Design and Construction of Indoor Full- Free Space Optical Communication System

Wasfi H. Rashid[1,*], Radhi M. Chyad[1], Lubna G. Abdulatif[1], Shehab A. Kadhim[1], Hider Y. Abraham[2], Ali M. Abbas[2]

1. Laser & Optoelectronics Research Center Directorate of Materials, Research Ministry of Science & Technology Baghdad, IRAQ.
2. Research and industrial development directorate, Ministry of Science & Technology Baghdad, IRAQ.

- Corresponding anthers[*]: wasfehameed1960@gmail.com

Abstract:

Next generation free-space optical communication systems have used fiber-optic technology as the seamless connection between free-space and optical fiber and known as the full- optical free – space optical communication system (F-FSOCS). In this project we designed and constructed a communication system by coupling optical fiber with the receiver in which we have employed an optical fiber as a signal receiver couples for free- space optical communication associated with beam tracking system for tracing light signal. The major benefit of this technique is to enhance the detection and tracking performance system for free space optical communication system by using fine-pointing mechanism unit to overcome the deflection of the beam propagation at the receiver such delectation caused by atmospheric turbulence effects which has influenced on the intensity fluctuation degree and position of signal arrival.

Keywords: *Free space optical communication system, Optical receiver, Full- optical free space communication system.*

تصميم وبناء منظومة إتصالات بصرية عبر الجو– تامة (F– SOCS) مختبرياً

وصفي حميد رشيد,[1] راضي محسن جياد[1] ، لبنى غازي عبد اللطيف[1], شهاب احمد كاظم[1], حيدر يوسف ابراهيم[2] ,علي مسعود عباس[2]

1. مركز الليزر والكهروبصريات, دائرة بحوث المواد, وزارة العلوم والتكنولوجيا, بغداد, العراق.
2. دائرة البحث والتطوير الصناعي , وزارة العلوم والتكنولوجيا, بغداد, العراق.

الملخص:

الجيل القادم من منظومات الاتصالات البصرية عبر الجو قد تُسْتَخْدِمْ التقنية البصرية الليفية كوصلة سلسة مابين الفضاء الحر والليف البصري وتُعرف بمنظومة الاتصالات البصرية عبر الجو- التامة(F-FSOCS). تم في هذا البحث تصميم وبناء منظومة أتصالات بأستخدام تقنية تعشيق الليف البصري مع المستقبل حيث وظف فيها الليف البصري كمستقبل للاشارة القادمة ضمن منظومة الاتصالات عبر الجو مرتبط مع منظومة تتبع الحزمة لتعقب الاشارة الضوئية المستلمة.احدى اهم مميزات هذة التقنية هي تحسين أداء آلية الكشف والتتبع باستخدام الوحدة المرتبطة التي تمثل ميكانيكية التتبع الدقيق للتغلب على الانحراف الذي يحدث في موضع مسار الحزمة عند المرسلة والناتج من تاثيرات الاضطراب الجوي والذي له تاثير على درجة تفاوت الشدة وموضع وصول الاشارة المستلمة.

الكلمات المفتاحية: *منظومة الاتصالات البصرية عبر الجو, المستقبل البصري, منظومة الاتصالات عبر الجو البصرية – التامة.*

I. INTRODUCTION

Free space optic communication system (FSO) refers to the transmission of modulated visible or infrared (IR) beams through the atmosphere to obtain broadband communication [1]. The narrow divergence and high bandwidth of optical beams enable point-to-point data links at rates exceed in 1Gbits/s. However, these links require large telescopes, lasers and highly accurate pointing systems to work [2]. These communication systems are immune to electromagnetic interference (EMI), jamming, or wiretapping. And they operate at frequency bands (around 300 THz) where the spectrum is unlicensed. The availability of FSO is the main concern since this technology uses free space as a transmission medium, the main challenge is the weather condition which directly affects the performance by attenuating the signal either through scattering, absorption, or scintillation [3].

On the other hand, optical fiber communication represents another type of optical communication systems, in which the signal transmits through physical medium (silica or plastic). Fiber works as a waveguide for transmitting light from one end of the fiber to another. It is mainly used for long distance transmission and with higher data rates than wire cables [4]. Fiber optics has been traditionally used for transmission of both digital and analog signals [5]. Fiber-optic cabling is still the preferred media for long haul, high-bandwidth transport. However, because of FSO's lower cost and significantly shorter installation time, FSO is now considered a viable option to fiber for short-haul access distances of 4 km or less [6].

In order to benefit from both of features for FSO communication system and optical fiber communication system and reducing their disadvantages, a new technology have been developed as the next generation of free- space optical communication systems in which fiber-optic used as the seamless connection between free- space and optical-fiber. This system in which optical fiber used as the receiver defined as full-optical free- space optical communication systems (F- FSOC). This kind of communication systems sometimes is known as all- optical system use optical fiber to get faster communication speed and to limit the influencing of atmospheric turbulence on optical wave propagated in terrestrial application [7]. Under the influence of thermal turbulence inside the propagation medium, random distributed cells are formed. They have variable size (10 cm - 1 km) and different temperature. These various cells have different refractive indexes thus causing scattering, multipath, variation of the arrival angles; the received signal fluctuates quickly at frequencies ranging between 0.01 and 200 Hz. The wave front varies similarly causing focusing and defocusing of the beam. Such fluctuations of the signal are called scintillation.

The all- optical system may be regarded as a “cut in the fiber” as shown in Figure (1). The general principle of F- FSO represents as an optical signal from the laser guided by an optical fiber to collimating optics. The beam, having passed the air hop, is then focused directly on the core of an optical fiber by using suitable receiver optics and the optical signal propagates down that fiber to the detector [8].

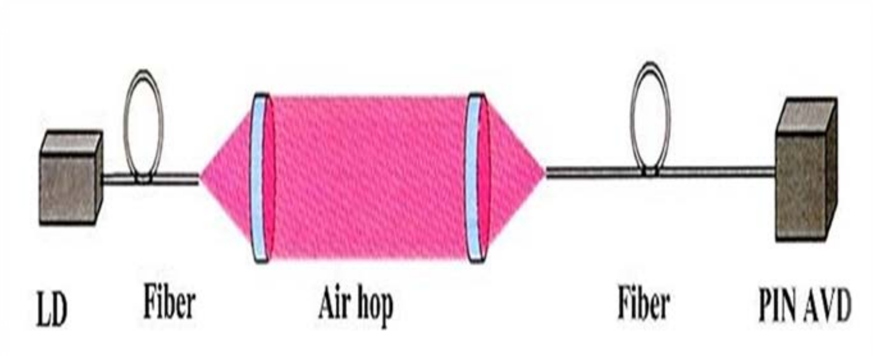

Fig. 1 The general principle of an all- optical FSO system [6].

II. EXAPERIMENTAL

The (F-FSO) communication system in this research consists of (1550 nm) diode laser source (OZ-5000 Laser Module) having (5 mw, 1mm beam size <1 mrad) as a transmitter and through free space the arrival signal collected directly by an optical fiber as the receiver in the next generation instead of photodiode which is usually and customary used in the commonly FSO communication system. Block diagram of improver F-FSO communication system is shown in figure (2). The incident parallel beam at the receiver was collimated by a beam collimator 3x (THORLAB Co.) type telescope as an optical antenna to receive incoming signal laser beam in 1550-nm wavelength band and to convert it into a smaller collimated beam, and then splitter by a beam splitter. One part of the received beam is incident on the optical fiber by means of focusing lens. The optical fiber which consists of single mode fiber (SMF) connected with InGaAs amplified detector (700-1800nm) from (THORLAB Co.). The other part from the beam splitter after reflected from a flat mirror incident on a position sensing detector (PSD) via convex lens .The PSD coupled with and on a movement tracking stage system (Nano Max-Ts (MAX343) and controlled by apt precision motor controller from (THORLABS Co.) and aligned together with the surface of the optical fiber receiver on the same stage, Where the whole optical elements have been aligned and coupled on the same stage in order to keep the precision in the collected laser beam. (PSDs) are used mainly to monitor position and track fine motion. The displacement signals along *x* and *y* axes are obtained from the difference of the signal received by the pair of the detector′s sectors. The difference of the signal power is a function of the irradiance, laser power and atmosphere conditions, and the distance between a laser source and photodiode.

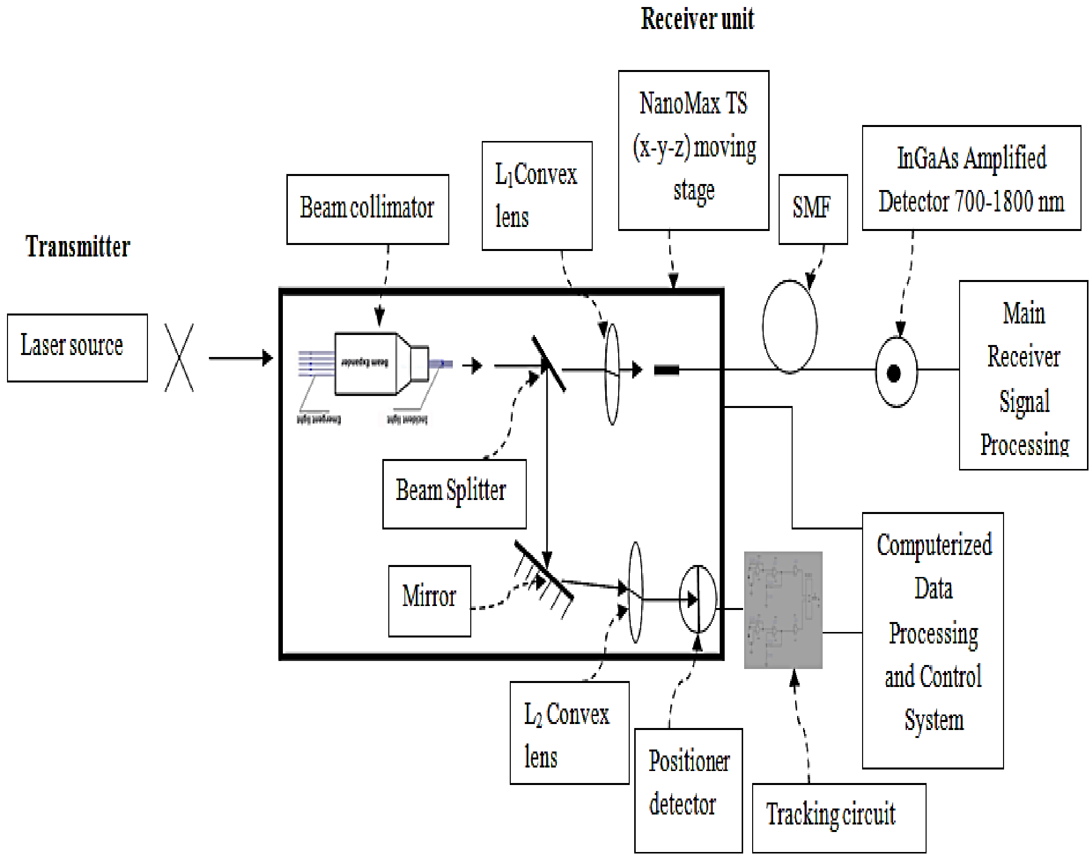

Fig. 2 The block diagram of improver F-FSO communication system.

Also Figure (3) presents the experimental setup for the improver F-FSO. The upper right side of this Figure represents the image of position detector (PSDs). Any deflection in the received laser beam position on the surface of the optical fiber receiver will cause the same displacement on the PSD. This displacement convert to voltage difference between the reference position and the next one which by means of tracking circuit, data processing and control system, the optical fiber receiver return to its original position where the maximum received signal power is collected.

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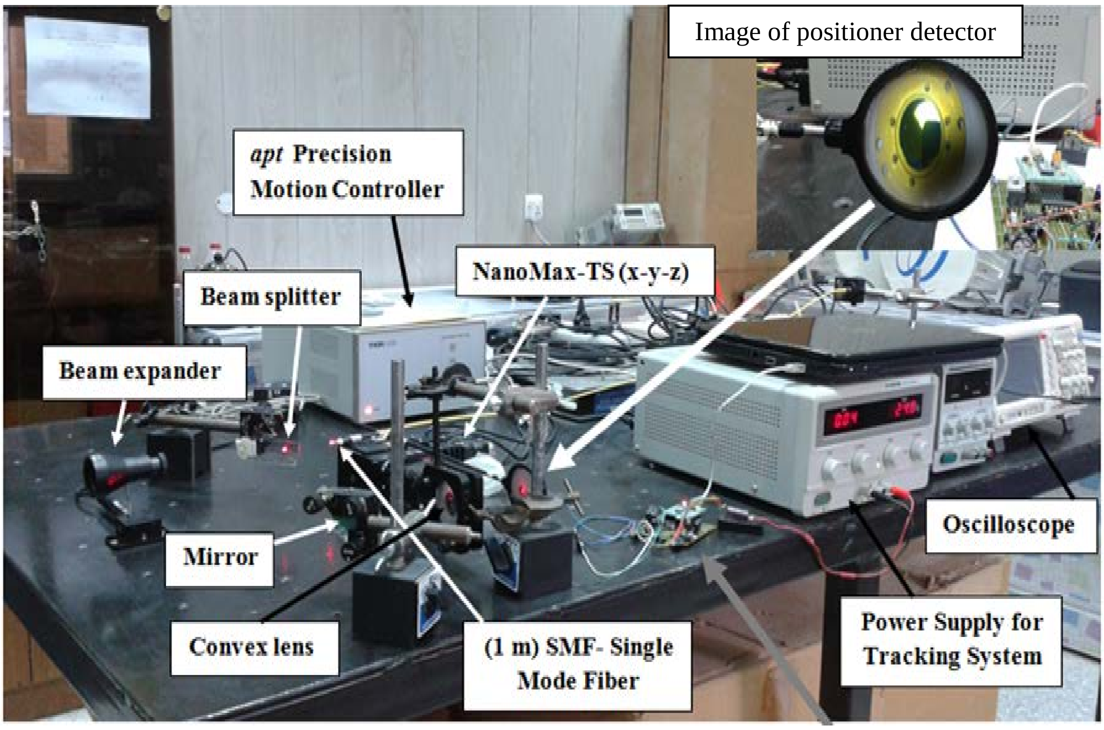

Fig. 3 Photograph of experimental setup of the F-FSO communication system.

A.The tracking System

The challenge in all- optical connection of FSO and SMF systems is not only to design an effective beam tracking and optical antenna alignment technique, but also an efficient method for focusing the light into the SMF at the receiver. Active tracking is required to maintain alignment of the received optical signal to the SMF. So the goal of our tracking system was to keep the location of received laser spot stationed within the surface of SMF and this is done by reading the information about the current laser beam spot from the tracking detector (PSDs) which connected with an tracking circuit, if the spot got lost by the fiber, the tracking model has to detect this error and recover the spot by a software programmer which orders the nano-station (NanoMax- TS) to change the optical fiber location in order to recover this error. The laser beam is usually pointed towards the dead center between the 4 PSDs and the beam diameter is selected to fit inside of the total PSD area. Although light falls on all four quadrants, the difference between the left and right quadrants (X output) and top and bottom quadrants (Y output) can be adjusted to zero voltage by centering the beam, whereas the SUM is at a maximum. The device X and Y output voltages thereby become very sensitive to slight deviations in the position of the beam from this initial centered setting. The SUM value on the other hand can be used to measure changes in the beam intensity, so this can be used to correct the X and Y output values for voltage changes that are due to intensity fluctuations.

The work of the electric circuit can be summarized by modification the laser signal receiving by the tracking detector (PSDs) and converts it from current signal to voltage signal by using operation amplifier (OPO7). Magnification the signal and isolated can be done by operation amplifier (LM324) to insert it to a microcontroller (PIC18F2550) in which its convert the signal from analogue to digital one through a (ADC channel). Finally, the signal will send to a computer through a (USB terminal). Figure (4) illustrated a block diagram for the tracking model circuit and in Figure (5) the circuit has been built.

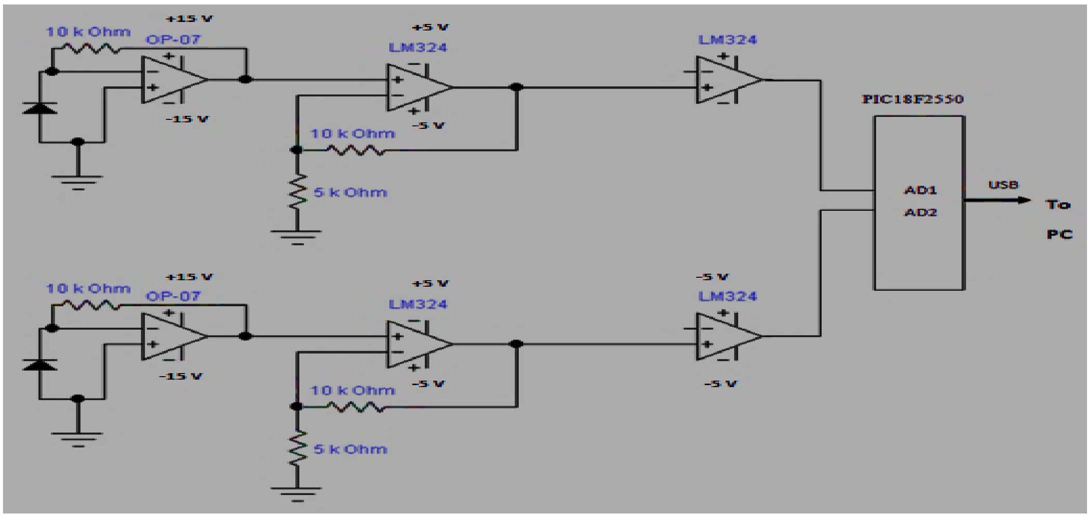

Fig. 4 Block diagram of the tracking circuit.

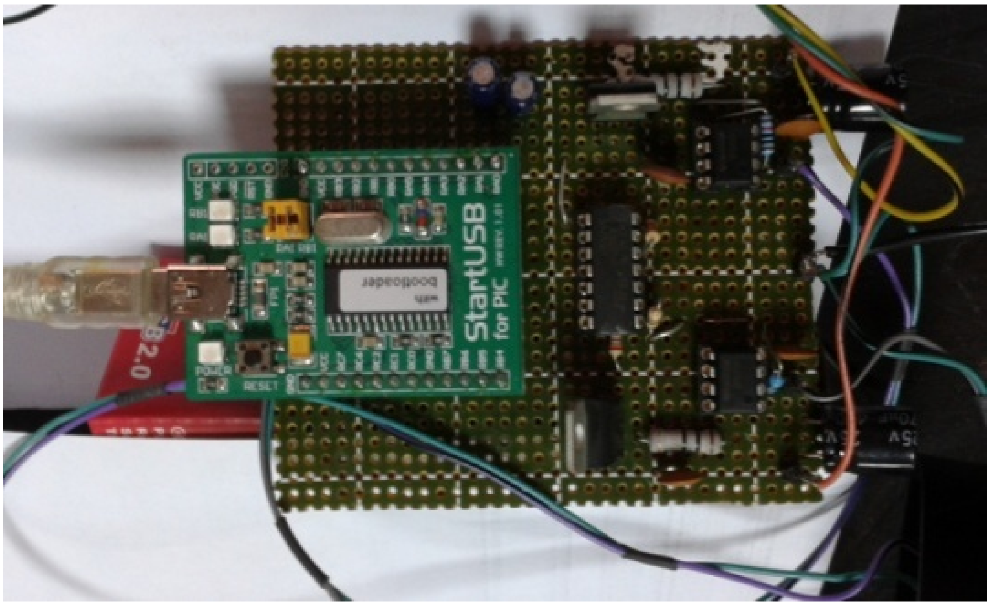

Fig. 5 The tracking circuit components.

B. Software Design

In order to control the movement of the SMF, one has to control the nano-max (x-y-z) lab jack. Computer programming software (by MikroC

PRO for PIC v.6.0.0 programming) has been designed to be a part of detection system when the power of the receiving laser beam decrease under the threshold power limit. As a result for the laser source movement, the software which is connected with the tracking system will order the nano-station to change the optical fiber location according to the laser spot to receive the maximum obtainable laser beam intensity. The receiving system software program consists from two parts: The first part controls the microcontroller (PIC18F2550) performance by using MikroC programming language. In this case the microcontroller reads the laser signal values from the tracking detector (positioned detector) then transform them to digital signals for transferring the data to computer through (USB) channel.

The second part, this part is related with the computer by using Microsoft Visual C++ language. In this part the program will receive the tracking detector data by the USB channel then performs subtraction between the values, if the difference in voltage was positive the engine which related to the nano-max (x-y) lab jack will motive to the right and so the SMF; on the other hand if the difference was negative so the engine will motive to the left until the value approaching to zero value which represents the maximum laser received power and in this case the engine will stop moving.

III. RESULIT AND DISSECTION

This system aims to control the deflection in the position from the maximum received optical signal that may be occur as a result of atmosphere turbulence also this system represent a convenient and compact receiver to overcome the Complexity in designing and construction of common free space optical communication system(past generation) alone.

In Figure 6 some examples and not the all to represent some of the value collected

From the tracking circuit and feed into the nano-max (x-y-z) lab jack to adjust the movement at the maximum received signal.

The upper left part of Figure 6(A, B, C, D, and E) represents the values of data we have got from ADC CH1 and ADC CH2 and the values of deference. Our built-in ADC convertor has 10 bit conversion so the maximum resolutions (STEP) in sampling are 1024 STEP. This mean that every step and since our controller operates at 5 volts which represent the $V_{reference}$ for the ADC convertor, so we can get 4.88 mV for every step in ADC conversion. In figure 6-A shows the position of maximum received power where the difference is zero. In figures 6 B (ADC1=9, ADC2=87, the deference=-78) and 6D (ADC1=9, ADC2=420, the deference=-411) have a negative deference values in which the movement of the light spot on the surface of the optical fiber is to left side from the maximum signal.

Also, in figures 6C (ADC1=96, ADC2=9, the deference=87) and 6E (ADC1=449, ADC2=9, the deference=440). The positive values here represent the movement to the right side from the maximum signal.

Fig.6 The representation of data obtained from ADC CH1 and ADC CH2

IV. CONCLUSION

This research represents an experimental attempt to describe and reported the design and operation of a Full- Free Space Optical Communication System (F- FSO) technology. The results showed the compatibility between FSO technology and optical fiber in one integrated system with the assistance of electric circuit system and computer programming to maintain the best received signal power. We have got a good and a precision coupling between the positioned detector and optical fiber movement which is controlled by beam tracking system consists of hardware and software also it is important to mentioned her that the role of the nano-max stage to response to any fine movement in the position of the signal at the surface of the optical fiber.

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