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## New Modulation Method in FSO Communication Using Different Wavelengths (650,532,405) nm in the Iraqi Weather

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### Abstract

The FSO technique depends on the compatibility of the optical path between the transmitter and the receiver (line-of-sight) to transmit data between two points. FSO system uses the light to provide optical Contact to send and receive various data. This study shows the design of a new optical system for the transmission of voice through free space at wavelengths (650,532,405) nm within point-point technology for specified distances. What distinguishes this work is the quality of the reflection-based modulation based on the Doppler phenomenon. Also, it is interested in studying the different attenuation conditions of the atmosphere at the wavelengths used, in addition to the attenuation caused by the large laser beam divergence for distant distances. This study shows the quality of modulation used under different weather conditions and is characterized by very low cost and high efficiency for power sent.

**Keywords:** FSO, laser communication, optical wireless, weather attenuation, modulation techniques.

## أسلوب التضمين الجديد في الاتصالات FSO باستخدام أطوال موجية مختلفة (650،532،405) نانومتر في الطقس العراقي

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### الخلاصة

أن تقنية نظام FSO تعتمد على التوافق البصري للمسار بين الأرسال والاستقبال (خط البصر) لنقل البيانات بين نقطتين. يستخدم نظام FSO الضوء لتوفير اتصال بصري لأرسال واستقبال البيانات المختلفة. وتبين هذه الدراسة تصميم نظام بصري جديد لنقل الصوت عبر الفضاء الحر عند أطوال موجية (650،532،405) نانومتر ضمن تكنولوجيا نقطة نقطة لمسافات محددة. ما يميز هذا العمل هو نوعية التضمين المبنية على الأنعكاس أستنادا إلى ظاهرة دوبلر. كذلك تهتم بدراسة ظروف التوهين المختلفة للغلاف الجوي للأطوال الموجية المستخدمة، بالإضافة إلى التوهين الناتج عن تباعد شعاع الليزر الكبير للمسافات البعيدة. وتبين هذه الدراسة جودة التضمين المستخدم في ظل ظروف الطقس المختلفة، ويتميز بتكلفة منخفضة جداً وكفاءة عالية للطاقة المرسله.

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## 1. Introduction

There is long list of uses of lasers, but the one which has received great attention from the days are the possibility of the laser in the development of a high-density communication system [1]. Free space optical communication (FSOC) grants the user, high bandwidth. FSO uses light to carry information through the free space that acts as a channel for signal transmission. The FSO system can provide data rate in the range 100 Gb/s and can transmit different data at a distance ranging from 1 to 4 km [2]. For this reason, many methods of modulation have been developed and are still under development. A laser beam in theory can be modulated in frequency, amplitude and pulse code [3-5]. The probability of the formidable number of channels which can be transmitted on a single carrier at these high optical frequencies along with the accompany features of high degree of coherence, mono-chromaticity, small beam divergence and the accurate angular resolutions attainable with antennae of quite small physical distance suggested laser as ideally appropriate for communication applications [1,6].

This work suggests a short-range optical communication system design in free space using laser beam within the electromagnetic spectrum of visible light (650,532,405) nm as a means of communication. Communications technology within the visible region of the available components at low cost and large modulation efficiency [7, 8, 9]. The system is designed as an optical point to point technology (laser diode) up to 200 m. And can supply free space for wireless transmission of voice or information signal.

## 2. Modulation Techniques

We can modulate the carrier wave by frequency, phase, and amplitude modulation; add to other digital methods such as pulse modulation. Amplitude modulation with direct detection and phase modulation most commonly systems used because it is simpler in implementation.

### 2.1. Amplitude Modulation

The amplitude configuration (AM) is the modulation technique used in electronic communications and is more generally used to transmit data across the carrier that is a radio signal. The operation is done by continuously changing the amplitude of the wave in proportion to the data transmitted [10].

### 2.2. Frequency Modulation

The FM frequency modulation is significantly different from the AM amplitude modulation techniques. The main difference is the amplitude mechanism that changes in the linear configuration according to the information signal and constant in the exponential modulation. Therefore, in exponential modulation the frequency of the carrier changes according to the signal of information over time [11].

### 2.3. Pulse Modulation

Consists basically of sampling analog information signals and then converting those samples into separate pulses and transporting the pulses from a source to a destination over a physical transmission medium. The four dominant methods of pulse modulation (pulse width modulation, pulse position modulation, pulse amplitude modulation, pulse code modulation).

#### 2.3.1. Pulse Code Modulation

The analog signal is sampled and then converted to a serial n-bit binary code for transmission (i.e, 1s for the high signal and 0s for weak signal). Each code has the same number of bits and requires the same length of time for transmission. It produces a series of digital or numbers this process is called digital [12].

## 3. Issues related to FSO

The various issues related to FSO are atmospheric attenuation due to (scattering, absorption and scintillation), as well as attenuation due to geometric losses. These standards affect the performance of the system [13, 14]. The search is going on to make the system more efficient and accurate.

### 3.1. Atmospheric Attenuation

The FSO communication link requires a good understanding of the atmosphere because the laser beam spreads across atmosphere. The atmosphere not only reduces the intensity of the optical wave but generates distortions and bends to those beam. Attenuation primarily occurs as a result of absorption and scattering due to atmospheric molecules and particles (aerosols) that significantly reduces the ability of the transmitted optical signal [15]. The attenuation in the atmosphere is given by the law (Lambert-Beers) as follows [16]:

$$T = \exp(-\alpha L) \dots\dots\dots(1)$$

Where:

T: The atmosphere transmittance.

$\alpha$  : The extinction coefficient.

L: The path length (distance between transmitter and receiver).

The atmosphere attenuation (A) is due to the transmittance (T) expressed in the decibel scale as follows [17]:

$$A_{10}(L,V) = -10 \log [ T( L,V) ] = -10 \log ( \exp (-\alpha L) ) \dots\dots\dots (2)$$

Where:  $A_{10}$ : The atmosphere attenuation (dB).

**3.2. Scintillation**

Atmospheric scintillation can be defined as changes in light intensity at time and space at the receiver that detects the optical signal. The signal received at the detector fluctuates because of changes in the refractive index that result from changes in air temperature along the transmission path. These changes in the index make the atmosphere work as a series of small lenses that deform parts of the beam of light to and from the prepared transmission path [18]. The effect of scintillation on the optical signal is higher when the day temperature is at the maximum level, usually occurring during midday [19]. FSO systems operate horizontally in the atmosphere near the surface (in case of terrestrial links), which suffer from the maximum scintillation possible.

**3.3. Geometric Attenuation**

Geometric losses are those losses caused by the propagation of the laser beam between transmitter and receiver. Typically, the beam is spread over a larger size than the receiver slot and leads to a loss in the received power. Generally, larger receive apertures and the smaller transmit divergences of the release of the laser beam in the transmission results in less engineering loss for a given range [2,20].The geometric loss of the FSO of the transmitted beam can be calculated as follows [21]:

$$G = 10 \times \log \left[ \left( \frac{d_r}{d_t(D \times R)} \right) \right] \dots\dots\dots (3)$$

where:

G: The geometric loss (dB).

$d_r$ : The diameter of the receiver aperture (m).

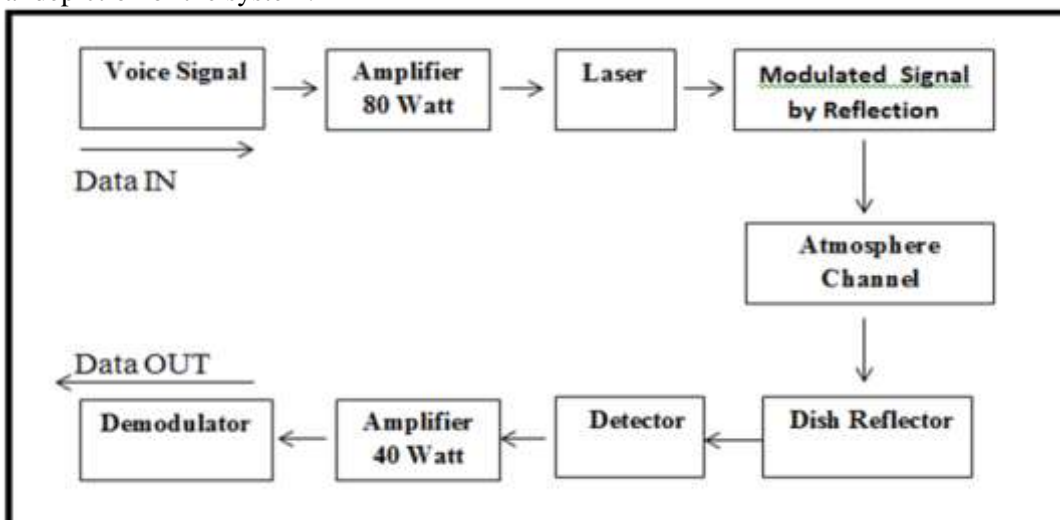
$d_t$ : The diameter of the transmitter aperture (m).

D: The beam divergence (mrad).

R: The distance between transmitter and receiver device (km).

**4. Experimental Setup**

In this section, we will explain how to design the FSO system using different wavelengths (650, 532,405) nm for voice transmission by reflection phenomenon across the atmosphere. The proposed system consists of a microphone that transmits sound to an 80-watt audio amplifier connected to speaker in transmitter with another 40-watt amplifier in the receiver by optical link over point-to-point technology. The speaker is responsible for modulation and transmitting the sound by reflection based on the doppler phenomenon and this is done by gluing a level mirror on speaker. Figure-1 shows the general depiction of the system.



**Figure 1-**Block diagram of the experimental set-up.

The modulation process is performed by using a loudspeaker when paste flat mirror on the loudspeaker to load the sound signal on the laser beam. When the speaker vibrates during the sound output, the mirror will vibrate same frequency. And when the laser beam falls on the mirror, the laser beam will be reflected with these frequencies based on Doppler phenomenon. This type called frequency modulation. Figure-2. shows the modulation by reflection.



**Figure 2-Reflection modulation.**

What distinguishes this type of modulation, which is based on the phenomenon of reflection, when compared with other modulation methods is the very low cost and high efficiency and the reason is due to the noise within the electronic circuit in other modulation methods.

To determine the quality of the modulation used, the efficiency of each wavelength was measured for specified distances during the day and night. Then we analyze the results obtained under different climatologic conditions. The issues related to the impact of the most important weather factors on the light of laser in free space were also discussed.

## 5. Results and Discussion

In our proposed design we will discuss the quality of the modulation performance used for the optical link through free space under the effect of atmospheric attenuation conditions (absorption and dispersion), in addition to the geometric attenuation of the laser beam divergence that affects the signal transmitted performance, this problem was solved using a dish plated by Nickel Chrome to collect and concentration of laser beams to some extent on the optical detector. In this part we will discuss the performance of the FSO system for sound modulation by reflectors and its transmission in free space under different weather conditions. As well as, in order to compare the efficiency of each wavelength in order to determine the best value of the area.

In Figure-3, the efficiency of each wavelength was measured during the day for the distance under different weather conditions (temperature-25°C, wind speed-15km/h and humidity-35%). From the figure we observe excellence the wavelength efficiency the 650 nm. The low efficiency of the (532,405) nm wavelengths is due to the scattering caused by dust minutes in the atmosphere where shorter wavelengths are affected by scattering more than long wavelengths.

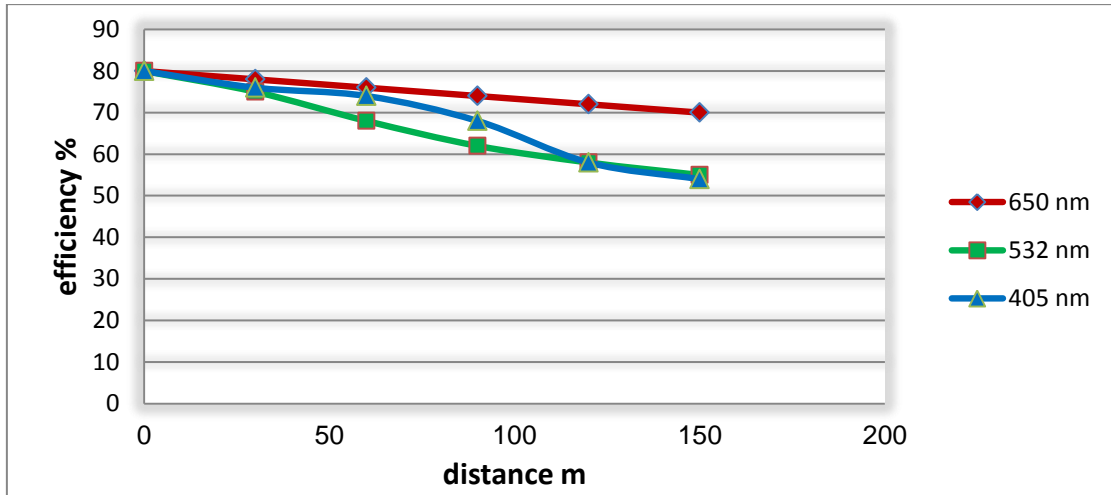


Figure 3-Efficiency % for (650,532,405) nm vs. distance m.

In Figure-4, the efficiency of each wavelength was measured during the night for distance under different weather conditions (temperature-20°C, wind speed-13km/h and humidity-44%). From the figure we observe excellence the wavelength efficiency of 650 nm. The low efficiency of the (532, 405) nm wavelengths is due to the scattering of dust minutes in the atmosphere as well as the absorption of water vapor.

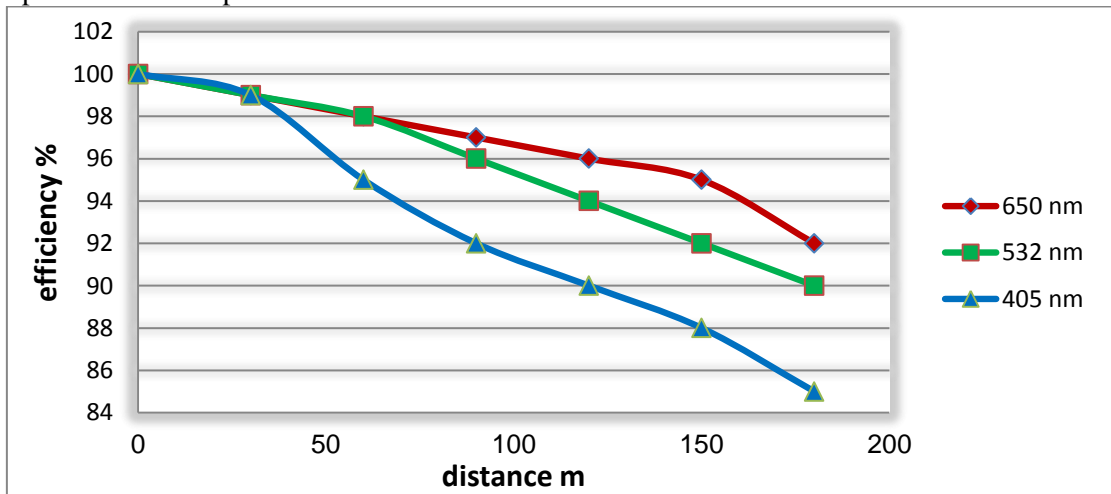


Figure 4-Efficiency % for (650,532,405) nm vs. distance m.

In Figure-5, the efficiency of each wavelength was measured during the day for a distance under different weather conditions (temperature-30°C, wind speed-11km/h and humidity-35%). From this figure we observe excellence the wavelength efficiency 650 nm.

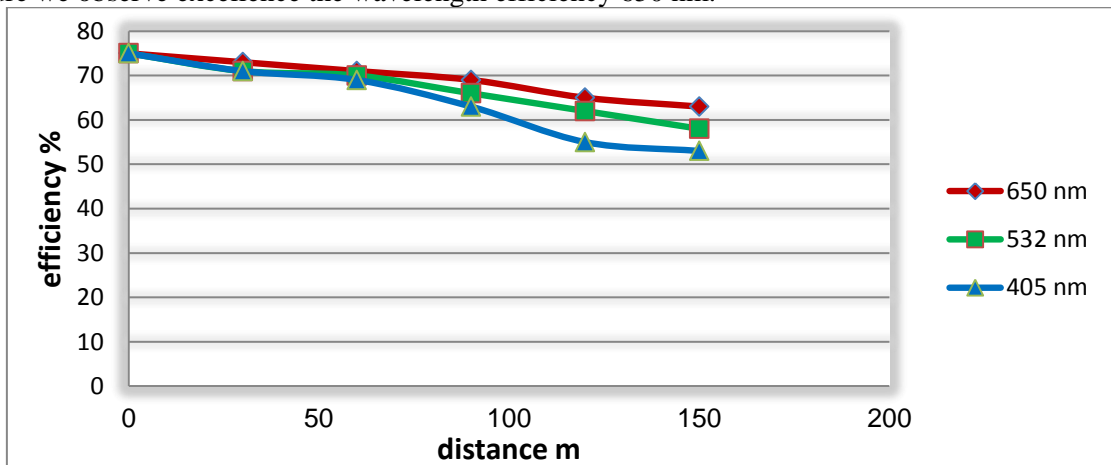
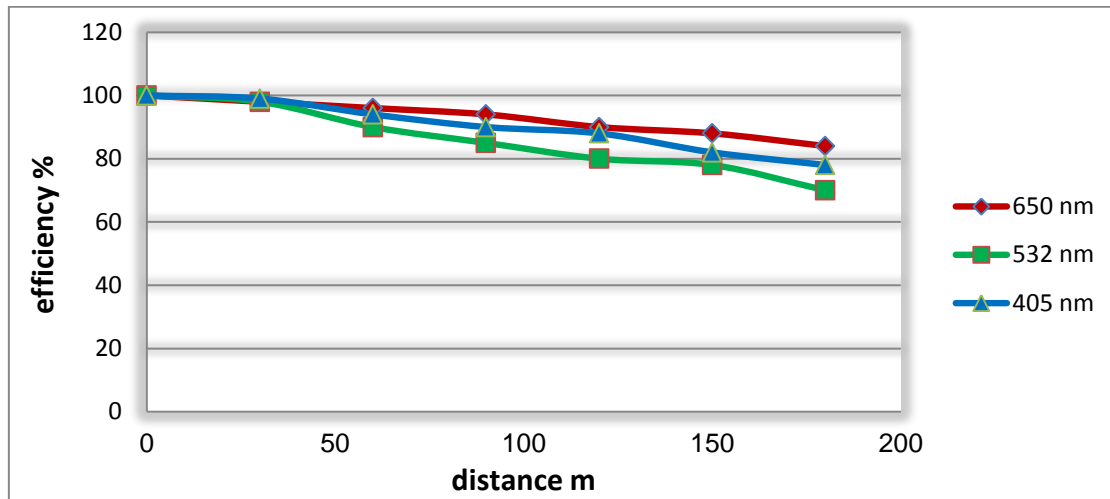


Figure 5-Efficiency % for (650,532,405) nm vs. distance m.

In Figure-6, the efficiency of each wavelength was measured during the night for a distance under different weather conditions (temperature-38°C, wind speed-17km/h and humidity-30%). From the figure we observe the efficiency of each wavelength was affected by temperature rise when compared to Fig.4. The reason for the efficiency of the 405 nm wavelength is greater than the 532 nm wave due to the small laser beam divergence angle. From the figure we can see the excellence efficiency the 650 nm wavelength because long wavelengths are less affected by different attenuation phenomena in the atmosphere.



**Figure 6-** Efficiency % for (650,532,405) nm vs. distance m.

From the previous drawings we note that the efficiency of the wavelengths used in working during the night better than the day and the reason for the impact of sunlight during the day where the interferes the infrared and visible light with laser beam and lead to a decrease in efficiency because of the difference in phase between them. We also note that increasing wind speed reduces atmospheric pressure and thus reduces the number of dust molecules affecting the dispersion process, thus improving transport efficiency. As well that efficiency transmission do not be affected too much in the rain compared to other conditions, the reason is that the rain radius is larger than the dust molecules, leading to the displacement of atoms from the atmosphere and thus saving lost energy due to dispersion and absorption. In addition, the large rain molecules do not remain long in the atmosphere, from here we conclude That attenuation due to the rain is a little compared to the fog .We also note that the scattering due to atoms and molecules of dust in the air where these impurities dislodging the light from the path leading to a significant reduction in the ability transmitted and received later and dust is one of the greatest effects in the low energy of the transmitted wave, especially for short wavelengths. It is known that the atmosphere of Iraq soaked in semi-continuous dust, so it is preferable to use long wavelengths in order to reduce this loss. Finally, we note the quality of the modulation used, which is highly efficient at different attenuation conditions.

## 6. Conclusion

In this study, we designed a optical communication system within point-point technique through free space for voice transmission by embedding the laser beam through the reflection phenomenon using wavelengths of (650,532,405) nm for a short range of approximately 200 meters under the influence of different weather conditions. This type of modulation Comparison with other complex modulation methods, where it is easily characterized by execution and at very low cost and high efficiency for signal sent. This is due to the use of plane mirrors to modulation laser beam, as well as the inverter dish to collect and focus the laser beam divergence for long distances. This study shows that the superiority wavelength of 650 nm under different attenuation conditions Comparison with other wavelengths. This is because long wavelengths are less affected by atmospheric attenuation phenomena.

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