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Fluorscent Noise Circumvention In Optical Wireless Communication

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***Abstract:*— Infrared wireless systems plays a significant role in indoor communication. It had replaced the existing RF wireless systems. There are several challenges for the practical implementation of the optical wireless communication. For this reason, the indoor optical wireless transmission systems are not easy to design and hence new design solutions are needed to be explored. One of the challenges faced by the LED optical wireless communication is the optical noise generated by the AC-LEDs or conventional fluorescent lamps. The main objective of this work is to circumvent background optical noises using OFDM. The orthogonal subcarriers which are affected by interference can be used to send training symbols rather than sending data. Training symbols can be used for channel estimation, based on the estimated parameters equalization is performed at the receiver side. Combining FEC along with OFDM an efficient optical wireless system can be designed.**

***Key Wards:* OFDM (Orthogonal Frequency Division Multiplexing); MMSE estimation channel estimation; least-square estimation; Fluorescent Noise;**

I. INTRODUCTION

Nowadays ,Optical wireless transmissions systems is replacing the RF(radio frequency) wireless systems . The performance of wireless optical systems is limited by several reasons : speed limitations of the optoelectronic devices ;the significant path loss which leads to the use of high optical power levels; multi-path dispersion; the receiver noise; the shot noise introduced by natural and artificial light on the receiving photodiode and the interference induced by artificial light. Wireless indoor optical transmission systems are affected by noise and interference induced by natural and artificial ambient light. The researches show that fluorescent lamps driven by solid state ballasts produce interfering signals, and are expected to be the more important source of degradation in optical wireless communication systems .This paper presents a characterization of the interference produced by artificial light and proposes a simple OFDM model along with Forward error correction to circumvent optical background noise.

Several researches had done in removing the background noises.VLC (Visible Light Communication) systems using RGB LED and their optimized cell structure are proposed to increase system flexibility and to reduce interference.[3]. Mitigation of Background Optical Noise in Light-Emitting Diode (LED) Optical Wireless Communication Systems using Manchester coding is carried out by C. W. Chow[4]. Instead of the optical filtering a signal processing based solution is proposed by J. R. Torres[8].Equalization of the received signal by a transmission channel inverse filter in order to reduce the effects of the channel in the transmitted signal is discussed by the author.

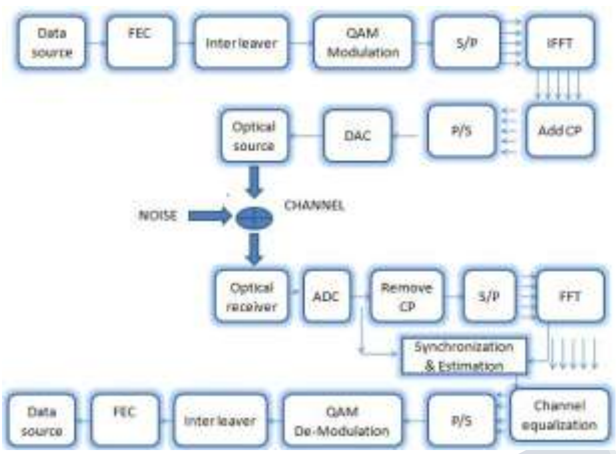
II. FLUORESCENT NOISE

Electronic ballasts operating fluorescent lamps at high switching frequency (from 20 kHz to 100 kHz) have widely been used nowadays for the purpose of saving energy in lighting. Like all lamps, fluorescent lamps emit not only visible light, but also a variable amount of infrared (IR) emission. The frequency of IR emission from fluorescent lamps is related to the lamp exciting frequency. The light emitted near the center of the lamp contains the IR component, whose fundamental frequency is twice as High as its exciting frequency, plus its higher harmonics, whereas the light emitted near both ends of the lamp contains the fundamental frequency of lighting frequency plus its higher harmonics. Due to the weaker power of the higher harmonic, harmonics above the third power can't be detected at the receiver side .These harmonic frequencies will act as a source of background noise in wireless optical systems.

III. PROPOSED WORK

Background noises can significantly affect the performance of the optical wireless communication link. The mitigation of the fluorescent noise can be controlled by adjusting the number of OFDM subcarriers. This can be easily achieved in the transmitter side by applying the training sequence on onto those subcarriers which are affected by fluorescent noise frequencies .These training symbols can be used for better channel estimation.

Fig. 1. below shows the block diagram of the OFDM wireless optical communication experiment.



First ,bit stream to be transmitted is Mapped into symbols, the mapping process may form different symbols composed of different amounts of bits depending on the scheme used (bit loading); then pilot symbols are added, pilots are known on both the transmitter and the receiver side and are used for synchronization and channel estimation purposes; afterwards the ifft is performed to modulate each symbol with a subcarrier, the size of the ifft will be linked to the serial to parallel conversion; once the modulation is done a parallel to serial conversion is executed and the cyclic prefix is added. This results on the digital complex ofdm signal, the real and imaginary parts of the signal are usually separated and passed through a digital to analog converter (dac),and it is fed to the channel.

Next , fluorescent noise is introduced to the channel. Some of the subcarriers are affected by the ambient light source. The signal is received at the receiver side and passed through ADC . Later on, cyclic prefix is removed from the received signal and fed to serial to parallel converter. Channel estimation and equalization is performed on the received signals. Estimated signals are demodulated and de-mapped into bits streams.

LDPC (Low density parity coding) is used to perform forward error correction. In general, FEC attempts to increase the reliability of transmission over a noisy channel by adding redundant information to the message to be transmitted. Low-density parity-check (LDPC) codes are highly efficient linear block codes made from many single parity check equations. They can provide performance very close to the channel capacity using an iterated soft-decision decoding approach, at linear time complexity in terms of their block length.

In an OFDM system, the received signal is usually distorted by the channel characteristics. In order to recover the transmitted bits sequence, the channel effect must be estimated and compensated in the receiver. The transmitted signal can be recovered by estimating the channel response at each OFDM subcarrier. In general, the channel can be estimated by using pilot symbols known to transmitter and receiver, which employ various interpolation techniques(linear ,cubical,..etc)to estimate the channel response of the subcarriers between pilot frequencies. In order to choose the channel estimation technique for an OFDM system, many different aspects of implementations, including the required performance, computational complexity and time-variation of the channel must be taken into consideration. Comb-type pilot arrangement in which, every OFDM symbol has pilot tones at the periodically-located subcarriers, which are used for a frequency-domain interpolation to estimate the channel along the frequency axis. The least-square (LS) and minimum-mean-square-error (MMSE) techniques are widely used for channel estimation when training symbols are available.

In conventional comb-type pilot based channel estimation methods, the estimation of pilot signals, is based on the LS method is given by :

$$\mathbf{H_{LS} = X^{-1}\,Y} \qquad (1)$$

Where H_{LS} is the least square estimate of the channel. Y is the received signal. X is the transmitted pilot tone signal. The MMSE channel estimation method finds a better (linear) estimate in terms of W ,where W is the weight matrix.

$$\mathbf{H_{MMSE}=W*H_{LS}} \qquad (2)$$

MMSE estimate is given by the equation:

$$\mathbf{H_{MMSE}\ estimate=R_{hh}(R_{hh}+I(\sigma^2_z / \sigma^2_x))^{-1}H_{LS}} \qquad (3)$$

R_{hh} is the channel autocorrelation function. I is an identity matrix. σ^2_z is the variance of noise(z). σ^2_x variance of transmitted signal.

IV. SIMULATION RESULTS

Simulation of the thesis is done on matlab software. Matlab is a high-level language and provides an interactive environment for numerical calculations, visualization, and programming. Using matlab, we can analyze data, create models and applications and develop algorithms. The language, tools, and built-in math functions enable us to explore multiple approaches and reach a solution faster than with other traditional programming languages, such as c/c++.

Generation of fluorescent noise:

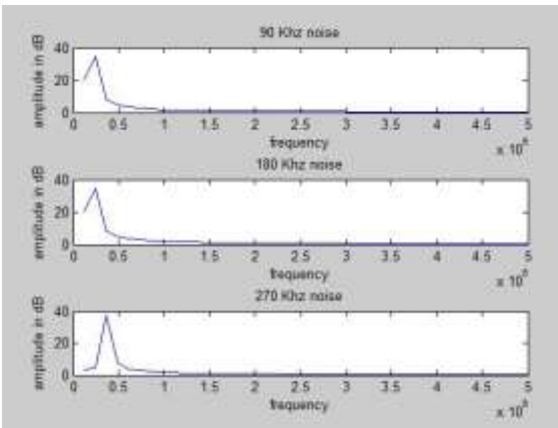


Fig. 2. Harmonics of fluorescent noise

Here as a part of the simulation ,an fluorescent lamp operating at a switching frequency of 45khz is considered. During the operation of ballast, lamp will generate a frequency of 90khz and its harmonics. These frequencies will act as an interference to the ofdm subcarriers . Since the switching frequency is 45khz lamp will generate harmonics up to its three harmonics ie 90 khz-180khz- 270khz. Harmonics of the fluorescent noise generated by 45khz ballast is shown in the fig. 2.overall fluorescent noise is plotted in the fig.3.

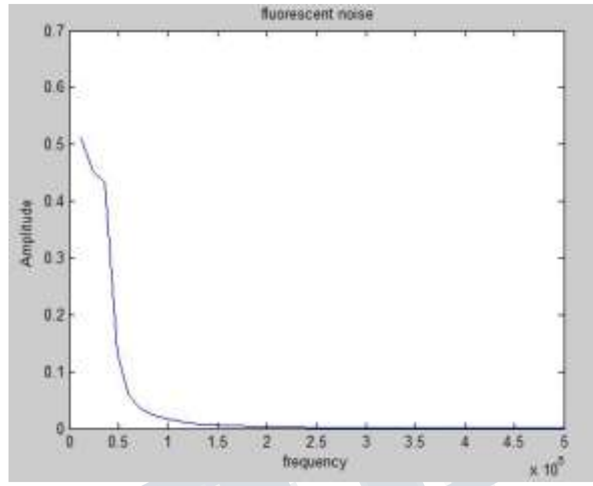


FIG. 3. FLUORESCENT NOISE

OFDM Simulation

The experimental results of the background noise circumvention by using a data rates of 5 Mb/s applying to the LED..64 OFDM subcarriers are considered and BPSK is used in each OFDM subcarrier. In the case of 5 Mb/s transmission, the bandwidth used is 2.5 MHz; the OFDM carrier spacing is 39.06 kHz (using 64 subcarriers). The CP used is (1/8) .2N, where N is the number of subcarriers.

When the fluorescent noises are introduced, the SNR at lower frequency OFDM subcarriers are affected. This is because the fluorescent noise is operated at low frequency (the dominant tone at 90 kHz) and will corrupt the lower frequency subcarriers namely subcarrier with indices 2 to 8 of the 64 subcarriers i.e. these subcarrier frequency range is between 78.12kHz (39.06kHz*2=78.12kHz) to 312.48 kHz.

One way to avoid these interference is to switch off those subcarriers which are affected by fluorescent noise ie affected subcarriers are not used for data transmission. In such a scenario the data rate of the communication system will get affected which leads to a decrease in data rate is observed. It is shown in Fig.4.

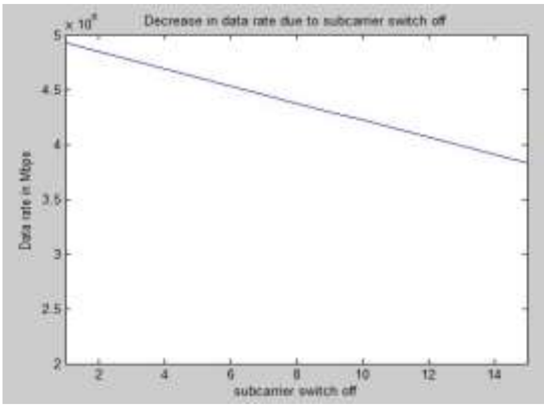


FIG. 4. EFFECT OF SUBCARRIER SWITCH OFF IN DATA RATE.

Data rate of wireless transmission system considered in the simulation is 5Mbps and we have N=64 subcarriers ,each subcarrier will have a data rate of 78Kbps. So ,switching off of each affected subcarrier will reduce the data rate by 78Kbps.

In order to increase the data rate , an efficient way is to insert pilot subcarriers. With the aid of pilot carriers it's possible to estimate the effect of channel and reconstruct the symbols which are affected by fluorescent noise. Pilot arrangement is shown in the Fig.5.

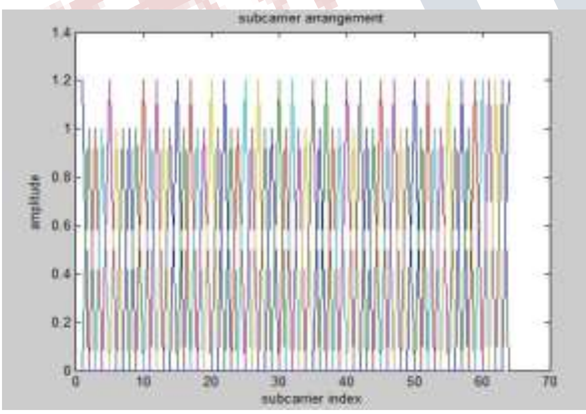


FIG. 5. PILOT CARRIER ARRANGEMENT .

Pilot aided channel estimation is carried out based on mmse and ls algorithm and results were analyzed. For simulation both cases are considered,

A) As a first case, the affected subcarriers are switched off during data transmission. During simulation subcarrier switch off is carried out with the help of filter which is designed to remove those subcarriers. Filtering the affected subcarriers is in effect equal to switching off those affected subcarriers.

B) Second case , data is transmitted on affected subcarriers with the help of pilot subcarriers. Channel estimation is carried out and affected subcarriers are reconstructed.

In both cases estimation is carried out ,but in first case affected subcarriers are kept off. So data rate will decrease. In the second method along with estimation affected subcarrier will transmit data. Random channel considered for the experiment and its estimation by each algorithm is shown in fig .6. From the figure it's clear that mmse estimation with pilots (yellow color plot) approaches the true channel response (blue color plot) than mmse with filtered subcarriers(magenta color line). Also by a quick analysis on the plot, mmse estimate of the channel lies nearer to true channel than the ls estimate . Hence mmse provides a better estimate of channel than ls algorithm.

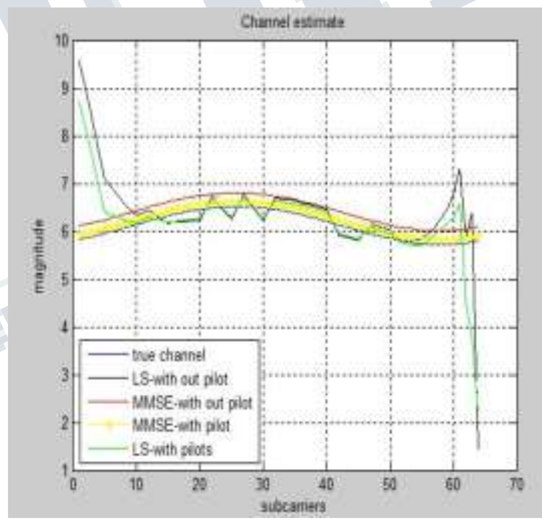


FIG. 6..ESTIMATE OF THE TRUE CHANNEL BY MMSE AND LS ALGORITHM .

Fig 7. Shows the bit error performance of above cases.ber performance of the simulation shows that pilot aided channel estimation provides a better performance than the subcarrier switch off case. Among the estimation algorithms mmse provides a better performance than the ls estimation.

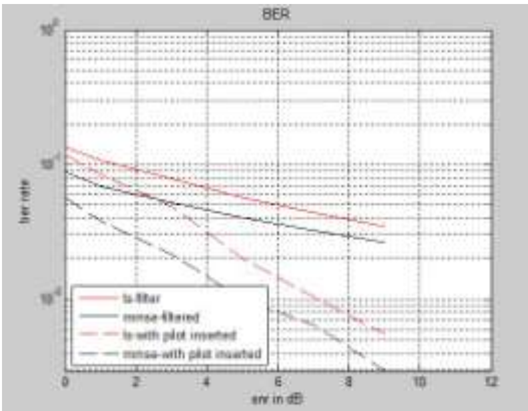


Fig. 7. BER performance analysis .

Among the estimation algorithms mmse provides a better performance than the ls estimation. Overall improvement in the snr(signal to noise ratio) of affected subcarriers can be evaluated using the simulation tool. Its shown in fig 8. Consider the subcarrier operating at frequency equal to the first harmonics of fluorescent noise i.e. 90 khz . It's the subcarrier with indices equal to 2. Fig 8 shows that the snr in db of 2nd subcarrier is less than 0db,with the help of pilot aided channel estimation snr value of that affected subcarrier is improved above 10db. Hence its clear that efficient reconstruction of data subcarriers is made possible without sacrificing the data rate.

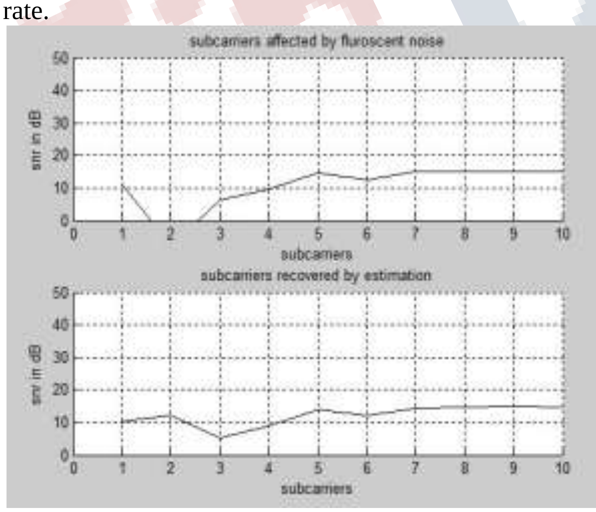


FIG. 8. SNR IMPROVEMENT OF AFFECTED SUBCARRIERS .

V. CONCLUSION

Ambient light sources produce a certain amount of background optical power density or irradiance that impairs the optical receivers performance. This paper presents a characterization of the noise and interference that artificial light sources induce in wireless indoor optical communication systems. Fluorescent lamps driven by conventional ballasts produce very strong interference with spectrum extending up to several kHz. Fluorescent lamps driven by electronic ballasts will produce lower amplitude interference extending to more that 1MHz. To evaluate the effects of the noise and interference induced by artificial light, a simple OFDM model to describe it was proposed and some examples of the parameters values were supplied. Its usual to switch off those subcarriers which are affected by fluorescent noise .But switching off the subcarriers will leads to a decrease in data rate. So by making using of MMSE estimation ,SNR of affected subcarriers can be increased, without sacrificing the data rate. Estimation in OFDM will enhance the capacity of the bandwidth-limited LED optical wireless communication link .

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