The Potential of Free Space Optics for Multimedia Content Transfer

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ABSTRACT: *Free Space Optics has capabilities to transfer multimedia content, and this work addresses this potential. This optical wireless communication has the potential to be used with features such as realization speed, and flow. Cost reduction is possible by using microwaves, telecommunication networks and optical network technologies so that all large, medium and small organisations benefit from them. Optical wireless/laser communication is used with modulated optical rays for developing wireless transmission. Traditional linear combinational techniques are employed for fading elimination, which is called the Selective Combining (SC) technique. It is based on the selection of a branch which is the most significant ratio of the mean power of the signal and the noise power, assuming that the power of the noise in all branches is equal. The MRC that is the Maximum Ratio Combining technique is viewed as equivalent to signal combination. The MRC is performed to enhance the efficiency.*

Keywords: FSO, Diversity, SC, EGC, MRC, SNR, BER

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1. Introduction

Mobile communications have been developing rapidly in recent years, as well as wireless channel models that are used to describe different effects. Laser wave propagation is a very complex phenomenon. If a sufficiently small wavelength of laser waves is assumed, their propagation obtains the form of the expansion of optical beams. Geometric optics separates several basic phenomena of expansion such as diffraction, scattering, transmission, reflection, refraction, and absorption. Diffraction is the bending of waves around an obstacle whose dimensions are significantly larger than the wavelength, which allows the duplication of waves to the receiver even though there is no optical visibility with the transmitter. This effect is also known as the effect of shadow or shadowing. Scattering occurs when the laser wave encounters obstacles whose dimensions are comparable to the wavelength of the laser waves. This is a phenomenon similar to diffraction, except that the laser wave is dispersed in several directions. Therefore, this effect is difficult to predict. Transmission occurs when a laser wave hits an obstacle that is somewhat transparent to the laser wave. This mechanism allows the existence of laser signals inside buildings. Reflection occurs when a laser wave hits an object that is significantly larger than the wavelength of the incident wave. The reflected wave can increase or decrease the signal at the mobile station. In the center where there are many reflected waves, the receiving signal at one point is usually variable.

These factors, in combination with the others atmospheric turbulences, are responsible for the difference between the transmission and the reception power of the signal. Since there is optical visibility between the receiver and the transmitter, then the component of the signal that crosses this line is far more intense than the components obtained by scattering and therefore it can be described by Rician's distribution. Rician fading occurs when several low-power signals (different reflections) on the receiving antenna, are accompanied by a strong signal (direct wave) -LOS (Line Of Sight propagation conditions). Signal distributions will be observed, also in cases when a signal that can be described by Gamma Gamma distribution and Lognormal distribution is present. The coefficients of signal weakening in the free space environment will be calculated, the SNR and BER will be expressed, and the methods will be proposed to improve the characteristics of the system.

Due to the different refractive index of the atmosphere, the paths of laser wave propagation are curved. As a result, the coverage area is usually higher. The signal strength changes due to the variable refractive index. As there is often no direct visibility between the transmitter and the mobile station, the received signal is the sum of the signals resulting from the above described phenomena. Because of this, the receiving signal is often time and spatial-varying.

2. Diversity Techniques

Traditional linear combinational techniques will be used, that is the selective combining (SC) technique, which is based on the selection of a branch in which there is the largest ratio of the mean power of the signal and the noise power, assuming that the power of the noise in all branches is the same; a technique based on equalizing the phases in all branches of the receiver, equal to gain and signal combining from all branches (EGC - Equal Gain Combining) and the so called MRC (Maximum Ratio Combining) technique where phase equalization is performed as well as greater evaluation of stronger diversity signals with the subsequent addition of signals from all branches.

Statistical analysis of these processes, as can be seen in the paper, requires the development of mathematical models, their processing, and solution proposal by application of a very complicated mathematical apparatus, so that the basic goal of this paper, based on the obtained results of statistical analysis of the signals in the environment.

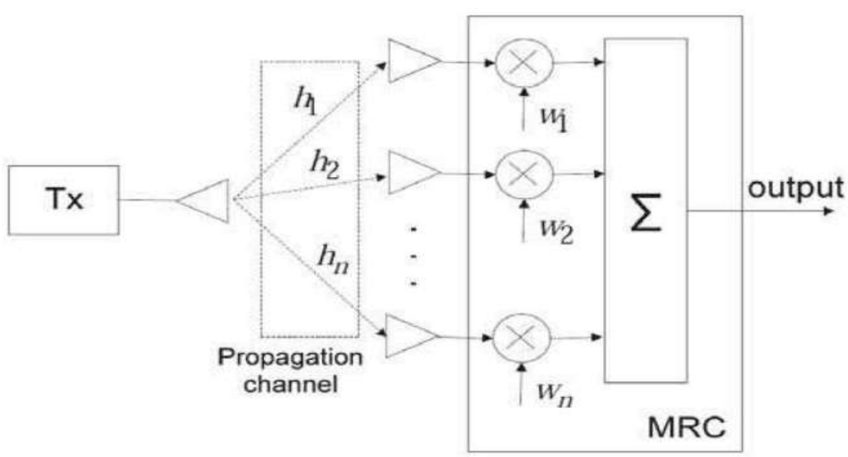

Figure 1. MRC Combining

2.1. MRC - Maximum Ratio Combining

MRC combiners use a linear combination of signals from coherent branches to maximize the output: signal to noise ratio SNR. MRC is the optimum linear multi-system signal combining diversity technique, which provides statistically best results in limiting fading effects. The signal in each of the branching branches is multiplied by an appropriate weight factor, equalizing the phases of all the signals, and with the greater contribution, the branches with the more favorable SNR ratio are taken, Figure 1. This results in a higher strength signal having a higher weight in, but it is therefore necessary to measure SNR ratio in all branches, which makes this technique a cost-effective set.

The following figure shows the SNR relationship depending on the number of receiving antennas, using the MRC technique, Figure 2.

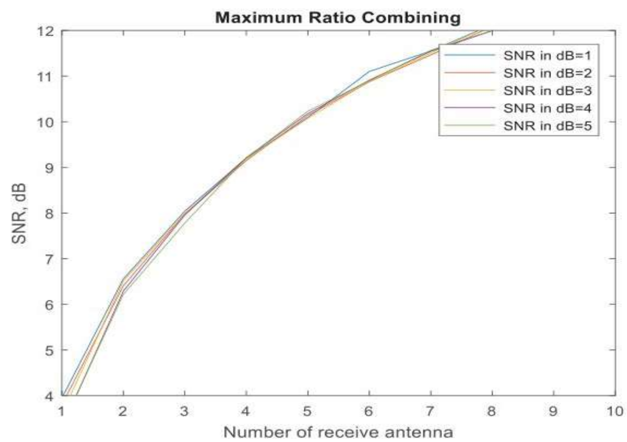

Figure 2. MRC Combining

2.2. EGC - Equal Gain Combining

In practice, such a scheme is useful for modulation techniques that have the same symbols energy (e.g., M-PSK) because the output signal is a linear combination of all the diversity branches, where those are in phase and are taken with the same weight. This kind of combination reduces the complexity of the receiver. When applying the EGC signal combining technique, the signal phase change over compensation is performed in all the different branches, so the signals are summed up. Unlike MRC techniques, all addends have the same weight factor, so no SNR measurement and estimation in all the different branches is required, making this technique simpler and cheaper for practical implementation. Prices are somewhat worse in relation to the case of MRC technique. In the simulation model of the EGC receiver, the reception signal is determined as the sum of the signals from the receiving antennas, whereby the phase compensation of the signal at the diversity branches was performed, Figure 3.

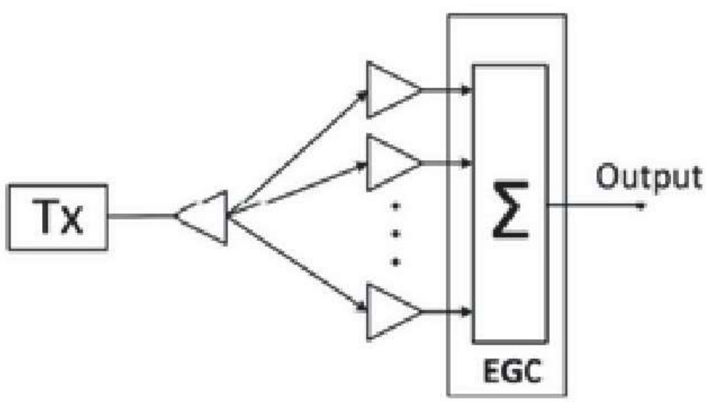

Figure 3. EGC Combining

The following figure shows the SNR relationship depending on the number of receiving antennas, using the EGC technique, Figure 4.

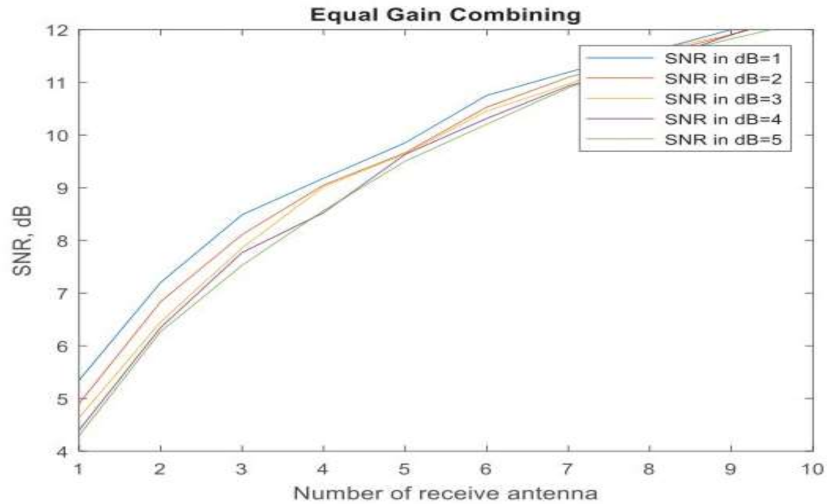

Figure 4. EGC Combining

2.3. SC - Selection Combining

SC combining means that in each given time period the signal will be received from the branch to which the signal / noise ratio SNR is greatest, Fig. 5. SC is the simplest and most commonly used combination signaling technology in a diversity systems based on the choice of branch with currently the most favorable SNR ratio. The SC receiver estimates the current SNR value in all branches and choose the one with the best SNR relationship. In the simulation model of the SC receiver, after the equalization of the received signal with the known complex channel parameter, the receiver selects the branch with the best relation SNR.

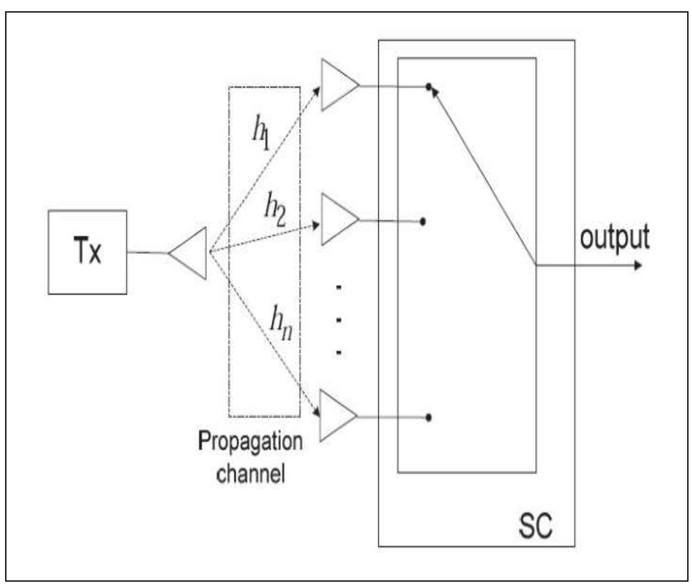

Figure 5. SC Combining

The following figure shows the SNR relationship depending on the number of receiving antennas, using the SC technique, Figure 6.

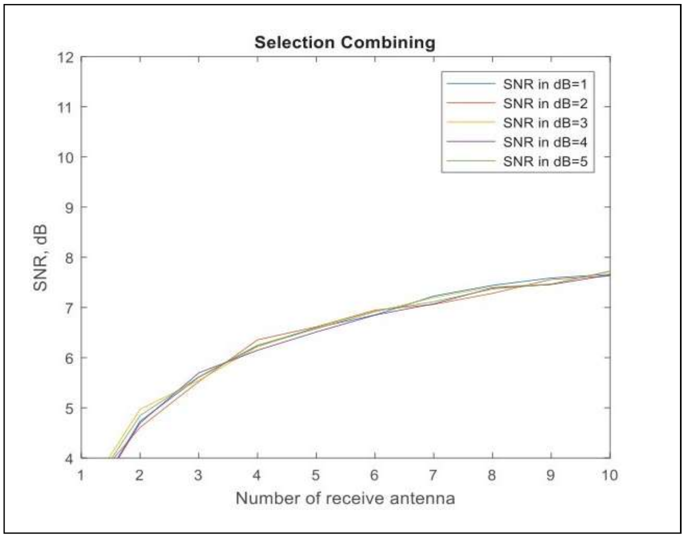

Figure 6. SC Combining

The analysis of the aforementioned various techniques shows that the best results are achieved by the MRC combining technique which for even a smaller number of receiving antennas offers a very favorable SNR ratio, Figure 7.

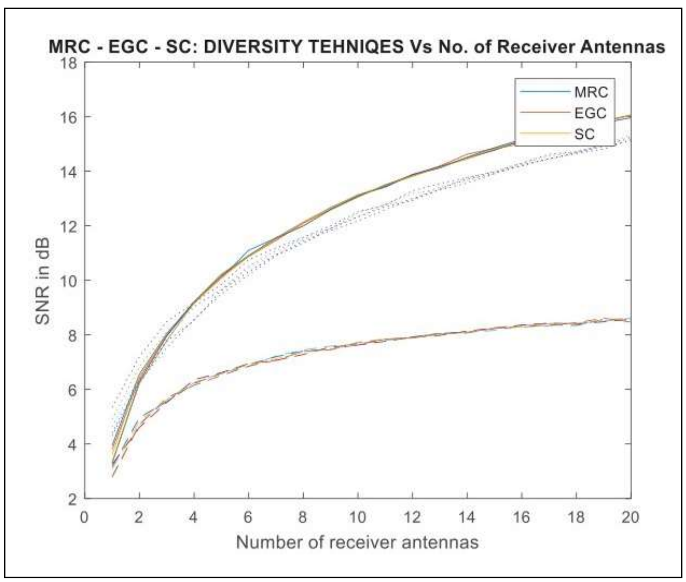

Figure 7. MRC, EGC, SC Comparation

3. BER Analysis

When there is no spatial diversity, the turbulence effect of the atmosphere results in a slow fading effecting for the symbol velocity through the channel. It is realistic to predict that the turbulent time of coherence is a great deal longer than two symbols time so that the demodulation of the DPSK of the programmed signal is possible. Direct detection of the wavefront on the receiver is used and sufficiently isolated so there is no correlation between them. BER for DPSK modulation can be written as:

$$P_{ec} = \frac{1}{2} exp\left(-\frac{1}{2} SNR_e\right), \quad (1)$$

SNR can be calculated:

$$SNR_e = (RAI)^2 / 2\sigma^2 \quad (2)$$

In the case of turbulence, the independent error value per bite is *BER Pe* = *E* [*Pec*] and is calculated using the Gauss- Hamilton quadrature integration:

$$P_e = \int_0^{\infty} \frac{1}{2}\, exp\left(-\frac{1}{2}\, SNRe\right) PI\,(I)\, dI = \frac{1}{2\sqrt{\pi}} \sum_{i=1}^{n} \omega_i\, exp\left(-K^2\, exp\left(x_i 2\sqrt{2}\,\sigma_i - \sigma_i^2\right)\right) \quad (3)$$

$$\text{where } K = \frac{RAI}{2\sqrt{2\sigma^2}},\ \{x\}_{i=1}^{n} \quad (4)$$

represents zeros of the n-order Hamilton polynomial combination and corresponding weight factor. The mean value for BER for multi-branch system can be expressed as:

$$BER = \frac{1}{M} \sum_{i=1}^{M} Pe_i \quad (5)$$

We can now calculate and present graphically the error per bite. The figure represents the ratio of BER and normalized function $SNR = (RE\,[I])\, 2 / \sigma^2$. For $M = 1$, $n = 20$, and when I_0, and R are normalized for $\sigma^1 = [5.0, 2.0]$. The results show that the BER error is 10^{-6} and turbulence levels $\sigma^1 = 0.2$ and 0.5, DPSK modulation requires an additional ~1dB and ~1.5dB signal / noise ratio SNR respectively, comparing with the use of BPSK modulation. However, the complexity contained in adjusting the absolute phase using BPSK modulation has to be estimated in the narrow band of SNR amplification.With the figures in Figure 8, when a greater number of subcarriers $M = [1, 5, 10]$ and $\sigma^1 = 0.5$ were taken into account it can be concluded for the specified turbulence level that an additional signal / noise SNR ratio is needed, of course, to maintain the required bit error performance level. For example, in order to maintain a BER in the range of 10^{-6}, an additional SNR ratio of ~6 dB to ~14 dB and 20 dB is required only if *M* is increased from one to two.

A reasonable and very good approach to calculating BER in FSO systems is to take into account only the weakness of the signal that it suffers during propagation through the atmosphere (not taking into account signal waves and thermal processes that affect the signal, and taking into account the movement of the optical air through the atmosphere). Then, for BER we can write:

$$BER = \frac{1}{2}\, erfc\left[\frac{RPr}{2\sqrt{2\sigma^2}}\right] = \frac{1}{2}\, erf\,c\left[\frac{\sqrt{SNR}}{2\sqrt{2}}\right] \quad (6)$$

where *R* is the aperture of the detector, *Pr* is the optical power on the detector and s is the thermal noise occurring on the receiver. Typical configuration on the receiver is *R* = 1 *A / W* and the receiver's diameter of the receiver (optic) is 13 cm, the optical signal power on the transmitter is 10 mW for the 1 km link spacing. The graph based on these results is shown in Figure 8.

4. Conclusion

We have presented an expression for evaluating the SNR and BER using DPSK for FSO system with in weak atmospheric turbulence. We also looked into the performance of SC, EGC and MRC spatial diversity as a possible means of circumventing the effects of scintillation. From our results, we found that the use of MRC spatial diversity in very weak turbulence resulted in reduction of link margin by up to 20 dB compared with case when no spatial diversity is used. However, as turbulence increases, MRC start to pay off, resulting in ~30 dB link margin with two photodetectors. But due to randomly varying characteristic of turbulence we do not suggest the use of SC spatial diversity with DPSK modulation.

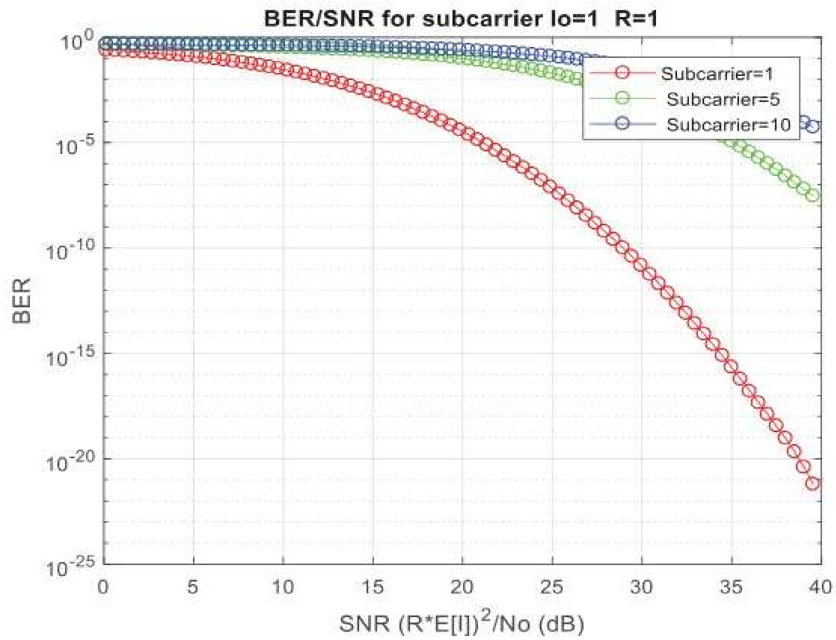

Figure 8. BER/SNR

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