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Impact of Modeling Different Fading Channels on Wireless MAN Fixed IEEE802.16d OFDM System with Diversity Transmission Technique

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Abstract—Wimax (Worldwide Interoperability for Microwave Access) is a promising technology which can offer high speed data, voice and video service to the customer end, which is presently, dominated by the cable and digital subscriber line (DSL) technologies. The performance assessment of Wimax systems is dealt with. The biggest advantage of Broadband wireless application (BWA) over its wired competitors is its increased capacity and ease of deployment. The aims of this paper are to model and simulate the fixed OFDM IEEE 802.16d physical layer under variant combinations of digital modulation (BPSK, QPSK, and 16-QAM) over diverse combination of fading channels (AWGN, SUIs). Stanford University Interim (SUI) Channel serial was proposed to simulate the fixed broadband wireless access channel environments where IEEE 802.16d is to be deployed. It has six channel models that are grouped into three categories according to three typical different outdoor Terrains, in order to give a comprehensive effect of fading channels on the overall performance of the system.

Keywords—WIMAX, OFDM, Additive White Gaussian Noise, Fading Channel, SUI, Doppler Effect.

I. INTRODUCTION

WImax is a new broadband wireless access technology that provides very high data throughput over long distance in a point-to-multipoint and line of sight (LOS) or non-line of sight (NLOS) environments [1] . In terms of the coverage, Wimax can provide services up to 20 or 30 miles away from the base station. Wimax standards were developed by IEEE 802.16 group. These standards are based on wireless metropolitan area networking (WMAN) standards [2]. The WiMAX Forum has two different system profiles: one based on IEEE 802.16-2004 OFDM PHY, called the fixed.system profile; the other is based on IEEE 802.16e-2005 scalable OFDMA PHY, called the mobility system profile [3]. The majority of aspects which make Wimax technology different from others that can be applied to the same scenario reside in its physical layer [4]. To this level, many numerical approximation models which are able to predict the behavior of radio channels can be found [5]. However, this work contains the description of mandatory and optional features of WiMAX PHY layers and simulate them in fading environment. The rest of this document is structured as follows: In section two, some of the basic features for fixed Wimax PHY layer are described. Various propagation models using the SUI based channel scenarios along with path loss and delay spread for arbitrary Transmitter/receiver (T-R) is explained in section three. The Section four and five are explaining structure of SUI channels and their implementation on 802.16d system, basic ideas about path loss and delay spread are presented in section six. The section seven is about simulation models and its parameter, section eight of paper discussion about the simulation result and experimental test carried out, finally section nine is conclusion of the paper and directions for the future work.

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II. WIMAX PHYSICAL LAYER FEATURE

In fixed WiMAX profile, the size of OFDM symbols are fixed at 256, 192 subcarriers are using for carrying data, for channel estimation and synchronization purposes 08 subcarriers used as pilot, and the rest symbols used as guard band. Since the FFT symbols are fixed in size, the spacing between subcarrier varies with channel bandwidth. When larger bandwidths are in use subcarrier spacing increases and symbol time decreases. According to [1], decreasing symbol time implies a larger fraction needs to be allocated as guard time to overcome delay spread. To allow system designers to make appropriate trade-offs between spectral efficiency and delay spread robustness, IEEE 802.16 OFDM-PHY allows a wide range of guard times [5]

III. VARIOUS PROPAGATION MODELS

From the many issues, the most important issue in the design implementation and operation of land mobile system is the knowledge of the received signal and its fluctuations. Propagation models take into account the type of the environment and the materials. The propagation models can be classified into theoretical and empirical categories according to [6]. In the first category are the theoretic models, which could be divided into deterministic and statistical ones. Theoretic models have an advantage that their results are valid independently of the range of input parameters especially when the result takes into account large scale effects. Moreover, deterministic models can have high computational requirements and their complexity makes it difficult to establish a clear relationship between technical parameters and results (e.g. between the height of an aerial and obtained SNR). Statistical models were developed to cope with this issue, but their predictions can become less reliable. However, their computational cost and complexity are notably lower [7]. In second category are empirical models. Those are based on experimental data. Their main advantage relies on their ability to show how practical parameters affect the average power. Nevertheless, their most significant drawback resides on the fact that they are not extensible to a wide range of parameters. Reference [8] bear out those empirical models are useful at predicting average power on WiMAX. Finally, models that combine stochastic and theoretic methods can be another alternative to calculate the behavior of a radio channel in a fairly accurate way. Their computational cost is lower than the one in theoretic models whereas they are more flexible than empirical ones. Models such Stanford University Interim (SUI) [8]can be classified into this group. Moreover, SUI models are the choice of WiMAX developers for Fixed Wireless Access (FWA). Due to their great acceptance, for this work SUI models have been chosen as the starting point to foresee fading effect on behavior of wireless links [9].

IV. SUI CHANNEL MODEL

For assessing technology for Broadband Fixed Wireless applications, an important requirement is to have an accurate description of the wireless channel. Almost, all channel models are significantly reliant upon the radio architecture. The wireless channel is characterized by [10]:

- Doppler spread
- Multipath delay spread
- Path loss (including shadowing)
- Co-channel and adjacent channel interference
- Fading characteristics

It is perceived, that the above mentioned parameters are arbitrary and no more than a statistical characterization is possible. Usually, mean and variance of parameters are specified. According to [8], [11], the SUI propagation model parameters are depend upon terrain, tree density, antenna height and beamwidth, season or time of the year and wind speed. The three typical terrains are associated with A, B or C letters. For A-type, a hilly topology with a high foliage density is considered, while for C-type terrains a mostly flat environment with low foliage density is considered. Last, B-type terrains satisfy a medium foliage density as well as a moderate hilly ground. Table 1 shows their characteristic features.

Noticeably, there are many possible combinations of parameters to obtain such channel description. In [8] a set of six typical channels were selected for the three types of terrain which are typical of the continental US. It is clear, that the system performance would vary greatly with the terrain where it is deployed, which leads to a different predefined threshold level. Furthermore, even in one terrain type, some factors such as antenna height, beam-forming, and Doppler frequency, would cause different system performance. Six SUI channel models are presented in this section. These channels were used with 30o directional antennas as a transmitter. In addition, the customized models can be used for further simulate, design and development and testing of suitable technologies in fixed broadband wireless applications. The parameters selected for customization were based on statistical models. A generic structure for the SUI channel model is depicted in figure1.

TABLE I: SUI PARAMETERS FOR 30^0 DIRECTIONAL ANTENNA [7]

			Relative attenuation (dB)		Max delay spread(Ms)	Max Doppler spread (Hz)
Channel	Terrain	Tape-1	Tape-2	Tape-3		
SUI1	C	0	-21	-32	0.9	0.5
SUI2	C	0	-18	-27	1.1	0.25
SUI3	B	0	-11	-22	0.9	0.5
SUI4	B	0	-10	-20	4	0.25
SUI5	A	0	-11	-22	10	2.5
SUI6	A	0	-16	-26	20	0.5

According to [7], [8], the generic structure for SUI model is a fundamental model for Multiple Input Multiple Output (MIMO) channels, includes other configurations like Single Input Single Output (SISO) and Single Input Multiple Output (SIMO) as subsets. For the primary and interfering signals, SUI channel structure is the identical. The input mixing matrix part (see Fig.1) models correlation between input signals if multiple transmitting antennas are used. The multipath fading of the channel is modeled by tapped delay line matrix as depicted in figure 1. The multipath fading is modeled as a tapped-delay line with 3 taps with non-uniform delays [13]. The gain associated with each tap is characterized by a distribution (Ricean with a K-factor ¿ 0, or Rayleigh with K-factor = 0) and the maximum Doppler frequency [12], [13]. The correlation between output signals if multiple receiving antennas are used is modeled with output mixing (See fig.1).

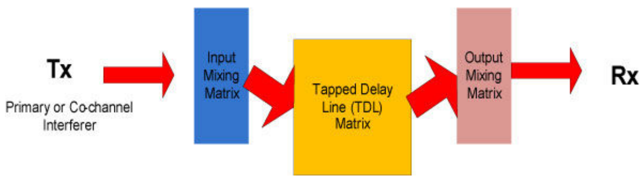

Fig. 1: Generic Structure for SUI Model

Using the generic structure of SUI channel model and assuming the scenarios explained in section five, six SUI channels are constructed which are representative of the actual channels. In this study we will present also the path's loss statistical model.

V. SCENARIO FOR MODIFIED SUI CHANNELS

Table II shows SUI channels parameters which are generally used for initialization.

According to [9], for 30o antenna beamwidth, 2.3 times smaller root-mean-square (RMS) delay spread is being used when compare to an omni-directional antenna Therefore, the 2nd tap power is attenuated an additional 6 dB and the 3rd tap power is attenuated an additional 12 dB. Whether, outdoor or indoor radio channel the average received signal power

TABLE II: SUI INITALIZATION PARAMETERS [8]

Cell Size	7km
Base Station(BTS)antenna Height	30 meters
Receiving antenna height	6 meters
Base Station(BTS)antenna Bandwidth	120^0
Receiving antenna Bandwidth	30^0
Vertical Polarization only applied	
90% cell coverage with 99.9%	

decreases logarithmically with distance, as indicated by both theoretical and measurement-base propagation models.

VI. PATH LOSS AND DELAY SPREAD

The average large scale path loss for an arbitrary T-R separation is expressed as a function of distance by using a path loss exponent, *nn*

$$\overline{PL}\left(d\right) = \left(\frac{d}{d0}\right)^n \tag{1}$$

$$\overline{PL}\left(db\right) = \overline{PL}\left(d0\right) + 10log\left(\frac{d}{d0}\right) \tag{2}$$

Where n is the path loss exponent which indicates the rate at which path loss increase with distance, *d0* is the close-in reference distance which is determined from measurement close to the transmitter, *d* is the T-R separation distance. The bar in Equations (1) and (2) denote the ensemble average of all possible path loss values for a given value of *d*. The value of *n* depends on the specific propagation environment, for example in free space *n* is equal to 2 and when obstructions are present *n* will have a larger value. Typical power delay profiles are illustrated in figure 2. The plots from outdoor and indoor channels, determined from a large number of closely sampled instantaneous profiles.

VII. SIMULATION MODEL

In order to validate the proposed work, the simulation scenario is focused in a link budget with 30o directional antennas and with Multi input single output transmission scheme (MISO). The cyclic prefix per symbol rate is lowest1/32, the standard coding technique is used with rate of 1/2 for BPSK, QPSK and with 3/4 for 16QAM. Moreover, the rest of simulation parameters are in table 2, for the sake of simplicity ideal channel estimation is considered at the receiver side. For characterizing OFDM symbol, two types of OFDM parameters (primitive and derived) can be used for simulation. Because of fixed relation between them, later one can be derived from the former one. The physical layer which implemented in MATLAB simulation according to the primitive parameters is specified as OFDM params and derived parameters are calculated as IEEE802.16 paparams which can be accessed globally.

The IEEE 802.16 channel models [7], [8] for fixed wireless applications are proposed for scenarios where the cell radius is less than 10 km, the directional antennas at the receiver are installed under-the-rooftop/windows or on the rooftop, and the base station (BS) antennas are 15 to 40 m in height. The channel models comprise a set of path loss models including shadowing (suburban, urban) and a multipath fading model, which describes the multipath delay profile, the K-factor distribution, and the Doppler spectrum. Due to the use of directional antennas, the antenna gain reduction factor is also characterized. Each modified SUI channel model has three taps. Each tap is characterized by a relative delay (with respect to the first path delay), a relative power, a Rician K-factor, and a maximum Doppler shift, relative powers are specified for SUI channel models for 30o directional antenna. Furthermore, for each set of relative powers, a K-factor for 90% cell coverage considered for simulations. Each modified SUI channel model is further assigned an antenna correlation, this

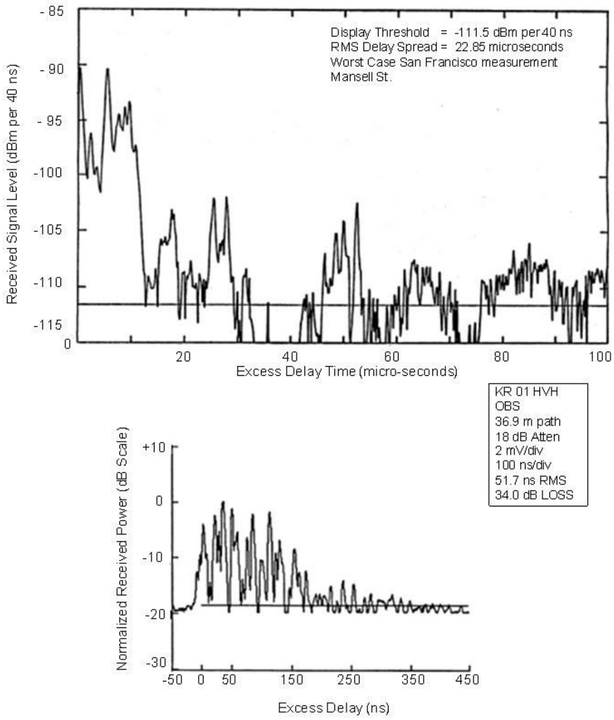

Fig. 2: Measured multipath power delay profiles: a) From a 900 MHz cellular system in San Francisco; b) inside a grocery store at 4 GHz [8]

TABLE III: PHY LAYER PARAMETERS

Value	Type	Parmater
Primitive	Nominal Channel Bandwidth, BW	28 MHzC
	Number of Used Subcarrier Nused	192
	Sampling Factor, n	8/7
	Ratio of Guard time to useful symbol time, G	1/32
	NFFT(smallest power of 2 greater than Nused)	255
	Sampling Frequency, Fs	Floor(n.BW/8000) X 8000
Derived	Subcarrier Spacing, Δf	Fs/NFFT
	Useful Symbol Time	Tb 1/ Δf
	CP Time, Tg	G.Tb
	OFDM Symbol Time, Ts	Tb+Tg
	Sampling Time	Tb/NFFT

correlation is defined as the envelope correlation coefficient between signals received at different antenna elements [**?**]. The simulation sampling rate is specified and kept the same for the remainder of the scenarios. The input to the channel simulator is oversampled by a factor of four. The channel model has 3 paths: the first path is Rician while the remaining two are Rayleigh. Each path has a rounded Doppler spectrum for its diffuse component: the parameters are specified in the default Doppler rounded object while different maximum Doppler shifts are specified for each path in [7]. We used the maximum value of the Doppler shifts for all paths.

VIII. SIMULATION RESULTS

We used 2 transmit antennas and 1 receive antenna, we carried out the simulation through different SUI channels (1 to 6). In this section, various BER vs. SNR plots presented which obtained for all the essential modulation profiles in the standard with the same ratio of cyclic prefix and almost equal channel bandwidth. We analyzed audio signal to transmit or receive data as considered for real data measurement. Figure 3, 4 and 5 displays the performance of SUI models under different modulation type, BFSK, QPSK, and 16 QAM, respectively. Figure 3 illustrates different fading channels simulation with BPSK modulation and smallest value of cyclic prefix with high channel bandwidth. We can see in this chart that the channels in category A (SUI5 SUI6) contain more noise and suffer from high attenuations, they need higher signal to noise ratio and that's means it needs more power for bit to transmit over a highly fading channel from base station toward subscriber station. In figure 4 the simulation result which is done for SUI channels set, with QPSK and maximum bandwidth 28MHz, it shows that the channels for Urban area with highly foliage density contain more degradations and reflect high attenuation, that's due to the characteristic of urban arias and the effect of multipath propagation is very clear on the behavior of the system, channels in Category A (SUI1 SUI2) seems to behave perfectly with this simulation parameters and they show minimum path loss, that's due to their flat terrain with light tree densities. In figure 5 implementation of SUI channel sets with 16QAM and with high bandwidth 24MHz have been done, the results come up explaining the variation in signal performance between different cases, SUI4 and 5 underlie on SUI6 and draw a straight ling which is means that channels undergo high fading affect with huge corruption and large amount of scatter in signal quality at the receiver side, it is also shows that the size of cyclic prefix is less than inter simple interference (ISI), it needs more SNR to transmit the signal to customer end correctly. In all three figures we calculated the theoretical AWGN channel with each. It is clear, that on SUI6, SUI5 the severity of corruption is highest and lowest in SUI1. By analyzing the tap power and delays of the channel models, the order of the severity of corruption can be easily understood. Since the Doppler Effect is reasonably small for fixed deployment. The performance of the system under BPSK modulation is quite satisfactory as compared to other modulation techniques.

It is clear that the SUI cannels in category A high delay spread contain maximum path loss with variety of modulation

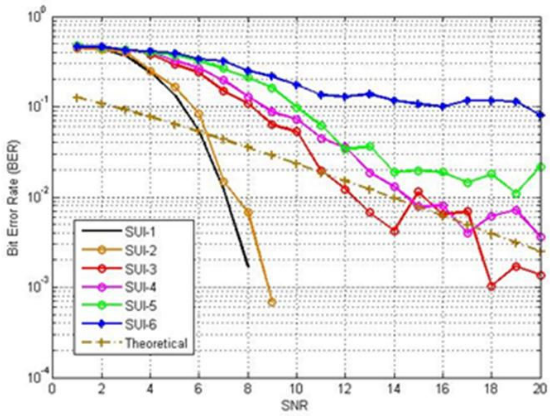

Fig. 3: Implementations of different SUI channel plus AWGN with BPSK modulation and with a maximum channel bandwidth 28MHz

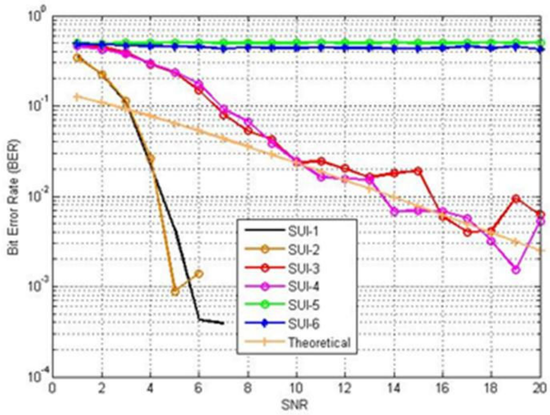

Fig. 4: Implementations of different SUI channel with QPSK modulation and with 28 MHz channel bandwidth

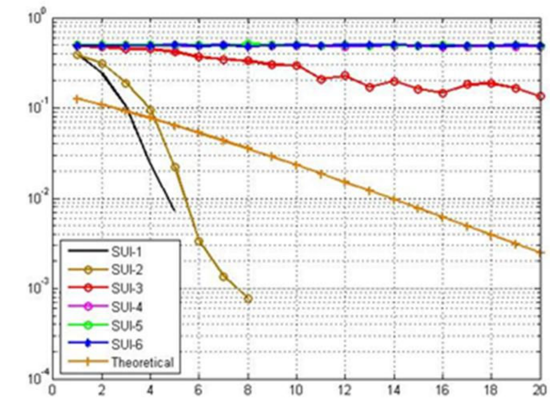

Fig. 5: BER of the received symbols for different SUI channels with guard equal to 1/32, channel bandwidth is 28 MHz using 16QAM as a modulation technique

schemes, even with BPSK which is reliable for long distance communication. The reason behind using 2 transmits antennas and 1 receive antenna is to achieve high data throughput and to overcome multipath propagation and delay spread, the correlation coefficient between the two signals on each path is taken equal to the antenna correlation, by Using multiple input single output (MISO), we tested one of the most well known optional feature of 802.16d which is known as diversity transmission, WiMAX system use diversity transmission as an optional feature. This part is about estimated the power spectral density (PSD) for an rural area. SUI2 channel has been taken as an example. PSD describes how the power of a signal or time series is distributed with frequency using Welch's modified periodogram method of spectral estimation.

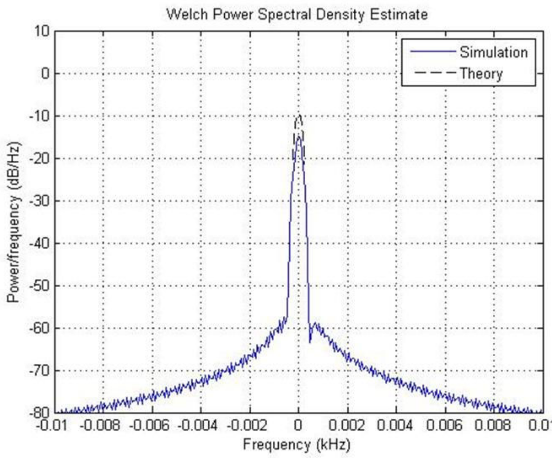

Fig. 6: The Doppler spectrum of the 1st link of the 2nd path is estimated from the complex path gains and plotted under SUI 2 channel condition.

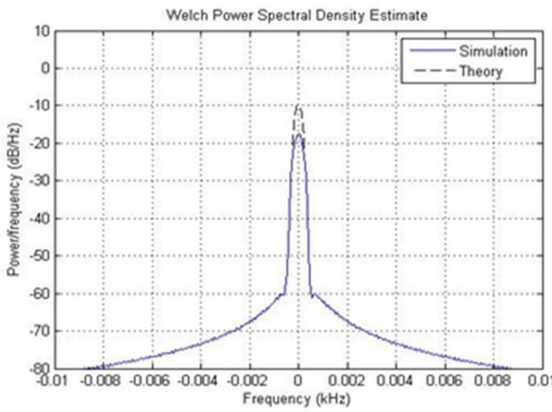

Fig. 7: The Doppler spectrum for the 2nd link of the 2nd path is also estimated and compared to the theoretical spectrum under low terrain condition (SUI 2)

In figure7 and 8 illustrate the Doppler spectrum of the first link of the 2nd path and the Doppler spectrum of the 2nd link

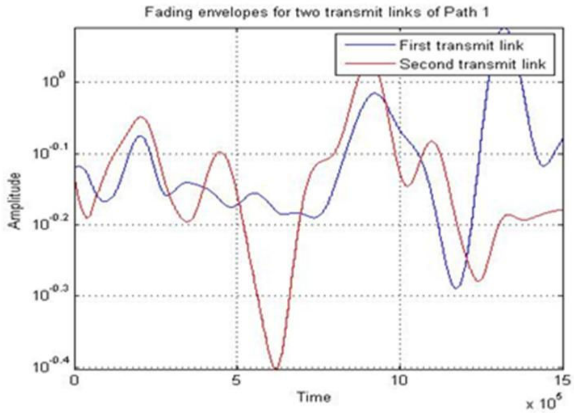

Fig. 8: Fading envelopes for two transmitted links of path 1in SUI2

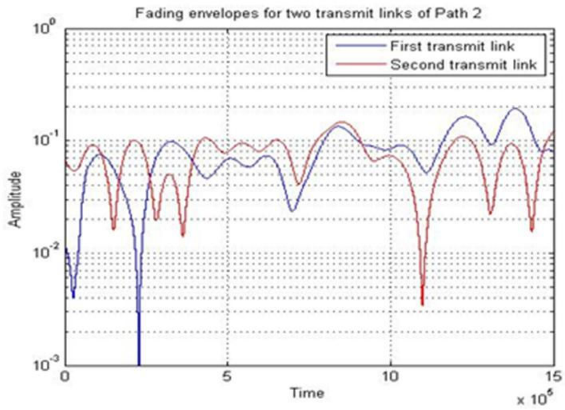

Fig. 9: Fading envelopes for two transmitted links of path 2 in SUI2

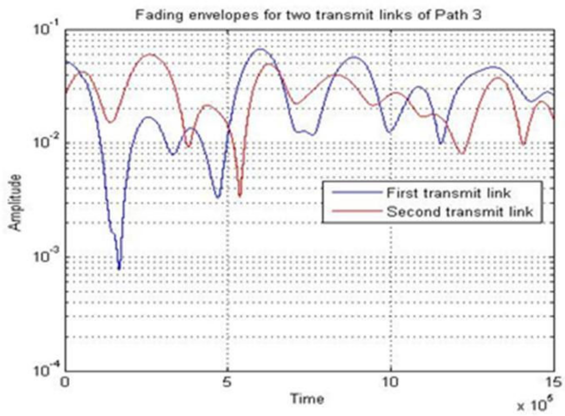

Fig. 10: Fading envelopes for two transmitted links of path 3 in SUI2

of the 2nd path respectively, as they have estimated and compared to the theoretical spectrum under low terrain condition (SUI 2).We also plotted the fading envelope waveform of both transmitted link as we can see in Figure 8, 9 and 10 for path1, 2 and 3 for both transmitter's antenna respectively under rural area channel (SUI2). We can notice, there is sort of correlation between both transmitted links for path 2 and 3, the channel condition change slowly and the channel fading is slow too which it means high temporal correlation and long coherence time, and that's all due to the characteristic of rural are with moderate tree density.

IX. Conclusion

A comparative study between different SUI channels model implemented with WiMAX 802.16-2004 profile, each one of them is described by appropriate parameters and specified for specific environment of propagation, these channels have been implemented using different modulation schemes. It is observed in simulation that, lower modulation and coding scheme provides better performance with less SNR. By looking at their constellation mapping it can be easily visualized. Larger distance between adjacent points can tolerate larger noise, which makes the point shift from the original place at the cost of the coding rate. The simulation of fixed wireless channel models SUI(1-6) which recommended by IEEE has been done in simulation. We tested this model with 30^0 directional antennas, K-factor 90% for cell coverage and 99.9% reliability of signal inside its own covered geographical area. By using directional antenna30^0 at transmitter side we utilized some of transmitted power, instead of spreading the signal in all directions as it happen with Omni antenna we focus the beamform on specific geographical area inside the cell, and this method achieves power utilization. It has been provide with simulation result that the minimum path loss category is mostly flat terrain with light tree densities (Category C), maximum path loss category is hilly terrain with moderate-to-heavy tree densities (Category A) and finally intermediate path loss condition is captured in Category B. Estimation the power spectral density (PSD) for a rural area channel has been illustrated using SUI2 profile.PSD describes how the power of a signal or time series is distributed with frequency using Welch's modified periodgram method of spectral estimation.The main goal of spectral density estimation is to estimate the spectral density of a random signal from a sequence of time samples. When the theoretical rounded Doppler spectrum is overlaid to the estimated Doppler spectrum, we observe almost a sort of fit between both. Using 2 transmits antennas and 1 receive antenna achieves diversity transmission and its highly recommended from WiMAX developer, to get high data throughput and to overcome multipath propagation and delay spread, the correlation coefficient between the two signals on each path is taken equal to the antenna correlation, at the end, to see whether the signals are correlated, plotting the fading envelopes waveforms for both transmitted likes for path one, two and three have been illustrated respectively.

Finally, channels modeling in this study are based on simulation results; sometimes wireless channel has non-logical behavior. In this case, we recommend to test and implement these channels in the real environment then making comparison between simulated and actual results is highly recommended as a future work.We also assumed perfect channel estimation at receiver side to make the simulation simple. As a next step, we can use channel estimation algorithm to get results more realistic. In addition; the SUI channels are envisaged to be modified in order to carry out evaluation of the mobile WiMAX(IEEE 802.fe). In results, it will give SUI channels more flexibility to be established on mobile radio channels.

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