Naval Research Laboratory

Washington, DC 20375-5320

NRL/MR/8125--20-10,177

Indirect Line-of-Sight Free Space Optics

Josh Beun

Advanced Systems Technology Branch
Space Systems Development Division

November 24, 2020

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
24-11-2020	NRL Memorandum Report	9/1/2020 – 9/28/2020

4. TITLE AND SUBTITLE

Indirect Line-of-Sight Free Space Optics

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Josh Beun

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
4X19

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
4555 Overlook Avenue, SW
Washington, DC 20375-5320

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/MR/8125--20-10,177

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Office of Naval Research
One Liberty Plaza
875 N Randolph Street
Arlington, VA 22217-1995

10. SPONSOR / MONITOR'S ACRONYM(S)

NRL

11. SPONSOR / MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A: Approved for public release; distriubution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This memorandum introduces a process for implementing an indirect line-of-sight (LOS) Free Space Optics (FSO) network. This process enables FSO systems without LOS to form an FSO network in scenarios where LOS is optically obstructed.

15. SUBJECT TERMS

Free space optics

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					Josh Beun
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	Unclassified Unlimited	6	**19b. TELEPHONE NUMBER** *(include area code)*
Unclassified Unlimited	Unclassified Unlimited	Unclassified Unlimited			(202) 767-2699

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

This page intentionally left blank.

Contents

This page intentionally left blank.

Indirect Line-of-Sight Free Space Optics

Introduction

Free Space Optics (FSO) enables networking between nodes without direct physical connection through transmission of light signals propagating in free space. The use of light beams mandate line-of-sight (LOS) between the FSO nodes and FSO operators choose locations of FSO nodes such that LOS is satisfied. In practice, scenarios exist where an FSO network is desired, but the location of the FSO nodes are outside of LOS or a temporary optical obstruction inhibits LOS. This memorandum introduces a process for achieving FSO networks without direct LOS through the use of a novel modulating retro-reflector (MRR) network relay.

Background

MRR systems couple an optical retro-reflector and an electro-optic shutter to allow two-way optical communications [1]. The figure below illustrates basic operation of an MRR. The concept of operation is as follows. As the MRR possess the same properties as a traditional optical retro-reflector, the FSO terminal points its transmit light beam at the MRR and acquires the reflected light beam. Upon successful acquisition, the FSO terminal enters a tracking stage to optimize signal-to-noise (SNR) of the light beam. Communication to the MRR operates by the FSO terminal modulating its data stream onto the transmitted light beam and the MRR employs an optical receiver to recover the data stream, using standard techniques. The MRR transmits data by modulating its data stream onto the reflected light beam. The FSO terminal receives the reflected light beam and recovers the data stream using standard techniques. See [1] for more details.

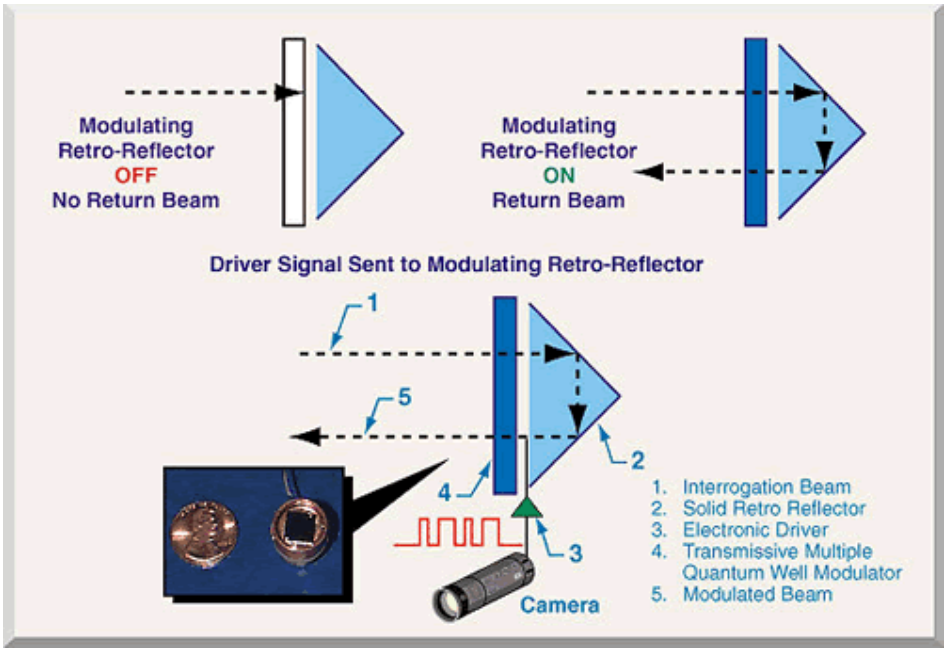

Figure 1- Modulating Retro-Reflector Operation [1]

Manuscript approved October 26, 2020.

Description and Operation

The figure below shows a block diagram of an exemplar indirect LOS FSO network. Only two FSO terminals are shown for clarity. The table below defines the components from the block diagram. The concept of operation follows.

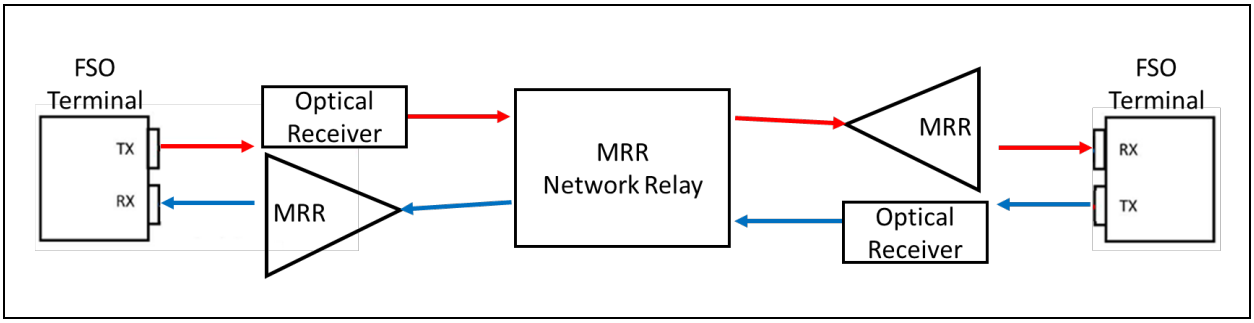

Figure 2 – Indirect LOS FSO Network Block Diagram

Component	Description
FSO Terminal	FSO endpoint, interfaces with external network, communicates data source optically
MRR	Functions as both an retro-reflector and modulates reflected light beam
Optical Receiver	Demodulates light beam into data source
MRR Network Relay	Coordinates network traffic between FSO terminals, provides network switch functionality

Table 1 – QoS FSO Component Descriptions

The concept of operation is now presented. A set of FSO terminals do not have LOS to each other, but have LOS to the MRR network relay; the figure below shows a two terminal configuration for illustrative purposes. Each FSO terminal connects to the MRR network relay using the standard procedure to connect to a traditional MRR as described above. The MRR network relay both coordinates and routes data among the FSO terminals. The MRR achieves coordination through network synchronization techniques. An example technique is time-division multiple access (TDMA). As terminals connect and disconnect from the MRR network relay, it constructs a routing table. As network packets are received from the FSO terminals, the MRR network relay routes the packets to the destination FSO terminal using this table.

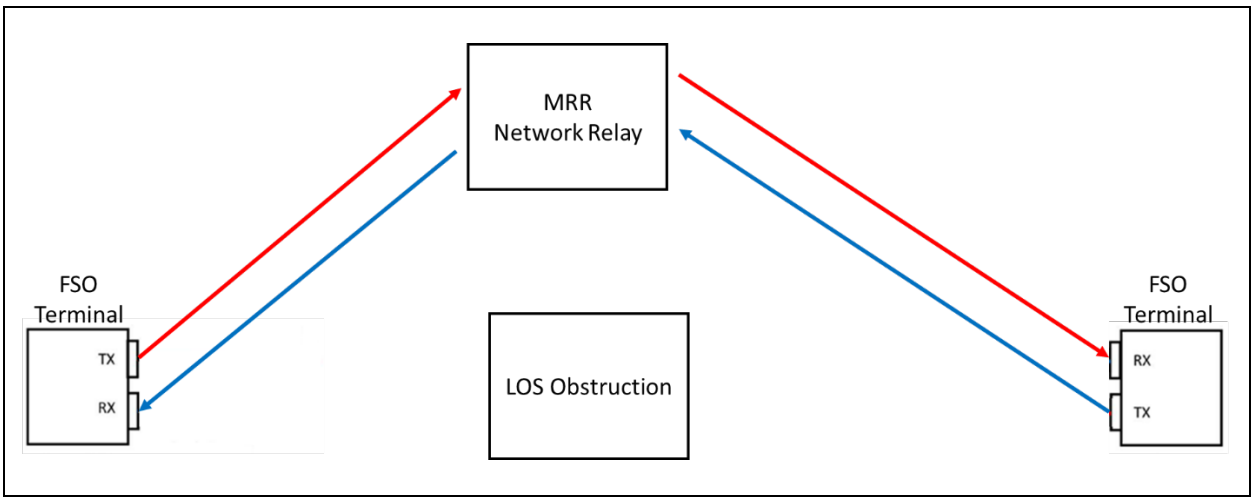

Figure 3- Indirect LOS FSO Example

Summary

This memorandum introduced a process for implementing an indirect LOS FSO network. This process enables FSO systems without LOS to form an FSO network in scenarios where LOS is optically obstructed.

References

[1] Naval Research Laboratory, "Modulating Retro-Reflectors," 27 September 20220. [Online]. Available: https://www.nrl.navy.mil/itd/fpco/research/modulating-retro-reflectors.