Algorithm for Cosmic Noise Suppression in Free Space Optical Communications

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Abstract: This article describes an algorithm to reduce cosmic noise in free space optical communication system. This method is intended to increase communication system's performance and to increase the sustainability of the communication system by means of image processing technique. Apart from these, methods employed in testing the model are also presented for the communication system that uses either terrestrial or extraterrestrial medium to propagate message using optics or visible light without considering environmental impact that is turbulence, atmospheric absorption,beam dispersion and light intensity on its performance.

Keywords: Algorithm, Cosmic Noise, Free Space Optics, RGB colour code

1.INTRODUCTION

Free-space optical communication (FSO) is one of the most promising technologies for high speed digital communications. Though it is very promising it has certain backlogs in order to implement practically to full extent.

They are:

1) Inter-signal interference(Interference from background light sources).
2) Beam dispersion
3) Turbulence of the medium.
4) Atmospheric absorption
5) Shadowing,Rain&Fog

1.1 Turbulence of the medium

It is not possible to predict the light propagation when there is turbulence in the medium as there is no governing equations available in fluid dynamics for turbulent flows. It is sad even after 400 years of study on continuum mechanics still proper understanding of the turbulent flows is not yet completely achieved. Thus it would be difficult to estimate a generic performance or behavior of a communication system which is subjected to turbulent fluid field.

Though several organizations and institutes are conducting research on this particular issue it can't be said how turbulence in medium is affecting light propagation and why.

***1.2** Atmospheric absorption*

Atmospheric absorption mainly limits range and probability of success. So far available literature survey suggests that selecting proper bandwidth and range with appropriate light intensity at the transmitter end will enhance performance of the communication system.

***1.3** Shadowing,Rain&Fog*

Similarly shadowing,rain and fog can be overcome by choosing proper path and range. Rain & Fog causes effect of beam dispersion. The change in refractive index of medium due to presence of moisture or water. This will cause reflection and refraction of the message signals being transmitted. This article mainly emphasizes on cosmic noise or inter-signal interference noise of the FSO communication system and algorithm is presented for following characteristics of the system.

2. ASSUMPTIONS & REQUIREMENTS

***2.1** Assumptions*

However this algorithm is mainly developed for a communication system with the following assumptions:

• Communication is assumed to be extra-terrestrial or Terrestrial communication system.

• It is assumed that communication system does not have any turbulence in the medium or else the effect of turbulence is assumed to be negligible.

Eg: Li-fi, Aerospace communication systems,Interstellar communication system.

• Effect of light dispersion, decay in light intensity,shadowing and rain are negligible.

***2.2** Requirements*

To perform cosmic noise suppression in FSO the following requirements have to fulfilled. They are:

1) A FSO system with transmitter and receiver within the range.
2) Camera as receiver
3) Memory Unit
4) Control Unit
5) Reference valves(Predetermined values)

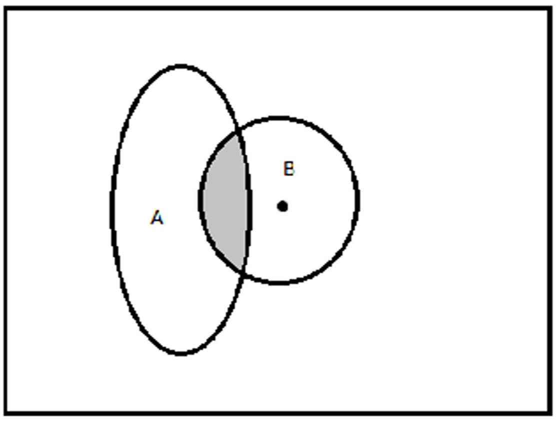

Fig. 1. Figure showing Range requirements of Transmitter and Receiver

This method is unlike photo detector reception system. Here a camera is used as a receiver in the systems. Free space optical communication generally uses photo detectors to perform demodulation but image processing techniques can be incorporated for better performance and accuracy. Free space optical communication is a line of sight communication and message is always transmitted as light rays[1]. Light rays can be detected by camera that are visible with in its range[1]. Hence image processing technique can be used to demodulate the message signal by using camera as receiver.

2.3 *Range of Transmission*

Both the transmitter(Tx) and Receiver(Rx) must be within Range. At the same time Range of Transmitter must be overlapping with range of receiver as shown in Figure.1.Here say A is the transmitter(Tx) and B is the receiver(Rx).

2.4 *Control Unit*

Data is collected as an image at reception. It may be subjected to cosmic noise or deviation. If it is affected by cosmic noise then corrections has to made computationally. As the received digital image contains m × n number of pixels which are just RGB colour codes(sampled values). Provided reference values and sampled values corrections can be made by control unit.

3. ALGORITHM

Once image is received(captured photograph) i.e a data packet is received at receiver(Rx) or data stream recorded for the entire duration of light emission i.e data stream which is stored in memory unit is processed[5].In case of recorded video(for stream line transmission),it is again splitted into frames or snapshots at regular intervals based on the intervals at which data is varying at the transmitter[5]. Now images are availed for further stages[5].

Stored data is subjected to an image processing software. Once the image is processed and corresponding RGB colour codes are obtained it is then noise suppression algorithm comes into picture[2][6].

While selecting pixels for sampling two types of samples has to be selected:

1) Message pixels:

These pixels have the message signal with some cosmic noise. The mean average of these pixels conveys the message signal. Lets say RGB colour code of any one pixel is (a_x,b_y).Here RGB colour code of corresponding pixel is designated in coordinate system with corresponding pixel notation and that mean value may be stated as S_f .Where i × j is number of pixels sampled and numerator represents algebric sum of RGB values for all the pixels in i × j.

$$S_f= \frac{\Sigma a_i,b_i+a_{i+1},b_i+.....a_i,b_{i+1}+.....a_j,b_j}{i\times j} \qquad (1)$$

If there are more than one signal or bit being transmitted as a packet then S_f may range from S_1 to S_n .

2) Ideal pixels:

Ideal pixels are those which does not carry any message in them but when processed they can give significant information regarding cosmic noise or inter-signal interference. Similar to the

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message pixels the mean value of the pixels are given as I_f .

$$I_f = \frac{\Sigma a_i, b_i + a_{i+1}, b_i + \ldots.. a_i, b_{i+1} + \ldots.. a_j, b_j}{i \times j} \quad (2)$$

However it is not mandatory to have number of message pixels is equal to number of ideal pixels. It is recommended that Ideal pixels have a RGB value nearly equal to [255-255-255]. This RGB colour code is colour code of white colour which reflects all visible spectrum. Thus it easy to detect any cosmic noise that interferes with message pixels causing change in the colour code of received message pixels at receiver end.

Evaluation of the data obtained by image processing is very important. Since demodulation and decoding is done at this stage only[6]. Based on the values obtained by image processing a logic evaluation of colours is done[2].Since transmitted lights are either red or green or blue only one of them has a decimal value rest are set to be zero[6].For a red colour red will have a decimal value where as green and blue are zero. Similarly for green and blue other two values will be zero corresponding to their colour. Though it is not exactly possible to obtain complete RGB colour codes of the transmitted light. The largest value among three RGB colour code values is considered to colour of the emitted light[2]. However, due to interference of noise decimal value to some extent may present in all three RGB colour code values which are neglected here. Therefore, the colour with largest decimal value is considered as transmitted light with certain tolerances. Tolerances and are determined by trail and error method prior to system setup.

***3.1** Reference values*

Reference values are predetermined RGB colour codes with tolerances for message pixels and ideal pixels. Tolerances are defined based on experimental data for certain light and environmental criteria.

Say RGB colour code for mentioned ideal pixels and message signals are :

$$I_r = [255 - 255 - 255] \pm \textit{Tolerances} \quad (3)$$

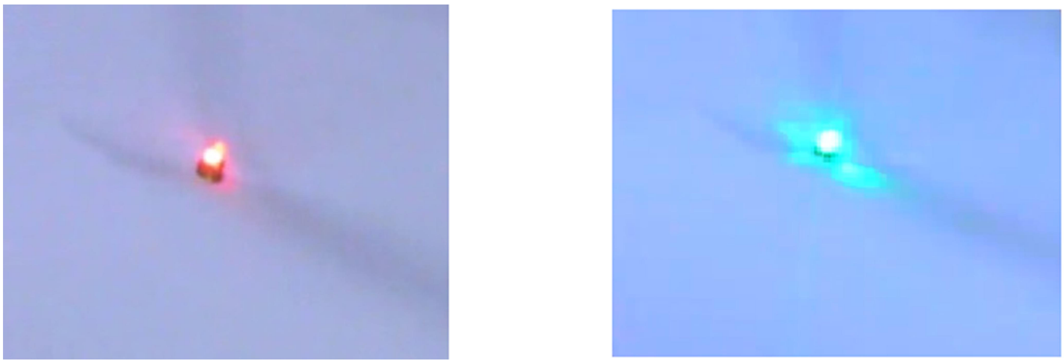
$$S_{r-R} = [250 - 75 - 75] \pm \textit{Tolerances} \quad (4)$$

$$S_{r-G} = [75 - 255 - 100] \pm \textit{Tolerances} \quad (5)$$

$$S_{r-B} = [75 - 95 - 255] \pm \textit{Tolerances} \quad (6)$$

Reference values shown in equations 4,5 and 6 are based on case studies performed. It is observed that various LED's which have capability to emit red,green and blue along with other colours in the visual spectrum has been manufactured and are available in the market. It is recommended to use light sources which emit primary colours in order to detect cosmic noise. Whereas for blue and green LED's manufacturing and performance is not extensively precise compared to red LED's. Hence red LED's are more recommended than green or blue for transmitting message through FSO.

Figure.2 illustrates two signals processed and their RGB values obtained through a program written in 'C'.



(a) Case I *(b) Case II*

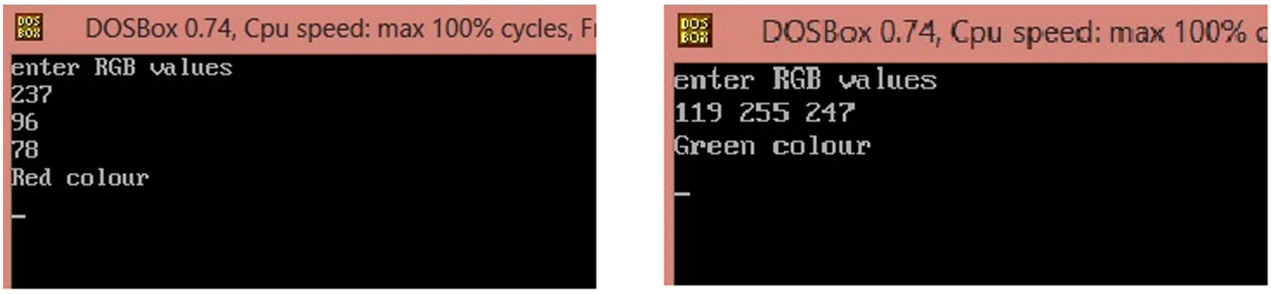


Fig. 2. Illustration of difference between green light and red light light detection

3.2 Corrections

Correction to message pixels can be stated as the difference between the reference values and the sampled values of the ideal pixels.

$$C_f = I_f - I_r \quad (7)$$

Here,

I_f is received ideal pixels RGB colour code,

I_r is reference ideal pixels RGB colour code

The correction C_f is performed on the message signal and compared with reference pixel values. If the corrected message signal is nearly equal to the reference value then message is successfully received or else it can be considered that transmitted message is lost.

$$S_r \pm Tolerances = S_{corrected} = S_f + C_f \quad (8)$$

Similarly condition for lost transmitted signal is

$$S_r \pm Tolerances \neq S_{corrected} = S_f + C_f \quad (9)$$

Here,S r is Reference message signal value in RGB colour code.

$S_{corrected}$ is Corrected message signal value in RGB colour code,

S_f is sampled message signal or received message signal value in RGB colour code,

C_f is correction value in RGB colour code

By using equations 8 and 9 cosmic noise can be suppressed in FSO system.

Corrections in this algorithm are typically altering colour codes and later verifying them whether these corrections are within the specific range or not.

When a background light source interferes with the light ray that is being received at the receiver end. Receiver / a camera typically experiences change in colour which can be corrected by removing the added colour.

To identify which colour is added and quantify the amount of excess colour on the digital image ideal pixels are used. Figure.3 shows the algorithm described.

4. CONCLUSION

The above mentioned algorithm can be used for cosmic noise suppression in FSO communications. However, if the intensity interfering light source is much higher than the intensity of transmitted message signal then receiver may fail to capture the image itself rather than to correct it. This problem is found to be very severe for receiver poor sensitivity. Further emphasis has to be done the above mentioned aspects along with beam dispersion, shadowing and rain or fog in the terrestrial medium such as air.

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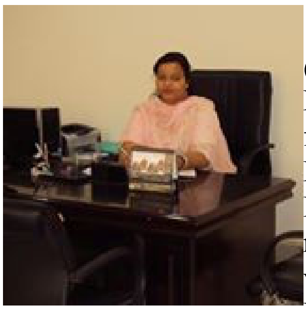

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