5G based Full-duplex Hybrid OCDMA-VLC system for secure IoT applications

Meet Kumari

Chandigarh University, Mohali, Punjab, India

Abstract

In this work, a full-duplex hybrid visible light communication (VLC) and optical code division multiple access (OCDMA) for varied transmission range and data rate for different codes and light emitting diodes (LEDs) is analyzed respectively. The simulation results show that out of all codes random diagonal (RD) code offers high VLC transmission range of 70m in uplink and 55m in downlink at 10Gbps information rate than multi-diagonal as well as zero cross correlation codes. Also, high data rate of 90Gbps in uplink and 75Gbps in downlink can be obtained by employing red LED and RD code in the designed system over 10m VLC range. In addition, the comparison of the proposed work with other previous is presented to show its superiority.

Keywords

Optical code division multiple access (OCDMA), internet of things (IoT), visible light communication (VLC), fifth generation (5G)

1. Introduction

The requirement for data intake of a mobile user improves continually. However in 2016, the information traffic was 7EB/month, the estimated information traffic for 21st centaury till now is supposed to be approximately 50EB. To manage such huge amount of data, latest and more effective techniques for data transmission must be evolved. The solution is to enhance a efficiency of spectral in recently downtrodden radio frequency bands. While even radio band is not suitable to cope with a spectrum crunch phenomenon. For this, visible light communication (VLC) permits an extended unlicensed spectrum bands which provides a high-speed transmission of data [1]. Also, VLC technology combines and complements with 5G and beyond this to meet the recent and next-generation high transmission rate as well as capacity utilization. Short distance communication within a campus, video monitoring and surveillance, disaster recovery, back-haul system etc. is some of the potential applications of VLC technology [2].

VLC has been regarded as a substitute to communicate huge sensing data generated by widespread internet of things (IoT) sensor nodes. These IoT smart sensors have capability to respond in the real world events in an rapid, automatic as well as enlightened way not only reveals new possibilities for handling critical or complex situations, but too allows a broad range of technologies operation to be optimized [3]. Various research work papers [4–6] focused on a VLC scenario.

Further, optical code division multiple access (OCDMA) is emerging as a promising solution that can offer quality of service in physical layer. OCDMA schemes are getting considerable attention due to its ability to behave asynchronously, improved capacity as well as privacy. Several OCDMA codes have been used to handle multimedia applications like random diagonal (RD) , zero cross correlation (ZCC), multi-diagonal (MD) etc. to cope with permitting large number of consumers to broadcasting high transmission rates adapted to various multimedia transmission [7]. Table 1 indicates the existing methodologies used in the previous work along with their pros as well as cons.

Proceedings of International Symposium on Securing Next-Generation Systems using Future Artificial Intelligence Technologies (SNSFAIT 2023), May XX-XX, 2023, Delhi, India
EMAIL: meetkumari08@yahoo.in(M. Kumari)
ORCID: 0000-0001-9975-1557

Table 1
Existing methodologies

Ref.	Year	System	Pros	Cons
[8]	2016	WDM-VLC	4.5m+20km	10Gbps
[9]	2020	WDM-VLC	2.3Tbps	1.5m
[5]	2021	wired/VLC	Range=10m+50km	Data rate=10/10Gbps
[10]	2022	wavelength division multiplexing (WDM)/VLC	50Gbps	12m

Previous recent work presents that, till now researchers have more focus on VLC system, but there is less work except [5], has been done on hybrid VLC-OCDMA system for IoT applications.

Thus in this paper a full-duplex hybrid VLC-OCDMA system using different OCDMA code on the basics of 5G for IoT applications has been reported. The novelty behind this work is to secure the IoT based VLC-OCDMA system using different OCDMA codes. It also enhances the transmission distance as well as data rate for various future based applications.

Main contributions of the proposed work:

- Design a full-duplex hybrid VLC-OCDMA system.
- Compare the designed system for different OCDMA codes like multi diagonal (MD), random diagonal (RD) and zero cross correlation (ZCC) codes.
- Identify the system performance for varied VLC link as well as transmission rate.

The work is organized as: Section 2 presents the proposed design of hybrid VLC-OCDMA system. Section 3 depicts the results and discussion. Lastly, conclusion is dawn in Section 4.

2. System design

The proposed hybrid VLC-OCDMA system is presented in Figure 1.

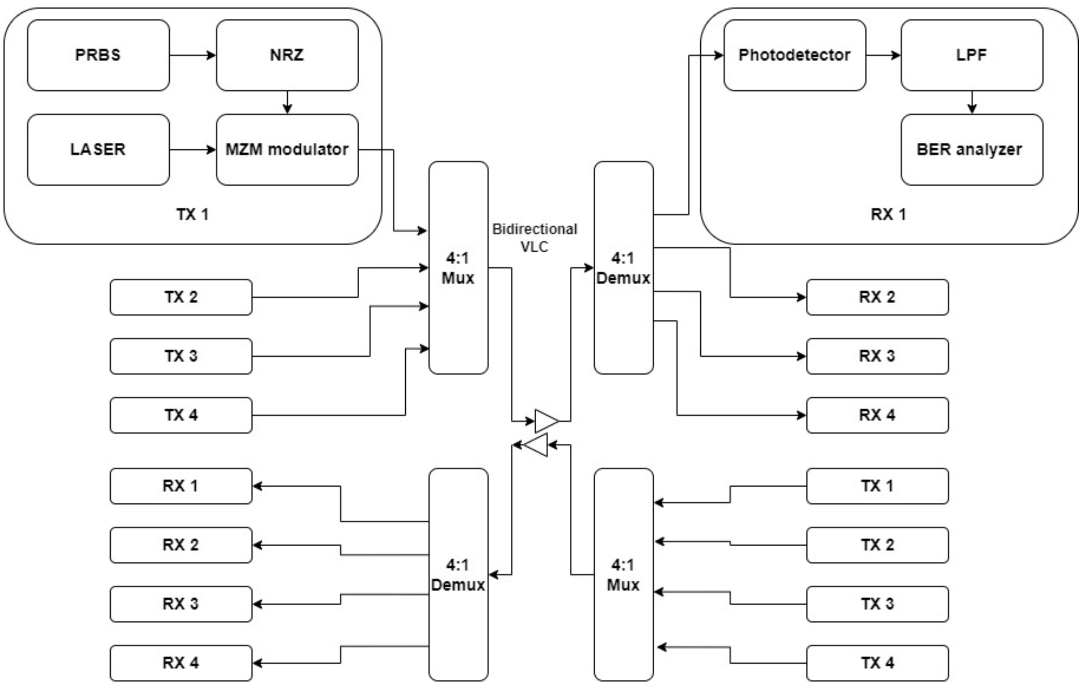


Figure 1: Block diagram of full-duplex hybrid VLC-OCDMA system

The proposed block diagram presents the full-duplex hybrid VLC-OCDMA system using RD, MD and ZCC codes for four users. It includes four downstream (DN) coded transmitters (TXs) and upstream (UP) coded TXs. For downlink transmission, each TX section consists of a series of pseudo random bit sequence generator with non return to zero data format to be modulated with incoming laser input signals via mach zehnder modulator. The code construction for three users RD, MD and ZCC code using three LEDs (red=640nm, white=625nm+514nm+450nm and violet=400nm) is reported below in Table 2.

Table 2

Code designs

Code	RD			MD			ZCC		
LED	U1	U2	U3	U1	U2	U3	U1	U2	U3
Red	0	0	1	1	0	0	1	0	0
White	0	1	0	0	1	0	0	1	0
Violet	1	0	0	0	0	1	1	0	0
Red	1	0	0	0	0	1	0	0	1
White	0	1	0	0	1	0	0	1	0
Violet	0	0	1	1	0	0	0	0	1

A 4:1 multiplexer is implemented at to multiplex the input wavelengths over bidirectional VLC channels. Likewise, a 1:4 de-multiplex is used at receiver to distribute the incoming wavelengths to different receivers. Each receiver consists of a photo detector for converting the optical energy to electrical. Low pass filter and BER analyzer are used to reduce the unwanted noise and to test the system performance respectively. The operation is performed for uplink transmission in the system.

The parameters used in the proposed system are tabulated in Table 3.

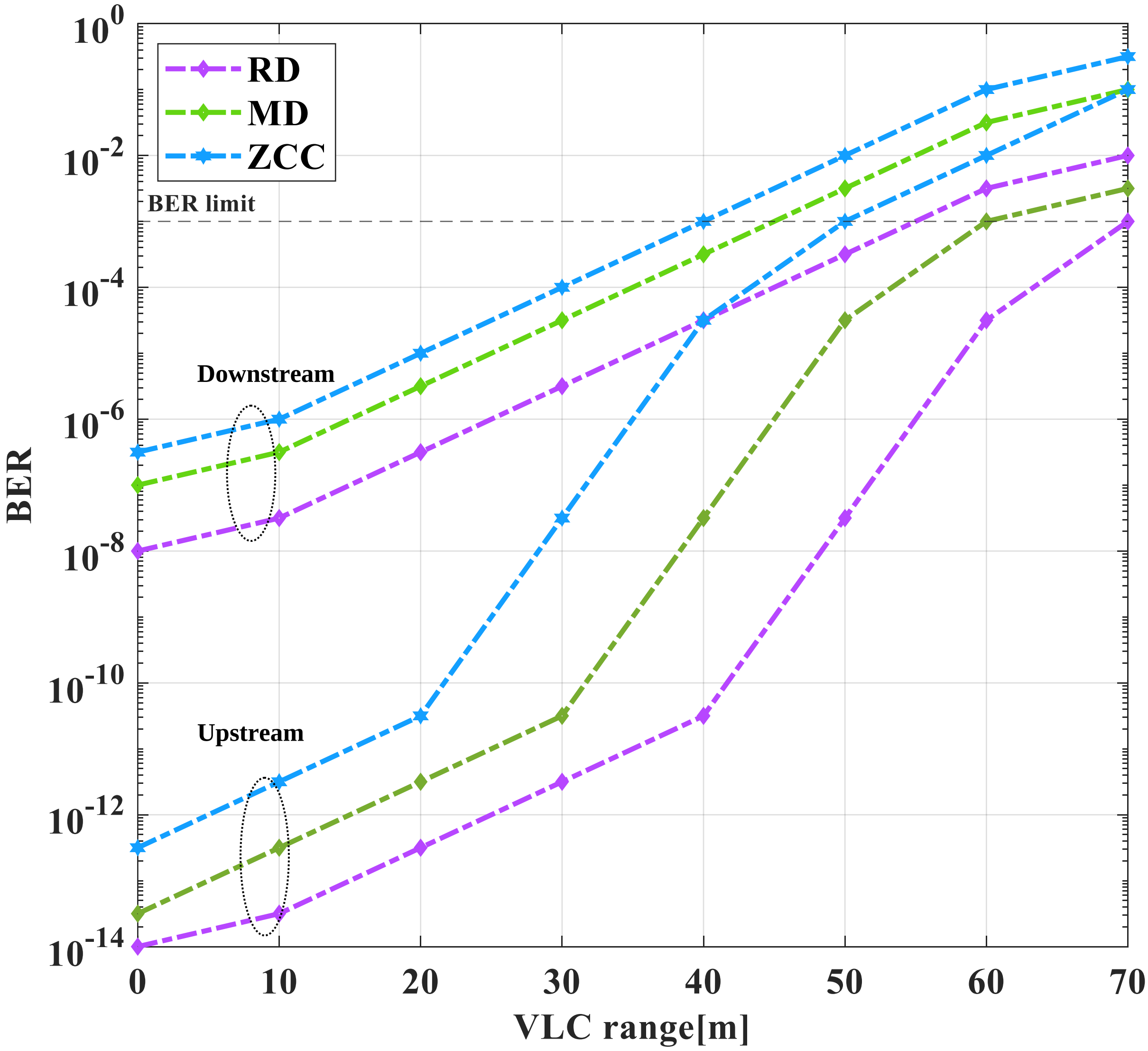
Table 3

Parameters Used in OptiSystem simulation software

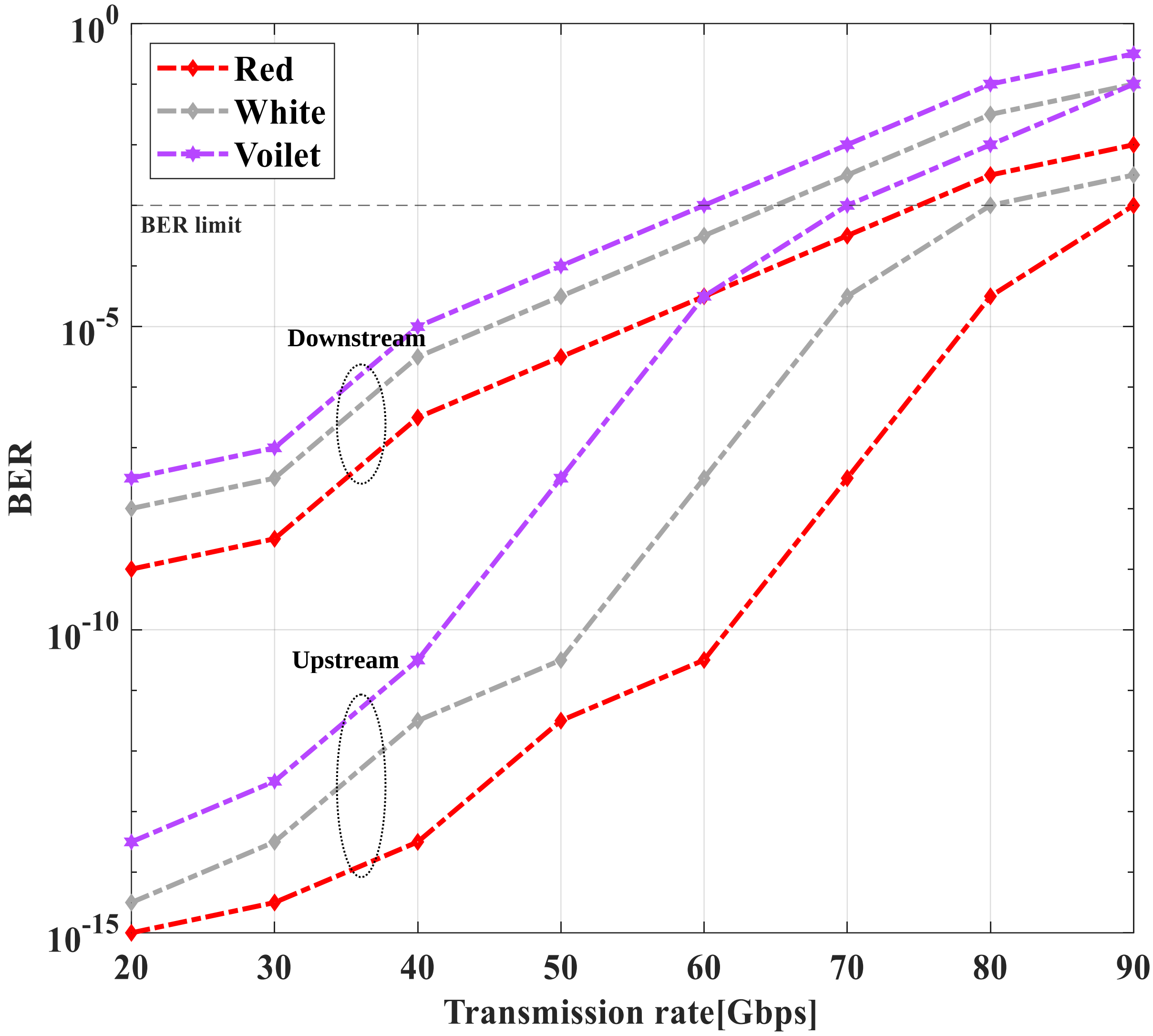
S. No.	Parameter	Value
1	Input power	10dBm
2	Transmission rate	20-90Gbps
3	Range	10-70m
4	Dark current	9nA
5	Responsitivity	1A/W
6	Thermal noise	10-22 W/Hz

3. Results and analysis

The proposed hybrid VLC-OCDMA system performance is measured under the influence of external interferences and noise in OptiSystem.


RD
MD
ZCC
BER limit
Downstream
Upstream
BER
VLC range[m]
10^0
10^-2
10^-4
10^-6
10^-8
10^-10
10^-12
10^-14
0
10
20
30
40
50
60
70

(a)

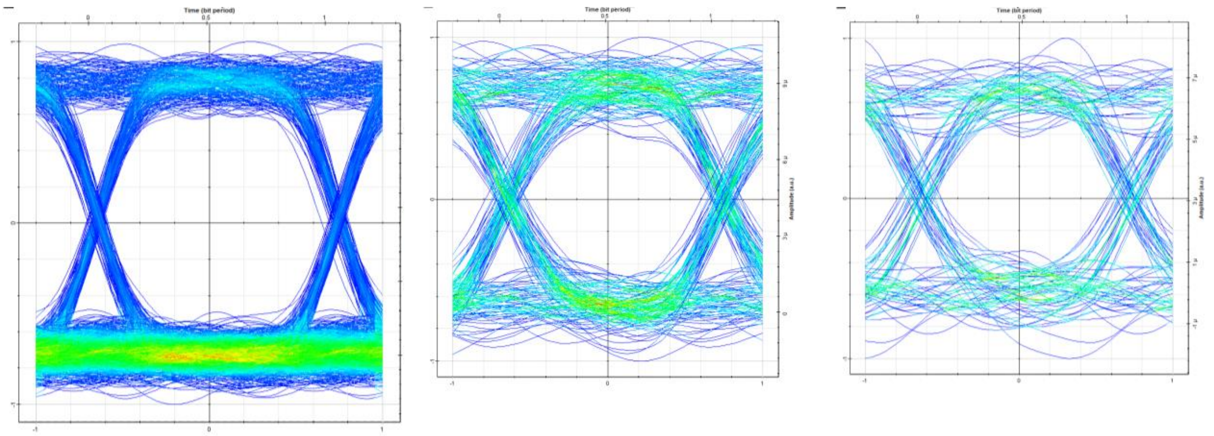


(b)

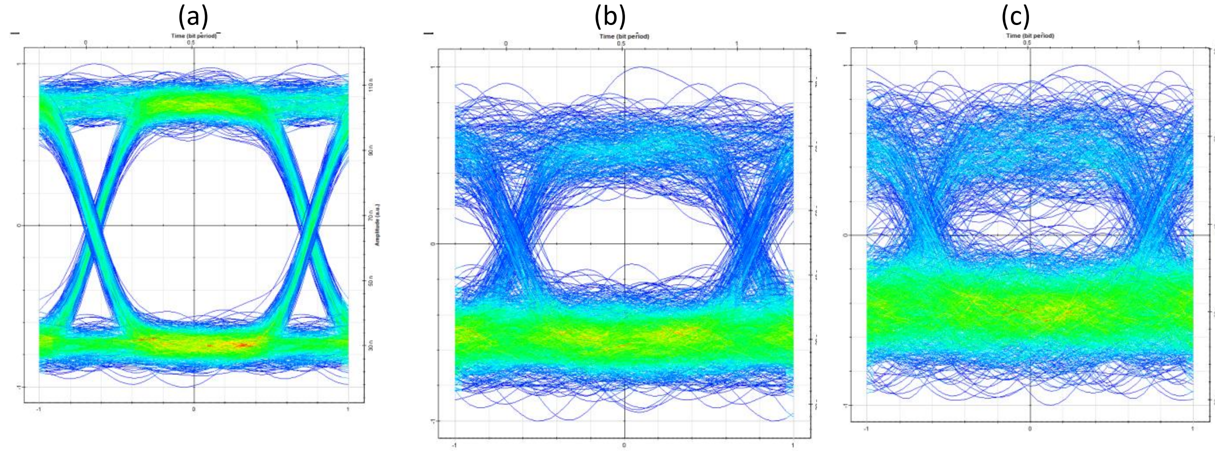
Figure 2: BER performance of proposed system for varied (a) VLC range employing different codes and (b) transmission rate for different LEDs using RD code

Figure 2(a) presents the BER performance of full-duplex VLC-OCDMA system employing RD, MD and ZCC codes for varied VLC range in both DN and UP transmission at 10/10Gbps data rate. It is seen that with increase transmission range, the performance of system degrades for various codes in both DN and UP directions. Also, RD code performs best compared to other codes in UP transmission as compared to DN transmission. The maximum achieved VLC range for RD, MD and ZCC code is 70, 60 and 50m in UP transmission, at 10^{-3} BER threshold. Also, the faithful VLC range for RD, MD and ZCC code is 55, 45 and 40m in DN transmission.

Figure 2(b) depicts the BER performance of full-duplex VLC-OCDMA system employing RD code for varied data rate in both DN and UP transmission over 10m range for different LEDs. It is noted that with increase transmission rate, the performance of system diminishes for various LEDs in both DN and UP directions. Also, out of all codes, red LED shows best performance than white and violet LEDs in UP transmission as compared to DN. The highest obtained transmission rate for red, white and violet LED is 90, 80 and 70Gbps respectively, at BER threshold in UP transmission. Moreover, in DN transmission, the maximum transmission rate for red, white and violet LED is 75, 65 and 60Gbps respectively.



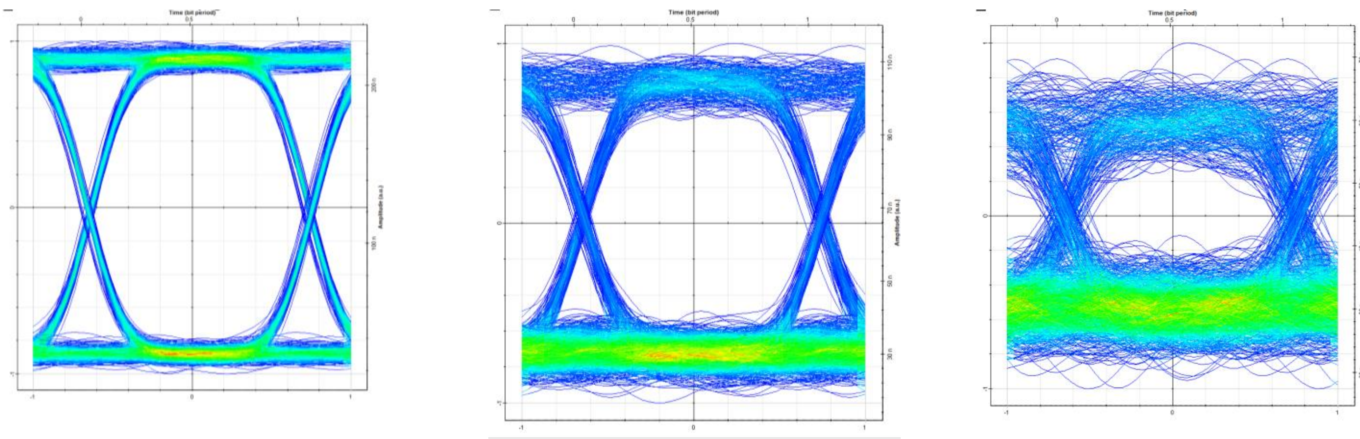
(a) (b) (c)



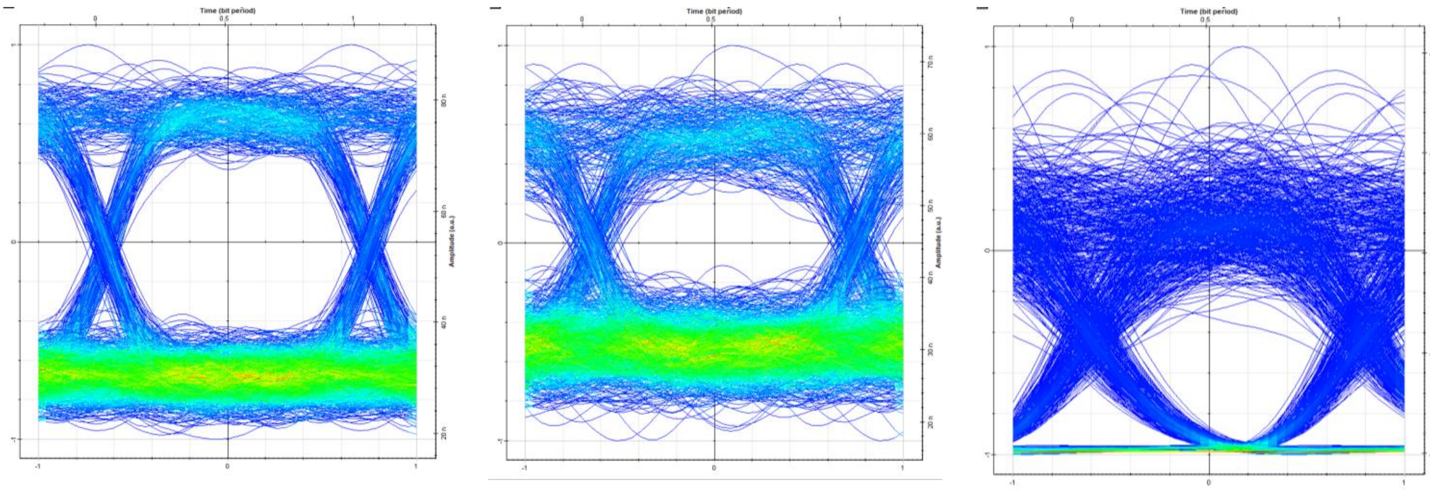
(d) (e) (f)

Figure 3: Eye patterns of the hybrid VLC-OCDMA system using RD code over (a)70m, (b)60m and (c)50m VLC range for UP; (d)70m, (e)60m and (f)50m VLC range for DN transmission

Figure 3(a)-3(f) illustrate that the eye patterns of the proposed system for different VLC range at 10Gbps data rate for UP and DN transmission. It is analysed that with increase in transmission range, eye patterns get disturbed causing decrease in system performance. Also UP transmission provides finer performance than DN.



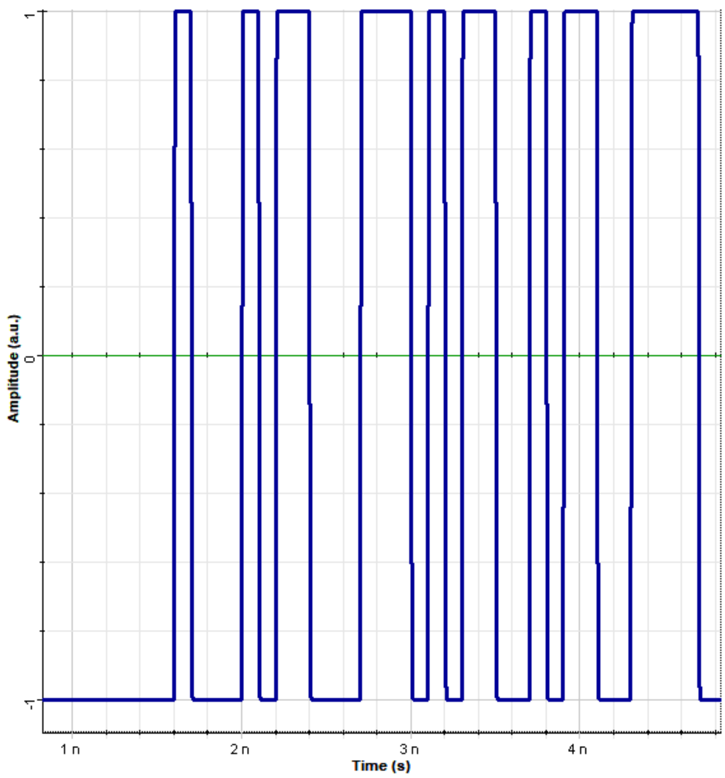
(a) (b) (c)



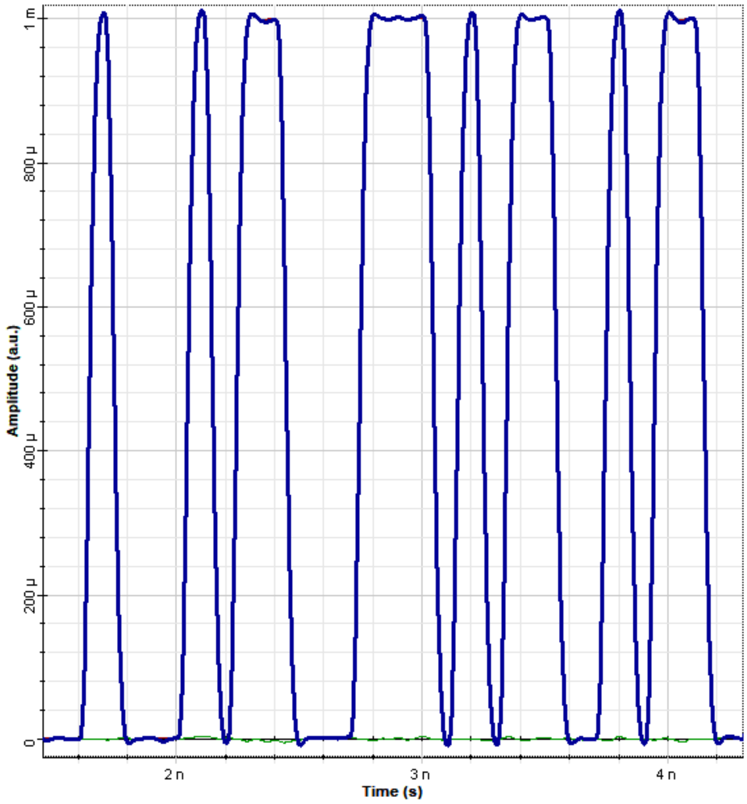
(d) (e) (f)

Figure 4: Eye patterns of the hybrid VLC-OCDMA system using RD code over (a)20Gbps, (b)60Gbps and (c)90Gbps VLC range for UP; (d)20Gbps, (e)60Gbps and (f)90Gbps VLC range for DN transmission

Figure 4(a)-4(f) illustrate that the eye patterns of the proposed system for different VLC traffic rate over 10m range for UP and DN transmission. It is observed that with increase in traffic rate, eye patterns get disturbed causing decrease in system performance. Also UP transmission provides finer performance than DN.



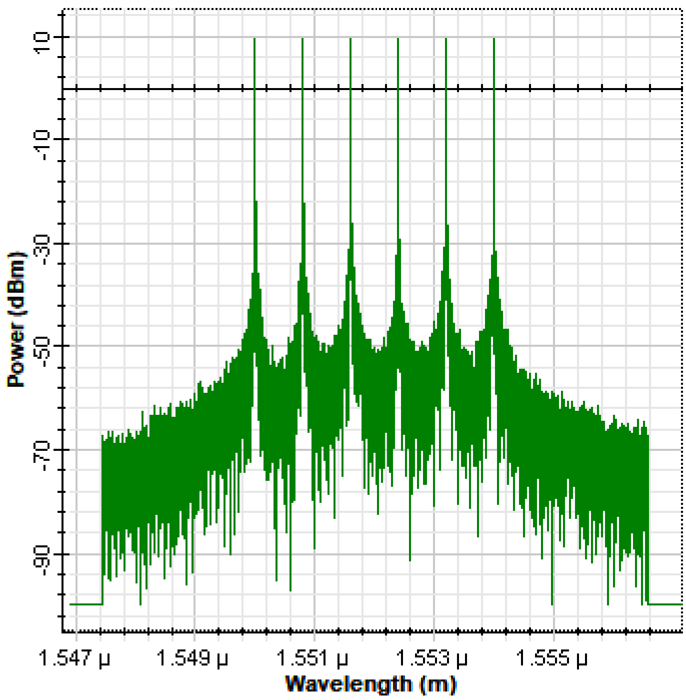
(a)



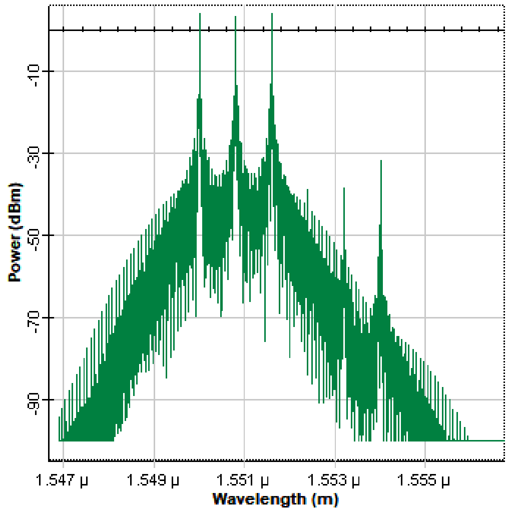
(b)

Figure 5: Measured spectra of the hybrid VLC-OCDMA system using RD code at (a) Tx and (b)Rx over 10m range at 10Gbps rate

Figure 5(a) as well as 5(b) report that the measured spectra of the proposed system at transmitter as well as receiver side.



(a)



(b)

Figure 6: Measured spectra of the hybrid VLC-OCDMA system using RD code at (a) Tx and (b) Rx over 10m range at 10Gbps rate

Figure 6(a) as well as 6(b) report that the measured spectra of the proposed system at transmitter as well as receiver side. Table 4 presents the comparative system performance with other existing systems.

Table 3
Comparative system performance

Ref.	Max. VLC range (m)	Max. data rate (Gbps)
[12]	2	10
[13]	1.5	2.3
[14]	1.2	1.45
[15]	0.3	1.35
[16]	3	12.6
[17]	10	2.5
Proposed work	70	90

Tables 4 reports that for the proposed work faithful VLC range is 70m at symmetric 90Gbps data rate which is maximum than other existing works. However, this work has some limitations like external noise, large codes length, limited range and design complexity. In future more work need to be done on VLC-OCDMA system using LASER and optimum code to support the large no. of customers.

4. Conclusion

A full-duplex hybrid VLC-OCDMA using three different codes and three LEDs is presented. It is concluded that RD code presents finest performance with VLC range of 70m in uplink and 55m uplink direction than MD as well as ZCC code at BER threshold at 10Gbps. Also, the transmission rate can be extended upto 90Gbps and 75Gbps in uplink and downlink directions respectively, using RD code for red LED. Besides this, the proposed work shows better work than other previous works.

5. References

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