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Analysis of OFDM Simulation for CDMA Wireless Communication System

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Abstract— **This paper investigates the effectiveness of Orthogonal Frequency Division Multiplexing (OFDM) as a modulation technique for wireless radio applications. The main aim was to assess the suitability of OFDM as a modulation technique for a fixed wireless phone system for rural areas of Myanmar. The performance of OFDM was assessed by using computer simulations performed using MATLAB. Most third generation mobile phone systems are proposing to use Code Division Multiple Access (CDMA) as their modulation technique. For this reason, CDMA was also investigated so that the performance of CDMA could be compared with OFDM. OFDM was found to have total immunity to multipath delay spread provided the reflection time is less than the guard period used in the OFDM signal. The performance of the OFDM signal was found to be the same as for a single carrier system, using the same modulation technique.**

Keywords— **OFDM, CDMA, Wireless Network, MATLAB, Radio Applications**

I. INTRODUCTION

One of the challenges in today's Wireless Broadband Access market is the ability to deploy and operate wireless systems while maintaining good performance, delivering high speed data rate in many different topographic and landscape areas. Natural and manmade obstacles affect the performance of the wireless systems. Whether it is due to non-line-of-sight (NLOS) conditions or multi-path, it's a challenge that many operators face today. An emerging technology called OFDM solves these challenges. Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique. It achieves high speed data rates, prevents intersymbol interference (ISI), and overcomes multi-path signals. It also allows communications in areas where non-line-of-sight (NLOS) is a limiting factor for wireless deployments. OFDM technology is not new.

Currently Global System for Mobile telecommunications (GSM) technology is being applied to fixed wireless phone systems in rural areas or Australia. However, GSM uses Time Division Multiple Access (TDMA), which has a high symbol rate leading to problems with multipath causing inter-symbol interference. Several techniques are under consideration for the next generation of digital phone systems, with the aim of improving cell capacity, multipath immunity, and flexibility. These include Code Division Multiple Access (CDMA) and Coded Orthogonal Frequency Division Multiplexing (COFDM). Both these techniques could be applied to providing a fixed wireless system for rural areas. However, each technique has different properties, making it more suited for specific applications.

OFDM/COFDM allows many users to transmit in an allocated band, by subdividing the available bandwidth into many narrow bandwidth carriers. Each user is allocated several carriers in which to transmit their data. The transmission is generated in such a way that the carriers used are orthogonal to one another, thus allowing them to be packed together much closer than standard frequency division multiplexing (FDM). This leads to OFDM/COFDM providing a high spectral efficiency.

II. PROPAGATION CHARACTERISTICS OF MOBILE RADIO CHANNELS

In an ideal radio channel, the received signal would consist of only a single direct path signal, which would be a perfect reconstruction of the transmitted signal. However in a real channel, the signal is modified during transmission in the channel. The received signal consists of a combination of attenuated, reflected, refracted, and diffracted replicas of the transmitted signal.

A. Attenuation

Attenuation is the drop in the signal power when transmitting from one point to another. It can be caused by the transmission path length, obstructions in the signal path, and multipath effects. Figure.1 shows some of the radio propagation effects that cause attenuation. Any objects that obstruct the line of sight signal from the transmitter to the receiver can cause attenuation.

Shadowing of the signal can occur whenever there is an obstruction between the transmitter and receiver. It is generally caused by buildings and hills, and is the most important environmental attenuation factor. Shadowing is most severe in heavily built up areas, due to the shadowing from buildings. However, hills can cause a large problem due to the large shadow they produce. Radio signals diffract off the boundaries of obstructions, thus preventing total shadowing of the signals behind hills and buildings. However, the amount of diffraction is dependent on the radio frequency used, with low frequencies diffracting more than high frequency signals. Thus high frequency signals, especially, Ultra High Frequencies (UHF), and microwave signals require line of sight for adequate signal strength. To overcome the problem of shadowing, transmitters are usually elevated as high as possible to minimize the number of obstructions. Typical amounts of variation in attenuation due to shadowing are shown in Table 1.

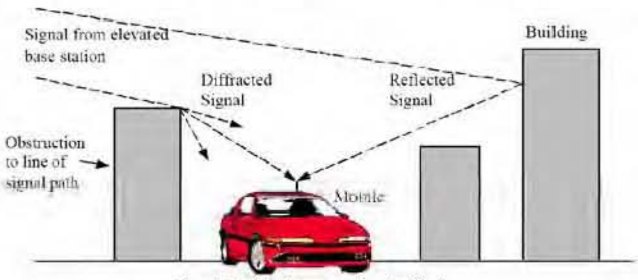

Fig. 1 Radio Propagation Effects

TABLE I
TYPICAL SHADOWING IN A RADIO CHANNEL

Description	**Typical Attenuation due to Shadowing**
Heavily built-up urban centre	20dB variation from street to street
Sub-urban area (fewer large buildings)	10dB greater signal power then built-up urban centre
Open rural area	20dB greater signal power then sub-urban areas
Terrain irregularities and tree foliage	3-12dB signal power variation

III. CODE DIVISION MULTIPLE ACCESS

Code Division Multiple Access (CDMA) is a spread spectrum technique that uses neither frequency channels nor time slots. With CDMA, the narrow band message is multiplied by a large bandwidth signal that is a pseudo random noise code. All users in a CDMA system use the same frequency band and transmit simultaneously. The transmitted signal is recovered by correlating the received signal with the PN code used by the transmitter. Figure.2 shows the general use of the spectrum using CDMA.

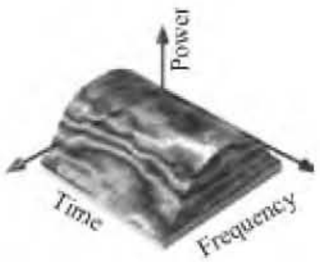

Fig. 2 Code Divisions Multiple Access (CDMA)

A. *CDMA Process Gain*

One of the most important concepts required in order to understand spread spectrum techniques is the idea of process gain. The process gain of a system indicates the gain or signal to noise improvement exhibited by a spread spectrum system by the nature of the spreading and despreading process. The process gain of a system is equal to the ratio of the spread spectrum bandwidth used, to the original information bandwidth. Thus, the process gain can be written as:

$$Gp=\frac{BW_{RF}}{BW_{Info}}$$

Where BW_{RF} is the transmitted bandwidth after the data is spread, and BW_{Info} is the bandwidth of the information data being sent.

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B. *CDMA Generation*

CDMA is achieved by modulating the data signal by a pseudo random noise sequence (PN code), which has a chip rate higher than the bit rate of the data. The PN code sequence is a sequence of ones and zeros (called chips), which alternate in a random fashion. Modulating the data with this PN sequence generates the CDMA signal. The CDMA signal is generated by modulating the data by the PN sequence. The modulation is performed by multiplying the data (XOR operator for binary signals) with the PN sequence. Figure.3 shows a basic CDMA transmitter.

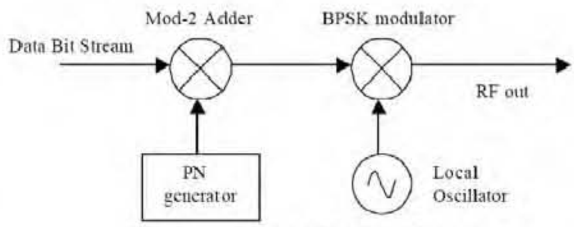

Fig. 3 Simple Direct Sequence Modulator

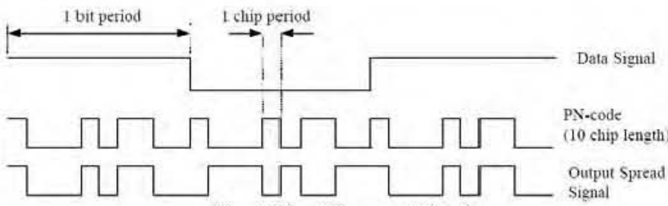

Fig. 4 Direct Sequence Signals

IV. OFDM Model Used

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal. The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components.

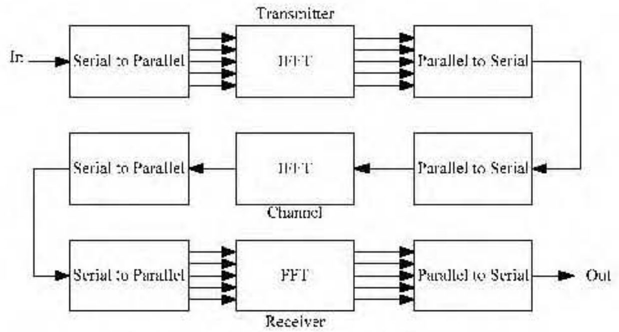

Fig. 5 OFDM Simulation Block Diagram

TABLE III
OFDM SYSTEM PARAMETERS USED FOR THE SIMULATIONS

Parameter	**2k Mode**
Elementary period T	7/64 µs
Number of carriers K	1,705
Value of carrier number K_{min}	0
Value of carrier number K_{max}	1,704
Duration T_U	224 µs
Carrier spacing $1/T_U$	4,464 Hz

The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal. The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time domain signal. An IFFT converts a number of complex data points, of length that is a power of 2, into the time domain signal of the same number of points. Each data point in frequency spectrum used for an FFT or IFFT is called a bin. The orthogonal carriers required for the OFDM signal can be easily generated by setting the amplitude and phase of each frequency bin, then performing the IFFT. Since each bin of an IFFT corresponds to the amplitude and phase of a set of orthogonal sinusoids, the reverse process guarantees that the carriers generated are orthogonal.

V. Simulation Results

The simulation results of OFDM transmitter and receiver output signal for time and frequency domain are shown in the following Fig. 6 to 13. In Fig. 6 and Fig. 7, we can observe the result of this operation and that the signal carrier uses T/2 as its time period. We can also notice that carriers are the discrete time baseband signal. We could use this signal in baseband discrete-time domain simulations, but we must recall that the main OFDM drawbacks occur in the continuous time domain.

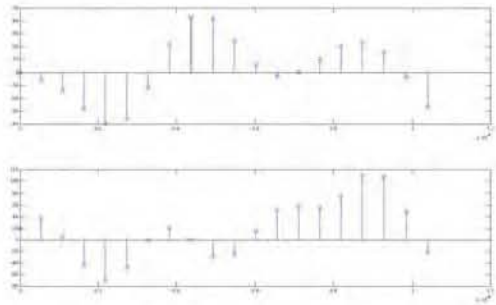

Fig. 6 Time response of signal carriers at IFFT Output

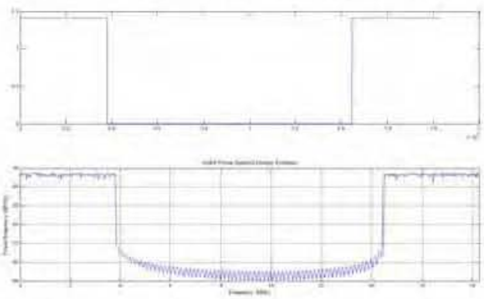

Fig. 7 Frequency response of signal carriers at IFFT Output

The time and frequency responses for the complete signal, s(t), are shown in Fig.6 and in Fig.7. We can observe the large value of the aforementioned PAR in the time response of Fig. 6.

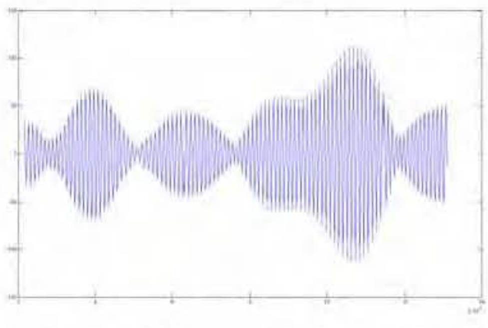

Fig. 8 Time response of signal at parallel to serial output

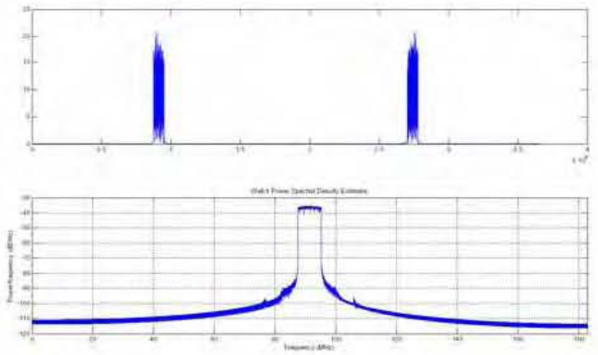

Fig. 9 Frequency response of signal at parallel to serial output

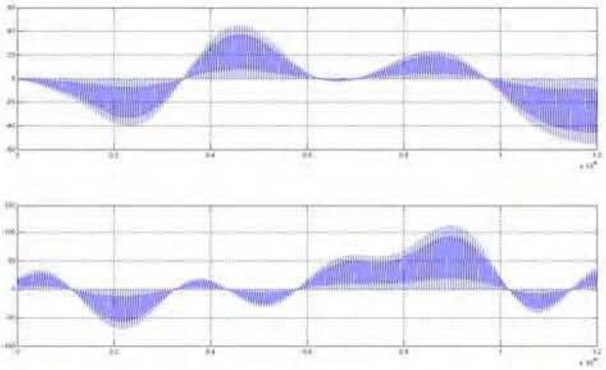

Fig. 10 Time response of signal at serial to parallel output

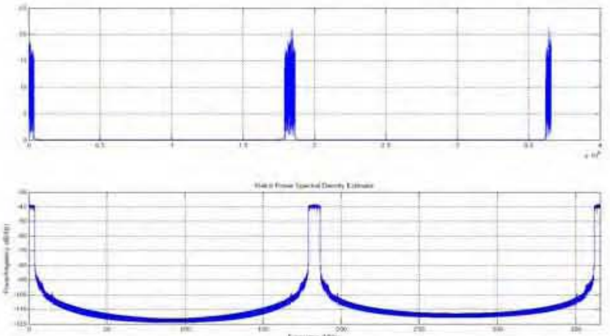

Fig. 11 Frequency response of signal at serial to parallel output

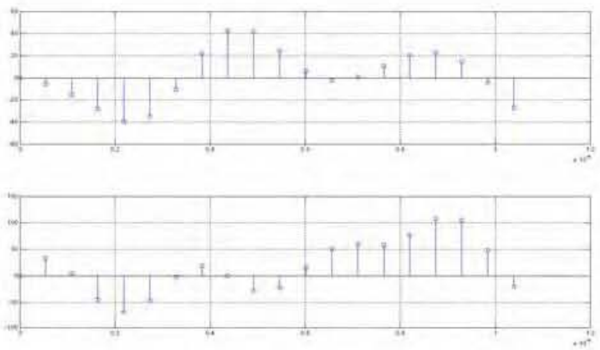

Fig. 12 Time response of signal carriers at FFT Output

The results of the OFDM receiver portions are the same as the transmitted portion. Fig. 10 to Fig. 13 show the time domain and frequency domain signal of the OFDM system.

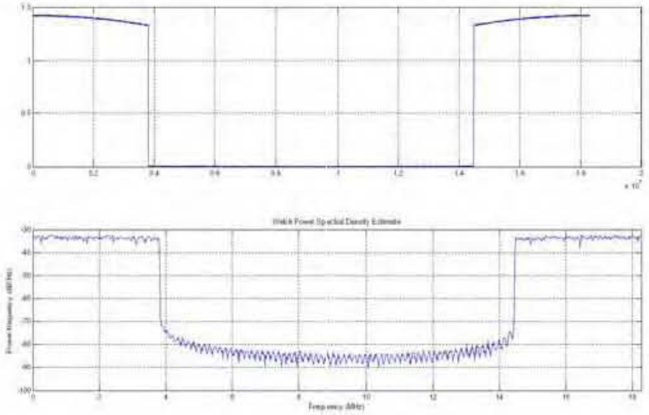

Fig. 13 Frequency response of signal carriers at FFT Output

VI. Conclusion

The current status of the research is that OFDM appears to be a suitable technique as a modulation technique for high performance wireless telecommunications. An OFDM link has been confirmed to work by using computer simulations, and some practical tests performed on a low bandwidth base-band signal. So far only four main performance criteria have been tested, which are OFDM's tolerance to multipath delay spread, channel noise, peak power clipping and start time error. Several other important factors affecting the performance of OFDM have only been partly measured. These include the effect of frequency stability errors on OFDM and impulse noise effects. OFDM was found to perform very well compared with CDMA, with it out-performing CDMA in many areas for a single and multicell environment.

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