 Thesis

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# Introduction

## The need for TTE:

### NIOSH

### Robot, rescue, first responders…

### Manufacturers: Ultra (Rock Phone), Lockheed- Martin (),,…

### Approaches:

* + - 1. E-field: https://www.cdc.gov/niosh/mining/researchprogram/contracts/contract\_200-2008-26818.html
      2. B-field
      3. Alertek, Lockheed, Stolar, E-spectrum, Ultra

## Electromagnetic analysis of VLF band

## Magnetic devices- Coils

## Channel model: Brazil figure 14

## The choice of OFDM

### Analog or FSK ( Brazil, p. 166)

### MSK (Brazil [2])

### impulsive noise (Brazil); frequency selective?

### No good model. (Brazil p.170 left)

### OFDM is flexible both on Tx and on Rx

### CSIT is of advantage

# System, Magnetic and analog devices

## 

## 

## 

## 

## 

## System requirements

### Throughput

### Range

### Antenna

### Frequency domain characteristics

### Direction sensitivity

## SIMO 1x3

### Ordinary use of SIMO: small scale fading

### Proposed use of SIMO: Large scale fading

## SDR concept

## Magnetic devices

### Tx

### Rx

## Analog devices

### D/A

### A/D

### Reconstruction & Anti-aliasing filters (Maxim)

## Link budget

### Calculation

### Simulation

# OFDM - General

## Need: Rx & Tx Selectivity

Along the years, communication systems have been challenged to provide higher data rates, to operate in increasingly difficult channel mediums and in increasingly densely occupied spectrum. The NLOS channels, in particular, confronted the communication system with highly frequency selective channels. All of the above created the need to provide waveforms with inherent frequency flexibility allowing both Tx and Rx chain to process the signal in frequency selective manner. The traditional single-carrier technology did come up with means of dealing with these impairments, with equalizers fora example, but this ability was limited to moderately selective channels and frequently did more harm than good

## Evolution of OFDM

OFDM and its ancestors are based on simultaneous transmission instead of serial transmission. A single carrier signal can be expressed as follows:



Where  is the pulse shaping function (usually belonging to the Raised cosine family),  is the n’th data symbol, and  is the symbol time. The separation between the consecutive symbols is in the time domain, and the pulse shaping function is such that enables the extraction of a given symbol form its predecessors and followers.

A multicarrier waveform is expressed as follows:



Where  are called the “sub-carrier” functions and are the data symbols, and  is again the symbol time. Here, the separation is achieved in the frequency domain

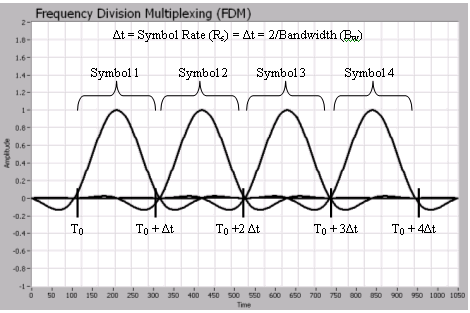
Naturally, in order to transmit the same amount of data symbols;



Hence, we can regard the multi carrier subcarriers as independent single-carrier waveforms, each spanning along a much longer duration in time that their corresponding true single carrier waveform. Longer duration means narrower bandwidth, which suggests why multi carrier waveforms deal better with frequency selective mediums.

### FDM

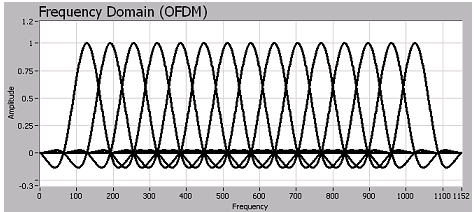
The basic waveform contains several sub carriers spectrally separated from each other. i.e; concatenated in such a way that a simple amplitude (e.g; brick wall, butterworth) filter bank can extract them with no significant loss of energy:



The implementation, however, is rather cumbersome and complex as it requires a bank of analog filters, frequency sources and mixers.

### Analog OFDM

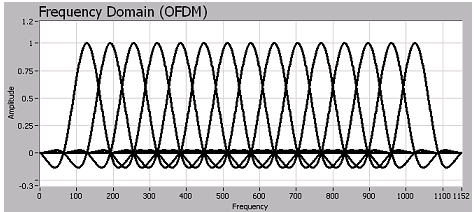
Orthogonal FDM uses the orthogonal Fourier basis for as the subcarrier family. That allows a denser arrangement, hence a better spectral efficiency



The analog implementation remains cumbersome

### Digital OFDM

The digital implementation of OFDM solves that problem of complexity of implementation as the simultaneous modulation/demodulation operations becomes IDFT/DFT operations. Those are naturally realized via the particularly efficient IFFT/FFT algorithms.



## Mathematical representation

### Tx

Additionally, it makes use of the DFT’s cyclic convolution property to easily estimate the channel and efficiently correct it.

## Mathematical representation

### Tx

the complex Fourier basis is:



i.e; a family of functions completing an integer number of cycles within the time span 



The transmitted signal, which is the linear combination of that basis with a QAM symbols stream as coefficients will be:



Will turn to:



The following figure demonstrates that procedure:

The symbol stream: multiplied by the above basis functions gives (real part)



Which look meaningless

### Rx: matched filtering as FFT

### Rx: matched filtering as FFT

## CP:

### General: Frequency domain equalization- Linear into cyclic convolution

### OFDM frequency domain equalization: flatness per subcarrier (channel=complex scalar)

### Preservation of orthogonality

### ISI (Guard time)

## Time synchronization problems: effect on signal (Prasad)

## Frequency synchronization problems: effect on signal (Prasad, NPTEL, my summary)

## Pilots

## Guard bands:

### The need to D/A

### the DC sc

## Preambles

### Long:

* + - 1. PN sequence

### Short:

* + - 1. Channel estimation
      2. SNR estimation

# OFDM –parameters calculations

## CP

## N FFT

## Length of preambles

1. Transmitter:

# 

## Preambles enhancement

## PAPR reduction

## Analog HW compensation: inverse sinc, differentiator

1. Receiver:

## Equalizer types (see findings document)

## Timing synchronization

## Frequency& phase synchronization

## MRC MIMO

1. Data Converters integration:

## Setting the Fs, Frec

## Synchronization

## Frequency error effect on signal integrity. My analysis (summary) and results

1. Results- Simulations
2. Results- Field experiments