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Simulation of High Data Rate Transmission over Optical Cable Channels Using OFDM/OQAM Modulation

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***ABSTRACT*:** OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique where linearly modulated data streams are divided into number of sub-streams each occupying a bandwidth less than the total bandwidth of the signal. Orthogonal frequency-division multiplexing/ offset quadrature amplitude modulation with 64-quadrature amplitude modulation is selected as the modulation format to provide a "perfect" rectangular spectrum that efficiently reduces the channel crosstalk. No timing or frequency alignment is required for the sub bands to form the super channel. The modulation format of orthogonal frequency-division multiplexing based on offset quadrature amplitude modulation (OFDM/OQAM) is selected to provide signal spectrum with high side-lobe suppression ratio, which can effectively reduce the electrical sub-band frequency interference. The optical fiber communication networks fulfill these requirements along with small attenuation loss and better quality of services.

KEYWORDS: OFDM, OFDM/OQAM

I. INTRODUCTION

A single-band self-coherent polarization-multiplexed optical orthogonal frequency-division multiplex system with a raw data rate of 120 Gbit/s. The transmitter uses a novel RF structure that eliminates the need for RF mixers and optical filters. The receiver uses a novel architecture where the optical carrier is filtered and amplified for self-coherent detection. The receiver is polarization diverse and allows for the usual frequency guard band between the carrier and the sideband to be reduced in width, thus increasing spectral efficiency. Using two commercial 20 GS/s arbitrary-waveform generators to generate a single information-carrying band per polarization, we achieve a raw data rate of 120 Gbit/s over 500 km of standard single-mode fibre[1]. Channel estimation in OFDM/OQAM-based cooperative systems is considered. Cooperation is based on a single AF relay, and a well established two-phase protocol is adopted for its operation.

The problem of optimally designing the preambles in the two phases is investigated for Least Square (LS) channel estimation, where optimality is in the sense of minimum Mean Square estimation error(MSE) subject to a transmit energy constraint. Optimal conditions are derived for the energy allocations and positions of the pilot symbols. Equalization is also considered, where a relay-induced interference term is identified at the destination node. A simple cancellation procedure is proposed and evaluated. Simulation results are reported that corroborate the analysis and provide a comparison with the corresponding CP-OFDM system[2]. Experimental demonstration and numerically investigation of a discrete-Fourier-transform (DFT) based offset quadrature amplitude modulation (offset-QAM) orthogonal frequency division multiplexing (OFDM) system. Investigation is based on the scheme using a set of square-rootraised- cosine functions and a set of super-Gaussian functions as signal spectra. It is shown that offset-QAM OFDM exhibits negligible penalty for all investigated spectra, in contrast to rectangular-function based Nyquist FDM (N-FDM) and sinc-function based conventional OFDM (C-OFDM). The required guard interval (GI) length for

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dispersion compensation in offset-QAM OFDM is analyzed and shown to scale with twice the subcarrier spacing rather than the full OFDM bandwidth. Experimental results show that 38-Gb/s offset-16QAM OFDM supports 600-km fiber transmission with negligible penalty in the absence of GI while a GI length of eight is required in C-OFDM. Further numerical simulations show that by avoiding the GI, 112-Gb/s polarization multiplexed offset-4QAM OFDM can achieve 23% increase in net data rate over C OFDM under the same transmission reach. Also discuss the design of the pulse-shaping filter in the DFT-based implementation and show that when compared to NFDM, the required memory length of the filter for pulse shaping can be reduced from 60 to 2 in offset-QAM OFDM regardless of the fibre length[3]. OFDM (Orthogonal Frequency Division Multiplexing) is a multicarrier technique where linearly modulated data streams are divided into number of substreams each occupying a bandwidth less than the total bandwidth of the signal. However, full justice was done in proper utilization of bandwidth in OFDM where subcarriers overlap orthogonally. M-ary modulation schemes are preferred because in these schemes more than one bit can be grouped & transmit at a time which is very effective for band limited channels. MQAM (M-ary Quadrature Amplitude Modulation) is the most effective digital modulation technique as it is more power efficient for larger values of M. The Simulink based model of the MQAM-OFDM system with normal AWGN channel and Rayleigh fading channel has been made for study error performance under different channel conditions. Lastly a comparative study of BER performance of 64QAM-OFDM & 128QAM-OFDM under AWGN channel & Rayleigh fading channel has been given[4].

A system design that integrates CO-OFDM with WDM to reach a data rate of 400 Gbits/s over 1000 Km Single Mode Fibre (SMF). The 400 Gbits/s signal is generated by multiplexing eight OFDM with 50 Gbits/s for each OFDM. The performance of CO- OFDM WDM back to back design by measuring the BER and the OSNR (Optical Signal to Noise Ratio) and the constellation diagram of each user. The performance of CO-OFDM WDM for 1000 Km SMF by measuring the BER and the OSNR of different WDM channels and studying the constellation diagram of each user is shown [5]. A 4QAM-OFDM visible light communication (VLC) system employing 641 nm laser pointer (laser diode) with directly modulating data signals is proposed and simulated in software opti system 10.0. With the assistance of PIN photo detector with ideal rectangular filter at the receiving sites, zero bit error rate (BER) at 163m/10Gbps operation is obtained. The use of class 3B laser and OFDM offer significant improvements for free space transmission performance. Improved performance of zero BER , as well as better and clear eye diagram were achieved in this proposed 4QAM-OFDM VLC systems. Laser pointer at visible frequency feature can be seen as a new category of data carrier which has the potential to achieve high-speed data rate, long transmission length, as well as easy handling and installation[6]. Orthogonal frequency division multiplexing (OFDM) carrying Offset QAM (OQAM) symbols is analyzed for wireless transmissions over frequency and time selective channels. Performance limits are evaluated assuming a maximum likelihood receiver that is able to exploit the diversity branches offered by the channel. Simplified equalization making use of the zero forcing criterion is proposed and discussed, pointing out the role played by prototype filter shape and length as well as the selectivity introduced by the radio channel[7]. Here propose an implementation method for Orthogonal Frequency Division Multiplexing Offset Quadrature Amplitude Modulation (OFDM/OQAM) with Faster- Than-Nyquist (FTN) signalling. The proposed scheme can bring several advantages: 1) it approaches the theoretical rate gain of FTN signalling; 2) it can flexibly switch between Nyquist and FTN modes; 3) it does not cause complexity increase for the modem components while switching from Nyquist to FTN mode, and vice versa. In addition, we also present an iterative detector method which can support high constellation order transmission. With the simulations, we intend to show the FTN limits, up to a rate increase by a factor of 2, that the proposed transceiver can reach with various pulse shapes[8].

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II. PROPOSED SYSTEM

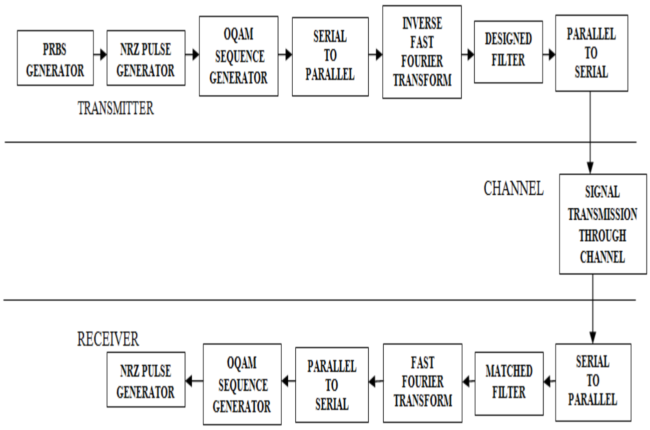

FIGURE 1: System Architecture

Figure 1 shows the architecture of proposed system. Orthogonal Frequency Division Multiplexing (OFDM) is a special type of multicarrier modulation with densely spaced sub carriers and overlapping spectra. The basic principles of OFDM are to split a high rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. Pseudorandom bit sequence generator is used whose output in turn is given to a pulse generator to generate NRZ pulses. The signals are converted into serial-to-parallel of N subcarriers and then passed to transmission filters. The signal is applied by FFT to change in to time domain. The quadrature-phase component is delayed with respect to the in-phase, which forms the offset quadrature amplitude modulation. The resulting signals are transmitted together in the same band. The signal is transmitted through optical fiber cable. At the receiver side, the received serial signal is converted into parallel and then demodulated by N subcarrier demodulators. The outputs are fed into the designed filters matched to those at the transmitter side. A fast Fourier transform (FFT) is applied to convert the time domain signals to the frequency domain. BER is calculated for input and output signals.

III. OPERATION PRINCIPLE AND RESULT DISCUSSION

The optical fiber falls into a subset (albeit the most commercially significant subset) of structures known as dielectric optical waveguides. The optical fiber works on principles similar to other waveguides, with the important inclusion of a cylindrical axis of symmetry. For some specific applications, the fiber may deviate slightly from this symmetry; it is nevertheless fundamental to fiber design and fabrication.This index difference requires that light from inside the fiber which is incident at an angle greater than the critical angle

$$\theta_c = \sin^{-1}\left(\frac{n_1}{n_0}\right)$$

be totally internally reflected at the interface . A simple geometrical picture appears to allow a continuous range of internally reflected rays inside the structure; in fact, the light (being a wave) must satisfy a self-interference condition in order to be trapped in the waveguide. There are only a finite number of paths which satisfy this condition; these are analogous to the propagating electromagnetic modes of the structure. Fibers which support a large number of modes (these are fibers of large core and large numerical aperture) can be adequately analyzed by the tools of geometrical optics; fibers which support a small number of modes must be characterized by solving Maxwell's equations with the appropriate boundary conditions for the structure.For waveguides such as optical fibers which exhibit a small change in refractive index at the boundaries, the electric field can be well described by a scalar wave equation,

$$\nabla^2\psi(r,\theta,Z) + k^2r^2(r)\psi(r,\theta,Z) = 0$$

the solutions of which are the modes of the fiber . Ê (r , q , z) is generally assumed to be separable in the variables of the cylindrical coordinate system of the fiber

$$\psi(r,\theta,Z) = R(r)\Theta(\theta)Z(z)$$

This separation results in the following eigen value equation for the radial part of the scalar field :

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$$\frac{d^2R}{dr^2}+\frac{1}{r}\frac{dR}{dr}+\left(k_0^2n^2(r)-\beta^2-\frac{m^2}{r^2}\right)R=0$$

In which m denotes the azimuthally mode number , and b is the propagation constant . The solutions must obey the necessary continuity conditions at the core-cladding boundary. In addition, guided modes must decay to zero outside the core region. These solutions are readily found for fibers having uniform, cylindrically symmetric regions but require numerical methods for fibers lacking cylindrical symmetry or having an arbitrary index gradient. A common form of the latter is the so-called a - profile in which the refractive index exhibits the radial gradient.

To achieve the 400-Gb/s transmission within 50-GHz grid, high order modulation formats are required, such as 64-QAM or higher. When applying electrical low pass filters at the transmitter to eliminate the aliasing-frequency terms and the channel crosstalk, the signal with very high order modulation could be severely distorted. Several techniques can be applied to overcome this issue. One is to increase the FFT size for the conventional OFDM. A FFT size of 12000 is required to load 128-QAM without much signal distortion. However, the laser phase noise varies greatly within such long OFDM symbol period. So, an additional pilot carrier is inserted to track the phase changes. Two stage phase noise estimation is also required. This brings much complexity in the system setup and digital signal processing. Another solution is using filter bank multicarrier (FBMC) techniques, which are widely investigated in wireless communication. Among various FBMC schemes, OFDM/OQAM is considered as the most efficient way to achieve high side lobe suppression ratio, even with short FFT sizes. At the transmitter, the transmitted signal S_{N*m} is serial-to-parallel (S/P) converted into N subcarriers and then passed to N subcarrier transmission filters. The quadrature-phase component is delayed by T = 2 with respect to the in-phase where T is the symbol period, which forms the offset modulation. Note that pulse shaping is operated at time domain and realized by cooperation of the inverse fast Fourier transform (IFFT) function and the bank of component filters. Then, the pulse shaped N outputs are modulated by N OFDM subcarriers with subcarrier spacing of $\Delta f=\frac{1}{T}$ .The baseband expression of the continuous-time OFDM/OQAM signal can be written as follows:

$$S(t)=\sum_{m=-\infty}^{+\infty}\sum a_{n,m}h\left(t-\frac{T}{2}*m\right)*e^{j2\pi n\Delta ft}*e^{j(n-1)(\frac{2\pi t}{T}+\frac{\pi}{2})}$$

where N is an even number representing the number of subcarriers, and h(t) is the designed filter for pulse shaping which is designed based on the criterion. $a_{n,m}$ are complex valued transmitted symbols which are obtained from M-ary constellations. At the receiver side, the received serial signal is firstly converted into parallel outputs and then demodulated by N subcarrier demodulators. The outputs are fed into the designed filters matched to those at the transmitter side. A fast Fourier transform (FFT) is applied to convert the time domain signals to the frequency domain. The prototype filter is able to enhance the side lobe convergence.

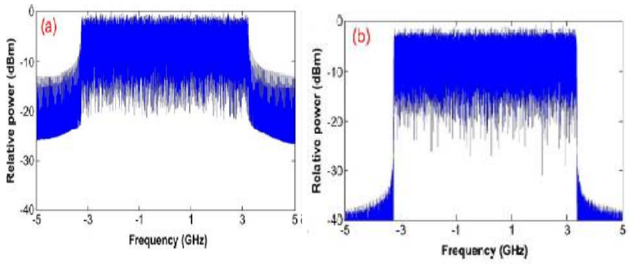

Figure 4: Power spectrum density for (a) conventional OFDM and (b) OFDM/OQAM.

Figure 4 shows the spectra of conventional OFDM and OFDM/OQAM with FFT size of 256. The impulse response h(t) is a square-root raised cosine filter with roll-off factor of 0.5. As a result, the side lobe suppression ratio of OFDM/OQAM signal is about 20 dB higher (> 35 dB) than conventional OFDM as shown in Figure 4. The advantages of OFDM/OQAM arise from the prototype filters h(t), which satisfy the perfect reconstruction condition. But the price paid is the induced computational complexity of using the digital filter in the transmitter and receiver end.

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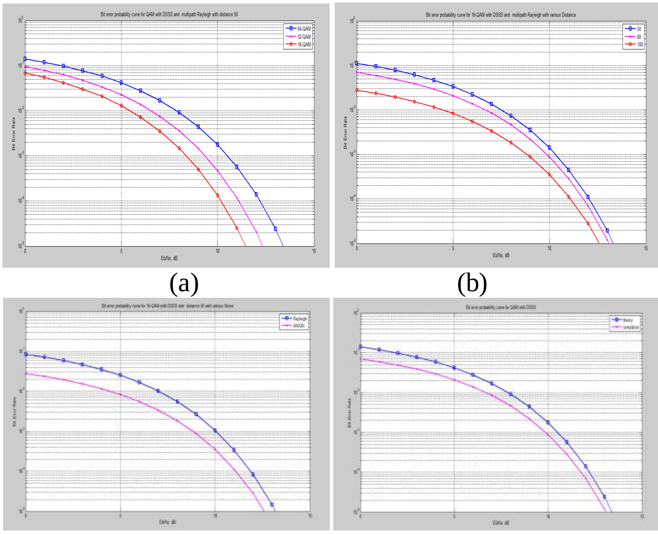

(a) (b) (c) (d)

figure 5: a) QAM comparison results b) 16 QAM comparison results for varying distance c) 16 QAM comparison results for varying noise d) overall comparison curve for QAM BER VS PSNR

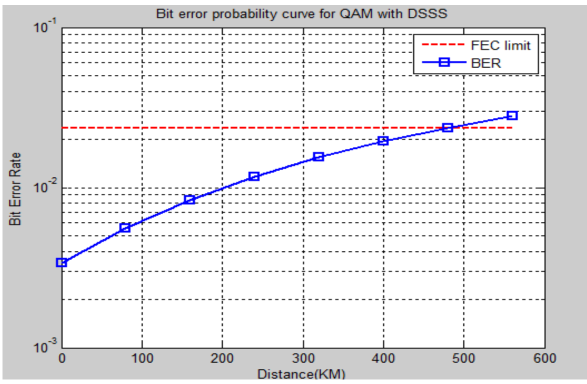

Figure 6: bit error probability for QAM with DSSS

IV. CONCLUSION

This work aims at offering a complete procedure for comparing orthogonal frequency division multiplexing and fourier transforms to present a QAM approach with FFT principles for transmission for a long distances. An additional encoding and decoding for the signals is achieved between input bits in above case. A low complexity account of decoding algorithm is able to be chosen, as boost in decoding difficulty does not offer important presentation differences. For outlook work dissimilar concepts regarding a computational proficient decoding force are investigated. Also FFT code lessons are compared to investigate results and found optic fiber for a wired medium obtains good results when compared to other schemes. Codes among iterative decoding like Low-Density-Parity-Check (LDPC) provide a supplementary coding gain compared to codes shown in this effort.

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