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Analysis of SNR distribution of MIMO Indoor VLC System Up to Second order of Reflection

Ashish Kumar, R. Umamaheswari, Subhrajit Barick, A. Sampath Dakshina Murthy

Abstract*: *In this paper, analysis of distortion of signal distribution of LOS and higher order reflection up to second order reflection has been done. Through simulation result it has been found that maximum SNR is received at the receiver's position for Line-of-sight (LOS) component whereas it is uniformly distributed for second order of reflection. This analysis helps in finding the required Field of view (FOV) at the different receiver position according to SNR distribution.

Index Terms*: *SNR, VLC

I. INTRODUCTION

Light based communication invisible range is widely used for unregulated and unlicensed bandwidth, energy efficient lighting and communication, security, robustness in case of radio Frequency interference. In the next decade, the huge demand of data is shifting demand the towards VLC system because of its huge bandwidth. In spite of so many advantages, it suffers from limited bandwidth of LED which limits the data rate. To overcome this limitation MIMO system with spatial multiplexing has been suggested [1]. The advantage of using MIMO system is that it doesn't need extra spectrum and also increases the illumination inside the room. VLC is based on intensity modulation and direct detection technique. Hence, channel gain is real unlike the channel gain of RF system where the channel gain is complex. In MIMO-Indoor VLC system the layout of transmitter plays very important role in SNR distribution. Therefore analysis of SNR distribution inside the room becomes one of the research topic. Many authors have done research work over the SNR analysis. P. J. Smith et al. [2] have tried to find the impact of feedback through SNR analysis.David Gesbert et al. [3] have comparision of BER performance over various transmission technique for 2×2 MIMO system w.r.t to received SNR. J. Grubor et al [4] have investigated the benefits and difficulties of angle diversity receiver in non-directed infrared wireless communication system. They have simulated the electrical SNR with the variation of diagonal position of receiver for MRC-combined channel using 100-Mb/s OOK. K.D.Dambul et al. [5] have demonstrated indoor 2×2 MIMO optical system using receiver with signal processing. They have simulated the case of adversely affected SNR vs BER for different results that low SNR has a strong impact on the device in matrix and resultant BER. Thomas Q. Wang et al. [6] have proposed a hemispherical simple receiver incapable of imaging VLC system which can provide wide FOV and high channel gain. They have investigated the performance measure of their proposed lens by analysing the received SNR at the four receiver position.

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First Author name, Department ECE, Vignan's Institute of Information Technology,Visakhapatnam

Second Author name, Department ECE, Vignan's Institute of Information Technology, Visakhapatnam

Third Author name, Department ECE, Vignan's Institute of Information Technology, Visakhapatnam

Fourth Author name, Department ECE, Vignan's Institute of Information Technology, Visakhapatnam

II. INDOOR VLC MODEL

In MIMO system, there are N_TLEDs on the ceiling of the roof and N_RPhotodetectors placed at some height above the floor. These photodetectors are positioned below the optical concentrator which collects light incident from a large area and refracts the light. Thus there is channel matrix H of the order of $N_R \times N_T$ whose elements are basically channel gain H (i, j) between the i^{th}photodetector and j^{th}LED. In our paper, first a 4×4 MIMO system MIMO system have been considered. Fig.1 shows the space geometry of 4×4 system where LEDs are placed symmetrically w.r.t to the concentrator. This 4×4 system will lead to a square matrix of the order of four and with sixteen elements each showing gain between the corresponding LED and photodetector.

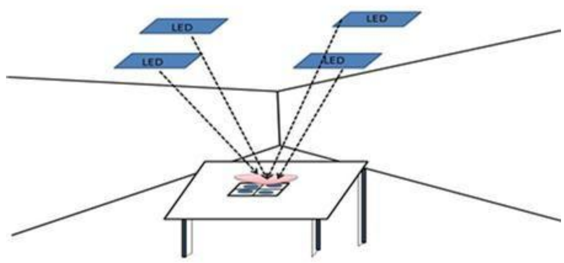

Fig.1. Indoor VLC model

LEDs with Lambertian pattern can be considered as

$$s(\phi) = P_t \frac{m+1}{2\pi} \cos^m(\phi) \quad (1)$$

where ϕ is the angle of radiance w.r.t normal axis, m is emission order which is given as

$$m = \frac{-\ln 2}{\ln[\cos(\emptyset_{1/2})]} \quad (2)$$

Here $\emptyset_{1/2}$is the LED half power angle. The DC gain of LOS channel is given as

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	Parameters	value
Room	**Size**	**10 × 10 × 3 m3**
	ρNorth= ρSouth = ρWest = ρEast	**0.8**
	Ceiling grids **Floor grids** **Wall grids**	**70×70** **70×70** **70×21**
Source	**Location (4 LEDs)**	**(1.25, 1.25, 3), (-1.25, 1.25,3), (-1.25, -1.25,3), (1.25, -.125, 3)**
	Half power condition	**70**
Channel model	**Barry model**	
	Active area (AR)	**1Cm²**
	Half-angle FOV	**60**
	Δt	**0.5 ns**
Noise	**Noise factor**	
	Irradiance factor	**5.8uw/cm².nm**
	Preamplifier noise	
	Electronic charge q	**1.6×10⁻¹⁹**
	Noise bandwidth factors I_2, I_3	**0.562, 0.0868**
	Receiver area A_r	**10^{-6} m²**
	Responsitivity of Photodiode R	**0.5 A/W**
	Feedback resistor	**1.4 KΩ**
	Value of input capacitance	**2 PF**

$$H_{LOS}(0) = \begin{cases} \frac{A_r(m+1)}{2\pi d^2}\cos^m(\phi)\cos(\varphi)\, g(\varphi), & 0 \le \varphi \le \varphi_{FOV} \\ 0, & \varphi > \varphi_{FOV} \end{cases} \quad (3)$$

Here d is the distance from LED to receiver, Ar is the effective area, φ_{FOV} is the FOV range , φ is the angle of incident angle, g(φ) is the optical gain of the receiver which is given as

$$g(\varphi) = \begin{cases} \frac{n^2}{\sin^2(\varphi_{FOV})}, & 0 \le \varphi \le \varphi_{FOV} \\ 0, & \varphi \ge \varphi_{FOV} \end{cases} \quad (4)$$

Here n is the RI of the concentrator. DC amplification of LOS is given as

$$H_{1st-ref}(0) = \begin{cases} \frac{A_r \Delta A \rho(m+1)}{2\pi^2 d_1^2 d_2^2}\cos^m(\phi_1) \cos(\alpha)\cos(\beta)\cos(\varphi_1)\, g(\varphi_1), & 0 \le \varphi_1 \le \varphi_{FOV} \\ 0, & \varphi_1 > \varphi_{FOV} \end{cases} \quad (5)$$

Where ΔA represents area for grids of minimum size on walls, ceiling and floor which act as reflectors, ρ is the reflection coefficients of walls, ϕ_1 is the irradiance angle from LED to wall, α is the incidence angle at impact point of wall, β is the irradiance angle from impact point of wall, φ_1 is related to the receiver, d_1 and d_2 are the source-wall wall-receiver respectively. Similarly, DC gain of the second reflected signal is given as

$$H_{2nd-ref}(0) = \begin{cases} \frac{A_r(\Delta A)^2 \rho^2(m+1)}{2\pi^3 d_1^2 d_2^2 d_3^2 d_4^2}\cos^m(\phi_1) \cos(\alpha)\cos(\beta)\cos(\gamma) \cos(\delta)\cos(\varphi_2)\, g(\varphi_2), & 0 \le \varphi_2 \le \varphi_{FOV} \\ 0, & \varphi_2 > \varphi_{FOV} \end{cases} \quad (6)$$

where γ is the incidence angle at impact point of second wall, δ refers to irradiance from impact point of second wall, φ_2 is the incidence angle at on next reflecting action , d_3 is the distance from impact point of first wall to impact wall of second wall, d_4 is the distance from impact point of second wall to receiver. So effective channel gain is sum of two reflections.

$$H_{dif}(0) = H_{1st-ref}(0) + H_{2nd-ref}(0) \quad (7)$$

Receiver's noise consists of shot noise and thermal noise, which is given as

$$\sigma_{noise}^2 = \sigma_{shot}^2 + \sigma_{thermal}^2$$

$$= (2qRP_rB) + \left(\frac{8\pi KT}{G}\eta A_r I_2 B^2 + \frac{16\pi^2 KT\Gamma}{g_m}\eta^2 A_r^2 I_3 B^3\right) \quad (8)$$

where q, R, and B are the electronic charge, responsivity of receiver and equivalent noise bandwidth respectively. K is the Boltzmann constant, G is gain of voltage, C_T is the input capacitance of PD, Γ is FET channel noise factor, g_m is ratio of output voltage to input current. Table I gives various factors used in simulation.

III. ANALYSIS OF RESULTS

In order to find quality of communication, analysis of SNR has to be done. In our simulation results, SNR distribution inside room of standard dimension has been carried out.

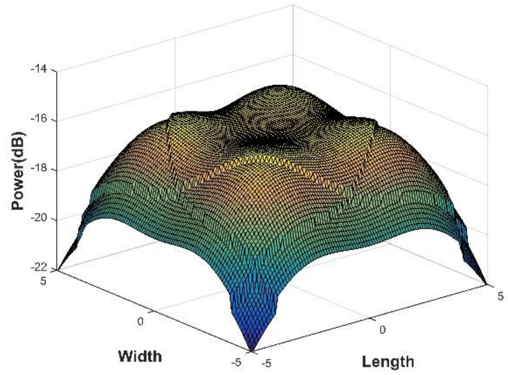

Figure 2 LOS SNR distributions on the receiver plane

Figure .2 show the SNR distribution considering Line-of-sight component (LOS) of light. It can be seen that the maximum signal power is beneath the four LEDs. The modulation technique is OOK in which the signal is transmitted with high and low intensity of light.

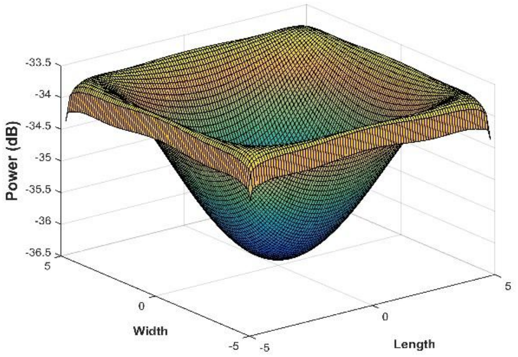

Figure 3. First reflected SNR distribution from all four walls and ceiling

Figure. 3 show the SNR distribution after first reflection from all the four walls and ceiling of room. It can be observed that the signal strength has reduced. Now the maximum SNR and minimum SNR is -33.5dB and -35.5dB respectively.

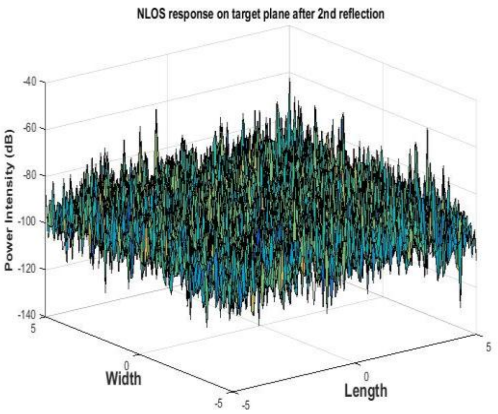

Figure 4. SNR distribution after second reflection

Figure. 4 show the SNR distribution after second reflection of the light. The signal strength as compared to first LOS and first reflection has further reduced. Also it can be observed that the SNR distribution has become uniform unlike LOS SNR distribution where the maximum SNR was found below the LEDs. The maximum and minimum SNR is 60dB and -140dB respectively.

The analysis of SNR distribution is important as it helps in the FOV requirement of receiver at different position of receiver plane.

IV. CONCLUSION

In this paper, the SNR distribution of indoor MIMO VLC system using four LED and Four PDs has been analyzed. Through, analysis it was found that the maximum SNR is below the LEDs for LOS value. For higher order reflection SNR is spread across the room. Moreover the highest and lowest SNR were also recorded. The analysis helps in finding the FOV of receiver as per requirements.

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