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The Impact of Oil Well Fires on the Free Space Optical Systems

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Abstract

Aerosol particles in oil fire plumes caused crucial air pollution. The smoke plumes from the blazes initially launched 200-400 m into the air and then continued to rise. The presence of liquid and solid aerosols may cause severe disturbance to the propagation of optical and infrared waves, thus can produce harmful effects on the wireless communication systems. In this paper, we analyze the bit error rate (BER), single to noise ratio (SNR), Q- factor and outage performance of single-input single-output (SISO) and multiple-input multiple-output (MIMO) FSO systems under attenuation of dense smoke conditions. Obtained results demonstrated that the performance of (SISO) FSO link is degraded from the Fog, Smoke and acid-rain Attenuation due to their chemical nature, their size and their concentration. As well, (MIMO) FSO link is a highly efficient way can be minimal smoke pollution effects.

Keywords: Air pollution, oil fire Aerosols, Free space optics and Q- factor.

الخلاصة

تسبب جسيمات الهباء الجوي في أعمدة حرائق النفط تلوث الهواء الحاد.كما أن لهيب الدخان المتصاعد من الحرائق يرتفع في البداية ٢٠٠-٤٠٠ متر في الهواء ثم يستمر في الارتفاع. قد يتسبب وجود الهباء الجوي السائل والصلب في اضطراب شديد في انتشار الموجات البصرية وموجات الأشعة تحت الحمراء ، مما يؤدي إلى آثار ضارة على أنظمة الاتصالات اللاسلكية .في هذا البحث ، نقوم بتحليل معدل أخطاء البتات (BER) ، ونسبة الإشارة إلى الضوضاء (SNR) ، وأداء العامل Q والجهد للإخراج أحادي الإدخال (SISO) والأنظمة FSO ذات المخرجات المتعددة (MIMO) متعددة المدخلات تحت توهين ظروف الدخان الكثيف.وقد أظهرت النتائج المستخلصة أن أداء نظام الربط FSO (SISO) تعاني تدهورا بسبب الضباب والدخان والامطار الحمضية بسبب طبيعتها الكيميائية وحجمها وتركيزها .كذلك فان نظام الربط FSO (MIMO) هو وسيلة فعالة للغاية يمكن أن يقلل من آثار التلوث الدخاني الى الحد الأدنى.

Introduction

Air pollution is one of the most disturbing atmosphere problems around the world, can produce harmful effects on human and his environment. Some pollutants are a result of human activity. Natural pollutants are occurred in nature or are rose from natural sources. Air pollutant is any smoke, soot, fly ash, dust, dirt, fume, non-naturally occurring gas, odor, toxin, or radioactive substance happening within an environment [1]. The smoke plumes from the oil burning primarily rose 200-400 m into the air and then continued to rise and disperse laterally downwind. The concentrations of accumulation-mode particles in the smoke were -45,000 cm^{-3} at 1.5 km from the fires, and they remained as high as -4,000cm^{-3} after an hour or more of travel time downwind. Total particle mass loadings in the plumes were over 1000 µg m^3 near the fires [2]. Another potentially deleterious effect of the in burning of crude oil is reduction in atmospheric visibility.

Smoke from petroleum products generally contains high concentrations of condensation nuclei. However, due to their hydrophobic nature, only a small percentage of the initially may be active as cloud condensation [3, 4]. This process has great effects on the environmental cycle and causes its decay [5]. The oil consists of a mixture of hydrocarbons [6]. Air pollution causes harmful effects that disrupt this ecological balance [7]. Air pollutants effect depend on their concentrations, dosages, exposure times and other factors [8]. Anthropogenic sources of aerosols are mainly due to oil wells burning, fossil fuel combustion, energy plants and other industrial activities.

A Free-Space Optics, also known as “FSO” or “Optical Wireless”, can be used to transmit optical data, voice and video information. FSO can be used by petroleum companies and other adjacent companies. Signal attenuation from smoke and fire can affect system performance [10, 11]. Our work focus on the performance of the FSO units in different levels of oil fire smoke and intermittent flames. Two techniques, single-input single-output (SISO) and multiple-input multiple-output (MIMO) FSO systems will serve as a benchmark for the performance analysis under attenuation of dense smoke conditions. The SISO and MIMO constructions are modeled by using (OptiSystem7.0) software.

Figure 1: Thick clouds of smoke blocked out the sun for months from the oil fire in Qayyarah (Iraq) 2017[9]

Materials and Methods

The dense smoke and acid-rain that rise from oil fires influence the FSO channel which can lead to signal loss and link failure due to their chemical nature, their size and their concentration. Proper measures should be used in transmitter and receiver designs under certain conditions of atmospheric pollution. The first step in designing a wireless communication system in different media channels is to know what happens to an optical signal as it travels through that medium. By using (Opti-System version 7.0), simulation of FSO links have been designed and divide into two parts: First we design the (SISO) Link at convenient operating parameters such as 1.5Km channel length, a wavelength of 1550 nm, PRBS (Pseudo Random Bit Sequence) generator, NRZ pulse generator, a laser source and MZM (Mach Zehnder Modulator). In the simulation, data generated by the PRBS generator at 2.5Gbps are encoded and light modulated using MZM where the laser source acts as the carrier source, the laser is Pass through the one air channels in free space, to be supplied the air channel capacity of approximately 30dBm.

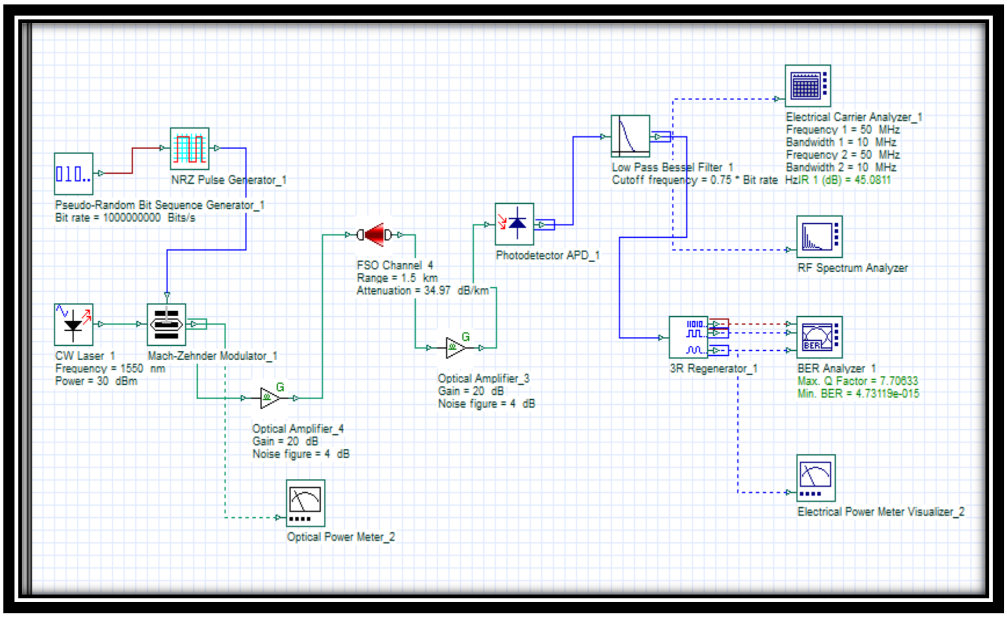

Figure 2: Simulation layout of 1TX/1 RX (SISO) FSO system.

The apertures of the transmitter and receiver are set to 2 cm and 10 cm and the beam divergence is 2 mrad. The full design can be shown in Figure 2.

The second simulation is done by using (MIMO) technique as shown in Figure 3. Four channels (4TX/4 RX) are used in MIMO link. The Fork is used for duplicating the input beam to all the channels, linked to this circuit with the main circuit through power combiner and more details are illustrated in Figure 3.

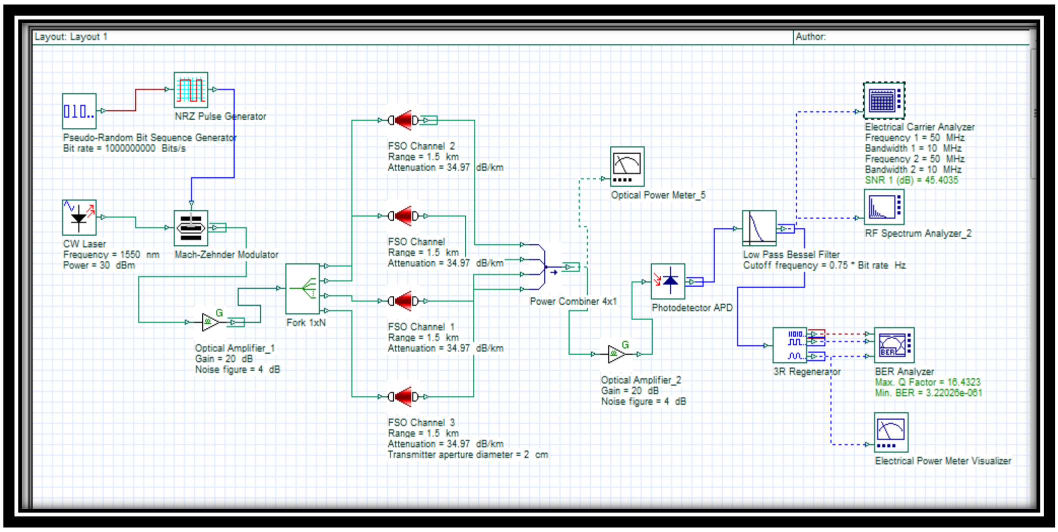

Figure 3: Simulation layout of 4TX/4RX (MIMO) FSO system.

The optical signals from the FSO channel are received by (APD) photo detector. These simulations use three visualizers namely optical power meter to measure the power received in both dBm and Watts, optical spectrum analyzer which provide the facility to analyze the optical spectrum, finally BER analyzer automatically calculates the BER value, Q-factor and display eye diagram.

Results and Discussion

It's necessary to consider in details the characteristics of the smoke plume influence optical propagation between two points. Therefore attenuation coefficient, received optical power, SNR, BER and Q-factor under the effect of smoke (heavy fog) and rain-acid arise from oil fires [12, 13]. Infrared laser were employed with parameters given in Table 1. The obtained results of heavy fog are shown in Table (2) for the individual communication system (SISO) and the quadruple system (MIMO) at a distance of (1.5Km). It illustrates increment in the receiving power, increases the Signal-to-noise ratio, BER goes on decreasing, as well as gets the highest percentage of Q-factor and thus increases the performance of the system by using the (MIMO) technique.
Table 3 also shows comparison between (SISO) and (MIMO) techniques by adding the effect of moderate acid-rain to the previous situation of the weather condition. These results also confirmed the results of table 2. Figure 4 shows eye diagram for the two system (SISO) and (MIMO) under same condition (heavy fog), as its show MIMO technique have a higher Q-factor that mean its work better than SISO.

Table 2: Compares results of (SISO) and (MIMO) techniques under Heavy fog.

Heavy fog	Received power (dBm)	SNR (dB)	BER	Q-FACTOR
SISO	-38.329	45.0811	4.73119E-15	7.70633
MIMO	-48.382	45.4035	3.22026E-61	16.4323

Table 1: System parameters which used in this simulation.

Parameter	Value
Transmitter optical power (dBm)	30
Transmitter divergence angle (mrad)	2
Transmitter efficiency	0.5
Receiver sensitivity (dBm)	-20
Wavelength (nm)	1550
Receiver diameter (cm)	10
Receiver efficiency	0.5

Table 3: compares results of (SISO) and (MIMO) techniques under Heavy fog with acid-rain.

Heavy fog with acid-Rain	Received power	SNR (dB)	BER	Q-FACTOR
SISO	-50.981	41.5994	2.23788E-8	5.42637
MIMO	-42.418	42.7595	4.42786E-35	12.2633

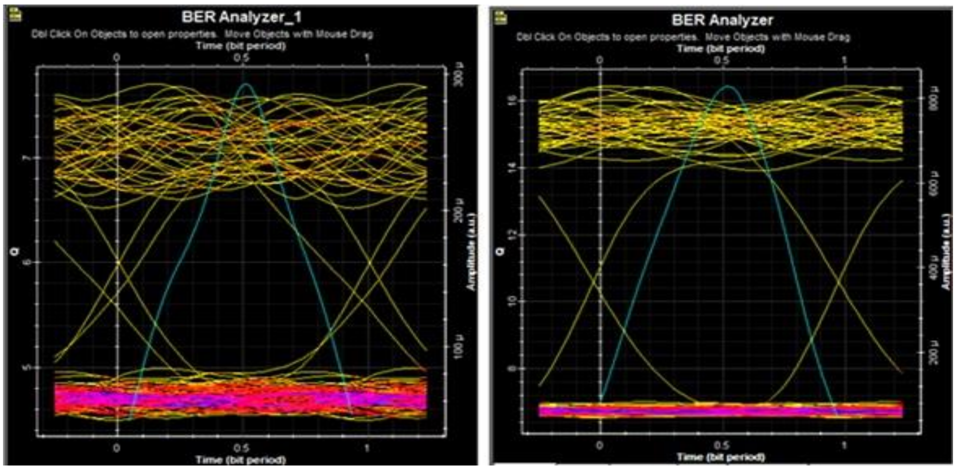

Figure 4: Compare eye diagram under heavy foggy weather (a): SISO, (b): MIMO.

Conclusion

The performance of (SISO) FSO link is degraded from the Smoke (Fog) and acid-rain Attenuation due to their chemical nature, their size and their concentration. As well, (MIMO) FSO link is a highly efficient way can be minimal smoke pollution effects. The results presented in this paper are helpful for designing a wireless communication system stable for regions suffer from frequent Oil well fires.

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