# Visible Light Communication for Downhole Monitoring

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**Abstract**- Sri Lanka is expected to initiate offshore oil and gas exploration in the near future. Sri Lanka's Petroleum Resources Development Secretariat (PRDS) has identified several blocks for offshore oil exploration in the Mannar Basin and Cauvery Basin as per the recent investigation. Downhole monitoring technologies have advanced considerably in terms of availability, reliability, performance and costs. In downhole monitoring systems deployed in the oil and gas industry measures at various parameters, such as the geological parameters are quantity, location, contents, level of lubricant and weight. Also, measures the environmental and reliable measurements such as downhole flow rate, density and water cut monitoring. Pressure and Temperature parameters are the most important and essential parameters in offshore wells. In this short paper, we discuss the existing wireless systems for downhole monitoring such as Mud Pulse Telemetry (MPT), Radio Frequency transmission and acoustic transmission. Further explanation about the comparison of the existing wireless systems will be also presented. Restrictions of existing technologies require a new and reliable wireless solution for real-time downhole monitoring. As a potential future avenue, we introduce a Visible Light Communication (VLC) based downhole monitoring scheme and, then, discuss the advantages of this system over the existing systems. According to the literature survey, RF transmission is identified as an established system in the oil industry nowadays. However, it is a high cost and power-hungry technique. However, the VLC system can be implemented with a low cost and use without power amplifiers. In this paper, we provide details of the existing schemes and offer a survey for all other competitive schemes in the literature for wireless downhole monitoring schemes.

**Keywords:** Visible Light Communication, Mud Pulse Telemetry, Electromagnetic Transmission and Acoustic Transmission.

## 1. Introduction

Based on the initial studies, data and regional studies the PRDS (Petroleum Resources Development secretariat) is estimating the Mannar basin alone could have to potential to generate 5 billion barrels of oil and 9 trillion cubic feet of natural gas, which would be sufficient for Sri Lanka's energy needs for the next 60 years.

Based on data acquired from seismic surveys, the government estimates that there are over one million barrels of oil resources in a 30,000 $km^2$ area in northern waters. The area of a Mannar basin 45,000 $km^{2.}$ Bathymetry of a basin ranges 20m to in excess of 4,000m. They found 25m hydrocarbon column in a sandstone between the depths of 3,044m-3,069m [1].

In the downhole monitoring system in an oil and gas industry measuring various parameters. The geological parameters are quantity, location, contents, level of lubricants, weight. Also measure the environmental and reliable measurements such as downhole flow rate, density and water cut monitoring. That measurement helps for reservoir engineers to improve the well performance.
Pressure and Temperature parameters are the most important and essential parameters in offshore wells. According to these measurements can decide the deep of the well.

Basically, there are two types of existing downhole monitoring systems, wired communication systems and wireless communication systems. In this paper talk about the wireless communication systems for downhole monitoring.

## 2. Wireless Communication Systems

There are three types of wireless systems for downhole monitoring the oil industry such as Mud Pulse Telemetry (MPT), Electromagnetic transmission/RF transmission and Acoustic transmission.

### 2.1 Mud Pulse Telemetry

A method of transmitting data obtained from downhole to the surface using pressure pulses in the hydraulic communication channel. This is a two-way communication system and Downlinking and up-linking are the two main processes executed by a telemetry system. The principle of MPT is there are two parts include downhole part and surface part. Data obtained from downhole sensors and creating mud pressure pulses and transfer encoded downhole data to the surface. The transmission of data is done through measurement while drilling tool in the borehole assembly by generating pressure pulses in the mud stream with the aid of a pressure generating device known as the mud-pulse[3].

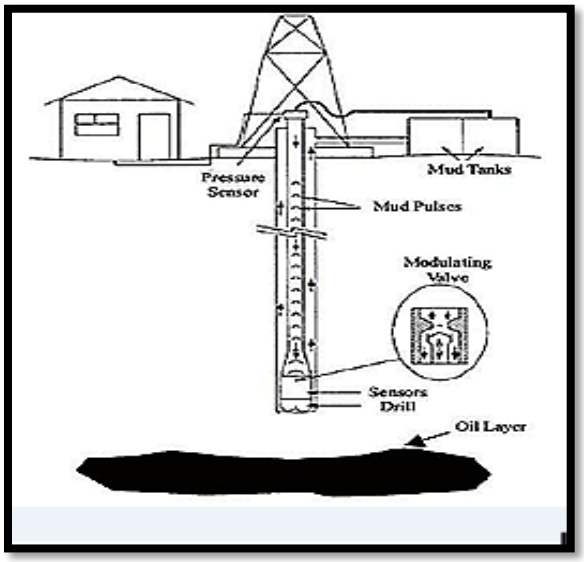


Figure 1- Mud-Pulse Telemetry system

Figure 1 shows the sample Mud Pulse Telemetry system in the downhole monitoring system in the Oil Industry. The diagram shows the placement of the sensors, mud tank and mud pulses.

Figure 2 shows the basic block diagram of the communication process of the downhole monitoring system. Obtained date from downhole sensors add to transmitter then compression, Encoding, modulation and transmit via mud to the receiver. After that, the receive data go through the process of De-

modulation, Decoding, De-compression and data out.

The transmitter located downhole and basic other components at the surface such as receiver and surface processing units. Obtained data from downhole sensors compressed and converted into a particular format. The processed data are encoded and transmit the signal to the mud channel. When transmitting the signal attenuated and distorted due to the various noise in the mud channel. The complication depends on the downhole tool used and the nature of the parameters going to measure. In the receiver side cancellation and removed the noise data from receiving data, decoded and corrected. At last decompressed data send to the permanent database [3].

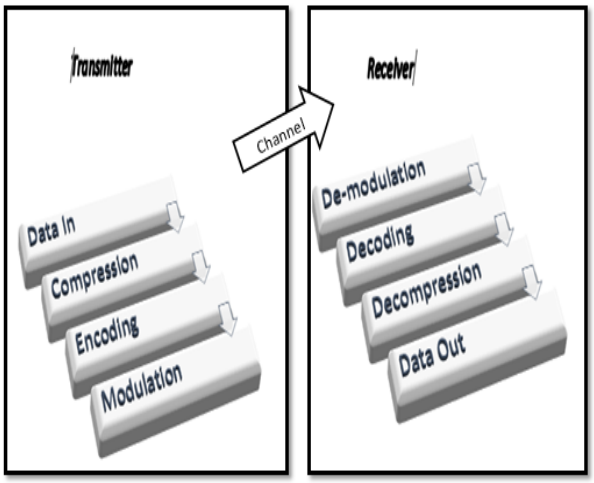


Figure 2-Block diagram of the MPT system represent the downhole and surface component

The benefit of the system is low-cost installation but this system has many disadvantages such as low bandwidth, very high possibility to loss the data from downhole to the surface, data transmission slow due to the influence of pulse and speed regulation and very easy to affect by noise [3].

### 2.2 Electromagnetic Transmission/RF Transmission

This is the two-way communication method and electromagnetic waves are created due to periodic fluctuation in the electromagnetic field. Stratum use as the medium for the transmission and drill string use as transmission conductor [2].

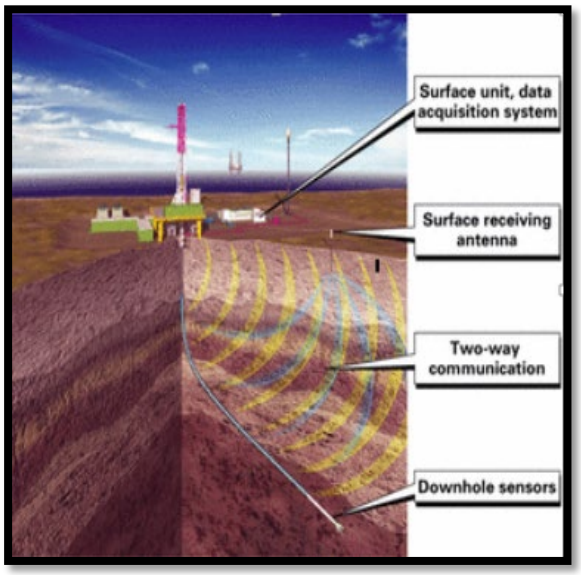


Figure 3- A Typical Electromagnetic system for Downhole monitoring.

Figure 3 shows the electromagnetic system for downhole monitoring and using electromagnetic waves transfer the data. Transmitter located at downhole and receiver units set to the surface. In this case, there is an antenna to transmit the signal and receive the wave signals [2].

There are two types of equipment on the downhole side, measuring equipment and signal to transmit equipment. All the sensors include the measuring equipment and signal processor, the signal transmitter and power supply include the transmitting equipment. On the surface includes signal receiving device and signal processors[2].

The electromagnetic transmission has various advantages, a large amount of data transmission with high speed, duplex communication system, simple structure, easy to install and use. As well as this system has the more disadvantages, fast

attenuation the signals, low frequency of the EM waves equal to the earth frequency, high-cost system and power-hungry system [2].

**Acoustic Transmission**

In this method optically transmit the data downhole to the surface. An acoustic signal obtained from the audio input and it sends to the microcontroller then encoded by the FPGA ( Field Programmable Gate Array) and transmit using optically help with the light-emitting diode. The detected optical signals convert into a digital form that can be processed by a computer at the receiver side [2].

The acoustic system has two advantages, investment is little and easy to operate. There are more disadvantages of the system such as easily interfered with the environment, small bandwidth and drilling equipment create the noises and it directly affected to the detect the signals [2].

## 3. New system design for the downhole monitoring for the oil industry

According to the literature survey, RF Transmission is an established system in the oil industry nowadays. But it is a high cost and power-hungry system. In the VLC system can implement with low cost and use without power amplifiers.

### 3.1 Overview of Visible Light Communication (VLC)

VLC is a wireless transmission method and it uses wavelength range from 380nm to 750nm (frequency range from 430THz to 790THz) for communication. For this system not needed power amplifiers, unlike RF communication. LED used as a transmitter and photodiode used as a receiver. Air use as a transmission medium.

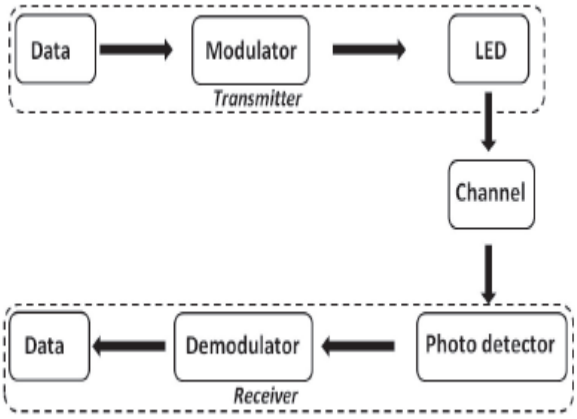


Figure 4- Basic block diagram of the VLC communication system

Figure 4 shows the basic block diagram of the VLC system. Mainly three parts of the VLC system such as a transmitter, receiver and the channel [6].

**Transmitter**

In the transmitter module contain basic three modules, data source, modulation module and LED. Two types of LEDs are used for the VLC system. Such as single colour LED and multi-colour LED. Red, Green and Blue (RGB) LEDs are used as a multicolour system.

**Channel**

The communication channel is the space between the transmitter and the receiver. There are two main types of channels are considered in this system. For single colour LED need single Photodiode to detect the colour and multicolour LED need more than one Photodiode to detect the multicolour [5],

**Receiver**

The main component of the VLC receiver is the photodiode. It detects the light radiation. There are six parts include the VLC receiver, concentrator, Optical filter, photodetector, Amplifier, equalizer and electric filter[5].

## 4.Comparison between RF and VLC in the downhole monitoring system.

Comparing with the radio frequency, VLC has more benefits than RF in the downhole monitoring system. VLC spectrum is plentiful. Consider the cost of VLC is very low for the reason that LED use as a transmitter. LEDs are very less expensive components. VLC can enhance security than RF. RF interferes with critical electronic devices and communication networks but VLC spectrum couldn't dangerous. VLC easily integrate with other systems and location-based transmission system. VLC can travel around 4000m and no need power amplifiers to the system. [6]-[9].

## 5.Applications

VLC has been investigated in recent existing works on downhole communication systems. In the authors have investigated the performance of the VLC modeling for the gas pipeline. VLC communication used for wireless monitoring in the gas pipeline. Investigated three-dimensional simulation platform and measure the parameters such as density, reflective index, and the transmittance in the gas pipeline[7]. Also, investigated about channel impulses (CIRs) for any ideal sources as well as specular and mixed specular diffuse reflections[4].

## 6.Conclusions

In this paper, we investigate the existing systems of downhole monitoring for oil and gas industry. Also, suggested the new wireless system design for downhole monitoring. Compared to the other existing systems for downhole monitoring, VLC has more advantages such as more reliable and low-cost system. RF communication is an established system for downhole monitoring. It is the power-hungry system and high-cost system. However, VLC can overcome these problems. In VLC communication use LED as a transmitter and photodiode used as a receiver. LEDs and photodiodes are very less expensive components. Also, no need to use power amplifiers like RF.

## 7.Future Works

There are three objectives for future works. Such as to establish the propagation characteristics of the downhole VLC channel, to design algorithm from propagation modelling in the physical layer and develop the transmission system and the associated the physical layer algorithms tailored for these channels to ensure high link reliability and Quality of Service (QoS).

Mentioned the methodology to follow for future work, Investigate the effect of the contents of the pipeline on the propagation characteristics of the optical channel. Determination of the optical path loss in the downhole. Also, consider the two systems operation. The first one is the direct transmission system if the target transmission distance allows this mode of operation. The second one is the optimization of the system design. All modules are assumed to be battery powered. Therefore reduce the path loss as opposed to using more optical transmit power. Finally determination of appropriate digital modulation.

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