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Performance Comparison of SUI communication channel with Wavelet implemented WiMAX Communication System

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ABSTRACT

The objective of this paper is to analyze the performance of WiMAX Communication Model by implementing Stamford University Interim(SUI)-1 and Stamford University Interim(SUI)-2 communication channel. We evaluated the performance of WiMAX Physical layer by implementing wavelet in place of IFFT, under different combination of digital modulation techniques (16-PSK, QAM and 16-QAM) over SUI 1 and SUI 2 Communication Channels. In our research work, we investigated the physical layer performance on the basis of bit error rate (BER) and signal to noise ratio (SNR). The simulation results of estimated Bit Error Rate (BER) displays that the implementation of wavelet transformation is highly effective against the implementation of FFT transformation. The simulation results also showed that WiMAX system that use SUI-2 Channel had Significantly less Bit Error Rate then the Model using SUI-1 Channel.

Keywords: *CC, IFFT, PSK, QAM, SUI-1, SUI2, SNR, WAVELET, WiMAX.*

1 INTRODUCTION

Wireless communication is an emerging field, which has seen enormous growth in the last several years. The huge uptake rate of mobile phone technology, Wireless Local Area Networks (WLAN) and the exponential growth of the Internet has resulted in an increased demand for new methods of obtaining high capacity wireless networks. Most WLAN systems provide a maximum data rate of 11 Mbps [1]. Newer WLAN standards, based on OFDM technology, provide a much higher data rate of 54 Mbps. However, systems of near future will require WLANs with data rates greater than100 Mbps, and so there is a need to further improve the spectral efficiency and data capacity of OFDM systems in WLAN applications [2]. In the WMAN application, OFDM is considered for the Worldwide Interoperability for Microwave Access (WiMAX) implementation. It is also being considered for the 3GPP Long Term Evolution, which in under development. The IEEE 802.16 Working Group created a new standard, commonly known as WiMAX [3] (Worldwide Interoperability for Microwave Access) which is an emerging wireless communication system that is expected to provide high data rate communications in metropolitan area networks (MANs). In the past few years, the IEEE 802.16 working group has developed a number of standards for WiMAX. The first standard was published in 2001, which aims to support the communications in the10–66 GHz frequency band. In 2003 IEEE 802.16a was introduced to provide additional physical layer specifications for the 2–11 GHz frequency band. These two standards were further revised in 2004 (IEEE 802.16-2004). Recently, IEEE 802.16ehas also been approved as the official standard for mobile applications [4].

2 RELATED WORKS

There is considerable research work going on in the field of WiMAX and the implementation of WiMAX with Inverse fast Fourier Transform (IFFT). Many researchers are also including the involvement of SUI channel which we have considered in our research work. M.A. Hasan compared the performance of WiMAX system over SUI-1 SUI-2 and SUI-3 channel model. In his research work he showed that Forward Error Correction (FEC) improved BER performance by almost 6db at the bit error rate level of 10^{-3}[5]. In a recent research journal by R. F. Chisab, Member and C. K. Shuklawho did their research over 4G-LTE SCFDMA under SUI and ITU channel modelshowed that the MMSE equalization is better than ZF method and the localized subcarrier mapping is better than the distributed subcarrier mapping [6]. In another performance evaluation of Different Wavelet Families Over Fading Environments for Mobile WiMAX System H. Kaur et al DWT-OFDM is better as compared to FFT-OFDM for all wavelets with regards to the BER performance but Biorthogonal wavelet performance is superior with Okumara model and with Hata model, Daubechies wavelet outperforms other wavelets [7]. Based on this paper we decided to compare the WiMAX Model with both IFFT and Wavelet over SUI channel model.

3 COMMUNICATION MODEL

The Communication model that we used is shown in Fig:1. The upper section shows the transmission section and the bottom part shows the reception. This structure corresponds to the physical layer of the WiMAX air interface.

In this setup, we have just implemented the mandatory features of the specification, while leaving the implementation of optional features for future work. The channel coding Part that is composed of three steps namely randomization, channel encoding and inner Convolutional Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. As our research work is mainly based on WiMAX model with SUI channel we will only discuss them here briefly.

3.1 Wavelet Transformation

Over the past ten years much has been accomplished in the development of the theory of wavelets, and people are continuing to find new application domains. However, at the present time most of the literature remains highly mathematical and requires a large investment of time to develop an understanding of wavelets and their potential uses. Wavelet transformation is a set of mathematical functions which is used in digital signal processing to recover weak signals from noise. In Internet Communication, however the purpose of wavelet is to this research is to provide an overview of wavelet theory by developing, from an intuitive standpoint, the idea of the wavelet transforms and how it might improve. Since a complete study of wavelets would encompass both a lengthy mathematical development and consideration of many application domains, we adopt a particular viewpoint that lends itself readily to signal processing applications. [8][9].

3.2 Communication Channel

A communication channel refers to the medium used to convey information from a transmitter to a receiver[10]. One of the objectives of this thesis work is to propose the use of a newly developed channel called Stanford University Interim (SUI) Channel Model that is described below.

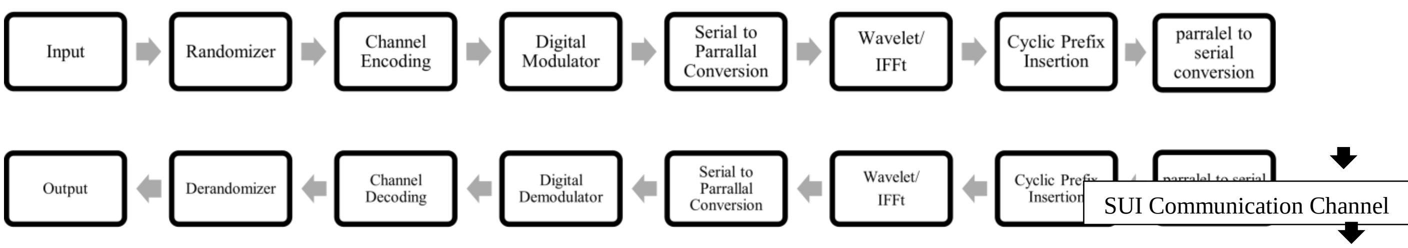

Fig. 1. WiMAX Simulation Model

3.2.1 Stamford University Interim (SUI) Channel Model

It is obvious that there are many possible combinations of parameters to obtain a channel description. A set of 6 typical channels was selected for the three terrain types that are typical of the continental US [11]. These Models can be used for simulations, designs, development and testing of technologies suitable for fixed broadband wireless applications the parametric view of the SUI channels are summarized in the following table.

The generic structure for the SUI channel Model is given below

Fig. 2. SUI Channel Model

The above structure is general for Multiple Input Output (MIMO) channels and includes other configurations like Single Output (SISO) and Single Input Multiple Output (SIMO) as subsets. The SUI channel structure is the same for the primary and interfering signals.

Table 1: SUI Channel Parameters

Channel	Terrain type	Doppler Spread	Spread	LOS
SUI-1	C	Low	Low	High
SUI-2	C	Low	Low	High
SUI-3	B	Low	Low	Low
SUI-4	B	High	Moderate	Low
SUI-5	A	Low	High	Low
SUI-6	A	High	High	Low

***Input Mixing Matrix*:** this part indicates correlation between input signals if multiple transmitting antennas are used.
***Tapped Delay Line Matrix*:** This part models the multipath fading of the channel. The Multipath fading is modeled as a tapped delay line with 3 taps with non-uniform delays. The gain associated with each tap is characterized by a distribution (Rician with k-factor >0, or Rayleigh with k factor =0) and the maximum Doppler frequency
.***Output Mixing Matrix*:** this part Models the correlation between output signals if multiple receiving antennas are used. Using the above general structures of the SUI channel and assuming the following scenario. Channels are constructed which are representative of the real channels.

Table 2: Design Parameters for SUI-1 Model

	Tap 1	Tap 2	Tap3	Units
Delay	0	0.4	0.9	Ms
Power (Omni. Ant.) 90% K-factor (Omni) 75% K-factor (Omni)	0 4 20	-15 0 0	-20 0 0	dB
Power (Omni. Ant.) 90% K-factor (omni) 75% K-factor (Omni)	0 16 72	-21 0 0	-32 0 0	dB
Doppler	0.4	0.3	0.5	Hz
Antenna Correlation ρ_{env}= 0.7 Gain reduction factor:GRF = 0db Normalization factor F_{omni}= -0.1771 db $F_{30}{}^{0}$ = -0.0371	Terrain type : C Omni Antenna τ_{RMS} = 0.111 µs Overall k: k= 3.3 (90%); k = 10.4 (75%) 30 Antenna: $\tau_{RMS=}$ 0.042 µs Overall k: k= 14.0 (90%); k = 44.2 (75%)			

The following modes the total channel gain is not normalized. Before Using a SUI model, the specified normalization factors have to be added to each tap to arrive at 0db total mean power. The specified Doppler is the maximum frequency parameter. Note that this implies that all 3 taps are affected equally due to the effects of local scattering. K-factors have linear values, not

Table 3: Design Parameters SUI-2 Channel Model.

	Tap 1	Tap 2	Tap3	Units
Delay	0	0.4	1.1	Ms
Power (Omni. Ant.) 90% K-factor (Omni) 75% K-factor (Omni)	0 2 11	-15 0 0	-20 0 0	dB
Power (Omni. Ant.) 90% K-factor (omni) 75% K-factor (Omni)	0 8 36	-18 0 0	-27 0 0	dB
Doppler	0.2	0.3	0.5	Hz
Antenna Correlation ρ_{env}= 0.5 Gain reduction factor:GRF = 2 db Normalization factor F_{omni}= -0.3930 db $F_{30}{}^{0}$ = -0.0768	Terrain type : C Omni Antenna τ_{RMS} = 0.202 µs Overall k: k= 1.6 (90%); k = 5.1 (75%) 30 Antenna: $\tau_{RMS=}$ 0.069 µs Overall k: k= 6.9 (90%); k = 21.8 (75%)			

0db values. K-factors for the 90% and 75% cell coverage are shown in the tables i.e., 90% and 75% of the cell locations have K –factors greater or equal to the K-factor value specified respectively. For the SUI channels1 and 2, 50% K-factor values are also shown.

3.2.2 SUI Channel implementation

The goal of the model implementation is to simulate coefficients. Channel coefficients with the specified distribution and spectral power density are generated using the method of filtered noise. A set of complex zero mean Gaussian distributed number is generated with a variance of 0.5 for the

real and imaginary part for each tap to achieve the total average power of this distribution is 1. In this way, we get a Rayleigh distribution (equivalent to Rician distribution with k=0) for the magnitude of the complex coefficients. In case of a Rician distribution (K>0), a constant path component m has to be added to the Rayleigh set of coefficients. The K-factor specifies the ratio of powers between this constant part and the variable part. The distribution of the power is shown below.
The total power p of each tap

$P = |m|^2 + \Phi^2$ 1.1

Where m the complex constant is and Φ^2 the variance of the complex Gaussian set. Second, the ratio of powers is

$K = |m|^2 / \Phi^2$ 1.2

From the above equations, we can find the power of the complex Gaussian and the power of the constant part is

$\Phi^2 = \frac{P.1}{K+1}$ 1.3

And the power constant part is

$|m|^2 = P.K / K + 1$ 1.4

The SUI channel model address a specific power spectral density (PSD) function for the scatter component channel coefficients which is given by.

$s(f) = \begin{cases} 1 - 1.72\, f_0^2 + 0.785\, f_0^4 |f| \leq 1 \\ 0 \; |f| > 1 \end{cases}$ 1.5

Where the function is parameterized by a maximum Doppler frequency fm and f0=f / fm

To generate a set of channel coefficients with this PSD function, the original coefficients are correlated with a filter which amplitude frequency response is

$H(f) = \sqrt{s(f)}$ 1.6

For efficient implementation, a non-recursive filter and frequency-domain overlap-add method has been used.
There are no frequency components higher than fm (for the construction formula of s(f) so the channel can be represented with a minimum sampling frequency of 2fmaccording to the Nyquist theorem. For this reason, we chose the sampling frequency equal to 2fm. The power of the filter has to be normalized to 1, so that the total power of the output signal is equal to the input one.

3.3 Symbol Parameters In The System Model

At first, we define the parameters that were used to develop the WiMAX PHY layer simulator. The used parameters are listed in Table 4: as follows:

Table 4: Parameter of the Simulator

Parameters	Values
Number of bits to be transmitted and received	44000
Number of Subcarriers	200
FFT Size	256
CP	1/8
CC	(1/2, 2/3)
SNR	0-20
Modulation	QPSK,16-PSK, 16-QAM
Noise channels	SUI -1 and 2

The parameters for SUI -1 and 2 channels are given below [12]

Table 5: SUI channel Model Parameters

P (power in each tap in dB)	[0 -15 -20] [0 -12 -15] [0 -5 -10] [0 -4 -8]
K (Rician K-Factor in Linear Scale)	[4 0 -20] [2 0 -15] [1 0 -10] [0 0 0]
Tau (Tap Delay)	[0 0.4 0.9] [0 0.4 1.1] [0 0.4 0.9] [0 1.5 4.0]
Doppler (Doppler Maximal frequency parameter)	[0.4 0.3 0.5] [0.2 0.15 0.25] [0.4 0.3 0.5] [0.2 0.15 0.25]
Ant_Corr (Antenna Correlation)	0.7, 0.5, 0.4, 0.3
F_{norm} (Gain normalization factor)	-0.1771, -0.3930, -1.5113, -1.9218

4 SIMULATION RESULTS AND BER PLOTS

In this section, we have presented various BER vs. SNR plots for all the essential modulation and coding profiles in the standard on different channel models. We analyzed synthetic data to transmit or receive data. To calculate Bit Error Rate (BER), “biterr” function (available in Matlab) was used.

After restoring the received bits the "biterr" function was used to compare unsigned binary representations of received data with those of the transmitted data. First we assumed a no noise channel, to calculate BER and it was seen that the value of BER was 0, which was expected. After ensuring that the WiMAX system was working well, then necessary modifications have been done in Matlab source code to run the simulation in SUI -1 and 2 Communication channels. By varying SNR, the plot of SNR vs BER was drawn with the help of "semilogy" function. The Bit Error Rate (BER) plot obtained in the performance analysis showed that model works well on Signal to Noise Ratio (SNR) less than 25 dB.

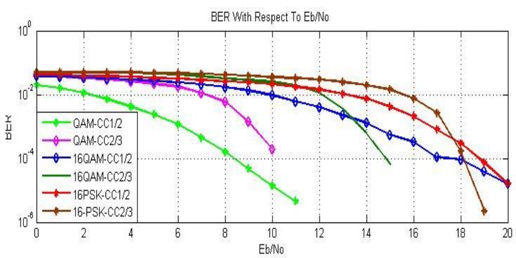

Fig. 3. System Performance Under Different Modulation Scheme for ½ & 2/3 Rated Using Convulation Coding (CC) in SUI-1 Channel.

In Figure 3, the bit error rate performance for several modulation technique when we used the SUI-1 communication channel are shown. The ½ and 2/3 rated CC encoded QAM, with ½ and 2/3 rated CC encoded 16-QAM and ½ and 2/3 rated CC encoded 16-PSK modulation techniques were all plotted together for a clear picture. The graph shows modulation technique having the best performance to be the ½ rated CC encoded QAM. It had the lowest bit error rate for the SNR value of 10dB. 2/3 rated CC encoded QAM showed slightly higher bit error rate comparing to the ½ rated CC encoded QAM. It was seen that½ and 2/3 rated CC encoded16-QAM along with ½ and 2/3 rated CC encoded 16-PSK achieved similar performance when we considered higher SNR values. A sharp reduction in bit error rate for 2/3 rated CC encoded 16-PSK was also monitored when the SNR value was of 19 dB.

In a similar fashion, Figure 4 illustrates the performance comparison for the same modulation techniques discussed in the previous figure when we changed the communication channel from the SUI-1 to SUI-2. Considering the SNR level

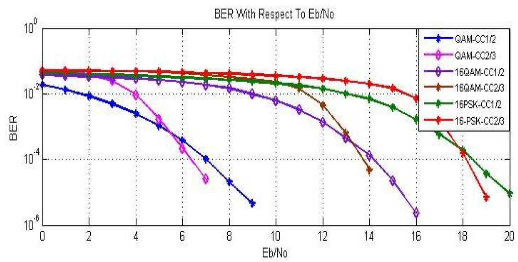

Fig. 4. System Performance Under Different Modulation Scheme for ½ & 2/3 Rated Using Convulation Coding in SUI-2 Channel

of 7dB it became quite easy for us to identify 2/3 rated CC encoded QAM as the modulation technique to outperform all the others. Its improvement in bit error rate was evident in SUI-2 communication channel comparing to SUI-1. ½ rated CC encoder showed a little higher bit error rate for 7dB SNR value. Similarly, ½ and 2/3 rated CC encoded 16-QAM had almost identical curve but still showed better bit error rates then ½ and 2/3 rated CC encoded 16-PSK. It should be noted that all the modulation technique improved in performance when we used SUI-2 communication channel.

5 CONCLUSION

The key contribution of this thesis was the implementation of the WiMAX (Worldwide Interoperability for Microwave Access) PHY layer using MATLAB in order to evaluate the WiMAX physical layer with implementation of wavelet transformation using SUI-1 and SUI-2 Channel.

The thesis focuses on the performance investigation by BER against SNR of IFFT and Wavelet based WiMAX system under newly developed SUI-1 and 2 channels using different digital modulations namely QPSK, QAM and 16-QAM.The BER simulation results are always in between 10-2 to 10-6. First we took a look at the performance of above said modulation technique using both SUI-1 and SUI 2 channel. Both channels performed well but among the modulation techniques ½ and 2/3 rated CC encoded QAM showed the least bit error rates. But among the SUI-1 and SUI-2 channels all the modulation techniques showed less bit error rates in SUI-2 then SUI-1. So far the best result was obtained using SUI-2 channel and 2/3 rated CC encoded QAM modulation.BER curves were used to compare the performance of different modulation techniques and coding scheme.

So therefore, after the above discussion we could say that the combination of Wavelet transformation and the usage of SUI-2 channel with error control coding involving 2/3 rated 16-PSK modulation technique is the most convenient for future WiMAX models.

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