# Comparative study of multiplexing technics DHT-OFDM and DFT-OFDM for IM / DD optical link

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01BP 2009

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*Abstract* — **This document makes a comparison between two techniques for generating orthogonal subcarriers named DFT (Discrete Fourier Transform) and DHT (Discrete Hartley Transform) for the implementation of OFDM (Orthogonal Frequency Division Multiplexing) in an IM / DD (Intensity Modulated Direct Detection) optical link. Two variants of OFDM have been identified in this work's context; ACO-OFDM (Asymmetrically Clipped Optical OFDM) and DCO-OFDM (DC biased Optical OFDM). To do this, a model of the OFDM transmitter and OFDM receiver which connected whith a channel affected by noise, has been made and implemented in MATLAB. The coding technique employed is the NRZ (Non Return to Zero). For every generation technique of subcarriers, simulation reveals that the ACO-OFDM technique is less sensitive to noise than the DCO-OFDM techniques. Similarly, we note that the implementation of the DFT for ACO-OFDM and DCO-OFDM has better performance than the DHT. However, in terms of useful bit rate, DHT is better performance than DFT.**

***Keywords: OFDM, DHT-OFDM, DFT-OFDM, ACO-OFDM, DCO-OFDM***

## I. INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is a multiplexing technique which allows data transition on orthogonal carriers. The implementation of this technique permits to increase spectral efficiency on IM / DD (Intensity Modulated Direct Detection) optical link. This type of optical link is extending more and more nowadays [1].

IM / DD optical links require at the transmitter output a real and positive signal because this signal is intended for intensity modulation. So, some transformations should be made on the classic OFDM signal to obtain these characteristics. For this purpose, several techniques have been developed. We can mention among them the DCO-OFDM (Direct Current-biased Optical OFDM) and ACO-OFDM (Asymmetrically Clipped Optical OFDM) [2][3].

Each of these techniques can be based on the DFT for every type of symbol to be transmitted or on the DHT when the symbols to be transmitted come from a real constellation for the generating of orthogonal subcarriers [3].

The objective of this work is to make a comparative study of these two methods of generating subcarriers. The encoding technique used is the NRZ (Non Return to Zero) which guarantees real symbols after modulation.

## II. MATERIALS AND METHODS

### A. *Theoretical and conceptual environment*

Indeed, the bits of the OFDM transmitter input are converted in symbols from NRZ encoding. For DFT-OFDM, these symbols are sent in parallel on the inputs of IDFT (Inverse Discrete Fourier Transform) after Hermitian symmetry operation whereas for DHT-OFDM, symbols are sent directly in parallel to the inputs of IDHT. The signal obtained at the end of these operations is real in both cases. In fact, IDHT (Inverse Discrete Hartley Transform) is a real transformation and the Hermitian symmetry permits to have real symbols after the Inverse Discrete Fourier Transform. This signal should directly modulate a laser. Therefore, it must be positive in addition to being real. To do this, two possibilities are envisaged to directly inject the OFDM signal to the laser. A sufficient continues component is added to the OFDM signal (real and bipolar) to obtain a real and positive signal (DCO-OFDM). The second technique (ACO-OFDM) consists in clipping all negative part of the bipolar signal. The different OFDM symbols are transmitted only on the odd subcarriers. In the second case, in reception, the demodulated symbols to be considered are those of the subcarriers of odd order. At the reception, the signal is demodulated and converted into binary elements. For the modeling performed, the entire optical domain was assimilated into a channel affected by noise.

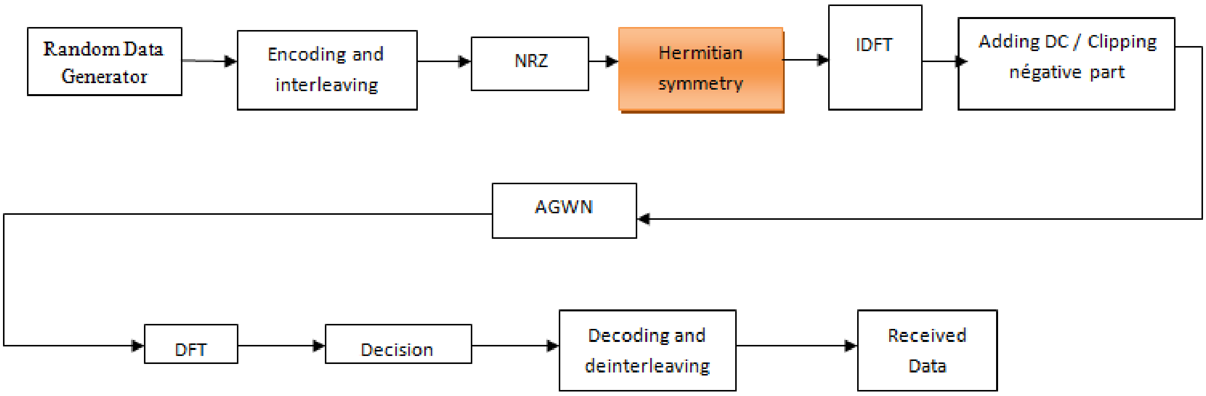


FIG 1: Block diagram of DFT-OFDM

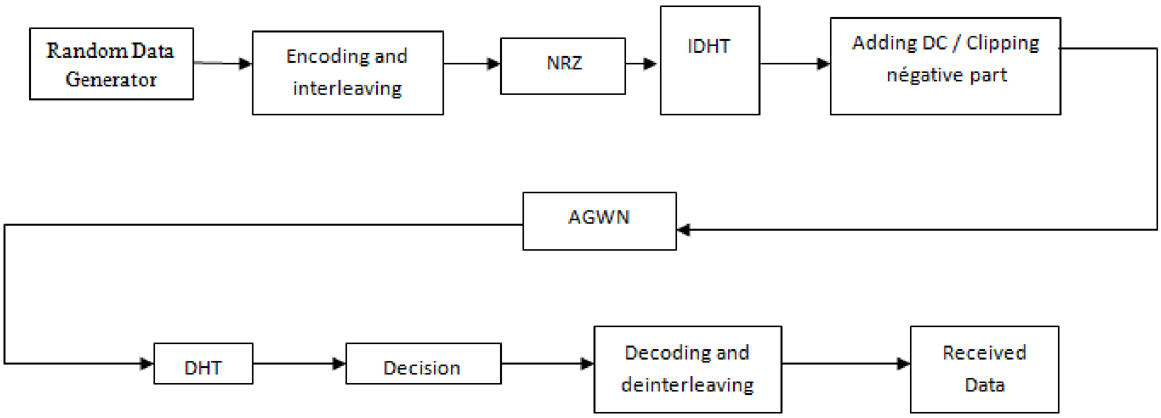


FIG 2: Block diagram of DFT-OFDM

The equations characterizing the IDFT, DFT, IDHT and DHT are respectively [3]:

$$IDFT\big(X(k)\big) = x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{jk\left(\frac{2\pi n}{N}\right)} \tag{1}$$

$$DFT\big(x(n)\big) = X(k) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} x(n) e^{-jn\left(\frac{2\pi k}{N}\right)} \tag{2}$$

$$IDHT\big(X(k)\big) = x(n) = \frac{1}{\sqrt{M}} \sum_{k=0}^{M-1} X(k) \left(\cos\left(2\pi \frac{kn}{M}\right) + \sin\left(2\pi \frac{kn}{M}\right)\right) \tag{3}$$

$$DHT\big(x(n)\big) = X(k) = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} x(n) \left(\cos\left(2\pi \frac{kn}{M}\right) + \sin\left(2\pi \frac{kn}{M}\right)\right) \tag{4}$$

### *B. Simulation tools*

We use MATLAB 7.10 to simulate these chains of transmission. The different blocks are designed and simulated with this tool.

## III. PRESENTATION OF RESULTS

- *Bit Error Rate (BER) depending on the Signal to Noise Ratio (SNR) for ACO-OFDM*

The BER as a function of SNR for ACO-OFDM for both DFT and DHT is shown in Fig 3 and Fig 4 using the NRZ encoding technique.

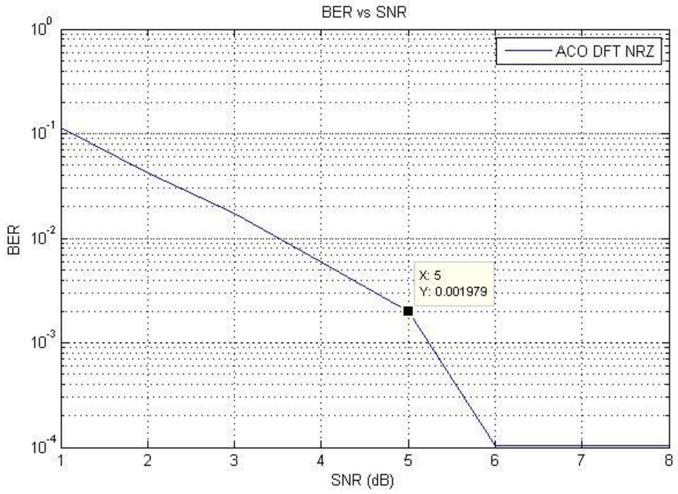


Fig 3: BER depending on SNR for ACO-OFDM based on DFT

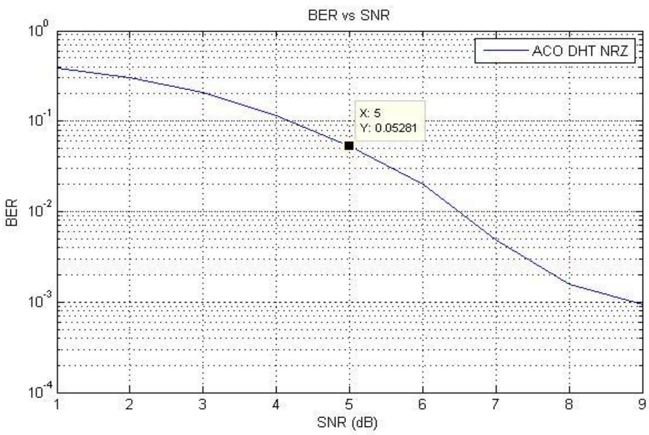


Fig 4 : BER depending on SNR for ACO-OFDM based on DHT

- *BER depending on the SNR for DCO-OFDM*

The BER as a function of the SNR for DCO-OFDM for both the DFT and DHT is shown as in Fig 5 and Fig 6 using the NRZ encoding technique.

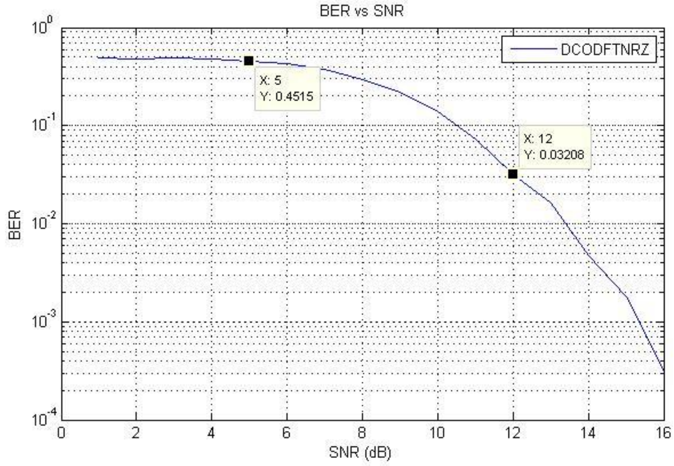


Fig 5: BER depending on SNR for DCO-OFDM based on DFT

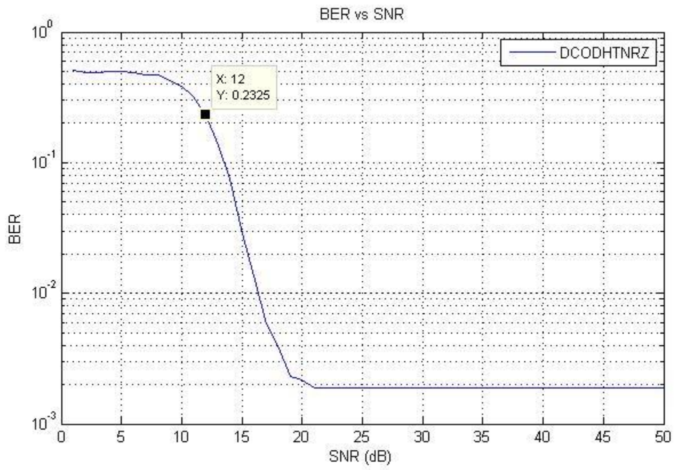


Fig 6: BER depending on SNR for DCO-OFDM based on DHT

## IV. DISCUSSION

We note that both for DHT and DFT, ACO-OFDM has better performance in comparison with the DCO-OFDM. Indeed, for the DFT-OFDM, for a Signal to Noise Ratio (SNR) of 5 dB, the ACO-OFDM has a Bit Error Rate (BER) of 0.001979 (Fig 3) while the DCO-OFDM BER has 0.4515 (Fig 5). This result is in agreement with the work [2] [3].
The technique of generation of orthogonal subcarriers based on the DFT has better performance than that based on the DHT. Indeed, when we take the ACO-OFDM, for a Signal to Noise Ratio (SNR) of 5 dB, the BER of DHT is 0.05281 (Fig 4) while the BER of DFT is 0.001979 (fig 3). Similarly, when we take the DCO-OFDM, for a SNR of 12 dB, the BER of DFT is 0.03208 (fig 5) while the BER of DHT is 0.2325 (Fig 6). This result is not in agreement with the work [6]. [6] found that DHT-OFDM and DFT-OFDM have the same performance. The divergence arises because we don't use the same transmission chain for DHT-OFDM and DFT-OFDM unlike [6]. Indeed, to have real symbols at IDFT output, Hermitian

symmetry is applied to the DFT-OFDM. Also, at reception, we don't have real symbols at the output of DFT due to channel noise for DFT-OFDM. We considered only the real part of the received symbols which reduces the effect of noise on the received channel signal for DFT-OFDM.

Another criterion of comparison of DHT-OFDM and DHT-OFDM is the useful bit rate. In fact, for the DFT, the Hermitian symmetry is essential for obtaining real output symbols from the OFDM multiplexer (IDFT). This operation doubles the number of symbols which must be run over the network. For DHT, this operation is not performed. In fact, the IDHT is a real transform. Therefore, if the modulation symbols are real, after the OFDM multiplexer (IDHT), the symbols still real.

## V. CONCLUSION

Throughout this work, we compared the techniques of generating orthogonal subcarriers based on DFT and DHT in the context of the implementation of IM / DD optical link based on the OFDM multiplexing technique. Two variants of OFDM have been proposed: the ACO-OFDM and DCO-OFDM. This study revealed that the technology of generation subcarriers based on DFT has better performance than that based on the DHT. In fact for a value of signal noise ratio, the DFT has a better bit error rate compared with DHT. However, for the useful bit rate and implementation complexity, we found that DHT is more interesting than the DFT.

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