Development of a Hybrid FSO/RF System During Link Misalignment

Kappala Vinod Kiran, Shikha Rathore, Ashok Kumar Turuk, Santos Kumar Das*
Department of Electronics and Communication
National Institute of Technology Rourkela, INDIA
*Email: dassk@nitrkl.ac.in

***Abstract*—Free-space optical (FSO) link offers high data rate and low system complexity but suffers from atmospheric attenuation due to fog, scintillation, and link misalignment. Radio-frequency (RF) communication have lower data rates but are relatively insensitive to weather conditions. A hybrid FSO/RF communication is implemented to combine the advantages of both the systems for providing a reliable communication link. This work focuses on the design of an FSO/RF transmission module and highlights the experimental verication of outdoor FSO communication system in combination with the redundant RF application. It provides high availability of uninterrupted communication during link misalignment and also over adverse weather conditions. Hard-switching is performed between FSO and RF application depending on the feedback from the receiver about the link status. An image of different data rates has been transmitted successfully under the different link scenario.**

***Keywords*—FSO, Hybrid FSO/RF, Misalignment**

I. Introduction

The rapid development of information technology, overcrowding in RF spectrum and the thrust for the mobile data services has lead to a huge demand for establishing high speed ubiquitous wireless networks [1]. Due to the limitation in data rate, security, and power consumption in the traditional RF communication, many of the researches are seeking for a new technology to overcome these problems. FSO communication is one such technology with high bandwidth, low-power consumption, and high security [2]. Despite its high data rate, the performance of FSO links are limited due to weather conditions such as fog, snow, scintillation, etc. and optical line-of-sight (LoS) alignment. The above factors makes FSO not a conventional technology as compared to the optical fiber mode of communication [1]. RF communication on the other hand can combat the weather conditions and LoS alignment. A hybrid structure of FSO with RF backup combines the advantage of both the technologies such as low cost, non line-of-sight applications, high data rate, and low latency [1]. A hybrid network based on FSO/VLC heterogeneous interconnection for future space-air-ground-ocean (SAGO) integrated communication architecture was proposed, especially for radio-frequency-sensitive environments [3]. It was proposed as a reliable and promising system architecture to improve wireless network reliability because such a hybrid RF/FSO system will use both available links to transmit data and can switch from RF to FSO and vice versa depending upon link conditions and electromagnetic interference levels [1]. To validate the concept of hybrid architecture and to realize its reliability in providing high speed connectivity without delay and in inexpensive manner, software-level algorithms supporting link monitoring, restoration, routing and coding of the FSO/RF hybrid network has been investigated [4] [5]. For designing flexible hybrid networks by developing scalable algorithms of dynamic traffic redistribution, topology control developments with reconfiguration, creation of new links and intelligent switching between FSO and RF is performed [6]. A hybird hardware system was proposed by assembling discrete components, monolithic integration, and hybrid packaging for fabrication [7]. A parallel and hybrid FSO/RF point-to-multipoint system consisting of a hybrid access point (HAP), multiple FSO users, and multiple RF users is designed to provide link quality scheduling strategy [8]. The superior energy efficiency of the proposed mixed RF/VLC heterogeneous network was investigated with numerical results [9]. An experimental outdoor wireless connection between two campuses using the structure of hybrid system for providing uninterrupted communication even in an adverse weather conditions with high availability is also proposed [10]. We propose a hybrid FSO/RF system which is capable of providing a reliable communication under link misalignment condition. Rest of the paper is organized as follows: Section II describes the system model. Section III discusses the proposed block diagram. Section IV describes the design part of FSO/RF transceiver. Section V presents the experimental results and Section VI concludes the work.

II. System model

The system model used is as shown in Fig. 1. It makes use of the best communication link of two transmission media at a particular instant. FSO and RF channels are established parallel to form a single, highly available, reliable and seamless wireless communication link. It comprises a relay switch which provides the switching function between FSO link and a backup RF link.

III. Block Diagram of Hybrid FSO/RF

With reference to the system model, a full duplex hybrid FSO/RF is designed to transmit and receive files of various sizes between two computers under link misalignment conditions. Fig. 2 shows the block diagram, where a file from one computer is transmitted serially using RS-232 protocol.

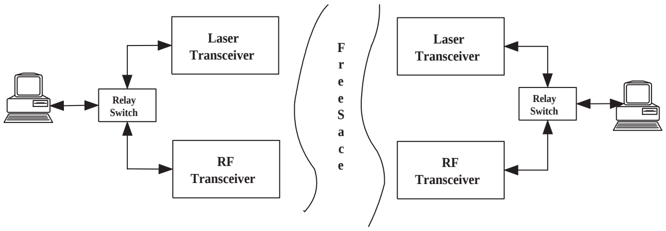

Fig. 1. System Model

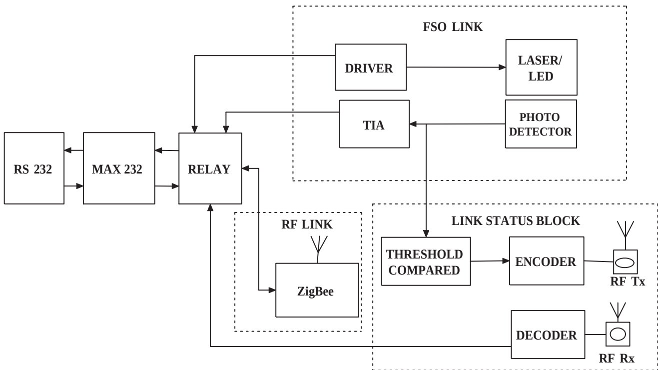

Fig. 2. Block Diagram of Hybrid FSO/RF Transceiver System

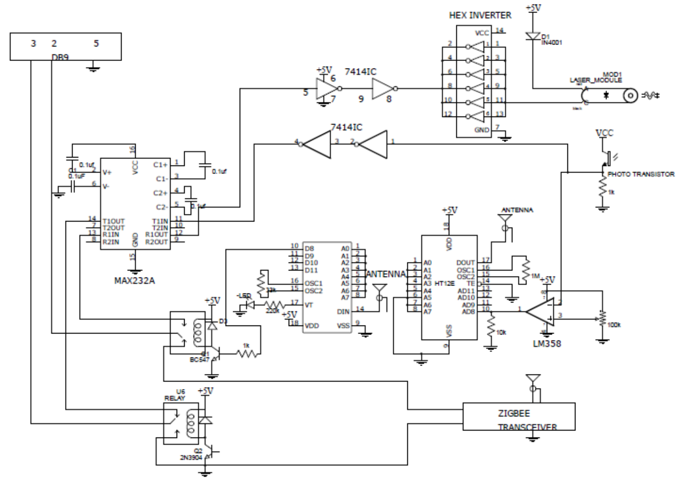

Fig. 3. Schematic of Hybrid FSO/RF Transceiver

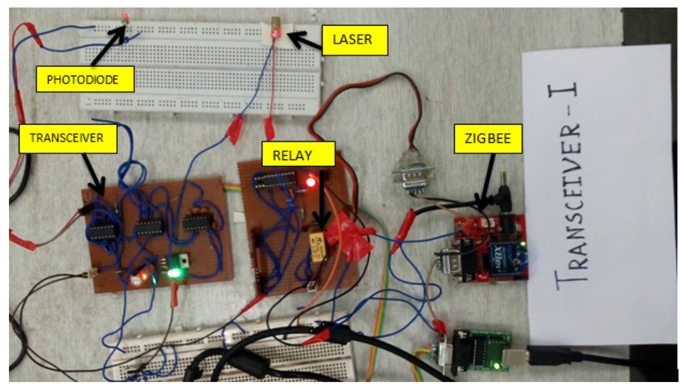

Fig. 4. Hardware prototype of Hybrid FSO/RF Transceiver

This serial data is switched by a relay between FSO or RF communication link depending on the channel conditions and availability. The transceiver FSO link module consists of various sub modules such as driver, trans-impedance amplifier (TIA), LASER/LED as transmitter and photo detector. MAX232 serial interface converts the file from the RS-232 to TTL logic and vice versa. A driver is used to modulate the Laser/LED according to the data. The received data from the photo-detector is a weak signal which is given to a TIA and then to level converter. In the RF module, a Zigbee transceiver is used for transmission and reception. A separate link status block comprises of a threshold detector which compares the optical power continuously with the threshold value, the relay switches between FSO and RF communication links according to the link status information.

IV. Design and Fundamental Description of the Hybrid FSO/RF Transceiver Module

The design of the hybrid system is implemented using off the shelf components. The schematic of transceiver is as shown in Fig. 3. The data to be transmitted from the computer is converted to TTL logic using the level converter MAX232A. This data is driven by driver IC 7405, open-collector hex inverter to modulate the LASER/LED. A low cost LASER/LED of 670 nm wavelength is used as optical transmitter. The received light is detected using the photo detector ST-IKL3B which is a low cost and highly sensitive NPN silicon transistor with an operating wavelength ranging from 500-1050 nm. The received electrical signal from a photo detector is a weak signal which is amplified using the TIA. The amplified data is level shifted suitably for RS232 protocol. Also, voltage across photo detector is compared with the threshold voltage using operational amplifier LM358 as comparator. The link status suitable for transmission is determined by the threshold detector. The relay then switches the transmission and reception between FSO or RF. A separate RF transmission link is employed for link status. At the receiver, HT12D is used to decode the link status information and switches the relay accordingly. A Zigbee transceiver with 2.4 GHz is used for transmission through RF which forms the backup link during the FSO link misalignment. Power level at the receiver is monitored continuously with respect to the certain threshold value. As soon as a link misalignment occurs when the received signal is level detected below the threshold value, the control is switched over to the RF back up communication link, which crosses a stand-by to the existing FSO link. When the link is aligned, there is an increase in the optical power which is above the threshold value triggering the control to switch to the FSO link. Fig. 4 shows the hardware prototype of FSO/RF transceiver. The data used for transmission is an image file transmitted through MATLAB environment simulink model as shown in Fig. 6. Image file is taken from the source block and is resized to obtain different data sizes such as 32X32, 64X64, 128X128, 256X256 etc. Data type conversion of this image file to uint8 is performed for suitable transmission. and then converted to 1D using convert 2D to 1D block. This 1D data is then sent to the unbuffer block. This unbuffers the image elements serially for transmission using serial com port. At the receiver section, image elements are unbuffered and converted to unit8 using data type conversion block. These elements are then captured by the buffer to obtain all the elements. This is then converted to 2D matrix using reshape block. The received image file is successfully obtained and can be viewed on the video viewer block.

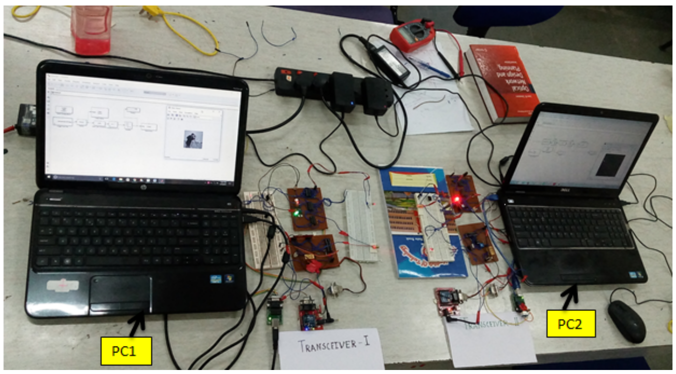

Fig. 5. Data Transmission between two computers

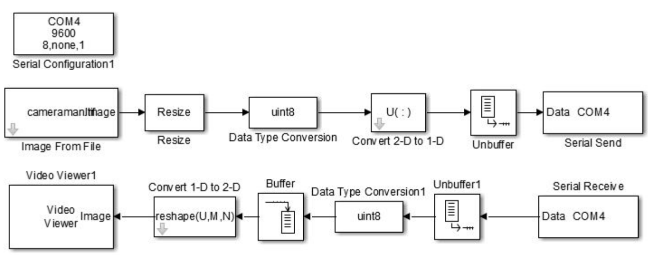

Fig. 6. Simulink Model for Image transfer

Fig. 7. Transmitted Image with different data rate

V. Results and Discussion

Experimental set up of the transceiver between two PCs is as shown in the Fig. 5. Image transmission through a hybrid FSO/RF system at different baud rate using MATLAB Simulink model has been experimentally performed as shown in Fig. 6. Fig. 7 shows image of different data sizes such as 16X16, 32X32, 64X64, 128X128 and 256X256 has been successfully transmitted through hybrid FSO/RF system under different link misalignment conditions.

VI. Conclusion

An hybrid FSO/RF system is designed for data transfer between two computers under different channel conditions. This design is tested and verified experimentally where a hard switching is performed under link misalignment of FSO transmission and data is routed through a RF backup communication system. Since some of the RF frequency bands requires licensing an unlicensed radio band would be more suitable when considering a backup for FSO in order to keep the entire communication system unlicensed. Therefore, ISM frequency band is selected for RF communication link. This module will act as a motivation to the current and future transmission systems for seamless and continuous data transmission.

VII. Acknowledgement

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References

[1] H. Dahrouj, A. Douik, F. Rayal, T. Y. Al-Naffouri, and M.-S. Alouini, “Cost-effective hybrid RF/FSO backhaul solution for next generation wireless systems,” *Wireless Communications, IEEE*, vol. 22, no. 5, pp. 98–104, 2015.

[2] J. M. Kahn and J. R. Barry, “Wireless infrared communications,” *IEEE Proceedings*, vol. 85, no. 2, pp. 265–298, 1997.

[3] Z. Huang, Z. Wang, M. Huang, W. Li, T. Lin, P. He, and Y. Ji, “Hybrid optical wireless network for future SAGO-integrated communication based on FSO/VLC heterogeneous interconnection,” *Photonics Journal, IEEE*, pp. 1–8, 2017.

[4] T. Rokkas, T. Kamalakis, D. Katsianis, D. Varoutas, and T. Sphicopoulos, “Business prospects of wide-scale deployment of free space optical technology as a last-mile solution: a techno-economic evaluation,” *Journal of Optical Networking*, vol. 6, no. 7, pp. 860–870, 2007.

[5] H. Izadpanah, T. Elbatt, V. Kukshya, F. Dolezal, and B. K. Ryu, “High-availability free space optical and RF hybrid wireless networks,” *wireless communications, IEEE*, vol. 10, no. 2, pp. 45–53, 2003.

[6] J. Liao, A. Mirvakili, A. O. Boryssenko, V. M. Joyner, and Z. R. Huang, “Packaging of PIN photodiode on patch antenna for a dual-mode indoor RF/FSO receiver,” *Transactions on Components, Packaging and Manufacturing Technology, IEEE*, vol. 1, no. 3, pp. 335–343, 2011.

[7] S. D. Milner and C. C. Davis, “Hybrid free space optical/RF networks for tactical operations,” *Military Conference on Communications, IEEE*, vol. 1, pp. 409–415, 2004.

[8] L. Chen, W. Wang, and C. Zhang, “Multiuser diversity over parallel and hybrid FSO/RF links and its performance analysis,” *Photonics Journal, IEEE*, vol. 8, pp. 1–10, 2016.

[9] M. Kashef, A. M. Ismail, Muhammad, K. A. Qaraqe, and E. Serpedin, “Energy efficient resource allocation for mixed RF/VLC heterogeneous wireless networks,” *Journal on slected areas in communications, IEEE*, vol. 34, pp. 883–893, 2016.

[10] A. Akbulut, H. G. Ilk, and F. Ari, “Design, availability and reliability analysis on an experimental outdoor FSO/RF communication system,” *Proceedings of International Conference on Transparent Optical Networks,IEEE*, vol. 1, pp. 403–406, 2005.