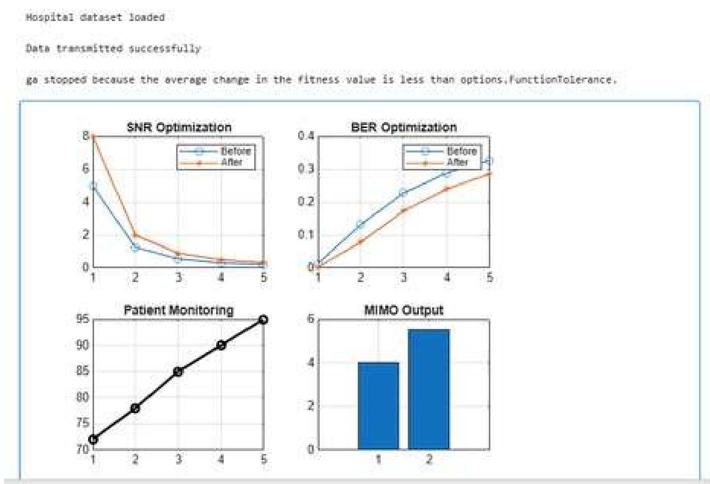


Fig 5.1 Plots(SNR and BER)


Network Diagram

Training Results

Training finished: Reached minimum gradient

Training Progress

Unit	Initial Value	Stopped Value	Target Value
Epoch	0	5	1000
Elapsed Time	-	00:04:37	-
Performance	9.87e-07	2.19e-09	0
Gradient	1.96e-06	8.59e-08	1e-07
Mu	0.001	1e-08	1e+10
Validation Checks	0	5	6

Training Algorithms

Data Division: Random dividerand
Training: Levenberg-Marquardt trainlm
Performance: Mean Squared Error mse
Calculations: MEX

Training Plots

Performance | Training State
Error Histogram | Regression

Fig 5.2 Training Data

```
Basic BER:
    0.0127    0.1318    0.2280    0.2881    0.3274

Optimized BER:
    0.0023    0.0786    0.1729    0.2398    0.2858

Predicted BER (ANN):
   2.1118e-04

--- GA OPTIMIZATION ---

Power: 10

Distance: 1

Max SNR: 100

--- MIMO OUTPUT ---
    4.0222
    5.4979

Communication Type: VLC

Energy Status: Power Maintained

Indoor Positioning Distances:
    1.1180    1.2910    1.4142

Received Data:
     7
   192
   125
   181
   101
```

Fig 5.3 Training output

The simulation results demonstrate that the VLC system provides reliable and efficient communication for hospital environments. As the transmission distance increases, the Signal-to-Noise Ratio (SNR) decreases due to signal attenuation, which leads to an increase in Bit Error Rate (BER). However, after optimization by increasing transmission power, the system shows a significant improvement in SNR and a reduction in BER, ensuring more accurate data transmission. The patient data such as heart rate and SPO_2 are successfully transmitted and recovered with minimal error, proving the system’s reliability. Additionally, the use of Artificial Neural Networks (ANN) helps in predicting BER values, while the Genetic Algorithm (GA) finds optimal parameters for better performance. The inclusion of MIMO enhances signal strength and reliability, and the hybrid VLC-RF model ensures uninterrupted communication even when light is unavailable. Overall, the system achieves secure, energy-efficient, and interference-free communication, making it highly suitable for real-time hospital monitoring applications.

5. CONCLSION

The proposed VLC system using MATLAB provides a reliable and efficient solution for hospital communication. It ensures low BER, improved SNR after optimization, and accurate transmission of patient data. Techniques like ANN, GA, and MIMO enhance performance, while the hybrid VLC-RF model ensures continuous communication. Overall, it is a secure, energy-efficient, and interference-free system suitable for real- time healthcare applications.

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