MASSIVE MIMO TECHNOLOGY FOR VISIBLE LIGHT COMMUNICATION (VLC)

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ABSTRACT

Visible Light Communications (VLC), and the idea of using LEDs for both illumination and data communications The main drivers for this technology include the increasing popularity of solid-state lighting, longer lifetime of high-brightness LEDs associated to additional sources of simulated light like the incandescent light bulbs, high bandwidth/data rate, data security, no health hazards and low power consumption The dual functionality provided by VLC (i.e., lighting and data communication from the same high-brightness LEDs) has created a whole range of interesting applications, including but not imperfect to home networking, high rapidity data communication through lighting infrastructures in offices, car-to-car communication, high-speed communication in aeroplane cabins, in-trains data communication, traffic lights management and communications to name a few The levels of power efficiency and reliability offered by LEDs today are by far superior compared to the traditional incandescent light sources used for lighting. Recent research in VLC has successfully established data transmission at over 500 Mbps over short links in office and home environments Further research and developments will open up new possibilities to partly resolve some of the issues associated with the present-day infrared, radio/microwave communication systems and lighting technologies.

I INTRODUCTION

In this paper, visible light communication (VLC) is a subset of optical wireless communication technologies. The technology procedures luminous lamps (conventional lamps, not special communication devices) to transmit signal at $10 kbps$ or LEDs for up to $500 Mbps$. Visible light communication (VLC) is a data communication medium which uses visible light between $400\ THz\ to\ 800\ THz (780nm\ to\ 375nm)$. It is used as a very small range of optical wireless communication (OWC) operating light emitting diode (LED) lighting. So that the LED can provide both illumination and communication[1].

Low rate data transmission at 1 and $2 Km (0.6\ and\ 1.2\ mi)$. VLC can be used as a communication medium for universal computing, because light producing devices (such as indoor and outdoor , TVs, Traffic signs, commercial displays and car head light/ tail light) are used everywhere.

The phenomenon in optoelectronics i.e., solid state light sources which is refers to the fact that light is generated through solid state electroluminescence. In 1990s, An introduction of another upcoming type of solid-state lighting source, known as the organic LED (OLED) OLED has relatively low luminous effectiveness (measured value of 100 lm/W and short lifetime compared with the LEDs, thuslimiting their application for various colour

displays and general illumination for thetime being Nevertheless, OLEDs may also be used as an alternative solution forlarge area lighting and communications[2].

Visible Light Communications (VLC) has establishedconsiderablycurrent attention done overdisplays as LiFi and IEEE 802.15.4. As a "smart lighting" paradigm, it has received significant interest by the scientific community since this new paradigm may be used for sensing, localization and data communication, in accumulation to the common lighting application. The main article of VLC is its potential for "double usage", providing both lighting and high speed information access. This aspect brings to several advantages that make VLC ainordinatesupplement to Radio-Frequency (RF) communications. Certainly, while exploiting the free use of the visible light spectrum, VLC usages the indicator of optical transmissions, and can offer secure transmissions.
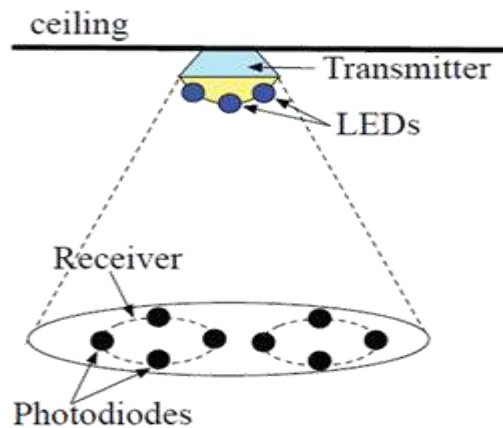

Figure 1:-Scheme of indoor MIMOLEDs.

II SYSTEM DESCRIPTION

A VLC link system is shown in figure. According to this figure, there are dimming control system is to be appear for challenging incandescent and gas discharge lamps whereas with LEDs it is quite convenient to accurately control or reducing the dimming level and dimming control system is connected to the input of driving circuit which is In electronics, a driver is an electrical path or other electronic element used to control another circuit or component, such as a great power transistor, liquid crystal display (LCD), and several others. The driver circuit is connected to an LED arrays and an Optical lenses. An LED arrays are assemblies of LED packages or dies that can be built using several systems. Each method pivots on the style and level to which the chips themselves are packaged by the LED semiconductor manufacturer.

While an optical lens is a trans-missive optical device that affects the focus of a light beam through refraction. A modest lens consists of aonlyone piece of material, while a compound lensconsists of several lenses (elements), generallybeside a common axis [3].

Then LED array & optical lens is connected to channel which means that A medium through which an information is transmitted to its anticipated audience, such as design media or broadcast (electronic) media.

After channel is to be connected to the optical concentrator which is the branch of optics concerned with the optimal transfer of light radiation amongst a source and a destination. Distinct traditional imaging optics, the techniques involved do not challenge to form an image of the source; instead an enhanced optical system for optical radiative transfer from a source to a target is desired.

After optical concentrator is connected to an optical filter. An Optical filters are devices that selectively spread light of different wavelengths, generally applied as plane glass or plastic devices in the optical route which are each highlighted in the bulk or have interference coatings. An optical filter is connected to the photodetector. A photodetector is a device that detects or responds to incident light by using the electrical effect of individual photons. And photodetector is connected to an amplifier which is used to amplify the signal and get the output at the destination.
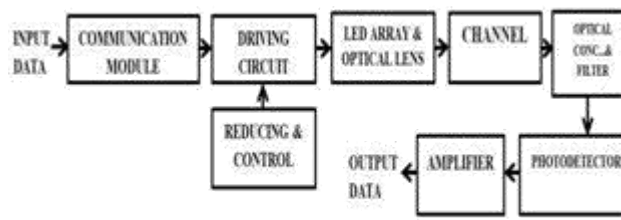

Figure 2:- VLC link system

III CHANNEL MODEL OF INDOOR VLC

In channel model for Indoor VLC, there are a number of topologies that are commonly used for indoor applications. the configurations can be categorized acc. to the degree of directionality of Tx-Rx and the existence of LOS path between the Tx-Rx. Intensity modulation with direct detection (IM/DD) is the methods of implementing optical wireless communication due to its reduced costs and complexity [4]. The gain of the optical concentrator at the receiver is defined by:-

$$g(\psi) = \begin{cases} \dfrac{n^2}{sin^2\psi_{cos}}, & 0 \leq \psi \leq \psi_{cos} \\ 0, & 0 \geq \psi_{cos} \end{cases}$$

The drive current of an optical source is directly modified by the moderatingsignal $m(t)$, which in turn varies the intensity of optical source $x(t)$, shown in figure:-
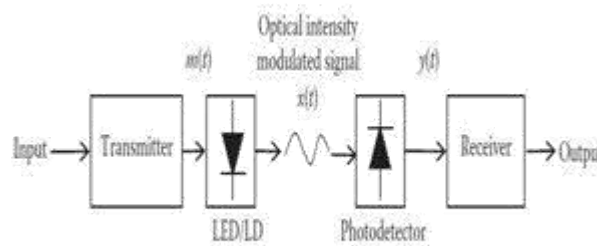

Figure3: - Block diagram of optical intensity, DD communication channel

The Rx employs a photodetector with a response which is the integration of tens of thousands of very short wave length of incident optical signal that generates a photocurrent $y(t)$[5].

This photocurrent is directly proportional to the instantaneous optical power incident on it, i.e., proportional to the square of received electric field.

An IM/DD based optical wireless system has ancorresponding baseband model that hides the high frequency environment of the optical carrier. The model is shown in figure:-
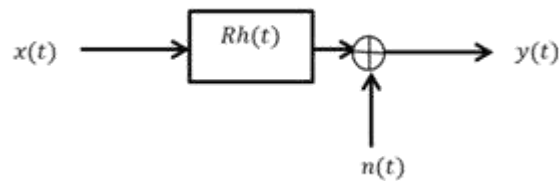

Figure4:-Equivalent baseband model of an optical wireless system using IM/DD

Where R the photodetector responsivity $h(t)$ is the baseband channel impulse response and $n(t)$ is the signal independent shot noise, modelled throughout the additive white Gaussian noise $(AWGN)$ with a dual sided power spectral density $(PSD)$of$N_0/2$ [6].

In indoor OWC links do not suffer from the effects of multipath fading, they do suffer from the effects of dispersion which manifests itself in an inter-symbol interference (ISI) [7].

Dispersion is modelled as a linear base-band channel impulse response$h(t)$. The channel characteristics of an OWC link is fixed for given position of Tx, Rx and intervening reflecting objects.

The channel characteristics only changes when these components are moved by distances of an order of cm.

Due the high bit rate, and the relatively slow movement of objects, the channel will vary only on the time scale of many bit periods, and may therefore be considered as quasi-static.

The equivalent baseband model of an IM/DD optical wireless link can be summarized:-

$$y(t) = Rx(t) \otimes h(t) + n(t)$$

$$= \int_{-\infty}^{\infty} Rx(\tau)h(t-\tau)d + n(t)$$

Where the symbol $\otimes$ represents the convolution.

The impulse response $h(t)$ can be used to consider or simulate the properties of multipath dispersion in indoor OWC channels. The channel impulse response was modelled as:-

$$h(t) = f(x) = \begin{cases} \dfrac{2t_0}{t^3 sin^2 (FOV)} & ,t_0 \leq t \leq \dfrac{t_0}{\cos (FOV)} \\ 0 & ,elsewhere \end{cases}$$

Where t_0 is the minimum delay.

while in above equation is simply a linear filter channel with AWGN, optical wireless systems differs from conventional electrical or radio system since the instantaneous optical power is proportional to the generated electrical current. $x(t)$ represents the power rather than the amplitude signal. This imposes two constraints on the transmitted signal.

Firstly, $x(t)$ must be non-negative, i.e.,

$$x(t) \geq 0$$

Secondly, the eye safety requirement limits the maximum optical transmit power that may be used. Generally, it is average power requirement which is the most restrictive [8].

LEDs are used for the dual purpose of communication, it is necessary to define the luminous intensity and transmitted optical power. The luminous intensity is used for expressing the brightness of an LEDs. The transmitted optical power indicates the total energy radiated from an LEDs [9]. The luminous intensity is the luminous flux per solid angle and is given by:-

$$I = \frac{d\Phi}{d\Omega}$$

where Φ is the luminous flux and Ω is the spatial angle.

Φ Can be calculated from the energy flux Φ_e as:-

$$\Phi = K_m \int_{380}^{780} V(\lambda)\Phi_e(\lambda)\, d\lambda$$

Where $V(\lambda)$ the standard luminosity is curve, and K_m is the max.Visibility, which is 683lm/W at 555nm wavelength [10].

The transmitted optical power P_t is given by:-

$$P_t = K_m \int_{\Lambda_{min}}^{\Lambda_{max}} \int_{0}^{2\pi} \Phi_e\, d\theta d\lambda$$

Where Λ_{max} and Λ_{min} are determined from the photodiode sensitivity curve.

Hence, average value of $x(t)$ must not exceed a specified maximum power value P_{max}. i.e.,

$$P_{max} = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x(t)\, dt$$

This is in contrast to the time averaged value of the signal $|x(t)|^2$, which is the case for the conventional RF channel when $x(t)$ represents amplitude [11].

III MODULATION TECHNIQUE OF INDOOR VLC

In the modulation of indoor visible light communication, both quadrature amplitude modulation (QAM) on discrete multi-tones (DMT) and multi-level pulse amplitude modulation (PAM) schemes is suitable for LEDs based communication but are less power efficient [12].

DMT is a baseband implementation of the more universal orthogonal frequency division multiplexing (OFDM) and most useful for channels with interferences or strong small frequency noise due to the synthetic ambient light sources (e.g., fluorescent and incandescent) [13].

3.1 On-off keying (OOK)

OOK is that modulation technique which is mostly used for IM/DD in optical communication. This is apparently due to its simplicity.
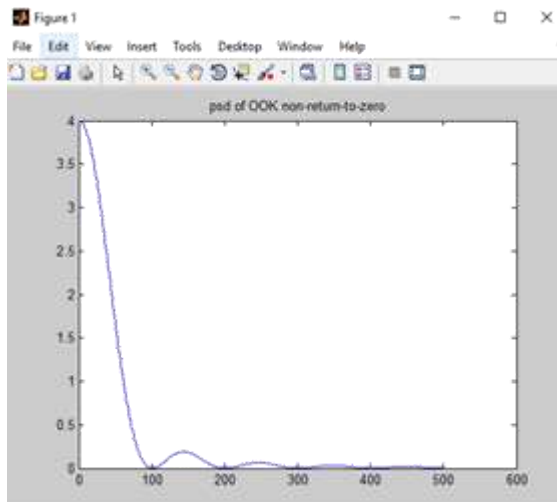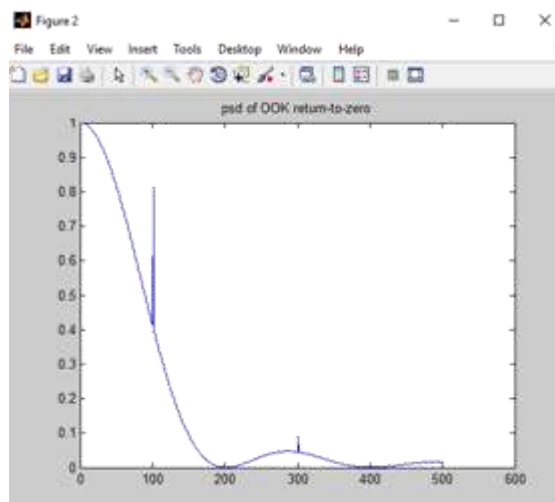

Figure 5:- PSD of OOK NRZ
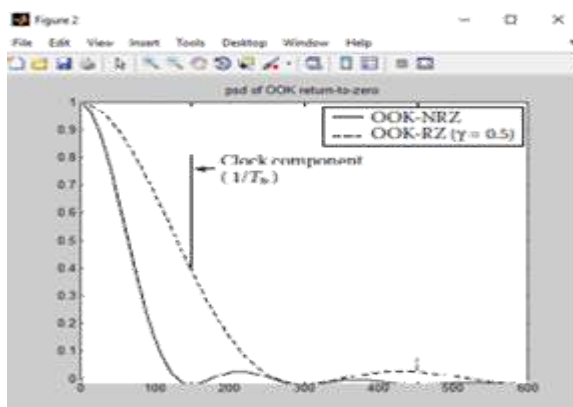

Figure 6:- PSD of OOK RZ

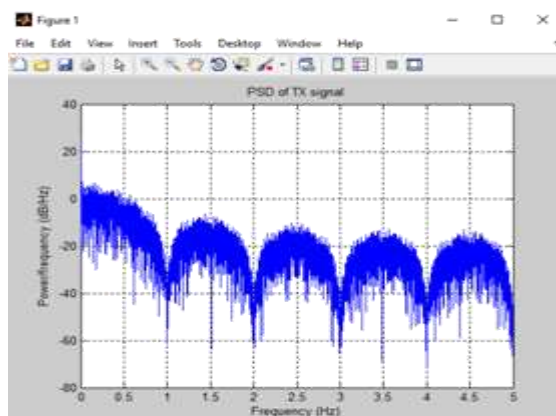**Figure 7:- Generate PSD of OOK NRZ and RZ**

Figure 8:- Generate PSD of OOK NRZ and RZ by simulation

A bit one is simply represented by an optical pulse that occupies the entire or part of the bit duration while a bit is zero is represented by the absence of an optical pulse.

Both the return-to-zero (RZ) and non-return-to-zero (NRZ) schemes can be applied. In the NRZ scheme, a pulse with duration equal to the bit duration is transmitted to represent '1' while in the RZ scheme, the pulse occupies only the partial duration of bit.

$$p(t) = \begin{cases} 2p_r, & for\ t \in [0, T_b) \\ 0, & elsewhere \end{cases}$$

Where p_t is the average is power and T_b is the bit duration [14].

3.2 Pulse position modulation (PPM)

In the optical wireless communication, Pulse Position Modulation (PPM) is an orthogonal modulation technique and a member of the pulse modulation family.

The PPM modulation technique improves the power efficiency of ON-OFF KEYING (OOK) but at the expense of an increased bandwidth requirement and greater complexity [15].
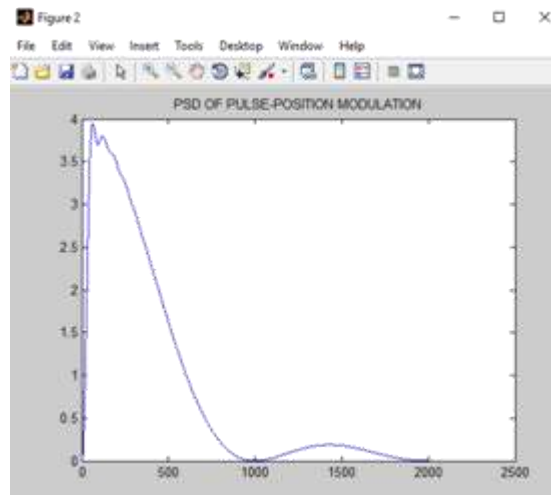

Figure 9:- PSD of PPM by simulation

An L-PPM symbol consistsof a pulse of constant power occupying one slot duration within $L(= 2^M$, wherebit resolution $M > 0$ is an integer) possible time slots with the remaining slots being empty.

Information is encoded within the position of the pulse andthe position of the pulse corresponds to the decimal value of the M-bit input data. Inorder to achieve the same throughput as OOK, PPM slot duration T_{s_PPM} is shorterthan the OOK bit duration T_b by a factor L/M, that is:-

$$T_{s\_PPM} = \frac{T_b M}{L}$$

The transmit pulse shape for L-PPM is given by:-

$$x(t)_{PPM} = \begin{cases} 1, for\ t \in [(m-1)T_{s,PPM}, mT_{s,PPM}] \\ 0, \qquad\qquad\qquad elsewhere \end{cases}$$

Where $m \in \{1,2,\dots\dots L\}$

Hence the PPM symbol sequences are given by:-

$$x(t)_{ppm} = LP_t \sum_{k=0}^{L-1} c_k p\left(t - \frac{kT_{symb}}{L}\right)$$

where $c_k \in \{c_0, c_1, c_2, \dots\dots c_{L-1}\}$ is the PPM symbol sequence, $p(t)$ is the pulse shaping function of unity height and of duration T_{symb}/L, $T_{symb}(=T_b M)$ is the symbol interval and LP_{avg} is the peak optical power of PPM symbol [16].

There are some criteria of an optical wireless communication channel of decreasing importance:-

3.3 Power efficiency

When evaluating the modulation technique suitable for indoor optical wireless communication systems is the power efficiency.

Each modulation schemes offers a certain optical average power and therefore they are usually compared in terms of the average optical power essential to succeed a desired BER performance or SNR

$$\eta_p = \frac{E_{pulse}}{E_b}$$

where E_{pulse} is the energy per pulse and E_b is the average energy per bit.

3.4 Bandwidth efficiency

The bandwidth efficiency η_B is defined as:-

$$\eta_B = \frac{R_b}{B}$$

where R_b is the achievable bit rate and B is the bandwidth of the IR Tx-Rx.

IV OUTDOOR VISIBLE LIGHT COMMUNICATION

A VLC transceiver is an optical electronic device that converts visible light into an electrical signal and vice-versa. The design of necessary devices for an outdoor application should take into account the particularities of the application scenario, such as the significant presence of noise components. LEDs have come a long way since their days has simple visual indicators. The advancements on LED technology during the last decade increased the luminous output, reaching barriers that were once only seen by technologies such as high-intensity discharge or ultra-high-performance lamps.

Furthermore, high energy efficiency and long lifetime assured LEDs a key role in the lighting market. They are spread from such generic applications as indoor lighting, to more specific ones like vehicle illumination and many others. In the area of general lighting, LEDs are gradually conquering the indoor consumers market, being mostly limited by the initial cost barrier. However, in the street, lighting market, municipalities are strongly embracing LEDs mostly driven by the segment reduction in electrical and maintenance costs, as well as political incentives to "green technologies". Other

applications, under which LEDs are becoming standard technology, include traffic control and warning light, large outdoor information panels, vehicle front and back lights among others

The widespread usage, combined with the inherent ability of fast switching has made LEDs a natural vehicle to the introduction of VLC as a complementary last mile access technology to the saturated RF spectrum. Operating as a dual function lighting and information transmission unit, Each LEDs light spot can become part of a communication networks as shown in figure 9.

In the particular field of ITS, LED-based traffic and vehicle lights provide support for data transmission of application that can be related with dynamic traffic routing, public transportation scheduling, road safety and many others.

Also, an access network supported by LED-based street lights and information panels can provide users with access to location applications, local and internet access spread throughout an entire city.

V SYSTEM DESCRIPTION

Figure 10 and 11 present a top level vies of generic emitter and receiver units. on the emitter side, digital data is processed and converted by an encoder into an electrical output signal that carries the information. These initial operations are commonly implemented on a FPGA that allows for easy system upgrade. The output electrical signal is passed to mixer module that combines it with the power signal. The outcome is then used to control the output driver module that switches the LEDs current, thus modulating the input signal from the encoder into the light output of the LED.
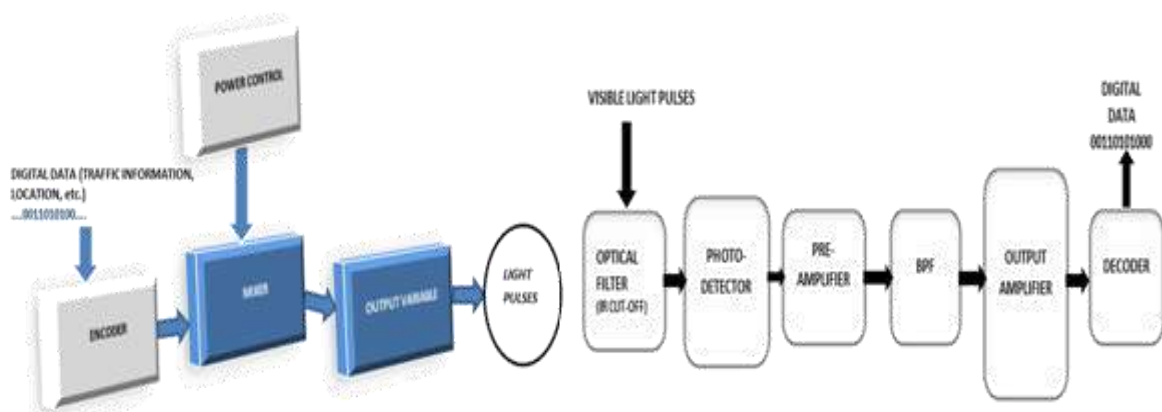

Figure 10:- VLC Emitter Block Diagram   Figure 11:- VLC Receiver Block Diagram

According to the desired communication range and the type of LEDs applied, an output lens can be applied to shape output light beam.On the receiver side, the visible light pulses pass through an optical filter, before hitting the photo-detector (PD). These results in small amplitude current which are then amplified and converted into voltages using trans-impedance amplifier [18]. The resulting signal is then filtered, amplified and converted into a digital format using an ADC. Synchronization, demodulation, frame processing and error detection/correction can be adequately implemented using FPGA [19].

VI OUTDOOR OPTICAL CHANNEL

VLC systems in outdoor applications are preferably based on line of sight (LoS) configurations. The emitted light from LED carries data information in wireless medium. Thus, the intensity of light of the emitter becomes an important parameter, constraining transmission range. There are many external light noise sources such as sun light, road street lights.

They deteriorate the transmitted signal and may cause false triggering of the receiver side. Both natural and artificial ambient light induce shot noise on the photo detector side [20].
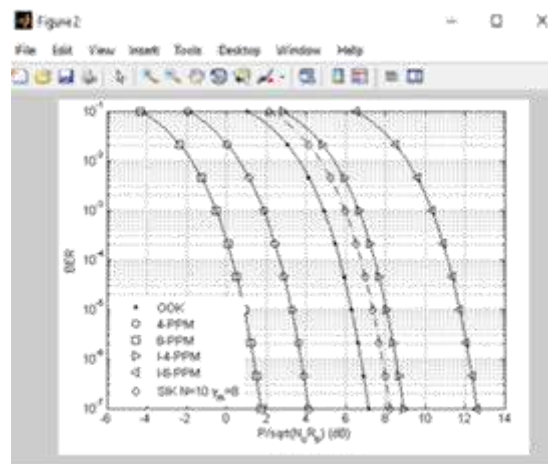

Figure 12:- Optical power requisites for traditional modulation schemes.

Quite often, this is the dominant noise source. Its effects must be included in the system's performance analysis, assuming that the shot noise power is proportional to the average optical power incident on the photo detector. The usage of optical filters at the receiver's side is an effective means to minimize the impact of shot-noise.

IR cut-off filters are commonly used to combat Sun light, since they are able to reduce the spectral content of the incoming optical signals.

Also, artificial light produce interference due to the time variations in the optical power impinging the photodiode. This interference induces power penalties in the performance of transmission systems which, quite often, are very large. In addition, propagation characteristics of VLC drastically change due to communication environment, especially, the effect of weather conditions is strong.

The received signal power fluctuates due to atmospheric obstacles such as rain or fog, in the propagation channel limiting the communication range. Therefore in addition to the usage of filters, appropriate modulation techniques must be deployed to enhance the performance of the VLC system in outdoor.

VII MODULATION TECHNIQUES

Modulation technique is one of the most important technical issues in the design of a communication system. VLC systems for outdoor applications are subject to many external noise sources and therefore, robust modulations techniques are especially required.

Bit error rate (BER)

The probability of error and SNR are two of the most important performance parameters of a communication receiver.

This section presents the BER performance for several traditional modulation schemes used in IR communication links.

These include, On-Off Keying (OOK), Pulse Position Modulation (PPM). Less traditional examples also explored are, Inverse PPM (IIPPM – a special form of Multiple PPM) and Direct Sequence Spread Spectrum (DSSS) [21].

The OOK transmitter emits a rectangular pulse of duration $1/R_b$ and intensity $2P$ (peak power) to signify a one bit, and no pulse to signify a zero bit. Assuming an additive white Gaussian noise (AWGN) channel, the BER is given as:-

$$BER_{OOK} = Q\left(\frac{P}{\sqrt{N_0 R_b}}\right)$$

Where, P is the average power and N_0 is the noise power spectral density.

Pulse position modulation (PPM)

PPM can offer higher average power efficiency making use of symbols with L time slots (chips).

A constant power LP is transmitted during one of these chips and zero during remaining $(L-1)$ chips therefore, encoding $\log_2 L$ bits in the position of the high chip. For any L greater than 2, PPM requires less optical power than OOK.

In principle, the average optical power requirement can be made arbitrarily small by making L suitably large, at the expense of increased bandwidth. The BER is given as[21]:

$$BER_{L-PPM} \approx Q\left(\sqrt{\frac{Llog_2L}{2}}\frac{P}{\sqrt{N_0R_b}}\right)$$

Inverted- pulse position modulation (PPM)

IPPM is obtained inverting the pulse position of conventional PPM. The optical intensity is $'off'$ during the $1th$ sub-interval and $'on'$ everywhere else. Thus LED remains $(L-1)$ times as bright as conventional L-PPM. The average power transmitted of I-L-PPM is $(L-1)P/L$. The BER is expressed as [22]:-

$$BER_{I-L-PPM} \approx Q\left(\frac{1}{L-1}\sqrt{\frac{Llog_2L}{2}}\frac{P}{\sqrt{N_0R_b}}\right)$$

Sequence inverse keying (SIK)

DSSS SIK is able to minimize the effect of external noise sources. In this method, the incoming data is multiplied by a spreading sequence. The transmitted signal consists of the spreading sequence itself, for binary $'1s'$ and its complement for binary $'0s'$. On the receiver, the detected signal is correlated with a version of the spreading sequence, thus recovering the original data. In this case, the SNR is given by:-

$$BER_{SIK} \approx Q\left(\left(\left(\sqrt{\left(\frac{\sigma_m P_m}{NP}\right)^2}\right) + \left(\sqrt{\frac{N_0R_b}{P}}\right)^2\right)^{-1}\right)$$

Where σ_m and P_m are the standard deviation and the optical power of the interfering signal, N is the spreading factor, and P is the average optical power of the transmitted signal. Above equation shows that without interfering sources, that is, under AWGN channel conditions, SIK and OOK have the same BER performance. However, under the influence of interference the performance of DSSS-SIK increases [23].

VIII CONCLUSION

We have to analyse the indoor characteristics, channel modulation and modulation techniques for indoor VLC in IM/DD by considering the visible light spectrum with respect to the single and multiple channels.

The entireestablished power from reflected paths and the RMS delay spread of the VLC cases are smaller than those of the IR circumstances, which means the VLC has a larger optical transmission bandwidth. For multiple optical sources, the channel bandwidth is imperfect in approximatelyatmospheres due to strong LOS modules.

This paper presented Visible Light Communication (VLC) systems for outdoor application. It is based on DSSS and it is feasible to establish a low data rate communication link ranging up to $40m$ using commercially available LEDs. This communication range is adequate for data broadcast using LED based traffic signals. It is also possible to explore similar system design concepts for data communication using public lighting system. We have to analyse the outdoor VLC and modulation techniques that is (:- BER, PPM, IPPM, SIK). Also, describe the emitter and receiver of outdoor VLC for communication link.

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