***Abstract*—OFDM (Orthogonal Frequency Division Multiplexing) is an efficient multi-carrier solution over the air interface. Frequency is a limited resource and hence it is regulated. Therefore, there are solutions to help optimize its use, have higher data rates and still avoid, as much as possible, inter-symbol interference (ISI) and Inter-carrier Interference (ICI). OFDM is an important technology for many developed and developing communications standards which require high throughput and multi-path advantages as much as possible. The air interface is an ever changing channel. Fading and noise, amongst other parameters, affect our efficient use of this channel. Thus, there are developed wireless channel models, and optimized over time, to improve on the efficient use of this channel.**

***Index Terms*—OFDM, ISI, cyclic prefix, Rayleigh fading, Rician fading, Matlab, filter method, spectrum method**

I. Introduction

This is the report for group C based on part II of the project work assigned to us. It is about the design and simulation over an OFDM communication system over the time-varying frequency selective channel.This report is arranged in sections sequentially, which contain concise explanations to our findings and answers to the posted questions.

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II. Part 2

A. Background information

The essence of the OFDM technology is for better efficient use of our frequency spectrum in a multi-carrier, multi-access environment. This is modelled with certain constraints and considerations in mind. QPSK modulation is adopted, which offers 4 symbols, with 2-bits per symbol. There is always some noise in communication systems and the effect should be minimized for accurate detection of the transmitted symbols. Interference should be avoided, or greatly minimized, either between symbols, or between sub-carriers. This is managed by using cyclic prefix,with, or without, guard bands. Also, the transmission is achieved with the bandwidth of each sub-carrier being lower than the coherent bandwidth. Furthermore, the OFDM symbol duration should be far lower than the coherence time of the channel. As long as there is mobility of the transmitter, or receiver, or both, there will be always a Doppler shift in frequency.

The transmitted symbols have an Energy, E. For the energy to be the same value for all symbols, there will be a mathematical relationship.

The communication system we are to design is to operate at 2 GHz carrier frequency with a bandwidth of 1 MHz. So we need to efficiently use this bandwidth to have usable number of sub-channels. The noise spectral density receiver is $N_0 = 2.07 \times 10^{-14} \mu W/Hz$. The wireless link has a path loss component of 101 dB. The effect of shadowing is negligible. The speed of receiver is 15 m/s and the delay spread is $5.4\mu s$. Coherence bandwidth is approximately the inverse of the delay spread, which thus gives us 185.19KHz, or 0.18519MHz. We are to design a communication system for a fading channel, built on the assumption that the tap gains $c_l(nT_s)$ are i.i.d. Rayleigh fading with Clarke's spectrum and a flat power delay profile.

B. Steps of implementing the OFDM system

1) Transmitter: At this stage we're generating a sequence of QPSK symbols $s_k^{(m)}$ of length N. Each m-th sequence should satisfy an energy constraint $E\{|s_k^{(m)}|^2\} = E$. To obtain the signal in the time domain we need to apply an IFFT:

$$z_n^{(m)} = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} s_k^{(m)} exp(j2\pi \frac{nk}{N}), n = 0, 1, ..., N-1 \quad (1)$$

After this we're adding a cyclic prefix of length $N_{cp} \geq 0$ to $z_n^{(m)}$ forming a vector of length $N + N_{cp}$. with $z_{-k}^{(m)}$ = $z_{N-k}^{(m)}$, for k = 1,..,N_{cp}. Thus we're forming OFDM symbols. Neglecting the D/A and A/D converters we're making an assumption that the pulse shape involved is a square pulse

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of duration T_s, which is $T_s = 1/F_s$, so our complex numbers $z_k^{(m)}$ are sent sequentially over the channel at a rate $1/T_s$.

2) Channel: We use a flat fading Rayleigh channel which we generated in the Project Part I. The channel during OFDM symbol m is denoted by $c_l^{(m)}(nT_s)$, $l = 0, 1, ..., L-1$ and $n = -N_{cp}, ..., N-1$. We denote L as a number of channel taps, set such that LT_s is larger than a delay spread τ_{DS} of the underlying physical channel. While designing the OFDM system we should keep the following constraints in mind:

- The channel should be close to constant during an OFDM symbol duration, meaning that an OFDM symbol time duration, T_o, should be larger than the coherence time, T_{coh}. This is satisfied when $(N + N_{cp})f_D T_s \ll 1$.
- The delay spread of the channel, σ, should be smaller than the cyclic prefix duration: $N_{cp} \geq L - 1$.

3) Receiver: At the receiver side we're working with the discrete-time signals. First, we're adding complex AWGN samples with variance N_o to the received signal. Here N_o equals to the noise spectral density multiplied by the bandwidth B. Then we're removing the cyclic prefix and applying FFT to the remaining N samples for each OFDM symbol to obtain samples of the form:

$$y_n^{(m)} = C_n^{(m)} s^{(m)} + w_n^{(m)} \qquad (2)$$

where $C_n^{(m)}$ is the FFT of $c_l^{(m)}(nT_s)$ and $w_n^{(m)}$ is the FFT of the noise. At the end, assuming that we know the channel $h(t)$, we're performing maximum likelihood detection to recover $s_k^{(m)}$. To ensure that we're not facing any residual scaling and rotations, we need to apply equalization to $y_n^{(m)}$ to get rid of any channel effects.

Fig. 1

C. Simulation Task

1) Part 1:

2) Part 2:

3) Part 3:

4) Part 4:

5) Part 5:

III. Conclusion

IV. Contributions

Appendix A
Title

Appendix B
Matlab code