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Design of IM-DD Optical Communication using Matlab

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Abstract: *A modulation scheme where the intensity of an optical source is modulated by the RF or mm-wave signal. Demodulation is achieved through direct detection of the optical carrier and conversion using a photo detector is called IM-DD Systems. In these systems the multi-layer modulation (MLM) is used to design both asymmetric clipped optical OFDM (ACO-OFDM) and dc-biased optical OFDM (DCO-OFDM) as a function. In this systems the DCO OFDM is more spectrally efficient than non-DC biased systems because this have better tradeoff between spectral and power efficiency. In the direct detection system, the detection process is non-linear due to the photo current proportional to absolute square of electric field intensity due to this the signal is slow. The equalizer is comprised of one hidden layer which leads to super-fast of the signal .The channel capacity for this systems can be measured by the transmitting of the signals. This IM/DD is a cost-effective optical communication which finds wide applications in fiber communication, free-space optical communication, and indoor visible light communication. In these systems when the bandwidth of signal exceeds the modulation bandwidth of LED, multi path effect occurs. Therefore, we use ACO-OFDM to avoid this multi path distortions. OFDM is a suitable efficient cost-effective solution for GPON deployment with benefit of use of low-cost laser bandwidth in comparison with DCO-OFDM. At the same BER performance, in comparison with D-C ACO-OFDM at high bit rates transmission, DCO-OFDM promises to deliver higher throughput.*

Keywords: Acoofdm, Dcoofdm, imdd, mlm, lpf, sp, da, ofdm

I. INTRODUCTION

Optical OFDM Using Intensity Modulation have many optical modes that are present at the receiver result in optical wireless systems being linear in intensity. The optical wireless systems and other systems where many modes are received, the OFDM signal must be represented as intensity. A real baseband OFDM signal can be generated by constraining the input signal X to have Hermitan symmetry. Two forms of unipolar OFDM have been used in this system . They are DC-biased optical OFDM (DCO-OFDM) and asymmetrically clipped OFDM (ACO-OFDM) . In DCO-OFDM the signal is made positive by adding a DC bias. Normally in DCO-OFDM both even and odd subcarriers are modulated and clipping noise affects all subcarriers. In ACOOFDM, only the odd subcarriers carry data symbols, while the even subcarriers form a bias signal which ensures that the transmitted OFDM signal meets the non-negativity requirement .The front-end of the ACO-OFDM transmitter is similar to a DCO-OFDM transmitter where is first serialized and a S/P is appended to it. Then signal is D/A converted and sent across an ideal LPF. As negative samples cannot be transmitted in an IM/DD system, signal is clipped at zero .In IM/DD systems, the electrical signal is modulated onto intensity of the optical carrier. Then, only real and non-negative signals can be transmitted. One way to get real signal at the transmitter is the use of inverse fast Fourier transform (IFFT) which input is constrained to have Hermitian symmetry at the expense of half of the spectral efficiency.

II. LITERATURE REVIEW

H. Songetal [1] ACO-OFDM and DCO-OFDM for Passive Optical Network: Performance Comparison in IM/DD Fiber Link We present a comparative study of Diversity Combined Asymmetrically Clipped Optical OFDM (DCACOOFDM) and DCbiased Optical OFDM (DCO-OFDM) techniques in 17Gbps intensity modulated and direct detected (IM/DD) fiber link of passive optical network (PON). From simulation results obtained with realistic

components parameters, we find that D-C ACO-OFDM offers an improved demodulation than DCO-OFDM. OFDM is a very suitable efficient cost
effective solution for GPON deployment with benefit of use of low-cost laser bandwidth in comparison with DC-OFDMLaith Farhan [2] At the same BER performance, in comparison with D-C ACOOFDM at high bit rates transmission, DCO-OFDM promises to deliver higher throughput. The Bit Error Rate (BER) performance value is fixed to 10-3 (limit value when Forward Error Codes are used).Channel Capacity of IM/DD Optical Communication Systems and of ACO-OFDM channel capacity of intensity modulated direct detection (IM/DD) wireless optical communication systems for an AWGN channel with a limit on the average transmitted optical power. It has recently been shown that asymmetrically clipped optical orthogonal frequency division multiplexing (ACO-OFDM) is the mor eefficient in terms of optical power than conventional optical modulation techniques such as pulse position modulation (PPM)B.R Chandavarkar[3] When ACO-OFDM is used, the transmitted signal has a clipped Gaussian probability distribution. We calculate the channel capacity for systems using transmitted signals with exponential and clipped Gaussian distributions, and for an ACO-OFDM system. For practical signal to noise ratios, ACO-OFDM has a slightly lower capacity than the other distributions, due to the correlation between samples caused by the ACO-OFDM modulation process. ACO-OFDM has many practical advantages including its tolerance to multi path distortion. This shows that it also makes efficient use of the available power and bandwidth. Yuanwei Liu [4] Multi-Layer Modulation for Intensity Modulated Direct Detection Optical OFDM.A Multi-Layer Modulation (MLM) aided Intensity-Modulated Direct-Detection (IM/DD) DC-Biased Optical OFDM (DCO-OFDM) and Asymmetrically Clipped Optical OFDM(ACO-OFDM) are considered. More explicitly, we propose a Double Turbo Receiver (DTR) for jointly detecting the MLM and for compensating the clipping distortion.

III. PROPOSED METHOD

This section gives a brief introduction on the principles of OFDM in radio frequency communication. It uses complex-valued QAM modulation and consists of N-modulated symbols. OFDM transforms a signal from the frequency domain to the time domain by using an N-point inverse fast fourier transform module.

3.1 System Architecture

This section gives a brief introduction on the principles of OFDM in radio frequency communication which serves as a basis for further reading. The baseband diagram of OFDM is shown. At the transmitter side, coded information bits are first mapped to symbols through digital modulation such as pulse amplitude modulation (PAM), quadrature amplitude modulation (QAM), and the phase shift keying (PSK). Typically, complex-valued QAM modulation is used in OFDM. Then, the modulated symbols are divided into multiple groups and each group consists of the N-modulated is defined as, where the group index is comitted here for simplicity. In OFDM, each modulated symbol is loaded on a subcarrier with center frequency and there are N subcarriers in total. All the symbols are transmitted on their subcarriers simultaneously. Mathematically, this is equivalent to transform the vector X by an N-point inverse fast fourier transform (IFFT) module, resulting in a new vector, that is as shown as Figure 1. In OFDM, X is generally considered as frequency domain signal and x is viewed as time-domain signal as shown in figure 1.

OFDM is used in many new and emerging broadband wired and wireless communication systems because it is an effective solution to inter symbol interference (ISI) caused by multi path transmission or by a dispersive channel. However it has not been used in any commercial optical communication systems. This is because OFDM signals are bipolar, while in optical systems that use intensity. modulation (IM), only unipolar signals can be transmitted. One way of converting the bipolar signal to unipolar is to add a large DC bias but this results in an optical signal with a high mean optical power. This is impractical in the many optical system. In DCO-OFDM, the signal is made positive by adding a DC bias value to the IFFT bipolar signal output after mapping and data carriers modulation. This bias value increases the power requirement of the system and cannot be easily optimized for any constellation size if Quadrature Amplitude Modulation (M-QAM) is used to modulate the different OFDM carriers. Because of very high peak-to-average ratio (PAPR) of OFDM signals, a very high bias would be required to eliminate all negative peaks. Instead, a moderate bias is normally used (practically 7dB) and the remaining negative peaks are clipped, resulting in clipping noise in both even and odd subcarriers. Two OFDM methods are often used for generating non-negative signals. One is is called DC-biased Optical OFDM (DCO-OFDM) and the second, Asymmetrically Clipped Optical OFDM.(ACO-OFDM). In Optical Wireless Communications (OWC), different alternative techniques with optical power efficiency exist and derive from DCO- and ACO-OFDM.

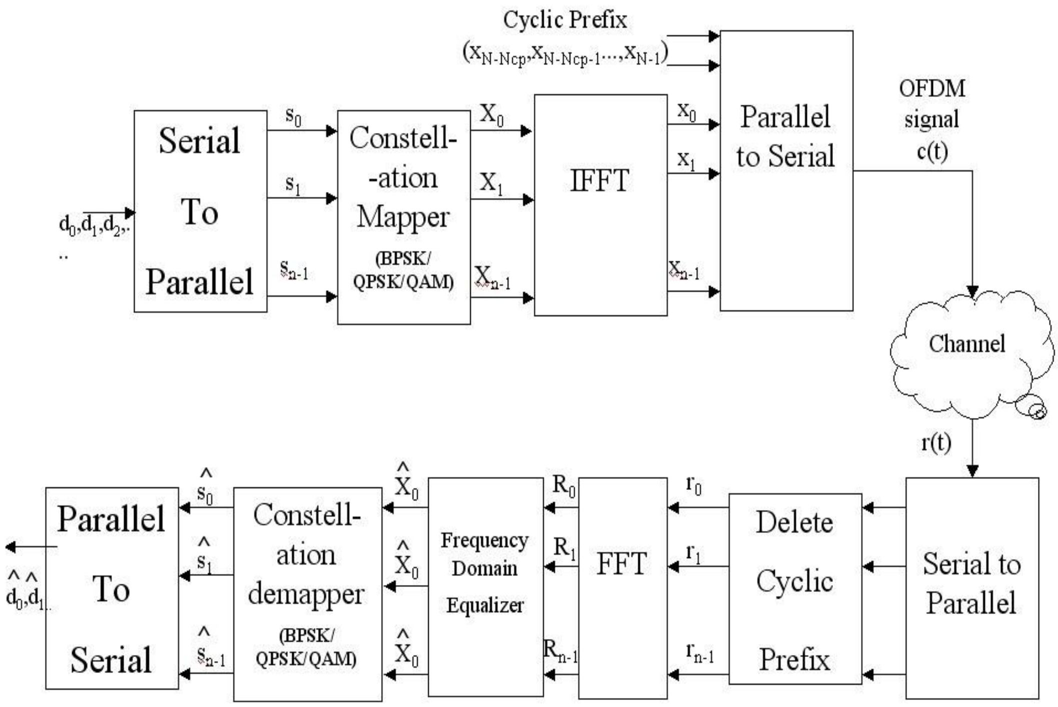

Figure 1: System Architecture OFDM

We have Noise cancellation in technique ACOOFDM (NC ACO-OFDM) where a noise cancellation process is operated at the demodulation using anti-symmetry property of the received signal and Diversity-combined ACOOFDM. Intensity modulation and direct detection (IM/DD) is a cost-effective optical communication strategy which finds wide applications in fiber communication, free-space optical communication, and indoor visible light communication. In IM/DD, orthogonal frequency division multiplexing (OFDM), originally employed in radio frequency communication, is considered as a strong candidate solution to combat with channel distortions. In this research, we investigate various potential OFDM forms that are suitable for IM/DD channel n IM/DD channel, there are still some non-ideal factors that may deteriorate 3the quality of communication. One key factor is the multi path effect. This effect is caused by several mechanisms. First, in wireless communications, the light could be reflected at multiple locations and by many times by the surroundings before arriving at the receiver side. Second, the modulation bandwidth of LED is limited, typically below 100 MHz. When the bandwidth of signal exceeds the modulation bandwidth of LED, multi path effect occurs. Third, in fiber communication, light components of different wavelength propagate through different paths, which also cause multi path effect. Therefore, effective means of mitigating the multi path effect are necessary in IM/DD optical communications. In the transmitter, input data which is in binary is encoded by a rate half convolution encoder. After interleaving, the binary values are converted to QAM values. Four pilot values are added to each 48 data value, so that coherency at the reception point can be achieved. It gives 52 QAM values per OFDM symbol. Application of IFFT modulates the symbol into 52 subcarriers. Cyclic prefix is added to make the system robust to multi path propagation. Narrower output spectrum is obtained by applying windowing. Using an IQ modulator, the signal is converted to analog, which is up converted to the 5 GHz band, amplified, and transmitted through the antenna. The receiver performs the reverse operations of the transmitter, with few additional tasks. In the first step, the receiver has to estimate frequency offset and symbol timing, using special training symbols in the preamble. After removing the cyclic prefix, the signal can be applied to a Fast Fourier Transform to recover the 52 QAM values of all subcarriers. The training symbols and the pilot subcarriers are used to correct for the channel response as well as remaining phase drift. The QAM values are then demapped into binary, and finally a Viterbi decoder decodes the information bits.

3.2 Intensity Modulation

Intensity modulation (IM) is a form of modulation in which the optical power output of a source is varied in accordance with some characteristic of the modulating signal. The envelope of the modulated optical signal is an analog of the modulating signal in the sense that the instantaneous power of the envelope is an analog of the characteristic of interest in the modulating signal. Recovery of the modulating signal is usually by direct detection, not heterodyning. However, optical heterodyne detection is possible. Bell Laboratories had a working, but impractical, system. Heterodyne and homodyne systems are of interest because they are expected to produce an increase in sensitivity of up to 20 dB allowing longer hops between islands for instance. Such systems also have the important advantage of very narrow channel spacing in optical frequency-division multiplexing (OFDM) systems. OFDM is a step beyond wavelength-division multiplexing (WDM). Normal WDM using direct detection does not achieve anything like the close channel spacing of radio frequency FDM. Intensity Modulation Fiber-Optic Sensors Intensity modulation is one of the simplest to measure because it only requires a photo detector to measure the light intensity. The intensity of the light wave traveling through an optical fiber can be modified by micro bending of the optical fiber, by a change in coupling of the fiber with the surrounding medium, or the fracture of the optical fiber. A photo detector is used to measure the intensity of the light transmitted through the fiber or reflected back to the input. One drawback of these simple sensors is that they cannot be multiplexed into sensor networks.

3.3 Direct Detection

A direct-detection (DD) system is a communication system based on detecting modulated optical power (also referred to as the optical field intensity or simply the optical intensity). In conventional DD systems the receiver consists of a single photo diode (PD) and, correspondingly, the transmitter modulates the optical power. Therefore such systems are often referred to as intensity-modulation and direct-detection (IMDD) systems. The architecture of a typical IM-DD . The transmitter has a laser as a light source. Light can be directly modulated inside the laser or can be externally modulated using a separate modulator. The receiver consists of a PD, a clock recovery module, and symbol decision module. This electronic circuit is usually referred to as a clock and data recovery unit. Compared with coherent systems that use digital-to-analog converters (DACs) and a dual-polarization I/Q modulator at the transmitter, an optical hybrid plus four pairs of balanced photo detectors and four analog-to-digital converters (ADCs) at the receiver, DD systems have simpler electronics and optics as shown in figure 2.

1. The quadrature bias point has been widely adopted for both analog and digital direct detection systems. The null bias point for CO-OFDM up-conversion signifies a fundamental difference between the optical intensity modulation and the
2. Optical field modulation.
3. Coherent detection systems, the transformation between the electrical drive voltage and optical field is of concern, whereas in the conventional direct detection systems.
4. Coherent detection systems, the transformation between the electrical drive voltage and optical field is of concern, whereas in the conventional direct detection systems.
5. Optimal modulator null bias point for the rto up-conversion is fundamentally independent of the detailed waveform of vi/q.
6. Direct detection optical ofdm, it is still optimal to bias the modulator at the null point to minimize rto up conversion nonlinearity

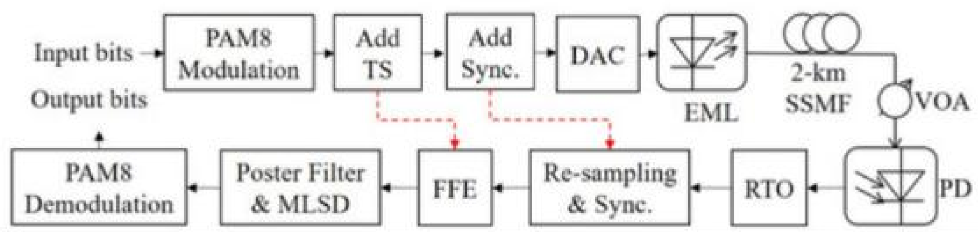

Figure 2: IM-DD Optical Communication

IV. EXISTING METHOD

In Existing method we can use two techniques from the extension of OFDM. They are

1. ACO-OFDM(Asymmetric Clipped -OFDM)
2. DCO-OFDM(DC-Baised Optical-OFDM)

4.1 Asymentric Clipped OFDM

In subcarriers carry data symbols, while the even subcarriers form a bias signal which ensures that the transmitted OFDM signal meets the non-negativity requirement. Figure 3 shows an ACO-OFDM system. The input signal to the IFFT consists of only odd components. Also, the elements of the vector have Hermitian symmetry. The front-end of the ACO-OFDM transmitter is similar to a DCO-OFDM transmitter where is first serialized and a CP is appended to it. Then signal is D/A converted and sent across an ideal LPF. As negative samples cannot be transmitted in an IM/DD system, signal is clipped at zero. which results in the ACO-OFDM signal. As a result of the anti-symmetry of signal, clipping does not result in any loss of information. The ACO-OFDM signal is then given as input to an ideal optical modulator and the resulting signal transmitted across a at AWGN channel. The processing in the receiver is similar to a DCO-OFDM receiver, except that in ACO-OFDM only the odd subcarriers are demodulated, as only they carry the data symbols. Orthogonal frequency division multiplexing (OFDM) allows high-speed data transmission across a dispersive channel, so is used in many new and emerging high-speed wired and wireless communication systems. However, OFDM is not used in commercial optical communication systems [1]. This is because OFDM signals are bipolar, while in optical systems that use intensity modulation (IM), only unipolar signals can be transmitted. Despite the many advantages of OFDM, and its widespread use in wireless communications, OFDM has only recently been applied to optical communications. This is partly because of the recent demand for increased data rates across dispersive optical media and partly because developments in digital signal processing (DSP) technology make processing at optical data rates feasible. However another important obstacle has been the fundamental differences between conventional OFDM systems and conventional optical systems. In typical (non optical) OFDM systems, the information is carried on the electrical field and the signal can have both positive and negative values (bipolar). At the receiver a local oscillator and coherent detector is used. In contrast in a typical intensity-modulated direct-detection optical system, the information is carried on the intensity of the optical signal and therefore can only be positive (unipolar). There is no laser at the receiver acting as a local oscillator and direct detection rather coherent detection is used. OFDM is now increasingly being considered as a modulation technique for optical wireless systems. Many optical wireless systems use intensity modulated/direct detection (IM/DD). In IM/DD systems the transmitted electrical signal is modulated onto the intensity of the optical carrier. Therefore, only real and non- negative signals can be transmitted.

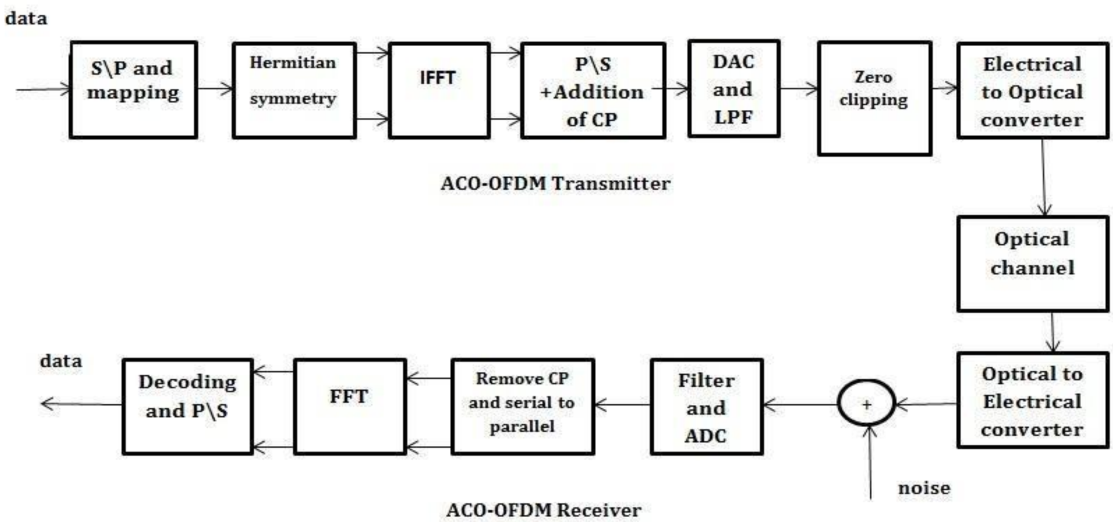

Figure 3: ACO-OFDM Model

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4.2 DC-Biased Optical OFDM

In DCO-OFDM all the subcarriers carry data symbols. The complex data signal, is input into the inverse fast Fourier transform (IFFT). The input signal is constrained to have Hermitian symmetry. Because of the Hermitian symmetry of the input, the output signal of the IFFT is real not complex. Signal is then converted from parallel to serial (P/S), a cyclic prefix (CP) is appended, the resulting signal is digital to analog (D/A) converted and low pass filtered resulting in x(t). In this paper, an ideal low pass filter (LPF) is assumed. For large subcarriers, the signal can be modeled as a Gaussian random variable. Next a suitable DC bias is added and then the remaining negative peaks are clipped. Because OFDM signals have a very high peak-to-average power ratio, so a very high bias is required to eliminate all negative peaks. If a large DC bias is used, the optical energy per- bit to single sided noise power spectral density, becomes very large, thereby making the scheme inefficient in terms of optical power. Instead, a moderate bias is normally used, and the remaining negative peaks are clipped, resulting in clipping noise. In typical DCO-OFDM systems both odd and even subcarriers carry data symbols and the clipping noise affects all the subcarriers. Any negative peak which remains after the addition of DC bias level is clipped at zero. The clipped signal is then input to an optical modulator. Here an ideal optical modulator is used; therefore the intensity of the output optical signal is directly proportional to the input electrical current. The resulting signal is transmitted across a flat channel. Shot noise which affects the signal is modeled as additive white Gaussian noise (AWGN), is added in the electrical domain. At the receiver, the received signal is first converted from an optical signal to an electrical signal using a photo diode. The processing after this point is the same as a conventional OFDM receiver. i.e. the output of photo diode is then filtered and the resulting signal is then analog to digital converted. Then the appended cyclic prefix is removed and the signal is converted from serial to parallel. The signal is given as the input of FFT. Then it is decoded and converted from parallel to serial and finally data signal is retained as shown in figure 4.

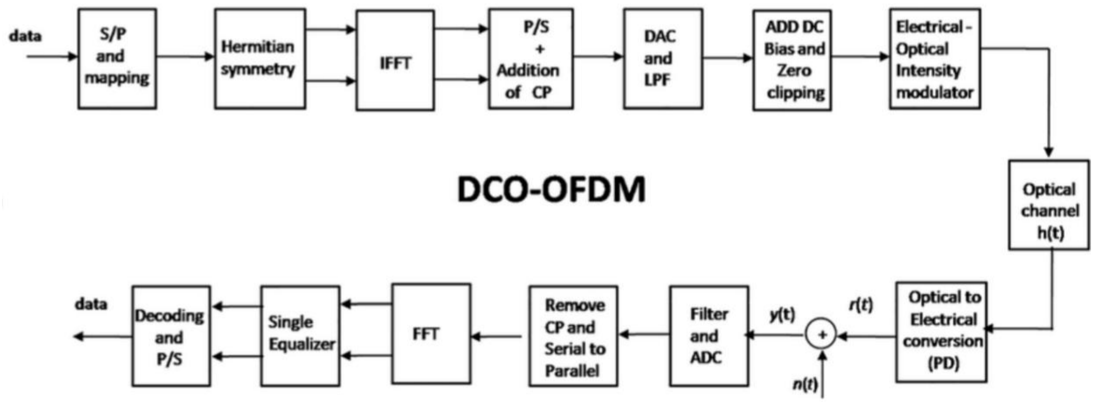

Figure 4: DCO-OFDM Model

V. SOFTWARE REQUIREMENT

5.1 MATLAB 2018a

Software Used	Version Used	Language Used
Matlab	2018Ra	C

VI. RESULT AND DISCUSSION

6.1 Original Data

In the original data the x-axis is data points and the y axis is taken as amplitude and the serial data is taken as the original data as an series with an discrete time as shown in figure 5.

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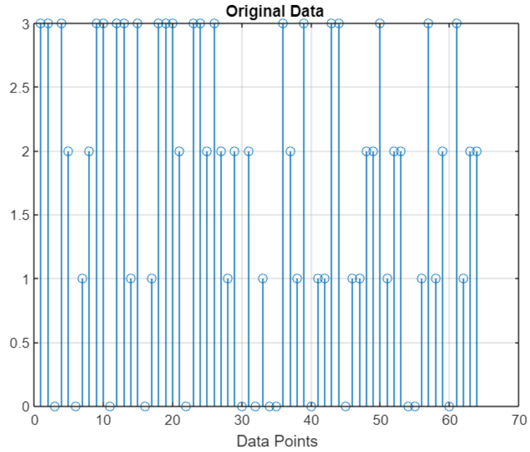

Figure 5: Original Data

6.2 QPSK Modulation

In the Qpsk-modulation the x-axis is data points and the y axis is taken as modulated data and the serial data of the pulse is modulated as shown in figure 6.

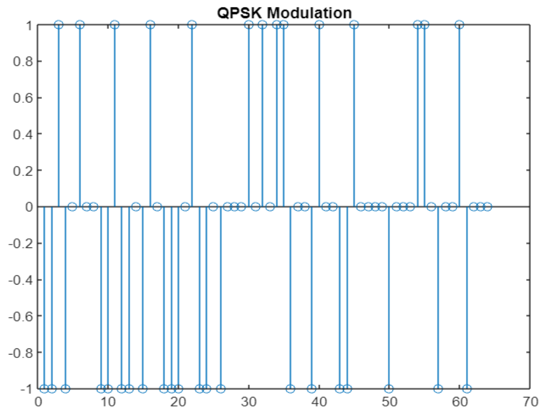

Fig6: QPSK Modulation

6.3 Data Subcarriers

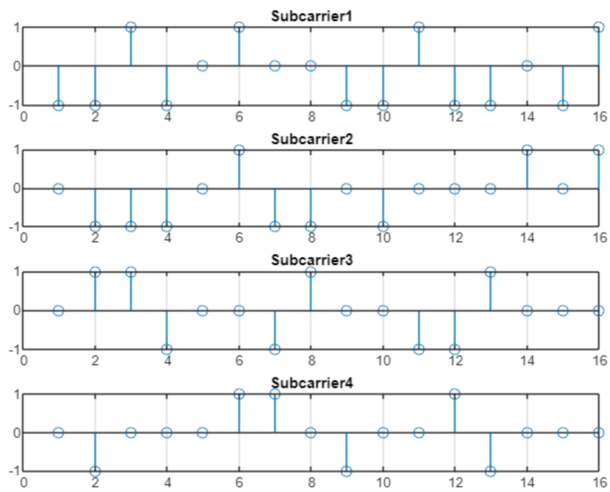

Figure 7: Data Subcarriers

After modulation there is a even and odd data points takes place .all the data points of even are set to zero and odd can carry the data and the modulation is an discrete pulses. A subcarrier is a side band of a radio frequency carrier wave, which is modulated to send additional information. Examples include the provision of colour in a black and white television system or the provision of stereo in a monophonic radio broadcast. There is no physical difference between a carrier and a subcarrier; the ”sub” implies that it has been derived from a carrier, which has been amplitude modulated by a steady signal and has a constant frequency relation to it as shown in figure 7.

6.4 IFFT Subcarriers

Both OFDM and OFDMA divided a channel into subcarriers through a mathematical function known as an inverse fast Fourier transform (IFFT). The spacing of the subcarriers is orthogonal, so they will not interfere with one another despite the labol containing a large number of bits as shown in Figure 8 Let’s say your 64 IFFT ck of guard bands between them. IFFT is as a way of constructing a single sym gives us 40 data subcarriers, These subcarriers will use the same modulation and coding schemes (MCSs) as 802.11ac and two new MCSs with the addition of 1024-QAM.which is modulated to send additional information. Examples include the provision of color in a black and white television system or the provision of stereo in a monophonic radio broadcast. even and odd data points takes place, all the data points of even are set to zero and odd can carry the data and the modulation is an discrete pulses.A subcarrier is a side band of a radio frequency carrier wave.

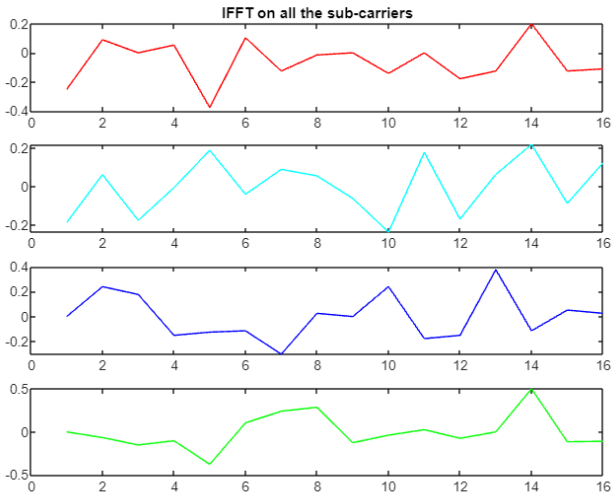

Figure 8: IFFT Subcarriers

VII. CONCLUSION AND FUTURE WORK

This project focuses on the topic on designing of OFDM’s . ACO-OFDM achieves half the spectral efficiency of DCO-OFDM for same modulation order. Therefore, in addition to 4QAM D-C ACO-OFDM, 16QAM D-C ACO-OFDM is simulated against a 4QAM DCO-OFDM scheme to compare the BER performance at a similar spectral efficiency of 1bit/s/Hz. ACO-OFDM system can reach BER improvement of almost over DCO-OFDM for similar spectral efficiencies to almost same modulation order. ACO-OFDM and DCO-OFDM schemes is studied and compared for PON IM/DD fiber link using realistic components parameters. We found at BER of 10-3 and split ratio of 1x32, that 45.3km of fiber length can be reached with D-C ACO-OFDM for almost the half (23km) with DCOOFDM of the same modulation order. It is shown for 20km distance that for BER value of 10-3, data rate of 24Gbps is allowed with 4QAM D-C ACO-OFDM for 17.8Gbps with 4QAM DCO-OFDM and 22.4Gbps with 16QAM D-C ACOOFDM. As for BER of 10-9, 14Gbps data rate is reached with 4QAM D-C ACOOFDM to only 2.5Gbps with 4QAM DCOOFDM, we found that D-C ACO-OFDM is an efficient cost effective solution for GPON networks over DCO-OFDM because of its throughput performance and lower radiated average optical power. In comparison with D-C ACO-OFDM of the same BER, the DCO-OFDM scheme promises to deliver higher throughput at high bit rates transmission. We also showed that D-C ACOOFDM allows the use of low-cost laser bandwidth in comparison with DCO-OFDM

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For the future work, we will verify the proposed rule OFDM makes resourceful utilization of the spectrum by overlapping. By dividing the channel into narrowband flat fading sub channels, OFDM is more resistant to frequency selective fading than single carrier systems. It can easily adapt to severe channel conditions without complex time-domain equalization. It reduces ISI and IFI through use of a cyclic prefix and fading caused by multi path propagation. Using sufficient channel coding and interleaving lost symbols can be recovered. Channel equalization becomes simpler than by using adaptive equalization techniques with single carrier systems. OFDM is computationally capable by using FFT techniques to implement the modulation and demodulation functions. It is less sensitive to sample timing offsets than single carrier systems are. It is robust against narrow-band co-channel interference. Unlike conventional FDM, tuned sub-channel receiver filters are not required.

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