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Comprehensive Study & Implementation of ANN based Optical Wireless System

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Abstract: High-speed wireless optical communication links have become more popular for personal mobile applications. This is a consequence of the increasing demand from the personal information service boom. Compared to the radio frequency domain, optical wireless communication offers much higher speeds and bit rates per unit power consumption. That paper is about indoor optical wireless systems, in that paper the data stream is get first modulated and then get demodulated as in the all cases. The different types of errors are getting introduced in the system which are ISI, artificial light interference and Bit error. The ISI caused by multipath propagation and artificial light interference from fluorescent lamp driven by electronic blast are two major interferences, and these need to be taken into account when validating modulation schemes. The main challenge faced by this work is to seek the most optimized modulation scheme that can provide maximum system throughput while capable of withstanding most if not all of the intense channel interferences at a target BER requirement. Bandwidth efficient schemes such as the OOK and PPM are prone to artificial lighting interferences. This led to a natural conclusion of a modulation scheme that can combine benefits from both above candidates and able to avoid the drawbacks of each individual scheme. So, in this work, Discrete Wavelet Transformation and ANN-based receiver for baseband modulation techniques including OOK, pulse position modulation (PPM) is proposed.

Keywords: Artificial neural network (ANN), optical wireless communication (OWC), wavelet transforms, survey papers.

I. INTRODUCTION

With current communication systems the bandwidth per end-user is limited at most to a few Mbps, because of the bottleneck imposed by the use of copper cables or radio frequency (RF) wireless links at the last mile [1]. Although, higher RF frequencies (beyond 60 GHz) have been suggested to overcome the bandwidth bottleneck per user, the cost is too high and therefore may not be adopted by many users. Dropping fiber cable to homes is one solution, but is costly.

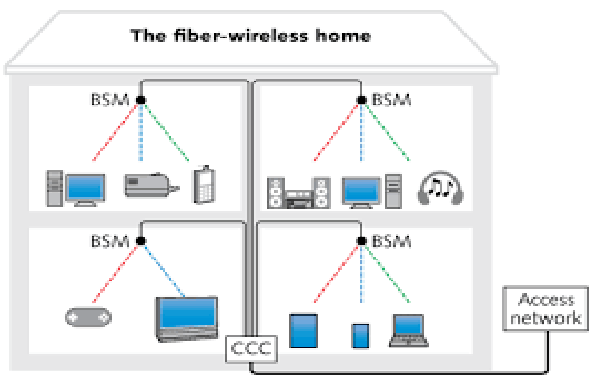

Figure 1: An Optical Wireless Communication System

One alternative solution would be to offer wireless links in the optical domain that could readily be linked to the high-speed optical fiber backbone link. Optical wireless (OW) systems (indoor and outdoor) offer all the advantages of optical fiber based systems plus rapid installation at a low cost and localized radiation resulting in no interference in adjacent cells/rooms. Compared with the RF based systems, OW offers a huge unregulated bandwidth at a single wavelength without resorting to the frequency reuse [2]. In fact the same wavelength could be used in a number of cells in the same geographical area with very little or no inter-channel interference. The cell size could be precisely defined in any shape for particular applications, a unique characteristic in OW systems.
However, in contrast to the RF system, OW links lacks mobility, blocking, eye and skin safety, ease of connectivity and suffers (only the non-line of sight (LOS)) from multipath induced inter-symbol-interference (ISI) similar to the RF links. But here in that paper we have to only concern with ISI, BIT ERROR and FLI (fluorescent light interference).
In optical wireless systems the combination of intensity modulation and direct detection (IM/DD) prevents multipath fading, ISI still constitutes a major system impairment especially at high bit rates in an indoor environment. A number of sub-optimum equalization techniques have been developed to combat the effect of ISI.In equalization schemes for OW indoor links employing on-off-keying (OOK), PPM(Pulse Position Modulation) [3].
The adaptive equalization is a preferred method in a non-stationary environment. Recently the equalization problem has been defined as a classification problem and ANN has been utilized as a classification tool. In fact, both the linear

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and adoptive equalizers belong to a class of ANNs. However, the classification capability of a linear equalizer is limited to a hyper plane decision boundary, which is a non-optimum classification strategy especially with respect to the time varying channel.

ANN with multiple layers of neurons is one of the best tools for implementing such a strategy it has been reported that the DWT (Discrete Wavelet Transform) based on the ANN offers significantly superior BER performance compared to the conventional for a severe amplitude distorted co-channel system and non-linear channels.

II. SYSTEM MODEL

1. Modulation for Optical Wireless Communication

The optical channel is quite different from the conventional RF channel. This consequently resulted in a different approach when it came to the modulation design. Modulation schemes which fit well in electromagnetic channels were not necessarily perform well in the optical domain [6].

Modulation techniques remained an active topics amongst both academic researchers and industrial communication system engineers. Depending on the nature of the information source, modulation can be summarized as analogue or digital formats.

1.1 On-Off Keying (OOK)

OOK is the simplest technique to implement in wireless infrared transmission. Prior to transmission, the information is translated to a specific code such as Manchester, RZ, or NRZ codes, to get a stream of pulses. In OOK, a pulse is transmitted if the code bit is 'one' during a fixed time slot and a 'zero' is represented by the absence of the pulse during the time slot.

The pulse can have different duty cycles (d). When using a duty cycle d<1, the required bandwidth is increased by a factor of 1/d while the average power requirement is decreased. This is the reason why OOK with RZ pulses is common in infrared systems.

1.2 Pulse-Position Modulation (PPM)

PPM [3] and its variants are widely considered as the best modulation techniques for power-limited intensity modulation with direct detection (IM/DD) communication systems. PPM has been widely used in optical communication systems, and has been adopted by the IEEE 802.11 working group for the infrared physical layer standard. L-PPM is defined to have L slots in a single symbol time.

These slots are called "chips". So, in an L-PPM, a constant optical power of LP_t watts is transmitted within only one of chips while the remaining (L-1) chips will have zero power [7]. Here, P_t is average transmitted power. Therefore, $\log_2(L)$ bits can modulated into L-PPM.

2. Wavelet Transformation for Optical Wireless Communication

The wavelet transform has become a useful computational tool for a variety of signal and image processing applications [8]. For example, the wavelet transform is useful for the compression of digital image les; smaller les are important for storing images using less memory and for transmitting images faster and more reliably. This Quick Study describes the wavelet transform, illustrates why it is effective for noise reduction, and brie y describes several improvements of the basic wavelet transform and basic noise reduction method used in the illustration.

2.1Continuous Wavelet Transform

- Historically, the continuous wavelet transform came first.
- It is completely different from the discrete wavelet transform
- It is popular among physicists, whereas the DWT is more common in numerical analysis, signal- and image-processing.
- Recall the CWT

$$W\Psi f - S(a,b) -\frac{1}{A}\int_{-\infty}^{\infty} f(t)\Psi\left(\frac{t-b}{a}\right)dt$$

This is an over complete function representation. (From one dimension, we trans- form into a 2D space!!). We want to be able to reconstruct f(t) from this representation. This is possible if the admissibility condition is satisfied:

$$C\psi = \int_{-\infty}^{\infty} \Psi(w)\frac{dw}{w} < \infty$$

A necessary (and normally also sufficient) condition is: $\Psi(0) = 0$ which means:

$$\int_{-\infty}^{\infty} \varphi(t)dt = 0$$

All functions with zero integral are wavelets

2.2 Discrete Wavelet Transform

Wavelet transforms provide a framework in which a signal is decomposed, with each level corresponding to a coarser resolution, or lower frequency band. There are two types of transforms, continuous and discrete. A continuous wavelet transform is performed by applying an inner product to the signal and the wavelet functions [9]. For a particular dilation a and translation b, the wavelet coefficient Wf (a,b) for a signal f can be calculated as $Wf(a,b) = < f\,\Psi(a,b) > -\int f(x)\,\varphi_{(a,b)}(x)dx$

The original signal can be reconstructed by applying the inverse transform:

$$f(x) = \frac{1}{c\varphi}\iint_{-\infty}^{\infty} w_f(a,b)\varphi_{a,b}(x)db\frac{da}{x^2}$$

where $C\varphi$ is the normalization factor of the mother wavelet. Although the continuous wavelet transform is simple to describe mathematically, both the signal and the

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wavelet function must have closed forms, making it difficult or impractical to apply.

2.3 Stationary wavelet Transform

The Discrete Wavelet Transform is a translation- variant transform. The way to restore the translation invariance is to use some slightly different DWT, called Stationary Wavelet Transform (SWT). It does so by suppressing the down-sampling step of the decimated algorithm and instead up-sampling the filters by inserting zeros between the filter coefficients.

Algorithms in which the filter is up-sampled are called “à trous”, meaning “with holes”. In this case, however, although the four images produced (one approximation and three detailimages) are at half the resolution of the original, they are the same size as the original image.

The approximation images from the un-decimated algorithm are therefore represented as levels in a Parallelepiped, with the spatial resolution becoming coarser at each higher level and the size remaining the same.

3. Artificial Neural Network Adaptive Equalizer

Fundamentally, the problem of adaptive equalization can be formulated as a classificationproblem and modern classifying tools like ANN can be utilised. ANN is moresuitable for channel equalization because of highly parallel structure, adaptability and learningcapability. Since there is no need for channel inversion then ANN equalization can beimplemented in any channel. The functional unit of ANN is a neuron [10].

A neuron cannotperform a complicated task on its own, but when combined and interconnected in somepredefined manner, the composed ANN create a powerful tool for difficult tasks includingnonlinear signal processing, adaptive learning, solution of nonlinear equations to name a few. Haykin has pointed out the rationale behind using ANNs instead of the traditional signalprocessing tools, the most importantly being the nonlinearity, universal approximation,adaptability to change its free parameter based on the environmental changes

III. PERFORMANCE ANALYSIS

As in this paper we use the two different modulation schemes which are on off keying and pulse position modulation. The different factors calculated are as follows

1. Bit Error Rate

The MIMO communication system consist of n transmit antenna and m receive antenna, and in some case with a slowly time-varying channel. Due to the wireless nature of the system, each receive antenna receive transmission from all transmitter. By slowly time-varying, we assume the channel remain constant over a block of data consists of N symbols.

SNR	3	6	9	12	15	18	21
BER (dB)	0.22 00	0.12 38	0.09 25	0.05 94	0.05 30	0.04 17	0.03 46

Table 1: SNR against BER in case of pulse Position Modulation

It becomes significant when we want to maintain an adequate signal-to-noise ratio in the presence of inadequate transmission through electronic circuitry and the medium for propagation.

$$P_e = \frac{1}{2}\text{erfc}[\sqrt{\frac{E}{4No}}]^*$$

Where E is the energy signal, the value of the bit error increase as the energy increases, the value of complementary error function erfc decreases and the value of bit error reduce.

Bit error rate the measure of performance of any communication system is usually bit error rate (BER).Bit Error Rate is given as follows

BER= Errors/Total Number of Bits.

Table 2: SNR against BER in case of on-off keying

SNR	3	6	9	12	15	18	21
BER (dB)	0.22 00	0.12 38	0.09 25	0.05 94	0.05 30	0.04 17	0.03 46

2. Signal to Noise Ratio

The signal to noise ratio at output is given as:

$$\left(\frac{S}{N}\right) = \frac{\text{signal power}}{\text{Noise power}}$$

With a strong signal and an unperturbed signal path, this number as small as to be insignificant.

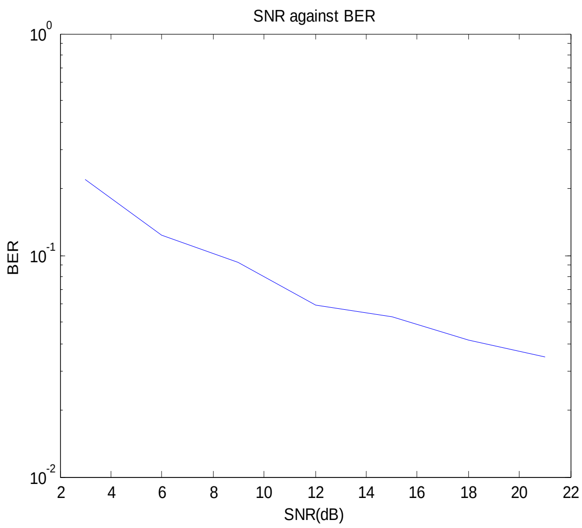

Figure 2: SNR against BER in case of on-off keying.

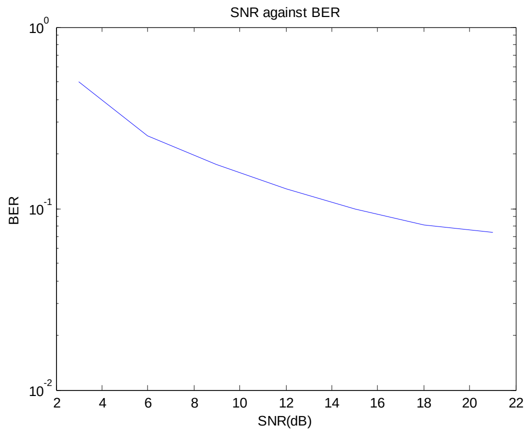

Figure 3: SNR against BER in case of pulse Position Modulation.

3.ISI

As we know that the receiver output y(t) at any instant t=t_i is given as;

$$Y(t_i) = \mu a_i + \sum_{k=-\infty}^{k=\infty} a_k \, p(i iT_b - k kT_b) + n\,(t_i) \quad ; k \neq i.$$

Now that equation has the two terms;

- The first term is produced by the ith transmitted bit . Theoretically this term is present but practically it is not so [11].
- The second term represents the residual effect of all the transmitted bits; obtain at the time of sampling the ith bit. This residual effect is called the Intersymbol Interference (ISI).

IV. CONCLUSION

This paper summarized the effectiveness of DWT and ANNto reduce the adverse effects of bit error rate, signal to noise ratio and ISI,in indoor OWC systems. The baseband modulation techniques OOK and PPM were selected for the comparativestudies. The studies showedthat OOK offers the efficient BER than PPM scheme. The bit error rate is 0.0346 when the signal to noise ratio is 21 in OOK. But in the case of PPM the BER is 0.736 when SNR is 21 which is not efficient than OOK. As from the performance we can see that the on-off keying technique is efficient than PPM. However, the DWT eliminates the effect of FLI. The ANN is effective inreducing the effect of ISI in a multipath channel and unlike unequalled cases. DWT-ANN-based receiver was successfully realized along with the help of modulation schemes and practical results are verified by comparing them with the simulation data.

V. FUTURE SCOPE

Though extensive study of the DWT-ANN based receiver had been carried for a number of channel conditions, it is imperative to provide a list of further works that is necessary to make the system more efficient and effective as well as for guidelines in further research perspective. A number of encouraging results were obtained and some of the results need further investigation in order to comprehend. The most important improvement can be obtained in the practical realization of the DWT-ANN.

Further enhancement can be obtained by soft decoding of the convolutional code as well as iterative decoding. Turbo decoding and equalization using ANN can be a topic of further investigation though such study can be very challenging due to limited investigations so far. One of the key limitations of the study is the focus on the indoor wireless applications though the proposed receiver design could easily be adapted to any digital communications. Since the ANN has adaptability, in principle ANN based receiver should perform equally well in nonstationary environment. The receiver design can be easily adapted to outdoor free space optical communications where the link is frequently exposed to the adverse environmental conditions like rain, fog, smoke. The adaptability of the DWT-ANN based receiver in such environment is very important for practical applications and is a subject of future research.

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