



Relay-Assisted Free Space Optical (FSO) Communication with LDPC Coding and Convolutional Coding

Alina Sunny¹, K. Karunakaran Nair², Sudhi.S³

M. Tech Student, Dept. of ECE, Amal Jyothi College of Engineering, Mahatma Gandhi University, Kottayam, Kerala,
India¹

Professor, Dept. of ECE, Amal Jyothi College of Engineering, Mahatma Gandhi University, Kottayam, Kerala, India²

Assistant Professor, Dept. of ECE, College of Engineering and Technology, Kerala University, Kottayam, Kerala,
India³

ABSTRACT: Over recent last decades free space optical communication (FSO) has become more interesting and it can be seen as an alternative to radio frequency communication. FSO is a very long technology to fix the optical radiation that pass through the atmosphere from one point to other. Atmospheric turbulence induced fading is one of the main disadvantage that affects the Free Space Optical communication. Relay assisted Free Space Optical communication employing ON-OFF Keying (OOK) is employed as modulation technique. FSO communication is done in LDPC coding and convolutional coding are being analysed. The performance results are evaluated in terms of bit error rate (BER). It is found that relay assisted LDPC coded Free Space Optical system with OOK modulation technique provides higher performance.

KEYWORDS: Free Space Optics (FSO); Low Density Parity Check (LDPC); Decode and Forward Relay.

I. INTRODUCTION

Free Space Optical Communication (FSO) is a technology that gives better transmission of information as optical radiation through the atmosphere from one point to another point and viceversa. Basically, FSO involves the transfer of data or information between two points using optical radiation as the carrier signal through unguided channels. Today's FSO system use either lasers or LED to transmit a modulated beam of visible or infrared light. The data to be transported could be modulated on the intensity or frequency or phase of the optical carrier. For the exchange of information between the transmitter and receiver we are using Line Of Sight (LOS) technology where the transmitter and receiver can directly see one another without any block or disturbance in their path. The optical wave propagation through the air experiences fluctuations in amplitude and phase due to atmospheric turbulence.

FSO communication link have various advantages over conventional microwave and optical fiber communication system. The main feature of Free Space Optics technology is that it is having a huge bandwidth. In any communication system, the amount of data transported is directly proportional to the bandwidth of the modulated signal, and it can be up to 20 % of carrier frequency. By using an optical carrier where the frequency ranges from 10^{12} to 10^{16} Hz could allow data bandwidth up to 2000 THz. Therefore optical communication guarantees higher information capacity when compared to radio frequency based communication system.

Optical radiation is mainly known for its narrow beam size. When laser beam are used divergence because of limited diffraction will be between 0.001 mrad to 0.1 mrad, means the transmitted power is concentrated to very narrow area which provides FSO link with spatial isolation from its interferences. Interference from adjacent carriers is main problem when RF is used, to minimize this interference FCC in US and Ofcom in UK take strict rules to pay high fees



International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

and several months of bureaucracy when slice of RF spectrum is allocated. In FSO, optical frequency are free from all this, which implies that initial setup cost is lower and deployment time is also shorter.

The fog, smoke, and turbulence have a great impact on FSO links performances. Absorption, scattering, and refraction of optical waves by gas molecules, smoke, rain and fog which leads to severe attenuation of optical intensity. Irradiance fluctuation of received optical signal due to the turbulence present a severe problem which mainly leads to the variation of refractive index. This may lead to severe system performance degradation. The effect of turbulence can be overcome by using MIMO systems and also selecting a modulation format that is also immune to scintillation is also important. OOK modulation scheme are widely used in commercial FSO system because of their ease of implementation, bandwidth efficiency and cost effectiveness.

II. RELATED WORK

Several techniques to reduce turbulence-induced intensity fluctuations [1] that is signal fading. These techniques are applicable in the system in which the receiver aperture is smaller than the correlation length of fading and the observation interval is shorter than the correlation time of fading. Here, the receiver has no knowledge of the instantaneous fading state and the receiver knows only the marginal statistics of the fading. A symbol-by-symbol ML detector can be used to improve detection performance. If the receiver has awareness of the joint temporal statistics of the fading, maximum likelihood sequence detection (MLSD) can be employed, which gives a better performance improvement, but at the cost of very high complexity. Spatial diversity reception with multiple receivers can also be used to overcome turbulence-induced fading. ML detection in spatial diversity reception is used to reduce the diversity gain penalty caused by correlation between the fading at different receivers. The [3] gives performance of the free space optics system by employing three different modulation techniques. The modulation techniques are On-Off Keying (OOK) with Non Return to Zero (NRZ) and Return to Zero (RZ) modulation and Binary Phase Shift Keying (BPSK) technique which operating under turbulent condition. Here the received signal is used to characterize the strength of turbulence in channel. The temperature gradient within controlled channel results in turbulence of log radiance variance of approximately 0.02, which is very weak turbulence. The analysis shows that performance of BPSK is better than OOK-NRZ and OOK-RZ at the expense of bandwidth and power efficiencies. A cooperative free space optical amplify and forward relay is considered to deal with the main challenges that are fading and path loss [4]. The photon counting method is used to find the system bit error probability performance and study of system performance with the effects of atmospheric turbulence, variations in background light, amplified spontaneous emission and system thermal noise and comparison of the system with multiple transmitter (MT) system can also be seen. The performance of relay assisted system is much better than MT systems. Analytical approach is done to evaluate the bit error performance of an LDPC coded Free Space Optical communication employing On-Off Keying (OOK [5], Binary Phase Shift Keying (BPSK), Q-ary Pulse Position Modulation (QPPM) as modulation technique. LDPC coded FSO communication system with QPPM provides significant coding gain over uncoded system when compared with other modulation techniques. This [2] paper present the concept of relaying to FSO. The fading variance is distance dependent in FSO systems which constitutes a major difference between RF (Radio Frequency) and wireless optical system. Multi-hop FSO transmission can achieve shorter distance in hops and brings improvements against the degrading effects of turbulence induced fading. Artificial broadcasting is obtained with the use of multiple transmitter apertures directed to relay nodes in parallel relaying.

III. OVERVIEW OF EXISTING SYSTEM

Free Space Optical communication system which is assisted by Decode and Forward (DF) relay is considered. Figure 1 shows relay assisted FSO communication link employing OOK modulation.

A. Source

Source is the initial part of FSO system where the message originates and the data signal is fed to the modulator part. The source that produce the input data is then transmitted to the receiver with the help of transmitter and atmospheric channel.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

B. Modulator

The OOK modulation technique is used to modulate the input or source data into the electromagnetic wave. In this part the data signal is modulated with carrier signal so that it can be transmitted over the channel.

OOK modulation

To improve the BER performance of a FSO system that cause due to scintillation, selection of appropriate modulation scheme is the main factor that determines the overall system performance. On-Off Keying is simple and commonly adopted modulation scheme. In this transmitted 1 is on and transmitted 0 is off. In RZ (Return to Zero) format, each optical pulse representing bit 1 is shorter than bit slot, and its amplitude returns to zero before the bit duration is over. It is used for long distance transmission because of its higher peak power, high SNR ratio and lower bit error rate. RZ pulses always create distinct transition between encoded bits and hence create a clean optical signal to the receiver end to read. In NRZ (Non Return to Zero), the optical pulse remain on throughout the bit slot and its amplitude does not decrease to zero between two or more successive 1 bits. The main advantage of NRZ-OOK is that the bandwidth required with the bit stream is smaller than RZ. In the OOK system, the data sequence is converted to electrical signal [7] by

$$z(u, t) = \sum_{i=-\infty}^{\infty} d_i g(t - iT_s) \tag{1}$$

where d_i is the signal level for the i^{th} data symbol, T_s is the symbol time and $g(t)$ is the shaping pulse.

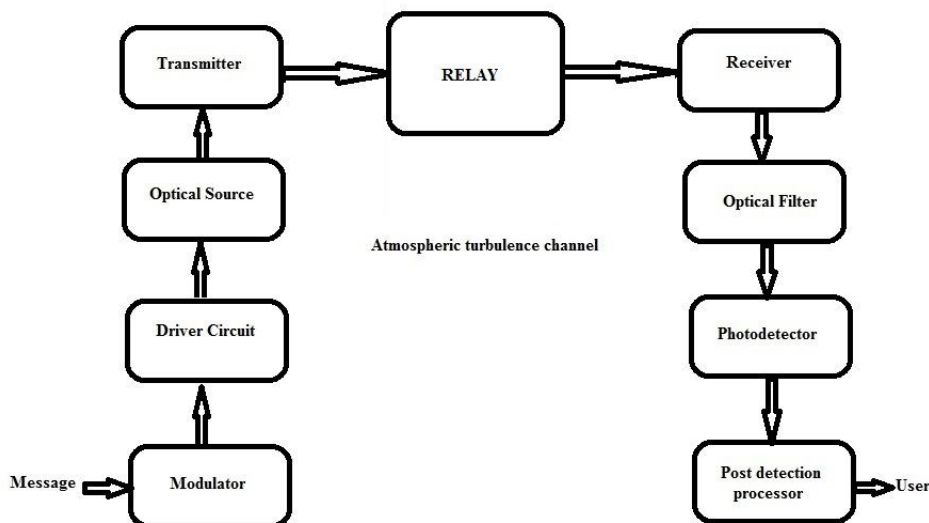


Figure 1: Block diagram of relay assisted FSO system

C. Transmitter and receiver

Transmitter modulates the data source into the optical carrier, which is then propagates through atmosphere to the receiver. The most commonly used modulation is intensity modulation, where the source data is modulated into the irradiance of optical radiation. The transmitter mainly used is telescope that collects, focus into narrow beam and then directs the optical radiation towards the receiver telescope at the other end of channel. The intensity of the transmitted beam [7] can be written as

$$s(t) = 1 + \sum_{i=-\infty}^{\infty} d_i g(t - iT_s) \tag{2}$$

The transmitter side, the encoding is done by convolutional coding and the data is interleaved to the filter block where the data is filtered i.e., the unwanted noise or signal that added during the reception and then transmitted. The majority of FSO systems are mainly designed to operate in 780nm to 850nm and 1520nm to 1600nm spectral windows. The 1550nm band is more attractive, that is 780nm band uses more power for transmission and it will finally affect the eyes, it is very harmful and also it can reduce the scattering in haze or fog environment.

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

At the receiver, the received signal after the optical to electrical conversion, the source beam is projected towards the receiver using an expanding telescope and the receiver is implemented based on P-I-N photo-detector. Optical band pass filter is used to reduce the amount of background radiation. The required amplification, filtering and signal processing is done by post detection processor which is necessary to guarantee the carried out data must be done with high fidelity data recovery. Then the output of this beam is transmitted to users.

D. Atmospheric channel

Atmospheric turbulence mainly caused due to the random fluctuation of the atmospheric refractive index along the path of optical field or radiation traversing the atmosphere. The random variations in atmospheric temperature from point to point is caused due to this refractive index fluctuation. Atmospheric turbulence mainly depends on i) atmospheric pressure or altitude ii) wind speed iii) variation of index of refraction due to temperature inhomogeneity. In the area of wireless communication, the loss in signal strength when it propagates through Line Of Sight (LOS) path in free space, with no obstacles nearby to cause reflection or diffraction is called Free Space Path Loss (FSPL) [10].

$$FSPL = \left(\frac{4\pi d}{\lambda}\right)^2 \quad (3)$$

where d is the distance between transmitter and receiver, λ is the wavelength (mostly used wavelength is 1550nm).

E. Convolutional Coding

The information and codewords of convolutional codes are of infinite length, and therefore they are mostly referred to as information and code sequence [9]. The encoding and decoding is done by trellis and viterbi state diagrams

IV. PROPOSED SYSTEM

Consider a high-energy dual-hop optical wireless communication system using intensity modulation with direct detection and On Off keying (OOK) modulation whose performance is limited by turbulence effect. Figure 1, shows the block diagram of Free Space Optical communication system with OOK modulation. The encoder and decoder configurations are given in Figure 2. Like any other communication systems, FSO systems mainly comprise of transmitter, channel and receiver. In addition to the basic parts, we are using Decode and Forward (DF) relay in between the transmitter and receiver to mitigate the effects of turbulence in channel.

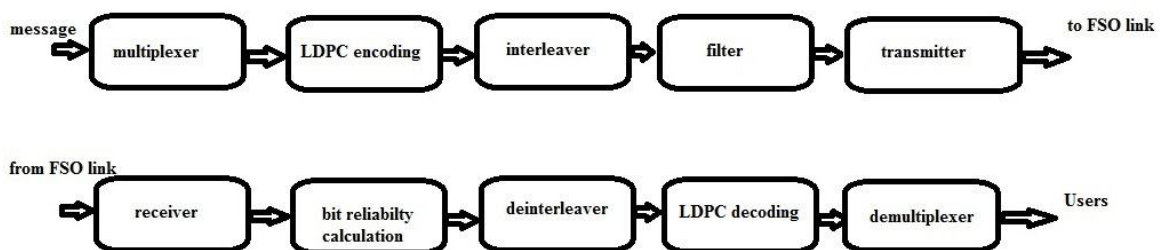


Figure 2: FSO transmitter side and processor configuration (LDPC Coded)

A. System Model

Block diagram of the proposed LDPC coded modulation with decode and forward relay is given in Figure 1, where the source are intensity modulated by the information source. The optical path may experience fading, the amplitude of the path gain as A_{nm} where the transmission is between the optical devices with distance MN , from source to detector. It transmits $L = \log_2 Q$ bits per symbol, which provides high power efficiency. The source stream coming from L source are encoded using $L(n,k)$ LDPC encoder of rate, $R = k/n$ where n is the codeword length and k is the dimension of the

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

component of LDPC code. The $m \times n$ block interleaver, collects the m code words written in row wise. The mapper receives m bits at a time from interleaver column wise and determines the corresponding slot for signaling. The total transmitted power is fixed and independent of number of lasers, therefore the emitted power is $P/\text{number of sources}$. This improves the tolerance to the turbulence that is affected in the system. At the receiver the received signal $r(t)$ after the optical to electrical conversion [11] is defined as

$$r(t) = \eta h(t) I_o + n(t) \quad (4)$$

where I_o is the transmitted light intensity, h is the channel fading coefficient and n is the receiver noise. The source beam is projected towards the receiver using an expanding telescope and the receiver is implemented based on P-I-N photo-detector.

B. Channel Model

The atmospheric free space optical channel is the medium for the outdoor optical wireless communication. The free space optical channel has a wide bandwidth. The reliability of the communication link can be determined if we use good probabilistic model. The wavelength of the signal (λ) is approximately 1.6 where visibility, $v > 50\text{km}$.

In an optical communication system through the turbulent atmosphere, the intensity $P(u,t)$ of the received signal [7] can be written as

$$P(u, t) = A(u, t) P_s(t) \quad (5)$$

where $A(u,t)$ is random process for the signal degradation due to atmospheric turbulence, u is an event in sample space and $P_s(t)$ is received optical intensity in the absence of turbulence.

C. Delay and Forward Relay

In Decode and Forward Relaying, Figure 3 shows the relay decodes the received signal and then modulates with optical power P , and if the received signal to noise ratio exceeds given decoding threshold it will transmit to the final destination. This threshold is used to avoid the error propagation. The total transmitted power, P_t is related to average transmitted optical power per transmit aperture, P can be defined as $P = P_t/2$. The channel gain [3] can be formulated by $g = \alpha^2 L$ (6)

where α is the turbulence induced fading amplitude and L denotes the normalized path loss with respect to the path between the source and destination.

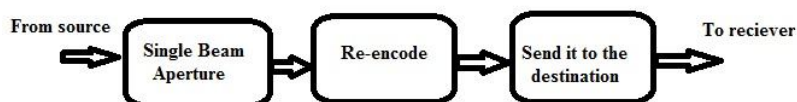


Figure 3: Block Diagram of Decode and Forward Relay

D. BER of the coded system

By OOK modulation, the output of the receiver in response, s_0 (OFF) and s_1 (ON), to symbol q are processed. When there is no turbulence only noise is present, the BER of the system [6] can be written as

$$P_{e_{OOK}} = \frac{1}{2} \operatorname{erfc} \left(\sqrt{\frac{E_b}{2\sigma_n^2}} \right) \quad (7)$$

For OOK modulation, the initial bit likelihood provided to the decoder is calculated from the symbol, $\lambda(s)$

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

$$L(s_l) = \log \frac{\sum_{s_l=1} \exp [\lambda(s)]}{\sum_{s_l=1} \exp [\lambda(s)]} \quad (8)$$

E. Channel Coding

The performance of the noisy channel relates the Signal to Noise Ratio (SNR) of the received signal to the Bit Error Rate (BER). An important issue is to use appropriate channel coding scheme when OOK modulation is used. There are a number of coding techniques which can be used, like Reed Solomon codes, Turbo codes, which is proposed so far. The problem of these codes is their decoding complexity that can be prohibitively large for practical use in Gbps rate transmission of a FSO system. The performance of the relay assisted system is calculated with LDPC coding [8]. This provides a better performance than convolutional coding. It can achieve performance that is close to Shannon's limit, when the code word length is long. Its main advantage is that it is having lower decoding complexity than turbo codes, that is decoding can be at significantly greater speeds than decoding of turbo code.

V. SIMULATION RESULTS

The graph of Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) is used for the performance analysis. Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. SNR is defined as the ratio between signal power to noise power and it is normally expressed in decibel (dB). A powerful fading mitigate tool is relay assisted transmission through atmospheric turbulence. Turbulence induced fading variance depends upon propagation distance that a light source that will travel through FSO system. To overcome this situation, relay assisted transmission will be a great advantage of resulting shorter hops from the transmitter to the receiver, to improve the significant performance. The parameters that are used for computations are shown in below table 1.

LDPC CODE	CONVOLUTIONAL CODE
Code Rate = 1/2	Code Rate = 1/2
Code word Length (n) = 128	Constraint Length = 7
Message Length (k) = 256	Trace back Length = 10
Size of G & H = 128x256	
SNR(dB) = 4	SNR(dB) = 4

Table 1: Simulation parameters used for computation

Figure 4 shows the relation between Bit Error Rate and Signal to Noise Ratio with relay in the system by convolutional coding and LDPC coding. Since the data that propagates through the atmosphere is affected by the turbulence effects, and hence the data may be faded and sometimes lost. To overcome that situation, the use of relay, that re-encode the received signal at the relay system and retransmits to the receiver, the receiver then processes the data to the users, where it can be used without a large loss that can be occurred due to the transmission through the free space. Here the dual-hop Decode and Forward Relay system is used to overcome this situation. Much better performance than a direct transmission is relay assisted transmission, where the fading and other abnormalities in the free space can be mitigated to a certain level. From the Figure 4, we can see that, at 4dB SNR, the relay assisted FSO system with LDPC coding gives very low BER than the relay system with convolutional coding. Hence it can be said that the system which is done in LDPC coding is giving better performance than when convolutional coding is done. As a result, we can say that, relay

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

assisted free space optical communication using LDPC coding can be used for transmissions in free space optical communication to get more accurate results when compared to the convolutional coding scheme.

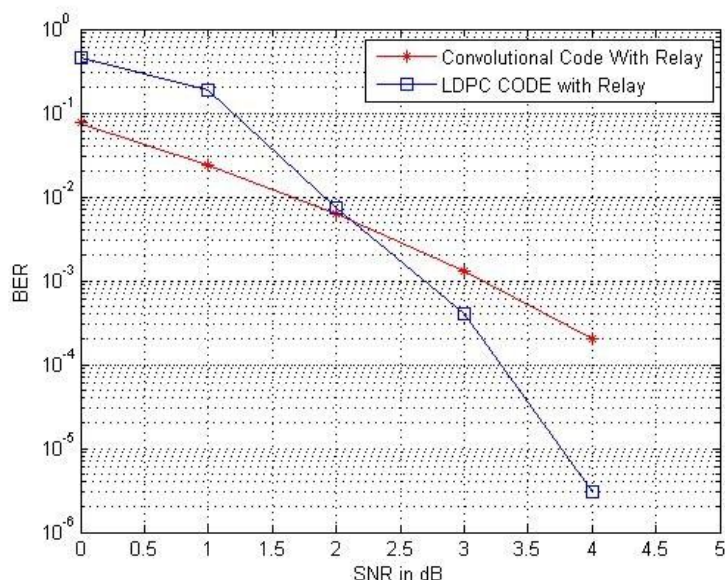


Figure 4. BER performance of relay assisted FSO communication system in LDPC coding and convolutional coding employing OOK modulation

VI. CONCLUSION

In this work, Relay assisted Free Space Optical communication is analyzed with LDPC coding and convolutional coding as channel coding scheme. The convolutional coding which is error correction coding technique is replaced with LDPC coding due to the greater performance which is close to Shannon limit and lower decoding complexity. The BER limit for OOK modulation is found. Considering the BER of relay assisted Free Space Optical system for both LDPC coding and convolutional coding, it is shown that relay assisted FSO in LDPC coding is superior to relay assisted FSO in convolutional coding with OOK modulation, in the presence of atmospheric turbulence. BER of an OOK system employing LDPC encoding and convolutional encoding with code rate 1/2 and constraint length 7 is calculated. Interleaving is used to overcome the relatively slow scintillation and it can also reduce the decoder complexity significantly and simplify the performance of decoding. Therefore, the LDPC coded relay assisted free space optical communication through atmospheric turbulence channel to improve the performance and reduce the transmission power.

REFERENCES

1. X. Zhu and J. M. Kahn, "Free-space optical communications through atmospheric turbulence channels", IEEE Trans. Commun., vol. 50, no. 8, pp. 1293-1300, 2002.
2. Majid Safari and Murat Uysal, "Relay assisted Free Space Optical Communication", IEEE Transaction on wireless communication", Vol.7, No.12, December 2008.
3. M.Ijaz, Ghassemlooy, S. Ansari, O. Adebajo and A. Gholami, "Experimental investigation of the performance of different modulation techniques under controlled FSO turbulence channel", 2010 5th international symposium on telecommunication (IST'2010).
4. M. Kamiri and N. Nasiri-Kerari, "Free-space optical communications via optical amplify-and-forward relaying", J. Lightwave Technol., vol. 29, no. 2, pp. 242-248, Jan. 2011.
5. Bobby Barua and S.P. Majumder, "Performance analysis of an LDPC coded FSO Communication System with different modulation technique under turbulent condition", 978-1-4673-2/12, 2102 IEEE.
6. Bobby Barua and S.P. Majumder, "Performance analysis of an LDPC coded FSO Communication System with different modulation technique under turbulent condition", 978-1-4673-2/12, 2102 IEEE.



ISSN(Online): 2320-9801
ISSN (Print) : 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 9, September 2015

7. Jia Li, John Q. Liu and Desmond P. Taylor, "Optical Communication Using Subcarrier PSK Intensity Modulation Through Atmospheric Turbulence Channels", IEEE Transaction on Communication, Vol.55, NO.08, August 2007.
8. Shu Lin, Shumei Song, LanLan, Linqi Zeng and Ying Y. Tai, "Construction of Nonbinary Quasi Cyclic LDPC codes", research supported by NASA under grant NNG05GD13G and NSF under Grant CCR-0117891 and ECS-0121469.
9. K. Giridhar "Information Theory and Coding", page no: 383-390, copyright 2005 by Pooja Publications.
10. Tejbir Singh Hanzra, Gurpartap Singh "Performance of Free Space Optical Communication System with BPSK and QPSK Modulation", IOSR Journal of Electronics and Communication Engineering (IOSRJECE), ISSN : 2278-2834 Volume 1, Issue 3 (May-June 2012), PP 38-43.
11. Bobby Barua and S.P. Majumder "LDPC Coded FSO communication system under strong turbulent condition", 7th International Conference on Electrical and Computer Engineering, 20-22 December, 2012.

BIOGRAPHY

- **Ms. Alina Sunny**, pursuing Master's Degree in Communication Engineering at AmalJyothi College of Engineering, Kottayam, Kerala, India. She has obtained her Bachelor's Degree from Noorul Islam College for Higher Education, India.
- **Mr. K. Karunakaran Nair**, works as professor at AmalJyothi College of Engineering, Kottayam, Kerala, India.
- **Mr. Sudhi. S.**, works as assistant professor at College of Engineering, Trivandrum, Kerala, India.