Wireless Receivers:

Algorithms and Arcitectures

OFDM Project

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Introduction:

In this project we want to Implement an acoustic OFDM transmission system in order to transmit and receive a sequence of data through an audio transmission channel

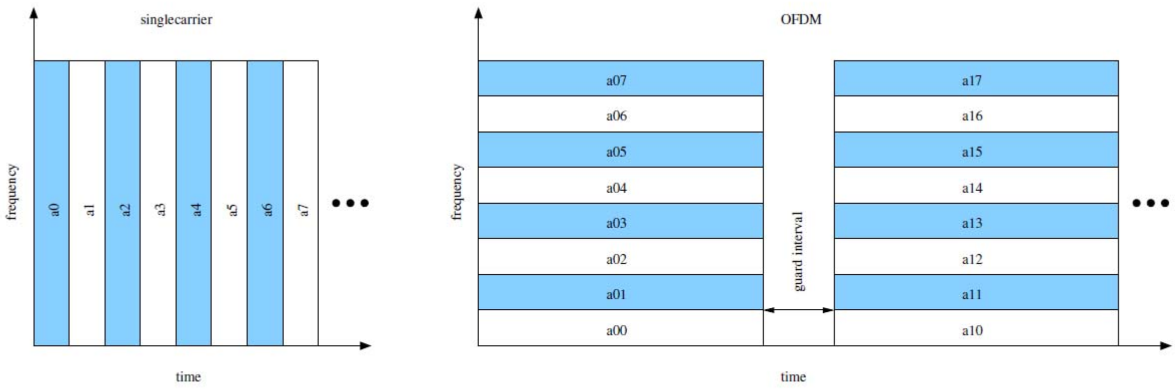
Why OFDM? :

Wideband single carrier systems require very complicated equalization and channel estimation schemes due to frequency selective fading. Orthogonal frequency division multiplexing (OFDM) is a way to convert a wideband channel into many intersymbol interference free narrowband channels, for which equalization and channel estimation are straightforward.

Concept of OFDM:

Imagine that we want to transmit a data stream, consisting of complex symbols, at a symbol rate R. In a single carrier system the data symbols would simply be transmitted one after the other, using the whole available bandwidth B, which is approximately equal to the desired symbol rate R.

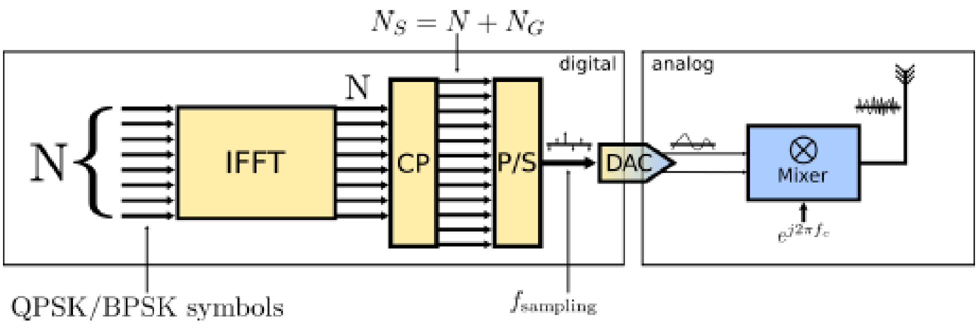
In a multicarrier system, the data stream is split into N parallel streams. Each stream is transmitted over a narrow frequency band of bandwidth B/N, at a rate R/N. The figure bellow illustrates the different concepts in the time-frequency plane. The left subfigure shows a singlecarrier system, where the symbol duration is T = 1/R.
The right subfigure shows an OFDM transmission. The symbol duration is now T=N/R, N times longer than in the singlecarrier system.



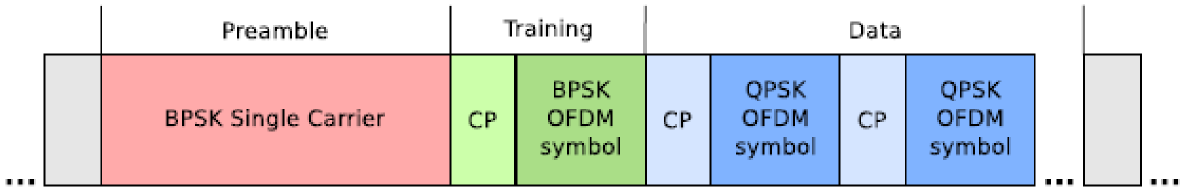
Implementation:

Transmitter:

The transmitter part is constructed according to following figures which describe respectively the overview of the transmitter part and the frame structure.



Transmitter structure



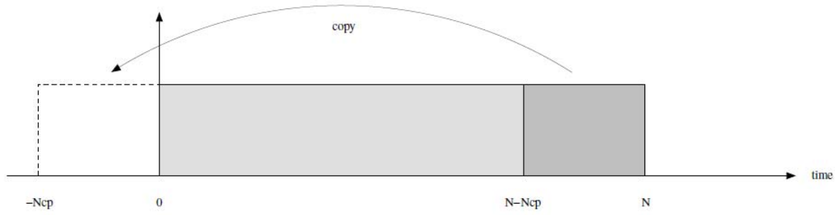
Frame structure

1) In transmitter, first a source emits a bit stream which is mapped onto a set of QPSK symbols .

2) We concatenate a known series of symbols with our QPSK symbols which is called training, in order to estimate the channel response in frequency domain so the receiver can estimate the channel response by dividing the value of received sequence and known sequence in each corresponding frequency

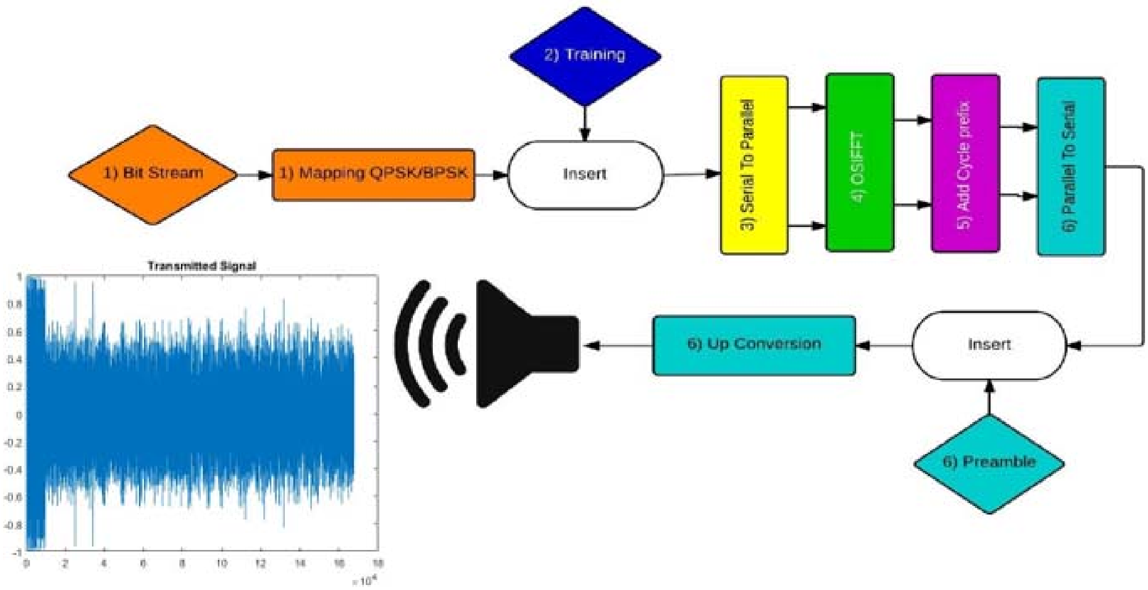
3) In the next step, the complex data symbols are converted into N parallel streams
4) Then the data symbols are transformed into time domain by given function OSIFFT (it takes care of the oversampling) for each row.
5) Now we add the cycle prefix which is of length a half of the OFDM symbols at the beginning of each row. We use cycle prefix in order to cancel the effect of intersymbol interference from the previous symbol, cycle prefix means that the last Ncp samples of each OFDM symbol are copied and inserted in front of the symbol. We do it, in order to have a

periodic form in transmitted signal because the periodic input sequence lets the convolution of the transmitted signal with CIR (channel impulse response) to be circular.



6) Now we reform our matrix in order to have a series sequence, then the transmitter adds this new sequence to oversampled and shaped BPSK preamble. Then the up conversion is done in order to transmit the signal in pass band frequencies, in our project to get the best results, our preamble and OFDM symbols are normalized by the maximum value of their own part.

Summary of transmitter:



Receiver:

In the receiver, we do the exactly the invers of what we did in the transmitter.

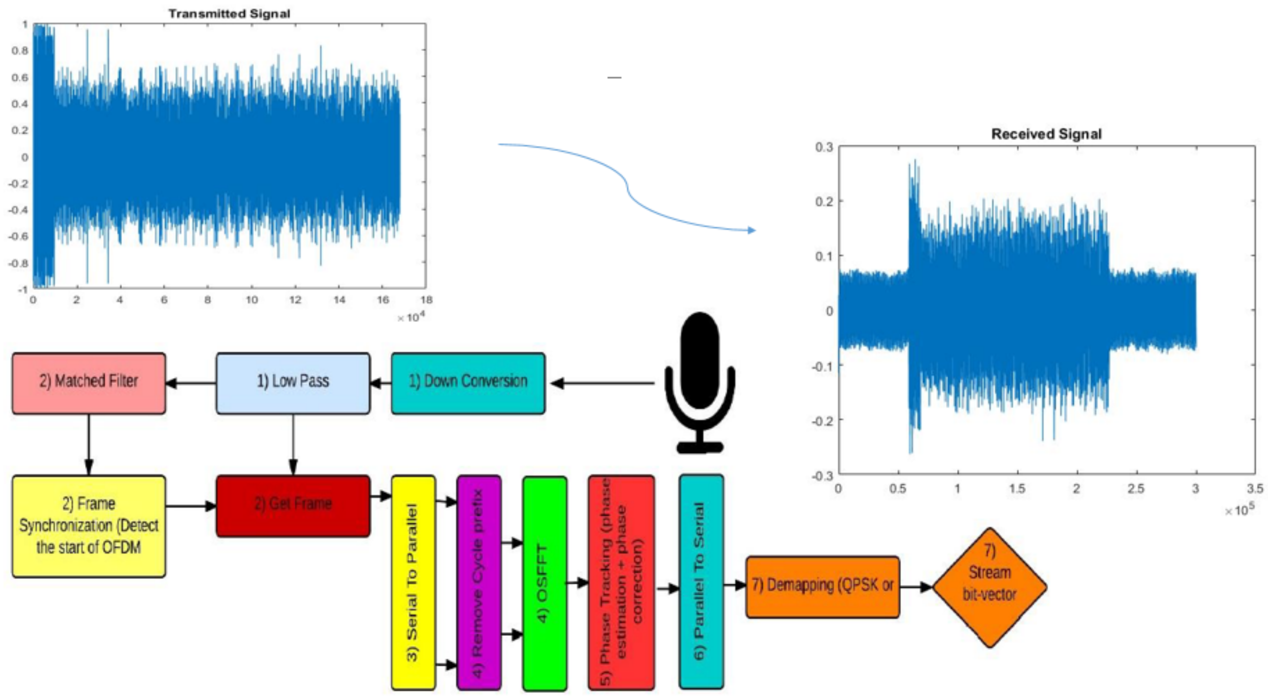
1) In receiver, first we receive the signal which is in time domain, then we have to do the down conversion in order to convert back the received signal into baseband then we apply a low pass filter. We know that base band bandwidth would be obtained from this equation

$$BW_{\mathrm{BB}} = \mathrm{ceil}\left(\frac{N+1}{2}\right) \cdot f_{\mathrm{spacing}}$$

Fspacing = 5 HZ and N = 256 so BWBB = 645 HZ so we used 1.05 * 645 HZ as a corner frequency of our lowpass filter

2) In receiver we apply the matched filter to the obtained signal in order to do the frame synchronization. We do the frame synchronization, to find the beginning of each OFDM frame
3) Now we convert the vector signal into matrix.
4) We remove the cycle prefix then we apply OSFFT (it takes care of the down sampling) to all the subsequences in time domain in order to obtain the OFDM symbols in frequency domain.
5) We do the phase estimation according to the received trained symbols and transmitted trained symbols, then we do the phase correction on all the received data symbols.
6) Now we reform our matrix in order to have a series sequence .At the end we do the demapping in order to obtain the data bit-stream.

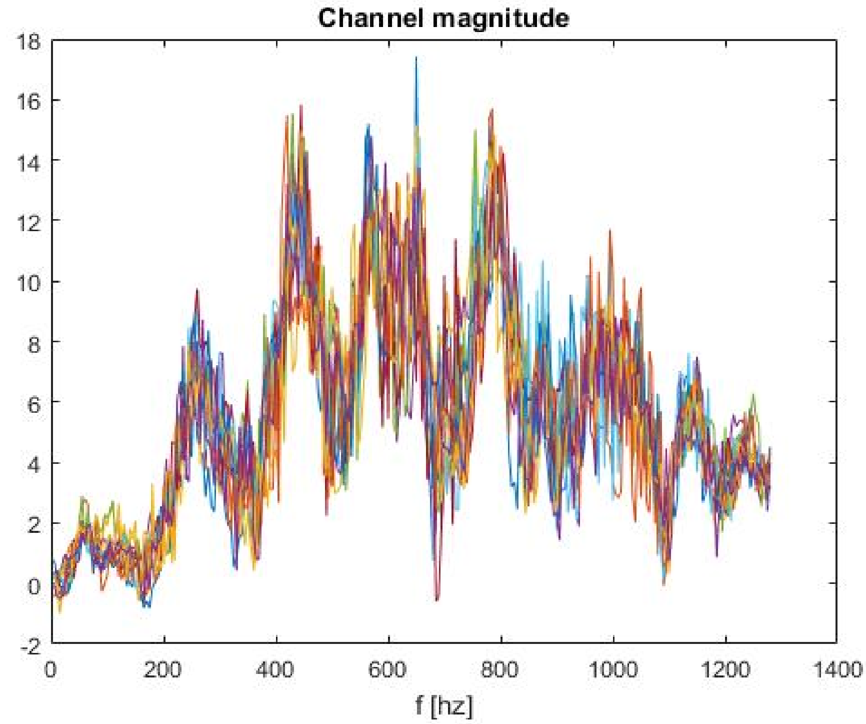
Summary of the Receiver:

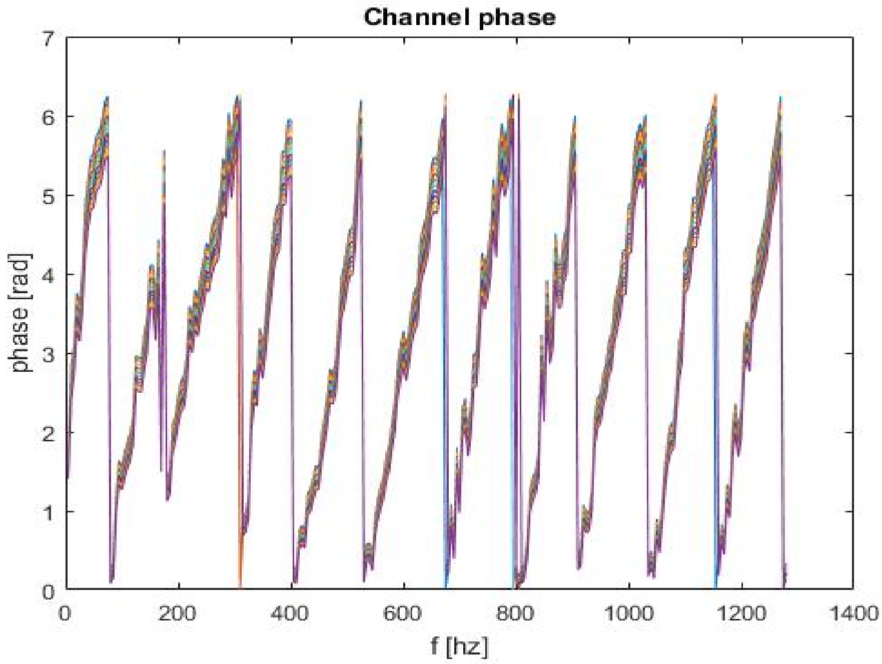


Results:

Channel frequency response:

These plots are obtaind using 10 OFDM training symbols the results are obtained by dividing the received training symbols by transmitted one

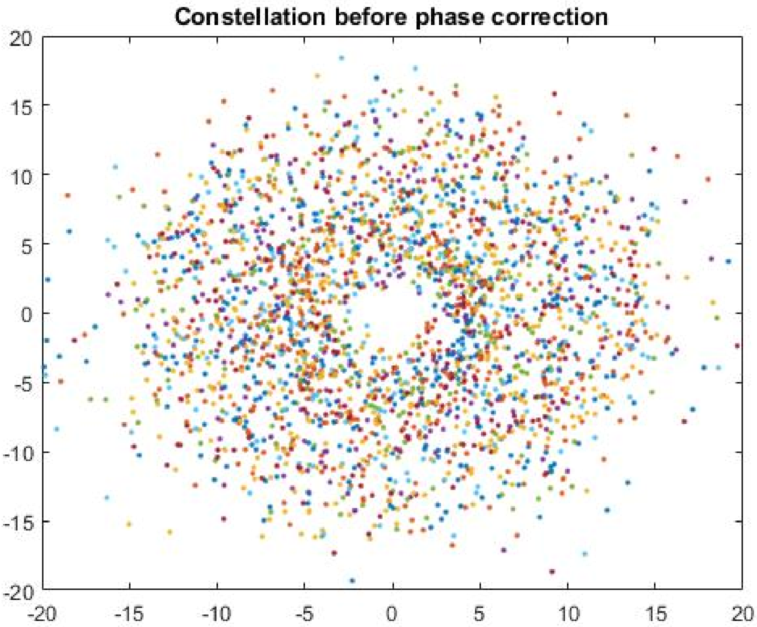


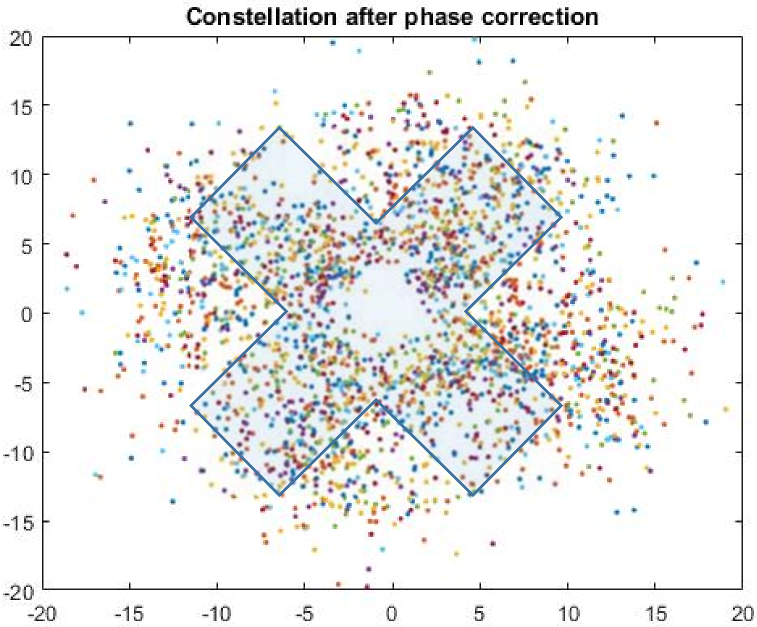


We can see that the channel has a linear phase response .

Phase correction:

Here We can see constellation before and after the phase correction:

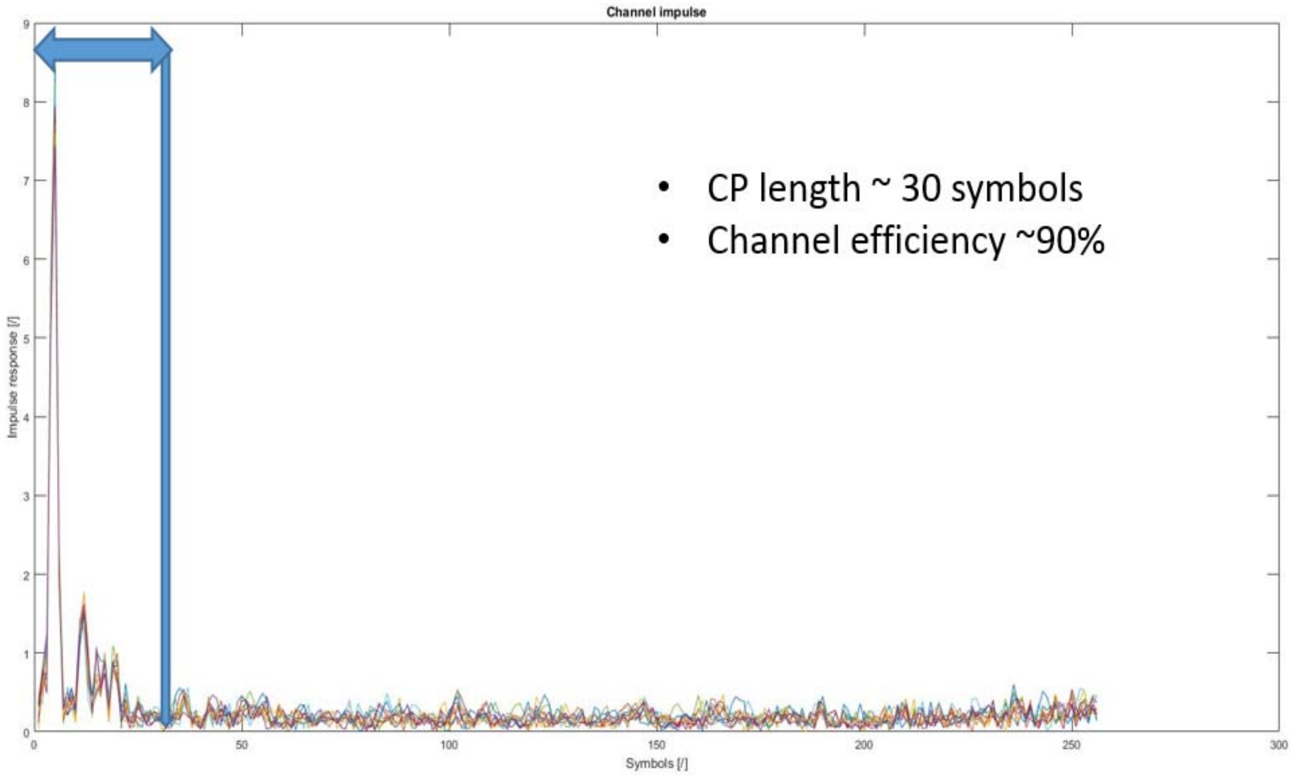




After phase correction It is more look like QPSK symbols

Time Response of Channel:

The inverse Fourier transform of the channel response gives us time response as depicted bellow



According to this figure minimum cp length should be 30 symbols so maximum efficiency would be 90%

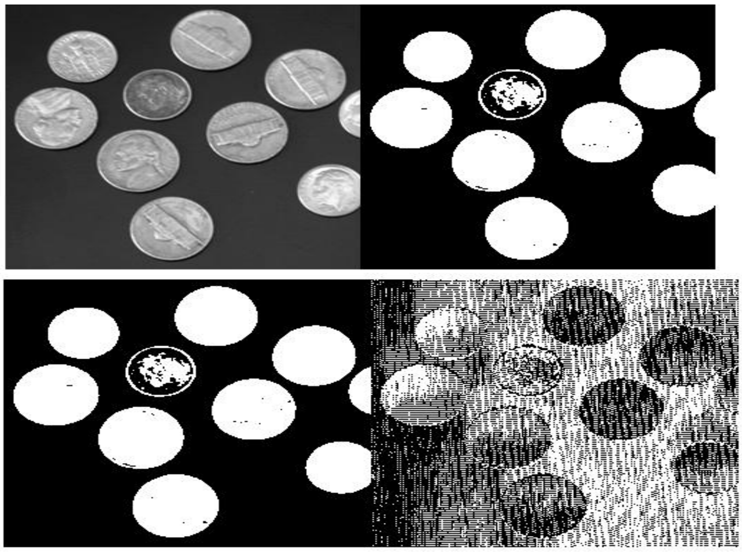
Efficiency = 256/(256+30)~90% $\dfrac{number\ of\ carrier}{number\ of\ carrier + cycle\ prefix}$

now, we want to find how many bits we can send without phase tracking, so we started increasing the number of bits, but unfortunately we didn't see any significant variation of BER we increase the number of bits up to 250 ofdm symbol but when we start moving between microphone and speaker(we create disturbance) we do need it.

Image transmission through acoustic channel:

Another thing we did in this project was that we convert a grayscale picture to black and white one (which consisted of only 0 and 1) and we send each column (256 bits) of the picture as an ofdm symbol

The received picture is not the same as transmitted one. The most probable reason is peak to average power ratio



Conclusion:

In this project, our system uses an acoustic channel to transmit the data, we know that this way is not the best way knowing that the range of the acoustic transmission is limited by the operating range of the audio hardware

We studied a multicarrier transmission system. We saw that how a multicarrier system works and what are the challenges we are confronted with in such system.

We tried to remove the effects of the channel in order to obtain our transmitted symbols in the best way.

We obtained a reasonable BER by using the training and phase tracking.

At the end, I find this project very interesting and effective to study a complete system.